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BARTON SPRINGS ROAD OVER BARTON CREEK
Bridge Inspection and Condition Assessment Report

Bridge 14-227-0-B002-26-001
Austin, Texas
January 2017

STATE OF TEXAS
DONALD N. CORDA
124208
LICENSED
PROFESSIONAL ENGINEER

1-31-2017

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2016 Bridge Inspection Report

Barton Springs Road over Barton Creek

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Limitations:

For Client Use Only

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Barton Springs Road over Barton Creek
Bridge 14-227-0-B002-26-001

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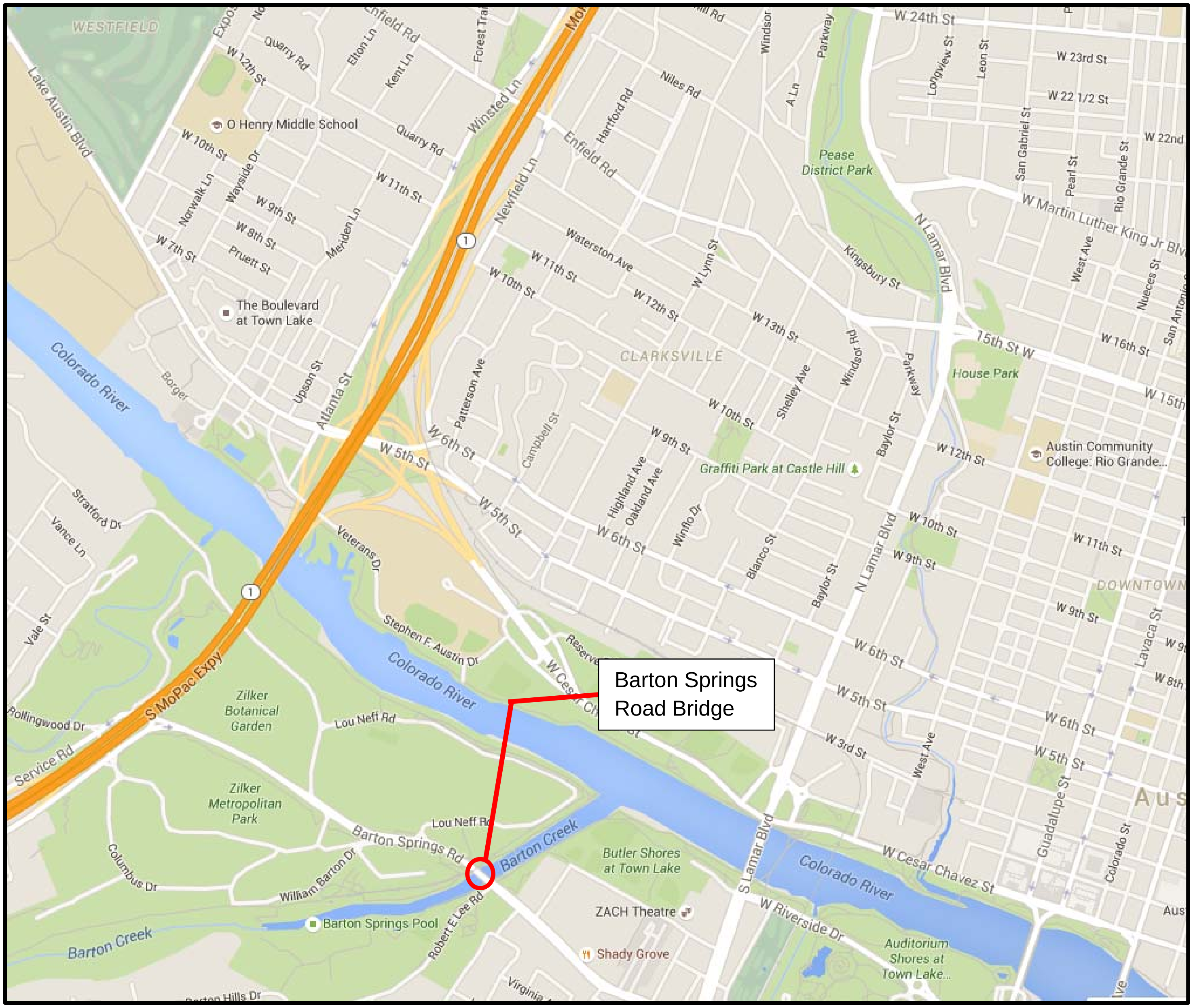
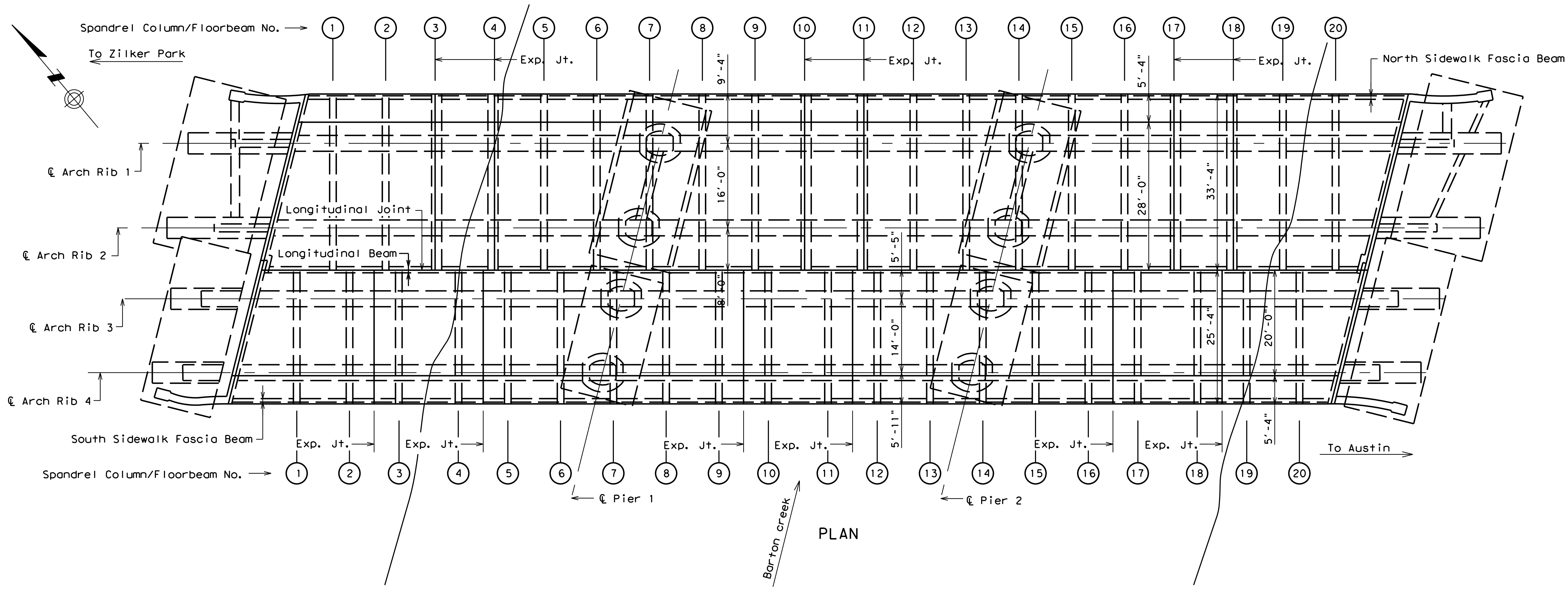


