Connecticut Department Of Transportation

Conservation And Restoration Plan
Merritt Parkway Bridges

Merritt Parkway

Bridge Restoration Guide

May 2002

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Acknowledgements

Acknowledgements:
This report was prepared by the following individuals: Nomy Zingher, *PE, Project Engineer* of Stone & Webster Engineering Corp., Nancy Wilks, *RA*, *Technical Architect* of Swanke Hayden Connell Architects, and Theodore Prudon, *Phd., AIA*, *Senior Preservation Architect.*

We wish to thank Bradley J. Smith, *Manager of State Design,* and Timothy Fields, *Project Manager* of the Connecticut Department of Transportation for their significant input in the development of this manual;

and for his significant contribution,
George L. Dunkelberger, the chief Architect of the Connecticut Highway Dept. who designed and oversaw construction of all of the Merritt Parkway bridges built in the 1930's, which continue to enrich the Connecticut public realm today.

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I. Introduction

1.1 PREFACE

1.1.1 Project Description

In 1995, Stone & Webster Engineering Corporation, in association with Swanke Hayden Connell Architects, Iffland Cavenaugh Waterbury, P.C., and Barakos-Landino, Incorporated, were retained by the Connecticut Department of Transportation to provide consulting services with regard to 65 historic bridges on the Merritt Parkway. The Parkway is considered one of the most important historic scenic parkways in the country and has been recognized to have a significant collection of historic bridges. These bridges and other features of the parkway have been the subject of study in prior years. For instance, the Parkway was listed in the National Register of Historic Places as a national scenic landmark and the bridges were included in a survey of historic bridges in Connecticut in 1991. The bridges were also the subject of a recording effort by the Historic American Engineering Record (HAER) in 1992 and the Merritt Parkway Working Group prepared a plan and recommendations for the maintenance and upkeep of the bridges and other features in 1994. Additionally, *A Landscape Master Plan for the Merritt Parkway* was prepared the same year. However, none of the above listed studies or reports were concerned with the practical task of maintaining the historically and architecturally significant bridges of the Parkway within the overall context of highway safety and maintenance responsibilities.

The purpose of this document is to provide historic preservation guidelines and related *special provisions* which will be used by bridge engineers in the development of bridge rehabilitation plans.

1.1.2 Special Requirements for Implementation

This guide is to be used as a general description of restoration procedures to be carried out in individual bridge rehabilitation. It is intended to instruct engineers, architects and consultants in the preparation of documents for future bridge rehabilitation, appropriate for historical structures. Sample specifications included herein are not necessarily specific to conditions or restorative techniques which might be required on individual bridges. They do, however, include general recognized techniques of good preservation practice and are meant to be followed as a guide for special provisions for rehabilitation work on the historic bridges.

1.2 RESTORATION PHILOSOPHY

1.2.1 Overview of Preservation Policies for Historic Highways

The period before WWII saw the construction of major parkways in different parts of the country. Many of these roads have become significant resources and an integral part of the arterial road systems surrounding major cities. With the growth in traffic and the increase in traffic speeds the generally narrower and winding character of the road has become more problematic from a safety point of view. This constitutes the inherent difficulty in the preservation of historic parkways both in their basic layout as well as in the configuration and design of the ornamental and other features of these roadways. This particular manual only addresses the preservation aspects of the bridges and their ornamental and design features with some reference to the design of the additional safety features and how these affect the original design of the bridges. In this context particular attention is given to the patching and repairing of remaining features as well as the identification and repair of original design and surface features. As discussed in more detail further below, the surface finishes and treatments for the concrete bridges forms a critical part of the original design but at the same time presents one of the most complicated and difficult preservation problems possible.

In preparing a manual and before presenting specific techniques and methods for the restoration and rehabilitation it is important to formulate and identify a comprehensive restoration philosophy. Such a philosophy will guide the work discussed in the manual and can serve as the basis for work not specifically covered. For the purposes of preservation and restoration in the US the guidelines and standards generally referred to as the "Secretary's Standards" have been used here also. These standards which were prepared on behalf of the Secretary of the Interior two decades ago have been used to guide the Federal and States' preservation work throughout the US.

In general, it can be said that it is the intention of these standards to retain as much as possible of the original fabric and where intervention is necessary because of conditions or continued use, that such intervention be as minimal and respectful as possible. Where replacement of deteriorated sections is required such replacement be done *in kind*, with the same materials as the original construction. It is these same standards that were the basis for the recommendations that were formulated by the Merritt Parkway working Group in June 1994 when formulating an approach policy for this scenic and architectural landmark.

To utilize these standards as the departure point for the formulation of a restoration philosophy of the significant features which are an integral part of the historic highway, presents unique preservation challenges for designers and engineers. The principles underlying preservation may sometimes conflict with current highway design standards. First and foremost must be the safety aspects which may involve the alteration or elimination of existing features. In the case of preservation, the primary interest is in preserving as much of the original fabric as possible and retaining existing important features.

1.2.2 Preservation of Merritt Parkway Historic Bridges

In the preparation of the manual and the formulation of specific repair techniques, the

underlying philosophy and approach used throughout reflects the recommendations of earlier studies and reports. Specifically, the "Merritt Parkway Guidelines for General Maintenance and Transportation Improvements" prepared by the Merritt Parkway Working Group (1994) has served as an important guideline in defining the appropriate repair and restoration techniques.

In the foreword of the above study, the parkway is referred to as "as one of the most beautiful and best-engineered highways of the time". While the aspect of engineering may no longer hold true, certainly the Merritt remains one of the most beautifully designed highways in the United States. Significantly, what continues to make this road interesting is the level of care and detail that has been given in the original design of its historic bridges.
One of the early median-divided, limited-access highways parkways in this country, the Merritt and other parkways traditionally and typically share certain design characteristics. As scenic roadways, the Merritt and other parkways have broad, gentle horizontal and vertical curves, a paved roadway limited to two lanes of travel in each direction, scenic views of landscapes or monuments, landscaped medians, wide, park-like grassy shoulders, wide rights-of-way including woodland buffers, extensive landscaping and aesthetically pleasing bridges and drainage structures. Built in the 1930's, when traffic volumes were less than half of those found today, and driving speeds were significantly lower, the Merritt Parkway was not designed for its current use as a high speed, primary commuter transportation artery.

Thus stated, it is the intent of the department that safety remain our primary priority. It is not our intent that current safety standards be significantly compromised or dismissed in order to maintain all aspects of the original appearance of the parkway.

1.3 RESEARCH AND INSPECTION

1.3.1 Source Materials/Historic Documentation

The following materials were supplied by the Connecticut State Department of Transportation to aid in bridge inspections and research: existing bridge files; the original bridge drawings; *Standard Specifications for Road and Bridge Construction*, 1932 by the State Highway Department; original bridge photographs; the *Connecticut Historic Bridge Inventory, Final Report: Preservation Plan,* May 1991; the Historic American Engineering Record (HAER) individual bridge reports; *Connecticut's Merritt Parkway: History and Design*, also by HABS/HAER; and the United States Department of the Interior, National Park Service, National Register of Historic Places, registration form and continuation sheets.

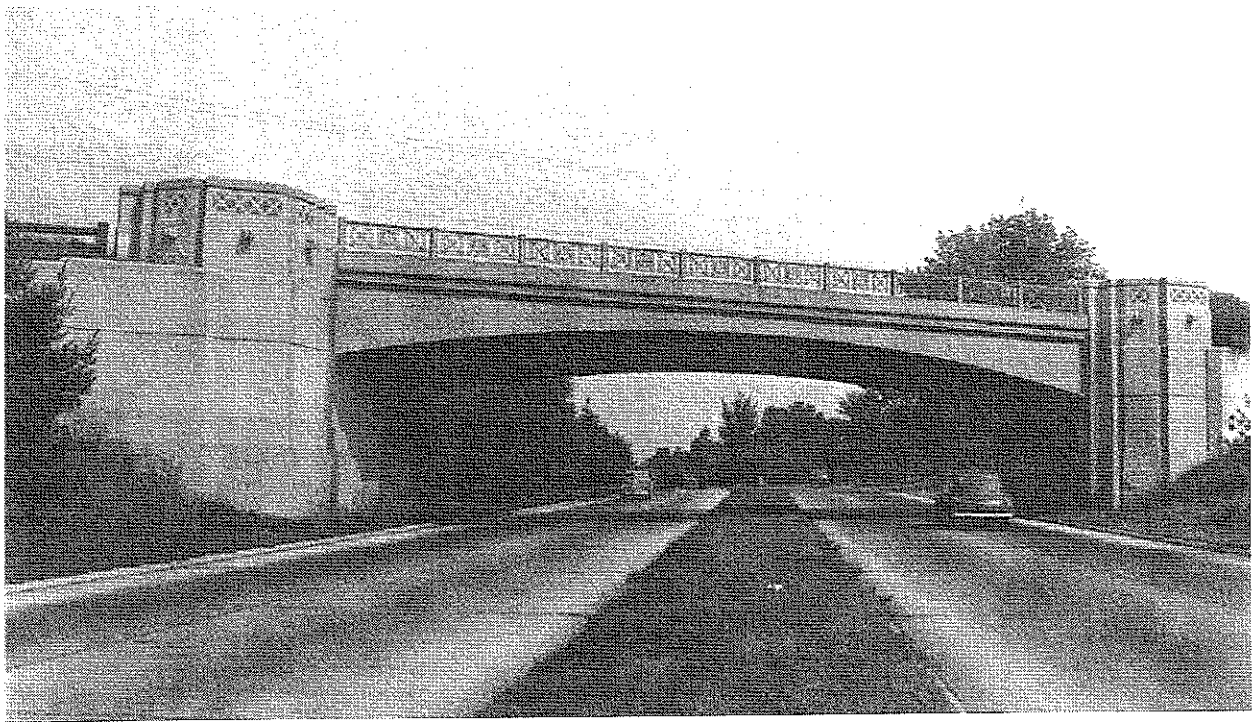
1.3.2 Bridge Inspections

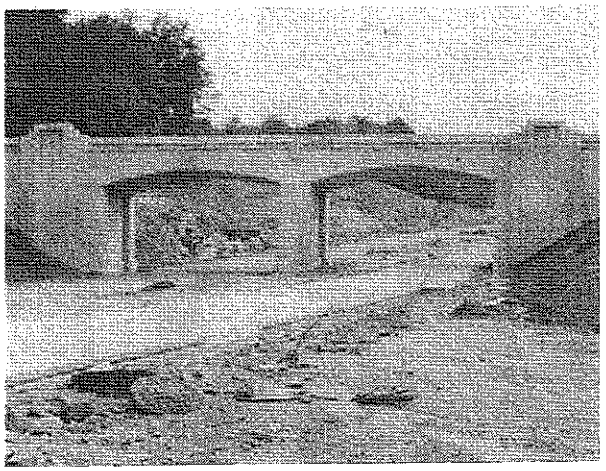
Each bridge was inspected by a structural engineer and an architect. Inspections were visual and did not include in-depth structural inspection or load ratings. The engineer's inspection included documentation of any changes in the structural condition since previous inspections were conducted, and identification of safety features. The architectural inspection focused on the appearance of the bridges. This included documentation of all alterations to the original design of the bridges as depicted in the original architectural drawings, a review of the quality of repair work, a general inspection of the finish condition of the bridge surfaces, and inspection of the ornamental features of the bridges. Samples of bridge material were taken for more in-depth analysis when deemed relevant to the investigation.

1.3.3 Project Documentation

The individual bridge reports completed for each of the 65 bridges include a written architectural description of each bridge based on the visual inspection, the HAER reports, inspection of the original drawings and early construction photographs. HAER documents were considered to be accurate accounts except where visual inspection dictated otherwise. The architectural observations included a description of the existing condition of the concrete, masonry, the various finishes, the ornamentation, vegetation, joints, graffiti and changes from the original drawings where observed. The engineer's comments included any changes in the structural condition of the bridge since the previous documented inspection to the roadways, superstructure, parapets and wingwalls, as well as conformance of safety features to ConnDOT standards and a general impression of the geometric alignment of the roadways to the bridge. Recommendations including replacement of portions of the superstructure, replacement of the road surface, repair of cracks, spalls, re-pointing of masonry, replacement of masonry units, replacement and repair of ornamentation, re-filling of joints, cleaning and restoration of the bridge finishes, repair and restoration of ornamental metalwork, removal of intruding or obscuring vegetation according to the *Merritt Parkway Landscape Master Plan,* 1994, and recommendations concerning safety features and signage. An approximate cost was given for the recommended improvements as well as a rating of the priority level for rehabilitation of the structure, and the life expectancy if no repairs are made. Approximately 10 - 25 color 3 1/2" x 5" captioned photos were included in each report.

II. Existing Conditions Evaluation



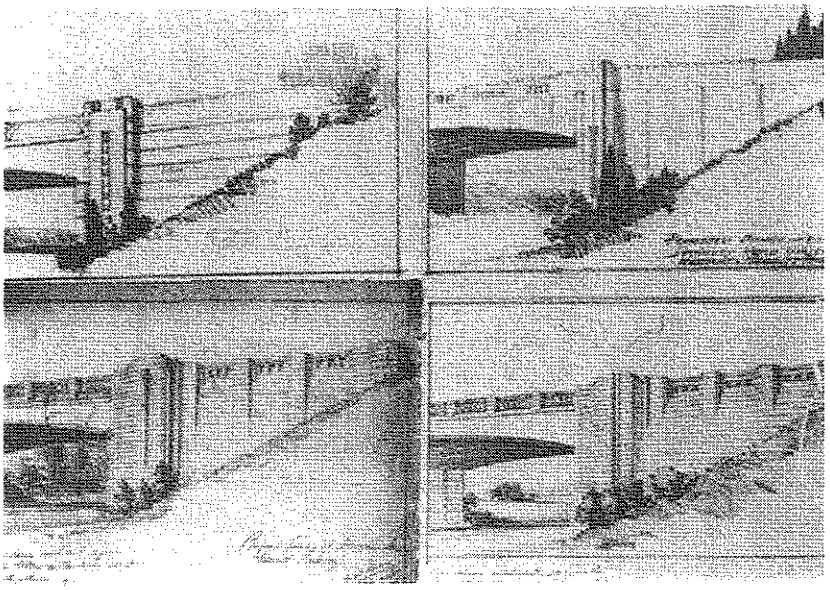


Top Photo:
Photograph of Bridge #729, Clinton Avenue shortly after completion.

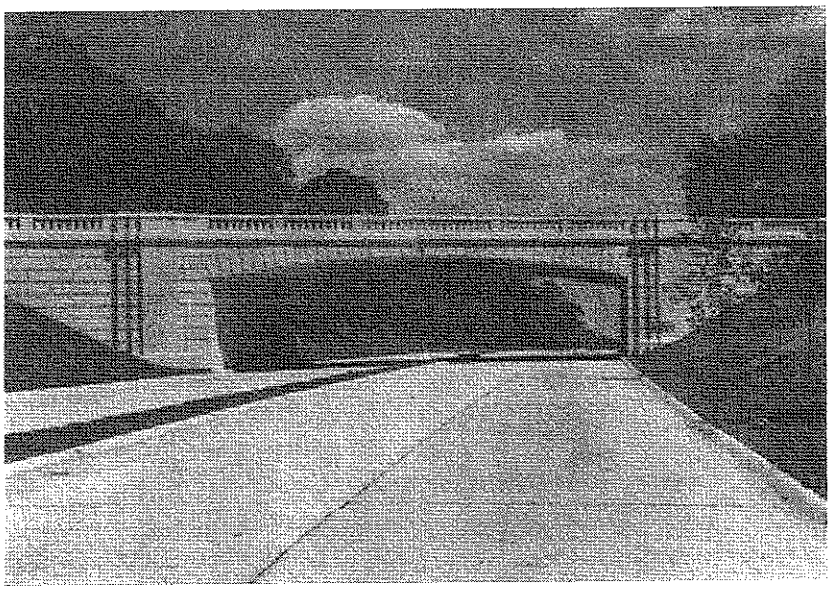
Bottom Photo:
Photograph of Bridge #710, Metro North Railroad nearing completion.

2.1 INTRODUCTION

According to Dunkelberger, in the design of the bridges, the State Highway Department sought to build in concrete what had previously been accomplished architecturally in stone, in order to compliment the type of road being envisioned, namely, a scenic parkway. While reinforced concrete was, and still is, widely used for bridge design, architecturally significant, ornate designs in concrete were rare. As stated by the architect, "each bridge must express individuality and also be designed in such a manner that the final result would be an asset, rather than a liability." As a result, a variety of material and methods of producing ornament were explored. This chapter describes the styles, choice of materials, architectural features, details, and types of ornamentation which exist in the bridges. Additionally, two sections address existing deficiencies in the bridges and alterations which have been made to the original bridge designs.



Top Photo:
Conceptual design sketches done by Dunkleburger for Danbury Road Bridge (top) and Merwins Lane Bridge (bottom).



Bottom Photo:
Bridge # 697, North Street Bridge in the Town of Greenwich.

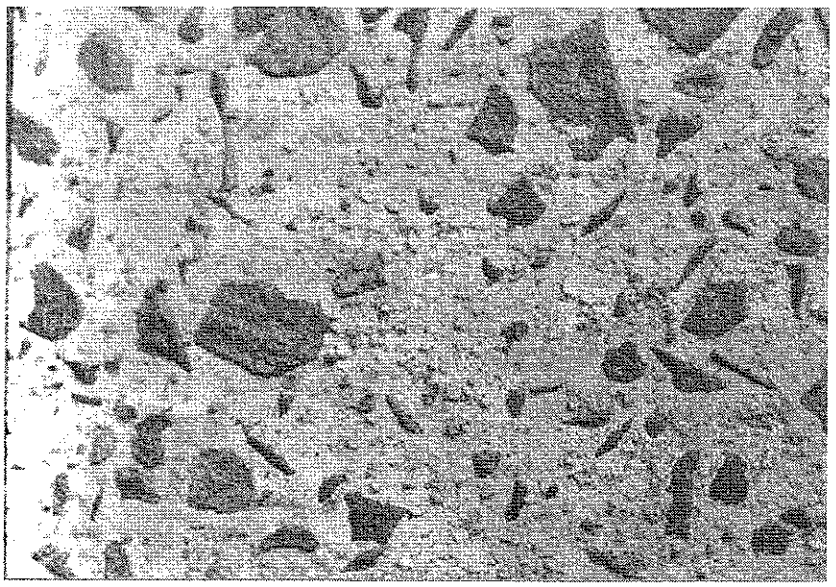
2.2 IDENTIFICATION OF SIGNIFICANT ARCHITECTURAL FEATURES

2.2.1 Style and Composition

The bridges were typically designed in the Art Deco style of the 1930's, however Art Moderne, Classic Revival, Rustic Classic Revival, and French Renaissance influences are also to be found in the bridges of the parkway. The most common type of structure was the reinforced concrete rigid frame with a barrel arch shape. The arch shape was ideal for spanning the four-lane parkway, typically about 65'-70', because the slab was deepest at the knee where most of the load is carried. The arch, pylons, wing walls and railings or parapets, were decorative elements which encased the utilitarian frame.

Other structural types, much less common, to be found on the parkway, include steel rigid frames, and concrete barrel arches. The latter were typically constructed for the shorter spans required for the roads crossing under the parkway. A few bridges on the Parkway were designed with horizontal steel frame structures, reinforced concrete slabs, and prestressed concrete beams.

Top Photo:
Concrete surface finish on Bridge #747 Madison Ave.

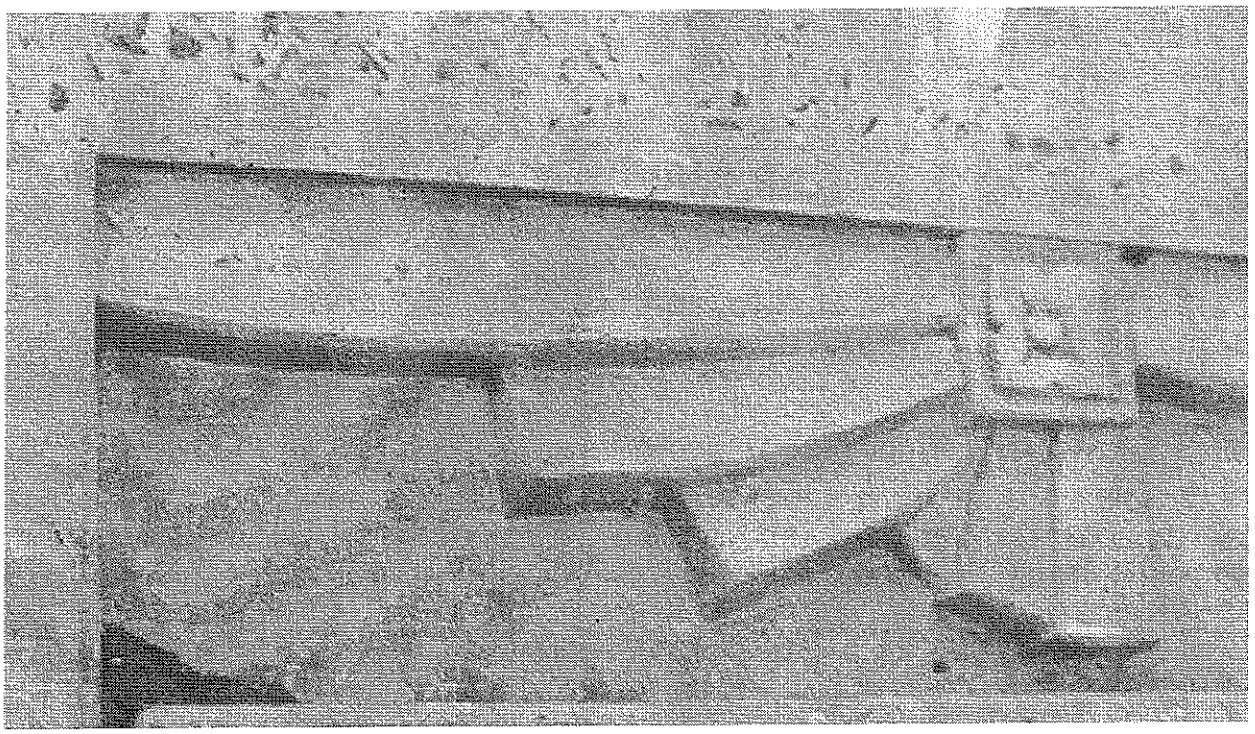


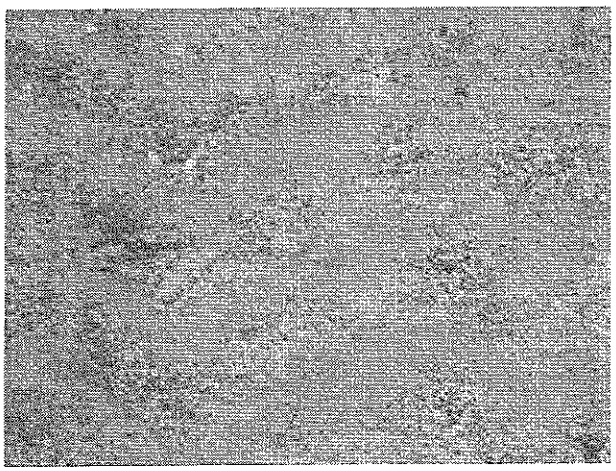
Bottom Photo:
Concrete surface finish showing exposed aggregate on Bridge #736, Redding Road.

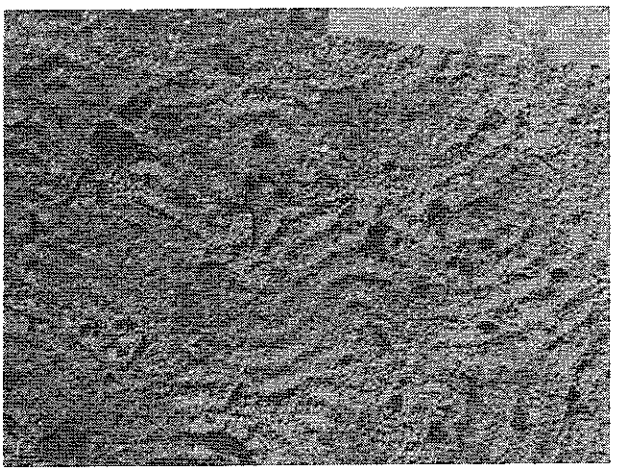
2.2.2 Materials

a. Concrete

The vast majority of bridges found on the Parkway were constructed of concrete composed of portland cement, fine aggregates consisting of quartz or other hard rock sand, and coarse stone, typically, black basalt. The aggregates were specified by the Highway Department as a variety of sizes. Surfaces were finished by rubbing, brushing, floating and grinding with a carborundum stone. Occasionally, panels were tooled after setting to expose the broken aggregate, with the aggregate left in "slight" relief. Scrubbed finishes were also employed. The concrete work of the bridges was strictly specified and controlled in the construction process to produce the desired effects. Concrete, widely used and highly appropriate structural material for bridges, was also the material of choice for the Parkway bridges, because of its low cost in comparison to stone, despite the objections of the local community.







Top Photo:
Detail of concrete surface on Bridge #747 Madison Avenue.

Bottom Left Photo:
Existing Concrete finish showing different coloration and textures on Bridge #760 , Main Street (River Road, Route 110).

Bottom Right Photo:
Detail of original shell-patterned textured surface on Bridge #708, Ponus Ridge Road.

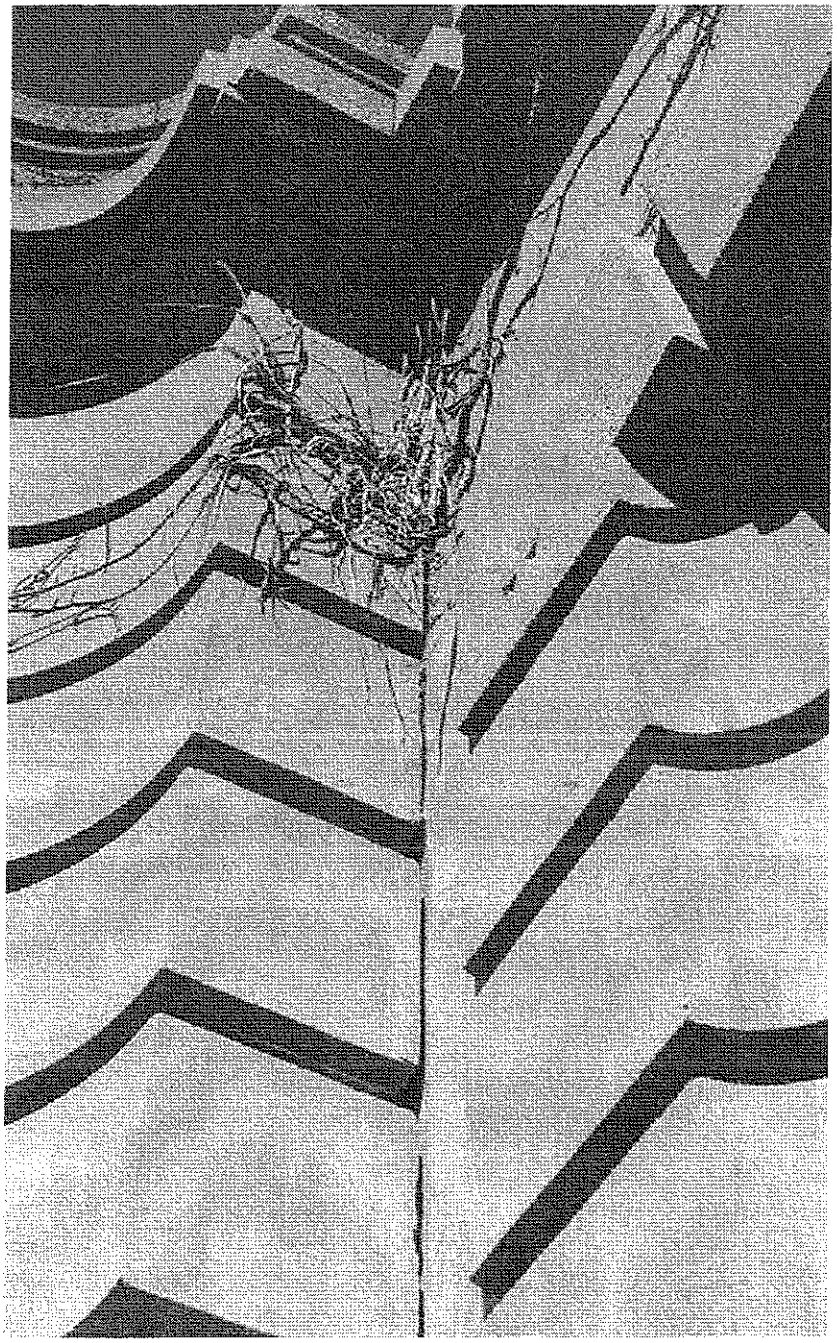
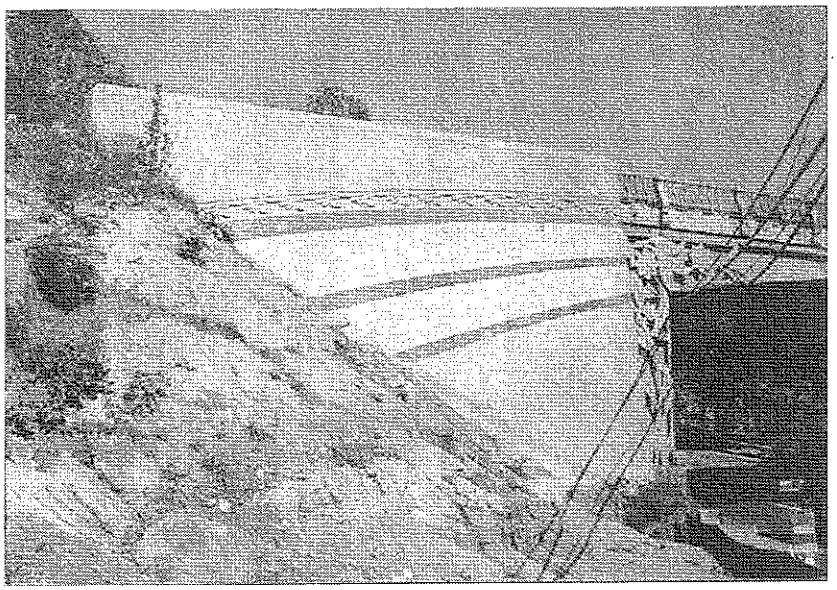
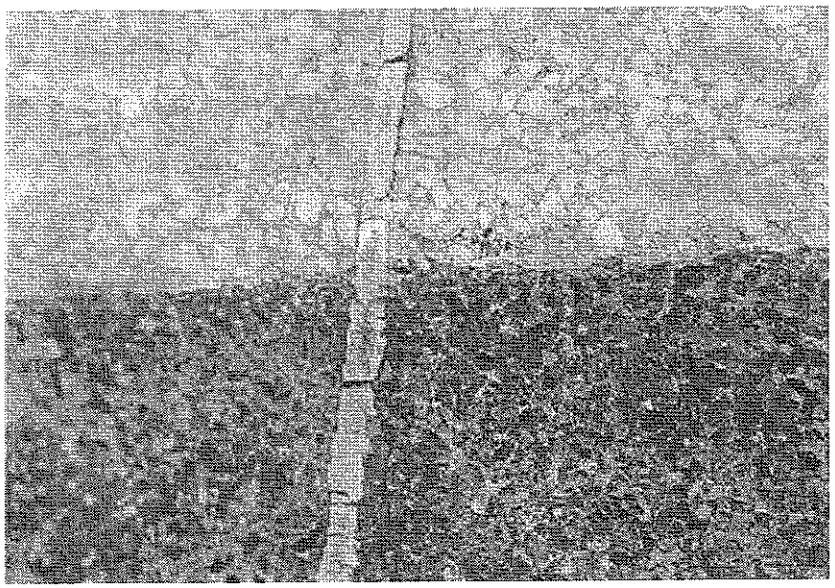


Photo:
Existing concrete finish with smooth surface and minimal exposed black aggregate on bridge #708, Ponus Ridge Road.



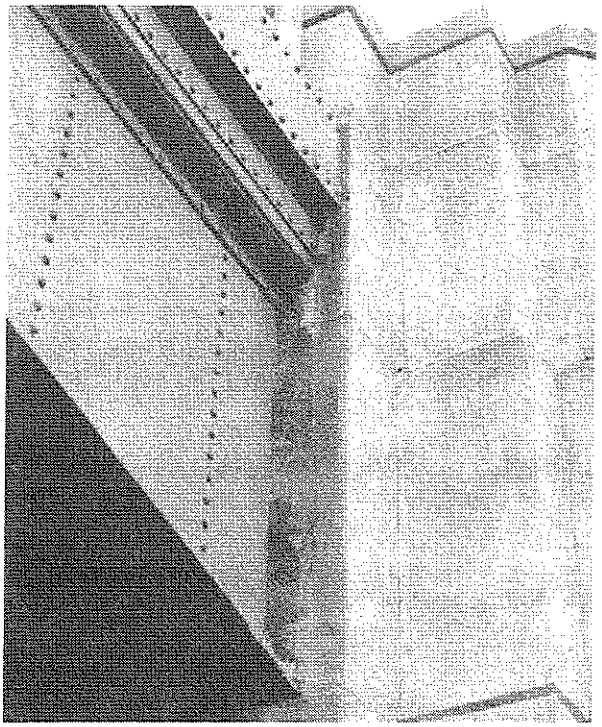
Top Photo:
Colored precast concrete banding on wingwall at Bridge # 760, Main Street (Route 110).



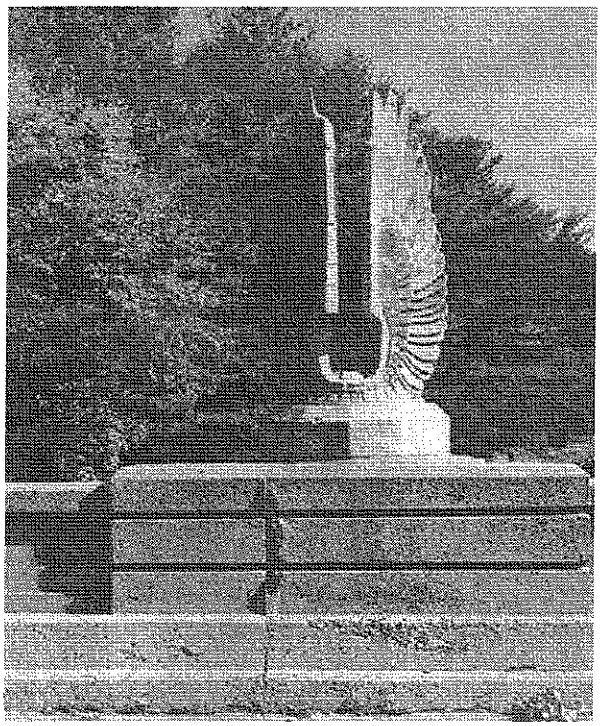
Bottom Photo:
Detail of precast banding on Bridge #760, Main Street (Route 110).

b. Precast Concrete

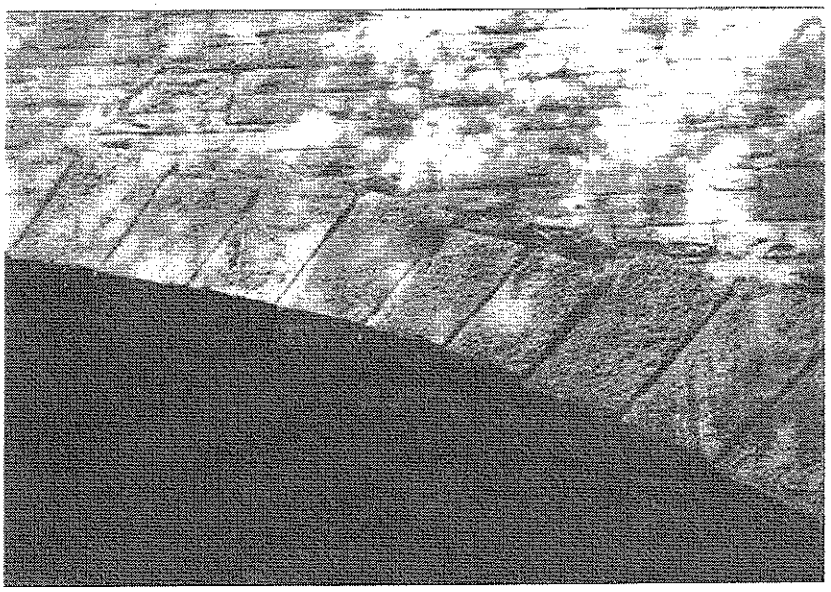
As a means to making each bridge unique, precast ornament and panels, differing in color and texture were employed at many bridges in order to relieve the monotony of the poured-in-place structural concrete. Most of the precast figures and designs are completely unique to the Merritt Parkway. Produced off site, ornament panels were delivered to the site, placed in the forms and anchored to the concrete poured around it. In some cases, large panels covered large sections of the bridges, such as at Bridge #729 at Clinton Avenue, in Westport, and Bridge #760 at Main Street in Stratford. Special aggregates, such as stony creek granite, white quartz, black onyx, colored glass, vitreous and ceramic aggregates were used. The colors produced on the bridges include red, green, black and white. According to Dunkelberger, every color of the rainbow could be produced with these materials for aggregates. The material has also proven to be less prone to weathering than cast-in-place concrete ornamentation, and less prone to the accumulation of dirt on the surface, a primary concern of Dunkelberger's.



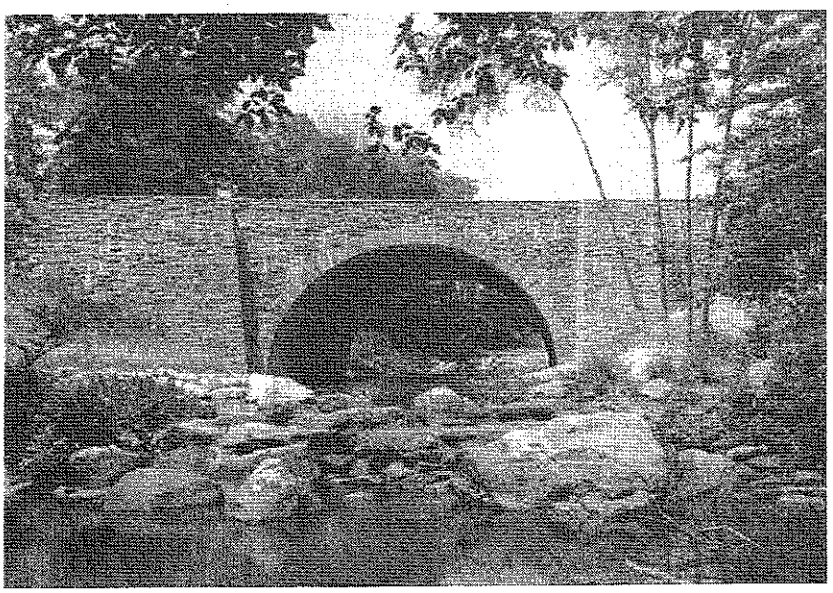
Top Photo:
At Bridge #729, Clinton Avenue precast concrete panels were used to face the reinforced concrete structure.



Bottom Photo:
Ornamental precast Nike wings by sculptor were used on Bridge #759, James Farm Road.



Top Photo:
Stone voissoirs at Bridge #705, Rippowan.

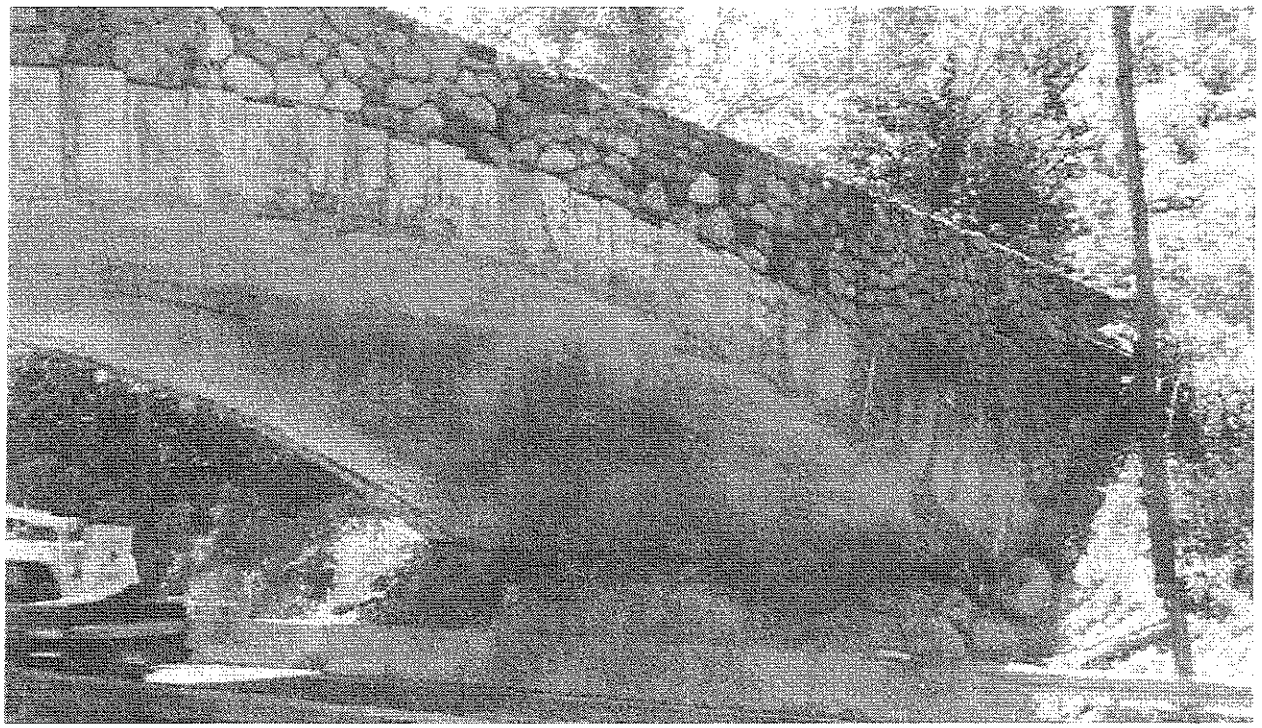


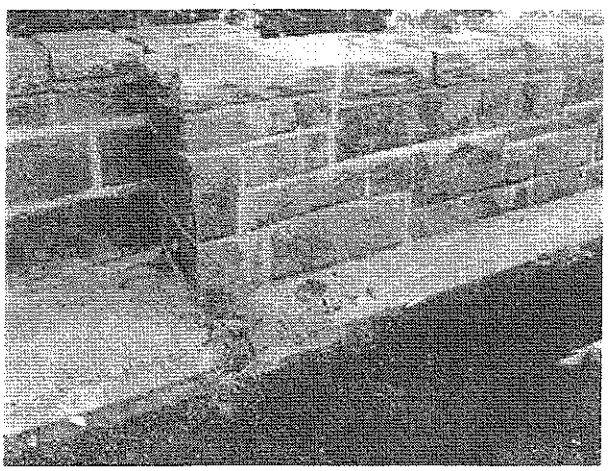
Bottom Photo:
Cut stone in ashlar pattern at Bridge # 726, Newton Turnpike.

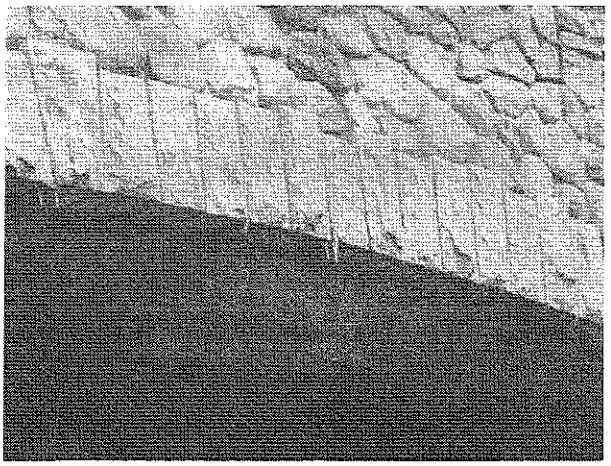
c. Stone Masonry

The use of stone as a construction material was deliberately kept to a minimum on the Parkway because of its additional cost, despite the fact that it was the accepted material for parkways of the period. During the 1920's and 30's stone was considered the best choice for a motorway passing through surroundings of natural beauty. However, only four (4) bridges were designed of stone masonry on the Merritt because of the State Highway department's determination to cut costs in the Depression era.

On some bridges, cut granite was used in an ashlar pattern as a facing material on the wingwalls, pylons and parapets of reinforced concrete frame bridges. Where rubble masonry stone was used as a facing material, cut granite was used for copings, voissoirs and quoins, as in the Main Street bridges (#530A and B) in Norwalk and Guinea Road (#700) in Greenwich. At the Lake Avenue bridge (#696), ashlar masonry stone abutments were combined with a steel frame and ornamental cast iron grilles.



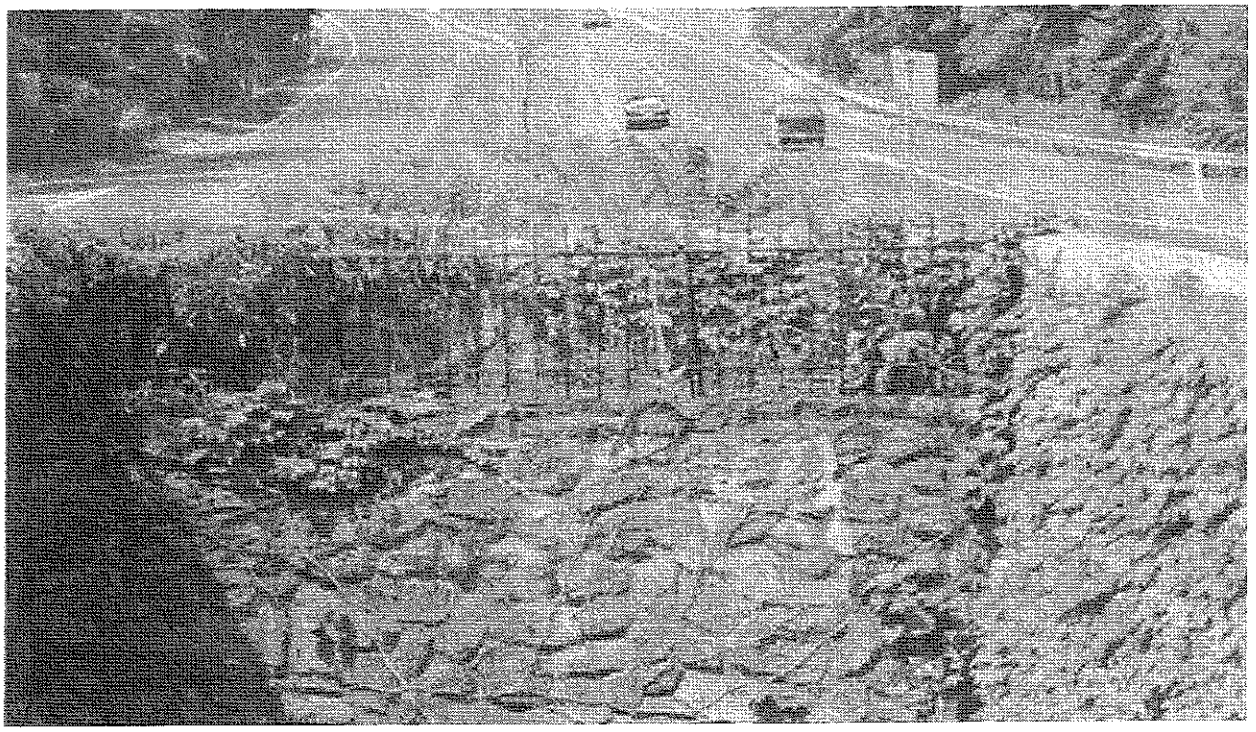


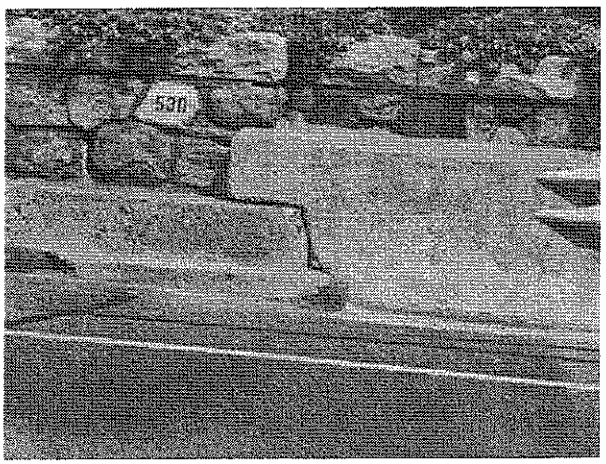


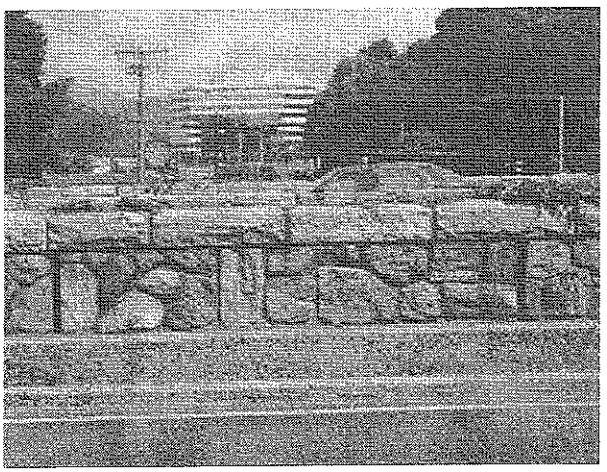
Top Photo:
View of rubble masonry spandrel wall and cut granite ring stones at Bridge #700, Guinea Road.

Bottom Left Photo:
Detail of ashlar stone parapet wall at Bridge #705, Rippowan

Bottom Right Photo:
Detail of stone Voussoirs at bridge #530, Main Street (Old Route 7)



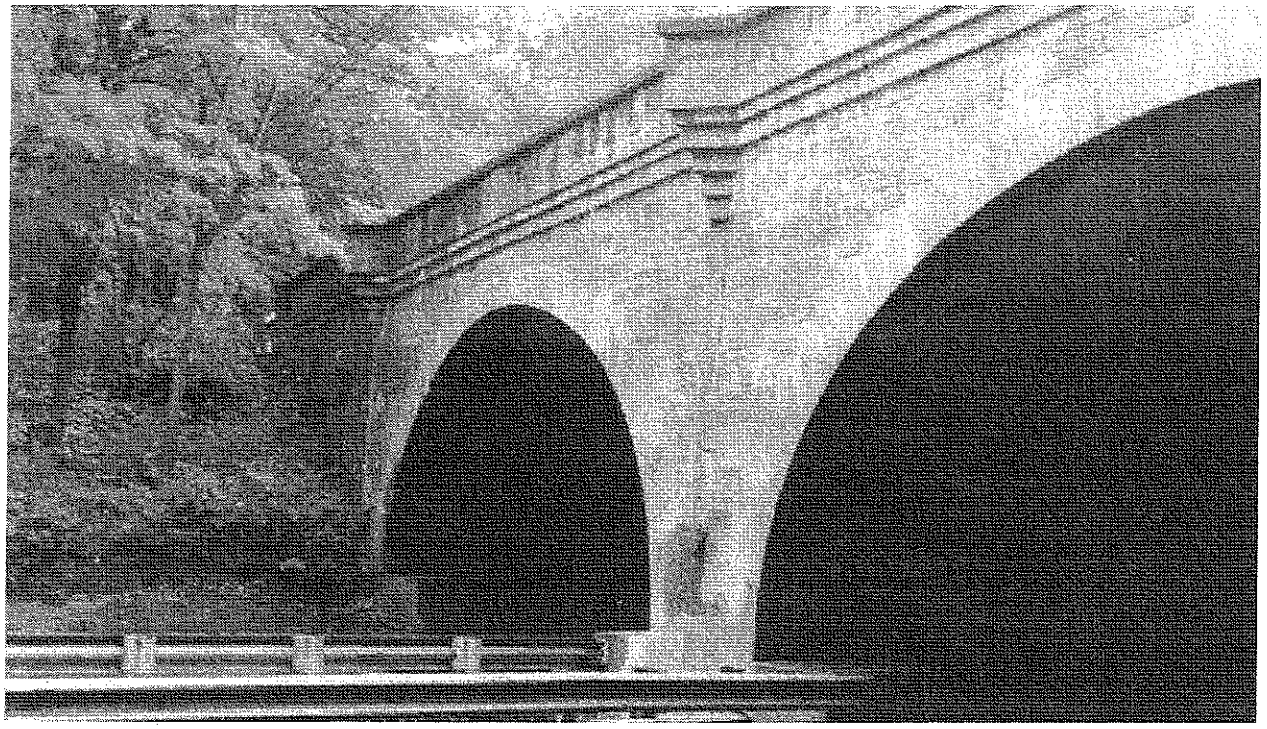


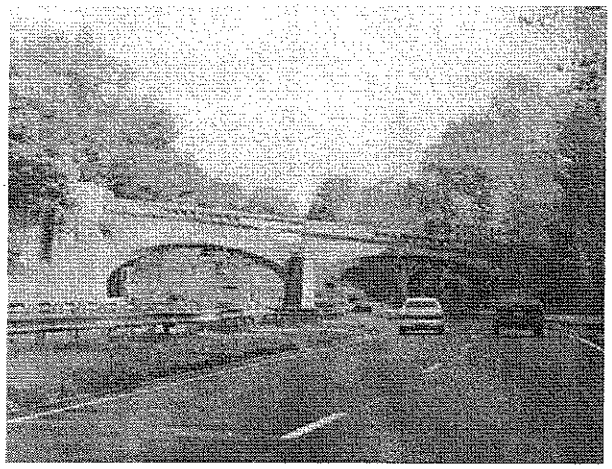


Top Photo:
Stone median wall between bridges # 530,A & B Main Street, (Old Route 7).

Bottom Left Photo:
Concrete barrier at parapet of bridges # 530,A & B Main Street, (Old Route 7).

Bottom Right Photo:
View of rubble masonry parapet at Bridge #530A, Main Street, (Old Route 7).



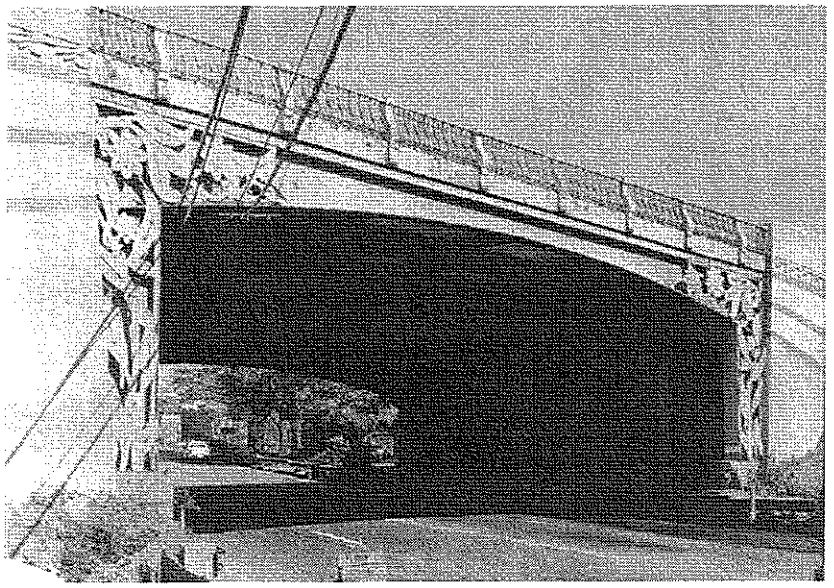


Top Photo:
Detail of cast-stone units at Bridge # 726, Newtown Turnpike.

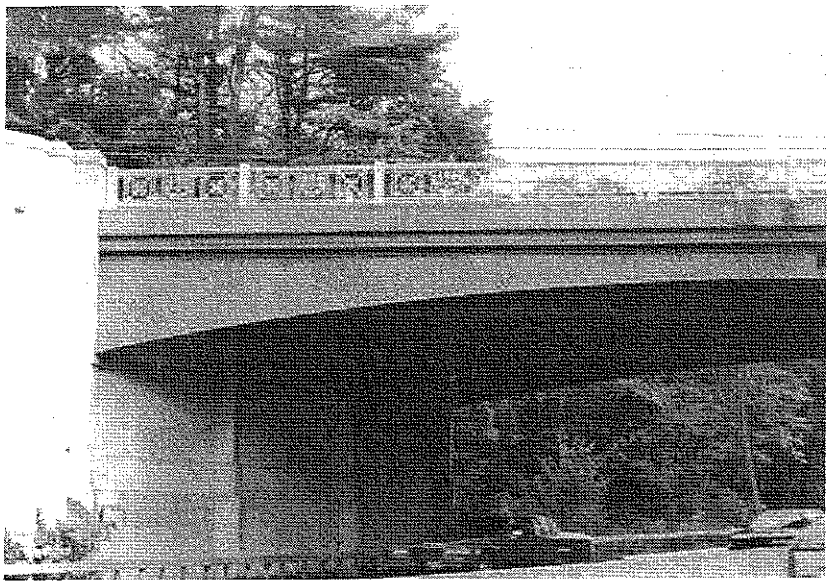
Bottom Photo:
Bridge # 749, Frenchtown Road, designed in cast-stone in the Neo-Renaissance.

d. Cast Stone Masonry

Cast stone masonry was experimented with in the design of two (2) bridges to give the appearance of real stone at a lower cost. Newtown Turnpike (#726) in Westport and Frenchtown Road (#749) in Trumbull were designed with similar cast stone facing, set in an ashlar pattern with mortared joints. The material contains a variety of colored stone aggregates in different sizes. Blue or black, red, brown and white stones were set in a portland cement mix. The size of the units vary, but are approximately 4" thick. The units were set in the structural concrete backup with steel anchors. The material gives the appearance of red-brown cut stone, such as sandstone, or granite, appropriate to the Neo-Renaissance style of both bridges.



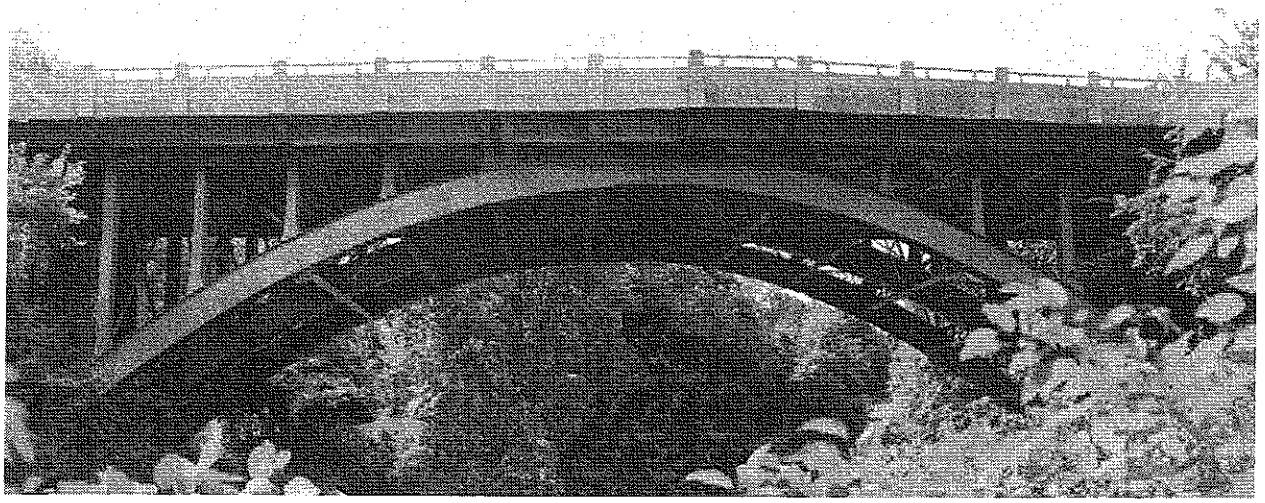
Top Photo:
Structural steel rigid frame with ornamental metal floral motif on Bridge #760, Main Street (River Road).

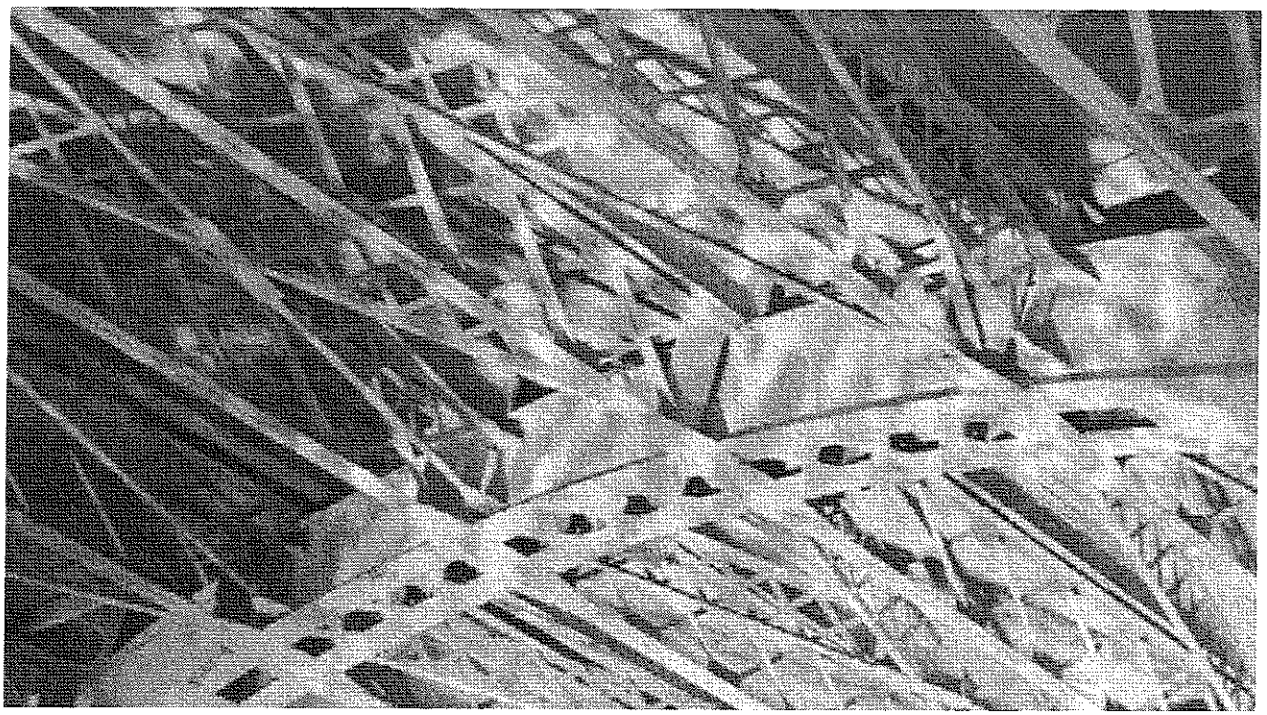


Bottom Photo:
Structural steel frame at Bridge #729, Clinton Avenue.

e. Structural Steel

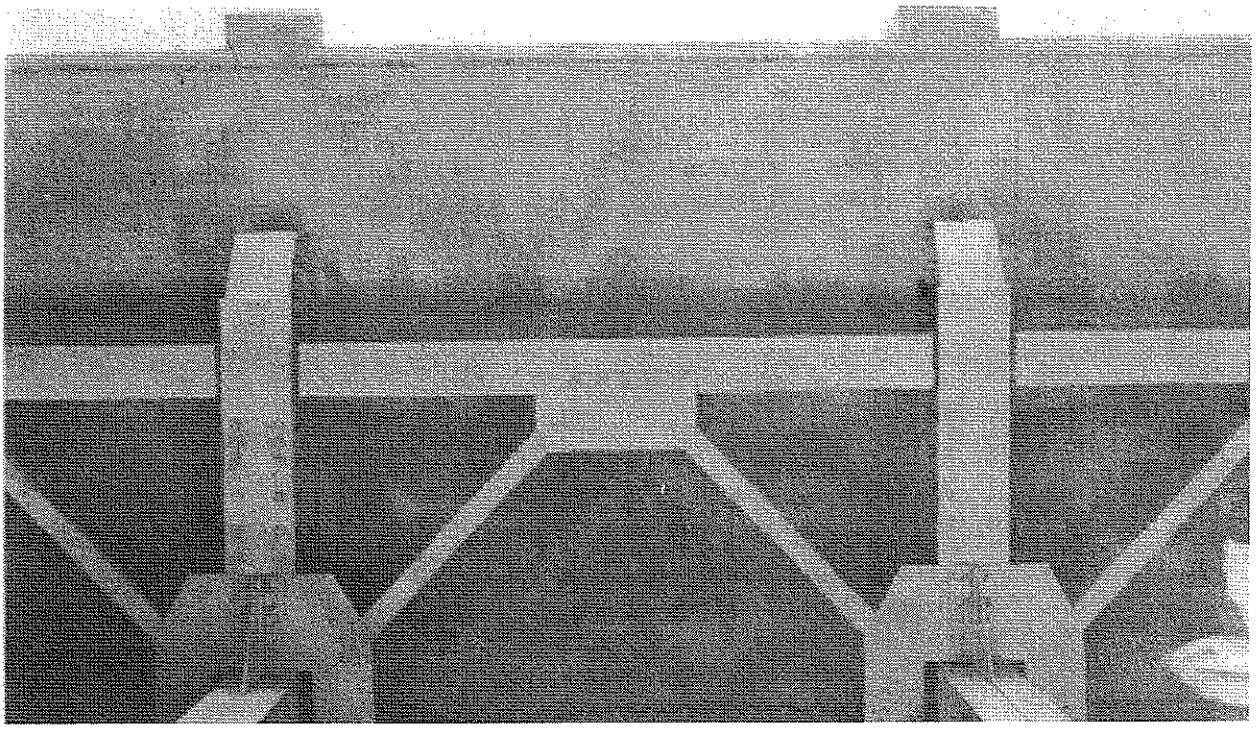
Exposed structural steel frames were used on approximately eight (8) bridges to provide another means of contrast to the grey, poured-in-place concrete which dominates the Parkway. Steel frames were combined with concrete abutments and wingwalls, or ashlar masonry stone, as at Lake Avenue (#696). The steel girders were typically arched with tapered legs. The sections were built-up of steel angles and plates with riveted connections. Color was an important feature of the steel frame bridges. Dunkelberger chose a range of warm greens, grays, browns and reds; earth tones intended to enliven the bridges while blending them into the surrounding landscape. All of the original colors have been painted over.

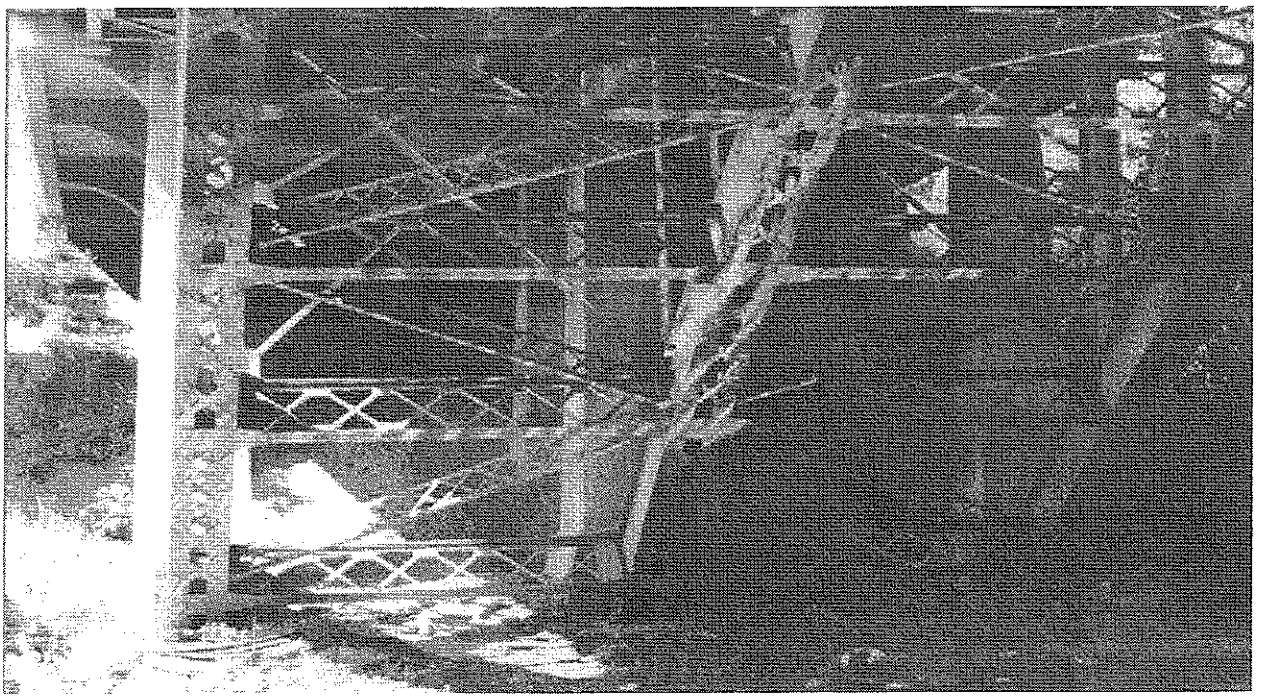




Top Photo:
Reconstructed panoramic photo with view of trussed structural steel frame and spandrel at Bridge #728, over the Saugatuck River.

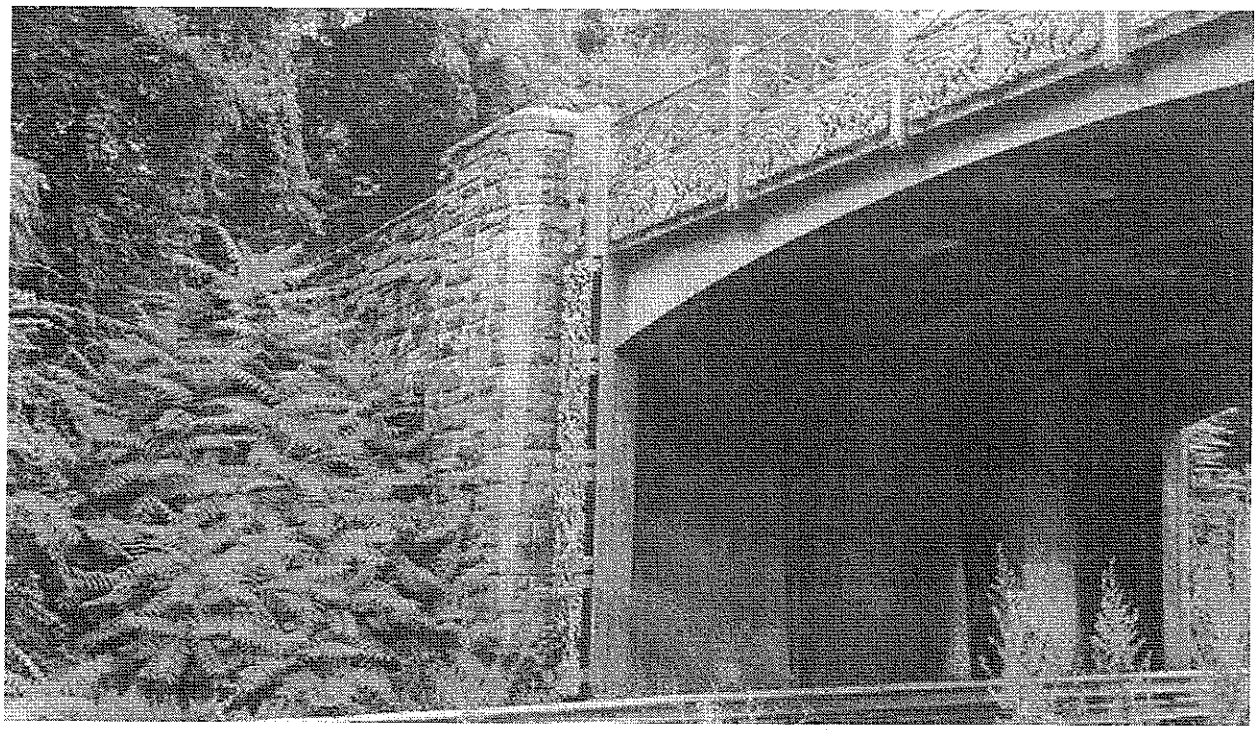
Bottom Photo:
Underside of steel frame of Bridge #728, over the Saugatuck River.

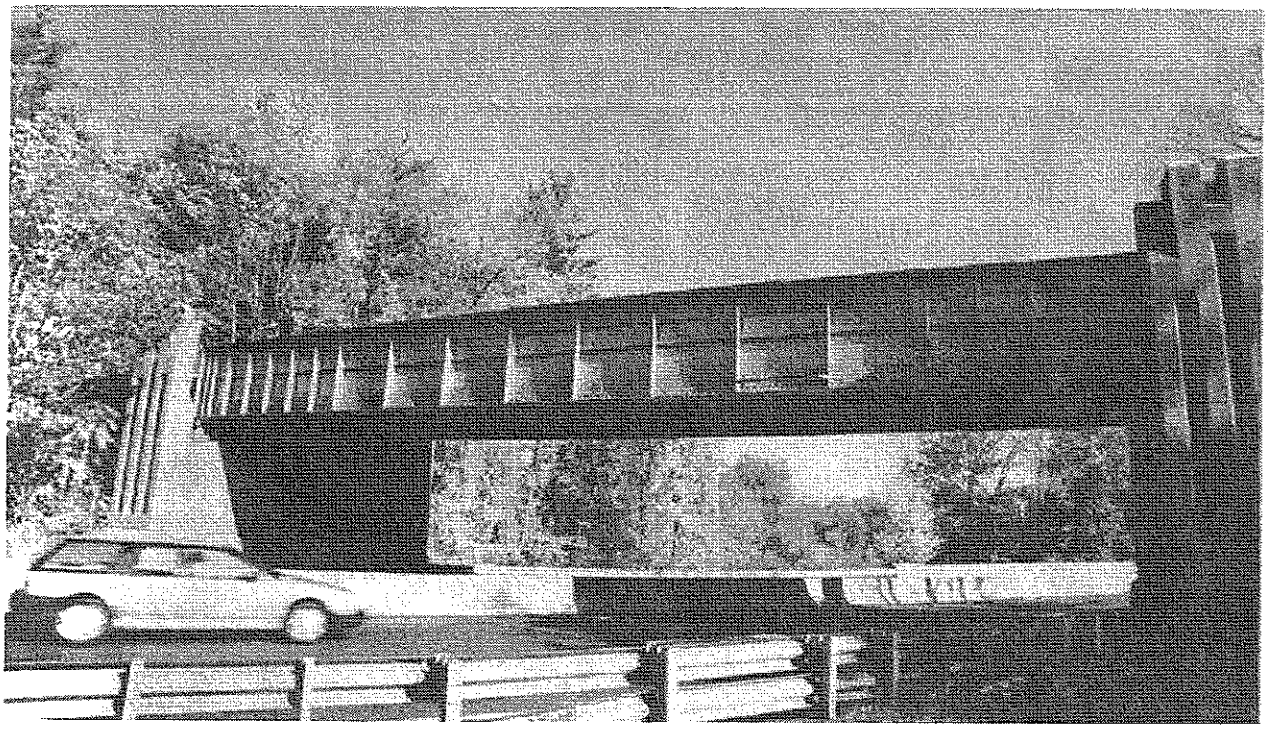




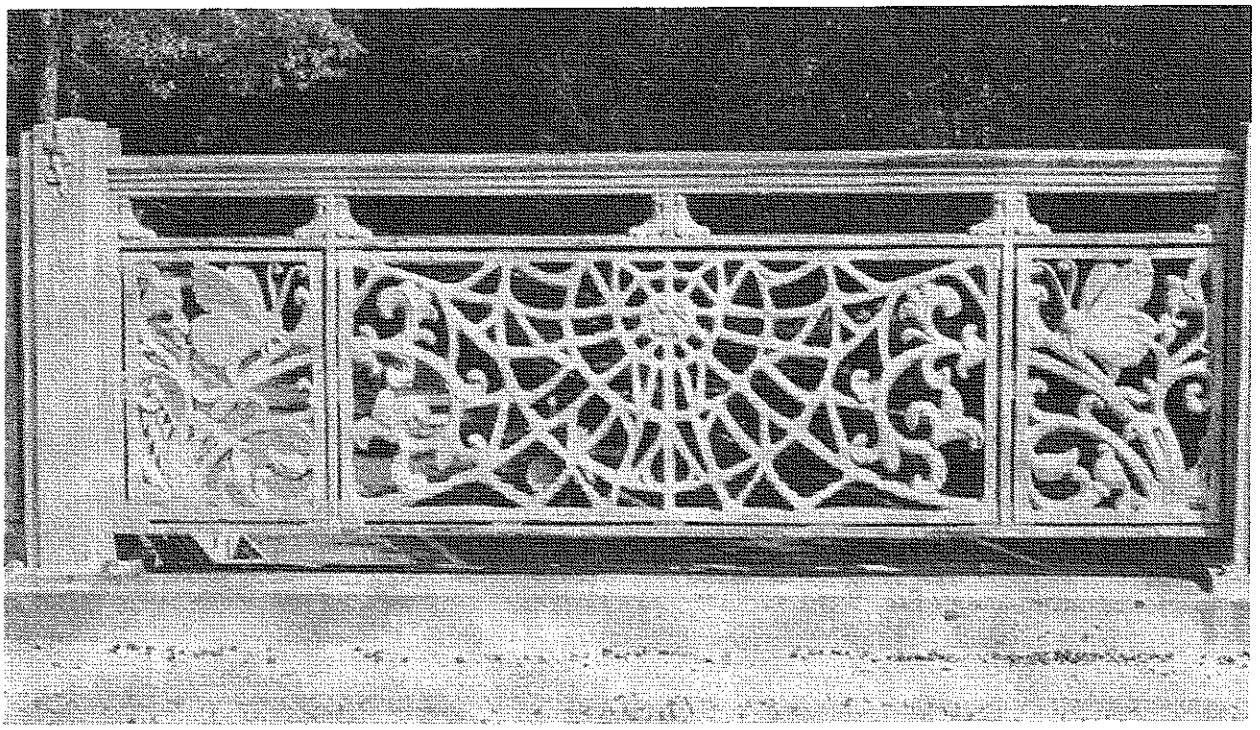
Top Photo:
Underside of steel frame of Bridge #728, over the Saugatuck River.

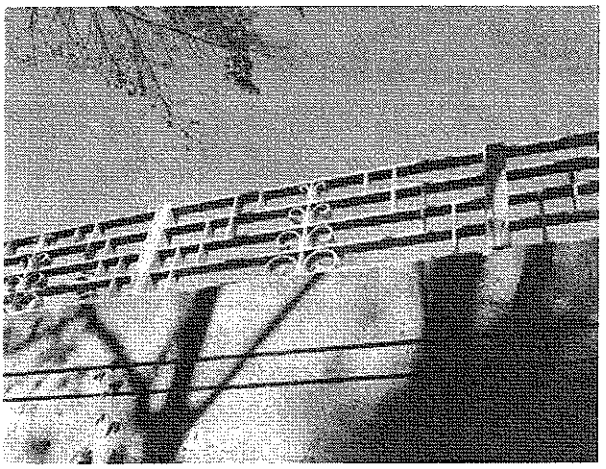
Bottom Photo:
Underside of steel frame of Bridge #728, over the Saugatuck River.





Top Photo:
Steel arched frame at Bridge # 696, Lake Avenue.
Bottom Photo:
Steel Box girder frame of railroad Bridge #751, Rocky Hill Road.



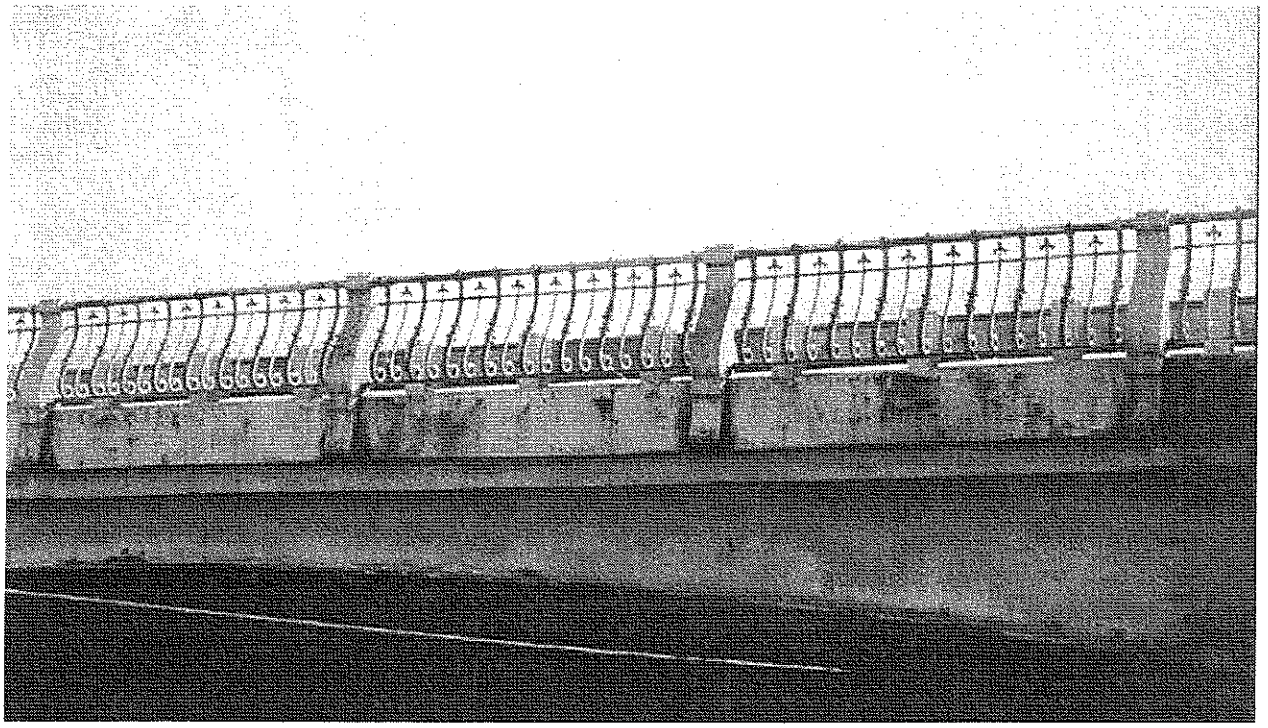


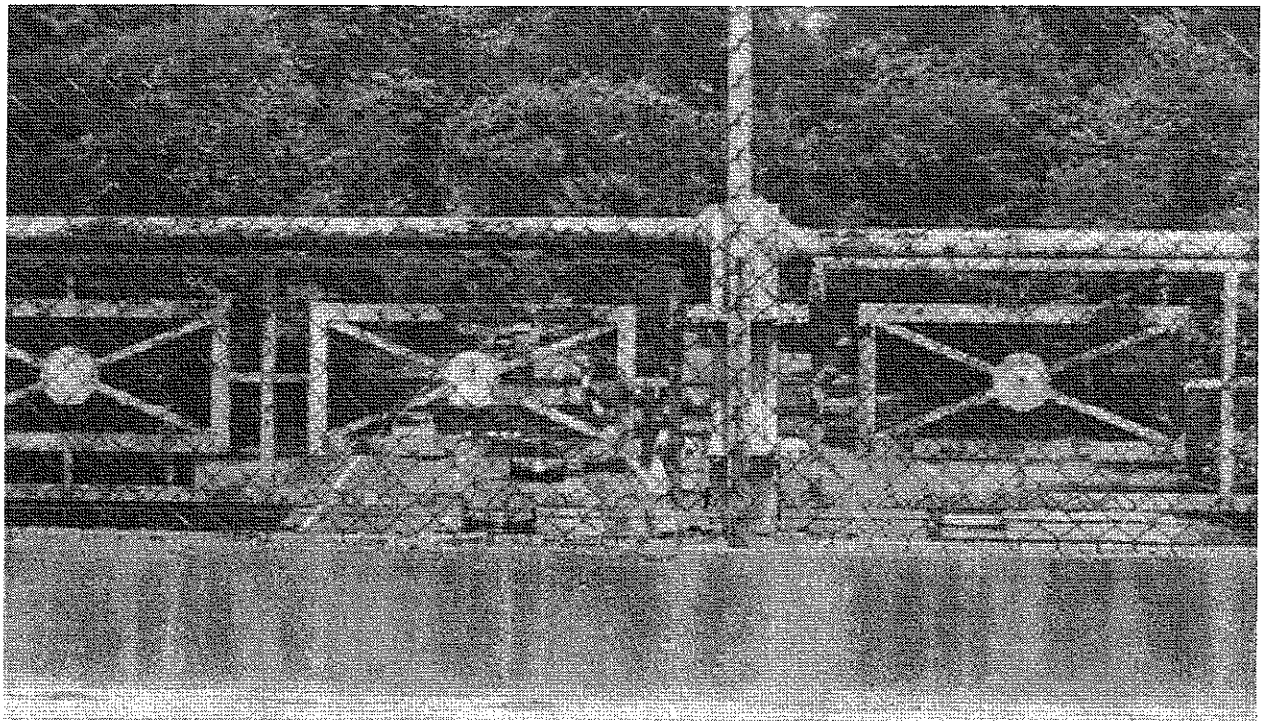
Top Photo:
Decorative cast iron railing at Bridge #735, Merwins Lane.

Bottom Photo:
Close up of ballustrade railing at Bridge #754, Main Street.

f. Ornamental Metals

A variety of ornamental metals were used for bridge railings and decorative panels attached to structural steel rigid frames. Ornamental metals were selected by Dunkelberger for use on the Parkway for the versatile forms which could be cast, hammered, bent, curved and twisted from them. The metal railings provide contrast in appearance to the concrete of the bridges, and to the more solid concrete railings. The original metals used include wrought iron, fabricated steel, cast iron, aluminum and cast brass. The metals were finished with paint, galvanized with zinc or in the case of the aluminum and brass, left uncoated.





Top Photo:
Decorative ballustrade railing on Bridge #760, Main Street.
Bottom Photo:
Corroded railing at Bridge #724, Grumman Ave.

Top Photo:
Close up of cast-in-place pilgrim ornament on pylon, Bridge #716, Comstock Hill Road.

2.2.3 Architectural Features and Details

Within the variety of architectural forms and structural systems which can be found on the bridges a number of significant elements can be identified. These features make up the distinctive architectural forms of the bridges along with the basic shapes, details, ornamentation, surface treatments, finishes, relief and sculpture. The descriptions of the bridges found in the individual bridge reports identify these features in greater detail.

Identification of the important elements of the bridge will serve to focus the restoration effort on those aspects of the bridge and emphasize the elements which are to be retained if modifications are made in the future.

Described below are bridge features which were given the greatest attention in the original design process. The particular details and treatment depends on the materials used. For instance, the decorative treatments for the concrete bridges are more elaborate than for the stone or cast stone masonry bridges. Similarly, decorative treatments and details for the steel frame bridges are also different.

While particular attention has been given to ornamental and decorative features of the bridges, the overall design is critical in the appearance of the bridge. This was an integral part of Dunkelberger and the State Highway Department's original design intent. Contemporary discussions of the bridges by Dunkelberger included detailed accounts of the thought that went into the original designs. Consideration of light reflectance and water shedding of surfaces are just a couple examples of the importance of detail in the overall design. The overall design should be taken into consideration when planning the preservation effort.

