3D Laser Scan Used to Assess Culvert Deformation

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3D laser scanning, combined with total station measurements and global positioning, were recently used by the Connecticut Department of Transportation (CTDOT) to evaluate the condition of two deteriorating culverts in Middletown, Connecticut.

The culverts were built in 1964 and are separate structures that convey an unnamed brook under Interstate 91 Southbound (SB) and Northbound (NB). The culverts were constructed of corrugated metal structural plate pipe-arches with the original design dimensions having a span of 8' 10", a rise of 6' 1" and 18" corner radii. The culverts are approximately 150' long and support about 15-20' of roadway embankment. Figure 1 is a photograph looking toward the inlet of the I-91 SB culvert.

Figure 1 - I-91 SB over Brook (Inlet)

Both culverts were rated in poor condition and were programmed for rehabilitation or replacement. The existing steel pipe-arches showed mass section loss, extensive perforations to the inverts and ribs, sagging bolt lines and shape deformations. Portions of the inverts had failed and deflected upward.

Due to their condition, the culverts were monitored on a regular basis. The monitoring consisted of inspectors going in the culverts to look for any changes and taking measurements at specified locations.

Subsequently, the condition of the culverts was determined to be worsening, and personnel were restricted from entering the structures. An emergency project was initiated to take corrective action.

The Average Daily Traffic (ADT) over each of the culverts is approximately 57,000 vehicles. Because of the high ADT and the fill height over the culverts, relining the existing pipe-arches and/or other trenchless methods were being considered for repair or replacement of the structures.

A 3D laser scan of the culverts was proposed to facilitate the evaluation of relining options. The scan, which could be performed without personnel entering the structures, would more accurately "map" the shape deformations and identify points of constriction that may control the size of the proposed structures and the relining operations.

The 3D laser scan of the culverts was performed by a survey crew from Close, Jensen & Miller, P.C., a consulting firm assisting CTDOT in the preparation of plans and environmental permits for the project. The survey crew used a single instrument that combines precise 3D laser scanning, total station capabilities, high resolution digital imagery and Global Navigation Satellite System (GNSS) connectivity. Using this instrument, the result is a merging of the data.

The images are synchronized with the 3D laser scans and the scans are tied into the total station measurements.

Two scans were performed at each culvert; one toward the inlet and one toward the outlet. The instrument was setup using a known backsight, and the accuracy was set for ¼" x ¼". Each scan took 45 minutes to 1 hour to complete. The survey/scans were tied into the system of GNSS base-station receivers owned and operated by CTDOT. The "point cloud" created by the scans consisted of approximately 2.8 million data points and a file size of 191 MB.

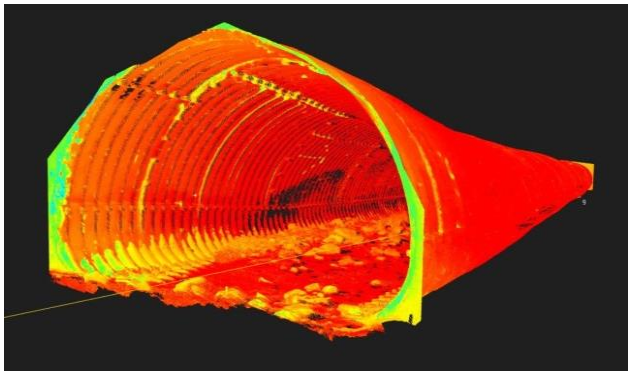

Figure 2 - Scanned Image of SB Culvert (Inlet)

Figure 2 shows the scanned image of the SB culvert looking toward the inlet. Figure 3 shows the scanned images of both culverts with the outlet of the SB culvert at the left side of the figure.

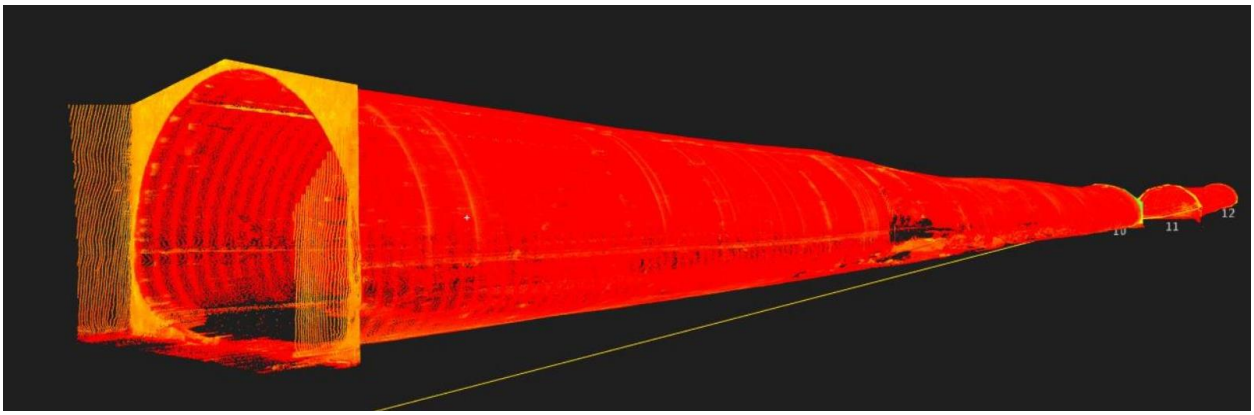

Figure 3 - Scanned Image of Culverts (SB outlet to left)

Figures 4, 5 and 6 show profiles and cross sections of the SB culvert developed from the scans.