LOCATION MAP



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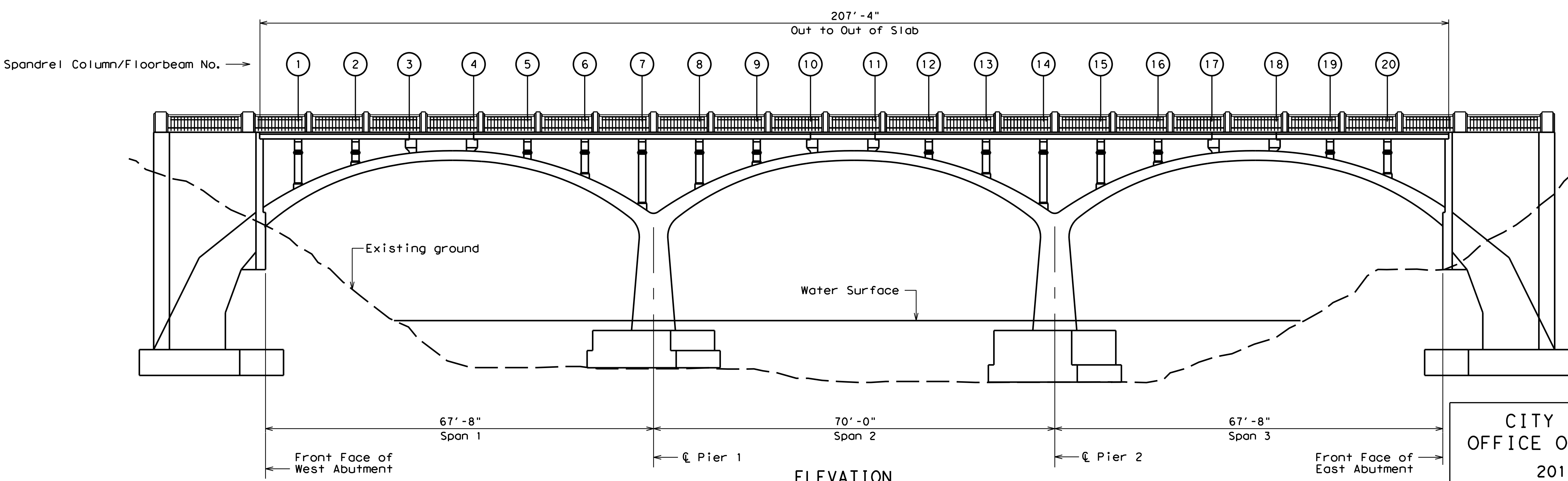
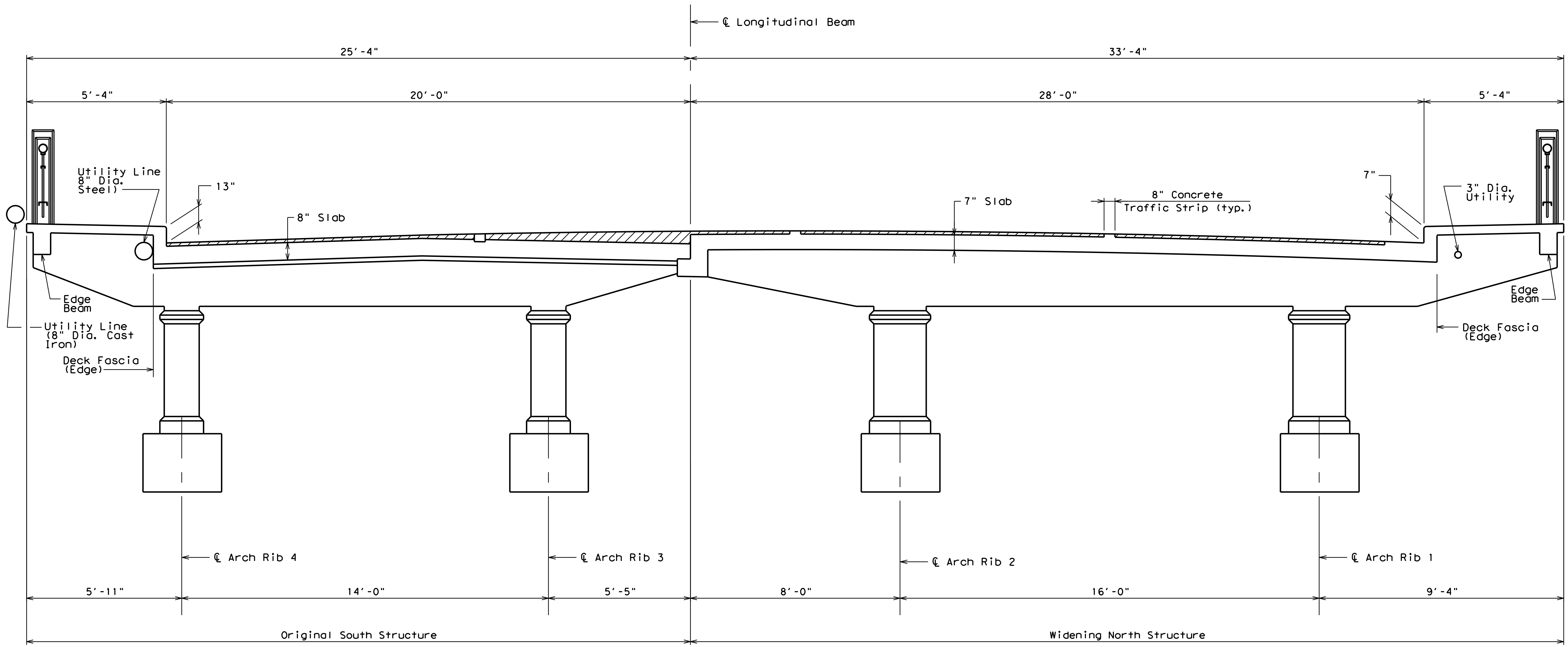


ELEVATION

CITY OF AUSTIN TEXAS
OFFICE OF CITY ENGINEERING

2016 INSPECTION OF
BARTON CREEK BRIDGE
PLAN AND ELEVATION

SHEET 5



ELEVATION LOOKING WEST

CITY OF AUSTIN TEXAS
OFFICE OF CITY ENGINEERING

2016 INSPECTION OF
BARTON CREEK BRIDGE
TYPICAL SECTION

SHEET 6

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BRIDGE INSPECTION REPORT

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Introduction and Background

The Barton Springs Road Bridge over Barton Creek is critical to the welfare of Austin's commuters because it provides a key connection for vehicular, bike, and pedestrian access to several major roads and portions of central and downtown Austin as well as Zilker Park and Barton Springs. The bridge is located immediately adjacent to the intersection of Robert E. Lee Road. The City has indicated that the roadway geometry is obsolete, and the bridge requires an assessment of the need for rehabilitation or replacement.

URS has been contracted (C.I.P. Project Number 9684.007, dated March 31, 2016 between the City of Austin [City] and URS Corporation [URS]) to provide design services for rehabilitation or replacement of the existing bridge. The original project scope included consideration of two rehabilitation options and additional options for bridge replacement. These general options were as follows:

Rehabilitation Option 1: One option to rehabilitate and preserve the existing structure in accordance with Interiors Standards for Rehabilitation…This option must also include consideration and feasibility of a complimentary structure or other means to adequately address additional capacity desired for bike and pedestrian traffic on both sides of the bridge.

Rehabilitation Option 2: One option to rehabilitate the existing structure and enhance the deck by widening it to incorporate wider sidewalks and a bike lane on both sides. This new bridge deck option may either be placed on the existing substructure or a widened, expanded substructure as necessary…

Replacement Options: Three options for complete reconstruction of the bridge…to include a wider bridge deck to allow for realigning the Barton Springs Road intersection for improved safety, bike lanes on both sides, and wider ADA compliant sidewalks.

The initial assessment of the above options is being conducted in the Preliminary Selection phase of the overall project; this will include preliminary design options and conceptual evaluations of each option. The evaluations will consist of assessments such as bridge structural engineering, architectural, roadway, utilities, and environmental documentation. These options will be supported and the evaluations vetted by City of Austin stakeholder departments and executive management. Public involvement will be conducted, with specific stakeholder and public meetings conducted at strategic milestones. The result of the Preliminary Selection phase will be a vetted/selected design option that will be presented to the City of Austin Mobility Committee and then the full City Council for confirmation; this phase will be documented in a Bridge Conceptual Engineering Report (BCER). The confirmed design option will then proceed to the design phase.

Due to funding limitations, the overall Preliminary Selection process has been divided into multiple phases (smaller scopes of work). The first scope of work, Phase 1, is the bridge condition inspection and the subject of this report. The objective of this phase was to understand the condition of the existing bridge based on a detailed visual inspection and selected sampling/ testing of the bridge concrete. It was also understood that the results of this phase may provide insight into the viability of one or both rehabilitation options.