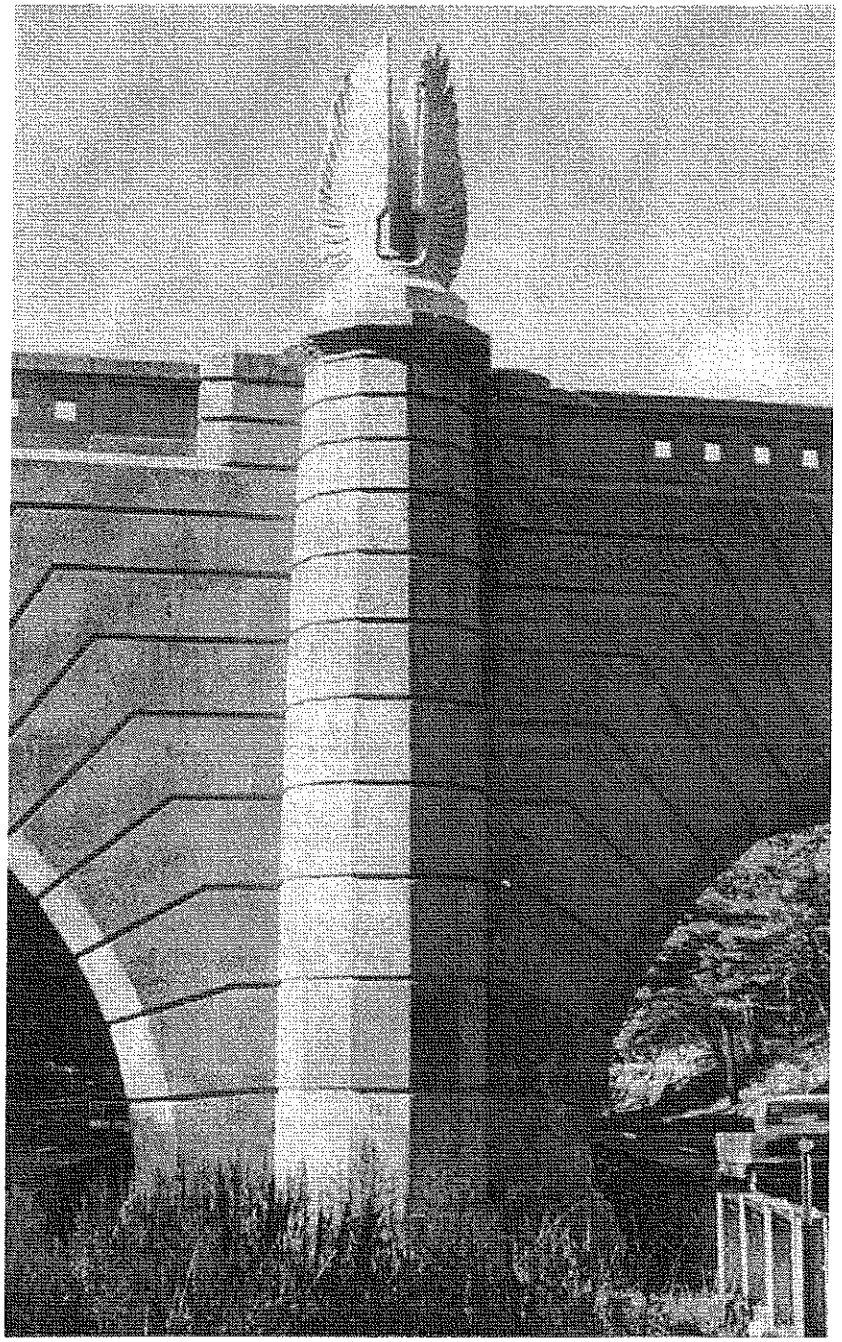


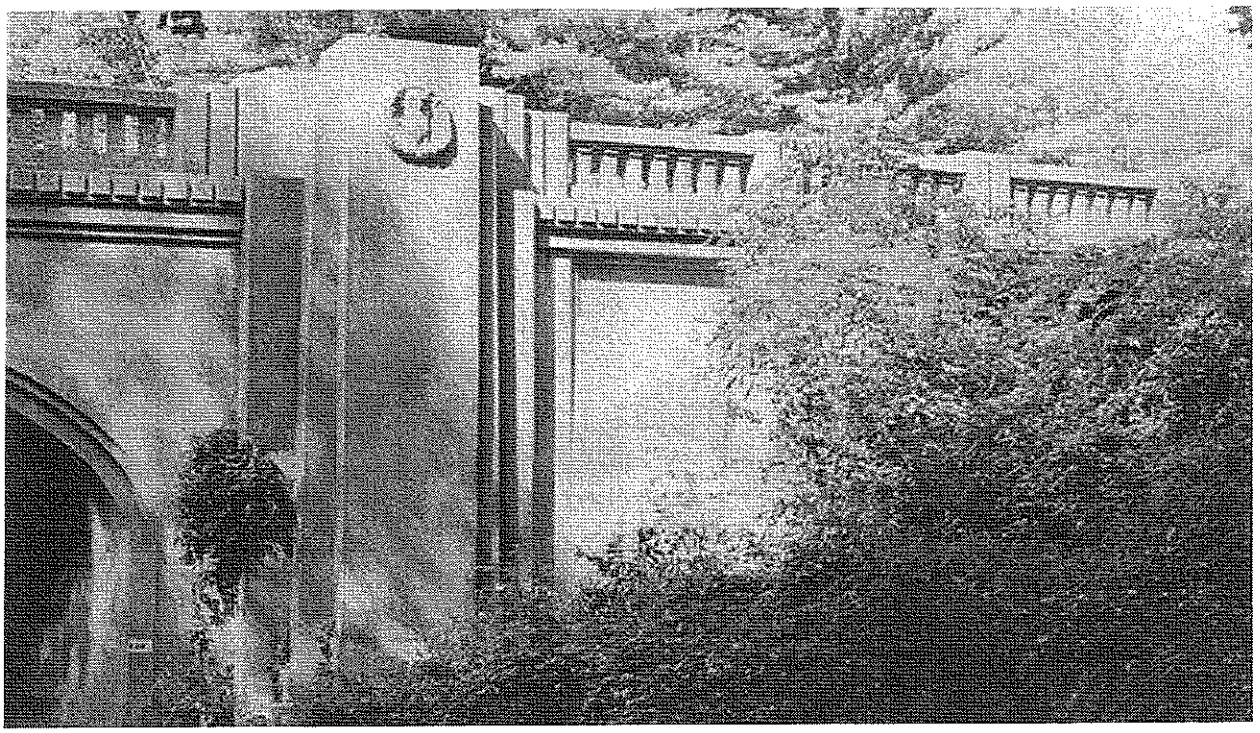
Photo:
Detail of center pylon , featuring a precast "Nike Wing" sculpture at Bridge #759, James Farm Road.

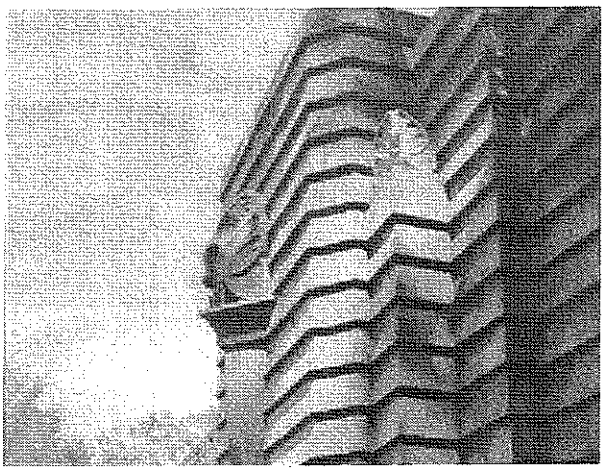
a. Pylons

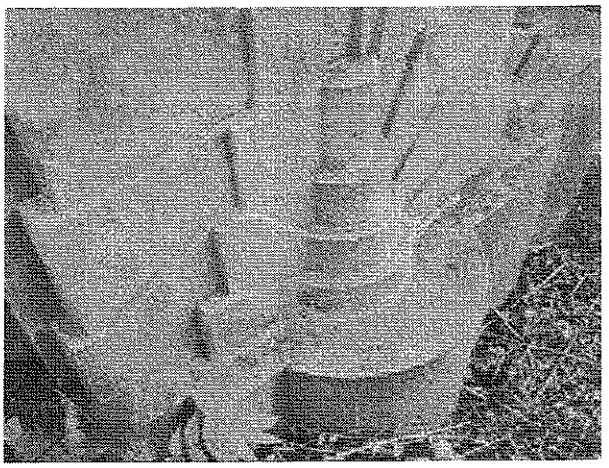
The bridge pylons facing the parkway, or roads crossing under the parkway, are prominent features which provided opportunities in the original design for vertical articulation and decorative panels or figures. Frequently extending above the parapet or railing by a few feet, the pylons break the horizontality of the bridges, and demarcate the opening. On the Art Deco bridges, the pylons were frequently designed to resemble a skyscraper of the period. Ornamentation of pylons range from the Native American and Pilgrim figures on the Comstock Hill bridge in Norwalk, to the original cast iron grills at the Huntington Turnpike overpass in Trumbull.

This often buttress-like feature at either side of the span is an important architectural and decorative feature of the bridges.The shape of the pylon adds to the architectural expression and is further enhanced through the use of ornamental features and finishing techniques.

On the masonry bridges the pylons are simpler and without ornamentation. The Guinea Road overpass at Stamford is a masonry bridge without pylons.



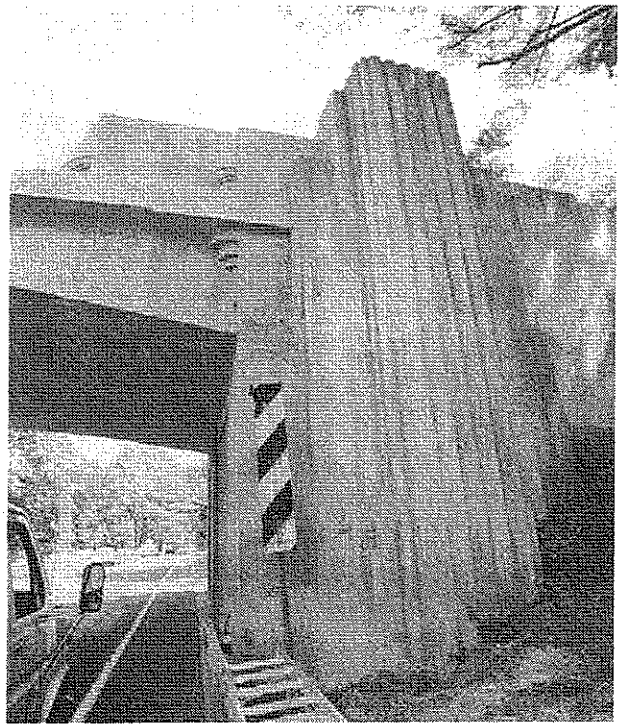


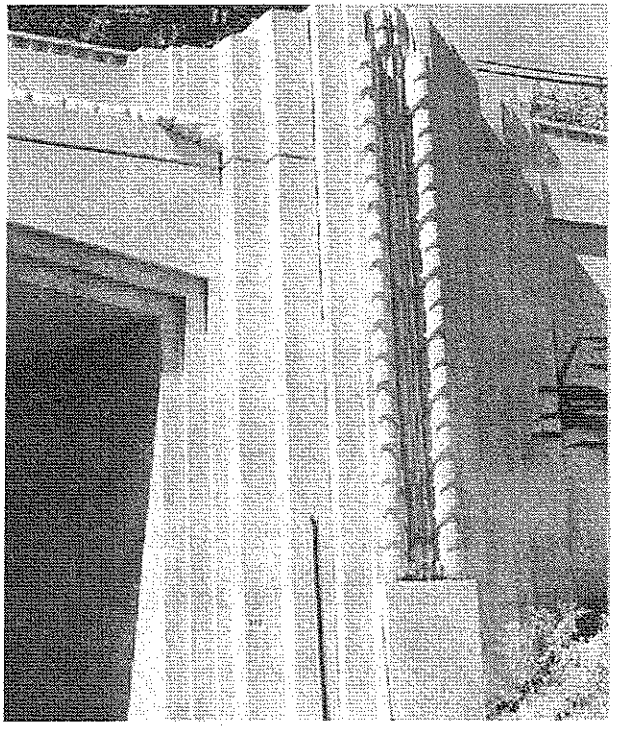


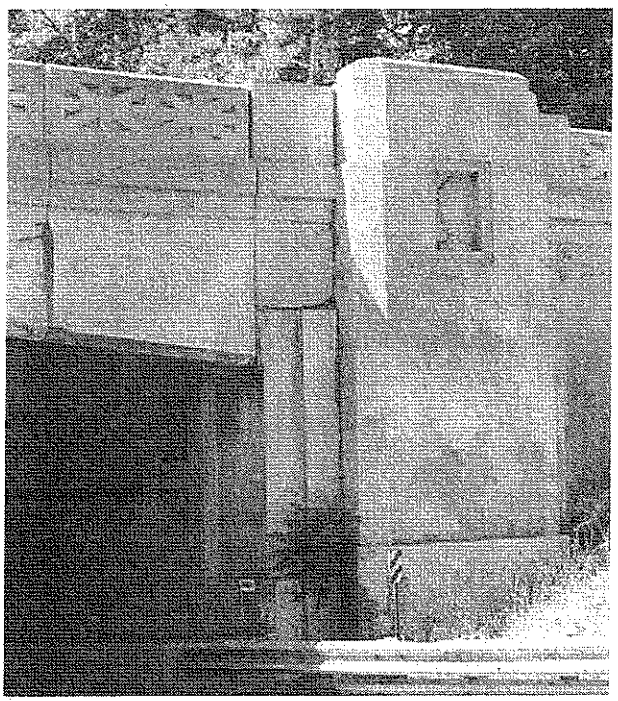
Top Photo
Pylon at Bridge #738, Hillside Road, featuring a cast in place owl ornament

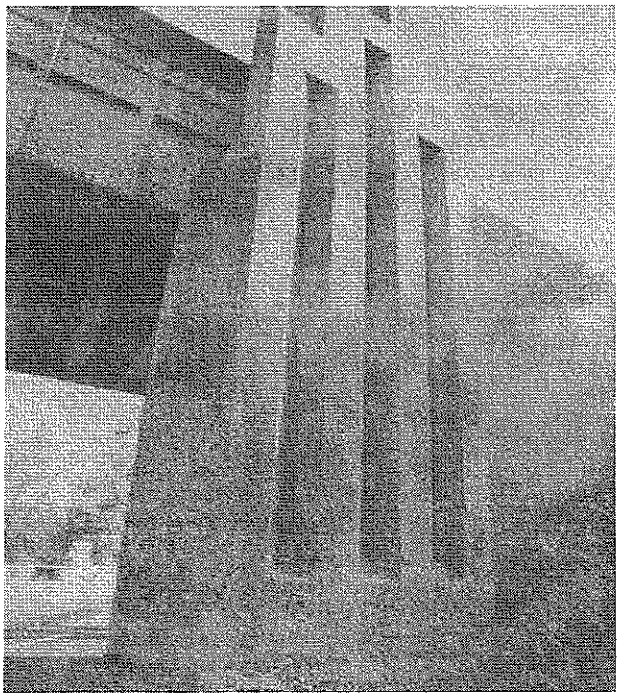
Bottom Left Photo:
Pylon at Bridge # 735, Merwins Lane featuring pre-cast butterfly ornaments.

Bottom Right Photo:
Detail of Art Deco pylon base at Bridge # 723, East Rock Road.



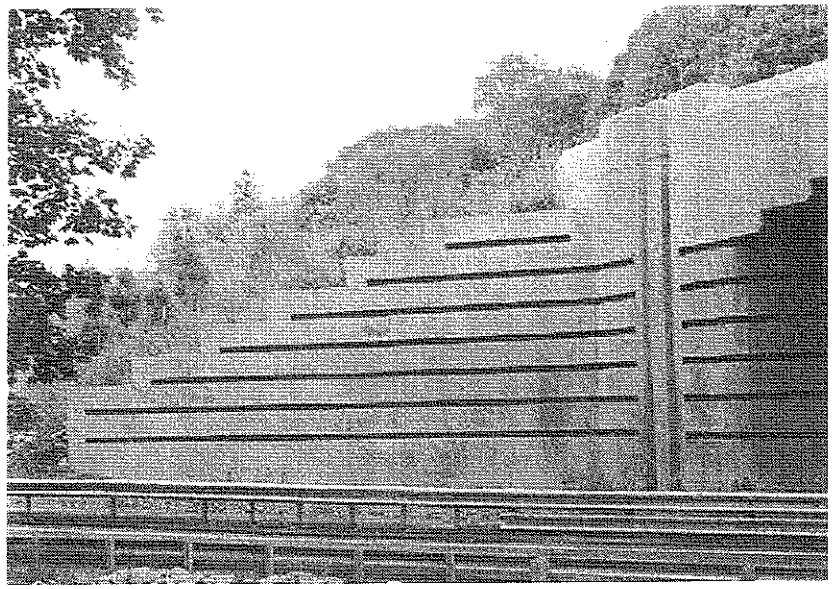




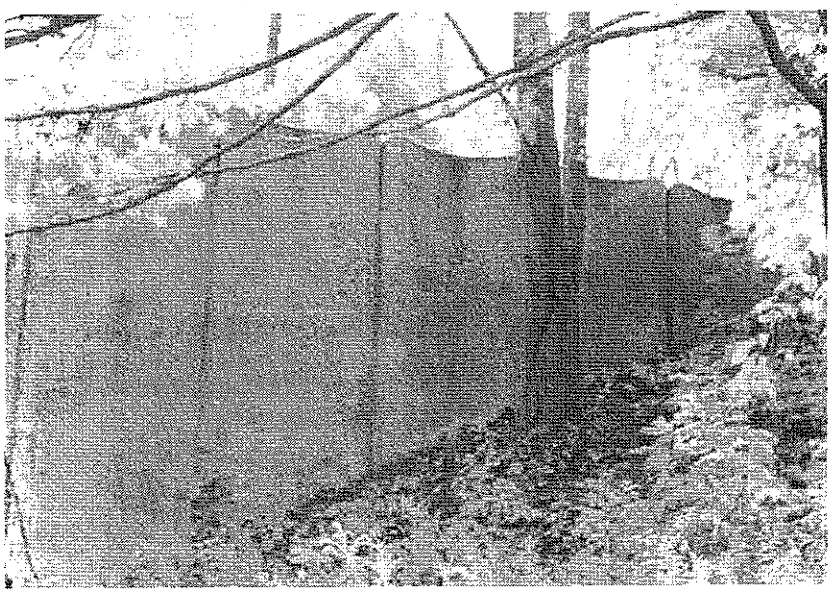


Top Left Photo:
Pylon at Bridge # 707, Newfield Avenue, incorporating a skyscraper motif.
Bottom Left Photo:
Pylon at Bridge # 714 (renumbered #5811), Marvin Ridge Road with inset urn.

Top Right Photo:
Pylon at Bridge # 713,White Oak Shade Road with floral motif.
Bottom Right Photo:
Pylon at railroad Bridge # 751,Rocky Hill Road features simple and bold design.



Above Photo:
Horizontal grooves create a strong pattern on the wing wall of Bridge # 731, Easton Avenue (Route 136).



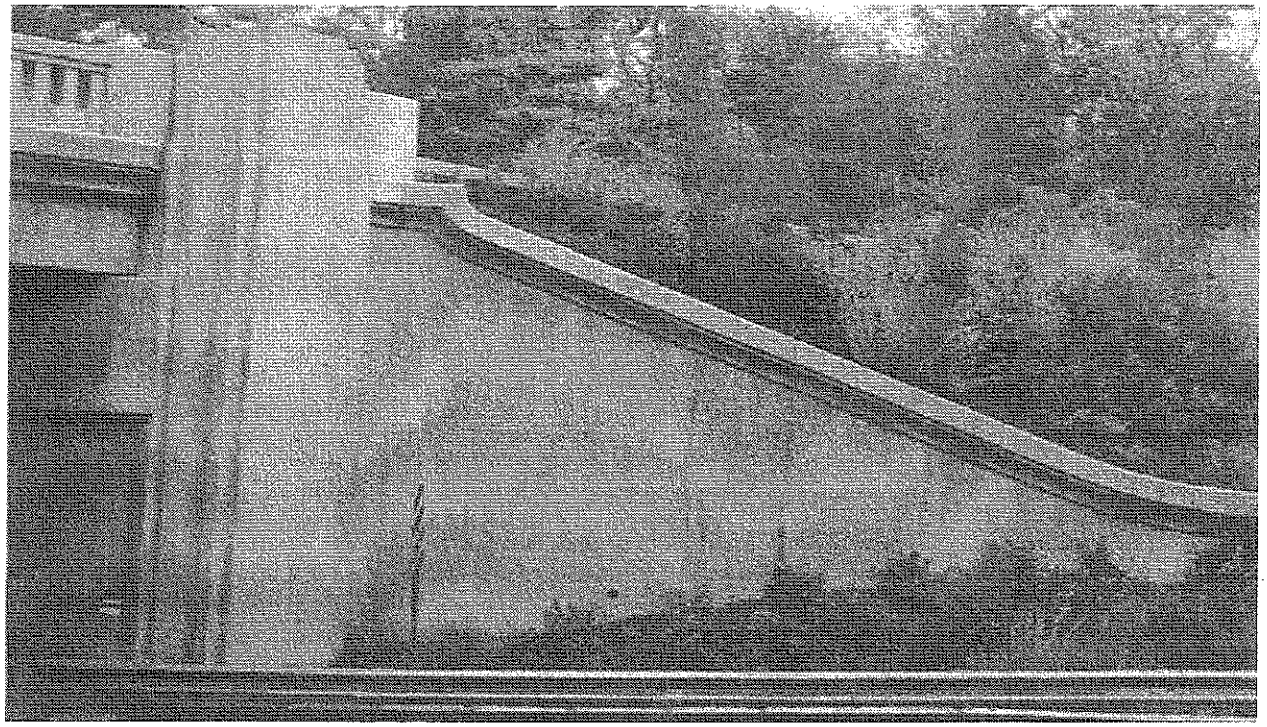
Above Photo:
Undulating cast-in-place concrete facade located on the wing wall at Bridge #747, Madison Avenue.

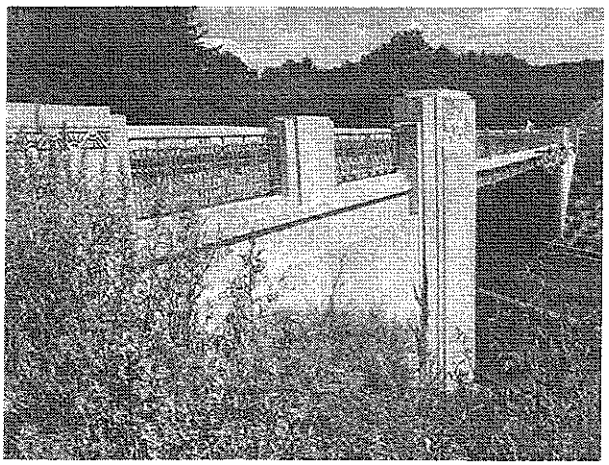
b. Wing walls

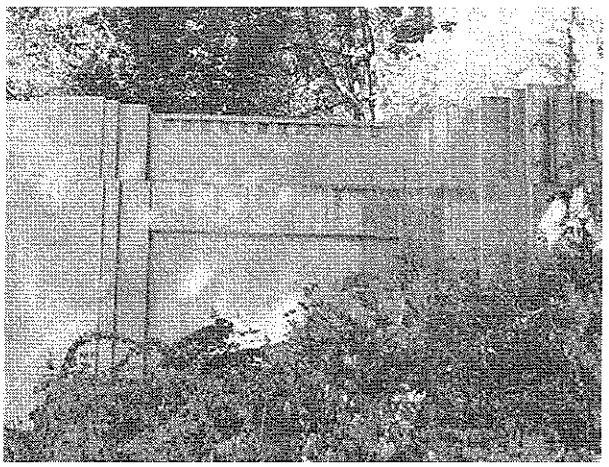
The integral design of wing walls with other features of the bridge was Dunkelberger's attempt to "relieve the flat surface" of concrete bridges, and to make a single structure instead of portions tied together by only a railing or parapet running the length of the bridge.

Like the other features that constitute the facade of the bridge, wing walls were often locations for ornamental treatment and articulation. Frequently the watertable or cornice molding is repeated across the face of the wing-walls, and end piers appear as smaller and more simplified versions of pylons. Some of the wing walls have pilasters with articulated panels between. Occasionally the panels, are arched, quoined or have a tooled concrete surface.

These flanking walls are no longer easily visible because of the overgrown existing vegetation.



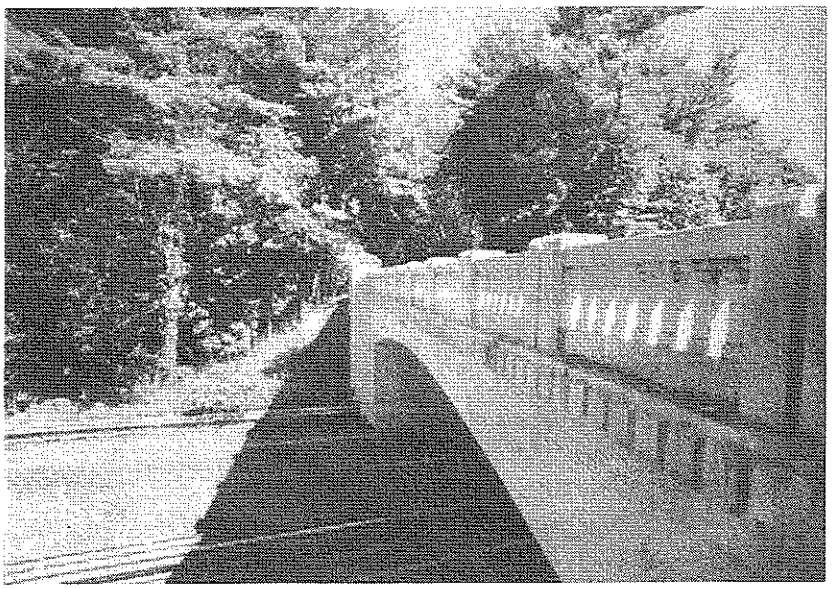




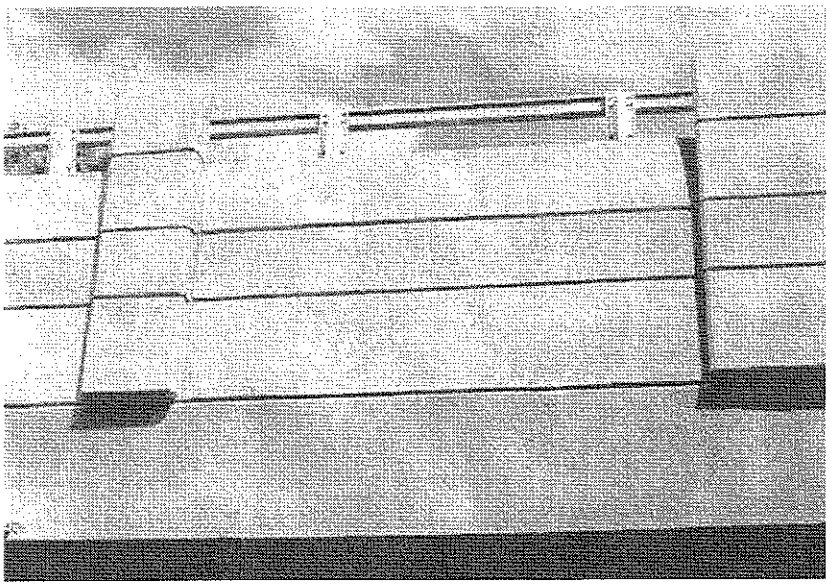
Top Photo:
Wingwall with classically detailed cap on Bridge # 727, Route 33 (Wilton Road).

Bottom Left Photo:
Reconstructed wingwall and balustrade of Bridge #706, High Ridge Road.

Bottom Right Photo:
Wingwall facade with geometric and floral motifs at Bridge #713, White Oak Shade Road.



Top Photo:
Simple classical forms and uncomplicated detailing create strong shadows on the Balustrade of Bridge #699, Stanwich Road.

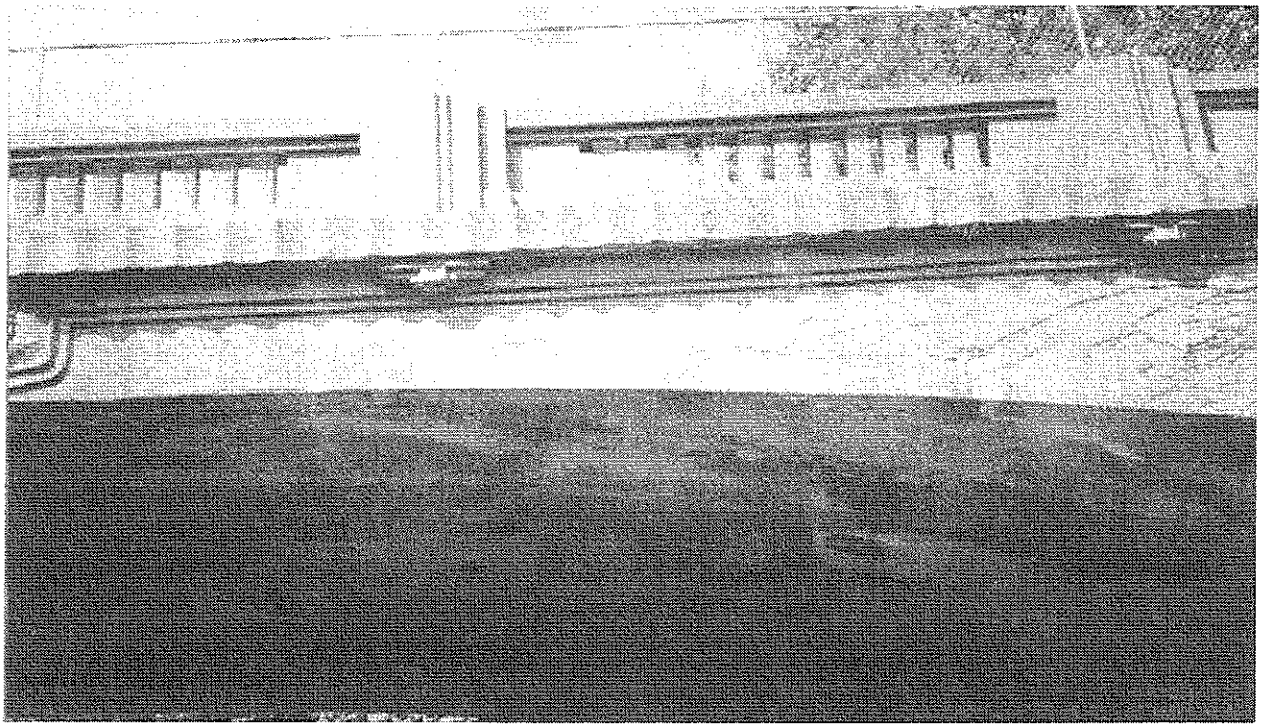


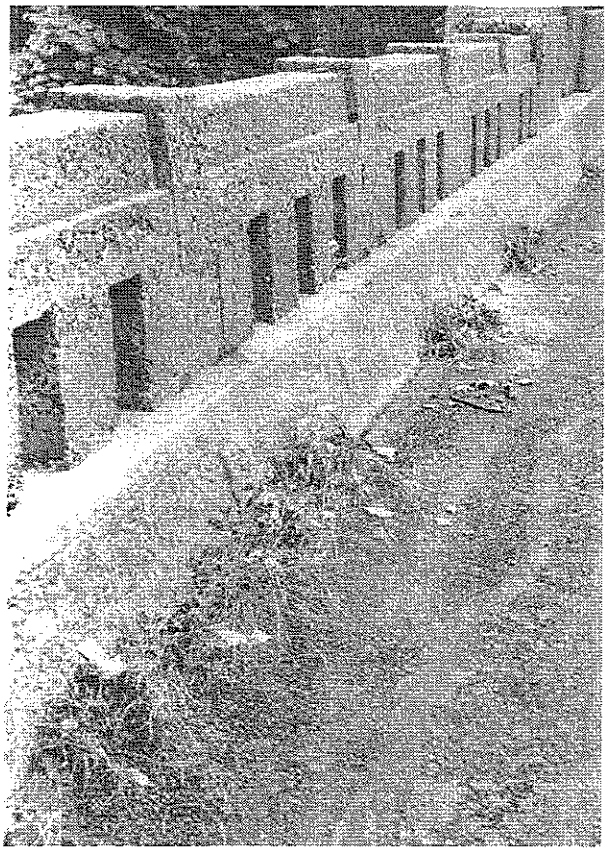
Bottom Photo:
Balustrade (non-original) on Bridge # 728, Saugatuck River.

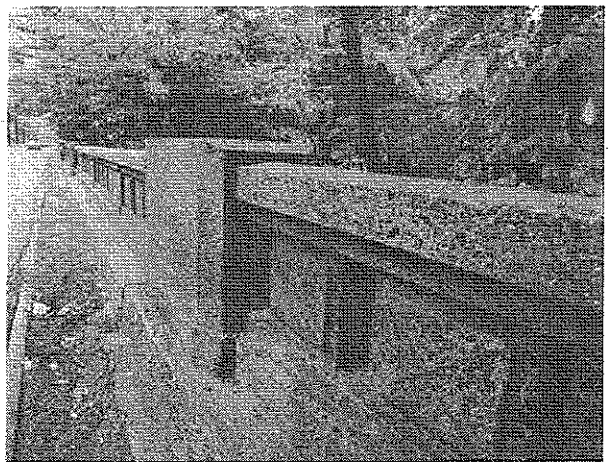
c. Railings and Parapets

An important element of all bridges is the railing or parapet which is an integral part of the overall design. Most often of concrete, they were also constructed of cast stone and ornamental metal. Depending on the material and particular design, the amount of transparency of the railing can vary substantially, with specific design adding further contrast and interest. Open concrete balusters created a lighter appearance and the added depth of shadows. Metal railings provided the most contrast with their light appearance and colored finishes. Ornament was integrated into the designs, with curved or bent wrought iron, steel or cast iron decoration welded to the railing. Occasionally stock components from catalogs of the period were used, but most often the railings were custom fabricated to the specifications of the architect's imagination.

Because they are important safety features, preservation of the original railings is a complex design consideration for the future of the Parkway. The contemporary use of safety barriers along the roadway has adversely affected the transparency and detailing of many of the original railings.



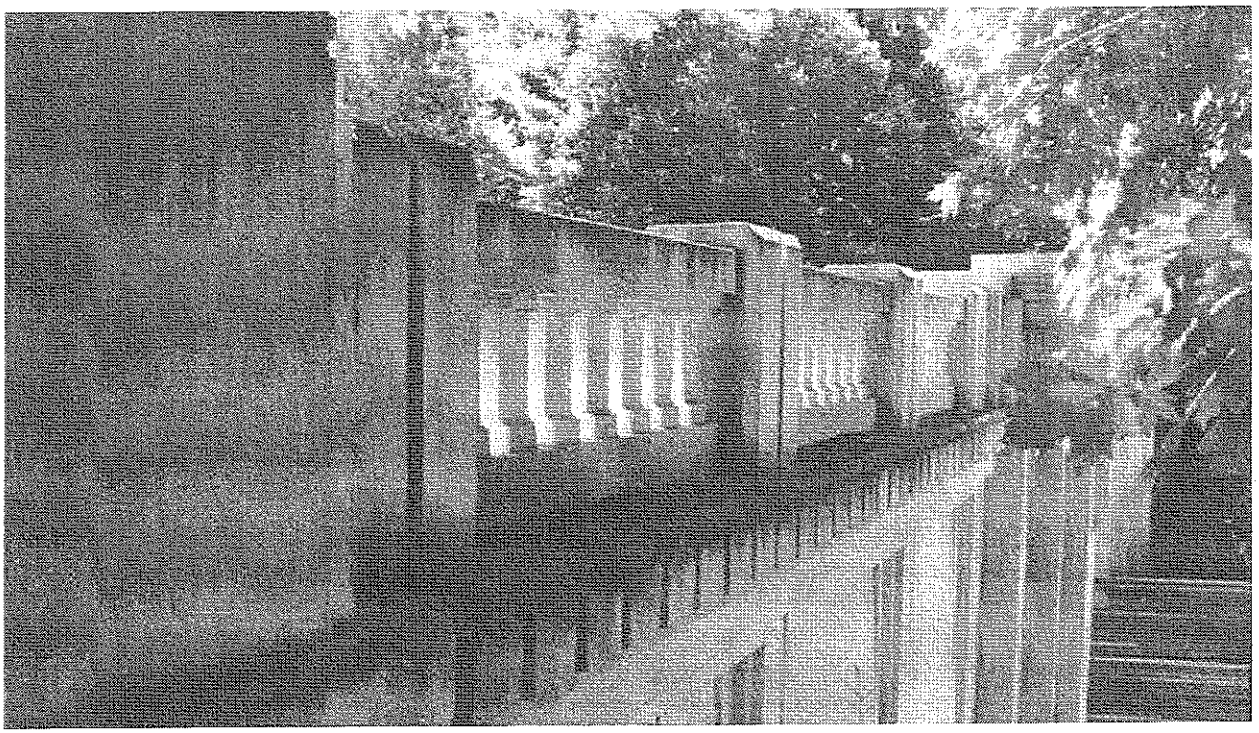


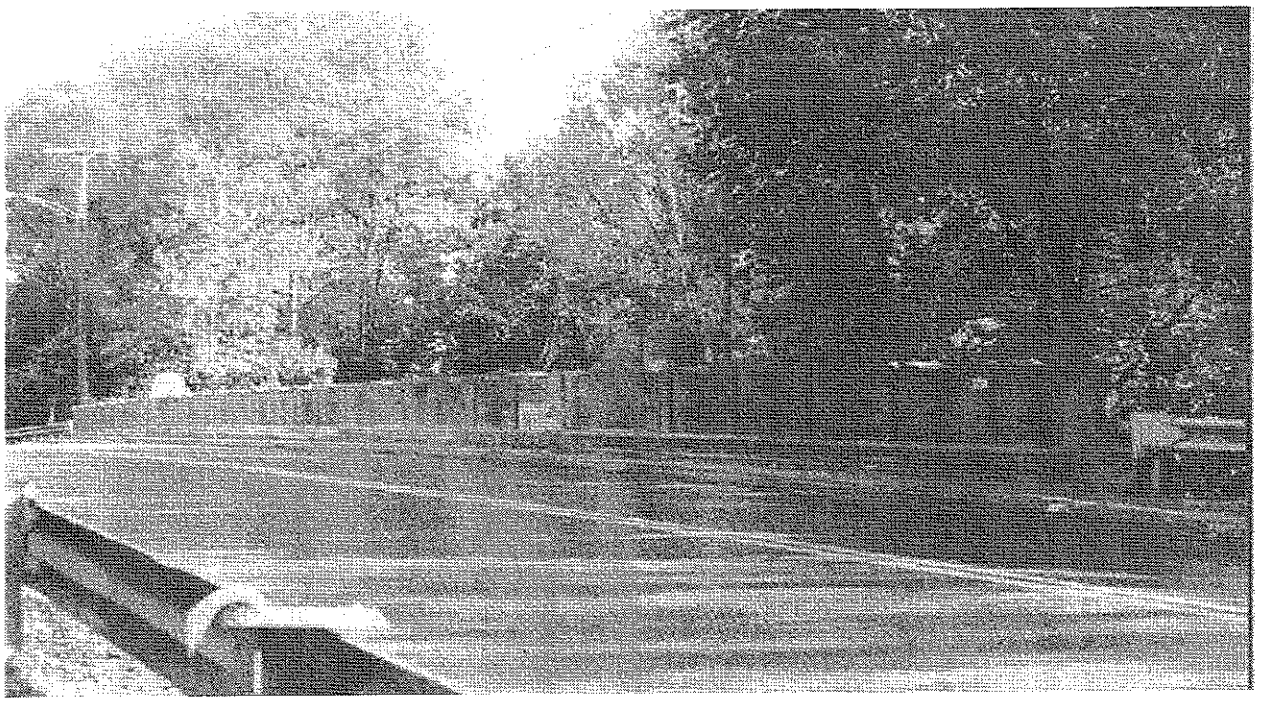


Top Photo:
Open concrete balustrade on Bridge #722, West Rock Road allows light to pass through railing.

Left Photo:
Concrete balustrade on Bridge # 734, Cross Highway. Note that the openings have been partly eliminated with the addition of the concrete safety barrier.

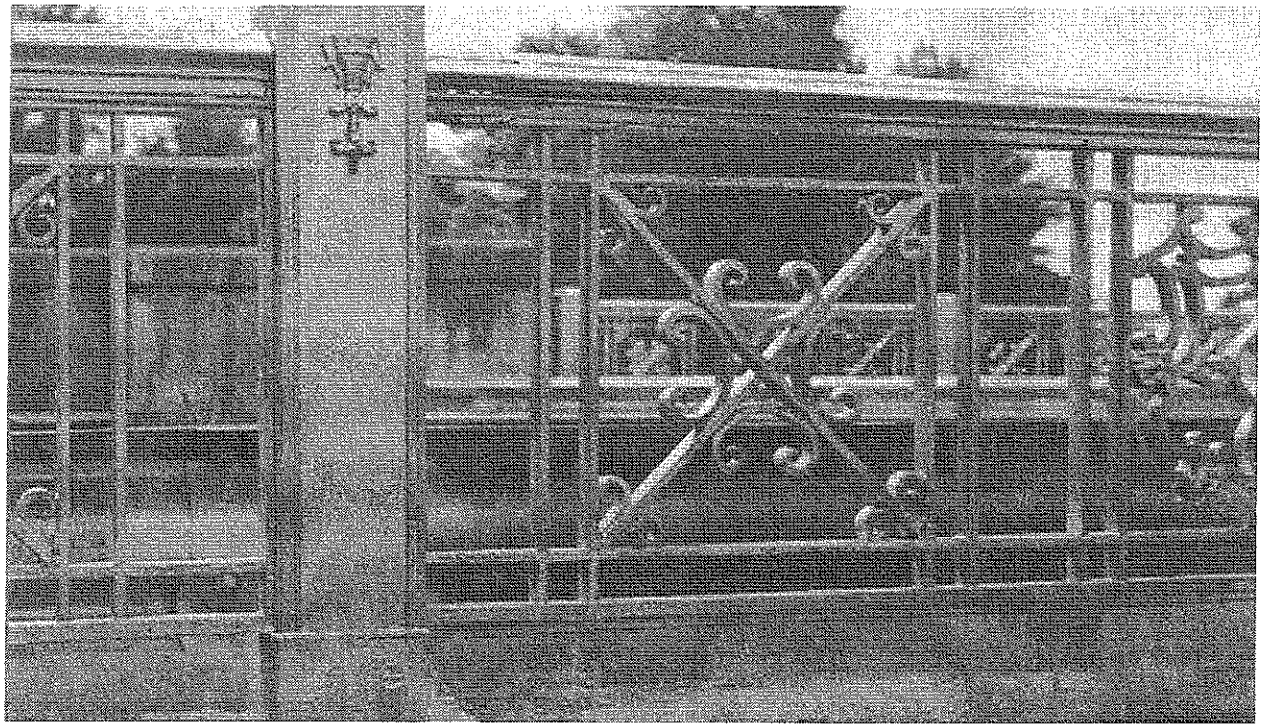
Right Photo:
Concrete balustrade on Bridge #733, Bayberry Lane.

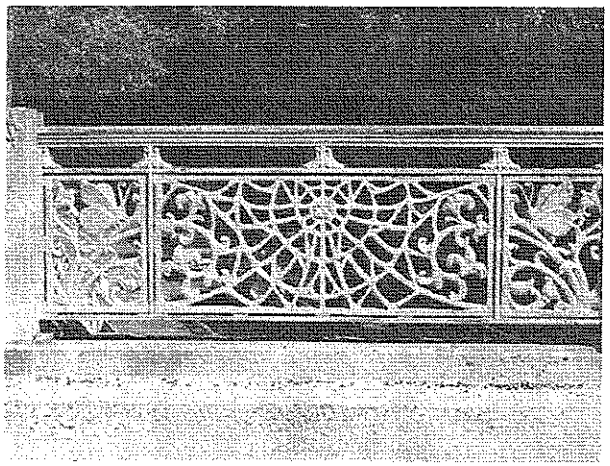


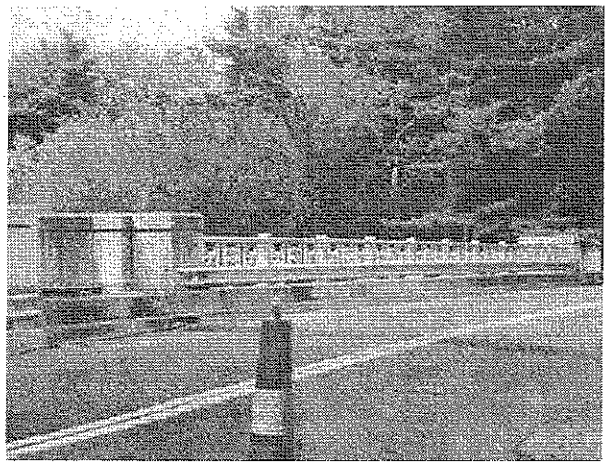


Top Photo:
Open concrete balustrade on Bridge #699, Stanwich Road.

Bottom Photo:
Overall view of undulating concrete balustrade, Bridge #747, Madison Avenue.



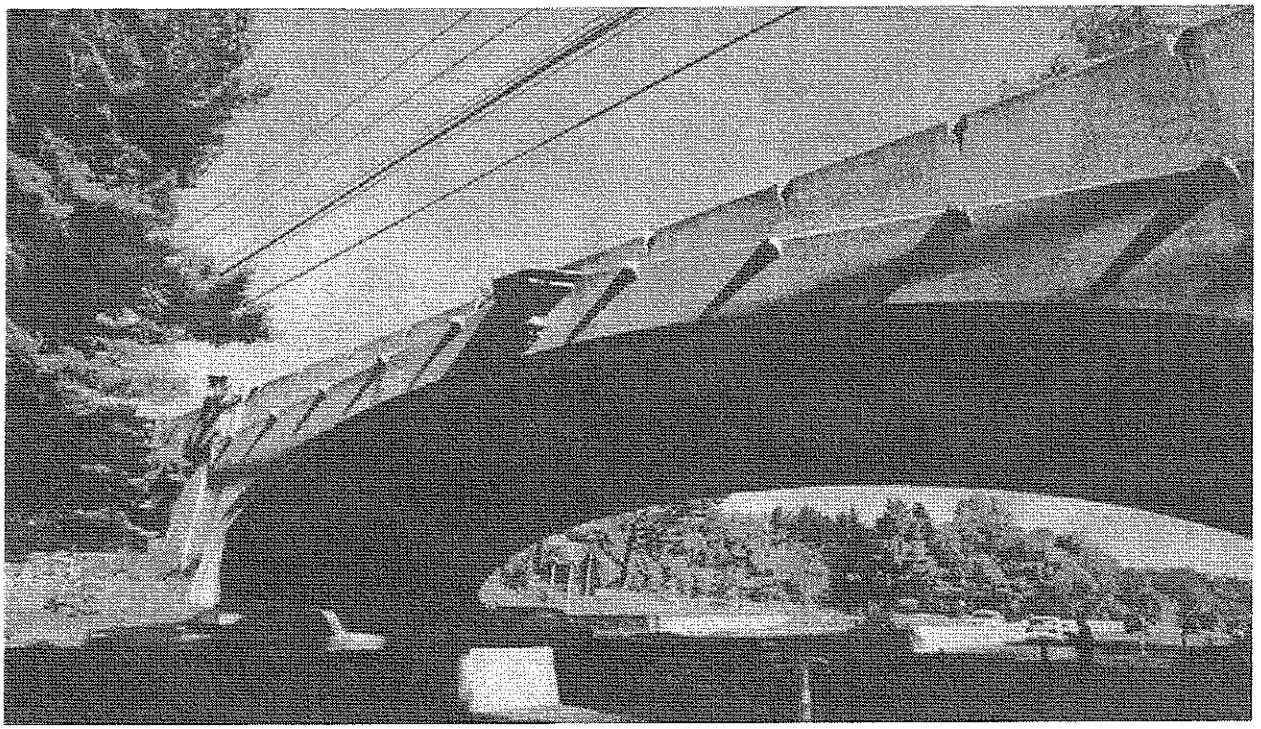


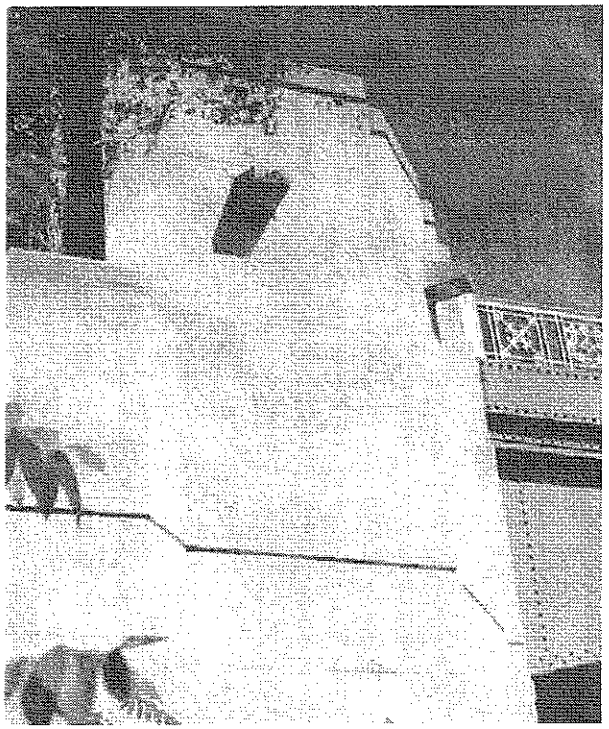


Top Photo:
Decorative ironwork on the balustrade of Bridge # 729, Clinton Avenue.

Bottom Left Photo:
Decorative cast ironwork, featuring spiderweb and butterfly motif on the balustrade of Bridge # 735, Merwins Lane.

Bottom Right Photo:
Overall view of iron balustrade of Bridge #729, Clinton Avenue.



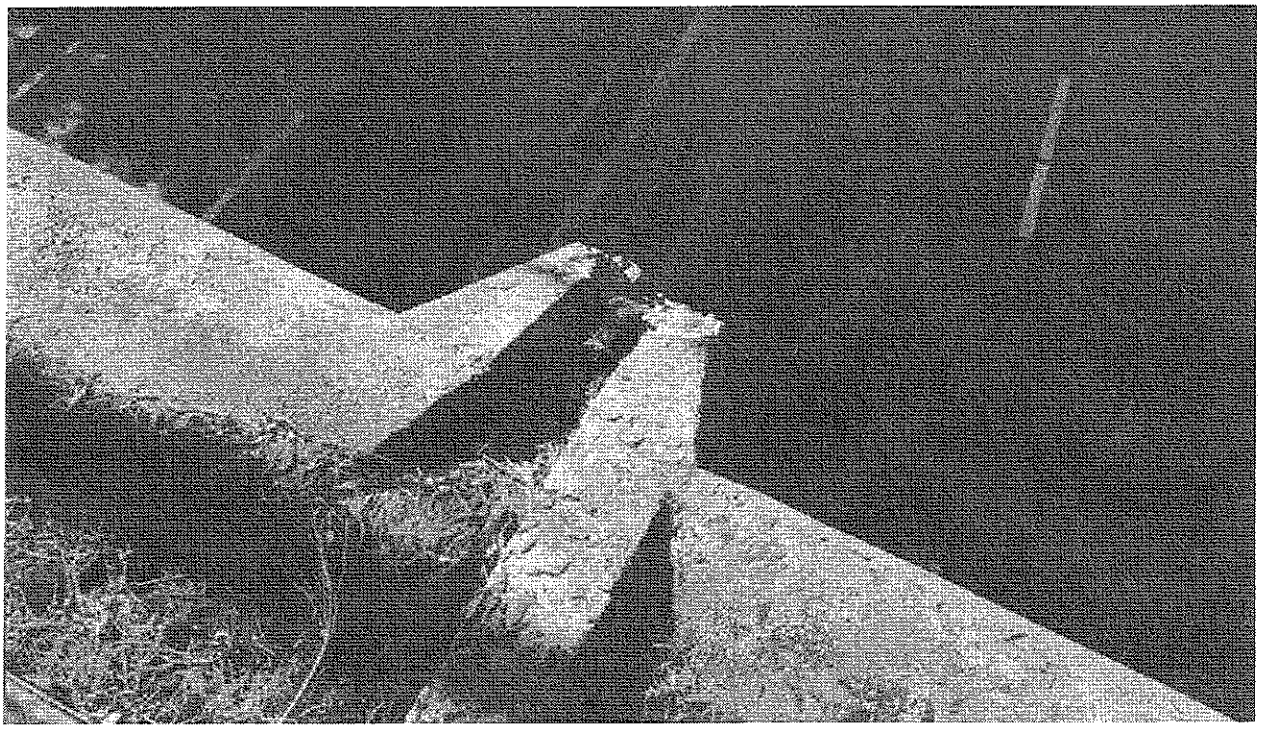


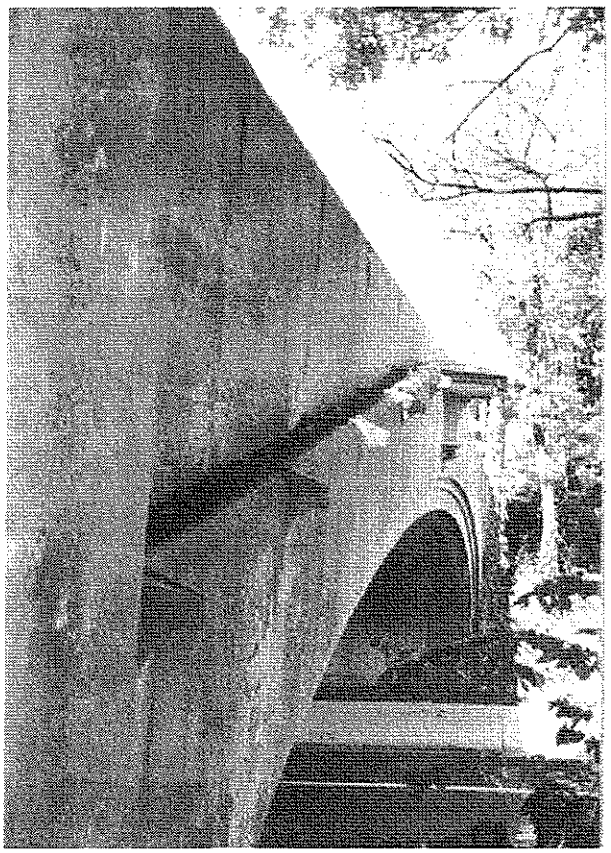
Top Photo:
Concrete water scuppers on Bridge #745, Park Avenue are incorporated in the bridge design.

Bottom Photo:
Projecting water scuppers are also incorporated into the design of the turreted pylons on Bridge #729, Clinton Avenue.

d. Watertables

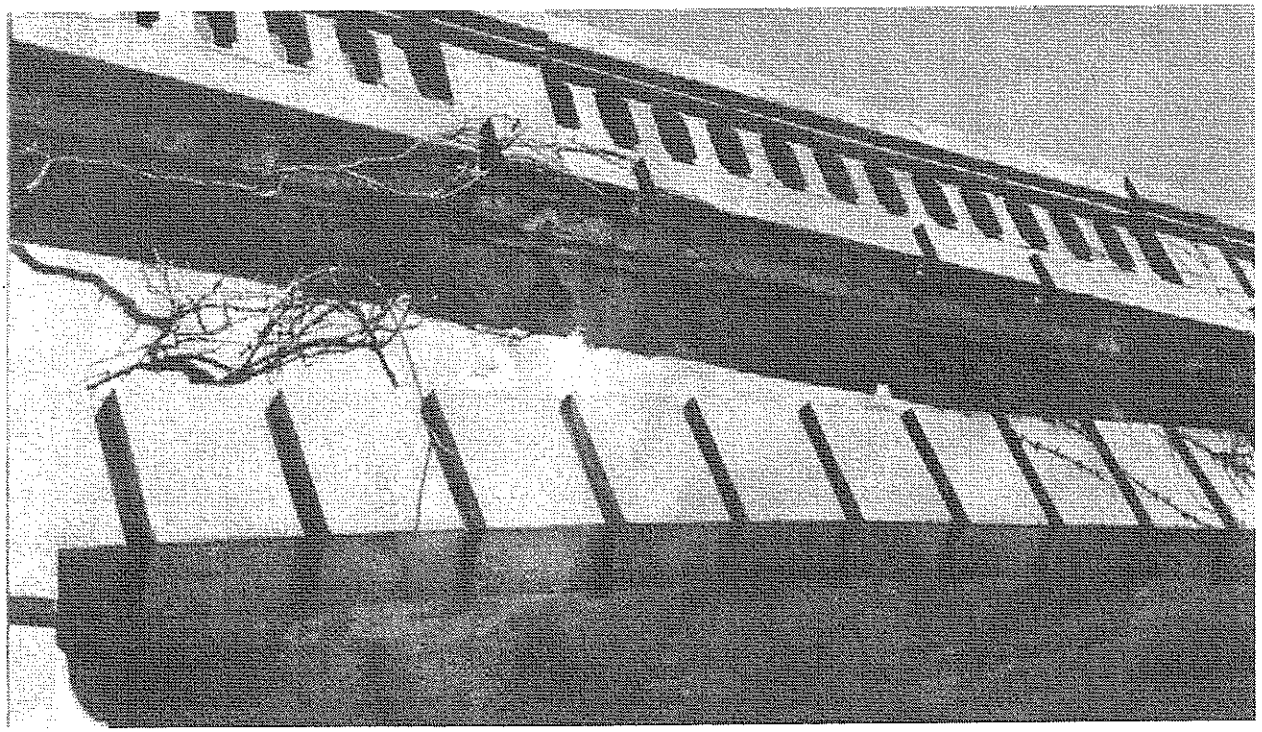
Watertables or scuppers, are incorporated into the majority of the concrete bridges to shed water and prevent the accumulation of dirt and stains on the vertical surfaces, a major concern of Dunkelberger. Typically drips were used on the underside to reduce staining of the face of concrete surfaces below the banding. The watertables frequently have ornamental treatments such as precast inserts or sawtooth banding. Water tables and scuppers are important to the overall design of the bridges as articulation and for their water shedding properties.

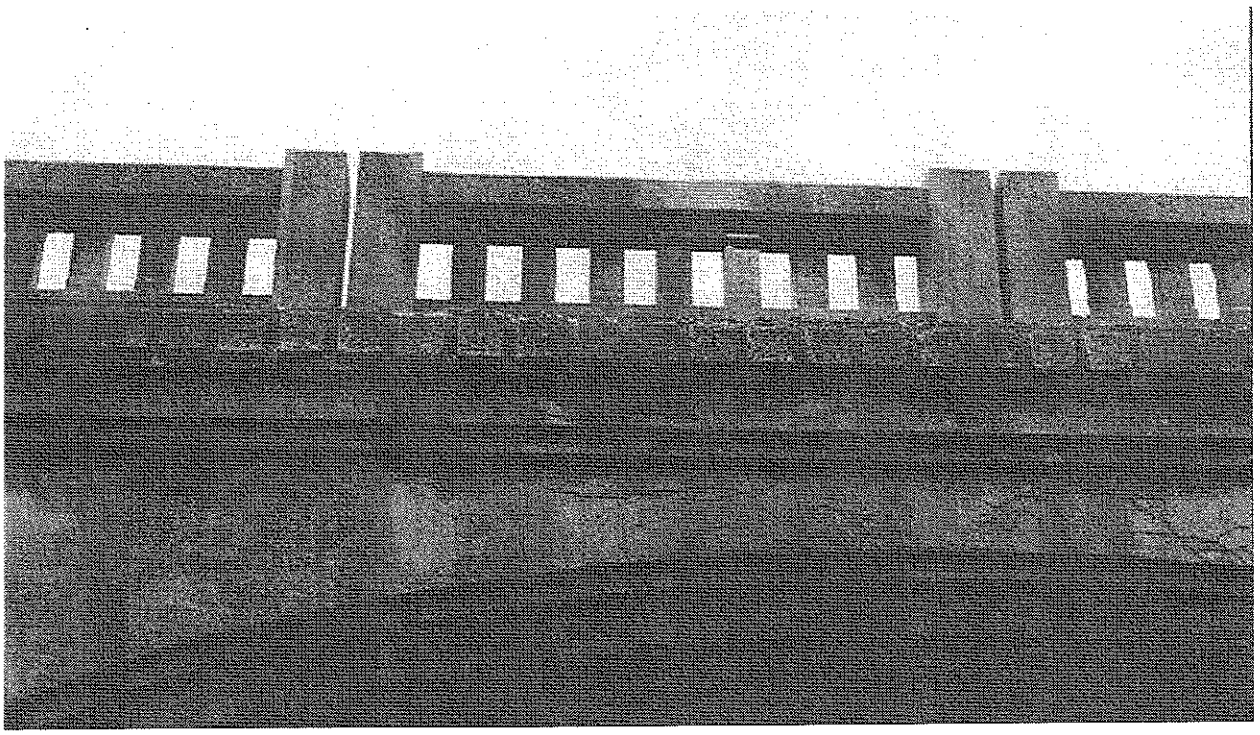




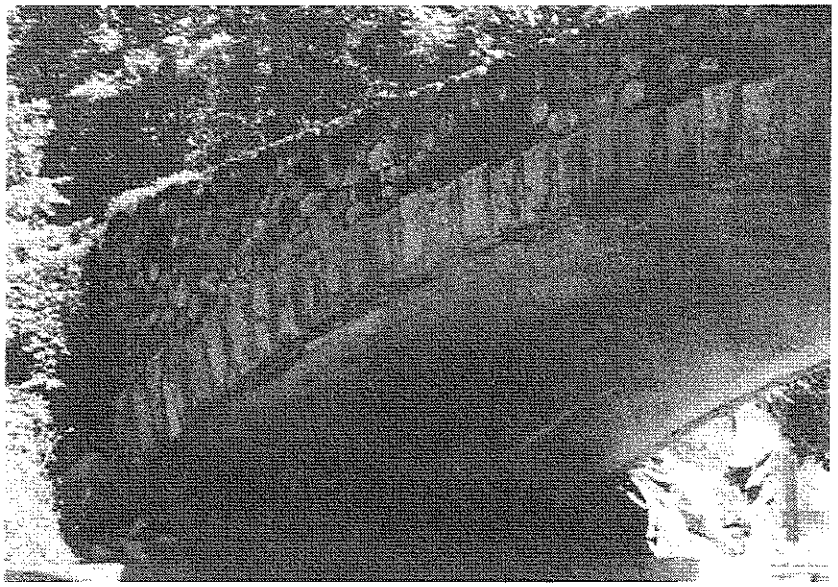
Top Photo:
Detail of concrete scupper on Bridge #745, Park Avenue. Note that vegetation has obstructed the path for water to flow and the scupper needs repair.

Left Photo:
View of Bridge #745, Park Avenue, showing watertable and projecting concrete scuppers.





Top Photo:
Watertable on Bridge #733, Bayberry Lane.
Bottom Photo:
View of concrete watertable with dentil work on Bridge #738, Hillside Road.



Top Photo:
Reinforced concrete arch on Bridge #700, Guinea Road

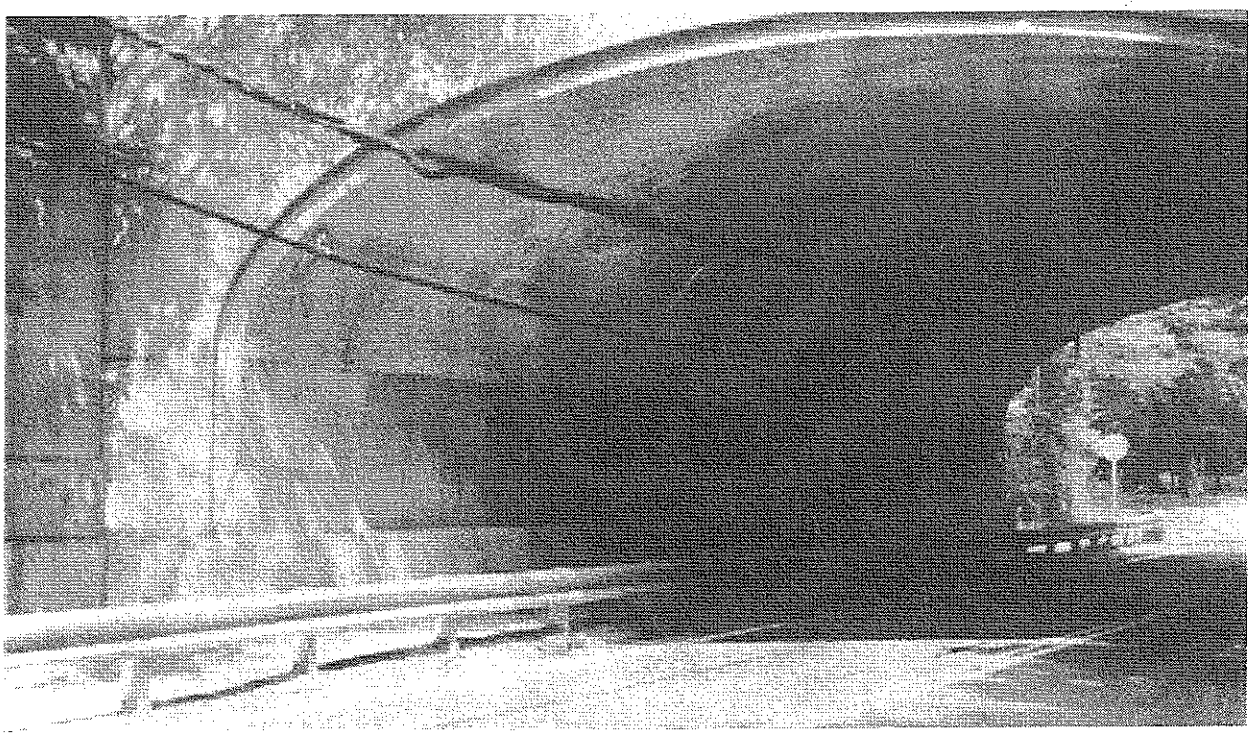
Bottom Photo:
Reinforced concrete rigid frame over Silvermine Avenue featured on Bridge #717.

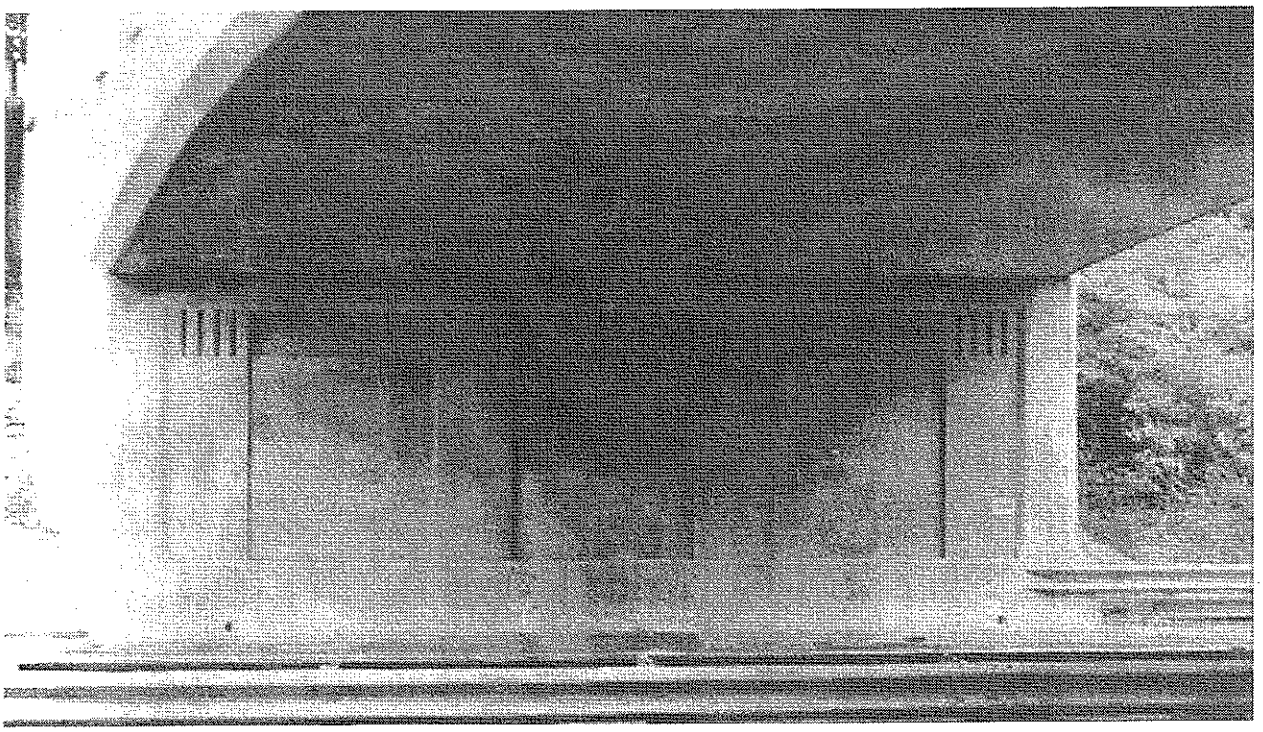
e. Intrados and Abutments

The *intrados* or underside of overpasses is typically vaulted expressing the form of the concrete frame, which is most often, arched. The intrados is typically smooth concrete , with a recessed drip edge located close to the outer edges. The intrados generally do not have significant architectural features beyond the overall shape of the arch itself.

In many instances the intrados has seen considerable repair work. The overall perception of this surface is important in terms of maintenance but the surfaces have limited historic significance.

Abutment walls facing the roadway are curbed at the base and often have vertical pilasters with articulation similar to the pylons, but much more simplified. Between the pilasters there may be panels which are arched or have a tooled concrete surface. While significant in the structural sense the abutement walls do not play a critical role from a historical perspective. The level and type of maintenance of this area is however important in the overall perception of the state of repair and preservation of the bridges.





Top Photo:
Barrel vault archway of Bridge #725, Route 53.
Bottom Photo:
View of underside of concrete vault on Bridge #739, Burr Street, with vertically grooved pilasters

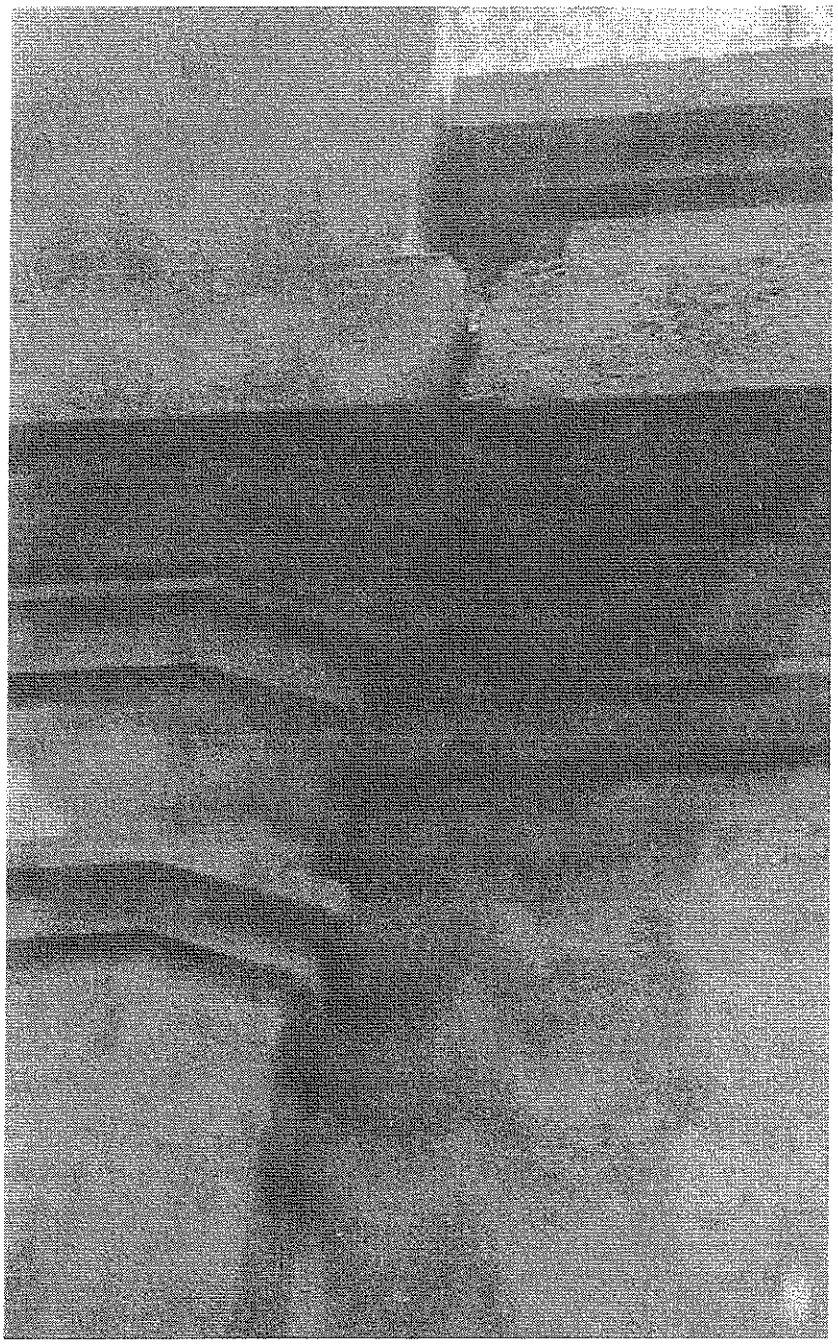


Photo:
Expansion joint at junction of parapet and pylon on Bridge #733, Bayberry Lane.

f. Expansion joints

The bridges were designed with vertical expansion joints located at the joint between the frames and the wing walls. The joints were designed to be continuous through the bridge parapet and deck of the upper roadway. The joints are important because they allow for movement between the spanning portion of the bridge and the abutments. The location of the joints was an important design consideration for Dunkelberger in order that they not interfere with the overall design.

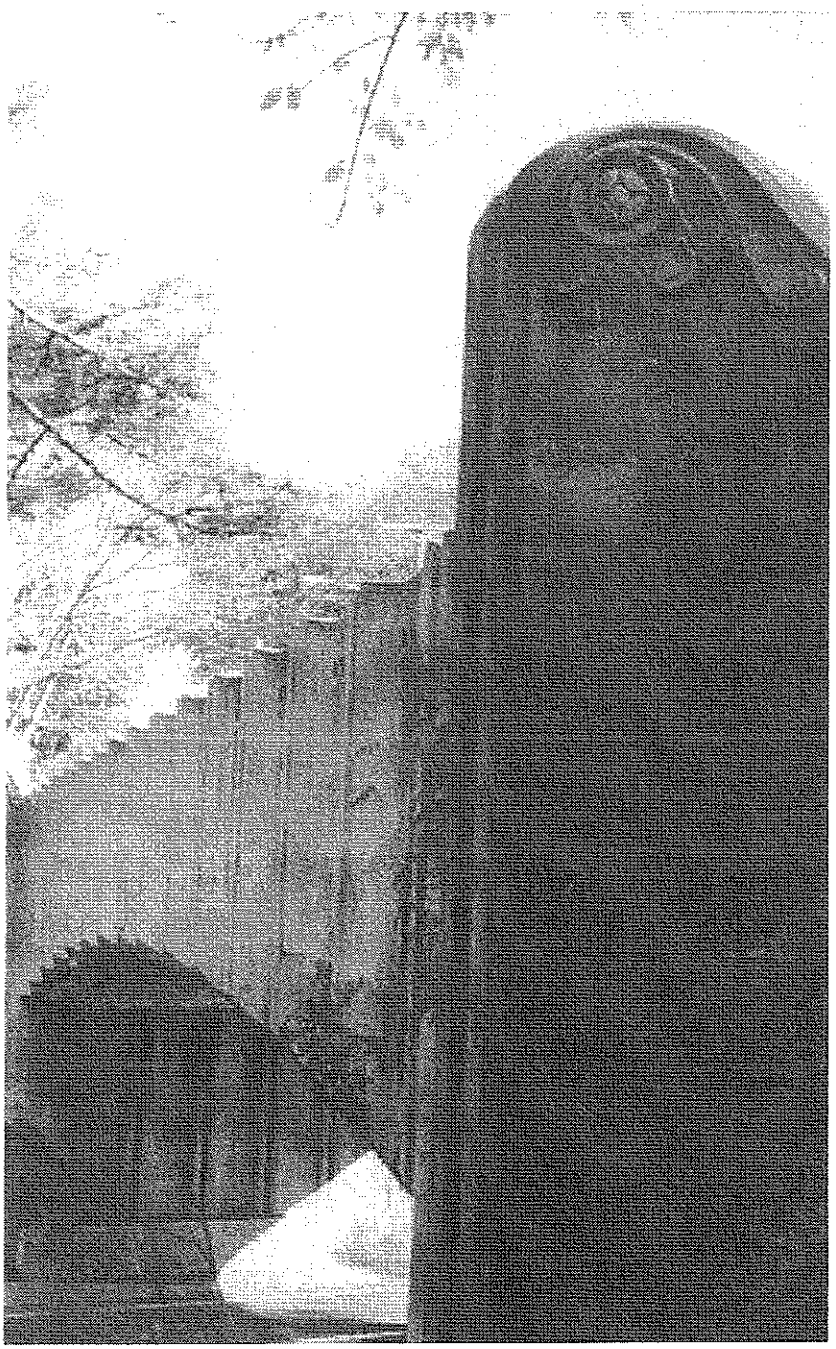


Photo:
Curved concrete spandrel panels at Bridge #747, Madison Avenue.

g. Spandrel

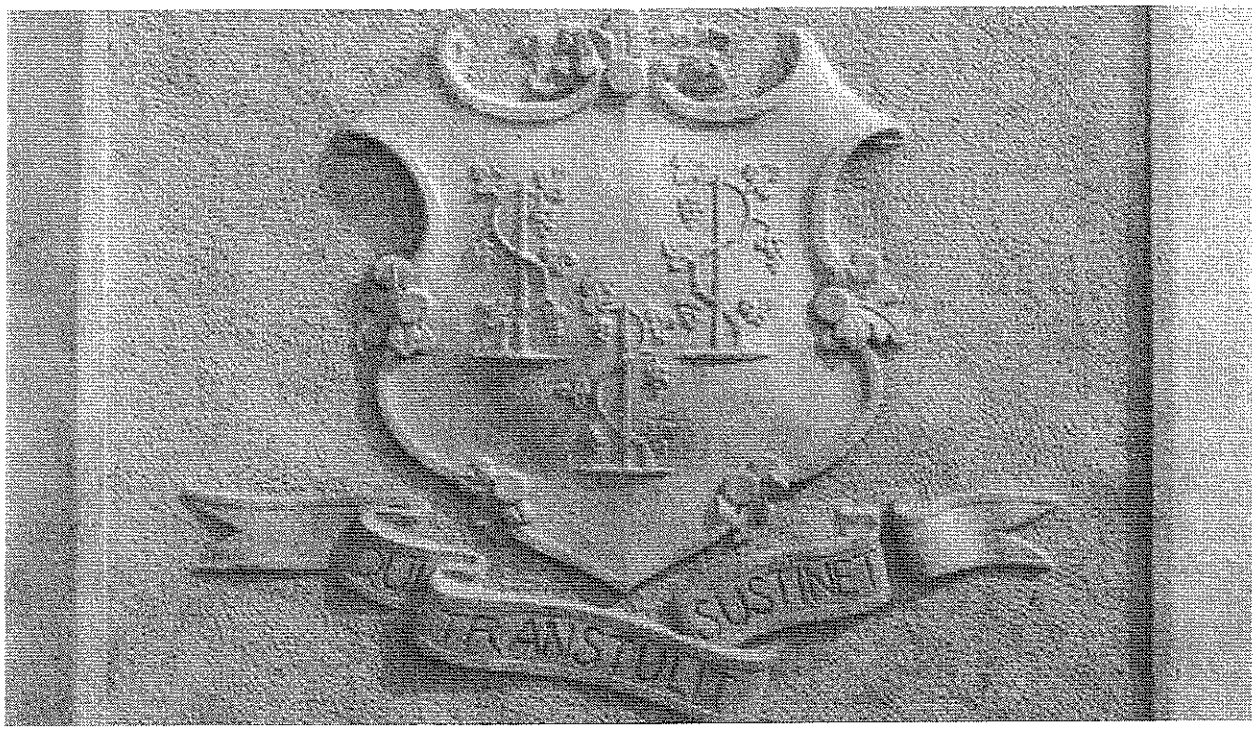
Typically the spandrel or fascia is the vertical face of the bridge extending over the roadway and was typically a favorite location for placing ornamentation. In the case of the concrete bridges, these were treated architecturally with a variety of articulated watertables (or cornice bands), vertical reveals, recesses, dentils, sawtooth forms, quoins, keystones, cast ornament, banding, or other projecting features. These elements reduce the amount of flat and untreated surfaces, articulate the span visually, and help to shed water. In every case, the surface of the spandrel was designed to be integral with the arched intrados, a detail which is not always been recreated on reconstructed bridges.

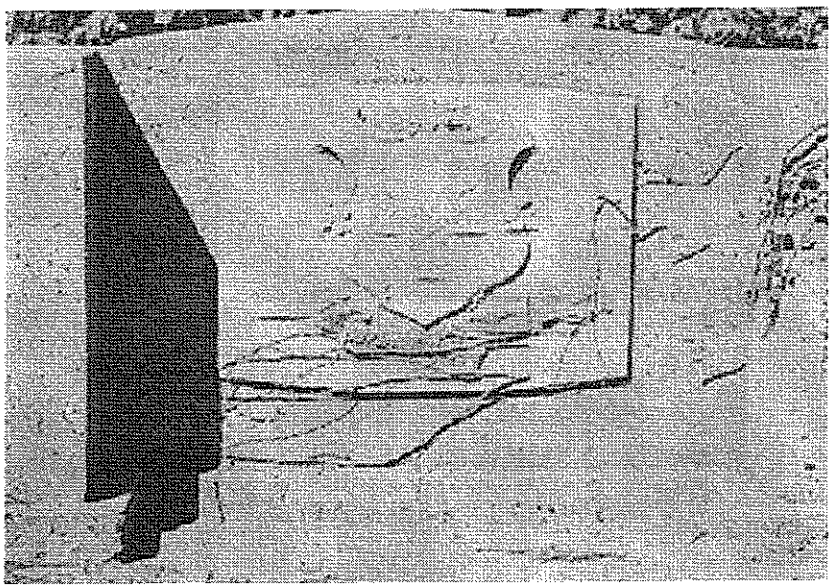
On the steel frame bridges, occasionally ornamental grille panels of cast iron or steel were attached directly to the frames, as at Lake Avenue (#696) in Greenwich, and Main Avenue (#760) in Trumbull. Frequently, the arched and riveted steel frames were left exposed, with no added decoration. At masonry bridges the stone facing was most often carried across the face of the spandrel, with the use of cut stone quoins to articulate the arched opening.

Photo:
Detail of various surface finishes on Bridge #712, South Avenue (Route 124).

h. Surface Treatments

An important feature of the concrete bridges are their surface treatments. A wide range of techniques were used originally and are described to some extent in the original descriptions of the Parkway and its construction. A serious challenge is presented by the fact that only a limited amount of information is known about the original finishes of the concrete and cast stone. Remaining surfaces have weathered significantly or have been completely altered or modified. Future restoration and repair projects should be conducted with great caution as to not further aggravate or eliminate the remaining traces of surface finishes.





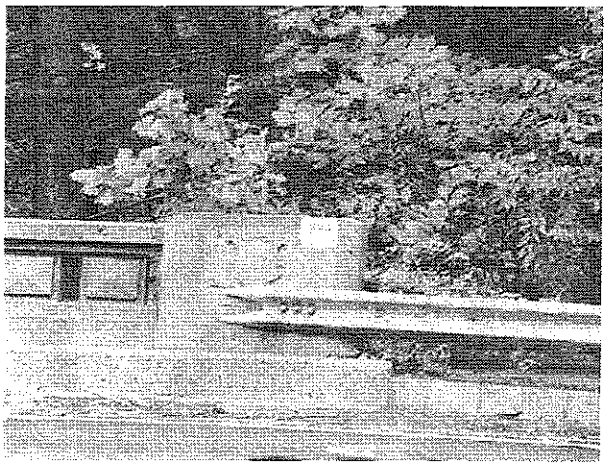
Top Photo:
Original historic photo of Coat of Arms on Bridge #712, South Avenue

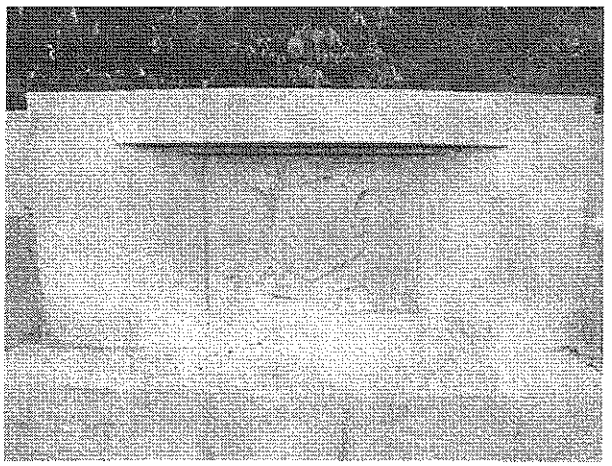
Bottom Photo:
Existing Coat of Arms on Bridge #712, South Avenue.

2.2.4 Ornamentation

a. Coat of Arms

Perhaps the only decorative feature on the bridges which was repeated, the Coat of Arms of the State of Connecticut is a common feature that can still be found on many bridges. The shields were cast in precast concrete, sgraffitto or stone. They are located at the center of the span, facing the parkway or on the inside face of the railings at alcoves.

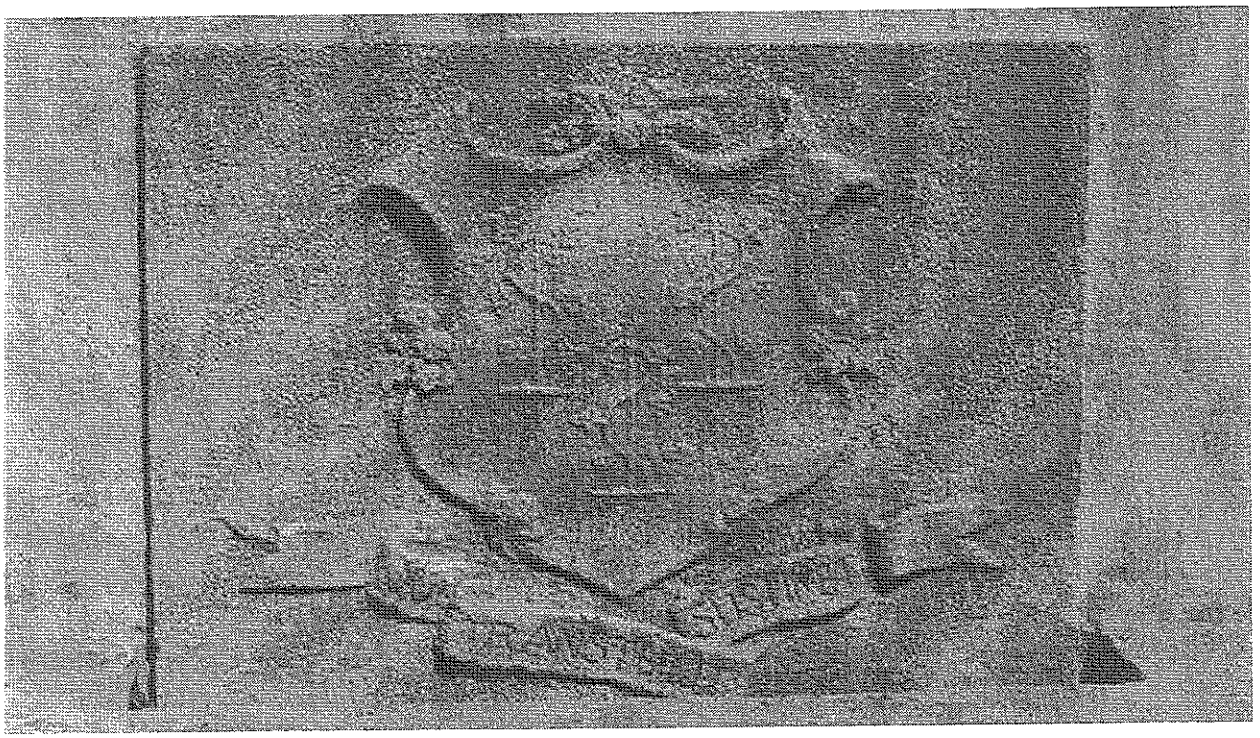


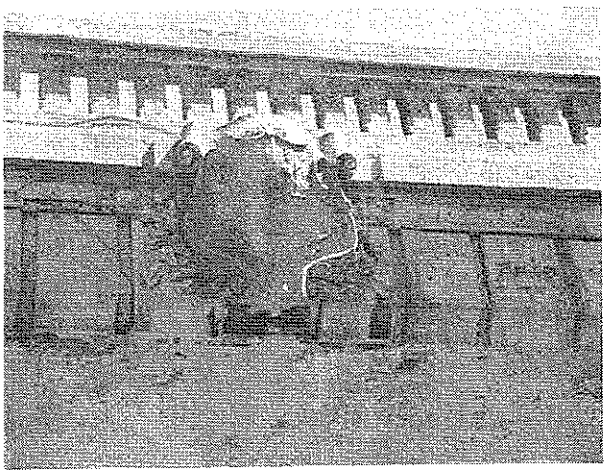


Top Photo:
Coat of Arms, Bridge #723, East Rock Road.

Bottom Left Photo:
Coat of Arms, Bridge # 733, Bayberry Lane.

Bottom Right Photo:
Coat of Arms, Bridge # 706, High Ridge Road.





Top Photo:
Coat of Arms, Bridge #714 (renumbered #5811), Marvin Ridge Road.

Bottom Left Photo:
Coat of Arms, Bridge #746, Plattsville Road.

Bottom Right Photo:
Coat of Arms, Bridge # 708, Ponus Ridge Road.

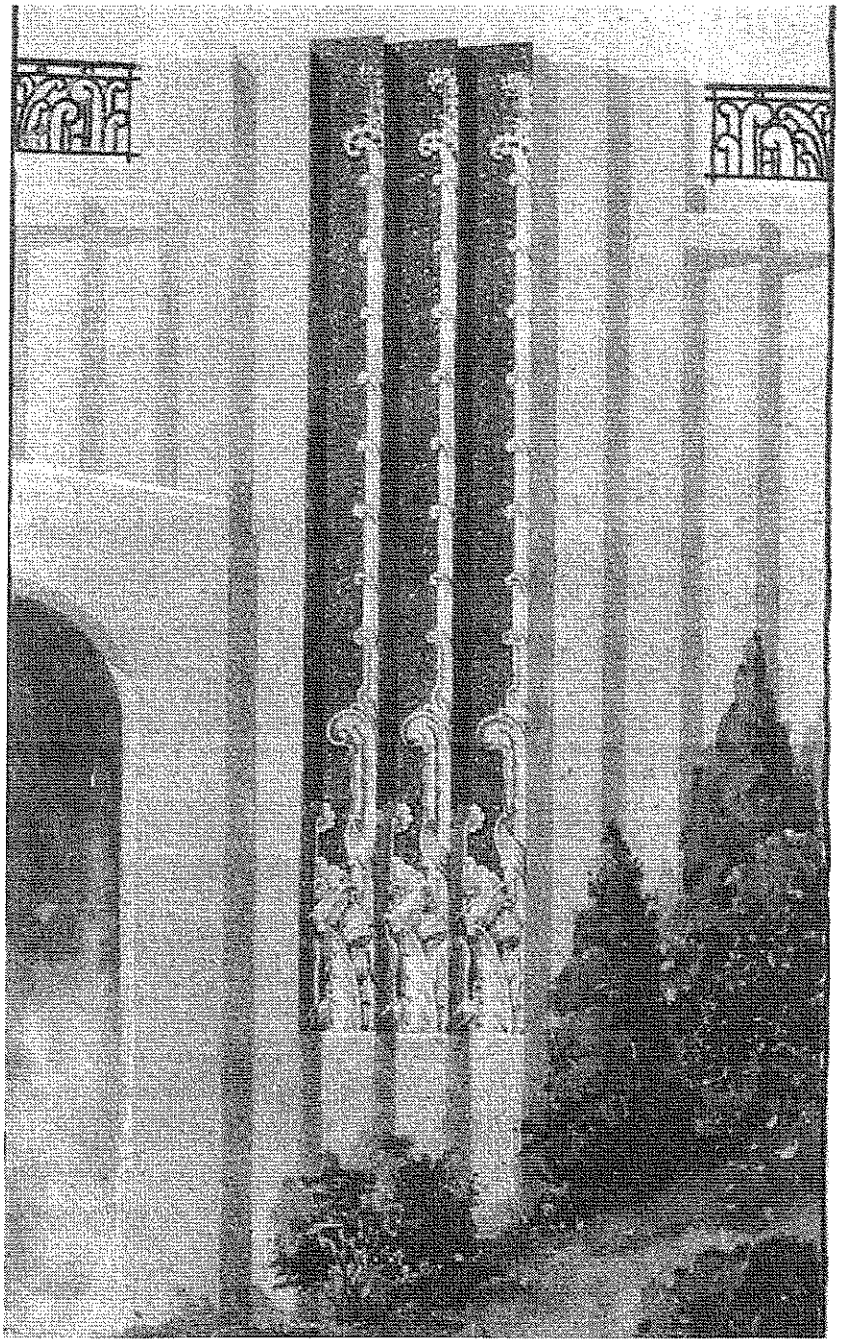
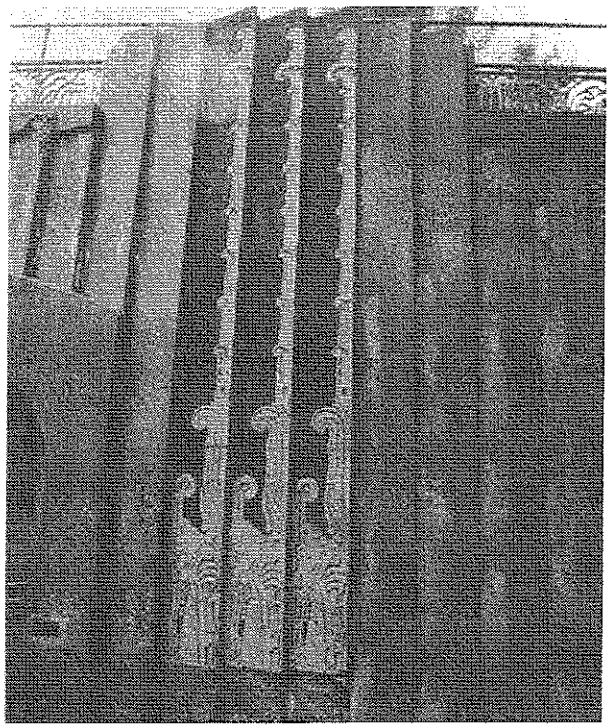


Photo:
Design drawing for sgraffito decorative ornament on pylon of Bridge #732, North Avenue.

b. Sgraffito

Concrete sgraffito ornament, consisting of mixes of different colors poured over each other in gelatin or plaster moulds, was employed by Dunkelberger to create relief and contrast to plain surfaces. Typically the top layer was chipped or etched away to reveal the contrasting layer. Sgraffito relief occurs on several bridges in the form of decorative horizontal bands and relief panels. The use of natural aggregates such as finely crushed trap rock, vitreous and ceramic aggregates mixed with a white cement paste resulted in designs having permanent colors.