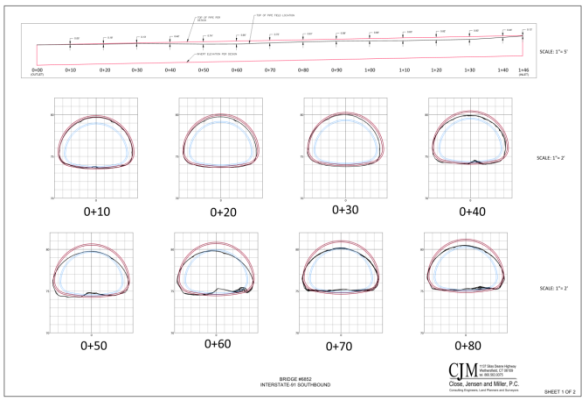

Figure 4 - SB Culvert Profile and Cross Sections

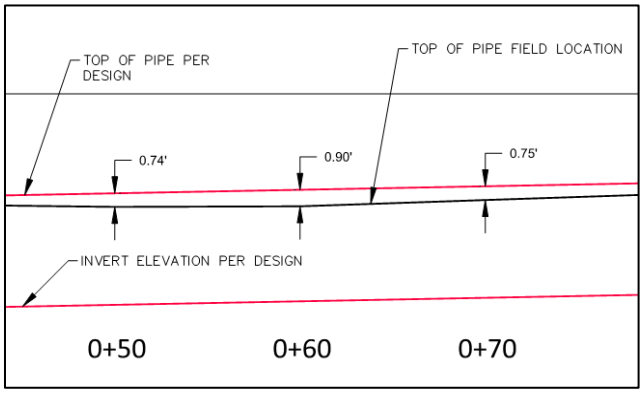

Figure 5 - SB Culvert Top of Pipe Profile

The profile at the top of Figure 4 and the enlargement in Figure 5 indicate the distortion along the crown of the existing pipe-arch based on the culvert scan ("TOP OF PIPE FIELD LOCATION") relative to the design rise (height) and slope.

Figure 6 is a cross section developed from the culvert scan showing the deformed shape of the existing pipe-arch ("PIPE FIELD LOCATION") as compared to the design shape and dimensions ("PIPE PER DESIGN").

The cross section also shows (in blue) the potential fit of a proposed, custom-sized, tunnel liner plate pipe-arch inside the existing pipe-arch. The intent was to maximize the size of the liner pipe for hydraulic capacity as well as to be large enough to allow workers inside.

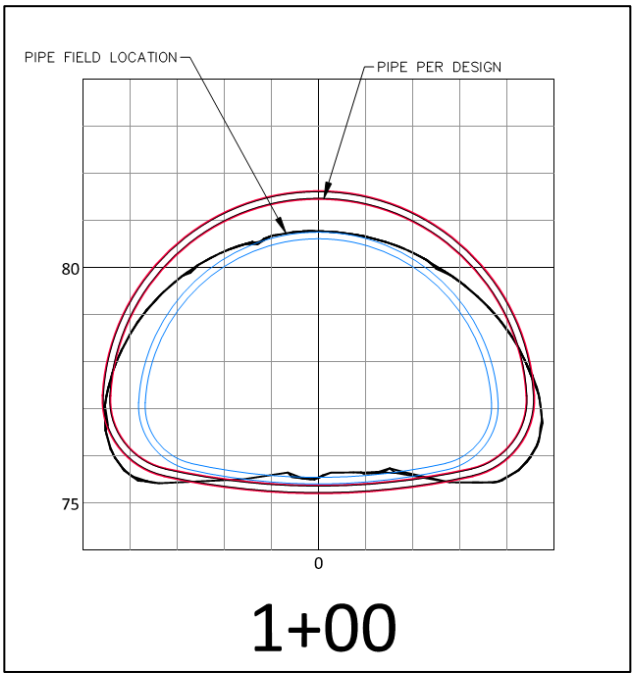

Figure 6 – SB Culvert Cross Section

The 3D laser scan survey provided for worker safety, while obtaining accurate field conditions within the culverts. This information has expedited a complicated hydraulic design, design and fabrication of the liner materials, and the contactor's means and methods of construction.