Phase 2 will expand on the bridge condition inspection and will focus on:

- Load capacity of the existing bridge and existing load requirements;
- Due to the Robert E. Lee intersection being integral to any future bridge work (rehabilitation or replacement), an assessment of roadway/intersection needs and intersection options to complement the options associated with bridge replacement and rehabilitation;
- An assessment of Rehabilitation Option 2; and
- Providing high-level bridge replacement concepts/options.

The intent of Phase 2 is to provide the City with an understanding of the roadway/intersection/ bridge needs and options to meet those needs, to guide the remaining phases of design refinement and bridge selection.

Phase 3 and beyond will provide the remainder of the Preliminary Selection phase and will focus on the full vetting of the rehabilitation and replacement options.

Description

Barton Springs Road Bridge (Bridge Number 14-227-0-B002-26-001) is a three span reinforced concrete arch bridge having an overall length of 207'-4" measured between the joints at the ends of bridge deck. The bridge carries Barton Springs Road over Barton Creek near the Zilker Metropolitan Park in Austin, Texas (see **Photos 1-8**). Span1 and Span 3 each have a span length of 67'-8" measured between the faces of the abutments to the centerline of the Piers, while Span 2 has a span length of 70'-0" measured between centerlines of the piers (see General Plan and Elevation on Sheet 5). Traffic flows east/west over the bridge and the creek flows from the south to the north.

The bridge consists of two side-by-side parallel structures (see Typical Section on Page 6). The original south bridge was built in 1925. In 1945, the bridge was widened on the north side of the original bridge. There is a retaining wall extending from the southeast corner of the bridge which restricts access to the wingwall at this location.

The superstructure for both the original south structure and the widened north structure is made of cast-in-place reinforced concrete, and consists of two arch ribs per structure (four arch ribs total) with connecting struts at the third points, 20 pairs of spandrel columns, and 20 floorbeams supported by the spandrel columns. The original south structure and the widened north structure are skewed 14 degrees from normal. The deck is made of cast-in-place reinforced concrete with an asphalt wearing surface. The deck has an overall out-to-out width of 58'-8" with clear roadway width of 48'-0" measured between curbs. Four lanes of traffic are carried on the bridge – two lanes in the eastbound direction and two in the westbound direction. There are 5'-4" wide sidewalks on each side of the bridge. The south sidewalk has a 3/4" concrete overlay. The concrete deck has three longitudinal 8" wide concrete “bright white” bump-outs that match the grade of the asphalt wearing surface, which served as traffic lane markings. However, additional reflective paint lane markers have also been placed which do not necessarily match the locations of the concrete bump-outs due to changes in lane configuration. An ‘L-shaped’ longitudinal beam was cast monolithically with the bridge deck on the south edge of the newer north structure to tie it to the existing south structure. As shown in the typical section, the longitudinal beam provides a ledge support for the north edge of the original south structure deck. There is a longitudinal joint extending the full length of the bridge at this interface. Transverse expansion joints are located on either side of the crown in each arch span. These joints do not occur at the same location for the north and south bridges.

The railings on the bridge consist of large concrete pilasters with horizontal steel pipe rails and vertical steel pickets spanning between the pilasters. No traffic barriers extend beyond the approaches. There is a lighted intersection at the East Approach. Barton Springs Road curves to the south at the West Approach.

The substructure of the 1925 and 1945 bridges consists of cast-in-place reinforced concrete abutments, wingwalls at each corner, and two reinforced concrete piers consisting of two columns and a top strut (cap) supported by spread footings for each bridge.

There is a small tourist train (Zilker Zephyr Miniature Train) that runs beneath the bridge in the West Span immediately adjacent to the West Abutment that is supported by a structure consisting of timber beams and ties, timber handrails and walkway, and steel outrigger brackets attached to the West Abutment backwall. There is also a weathering steel prefabricated truss pedestrian bridge supported by hammerhead piers located under the West Span that carries the Ann and Roy Butler Hike and Bike Trail under the bridge above the west bank of Barton Creek.

Under the East Span near the East Abutment, there is a concrete pathway that caries the Lady Bird Lake Hike and Bike Trail along the East Bank of Barton Creek. The Lady Bird Hike and Bike Trail concrete pavement under the bridge is partially elevated above the waterway embankment by a longitudinal edge beam (or thickened slab); however erosion of the waterway embankment at the south side of the bridge has undermined the concrete pavement vertically by about 1 to 2 feet above ground exposing lines of concrete piles.

The bridge is not posted for weight limit.

The bridge was inspected by AECOM from June 13, 2016 to June 17 2016.

In addition to the physical inspection of the bridge, a concrete testing survey was conducted. The concrete survey involved the extraction of eighteen concrete cores from various elements of the bridge superstructure and substructure. Laboratory tests were then performed using these concrete cores which included the determination of compressive strength, chloride diffusion tests, and petrographic examination including carbonation on selected cores for the purpose of evaluating the condition of the concrete.

Inspection Access

The inspection of the underside of the Barton Springs Road Bridge deck and superstructure was accomplished from an Aspen A-62 Bridge Inspection Vehicle positioned on the bridge deck. Since the operation of the Aspen-A-62 required closure of the outside eastbound lane, maintenance of traffic on eastbound Barton Springs Road was provided. A safety boat and operator were also provided. When the Aspen A-62 was not in operation, the boat was used to inspect the lower portions of the piers and to conduct streambed soundings. Since there are power lines adjacent to the North side of the bridge, the Aspen A-62 basket was deployed from the South side of the bridge only, but the reach was sufficient to reach the north side.

The westbound traffic lanes and the inside eastbound traffic lane remained in operation throughout the inspection, and the top of the deck surface in those lanes was only accessible for visual inspection from the sidewalks or from the outside eastbound traffic lane.

There was a small section of the underside of the bridge deck and superstructure in Span 1 that did not receive a hands-on inspection in an area from the West Abutment to approximately 20 feet east. Very tight clearances over the track for the Zilker Zephyr Miniature Train and the pedestrian bridge precluded access from the Aspen A-62 basket for a hands-on inspection in this area. However, a visual inspection of the deck and superstructure in this area was performed from the pedestrian walkway and from the ground.

The inspection of the underwater portions of the Pier Columns and footings was not included in the scope of work and a hands-on inspection of the footings was not performed. However, since the water clarity was good, the top of the footings are visible and a visual cursory inspection of the top surfaces was performed.

The southeast wingwall at the East Abutment could not be inspected because a retaining wall along Robert E. Lee Road blocked access.

Structure Orientation

The orientation of the bridge is generally in an east-west direction. The spans are numbered from west to east. The spandrel columns and floorbeams are also numbered consecutively from west to east. The General Plan and Elevation on page 5 shows the overall span arrangement and the naming convention used to identify the various elements of the bridge.

The arch ribs are numbered in a north to south direction (downstream to upstream). Arch Ribs 1 and 2 are located within the widened structure (north half), built in 1945. Arch Ribs 3 and 4 are located within the original structure (south half), built in 1925.

Summary – Structural Condition

The bridge is in overall fair condition, corresponding to a condition rating value of approximately 5 out of 9 and a description of "all primary structural elements are sound but may have minor section loss, cracking, spalling, or scour", based on the condition rating guidelines in the Federal Highway Administration's Publication *FHWA-NHI-16-013, Bridge Inspectors Reference Manual*. The component condition rating guidelines from that Manual is included in Appendix B as a reference. It is important to note that while the overall condition rating is fair at this time, there are elements of the structure that are rated in the poor range (value of 4 out of 9 with description of "advanced section loss, deterioration, spalling or scour"). Also, the condition rating value does not take into account material testing data or the current rate of deterioration of the structure. It is an estimate of the condition of the overall structure based on the visual and arms-length inspection at the time of the inspection. The material testing is discussed in more detail in following sections. The overall fair condition is based on localized areas that are deteriorated as summarized below:

The topside of the reinforced concrete deck is not observable due to an asphalt wearing surface. This wearing surface is in satisfactory condition. It is generally raveling and weathering throughout. There are wide reflective cracks with edge spalls in the asphalt where the deck joints are located below. The concrete bump-out lane markers typically exhibit numerous cracks throughout their lengths. There are several locations where the asphalt wearing surface has spalled adjacent to the concrete lane markers.