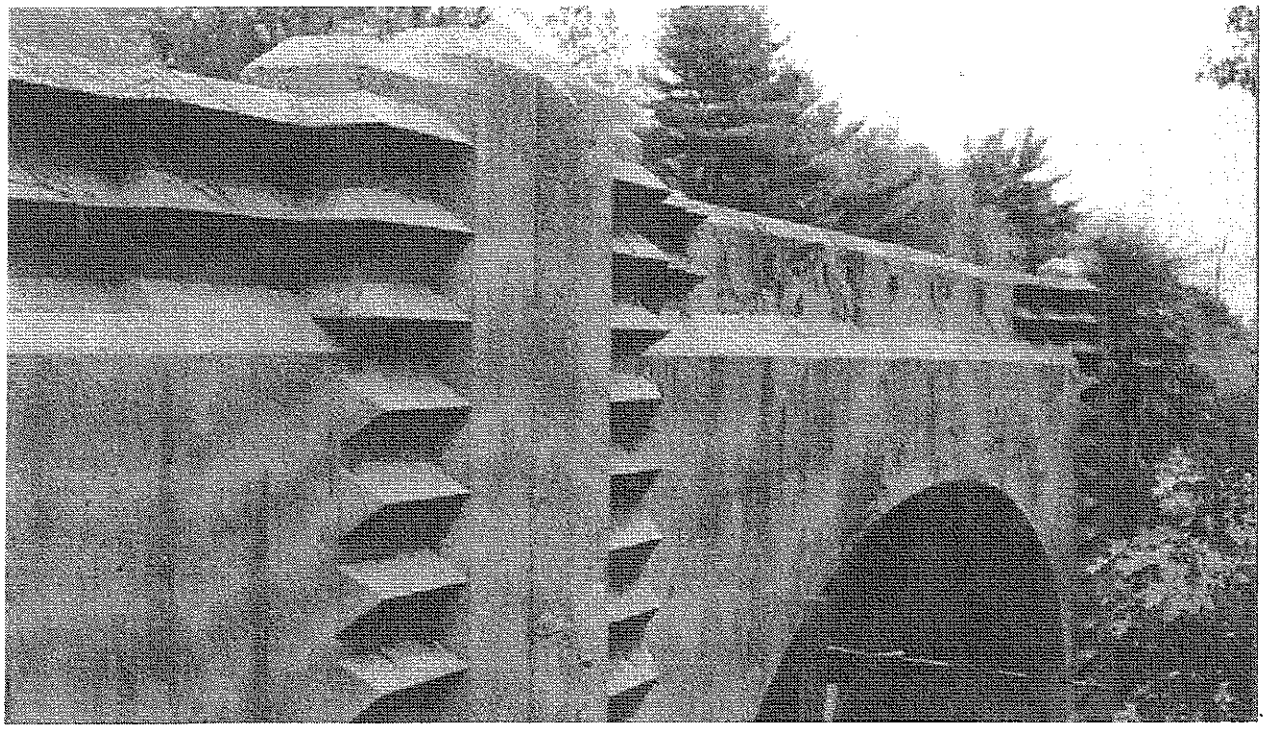


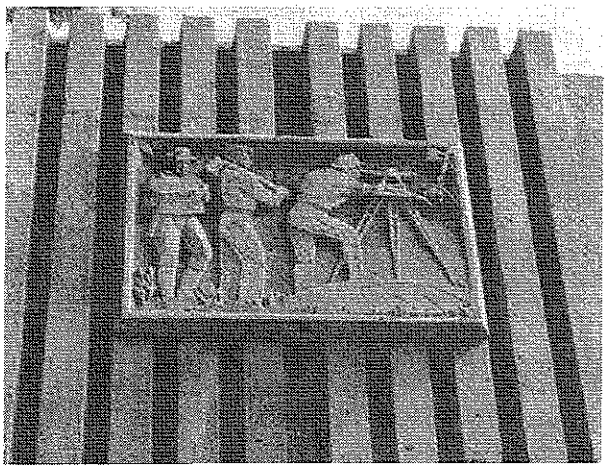
Top Photo:
Decorative sgraffito work on abutement pylon on Bridge #732, North Avenue.

Bottom Photo:
Detail of sgraffito work , Bridge #732, North Avenue.

Top Photo:
Close up view of decorative sgraffito work, Bridge#732

Bottom Photo:
Detail of decorative sgraffito work, Bridge #732. Note efflourescence.





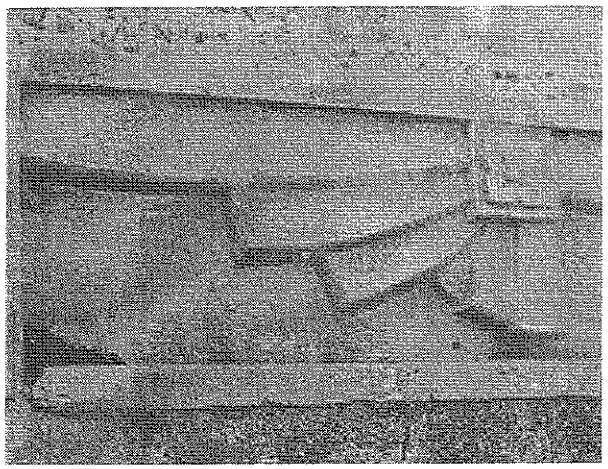
Top Photo:
Simple geometric forms of the cast-in-place ornamentation at Bridge #756, Huntington Avenue reflects the Arte Moderne style of the 1930's

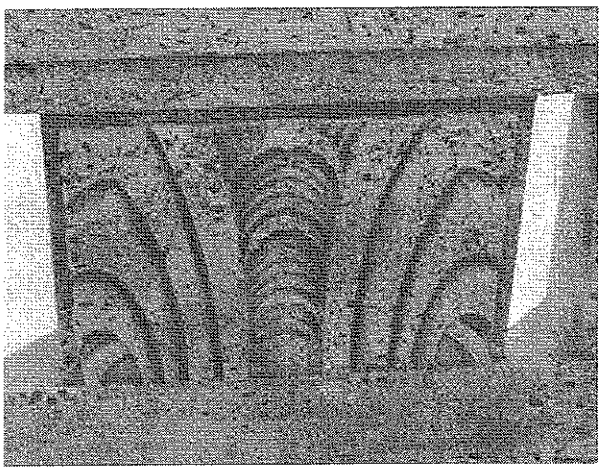
Bottom Photo:
Edward Ferrari's relief sculpture commemorating the engineers who worked on the Merritt Parkway is cast into the abutement pylon of Bridge #739, Burr Street.

c. Cast in Place

Ornamental concrete was described by Dunkelberger as concrete work that relieved the flat surfaces of concrete typically found on the concrete bridges in existence at the time the Parkway was being designed. Ornamental cast in place concrete would provide contrast, allow for the casting of shadow, and provide detail and decoration to the surface. Cast in place ornament was achieved through the use of reverse plaster moulds or wood dividers set into the wood formwork. After the pour, the concrete had to be well vibrated to ensure that the mould was completely filled.

Reverse moulds were used to create dentil mouldings, beveled or stepped edges, the clapboard ornamentation covering the surface of the Merwins Lane bridge (#735) in Fairfield and the Native American and Pilgrim panels at Comstock Hill Road (#716) in Norwalk.

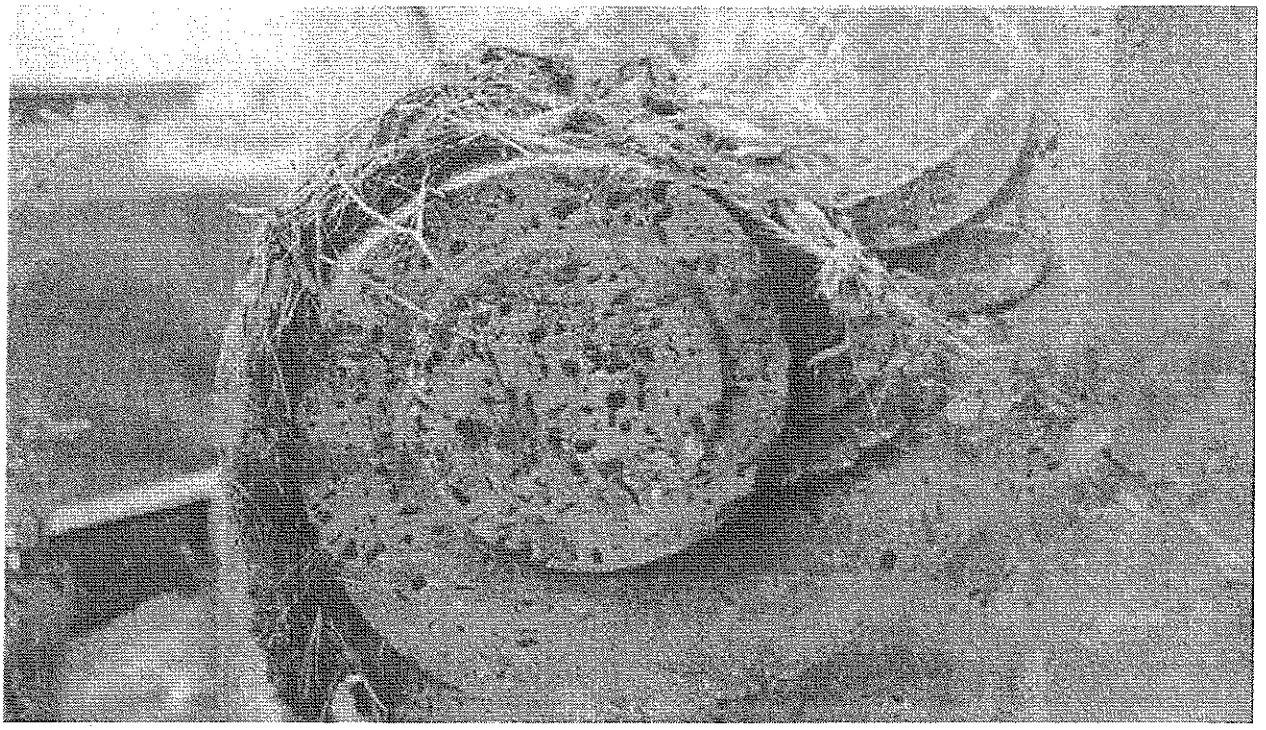


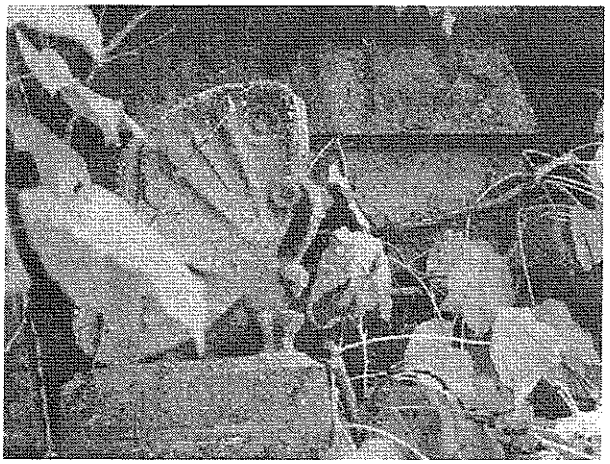


Top Photo:
Detail of end abutement pylon on Bridge #747, Madison Avenue

Bottom Left Photo:
Cast ornament at Bridge #760, Main Street (River Road,Route 110).

Bottom Right Photo:
Cast ornament on balustrade of Bridge #740 Black Rock Turnpike, (Route 58).

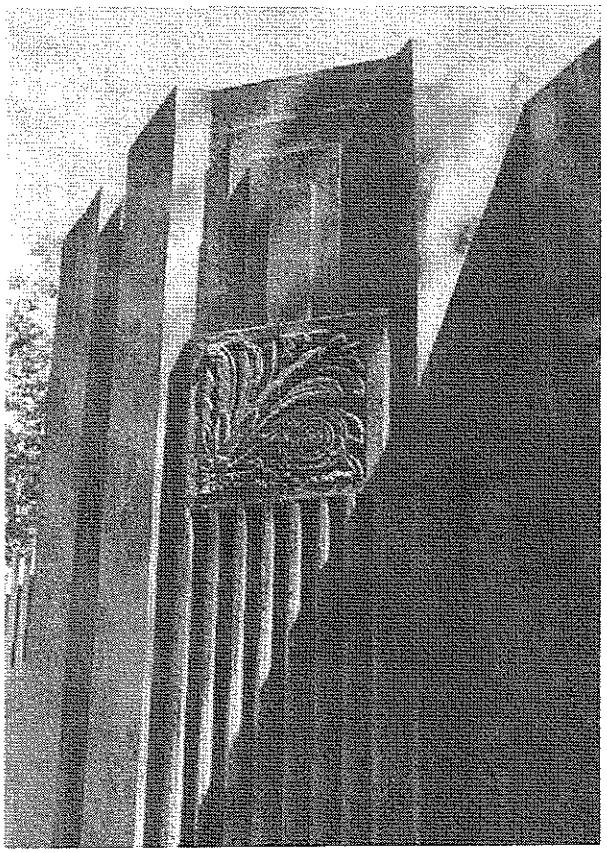


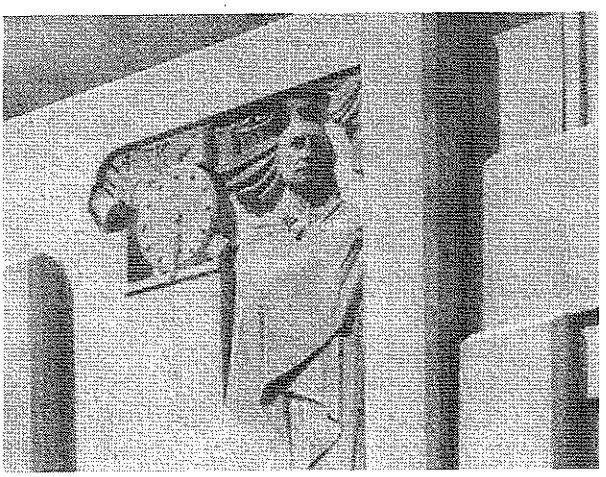


Top Photo:
Detail of end abundment pylon on Bridge #747, Madison Avenue.

Bottom Left Photo:
Cast ornament of butterfly on Bridge #713, White Oak Shade Road.

Bottom Right Photo:
Cast ornament at Bridge #745, Park Avenue.





Top Photo:
Decorative inset relief on Bridge #747, Madison Avenue.
Bottom Left Photo:
Low relief sculpture by Edward Ferrari , on the abutement pylon of Bridge #711 (renumbered #5810), Lapham Road.
Bottom Right Photo:
Reverse molds were used to create the Native American panel on Bridge #716, Comstock Hill Road.

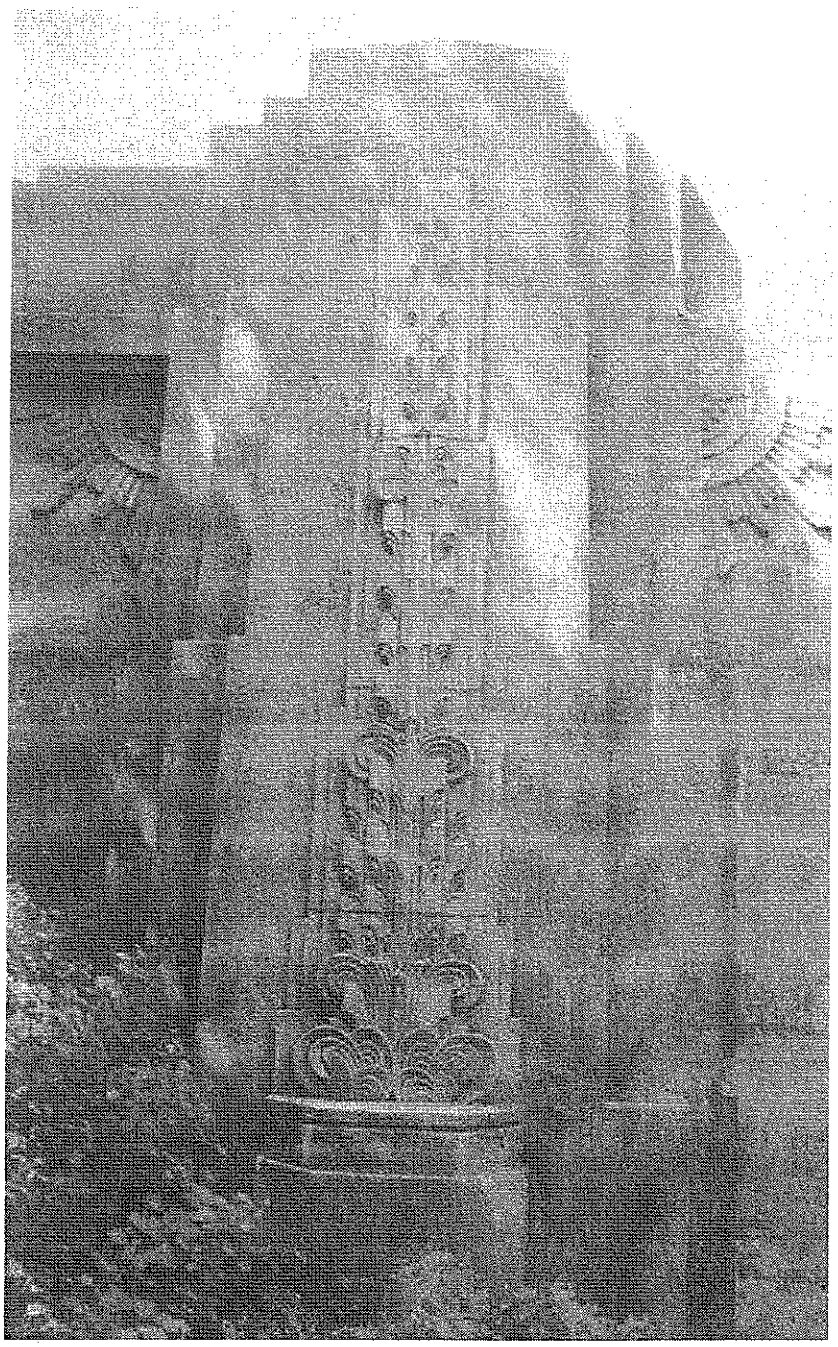
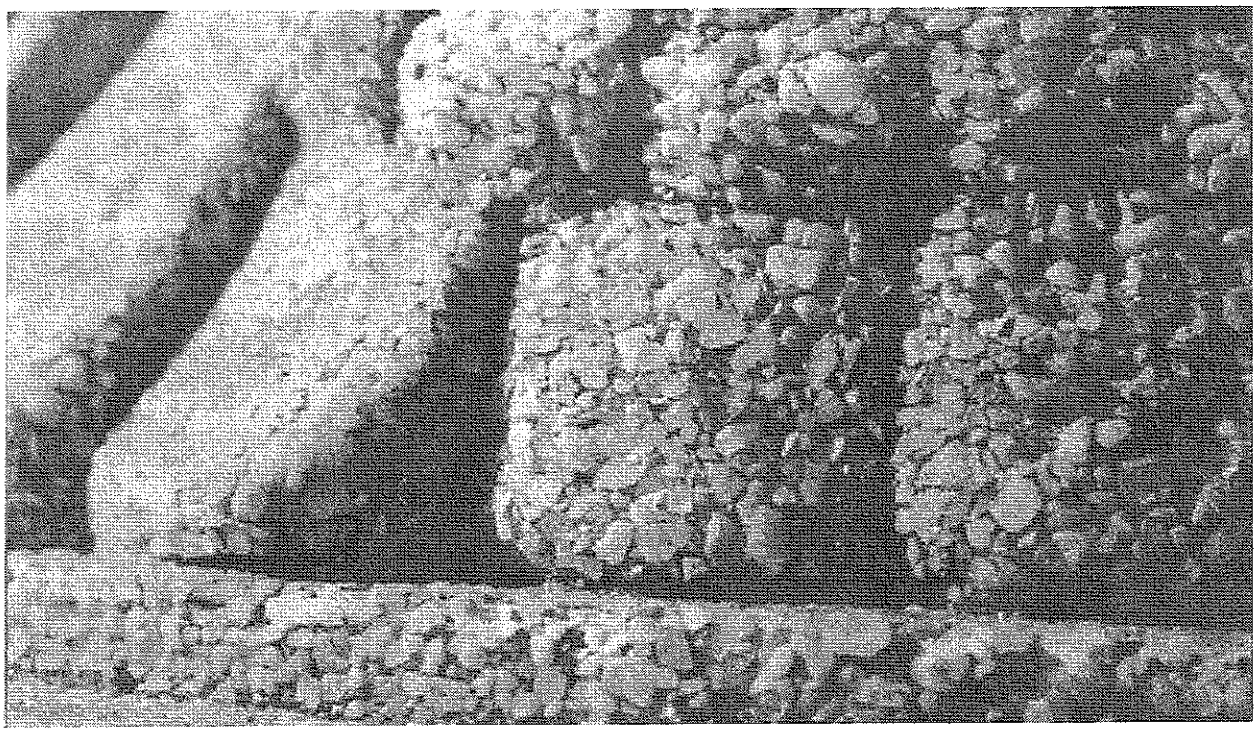


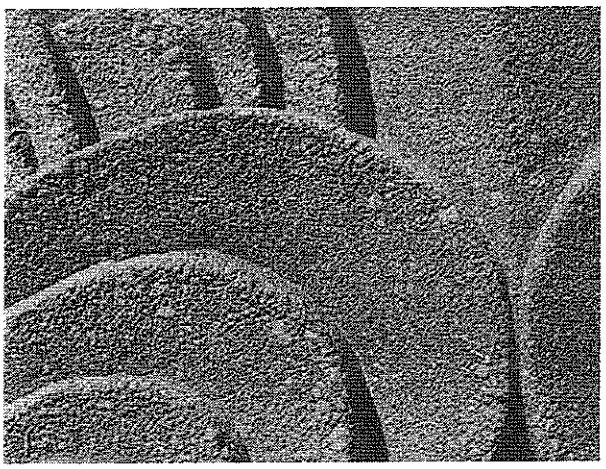
Photo:
Precast Art Deco "fountain" ornament adorns pylon at Bridge #712, South Avenue (Route 124).

d. Precast Ornament

Many imaginative designs on the bridges, were created with precast concrete such as butterflies, fountains, sunbursts, ziggurats, and most commonly the Connecticut Coat of Arms, to name just a few. Special aggregates, such as stony creek granite, white quartz, black onyx, glass, vitreous and ceramic aggregates were used. The colors produced on the bridges include red, green, black and white. According to Dunkelberger, every color of the rainbow could be produced with these materials for aggregates. The material has also proven to be less prone to weathering than cast-in-place concrete, and less prone to the accumulation of dirt on the surface, a primary concern of Dunkelberger. Typically the precast units were suspended from the tops of the forms and concrete was poured around them.

Precast concrete facing panels were used on the Main Street Bridge (760) in Trumbull and the Clinton Avenue Bridge (#729) in Westport. Concrete facing panels contained a special aggregates and were approximately 2" thick. They were set in formwork, braced and the structural concrete poured behind the panels. L-shaped steel ties projecting from the backs of the panel anchored them to the concrete.

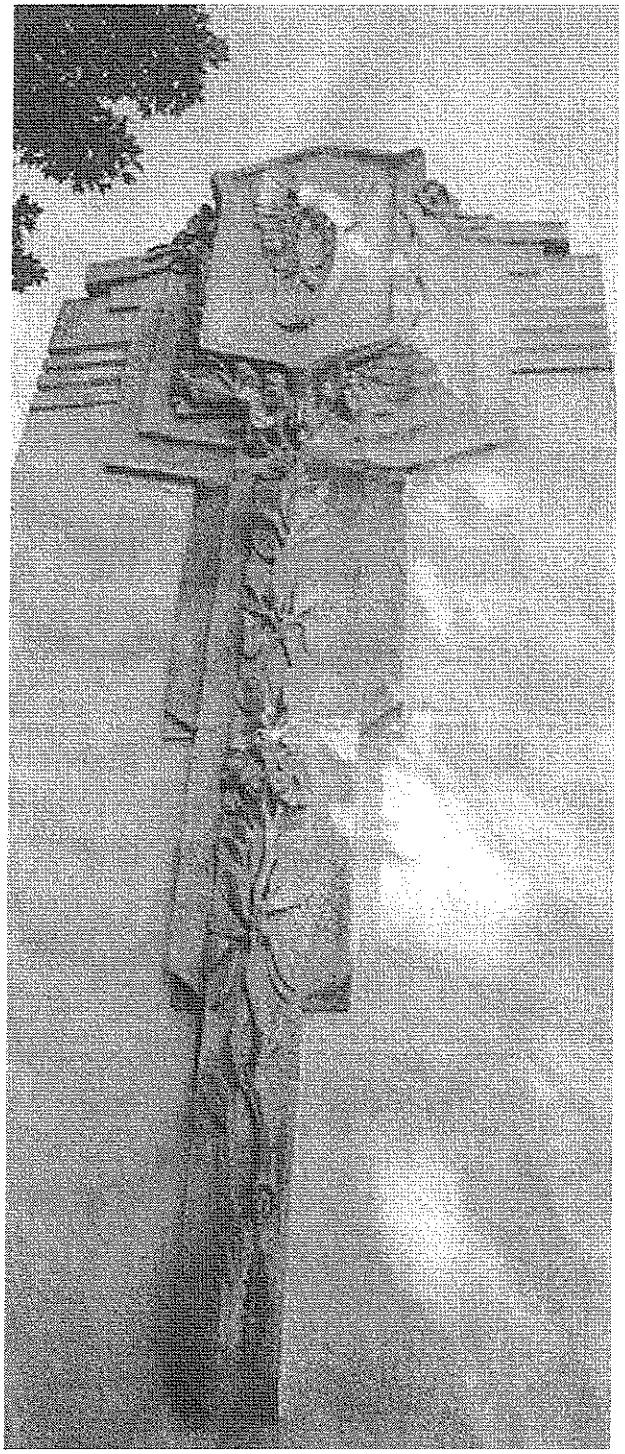


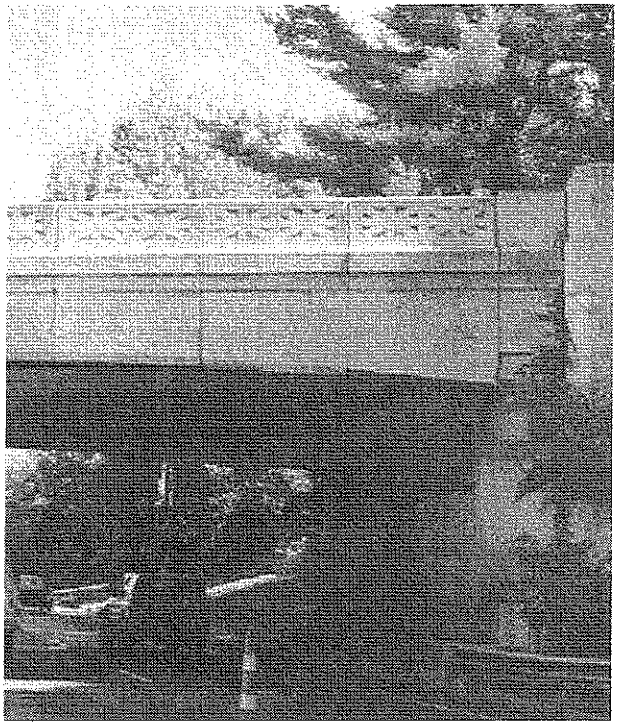


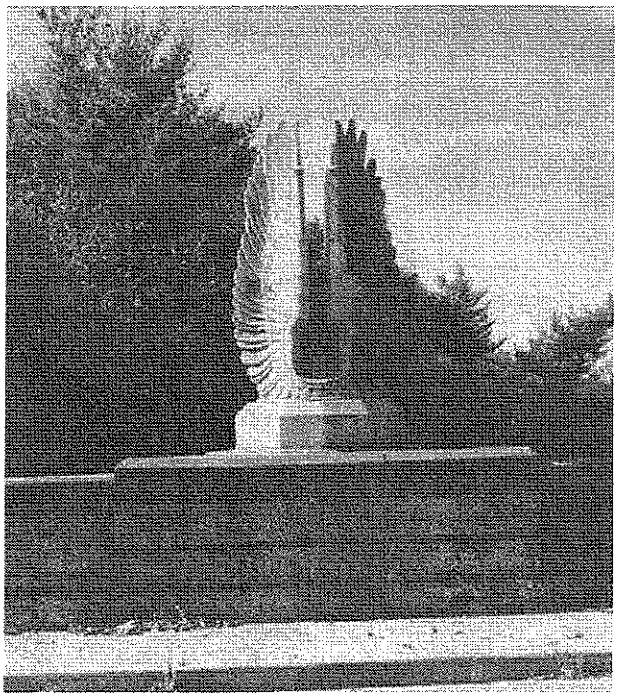
Top Photo:
Detail of precast Nike wing sculpture on Bridge #759, James Farm Road.

Bottom Left Photo:
Detail of precast ornament on Bridge #712, South Avenue (Route 124).

Bottom Right Photo:
Detail of precast coat of arms ornament on Bridge #712, South Avenue (Route 124).



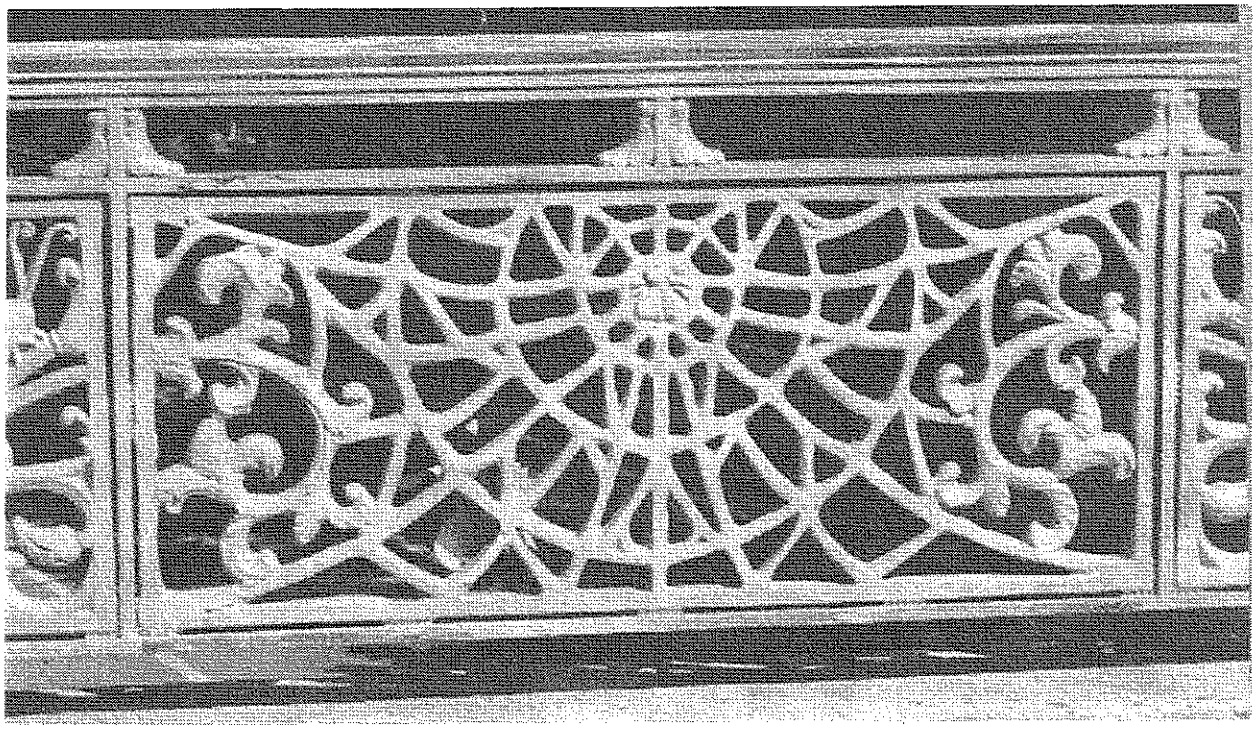


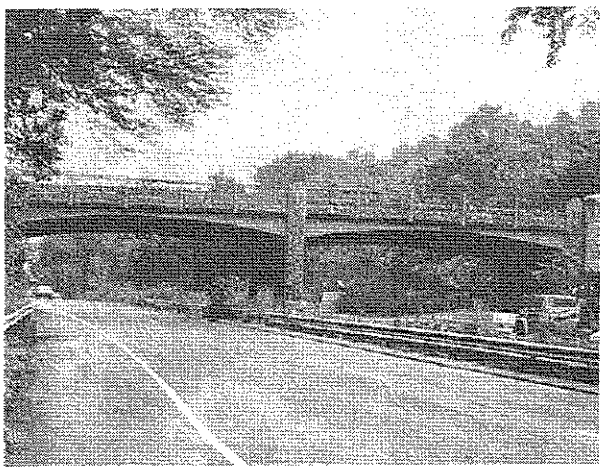


Top Photo:
Precast Ornament on Bridge #699, Stanwich Road.

Top Right Photo:
Precast concrete fascia panels (non-original), Bridge #714 (renumbered 5811), Marvin Ridge Road.

Bottom Right Photo:
Precast Nike wing sculpture on Bridge #759, James Farm Road.



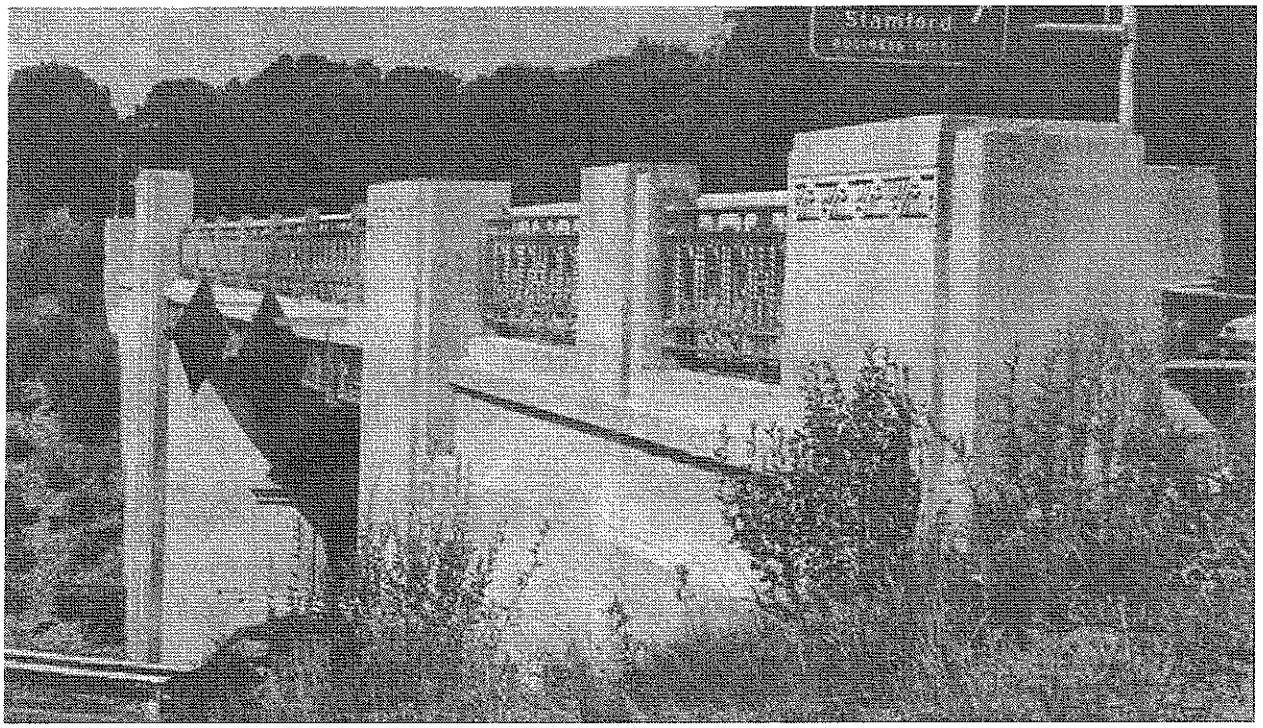


Top Photo:
Ornamental cast iron railing on balustrade of Bridge #735, Merwins Lane.

Bottom Photo:
Ornamental cast iron grille work on Bridge #696, Lake Avenue.

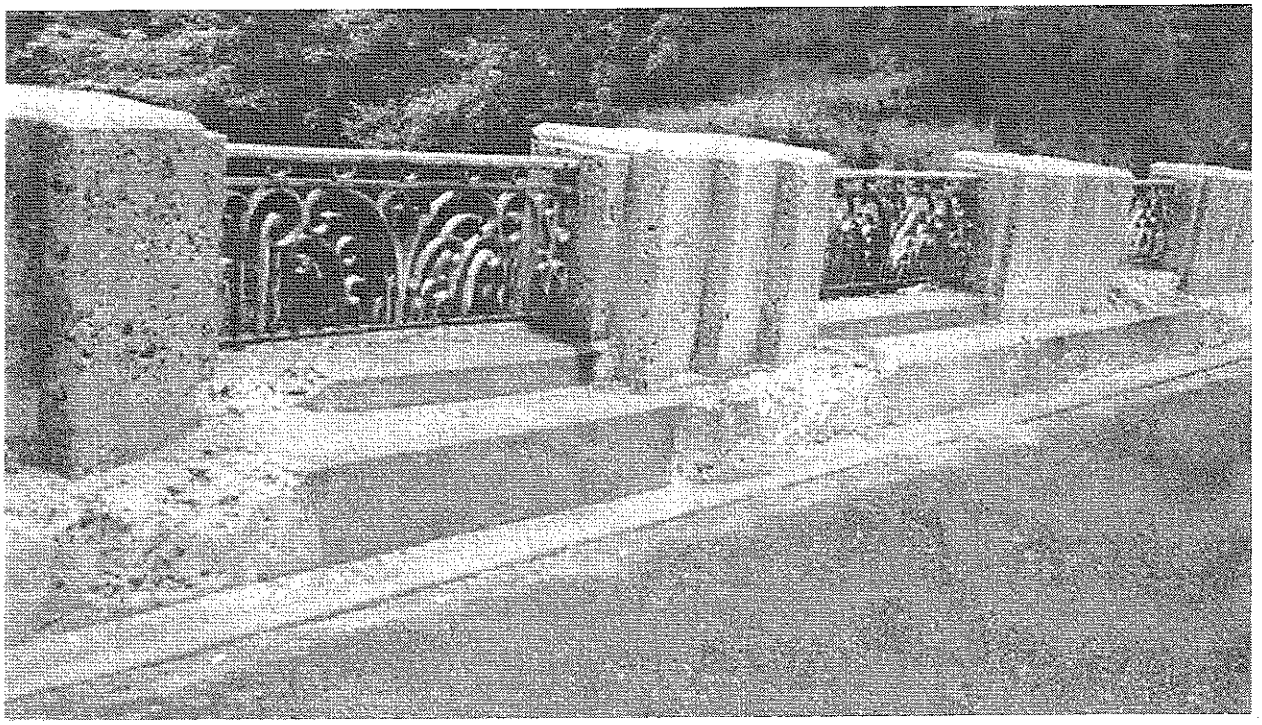
e. Cast Iron

Cast iron was incorporated into the design of bridges as decorative grillework attached to the steel frame of the bridge or as components of the railings. At the Lake Avenue Bridge (696) in Greenwich, vertical and horizontal grillework cast to imitate grapevines are attached to the structure on both elevations facing the Parkway. At the Merwins Lane Bridge (735) in Fairfield a galvanized cast iron railing features ornate, whimsical spider webs, flanked by butterflies on bent stalks. Each of the approximately 7' long panels are unique. Other bridges have cast iron railing components.



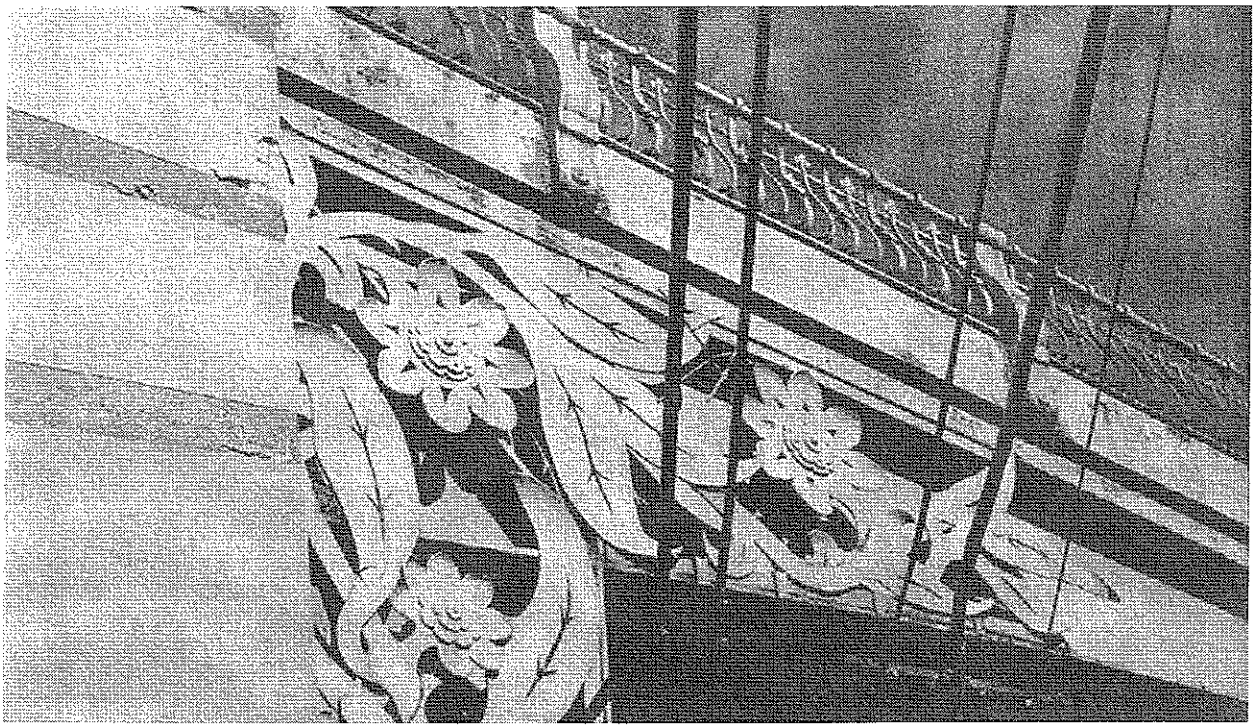
Top Photo:
Iron railing on reconstructed Bridge #706, Long Ridge Road (Route 137).

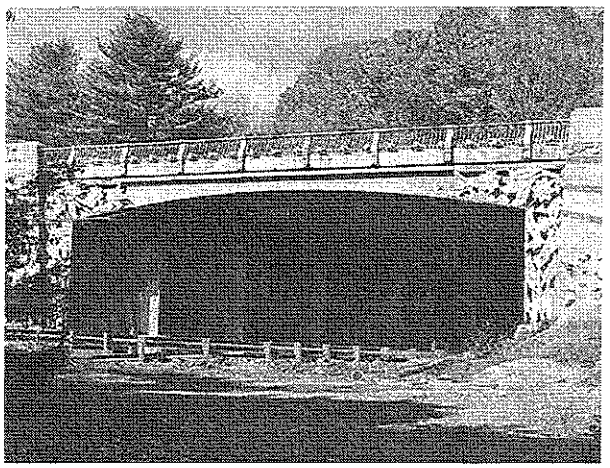
Bottom Photo:
Detail of decorative ironwork, Bridge #696, Lake Avenue.



Top Photo:
Deteriorating iron railing on Bridge #732, North Avenue.

Bottom Left Photo:
Detail of ornamental ironwork on the balustrade railing of Bridge #735, Merwins Lane.



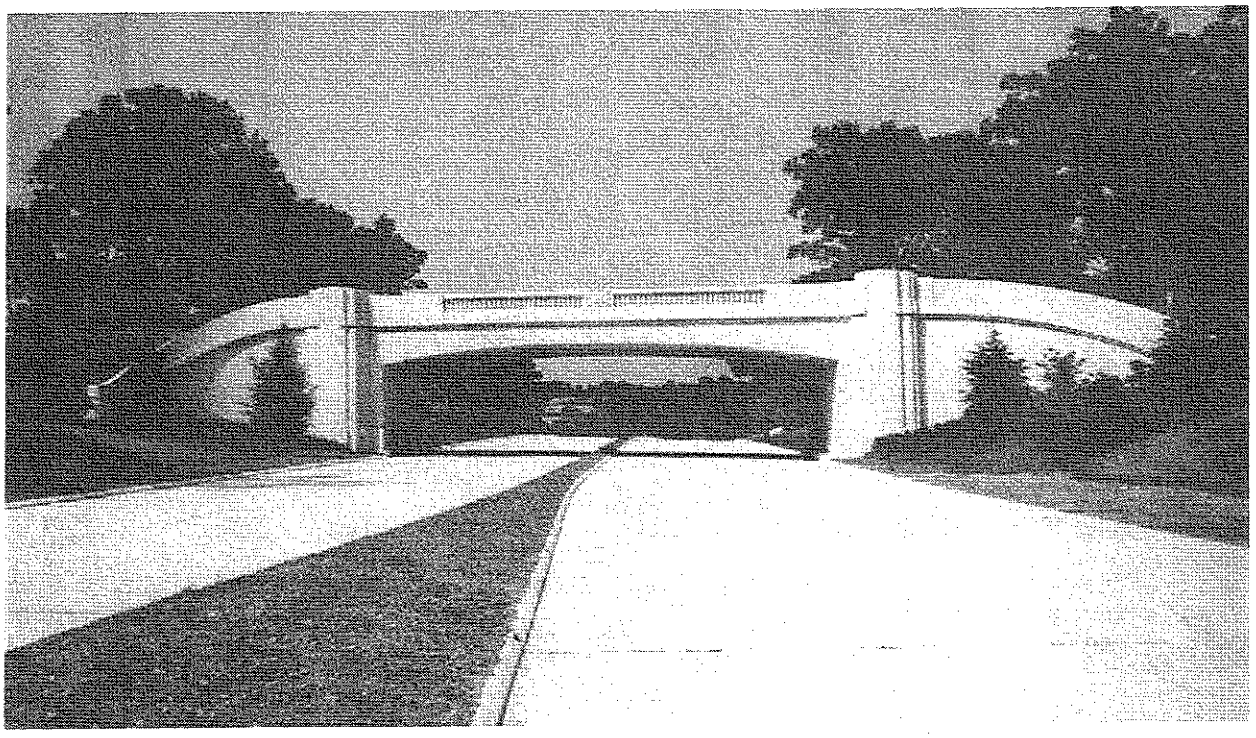


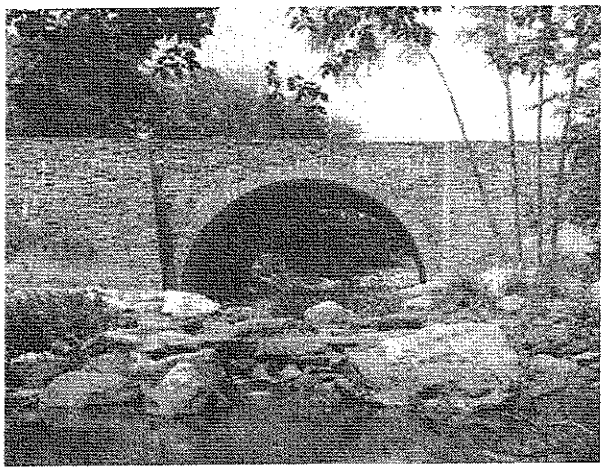
Top Photo:
Close up view of decorative motif, made of fabricated steel on Bridge #760, Main Street.

Bottom Photo:
Overall view of ornamental steel on Bridge #760, Main Street.

f. Ornamental Metals

A variety of ornamental metalwork occurs on bridge railings and is described in the section on 2.2.2, Ornamental Metals.



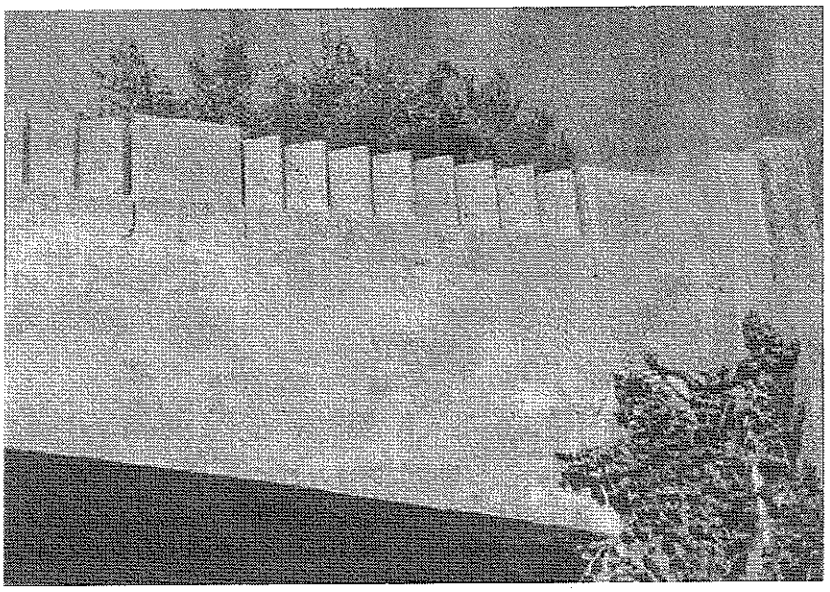


Top Photo:
Bridge #704, Wire Mill Road in Stamford is constructed of concrete and is articulated by curvilinear wingwalls.

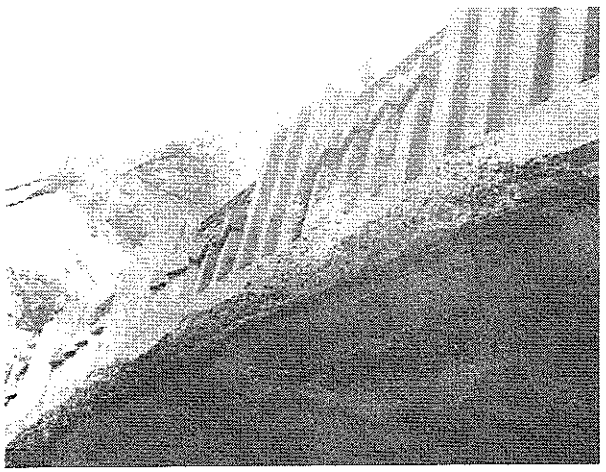
Bottom Photo:
Stone masonry on Bridge #705, Rippowan River in Stamford.

2.2.5 Workmanship

Good workmanship was essential to the handling of the various types of materials used in the construction of the bridges, which included concrete, stone, precast, structural steel and various metals, in order to prevent damage to them during the construction process. Because of the ornate character of the bridges, the unique decoration and combination of materials, intricate formwork, special moulds, and architect-controlled surface treatments, Dunkelberger made a special effort to educate the contractors and demanded close and continuous supervision of the work.



Top Photo:
Scaling concrete on the spandrel of Bridge #712, South Avenue



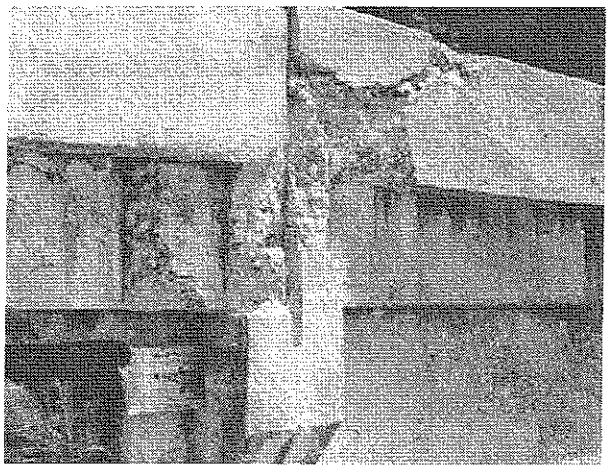
Bottom Photo:
Weathering (and spalling) of concrete has exposed the medium black aggregate on Bridge #732, North Avenue.

2.3 IDENTTIFICATION OF DEFICIENCIES

2.3.1 Concrete Weathering

The concrete bridges of the Parkway have suffered from the intrusion of water, over sixty years of freeze-thaw cycles, atmospheric pollutants, inadequacies in the materials and the original workmanship and insufficent maintenance. If the concrete was not vibrated properly, voids may have been left at critical structural locations. Open joints and cracks in the upper roadway and deck have allowed water and road salts to enter. Open vertical expansion joints have provided places for vegetation to grow and more water to enter. Eventually deferred repair of cracks allowing water penetration and freeze-thaw attacks have caused structural damage which has required the entire structure to be replaced.

Weathering (or erosion) of the original concrete surface by wind, precipitation, salt air and inadequate drainage has exposed the black basalt medium-sized aggregate and gives the concrete a rough appearance. Less weathered surfaces are smoother, tan or gray in color and only the fine sand or very small pebbles can be seen. All of the exposed concrete surfaces of the bridges have weathered, by degree.



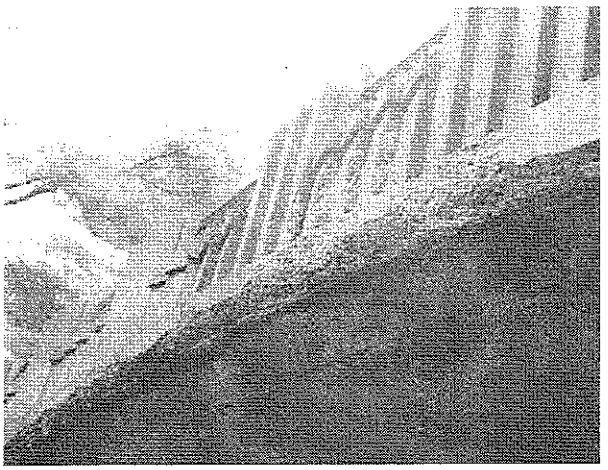
Top Photo:
Severe concrete spalling on the spandrel of Bridge #724, Grumman Avenue.

Bottom Photo:
Detail of concrete spalling on watertable of Bridge #710, Metro North Railroad.

2.3.2 Concrete Spalling

Spalling of concrete on the bridges is extremely common, despite the Department's efforts to repair them. Spalling will occur on the bridges whenever high stresses occur. Some of the causes may include the corrosion of steel reinforcing bars, the freezing of water which has entered the concrete, and improper workmanship. Thoughout the bridges thin cement paste near the surface is scaling in thin layers.

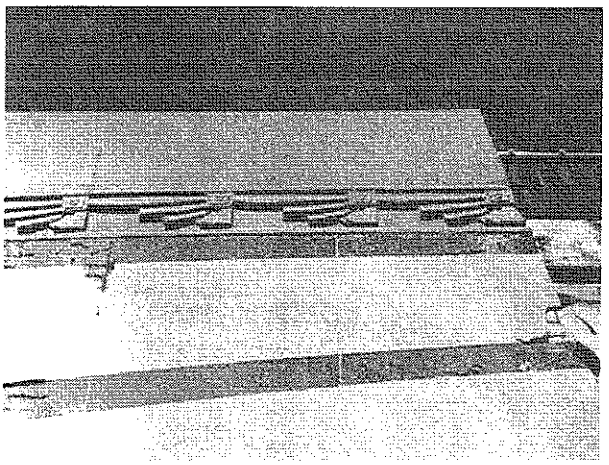
Spalls are common on roadway curbs, corners, edges, and protruding elements such as concrete railings and ornament. Minor spalls can be easily repaired. Typically spalling exposes the steel reinforcement bars to the corrosive elements of moisture, air, pollution and salts. Major spalling will eventually compromise the integrity of the structure requiring extensive reconstruction efforts.

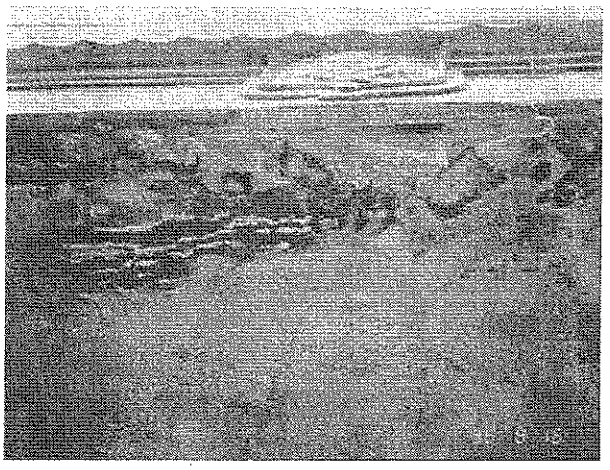


Top Photo:
Concrete deterioration on Bridge #710, Metro North Railroad.

Bottom Left:
Severe concrete deterioration on the balustrade parapet of Bridge #717, Silvermine Avenue.

Bottom Right:
Concrete deterioration on the spandrel of Bridge #732, North Avenue.

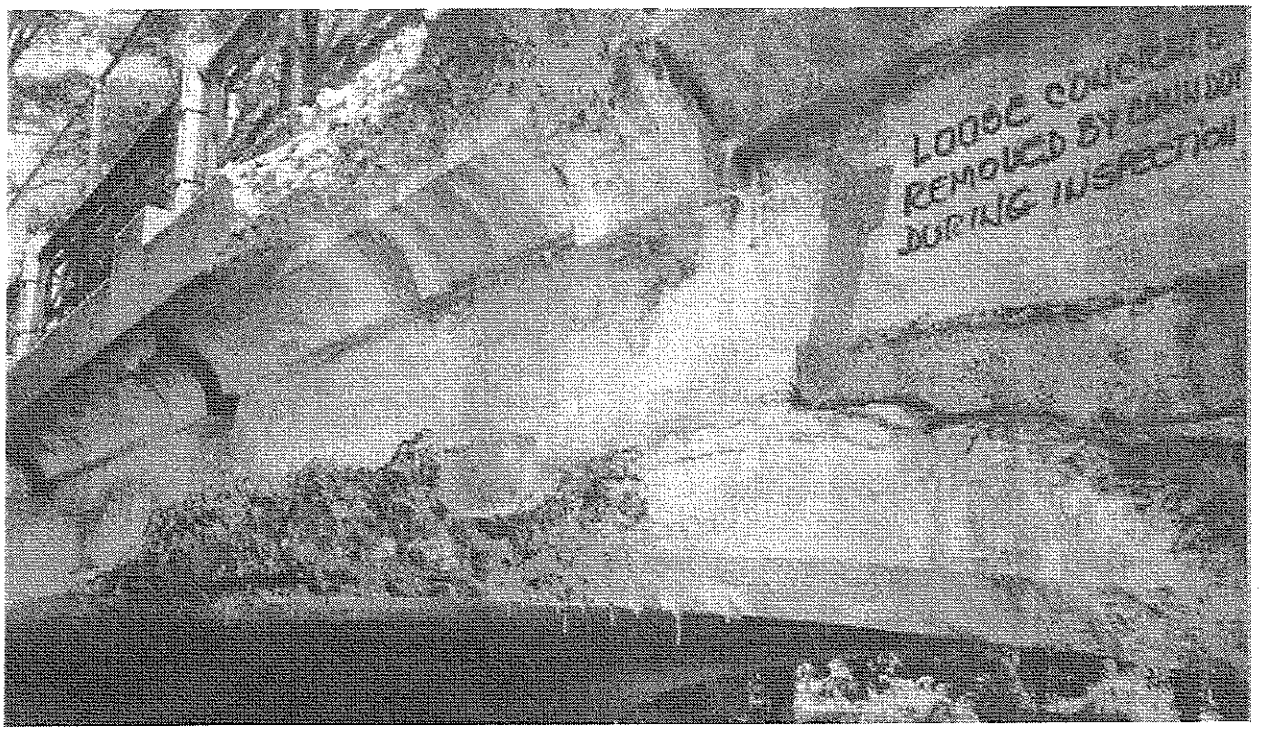


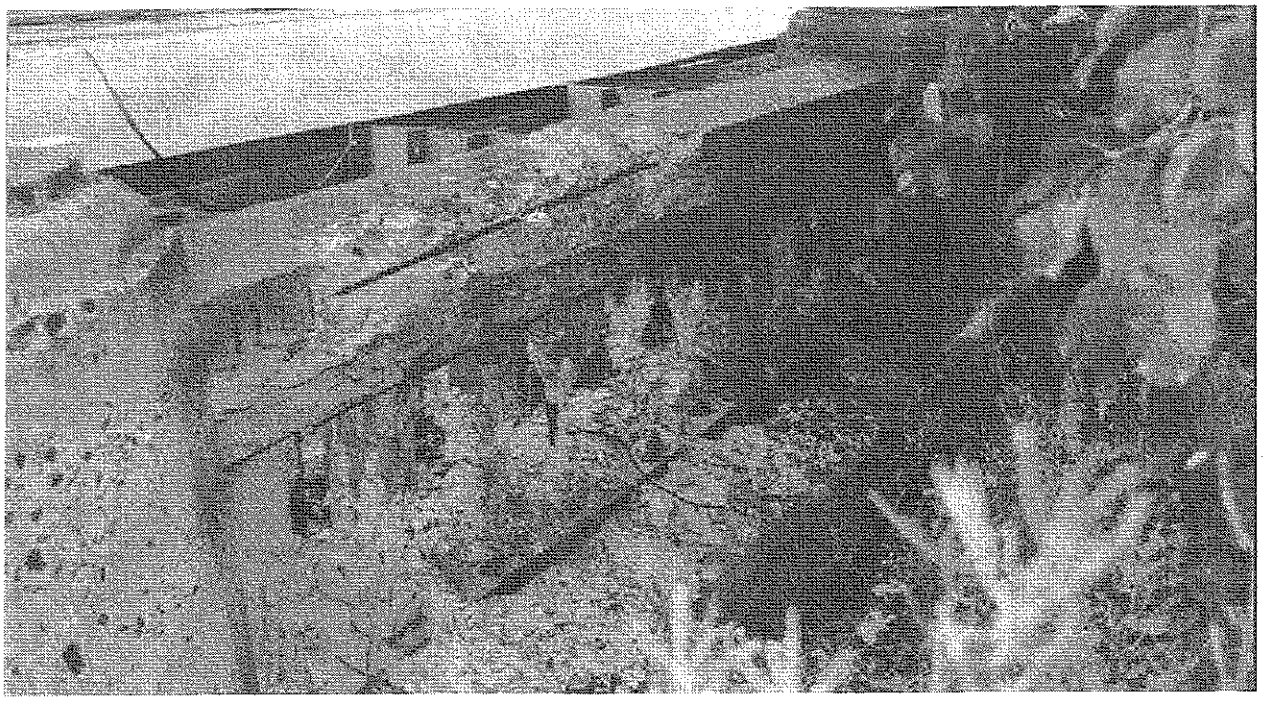


Top Photo:
Spalling at pylon base of Bridge #723, East Rock Road.

Bottom Left Photo:
Spalling at precast ornament at Bridge #760, Main Street (River Road, Route 110), leaves anchoring system exposed to the elements.

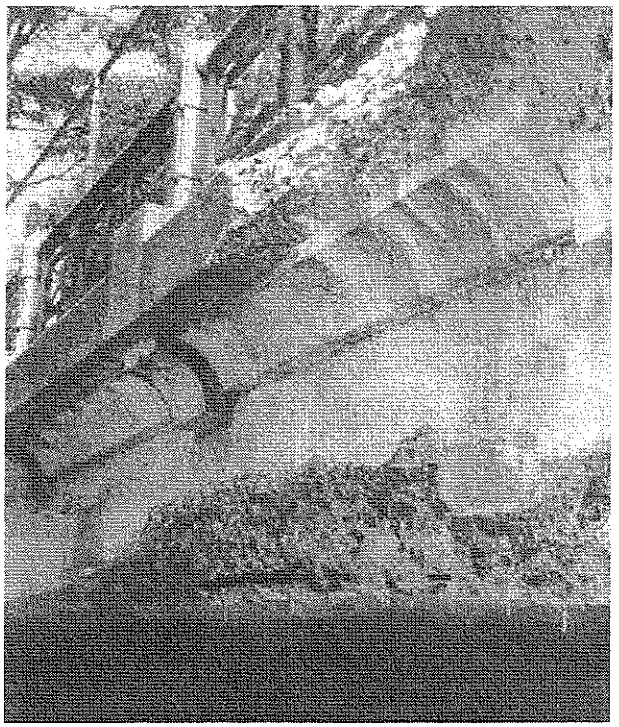
Bottom Right Photo:
Spalling at crown of vault on Bridge #723, East Rock Road.

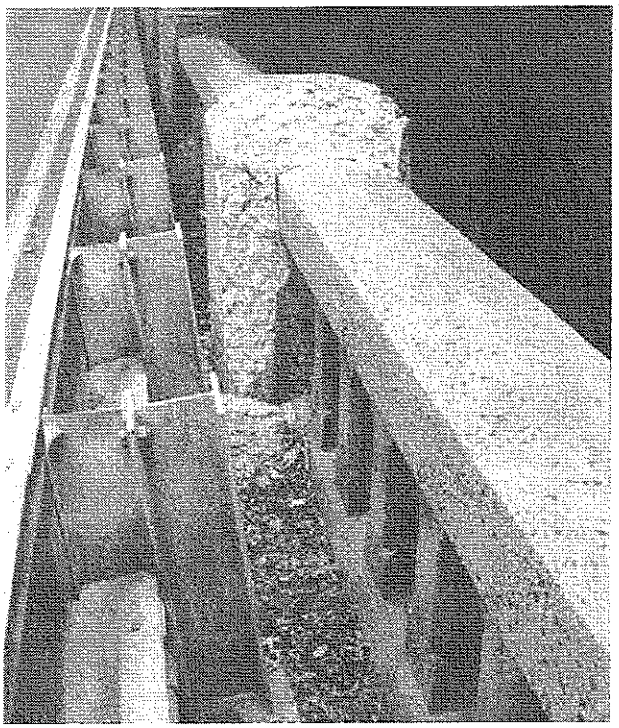


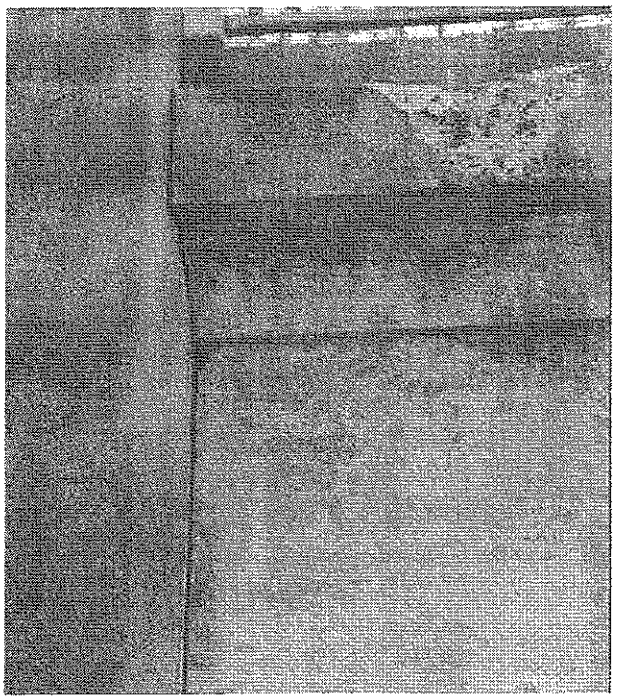


Top Photo:
Severe spalling at spandrel of Bridge #724, Grumman Avenue.

Bottom Left Photo:
Spalling at parapet balustrade at Bridge #698,Taconic Road.





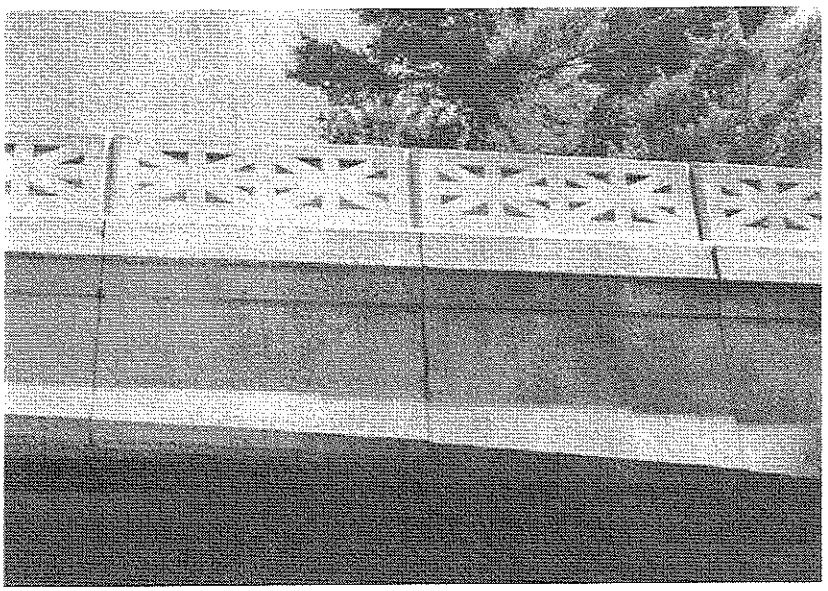


Top Left Photo:
Severe concrete spalling on Bridge #708, Ponus Ridge Road.

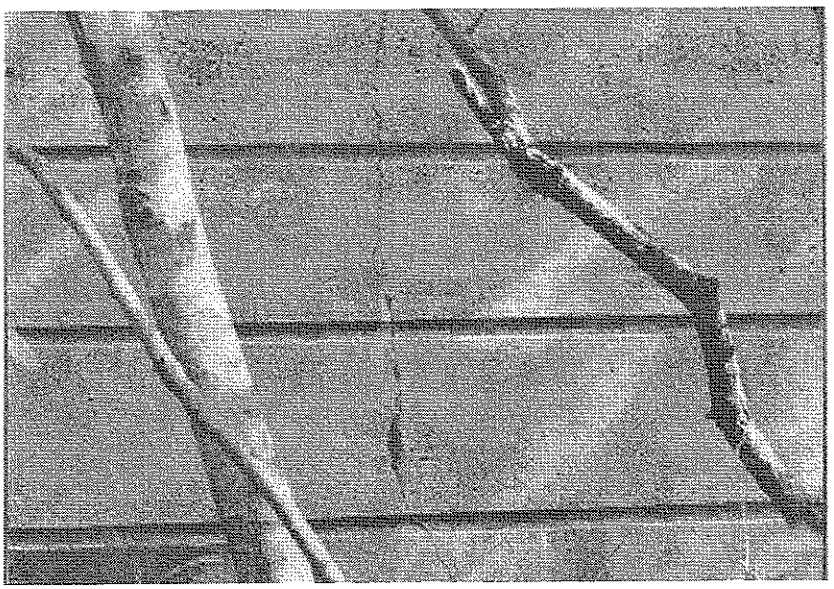
Bottom Left Photo:
Spalling and surface blotching on Bridge #742, Morehouse Highway.

Top Photo:
Spalling at parapet balustrade at Bridge #698, Taconic Rd.

Bottom Photo:
Spalling on balustrade of Bridge #724, Grumman Avenue.



Top Photo:
Cracking on non-original precast fascia panels of Bridge #714 (renumbered 5811), Marvin Ridge Road.



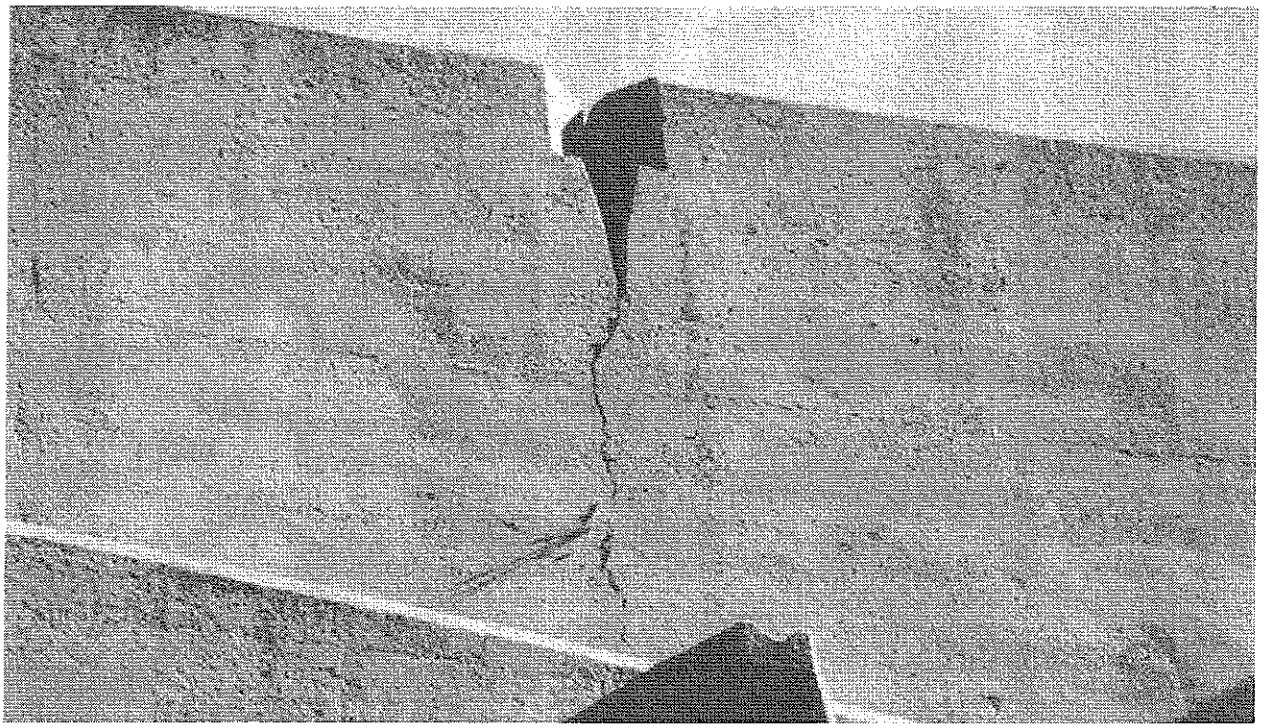
Bottom Photo:
Vertical cracks on the wingwall of Bridge #759, James Farm Road.

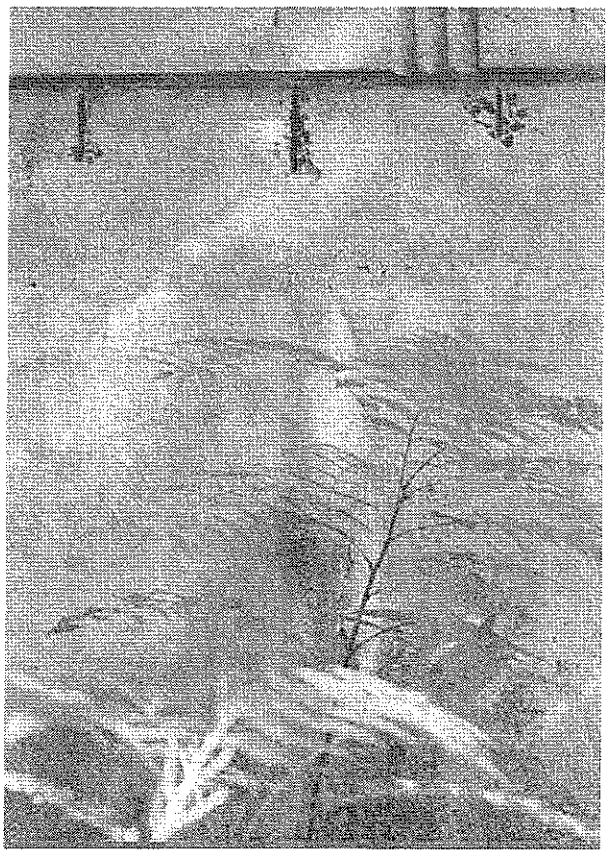
2.3.3 Concrete Cracking

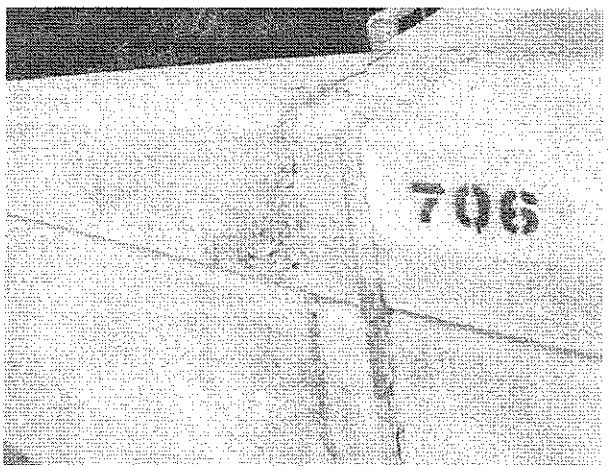
Cracks occur over time in all concrete. Cracks on the Parkway bridges are extremely common, and vary in depth, width, direction, pattern, location and cause. Dormant cracks, such as those caused by shrinkage during curing, may not increase over time. Active structural cracks may deepen and widen over time.

The cracking on the bridges has occurred due to overloading, uneven foundation settling, original design inadequacies, changes in temperature, inadequate expansion joints, and "map" cracks which at times exudes a hard white gel as result of chemical (alkali) reactions within the concrete. Cracks left open allow for the intrusion of water, freezing and thawing, thus further speeding up the process of deterioration.

Superficial repairs which do not eliminate the underlying causes of cracking only agravate the problems. Any visible cracks should be inspected on a routine basis by a qualified professional and a regular repair program be implemented.



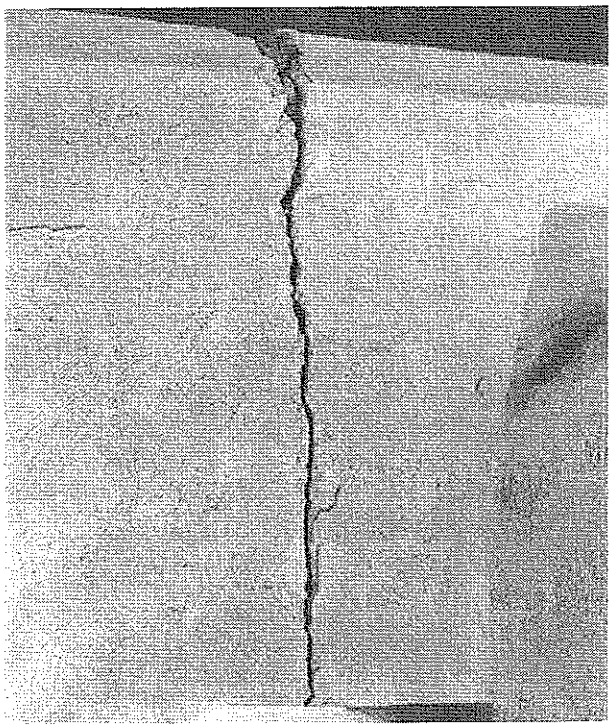


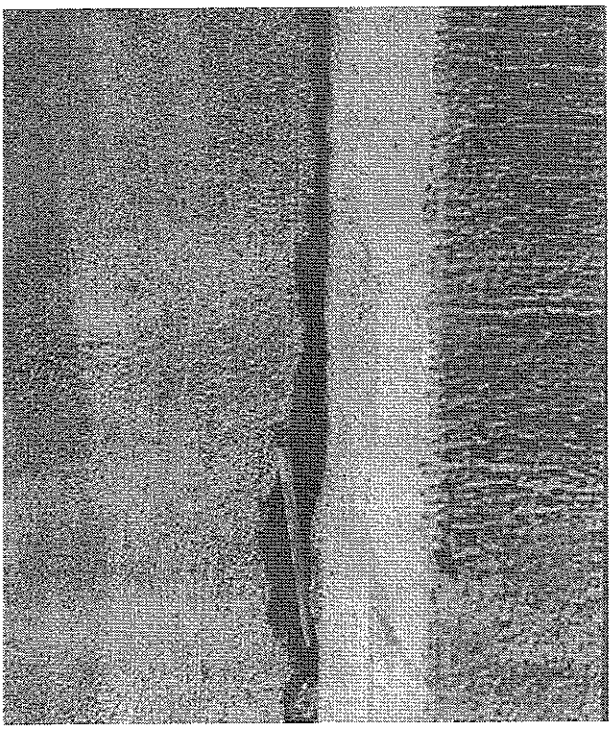


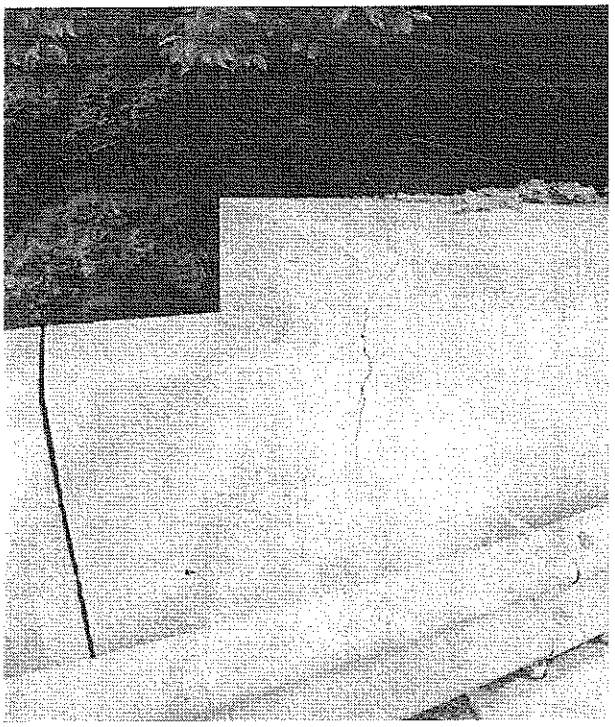
Top Photo:
Scupper on Bridge #745, Park Avenue provides the perfect opportunity for a vertical crack to form.

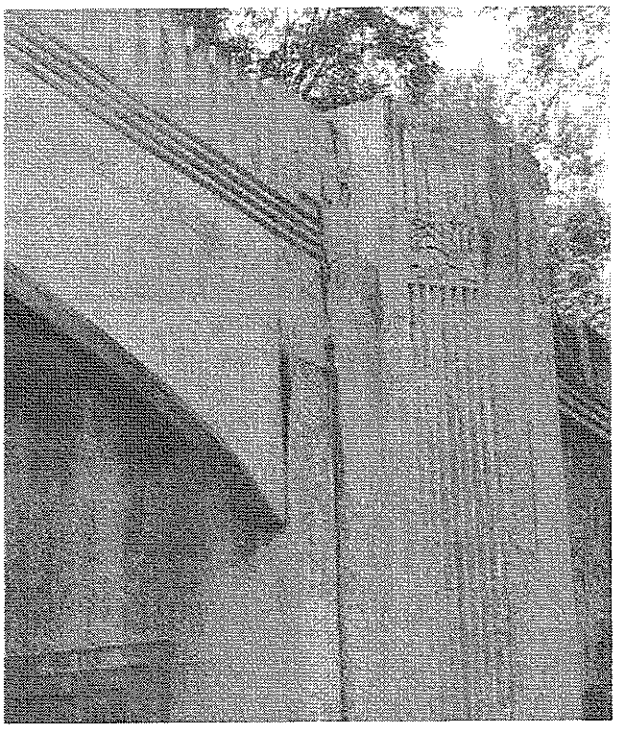
Bottom Left Photo:
Cracking in wingwall of Bridge #737. Note the hard white gel which has forced its way through the surface.

Bottom Right Photo:
Cracking and attempted patch on balustrade of Bridge #706, High Ridge Road.



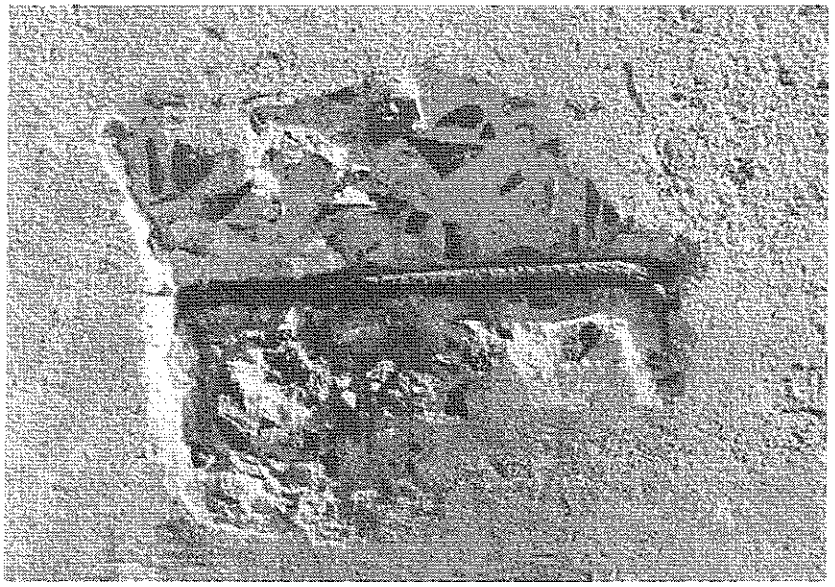




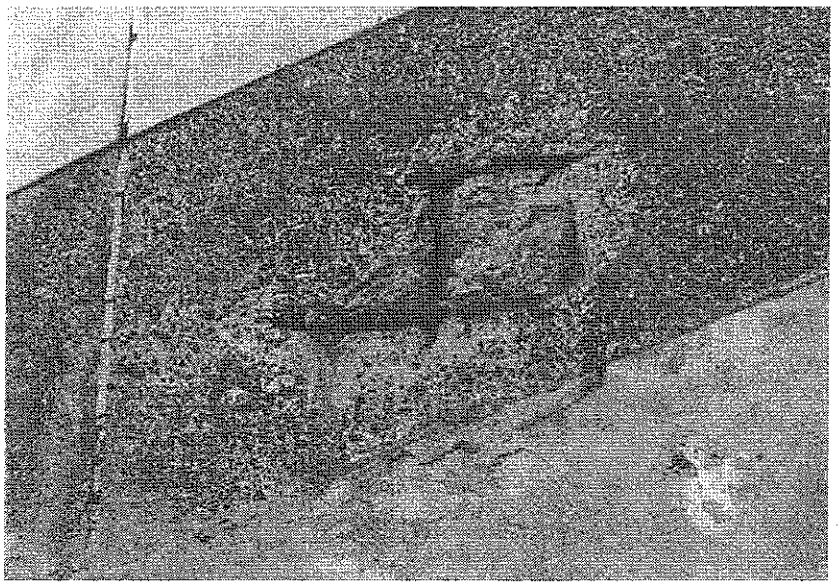


Left Top Photo: Vertical crack at Bridge #730, Weston Avenue.
Left Bottom Photo: Cracking on parapet of Bridge #716, Comstock Hill Rd.

Right Top Photo: Cracking due to poor expansion joints on Bridge #711, Lapham Road.
Right Bottom Photo: Cracking on pylon of Bridge #711 (renumbered 5810), Lapham Road.



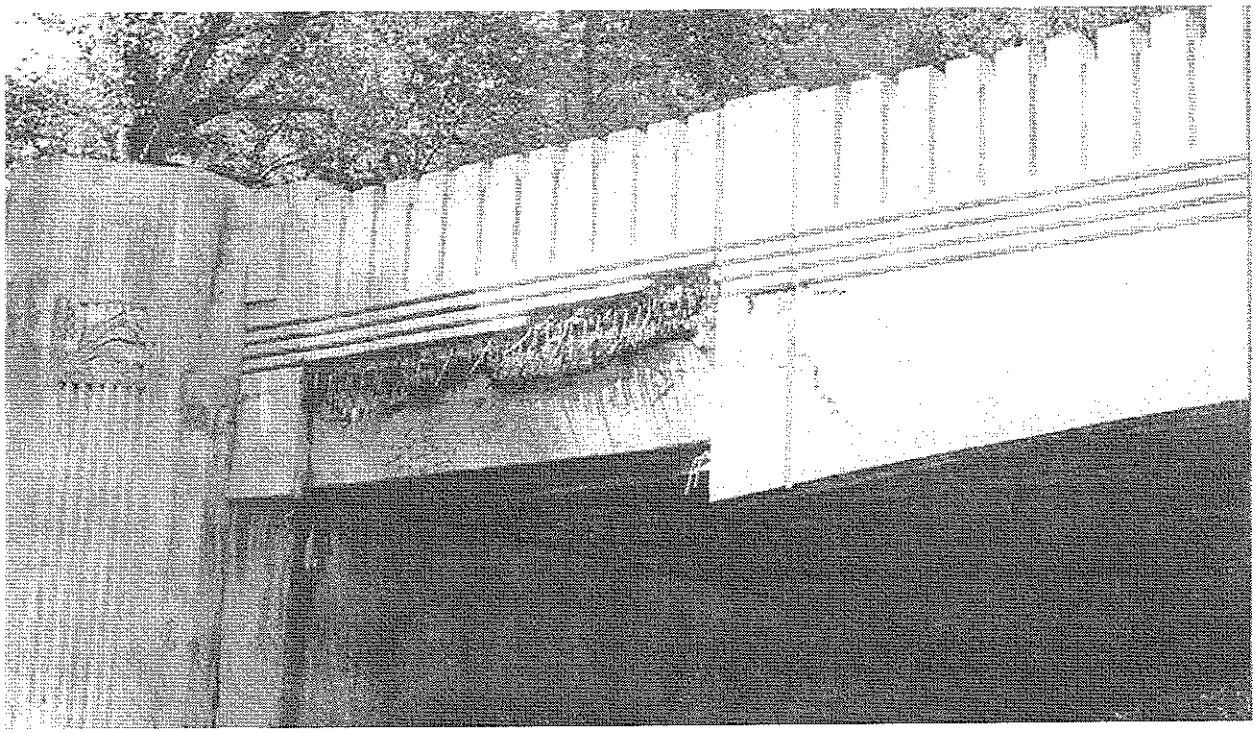
Top Photo:
Concrete spall, leaves steel reinforcing bar exposed on Bridge #759, James Farm Road.