The sidewalks are generally in good condition. However, the south sidewalk has a thin concrete overlay that is delaminated throughout the length of the sidewalk with several areas where the overlay has spalled. Numerous transverse cracks were also noted in the overlay.

For the most part, the undersides of the reinforced concrete decks in the original south structure and in the widened north structure are in fair condition. There are isolated areas of spalling with corroded reinforcing steel exposed and areas of delamination on the underside of the decks. The majority of the spalling occurs in the newer North Structure in the bay between Arch Rib 2 and the longitudinal beam in Spans 2 and 3. There are also a few spalls along transverse deck expansion joints in the original south structure and in the widened north structure. Horizontal cracks were also observed on the south deck edge at several locations, appearing to correspond to the level of the top of deck at the gutter line.

The L-shaped longitudinal beam located near the centerline of the bridge is in poor condition. It is heavily encrusted with dirt due to leakage through the joint and has numerous large spalls with exposed reinforcement throughout it length, especially in Span 3.

The north and south longitudinal sidewalk fascia beams are in good condition although a crack was observed at one location on the south sidewalk fascia beam.

The arch ribs are generally in satisfactory condition. A few isolated spalls and cracks are present.

The spandrel columns in the widened north structure are in good condition. In the original south structure, the taller spandrel columns near the springing lines are in good condition. Some of the shorter spandrel columns in the vicinity of the crown of the arches are in fair condition where spalling and delamination were noted.

The floorbeams in the widened north structure are generally in satisfactory condition. A few spalls with exposed reinforcing are noted on the underside of some floorbeams.

The floorbeams in the original south structure are in poor condition. Many of the floorbeams sound delaminated on the side faces over the spandrel columns. It is unclear as to why the faces of the floorbeams are delaminated over the spandrel columns. One possible cause could be that longitudinal forces transmitted from the spandrel columns to the caps may have created tensile forces within the floorbeams normal to the plane of the column vertical reinforcing bars that resulted in internal cracking in the plane of the vertical column reinforcing.

Piers 1 and 2 are in satisfactory condition.

At the time of inspection the top of the pier footings are approximately 1’-6” below the water surface. Since the water clarity is very clear, the top surfaces of the pier footings are visible, but the foundations at the mudline cannot be seen. Although the inspection of components below water is not included in this inspection, a visual cursory inspection indicates that the top surface appears to be in good condition. In general, the top surfaces and the sheet piling around the perimeter are covered by a light coating of sediment and marine growth.

Summary – Concrete Testing Results

For both the Northbound and Southbound Structures, nine concrete cores samples were extracted for a total of 18 concrete samples. Laboratory testing on selected core samples was then conducted to evaluate the concrete properties/characteristics for the purpose of making an assessment of the condition of the concrete in various components of the bridge and to determine the reinforcement’s susceptibility to corrosion. The tests performed included compressive strength (seven samples), petrographic examination (ten samples), and chemical analysis (one sample).

For a more detailed discussion about the concrete testing and the concrete test results, see Appendix A. The results are summarized below.

Compressive Testing

Concrete Samples used for compressive tests were extracted from locations on the arch ribs, spandrel columns, and floorbeams. The measured compressive strength of samples extracted from the arch ribs and floorbeams varies from 4,040 psi to 4,380 psi with one sample having a compressive strength as high as 6,670 psi. The two concrete samples taken from the Spandrel Columns however, have significantly lower measured compressive strength. The compressive strength measured only 2,370 psi and 2,680 psi for a spandrel column in the South Structure and North Structure, respectively. Generally compressive strength of components with less than 3000 psi compressive strength may not be adequate for bridge rehabilitation and may require replacement.

Petrographic Examination

Petrographic examination of concrete core samples is used to evaluate the physical characteristics and the condition of the concrete and to look for signs of deterioration within the concrete under the microscope. Petrographic examination can determine a range of parameters, including the following:

- The type, proportions, grading, shape, and condition of the aggregates.
- The nature of the cement paste, including mineral additions such as fly ash, and the degree of hydration
- The presence of deleterious material, cement paste, and air voids
- The depth of carbonation
- The bond between aggregate and the paste
- Evidence of sulfate attack, frost damage, some forms of chemical attack, and alkali silica reactions
- Measurement of air entrainment

Ten core samples extracted from the piers, arch ribs, and deck were used for petrographic examination. Of the ten samples, only two samples, one from Arch Rib 3 and one from Arch Rib 4 in the South Structure exhibited any notable cracking. In one of these samples, the cracking is attributed to alkalis-silica reaction. The cause of the cracking in the other core was not discerned petrographically. The concrete in the other eight cores appear to be in generally good condition. A few micro-cracks are present in these core samples, but they do not appear to be of any consequence. It should be noted that the paste quality is not optimum in all of the samples examined. In general, the paste is generally moderate to moderate soft with a moderately weak to weak bond to the aggregate. But despite these conditions, very little deterioration is observed in the paste.

The depth of carbonation from the surface of the core samples is fairly deep, and is approaching the depth to the reinforcing steel. The depth of carbonation is a key factor in the estimation of the threshold for chloride content when reinforcing bar corrosion is likely to occur. Generally, for carbonated concrete, the threshold chloride content is considerably less than that for un-carbonated concrete.

In the absence of chloride ions and carbonation, a passive layer of iron-oxide forms around reinforcement embedded in concrete, protecting the reinforcement from corrosion. Carbonation and chlorides lowers the pH of the concrete environment and destroy the passive layer around the reinforcement. The reinforcement then begins to corrode in the presence of both oxygen and water. Initiation of corrosion is followed by corrosion propagation, build-up of corrosion products, and finally cracked and spalling concrete. Estimates of the time duration between initiation of corrosion and cracking and spalling differ, but generally fall in the range of 5 to 10 years.

The initiation of corrosion may have already begun at localized areas of the bridge where the cover to the reinforcing is relatively small and the concentration of carbonation is relatively high. It is expected that continued intrusion of carbonation will lead to cracking and spalling in more areas of the structure.

Chemical Analysis

One concrete core, extracted from Arch Rib 3 in the South Structure, was evaluated for the depth, concentration, and profile of chloride concentration (chloride profile testing). The test determined the chloride concentration at certain depth increments from the surface of the sample. The test indicates that at the level of the reinforcing steel (1 inch of cover), the chloride content approaches 0.016 percent by mass concrete.

As noted in the report in Appendix A, chloride content above 0.02 to 0.03 percent by mass concrete can promote corrosion of embedded steel, depending on many factors, including the composition of the concrete and the presence of moisture and oxygen. The report also indicates there are many factors that affect the threshold value where corrosion can occur, and there is no single value of chloride content where corrosion of the reinforcing steel will occur.

While it is not possible to determine the rate of chloride intrusion based on a single sample, or the exact threshold concentration to initiate corrosion, it is clear that at some locations, the chloride content is at or near the lower range of reported threshold values for corrosion initiation. Based on the chloride concentration and depth of carbonation observed in these samples, it is probable the threshold for initiation of corrosion in the reinforcing steel will be reached in the next few years.

Inspection Findings

Deck - Topside

The deck is in satisfactory condition (see **Photo 9**).

The top surface of the concrete deck is not observable due to the asphalt wearing surface with the exception of the three 8 inch wide concrete bump-outs that serve as traffic stripes and an 18 inch wide strip along the north gutter line. The observed distressed areas are as follows:

1. The concrete traffic stripe bump-outs, which run the length of the deck and match the grade of the asphalt wearing surface, typically exhibit cracks up to 1/16 inch wide, generally spaced at 18-inch intervals throughout the length of the bridge (see **Photo 10**).

2. There is a full-length longitudinal joint separating the North and South Structures. There are also two full-width transverse deck expansion joints centered about the crown in each span. In the North Structure, the transverse expansion joints are spaced 11’-3” apart, whereas in the South Structure, the transverse expansion joints are spaced 19'-10" apart. The expansion joints are typically paved over with asphalt. However, the asphalt wearing surface exhibits reflective cracking, up to 1½ inches wide, and edge spalling for the full length and width at all the deck expansion joint locations (see **Photos 11 and 12**).

3. In the South Structure, the concrete traffic stripe bump-out is spalled 11 inches long by its full width at the first transverse joint from the West Abutment that has resulted in a pot hole (see **Photo 13**).

4. In the South Structure East Approach Transition, there is a crack in the wearing surface up to 6 inches wide and up to 4 inches deep along the joint that has been patched with asphalt at several locations. Some of the patches are failing or have failed (**see Photo 14**).

5. In the South Structure, there is a 25 inch long by 5 inch high imminent spall on the vertical face of the southeast concrete curb at the East Abutment (see **Photo 15**).

6. In the North Structure, the wearing surface has a full width crack with edge spalling up to 4 inches wide at the West Approach Transition Joint exposing the top of the concrete deck (see **Photos 16 and 17**).

7. In the North Structure, the wearing surface has a 3 ft. long by 1.5 ft. wide pothole in the north shoulder at the West Abutment which is failing (see **Photos 16 and 18**).

8. In the North Structure, the concrete traffic stripe bump-out near the West Abutment joint has spalled away for a 30-inch length and the area has been patched with asphalt (see **Photo 19**).

9. In the North Structure, the asphalt wearing surface adjacent to the concrete traffic stripe bump-out is spalled resulting in a 2 ft. long by 1 ft. wide pothole, located 72 feet east of the West Abutment (see **Photo 20**).

10. In the North Structure, the asphalt wearing surface at the East Approach Transition Joint is cracked with edge spalling similar to that observed in the South Structure East Approach Transition as described in Item 4 above (see **Photo 21**).

Deck - Underside

The underside of the deck and the north and south deck edge are visible for inspection. For the most part, the underside of the deck is free of any defects such as cracks, delamination, or spalls over most of the deck area. However, there are localized areas of cracking, spalling, delamination, and exposed rebar at isolated locations; and the overall condition of the deck is considered as fair. The areas of deterioration are noted below:

1. The south deck edge is horizontally cracked up to 1/32 inch wide at the mid-height of the slab depth, apparently at the level of the top of the deck at the gutter line, with efflorescence and heavy mold buildup below the crack at the following locations:

    - In Span 1 between Floorbeam 2 and Floorbeam 3 for a length of 4'-0" (**see Photo 22**)
    - In Span 1 between Floorbeam 4 and Floorbeam 5 for a length of 5'-0"
    - In Span 2 between Floorbeam 9 and Floorbeam 10 extending westward from the expansion joint for a length of 4 feet and eastward for a length of 2 feet for a total length of 6 feet (**see Photo 23**)
    - In Span 2 between Floorbeam 11 and Floorbeam 12 extending eastward for a length of 4'-0" from the expansion joint (**see Photo 24**)
    - In Span 3 between Floorbeam 16 and Floorbeam 17 extending eastward and westward from the expansion joint for a length of 4 feet for a total length of 8 feet (**see Photo 25**)
    - In Span 3 for the entire distance from Floorbeam 18 to Floorbeam 19 extending eastward and westward from the expansion joint. In addition, there is a spall adjacent to the expansion joint measuring 4 inches wide by 4 inches high by 2 inches deep that exposes an embedded metal pipe **(see Photo 26**). The as-built plans indicate that this pipe is an expansion sleeve for a shear dowel that crosses the expansion joint.
    - In Span 3 between Floorbeam 19 and Floorbeam 20 for a length of 6'-0" (**see Photo 27**).

2. The underside of the deck (South Structure) is spalled directly over Arch Rib 4 near the expansion joint located midway between Floorbeam 4 and Floorbeam 5 measuring 12 inches square by 1 inch deep. There are four badly corroded reinforcing bars exposed in this spall. There are also three other smaller spalls approximately 3 inches wide by 6 inches long by 1 inch deep with a reinforcing bar exposed in this area (**see Photo 28**).

3. There is a spall along the expansion joint (South Structure) located midway between Floorbeam 11 and Floorbeam 12 measuring 24 inches long by 10 inches wide by 3 inches deep at the end adjacent to the longitudinal beam. There are five reinforcing bars exposed in this spall (**see Photo 29**).

4. The underside of the deck (North Structure) is spalled at three locations immediately east of Floorbeam 11. The first spall measures 20 inches long by 15 inches wide by 2 inches deep located midway between Arch Ribs 1 and 2 with two reinforcing bars exposed (**see Photo 30**). The second spall measures 12 inches square by 2 inches deep with one rebar exposed directly over Arch Rib 2 (**see Photo 31**). The third spall is located directly over Arch Rib 1 measuring 12 inches long by 8 inches wide by 2 inches deep with one reinforcing bar exposed (**see Photo 32**).

5. The underside of the deck (North Structure) between the longitudinal beam and Arch Rib 2 in the panel between Floorbeam 11 and Floorbeam 12, has nine spalls with corroded reinforcing bar exposed, each measuring approximately 10 inches long by 8 inches wide by 1 ½ inches deep **(see Photo 33)**. There are also three additional imminent spalls of similar dimensions in this area.

6. The underside of the deck (North Structure) between the longitudinal beam and Arch Rib 2 in the panel between Floorbeam 14 and Floorbeam 15, has three areas of spalling with reinforcing bar exposed with associated delamination measuring 8 inches wide by 30 inches long, 8 inches wide by 20 inches long, and 8 inches wide by 30 inches long, respectively (**see Photo 34**).

7. The underside of the deck (North Structure) between the longitudinal beam and Arch Rib 2 in the panel between Floorbeam 15 and Floorbeam 16 is spalled with corroded reinforcing bar exposed at two locations. The first spall measures 30 inches long by 12 inches wide by 1 inch deep; and the second measures 36 inches long by 12 inches wide by 1 inch deep (**see Photo 35**).

8. The underside of the deck (North Structure) has a rectangular hole measuring 4 inches by 2 inches by 5 inches deep located over Arch Rib 1 between Floorbeam 15 and Floorbeam 16 (**see Photo 36**).

9. The underside of the deck (North Structure) is spalled with corroded reinforcing bar exposed 2 feet north of the longitudinal beam, located one foot west of Floorbeam 19 measuring 15 inches square by 2 inches deep **(see Photo 37)**.

10. The underside of the deck (North Structure) has an imminent spall 2 feet north of the longitudinal beam located 2 feet east of Floorbeam 19 measuring 20 inches long by 10 inches wide.

11. The underside of the deck (South Structure) is spalled with corroded reinforcing bars exposed along the south edge located near the expansion joint between Floorbeam 16 and Floorbeam 17 measuring 15 inches long by up to 15 inches wide by 2 inches deep (**see Photo 38**).

Joints

In Span 1, the edges of the deck along the expansion joint (South Structure) located midway between Floorbeam 4 and Floorbeam 5 exhibit spalling up to 3 inches wide by 2 inches deep at several locations along the joint. The expansion joint filler material is badly weathered and is disintegrating within the joint (**see Photo 39**).

In Span 3, the edges of the deck along the expansion joint (South Structure) located midway between Floorbeam 16 and Floorbeam 17 are delaminated at several locations along the joint (**see Photo 40**).

Superstructure

There are numerous mud dauber (wasp-like insect) nests, consisting of vertical dirt tubes, throughout the structure on the faces of floor beams, arch ribs, spandrel columns, and underside of the deck (see **Photo 41**). In addition, a blackish-green mold is present on faces of the arch ribs at various locations and on the floorbeams located below deck joints throughout the length of the bridge (see **Photo 22**).

Arch Ribs

The arch ribs in both the original and widened structure are in overall satisfactory condition. The following deficiencies were observed:

1. Arch Rib 4 is heavily stained with mold throughout Spans 1, 2, and 3 (**see Photo 42**).

2. In Span 1, the south face of Arch Rib 3 is spalled at the lower corner adjacent to the West Abutment springing line measuring 22 inches long by 8 inches high by 6 inches wide with a corner reinforcing bar exposed. The exposed reinforcing bar is corroded with 10 percent section loss (**see Photo 43**).