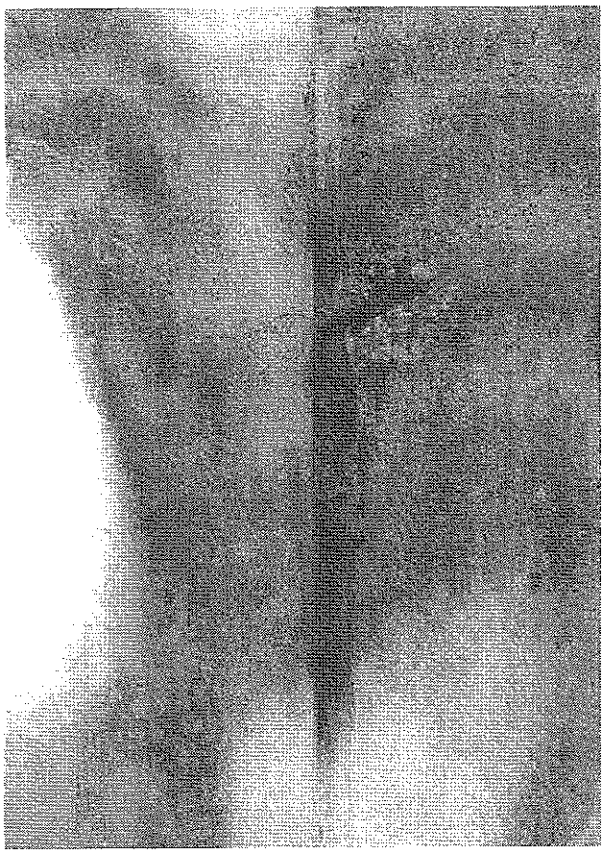


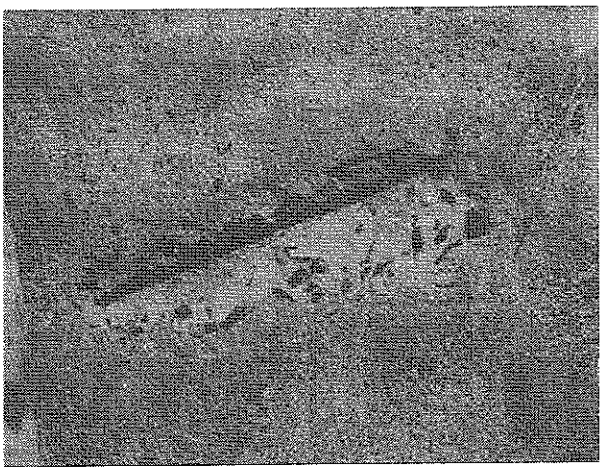
Bottom Photo:
Exposed reinforcing on precast panel at Bridge #760, Main Street (River Road, Route 110).

2.3.4 Exposed Concrete Reinforcing

Spalling concrete and cracks expose the steel reinforcing to the air and to moisture. The steel corrodes and can no longer perform its function as reinforcement. As the steel continues to corrode it expands, cracks and further spalling occurs, exacerbating the problem until underlying causes are addressed and repairs are made.



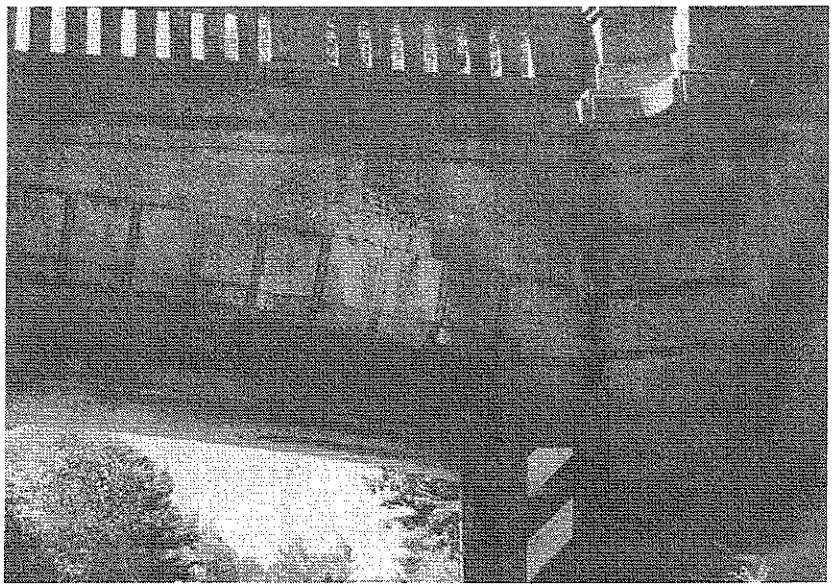




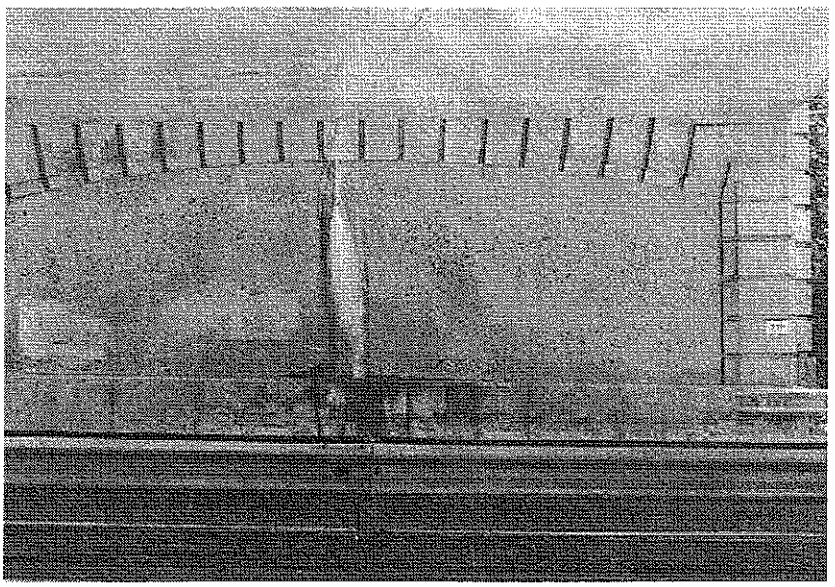
Top Photo:
Impact damage on non-original precast panel, exposing reinforcing on Bridge #711 (renumbered 5810), Lapham Road.

Bottom Left Photo:
Exposed steel reinforcing on Bridge #738, Hillside Rd.

Bottom Right Photo:
Exposed steel reinforcing on Bridge #738, Hillside Rd.



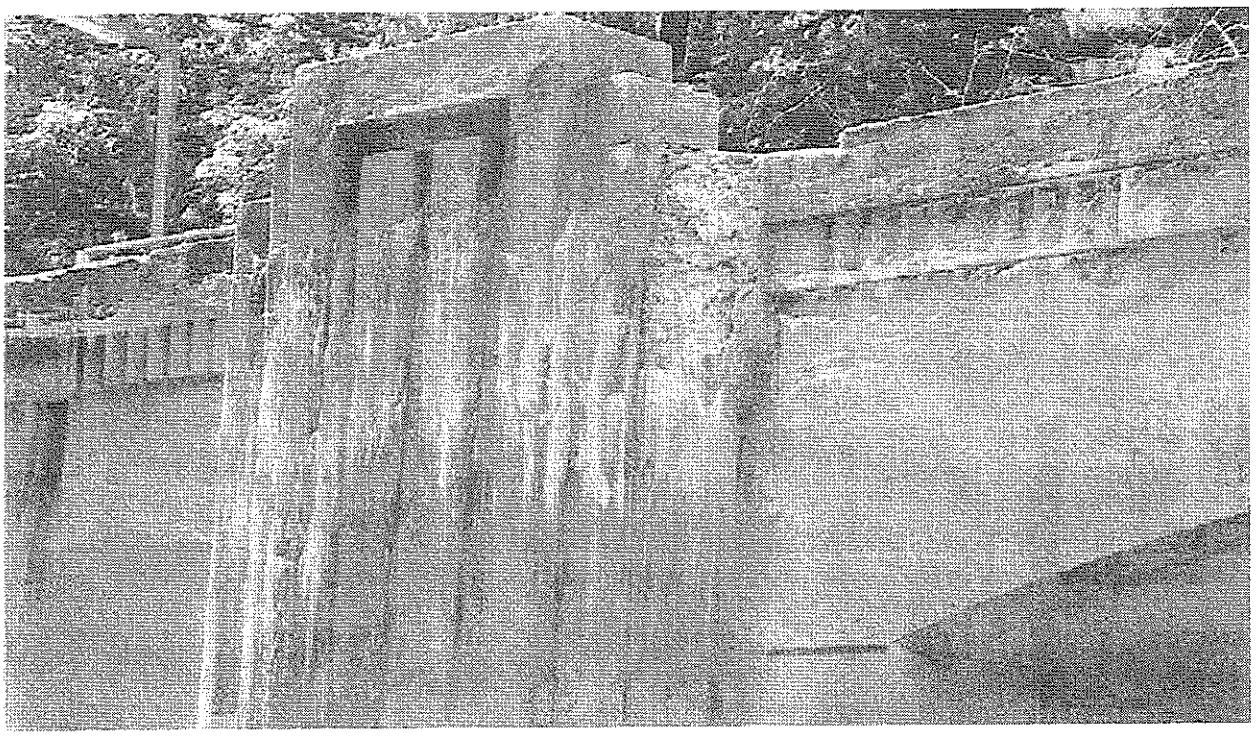
Top Photo:
Efflorescence on spandrel of Bridge #708, Ponus Ridge Road.

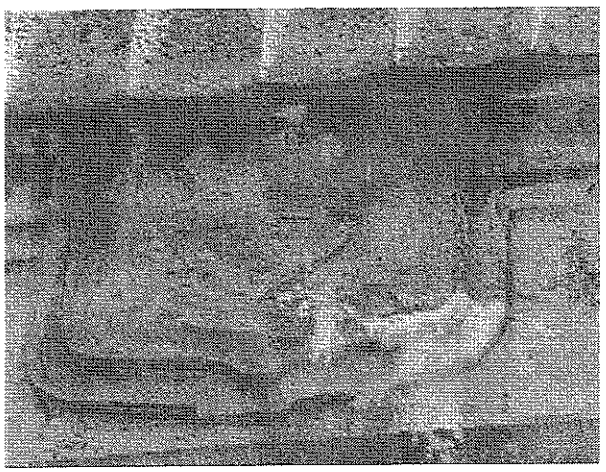


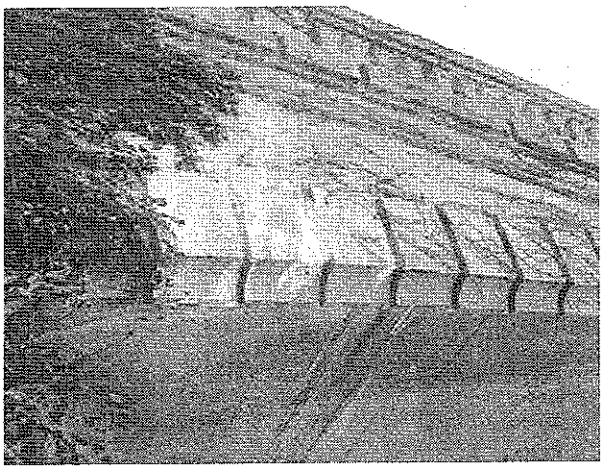
Bottom Photo:
Efflorescence on abutement of Bridge #708, Ponus Ridge Road.

2.3.5 Concrete Efflorescence

Efflorescence, a white powdery stain on the surface of the concrete occurs on a number of bridges. It is one more sign of moisture intrusion into the structure and results from the leaching of the lime in the Portland cement. The occurance of these white stains generally indicates that the deck water proofing is failing in some manner.



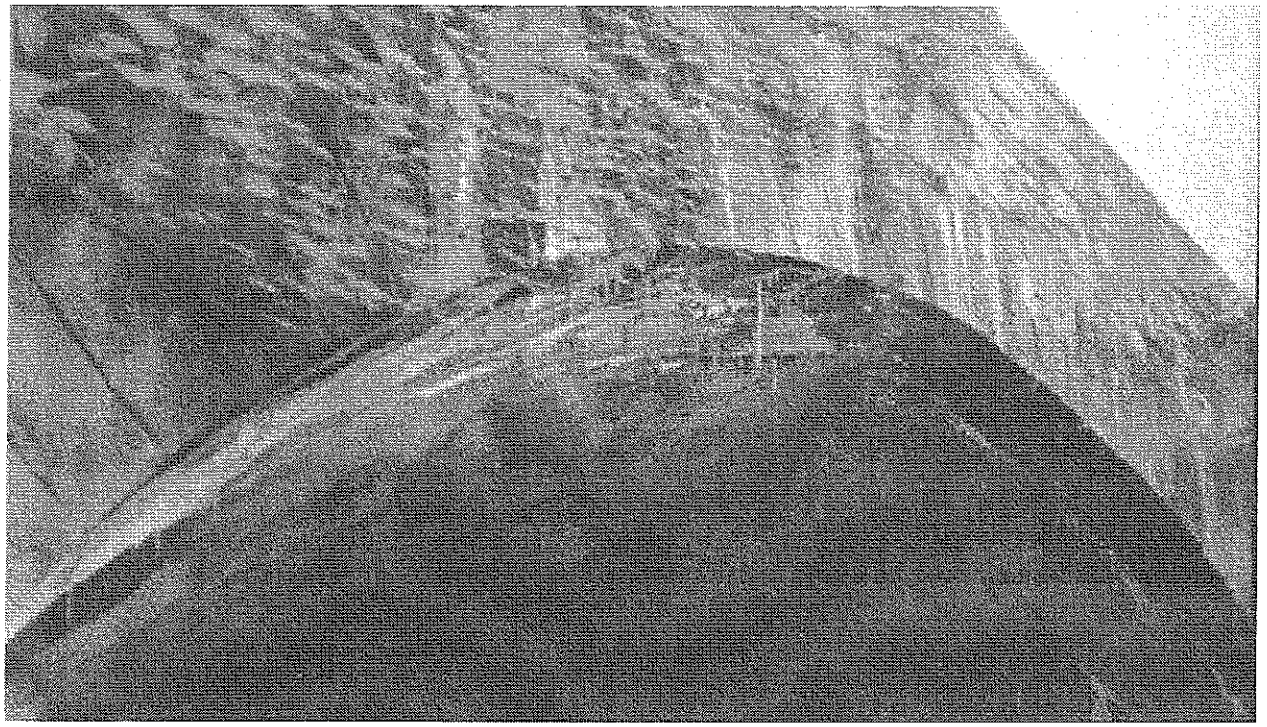


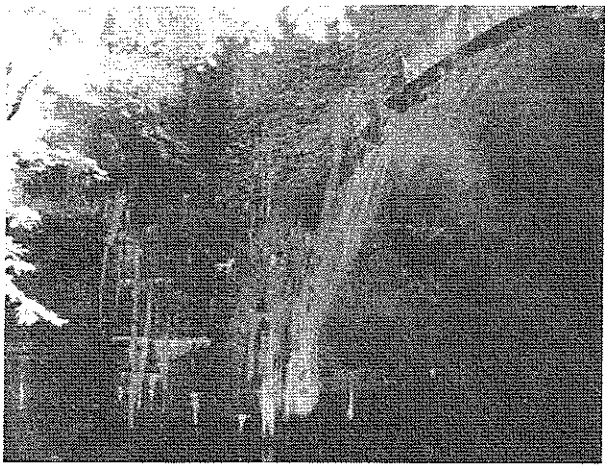


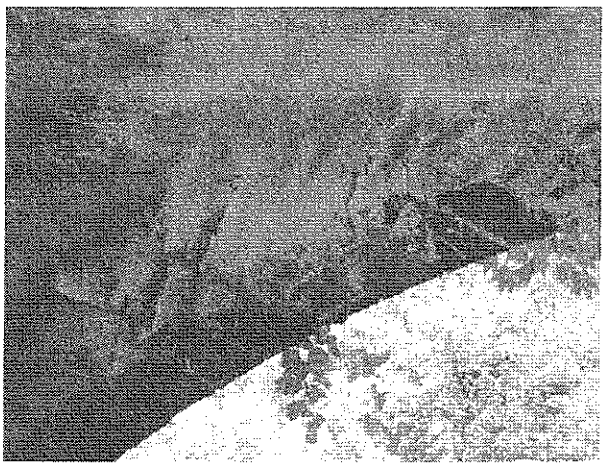
Top Photo:
Efflorescence on pylon of Bridge #710, Metro North Railroad, indicates that more serious deficiencies will follow.

Bottom Left Photo:
Efflorescence on coat of arms at Bridge #723, East Rock Road.

Bottom Right Photo:
Efflorescence on spandrel of Bridge #708, Ponus Ridge Road.



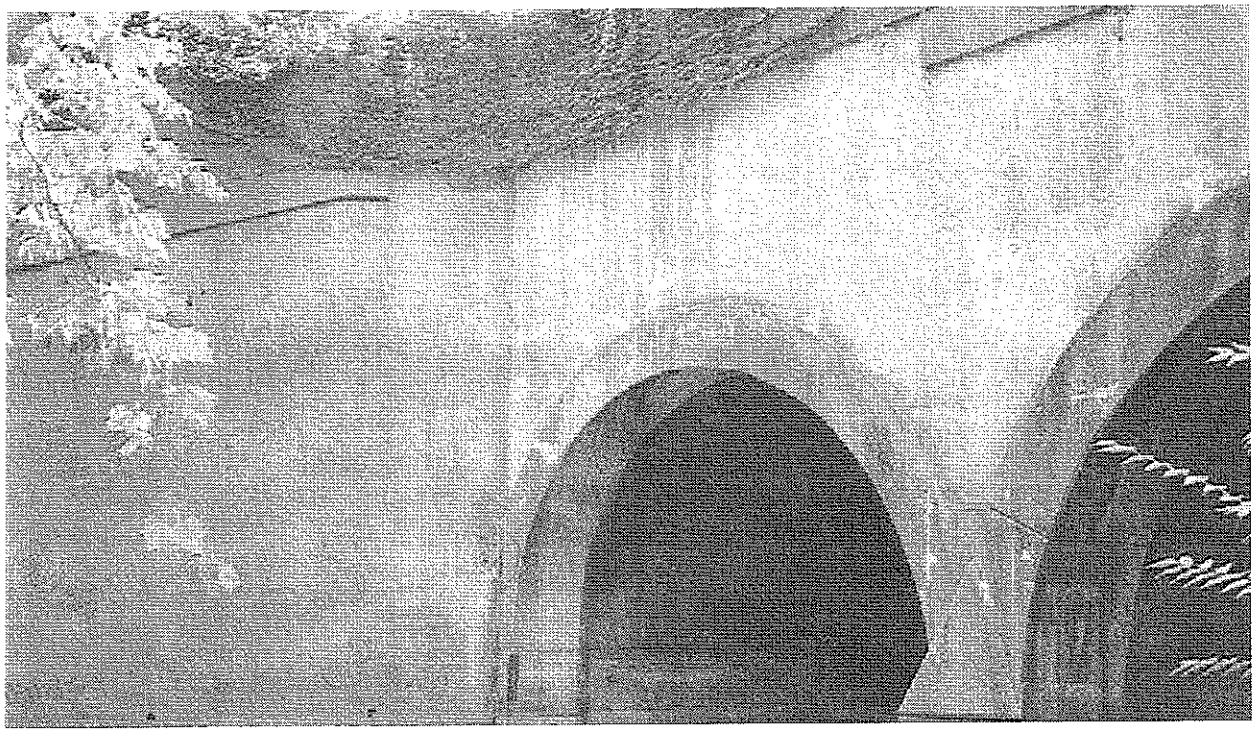


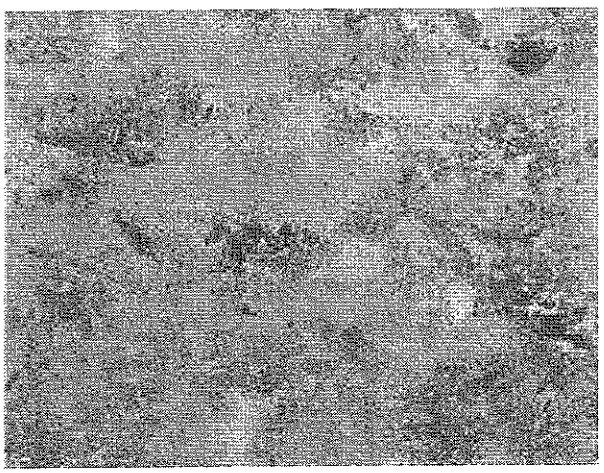


Top Photo:
Detail of leakage under Bridge #705, Rippowan

Bottom Left Photo:
Severe efflorescence from masonry joints on pylons, Bridge #705, Rippowan.

Bottom Right Photo:
Efflorescence under Bridge #705, Rippowan.



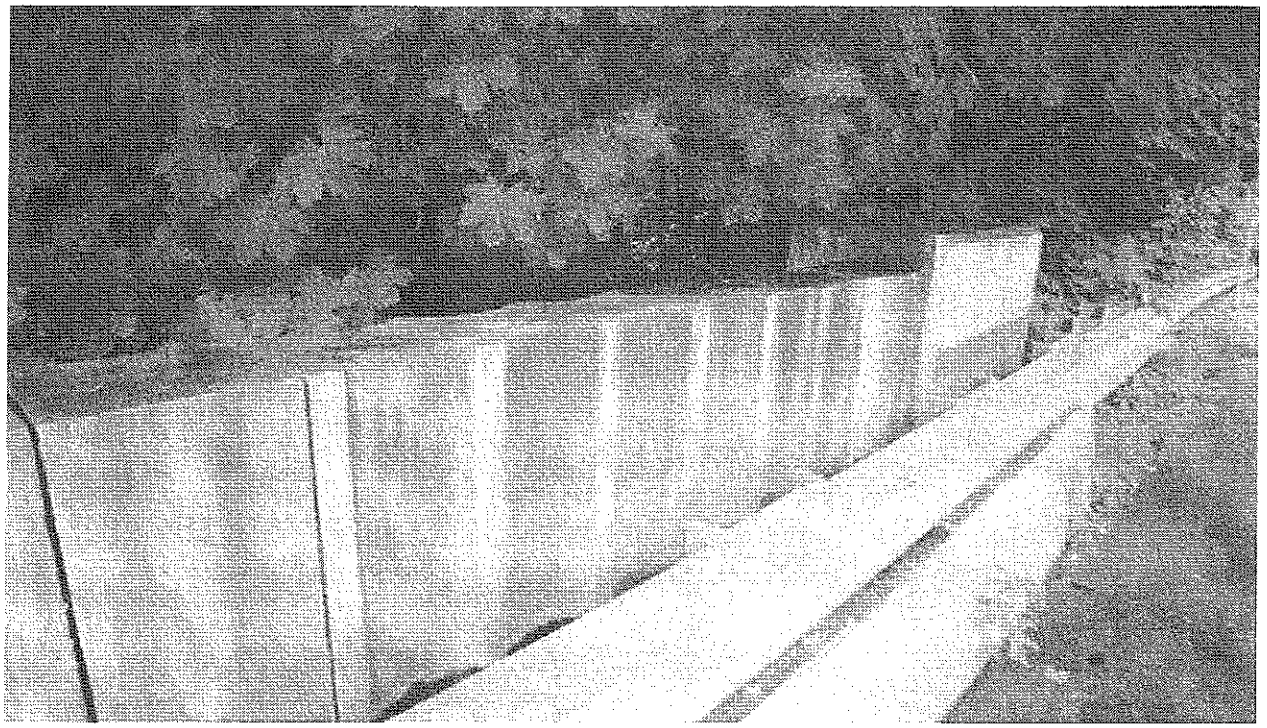


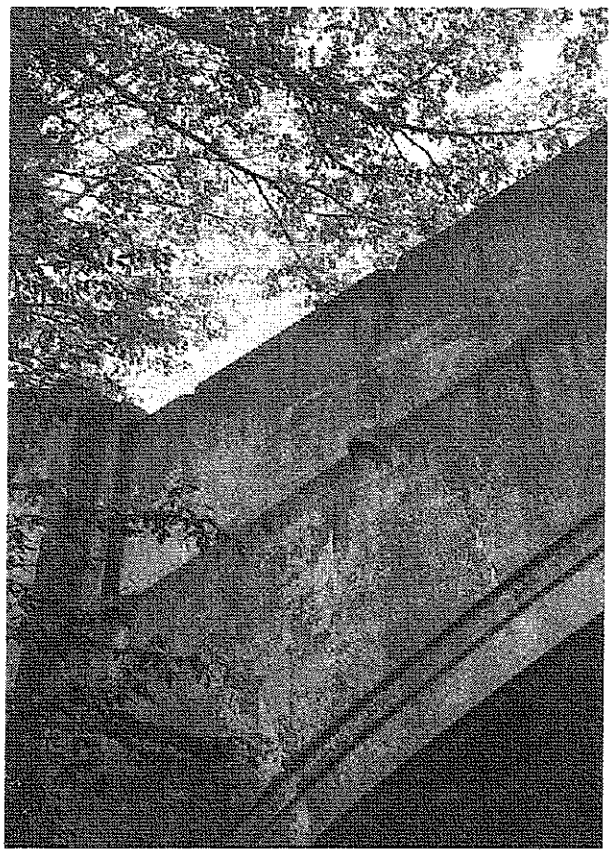
Top Photo:
Vegetation and weathering stains are dominant on the surfaces of Bridge #721, Norwalk River.

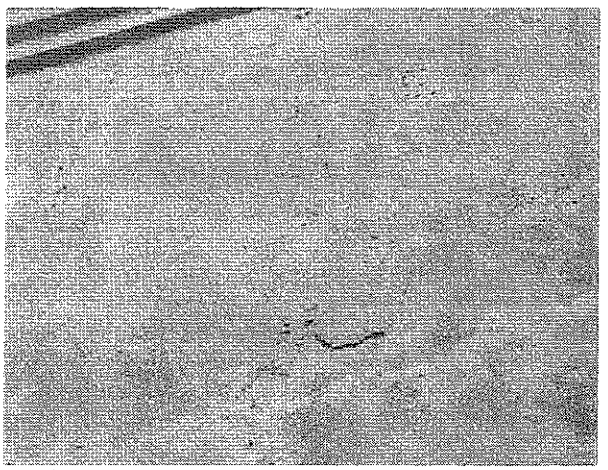
Bottom Photo:
Discoloration and staining on concrete surfaces of Bridge #747, Madison Avenue.

2.3.6 Concrete Stains

Bridges which are beginning to deteriorate internally may frequently exhibit stains. Stains may also result from environmental factors such as windblown debris, air pollution, sea air, and biological growth such as algae and moulds. Reddish-orange stains usually signify the corrosion of the steel reinforcing, within the bridge. Cleaning to remove stains should be the last step in the process to repair underlying deficiencies, or staining will reoccur.



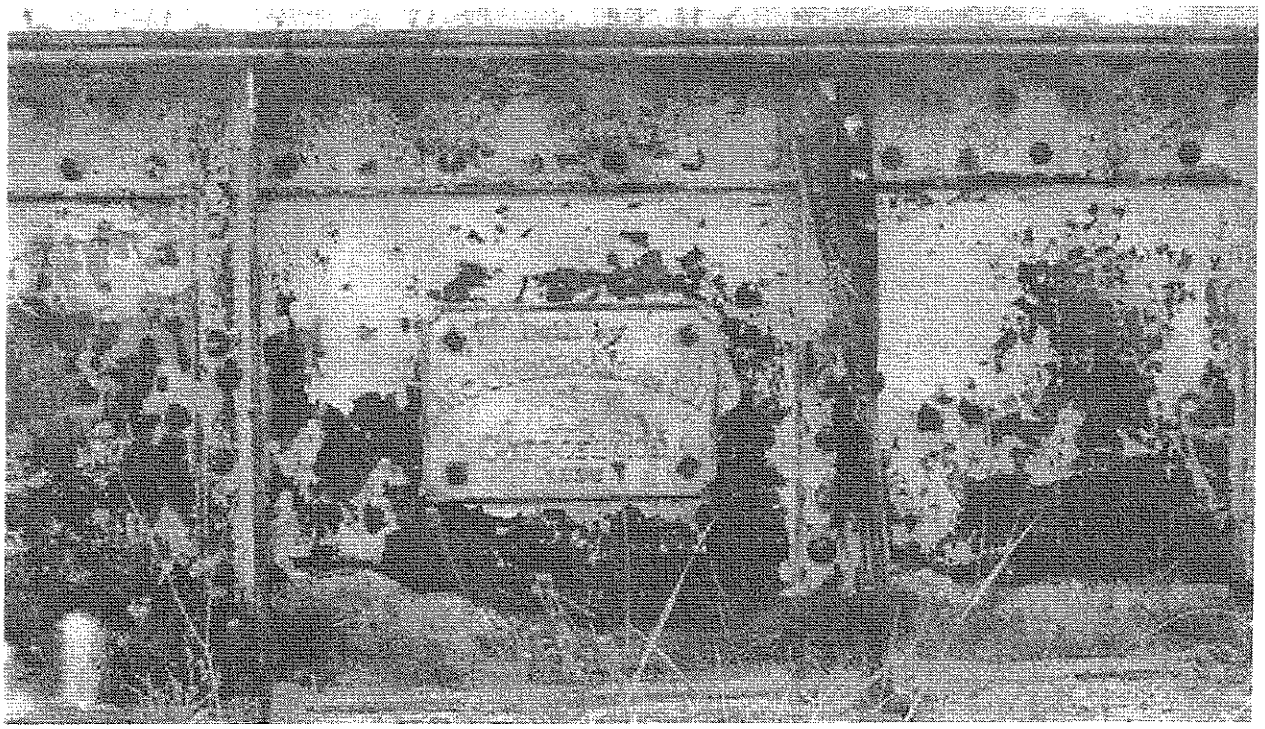


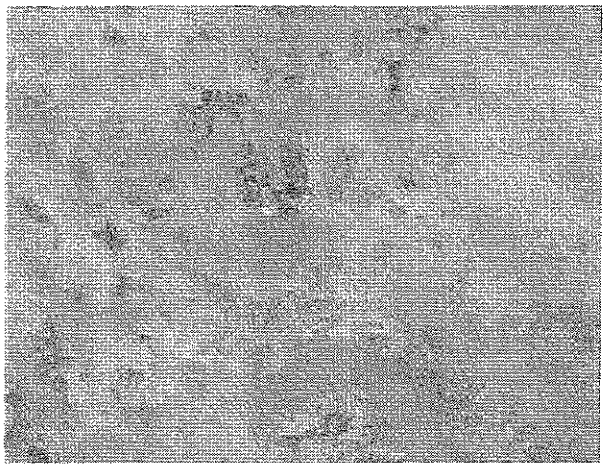


Top Photo:
Biological staining and discoloration on the concrete surface of Bridge #719, Perry Avenue.

Bottom Left Photo:
Staining on Bridge #745, Park Avenue.

Bottom Right Photo:
Discoloration and staining on concrete surfaces of Bridge #733, Bayberry Lane.



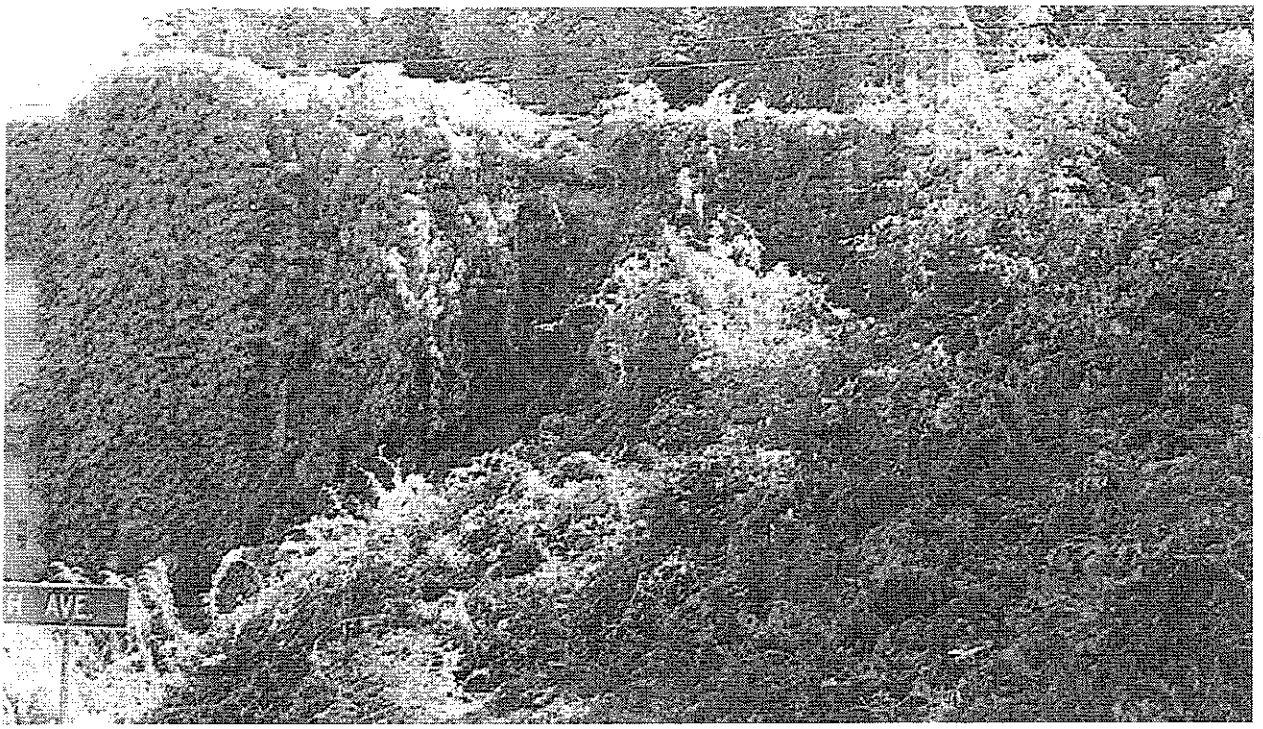


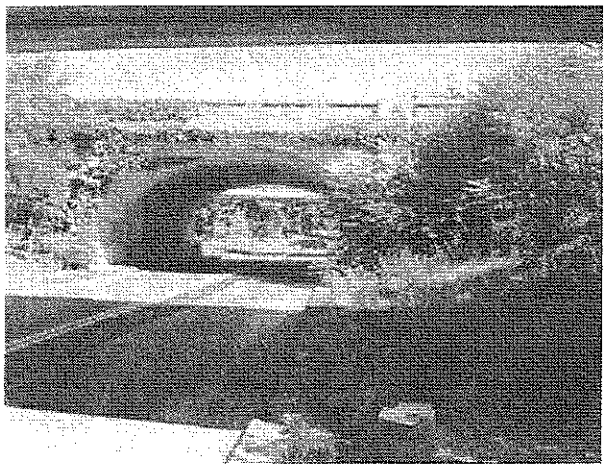
Top Photo:
Corrosion and deterioration of built up plate girder parapet on Bridge #751, Rocky Hill Road.

Bottom Photo:
Close up showing corrosion of metal at Bridge #722, West Rock Road.

2.3.7 Structural Steel Deterioration

Steel is highly susceptible to corrosion and oxidizes rapidly when exposed to moisture and air. On the Parkway, the steel rigid frame structures which exist on several bridges have been exposed to corrosive substances in the air, automobile exhaust, road salts, moisture, heat and salt air for 60 years. The steel has not received adequate maintenance (re-painting) and is rusting in many locations. A routine maintenance program will extend the life of the structure, indefinitely.



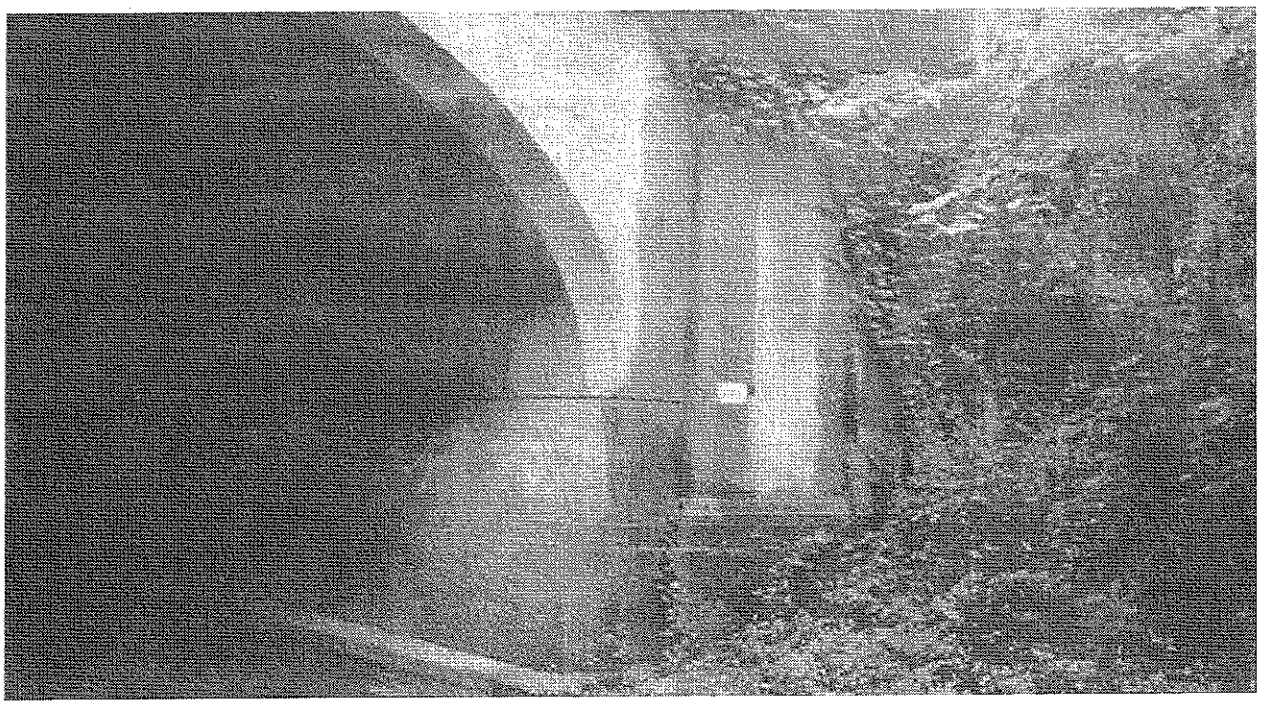


Top Photo:
Heavy vegetation conceals the wingwall at Bridge #712, South Avenue (Route 124).

Bottom Photo:
Extensive overgrowth and vegetation is visable on Bridge #719, Perry Avenue.

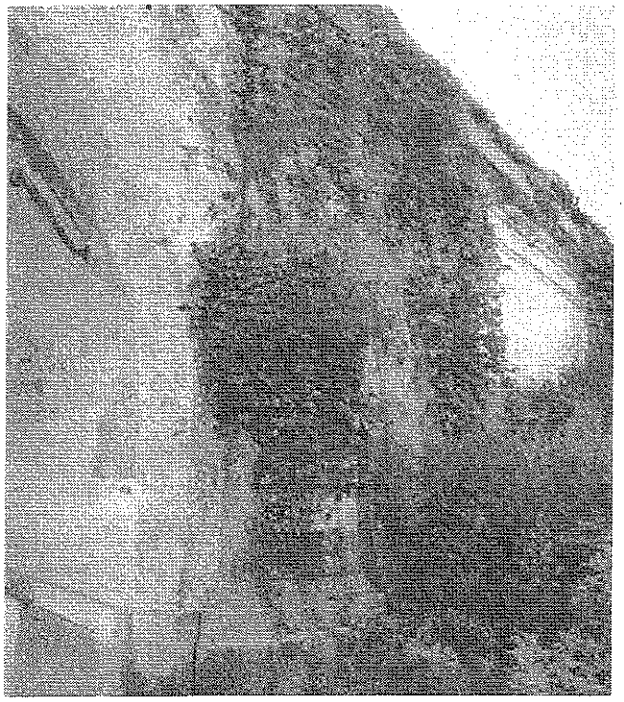
2.3.8 Obtrusive Vegetation

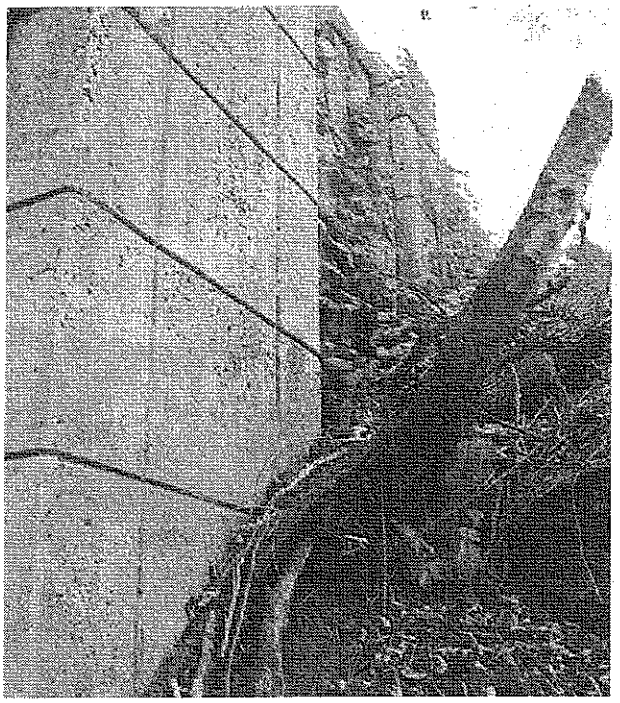
Views of the entire bridge facades, facing the parkway or the local roads which pass under the parkway, including the pylons, wingwalls, and parapets have long been obscured by vegetation. Climbing vines, overgrown tree limbs and shrubs, and undesirable volunteer growth physically cover, or block views of the much of the architectural detail of the majority of bridges. Climbing vegetation may hide deficiencies in the structure, reducing the likelihood of repairs being made. The vegetation also will stain the surface.

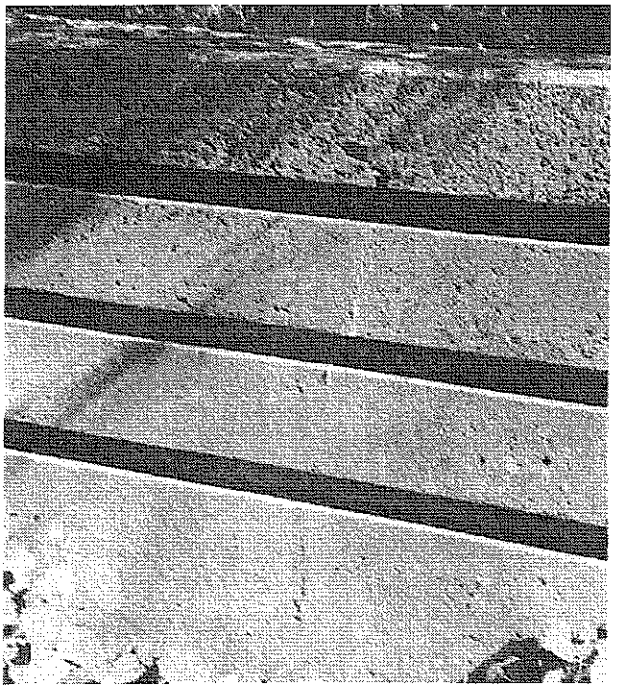


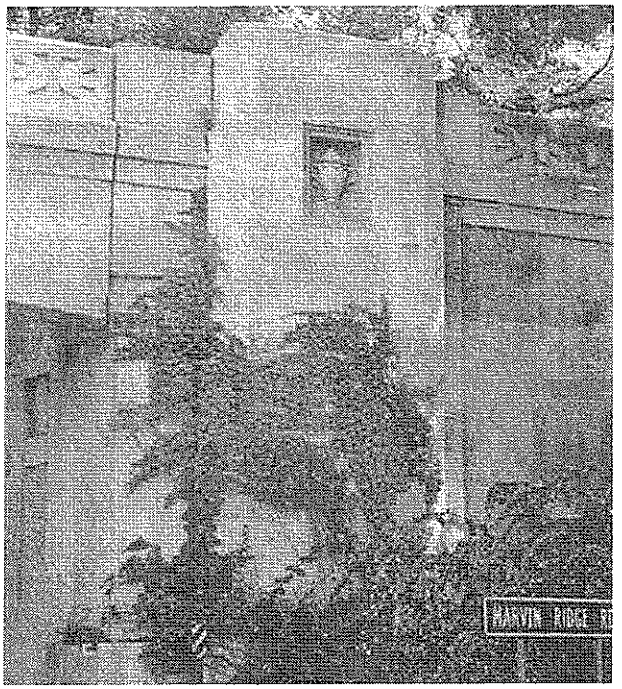
Top Photo:
Bridge #721, Norwalk River, vegetation obscures the view of the bridge.

Bottom Photo:
Bridge #733, Bayberry Lane, vegetation makes inspection practically impossible.



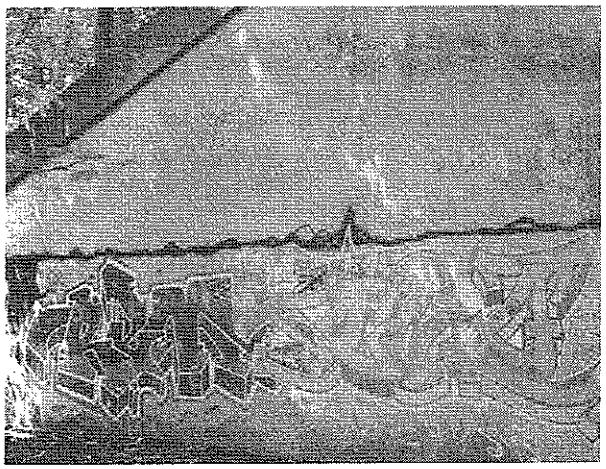






Top Photo:
Growth on Pylon at Bridge #719, Perry Avenue obscures architectural features.
Bottom Photo:
Growth discolors surface of parapet , Bridge #746, Plattsville Rd..

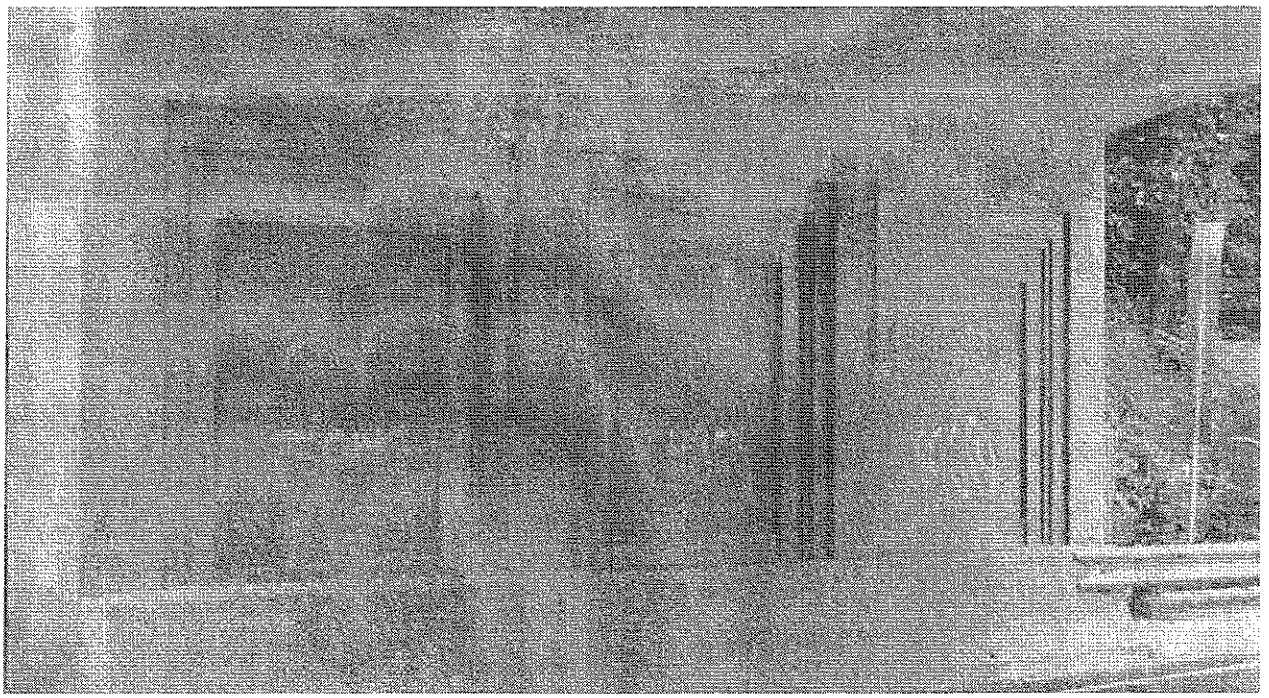
Top Photo:
Embankment at Bridge #742, Morehouse Highway, where the roots of a tree compete for space with the bridge.
Bottom Photo:
Growth on pylons at Bridge #714 (renumbered 5811), Marvin Ridge Road.



Top and Bottom Photos:
Enthusiastic graffiti artists completed these murals on the Norwalk River Bridge (#721).

2.3.9 Graffiti

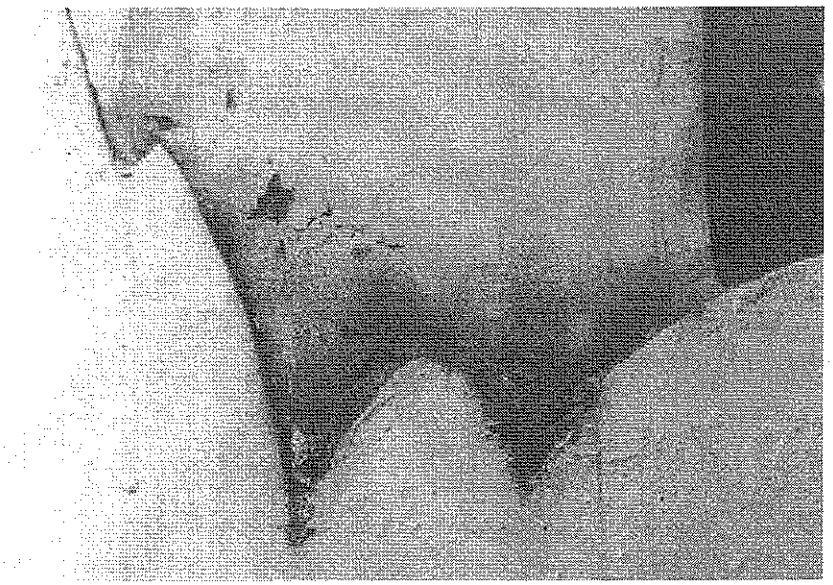
Graffiti is common on the smooth surfaces of wingwalls, concrete parapets and railings, and abutment walls of the concrete bridges. It also can be found on many ornamental features such as precast and sgraffitto panels. On the masonry bridges it is common on the abutment walls which are concrete. Occasionally graffiti is present on the stonework. A variety of graffiti coatings have been used which mar the surface of the original materials and may attract more graffiti.



Top Photo:
Graffiti on parapet of Bridge #742, Morehouse Highway.

Bottom Photo:
Graffiti on abutement of Bridge #723, East Rock Road.

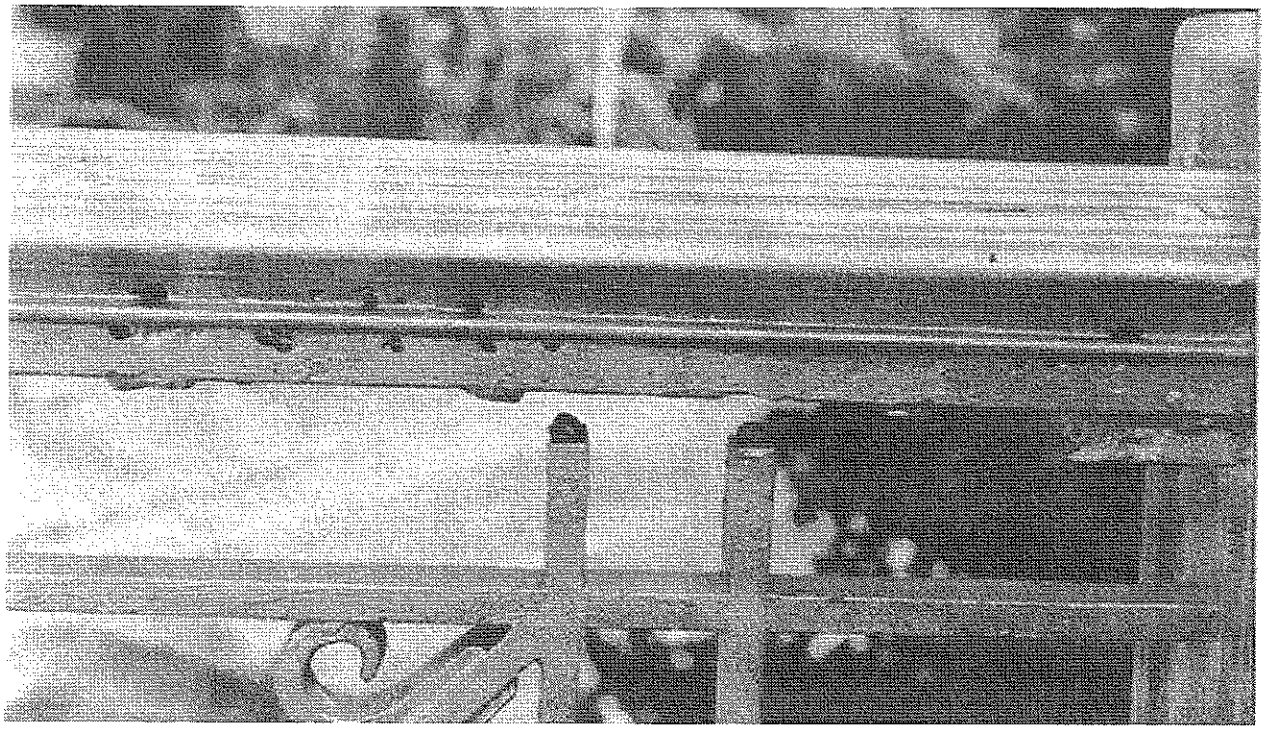
Top Photo:
Corrosion of metal parapet railing on Bridge #732 North Avenue.

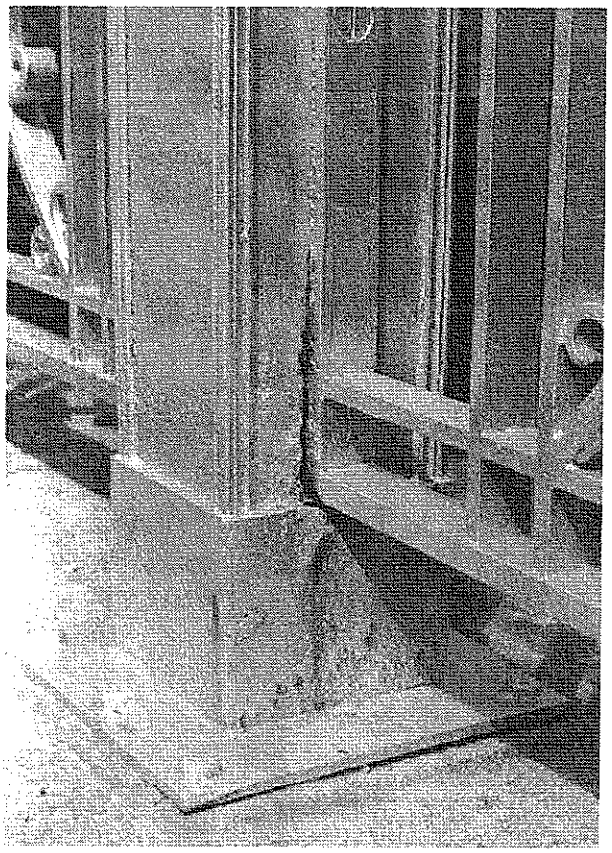


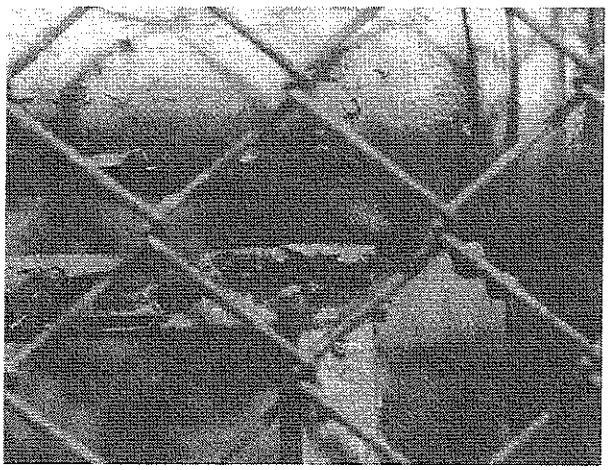
Bottom Photo:
Close up view of metallic corrosion on Bridge #760, Main Street (River Road, Route 110)

2.3.10 Corrosion of Ornamental Metals

The metal railings and ornamental grilles on the parkway are corroding rapidly, where they have been neglected. Cast iron, while less prone to corrosion than steel, is still highly susceptible. Wrought iron and fabricated steel components are prone to the same environmental conditions as structural steel, and will disintegrate more rapidly because they are generally thinner and have more exposed surfaces and pockets. Aluminum, cast brass and the galvanized cast iron at Merwins Lane (#735) in Fairfield are generally more resistant to corrosion but some corrosion has still taken place.



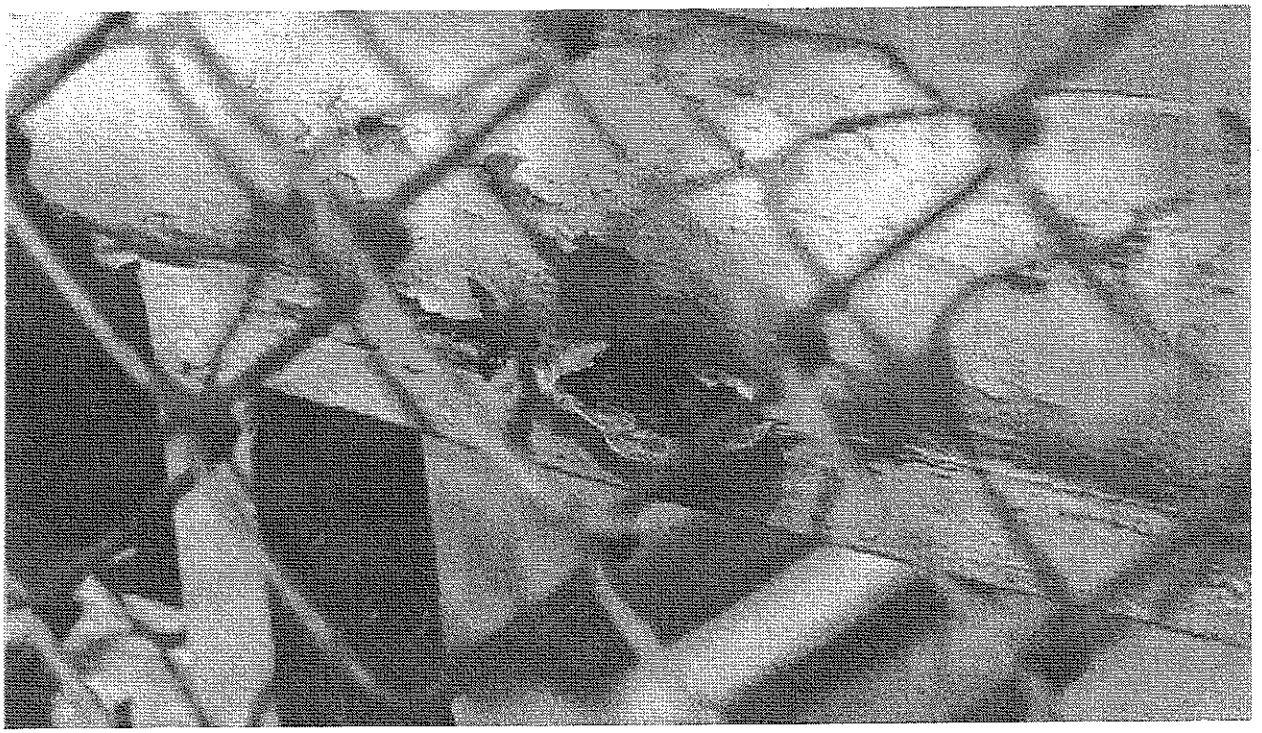


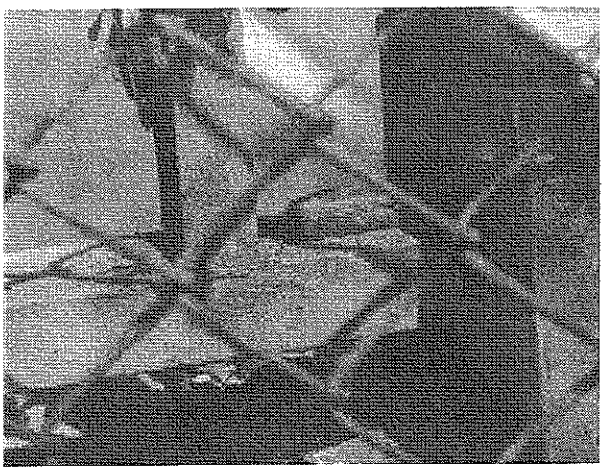


Top Photo:
Detail of parapet handrail on Bridge #729, Clinton Ave. Corrosion has completely disintegrated bar sections.

Bottom Left Photo:
Detail of railing post base on Bridge #729, Clinton Ave.

Bottom Right Photo:
Detail of metallic corrosion on Bridge #724, Grumman Ave, compromises integrity of railing as a safety feature.

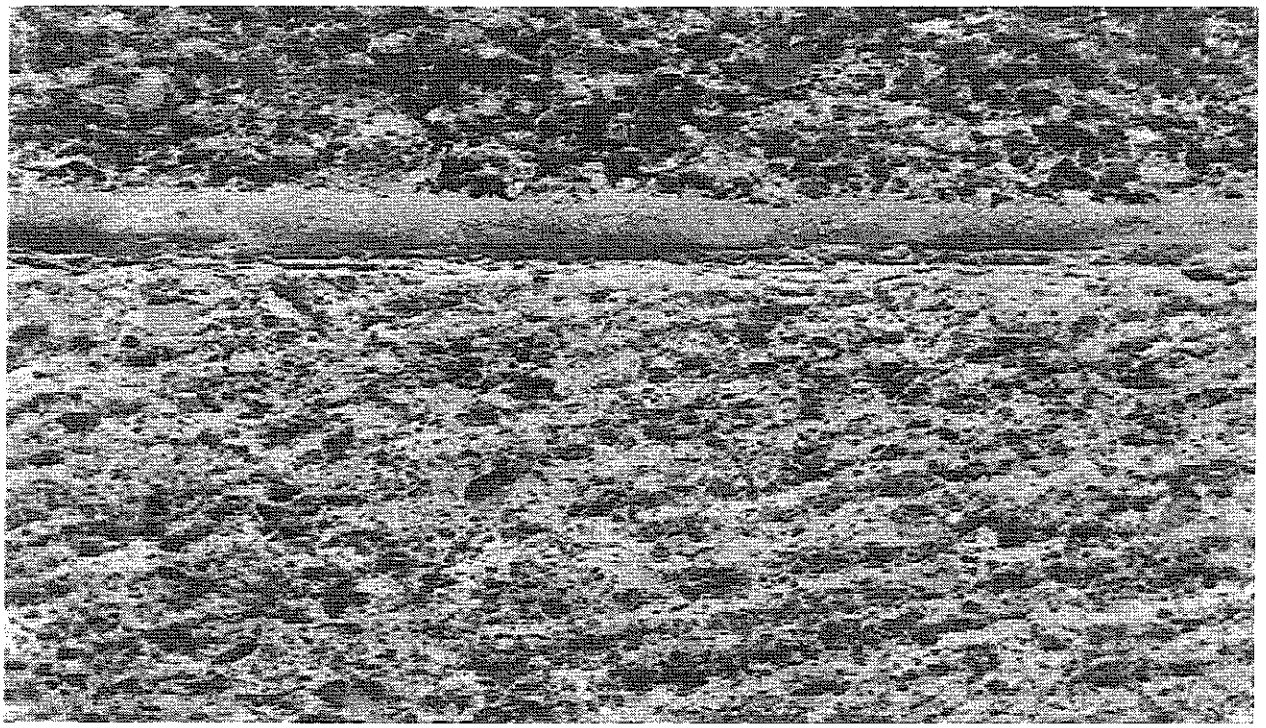


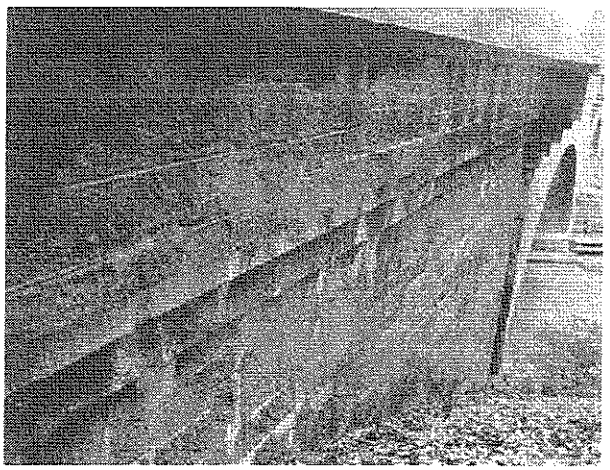


Top Photo:
Detail of metallic corrosion on handrail of Bridge #724, Grumman Ave. Routine maintenance would prevent costly replacement.

Bottom Left Photo:
Detail of metallic corrosion on railing of Bridge #724, Grumman Ave.

Bottom Right Photo:
Detail of metallic corrosion on railing of Bridge #724, Grumman Ave.





Top Photo:
Unavoidable weathering of surface of stone masonry on Bridge #726, Newtown Turnpike.

Bottom Photo:
Wingwall of Bridge #726, showing leeching of moisture and salts from roadway above through mortar joints.

2.3.11 Masonry Deterioration

The natural stone bridges of the parkway remain in fair to good condition with some defects in the mortar joints, such as cracks, missing mortar and separation. No major structural cracks were apparent. The ashlar and rubble stone, and granite capstones and voussoirs are generally heavily soiled and have vegetation growing on them.

The cast stone bridges show further deterioration and are in fair condition. Some of the units are cracked, broken or are missing altogether.

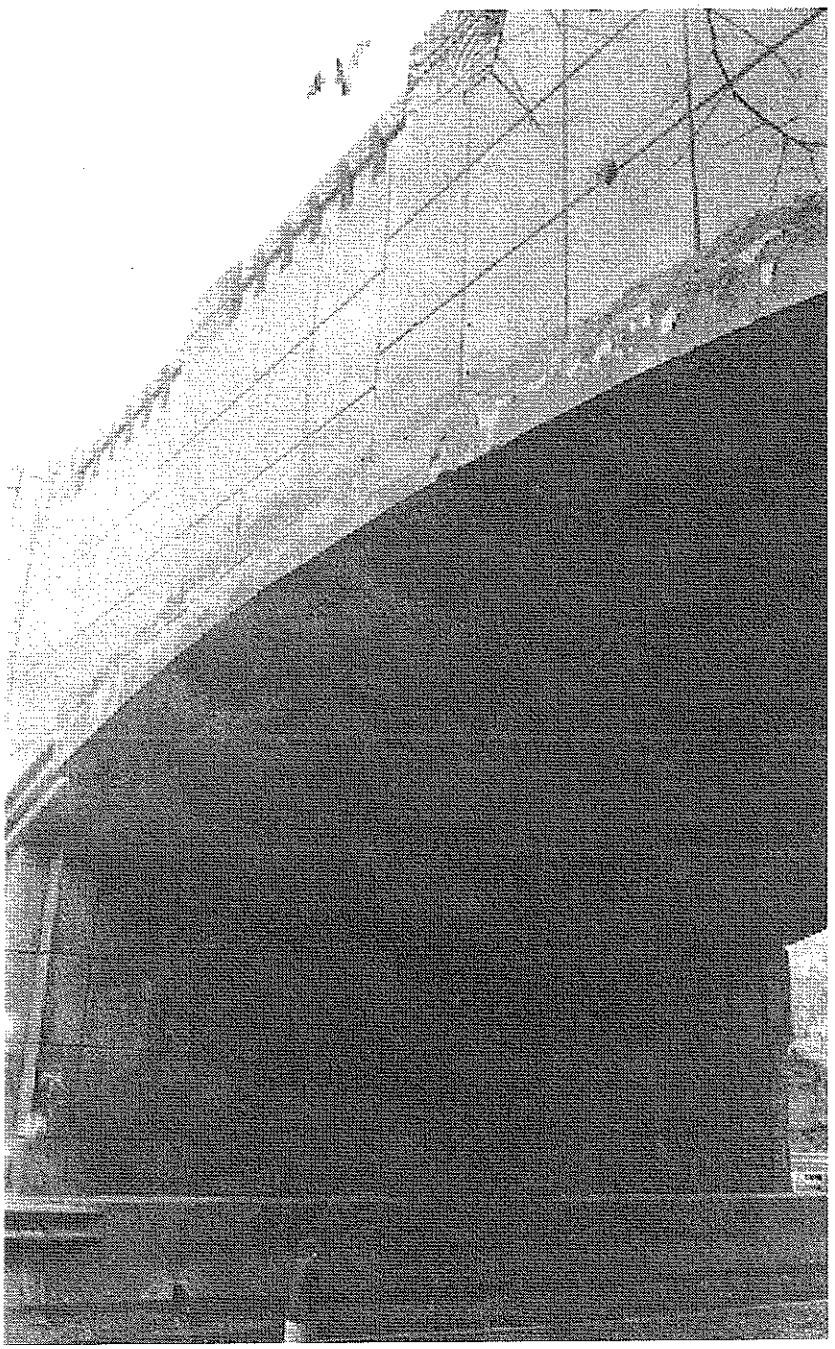


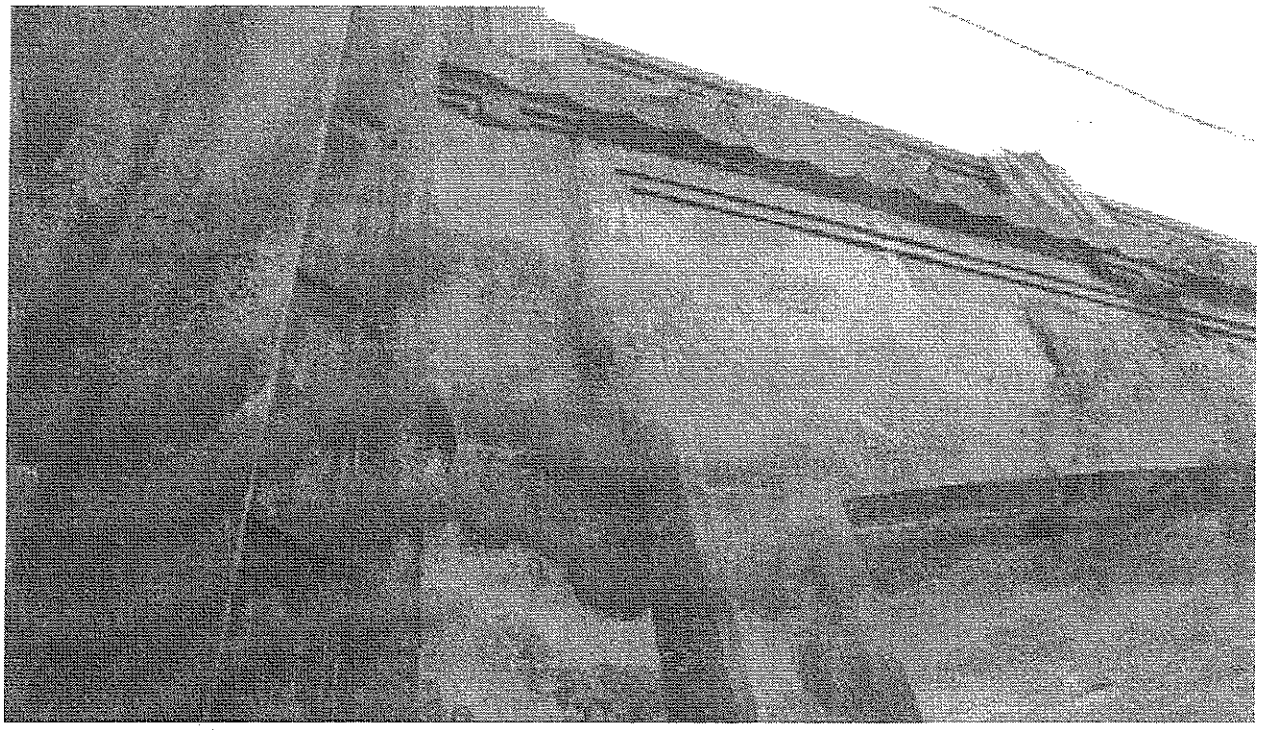
Photo:
Repair of spandrel edge on Bridge #742, Morehouse Highway. It appears that no attempt was made to match the color of the existing concrete or architectural design pattern of the primary structure.

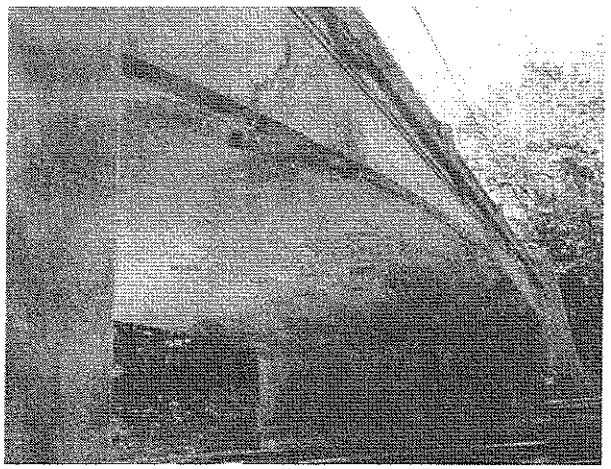
2.4 ALTERATIONS AND MODIFICATIONS MADE TO THE BRIDGES

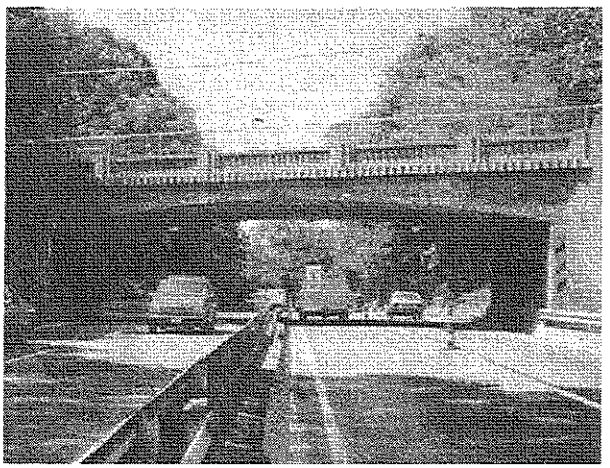
2.4.1 Repairs and Maintenance

a. Repair of Concrete

Repairs which have been made to spalling concrete curbs, spandrels, and parapets generally do not match the original, adjacent concrete in terms of color or texture, compromising the appearance of the bridges.



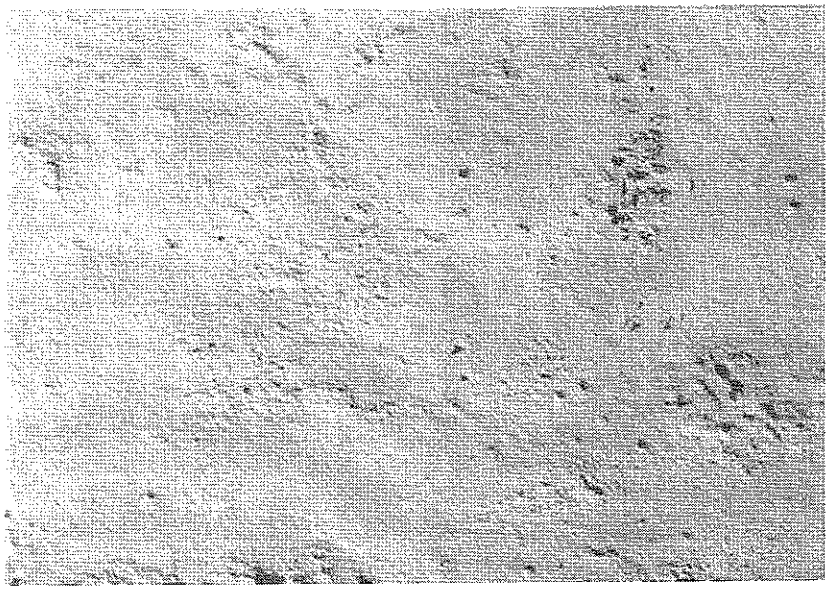




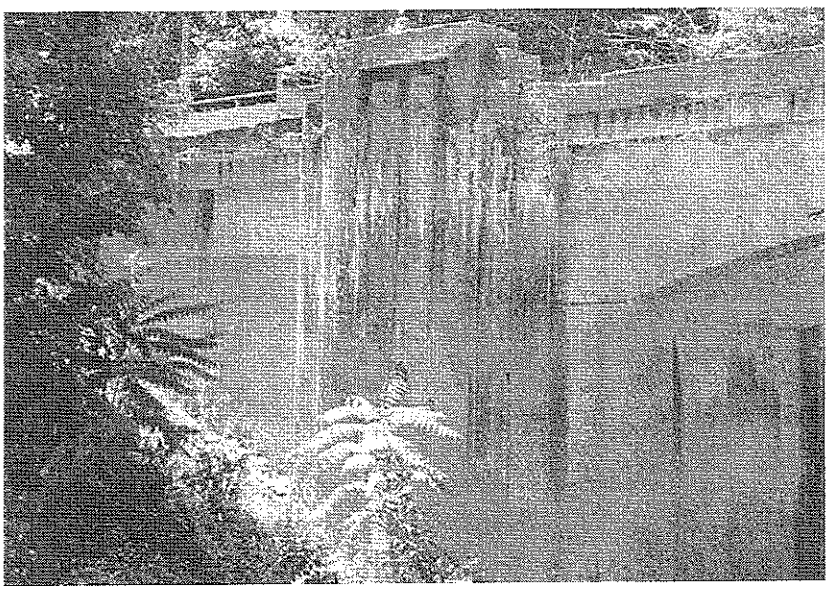
Top Photo:
Patch repair of concrete at spandrel of Bridge #723, East Rock Road.

Bottom Left Photo:
Patch repair of concrete at spandrel of Bridge #723, East Rock Road.

Bottom Right Photo
Overall view of Bridge #723, East Rock Road. Note that the color of the repairs do not match the adjacent (original) finish Additionally, the concrete continues to deteriorate because the overall deficiencies have not been addressed.



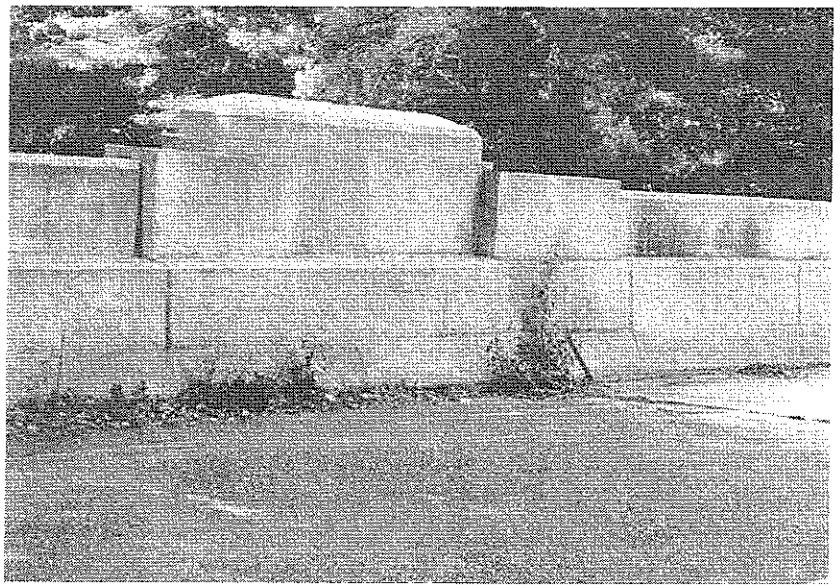
Top Photo:
Detail of cream colored coating Bridge #713, White Oak Shade Road with non-matching graffiti patching.



Bottom Photo:
Graffiti coating (paint) applied to lower portion of pylon at Bridge #716, Comstock Hill Road.

b. Graffiti Coatings

Graffiti coatings which have been used on the bridges, typically grey or tan in appearance do not match the original, or adjacent concrete finish in color or texture. The patches may serve to atttract further graffiti activity, because they highlight smooth and accessible portions of the bridges.



Top Photo:
New concrete crash barrier added to parapet on Bridge #714 (renumbered #5811, Marvin Ridge Road.

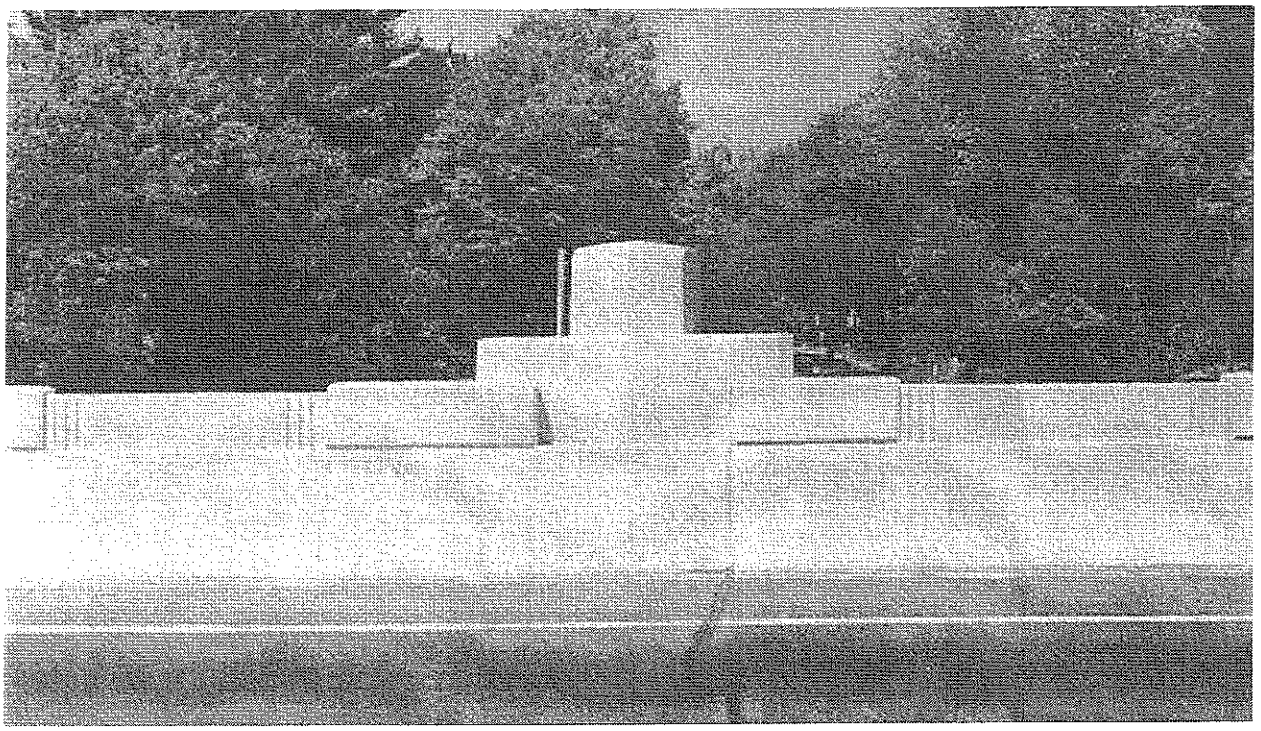
Bottom Photo:
Steel guardrail obscuring coat of arms on Bridge #698, Taconic Road.

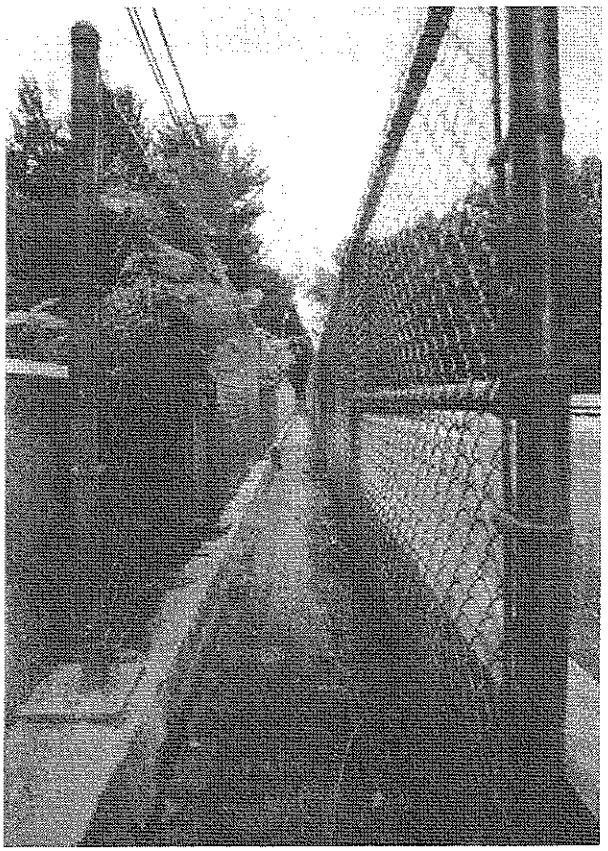
c. Incorporation of Safety Features

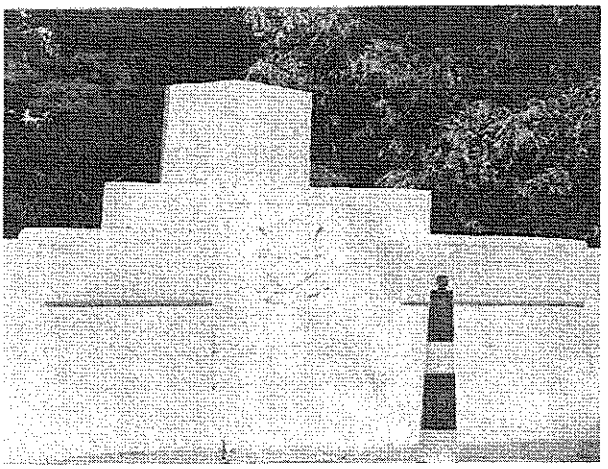
Sloped concrete barriers have been added to many of the bridges along the Parkway. At abutment walls facing the Parkway, or roads passing under the Parkway, which were originally curbed, the barriers significantly enhance the safety of the bridge, without significantly altering the appearance.

Many of the original railings on the Parkway and on overpasses have been significantly altered by the use of concrete sloped barriers. This feature does not preserve the effect of light passing through the rail, an important aesthetic feature of the bridges which should be preserved. When traffic volume and speeds allow, applications for design exceptions to AASHTO or ConnDOT standards should be considered.

When traffic volume and speeds dictate, the barriers should be placed an adequate distance from the original railing, to allow for the transmission of light.



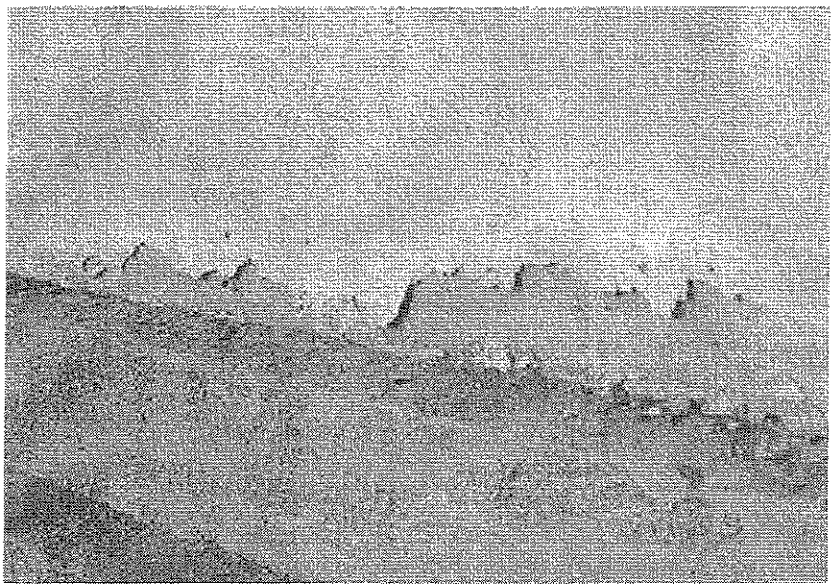




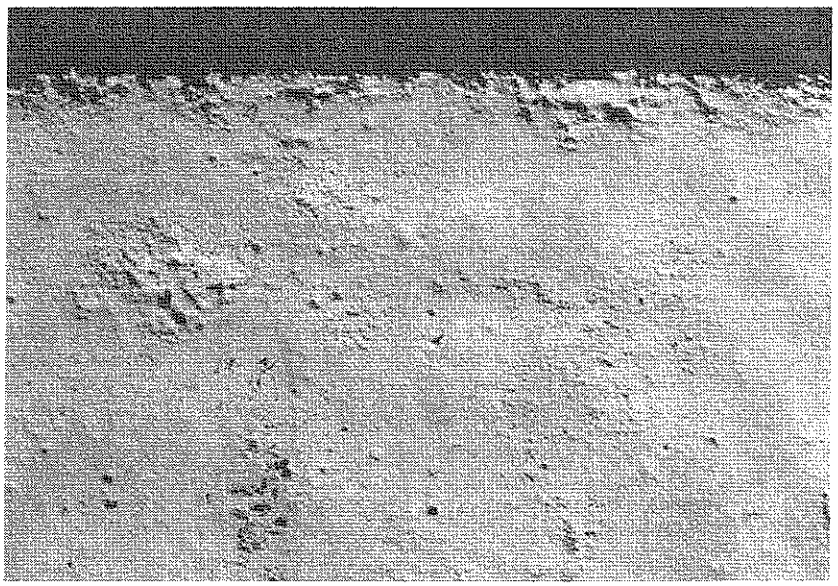
Top Photo:
New concrete crash barrier added to parapet on Bridge #709, Route #16.