3. In Span 1, the underside of Arch Rib 3 has an imminent spall measuring 6 inches square located 7 feet from the West Abutment springing line.

4. In Span 1, the north side face of Arch Rib 3 is spalled adjacent to the top edge measuring 10 inches square by 1 ½ inches deep, located between Floorbeams 3 and 4 **(see Photo 44**).

5. In Span 2, the top north corner of Arch Rib 2 is spalled measuring 10 inch wide by 4 inches high by 1 inch deep, located just west of Floorbeam 10 **(see Photo 45**).

6. In Span 2, the lower south corner of Arch Rib 3 has an imminent spall measuring 24 inches long by 3 inches high, located directly below Floorbeam 12 (**see Photo 46**).

7. In Span 2, the underside of Arch Rib 3 is deteriorated up to 4 inches wide by 1 ½ inches deep along the cold joint at the Pier 2 springing line over a length of 10 inches adjacent to the south edge (**see Photo 47**).

8. In Span 2, the south face of Arch Rib 4 has a shallow surface defect measuring 10 inches by 8 inches by ¼ inch deep located 2 feet west of Floorbeam 12 (**see Photo 48**).

9. In Span 3, the north side of Arch Rib 2 is longitudinally cracked below Floorbeam 16 for a length of 30 inches, located 2 inches below the top edge. The top corner above this crack is delaminated (**see Photo 49).**

10. In Span3, Arch Rib 1 has a horizontal hairline crack across the width of the underside at the cold joint between Floorbeams 19 and 20.

11. In Span 3, the south face of Arch Rib 3 is spalled along the lower south corner over a length of 12 inches by 10 inches high by 1 ½ inches deep, located 2'-6" from the East Abutment springing line (**see Photo 50**). In addition, there is a hairline crack at the lower south corner that extends transversely across the underside for 12 inches and diagonally up the south face for 30 inches, located 3'-6" from the East Abutment springing line (**see Photo 50**).

12. In Span 3, there is a fine hairline crack at the lower south edge of Arch Rib 4 that extends transversely across the underside for 10 inches and vertically upward for 5 inches from the south corner, located 2'-0" and 5'-0" from the East Abutment springing line (**see Photos 51 and 52**).

13. Typically, several of the arch ribs exhibit a fine hairline crack at the cold joints between the arch rib and the pier at Piers 1 and 2 (**see Photo 53**).

Arch Rib Struts

The reinforced concrete arch struts between Arch Ribs 1 and 2 and between Arch Ribs 3 and 4 are in good condition.

Longitudinal Beam

There is an L-shaped longitudinal beam near the centerline of the bridge that is constructed monolithically with the deck in the widened structure (north half). The longitudinal beam provides a ledge to support the north edge of the original south structure deck. The longitudinal beam is in poor condition. In general, the longitudinal beam is encrusted with dirt and is stained with mold due to water and contaminants being able to leak through the deck joint located above, especially in Span 3. There is also a gap between the underside of the deck and the longitudinal beam ledge. The gap width varies and the gap was observed to widen and narrow due to relative differential deflection of the deck under live load. Due to the exposure to water and contaminants, the longitudinal beam has numerous spalls or areas of deterioration at the following locations:

<u>Span 1</u>

1. The underside of the longitudinal beam is spalled across the full width up to 6 inches deep for a length of 24 inches adjacent to the expansion joint at Floorbeam 4 (North Structure). There are three longitudinal reinforcing bars and a tie exposed in this spall. The spalling also continues vertically on the side faces up to 2 inches deep at this location (**see Photo 54**).

2. The longitudinal beam is spalled on the underside along the south edge up to 4 inches deep with five stirrups and one longitudinal bar exposed for a length of 30 inches by 15 inches wide, located between Floorbeam 2 and Floorbeam 3 (North structure) **(see Photo 55**).

3. The lower south edge and south face of the longitudinal beam are spalled for a length of 24 inches by 6 inches high by 3 inches deep with a longitudinal reinforcing bar exposed at Floorbeam 2 (North Structure) (**see Photo 56**).

<u>Span 2</u>

4. The lower south edge of the longitudinal beam is spalled for a length 20 inches by 6 inches wide by 6 inches high located immediately west of Floorbeam 11 (South Structure) with a longitudinal reinforcing bar exposed (**see Photo 57**).

5. The lower south edge of the longitudinal beam is spalled for a length of 15 inches by 6 inches high by 2 inches deep, located below the deck expansion joint between Floorbeam 11 and Floorbeam 12 (South Structure) (**see Photo 58**).

6. The lower south edge of the longitudinal beam is spalled for a length of 20 inches by 8 inches wide on the underside by 2 inches deep adjacent to the expansion joint at Floorbeam 11 (North Structure). There are four ties and a longitudinal reinforcing bar exposed in the spall (**see Photo 59**).

7. The longitudinal beam from Floorbeam 13 to Floorbeam 14 (South Structure) is heavily spalled and/or deteriorated with crumbling concrete on the south face and south lower edge for a length of 8 feet up to 12 inches high on the south face and 10 inches wide on the underside and up to 3 inches deep. There are three longitudinal reinforcing bars exposed on the south face and several ties exposed within this area (**see Photos 60 and 61**).

<u>Span 3</u>

8. The north face of the longitudinal beam has a horizontal 1/64 inch wide crack located 4 inches above the lower edge between Floorbeam 14 and Floorbeam 15 (North Structure) (**see Photo 62**).

9. In Span 3, the longitudinal beam is heavily spalled for a length of 4 feet along the south face and lower south edge at Floorbeam 15 (north structure) measuring 10 inches high on the south face by 10 inches wide on the underside. There is a longitudinal reinforcing bar exposed at the lower corner and several exposed ties in this spall (**see Photo 63**).

10. The longitudinal beam is heavily spalled for a length of 6 feet along the south face and lower south edge between Floorbeam 15 and Floorbeam 16 (North Structure) measuring 10 inches high on the south face by 10 inches wide on the underside. There is a longitudinal reinforcing bar exposed at the lower corner and several exposed ties in this spall (**see Photo 64**).

11. The longitudinal beam is spalled for a length of 3 feet along the south lower edge and underside between Floorbeam 16 and Floorbeam 17 (North Structure) measuring 12 inches wide on the underside by 6 inches high on the south face (**see Photo 65**).

12. In Span 3, the joint in the longitudinal beam at Floorbeam 17 (north structure) is heavily encrusted with dirt (**see Photo 66**). The beam on the east side of the joint was observed to deflect downward ¼ inch relative to the beam on the west side as highway traffic traverses the roadway joint.

13. The south face of the longitudinal beam is heavily encrusted with dirt throughout the length of Span 3. The gap between the underside of the deck and the ledge of the longitudinal beam is approximately 1 inch wide and the deck floats over the ledge in Span 3. The top edge of the ledge is also very irregular.

Floorbeams – South Structure

The floorbeams in the original south structure are in poor condition. Although under visual inspection the floorbeams appear to be in good condition, many of the floorbeams in the original south structure sound delaminated over the spandrel columns at the following locations:

Span 1

1. The east face of Floorbeam 4 has an area of delamination over the spandrel column at Arch Rib 4 measuring 10 inches square (**see Photo 67**). In addition, the underside of the floorbeam immediately adjacent to the spandrel column has a few hairline cracks and is delaminated as well.

2. The east face of Floorbeam 4 has an area of delamination over the spandrel column at Arch Rib 3 measuring 36 inches horizontal by 15 inches vertical (**see Photo 68**).

3. The west face of Floorbeam 5 has an area of delamination over the spandrel column at Arch Rib 3 measuring 40 inches horizontal by 12 inches vertical (**see Photo 69**). Similarly, the east face also has an area of delamination over the spandrel column at Arch Rib 3 measuring 40 inches horizontal by 12 inches vertical (**see Photo 70**).

Span 2

4. The east face of Floorbeam 10 has an area of delamination over the spandrel column at Arch Rib 3 measuring 30 inches horizontal by 12 inches vertical **(see Photo 71**).

5. The east face of Floorbeam 12 has an area of delamination over the spandrel column at Arch Rib 3 measuring 15 inches horizontal by 12 inches vertical (**see Photo 72**).

Span 3

6. The west face of Floorbeam 16 has an area of delamination over spandrel column at Arch Rib 3 measuring 15 inches square (**see Photo 73**).

7. The east face of Floorbeam 16 has an area of delamination over the spandrel column at Arch Rib 4 measuring 15 inches square (**see Photo 74**).

8. The west face of Floorbeam 17 has an area of delamination over spandrel column at Arch Rib 3 measuring 40 inches horizontal by 15 inches vertical (**see Photo 75**). Similarly, the east face over spandrel column at Arch Rib 3 is also delaminated measuring 30 inches horizontal by 15 inches vertical (**see Photo 76**).

9. The east face of Floorbeam 18 has an area of delamination over spandrel column at Arch Rib 3 measuring 20 inches horizontal by 15 inches vertical (**see Photo 77**).

Other defects noted on the floorbeams in the original south structure include the following:

Span 3

1. The lower edge of the south cantilever on the west side of Floorbeam 17 is delaminated in an area 30 inches wide by 10 inches high centered about the point where the level bottom edge and the sloped bottom edge of the cantilever intersect (**see Photo 78**).

2. The lower edge of the south cantilever of Floorbeam 18 is cracked on the west face up to 1/64 inch wide for a length of 20 inches, located 4 inches above the point where the level bottom edge and the sloped bottom edge of the cantilever intersect (**see Photo 79**).

3. The south cantilever of Floorbeam 19 (below the south sidewalk) has a few cracks that are up to 1/32 inches wide (**see Photo 80**).

The north ends of the north cantilevers of the floorbeams adjacent to the longitudinal beam throughout Spans 1, 2, and 3 typically exhibit varying degrees of deterioration such as spalling, deteriorated concrete, and exposed reinforcing steel up to 12 inches in length along the bottom face. Apparently, when the bridge was widened, portions of the north deck edge and curb were removed. The structure removal may have been in a haphazard manner such that the appearance of the floorbeam ends look like they are spalled. Secondly, reinforcement that may have been cut and they are now exposed to corrosion, thus leading to additional spalling. **See Photos 81 and 82** for typical condition of the ends of the north cantilevers.

Floorbeams – North Structure

The floorbeams in the widened north structure are in overall satisfactory condition. There are areas of spalling or delamination at the following locations:

Span 1

1. Floorbeam 3 is delaminated with some shallow spalling on the lower east corner of the east face measuring 6 inches wide by 6 inches high adjacent to the notch on the north side of Arch Rib 2. The delamination and shallow spalling also continues across the width of the underside of the floorbeam adjacent to Arch Rib 2 (**see Photo 83**). In addition, there is a spall on the underside measuring 12 inches by 6 inches by 2 inches deep with one corroded reinforcing tie bar exposed located 4 feet north of Arch Rib 2 and an imminent spall of similar dimensions located 5 feet north (**see Photo 83**).

2. Floorbeam 4 is delaminated with some shallow spalling on the lower corner of the east face measuring 8 inches wide by 6 inches high adjacent to the notch on the north side of Arch Rib 1. The spalling and delamination also continues on the underside of the floorbeam adjacent to the arch rib notch (**see Photo 84**).

3. The underside of the south cantilever of Floorbeam 3 has a spall measuring 6 inches square by 1 inch deep with a reinforcing tie bar exposed located 1 feet south of Arch Rib 2 (**see Photo 85**).

Span 2

4. Floorbeam 8 has a fine hairline crack visible on the east and west faces, extending vertically down from the top of the floorbeam to about 2 inches from the bottom edge, located 6 feet south of the spandrel column at Arch Rib 1. The crack also continues on the underside of the deck slab for 2 feet on each side of the floorbeam (**see Photo 86**).

5. The south cantilever for Floorbeam 10 is spalled along the lower west edge measuring 15 inches long by 6 inches wide by 2 inches deep with a longitudinal reinforcing bar and two ties exposed located 2 feet north of the center longitudinal beam (**see Photo 87**).

6. Floorbeams 10 and 11 are covered by heavy mold buildup throughout their lengths, apparently due to leakage through the deck joints.

Span 3

7. The underside of the south cantilever for Floorbeam 17 is spalled 2 inches deep across its full width for a length of 4 feet adjacent to the south side of Arch Rib 2. There are three longitudinal reinforcing bars and three transverse ties exposed within this spall (**see Photo 88**). The underside of the north cantilever adjacent to the north side of Arch Rib 1 is also spalled 2 inches deep along the west edge for a length of 15 inches by 6 inches wide with one longitudinal reinforcing bar and a transverse tie exposed (**see Photo 89**).

8. Floorbeam 17 is covered by heavy mold buildup throughout its length, apparently due to leakage through the deck joint.

9. The top edge of Floorbeam 18 on the east side has a spall measuring 12 inches wide by 6 inches high by 1 inch deep, located over Arch Rib 2 (**see Photo 90**).

10. The lower west edge of Floorbeam 17 has a 1/64 inch wide crack 15 inches long extending southward from the notch on the south side of Arch Rib 1. The lower west edge is delaminated about this crack (**see Photo 91**).

11. Floorbeam 18 has a diagonal hairline crack, visible on both the east and west face, that extends diagonally upward from the top corner of the notch at the south side of Arch Rib 1 to the underside of the deck (**see Photo 92**).

Spandrel Columns – South Structure

The taller spandrel columns, which are located in the vicinity of the abutment and pier springing lines, are in good condition. However, several of the shorter columns/pedestals in the vicinity of the crowns of the arches exhibit spalling and/or delamination as noted below:

<u>Span 1</u>

1. The northeast corner of Spandrel Column 4 over Arch Rib 3 sounds delaminated, although it looks good (**see Photo 68**).

2. Spandrel Column 5 over Arch Rib 3 is in poor condition. The northwest corner is badly spalled vertically for a length of 18 inches by 12 inches wide on the west face by 4 inches deep with a vertical reinforcing bar is exposed in this spall (**see Photo 93)**. The southwest corner of the column is also heavily delaminated with a 1/8 inch wide crack located 8 inches from the corner on the south face, and the corner will eventually spall away similar to the northwest corner. Similarly, the northwest corner of the column is delaminated with a 1/16 inch wide crack on the north face approximately 8 inches from the corner (**see Photo 94**).

<u>Span 2</u>

3. The pedestal for Spandrel Column 10 over Arch Rib 3 sounds delaminated on the west face, although no spalling or delamination is visible (**see Photo 95**).

4. Spandrel Column 11 over Arch Rib 3 has a small delamination at the southeast corner measuring 4 inches vertical by 3 inches wide.

<u>Span 3</u>

5. The upper collar for Spandrel Column 16 over Arch Rib 3 has a hairline crack on north face located 4 inches from the northeast corner; and the upper collar across the width of the east face sounds delaminated beginning at this crack (**see Photo 96**). There is also a horizontal hairline crack at the northwest corner extending for a length of 10 inches from the corner on the north and west faces, located 6 inches above the pedestal.

6. The northwest corner of the pedestal for spandrel column 17 over Arch Rib 3 sounds delaminated with some surface scaling (**see Photo 75**).

7. Spandrel Columns 17 and 18 over Arch Rib 3, which are only 4 inches tall, are spalled at the northwest and southwest corners, respectively with a rebar exposed measuring 4 inches wide by 4 inches high by ½ inch deep. There is only ¼ inches of cover over the reinforcing bars, which may have contributed to the spalls (**see Photo 97**).

8. Spandrel Column 19 over Arch Rib 3 has a full height diagonal crack on the north face located 8 inches from the northwest corner; the northwest corner of the collar sounds delaminated (**see Photo 98**).

Spandrel Columns – North Structure

The spandrel columns over Arch Ribs 1 and Arch Rib 2 in the north structure are in good condition. No defects were noted.

Sidewalk Fascia Beam – South Structure

The reinforced concrete south sidewalk fascia beam is in good condition. However, at the west side of Floorbeam 20, the lower north edge is cracked 1/8 inch wide for a length of 20 inches (**see Photo 99**).