Bottom Left Photo:
Steel Fencing added to walkway on Bridge #716, Comstock Hill Road.

Bottom Right Photo:
Coat of arms incorporated into the concrete crash barrier on Bridge #709, Route 16.



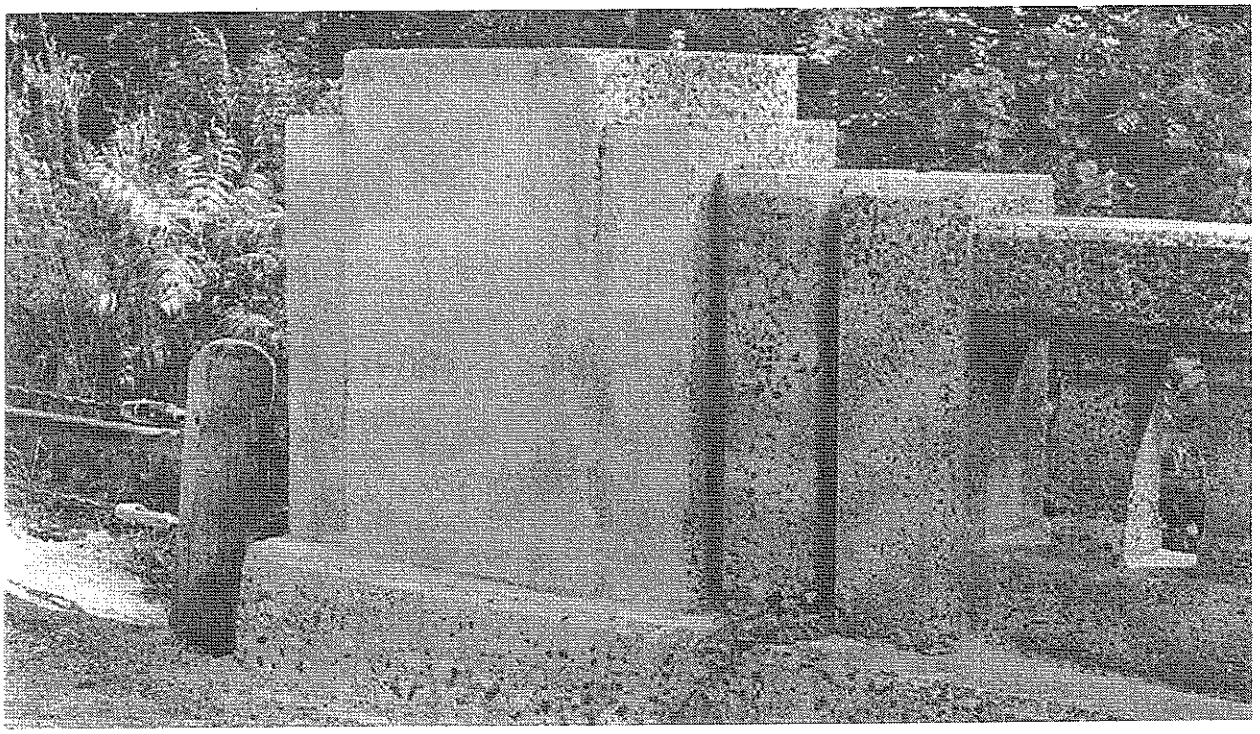
Top Photo:
Delaminating coating application applied to Bridge # 719, Perry Avenue.

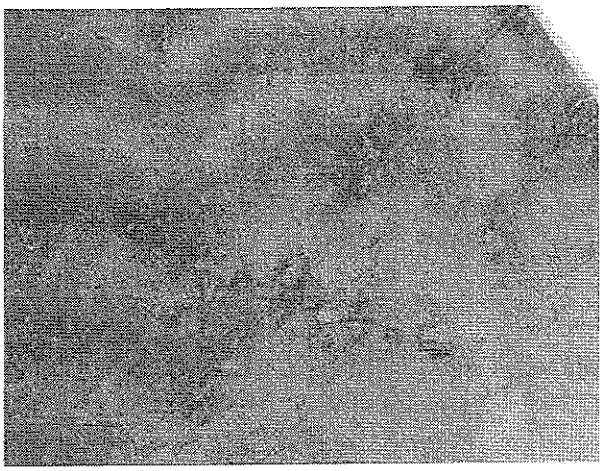


Bottom Photo:
Paint coating applied to Bridge # 713, White Oak Shade Road.

d. Applied Coatings

Opaque coatings have been applied to some of the bridges. They significantly alter the appearance of the original concrete, in terms of color, texture and reflectivity. They also interfere with the breathability of the material trapping moisture inside the bridge structure. Additionally, they require frequent reapplication.

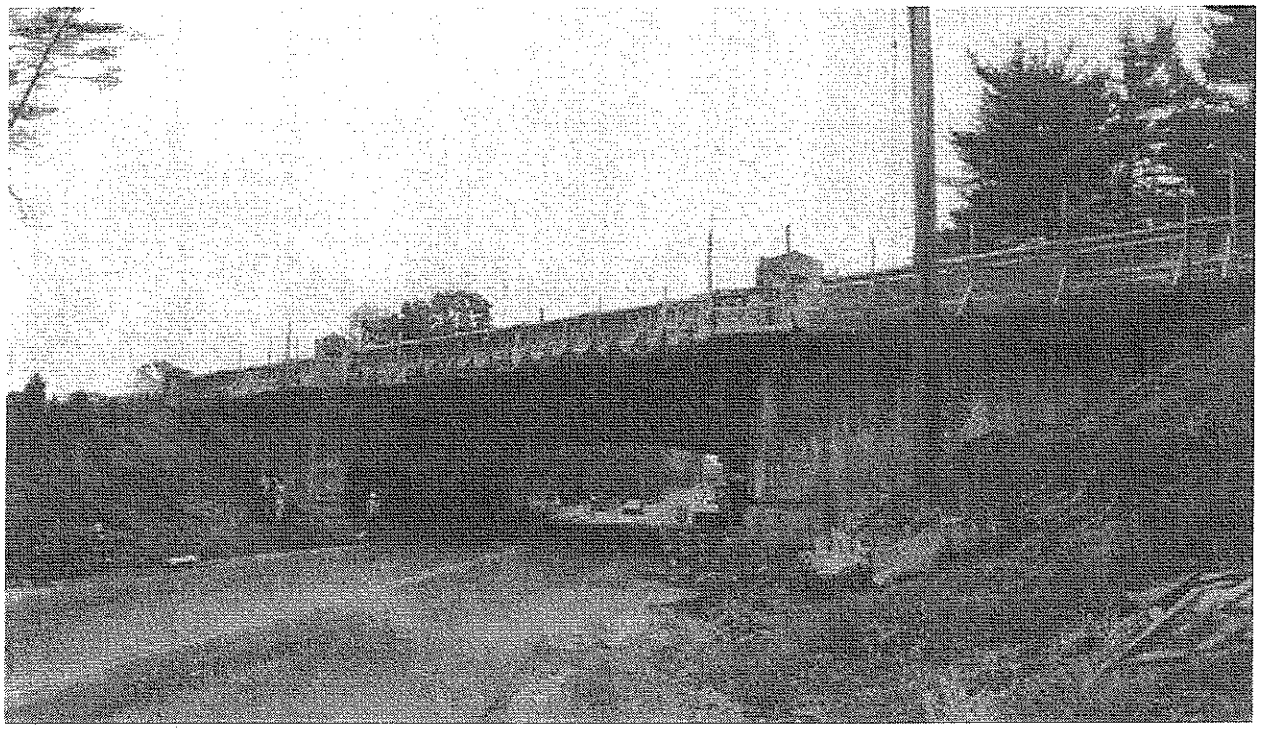




Top Photo:
Repair and surface coating applied to parapet at Bridge #738, Hillside Road.

Bottom Left Photo:
Blistering of paint on underside of the frame on Bridge #716, Comstock Hill Road.

Bottom Right Photo:
Close-up of blistering paint on Bridge #716, Comstock Hill Road.

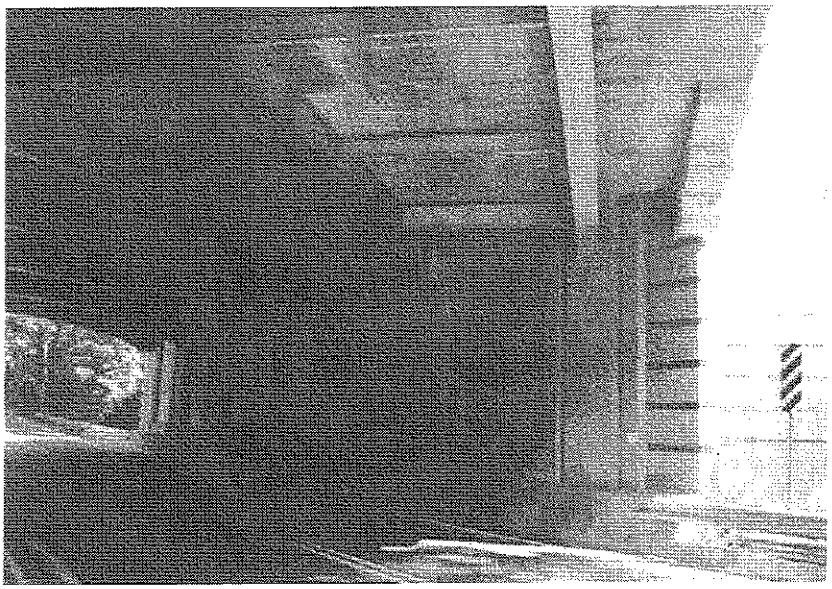


2.4.2 Reconstructed Bridges

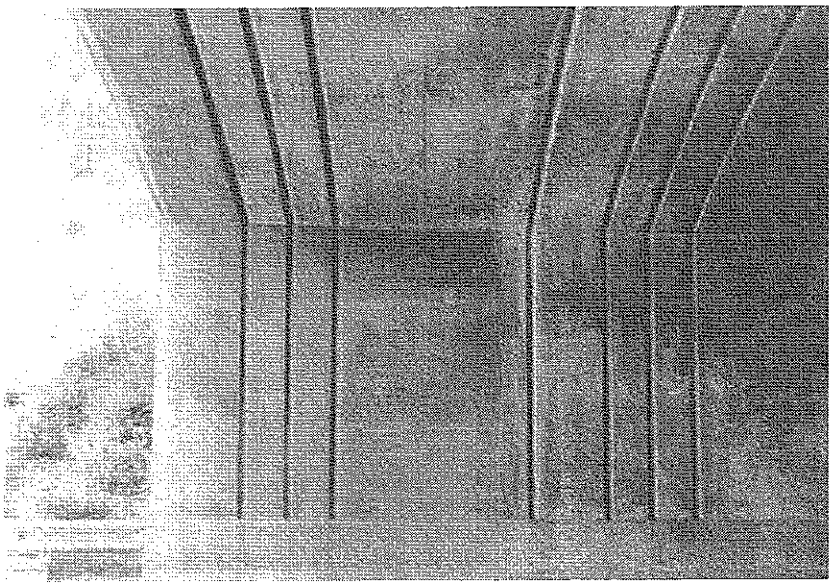
a. Introduction

During the past several years many Merritt Parkway bridges have had a major portion of their structure reconstructed. Bridges have been widened to accommodate new acceleration or deceleration lanes on the Parkway, superstructures have been replaced with new structural systems, concrete road decks have been replaced, steel girders have been replaced, and arched reinforced concrete rigid frames have been recast. Along with the major structural alterations and repairs, original elements of bridges have been replaced such as wingwalls, pylons, spandrels, parapets, and railings. Consequently significant architectural detailing and ornamentation has had to be reconstructed. In general, while the overall structural replacement of individual bridges have extended the life of the bridge significantly, enough original detail and finish has been lost or altered, to significantly alter the original appearance of the bridge.

Top Photo:
View of Bridge #715, New Canaan Avenue (Route #123) under reconstruction.



Top Photo:
View of reconstructed steel frame and deck from underside of Bridge #731, Easton Avenue (Route 136)



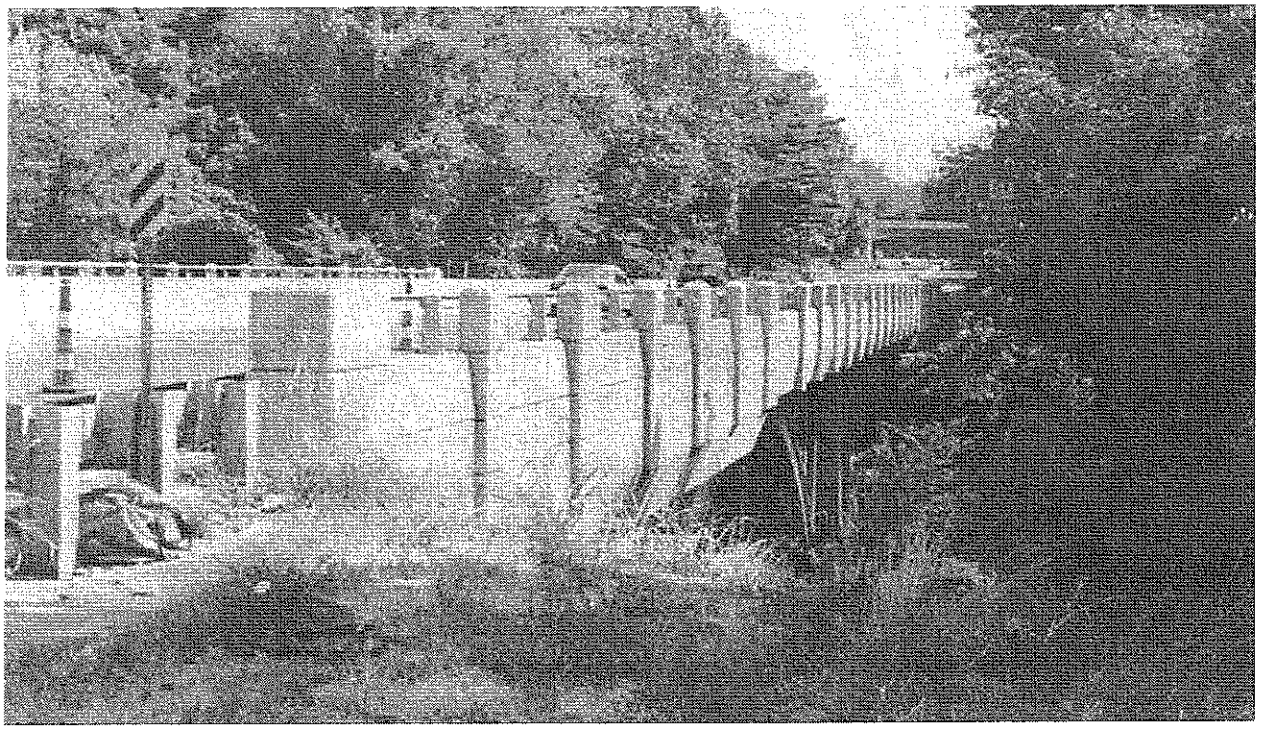
Bottom Photo:
View of Bridge #730, Weston Avenue showing new (left) abutement wall adjacent to existing (right) abutement.

b. Bridges Affected by the Addition of Acceleration or Deceleration Lanes to the Parkway

Bridges which have been widened to accommodate new acceleration or deceleration lanes are:

Bridge #709 - Route 106 (Old Stamford Road)
Bridge #715 - New Canaan Avenue (Route 123)
Bridge #727 - Route 33 (Wilton Road)
Bridge #728 - Saugatuck River
Bridge #730 - Weston Avenue
Bridge #731 - Easton Avenue (Route 136)
Bridge #753 - White Plains Road (Route 127)

Bridges which have been widened typically have one or more facades below the Parkway completely reconstructed, and the abutment walls of the vault extended to accommodate the new lane, or partial lane, on the Parkway above. New parapets and bridge railings are constructed on the Parkway at the new lane. Typically at the widened bridges, the original structure has been replicated, with the extension of the arched reinforced concrete frame, as on Bridges 709 and 713, or the concrete deck, over new arched steel frames, as was done at Bridge 715.



Top Photo:
View of new railing at widened Bridge #728, Saugatuck River.

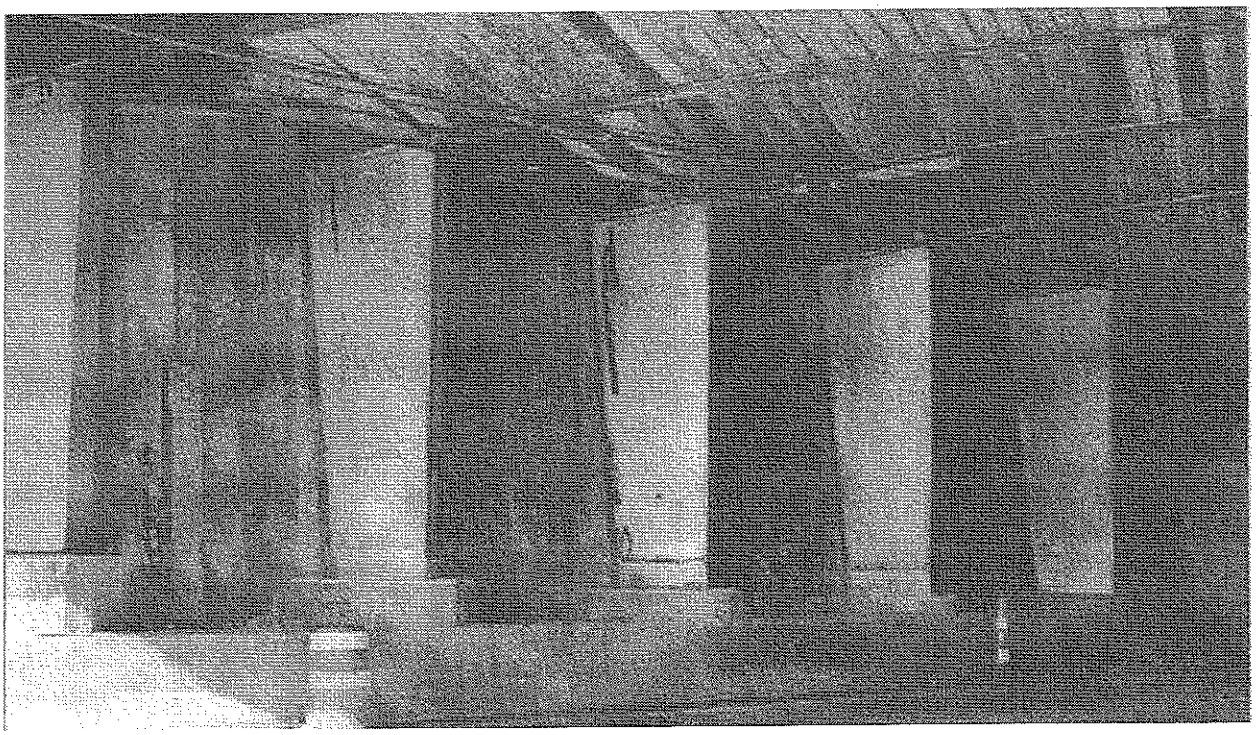
c. New Railings at Widened Bridges/ Incorporation of Safety Features

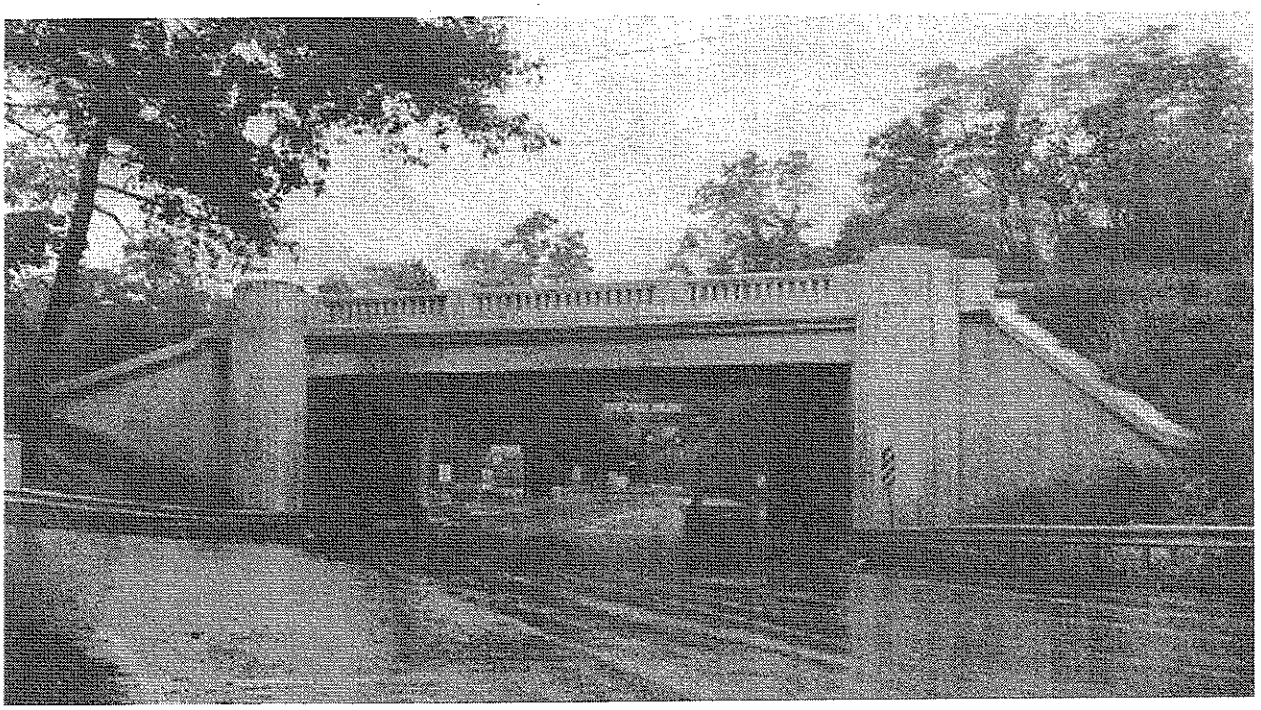
New parapets and bridge railings at the widened bridges along the Parkway typically have concrete sloped ('jersey') barriers integrated into their design. This means that the effect of light passing through the original railing has been lost. The reconstructed railing on the Saugatuck River bridge (#728) replaced an open metal railing with solid concrete topped with a pipe rail.

d. Other Major Rehabilitations

Additional bridges which have undergone major rehabilitation:

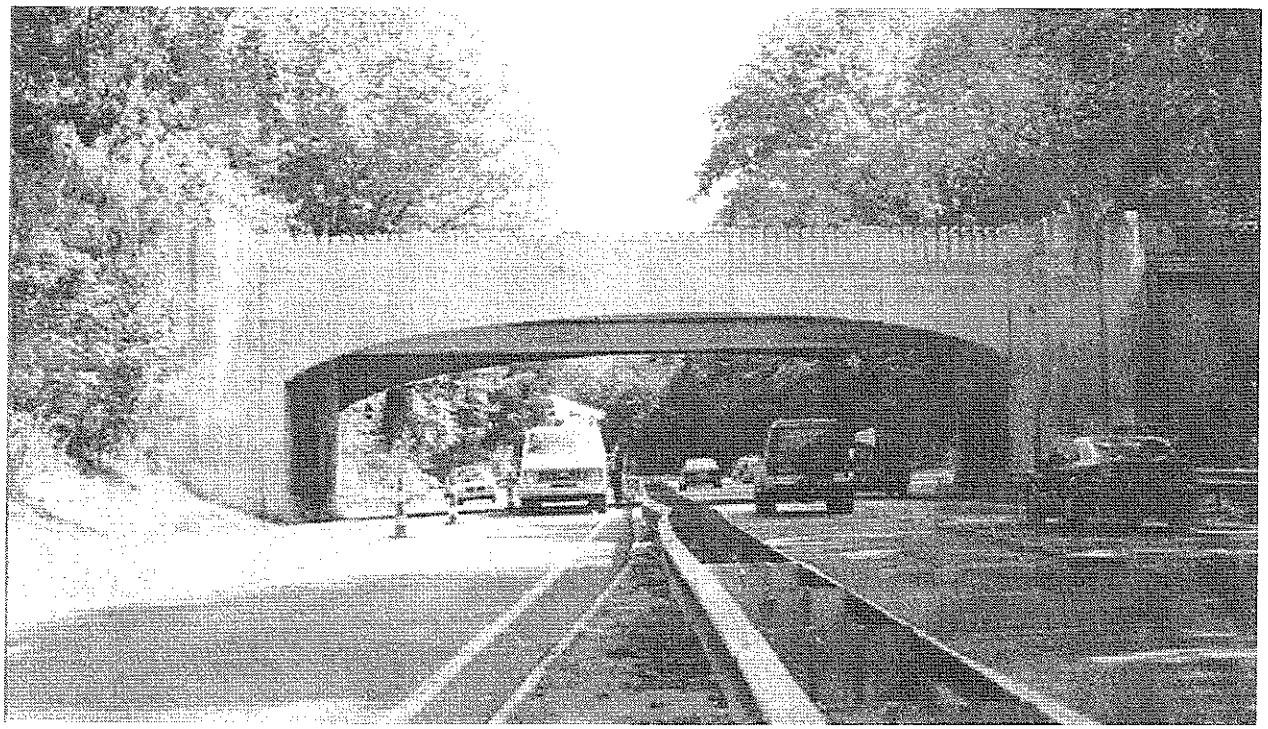
Bridge #711- (Renumbered #5810) Lapham Road, New Canaan; Rehabilitated, 1989
Bridge #713 - White Oak Shade Road, New Canaan; Rehabilitated, 1991
Bridge #714 - (Renumbered #5811) Marvin Ridge Road, New Canaan; Rehabilitated, 1989
Bridge #716 - Comstock Hill Road, Norwalk; Rehabilitated, 1989
Bridge #721 - Norwalk River, Norwalk; Rehabilitated, 1988
Bridge #739 - Burr Street, Fairfield; Rehabilitated, 1994
Bridge #754 - Unity Road, Trumbull; Rehabilitated 1975
Bridge #760 - Main Street, Stratford; Rehabilitated, 1997

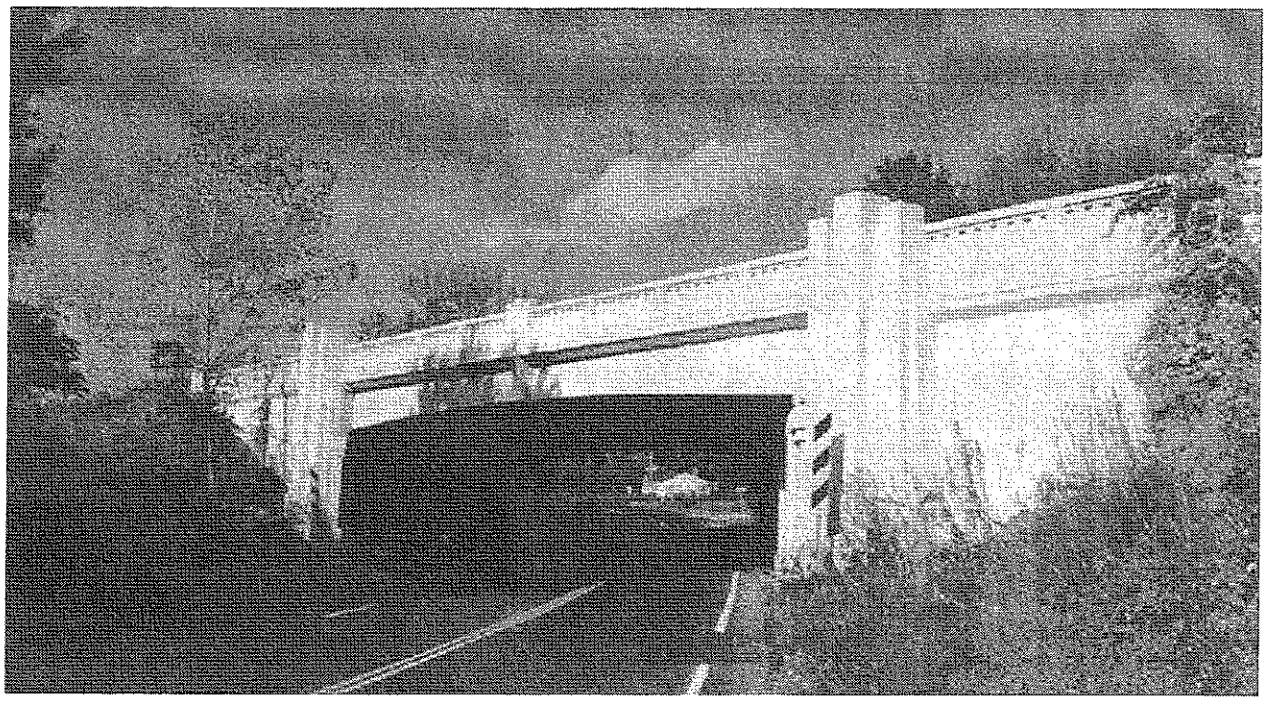




Top Photo:
View of Bridge #760, Main Street under rehabilitation.

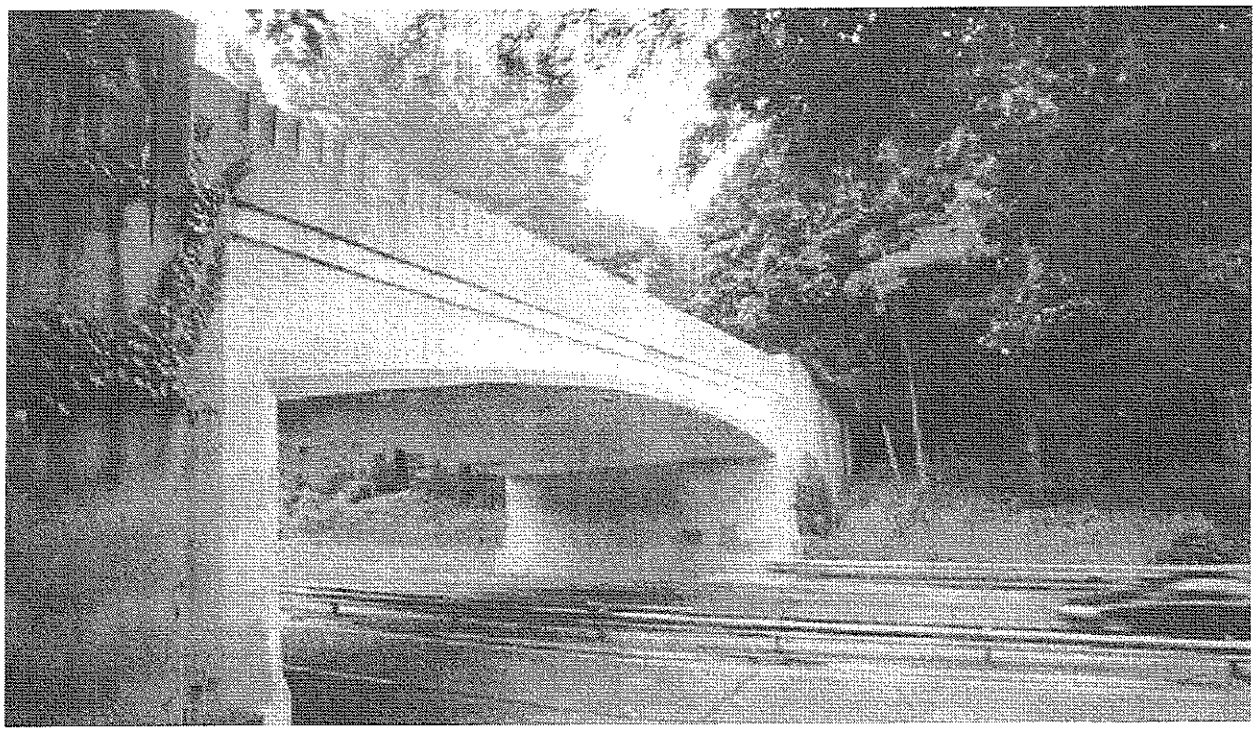
Bottom Photo:
View of reconstructed Bridge #727, Route 33 (Wilton Road)





Top Photo:
View of rehabilitated Bridge #711 (renumberted 5810), Lapham Road. The original arched frame structure was replaced with horizontal box beams. Precast fascia panels imitate the original arch shape.

Bottom Photo:
View of reconstructed Bridge #753, White Plains Road (Route127).



e. Rehabilitation of the Original Structure

Where the original structure of a bridge has been reconstructed, but not altered, the bridge retains much of its original character. An example is the Comstock Hill Road bridge (#716) in Norwalk, where the original form of the arched reinforced concrete frame has been replicated. Additionally, at the Main Street bridge (#760) in Stratford, the concrete deck has been replaced with the existing arched steel frames given new concrete pedestals but left intact.

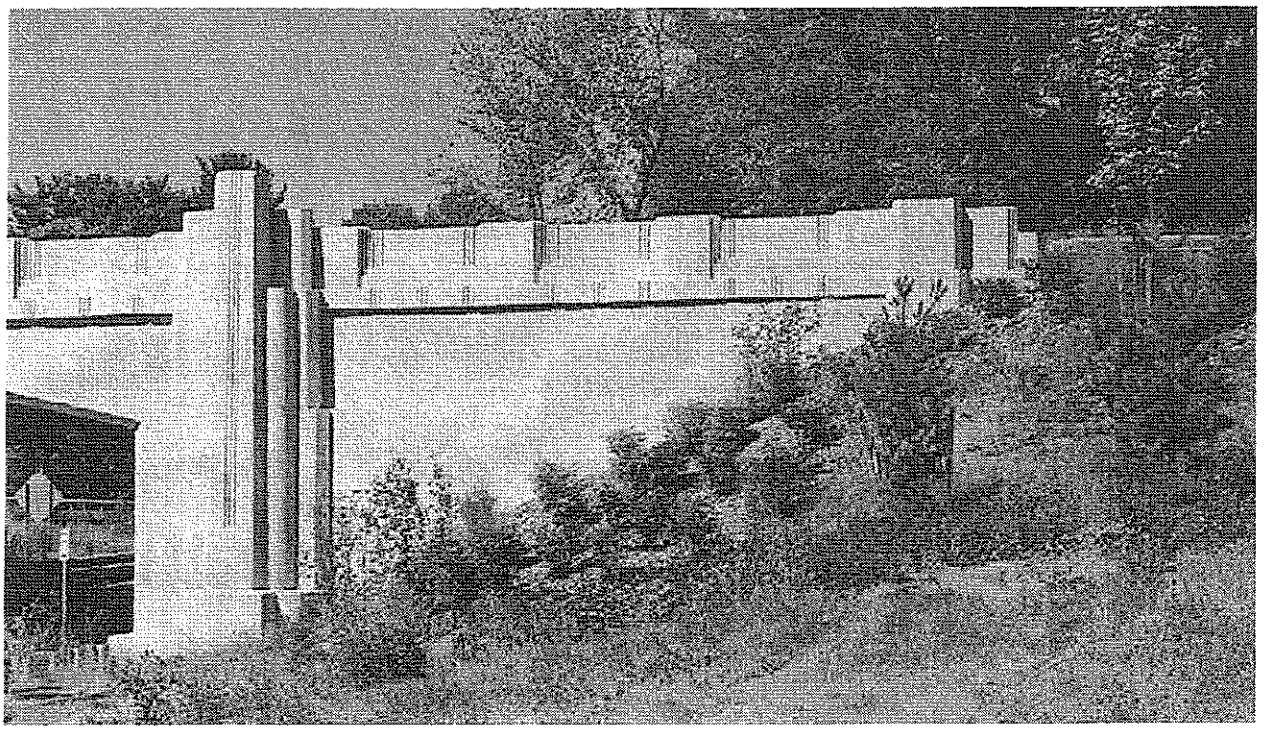
Several bridges have had their original structures replaced by new structural systems. The new systems generally have had the affect of significantly altering the appearance and experience of the bridges. An example is Lapham Road bridge #711 (renumbered #5810), New Canaan, where the horizontal, prestressed box beams have replaced the original arched concrete rigid frame. A series of arched precast fascia panels with vertical expansion joints hang from the new structure. Not only has the appearance of the bridge been significantly altered, the new panels have not held up to impact and at least one panel has been removed.

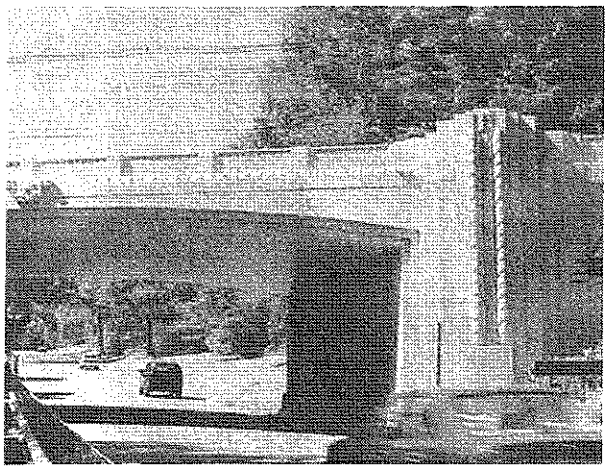
f. Replication of Architectural Detail and Ornament

Typically on all reconstructed or widened bridges, where attempts to replicate original architectural detail are made on wingwalls, pylons or other elements of the bridge, detail has been lost. The crisp edges and level of articulation of the original, has not always been maintained.

Ornamental elements in cast in place or precast concrete have been recast with different concrete mixes, or coated.

Top Photo:
View of rehabilitated Bridge #716, Comstock Hill Road. The original shape of the arch, vault and parapet were maintained in the reconstruction.



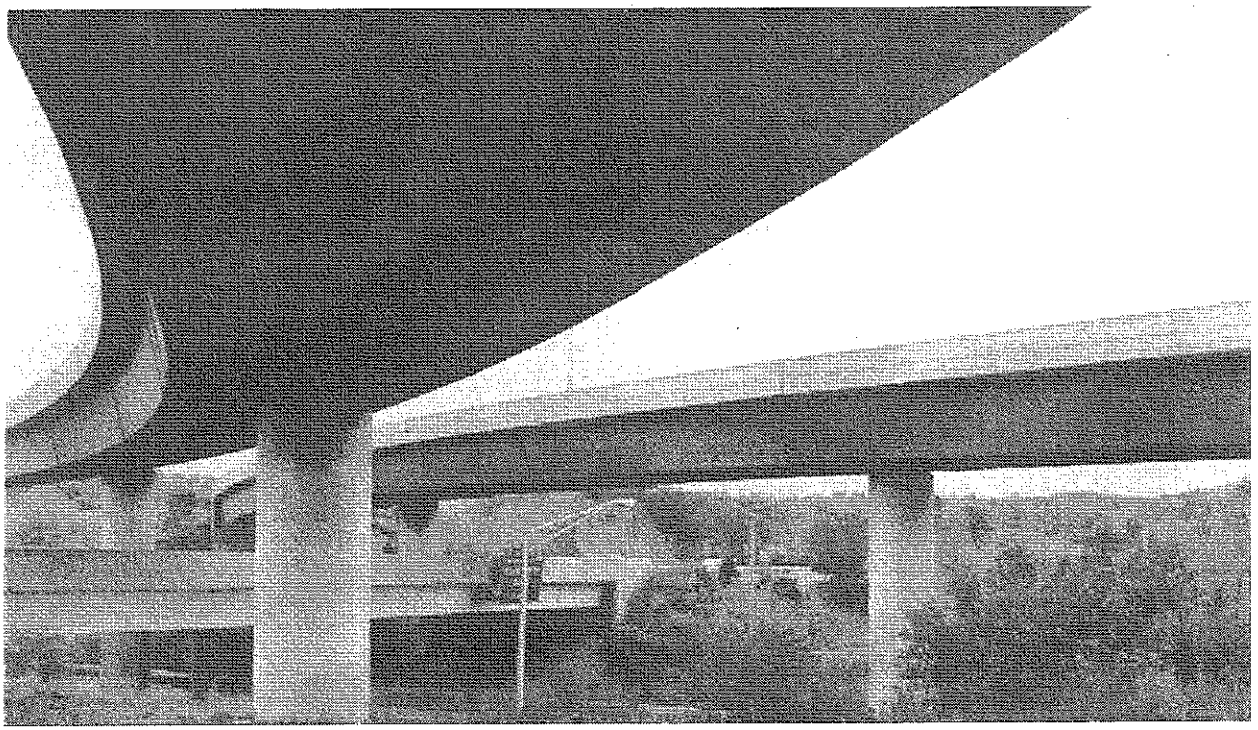


Top Photo:
View of reconstructed wingwall on Bridge #709, Route 106 (Old Stamford Road). The original forms were replicated, however a new coating significantly alters the overall appearance.

Bottom Photo:
View of rehabilitated Bridge #713, White Oak Shade Road. Color, texture and reflectivity of the new coating does not resemble the original concrete appearance.

g. Finishes

Perhaps the most significant alteration to the appearance of the reconstructed bridges is the finish of concrete. Frequently an opaque coating is applied to the entire bridge, as at bridges 709 and 713. The new coating bears no relation to the original concrete finish, in terms of color, texture and reflectivity.



2.4.3 New Highway Bridges

The design of new highway bridges on the Merritt Parkway built during the early 1980's generally demonstrated little attempt to replicate the form of an original bridge. These bridges include the following:

Bridge #4363 - Route 25, Trumbull, built 1981
Bridge #4364 - Route 25, Trumbull, built 1981
Bridge #4375 - Route 25, Trumbull, built 1981
Bridge #4378 - Route 25, Trumbull, built 1981
Bridge #5256 - Route 8, Trumbull, built 1983
Bridge #5257 - Route 8, Trumbull, built 1993
Bridge #5275 - Route108, Trumbull, built 1983
Bridge #5294 - Route108, Trumbull, built 1983

The above listed bridges are long-span structures with deep steel girders. These bridges are listed in the National Register of Historic Places, for the Merritt Parkway, as being "Utilitarian" in style and are not considered to be architecturally or historically significant. They are distinctly out of character with rest of the parkway.
The design of replacement highway bridges built after the mid-1980's typically include replication of original architectural details to varying degrees. These bridges include the following:

Bridge #744-Route 59 (Easton Turnpike), Fairfield; Replaced, 1995
Bridge #748-Route 111 (Main Street), Trumbull; To be completed 2004
Bridge #752 - (Renumbered #6234) Pequonnock River, Trumbull; Replaced, 1993

The design for the replacement of any historic Parkway bridge should maintain appearance of the original structure's proportion in regard to horizontal and vertical dimension, as well as to its forms, textures, colors and architectural detail to the greatest extent possible. Original architectural fabric or ornamentation should be salvaged and reused in the new structure's design wherever possible. The design of any new bridges for new roadway crossings or for the replacement of non-historic utilitarian structures should be as unobtrusive as possible, and compliment the Parkway's aesthetic character.

Top Photo:
Route 8 overpass, Trumbull, constructed in 1983.

2.5 Conclusions

The Connecticut State Highway Department and its chief architect George Dunkelberger created unique and ornate Art Deco and other popular styled bridges on the Merritt Parkway in the 1930's. The vast majority of these bridges were designed in concrete, at a time when Parkway bridges, such as those along the Hutchinson Parkway, in New York were faced in stone. A variety of decorative materials, means of producing ornament, and concrete finishing techniques resulted in individual designs for each bridge that significantly enhanced the experience of the Parkway.

Recent and ongoing repair and rehabilitation efforts, along with widening of the parkway at particular bridges, has resulted in the loss of original features and details, at times, significantly altering the original appearance of the bridges. This guide, and specifically the next chapter, provides a plan to restore and maintain the original character of the bridges, thus leaving the scenic character of the parkway intact, for generations to come.

III. Restoration Guidelines

3.1 INTRODUCTION

3.1.1 Planning for Preservation

The bridges, both overpasses and underpasses, are significant architectural and historical components of the Merritt Parkway. While the bridges on many parkways are built of stone, the Merritt bridges are uniquely constructed of concrete and cast with stylized Art Deco, Art Moderne or Neo-classical details. As unique man-made resources, recognized by national, state and local agencies, the bridges as a group represent some of the State of Connecticut's most important and unique historic resources. The Department is committed to maintaining and restoring the original character of the bridges to the greatest extent possible within the context of current highway traffic safety standards.

The preservation and restoration of the bridges of the Merritt Parkway forms an integral part of an overall rehabilitative and maintenance plan of the Parkway as presented through the *Merritt Parkway Landscape Master Plan,* adopted by ConnDOT in 1995. Future bridge projects prepared or executed by agency's design and engineering staff, contractors and maintenance personnel will conform, where possible, to the overall conservation and restoration plan as presented through the *Merritt Parkway Landscape Master Plan* and this manual (*Merritt Parkway - Bridge Restoration Guide).*

Work to be performed on the bridges, as stated in the *Merritt Parkway Guidelines for General Maintenance and Transportation* (see bibliography) should also be in accordance with the Secretary of the Interior's, "*Standards for Rehabilitation and Guidelines for Rehabilitating Historic Buildings.*" All projects on the historic bridges, including rehabilitation, widening, repairs and maintenance shall use this Manual, and incorporate the recommendations for historical analysis, testing, field applications, and materials and restoration techniques of
the various materials of the bridges, contained within this chapter.

Plan proposals for all bridge restoration projects involving the historic Merritt Parkway bridges must be submitted for review and approval to the State Historic Preservation Office and the Merritt Parkway Advisory Committee.

3.2 APPROACH TO BRIDGE RESTORATION ON THE MERRITT PARKWAY

3.2.1 Intent of Restoration

The intent of the restoration techniques outlined in this manual is to preserve as much as possible the character of the bridges for future generations, specifically the original appearance, structural forms, architectural details, ornamentation, materials, colors, textures and finishes as originally designed and constructed. To achieve this goal, what is original or what has been lost or altered, needs to be identified and to be understood in the context of the original intent of the chief architect and designer, George L. Dunkelberger and the Connecticut State Highway Department as the agency was known.

The restoration techniques address only the visual and architectural aspects of the bridge restoration and repair work. This manual does not provide specific design requirements for structural rehabilitative or repair work that may be required. That portion of the work is to comply, as closely as possible, with the restoration guidelines without compromising public safety on the Parkway.

3.2.2 Criteria for Restoration

The information about the physical condition of the bridges gathered during the site inspections has provided an indication of the bridges as they are presently existing.

To effect a good repair and restoration of the original bridge surfaces that is visually acceptable, the following criteria should be satisfied:

a. Patching should not be performed in a haphazard or indiscriminate manner. Many objections to the visual appearance of the bridges stem from the indiscriminate and random patching that has occurred over time. Areas to be repaired need to be well defined and delineated, for instance, in cast-in-place concrete repair work, by extending the patch area from ledge to ledge or joint to the corner. This will mask a great deal of the visual dissimilarities that are unavoidable. By not placing new and old work directly next to each other in flat areas variations in color are less obvious and therefore less objectionable. While this may lead to a repair that is larger than absolutely necessary, the overall visual quality will improve.

b. The original shapes and forms as well as the details are known from the original drawings and photographs and are important. The early descriptions emphasize the unique nature of specific details, for instance, the drip detail at the bottom of the arch or the slope of the ledge. Repair work must have the 'crispness' of the original appearance of the bridges and not the elimination or simplification as has too often occurred in more recent work. A sample or field mock up may be necessary to establish the required scale and shape of the missing details or ornaments.

c. Composition of the original material must be known to achieve a visually and technically compatible repair material. Detailed petrographic analysis and other tests are necessary to establish components and mixing ratios. The grading and type of the aggregates as well as their distribution needs to be determined and matched as closely as possible. A procedure for testing has been established for future restoration

projects to assist in gathering the necessary and additional information.

d. Color, surface treatment and texture are critical to the success of the final result. Careful study of the surviving section should be done to establish the original finishes when the documents for the repairs are prepared. Surface coatings, whether clear or pigmented, are not recommended. They present an on-going maintenance requirement, they are likely to fail and are not in keeping with the original appearance of the bridges. Moreover, such coatings are likely to be ineffective because a great amount of water migration and efflorescence has always occurred in these bridges (as seen in the early photographs).

e. Field Application and Mock-ups of Restoration Materials: Mock-ups are an essential part of the project and are to be executed wherever appropriate and called for in this manual. The mock-ups should demonstrate surface restoration examples including detail repair and combinations of all techniques proposed for the final restoration. Mock-ups should be included within contract special provision items for the repair of all concrete, masonry, precast, and ornamental concrete elements.

3.2.3 Priority for Restoration

The priority for repairing the individual historic bridges of the Parkway is to be determined on the basis of the condition of the bridge as rated in routine inspections performed by Bridge Safety and Evaluation. New highway bridges and other utilitarian structures, such as culverts, that are not listed as "historic" are not subject to the restoration work outlined in this manual.

Priority ranking for the restoration or reconstruction of individual bridges on Merritt parkway projects where construction funding may be limited is indicated below:

1) "High Priority"
   A) Local road underpasses.
   B) Local road overpasses..
   C) Parkway bridges over bodies of water (river, creek, etc.)

The above bridges are not likely to be reconstructed or replaced as part of a traffic improvement project. Therefore, where project construction funding is limited, bridges of this ranking are better candidates for complete restoration expenditures.

2) "Medium Priority"
   A) Major road underpasses.
   B) Major road overpasses.
   C) Not visible.

These bridges, which include major road crossing under or over the Parkway, are more likely than the "High Priority" bridges to be replaced or reconstructed as part of a traffic improvement project. As such, these bridges would be of lower priority for the expenditures associated with complete structure restoration where project funding may be limited.

3) "Low Priority"
   A) Bridges that are architecturally and historically not significant *(utilitarian culverts at streams or drainage systems)*. These structures were not included

within the overall scope of work of this project.

B) Bridges that have already been rehabilitated.

3.2.4 Future Bridge Widening Projects

Section 2.4.2 of this manual discusses bridges that have been widened to create acceleration or deceleration lanes for traffic entering or leaving the Parkway. In the original design for the Merritt Parkway, the on and off ramps are not geometrically aligned and do not allow for much acceleration and deceleration. The current higher traffic volumes and driving speeds have only further aggravated that condition. The additional lanes created by bridge widening projects have increased the overall safety of the Parkway. However, from the perspective of historical preservation, the widening of bridges to accommodate new on and off ramps should be undertaken only for the purpose of correcting serious and unacceptable safety hazards recognized by the Department.

The replacing of these historic bridges in their entirety should be undertaken only when absolutely justifiable for the correction of "serious and unacceptable safety hazards", and/or for the "intolerable restrictions on transport and travel", as stipulated in Section 4(f) of the U.S. Department of Transportation Act of 1966, and as further refined by the Federal Highway Act of 1987.

When bridge widening has been deemed unavoidable, original architectural fabric and ornamentation is to be salvaged and reused in its entirety as much as is feasible. New construction should be kept to a minimum and, where appropriate, is to replicate the original appearance of the bridge as closely as possible. Such reconstructed portions can include railings and parapets *(refer also to "Future Bridge Railing Rehabilitation or Replacement," in section 3.2.5, below)*, wing walls, abutment walls, and intrados. Original proportions, horizontal and vertical dimensions should be maintained wherever possible, except as required to achieve the actual widening of the roadway. Original bridge materials (including their color and texture) and details are to be replicated as closely as possible.

Bridges that are to be altered or reconstructed, in part or in their entirety, as part of a traffic improvement project, must be reviewed and mitigated in accordance with the procedures established under Section 106 of the National Historic Preservation Act of 1966 and its amendments. The recommendations and restoration techniques outlined in this manual are also to be considered.

3.2.5 Future Bridge Railing Rehabilitation Projects

Railings and parapets generally are an integral and significant part of the bridges on the parkway and are to remain as much as possible. Replacement is to be avoided if the original railings can be repaired and restored. If a bridge is to undergo widening and one or both of the railings and parapets are affected, the original railings are to be restored and relocated using as much of the original material and detail as possible. For ornamental metal railings, such a re-location is highly feasible. As much as possible, such details as panels, balusters, base, coping and any associated ornamentation are to be incorporated and restored as unobtrusively as possible. Particular care is to be taken in locating the construction and expansion joints.

Where original railings can not be restored because of severe deterioration, the features of the original railing are to be replicated as closely as possible in overall form and

location, dimensions and proportions as well as architectural detailing, materials, finishes, color and texture.

Regarding the rehabilitation and replacement of bridge railings, the primary concern is safety, and the present ConnDOT policies are provided below:

a. For bridges carrying the Merritt Parkway, existing bridge parapets should be retrofitted to an approved crash test compliant design *(NCHRP 350 Test Level 3)*, the design of which should have a minimal visual impact on the existing bridge rail or parapet. Bridge parapets should be repaired or reconstructed in kind, with the addition of a metal open-rail crash-test compliant bridge railing system. This approach will preserve the light passage characteristics of the original open bridge railing systems and as such will maintain the architectural intent of the bridge fascias.

b. For bridges over the Merritt Parkway, where the overpassing road is of low speed and low ADT, and where there is no significant history of traffic accidents, consideration should be given to restoring and maintaining existing railings in their original configurations. This approach may not meet current crash test standards however and would therefore require the concurrence of the ConnDOT on a case-by-case basis.

c. For all other bridges over the Merritt Parkway, not included above *(in item 'b')*, a new railing shall be installed, as similar in design as possible to the original railing, with openings in keeping with the original, and which has been crash tested and meets or exceeds ConnDOT standards, or, an approved crash tested barrier shall be installed as described above *(item 'a')*.

d. For bridges over the Merritt Parkway which have pedestrian sidewalks, standard practices developed by ConnDOT concerning protective fences *(see Bridge Design Manual)* may not be historically or aesthetically appropriate. The need for protective fencing should be studied on a case-by-case basis with consideration given to the history of incidents at the site. Any determination must be made with concurrence of ConnDOT.

e. The transition guide rail systems at approaches on bridge overpasses and underpasses should comply with the crash test performance criteria established according to ConnDOT Highway Design Standards.

The above recommendations shall be evaluated against current ConnDOT policies, prior to the commencement of bridge rehabilitation projects.

3.2.6 Future Bridge Rehabilitation Projects

In the event that bridges are severely deteriorated and have to undergo a major structural rehabilitation, the original structure is to be preserved or visually replicated as closely as possible. In general, the replacement of the original structure with structural systems of a different type is not recommended. As in all restorative work, preservation of as much of the original bridge fabric as possible is a priority. Section 2.4.2, Reconstructed Bridges, describes the adverse effects or relative success of such alterations on the visual appearance of existing bridges. Reconstructed detail and ornamentation is to replicate the original forms and materials of

the bridge, using the restorative techniques in Section 3.5. However, at all times original features are to be restored and reused as much as possible. Ornamental cast in place and precast elements are to be restored or recast with materials, forms or molds that match the original. Where structural steel and ornamental metals are involved, restoration of existing original elements is to be considered first. Only when corrosion of structural steel or metals is severe and extensive, and loading cannot be maintained, should replacement be considered.

3.2.7 Utilities

Many bridges are adversely affected visually by existing utilities such as overhead cables, exposed conduit passing through the span openings or substantial cast iron water or sewage mains that transverse the bridge overpasses. Large, physically and visually obtrusive, cast-in-place concrete enclosures for the mains rise well above the level of the original curbs and sidewalks.

Utility relocation should be part of bridge replacement projects whenever possible. Utilities should be relocated to minimize the visual impact on the original appearance of the bridge.

3.2.8 Placement of Signs

As stated in the *Merritt Parkway Guidelines for General Maintenance and Transportation Improvement,* "Traffic control devices will respect the scenic and historic character of the road while following the guidance of the *Manual on Uniform Traffic Control Devices* and other Federal standards."

Signs should generally not to be mounted directly on the bridge structure. Wherever possible, signs identifying overpassing roads should be placed adjacent to the roadway immediately prior to the bridge. All other signs, including guide signs, regulatory and warning signs, service area signs and variable message signs should not be placed within 500 feet prior to a bridge, whenever possible.

3.2.9 Vegetation

Views of entire bridge elevations, whether facing the parkway or underpassing roads, are one of the most significant elements of the parkway's scenic and historic character. However, many of the bridges' architectural elements, including pylons, wingwalls, parapets and railings, which contribute to making each bridge unique are partially or completely obscured by climbing vines, overgrown tree limbs, shrubbery, and other undesirable volunteer growth.

The *Landscape Master Plan for the Merritt Parkway*, prepared in 1994, calls for removal of obscuring, undesirable growth at bridges, and the reestablishment of plant material typically used in the original landscape design of the parkway. Specific recommendations can be found in Section 5.2.1 of the *Landscape Master Plan.*

Landscaping at reconstructed bridges should be designed to be compatible with the original, now mature, landscape plan, in accordance with the *Master Plan.*

3.3 PROCESS OF HISTORICAL ANALYSIS OF BRIDGES

3.3.1 Original Document Review

Prior to planning major rehabilitation or repair work on bridges, the original documents are to be reviewed, particularly the original *Merritt Parkway* bridge construction drawings *(24" x 36" linens)* produced by the Connecticut State Highway Department in the 1930's and which are on file at ConnDOT. In addition the original State Highway Department, State of Connecticut, *Standard Specifications for Road and Bridge Construction,* issued April 1932 and December 1935 provide useful information.

The original bridge construction drawings contain plans, elevations, sections, details, material lists and notes pertaining to the construction of each bridge. Alterations or missing ornamentation and the type of materials used originally, may be identified through a comparison of the existing bridges and these drawings.

Structural elements and different construction methods are also identified. For instance, reference is made to the different types of cast-in–place concrete including mixing ratios and type of use. Typically, Class "A" concrete mixtures with cement/sand/stone ratio of 1:2:4 were specified for substructure components including foundation, rigid frame elements, and wingwalls. Coarse aggregate for Class "A" concrete was typically Class "C" stone (*1-1/2" stone*). Class"C" concrete mixtures with a cement-sand-stone ratio of 1:2:3 were commonly specified for bridge rail features having smaller dimensional components. Coarse aggregate for Class"C" concrete was typically comprised of a ratio of 70% Class "C" size (*1-1/2"*) and 30% Class "E" size (*3/4"*) except for concrete elements less than 6" in depth where coarse aggregate would be limited to Class "E" size alone. The use of these design mixture ratios has not been entirely consistent and may have varied from town to town *(apparently the result of variations in local building codes).* Important is that in the specifications reference is made to how the concrete was to be finished and the larger aggregate was to be worked away from the outer surface. *(See selected portions of 1934 Form 804 pertaining to concrete in Appendix 4.3.)*

The architectural design intent and the nature of the concrete treatment are best known from the writings of the architect Dunkelberger (*see Section 4.2, "Bibliography," in the Appendix*). Several of his articles from the 1930's identify important design decisions that are critical to formulating repair and restoration procedures. Some examples are:

- Overall design and detailing is to be water shedding as much as possible to avoid unsightly staining on the surfaces and is to be used to separate structural and architectural elements. For instance, he recommends concealing the joint between the abutment and the bridge structure in the architectural treatment.

- The architectural detailing in some instances is intended to achieve subtle effects like a better light reflectance or light reflection against the railing by tilting the upper ledge inwards *(although he admits that good practice would have been to pitch that ledge outward).*

- Through the use of different concrete techniques, as identified above, different levels of detail and quality can be achieved. Integral color and texture is obtained through the use of aggregates and other stone in the concrete mix.

Because the original specifications describe typical information on bridge and road construction in the 1930's, such as materials for construction and construction techniques, they can be helpful in supplementing the results of testing and analysis of materials and their components *(outlined in Section 3.4, Testing and Analysis)*

Historic black and white *photographs (8 x 10" format)* taken shortly after the original construction of the bridges exist for most of the historic bridges. Because of their clarity, the photos provide information about all significant architectural detail as well as the overall setting and configuration of the bridges. Copies of the original black and white photographs, for some of the bridges are included in the Bridge Reports.

The original photographs show the bridge surfaces to be quite light in color. Because the photographs are black and white only relative tonal values can be established. Laitance, efflorescence, shrinkage cracking, marks of form work and other surface blemishes can be seen. However, the concrete work in general, was very high quality in terms of the appearance of the finished surface and the sharpness of architectural detail.

3.3.2 Review of Original Construction Methods

The original construction documents listed in Section, 3.3.1, above (*see also Appendix 4.3*), provide a large amount of information on the original appearance, construction, details and materials of each bridge and should be examined thoroughly prior to any bridge project.

Four basic fabrication methods for the concrete are identified as follows:

1. Cast-in-place structural concrete: Plain (*mostly utilitarian*) concrete, which, in some instances, shows formwork marks and other markings from the installation process.

2. Cast-in-place concrete with inserts: Strips and other shapes were added to the formwork to create architectural moldings, drips and recesses. To allow for the stripping of the forms these details remained simple.

3. Cast-in-place with reverse plaster molds: To achieve more elaborate designs reversed plaster molds were placed in the form work. Special protection of the plaster was recommended to prevent damage.

4. Precast Concrete (*Cast stone*): For greater detail and more color, cast stone units were used. The cast stone was typically installed after the structural concrete work had been completed.

The original specifications *(see Section 3.3.1, above and appendix Section 4.3)* give information on such aspects as concrete mixing, pouring, construction joints, forms, placement of anchors and metal ties, form work, removal of forms, curing, expansion joints and finishing *(including rubbing, brushing, floating, tooled and sandblasting)* of concrete. Information on the fabrication, riveting, field connections, shop assembling, bolting, and welding of structural steel, and other metals is also included.

3.3.3 Review of Maintenance Records

The bridge files of the office of Bridge Safety & Evaluation of CONNDOT contain, for each bridge, inspection reports, maintenance

records and documentation of rehabilitation or repair work. Together with the original construction documents, the bridge files give a comprehensive history of the bridge including the extent of original fabric that has been altered or removed.

3.3.4 Field Survey

Together with inspections to determine the extent of deterioration, safety concerns, such as spalling concrete, inadequate or damaged barriers at bridge approaches, or unsafe sidewalks or railings, a field survey of the architectural aspects of the bridge should be conducted. Along with a review of the original project construction documentation individual bridge reports and bridge files, a field survey is necessary to verify as-built information. The field survey will provide necessary information not provided in the original documentation such as actual concrete finishes provided, the extent of original bridge fabric still existing, the amount of missing ornamentation and the scope and detail of subsequent alterations.

Other conditions that cause deterioration of the bridge are to be rectified before any restoration work is undertaken either as an initial phase of the same project or separately. Where feasible, the replication of missing bridge features, details and ornament, is also to be included in the work

3.3.5 Review of Repairs and Alterations

After completion of the review of existing documentation and before the field surveys and inspections, the extent and type of previous repairs and alterations is to be established. Alterations and repairs as identified in Section 2.4.1 that have significantly altered the original appearance of the bridge are to be corrected as part of the total project, in accordance with the recommendations of the individual Bridge Reports.

3.3.6 Documentation of Existing Conditions

During the field survey, the condition of the bridge and its appearance is to be documented through graphic means and photography. Deteriorated conditions, existing original architectural details and ornaments, previous repairs and alterations are to be noted as the basis for the preparation of appropriate contract documents. Many of the Merritt Parkway bridges have elements of sculpture and decorative relief and other artwork shown in concept but not fully detailed on the original design plans. Such ornamentation should be completely documented through the use of plaster molds or digital modeling prior to the initiation of demolition or construction restoration procedures which may pose a risk of damage.

3.3.7 Identification of Existing Materials

Proper identification of existing materials is critical to any restoration project. Samples can be examined visually as well as tested to identify the original materials, such as poured-in-place concrete and precast concrete. The examination of concrete is to include the identification of the cement, sand, aggregates, and additives in relative amounts. The composition of the original concrete is the basis for specifying the replacement mix.

Similarly, ornamental metals and paint finishes are to be examined visually and tested to identify original colors for providing a proper match. For stone masonry work, mortars and stone are to be tested to assure that repointing and replacement materials visually and physically match the original materials as closely as possible.

3.4 TESTING AND ANALYSIS

3.4.1 Concrete Testing

a. Overview of Sample Testing

The concrete work is one of the most important aspects of the shape and detail of the bridges. Testing of the concrete is necessary, particularly, to match the quality and color of the surface of the concrete.

The testing must be supplemented with a thorough understanding of original design intent obtained through study of the original drawings and specifications. As noted in Section 3.3.1, Class "A" concrete was used throughout most cast-in-place portions of the bridge elements except for concrete railings and bridge decks which were typically comprised of Class "C" concrete as referenced in the "Standard Specifications for Roads, Bridges and Incidental Construction Form 804, issued in 1935. *(See Appendix Section 4.3, Form 804 - "Section 226 - Concrete")*

A series of cores must be removed from a bridge to establish the composition of the concrete, to formulate appropriate patching materials and to establish if and what type of surface finishes were originally applied. The information yielded should be consistent with the historic documentation available.

In the identification of the composition of the original concrete, a black basalt aggregate ranging between less than 1" to 2" in diameter will most likely be encountered. Other aggregate materials *(less than No. 4 mesh size)* such as quartz are likely to be present together with some minor minerals typical for the metamorphic terrains of southwestern Connecticut and southeastern New York. Such a composition will be entirely consistent with the use of traprock as described in the writings of Dunkelberger. Traprock was selected because the angular shapes of the traprock particles contribute to the "sparkling" appearance of the concrete bridges.

In the analysis of the basalt fragments a thin white paste that covers the particles may be encountered. Such covering is most likely not the result of a distinct and deliberately applied surface coating but was, probably, formed as the result of the rubbing of the concrete surface. The presence of larger fragments of the basalt aggregate with ground or polished sides will further support the existence of a rubbed surface. Fragments came too far to the surface and were ground back by the rubbing.

b. Quantity and Size of Samples Required for Testing

A minimum of two (2) samples from each existing concrete class shall be removed from each bridge. Core size diameter should generally be about 3 times the maximum anticipated aggregate size. For existing Class "A" concrete core size should be 4 inches in diameter. For existing Class "C" concrete in elements greater than 6 inches in depth, core size should be 4 inches in diameter. For existing Class "C" concrete in elements less than 6 inches in thickness, core size may be 2 inches in diameter. Additional samples may be necessary, when the laboratory testing is inconclusive, or the samples were inappropriately taken from repaired areas.

c. Selection of Area for Test Sampling and Procedure for Sample Removal

Efforts should be made to remove the samples where the most original surface finish is remaining.

The best location for removal of core samples of concrete on the bridges is generally on the

wingwalls. These areas typically have the least deteriorated, or weathered, surfaces and the most original concrete finish. These areas are remote from the bridge deck and are less likely to have been affected by the moisture and chlorides that may penetrate the bridge structure. When more than one core sample is being taken, the cores should be removed at distinctly different locations as far apart from each other as possible. For example, if the first sample is removed from the southeast wingwall, the second should be removed from the northwest, assuming the different areas are sufficiently representative.

Samples should not be removed from areas that have been repaired, altered or coated or from areas where the material is clearly not original. Where a pigmented *(white or gray)* cementitious coating has been applied to the entire bridge surface, as is the case for the more recently rehabilitated structures, it will be necessary in the laboratory to differentiate the new surface coating or patching material from the original concrete.

Core samples are to be taken from each bridge under consideration for repair. Standard concrete coring equipment can be used provided that care is used. The core has to contain both surface and base concrete material, including the fine and coarse aggregate. If during the coring the concrete breaks up, all portions of the core are to be carefully collected, placed in a sealed plastic bag and labeled, with the following information:

Bridge #
Name of over or underpassing route
Location of core with orientation
(for instance, northeast wingwall, 4' above grade)

The samples are to be kept clean and dry, and sealed in a plastic bag until delivered to the laboratory.

d. Wet Chemical and Petrographic Analysis

The concrete cores are to be tested to determine original composition and the type of deterioration process as well as to formulate accurate repair and replication mixes for the original concrete. Appendix 4.4 includes the results of wet chemical and petrographic analysis and the development of replication concrete mix designs for several Merritt Parkway bridges.*(The bridges studied include South Avenue-Route 124, #712; East Rocks Road, #723; Merwins Lane, #735 and Burr Street, #739 were studied)* On the basis of these earlier studies, it is believed that wet-chemical and petrographic microscopic analysis are most likely to provide the necessary information for the development of accurate replication concrete mixes. *(Appendix 4.4 contains a Surface Coat section for the development of concrete surface finish mixes for the repair of scaled areas or for widespread application for the creation of a uniform surface appearance. However, the use of concrete surface mixes is not endorsed by the Department due to the poor durability of such repairs historically as well as for the loss of original concrete surface finishes.)*

Wet-Chemical Analysis involves the separating of the hardened concrete into its component parts, or, more precisely, in its acid indigestible components to allow for the study of the aggregates *(sand and crushed rock)* present. Once the component ingredients have been separated, the types and distribution of the original aggregates as well as the quantities and mixing ratios can be determined and the origins of the aggregates can be established. Color, texture and other factors that will affect the

appearance of the replication and repair mixes can be recorded and measured in this test. Aggregates can be sourced in this manner.

The petrographic analysis, in accordance with ASTM C856 is a microscopic examination of thin sectioned samples of concrete. In this analysis all minerals present, coarse and fine aggregates gradations and proportions, the extent of cement hydration, mix characteristics and deterioration mechanism can be identified. On the basis of this analysis the original design mixes can be formulated.

Specific Methodology for Wet Chemical Analysis:

The freshly broken surfaces of each core are to be examined under 20X magnification and natural daylight. At this time the binder of each sample is to be matched to a color standard of the Munsell Color Chart (as per ASTM- D 1535 Specifying Color by the Munsell System). After the initial examination the concrete samples are to be separated into three components: the acid-soluble fraction, the "fines" (i.e. pigments, clay or cement residue), and the aggregate or sand fraction. The separation is to be accomplished through wet-chemical techniques, such as the removal of the acid-soluble fraction by digestion with 3M Hydrochloric Acid. Levigation and filtration will then further separate the "fines" from the aggregate (sand) fraction and will allow for the percent weights to be calculated. The color of the "fines" of each sample is to be matched to the Munsell Soil Color Chart noting the predominating colors and shapes of sand grains during examination of the aggregate fraction. Several sieve analyses may be in order. When the concrete is extremely hard, the measurement of the grain size of fine sand may be impossible. The undissolved Portland cement will continue to encircle the sand grains, effectively increasing their grain size and invalidating the sieving procedure.

The Petrographic Analysis of the original concrete must be performed for future bridge rehabilitation projects in accordance with ASTM C-856. Reflected, plain and cross polarized light microscopy is to be used to identify mineralogy, texture, and void content of the thin sectioned epoxy impregnated samples from the concrete core. Particularly the original components of the concrete are to be identified in addition to damage caused by such factors as sulfate attack, freeze-thaw cycling and alkali-aggregate reactivity.

The information obtained from these analyses provides the data necessary to formulate accurate, visually acceptable and physically compatible replication mixes for each individual bridge project. In the formulation of these replication mixes historic or original materials *(coarse and fine aggregates)* are to be located. Where possible, improvements in concrete's resistance to weathering, namely air-entrainment, are to be incorporated into the replication mix design to achieve more durable concrete.

Restoration techniques, such as surface repair and concrete replacement described in Section 3.5.2 of this manual, will all require these same testing procedures and formulation of replication mixes. The results of the Wet Chemical and Petrographic Analysis conducted on four bridges, specifically for the purposes of this manual, are given in the Appendix, Section 4.4.

e. Replication Mix Development

Replication mixes are to be formulated and will have to identify the type and quantity of materials to be used. For a successful

replication mix, the appropriate commercial sources for the coarse and fine aggregates must be located. Most traprock suppliers in the lower Hudson Valley Region and southern Connecticut are likely to carry the desired aggregate but samples of their crushed rock are to be examined to assure appropriate results. Based on the earlier testing, basalt, available in 3/4" - 1 1/4", and dark in color, tending toward black when wetted, and of a fine texture will probably be the most successful. Commercially available sand, to be used in the body of the concrete as a match for the finer aggregate in the concrete surface or as a grout mix, must also match the original materials as much as possible.

The closest crushed basalt or traprock match was located in Connecticut, at Balf of 301 Hartford Avenue, P.O. Box 310903, Newington, CT 06131, (860)549-3200. Tilcon Connecticut (formerly The New Haven Trap Rock Company) provided the next closest match, North Branford Quarry, P.O. Box 1357, New Britain, Connecticut 06050, (203) 223-3651. Fine aggregates or sands are, for instance, available from George Schofield Co. Inc., P.O. Box 110, Bound Brook, NJ 08805, (201)356-0858 and include a concrete grade white sand (#181) with milky, clear quartz particles, with variable sized and sub-angular grains as well as a mason's grade white sand (#180) with milky, clear quartz particles, and variable sized and sub-angular grains. These aggregates meet ASTM-C33 requirements.

In the formulation of the replication mixes a light colored Portland Cement Type I or Type II should be used. Additional alkali-stable coloration pigments may be required to achieve the matching concrete color. To obtain the historic appearance and to achieve the performance qualities of modern concrete, the historic mix proportions obtained through the testing must be adjusted to accommodate an air-entraining agent for greater freeze-thaw resistance and a water reducer. How much of these admixtures is to be added is to be determined through trial batches prior to field mixing. Dry components should be premixed.

Where materials are substituted, the appearance of the concrete will vary. Also replacement concrete will generally appear darker when wetted and this may differentiate the older concrete from the new material. Because it is newer and less carbonated, the new concrete will have a higher absorption and therefore slightly different wetting characteristics.

All replication mixes are to be prepared in sample form, prior to any field application. This is to assure that an adequate match is achieved. Further adjustments of the final mix may be necessary in the field during the mock-up installation to obtain the closest match possible.

f. Replication Mix Recommendations

To achieve the closest match possible, the replication mixes must follow the historic mixing ratios adjusted for modern requirements for air-entrainment and a compressive strength of 3,000 psi in 28 days for Class "A" concrete and 4,000 psi in 28 days for Class "C" concrete. A typical replication mix based on the earlier testing *(See Appendix Sect. 4.4)* contained the following: a light gray Portland cement, Type I; coarse aggregate of crushed basalt (such as supplied by Balf) known as traprock *(3/4" - 1 1/4")*; a finer aggregate of concrete sand *(such as #181 supplied by Schofield)*, with no pigmentation added. For nine cubic feet *(9 ft^3)* batch, the mix consisted of the following quantities:

618 lbs. coarse aggregate
489 lbs. finer aggregate
175 lbs. Portland Cement, Type I
9.44 gallons of potable water

Air-entrainment *(approximately 5-1/2%)* must be added. Water reducing agents may be added.

g. Review of Sample Analysis

After the replication mixes are developed for each bridge under consideration, *(note that the replication mixes for the different types of concrete may also be different and needs to be verified),* samples are to be prepared. The samples are to be of sufficient size to allow for a visual evaluation in the field. In comparing and matching, the new samples are to be compared to clean original concrete, taking into consideration the effects of weathering on the original surfaces.

h. Applications of Test Results and Mock-ups

If the samples of the replication mixes are found to be a sufficient close match, installation of a mock-up is recommended. Here the use of the different mixes and the necessary surfaces textures and finishes can be replicated to assure that the final work will match as closely as possible *(see also Section 3.2.2, Criteria for Restoration, this manual).*

3.4.2 Paint Analysis

a. Historic Paint Analysis

A historic paint analysis is a study of the sequence of all the coating and paint layers *(i.e. a 'serriation' study)* of painted surfaces. The intent is to identify and recreate the historic color and appearance of the bridges of the Merritt Parkway.
A 'paint serriation' must be performed during the project design stage for all surfaces that were originally painted. This will include, but is not limited to, ornamental bridge railings, grilles and structural steel members. The 'seriation' study consists of the careful exposure of the different layers and matching the colors of these layers to the Federal Standard No. 595a Colors numbering system. Paint serration should include on-site visual examinations of the paint layers on painted surfaces, sampling and laboratory analysis.

The matching of exposed layer and color code is to be conducted under natural daylight or similar artificial lighting conditions. The obtained information is summarized in a chart and paint chips that represent the color selected.

The paint analysis and 'paint serriation' study is to include a written record of all of the paint layers for each location, identifying the substrate, primer, first finish layer, second finish layer, and so on, with the present paint layer shown last, at the bottom of the chart. Original or otherwise significant layers are to be clearly noted.

The historic paint analysis generally should include the following items:

1. Paint Serriation Chart indicating all the paint layers found in the location in which the sample was removed *(as described above).*

2. Federal Standard color number associated with the color of the original finish coat.

3. Outline Specifications of the restoration colors, paint materials, manufacturers, application techniques and any special conditions, as required.

b. Assessing the Condition of Painted Metal Surfaces

For existing metal surfaces the first method of analyses shall be to determine the adequacy of the existing paint. The important parameters are paint adherence, thickness and condition. Paint adherence is determined in accordance with ASTM standards *(D4541 and D3359)*. Paint thickness is determined by a measurement using a thickness gage per ASTM D1186 or SSPC-PA2. Paint condition is determined by estimating the percent surface damage and the coating porosity using a pin hole detector. The above tests for metal shall be followed by the paint seriation analysis.

Repairs can be either local or the entire surface can be re-coated.

3.4.3 Metal Analysis (of ornamental metals)

a. Introduction

Ornamental metals on the Merritt Parkway are exposed to environmental atmospheric conditions which promote the degradation of the components of the metals. For example, in addition to the natural atmospheric conditions of moisture and dust deposition, ornamental metals on the Parkway are exposed to industrial effluents, automobile emissions and salt deposition. All of these conditions promote pitting and crevice corrosion of metals. Bridge components fabricated from iron alloys such as cast iron, wrought iron and mild steel were originally primed and painted to provide surface protection and to create a pleasing appearance. Survival of these alloys depends upon the maintenance of their painted finishes. Other less corrosive metal alloys, such as aluminum and brass, were originally not coated and potentially may remain so.

b. Alloy Identification

Visual inspection combined with an examination of the original drawings will determine the general type of metal, such as cast iron, wrought iron, mild steel, aluminum or brass, and is usually sufficient for determining a cleaning and protection program *(i.e. the type of paint or other coating to be specified, if any)*. Where replacement parts are required and will be placed in contact with original metal elements, identification of the exact types and percentages of alloys should be determined by laboratory testing in order to successfully plan for the prevention of galvanic action between new and old components. In this case, a sample should be obtained by removing a portion of the material from a visually obscure location. Any paint should be removed locally in the area of the sample, and care taken not to contaminate the sample to be analyzed, with the instrument used to obtain the sample. The sample should then be analyzed by an approved conservation laboratory.

c. Assessing the Condition of Metals

The condition of ornamental iron alloys such as cast iron, wrought iron and mild steel, can be assessed by either visual or metallurgical evaluations by a qualified professional engineer. Where visual assessments are not sufficient for determining the structural conditions of a railing or large ornament, ultrasonic techniques can be employed, as is often used in the assessment of larger historic structural members. In wrought iron and cast iron, microscopic analysis in a laboratory is generally required to determine

if graphitization is occurring. The presence and the extent of corrosion will help to determine the type and extent of restoration (*i.e. replacement, partial replace or repair*). Assessment of the condition of ornamental metals should undertaken as part of a standard bridge inspections.

Aluminum alloys are very resistant to corrosion in most environments. However under specific conditions such as salt sprays or near the seacoast aluminum alloys can undergo pitting corrosion. The first sign of attack is usually the appearance of white spots that can be visually observed on the metal surface.

Some aluminum alloys are also susceptible to exfoliation corrosion. This type of corrosion occurs below the surface of the metal, between layers of uncorroded material, eventually resulting in the material splitting apart. This form of corrosion can also be found easily by visual inspection and is found most commonly in heavily rolled products such as bars and rods. These products are usually used to fabricate railings.

The atmospheric exposure of cast brass *(a copper alloy)* usually causes a natural protective green patina surface coloration. However, design details which may allow moisture to collect in crevices and bends can result in the accelerated corrosion of copper alloys. The level of corrosion can be determined by visual or microscopic inspection. The presence and the extent of corrosion will help to determine the type and extent of restoration required.

3.4.4 Mortar Analysis *(for Stone and Cast Stone Masonry)*

Mortar analysis is an on-site visual and laboratory analysis of mortar for the purposes of determining the proper composition and application techniques for repointing masonry. Testing of existing, original mortar on the Parkway bridges is critical in order that the mortar material and treatment act as an integral part of the existing masonry construction. New restoration mortars shall match existing mortars in color, strength and makeup.

Samples are to be taken from mortar at all masonry types present on the parkway bridges. The locations of all samples removed shall be noted in the mortar analysis report. Samples are to be removed with hand tools, such as a hammer and chisel, taking care to not disturb adjacent materials, stored in properly marked cloth bags with the following information:

1. Bridge #.
2. Name of over- or underpassing road.
3. Location of Sample Removal

Samples should be transported to an approved architectural conservation laboratory for analysis. Samples taken from repaired areas are not acceptable.

Mortar analysis by standard wet chemical technique shall be conducted to obtain volumetric, whole number ratios or percentages, of cement, lime and sand. This ratio influences the compressive strength of the mortar, an important design consideration in the preparation of the repair mortar. The repair mortar, determined for each type of masonry, at each bridge, should have compressive strengths and porosity

characteristics similar to the original masonry to prevent the spalling and cracking of the units.

Physical analysis shall consist of an analysis and identification of the sand and cementitious components of samples. The analysis shall determine the color, opacity, aggregate size and shape, and the presence and nature of impurities. Color value shall be designated by Munsell number. The matching of all of the physical characteristics, as listed above, are crucial to the formation of a repair mortar which matches the original as closely as possible.

3.5 MATERIALS AND RESTORATION TECHNIQUES

3.5.1 Introduction

This chapter identifies materials and techniques appropriate for restoration and repair work. Emphasis has been placed on how to define and identify original materials, finishes and colors as well as what are the appropriate methods for restoration. The discussion of the repair techniques is divided into the types of materials found on the bridges of the Parkway.

Structural and highway safety issues, while of the primary importance, are outside the scope of this manual and are only referenced in passing. For more detail other manuals have to be reviewed.

Restoration of the historic bridges involves, to a large degree, two aspects that are critical to the overall appearance of the structure: the restoration or replication of missing or severely altered detail and the recreation of original surface finishes. The replication of original features is generally limited to architectural, decorative, ornamental or sculptural elements. The recreation of original surface finishes is often necessary because of earlier inappropriate treatments and actions that have adversely affected the original appearance of the bridges.

A distinction has been made between maintenance and substantial rehabilitation and restoration projects; however, both have a significant impact on the overall appearance of the bridges. Although regular maintenance should not significantly alter the physical configuration of the original bridges and their architectural details, the potential impact of these routine operations on the visual appearance of the original detail should not be underestimated. Changing of colors, application of surface coatings or cleaning of masonry, while routine, have an immediate and significant visual impact. Maintenance procedures are to be in line with the procedures and recommendations described in this chapter.

Maintenance recommendations contained in the earlier Merritt Parkway Guidelines for General Maintenance and Transportation Improvement discuss at length how the historic integrity of the parkway is to be preserved. On-going maintenance has a long range, mostly visual, impact on the historic or architecturally important elements and is therefore to be considered carefully. Also the desire to preserve the original architectural fabric need not to be in direct conflict with public safety. Frequently these seemingly contradictory needs are satisfactorily reconciled.

3.5.2 CONCRETE

a. Summary

This section concerns the patching, crack repair, and replacement of cast-in-place concrete on the historic bridges of the Merritt Parkway. Also included is the repair of concrete surfaces and refinishing; the repair and replacement of ornamental cast-in-place concrete and pre-cast concrete; the cleaning of concrete masonry; the removal of graffiti; and recommendations for the use of protective coatings on concrete.

These restoration techniques are consistent with existing repair and maintenance procedures but they place considerably more emphasis on the preservation of the historic and aesthetic qualities of the individual bridges. Both acknowledge that proper repair and maintenance procedures are essential to the continued life of the bridges. Restoration measures identified here do not eliminate the need for structural inspection of the existing conditions by a qualified engineer.

Identification of original concrete materials through laboratory testing of samples removed from individual bridges is required for all concrete repair *(see also section 3.4. Testing and Analysis in this manual)*.

Replication mixes are necessary for patching, replacement, etc. in order to achieve satisfactory repairs. Mixes are to be formulated with materials that match the original concrete materials. Satisfactory applications of these mixes must be made on test panels and mock-ups in the field and must replicate the original materials, colors and textures as closely as possible.

All the above work is intended to preserve the original appearance of the bridges and is to be incorporated in other projects that may involve such work items as: structural rehabilitation, widening (when necessary), railing rehabilitation, minor spalling and surface repairs, and routine maintenance procedures.

b. Description

Cast-in-place concrete and cast stone are extremely durable materials when properly maintained. The reinforced cast-in-place concrete of the bridges has been deteriorating because of water penetration, freeze-thaw cycles, chloride contamination *(road salts)*, rebar corrosion, impact damage, vegetation, biological growth, graffiti, and air pollution. The constant exposure to the atmosphere has also weathered away much of the original surface finish and has affected the 'crispness' of the details and features of the cast-in-place and precast ornamentation as well.

The single most contributing factor to the deterioration of concrete bridges is the failure of the deck, its waterproofing membrane and bituminous or concrete overlay. As a result moisture and chlorides are able to penetrate. The bridges of the Merritt Parkway are no exception to these conditions.

c. Materials

In order to achieve an appropriate match but to maintain the required standards, the mix composition and proportions shall match the original concrete for each bridge in terms of its coarse aggregate, fine aggregate, and cement.

A review of the original Merritt Parkway Bridge Plans will show that generally, Class "A" concrete was specified for the bridge

substructure including rigid frame and wingwall elements, while Class "C" concrete was specified for concrete bridge railings. *(Class "B" concrete utilizing large aggregate was used for "Piers to Rock", concrete pier shaped sub-footings, providing direct substructure bearing to bedrock where bedrock was relatively shallow. As the placement of all Class "B" Concrete was below grade and not visible, it need not to be replicated.)*

Class "A" concrete commonly specified on original bridge plans typically had a cement-sand–stone ratio of 1:2:4. Large aggregate in Class "A" concrete was typically Class "C" *(1-1/2" size stone).* Class "C" concrete commonly specified for bridge rails had a cement-sand-stone ratio of 1:2:3. Large aggregate for concrete depths less than 6" would be Size "E" *(¾" stone size)* exclusively. Where concrete depths were greater than 6", a blend of course aggregate could be used with a makeup of 70% Size "C" and 30% Size "E". *(See Appendix, Section 4.3 for more information)*

Concrete core samples should be taken from individual bridges. The material of the concrete cores should be identified through laboratory testing in accordance with Section 3.4, Testing and Analysis.

The materials for sample replication mixes for four (4) bridges are given in the Appendix 4.4, Results of Laboratory Testing. These sample mixes are provided for information only. For other bridges, new core samples are to be taken and tested to establish and verify the composition of the concrete of the different bridges.

Patching mixes should meet the requirements of the Special Provisions for "Class 'S' Concrete for Historic Bridges - (Site No.)"

All other material requirements including design strength and air entraining criteria of Class "A" and "C" concrete specified in Article M.03.01 shall be satisfied.

Section 3.6 of Chapter III contains guide special specifications for "Class 'S' concrete for Historic Bridges", "Class 'A' Concrete – Replicated (Site No.), and "Class " 'C' Concrete Replicated (Site No.)
All other materials necessary for the cast-in-place concrete repair work are to be according to the Standard Specifications, Sections M.03.01 and the Special Provisions unless otherwise noted below.

d. Construction Methods

Construction methods should be in accordance with the Standard Specifications, Section 6.01, Concrete for Structures, except Article 6.01-03-21 in regard to surface finish requirements. *(For surface finish requirements, see Guide Section 3.5.2-h.)*

e. Patching of Original Concrete

Patching of concrete on the Merritt Parkway may range widely in scope and may involve repair of isolated spalls, the application of the patching material for large repairs, or even the recasting of entire sections of the bridge superstructure using appropriate formwork. Also correcting of earlier repair work that does not match or is defective should be included.

The surface weathering of the original concrete surface has, in many instances, exposed the coarse aggregate *(black basalt or traprock)*. Occasionally the steel reinforcing is also exposed. Where the surface weathering is severe over a large enough area, the surface is to be repaired with "Class 'S' Concrete for Historic Bridges (Site No.)".

The limits of the repairs will follow the design lines. The repairs for areas not directly visible, like bridge intrados, the patching will be performed according to the Special Provision for "Variable Depth Patch". *(See Appendix Sec 4.1)*

Prior to the beginning of the repair work, it is necessary to determine the following:

- Composition of the original concrete by core sampling and laboratory testing in accordance with Section 3.4 of this manual.
- Condition of the pre-existing repairs. The repairs that are defective or contain an incompatible patching material shall be removed and replaced.

All spalled concrete shall be removed and patched. Where spalls are within 6 inches of each other, the areas shall be combined into one single repair. Large areas of deterioration shall be re-cast using appropriately designed and constructed formwork.

f. Crack Repair and Sealing

Existing cracks shall be inspected and evaluated. The repair of cracks should generally not be undertaken unless the crack is determined to be the result of structural deficiency. Structural deficiencies that have caused cracks should be addressed before any type of crack repair shall be made.

g. Replacement of Cast-in-Place Concrete

In many instances large areas of the concrete are severely deteriorated requiring entire sections or components to be re-cast. This may involve such architectural elements as railing posts, piers, parapet walls or the intrados. Because of the size of the area, patching is not to be considered. The following is recommended:

Major elements or portions of a bridge, which are to be replaced, are to be recast following the original bridge design. This is to include all architectural details and ornamentation and is to be based on original details still remaining on the bridge or as shown on the original drawings *(See also Section 3.3)*.

The replacement concrete materials shall be in accordance with the recommendations of the Materials section and the test results *(Section 3.4)*. All new work shall comply with Standard Specifications, Section 6.01, Concrete for Structures.

Replacement sections on the bridges are to match the original bridge concrete in color, texture, 'crispness' and architectural detailing as closely as possible.

h. Concrete Surface Finish

The standard methods of finishing concrete surfaces were described identically in both the State Highway Department Standard Specifications Form 803 (1932) and the Form 804 (1935) that were in effect sequentially during the period of the Merritt Parkway bridge construction (See Appendix 4.3 for Form 804, Section 243).

The external surface of all concrete would be thoroughly worked during placement

operations so as to force all coarse aggregate away from the surface and thoroughly work the mortar against the forms to produce a smooth finish, free from water, air pockets, and honey combs.

Immediately after removal of forms, all form tie holes and honeycombing would be "pointed" with a mortar of sand and cement in the proportions employed in the particular class concrete being used.

Immediately following the setting of filled voids, surface finish operations would be undertaken.

Concrete surface finish types differ somewhat from concrete surface finish types described in Article 6.01.03-21 of the current Standard Specifications.

Vertical concrete surfaces were rubbed, or otherwise specified on the plans. The Rubbed Finish, essentially unchanged from the rubbed finish specified in the current Standard Specifications, was achieved by wetting the concrete surface with a brush and rubbing with a No. 16 carborundum stone or abrasive of equal quality, bringing the surface to a paste. The rubbing would continue as needed to remove all form marks and projection, producing a smooth dense surface without pits and irregularities. The paste formed by the rubbing was finished either by "striping" by brush, or by spreading uniformly, and following the reset of the paste, floating with a canvas, carpet faced or cork float, or rubbed with dry burlap.

Horizontal concrete surfaces not subject to wear such as the tops of parapets, handrail posts, railing caps, copings and bridge seats were formed by placing an excess amount of material in the forms which was then struck off using an approved tool while forcing coarse material below the mortar surface. All horizontal surfaces except tops of parapet caps and bridge railings would typically receive no further finishing. The final finish for parapet and railing caps would be the Brush Finish, Float Finish, or Ground *(or Terrazzo)* Finish as specified.

The Brush Finish was achieved with fine brush following floating of the concrete surface. After the concrete was struck off following placement, the concrete surface would be thoroughly worked and floated with a wooden, canvas or cork float. Before final set of the concrete, the surface would be lightly striped with a fine brush, to remove the surface cement film, leaving a fine grained, smooth, but sanded texture.

The Float Finish was achieved with a rough carpet float or other "suitable device". After the concrete was struck off following placement, the surface would be finished with a rough carpet float *(or other suitable device)*, leaving the surface even, but with a sandy or pebbled texture.

The Ground or Terrazo Finish would be constructed on a bridge railing, parapet cap, or other surface as specified following the removal of concrete forms. This surface finish was accomplished by grinding, wet or dry, with a No. 16 carborundum stone or equally good abrasive, until the individual particle are cut and polished. After cleaning the surface with water, a final rubbing would be done with a No. 30 stone. The finished surface would show the various aggregate particles in polished marble- like form.

Other concrete surface finish methods described in the Forms 803 and 804 included the Tooled Finish, the Sand Blast Finish, and the Wire Brush (*or Scrubbed Finish*).

The Tooled finish, when specified, was

applied to panel sections by use of bushhammer, pick, crandall, or other like tools. Tooling would not be done until the concrete had gained sufficient strength *(at least 14 days)* so as to prevent aggregate particles form being picked out of the surface. The finished surface would display a grouping of broken aggregate particles in a matrix of mortar, each particle being in slight relief.

The sandblast finish, when specified, was similar to a tooled finish but had a more finely grained texture. Sandblasting would be done in a manner as to produce an even, fine grained surface in which the mortar has been cut away, leaving the aggregate particles exposed.

The Wire Brush or Scrubbed Finish was produced by scrubbing the surface of "green" concrete with a stiff wire or fiber brush, using a solution of muriatic acid in the proportion of (1) part acid to four parts water. This finish technique would be undertaken as soon as form work was removed. The concrete surfaces would be thoroughly and evenly scrubbed until the cement film or surface was completely removed and the aggregate particles were exposed. The resulting effect would be an even pebbled texture, presenting an appearance grading from that of fine granite to coarse conglomerate, depending on the size and grading of the aggregate used. As soon as the desired texture was achieved, the entire surface would be thoroughly washed with water containing a small concentration of ammonia to neutralize any remaining traces of the acid.

One common concrete finish method that is not appropriate for the Merritt Parkway bridges is the grout-clean down finish. This method is included in the current Standard Specifications but was not included in the 1935 Form 804 Standard Specifications This finish method involves the application of a cement sand grout mixture to vertical concrete surfaces. Color variation in the final finished surface is not uncommon where this method is employed. As the Grout Clean-Down Finish method is not historically accurate, the method must not be used in the restoration of the Merritt Parkway bridges.

As noted earlier, the 1935 Form 804 Standard Specifications stated that the concrete finish should be a Rubbed Finish unless otherwise stated on the plans. While, none of the original Merritt Parkway Bridge Plans indicated concrete surface finish requirements, it is clear from a study of the bridges that a variety of concrete surface finish types were employed. It is not known whether specific surface finish types were specified in original contract special provisions (*not currently available*), or whether specific concrete finishes were directed by the Department during construction.

Because there is extremely limited information on existing contract plans regarding concrete surface finish requirements, it is critical for accurate replication that the designer determine from a careful field study the finishes originally constructed on exposed concrete surfaces. The assessment of original concrete finishes may be difficult given some degradation of concrete surfaces, as a result of long term atmospheric exposure.

i. Ornamental Cast-in-Place Concrete

Many bridges on the Parkway have important cast-in-place ornamentation. The ornament was created as follows:

Concrete was placed in wooden formwork that had wooden dividers, inserts or reverse plaster waste molds to achieve the desired detail.

A wide variety of continuous ornamental detail was achieved with wooden forms, for instance, the dentil molding on Bridge 704 - Wire Mill Road, Stamford or the clapboard ornamentation over the surface of Bridge 735 - Merwins Lane, Fairfield.

Smaller, isolated panels with finer and more complex detail, such as the Pilgrim and Native American ornament panels at Bridge 716 - Comstock Hill Road, Norwalk, were produced with reverse plaster waste molds set in the wood formwork.

For the cast-in-place ornament, it was critical that the concrete in the forms was thoroughly worked or vibrated, directly after placement in the forms. After removal of all formwork the concrete was finished to produce a surface of uniform color and texture removing all unwanted form marks and other faults *(See Section h, Concrete Surface finish).*

Prior to the repair of any cast-in-place ornament, all other deterioration that affects the ornament or the areas directly adjacent is to be addressed. Cast-in-place ornamentation is to be repaired as follows:

For the repair of the cast-in-place ornament, sample removals are to be limited *(preferably not an entire core)*. Testing is to identify the composition of the mix, in particular, any special aggregates. For the replacement mix the same aggregates and cement is to be used. Approved bonding agents, admixtures or adhesives can be added to repair the spall.

Any corroded reinforcement or anchorage should be cleaned in accordance with the specifications.

Field test panels *(mock-ups)* or pieces are to be constructed in the field, for each ornament to be repaired or re-cast, for approval by the engineer. It is the intention to match the detailing, finish, color and texture of the cleaned, original work or the clean adjacent concrete depending on where the missing or severely deteriorated original is located.

Replacement of entire ornaments is to be conducted in the field using molds that match the original work. The replication mix is to be used for casting the ornament.

j. Ornamental Precast Concrete

Many ornamental concrete elements were cast off site in custom molds and under more controlled conditions. Often not only were the molded forms unique but also special colored aggregates were used.

The precast or cast stone units were installed in the formwork and suspended from the top in such a way as to protect the unit from damage and to allow the pouring of the structural concrete. Where many heavy units had to be suspended, additional stiffening was provided in the form of a system of cross braces and vertical threaded rods.

The precast concrete ornament had a different tone and color than the cast-in-place concrete used on the bridges. Where a closer color match was desired or where the cast stone unit could not easily be

incorporated, the use of waste molds set in the formwork was preferred.

Where a wide or different variety of color and texture was desired, such components as quartz, vitreous and ceramic aggregates or white cement were used either alone or in combination. In addition, mineral pigments may have been used to tint the cement.

The precast concrete designs range from human figures, to animals and flowers. The ornament may be free standing like the butterfly ornament on Bridge 735 - Merwins Lane, Fairfield, and the six foot tall Nike wings (*by sculptor Edward Ferrari*) on the James Farm Road overpass in Stratford, or may be in the form of relief panels set into the structural concrete. Four such panels depicting pilgrims and Native Americans exist at Bridge 716 - Comstock Hill Road, Norwalk.

Another type of pre-cast ornament was the sgraffito concrete panel. Named after an early Italian technique, separate mixes were placed in a mold in at least two layers. The thin outermost layer was usually white cement that sometimes contained colored aggregates. The next layer consisted of gray cement with a dark colored aggregate. The design was then created by chipping or etching away the outer layer in order to reveal the darker and contrasting inner layer.

For the repair of pre-cast units, the same principles apply as those described for cast-in-place ornament. Elimination of other conditions that cause deterioration is again critical before the restoration of ornamental surfaces is begun.

The following applies to the repair or replacement of spalled or severely deteriorated precast ornament:

A sample of the pre-cast panel is to be removed for analysis. Care must be taken that the sample contains all of the layers of mixes that might be present. The testing of the original precast is to provide all the components and their relative ratios in order to match the color and finish. The laboratory analysis results and samples of the mix should be presented for approval.

Any corroded reinforcement or anchors are to be cleaned and repaired in accordance with the specifications.

At all times it is the intent of the repair or replacement work to match the form, detail, color and texture of the cleaned, original work, as closely as possible.

k. Cleaning of Historic Cast-in-Place Concrete

Cleaning the concrete is important. However, the purpose should be clearly delineated prior to undertaking in any cleaning specification. At all times the gentlest methods that provide the desired result should be used. Soil, stains, biological growth and graffiti are to be removed from original materials without damaging the original surfaces. Non-toxicity and the protection of adjacent materials, property and vegetation are essential.

Cleaning is not intended to remove pigmented coatings uniformly applied to entire bridge surfaces. While pigmented coatings are not desirable from a historic preservation perspective, removal of such previously applied coatings would be cost prohibitive and would likely cause damage to underlying concrete surfaces. Pigmented coatings shall be used only in the maintenance of bridges that have been previously coated throughout all concrete surfaces.

The following needs to be considered for any cleaning program on the Parkway:

- Clear Purpose and Goals
- Stain identification
- Specification of cleaning products and methods
- Test panels in the field
- Quality control during implementation
- Stain Removal (*with poultices*)
- General Cleaning *(potable water)*
- Environmental permits, Water quantities, discharge and containment.

General cleaning is to be accomplished with a low-pressure water washing system ("power" wash). Starting at the lowest pressure possible the pressure is to be increased only as much as is necessary to adequately clean the surface. Heavy soiling can be removed in conjunction with the "power washing" by hand brushing with nylon or bristle brushes (not metal).

Because of the quantities of water used in "power washing", containment of site run-off is to be considered carefully.

Acidic cleaners are not recommended for use on the parkway bridges.

Where algae, lichens or other fungal growth is to be removed, brushing with a stiff bristle brush, after wetting during the general cleaning, is generally sufficient. Mildew *(fungus)* is best treated with a weak solution of bleach and water. A contractor will need to obtain a discharge permit for the use of cleaning agents containing bleach prior to the start of such cleaning operations.

Where vegetation such as growing vines are to be removed, the root is to be cut first allowing the vine to dry before removal.

Any remnants or stains can be removed with scrubbing and water.

Because most salts and efflorescence are water soluble, they can usually be brushed and washed off with water. However, efflorescence is the result of water penetration into the masonry and will, therefore, continue to reappear until the source of moisture intrusion is removed.

I. Paint and Graffiti Removal

Graffiti on the wing walls, abutment walls facing the roadway, and occasionally on the railings and parapets disfigures many bridges along the Parkway. Sometimes graffiti are not directly visible from the parkway or other roadways because of obscuring vegetation. Graffiti and coatings applied to cover graffiti should be removed in accordance with a special provision item for graffiti removal.

Over time pigmented coatings have been applied to mask the graffiti. While attempts were made to match the colors of the adjacent concrete, the results have not been entirely successful. The coatings are clearly identifiable and visually disrupt the appearance of the bridges and consequently, the scenic beauty of the parkway. In many areas in fact, the painted sections actually highlight the problem, identify the accessible portions of the bridges and as a result attract more graffiti. Pigmented coatings are generally not preferred as a permanent measure to cover up graffiti.

Coatings applied to cover earlier graffiti should be removed to restore the original appearance.

Prompt removal, without the use of a pigmented coating, is visually the best

solution and also the most effective in deterring graffiti because it removes the desired visibility and attention. The removal of graffiti is a major problem that has large cost implications. However, it is possible that with general improvements in the appearance and upkeep of the bridges, and the implementation of the Landscape Master Plan, 1995, that the problem can improve.

Graffiti and the pigmented coatings used to cover graffiti are generally best removed with a poultice. An absorbent material or powder is mixed with a liquid solvent to form a paste that is applied to the surface. Commercial paint remover, lacquer thinner, acetone or a methylene chloride remover are used for that purpose. When dry the poultice can be removed with a wooden scraper and the surface is washed with water. This method allows for the containment of the chemical residue and disposal.

Other methods may sometimes be required. However, the goal is to remove as much of the graffiti and paint as possible without damaging the concrete surface. Upon completion some shadowing of the graffiti may remain because the paint has been somewhat absorbed into the surface.

Included as a reference in Appendix Section 4.8 is *Preservation Brief No. 38 – Removing Graffitt from Historic Masonry*, issued in 1995 by the Department of Interior National Park Service. Various graffitti removal agents and methods including poulticing, water and detergent, organic solvents, alkaline compounds, and bleaches. These guidelines should be incorporated into project special provisions for graffiti removal as appropriate.

m. Protective Coating

Pigmented coatings used in recent repair, rehabilitation and widening projects are visually not entirely satisfactory. They have varied from a vinyl surface skimming material to cementitious coatings that bond with the concrete. The colors have also varied widely ranging from shades of white to cream, gray or tan. The pigmented coatings seem to be an attempt to replicate the whitish or light colored appearance of the concrete, as known from and seen in the original black and white photography of the bridges. These recent surface coatings have begun to spall at some of the bridges.

Coatings reduce the penetration of moisture and chloride ions into the concrete. Theoretically this reduces the amount of corrosion of the steel reinforcement and tends to slow down the rate and depth of carbonation of the cement. Where the concrete has been exposed as long as the bridges on the Merritt Parkway the use of such coatings may not be effective and is probably best avoided because of the visual impact.

The original chief architect, George Dunkelberger, discusses at some length the use of special aggregates, such as quartz sands, to enhance the finish of the concrete on the bridges. The use of pigmented coatings eliminates the reflectivity of the original concrete and significantly alters the appearance of the bridges. Pigmented coatings are not recommended, even as a temporary solution, because of the difficulty of removing them.

3.5.3 STONE MASONRY

a. Summary

This section concerns the repointing, repair, replacement and cleaning of natural rubble fieldstone, ashlar stone, cut granite and cast stone masonry construction as found in several of the historic bridges of the Merritt Parkway. Repointing is to include the repointing of all joints where mortar is found to be missing, cracked or separated from the masonry units or otherwise deficient. Repair includes patching of cracked units with mortar, epoxy, or pins and spalled units with a cut stone patch *(commonly referred to as a 'dutchman')*. Replacement is to include replacement of entire natural or cast stone units, to match, existing adjacent masonry, as required. Cleaning is to include general, non-abrasive cleaning to remove soil and specialized cleaning to remove biological growth, exudation, and graffiti.

The restoration techniques used on natural and cast stone masonry shall be consistent with recognized repair and maintenance procedures, modified according to this section in order that the historic and significant architectural features of each bridge is preserved, according to the original designs. Restorative measures performed in accordance with this section, require an analysis of existing conditions by a qualified professional engineer.

b. Description

Natural stone masonry is an extremely durable material and has been found to be in generally good condition, with a few minor repair problems, on the bridges of the Merritt Parkway. The unique cast stone masonry developed by Dunkelberger in the 1930's, has proven to be less resistant to deterioration than natural stone. As with the cast-in-place concrete bridges, the condition of the natural and cast stone masonry bridges has depended primarily on the original quality of construction and the quality and frequency of on-going repair. The cast stone also appears to be less resistant to freeze-thaw cycles.

c. Materials

Material requirements for dimensioned masonry stone, ashlar masonry stone, cement rubble masonry and dry rubble masonry shall be provided according to the Standard Specifications, as modified below.

Repointing and repair mortar should match the original mortar in composition *(proportions and types of sand, cement, lime and water)*, strength, color and texture. The appropriate replication mortar should be determined through standard mortar testing, conducted by an approved architectural conservation laboratory, in accordance with Section 3.4.4, Mortar Analysis, of this manual. By varying the composition, the strength of the mortar may be adjusted to match the original mortar. Repair mortar with a higher compressive strength than the original, historic mortar may not allow adequate movement between individual stones, resulting in the spalling of the masonry. Cast stone is especially vulnerable to incompatible mortars because of its square corners and weaker compressive strength.

Color and texture are important aesthetic characteristics that directly affect the overall appearance of the bridge, and are to also be determined as a part of the mortar analysis.

Mortar analysis is to be conducted on several samples taken from the bridges. The type of sand and its source, is also to be identified. Test samples should be removed from areas which have not received repairs.

Materials for replacement units of cast stone masonry are to be determined according to the guidelines established for cast-in-place concrete. The composition of cast stone masonry units should be determined by the laboratory analysis of core samples taken from the bridges *(see Section 3.4.1 - Concrete Testing and Section 3.6.4, special provision item, "Testing and Analysis of Concrete (Site No.)", in this manual).* New cast stone masonry units should be cast with materials matching the components of the original mix, including the type of cement and aggregates in the original proportions. The new unit is to match the original units after cleaning in color, dimensions, shape and finish.

All other materials necessary for repair and replacement are to be according to the Standard Specifications.

d. Construction Methods

Construction methods are to be according to Standard Specifications for each type of masonry construction including masonry facing, cement rubble masonry, dry rubble masonry and repointing, and cast stone masonry, as modified below:

All replacement stones should be cut to match the size and shape of the original masonry, prior to being laid. The exposed surface finish shall match the original, such as sawed face, rock face, split face, etc., and have as similar contour and project from the true line of the wall to match the original work.

Joints should be of the same shape and width as the original joints and should be finished with the appropriate pointing tool to produce a joint that matches the original joints.

Where walls or sections of walls are to be rebuilt, existing stones should be salvaged and reused as much as possible and a sample section mock-up should be built on site, for approval. New ashlar stone should be laid as to provide the general affect of original work.

Cracked stone units should be repaired with mortar, *(see materials above)* which may be pigmented to match the overall color of the stone or cast stone as closely as possible.

Spalled stones should generally be replaced with matching stone patch units *(commonly referred to as "dutchmen")* and epoxy adhesive. Large pieces should be pinned in place using stainless steel pins with epoxy adhesives.

In the repair of natural stone masonry, a replacement stone or "dutchman" should be sized and shaped to fill the cavity, maintaining the contour and projection lines of the wall, as closely as possible. Matching holes for pinning should be drilled in the the replacement stone and the existing masonry to receive the replacement stone. The replacement stone would then be inserted in the opening with pins and would be braced as needed until mortar and epoxy have gained adequate strength.

Cast stone should be repaired by cast-in-place methods, using replication concrete mixes. Finishing of the cast stone unit should be accomplished in a manner similar to the techniques provided for concrete *(see section 3.5.2 of this manual).* Rubbing or other abrasive techniques should be performed to match the surface texture of the surrounding, original cast stone masonry.

All masonry repairs are to be within the original joint lines, horizontal and vertical of the original work, to the fullest extent possible. In large repair areas involving the replacement of several stones, the effect of the original wall is to be maintained.

e. Cleaning of Masonry

Although stone masonry is one of the most durable of historic bridge materials, it is nonetheless susceptible to damage by improper, harsh or abrasive cleaning methods. Cleaning of natural and cast stone masonry shall be conducted according to the following guidelines and requirements:

Cleaning of masonry is recommended only to remove heavy soiling and after a testing program to determine the gentlest and least toxic methods available.

The reasons for cleaning should be clearly established. A limited cleaning program is recommended to remove graffiti in localized areas, efflorescence and exudation and heavy soiling to improve the overall appearance of the masonry bridges.

Abrasive methods, such as grit or sand blasting are NOT RECOMMENDED for the cleaning of historic masonry, under any circumstances, as it will damage the original material. Cleaning shall always be attempted first with filtered water applied with low pressure. If necessary, a low pressure water wash can be supplemented by scrubbing with natural or nylon bristle brushes *(NO METALLIC BRUSHES SHOULD EVER BE USED)*, and non-toxic, non-ionic detergents Cleaning should be scheduled to take place within a period of moderate temperatures with daytime and nighttime temperatures consistently above 40F.

Staining from biological growth *(mold, mildew or algae)* can be cleaned with a mild solution of bleach and water. Rust and paint *(graffiti and graffiti coatings)* should be removed using specialized poultices, using extreme caution to protect adjacent materials, vegetation and the soil from any contamination. Methods of protection should be developed as part of the cleaning program.

Acidic cleaners should NOT be used under any circumstances for general cleaning as they are likely to harm adjacent materials, vegetation and the soil.

Cleaning should always be the last step in the restoration process.

3.5.4 STRUCTURAL STEEL

a. Summary

This section concerns the cleaning, repair, replacement and painting of exposed structural steel rigid frames on the historic bridges of the Merritt Parkway. Cleaning is to include removal of corrosion, dirt and excessive layers of paint. Repair is to include the fabrication and replacement of elements, portions of members and entire members as required, such as arched structural steel girders, plates, angles, stiffeners, rivets and fastening systems.

These restoration techniques are consistent with existing repair and maintenance procedures but they place considerably more emphasis on the preservation of the historic and aesthetic qualities of the individual bridges. Both acknowledge that proper repair and maintenance procedures are essential to the continued life of the bridges. Restoration measures identified here do not eliminate the need for structural inspection of the existing conditions by a qualified professional engineer.

b. Description

An alloy of iron, steel is highly susceptible to corrosion and oxidizes rapidly when exposed to moisture and air. Unlike other metals which may form a protective coating upon exposure to air, iron and iron alloys form a thin film which actually promotes the continuous process of deterioration. On the Merritt Parkway, the structural steel rigid frames are constantly exposed to corrosive substances in the atmosphere, as well as to heat, moisture, pressure, and other deteriorating agents. This causes the exposed portions of steel structures to rust. The rusting of steel is accelerated by pollutants, such as automobile exhaust, road salts, and the proximity of sea water. Once rust develops on the surface of steel, its porous surface acts as a reservoir for moisture, again accelerating the process of corrosion. Proper maintenance is essential to the continued performance of the exposed structural steel of the bridges.

c. Materials

The materials for structural steel repair and replacement shall be determined according to the Standard Specifications and Special Provisions, as modified below.

Steel replacement sections should match the original shape and dimensions of the original section. However, existing built-up members should be replicated in size and dimension by welded shapes.

Connections should be replicated in the type and pattern of the original members. However, button head bolts may be used in to replicate rivets in restoration work in bridge locations where such connections may be highly visible. Provisions are to be made for current ConnDOT performance criteria and design load requirements, with the minimum affect on the original appearance of elements.

d. Construction Methods

Construction methods are to conform to Standard Specifications and Special Provisions as modified below.

Fabrication shall result in members that replicate the original size, shape and dimensions of the original steel members on individual bridges.

The cleaning process may expose additional defects and/or deterioration such as cracks, pits and voids in the steel. Such areas should be examined closely by a qualified professional engineer during construction in

order to determine the need for additional repairs.

In the repair of existing members that are to remain, the repairs should minimize alteration to the original structural details.

In the replacement of entire members, such as girders, bents or columns, the original member should be replaced in kind to the greatest extent possible. However, an existing built-up member should be replaced with a new rolled shape or welded steel member, which is similar to the original in size, shape, and dimension.

e. Painting of Structural Steel

Iron and steel are most commonly protected from oxidation and other forms of corrosion with paints. Painting shall be performed in accordance with the Special Provision, "Abrasive Blast Cleaning and Field Painting of Structure (Site No.) ". As the existing coatings are likely to contain lead paint, the related special provisions for "Class (1, 2 or 3) Containment and Collection of Surface Preparation Debris", "Disposal of Lead Debris", "Portable Hand Wash Facility", "Decontamination Facility" and "Lead Health Protection Program (LHPP)" must also be included with the contract plans.

During the project design and plan development stage, microscopic analysis of samples of the historic paint sequencing *(Paint Analysis, see section 3.4.2 of this manual)* should be performed. The analysis should determine:

- the original primer
- the original, historic paint color
- the paint finish, i.e. matte or gloss
- additives, if any, such as sand
- a sequencing of all existing paint layers

The original drawings do not specify the colors used for the bridges, thus a Paint Analysis is critical in future bridge rehabilitation and maintenance projects, for the purpose of historic accuracy. Finish coats shall match, as closely as possible, the original, historic color and finish, as determined in the Paint Analysis. The results of the Paint Analysis will become part of the permanent ConnDOT bridge file.

Adjacent portions of the bridge, landscaping and soils should be completely protected from damage, disfigurement, and contamination during the cleaning and painting process.

3.5.5 ORNAMENTAL METALS

a. Summary

This section concerns the cleaning, repair, replacement and re-finishing of ornamental metal railings and decorative panels found on many of the historic bridges of the Merritt Parkway.

Cleaning should include the removal of all corroded material and generally all existing paint. Repair includes the replacement of missing or severely deteriorated stock, cast or wrought bars, rails, posts, ornamentation, anchors, fasteners and other components. Replacement may include the replacement of sections of a rail, or of an entire railing where severely deteriorated or damaged, previously removed and demolished, or otherwise missing. Re-finishing includes testing, surface preparation, application of paints, primers or galvanizing, as required to match the original surface coating, in color and finish. The removal and replacement of existing painted coatings however must be done in accordance with the ConnDOT special provisions for field painting structures as described in Section 3.5.4-e of this guide.

b. Description

The ornamental metals used in the original railings of the bridges of the Merritt Parkway are known to include wrought iron, mild steel, cast iron, cast brass and aluminum. Other metals may be present. All original metals should be tested for identification purposes. It is not uncommon for a railing to be composed of more that one metal, or more than one alloy of a similar metal, such as steel *(posts and handrails)*, wrought iron (*grillwork)*, and cast iron (decorative grilles or finials).

Cast iron, wrought iron, and mild steel are alloys of iron. In its pure form, iron is relatively soft, tough, malleable, ductile, magnetic, and high in tensile strength. However iron alloys are prone to rapid oxidation when exposed to the atmosphere, and therefore corrosion.

Historically, cast iron, wrought iron, and steel were commonly used for structural and ornamental purposes, such as columns, beams, ornamental facades, fences, railings and sculpture. Ornamental metals were selected by Dunkelberger for use as bridge railings for the versatile forms which could be cast, hammered, bent, curved and twisted from them. The railings provide contrast to the heavier and more solid, concrete and masonry railings. Metal railings were also less expensive and could also be painted a variety of colors or be galvanized. Descriptions of each metal are given below to help the user of this guide in determining appropriate restorative and protective treatments:

Cast iron has a high carbon content and is relatively more resistant to corrosion than wrought iron or steel. Molten iron is poured into molds, to create almost unlimited decorative and structural forms, making cast iron an extremely versatile material. It is very hard, strong in compression, but weak in tension, and therefore not appropriate for horizontal structural members. Cast iron grill work and decorative portions of railings are common to the parkway bridges.

Wrought iron is almost pure iron, with small amounts of carbon and slag *(iron silicate)*. The presence of slag differentiates wrought iron from steel. The slag exists in a purely physical association, that is, it is not alloyed, which gives the material a laminated structure. In processing, wrought iron is

removed from the furnace at a lower temperature than steel, semi-molten with slag, and formed into bars with most of the slag hammered out. Wrought iron is relatively soft, malleable and easily worked by forging, bending, rolling and drawing. Wrought iron corrodes more quickly than cast iron, but is resistant to progressive corrosion, due to the slag content. Wrought iron is not uncommon on the Parkway, and the iron railings should be tested for it, in order that appropriate methods aree used to restore it.

Mild steel is a malleable alloy of iron and carbon. It is specifically defined as having 0.2 - 0.25% carbon content. Mild steel is generally used now to fabricate hand-worked metal work or to repair wrought ironwork, although it will corrode faster if not routinely maintained. It is not as resistant to corrosion as either wrought or cast iron. Many of the original railings and ornamental grillwork on the parkway were constructed partially or wholly in mild steel.

Brass is an alloy of copper and zinc and small quantities of other elements. The composition of brass may vary from 95% copper and 5% zinc to 55% copper and 45% zinc. Brass can vary in color from a deep golden brown to lemon yellow or silver white, depending on the amount of surface oxidation *(tarnish)* and the amount of zinc. The color of brass can also be altered with patinas. Brass is softer than the iron alloys, but is more resistant to corrosion. However, brass is still subject to corrosion from moisture, air pollution, chlorides, and bird droppings. Brass was documented to have originally existed on the Parkway on only a few bridge railings.

Aluminum is a light-weight metal which is highly, but not completely, resistant to most environmentally caused corrosion, and is easily worked by most fabrication methods. A number of aluminum alloys have been developed for higher strength. Structural aluminum *(a copper alloy)*, however, is not appropriate for exterior use. Only a few bridge railings on the Merritt Parkway are known to have been originally constructed of aluminum.

Aluminum is generally resistant to attack by air, moisture and many kinds of soils, however it is corroded by alkalis, acids and acid rainwater, lead-based paint, chlorides *(road salts)*, wet mortar and wet cement. Aluminum is also damaged by galvanic action with other metals, especially copper. Aluminum is also highly prone to fatigue from thermal expansion and contraction, and mechanical abrasion.

The surface treatment or finishes used historically on aluminum include anodization, the use of chemical conversion coatings, paint, lacquer, plating, enamel, or lamination. Anodized aluminum has a special oxide film produced by electrochemical treatment, which is extra thick, and may have pigments added to it. "Non-finished" aluminum, or bare aluminum was most commonly used historically, and in actuality the surface may have been polished smooth, brushed or patterned by machining. Bare aluminum *(non-finished)* creates its own naturally protective, oxide patina.

c. Materials

The materials for repair and replacement of the ornamental metal bridge railings of the Merritt Parkway are not provided in the Standard Specifications. The materials provided in the Standard Specifications are for the new construction of concrete, structural steel and aluminum alloy railings for new highway bridges, or for replacement purposes of non-historic bridge railings. Materials for the restoration and preservation

of the historic bridge railings on the Merritt Parkway should be developed as follows:

Materials for the repair and replacement of original metal railings should match the original materials, in type of metal, dimensions and shapes of all components, including but not limited to, bars, posts, handrails, caps, and decorative features, and finishes. Visual analysis in the field, should be supplemented with metal analysis *(see section 3.4.3 of this manual)* conducted in a laboratory by a qualified Architectural Conservator to determine the following:

- type of metal
- proportions of elements (alloys)
- additional elements present

The matching of the original metal is important in preventing galvanic action between dissimilar metals in proximity.

The following exception is recommended to the above:

Anchors and fasteners should generally be of stainless steel, to further prevent corrosion and galvanic action where metal railings are anchored in, or otherwise fastened to concrete or masonry.

Mild steel may be generally acceptable in the repair and replacement of wrought iron railings.

d. Construction Methods

Original ornamental railings should be retained, repaired and restored to their original condition, preserving as much of the original material as possible. Where replacement is necessary of parts, sections or entire rails, the new work should replicate the original work.

(See section 3.2.5, Future Bridge Railing Rehabilitation Projects, for general guidelines).

The specific construction methods for the restoration of cast iron, steel and wrought iron railings shall be according to Section 3.6.6 - Cleaning, Painting and Repair of Ornamental Iron Work for Historic Bridges, of this manual and as stated below.

Procedures for the restoration of existing metal railings are discussed below for each type of metal.

e. Repair of Cast Iron

Decorative cast iron ornament and railing components require removal of all corroded *(oxidized)* material from elements which are to be preserved, removal of existing coatings replacement and recasting of missing or severely corroded, unsalvageable elements, surface preparation and application of new coatings consistent with the original design.

The removal and replacement of existing painted coatings must be done in accordance with the ConnDOT special provisions for field painting structures as described in Section 3.5.4-e of this guide.

Additional testing will be required to determine the color and texture of the original coatings. Cleaning and removal of coatings should be accomplished with minimal disturbance of original material which is intact.

1) Removal of Corroded Material:

All components exhibiting corrosion should be removed to a controlled

environment prior to removal and cleaning techniques being employed in order to prevent the airborne transmission of potentially dangerous substances and to prevent further oxidation of exposed iron. This will also allow for the application of any new coatings under optimal conditions.

Low pressure grit blasting *(100 psi or less)* will effectively remove even substantial corrosion as well as layers of paint, quickly, thoroughly and economically. Iron slag or sand should be used as an abrasive, not copper because of its electrolytic reaction with iron. Very sharp or hard aggregates or higher pressures in excess of 100 psi should not be used. Surface preparation Removal Proper eye protection, protective clothing and safety techniques should be used at all times. The release of airborne materials and disposal of materials should strictly comply with Federal, State and Local environmental guidelines.

2) Patching, Repair, Recasting and Replacement of Elements:

The cleaning process will expose defects such as cracks, pits and voids in the cast iron. Because cast iron does not weld easily, superficial cracks and small defects must be repaired using filler compounds containing iron particles in an epoxy resin binder. For major cracks or defects or when entire pieces or components are missing, severely corroded or damaged beyond repair, replacement is usually most practical with re-casting. Welding or brazing of cast iron is possible but difficult.

The re-casting of small, non-structural decorative elements should be accomplished using intact original elements as a casting pattern. Larger sections will require new patterns of wood or plastic, allowing for the shrinkage of the molten iron as it cools from a liquid to a solid. For stock items, such as the smaller rosettes and railing crests, a matching replacement may be found in existing catalogs of iron foundries.

Decorative cast iron was traditionally cast in special, moist sands. Two part molds are required for elements with relief on both sides. Molding sand is compacted in forms around the pattern, either an original element or a new pattern of wood or plastic. The molten iron, heated to 2700 degrees Fahrenheit, is then poured into the molds and allowed to cool. All burrs should be ground smooth, and the new casting should be primed with a rust inhibitor. Pre-assembly should be done at the foundry to insure proper alignment and fit of the various new and original elements. Final assembly of larger elements should occur at the site, to assure proper alignment under the actual field conditions. Fasteners and fastening techniques should match the original in size and type, whenever possible, with the exception that they should be of stainless steel.

3) Painting:

The ornamental cast iron, wrought iron and mild steel railing components on the Merritt Parkway were most commonly finished and protected from oxidation *(corrosion)* with paints. The paint color should be determined by the following:
Prior to removing paint from any historic metalwork a microscopic analysis of samples of the historic paint sequencing *(see section 3.4. Paint Analysis)* shall be performed by a qualified Architectural

Conservator. The analysis should determine:

- the original primer
- the original, historic paint color
- the paint finish - matte or gloss
- any additives, such as sand
- any polychroming or marbleization
- a sequencing of all paint layers

New painting applications shall follow the recommendations of Section 3.5.4-e of this Guide, with the color of the finish coat to match the original, historic color as determined by the paint seriation analysis.

f. Repair of Wrought Iron and Steel:

Removal of corrosion and scaling paints, cleaning, the selection, preparation and application of paints are generally the same for cast iron, wrought iron and mild steel. However, the repair and replacement of severely corroded, severely damaged or missing original elements is simpler for wrought iron and steel.

Mild steel is acceptable for the repair of old wrought iron elements. Stock steel bars, pipes and top rails are generally readily available or easy to fabricate when custom pieces are required. Additionally, unlike cast iron, steel and wrought iron elements can be readily welded, either in the shop or the field.

g. Replacement of Cast Brass:

Cast brass was originally incorporated into the design of the railing on:
Bridge 724 -Grummen Avenue, Norwalk, CT

According to the original drawings, small cast brass shields were braze-welded to circular insets on the steel railing. They were found to be missing.

The missing brass shields can be recast with new patterns incorporating the original design as indicated in the original bridge drawings, and braze-welded to the circular insets on the steel railing. As the original shields most likely were removed by vandals, consideration may be given to the design of more secure attachments, or the substitution of painted cast iron shields for the original brass shields.

h. Repair of Aluminum

The aluminum railing on Bridge 746 - Plattesville Road, Trumbull, CT was the only original aluminum railing found on the Parkway, although with metal testing, it is possible that others will be found to exist.

The aluminum rail should be tested to determine the type of aluminum, if an alloy was used, and whether the railing is bare, "non-finished" aluminum or anodized. Bare aluminum was the most common type of finish for aluminum used before 1950. The natural patina film on non-finished aluminum is thin and transparent, but it is generally tough and highly protective.

The cleaning solution used on aluminum should generally be mild enough for bare hands. The most gentle cleaning methods should be used to perform the cleaning to preserve the historic material. The rail should be thoroughly rinsed with filtered water and wiped dry. All cleaning methods should first be spot-tested to determine if discoloration will occur.

The railing is to be protected from further corrosion with a non-absorptive, insulative coating, such as clear varnish or lacquer. Where damage is severe, sections can be replaced.

Although welding is possible, with aluminum the most practical solution to a highly corroded, or damaged railing component, is replacement, as the material is easily cast, or fabricated. Replacement sections should match the original section in terms of dimensions, shape, thickness, type of aluminum, and finish. Replacement should occur within the original 'design lines,' with joints in the work and fasteners occurring in the same locations as in the original work.

3.5.6 JOINT SEALERS

a. Summary

This section concerns the removal of existing, defective joint filler material, the repair and cleaning of the substrate and the installation of sealant and filler material on the historic bridges of the Merritt Parkway.

b. Description

Expansion joints in existing structures allow movement to occur between portions of a structure which have to react to differing loads or loads applied from various directions. On reinforced concrete rigid frame bridges, the deck is reacting to different forces than the frame, and the wingwalls react to different loads than the frame and frame legs. The interface between these portions of a bridge structure generally requires a continuous expansion joint, which allows for movement due to thermal expansion and contraction, settling, moisture-related movement, wind loads, vibration and strain under changing loads *(from the roadway above).*

Joint sealers, usually used with a backing rod or filler material, function to keep moisture, vegetation, dirt and debris out of the joint while allowing for movement to occur within the joint. Joint sealers have to maintain their elasticity through changes in temperature, humidity, and ultraviolet radiation.

Dunkelberger incorporated expansion joints into the design of the Merritt Parkway bridges. As specified in the original drawings, joints were 1/2" and to be filled with cork or rubber. However, they may have been sealed with an oil base caulk which was prevalent at the time, or left open. An oil base caulk or cork filler would have provided weather protection as long as joint movement was minimal. Elastomeric *(or synthetic rubber)* sealants are able to expand and contract with constant joint movement.

Expansion joints on the parkway bridges were found typically to be open, or filled with badly weathered black caulk. The old caulk was torn, cracked, badly weathered and often missing. Frequently, vegetation was found to be growing out of the joints, including small trees and their root systems. The open joints commonly act as "weep holes" for the bridges.

c. Materials

New expansion joint fillers should satisfy the requirements of the Standard Specifications Section M.03.01 - 7, "Expansion Joint Fillers for Structures," and M.03.01 - 8, "Joint Sealants," and the following:

> Sealant should match the color of the adjacent material (concrete or masonry) as closely as possible and be tooled to form the proper appearance.

d. Construction Methods

Joint seal should be installed in accordance with Standard Specifications Section 6.0.03 - 24, "Joint Seal."

3.5.7 DECK REPAIRS

Reinforced concrete bridge deck repairs are to be performed in accordance with ConnDOT bridge standard practices.

3.6 GUIDELINE SPECIFICATIONS

Introduction

These provisions have been written for deficiencies identified in Section 2.3 of this manual and the *Individual Bridge Reports,* 1995. An existing conditions survey of the bridges and study of the original drawings and specifications conducted in 1995, was the basis for determining the scope of the work. These specifications are provided as a guide only. No contract or construction work should incorporate these documents without further review of the existing conditions and the updating of these provisions to cover recent techniques in the treatment of historic fabric.

3.6.1 CLASS "S" CONCRETE FOR HISTORIC BRIDGES (SITE NO.___)

Work under this item shall conform to the requirements of Section 6.01 supplemented and amended as follows:

Article 6.01.01 – Description: Add the following:

Class "S" Concrete for Historic Bridges is to be used to repair deteriorated concrete or poorly matched existing concrete patches on both vertical and horizontal surfaces as shown on the plans and as directed by the Engineer. Individual patch areas under this item shall be no smaller in area than one (1) square foot and shall be no shallower in depth than three (3) inches. The Class "S" concrete for historic bridges shall be comprised of a replication mix, designed by the Contractor in accordance with the requirements of the related special provision item "Testing and Analysis of Concrete (Site No.)".

Work under this item shall consist of surveying the existing vertical faced concrete of structures to be repaired with this material; locating and removing loose concrete, deteriorated concrete, and concrete overlaying hollow areas; patching these areas as well as spalled and scaled areas with Class "S" Concrete formed to the original contour. The work shall also include any sandblasting and cleaning of areas to be patched and filled and any exposed reinforcing steel, prior to placing concrete.

This work shall also include the preparation of a test panel mockup of the Class "S" concrete patching material for the approval by the Engineer.

The Contractor shall not perform any repair work without prior approval by the Engineer for location, limits, type of repairs, and approval of the test panel mockup.

Article 6.01.02 - Materials:

A. <u>CONCRETE</u>

Materials shall conform to Section M.03 as modified herein below:

<u>Subarticle M.03.01 - General Composition of Concrete Mixes</u>: After the fourth paragraph, add the following:

A mix design for Class "S" Concrete for Historic Bridge (Site No.)" shall be prepared and submitted by the Contractor to the Engineer. The mix design shall attain a 28 day compressive strength (f'c) of 3,000 psi.. The mix design shall replicate the color, fine and coarse aggregates of the original bridge as determined through the analysis and testing of concrete samples completed through the special provision item "Testing and Analysis of Concrete (Site No.___)" with the exception that coarse aggregate be limited in size to ¾" (No. 6).

Subarticle M.03.01-1 - Coarse Aggregate: Add the following:

(c) Grading:

The grading of Coarse Aggregate for "Class 'S' Concrete for Historic Bridges (Site No.)" shall be as determined through the related special provision item "Testing and Analysis of Concrete (Site No.)" except that maximum size shall be limited to ¾" *(No. 6)* in size.

Subarticle M.030.01-2 - Fine Aggregate: Add the following:

(c) Grading:

The grading of fine Aggregate for "Class 'S' Concrete for Historic Bridges (Site No.)" shall be as determined through the related special provision item "Testing and Analysis of Concrete (Site No.)".

Subarticle M.03.01-3 - Cement: Add the following:

Type I or II Portland Cement shall be used for Class "S" Concrete for Historic Bridges (Site No.) unless otherwise determined through "Testing and Analysis of Concrete Site No.). Gray and white cements may be blended to achieve the matching historic coloration, as approved by the Engineer. Type II Portland Cement generally yields mixtures lighter in color than Type I.

Subarticle M.03.01-9 - Admixtures: Delete Subsection "c" in its entirety and substitute the following:

Superplasticizing Admixtures: The superplasticizer admixture shall be a high-range water reducer (HRWR) capable of increasing the slump of the mix from approximately 2.5" to 7" upon the addition of the amount recommended by the respective manufacturer. The HRWR shall conform to ASTM C494 Type F or Type G and shall be approved by the Engineer. The use of this material shall be in strict accordance with the respective manufacturer's written instructions and procedures.

Colorants/Pigments:

Coloration or pigments if desired for color-matching shall have alkali-stable cement color properties but shall only be used if concrete is mixed in a central batch plant.

Subarticle M3.01.03-10 - Curing Materials:

(c) Liquid Membrane Forming Compound: Add the following:
No liquid membrane forming compound shall be used for Class "S" concrete.

B. REINFORCING STEEL

Materials shall conform to the requirements of Article M.06.01.

1 – Bar Reinforcement: ASTM A615, Grade 60

Article 6.01.03 - Construction Methods: Add the following:

Subarticle 6.01.03-5 - Composition: Add the following:

Class "S" concrete shall conform to the requirements as specified in M.03.01 as amended herein. Class "S" concrete shall contain not less than 6.5 percent and not more than 8.5 percent entrained air at the time of placement.

Subarticle 6.01.03-6 - Consistency: Add the following:

Class "S" concrete shall have a slump range of 2 to 4 inches prior to the addition of the HRWR and from 6 to 8 inches slump after the addition of the HRWR. The addition rates of the air-entraining admixture (A.E.A.) and the HRWR will vary. Frequent field testing of the air content and slump prior to and after addition of the HRWR will be the determining factor of actual addition rates for each admixture.

Subarticle 6.01.03 -7 - Mixing Concrete: Add the following:

For hand mixing of Class "S" concrete, the Contractor shall provide scale(s) approved by the Engineer in which cement and aggregate can be accurately weighed for the required mix proportions.

The Contractor shall also have measuring graduates marked in ounces for the proportioning of the A.E.A. and the HRWR. Do not mix the A.E.A. and the HRWR together before adding to the mix; the resultant solution will not work. DO NOT add the A.E.A. and the HRWR at the mixer simultaneously; these admixtures must be added separately in the mixing cycle. All manufactured materials shall be stored, mixed and used in strict accordance with the written recommendations of the respective manufacturers.

Subarticle 6.01.03 - 19 - Curing Concrete: Add the following:

Concrete shall be moist cured for a minimum of 7 days to prevent shrinkage cracking. Forms may be left in place during the curing period if helpful, providing the concrete can be monitored for moisture.

Subarticle 6.01.03-21 – Surface finish: Delete the entire sub-article and add the following:

The external surface of all concrete shall be thoroughly worked during the operation of placing by means of tools of an approved type. The working shall be such as to force all coarse aggregate from the surface and thoroughly work the mortar against the forms to produce a smooth finish free from water and air pockets, segregated materials, or honeycomb. All horizontal surfaces shall be formed by placing an excess of material in the forms and removing or striking off such excess by means of a tool of an approved type, forcing the coarse aggregate below the mortar surface.

Immediately after the forms have been removed, all voids and honeycombs on the surface shall be filled and finished to conform to the surrounding concrete surface with a mortar of fine aggregate and portland cement of the same materials and coloration as that of the particular concrete being treated. This work shall be performed immediately after removal of forms and before the finishing process is started.

Following the filling of voids and honeycombs, concrete surface shall be given one of the following concrete finishes, similar to adjacent existing concrete surface, as indicated on the plans, or as directed by the Engineer. Generally but not in all cases, a Rubbed surface finish as described herein will be constructed on vertical exposed surfaces, and a Brush finish will be constructed on horizontal surfaces (eg., parapet tops, railing caps, bridge seats) as described herein

Rubbed finish:

As soon as the filling of voids and honeycombs has set sufficiently to permit it, the entire surface shall be thoroughly wet with a brush and rubbed with a No. 16 carborundum stone or an abrasive of quality, bringing the surface to a paste. The rubbing shall be continued sufficiently to remove all form marks and projections, producing a smooth dense surface without pits or irregularities.

The paste formed by the rubbing may be finished by carefully striping with a clean brush, or it may be spread uniformly over the surface and allowed to reset. Following the reset of the paste, the surface shall be finished by floating with a canvas, carpet-faced or cork float or rubbed down with dry burlap.

Brush Finish:

After the concrete has been struck off as described above, the surface shall be thoroughly worked and floated with a wooden, canvas, or cork float, the operation to be performed by skilled and experienced concrete finishers. Before this finish has set, the surface shall be lightly striped with a fine brush to remove the surface cement film, leaving a fine grained, smooth, but sanded texture.

Float Finish:

After the concrete has been struck off as described above, the surface shall be thoroughly worked and finished with a rough carpet float or other suitable device, leaving the surface even, but distinctly sandy or pebbled in texture.

Ground or Terrazzo Finish:

The upper surfaces of rail caps, parapets or other surfaces when indicated on the plans shall be finished by grinding with a carborundum stone, or equally good abrasive to a smooth dense, terrazzo finish.

Using a No. 16 carborundum stone or an abrasive of equal quality, the surface shall be ground dry or wet until it is smooth and individual pebbles and aggregate particle are cut and polished. The surface shall then be completely cleansed with water, the final rubbing done by means of a No. 30 stone. The finished surface shall present the texture of polished marble and shall show the various aggregate particles in polished outline.

Tooled Finish:

This finish, typically for panels and other like work, shall be produced by the use of pneumatic tools, bush-hammer, pick, crandall or other approved tool. No tooling shall be done until the concrete has cured for at least fourteen (14) days but as long as needed to prevent the aggregate particles from being "picked" out of the surface. The finished surface shall show a grouping of broken aggregate particles in a matrix of mortar, each aggregate particle being in slight relief.

Sand Blast Finish:

This finish, typically for panels and other like work, shall be produced by sand blast methods. No sand blasting shall be done until the concrete has cured for at least fourteen (14 days). The sand blasting must be done by means of approved equipment and in such a manner as to produce an even grained surface in which the mortar has been cut away, leaving the aggregate particles exposed.

Wire Brush or Scrubbed Finish:

This type of finish shall be produced by scrubbing the surface of "green" concrete with stiff wire or fiber brushes, using a solution of muriatic acid in the proportion of one (1) part acid to four (4) parts water. As soon as the forms are removed, the concrete surface shall be thoroughly and evenly scrubbed as described above until the cement film or surface is completely removed and the aggregate particles are exposed, leaving an even pebbled texture, presenting an appearance grading from

that of fine granite to coarse aggregate, depending on the size and grading of aggregate used. As soon as the scrubbing has progressed sufficiently to produce the required texture, the entire surface shall be washed thoroughly with water, to which a small amount of ammonia has been added, to remove to neutralize the affects of the acid.

After Subarticle 6.01.03-24, add the following::

Material Storage:

The Contractor shall store and maintain the A.E.A. and the HRWR materials in clean original containers as delivered by the manufacturer.

Repair Procedure:

The Contractor shall clean all exposed surfaces of the historic concrete bridge in accordance with the special provision item "Clean Historic Concrete Bridge (Site No.)" before the construction of the Class "S" concrete trial mix mockup panel

A survey shall be undertaken by the Contractor of the vertical or horizontal faces of the concrete to be patched with this material, under the direction and to the satisfaction of the Engineer to determine the exact limits and locations of all areas to be repaired under this item.

After the completion by the Contractor of the surface cleaning of the bridge and the survey of areas to be repaired , the Contractor shall construct a test trial mockup of the Class "S" concrete mix. The mock-up shall have exposed surface areas of 2 feet by 2 feet or larger on a single face, unless otherwise approved by the Engineer. The test trial mockup shall be positioned adjacent to the cleaned existing concrete surface for the demonstration of concrete color match in the concrete repair mockup as approved by the Engineer. The concrete finish type shall be as indicated on the plans. Production work may not start until the color and surface finish qualities of the concrete mockup are approved by the Engineer. Once approved, the mix design of the approved mockup shall be carefully adhered to in the production work to follow.

The limits for patching of the concrete for historic preservation shall follow the original design lines, as supervised by the Engineer, to make the patch less obtrusive. Where the configuration of the adjacent area to the patch is extensive, the patch is to be blended with the adjacent concrete. Patch limits shall be delineated by ½ inch deep saw-cut, perpendicular to the surface. Saw cuts shall not extend beyond angle points of the delineated patch limits.

Loose and deteriorated concrete shall be chipped away back to sound concrete. The exposed surfaces shall be thoroughly sandblasted and vacuumed immediately prior to forming.

Hollow areas in the existing concrete shall be completely exposed by chipping away back to sound concrete and thoroughly sandblasted and vacuumed immediately prior to forming.

Spalled and scaled areas shall be cleaned of all loose and deteriorated concrete. The exposed surfaces shall be thoroughly sandblasted and vacuumed immediately prior to forming.

Removal of unsound concrete material shall be such to facilitate uniform placement of fresh concrete; all areas of excavated voids shall slope evenly out to within one inch (1") of the face of the concrete to preclude entrapping air and forming hollow spots in the freshly placed concrete. Within one inch (1") of the surface, the outline shall be perpendicular to the surface.

All surfaces of exposed concrete and reinforcing steel shall be free of oil, solvent, grease, dirt, dust, bitumen, rust, loose particles and foreign matter. Prior to sandblasting of concrete and steel surfaces, all petroleum contamination on these surfaces shall be removed by an appropriate solvent or detergent cleaning operation.

Extreme care shall be taken, where reinforcing steel is uncovered, not to damage the steel or its bond in the surrounding concrete. Pneumatic tools shall not be placed in direct contact with reinforcing steel. Maximum 30# size hammers shall be used for general chipping and removal while maximum 15# size shall be used behind reinforcing steel. Exposed reinforcing shall remain in place except where specifically indicated for removal by direction of the Engineer. Exposed reinforcing steel shall be sandblasted in accordance with SSPC-SP-6, Commercial Blast Cleaning, to remove all contaminants, rust and rust scale.

In areas where reinforcing steel is found to be surrounded by deteriorated concrete or has at least one-half its surface area exposed or has less than 1" cover, the depth of removal shall be such as to include all deteriorated concrete but not less than 3/4" below or behind the reinforcing steel.

Where the existing reinforcing steel is severely corroded or damaged, it shall be cut out and replaced with new reinforcing steel of the same size and spacing. Where existing steel is determined by the Engineer to have insufficient cover, it shall be either replaced or adjusted as directed. New steel shall be attached behind existing steel with a minimum lap of 15". Concrete shall be removed to a minimum depth of 3/4" behind the new steel.

When using sandblasting equipment, all work shall be shielded for the protection of the public.

All excavated areas on vertical surfaces of concrete members shall be formed using forms coated with a plastic or similar film to preclude the use of form release agents. Forms and support systems shall be properly designed in accordance with M6.01.03-3. Forms shall be so designed that placement access shall be allowed at the top of each respective formwork assembly for contiguous void areas.

No bonding compounds shall be used before or during the placement of this concrete material. Concrete surfaces against which this material is to be placed shall be sound, tight, and thoroughly roughened by the removal and sandblasting procedures specified above. The exposed concrete surfaces shall be kept moist for at least twenty-four (24) hours prior to placement of the concrete repair material.

Prior to forming up vertical surfaces, 4 x 4 -6 gauge reinforcing steel wire fabric conforming to the requirements of M.06.01-3 shall be installed at the proper depth to those areas greater than four (4) square feet and 3" deep or as approved by the Engineer. The fabric shall be tied to any exposed reinforcing steel or anchored to sound concrete with 1/4" powder actuated anchors such as the Hilti "Gunite Slip" or W-6 Threaded Stud and Eye-Coupling or equivalent and as approved by the Engineer.

Placement of the fresh concrete shall be in the maximum height lifts possible under the circumstances and all freshly placed concrete shall be consolidated during placement with adequately sized and effective vibrators.

Following curing and stripping of forms, the exposed faces of new concrete patches shall be finished similarly to adjacent existing concrete surfaces, with a specific surface finish as indicated on the plans, or as directed by the Engineer, in accordance with the aforementioned requirements of this special provision.

Cured patches shall be sounded by the Engineer to detect the presence of any hollow spots. Such spots shall be removed and replaced by the Contractor at his cost.

6.01.04 - Method of Measurement: Add the following:

Class "S" Concrete For Historic Bridges (Site No.) shall be measured for payment by the actual volume in cubic feet of concrete placed, and accepted by the Engineer. Wire fabric and reinforcing steel will not be measured for payment.

6.01.05 - Basis of Payment: Add the following:

Class "S" Concrete For Historic Bridges (Site No.) will be paid for at the contract unit price per cubic foot, complete in place, which price shall include locating and removing unsound material, selective sample removal, development of historic mix, providing test panel mockup of concrete patch acceptable to the Engineer, placing, curing, stripping and finishing new concrete, and all materials, including wire fabric, and all equipment, tools, labor and clean-up incidental thereto.

All work associated with the testing and analysis of the existing concrete shall be paid for in accordance with the special provision item "Testing and Analysis of Concrete (Site No.)".

The cleaning of the historic concrete bridge shall be paid for under the item "Clean Historic Concrete Bridge (Site No.)".

END OF SECTION

3.6.2 CLASS "A" CONCRETE – REPLICATED (SITE NO.____)
CLASS "C" CONCRETE – REPLICATED (SITE NO.____)

Work under this item shall conform to the requirements of Section 6.01 supplemented and amended as follows:

Article 6.01.01 - Description: Add the following:

Work under this item shall consist of developing a cast–in-place concrete replication mix and casting concrete for use in historic bridges for reconstruction or extension of existing cast–in-place concrete or portions thereof. The replication mix shall contain fine and coarse aggregates, cement, and coloration in conformance with the approved concrete test report prepared in accordance with the special provision item "Testing and Analysis of Concrete (Site No.)" developed for the subject bridge site.

This work shall also include the preparation of a test panel mockup of the subject concrete material for the approval by the Engineer. The mockup shall be done only after completion of surface cleaning of the historic concrete bridge in accordance with the related special provision item "Clean Historic concrete Bridge (Site No.)."

Article 6.01.02 - Materials:

Subarticle M.03.01 – General Composition of Concrete Mixes: Add the following:

The Contractor shall design and submit to the Engineer concrete mixes which shall attain the following compressive strengths:

CONCRETE TYPE	28 DAY MINIMUM COMPRESSIVE STENGTH	Water/Cement; or Water/Cement plus Other approved Cementitious Material (by weight) Maximum	Minimum Cementitious Material Required lbs/cubic yard
CLASS "A" CONCRETE – REPLICATED	3,000 psi	0.53	611
CLASS "C" CONCRETE – REPLICATED	4,000 psi	0.44	658

Subarticle M.03.01-1 -Coarse Aggregate: Add the following:

The proportions of the various sizes of coarse aggregate shall match the proportions in the original mix as identified through the testing of the existing concrete in accordance with the special provision item "Testing and Analysis of Concrete (Site No.)"

Subarticle M.03.01-2 -Fine Aggregate: Add the following:

The proportions of the various sizes of fine aggregate shall match the proportions in the original mix as identified through the testing of the existing concrete in accordance with the special provision item Testing and Analysis of Concrete (Site No.)

Subarticle M.03.01-3 - Cement: add the following:

Cement shall be Type 1or II. Gray and white cements shall be blended to achieve the matching historic coloration, as approved by the Engineer. Type II Portland Cement generally yields mixtures lighter in color than Type I.

Subarticle M.03.01-9 (c) - Admixtures: Following the first sentence, add the following:

If additional coloration or pigments are required to achieve the matching concrete color, only alkali-stable cement pigments colors shall be used as approved by the Engineer but only when concrete is mixed in a central mix plant.

Subarticle M.03.01-10 - Curing Materials:

(c) Liquid Membrane Forming Compound: Add the following:

No liquid membrane forming compound shall be used for cast-in-place concrete.

Article 6.01.03 - Construction Methods: Construction methods shall comply with the requirements of Article 6.01.03 as modified herein. :

Subarticle 6.01.03-3 - Forms: Replace the third paragraph with the following:

Plans for form shall be submitted by the Contractor to the engineer for approval before any form work is constructed. The furnishing of such plans, however, shall not serve to relieve the Contractor of any of his responsibilities for the successful completion of the work.

Continuous ornament (such as dentil molding, clapboard ornamentation or other) shall be formed with wood forms set with wood dividers.

Ornament or Reverse Molds: Replace the first sentence with the following:

Ornamental work, when so noted on the plans, shall be formed by the use of reverse plaster molds.

Subarticle 6.01.03 - 5 - Composition: Add the following to the first paragraph:

Class "A" Concrete – Replicated (Site No.) and Class "C" Concrete– Replicated (Site No.)

shall contain not less than 5% nor more than 7% entrained air at the time the concrete deposited in the forms.

After the completion by the Contractor of the surface cleaning of the bridge, the Contractor shall construct a test trial concrete mix. The trial mix mock-up shall have exposed surface areas of 2 feet by 2 feet or larger on a single face, unless otherwise approved by the Engineer. The test trial mockup shall be cured for a minimum of fourteen (14) days allow for color change prior to evaluation by the Engineer. The mockup shall be positioned adjacent to the cleaned existing concrete surface for the demonstration of concrete color match in the concrete repair mockup as approved by the Engineer. The concrete finish types shall be as indicated on the plans. Production work may not start until the color and surface finish qualities of the concrete mockup are approved by the Engineer. Once approved, the mix design of the approved mockup shall be carefully adhered to in the production work to follow.

Subarticle 6.01.03 - 16 - Construction Joints: Add the following:

The limits of patching shall follow the lines of the original construction joints or design limits to make the area of repair less obtrusive.

Subarticle 6.01.03-21 - Surface Finish: Delete the entire section and add the following:

The external surface of all concrete shall be thoroughly worked during the operation of placing by means of tools of an approved type. The working shall be such as to force all coarse aggregate from the surface and thoroughly work the mortar against the forms to produce a smooth finish free from water and air pockets, segregated materials, or honeycomb. All horizontal surfaces shall be formed by placing an excess of material in the forms and removing or striking off such excess by means of a tool of an approved type, forcing the coarse aggregate below the mortar surface.

Immediately after the forms have been removed, all voids and honeycombs on the surface shall be filled and finished to conform to the surrounding concrete surface with a mortar of fine aggregate and portland cement of the same materials and coloration as that of the particular concrete being treated. This work shall be performed immediately after removal of forms and before the finishing process is started.

Following the filling of voids and honeycombs, concrete surface shall be given one of the following concrete finishes, similar to adjacent existing concrete surface, as indicated on the plans, or as directed by the Engineer. Generally but not in all cases, a Rubbed surface finish as described herein will be constructed on vertical exposed surfaces, and a Brush finish will be constructed on horizontal surfaces (eg., parapet tops, railing caps, bridge seats) as described herein.

Rubbed finish:

As soon as the filling of voids and honeycombs has set sufficiently to permit it, the entire surface shall be thoroughly wet with a brush and rubbed with a No. 16 carborundum stone or an abrasive of quality, bringing the surface to a paste. The rubbing shall be continued sufficiently to remove all form marks and projections, producing a smooth dense surface without pits or irregularities.

The paste formed by the rubbing may be finished by carefully striping with a clean brush, or it may be spread uniformly over the surface and allowed to reset. Following the reset of the paste, the surface shall be finished by floating with a canvas, carpet-faced or cork float or rubbed down with dry burlap.

Brush Finish:

After the concrete has been struck off as described above, the surface shall be thoroughly worked and floated with a wooden, canvas, or cork float, the operation to be performed by skilled and experienced concrete finishers. Before this finish has set, the surface shall be lightly striped with a fine brush to remove the surface cement film, leaving a fine grained, smooth, but sanded texture.

Float Finish:

After the concrete has been struck off as described above, the surface shall be thoroughly worked and finished with a rough carpet float or other suitable device, leaving the surface even, but distinctly sandy or pebbled in texture.

Ground or Terrazzo Finish:

The upper surfaces of rail caps, parapets or other surfaces when indicated on the plans shall be finished by grinding with a carborundum stone, or equally good abrasive to a smooth dense, terrazzo finish.

Using a No. 16 carborundum stone or an abrasive of equal quality, the surface shall be ground dry or wet until it is smooth and individual pebbles and aggregate particle are cut and polished. The surface shall then be completely cleansed with water, the final rubbing done by means of a No. 30 stone. The finished surface shall present the texture of polished marble and shall show the various aggregate particles in polished outline.

Tooled Finish:

This finish, typically for panels and other like work, shall be produced by the use of pneumatic tools, bush-hammer, pick, crandall or other approved tool. No tooling shall be done until the concrete has cured for at least fourteen (14) days but as long

as needed to prevent the aggregate particles from being "picked" out of the surface. The finished surface shall show a grouping of broken aggregate particles in a matrix of mortar, each aggregate particle being in slight relief.

Sand Blast Finish:

This finish, typically for panels and other like work, shall be produced by sand blast methods. No sand blasting shall be done until the concrete has cured for at least fourteen (14 days). The sand blasting must be done by means of approved equipment and in such a manner as to produce an even grained surface in which the mortar has been cut away, leaving the aggregate particles exposed.

Wire Brush or Scrubbed Finish:

This type of finish shall be produced by scrubbing the surface of "green" concrete with stiff wire or fiber brushes, using a solution of muriatic acid in the proportion of one (1) part acid to four (4) parts water. As soon as the forms are removed, the concrete surface shall be thoroughly and evenly scrubbed as described above until the cement film or surface is completely removed and the aggregate particles are exposed, leaving an even pebbled texture, presenting an appearance grading from that of fine granite to coarse aggregate, depending on the size and grading of aggregate used. As soon as the scrubbing has progressed sufficiently to produce the required texture, the entire surface shall be washed thoroughly with water, to which a small amount of ammonia has been added, to remove to neutralize the affects of the acid.

Article 6.01.04 - Method of Measurement: Add the following:

Class "A" Concrete–Replicated (Site No.) and Class "C" Concrete–Replicated (Site No.) shall be measured for payment by the actual volume in cubic yards of concrete placed, and accepted by the Engineer.

Article 6.01.4 Basis of Payment: Add the following:

Subarticle 6.01.04 -1 - Concrete: Add the following:

This material will be paid for at the contract unit price per cubic yard for "Class 'A' Concrete – Replicated (Site No.) or "Class 'C ' Concrete – Replicated (Site No.)", complete in place, which price shall include constructing an approved trial concrete mix mockup panel, all materials, equipment, tools, labor and work incidental thereto, including heating, all admixtures and joint sealer.

Cleaning of the historic concrete bridge shall be paid for under the special provision item "Clean Historic Concrete Bridge (Site. No.)

END OF SECTION

3.6.3 ORNAMENTAL PRECAST CONCRETE, CAST STONE AND SGRAFFITO FOR HISTORIC BRIDGES

(to be developed)

END OF SECTION

3.6.4 TESTING AND ANALYSIS OF CONCRETE

Description: This work includes the testing and analysis of historic concrete on bridges, including the removal of core samples, testing and analysis of the concrete core samples for the determination of the constituents and ratios of the original cement, water, sand and coarse aggregate for the replication of the cast-in-place concrete, precast concrete, cast stone or sgraffito as indicated on the plans, and the submission of an investigative report individual to the site. The testing and analysis of concrete samples shall be performed by an independent Conservation Laboratory, approved by the Engineer. The conservation laboratory to perform the subject testing and analysis of concrete cores shall be a Professional Affiliate of the "American Institute for Conservation of Historic and Artistic Works".

Materials: None

Construction Methods:

Concrete core samples of historic concrete material shall be taken for testing purposes at locations shown on the plans and as directed by the Engineer. The Contractor shall remove two (2) concrete core samples of each existing concrete class or type as shown on the plans and as directed by the Engineer. The two (2) core samples shall be taken from inconspicuous areas least affected by deterioration, moisture and staining, or from portions designated for replacement, as directed by the Engineer. Under no circumstances shall samples be removed from areas which have previously received repairs.

Surrounding surfaces of the bridge and site shall be protected from damage and staining during the core removal work. All adjacent surfaces on bridges and in the vicinity including grass, shrubs and trees shall be protected.

Cores shall be taken with standard concrete coring equipment, taking care to produce a core which contains both surface and base concrete material, including fine and coarse aggregates. Core samples shall be four (4) inches in diameter by eight (8) inches deep unless otherwise approved by the Engineer. For the analysis of historic precast concrete, precast stone or sgraffito, core samples shall be ***(designer, please specify size)*** in size, respectively. Each core is to be labeled with the following information:

- Bridge #
- Name of over- or under-passing route
- Location of core with orientation (i.e. northwest wingwall, 4'-0" above grade)

Core samples are to be kept clean and dry, sealed in a plastic bag and adequately labeled until delivered to the laboratory.

The Contractor shall submit the cores to a testing laboratory approved by the Engineer. The testing laboratory shall be a Professional Affiliate of the "American Institute of Conservation of Historic and Artistic Works" (AIC), listed in good standing by AIC, having a minimum of five (5) years experience in performing the required testing and analysis.

The following testing laboratories are known to be professional affiliates of the "American Institute for Conservation of Historic and Artistic Works" and are known to have the required testing and analysis experience:

- Jablonski Berkowitz Conservation, Inc.
  150 West 25th Street, NY, NY (212) 242-8290

- Integrated Conservation Resources, Inc.
  247 West 30th Street, NY, NY (212) 947-0066

- Building Conservation Resources, Inc.
  902 Broadway, NY, NY (212)777-1300

The testing laboratory shall perform the following tests on the two concrete cores submitted:

- Petrographic Analysis - ASTM C-856, "Petrographic Examination of Hardened Concrete ". The testing laboratory shall perform the Petrographic testing using microscopic qualitative and semi-qualitative visual surveys of the concrete cores. Reflected, plain and cross polarized light microscopy shall be employed to identify mineralogy, texture, and void content of sectioned epoxy impregnated samples from each core submitted. Original component shall be identified. The testing laboratory shall include in the report a description of evidence of any apparent damage from environmental exposure.

- Wet Chemical Analysis - separation of hardened concrete into its indigestible component parts, cementitious matrix, sand and aggregates: Under 20x magnification examine freshly broken surfaces of each sample core, using natural daylight. Binders (Portland Cement) are to be matched to the Munsell Color Chart (as per ASTM-1535). Perform separation by chemical process of cementitious binder (Portland Cement) from all aggregate (sand and crushed rock). Appropriate filtration techniques are to be used to separate 'fines' from sand. Fines are to be matched to the Munsell Soil Color Chart. Determine grading, weight and percentage ratios of the concrete.

- Munsell Color Matching - ASTM-1535: The color matching test shall be employed for determination of a cement 'fines' color match.

The written report shall prepared by the Conservation Laboratory for the testing and analysis of the concrete core sample, including all test data, test procedures employed, and a detailed set of recommendations for concrete mix design replication required for the related

special provision items "Class 'S' Concrete for Historic Bridges (Site No.), "Class 'A' Concrete – Replicated (Site No.)", or "Class 'C' Concrete – Replicated (Site No.)" ***(or other ; Designer please indicate)*** where so indicated on the plans, for the approval of the Engineer. The report shall substantiate that the test procedures used comply with the requirements of these provisions.

Method of Measurement: Work under this item will be measured for payment by the number, each, of written reports for the testing and analysis of concrete, prepared and submitted by the Contractor and approved by the Engineer.

Basis of Payment: This work will be paid for at the contract unit price each for "Testing and Analysis of Concrete" which price shall include the taking of two (2) concrete cores, analysis of concrete samples, preparation of a report containing concrete replication mix recommendations, all material, equipment, tools, laboratory fees and labor incidental thereto.

END OF SECTION

3.6.5 CLEAN HISTORIC CONCRETE BRIDGE (SITE NO.)

Description: The work includes the cleaning of exposed concrete surfaces of bridges within the limits specified by the Engineer, including general and specialized cleaning to remove soil, stains, carbon deposits, biological growth, bird guano, and all other substances specified below. Also included is the full containment, collection and proper disposal of all wash water and materials removed from the concrete surfaces during cleaning operations.

This work will include the trial demonstration by the Contractor of specific cleaning methods on selected areas of the bridge surface to demonstrate the adequacy of materials and methods to be used for cleaning each type of condition on areas of the bridge for approval by the Engineer.

The Contractor to perform this work shall demonstrate a minimum of five (5) years of successful cleaning experience in masonry restoration projects for historic structures. The Contractor shall provide names, dates, and locations of a minimum of three (3) similar projects.

This provision contains recommendations for materials which may be TOXIC. The manufacturer's literature on application techniques, appropriate protection for workers and disposal procedures for materials should be complied with in conjunction with all federal and state regulations. All required Federal and State permits shall be obtained prior to use and/or discharge.

The removal of graffiti and other coatings will be paid for under the special provision item "Removal of Graffiti".

Materials:

1 - Cleaning Tools and Product Data:

The Contractor shall submit manufacturer's technical data for each cleaning product proposed to be used, including written instructions by the manufacturers for their application and use, and Material Safety Data Sheets (MSDS). The Contractor shall demonstrate Include test reports and certifications substantiating product compliance with requirements.

The use of acidic cleaners shall not be permitted.

All water used in the cleaning operation shall be potable, free of deleterious quantities of iron, alkalis, oil or other staining materials. Prior to the cleaning, a sample of the water shall be tested to determine that the water will not cause staining. The Contractor shall provide all necessary filters at the water source to remove mineral contents that cause the staining. No water is to be drawn from ponds or streams without the approval by the Engineer and the Office of Environmental Planning. At no time will a general permit limit be reached for the removal of water.

All cleaning brushes shall have natural fiber bristles only. The use of wire brushes or steel wool shall not be permitted.

3 - **Delivery, Storage and Handling:** All materials shall be delivered to the site in the Manufacturer's original and unopened containers and packaging, bearing labels as to the type of material, brand name and Manufacturer's name. Delivered materials should be identical to tested materials.

Material shall be stored off the ground in a clean, dry location. All materials that are damaged or otherwise unsuitable for use shall be removed from the site.

All materials shall be handled, stored and treated in strict accordance with manufacturer's instructions, with regard to application and shelf life, spillage, clean-up, safety precautions, and protective means and methods.

Construction Methods:

1 - **Cleaning Program:** Prior to commencing cleaning operations, the Contractor shall submit a written cleaning procedure plan including all materials, methods, and equipment proposed for each phase of cleaning including protection of surrounding materials during operations. The written cleaning procedure shall include all cleaning products and chemical components to be used, method of application, dilution of the application, temperature of application, length of time of surface contact, method of rinsing surface *(temperature, pressure, and duration*), and repetition of procedures, methodology for full collection of all water, proper disposal of all materials.

2 - **Protection Program:** Prior to commencing the cleaning operations, the Contractor shall submit for approval, a written description of proposed materials and methods of protection for preventing damage to adjacent materials, soil, water bodies, wetlands, wells, vegetation, vehicular and pedestrian traffic, and adjacent property.

3 - **Demonstration Test Area:** Prior to commencing the cleaning operations, the Contractor shall demonstrate a trial application of the proposed cleaning method on a portion of the wingwall or abutment face, as directed by the Engineer. The surface area of the cleaning demonstration test shall be approximately six (6) feet by six (6) feet in area. The demonstration test area shall be cleaned using methods, materials and working pressures previously submitted and approved. The demonstration test shall be performed in the presence of the Engineer.

Where chemical poultices are tested, perform testing in the presence of the Manufacturer's representative.

The production work of cleaning the bridge concrete surfaces shall not begin without approval from the Engineer of the cleaning methods, working pressures, materials, equipment used. The evaluation by the Engineer of the acceptability of the Contractor's proposed cleaning method will include a seven (7) day observation period after completion

of the trial cleaning demonstration for verification that the requested cleaning method has caused no surface damage to historic concrete surfaces.

4 - Preparation:

a. Demonstration Test Area: Prepare test area as specified above.

b. Cleaning Program: The cleaning program shall be submitted as specified above.

c. Protection: All painted and unpainted metal structure, railings and decorative elements shall be protected from contact with chemical cleaners by covering with polyethylene film, waterproof masking or other proven measures, firmly fixed and sealed to the surface.

The Contractor shall comply with the cleaning product manufacturer's recommendations for protecting adjacent surfaces from exposure to their products.

Over-spray and splashing of the cleaning materials shall be prevented.

All persons, soil, surrounding vegetation and adjacent property shall be protected from injury, damage and contamination at all times during the cleaning process.

5 - General Cleaning:

a. Dilution of cleaning materials shall be with clean water in accordance with the manufacturer's printed instructions.

b. All bridges surfaces shall be cleaned in accordance with the cleaning procedure approved by the Engineer. While it is not expected that the aged concrete bridge surfaces will be truly uniform in appearance following cleaning, the surface cleaning should be done in strict accordance with the methods approved by the Engineer on the demonstration test area.

c. All painted and unpainted metal structure, railings and decorative elements shall be protected from contact with chemical cleaners by covering with polyethylene film, waterproof masking or other proven measures, firmly fixed and sealed to the surface.

6 - Specialized Cleaning:

Additional and more local cleaning methods are to be used, subject to the Engineer's approval. Detergents and other non-detrimental chemicals can be applied to the surface with fibrous, non-ferrous bristle brushes. When soil is sufficiently loosened, the concrete shall be thoroughly rinsed so that no residue remains. Poultices may also be used if approved by the Engineer.

Prior to any stain removal treatment, thoroughly wet the surface of the concrete around the stained area with clear, clean water at low pressure. Apply specialized stain removers with soft bristle brushes and rinse thoroughly with clean, clear water, or apply as otherwise recommended by the manufacturer.

Method of Measurement: Work under this item being paid for on a lump sum basis for each site, will not be measured for payment.

Basis of Payment: This work will be paid for at the contract lump sum price for "Clean Historic Bridge (Site No.)" which price shall include all equipment, tools, labor and work incidental thereto, including acquisition of required permits, containment, collection and proper disposal of all waste, wash water and other cleaning elements used.

Removal of Graffiti where directed shall be paid for under the special provision item, "Removal of Graffiti".

END OF SECTION

3.6.6 REMOVAL OF GRAFFITTI

(to be developed)

END OF SECTION

IV. Appendix

4.1 CONNDOT SPECIAL PROVISIONS

Some of ConnDOT's special provisions are available over the internet. The Department's Home page from which special provisions can be accessed is located at the following address:

http://www.dot.state.ct.us/pub/eng.asp

4.2 BIBLIOGRAPHY

Bridge Construction - General

State of Connecticut, Department of Transportation (ConnDOT), *Standard Specifications for Roads, Bridges and Incidental Construction*, Form 814A, 1995 and *Guide Special Provisions*, 1996.

State of Connecticut, State Highway Department, *Standard Specifications for Road & Bridge Construction*, 1932 and 1935.

Bridge Restoration - General

Department of Civil Engineering, Ohio State University, *Proceedings of the Third Conference on Historic Bridges*, Columbus, Ohio, 1990.

U.S. Department of the Interior, National Park Service, "Columbia River Highway Project - Guide to Maintenance," 1981, (20 pp.)

U.S. Department of the Interior, National Park Service, CRM Supplement, Volume 15: No. 2, *Preserving Historic Bridges*, by Thomas C. Jester, 1992.

Concrete Restoration

A.C.I. Committee 201, *ACI Manual of Concrete Practice, Part I*, 1981, "Guide for Making a Condition Survey of Concrete in Service."

Joan Berkowitz, "The Merritt Parkway Bridges: A Methodology and Analysis for the Replication of Historic Concrete," (unpublished), presented at the Association for Preservation Technology International Conference, September 1997, Chicago, Illinois.

William B. Cooney, AIA, "Preservation of Historic Concrete: Problems and General Approaches," *Building Preservation Plan Procedure 03732-01-S, Preservation Brief #15,* U.S. Dept. of the Interior, National Park Service.

Theo Prudon, "Confronting Concrete Realitities, " *Progressive Architecture*, November, 1981.

W.S. Gray and H.L. Childe, *Concrete Surface Finishes, Renderings, and Terrazzo,* Concrete Publications Limited, Westminster, England, (year unknown).

Cleaning Concrete and Masonry

U.S. Department of the Interior, National Park Service. *Keeping It Clean, Removing Exterior Dirt, Paint, Stains and Graffiti from Historic Masonry Buildings*, by Anne E. Grimmer, 1988.

Coatings for Concrete and Masonry

McGettigan, Edward. "Selecting Clear Water Repellents," *The Construction Specifier*, Vol. 47, No. 6 (June 1994), pp. 121-132.
McGettigan, Edward. "Application Mechanism of Silane Weather Proofers," *Concrete International*, reprinted with permission, (October 1990).

McGettigan, Edward. "Silicon Based Weatherproofing Materials." *Concrete International* (June 1992), pp. 52-56.

Wiss, Janney, Elster Assoc. *Concrete Sealers for Protection*, NCHRP - 244 (National Cooperative Highway Research Program publication. Transportation Research Board, National Research Council, Washington, D.C.

Weaver, Martin E. *Conserving Buildings*, A Guide to Techniques and Materials. Chapter 14 - "Synthetic Resins, Polymers and Preservation."

Graffiti Removal

U.S. Department of the Interior, National Park Service, *Removing Graffiti from Historic Masonry,* by Martin E. Weaver, October 1995.

Ornamental Metals

Gayle, Margot, David W. Look, AIA, and John G. Waite, AIA. *Metals in America's Historic Buildings*: Uses and Preservation Treatment. Washington, D.C: Preservation Assistance Division, National Park Service, US Dept. of the Interior, 1980. Revised 1992.

Geerlings, Gerald. *Metal Crafts in Architecture.* Charles Scribner's Sons, 1929. Reprinted by Bonanza Books, 1957.

Geerlings, Gerald. Wrought Iron *in Architecture.* Charles Scribner's Sons, 1929. Reprinted by Bonanza Books.

Meadow, Robert E. *Historic Building Facades*, A Manual for Inspection and Rehabilitation. Technical Preservation Services Center, New York Landmarks Conservancy, 1986.

Sivinski, Valerie. "Preserving Historic Materials: Ferrous Metals." *Architecture.* Vol. 75, No. 11 (November 1986), pp. 108-109.

Wranglen, Gosta. *Corrosion and Protection of Metals*, Chapman and Hall, London and New York, 1985. (288pp)

Weaver, Martin E. *Conserving Buildings*, A Guide to Techniques and Materials. Chapter 9 - "Architectural Metalwork."

Joint Sealers

American Institute of Architects, *Master Spec - Evaluations, Section 07900 - Joint Sealers*, copyright AIA, 1987.

Sealant, Waterproofing & Restoration Institute. *Sealants: The Professionals' Guide.* SWRI, 1990. (75 pp)

Merritt Parkway

Dunkelberger, George L., Architect, Connecticut State Highway Department, "Design of the Merritt Parkway Bridges," *New England Construction,* February, 1937, vol. 1, number 9.

Dunkelberger, George L., Architect, Connecticut State Highway Department, "Highway Architecture," presented at the 58th Annual Meeting of the Connecticut Society of Civil Engineers, Inc., Hartford Connecticut, March 18, 1942.

"Nominating the Merritt Parkway to the National Register Brings New Information to Light, " *Connecticut Preservation News,* January - February 1991, vol. 14 #1.

The Merritt Parkway Working Group, *Merritt Parkway Guidelines for General Maintenance and Transportation Improvements,* June 1994.

Radde, Bruce. *The Merritt Parkway.* Yale University Press, New Haven & London, 1993.

State of Connecticut, Department of Transportation, "Connecticut Historic Bridge Inventory, Final Report: Preservation Plan, " Federal Aid Project #HPR-PR-1 (27), by Historic Resource Consultants, Hartford, Connecticut.

L. G. Sumner, "Bridges on the Merritt Parkway," *Engineering News-Record,* September 23, 1937.

U.S. Department of the Interior, National Park Service, Historic American Engineering Record and Historic American Building Survey (HABS/HAER), Robert J. Kapsch, Chief, *Written Historical and Descriptive Data for the Historically Significant Merritt Parkway Bridges,* prepared under the general direction of Eric N. DeLony, HAER Chief, and Sara Leach, HABS Historian, Summer 1992. [The most extensive recording effort undertaken of the Merritt Parkway, prior to this report, includes measured drawings, historical reports and photographs.]

Milone & MacBroome Inc., *A Landscape Master Plan for the Merritt Parkway, Final Report,* October 31, 1994

Paint Analysis

U.S. Department of the Interior, General Services Administration, National Capitol Region, *Standards for Paint Seriation Analysis and Scope of Work.*

Preservation - General

U.S. Department of the Interior, National Park Service, *The Use of Substitute Materials on Historic Building Exteriors,* by Sharon C. Park.

Structural Steel - Restoration

Gayle, Margot, David W. Look, AIA, and John G. Waite, AIA. *Metals in America's Historic Buildings: Uses and Preservation Treatment.* Washington, D.C: Preservation Assistance Division, National Park Service, US Dept. of the Interior, 1980. Revised 1992.

4.3 FORM 804 (1935) STATE OF CONNECTICUT STATE HIGHWAY DEPARTMENT – STANDARD SPECIFICATIONS FOR ROADS, BRIDGES AND INCIDENTAL CONSTRUCTION

(SELECTED SECTIONS)

Form 804

STATE HIGHWAY DEPARTMENT
STATE OF CONNECTICUT

STANDARD SPECIFICATIONS
FOR
ROAD AND BRIDGE CONSTRUCTION

ISSUED DECEMBER 1935

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MATERIALS OF CONSTRUCTION

70. **Source of Supply and Quality.** These specifications contemplate the use of first class materials throughout the work, incorporated in such manner as to produce completed construction which is workmanlike and acceptable in every detail. Only materials conforming to the requirements of these specifications shall be used.

If it is found, after trial, that sources of supply previously approved do not produce uniform and satisfactory products, or if the product from any source proves unacceptable at any time, the Contractor shall furnish materials from other approved sources.

Tests will be made and reports rendered, but it is understood that such tests shall in no way be construed as a guarantee of acceptance of any material which may be delivered later for incorporation in the work. Only the materials actually delivered for the work will be considered and their acceptance or rejection will be based solely on the results of the tests prescribed in these specifications. The Contractor shall assume full responsibility for the production of uniform and satisfactory materials from such local deposits and shall indemnify and save harmless the Department from any and all claims for loss or damages resulting from the operation thereof, or from the failure of the deposit, after development, to produce materials acceptable to the Department.

All materials shall conform to the recommendations of the Standing Committees on Simplified Practice of the U. S. Department of Commerce as adopted to date of contract, in so far as they apply.

71. **Samples and Tests.** The Contractor or Producer shall afford such facilities as the Engineer may require for collecting and forwarding samples, and shall not make use of or incorporate in the work any material represented by the samples until the tests have been made and the materials found to be acceptable in accordance with the requirements of the specifications.

When required by the Engineer, representative preliminary samples of the character and quantity prescribed shall be submitted by the Contractor or Producer for examination and shall be tested in accordance with the methods referred to herein.

All tests of samples of materials shall be made by the Department at the Laboratory or such other places as may be indicated.

Unless otherwise noted methods of sampling and testing materials shall be in accordance with latest standard methods of the American Society for Testing Materials for the material in question except that, at the option of the Department or where the methods of the A. S. T. M. do not apply, the methods and requirements of the latest Standard Specifications for Highway Materials and Methods of Sampling and Testing of the American Association of State Highway Officials shall be used.

Whenever sieve numbers are given, the sieves shall conform, as to size of sieve openings, with the requirements of the Standard Specifications of the American Society for Testing Materials, serial designation E 11-26 with subsequent amendments adopted by the Society.

When tests are made at places other than the Laboratory, the Contractor or producer shall furnish every facility for conducting the tests and for the verification of all scales and measures.

72. **Storage.** Materials shall be stored so as to ensure the preservation of their quality and fitness for the work and shall be located so as to facilitate prompt inspection. When considered necessary they shall be placed on wooden platforms or other hard, clean surfaces and not on the ground, and when directed shall be placed in weather proof buildings which shall be securely locked to prevent theft.

Stored materials even though approved before storage shall be inspected prior to their use in the work and shall meet the requirements of the specifications at the time it is proposed to use them.

73. **Defective Materials.** All materials not conforming to the requirements of these specifications shall be considered as defective and all such materials, whether in place or not, shall be rejected and shall be removed immediately from the work, at the expense of the Contractor unless otherwise permitted. No material which has been rejected, the defects of which have been corrected or removed, shall be used until approval has been given.

74. **Shipping Materials.** Railroad cars or barges used for transporting such materials as stone, gravel, sand, Portland cement, bituminous material, etc., must be clean when any of these materials are placed therein. Materials shipped in cars or barges the sides or bottoms of which are coated with coal dust, manure, ashes, clay, loam, earth, hay, straw, etc., will be rejected regardless of the quality of said material.

Trucks, wagons or other vehicles used in transporting road material must be kept clean, in proper working condition, have strong, substantial bodies which will prevent the escape of materials during transportation, and be approved by the Engineer before being used.

Materials shipped from approved deposits or sources of supply which appear to be defective upon arrival at destination, shall not be used until reapproved.

During the handling of all stone, sand or other materials which are to be used in concrete work, extra care shall be taken that no earth or subgrade material becomes mixed therewith.

75. **Broken Stone.** The grade and sizes of broken stone required for the different items are specified under those items. Broken stone shall be obtained from clean, tough, durable rock; it shall be crushed by the most approved modern machinery and shall have a per cent of wear conforming to the requirements as stated in Table I for the grades of stone specified. All broken stone must be of such quality that it shall not lose more than fifteen (15) per cent, by weight, when subjected to five (5) cycles of the Soundness Test for Coarse Aggregates.

Stone having a specific gravity of more than 3.0, if used, will be paid for on the basis of a stone having a specific gravity of 3.0.

Broken stone regardless of grade, must not contain more than five (5) per cent of decomposed or partly decomposed rock or rock of another physical or chemical structure than that being used. Seamed faced stone, discolored or weathered on the surface only, shall not be considered as partly decomposed rock as long as the rock is sound. When broken stone is used with bituminous material it shall be free from pieces coated or partly coated with mud, dirt, or foreign material and shall also be free from stone dust.

When broken stone is used in concrete it shall be free from pieces coated or partly coated with mud, dirt, or foreign material and shall not contain more than one (1) per cent. stone dust by weight.

When stone dust is used in water bound macadam construction it must not contain more than 6% by weight of moisture, and it must not contain more than 5% by weight, of silt, clay or foreign material.

When broken stone is used in waterbound macadam or base construction it shall be free from pieces coated or partly coated with mud, dirt, or foreign material and shall not contain more than three (3) per cent. stone dust by weight.

The stone shall be screened accurately to the size specified for each size in the following Table II. This table shows the minimum and maximum percentages passing the various laboratory screens having square openings of the size stated.

Broken stone of a size retained on a 1⅛" screen shall not contain more than ten (10) per cent. of flat or elongated pieces, whose length exceeds five times their least dimension.

The various stone fragments comprising any particular class shall be uniformly distributed throughout the mass of stone as shipped.

TABLE I

Grades	Per Cent of Wear Los Angeles type of Rattler not more than
Grade A	25
Grade B	35
Grade C	30

(3) Test Sample—The test sample shall consist of 5,000 grams of clean, dry aggregate and shall conform to either of the following gradings. The grading used shall be that most nearly representing the aggregate furnished for the work.

Sieve Size Square Openings		Weight Grading "A" grams	Weight Grading "B" grams
Passing inches	Retained inches		
1½	1	1,250	0
1	¾	1,250	0
¾	½	1,250	2,500
½	⅜	1,250	2,500

(4) Procedure—The test sample and the abrasive charge shall be placed in the abrasion machine and the machine rotated at 30 to 33 r.p.m. for 500 revolutions. At the completion of the test, the material shall be removed from the machine and sieved on a No. 12 sieve conforming to the requirements of the standard specifications for Sieves for Testing Purposes (A. S. T. M. Serial Designation E 11-26.) The material retained on the sieve shall be washed, dried, and weighed to the nearest gram.

(5) Calculation—The difference between the initial and final weights of the test sample shall be expressed as a percentage of the initial weight. This value shall be reported as the percentage of wear.

TABLE II

Size	Per Cent Passing Square Opening Screens								
	3"	2½"	2"	1½"	1"	¾"	½"	⅜"	¼"
A	100	95–100	20–80	0–65		0–15	0–5		
B	100	95–100	55–80	0–50	0–15	0–5			
C		100	90–100	0–70		0–10			0–5
D			100	95–100	80–100	0–15	0–5		
E				100	95–100	80–100	0–30		0–5
F					100	95–100	60–90		0–10
G							100	95–100	70–100

76. **Sub-base Stone.** This stone shall be prepared from sound, tough, durable rock. No decomposed, weathered, shattered or soft stone shall be included. The stone shall be as nearly rectangular in shape as practical and of such size that after knapping, they will produce a foundation of the required thickness. When no special size is specified the stone shall be of such dimensions that, after knapping, they will have a depth of approximately eight (8) inches and a length or breadth of not more than twice the depth.

77. **Rubble Stone.** This stone shall consist of clean, sound, tough, durable rock, free from weathered or decomposed stone, shattered ends or structural defects and shall be approved by the Engineer for the use intended.

When rubble stone is to be embedded in plain mass concrete work, the pieces shall be "one man" stone and shall be free from coating of any character.

When rubble stone is to be used for slope paving, the pieces shall have an exposed surface area of not less than two (2) square feet and a depth of at least nine (9) inches. The stone for the two bottom rows shall be of such size that they can be embedded at least two (2) feet into the embankment and shall have a thickness of at least twelve (12) inches.

When rubble stone is to be used for rip-rap at least sixty (60) per cent of the pieces shall be "two man" stone or larger and the remaining forty (40) per cent shall be graded in sizes from "two man" to pieces weighing not less than twenty (20) pounds.

78. **Masonry Stone.** The stone used for the construction of stone masonry, such as retaining walls, abutments, piers, endwalls, etc., or as surface course or veneer on concrete work shall conform to the following requirements. The kind of masonry required will be stated on the plans and proposal form.

(a) **Rubble Masonry Stone** shall be sound and durable, free from structural defects and coating of any character and shall be approved by the Engineer for the use intended. The stone shall be fairly rectangular in shape, have at least one smooth even face and have a volume of not less than five (5) cubic feet except when the size of the structure renders this impossible or when smaller stone are required for closure. Smaller stones of similar quality may be used for pinning and filling interstices in the heart of the wall.

(b) Masonry Facing Stone shall be of the kind specified in the proposal or on the plans and shall be of a size, quality and color acceptable to the Engineer. The stone shall be sound and durable, resistant to weathering action, reasonably fine grained, and free from seams, cracks, pyrite inclusions or other structural defects. Preferably the stone shall be from a quarry the product of which is known to be of a satisfactory quality. All stones shall be quarried in sufficient time so that they may be thoroughly seasoned before being incorporated in the work. Stone shall be of such character that it may be truly cut to such line and surfaces, either plain or curved, as may be required. Any stone having defects which have been repaired with cement or other materials will be rejected. Masonry facing stone shall be of two grades; "Dimensioned Masonry Stone" and "Random Ashlar Masonry Stone."

(1) Dimensioned Masonry Stone shall be large and well proportioned. Controlling dimensions shall be shown on the plans. The Contractor shall prepare, and submit for approval, detailed plans of all stone not fully detailed on the plans. Samples of stone shall be submitted when required. Stone shall be dressed to exact size and shape before being laid and shall lie on their natural beds. Hollow beds will not be permitted. The bottom bed shall be the full size of the stone and no stone shall have an overhanging top. All beds and joints shall be dressed at least two (2) inches in from the arris lines and the balance shall not fall off more than one-sixth (1/6) of the minimum dimension of the stone.

(2) Random Ashlar Stone shall be of such size as to produce the general effect shown on the plans and shall be of a quality and color acceptable to the Engineer. All beds and joints shall be dressed so that the masonry may be laid up with a mortar joint not to exceed one (1) inch in width at exposed surfaces.

For the purpose of these specifications the surface finishes of Masonry Facing Stone are defined as follows:

Smooth Finished—Having a surface in which the variations from the pitch line do not exceed one-sixteenth ($\frac{1}{16}$) inch.

Fine Finished—Having a surface in which the variations from the pitch line do not exceed one-quarter (¼) inch.

Rough Finished—Having a surface in which the variations from the pitch line do not exceed one-half (½) inch.

Scrabbled—Having a surface finish in which the variations from the pitch line do not exceed three-quarters (¾) of an inch.

Rock Faced—Having an irregular projecting face without indication of tool mark. The projections beyond the pitch line shall not exceed three (3) inches and no part of the face shall recede back of the pitch line.

Exposed surfaces of face stone shall be given the surface finish indicated on the plans. Holes for dowels and straps shall not show in exposed surfaces.

79. **Cobble Stone.** This stone shall consist of approved sound, tough, durable rock, having a depth of not less than six (6) nor more than eight (8) inches, a width of not less than two (2) inches and a length at least equal to the depth. The stone must have fairly smooth, even faces that will permit the construction of a gutter surface with a uniform contour.

80. **Stone Curbing.** This curbing shall consist of approved granite, sandstone or other approved stone of the required dimensions. The type of curbing will be indicated in the proposal.

(a) **Straight Five Inch Stone Curbing.** This straight five (5) inch stone curbing shall consist of granite or sandstone of approved quality, or other approved stone, free from structural defects. It shall be five (5) inches in thickness, not less than twenty (20) inches in depth and in lengths of not less than four (4) nor more than eight (8) feet. The top surface shall be dressed and beveled one-quarter (¼) of an inch, the face shall be dressed and the end cut square to a depth of not less than twelve (12) inches below the top and the back dressed to a depth of three (3) inches. The top and dressed face shall be free from depressions, projections or other irregularities and defects.

(b) **Straight Six Inch Stone Curbing.** This straight six (6) inch stone curbing shall consist of approved, first quality granite, neither laminated or stratified. It shall be hammer dressed on the face to a depth not less than twelve (12) inches below the top, on the entire top surface and for a depth of three (3)) inches on the back. The ends shall be cut square for the full depth and width of the stone. This curbing shall be six (6) inches in width on the top, not less than twenty (20) inches in depth and not less than eight (8) inches in width at the base.

If eight (8) inch curbing is specified it shall be of the same quality as straight six (6) inch curbing and eight (8) inches in width on the top, not less than twenty (20) inches in depth and not less than ten (10) inches in width at the base.

Straight six (6) or eight (8) inch stone curbing shall be in lengths of not less than six (6) feet, except when necessary for closures where no piece shall be less than four (4) feet in length.

(c) Curved Stone Curbing. All curved curbing shall consist of approved, first quality granite having a width at the top of six (6) or eight (8) inches as specified and the bottom shall be not less than two (2) inches wider than the top. It shall be dressed as specified for the straight curbing, shall be twenty (20) inches in depth and in lengths of not less than five (5) feet. It shall be cut exactly true to the radius specified and with a tangent or tangents if required.

81. Gravel. Gravel shall be classified as "Sub-base or Bankrun Gravel", "Screened Gravel" or "Crushed Gravel" in accordance with the following specifications. The material required for any particular item will be stated under that item.

(a) Sub-base or Bankrun Gravel shall consist of material free from rotten stone, loam, vegetable matter or excess sand and so graded that it will sustain traffic without excessive rutting. Bankrun Gravel shall be so selected that all will pass a screen having three and one-half (3½) inch square openings and at least fifty (50) per cent. shall be retained on a screen having one-quarter (¼) inch square openings. Sub-base Gravel shall be so selected that all will pass a screen having five (5) inch square openings and at least fifty (50) per cent. will be retained on a screen having one-quarter (¼) inch square openings. All material shall be approved by the Engineer for the use intended.

(b) Screened Gravel shall consist of pieces of clean, tough, durable rock, free from rotten stone, loam or vegetable matter and shall be screened by approved methods to produce a well graded product which shall all pass through a screen having three and one-half (3½) inch square openings and be retained on a screen having one-half (½) inch square openings. Washed gravel will not be acceptable under this item. All material shall be approved by the Engineer for the use intended.

(c) Crushed Gravel shall be composed of hard durable particles of stone, having a per cent of wear of not more than fifteen (15) (Abrasion test for gravel) thoroughly clean,

and shall be free from an excess of thin or elongated pieces, frozen lumps, vegetable or other deleterious matter. When used in conjunction with reinforcing steel, the gravel shall be free from salt or alkali. It shall contain not less than fifty (50) per cent. of pieces that have been broken by the crusher and shall meet the gradation requirements for broken stone as given hereinbefore.

When intended for use as coarse aggregate for concrete base course class "A," "C" or "D" concrete or concrete pavement, this material shall have a per cent of wear of not more than ten (10) (abrasion test for gravel) and shall be washed if so directed. When subjected to five (5) cycles of the sodium sulphate soundness test, it shall lose not more than fifteen (15) per cent by weight. It shall contain not less than seventy-five (75) per cent of pieces that have been broken by the crusher and shall meet the gradation requirements for broken stone as given hereinbefore. The specific gravity of the gravel proposed for use shall be determined by the Department in advance of the work and the batch weight shall be set to conform thereto.

The sizes of crushed gravel required for the different items are specified under those items.

82. **Brick.** All brick shall conform to one of the following requirements. The type of brick required for any particular item will be stated under that item.

(a) **Paving Brick** shall conform to the requirements of the specifications of the American Society for Testing Materials, Serial Designation C 7-30 with subsequent amendments and additions adopted by the Society. The brick used shall be one of the varieties recommended by the Standing Committee on Simplification of Varieties of Vitrified Paving Brick of the Department of Commerce of the United States.

(b) **Building Brick** shall conform to the requirements of the specifications of the American Society for Testing Materials, Serial Designation C 62--30 with subsequent amendments and additions thereto adopted by the Society. Unless otherwise specified, all bricks shall conform to the class requirements for Grade A Brick.

(c) **Sewer Brick** shall conform to the requirements of the specifications of the American Society of Testing Materials, Serial Designation C 32-24 with subsequent amendments and additions adopted by the Society.

83. Sand. Sand shall consist of grains or particles of quartz or other hard, durable rocks, the surfaces of which are not coated with any injurious foreign material. The grains shall be sharp, free from decomposed sand, loam, salt, organic matter or other foreign materials.

Sand shall be classified as "Concrete Sand," "Mortar Sand," "Bituminous Sand" or "Filler Sand," and the class required for any particular item will be stated under that item.

(a) Concrete Sands are those intended for use in Portland cement concrete and shall be either Grade "A" or Grade "B" as specified. They shall consist of clean, hard, durable, uncoated particles, free from lumps of clay, soft or flaky material, loam or organic material. In no case shall sand containing lumps of frozen material be used. When tested by means of laboratory screens and sieves, they shall conform to the following requirements:

Grades	A		B	
Screen and Sieve Tests	Min.	Max.	Min.	Max.
Passing a ⅜" Sieve	100%	....	100%	....
Passing a No. 4 Sieve	95%	....	90%	....
Passing a No. 50 Sieve	5%	25%	5%	30%
Passing a No. 100 Sieve	0	5%	0	10%

Grade "A" sand shall contain not more than three (3) per cent. of clay and inorganic silt by actual dry weight, and must produce a Portland cement mortar which will have, at the age of seven (7) and twenty-eight (28) days, a tensile or compressive strength of not less than one hundred (100) per cent. of that developed by a mortar prepared in the same manner, of the same proportions and consistency, made of the same cement, and standard Ottawa sand. The sand must be washed sand and, when subjected to the color test for organic impurities, it shall produce a color in the sodium hydroxide solution not darker than Plate I.

Grade "B" sand shall contain not more than five (5 per cent. of clay and inorganic silt by actual dry weight and shall produce a mortar having a strength of not less than

ninety (90) per cent. of that obtained with standard Ottawa sand. When subjected to the color test for organic impurities, it shall produce a color in the sodium hydroxide solution not darker than Plate II.

(b) **Mortar Sand** is that intended for use in Portland cement mortar, and when tested by means of laboratory sieves, shall conform to the following requirements:

Sieve Tests	Min.	Max.
Passing a No. 8 Sieve	100%	
Passing a No. 50 Sieve	15%	40%
Passing a No. 100 Sieve	0	10%

Mortar sands shall contain not more than three (3) per cent. of clay and inorganic silt by actual dry weight, and must produce a mortar having a strength of not less than sixty (60) per cent. of that obtained with standard Ottawa sand. When subjected to the color test for organic impurities, it shall produce a color in the sodium hydroxide solution not darker than Plate II.

(c) **Bituminous Sands** are those intended for use in sheet asphalt pavements and when tested by means of laboratory sieves, shall conform to the following requirements:

Grades	Binder Course		Top Course	
Sieve Tests	Min,	Max.	Min.	Max.
Passing a No. 4, retained on No. 10 sieve	0	5%	0	5%
Passing No. 10, retained on No. 40 sieve	....	....	12%	40%
Passing No. 40, retained on No. 80 sieve	....	....	25%	60%
Passing No. 80, retained on No. 200 sieve	....	....	20%	45%
Passing a No. 200 sieve	....	6%	....	6%

(d) **Filler Sands** are those intended for use in the construction of broken stone base courses, gutters, and for such other miscellaneous purposes as may be defined herein. They shall be composed of clean, sharp, durable grains, graded from

coarse to fine, shall not contain more than five (5) per cent. of clay and inorganic silt by actual dry weight, shall be of such size that all will pass a screen having five-eighths (⅝) inch square holes and not less than sixty (60) per cent will be retained on a No. 50 sieve and shall be approved by the Engineer for the use intended.

84. **Mineral Filler.** Mineral filler for use in sheet asphalt pavements or bituminous mastics shall be Portland cement or other materials approved by the Engineer conforming to the following requirements:

Passing a 200 mesh sieve.....not less than 65%
Total passing 80 mesh sieve.....not less than 95%
Total passing 30 mesh sieve.....not less than 100%

It shall be free from lumps or balls, or any foreign material which may injure it for the purpose intended.

85. **Portland Cement.** All cement used shall be Portland cement which shall comply with the requirements of the specifications of the American Society for Testing Materials, Designation C 9-30 with all subsequent changes or additions.

All cement shall be produced by mills so located that both the raw materials and the process of manufacture may be readily, easily, and conveniently inspected by representatives of the Department.

The use of cement of a temperature in excess of 140 degrees F. will not be permitted.

(a) **Supply of Cement to Be Kept on Hand.** On all projects having a length equivalent to two (2) miles or more of pavement twenty (20) feet in width, the Contractor must have storage for and must keep constantly in reserve two thousand five hundred (2500) barrels of cement, until the concrete work is at least half completed.

(b) **Ordering.** Before starting work, the Contractor shall notify the Engineer in writing of the name of the manufacturer and the name of the brand of cement which he proposes to use on the work.

All cement shall be shipped from bins approved by the Department.

Copies of all orders for cement placed by the contractor shall be forwarded to the Department. When an order is placed through a broker or local dealer, the said broker or local dealer shall furnish the Department with a copy of his order to the cement company for the cement required.

Orders must be placed with the cement company at least ten (10) days before the date of initial shipment and no cement shall be used until it has passed the test requirements specified.

(c) **Testing.** All cement shall be sampled at the mill by a representative of the Department.

The cement shall be tested according to the method of tests and shall meet the requirements of the above described A. S. T. M. specifications.

Cement may be accepted if it passes the seven-day tests satisfactorily. Cement not satisfactory on the seven-day tests may be held to await the results of the twenty-eight day tests before final acceptance or rejection. The Department reserves the right to reject any cement that fails to meet the requirements of the twenty-eight day tests, even though it had been previously accepted on the seven-day tests. Samples of each lot shall be required to show practically uniform results in tests; marked deviation from such results may be considered cause for rejection, even though test requirements may be otherwise fulfilled.

(d) **Shipment and Storage.** The cement shall be delivered in suitable cloth or paper bags of an approved type with the name and brand of the manufacturer plainly marked thereon. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net. One bag of cement shall be considered as containing one cubic foot.

Bulk cement may be used provided it is batched by an approved weighing device meeting the following requirements:

The weighing hopper and scale shall be entirely encased and arrangements made for locking.

The discharge chute shall be so arranged that cement will not lodge there and so that there will be no loss of cement.

The hopper mechanism shall be interlocked against opening when the discharge gate is open.

The discharge mechanism shall be interlocked against opening until the full batch is in the hopper and the scales balance; against opening while the hopper is being filled; against closing until the hopper is entirely discharged and the scales back in balance, and against opening if the batch in the hopper is either over or underweight by more than one (1) per cent. of the amount specified.

The weighing hopper discharge gate shall be mechanically operated in such a manner as not to affect the scale balance.

The weighing hopper discharge chute shall be suspended from the encasement and not from the weighing hopper.

When bulk cement is used, it shall be transported in a separate, closed compartment.

Provision shall be made by the contractor for storing cement in a dry place and in such a manner as to permit easy access for proper inspection and identification of each shipment.

All cement stored over winter by the contractor shall not be used until re-tested by the Laboratory.

Cement failing to meet the requirements of the specifications shall not be re-sampled or re-tested except as provided for in the Standard Specifications of the American Society for Testing Materials.

Approved cement which has become damaged by the action of the elements or for any other cause prior to being placed in the work, shall be rejected and removed from the site of the work.

All empty paper cement bags shall be removed from the site of the work by the contractor, at his own expense, within twenty-four (24) hours after being emptied.

(e) **Basis of Payment.** This material will be paid for at the contract unit price per barrel of 376 pounds net weight for "Portland Cement" actually incorporated in the work in accordance with the provisions of these Specifications, except in the case of cement furnished for Catch Basins, Manholes and for the installation of Reinforced Concrete Pipe when the cement shall be furnished by the Contractor and the cost included in the bid price for these items.

Should the Contractor elect to use cement delivered in cloth bags, he will be required to add to the mix, two (2) pounds of cement extra for each bag of cement so furnished. This additional cement shall be furnished by and at the expense of the Contractor.

86. **Water.** Water for use with cement in mortar or concrete shall be reasonably clear, shall not be salty or brackish, and shall be free from oil, acid and injurious alkali or vegetable matter. When required by the Engineer, the quality of the mixing water shall be determined in accordance with the "Method of Test of Quality of Water to be

used in Concrete," Standard Specifications of the American Association of State Highway Officials, Method T-26. When comparative tests are made with a water of known satisfactory quality, any indication of unsoundness, marked change in time of set, or reduction in mortar strength shall be sufficient cause for rejection of the water under test.

Samples submitted for test shall consist of at least one (1) quart of water, shipped in a clean glass container. This bottle shall be packed carefully and forwarded to the laboratory in a box properly labeled and containing a card giving full information relative to the sample.

The Contractor shall not take water for use in concrete from shallow, muddy, or marshy surfaces. Water from suspected sources shall not be used until tested and approved. In cases where sources of supply are relatively shallow, they shall be so enclosed as to exclude silt, mud, grass, etc.; the water in the enclosure shall be maintained at a depth of not less than two (2) feet under the intake of the suction pipe.

87. **Bituminous Materials.** Description. Bituminous materials shall include asphalt cements, asphaltic road oils, asphaltic emulsions, asphaltic cold patch, and tars. All bituminous materials used in a given construction shall be uniform in character, appearance and consistency. The bituminous materials should have a consistency which is approximately the midpoint of the range specified but in no case shall the deviation exceed the limits specified.

Payment. Prices submitted for all bituminous materials must be on the basis of a United States standard gallon of two hundred and thirty-one (231) cubic inches at 60° F.

The number of gallons furnished will be determined by weighing the material on scales furnished by and at the expense of the Contractor.

The price shall include the cost of heating, when ordered by this Department, of all materials for which a furnished and applied price is quoted.

Payment for surface treatment tar, asphaltic road oils and 85-100 penetration asphalt, delivered in tank trucks, will be made on a gallon basis, computed by using the weight per gallon as established by the Department for a standard gallon of the material in question at 60° F. A list of the standard weights established will be furnished to interested parties on request.

incidental thereto. When new frames, gratings or covers are required, payment shall be made on a "Cost Plus" basis for such material, delivered at the site of the work, as shown by original receipted bills. Under this item, the amount of change in elevation of any catch basin or manhole frame shall not exceed two (2) feet.

CONCRETE.

226. **Description.** All concrete for structures shall be composed of Portland Cement, fine aggregate, and coarse aggregate. The concrete shall be of four classes: "Class A Concrete", "Class B Concrete", "Class C Concrete" and "Class D Concrete" respectively, and the materials shall be mixed in such proportion and of such consistency as specified and deposited in such places and of such forms and dimensions as shown on the plans or as ordered. Each class of concrete shall be used in that part of the structure in which it is called for on the plans or as directed, and shall be constructed in accordance with these specifications.

PROPORTIONS BY WEIGHT

Class	Amounts in Pounds		
	Portland Cement	Fine Aggregate	Coarse Aggregate
A	94	190	380
B	94	285	475
C	94	190	285
D	94	190	380

Where proportioning by volume is permitted, as provided elsewhere herein, the following proportions, by loose volume, shall be used:

PROPORTIONS BY VOLUME

Class	Parts		
	Portland Cement	Fine Aggregate	Coarse Aggregate
A	1	2	4
B	1	3	5
C	1	2	3
D	1	2	4

(a) Class "D" Concrete shall be the same in all respects as Class "A" concrete as described herein and shall be subject to the same requirements, its only distinction being the uses specifically stated in Paragraph 225 (d).

227. **Materials.** The materials for this work shall conform to the following requirements:

(a) **Portland Cement** shall conform to the requirements of Paragraph 85.

(b) **Fine Aggregate** for Class "A" and Class "C" concrete shall be Grade A Concrete Sand and fine aggregate for Class "B" concrete shall be Grade B Concrete Sand, conforming to the requirements of Paragraph 83 (a).

(c) **Coarse Aggregate** for Class "A", Class "C" and Class "D" concrete shall consist of grade "B" stone conforming to the quality requirements of Paragraph 75, or Crushed Gravel conforming to the quality requirements of Paragraph 81 (c) for Crushed Gravel for Class "A," "C" or "D" concrete. The required grading shall be produced by combining size C and E in the proportions of 70 per cent size C and 30 per cent of size E. For walls, slabs, etc., less than six (6) inches in depth or thickness, the coarse aggregate shall consist of size E only.

The coarse aggregate for concrete encasement around structural steel shall be size F gravel conforming to the requirements of Paragraph 81 (c), except that under this item, the gravel may consist entirely of rounded pieces that have not been broken by the crusher, provided the grading, hardness and freedom from foreign substances requirements are complied with.

The coarse aggregate for Class "B" concrete shall consist of grade C stone or crushed gravel conforming to the quality requirements of Paragraphs 75 or 81 (c) respectively. The required grading shall be produced by combining size C and E stone or crushed gravel in the proportions of 70 per cent. of size C and 30 per cent. of size E.

(d) **Rubble Stone** shall conform to the requirements of Paragraph 77.

(e) **Water** shall conform to the requirements of Paragraph 86.

(f) **Hydrated Lime** shall conform to the requirements of Paragraph 95.

228. **Measuring Materials.** Fine and coarse aggregates shall be proportioned by weight, using for this purpose a three (3) bin batcher of the weighing type. The total bin capacity of the equipment shall be comparable to the volume of concrete to be placed and shall be approved by the Engineer.

The weighing hopper and scales shall conform to the general requirements as given in Paragraph 180 (a). The materials shall be mixed in the hereinbefore described proportions and for purposes of proportioning one bag of cement weighing ninety-four (94) pounds net shall be considered the equivalent of one cubic foot.

In cases where the volume of concrete to be placed is small or where, for other reasons, proportioning by weight is impractical or would work an undue hardship on the Contractor, the aggregates may, with the approval of the Engineer, be proportioned by loose volume. These volumes shall be measured separately in an approved manner for which purpose the Contractor will be required to use such equipment as will insure uniformity of proportion. The use of approved wheelbarrows or bottomless boxes whose contents have been carefully predetermined, or other equally satisfactory method may be employed. Proportioning by means of shovels will not be permitted. In determining the volumes of the aggregates due consideration shall be given to the bulking effect of any moisture contained in these materials.

229. Mixing Concrete.

(a) Machine Mixing. Concrete shall be thoroughly mixed in a batch mixer of an approved size and type and one so designed as to positively insure a uniform distribution of the materials throughout the mass. Batches shall be proportioned on the basis of integral sacks of cement.

All concrete shall be mixed for a period of not less than one and one-half (1½) minutes after all materials, including water, are in the mixer.

During the period of the mixing, the drum shall operate at the speed for which it has been designed. Such speed, however, preferably shall be not less than one hundred seventy-five (175), nor greater than two hundred twenty-five (225) feet per minute at the periphery of the drum, and not less than fourteen (14), nor more than twenty (20) revolutions per minute. The entire contents of the mixer shall be removed from the drum before materials for the succeeding batch are placed therein and the mixer preferably shall be equipped with mechanical means for preventing the addition of aggregates after mixing has commenced.

The mixer shall be equipped with adequate water storage and a device for accurately measuring the amount of water used in each batch and preferably shall be equipped with a batch meter or other device for accurately recording the

number of revolutions for each batch, and an attachment for automatically locking the charging device so as to prevent the emptying of the mixer until the materials have been mixed the minimum specified time. No mixer shall be operated above its rated capacity and no mixer shall be used which has a rated capacity of less than a two-bag batch.

The first batch of concrete materials placed in the mixer shall contain an additional quantity of sand, cement and water sufficient to coat the inside surface of the drum without diminishing the mortar content of the mix. Upon the cessation of mixing for any considerable length of time, the mixer shall be thoroughly cleaned.

(b) **Hand Mixing.** Hand mixing shall not be permitted, except in case of emergency and under written permission from the Engineer. When permitted, it shall be done only on watertight platforms. The sand shall be spread evenly over the platform and the cement spread upon it. The sand and cement shall then be thoroughly mixed while dry by means of shovels until the mixture is of a uniform color, after which it shall be formed into a "crater" and water added in an amount necessary to produce mortar of the proper consistency. The material upon the outer portion of the "crater" ring shall then be shoveled to the center and the entire mass turned and sliced until a uniform consistency is produced. The coarse aggregate shall then be thoroughly wetted and added to the mortar and the entire mass turned and re-turned at least six times and until all of the stone particles are thoroughly covered with mortar and the mixture is of a uniform color and appearance. Hand mixed batches shall not exceed one-half cubic yard in volume. Hand mixing will not be permitted for concrete to be placed under water.

(c) **Retempering.** Concrete shall be mixed only in such quantities as are required for immediate use, and shall be used while fresh and before initial set has taken place. Any concrete in which initial set has begun shall be wasted and not used in the work. No retempering of concrete shall be allowed.

(d) **Hydrated Lime.** When required by the Engineer, hydrated lime conforming to the requirements as specified elsewhere herein, in the proportions of four (4) pounds of lime for each bag of cement in the mix shall be added to the concrete while being mixed. The lime shall be added with the cement and shall be considered as an additional material and not as replacing or reducing the amount of cement required.

All hydrated lime shall be furnished by the Contractor and there shall be no direct payment for furnishing and using this material, but the cost thereof shall be considered as included in the concrete items.

230. Consistency. The quantity of mixing water to be used shall be determined in each case by the Engineer and no changes shall be made without his consent. A mixture shall be used which contains the minimum amount of water consistent with the required workability.

In general, the consistency of concrete mixtures shall be such that:

1. The mortar clings to the coarse aggregate.
2. The concrete is not sufficiently fluid to segregate when transported to the place of deposit.
3. The concrete, when dropped directly from the discharge chute of the mixer, shall flatten out at the center of the pile but shall stand up and not flow at the edges.
4. The mortar shall show no free water when removed from the mixer.
5. The concrete shall settle into place when deposited in the forms and, when transported in metal chutes at an angle of 30 degrees with the horizontal, it shall slide and not flow into place.
6. The upper layer of the set concrete shall show a cement film upon the surface but shall be free from laitance.

231. Placing Concrete. Concrete shall be placed in the forms immediately after mixing and in no case shall concrete be used which does not reach its final position in the forms within 30 minutes after the time that water is first added to the mix. The method and manner of placing shall be such as to avoid the possibility of segregation or separation of the aggregates or the displacement of the reinforcement.

The use of long chutes for conveying concrete from the mixing plant to the forms will be permitted only on written authority from the Engineer. If chutes are allowed and the quality of concrete as it reaches the forms or the methods of placing or working it therein are not satisfactory, the Contractor shall, upon orders from the Engineer, discontinue the use of chutes and re-equip his plant for placing the concrete in a satisfactory manner. Under no conditions shall this system be used on work exposed to the effects of salt or brackish water.

Troughs, pipes or short chutes used as aids in placing concrete shall be arranged and used in such a manner that the ingredients of the concrete are not separated. Where steep slopes are required the chutes shall be equipped with baffle boards or be in short lengths that reverse the direction of movement. When pipes are used they shall be kept full of concrete and have their lower ends kept buried in fresh concrete in the same manner that a tremie is used. All chutes, troughs and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. Water used for flushing shall be discharged clear of the concrete in place. Open troughs and chutes shall be either of metal or metal lined and shall extend as nearly as possible to the point of deposit. When the discharge must be intermittent, a hopper or other device for regulating the discharge shall be provided.

Dropping the concrete a distance of more than five (5) feet or depositing a large quantity at any point and running or working it along the forms will not be permitted.

Placing of concrete shall be so regulated that the pressures caused by the wet concrete shall not exceed those used in the design of the forms.

Special care shall be taken to fill each part of the forms by depositing concrete directly as near final position as possible; to work the coarser aggregates back from the face and to force the concrete under and around the reinforcement bars without displacing them. After the concrete has taken its initial set, care shall be exercised to avoid jarring the forms or placing any strain on the ends of projecting reinforcement.

Concrete shall be compacted by continuous working with a suitable tool in a manner acceptable to the Engineer. Slab and girder work, arch ribs and all thin section work shall be thoroughly worked with a steel slicing rod. All faces shall be well spaded and the mortar flushed to the surface of the forms by continuous working with a concrete spading implement acceptable to the Engineer.

In all cases where, on account of the obstructions produced by reinforcement metal, shape of forms, or any other uncontrollable condition, difficulty is encountered in puddling the concrete adjacent to the forms, and when so directed by the Engineer the mortar content of the mix shall be brought into proper contact with interior surfaces by vibrating the concrete. The vibrations shall be produced by the use of mechanical vibrators of a type satisfactory to the Engineer and having a vibrating frequency of not less than thirty-five hundred (3500)) pulsations per minute. The number

and type of vibrators required, the length of vibrating period and the location of the vibrators shall be as required by the Engineer.

Concrete shall be placed in continuous horizontal layers, the thickness of which generally shall not exceed ten (10) to twelve (12) inches. When it is necessary by reason of an emergency to place less than a complete horizontal layer at one operation, such layer shall terminate in a vertical bulkhead. In any given layer the separate batches shall follow each other so closely that each one shall be placed and compacted before the preceding one has taken initial set, in order that the green concrete shall not be injured and that there shall be no line of separation between the batches. Each layer of concrete shall generally be left somewhat rough to secure efficient bonding with the next layer above. A succeeding layer placed before the underlying layer has become set shall be compacted in a manner that will entirely break up and obliterate the tendency to produce a construction joint between the layers.

Layers completing a day's work or placed just prior to temporarily discontinuing operations shall generally be cleaned of all objectionable material as soon as the surface has become sufficiently firm to retain its form. To avoid visible joints as far as possible upon exposed faces, the top surface of the concrete adjacent to the forms shall be finished by being smoothed with a plaster mason's trowel.

Horizontal layers so located as to produce a construction joint at a location wherein a "feather edge" might be produced in the succeeding layer, shall be so formed by inset form work that the succeeding layer will end in a body of concrete having a thickness of not less than six (6) inches.

In no case shall the work on any section or layer be stopped or temporarily discontinued within eighteen (18) inches below the top of any face, unless the details of the work provide for a coping having a thickness of less than eighteen (18) inches, in which case, at the option of the Engineer, the construction joint may be made at the under side of the coping.

After the concrete in finished surfaces has begun to set, it shall not be walked upon or otherwise disturbed in less than forty-eight (48) hours.

The method and manner of placing concrete shall be so regulated as to place all construction joints across regions of low shearing stress and in such locations as will be hidden

from view to the greatest possible extent. The method and sequence of placing concrete for the various types of concrete construction shall be as specified by the Engineer for the particular type of construction involved.

The operation of depositing and compacting the concrete shall in general be conducted so as to form a compact, dense, impervious, artificial stone of uniform texture which shall show smooth faces on exposed surfaces. If any section of concrete is found to be defective, it shall be removed or repaired as directed by the Engineer.

232. **Depositing Concrete Under Water.** Concrete shall not be exposed to the action of water before setting, or deposited in water, except with the approval of the Engineer and under his immediate supervision. When concrete is so deposited, the method and manner of placing shall be as hereinafter designated.

All concrete deposited under water shall be mixed in the proportions designated for Class "A" concrete with ten (10) per cent. excess cement added.

Concrete deposited under water shall be carefully placed in a compacted mass in its final position by means of a tremie, a closed bottom dump bucket or other approved method and shall not be disturbed after being deposited. Special care must be exercised to maintain still water at the point of deposit. No concrete shall be placed in running water and all form work designed to retain concrete under water shall be water-tight. The consistency of the concrete shall be carefully regulated and special care shall be exercised to prevent segregation of the materials. The method of depositing concrete shall be so regulated as to produce approximately horizontal surfaces.

When a tremie is used, it shall consist of a tube having a diameter of not less than ten (10) inches, constructed in sections having flanged couplings fitted with gaskets. The means of supporting the tremie shall be such as to permit the free movement of the discharge end over the entire top surface of the work and shall be such as to permit it to be rapidly lowered when necessary to choke off or retard the flow. The discharge end shall be plugged at the start of the work so as to prevent water entering the tube and shall be entirely sealed at all times and the tremie tube kept full to the bottom of the hopper. When a batch is dumped into the hopper the tremie shall be slightly raised, but not out of the concrete at the bottom, until the batch discharges

to the bottom of the hopper. The flow is then stopped by lowering the tremie. The flow shall be continuous and in no case shall be interrupted until the work is complete.

When concrete is placed by means of a bottom dump bucket, the bucket shall have a capacity of not less than one-half (½) cubic yard. The bucket shall be lowered gradually and carefully until it rests upon the concrete already placed. It shall then be raised very slowly during the discharge travel, the intent being to maintain, as nearly as possible, still water at the point of discharge and to avoid agitating the mixture.

233. **Bonding Construction Joints.** In joining fresh concrete to concrete that has already set, the work already in place shall have its surface cut over thoroughly with a suitable tool to remove all loose and foreign material. This surface shall then be washed and scrubbed with wire brooms and thoroughly drenched with water until saturated. It shall remain saturated until the new concrete is placed. Immediately prior to the placing of the new concrete, all forms shall be drawn tight against the concrete already in place and the old surface shall be thoroughly coated with a very thin coating of mortar, neat cement or other suitable bonding material.

In order to bond successive courses, suitable keys or construction joints shall be formed at the top of the upper layer of each day's work and at other levels where work is interrupted. These keys shall be built in the location and to the form and dimensions shown on the plans or as ordered by the Engineer and shall include steel dowels when so indicated or directed.

In construction joints exposed to view or in other construction joints where seepage of water is particularly objectionable, a metal baffle strip, preferably of copper, zinc or sheet lead, shall be inserted. This strip shall be placed not less than 3 inches from the face of the concrete and shall extend into each section of the concrete a distance of not less than two (2) inches.

234. **Rubble or Cyclopean Concrete.** Rubble or cyclopean concrete shall consist of Class "B" concrete in which is embedded large individual stones in accordance with the following requirements:

This class of concrete shall be used only in massive piers, gravity abutments and heavy footings and only with the approval of the Engineer.

The stone for this class of work shall be rubble stone as specified herein.

The stone shall be carefully placed (not dropped or cast) and the method of placing shall be such as to avoid injury to the forms or to the partially set adjacent masonry. Stratified stone shall be placed upon its natural bed. All stone shall be thoroughly washed and saturated with water before being placed.

The total volume of the stone used shall not be greater than one-third of the total volume of the portion of the work in which it is placed.

Each stone shall be completely surrounded by a layer of concrete not less than six inches in thickness. No stone shall extend above a point one foot below the top surface of any wall or pier nor shall it extend within less than six inches of any coping.

For walls or piers greater than four (4) feet in thickness derrick stone may be used. Each stone shall be completely surrounded by a layer of concrete not less than one foot in thickness. No stone shall extend above a point two (2) feet below the top surface of any wall or pier nor shall it extend within less than eight (8) inches of any coping.

235. **Concrete Exposed to Sea Water.** Concrete structures so located as to be subject to the action of sea water shall be constructed to provide a maximum resistance to its disintegrating action.

The concrete shall be mixed not less than two (2) minutes. The water content shall be carefully controlled and so regulated as to produce concrete of maximum impermeability. In placing concrete, care shall be exercised to avoid the formation of stone pockets and the concrete shall be thoroughly compacted to the satisfaction of the Engineer. The original surface as the concrete comes from the forms shall be left undisturbed. In order to secure a thick and dense surface film, the form surfaces shall be heavily coated with shellac or an approved form oil.

The range of possible disintegration of the concrete from an elevation below that of extreme low tide to an elevation above that of extreme high tide shall be determined by the Engineer and, except with his special permission, no construction joints shall be located within this range. In the determination of this range due consideration shall be given to wave action, ice formation and other conditions affecting the extreme limits of possible deterioration and disintegration.

Concrete exposed to the action of ice, drift, or other forces producing shock and abrasion, shall be protected by encasing that portion of the surface so exposed with a special sheathing or protective armor as shown on the plans or noted in the Special Provisions, and provision shall be made in the size of the original cofferdam for sufficient clearance to permit access to the masonry surface for the installation and effective anchorage of this sheathing.

The protective armor above noted may be of metal plates, a vitrified brick or dense stone facing, a dense mortar facing placed simultaneously with the interior of the wall by means of baffle plates, a treated timber sheathing or other approved construction.

When so specified, cofferdams may be constructed above the mud line with treated material and left permanently in place. In this case, the space between the neat masonry lines and the interior of the cofferdam shall be filled with waterproof material.

Concrete in sea water within the range as above determined shall, in all cases, be deposited in the dry. In no case shall sea water be allowed to come in direct contact with the concrete until it has been permitted to harden at least ten (10) days and preferably for a longer period.

Concrete piles exposed to conditions subjecting them to possible rupture and abrasion shall, when so specified or ordered by the Engineer, be protected by a special protective shell of metal, vitrified pipe or other suitable construction. When concrete piles are used in sea water special care shall be exercised to avoid slight deformation cracks and all piles extending above the mud line shall be securely braced to avoid excessive deformation due to sway or vibration under service. Concrete piles for use in sea water shall be cured for not less than sixty (60) days before being used.

236. **Falsework.** Detailed plans for falsework or centering shall be supplied to the Engineer on request, but his approval of them, or acquiescence in the work constructed according to them, shall not relieve the Contractor of responsibility for satisfactory results. For calculating the strength of falsework or centering, a weight of one hundred fifty (150) pounds per cubic foot shall be assumed for green concrete.

In general, falsework which cannot be founded upon a solid footing, shall be supported by falsework piling. Falsework piling shall be spaced and driven as ordered by the Engineer.

No extra compensation for falsework or falsework piling will be allowed, such work being considered as part of the form work.

The Contractor shall employ screw jacks or hardwood wedges in connection with the centering or falsework in order to take up any slight settlement in the form work either before or during the placing of concrete.

Centering shall not be removed for a period of at least twenty-one (21) days after the concrete is placed. This requirement may be varied to meet special conditions, but only under written orders from the Engineer.

Falsework shall be set to give the structural camber indicated on the plans or specified, plus allowance for shrinkage and settlement.

237. Forms. If required, form work plans shall be submitted by the Contractor and approved by the Engineer before being used on the work. No special remuneration shall be made for form work, the cost of such work being included in the price bid for concrete.

All forms shall be built mortar tight and of material sufficient in strength to hold the concrete without bulging between supports. Forms shall be so maintained as to eliminate the formation of joints due to shrinkage of the lumber.

Forms for all exposed surfaces including railings, outer surfaces of beams and girder encasing, exposed surfaces of piers, abutments and wingwalls, etc., shall be lined with an approved type of wood fibre board of a quality satisfactory to the Engineer. The sizes of board used shall be such as to eliminate all unnecessary joints. Joints, when necessary, shall be straight, true and butted tight, and shall be rigidly supported throughout their length to prevent movement.

Forms shall be designed for a fluid pressure of one hundred fifty (150) pounds per cubic foot and in addition thereto a live load allowance of fifty (50) pounds per square foot on horizontal surfaces.

Forms shall be filleted at all sharp corners and shall be given a bevel or draft in the case of all projections, such as girders, copings, etc., sufficient to insure easy removal.

The form lumber for the exposed surfaces of all girders, copings, wing walls and other faces, shall be not less than 1¼ inches in thickness after being surfaced. This does not apply to curved or special surfaces. Ample studding and waling shall be used to effectively prevent bulging of the forms.

Special attention must be paid to bracing, and where the forms appear to be insufficiently braced, or unsatisfactorily built, either before or during the placing of concrete, the Engineer shall order work stopped until the defects have been corrected to his satisfaction.

Any metal ties or anchorages which are required within the forms to hold them to correct alignment and location shall be so constructed that the metal work can be removed to a depth of at least 2 inches from the face surface of the concrete without injury to such surface by spalling or otherwise. All cavities produced by the removal of metal ties shall be carefully filled with cement mortar and the surface left smooth and even and uniform in color.

All forms shall be set and maintained true to the line designated until the concrete is sufficiently hardened. In general, form work shall remain in place, after placing of concrete, for the approximate periods specified in Paragraph 239. To facilitate finishing, side forms carrying no load may be removed after twenty-four (24) hours, if permitted by the Engineer.

For narrow walls where access to the bottom of the forms is not readily attainable otherwise, the lower form boards shall be left loose so that they may be removed for cleaning out all chips, dirt, sawdust or other extraneous material immediately prior to placing concrete.

The interior surfaces of all forms in contact with concrete surfaces which will be exposed in the finished work shall be of lumber dressed on one face and both edges and having mortar-tight joints, and shall be so constructed as to leave all such exposed concrete surfaces with a smooth, even finish.

Forms reused shall be maintained at all times in good condition as to accuracy of shape, strength, rigidity, watertightness and smoothness of surface. Any warped or bulged lumber must be carefully resized before being reused. Forms unsatisfactory in any respect shall not be used and, if condemned, shall be removed immediately from the work.

All forms shall be treated with oil or thoroughly drenched and saturated with water on both faces immediately before concrete is placed therein. For rail members, and the exposed faces of girders, arch ribs, copings, etc., forms shall be treated with an approved oil to prevent the concrete adhering to them. Any other material, such as tar paper or oil, that will stick to or discolor the concrete, shall not be used.

238. **Metal Forms.** The foregoing specifications for "Forms," as regards design, mortar tightness, filleted corners, beveled projections, bracing, alignment, removal, reuse and oiling, shall apply with equal force to Metal Forms. The metal used for forms shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be counter-sunk. Clamps, pins or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or line up properly, shall not be used. Special care shall be exercised to keep metal forms free from rust, grease or other foreign matter such as will tend to discolor the concrete.

239. **Removal of Forms.** In the determination of the time for the removal of falsework, forms and housing, and the discontinuance of heating, consideration shall be given to the location and character of the structure, the weather and other conditions influencing the setting of the concrete and the materials used in the mix. In general, the forms for any portion of the structure shall not be removed until the concrete gives forth a clear, sharp ring when struck upon a flat surface with a small hammer and is strong enough to prevent injury to the concrete from such removal. Forms and their supports shall not be removed without the approval of the Engineer. Supports shall be removed in such a manner as to permit the concrete to uniformly and gradually take the stresses due to its own weight.

If field operations are controlled by beam tests, the removal of forms, supports and housing and the discontinuance of heating and curing may be begun when the modulus of rupture of the concrete reaches the value or values fixed for the particular method of testing which is to be used. The beams shall be cured under conditions which are not more favorable than the most unfavorable conditions for the portions of the concrete which the beams represent.

If field operations are not controlled by beam tests, the following periods, exclusive of days when the temperature is below forty (40) degrees F., for the removal of forms and supports may be used as a guide:—

Arch centers	28 days
Centering under beams	28 days
Floor slabs	14 to 28 days
Walls	7 days
Columns	10 days
The sides of beams, and all other parts	7 days

240. **Concreting in Cold Weather.** During cold weather, concrete may be mixed when the air temperature in the shade and away from artificial heat is forty (40) degrees F. or above, and rising. It shall not be mixed when the air temperature in the shade and away from artificial heat is below forty (40) degrees F.

When directed by the Engineer, the Contractor shall enclose the structure in such a way that the air within the enclosure or the concrete aggregate can be kept above sixty (60) degrees F. for a period of ten (10) days after placing the concrete, and above forty (40) degrees F. for a period of fourteen (14) days. The temperature shall then be gradually lowered to that of the surrounding atmosphere. These periods may be reduced if, in the opinion of the Engineer, the beam tests indicate that the concrete has attained a sufficient strength in a shorter time.

Sufficient heating apparatus, such as stoves, salamanders, or steam equipment, and fuel to furnish all required heat, shall be supplied. All water used for mixing concrete shall be heated to a temperature of at least seventy (70) degrees, but not over one hundred fifty (150) degrees Fahrenheit. Aggregates shall be heated either by steam or by dry heat to a temperature of at least seventy (70) degrees, but not over one hundred fifty (150) degrees Fahrenheit. The heating apparatus shall be such as to heat the mass uniformly and preclude the possibility of the occurrence of hot spots which will burn the material.

The temperature of the mixed concrete shall not be less than sixty (60) degrees Fahrenheit at the time of placing in the forms.

In cases of extreme weather conditions, the Engineer may, at his discretion, raise the lower limiting temperatures for water, aggregate and mixed concrete.

241. **Curing Concrete.** Concrete surfaces exposed to conditions causing premature drying shall be protected by covering, within twenty-four (24) hours of placing, with canvas, straw, burlap, sand or other satisfactory material which shall be kept wet. If the surfaces are not covered, they shall be kept wet by flushing with a hose. Curing shall continue for a period of not less than ten (10) days after placing the concrete. Other precautions to insure the development of strength or to prevent injury shall be taken as the Engineer may direct.

242. Expansion Joints. Expansion joints may be of the following types:

Friction joints.
Open joints.
Filled compression joints.
Mortise joints.
Special expansion joints.

Friction joints, when of metal, shall be composed of cast iron or bronze plates as noted on the plans. Sliding surfaces shall be planed true and smooth, the marks of the plane paralleling the movement of the joint. Expansion plates shall be well anchored as shown on the plans. All sliding surfaces of expansion plates shall be thoroughly coated with graphite and grease just before being placed in position and special care taken to avoid placing concrete in such manner as to interfere with their free action.

Open joints shall be placed at locations designated on the plans and shall be formed by the insertion and subsequent removal of a templet of timber, metal or other suitable material. The method of insertion and removal of joint templets shall be such as to avoid the possibility of chipping or breaking down at the edges and the templets shall be so constructed that their removal may be readily accomplished without injury to the work.

Filled compression joints shall be made with a joint filler, the materials for which shall conform to the requirements of Paragraph 92.

Mortise joints shall be as shown on the plans and, in general, shall consist of a tenon of concrete or metal sliding in a suitable concrete or metal socket or mortise. Concrete tenons in concrete mortise sockets, brass or bronze tenons, sliding in concrete sockets or metal tenons sliding in galvanized pipe sockets may be specified. In any case, the construction shall be such as to permit freedom of movement and such as to be, as far as possible, watertight and rust proof.

Special types of expansion joints may be used when so specified on the plans or ordered in writing by the Engineer.

Expansion joints through bridge floors preferably shall be constructed with a waterproof flashing of copper or zinc to prevent the entrance of water into the joint. Such flashing shall be so arranged as to lead all drainage water to a point of discharge such as will avoid any staining of the exposed concrete surfaces.

243. **Surface Finish.** The external surface of all concrete masonry shall be thoroughly worked during the operation of placing by means of a broad-tined fork or a concrete spade of an approved type. The working shall be such as to force all coarse aggregate from the surface and thoroughly work the mortar against the forms to produce a smooth finish free from water and air pockets or honeycomb.

As soon as the concrete has set sufficiently to permit, the forms shall be carefully removed and all depressions resulting from the removal of metal ties and all other holes and rough places shall be carefully pointed with a mortar of sand and cement in the proportion which has been employed for the particular class of concrete treated. The surface film of all such pointed surfaces shall be carefully removed before setting occurs. The surface shall then be given one of the following finishes, the particular finish to be used in any case to be as specified on the plans, but when not so specifically indicated, the Contractor shall make a "rubbed" finish on all exposed surfaces.

(a) **Rubbed Finish.** As soon as the pointing has set sufficiently to permit it, the entire surface shall be thoroughly wet with a brush and rubbed with a No. 16 carborundum stone or an abrasive of equal quality, bringing the surface to a paste. The rubbing shall be continued sufficiently to remove all form marks and projections, producing a smooth dense surface without pits or irregularities.

The paste formed by the rubbing as above described may be finished by carefully striping with a clean brush, or it may be spread uniformly over the surface and allowed to take a "reset," after which it may be finished by floating with a canvas, carpet-faced or cork float or rubbed down with dry burlap.

(b) **Horizontal Surfaces Not Subjected to Wear.** All upper horizontal surfaces such as the tops of handrail posts and caps and the tops of parapets, copings and bridge seats shall be formed by placing an excess of material in the forms and removing or striking off such excess with a wooden templet, forcing the coarse aggregate below the mortar surface. The use of mortar topping for concrete railing caps and other surfaces falling under this classification shall in no case be permitted.

The final finish for caps and railings shall be obtained in one of the following ways, as specified.

Brush Finish. After the concrete has been struck off as above described, the surface shall be thoroughly worked and floated with a wooden, canvas or cork float, the operation to be performed by skilled and experienced concrete finishers. Before this last finish has set, the surface shall be lightly striped with a fine brush to remove the surface cement film, leaving a fine grained, smooth, but sanded texture.

Float Finish. In lieu of the above, the surface may be finished with a rough carpet float or other suitable device leaving the surface even, but distinctly sandy or pebbled in texture.

Ground or Terrazzo Finish. When specified, the upper surfaces of rail caps, parapets, etc., may be finished by grinding with a carborundum stone, or equally good abrasive, to a smooth, dense, terrazzo finish. Finishing of this character shall be done as follows:—

Using a No. 16 carborundum stone or an abrasive of equal quality, the surface shall be ground dry or in water until it is smooth and the individual pebbles and aggregate particles are cut and polished. The surface shall then be completely cleansed with water, and the final rubbing done by means of a No. 30 stone. The finished surface shall present the texture of polished marble and shall show the various aggregate particles in polished outline.

(c) **Tooled Finish.** Finish of this character for panels and other like work may be secured by the use of a bush-hammer, pick, crandall or other approved tool. Air tools preferably shall be employed. No tooling shall be done until the concrete has set for at least fourteen (14) days and as much longer as may be necessary to prevent the aggregate particles from being "picked" out of the surface. The finished surface shall show a grouping of broken aggregate particles in a matrix of mortar, each aggregate particle being in slight relief.

(d) **Sand Blast Finish.** The type of finish desired in this connection shall be similar to that above described for tooled finish, but finer grained in texture. The sand blasting must be done by means of approved equipment and in such manner as to produce an even, fine grained surface in which the mortar has been cut away, leaving the aggregate particles exposed.

(e) **Wire Brush or Scrubbed Finish.** This type of finish shall be produced by scrubbing the surface of a green concrete with stiff wire or fiber brushes, using a solution of muriatic acid in the proportion of one (1) part acid to four (4) parts water. As soon as the forms are removed and while the concrete is yet comparatively green, the surface shall be thoroughly and evenly scrubbed as above described until the cement film or surface is completely removed and the aggregate particles are exposed, leaving an even pebbled texture, presenting an appearance grading from that of fine granite to coarse conglomerate, depending upon the size and grading of aggregate used. Granite chips or colored aggregates may be used in this connection if desired. As soon as the scrubbing has progressed sufficiently to produce the texture desired, the entire surface shall be thoroughly washed with water, to which a small amount of ammonia has been added, to remove all traces of the acid.

244. **Concrete Sidewalks.** Concrete sidewalks shall be built in the location and to the form and dimensions shown on the plans. The sidewalks shall be built of Class "A" concrete and the materials, forms, equipment, method of mixing, placing, curing, etc., shall be in accordance with the requirement given elsewhere herein. They shall be finished to a smooth, even surface by the use of wood floats or other approved means and any surface irregularities exceeding one-quarter (¼) inch as revealed by the application of a ten (10) foot straight edge shall be corrected before the concrete has attained its initial set. The surface shall be grooved and divided into rectangles as directed. At transverse joints and exposed edges, the edges of the walk shall be finished with an edging tool of one-quarter (¼) inch radius.

245. **Drainage and Weep Holes.** Drainage openings and weep holes shall be constructed in the manner and where indicated on the plans, or directed, and no additional allowance will be made for such work, nor for furnishing and placing such pipes and broken stone as may be necessary to complete such weepholes, except that no deduction will be made for such openings having a surface area of less than nine (9) square feet in payment for this concrete.

246. **Placing Pipes and Conduits.** Pipes and conduits which are to be carried by the structures as shown on the plans or as ordered shall be placed by the Contractor during construction. Such pipes and conduits will be delivered to

the Contractor unless otherwise stated, at the site of the structure by the Department or by other Departments or persons for whose use they are intended. Payment for placing these pipes and conduits shall be by arrangement between the Contractor and the Department or persons owning the pipes.

247. **Placing Anchors, Bolts, Grillages, Etc.** The Contractor shall place all anchors, bolts, grillages, etc., securely and accurately in the locations shown on the plans or as otherwise required. No compensation will be made for placing such anchors, bolts, grillages, etc., as may be furnished at the bridge site by the Department. The cost of those included in the approximate estimate for the "Structural Steel and Iron" items will be included in the contract prices for those items. No deduction will be made for the volume of concrete occupied by any of the materials specified above.

248. **Basis of Payment.** The concrete will be paid for at the contract unit price per cubic yard for "Class 'A' Concrete," "Class 'B' Concrete," "Class 'C' Concrete" or "Class 'D' Concrete" as the case may be, complete in place, which price will include the cost of all equipment, tools, material, except Portland Cement which will be paid for as specified in Paragraph 85, and all falsework, forms, bracing, labor, surface finish and all items required to complete the concrete work shown, except reinforcing steel, expansion plates, or other metal. Unless otherwise provided, payment for concrete will include the cost of scuppers and drains. Payment will be made on the basis of the actual yardage within the neat lines of the structure as shown on the plans or revised by authority of the Engineer except that no deduction will be made for panels less than one and one-half (1½) inches in depth nor for the volume of reinforcing bars nor for the volume of structural shapes when used in encasement work nor for the volume occupied by culvert or drainage pipes having an exposed surface area of less than nine (9) square feet. If a bid is asked on handrail, that portion of the railing above the top of the curb shall not be included in the yardage of concrete, but shall be paid for as handrail. Unless otherwise provided, the reinforcement in railings shall be paid for as reinforcement and shall not be included in the cost of the railing.

Expansion joints will not be paid for directly except that where their construction involves the use of steel reinforcement, structural steel shapes or premoulded joint filler, these materials will be paid for at the contract unit prices per

pound or per square foot as the case may be, complete in place including all incidental expense. Where metal flashing or similar construction is specified, the cost of furnishing and placing this material will not be paid for directly but shall be considered as included in the cost of the concrete items.

There shall be no direct payment for the cost of forming keys or construction joints as shown on the plans or as ordered, but the cost of such construction shall be considered as included in the cost of the concrete items. Where steel dowels are used, this material will be paid for under the reinforcement item as provided elsewhere herein.

Concrete sidewalks which are an integral part of the structure, will be paid for at the contract unit prices for the class of work performed. There shall be no additional compensation for surface finish, edging joints or other incidental work.

Where concrete sidewalks are placed on a fill or base course and do not constitute a supporting part of the structure, they will be paid for at the contract unit price per square foot for "Concrete Sidewalks" complete in place including all materials except Portland Cement, tools, equipment, labor and work incidental thereto. Portland Cement will be paid for as specified above. The cost of gravel, cinder or earth fill or base for concrete sidewalks shall be included in the contract unit price for the sidewalk.

REINFORCEMENT.

249. **Description.** All reinforcement for concrete structures shall consist of deformed bars, steel fabric or structural steel shapes as specified.

250. **Materials.** The materials for this work shall conform to the following requirements:—

(a) **Deformed bars** shall conform to the requirements of Paragraph 96 (a).

(b) **Steel Fabric** shall conform to the requirements of Paragraph 96 (c).

(c) **Structural Steel Shapes** shall conform to the requirements of Paragraph 97.

(e) **Expanded Metal** shall conform to the requirements of Paragraph 96 (d).

251. **Order Lists.** Before ordering material, all order lists and bending diagrams furnished by the Contractor shall be approved by the Engineer.

252. **Protection of Material.** Steel reinforcement shall be protected at all times from injury and when placed in the work, shall be free from dirt, mill and rust scale, paint, oil or other foreign substance.

253. **Bending.** The reinforcement shall be bent to the shapes indicated on the plans. When bars are heated for bending, they shall not be heated to a higher temperature than that producing a dark cherry red color. Only competent men shall be employed for cutting and bending, and proper appliances shall be provided for such work.

254. **Placing and Fastening.** Steel reinforcement shall be placed in the exact positions shown on the plans and held securely during the placing of the concrete. In general, all reinforcement shall be placed and securely wired and blocked before placing concrete in any section. All abrupt bends shall be avoided except where one steel member is bent around another. Vertical stirrups shall always pass around the main tension members or be securely attached thereto. All reinforcing metal shall be securely blocked from the forms by means of small mortar cubes or other approved devices.

Before any concrete is placed, all mortar shall be cleaned from the reinforcement.

No concrete shall be deposited until the Engineer has inspected the placing of the reinforcing metal and given permission to place concrete. All concrete placed in violation of this provision shall be rejected and removed.

255. **Splices.** All reinforcement shall be furnished in the full lengths indicated upon the plans. No splicing of bars, except where shown on the plans, will be permitted without the written approval of the Engineer.

Splices which are permitted shall have a length of not less than forty (40) times the nominal diameter of the reinforcement, and shall be well distributed or else located at points of low tensile stress. No splices will be permitted at points where the section is not sufficient to provide a minimum distance of two (2) inches between the splice and the nearest adjacent bar or the surface of the concrete. The bars shall be rigidly clamped or wired at all splices in a manner approved by the Engineer. Sheets of fabric shall overlap each other sufficiently to maintain a uniform strength and shall be securely fastened at the ends and edges.

256. **Basis of Payment.** This material will be paid for at the contract unit price per pound or per square yard, as the case may be, for "Deformed Steel Bars,," "Steel Fabric" "Expanded Metal" or "Structural Steel Shapes" complete in place, which price will include the cost of furnishing, fabricating and placing all reinforcement in the entire structure, including metal in the handrail unless otherwise provided. In the case of structures of reinforced concrete where there are no structural steel bid items, such minor metal parts as expansion joints, bolts and the like shall, unless otherwise specified, be paid for at the price bid for deformed bars.

Payment shall be made per pound or per square yard for all the reinforcement actually in place as shown on the plans or as ordered by the Engineer. The weight paid for shall be the theoretical weight or the inspector's certified shipping weight as may be specified. In the latter case no allowance will be made for any over-run in weight greater than five (5) per cent. of the theoretical weight. No payment will be made for any fastening devices that may be used by the Contractor for keeping the reinforcement in correct position. In case the Engineer allows the substitution of larger bars than have been specified, payment will be made for only that amount of metal which would have been required if the specified size of bar had been used. In case short bars are used when full length bars might reasonably be required, the weight paid for shall be only that which would obtain if full length bars were used, no allowance being made for laps.

MASONRY FACING.

257. **Description.** This material shall consist of a surface course or facing of masonry of the hereinafter specified quality, applied to the exposed surfaces of concrete structures as a protection or ornamentation. It shall be constructed to the dimensions indicated on the plans or as ordered and in accordance with these specifications.

258. **Materials.** The materials for this work shall conform to the following requirements:—

(a) Stone shall conform to the requirements of Paragraph 78 (b) and shall be either "Dimensioned Masonry Stone" or "Random Ashlar Masonry Stone" in accordance with the provisions of the plans or as ordered.

(b) Mortar for laying the stones and pointing shall be composed of one (1) part of Portland cement conforming to the requirements of Paragraph 85 and two (2) parts of mortar sand conforming to the requirements of Paragraph 83 (b).

(c) Water shall conform to the requirements of Paragraph 86.

(d) Lead for pointing joints exposed to salt water shall be in accordance with standard commercial specifications and of a quality satisfactory to the Engineer.

259. Backing. The backing for masonry facing shall consist of concrete of the class specified on the plans or as ordered and shall conform to the requirements given elsewhere herein for Concrete. In general the backing shall not be placed until the masonry facing and any required dowels or tie bars have been properly placed. The work may be carried on in successive layers or lifts as permitted by the Engineer. Care must be taken to prevent any movement of masonry already in place during the placing and compaction of the backing. When required, the masonry facing stone shall be supported by such bracing and form work as the Engineer may require, to prevent the possibility of movement during the placing of the backing.

260. Mixing Mortar. The mortar shall be hand or machine mixed as may be required by the Engineer. In the preparation of hand-mixed mortar, the sand and cement shall be thoroughly mixed together in a clean, tight mortar box until the mixture is of uniform color, after which clean water shall be added in such quantity as to form a stiff paste. Machine mixed mortar shall be prepared in an approved mixer and shall be mixed not less than one and one-half (1½) minutes. Mortar shall be used within forty-five (45) minutes after mixing. Retempering of mortar will not be permitted.

261. Laying Stone. Stone masonry shall not be constructed in freezing weather or when the stone contains frost, except by written permission of the Engineer and subject to such conditions as he may require.

"Dimensioned Stone" shall be carefully placed in accordance with the provisions of the approved plans. "Random Ashlar Stone" shall be so placed as to produce the general effect shown on the plans and its appearance shall be subject to the approval of the Engineer.

Cofferdams shall be so maintained that the masonry is not exposed to the action of running water until such time as the mortar has attained a strength sufficient, in the opinion of the Engineer, to prevent injury to the work from such exposure.

Stone shall not be dropped on or slid over the wall, but shall be carefully set without jarring stone already laid and shall be handled with a lewis or other appliance which will not cause disfigurement.

Each stone shall be cleaned and thoroughly saturated with water before being set. All stones shall be well bedded in freshly made mortar and settled in place with a suitable wooden maul before the setting of the mortar. Whenever possible the face joints shall be properly pointed before the mortar becomes set. Joints which cannot be so pointed shall be prepared for pointing by raking them out to a depth of two (2) inches before the mortar has set. The face surfaces of stones shall not be smeared with the mortar forced out of the joints or that used in pointing. No hammering, rolling or turning of stones will be allowed on the wall. No pinning up of stones with spalls will be permitted and no spalls will be permitted in beds.

Headers shall bond with the core or backing, shall hold in the heart of the wall the same size shown in the face and shall be spaced not further apart than eight (8) feet center to center. There shall be at least one header to every two stretchers.

Joints and beds shall be not less than three-eighths (⅜) of an inch nor more than one (1) inch in thickness.

Headers shall be placed over stretchers and, in general, the headers of each course shall approximately divide the spaces between the headers of adjoining courses, but no header shall be placed over a joint and no joint shall be made over a header.

262. **Leveling Courses.** Backing shall be carried up to the approximate level of the face course before the succeeding course is started.

The construction joints produced in concrete cores or backing by the intermittent placing of concrete shall be located, in general, not less than six (6) inches below the top bed of any course of masonry.

263. **Resetting.** In case any stone is moved or the joint broken, the stone shall be taken up, the mortar thoroughly cleaned from bed and joints, and the stone reset in fresh mortar.

264. **Dowels and Ties.** The method of fastening the stone together or to the backing by means of metal dowels or ties shall be as indicated on the plans.

265. **Copings.** Stones for copings of walls, piers and abutment bridge seats shall be carefully selected.

Joints in copings shall be located so as to provide not less than a twelve (12) inch bond with the stones of the under course and so that no joint will come directly under the superstructure masonry plates.

266. **Pointing.** Pointing shall not be done in freezing weather or when the stone contains frost.

Joints not pointed at the time the stone is laid shall be thoroughly wet with clean water and filled with mortar. The mortar shall be well driven into the joints and finished with an approved pointing tool. The wall shall be kept wet while pointing is being done and in hot or dry weather the pointed masonry shall be protected from the sun and kept wet for a period of at least three days after completion.

After the pointing is completed and the mortar set, the wall shall be thoroughly cleaned and left in a neat and workmanlike condition

(a) **Lead Pointing** shall be done when called for on the plans or Special Provisions. In general, all joints which are exposed to the action of salt water shall be leaded. The joints shall be cleaned out as specified above for mortar pointing, filled with lead which shall be firmly driven into the joints so as to completely seal all openings, and then finished with an approved pointing tool.

267. **Method of Measurement.** Where the masonry facing is backed with concrete, the quantities to be paid for under these items shall be determined by assuming that the facing has the average thickness stated on the plans. For railings and similar construction, where there is no concrete backing and the construction is solid masonry, the actual dimensions of the finished work shall be used in determining the quantities.

268. **Basis of Payment.** This work shall be paid for at the contract unit price per cubic yard for "Dimension Stone Masonry" or "Random Ashlar Stone Masonry" respectively. The quantity of stone masonry to be paid for under this item shall be measured as hereinbefore described and the limiting dimensions shall not exceed those shown upon the plans or fixed by the Engineer. The contract price shall include all labor, tools, materials and other expense incidental to the

satisfactory completion of the work except that metal dowels or ties, when used, will be paid for at the contract unit price per pound for the kind of metal used. Lead, used for pointing will not be paid for directly but its cost must be included in the general cost of the masonry items. The cost of drilling holes for ties or dowels shall be considered as included in the general cost of the work.

CEMENT RUBBLE MASONRY.

269. **Description.** Cement Rubble Masonry shall be composed of approved stone, laid in full mortar beds, and constructed in such shapes and at such places as indicated on the plans or where directed, in accordance with these specifications.

270. **Materials.** The materials for this work shall conform to the following requirements:—

(a) Stone shall conform to the requirements of Paragraph 78 (a).

(b) Mortar shall conform, as regards materials, proportions and mixing, to the mortar specified for "Masonry Facing."

(c) Water shall conform to the requirements of Paragraph 86.

271. **Headers.** Headers shall hold in the heart of the wall the same size shown in the face and shall extend not less than 12 inches into the core or backing. They shall occupy not less than one-fifth of the face area of the wall and shall be evenly distributed. Headers in walls two feet or less in thickness shall extend entirely through the wall.

272. **Shaping Stone.** The stones shall be roughly squared on joints, beds and faces. Selected stone, roughly squared and pitched to line, shall be used at all angles and ends of walls. If specified, all corners or angles in exterior surfaces shall be finished with a chisel draft.

All shaping or dressing of stone shall be done before the stone is laid in the wall and no dressing or hammering which will loosen the stone will be permitted after it is placed.

273. **Laying Stone.** Stone masonry shall not be constructed in freezing weather or when the stone contains frost, except by written permission of the Engineer and subject to such conditions as he may require.

454. **Basis of Payment.** This work will be paid for at the contract unit price per linear foot for "Straight Five (5) Inch Stone Curbing," "Straight Six (6) Inch Stone Curbing," "Straight Eight (8) Inch Stone Curbing," "Curved Six (6) Inch Stone Curbing," or "Curved Eight (8) Inch Stone Curbing," as the case may be, complete in place, which price will include all materials, equipment, tools, labor and work incidental thereto, also all drainage openings, excavation for the curbing, refilling and disposal of surplus material.

RESET CURBING

455. **Description.** Reset curbing shall consist of the readjustment or resetting of the existing curbing to line and grade given and cementing the joints in accordance with these specifications.

456. **Materials.** All existing curbing which is acceptable, shall be used. No curbing less than four (4) feet in length shall be used. The mortar for pointing shall be composed of one (1) part of Portland Cement, meeting the requirements of Paragraph 85, and two (2) parts of approved sand.

457. **Construction Methods.** The existing curbing shall be readjusted in a satisfactory manner, suitable material being tamped thoroughly under and around it.

Where necessary curbing shall be removed, all unacceptable material being disposed of as directed, the subgrade shaped to the required elevation and the acceptable curbing reset on a firm, compact foundation.

Joints shall be cemented and refilling shall be done in accordance with the requirements for new stone curbing.

458. **Basis of Payment.** This work will be paid for at the contract unit price per linear foot for "Reset Curbing" complete in place, which price will include all materials, equipment, tools, labor and work incidental thereto, also all necessary excavation, refilling and disposal of surplus material.

RAILINGS AND FENCES.

CONCRETE BRIDGE RAIL.

459. Description. This railing shall consist of concrete and reinforcement when required, built in accordance with the details and dimensions given on the plans or as ordered and in conformity with these specifications.

460. **Materials.** The materials for the concrete shall be as specified in Paragraph 227 for Class "C" concrete and the reinforcement shall be as specified in Paragraph 250.

461. **Construction Methods.** All forms shall be carefully and accurately made of smooth surfaced lumber, free from all knots or rough places, or of metal which presents a smooth surface having the desired contour. At all sharp corners one of the surfaces shall be given a small draw or bevel in order that the forms may be easily removed without injury to the corner.

The concrete shall be mixed and placed as specified in Paragraphs 228 to 231 inclusive and the reinforcement as specified in Paragraph 249 to 255 inclusive. All exposed surfaces shall be given a "rubbed" finish as specified in Paragraph 243, except that when called for on the plans, certain panels of the railing shall be given a "tooled" finish.

Suitable provision for expansion shall be made by constructing expansion joints of the type and in the locations shown on the plans.

Particular care shall be taken to secure an exceptionally good appearance on this class of work and to insure this result the Engineer will insist upon the best possible materials and workmanship at all stages.

462. **Basis of Payment.** This work will be paid for at the contract unit prices per linear foot for "Concrete Bridge Rail" and per pound or per square yard for "Reinforcement" in place complete, which price will include furnishing and placing all necessary concrete and reinforcement, forms, expansion joints and materials, except Portland cement which will be paid for as specified in Paragraph 85, finishing and miscellaneous work, together with all equipment, tools and labor incidental thereto.

IRON BRIDGE RAILING.

463. **Description.** This railing shall consist of approved iron or steel pipe and malleable iron fittings or a combination of iron or steel pipe, malleable iron fittings and steel flats or other structural steel shapes as may be shown on the plans, erected on the parapets of bridges, or elsewhere as directed and in accordance with these specifications.

464. **Materials.** The pipe and fittings shall conform to the requirements of Paragraph 111.

Structural steel shapes shall conform to the requirements of Paragraph 97.

Paint shall conform to the requirements of Paragraph 117 for the quality of paint specified by the Department.

465. **Construction Methods.** The railing shall be accurately fabricated in accordance with the requirements of the plans. After fabrication it shall be thoroughly painted with one (1) coat of red lead and oil and any parts which cannot be reached by the brush after the railing is assembled shall be painted before being placed in position. All pipe joints shall be thoroughly leaded before being assembled. Provisions shall be made for expansion as shown on the plans.

The railing shall be erected and fastened in position as shown on the plans or as ordered. It shall be brought to a true alignment both horizontally and vertically and shall be firm and substantial.

After erection it shall be painted with two (2) coats of paint of the quality specified by the Engineer which shall be brushed in thoroughly so as to fully cover all exposed parts of the railing.

466. **Basis of Payment.** This work will be paid for at the contract unit price per linear foot for "Iron Bridge Railing," complete in place, which price will include all materials, tools, labor, equipment, paint and painting incidental thereto.

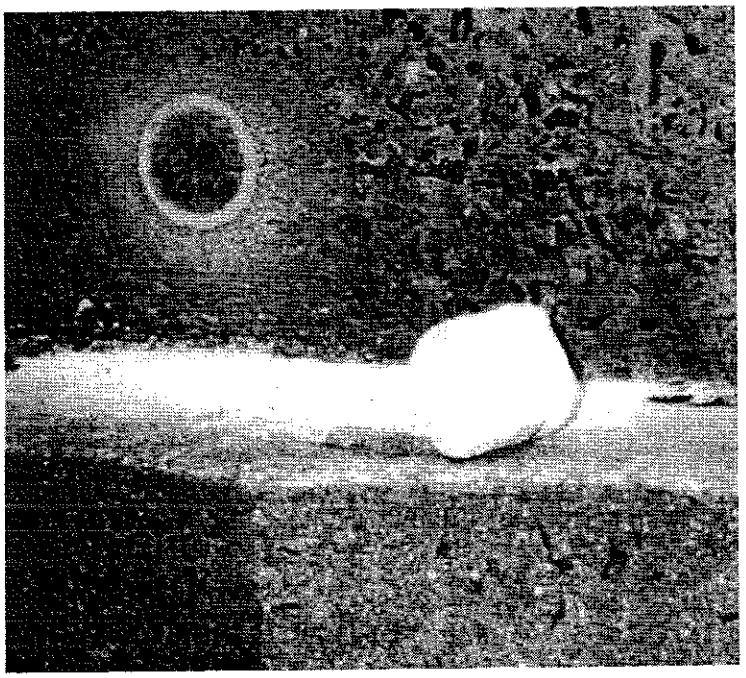
STONE WALL FENCES.

467. **Description.** Stone wall fences shall be composed of approved rubble stone laid without the aid of mortar so as to fit neatly and firmly, and shall be constructed in such places as indicated on the plans or where directed and in accordance with these specifications.

Unless otherwise directed all existing stone wall fences within the limits of the highway shall be removed as directed and fences so removed shall be rebuilt, if required, in the location shown on the plans or as ordered. All stone wall fences thus rebuilt shall conform to the requirements of these specifications.

468. **Stone.** All stone for this work shall be rubble stone of suitable size and of a quality satisfactory to the Engineer. Small stones may be used for pinning and for interstices in the heart of the wall.

4.4 CONCRETE ANALYSES & REPLICATION RECOMMENDATIONS MERRITT PARKWAY BRIDGES



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October 29, 1996

INTRODUCTION TO THE STUDY

At the request of Swanke Hayden Connell Architects, concrete cores taken from four bridges on the Merritt Parkway in Connecticut were studied to determine their original composition and deterioration processes in order to formulate accurate replication concrete mixes and concrete repair mixes. Two types of analysis, wet-chemical and petrographic microscopic, were executed as part of this study. The four concrete cores were analyzed via standard wet-chemical techniques by Jablonski Berkowitz Conservation, Inc. in our laboratory. Four additional samples were examined petrographically by Steven Stokowski of Stone Products Consultants of Ashland, MA.

The bridges studied were (identified by name and their CONDOT number): South Avenue-Route 124 #712, East Rocks Road #723, Merwins Lane #735 and Burr Street #739. All of the cores were taken by Swanke Hayden Connell and supplied to Jablonski Berkowitz Conservation, Inc. Together these concrete analyses will provide a basic characterization of the historic concrete types and aggregates originally used on the four bridges, information which is essential in the formulation of appropriate replication and patching mixes.

Wet-Chemical Analysis allows for the separation of hardened concrete into its component parts, or at least the acid indigestible components. Once this separation of aggregate from its binder or cementitious matrix (Portland Cement) is accomplished, the aggregates (sand and crushed rock) present can be easily studied. This method of analysis also yields basic information regarding the mix such as the approximate weight percents of ingredients and their solubility in acid.

The **Petrographic Analysis** of Hardened Concrete was carried out according to ASTM C-856 and with ASTM C-457 Microscopic Determination of Air-Void Content and Parameters of the Air-Void System in Hardened Concrete. These microscopic analyses are qualitative and semi-quantitative visual surveys of the concrete cores. Reflected, plain and cross polarized light microscopy are all used to identify mineralogy, texture, and void content of thin sectioned epoxy impregnated samples from each core. Original components of the concrete can be identified, as well as damage to the concrete from various factors including, sulfate attack, freeze-thaw cycling and alkali-aggregate reactivity.

The combined analyses provided the information necessary to formulate accurate, aesthetically acceptable and physically compatible replication mixes for each of the bridges. Historic or original materials (coarse and fine aggregates) were located for use in the mixes where possible. Improvements in concrete's resistance to weathering, namely air-entrainment, have however been incorporated into the replication mix design for more durable concrete.

METHODOLOGY OF WET-CHEMICAL ANALYSIS:

Under 20X magnification freshly broken surfaces of each sample core were examined. Using natural daylight. The binder of each sample was matched to a color standard of the Munsell Color Chart (as per ASTM-1535 Specifying Color by the Munsell System). The examination also included separating the concrete samples into three components: the acid-soluble fraction, the "fines" (i.e. pigment, clay or cement residue), and the aggregate or sand fraction. The separation was accomplished via wet-chemical techniques. The acid-soluble fraction was removed by digestion with 3M Hydrochloric Acid. Levigation and filtration were then used to separate the "fines" from the aggregate (sand) fraction. Percent weights were then calculated for further assessment. The color of the "fines" of each sample was matched to the Munsell Soil Color Chart.

The predominating colors and shapes of sand grains were noted during examination of the aggregate fraction. Only one sieve analysis was performed, because the incomplete dissolution of the extremely hard concrete rendered the measurement of grain size for the fine sand impossible by this method. The undigested Portland cement encircled the sand grains, effectively increasing their grain size and invalidating the sieving procedure.

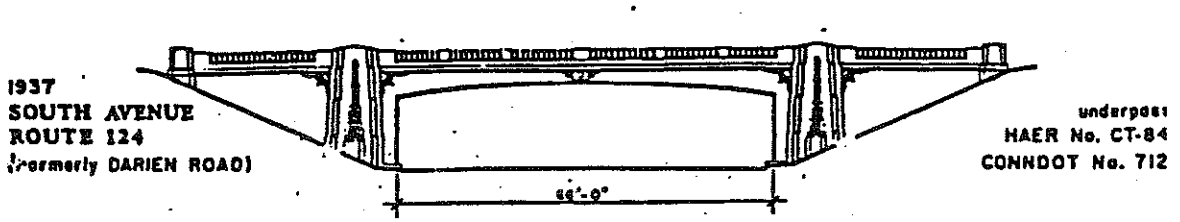
RESULTS OF WET-CHEMICAL ANALYSES

Results of the four wet-chemical analyses are on the following pages, by Bridge number and name. Below can be found a summary of weight percents obtained in the analyses.

Table 1. Comparison of Values Obtained in Wet-Chemical Analysis.

Bridge #	Acid Solubles	"Fines"	Aggregate
#712	29%	8%	63%
#723	33%	5%	62%
#735	23%	5%	72%
#739	32%	7%	61%
Average	29.25 %	6.25 %	64.5 %

Concrete Analyses - Merritt Parkway Bridges 10/9/96



Sample # 712 - South Avenue, New Canaan, CT (1937):

General Description: In cross-section the concrete matrix appears white (Munsell 10YR 8/1) in color. Examination would suggest that the binder in this concrete was a light grey Portland Cement. The binder of a freshly broken section is lighter than the exposed face of the sample core. The outer 1/4" of the core consists of a slightly different "phase", with visible fine aggregate of a concrete grade. This weathered and eroded face is covered with green algae. The core is rich in coarse and fine aggregate, crushed traprock (basalt) 1 - 1/4", and variably sized fine natural sand, well blended throughout. The core sample measures approximately 2" in diameter.

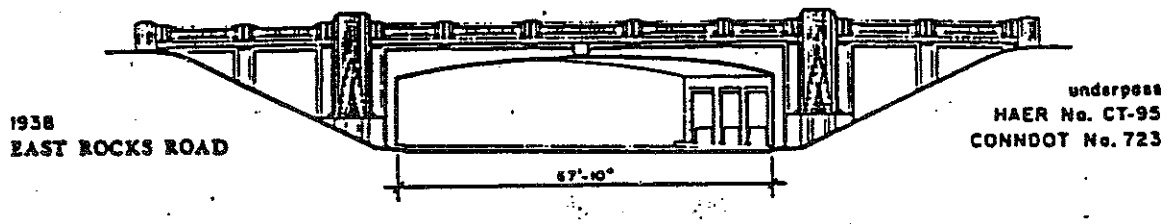
Components:

acid-soluble fraction - 29 % of the total sample weight. Little reaction with the evolution of a small quantity of gas upon the addition of acid to the crushed sample suggests that the binder (cement) contains a small fraction of lime added during the manufacturing process as crushed limestone or lime.

"fines" - 8 % of the total sample weight. "Fines" are light brownish grey (Munsell 10YR 6/2) in color. These colored "fines" would indicate that no colorant or pigment was originally added to the mix.

aggregate - 63 % of the total sample weight. Overall color of the sand fraction is white, with fine aggregate comprised of coarse (2mm) to fine (1/8mm) sized sand grains. Grains are predominantly quartz, and feldspar and are sub-angular in nature.

Concrete Analyses - Merritt Parkway Bridges 10/9/96



Sample # 723 - East Rocks Road, Norwalk, CT (1938):

General Description: In cross-section the concrete matrix appears white (Munsell 10YR 8/1) in color. Visual examination would suggest that the binder was light Portland Cement. The binder of a freshly broken section is lighter than the exposed face of concrete sample. The face (outer 1/8") of the core is largely intact and unweathered, and still covered with a cement paste containing a finer aggregate, mason's grade. The core is rich in coarse crushed stone aggregate, which is traprock (basalt) measuring 3/4". Fine aggregate is a variably sized fine white sand, well blended throughout. The sample core measures 2" in diameter.

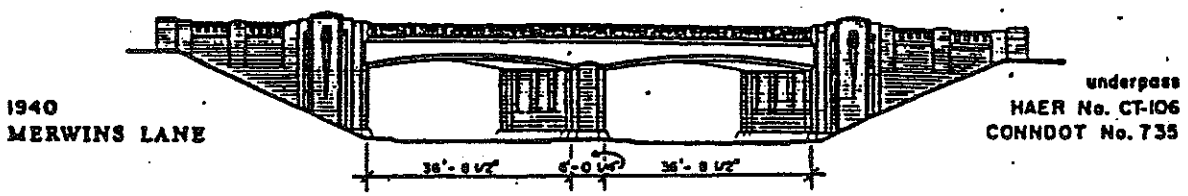
Components:

acid-soluble fraction - 33 % of the total sample weight. The brief reaction with evolution of gas upon the addition of acid to the crushed sample suggests that the binder contained only lime added as part of the Portland cement manufacturing process.

"fines" - 5 % of the total sample weight. The "fines" are very pale brown (Munsell 10YR 7/3) in color. It does not appear that any colorant was added to the mix.

aggregate - 62 % of the total sample weight. Overall color of the sand fraction is white, with fine aggregate comprised of coarse (2mm) to fine (1/8mm) sized sand grains. Grains are predominantly quartz and feldspar and are sub-angular in nature. This sand was derived from a pit.

Concrete Analyses - Merritt Parkway Bridges **10/9/96**



Sample #735 - Merwins Lane, Fairfield, CT (1940):

General Description: In cross-section the matrix appears white (Munsell 10YR 8/1) in color. Examination would suggest that the binder was comprised of Portland Cement. The binder of a freshly broken section is lighter than the exposed face of the sample core. The exposed face is covered with green algae which sits on a thin (1/8") zone of slightly weathered cement with fine aggregate only. The core is rich in coarse and fine aggregates, with variably sized fine sand well blended throughout. The coarse aggregate is traprock (basalt) which measures 1 - 1 1/4". The sample measures 2" in thickness.

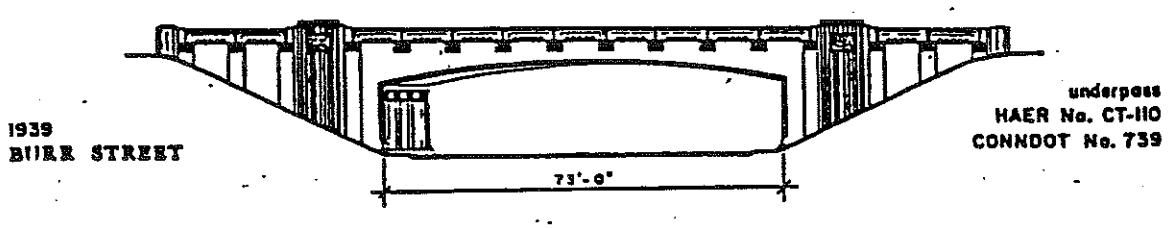
Components:

acid-soluble fraction - 23 **%** of the total sample weight. The brief reaction with evolution of gas upon the addition of acid to the crushed sample suggests that the binder contained little to no lime, except for that added as part of the Portland Cement manufacturing process.

"fines" - 5 **%** of the total sample weight. The "fines" are light grey (Munsell 10YR 7/2) in color. The fines indicate that no colorant was added to the mix.

aggregate - 72 **%** of the total sample weight. Overall color of the sand fraction is white, with this fine aggregate comprised of coarse (2mm) to fine (1/8mm) sized sand grains. Grains are predominantly quartz, and feldspar and are sub-angular in nature indicating that it was quarried from a pit.

Concrete Analyses - Merritt Parkway Bridges 10/9/96



Sample # 739 - Burr Street, Fairfield, CT (1939):

General Description: In cross-section the concrete matrix appears white (Munsell 10YR 8/1) in color. Examination would suggest that the binder is comprised of Portland cement. The binder of a freshly broken section is lighter than the exposed face of the sample core. The exposed or outer face is covered with a slightly weathered cement paste containing a finer mason's grade aggregate. The concrete core is rich in coarse aggregate, which is referred to as Traprock (basalt), and sized from 1 - 1 1/4". The fine aggregate is white, with variably sized, sand well blended throughout. The sample measures 2" in thickness.

Components:

acid-soluble fraction - 32 % of the total sample weight. The brief reaction with evolution of gas upon the addition of acid to the crushed sample suggests that the binder contained little to no lime, except for that added as part of the Portland Cement manufacturing process.

"fines" - 7 % of the total sample weight. The "fines" are light brownish grey (Munsell 10YR 6/2) in color. It appears that no colorant was added to the mix.

aggregate - 61 % of the total sample weight. Overall color of the sand fraction is white, with fine (1/8mm) aggregate comprised of fine to coarse (2mm) sand grains. Grains are predominantly quartz, with feldspar present and are sub-angular in nature, indicating that they were quarried from a pit.

WET-ANALYSIS CONCLUSIONS

All four concrete cores were found to be quite similar in composition. Three cores contained the same crushed stone coarse aggregate (traprock) in the 3/4" - 1 1/4" range. The different core, # 723, contains the same traprock, but of a slightly smaller size (3/4"). The crushed rock is basalt, quite finely grained. The weight percentages of acid solubles, fines, and aggregates were calculated and are quite similar. The slight range in numbers would be expected from location to location or batch to batch variation. The finer aggregate in each of the cores was alike, and probably the same in each core.

None of the concrete cores contained evidence of added pigmentation, but rather were colored with the aggregates and Portland cement components. The acid solubles and aggregate fraction of #735 are slightly out the range of the other three cores, but a small amount of additional aggregate added to one batch would be sufficient to alter the acid soluble fraction slightly.

The only true differences in the cores are in the current surface appearance. Sample #723 retains the smoothest and least weathered surface, and sample #712 the most heavily weathered surface. Core #739 and #735 are quite similar in the appearance of the exposed faces, which are slightly weathered.

It does not appear that any of these cores were ever faced with a pigmented cement or other decorative material. The cores do appear to have been faced with a cement wash containing a mason's grade fine aggregate very similar to that in the body of the mix, but finer in grade. This was standard concrete practice to cover voids and bug holes left from the pouring process.
The "wash" may have been added to cover voids as a slurry coat, or created as part of the finishing process by the rubbing of the concrete surfaces. The paste formed by the rubbed concrete may have been allowed to take a "reset", after which the dried paste formed the new surface finish.

METHODOLOGY OF REPLACEMENT MIX DEVELOPMENT

As accurate replication mixes are difficult to formulate, the type and quantity of materials used are essential to ensure on-site reproduction. As the first step in replication mix development the identification of existing commercial sources for the coarse and fine aggregates. An extensive telephone survey of all traprock suppliers in the lower Hudson Valley Region and southern Connecticut area was conducted. Samples were requested from any supplier indicating that their crushed rock was basalt, available in 3/4" - 1 1/4", and was dark in color, tending toward black when wetted and of a fine texture. Our in-house sand library contained a commercially available match for the concrete sand or fine aggregate used in the body of the concrete, and a match for the finer aggregate in the concrete surface or grout mix. Materials recommended in this report or their equal may be used. If materials are substituted, the resulting appearance of concrete may vary. New concrete will probably be more absorptive as it is newer and less carbonated, and therefore have slightly different wetting characteristics than the historic concrete.

Trial Replication Mixes

Approximately 20 small scale trial batches of concrete were made in the laboratory in the effort to best match the inner appearance and exterior surface appearance of the four client supplied cores. The Type I grey Portland cements used were: Hercules, Lehigh, Allentown, and Norval (white and grey). Coarse aggregate used was Balf Quarry 3/4" Traprock, and fine aggregates were George Schofield (#181 & #180) and New Jersey Pulverizing Company's 1/8" pea gravel and 1/4 sand.

GENERAL REPLICATION CONCLUSIONS

Base Concrete

The mix should be made from the historic proportions and materials, with adjustments made for modern air-entrainment technology. The recommended concrete should achieve a compressive strength of 4000 psi in 28 days. It can be made with buff grey Portland cement, Type I, or with a blend of Type I White and Grey cements, coarse aggregate of crushed basalt (such as supplied by Balf) known as traprock (3/4" - 1 1/4"), with a finer aggregate of concrete sand (such as #181 supplied by Schofield), no added pigmentation, but with admixtures for air-entrainment (approximately 5 1/2%) and water reduction. Concrete should be mixed to match that being treated or replicated in color, aggregate types, and concentration.

A **general base mix** to achieve nine cubic feet (9 ft^3) of concrete is as follows:

618 lbs. coarse aggregate
489 lbs. finer aggregate
175 lbs. Portland Cement, Type I
9.44 gallons of potable water

Surface Coat

The surface grout or wash should be made of a Type I Portland Cement chosen specifically for color of concrete produced and sand to match that contained in the surface to be replicated, and watered to a "paintable" or brushable consistency. Sand that matches the existing sand (seen on the surface or isolated during analysis) in color, grain size and shape should be used. Type I Portland cements can be blended to achieve concrete colors to match those to be treated. As is standard procedure, dry components should be premixed. After concrete is poured and set, it should be rubbed to the desired smoothness and rinsed down. The grout or mason's sand mix can be applied by brush to cover all new and old surfaces. The mason's sand\Portland mix should be brush applied as desired to replicate historic or existing surface finishes and rubbed, floated or brushed to match that being treated.

A general base mix for **slurry or surface coat** for concrete is as follows:

175 lbs. Portland Cement, Type I
440 lbs. fine aggregate
water to achieve desired consistency

Pigmentation if added to achieve a match with the historic material, should never exceed 10% of the weight of the cement.

Replication Mixes For The Bridges #712, South Avenue, #723 East Rocks Road, #735 Merwin Lane, #739 Burr Street.

Bridge #712 South Avenue -

Surface Mix: Mix #1B or 4, plus a drizzle of Schofield #181, and N.J. Pulverizing 1/8 pea gravel.

Portland Cement: Keystone Grey, Type I, 33 lbs.
Norval White, Type I, 140 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: to achieve desired consistency
Pigmentation: none.

Body Mix: Mix #4.
Portland Cement: Keystone Grey, Type I, 33 lbs.
Norval White, Type I, 140 lbs.
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Bridge #723 East Rocks Road -

Surface Mix: Mix #1A.

Portland Cement: Keystone Grey Type I, 175 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: to desired consistency
Pigmentation: none.

E. Rocks Rd. cont.

Body Mix: Mix # 2.
Portland Cement: Allentown Grey Type I, 173 lbs.
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Bridge #735 Merwins Lane -

Surface Mix: Mix # 1A or 2, plus a drizzle of Schofield #180.

Portland Cement: Allentown Grey Type I, 173 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: to desired consistency
Pigmentation: none.

Body Mix: Mix # 3.
Portland Cement: Keystone Grey, Type I, 63 lbs.
Norval White, Type I, 110 lbs
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Bridge #739 Burr Street -

Surface Mix: Mix # 2, plus a drizzle of Schofield #180.

Portland Cement: Allentown Grey Type I, 173 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: to desired consistency
Pigmentation: none.

Body Mix: Mix # 3.
Portland Cement: Keystone Grey, Type I, 63 lbs.
Norval White, Type I, 110 lbs
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Recommended Replication Mixes

Mix 1A. Portland Cement: Keystone Grey Type I, 175 lbs.
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Mix 1B. Portland Cement: Norval White, Type I, 149 lbs.
Norval Grey, Type I, 26 lbs.
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs
Water: 9.44 gallons
Pigmentation: .85 lbs Burnt Umber
2.10 lbs. Raw Sienna

Mix 2. Portland Cement: Allentown Grey Type I, 173 lbs.
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Mix 3. Portland Cement: Keystone Grey, Type I, 63 lbs.
Norval White, Type I, 110 lbs
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Mix 4. Portland Cement: Keystone Grey, Type I, 33 lbs.
Norval White, Type I, 140 lbs.
Coarse Aggregate (Balf): 600 lbs.
Fine Aggregate (Schofield #181): 480 lbs.
Water: 9.44 gallons
Pigmentation: none.

Recommended Materials and Suppliers (or equal)

Coarse Aggregates

The closest crushed basalt or traprock match was located in Connecticut, at Balf of 301 Hartford Avenue, P.O. Box 310903, Newington, CT 06131, (860)549-3200. The next closest match was provided by Tilcon Connecticut (formerly The New Haven Trap Rock Company), North Branford Quarry, P.O. Box 1357, New Britain, Connecticut 06050, (203) 223-3651.

Fine Aggregates

The fine aggregates or sands are described below and are available from George Schofield Co. Inc., P.O. Box 110, Bound Brook, NJ 08805, (201)356-0858. A concrete grade white sand (#181) with milky, clear quartz particles, with variable sized and sub-angular grains. A mason's grade white sand (#180) with milky, clear quartz particles, and variable sized and sub-angular grains. The New Jersey Pulverizing Co, 1140 Close Avenue, Bronx, NY, (718) 378-0200, carries 1/8" Pea Gravel, and 1/4 sand. These aggregates meet ASTM-C33 requirements.

Portland Cements

Several light (white, grey, buff-grey) colored Portland Cements, all Type I, are recommended for use in the replication concrete mixes. Grey and white cements should be blended to achieve the desired historic coloration. Keystone, Type I Grey is very buff in color (typical of the Pennsylvania Region cements) and is recommended as the closest to the original in color of concrete produced. Keystone Cement Co., is located in Bath, PA, telephone number (610) 837-2301. Norval White and Grey Type I cements were used in blended mixes. Norval Inc., is located at Flushing Avenue, Brooklyn, NY. (718) 522-0800. Allentown Grey Type I Cement, Blandon, PA (610) 926-1024.

Added Colorants

If additional coloration or pigments are required to achieve the desired concrete color, then alkali-stable cement colors are recommended. Lansco Colors, sold by the Landers-Segal Company in Passaic, NJ were used in the test batches and are recommended. Call (201) 779-5001.

Admixtures

To achieve the historic appearance with performance qualities adjusted for modern concrete technology, the historic mix should be adjusted to accommodate an air-entraining agent for greater freeze-thaw resistance. It will be necessary to add an air-entraining admixture to this mix, as well as a water reducer. Both are available from the W.R. Grace Company, MA or Master Builders, OH. Exact amounts of these admixtures should be determined in trial batches prior to bulk mixing.

STONE PRODUCTS CONSULTANTS
Aggregates • Concrete
Industrial Minerals • Silica Sand
10 Clark St., Suite A, Ashland, MA. 01721-2145 (508) 881-6364 (phone & fax)

October 7, 1996
SPC Project 96145

RESULTS OF PETROGRAPHIC ANALYSIS

SAMPLE ID:

Concrete samples from the wingwalls of four bridges of the Merritt Parkway Bridges System, near New Canaan, Norwalk, and Fairfield Connecticut. The bridges were built between 1936-1940. The samples consisted of one core, two wedges, and a slab labeled respectively: Bridge 712 - South Ave., Rt. 124, core taken from S.E. elevation wingwall 9/4/96 (herein Sample 712), Bridge 723 - East Rocks Rd., wedge taken from S.W. elevation wingwall 9/4/96 (herein Sample 723), Bridge 735 - Merwin Lane, wedge taken from S.W. elevation wingwall 9/5/96 (herein Sample 735), and Bridge 739 - Burr St., wedge taken from S.W. elevation wingwall 9/5/96 (herein Sample 739). Stone Products Project No. 96145. Jablonski Berkowitz Project No. 09960388. Samples submitted by Ms. Joan Berkowitz, Jablonski Berkowitz Conservation, Inc., New York, NY.

SUMMARY

The concrete has a normal composition. It contains a crushed traprock (basalt) coarse aggregate, natural sand fine aggregate, and Type I Portland cement. The concrete has approximately a 0.49 water/cement ratio, and is not air-entrained. It contains approximately 525 pounds of cement per cubic yard of concrete. Two coarse aggregate sizes were used: 1.25 inch nominal maximum size (Bridges 712, 735 and 739) and 0.75 inch nominal maximum size (Bridge 723). A quarry in the Triassic basalts of the Connecticut River Valley probably supplied the basalt coarse aggregate. The fine aggregate is a white, natural sand. The source area for this type of sand would be a pit in western Connecticut or eastern New York.

The concrete has deteriorated slightly from freeze/thaw. It is not frost resistant because it is not air-entrained. It has not deteriorated because of alkali-silica deterioration or sulfate attack.

PROCEDURES:

Stone Products Consultants examined the samples in accordance with ASTM C 856 (Petrographic Examination of Hardened Concrete). We further examined Sample 739 in accordance with ASTM C 457 because the usable area (32.5 in.^{2}) met the minimum (24 in.^{2}) required for the nominal 1¼" size of the coarse aggregate. Sample 739 served as a standard by which to compare the other samples, and we took the measured proportion values for this sample as the probable mix design values for the rest of samples. The usable areas (6 - 10 in.^{2}) of the finished surface of the specimens from Samples 712, 723, and 735 did not meet the minimum (11 - 24 in.^{2}) required in Table 1. of ASTM C 457 for the nominal ¾"-1¼" size of the coarse aggregate.

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The coarse aggregate was defined as all basalt, with the fine aggregate classification including all white sand. Cement or pozzolan is defined as material below 50μ size. The water/cement ratio was determined by comparison with reference thin sections. Points counted = 508 (#712) 894 (#723) 731 (#735) and 1,530 (#739); required = 1,350 - 1,500.

The samples were sawn and lapped to yield specimens for point-count analysis. We tested a portion of each core with 5% phenolphthalein in 70% isopropyl alcohol to detect any severely carbonated zones. We dyed the surfaces for point-count analyses with red food coloring to help discriminate micro-porosity in the cement paste.

Stone Products Consultants (F. Medina) point counted the cores.

To conduct ASTM C 856 analysis we had a thin (30μ thick) section (27x46 mm and/or 2x3 in.) prepared from a the exterior portion of each sample, with the exception of #723 from which a section was taken of a fragment. To determine the lithology of the coarse aggregate, a thin-section was taken of a large particle herein referred to as sample 735-B. Mineral Optics Lab, Wilder, VT prepared the sections with blue-dyed epoxy to preserve any delicate cement minerals. Stone Products Consultants (S. Stokowski) analyzed the sections.

SAMPLE CHARACTERISTICS & DISCUSSION:

Four concrete samples from the wingwalls of four bridges of the Merritt Parkway Bridges System near New Canaan, Norwalk, and Fairfield, CT. Sample 712 is a core 2.2" in diameter, and 2.2" long. Sample 723 is a wedge 7.3" long, the width tapering from 1.5" at the exterior surface to 0" at ~2" depth. Sample 735 is a rough slab 7.8" long, 0.8" in width, the depth tapering from 1.6" at the top of the sample to 0" at the bottom of the sample. Sample 739 is a wedge 7.7" long, the width tapering from 1" at the exterior surface to 0" at 2.7" depth.

The exterior surfaces of the concrete samples are weathered, the mortar being etched back to expose sand and/or coarse aggregate. Ten to fifteen percent (10 - 15 %) of the surface of sample 723 is coarse aggregate exposed by weathering. The present surfaces of the samples contain some green algae. Scaling and spalling has occurred in samples 712 and 723. The interior surfaces of the samples are saw-cut and/or fractured.

The samples did not intersect any steel reinforcement.

The concrete is slightly carbonated. The concrete shows 2 - 10 mm of carbonation. This degree of carbonation is very low for the age of the concrete.

There are minor secondary deposits of Ettringite in the concrete pores. Ettringite forms normally in concrete; the quantity is not excessive.

Efflorescence deposits did not form on the prepared surface of the specimens. The concrete does not contain extremely large quantities of NaCl, $CaCl_2$, silica gel, etc.

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Table 1. Results of Point-Count Analysis,
Concrete sample 712, South Avenue, Merritt Bridges Pkwy., CT.

Measured, Effective Values

Description	Value
Coarse Aggregate (vol. %)	40.0
Fine Aggregate (vol. %)	33.1
Cement Paste (vol. %)	25.8
Total Air (vol. %)	1.4

Effective cement content, #C/yd.^{3} Ω

w/c = .44	574
w/c = .49Φ	*538*
w/c = .53	513

508 points counted.
Ω@ 3.15 assumed specific gravity
Φestimated w/c

*Probable Design Values**

Description	Value
CA/totalA ratio	0.50
Coarse Aggregate (#/yd.^{3})♣	1,762
Fine Aggregate (#/yd.^{3})♣	1,576
Total Air (vol. %)	1.5

As-batched cement content, #C/yd.^{3}

w/c = .44	615
w/c = .49Φ	*577*
w/c = .53	549

* based upon 50/50 CA/total Aggregate.
♣@ 2.95 CA & 2.64 FA assumed specific gravity
Φestimated w/c

Table 2. Results of Point-Count Analysis,
Concrete sample 723, East Rocks Road, Merritt Pkwy. Bridges, CT.

Measured, Effective Values

Description	Value
Coarse Aggregate (vol. %)	35.1
Fine Aggregate (vol. %)	32.7
Cement Paste (vol. %)	28.9
Total Air (vol. %)	3.4

Effective cement content, #C/yd.^{3} Ω

w/c = .44	642
w/c = .49Φ	*602*
w/c = .53	574

894 points counted.
Ω@ 3.15 assumed specific gravity
Φestimated w/c

*Probable Design Values**

Description	Value
CA/totalA ratio	0.50
Coarse Aggregate (#/yd.^{3})♣	1,664
Fine Aggregate (#/yd.^{3})♣	1,489
Total Air (vol. %)	3.4

As-batched cement content, #C/yd.^{3}

w/c = .44	658
w/c = .49Φ	*617*
w/c = .53	588

* based upon 50/50 CA/total Aggregate.
♣@ 2.95 CA & 2.64 FA assumed specific gravity
Φestimated w/c

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Table 3. Results of Point-Count Analysis,
Concrete sample 735, Merwin Lane, Merritt Pkwy. Bridges, CT.

Measured, Effective Values

Description	Value
Coarse Aggregate (vol. %)	37.9
Fine Aggregate (vol. %)	39.3
Cement Paste (vol. %)	21.8
Total Air (vol. %)	1.1

Effective cement content,
#C/yd.^{3} Ω

w/c = .49	454
w/c = .53Φ	*432*
w/c = .60	399

731 points counted.
Ω@ 3.15 assumed specific gravity
Φestimated w/c

*Probable Design Values**

Description	Value
CA/totalA ratio	0.50
Coarse Aggregate (#/yd.^{3})♣	1,925
Fine Aggregate (#/yd.^{3})♣	1,723
Total Air (vol. %)	1.1

As-batched cement content,
#C/yd.^{3}

w/c = .49	448
w/c = .53Φ	*427*
w/c = .60	394

* based upon 50/50 CA/total Aggregate.
♣@ 2.95 CA & 2.64 FA assumed specific gravity
Φestimated w/c

Table 4. Results of ASTM C-457 Analysis,
Concrete sample 739, Burr Street, Merritt Pkwy. Bridges, CT.

Measured, Effective Values

Description	Value
Coarse Aggregate (vol. %)	37.4
Fine Aggregate (vol. %)	37.7
Cement Paste (vol. %)	23.5
Total Air (vol. %)	1.4

Effective cement content,
#C/yd.^{3} Ω

w/c = .40	553
w/c = .44Φ	*523*
w/c = .49	491

1,530 points counted.
Ω@ 3.15 assumed specific gravity
Φestimated w/c

*Probable Design Values**

Description	Value
Coarse Aggregate (#/yd.^{3})♣	1,866
Fine Aggregate (#/yd.^{3})♣	1,670
CA/totalA ratio	0.50
Total Air (vol. %)	1.4

As-batched cement content,
#C/yd.^{3}

w/c = .40	551
w/c = .44Φ	*522*
w/c = .49	490

* based upon 50/50 CA/total Aggregate.
♣@ 2.95 CA & 2.64 FA assumed specific gravity
Φestimated w/c

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The mortar phase of the concrete specimens is approximately white (Munsell 10 YR 8/1) when dry and gray (Munsell 10 YR 7/1) when wet. These colors are normal.

The coarse aggregate is a crushed stone. The nominal maximum particle size in sample 723 is ¾" and 1 - 1¼" in the other samples. The grading of the coarse aggregate appears normal. The coarse aggregate consists exclusively of basaltic rock types. Most of the basalt has a 0.4 to 0.5 mm grain size of the constituent minerals (plagioclase feldspar, Augite (pyroxene), and Magnetite). The basalt has a sub-ophitic texture (def.: the pyroxene grains enclose some of the plagioclase crystals, but they are generally larger than the pyroxene). The plagioclase is a calcium plagioclase is present as euhedral laths with little zoning. The Augite is not colored, and generally anhedral. The Magnetite is generally anhedral and embayed. In finer-grained varieties of the basalt, the magnetite is dendritic (suggestive the finer grained varieties were derived from the chilled margins of basalt flows or intrusions). The minerals in the basalt are unweathered and unaltered. Alkali-aggregate reactions are not present. A quarry in the Triassic basalts in the Connecticut River Valley probably supplied the coarse aggregate.

The fine aggregate in the concrete contains well-rounded particles of a white natural sand. It appears normally graded and within the ASTM C-33 concrete sand specifications. The larger sizes of the natural sand contain much quartzite. The finer sizes are quartz plus a few other minerals, notably Microcline feldspar. Alkali-aggregate reactions are not present. The mineralogy of the natural sand suggests that the pit for this material came from drainage from the Shaugunk Mountains. This pit may have been located in western Connecticut or eastern New York.

The bond between the aggregate and the cement paste is normal. Excessive dust is not present on the aggregate.

The absolute volumetric proportion of coarse to total aggregate is about 50 percent. This is normal for concrete designed with American Concrete Institute procedures, and suggests that the original design followed these methods.

The concrete is not air-entrained. Most of the air voids are small and sub-spherical, though some are as large as 1 cm in diameter. The measured air contents for the samples (1.1 to 3.4%) are within the expected range for normal non-air-entrained concrete design values.

The cement is a Portland cement. Fly ash or other mineral admixtures are not present. The mineralogy of the Portland cement semiquantitatively contains the usual proportions of Alite (C3S) and Belite (C2S) for a Type I cement. The coarsest grains have a size (105 - 110μ) typical of older Type I cement.

The texture of the concrete indicates that it has a normal water/cement ratio. The paste absorbs blue-dyed epoxy in a similar manner to reference thin sections at known w/c ratio's. The paste also absorbs red food dye well. Water voids are present. Bleed-water channels are uncommon. These features in combination indicate that the water/cement ratio was

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approximately 0.44 - 0.49 . Specimen #735 sampled concrete with a greater w/c ratio, approximately 0.53 .

The cement is well hydrated in each of the specimens. Only a few "Belite knots" contain unhydrated cores of cement. This is normal for concrete over 30 years old.

The effective cement contents per yd.^{3} are probably adequate to achieve a design compressive strength of 4,200 psi @ 28 days. This presumes the normal strength yield of Portland cement of 8-12 psi./lb./yd.^{3} , and a cement content of 525 lb./yd.^{3} (the value for #739, the best sample for these analyses).

S. J. Stokowski Jr.

S. J. Stokowski, Jr. ** Concrete Petrographer

● original
○ non-original

Bridge Restoration Guide for the Merritt Parkway

Basic Bridge Data Including Materials

April 24, 1996

Bridge #	Year Built	Rehab.	Widened	Span (ft.)	Superstructure: Rein. Conc.	Rigid Frame	Steel	Rigid Frame	Rein. Conc.	Arch	Horizontal Steel Frame	Prestressed Conc.	Beam	Horizontal (R.C.)	Slab	Materials: Cast Stone	Masonry	Stone	Masonry	Precast Panels	Concrete	Precast	Ornament	Cast-In-Place	Ornament	Cast Iron	Ornament/Railing	Steel	Ornament/Railing	Wrought Iron	Ornament/ Railing	Aluminum	Railing	Casting	Notes
530 A & B	1937			54 '	●													●			●							○					○	
692	1935	○	○	61 ', 67 '									○								●													
693	1935			52 '	●																●													
694	1935			27.6 '										●							●													
695	1935			69.25 '	●																●													
696	1940			(2) 50 '			●											●			●					●		●						
697	1937			71.6 '	●																●												○	
698	1937			55.5 '					●												●	●												
699	1937	○	○	63.8 '	●																●	●												
700	1937			60 '					●									●			●													
701	1937			(2) 12 '										●							●													
702	1937			64.7 '																	●	●												
703	1936			52 '	●																●													
704	1938			67.6 '	●																●													
705	1936			52 '					●									●			●	●												
706	1937	○		64 '			●														●	●				●		●	●	●				
707	1937	○		62.2 '	●																●													
708	1937			64.8 '	●																●	●												
709	1937	○	○	49.5 '	●																●	●											○	
710	1937			(2) 32 '	●																●													
711	1937	○		62 '									○							○	●			●									○	
712	1937			67.7 '	●																●	●		●										
713	1937	○		69.4 '	●																●			●									○	
714	1937	○		67.7 '									○							○	●	●		●									○	
715	1937	○	○	64 '			●														●	●		●									○	1
716	1938	○		63 '	●																●			●									○	
717	1938			32.7 '	●																●	●												
719	1936			33 '					●												●	●												
720	1937			37 '	●																●													
721	1937	○		(3) 27 '					●												●												○	2
722	1938			79.33 '			●														●			●				●						
723	1938			67.8 '	●																●			●										
724	1938			63.25 '	●																●	●		●				●						3
725	1938			35.7 '					●												●													
726	1937			(2) 46.7 '	●												●				●	●												
727	1938	○	○	61.25 '										○							●												○	
728	1938	○	○	130 '																	●								●				○	4, 5
729	1940			89.5 '			●													●	●	●					●	●	●				○	
730	1938	○	○	48.5 '	●																●												○	
731	1938	○	○	48 '			●														●													
732	1939			63.8 '	●																●	●								●	●			6
733	1939			33.33 '						●											●	●												
734	1938			36.5 '						●											●				●									

Bridge Restoration Guide for the Merritt Parkway

Basic Bridge Data Including Materials

April 24, 1996

● original
○ non-original

Bridge #	Year Built	Rehab.	Widened	Span (ft.)	Superstructure: Rein. Conc.	Rigid Frame	Steel	Rigid Frame	Rein. Conc. Arch	Horizontal	Steel Frame	Prestressed Conc. Beam	Horizontal (R.C.) Slab	Materials: Cast Stone	Masonry	Stone Masonry	Precast Panels	Concrete	Precast Ornament	Cast-in-Place Ornament	Cast Iron Ornament/Railing	Steel Ornament/Railing	Wrought Iron Ornament/ Railing	Aluminum Railing	Coating	Notes
735	1940	○		(2) 40 '	●													●		●	●	●				7
736	1939			71.8 '	●													●								
737	1938			63.4 '	●													●								
738	1940			34.1 '					●									●		●						
739	1939	○		73 '	●													●		●						
740	1938			'	●													●		●						
742	1939			(2) 36.25 '	●													●		●						
743	1940			30 '	●													●								
745	1940			90 '					●									●		●						
746	1939			74.7 '	●													●		●				●		
747	1939			67.7 '	●													●		●						
748	1936			64.6 '	●													●								
749	1942			(2) 49.5 '					●					●				●	●							
750	1939	○		32 '	●													●								8
751	1935			80 '						●								●								9
752	1935	○		86 '								○						●								
753	1934	○	○	48 '						○								●							○	10
754	1940	○		61 '			●											●			●	●				1
756	1940			35.4 '					●									●								
757	1940			48.2 '	●													●	●	●						
759	1940			(2) 38.25 '					●									●	●	●						
760	1940	○		62 '			●										●	●		●	●	●				1

Notes:

1. Under construction at time of inspection.
2. Center span is 32' wide.
3. Original cast brass shields were missing.
4. Superstructure is an arched steel truss.
5. Original ornamental steel railing has been removed.
6. Top rail of bridge railing is extruded aluminum.
7. Railing is hot-dipped galvanized.
8. Steel median extension (alteration).
9. Abandoned railroad overpass.
10. Composite steel and concrete beam structure.

4.6 THE SECRETARY OF THE INTERIOR'S STANDARDS FOR REHABILITATON

(rev. 1990) The Standards (Department of Interior regulations, 36 CFR 67) pertain to historic buildings of all materials, construction types, sizes and occupancy and encompass the exterior and the interior, related landscape features and the building's site and environment as well as attached, adjacent, or related new construction. The Standards are to be applied to specific rehabilitation project in a reasonable manner, taking into consideration economic and technical feasibility.

1. A property shall be used for its historic purpose or be placed in a new use that requires minimal change to the defining characteristics of the building and its site and environment.
2. The historic character of a property shall be retained and preserved. The removal of historic materials or alteration of features and spaces that characterize a property shall be avoided.
3. Each property shall be recognized as a physical record of its time, place and use. Changes that create a false sense of historical development, such as adding conjectural features or architectural elements from other buildings, shall not be undertaken.
4. Most properties change over time; those changes that have acquired significance in their own right shall be retained and preserved.
5. Distinctive features, finished, and construction techniques or examples of craftsmanship that characterize a historic property shall be preserved.
6. Deteriorated historic features shall be repaired rather than replaced. Where the severity of deterioration requires replacement of a distinctive feature, the new feature shall match the old in design, color, texture, and other visual qualities and, where possible, materials. Replacement of missing features shall be substantiated by documentary, physical, or pictorial evidence.
7. Chemical or physical treatments, such as sandblasting, that cause damage to historic materials shall not be used. The surface cleaning of structures, if appropriate, shall be undertaken using the gentlest means possible
8. Significant archeological resources affected by a project shall be protected and preserved. If such resources must be disturbed, mitigation measures shall be undertaken.
9. New additions, exterior alterations, or related new construction shall not destroy historic materials that characterize the property. The new work shall be differentiated from the old and shall be compatible with the massing, size, scale and architectural features to protect the historic integrity of the property and its environment.
10. New additions and adjacent or related new construction shall be undertaken in such a manner that it removed in the future, the essential form and integrity of the historic property and its environment would be unimpaired.

POLICY RESOLUTION PR-2-9
TITLE: NATIONAL HIGHWAY SYSTEM DESIGN STANDARDS

WHEREAS, AASHTO supports the National Highway System (NHS), which is comprised of a cross section of rural and urban roads in a wide variety of natural and cultural settings; and

WHEREAS, the application of Interstate design standards across all NHS routes or the application of a design standard higher than warranted by the type of traffic using the particular NHS route would be inappropriate and counterproductive: and

WHEREAS, design solution should be encouraged that respect the integrity and value of historic preservation, communities, rivers, streams, lakes and coastal areas, wetland preservation, other environmental, scenic, and aesthetic consideration, and impacts on agricultural lands; and

WHEREAS, design standards on NHS routes should seek to preserve and enhance access for bicycle and pedestrian traffic;

WHEREAS, each state is the appropriate judge of the balance of these factors.

NOW, THEREFORE, BE IT RESOLVED, that the Board of Directors for the American Association of State Highway and Transportation Officials (AASHTO) is not in favor of any Federal requirement to establish a single standard for the NHS.

BE IT FURTHER RESOLVED, that AASHTO recommends that design standard determinations for NHS routes be delegated to each State, with the goal that each State's selected standards be in accordance with AASHTO design standards as appropriate.

BE IT FURTHER RESOLVED, that the Member Departments of AASHTO will work through AASHTO's design standards committees, with DOT, and with interested parties on design criteria and a design process for NHS routes that integrate the safety, environmental, scenic, historic, community and preservation concerns, and on standards which also foster access for bicycles and pedestrian traffic along with other transportation modes.

As approved by the AASHTO Board of Directors on April 11, 1994

4.8 Preservation Brief No. 38 *Removing Graffiti from Historic Masonry* (U.S. Department of Interior National Park Service)

38 PRESERVATION BRIEFS

Removing Graffiti from Historic Masonry

Martin E. Weaver

U.S. Department of the Interior
National Park Service
Cultural Resources
Preservation Assistance

In Cooperation with the
New York Landmarks Conservancy

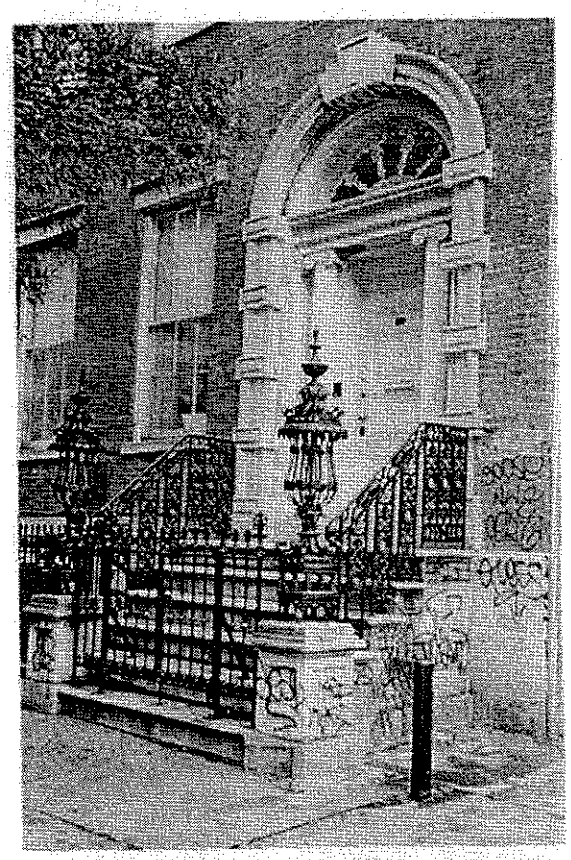


Figure 1. Many stones resemble others, and even concrete can sometimes be mistaken for stone. The stone trim on the Old Merchant's (Seabury Tredwell) House (1832), in Greenwich Village, New York City, is documented as Vermont marble. After establishing the stone type, cleaning methods should be tested in a discrete location in order to determine the most effective means of removing the graffiti without damaging the stone. More than one kind of removal technique may be required when both stone and brick require cleaning. Photo: Mark A. Weber

Removing graffiti as soon as it appears is the key to its elimination—*and* recurrence. Thus, the intent of this Preservation Brief is to help owners and managers of historic masonry structures find the best way to remove exterior, surface-applied graffiti* quickly, effectively, and safely. The Brief will discuss the variety of materials used to apply graffiti, and offer guidance on how to remove graffiti from all types of historic masonry without harming either the surface or the substrate. Suggestions will also be given regarding the use of physical barriers to protect masonry surfaces from graffiti, and the application of barrier coatings to facilitate graffiti removal. Building managers and owners of historic properties will be advised on the importance of being prepared for rapid graffiti removal by testing different cleaning techniques in advance in order to select the most appropriate and sensitive cleaning technique. Health and safety and environmental concerns are addressed, as well as regulatory matters. Removing graffiti without causing damage to historic masonry is a job for trained maintenance crews, and in some cases, professional conservators, and generally should not be attempted by untrained workers, property owners or building managers. Although the focus of this Preservation Brief is on *historic* masonry, the same guidance may be applied equally to removing graffiti from non-historic masonry.

Identifying the Graffiti and the Masonry

Successful graffiti removal from historic masonry depends on achieving a balance between breaking the bond between the graffiti and the masonry surface without damaging the masonry. This generally requires knowledge both of the materials used to make the graffiti and the masonry on which the graffiti has been executed, as well as knowledge of cleaning methods and materials (Fig. 1). Without this, masonry surfaces can be badly disfigured or damaged during graffiti removal.

Graffiti. Most graffiti is made with spray paints. Although a number of solvents and paint strippers are capable of dissolving or breaking down these paints, some may permanently discolor or stain the masonry surface if not used correctly. As a result, the remaining paint may become

more difficult, or even impossible, to remove. Poorly thought-out and generally hasty attempts to remove graffiti using harsh chemicals or abrasives can also cause permanent damage to the masonry that may be worse than the graffiti (Fig. 2).

The ability to identify the graffiti material is an important step in successful removal. Numerous kinds of spray paint (polyurethanes, lacquers, and enamels), and brush-applied paints (oils and synthetic resins such as vinyls, acrylics, acetates, methacrylates, or alkyds), as well as permanent felt markers are the materials most often used to make graffiti. But other materials are also used for graffiti, including water-soluble felt markers, ballpoint pens, chalk, graphite and colored pencils, pastels, wax and oil crayons, liquid shoe polish, and lipstick (Fig. 3). The range of materials adopted by graffitists continues to expand.

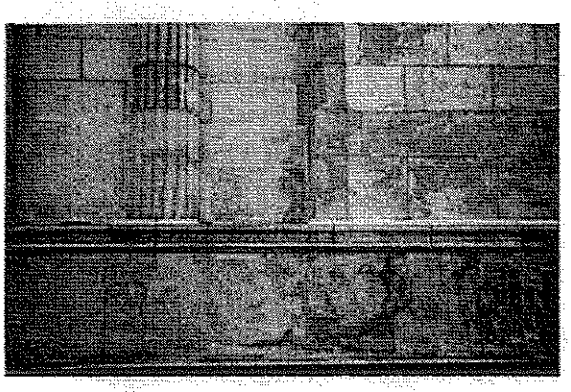
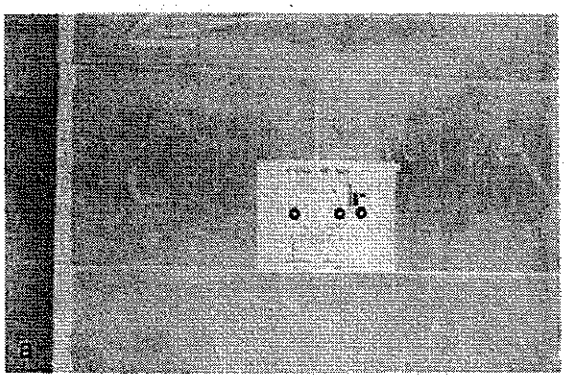
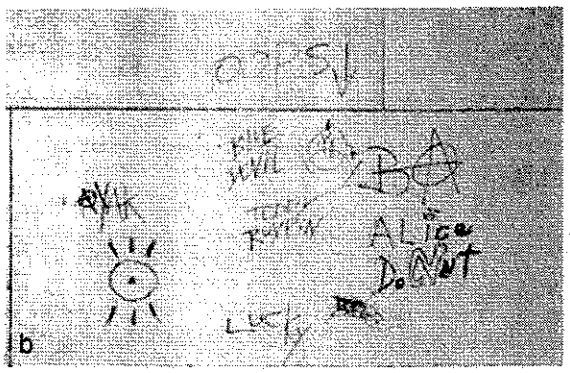


Figure 2. Harsh, but ineffective, graffiti removal methods have resulted in permanent damage to granite walls at the General Grant National Memorial in New York City. Photo: Judith M. Jacob





Paints are composed of pigments that provide color and hiding power; binder that holds the pigments together and to the substrate; and a solvent that allows the pigment/binder mixture to flow. Some spray paints and markers may contain dyes instead of pigments. Paints are applied wet. Generally, as the solvent evaporates, the binder solidifies. The greater the solvent content of the paint, the greater the flow rate, and thus, the greater the ability of the paint to penetrate into masonry pores

The two primary components contained in most graffiti materials—pigment or dye, and binder—may simply remain on the masonry surface, or penetrate into the masonry to varying depths depending on a number of factors, including the surface tension of the substrate and viscosity of the solvent or vehicle. Thus, even the total removal of the pigment or the binder may leave residues of the other component actually in, or below, the surface of the stone. Residual stains, or graffiti "ghosts," such as those from any kind of red paint or the fine black pigments used in spray paints, may be particularly difficult to remove (Fig. 4). With painted graffiti, it is helpful to establish how long it has been on the surface. For most paints that have been on the surface for several weeks or months, hardening processes are likely to be complete or well-advanced; the solubility of the paint is proportionately reduced and it will be more difficult to remove.

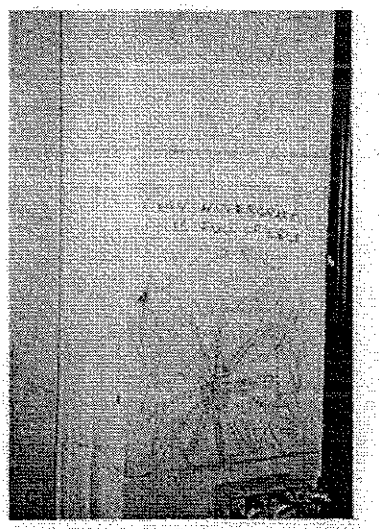
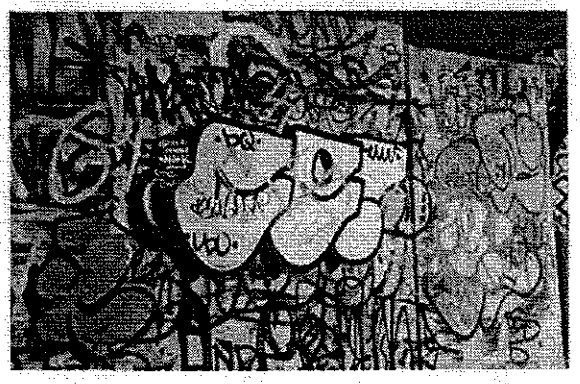


Figure 3 (a-d). A wide variety of materials is used to make surface-applied graffiti on masonry, including (a) chalk, (b) felt-tip marker, (c) felt-tip marker combined with crayon, and (d) felt-tip marker and spray paint on concrete. Photos: (a) Anne Grimmer, (b) Frances Gale, (c) Martin Weaver, (d) Anne Grimmer.



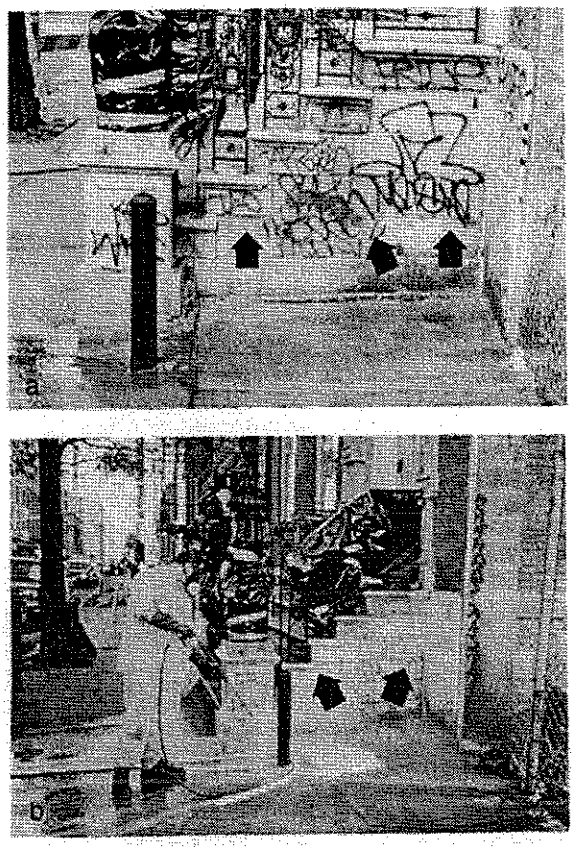


Figure 4 (a-b). After cleaning with an alkaline paint remover, remnants or ghosts of black spray-painted graffiti are still visible and may require poulticing, while the blue paint has been almost completely removed. Photos: Mark A. Weber.

Masonry. The historic masonry substrate must also be identified. As used here, the term *masonry* encompasses all types of natural stones; manufactured clay materials, including brick and terra cotta; and cementitious materials, such as cast stone, concrete and mortar. The common factor among masonry materials is that they are porous, to a greater or lesser extent, and sensitive to abrasion. After identifying the masonry, its condition, including fragility, porosity and permeability, must also be assessed prior to beginning graffiti removal. For example, a smooth, newly-polished granite surface is comparatively easy to clean because it is relatively impermeable and paint vehicles tend to stay on the surface rather than penetrate into microscopic pores. A very smooth, polished surface also has no pits or crevices that will retain particles of pigment or binder. In contrast, weathered marble or limestone may be extremely porous and permeable, with a rough surface on which particles of pigment can easily lodge. The fragility of such a surface can make it impossible to clean the surface even with a bristle brush without risking severe surface loss. A difference in surface texture or finish may also be the reason hat a particular cleaning agent will work in one situation t not another.

e types of masonry may react adversely to contact with rious cleaning agents required to break or dissolve d between the graffiti and the masonry surface.

Thus, for purposes of cleaning, masonry types are often categorized according to whether they are acid-sensitive, non-acid sensitive, or alkali-sensitive. *Acid-sensitive* stones consisting of carbonate materials may be damaged or even destroyed by contact with acids. Although, in many instances, acidic cleaning compounds are not effective for graffiti removal and generally should not be used for this purpose, it is useful to know that some acid-sensitive materials include: stones such as limestone, marble, travertine, calcareous sandstones and shales; most polished stones; and glazed architectural terra cotta and glazed brick. *Non-acid sensitive* masonry materials include slate, granite, unglazed architectural terra cotta and unglazed brick. *Alkali-sensitive* stones may contain silicates, or ferrous, soluble iron compounds that can react with alkalis or water to form severe staining. *Alkali-sensitive* stones include some granites, Indiana limestone, and many types of sandstone, especially those that are green or grey in color. Glazed and polished surfaces tend to be damaged by both strong acids and strong alkalis.

Graffiti Removal Methods and Materials

A variety of treatments are available from which to choose the most appropriate method of graffiti removal that will not damage the surface of historic masonry. Removal techniques, which are chosen according to the type of graffiti and the masonry, range from simply erasing pencilled graffiti with soft erasers, or removing chalked graffiti with soft brushes, to poulticing with water (with or without detergents), poulticing with organic solvents or alkali-based paint removers, or applying bleach to remove painted graffiti. In very limited situations, it may mean using very delicate and controlled abrasive means. Successful graffiti removal often requires a combination of cleaning materials and methods.

Poulticing

The most effective method of removing graffiti from masonry usually involves the use of a poultice. A poultice consists of an absorbent material or powder—inert clays such as kaolin or sepiolite, diatomaceous earth (fuller's earth); or cellulose products such as fluff pulp cellulose or shredded paper—mixed with a cleaning solution (a liquid reagent such as water, organic solvent, paint stripper or bleach) to form a paste or slurry. The purpose of a poultice is twofold: it enables a cleaning solution to be kept in contact with the stained area as long as possible, while allowing the cleaning solution to pull the staining material out of the substrate via the poultice without redepositing it in, or restaining, the masonry. A poultice is often covered with a plastic sheet to retard evaporation (Fig. 5). With some extremely porous types of stone, such as marble, although a poultice may remove a stain from one side of the stone, stains can pass completely through the stone and be redeposited on the other side of the masonry slab. Thus, caution should always be exercised in stain and graffiti removal.

Water and Detergent. Graffiti removal from historic masonry should always begin with the gentlest means possible. In some instances, this means low-pressure water washing. Fresh graffiti— one or two days old—made with water-soluble markers may sometimes be removed with water, possibly aided by a neutral or non-ionic detergent.

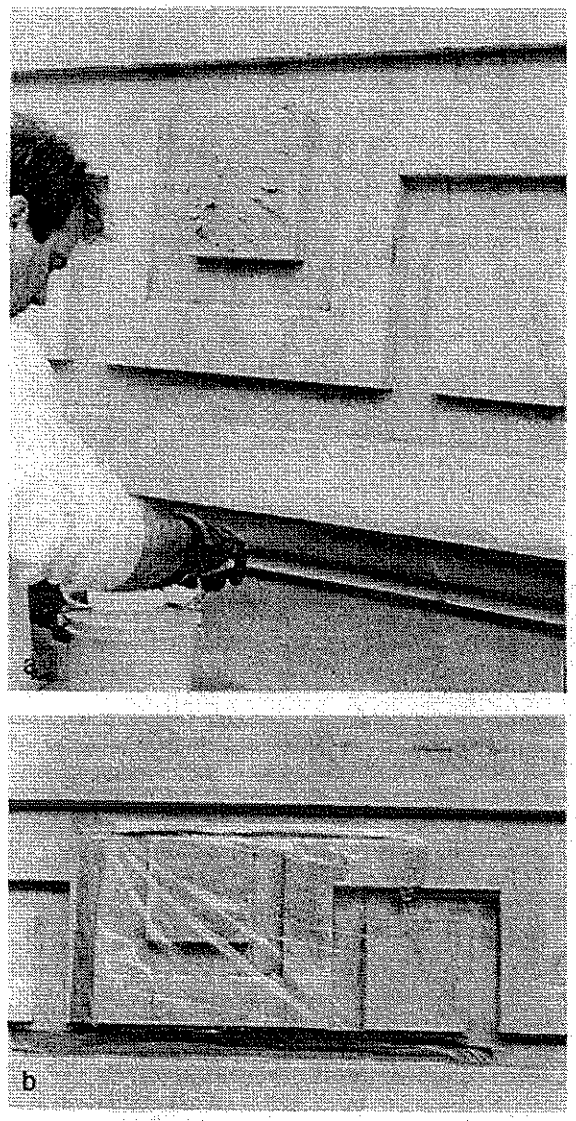


Figure 5. (a) Here, a commercially-manufactured poultice is being applied to the graffiti ghost that remains on this limestone building after an initial treatment with paint remover; (b) a plastic sheet has been taped over the poultice to slow down the rate of evaporation of the solvents contained in the poultice. Photos: Ken Lustbader.

(Non-ionic detergents which do not ionize in solution, do not deposit a solid, visible residue.) Ammonia can also be effective in removing fresh graffiti. Any detergent should be approached with caution and tested before using because most commercial laundry detergents are not neutral and contain substances which may leave undesirable residues on masonry materials. Usually, the water and detergent should be mixed with an absorbent material and applied in the form of a poultice. Although water washing is often likely to be the gentlest cleaning method for historic masonry, it may not be as effective for removing graffiti because many graffiti materials are not soluble in water.

Organic Solvents and Paint Removers. Most graffiti can be removed without damaging the masonry with proprietary graffiti-removal products and commercial paint strippers containing organic solvents. But, these products should always be tested and used in accordance with manufacturer's instructions included in the product literature. Normally, solvents should be used in a poultice form to prevent them from penetrating into the substrate, and permanently discoloring or staining the masonry. A number of paint-removers are manufactured as thick gels or pastes that cling to the surface, and some commercial paint-removal products include a tough fiber-reinforced paper or cloth backing that retards evaporation and also facilitates neat and clean removal of the used stripper. The advantage of using organic solvents is that they evaporate completely, leaving no residual material in the masonry. However, organic solvents may present a severe health hazard, and workers using them must wear adequate protection. "Off-the-shelf" aerosol graffiti removers generally should not be used because the dissolved paint being removed may run down the wall "staining" a previously clean area; or pigments may also be redistributed by the rinsing and scrubbing recommended by the product manufacturer (Fig. 6).

Alkaline Compounds. Alkaline compounds may be used to remove some oils and greases, and waxes from *non-alkali* sensitive masonry. Like organic solvents, alkaline compounds should generally be used in conjunction with a poultice when removing graffiti. The use of alkaline compounds should always be followed by a weak acid

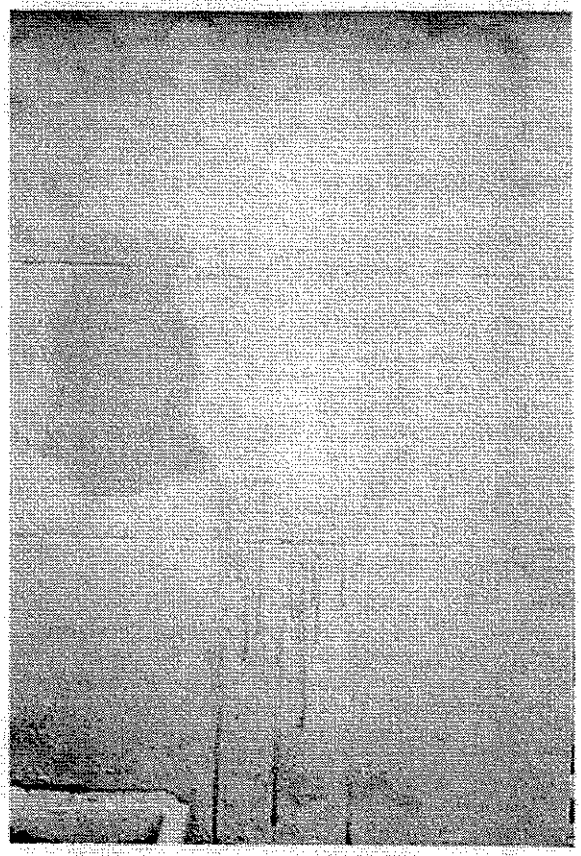


Figure 6. Although an aerosol graffiti remover has taken off much of the graffiti, it has left new stains where it dripped down the masonry surface. Photo: Ken Lustbader.

wash and a water rinse in order to neutralize—or remove—all the alkaline residues from the masonry. Strong alkalies (pH13-14), such as sodium hydroxide-based paint removers (caustic soda or lye), generally should not be used as they can cause efflorescence and staining on masonry surfaces, if not properly neutralized. Potassium and other hydroxide paint removers may react with iron compounds in some masonry, particularly Indiana limestone, to form dark brown (rust-colored), or black ferric hydroxide stains, which are very difficult to remove.

Bleaches. Alkali-based bleaches such as calcium hypochlorite can sometimes be used very successfully in a poultice to bleach or decolorize certain dyes contained in some paints and inks that cannot readily be removed by other means.

Mechanical or Abrasive Methods. Mechanical treatments include dry or wet blasting, using abrasive grits, such as sand, dolomite powder, aluminum oxide, ground-walnut shells, sodium bicarbonate (baking soda), and others; high-pressure water washing; and mechanical sanding or grinding. All of these abrasive methods will cause damage to masonry and, in most instances, should never be considered as a method of removing graffiti from historic masonry. Abrasive methods used mistakenly by untrained workers to remove graffiti usually result in etching the outline of the graffiti permanently into the masonry (Fig. 7). Some historic masonry materials can be easily damaged by pressure washing even at low or moderate pressures (100-400 psi). Occasionally, however, under very controlled circumstances, a *micro-abrasive* technique may be appropriate for removing graffiti from delicate masonry surfaces, if used at low pressures of 35-40 psi with fine abrasives. This treatment, which must be done very slowly and carefully to avoid damaging the masonry, should be tested first, and undertaken only by a professional conservator. Another exception, even though it is not strictly an abrasive treatment, is using a razor blade as a first step to remove spray paint or felt-tip marker from polished granite. However, this too, should be undertaken only by a *professional conservator*, and only on *polished granite*, which is very hard and generally impervious to scratches.

Laser Cleaning. Although not in general use as a cleaning technique, laser technology offers great promise in the future as a non-damaging method of graffiti removal.

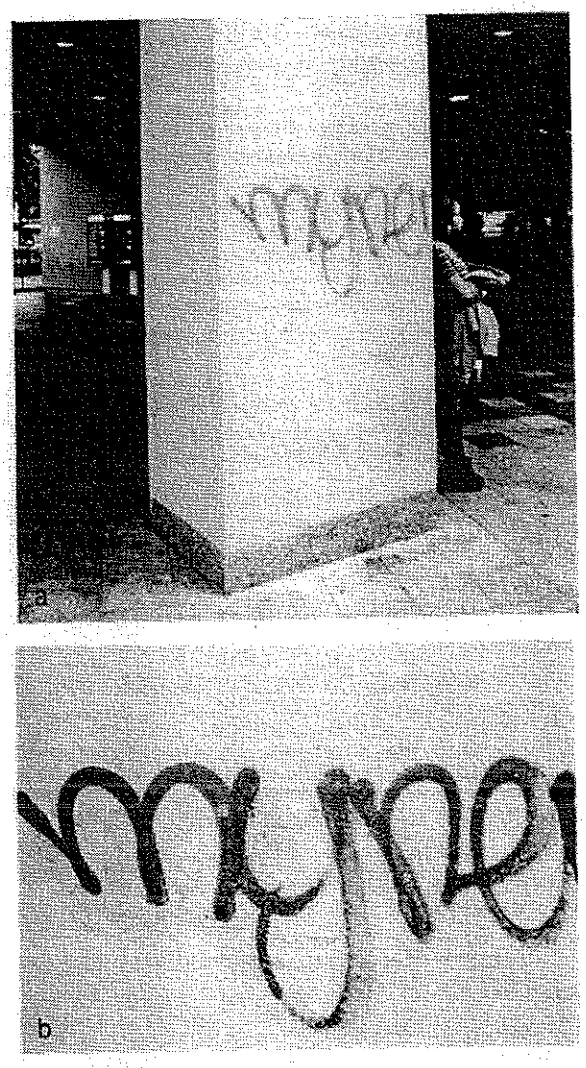


Figure 7 (a-b). The first time this spray-painted graffiti appeared it was removed abrasively. As a result, the graffiti was permanently etched into the limestone and cannot be concealed even by the pigmented barrier coating painted over it later. The barrier coating did, however, facilitate non-abrasive removal of graffiti the next time it was applied.
Photos: Anne Grimmer.

Testing

Before selecting a removal method, all cleaning materials and techniques for removing graffiti from a historic masonry building should be tested on mock-ups or areas of the resource that are not highly visible, but which are representative of typical conditions. Visual observation should be supplemented by the use of a magnifying glass, and spot tests should be carried out with various solvents to help identify the specific graffiti medium, which will aid in its removal. More complex testing using laboratory equipment and more scientific analytical processes may sometimes be necessary in complex situations. Sample reas that represent the desired degree of "cleanliness" ould be approved in writing by client, architect, servator or other appropriate authority. The materials ll the other data necessary to reproduce the desired cleaning results should be meticulously recorded and the accepted sample area preserved for reference until the end of the job. The existence of a "clean" sample for comparison and a signed agreement can avoid unpleasant surprises, misunderstandings, and perhaps legal actions.

When a type of graffiti appears for the first time that was executed with a material not immediately recognizable and for which no countermeasures have been developed, tests may need to be carried out by an architectural conservator to identify the material and to determine effective removal treatments. Agencies with large inventories of graffiti-prone buildings and structures should watch for graffiti made with new materials and experiment with different cleaning methods in order to be prepared when it appears. Such early action can save large sums of money in the long term. (See "Development of a Treatment Plan.")

Development of a Treatment Plan

For managers or owners of historic masonry buildings, or agencies responsible for large inventories of graffiti-prone properties, including parks, highway and railroad bridges and viaducts, bus, train and subway stations, and cemeteries, the development of a treatment plan may be the first step toward an effective graffiti-removal program. It is becoming increasingly common for large or important historic properties to have regular maintenance and disaster plans that include graffiti removal.

When feasible, a separate treatment plan should be prepared for each structure. However, if this is not possible, it is advisable to prepare a variety of treatment plans for specific masonry types. Plans should be prepared to cover all types of masonry that fall under one jurisdiction, management or ownership that are potential targets for graffiti.

Guidance contained in treatment plans should be based on the results of carefully controlled testing to remove a wide variety of common graffiti materials safely, and without damaging the various types of masonry. Individual treatment plans should address all parts of the building or structure that could be disfigured by graffiti, and any features too fragile to be cleaned by anyone other than a conservator should be noted on the plan.

A treatment plan is essentially a cleaning specification, but it should also include information on the following:

- the types and conditions of masonry likely to be targeted by graffiti;
- methods, materials and techniques known to work most successfully in the removal of specific types of graffiti from the surface of each type of masonry;
- sources for materials;
- a list of contractors with expertise in graffiti removal, including names, telephone numbers, information on emergency access to the property, and storage location of materials;
- graffiti-removal methods which may be harmful to the masonry surface;
- contractors or consultants who are **not acceptable** and should not be considered for graffiti removal;
- scaffolding, pumps, or safety equipment that might be required, where it is available, and costs involved; and
- health and safety concerns regarding specific removal treatments, product literature and Material Safety Data Sheets (MSDS).

Health and Safety Considerations

Most of the chemicals used for graffiti removal are dangerous to workers, as well as to others who may be in the vicinity. Organic solvents are toxic by ingestion, inhalation, and skin contact. Material Safety Data Sheets (MSDS), available from the product manufacturer for all paint-removal products, should always be consulted and followed. Identification of hazardous components and checking with chemical reference works will help assure that the least hazardous, but most effective, products are selected.

Generally speaking, it is a sensible policy to carry out all graffiti removal in well-ventilated conditions. Some solvents can be used only outdoors, and sometimes forced ventilation may be necessary even *there*, requiring workers to use air-fed respiratory equipment to avoid wind-blown fumes. Smoking, eating or drinking must not be allowed when cleaning is in progress.

Some materials used for graffiti removal are so corrosive that accidental contact can cause serious, permanent scarring and painful injuries. Wearing appropriate protective clothing must be strictly enforced. Mandatory personal protective equipment (PPE) normally includes face shields or safety glasses; long, chemical-resistant gloves; face masks with respirators for organic solvents; and possibly, full protective clothing with an independent air supply.

All smoking and open flames should be rigorously excluded from work areas; many solvents are flammable or highly explosive in vapor or liquid form when mixed with air. Solvent residue, used swabs, cloths, overalls and all other solvent-contaminated items should be safely and legally disposed of, or properly stored—even overnight—away from potential sources of fire. Electrical equipment may require explosion-proof fittings when used with certain solvents.

When electric pumps and pressure-spraying equipment are used, it is especially important that all necessary precautions be taken to avoid electric shock. Water sprays and puddles on the ground present a potentially dangerous situation, if they come into contact with temporary wiring at worksites where graffiti is being removed. Such hazards must be carefully monitored and controlled.

As with any construction project, attention should always be directed toward the general safety of the workers and passers-by, but also toward possible damage to the resource itself that might result from careless placement of ladders, or scaffolding. Chemicals used for masonry cleaning can also damage adjacent metals, glass, and painted surfaces, as well as vegetation (Fig. 8). Product manufacturers' instructions should always be closely followed to avoid such inadvertent "collateral" damage.

Environmental Considerations

To protect against environmental contamination, including the formation of unwanted ozone at ground level and damage to the ozone layer in the earth's outer atmosphere, legislation has been enacted in some states making it illegal to use even moderate quantities of some solvents — *volatile organic compounds (VOCs)* contained in paint removers. In response to this legislation, many new products are being developed that do not contain VOCs.

After completing graffiti removal, the disposal of chemical products and rinsing effluent must be taken into account. Arrangement for disposal of the cleaning waste should be made *prior* to beginning graffiti removal, especially if it is a project of considerable size. In many places it is illegal to discharge solvents and/or paint residues into sewers or storm drains. The owner or manager of a historic property, or in some cases the individual or firm doing the cleaning or graffiti removal, is responsible for being informed of, and complying with, relevant laws and regulations. Under provisions of the National Historic Preservation Act of 1966, as amended, approval may be required from a state or federal preservation agency before any work can be undertaken on buildings or structures listed in or eligible for listing in the National Register of Historic Places, if such a project involves federal funding or licensing. Many state and local historic district commissions and review boards have their own regulations that require approval for cleaning or graffiti removal work that is undertaken on landmarks or properties in locally designated historic districts.

Barrier Coatings

Anti-graffiti or barrier coatings are intended to facilitate the removal of graffiti from porous as well as non-porous surfaces. These coatings are most commonly transparent, but may also be pigmented. They are available in a variety of formulations designed to serve different needs. The use of barrier coatings to protect graffiti-prone historic masonry surfaces may seem to be an easy preventive solution to a persistent graffiti problem. However, for the most part, these coatings are not the panacea that some advertising might suggest. Some of them simply do not work, and others may cause physical or aesthetic changes or damage to the masonry.

Transparent Coatings. Transparent coatings serve as a barrier between the masonry surface and graffiti, preventing graffiti from penetrating into the masonry. They are also intended to make graffiti removal easier since most graffiti does not adhere well to them. Generally, graffiti applied over transparent barrier coatings can be removed with low-pressure water and a detergent, or with a solvent.

There are basically two kinds of transparent barrier coatings: temporary and permanent. Temporary, or "sacrificial" coatings are removed when graffiti is removed and then must be reapplied. Permanent transparent barrier coatings are more resistant to the water or solvents used to remove graffiti, and remain on the masonry surface when graffiti is removed (although this type of coating also must usually be reapplied after several cleanings). A third type of transparent barrier coating combines temporary and permanent coatings, based on a two-part system. A water-based acrylic sealer is first applied to the masonry surface, after which a sacrificial layer consisting of a polyethylene wax emulsion or dispersion coat is applied over the sealer. When graffiti is removed, the sealer coat remains on the masonry, but the sacrificial coat dissolves and is removed with the graffiti, and thus must be reapplied. (With this two-part system, even the first coat will eventually wear off after multiple cleanings, and must also be reapplied.)

Unfortunately, in application, there are a number of drawbacks inherent to transparent barrier coatings that generally prevent their being recommended for use on historic masonry. First, clear coatings may alter the color of the masonry surface and add a gloss that may be highly visible, or apparent only in certain lighting conditions or when it rains. Second, clear coatings may reduce the water-vapor permeability of the masonry, thereby contributing to possible water-related deterioration. Third, the coating may discolor and change over time. Exposure to ultra-violet light can cause a coating to yellow; dirt build-up may darken the treated surface; and some coatings acquire a sheen when rubbed or brushed against. Such changes are especially noticeable when only a portion of the building has been coated. Furthermore, if coatings are not maintained on a regular basis, usually through periodic removal and reapplication, many coatings tend to fail. What often results is an uneven, "patchy" look to the masonry that can have a very negative impact on the character of the historic building (Fig. 9).

Despite these potential drawbacks, there may be some instances in which the graffiti problem or frequency of occurrence is so severe that application of a transparent barrier coating on historic masonry may be worth considering. Some water-based polysaccharide coatings, and silicone and silicone-based coatings have been used with success on masonry structures. They are essentially

Criteria to Consider Before Selecting a Barrier Coating as the Primary Protective Means of Combating Graffiti

What to look for in a Barrier Coating:

- Water-vapor permeable, or "breathable".
- "Invisible" without gloss or sheen, when applied to masonry.
- No change in appearance from uncoated areas when masonry is wet.
- Does not discolor or attract dirt.
- Weathers evenly.

Questions to Ask:

- Will the coating last long enough to offset its cost?
- Will the application and reapplication of the coating be cost effective?
- Will the coating be effective against more than one type of graffiti?
- Can the coating be completely and thoroughly removed, so that, if necessary, paint, or another coating will adhere to the masonry surface?
- Will the building ever need to be repointed or patched? A barrier coating may make this difficult or even impossible.

Before Application:

- Seek advice of an architectural conservator.
- Test coating on an inconspicuous area of masonry, or study the success/failure of the coating in other locations where it has been used.

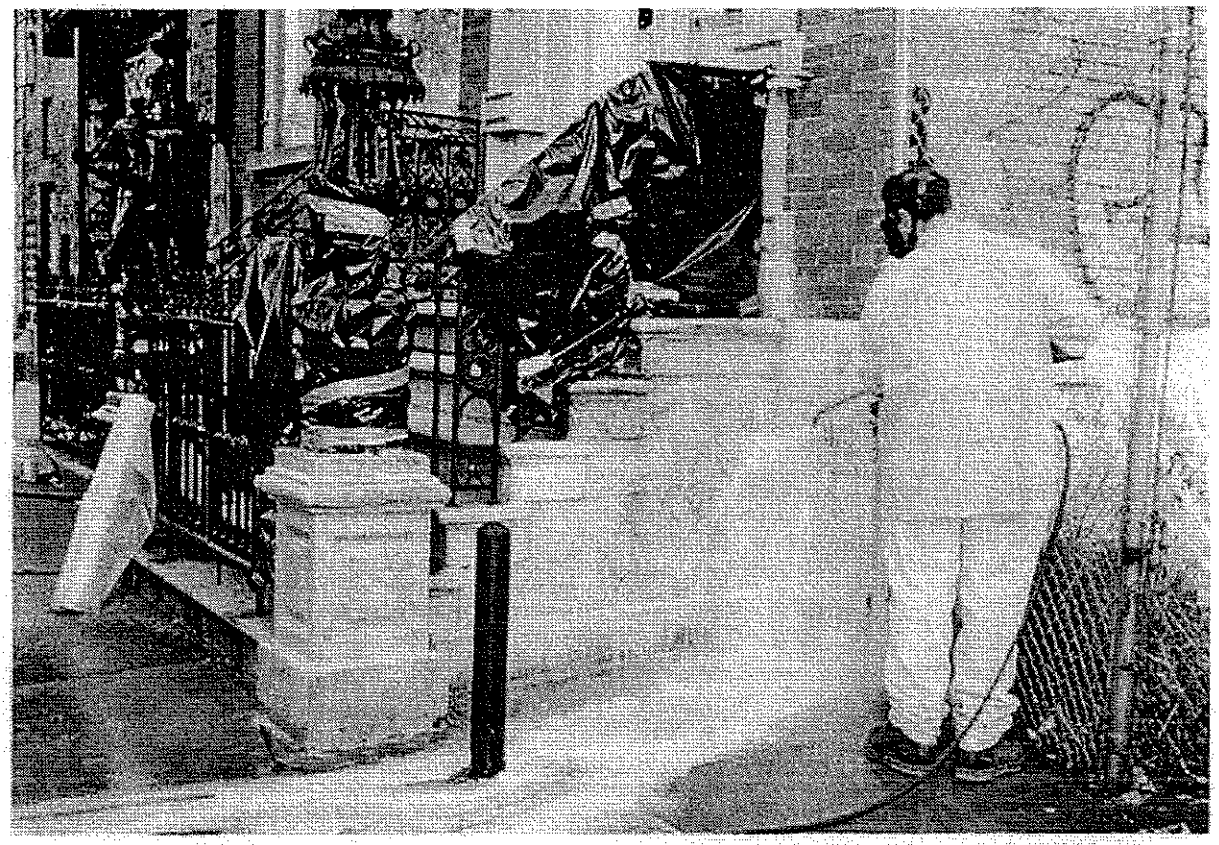
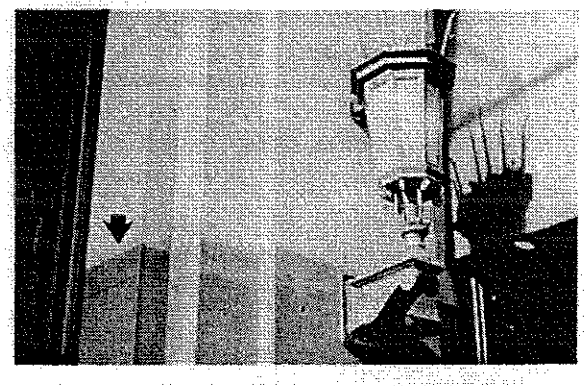
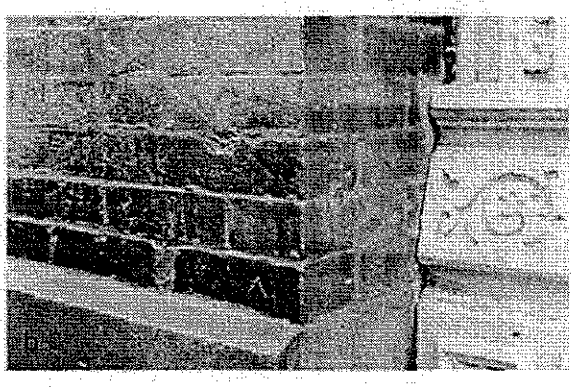


Figure 8. The cast-iron railing and light fixtures on this stone stoop have been wrapped with plastic sheeting to protect them from damage by chemicals being used to remove the graffiti. Photo: Mark A. Weber.





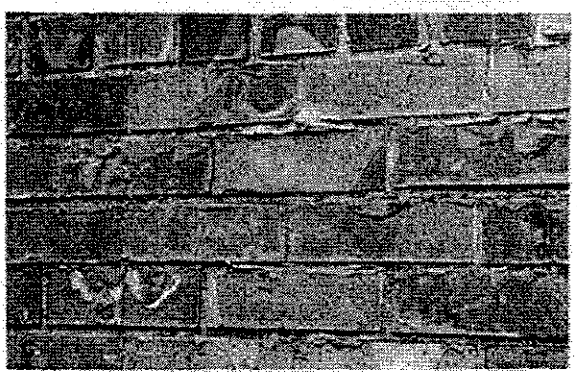


Figure 9. These photographs illustrate some of the problems inherent in clear barrier coatings. (a) The transparent coating applied to the lower portion of this granite entranceway has darkened it, thus changing the character of the historic masonry. (b) But it is not nearly so obvious or damaging to the building's historic character as the thick and shiny clear coating applied here which resembles a plastic sheathing over the brick. Scratches are highly visible and a surface haze indicates that the coating has begun to deteriorate. (c) This transparent coating is peeling and has failed completely; not only is it an eyesore, but it may also be hard to remove from the brick. Photos: (a–b) Mark A. Weber, (c) Martin E. Weaver.

invisible, and do not change the natural appearance of the masonry. Although less durable than solvent-borne coatings, they are water-vapor permeable (breathable), and may be reapplied to the masonry surface immediately after removing graffiti, while the surface is still damp.

However, extreme caution must be exercised before applying a transparent barrier coating. Experimental test applications should always be tried first on discrete areas that are not highly visible, and the treated areas evaluated over a period of time. Laboratory test results on the performance of coatings applied to samples of like masonry types may be useful to some extent. But because the tests are carried out in a controlled environment, they may not be as accurate or reliable as tests actually carried out on-site where the factors of weather and pollution are the same as those at the location where the coating will be used. If circumstances warrant, and the use of a barrier coating is determined necessary, an architectural conservator should evaluate the test performance of a variety of coatings before selecting one to be applied to historic masonry. Because of the potential for disfigurement, owners of landmark-designated buildings are required by some preservation review boards and landmark commissions to obtain approval before they apply a barrier coating.

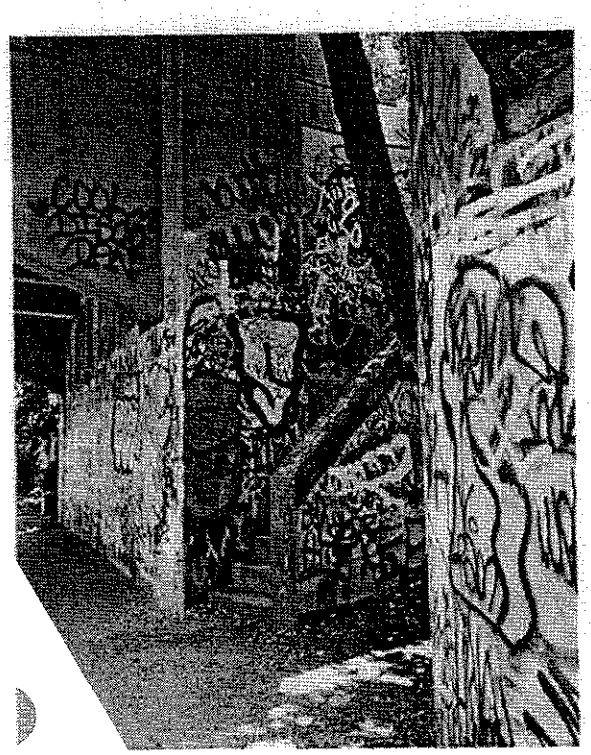
Pigmented Coatings. A pigmented barrier coating may be used on masonry as a permanent, preventive barrier coating, or as a *temporary* means of concealing graffiti until it can be removed.

Like a transparent barrier coating, a pigmented barrier coating facilitates the removal of graffiti because graffiti does not adhere well to it. Pigmented barrier coatings that are water-vapor permeable may sometimes be used as a *permanent* barrier coating on non-historic masonry where there is frequent recurrence of graffiti, and when constant surveillance is not possible (Fig. 10). Although there are some instances in which pigmented barrier coatings may be appropriate on painted historic masonry, they are **not** recommended for unpainted historic masonry because they will change the appearance of the masonry. There is also another kind of pigmented coating that is specially formulated to be used as a *temporary* measure to conceal graffiti that cannot be removed right away. This temporary, vapor-permeable paint is removed when the graffiti is removed.

Pigmented coatings are also not generally recommended as a permanent measure to cover up graffiti. Some graffiti materials, particularly felt markers, bleed through the coating; and repeated applications of the coating or paint can result in a heavy paint build-up on a masonry surface. Another disadvantage of using paint or a pigmented coating to hide graffiti is that it usually appears as an obvious patch on unpainted masonry and tends to attract more graffiti unless the paint can be applied in a discrete, and well-defined area (Fig. 11). If incompatible with either the masonry or the graffiti, such a coating may peel off the masonry surface in an unsightly manner. Like transparent coatings, pigmented coatings may be difficult or impossible to remove completely once their performance or appearance is no longer satisfactory (Fig. 12).

Preventing and Controlling Graffiti

Experience shows that prompt removal of graffiti is one of the most effective measures against its recurrence. Graffiti that is not removed quickly tends to attract more graffiti. Often motivated by a need to have their work seen, graffitists tend to be discouraged from repeating their efforts in a location where their work is quickly removed.



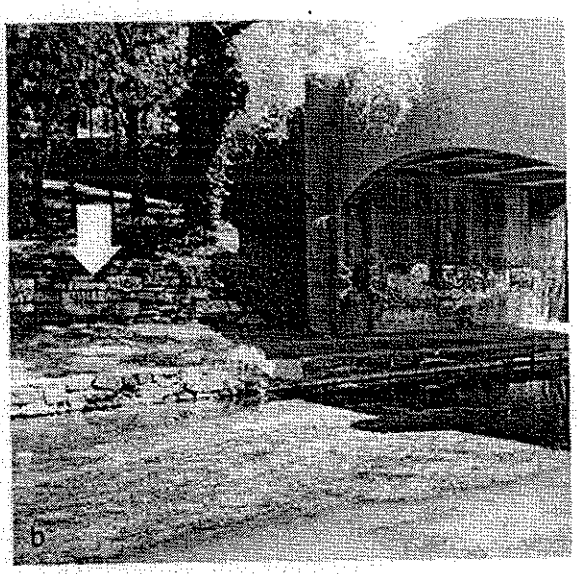


Figure 10 (a) It may be appropriate to consider the application of a barrier coating in order to facilitate removal in some out-of-the-way locations where full-time security is not possible, such as this stairway and bridge underpass next to the C&O Canal. (b) Overpainting graffiti on the stone wall at the left has not been successful; it has resulted in highlighting the defaced stones, thereby attracting more graffiti. Photos: Anne Grimmer.

Figure 11. (a) The first floor of this limestone storefront was painted in an effort to cover graffiti. However, because the paint is poorly matched to the color of the building stone, it is highly visible and now acts as a "magnet" for new graffiti. (b) Similarly, the lowest horizontal band on this stone building, overpainted to cover graffiti, has also attracted more graffiti. Photos: (a) Mark A. Weber, (b) Marlin E. Weaver

Apart from removal, effective graffiti-prevention measures can be considered under two headings. The first consists of physical measures involving maintenance, lighting, security and the erection of barriers on or around the property itself. The second focuses on community awareness programs that include neighborhood patrols, community service programs and educational programs in the schools.

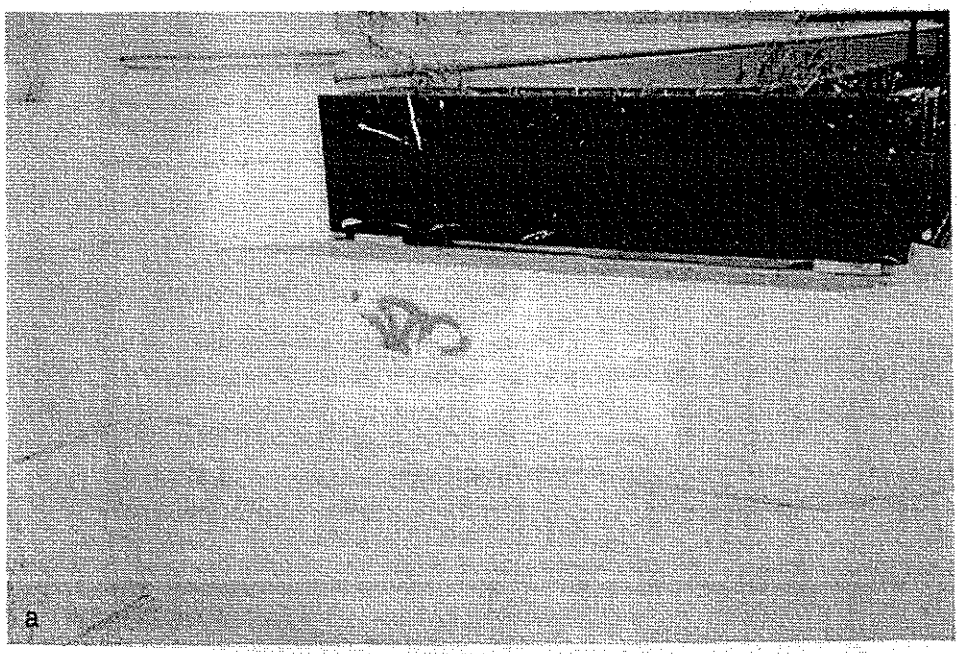
Maintenance and Security. Neglect invites vandalism, whereas a well-maintained property encourages civic pride. Thus, careful attention should be given to establishing regular maintenance programs which do not allow properties to reach a point of obvious deterioration or abandonment. Cyclical maintenance also makes good sense economically.

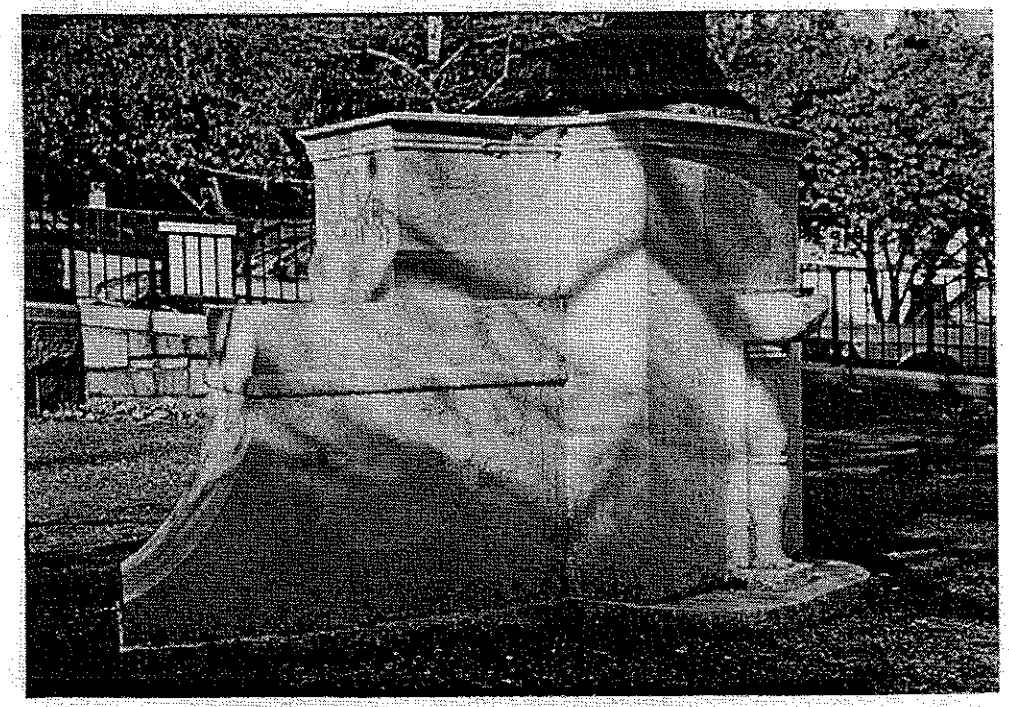
Graffiti is less likely to occur if graffitists can be clearly seen. It is often recommended that accessible, graffiti-prone areas be illuminated with floodlighting or spotlights. Graffiti may also be reduced or prevented by the presence of security guards, park rangers or police officers, or by the visible presence of surveillance cameras. Publicity about arrests and punitive measures against the graffitists, and the general vigilance of the security system may also reduce graffiti.

If they are historically appropriate and compatible with the historic property, soft barriers in the form of low, possibly thorny, shrubs and bushes or other forms of landscaping and planting may be effective deterrents. Such plantings can make it difficult to reach the property by any route other than the approved secure one. Hard barriers provided by fences and transparent screens or shields, such as clear acrylic or other polycarbonate sheets, may also afford some degree of protection. But these can have a negative aesthetic impact on the property's appearance, particularly if the barriers themselves become disfigured by graffiti.

Community Awareness. Community action and education often play an important role in a successful anti-graffiti program. Neighborhood watches can effectively deter graffitists, and can help police and other security agencies in

the detection and prevention of graffiti. Intensive public campaigns against graffiti, including presentations in schools, developing programs to foster community pride, and sentencing offenders to remove graffiti in their own community can also be useful. Publicity concerning arrests of graffitists can be a useful preventive tool. (But, on the other hand, frequent newspaper coverage of graffiti outbreaks or even of new community efforts at deterring graffiti can sometimes have the opposite effect by challenging the "creativity" of graffitists.) Community groups trained in proper cleaning techniques can also assist property owners in prompt and non-damaging graffiti removal.





re 12. (a) Graffiti that was overpainted has been exposed here as a result of the coating's failure. The uneven edges where the overpainting has peeled will make inconspicuous touch-up difficult. (b) The unsightliness of graffiti bleeding through layers of cracked and peeling paint makes an obvious at using a pigmented coating was not an appropriate maintenance technique for this stone sculpture base. Photos: (a) Martin E. Weaver, (b) Judith

Tips for Successful Graffiti Removal

- It is important to pre-wet the masonry surface when using an alkaline paint remover; it is also advisable to pre-wet the masonry surrounding a graffitied area to dilute the effect of any cleaning agents that might be inadvertently splashed or spilled on the unsoiled surface. **Do not wet the area to be cleaned if the cleaning agent is solvent-based or incompatible with water.**

- Always rinse the cleaning agent off the masonry surface starting at the bottom and moving up. This prevents the cleaning agent from running down and staining a lower surface.

- Air temperature can be a factor in graffiti removal. Most paint removers do not work when the air temperature is either very cold or very hot. This may sometimes explain why a method that worked in one instance may not be effective again in another, similar situation.

- Variations within the same type of stone, such as bedding planes, density, finish, or degree of weathering, may explain why some areas of the same stone sometimes clean better that others.

- Even if advance testing has been done and a treatment plan exists, at least some on-the-spot testing will probably be necessary.

- Mortar joints react differently from masonry units, and may require a different cleaning material and/or method to be cleaned effectively.

- Graffiti removal may result in an obviously "clean" spot. Always clean the entire masonry unit that is bounded by mortar joints (but not the joints themselves, unless necessary). The prominence of the clean spot may be minimized by fanning the cleaning out from the spot, and "feathering" it by gradually reducing the strength or thoroughness of the cleaning.

- If it is not possible to completely remove all traces of graffiti without removing some of the masonry surface, it may be preferable to leave the masonry alone. Some graffiti ghosts become less noticeable with time due to fading of the dyes used in paints and markers. Sometimes it may be possible to conceal more obvious graffiti ghosts with carefully-matched paint.

- After graffiti removal, the masonry surface should always be tested with pH strips to make sure all the cleaning materials have been completely removed. Non-staining pH strips, available from chemical supply companies, will indicate whether acids or alkalis remain on the masonry surface.

- Although alkaline paint removers are sometimes ineffective on modern formulations of aerosol paints, they can work well in removing multi-layered graffiti because they last longer.

- What removes graffiti in one instance may not always work again even in what appears to be an identical situation.

- More than one cleaning material and technique may be required to clean a heavily graffitied area if different materials were used to make the graffiti. For example, shapes are often outlined with broad-tip felt markers and then filled in with spray paint.

- Effective graffiti removal often depends on trial-and-error testing, as well as a knowledge of masonry materials, graffiti materials and cleaning techniques.

Suggestions for Removing Graffiti from Historic Masonry		
Graffiti	**Removal Method**	**Health and Safety Cautions**
Pencil	1. *Erase* with non-abrasive **pencil eraser.** 2. *Wash* with **water and non-ionic detergent.** 3. *Rinse* with **water.**	None.
Chalk/Pastel (not wax or oil-base)	1. *Brush* off with **bristle brush.** 2. *Wash* with **water and non-ionic detergent.** 3. *Rinse* with **water.**	None.
Paint Spray (aerosol) Non-spray paint	1. *Poultice* with **paint remover*, organic solvent, or petroleum-based compound**.** 2. *Rinse* with **water, denatured alcohol or mineral spirits.** 3. *Wash* with **water and non-ionic detergent.** 4. *Rinse* with **water.**	+See cautions below for NMP, solvents and petroleum-based compounds. Wear proper respirator, gloves and eye protection.
Permanent (felt-tip) Marker	1. *Wash* with **water and non-ionic detergent,** if necessary. 2. *Poultice* with **bleach***, paint remover*, organic solvent** or **petroleum-based compound**.** 3. *Wash* with **water and non-ionic detergent.** 4. *Rinse* with **water.**	+See cautions below for NMP, solvents and petroleum-based compounds. Bleach is corrosive, causes chemical burns, and forms toxic gases (chlorine). Wear proper respirator, gloves and eye protection.
Water Soluble (felt-tip) Marker	1. *Wash* with **water and non-ionic detergent.** 2. *Poultice* with **bleach***.** 3. *Wash* with **water and non-ionic detergent.** 4. *Rinse* with **water.**	Bleach is corrosive, causes chemical burns, and forms toxic gases (chlorine). Wear proper respirator, gloves and eye protection.
Ballpoint Pen	1. *Erase* with **non-abrasive pencil eraser.** 2. *Poultice* with **organic solvent** or **petroleum-based compound**.** 3. *Wash* with **water and non-ionic detergent.** 4. *Rinse* with **water.**	+See cautions below for NMP, solvents and petroleum-based compounds. Wear proper respirator, gloves and eye protection.
Crayon Lipstick Shoe Polish	1. *Poultice* with **denatured alcohol, paint remover*** or **organic solvent**.** 2. *Wash* with **water and non-ionic detergent.** 3. *Rinse* with *water.*	+See cautions below for NMP, solvents and petroleum-based compounds. Wear proper respirator, gloves and eye protection.

* Paint Remover based on N-methyl-2-pyrrolidone (NMP).
** Organic Solvent such as acetone, lacquer-thinner, or petroleum-based compound such as dimethyl adipate.
*** Bleach such as calcium hypochlorite.
\+ N-methyl-2-pyrrolidone (NMP) is mildly toxic and may have adverse reproductive effects.
Solvents and petroleum-based compounds have toxic vapors, are flammable, and require well-ventilated conditions.

› are *suggestions* to assist in graffiti removal. Methods should always be tested first under the supervision and guidance of an ·tural conservator.

Summary

Although rapid graffiti removal is the most effective weapon in eliminating graffiti and preventing its recurrence in the same location, hasty, untested removal attempts can disfigure and cause harm to historic masonry. Thus, it is important that the owner or manager of a historic masonry building or structure be prepared with a plan to ensure the prompt removal of graffiti when it occurs. Regularly scheduled maintenance and cleaning programs to eliminate graffiti from historic masonry properties may be assisted by the installation of physical barriers, security systems and lighting, as well as increased community involvement. Successful graffiti removal from historic masonry requires knowledge of a variety of cleaning methods and materials, and an awareness that what works to remove graffiti from one kind of masonry surface may not remove it from another. By testing different cleaning methods in advance, treatment plans will be available, when needed, to provide guidance for safe and sensitive graffiti removal from historic masonry.

Selected Reading

American Geological Institute. *AGI Glossary of Geology and Related Sciences*. Washington, D.C.: American Geological Institute, 1960.

Ashurst, Nicola. *Cleaning Historic Buildings. Vol. I: Substrates, Soiling and Investigations; Vol. II: Cleaning Materials and Processes*. London: Donhead Publishing Ltd., 1994.

"Chemistry Leaves Its Mark on Graffiti." *Chemical Marketing Reporter*. November 14, 1993.

Ehrenkrantz & Eckstut Architects, P.C. *Technical Tips: Removing Graffiti*. New York: New York Landmarks Conservancy, n.d. (1994).

Graffiti Removal Manual. Providence, RI: Keep Providence Beautiful, September 1986.

Grimmer, Anne E. *Keeping it Clean: Removing Exterior Dirt, Paint, Stains and Graffiti from Historic Masonry Buildings*. Washington, D.C.: Preservation Assistance Division, National Park Service, U.S. Department of the Interior, 1988.

Lewis, Richard J. *Hazardous Chemicals Desk Reference*. Second Edition. New York: Van Nostrand Reinhold, 1991.

NIOSH Pocket Guide to Chemical Hazards. Washington, D.C.: National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention, Public Health Service, U.S. Department of Health and Human Services, June 1994.

Reisner, Robert. *Graffiti: Two Thousand Years of Wall Writing*. Chicago: Cowles Book Company, 1971.

Science for Conservators: Conservation Teaching Series. The Conservation Unit of the Museums and Galleries Commission. 3 volumes. New York: Routledge, A Division of Routledge, Chapman and Hall, Inc., 1992.

Torraca, Giorgio. *Porous Building Materials*. Rome: ICCROM, 1988.

Torraca, Giorgio. *Solubility and Solvents for Conservation Problems*. Rome: ICCROM, 1990.

Weaver, Martin E. *Conserving Buildings: A Guide to Techniques and Materials*. New York: John Wiley & Sons, Inc., 1993.

Whitford, Maurice J. *Getting Rid of Graffiti: A practical guide to graffiti removal and anti-graffiti protection*. New York: Van Nostrand Reinhold, Inc., 1992.

Wollbrinck, Thomas. "The Composition of Proprietary Paint Strippers." *Journal of the American Institute for Conservation*. Vol. 32 (1993), pp. 43-57.

Young, Daniel J. *How to Comply with the OSHA Hazard Communication Standard: A Guide to Compliance with OSHA Worker Right-to-Know Regulations*. New York: Van Nostrand Reinhold, 1989.

Acknowledgements

This Preservation Brief was developed under a cooperative agreement between the New York Landmarks Conservancy and the National Park Service. **Mark A. Weber**, Director, Technical Services Center, served as project coordinator for the Conservancy. The author, **Martin E. Weaver**, is the Director of the Center for Preservation Research at Columbia University. He is an internationally recognized expert in the conservation of architectural and cultural resources, a noted lecturer, and author of Conserving Buildings: A Guide to Techniques and Materials, as well as numerous articles on the subject.

Anne E. Grimmer, Senior Architectural Historian, Technical Preservation Services, Preservation Assistance Division, National Park Service, coordinated the development of this Preservation Brief and served as Technical Editor. Technical review of this publication by the following is gratefully acknowledged: Frances Gale, Training Coordinator, National Center for Preservation Technology and Training, National Park Service, Natchitoches, LA; Judith M. Jacob, Architectural Conservator, Building Conservation Branch, Northeast Cultural Resources Center, National Park Service, NY, NY; Andrea Mones-O'Hara, Regional Historic Preservation Officer, National Capital Region, General Services Administration, Washington, DC; Nicolas F. Veloz, Conservator of Outdoor Sculpture and Monuments, National Capital Area Office, National Park Service, Washington, DC; and Michael J. Auer, Timothy Buehner, Charles E. Fisher, and especially Kay D. Weeks, Technical Preservation Services, Preservation Assistance Division, National Park Service, Washington, DC.

This publication has been prepared pursuant to the National Historic Preservation Act of 1966, as amended, which directs the Secretary of the Interior to develop and make available information concerning historic properties. Comments on the usefulness of this publication may be directed to: Technical Preservation Services, Preservation Assistance Division, Center for Cultural Resource Stewardship and Partnerships, National Park Service, P.O. Box 37127, Washington, DC 20013-7127, or Technical Services Center, New York Landmarks Conservancy, 141 Fifth Avenue, NY, NY 10010. This publication is not copyrighted and can be reproduced without penalty. Normal procedures for credit to the author, the National Park Service, and the New York Landmarks Conservancy are appreciated.

ISSN: 0885 7016

October 1995

*The word *graffito* (*graffiti*, plural) — is derived from the old Italian diminutive of graffio — to scratch, and the Latin *graphire* — to write. *Graffiti* in contemporary usage has come to mean an inscription, drawings, or markings. Except in very formal or technical applications, *graffiti* is generally considered a "mass" noun and paired with a singular verb.

Cover Photograph: Sandstone gatepost, Springfield Armory National Historic Site, Springfield, Massachusetts. Photo: Judith M. Jacob.