Sidewalk Fascia Beam – North Structure

The reinforced concrete north sidewalk fascia beam is in good condition.

Substructure

The orientation of the bridge as shown on the General Plan and Elevation is in an east-west direction. The piers and pier struts are numbered from west to east. The pier columns are numbered from the north to the south. Pier Columns 1 and 2 are located within the widened structure (north half) and Pier Columns 3 and 4 are located in the original structure (south half).

Piers

The struts at the top of the Pier 1, between Columns 1 and 2 and between Columns 3 and 4 are in satisfactory condition. Columns 1 to 4 at Pier 1 are in good condition although Column 4 has a few minor random cracks and has hairline cracks visible at various cold joints (see **Photo 100**).

The struts at the top of Pier 2, between Columns 1 and 2 and between Columns 3 and 4 are in good condition. Columns 1 to 4 at Pier 2 are in good condition (See **Photo 101**). However the following minor superficial defects were noted on the columns:

1. Column 2 has a 10 inch square by 1 ½ inch deep spall at the northeast corner, located 6 feet above the waterline.

2. Columns 3 and 4 have a few random small surface spalls/defects.

Abutments and Wingwalls

The abutments and wingwalls are in overall satisfactory condition. In general, there is some hairline map cracking on both the East and West Abutment wall at random locations. In addition, the following deficiencies are noted:

1. At the West Abutment there is a small delamination located 3-0” north of Arch Rib 1 at 3’-4” below the springing line measuring 5" wide by 2" high (see **Photo 102**).

2. There is a 6" wide by 6" high spall at the top of the West Abutment wall adjacent to the deck/slab interface located 4 ft. north of the north/south structure joint cover (see **Photo 103**).

3. At the West Abutment, there is a 5" wide by 5" high spall in the backwall with an exposed reinforcing bar at the seat located 2’-6” below the springing line, located 2’-4" north of Arch Rib 3 (see **Photo 104**). The rebar has 70% section remaining.

4. At the West Abutment, there is a 6" deep hole (1" by 1/2") 2' north and 1' from the bottom of Arch Rib 1. Expansion material at the North/South Structure Joint is partially exposed and worn, but fully intact (see **Photo 105**).

5. The sleeve around the steel natural gas pipeline, located at the top of the West Abutment under the south sidewalk is leaking leaving water stains running down the face of the backwall (see **Photo 106**).

6. The upper 15' of the East Abutment backwall is heavily covered by dirt over the width of the North Structure, apparently due to water leaking through the roadway joint at the East Abutment. The lower 15' of the abutment wall is painted and is clean.

7. At the East Abutment there is a 6 inch by 6 inch spall located 9-ft. south of Arch Rib 1 6'-8" below the springing line.

8. The North/South Structure Joint Cover at the East Abutment exhibits several edge spalls up to 3 inches deep and other delaminated areas along the full height of the south side of the cover (see **Photos 107 and 108**).

9. At the East Abutment, there is a delamination in the backwall measuring 12 inches long by 8" high at the top of the backwall underneath the longitudinal beam where it frames into the backwall (see **Photo 109**). In addition, there are four hairline to 1/16" wide horizontal cracks in the upper four feet of the backwall that propagate southward for a

length of approximately 4 ft. past the longitudinal beam from a point below the longitudinal beam (see **Photos 110 and 111**).

10. The sleeve around the steel natural gas pipeline, located at the top of the East Abutment under the south sidewalk, is leaking, leaving water stains running down the face of the backwall.

11. The West Slope Embankment has no vegetation or slope protection resulting in erosion (see **Photo 112**). The North/South Bridge Joint Cover is partially undermined for a 9" wide section (see **Photo 113**). There is a 3 ft. long section between Arch Ribs 3 and 4 that is undermined and can be probed up to 6 inches deep (see **Photo 114**).

12. The slope beneath the pedestrian path at the East Abutment is severely eroded and undermined (see **Photo 115**) exposing the foundation of the path.

13. The slope at the Northeast Wingwall is eroded with evidence of movement of placed riprap (see **Photo 116**).

The west wingwalls are in good condition with no notable defects. The Northeast Wingwall is in good condition with no notable defects observed. A pedestrian crosswalk traffic light is attached to the top of the wingwall column. A retaining wall along Robert E. Lee Road limits access to inspect the Southeast Wingwall.

The slopes in front of the West Abutment are not protected and are eroding. The slope immediately in front of the East abutment is in good condition since a concrete pedestrian trail runs adjacent to the East Abutment confining the slope in front of the East Abutment wall. However, on the south side of the bridge beyond the south corner of the east abutment, the concrete pedestrian trail is undermined vertically up to 2 feet high due to erosion of the embankment, exposing lines of concrete piles beneath the concrete pavement.

Sidewalks and Railings

The sidewalks are in satisfactory condition. The north and south sidewalks both exhibit hairline map cracking throughout.

1. The North Sidewalk is sound and in good condition with a few random popouts and minor spalls. The following distresses are observed:

   - There is a full width by 4" edge spall at the West Abutment joint (see **Photo 117**)
   - A 4" long by 4" wide by 2" deep spall in the curb at the expansion joint 104'-4" east of the West Abutment is observed (see **Photo 118**)
   - There is a 4" wide by 7" long spall at the pilaster 153'-8" east of the West Abutment (see **Photo 119**)
   - A 28" long by 13" wide spall at the East Abutment joint is noted (see **Photo 120**)

- There are typical cracks up to 3/8" wide located at the bridge expansion joints (see **Photo 121**).

2. The South Sidewalk has a 3/4" concrete overlay and metal armoring on the sidewalk curb corners. The concrete overlay is delaminating throughout the length of the South Sidewalk from the concrete overhang below. The following additional defects are noted:

    - There is a 7" long by 1" wide spall at the sidewalk slab joint 47' east of the West Abutment (see **Photo 122**)
    - A 26" long by 3" wide spall at the sidewalk slab joint 97' east of the West Abutment (see **Photo 123**) is observed
    - There is a 30" long by 8" wide spall at the sidewalk slab joint 117' east of the West Abutment (see **Photo 124**)
    - There is a 29" long by 11" wide spall at the sidewalk slab joint at the face of the East Abutment (see **Photo 125**). The expansion joint material in the sidewalk 167' east of the West Abutment has failed and is dislodged leaving a 1/2" gap (see **Photo 126**).
    - Similarly to the North Sidewalk, there are typical cracks, up to 3/8" located at the bridge expansion joints.

3. The railings on the bridge are in good condition. The concrete pilasters sound solid and the steel pipes and pickets experience light surface rust. There is impact damage to the north steel rail and pickets 139'-8" from the West Abutment (see **Photo 127**). Three pickets are bowed north away from the bridge. The 7th pilaster from the Northwest corner of the bridge is cracked at the rail connection (see **Photo 128**). There is an existing patch to repair the defect which sounds solid.

Stream Channel

The overall stream channel is in good condition. There were no debris or obstructions noted.

A streambed profile was taken along the north and south sides of the bridge. A comparison of the current upstream streambed profile to the upstream profile taken in the previous 2014 Bridge Inspection Report shows no significant changes. The 2014 Bridge Inspection Report only provided an upstream profile. The streambed sounding data and profiles are shown on Pages 113 to 117.

Radial soundings were also taken at discrete intervals around the perimeters of Pier 1 and Pier 2 foundations at 0.0 ft., 5.0 ft., and 10 ft. from the faces of the footings (see Figure on Page 118). There is no baseline or previous sounding information for this type of sounding in previous inspection reports to compare to. The soundings indicate that the streambed around the pier footings is generally uniform and there is no evidence of any scour pockets around the footings.

STRUCTURE NEEDS AND ESTIMATED REMAINING LIFE

The structure needs and estimated remaining life are primarily a function of the deterioration of key structural elements and the result of the material investigation study.

The south structure is 91 years old and the north structure is 71 years old. The bridge overall has a condition rating of fair, and most structural components generally have a condition rating of good or satisfactory, based on the scale in Appendix B. However, the longitudinal beam at the interface between the north and south structures is in poor condition due to leakage through the longitudinal joint above. If joint leakage is permitted to continue, deterioration will advance into other structural components below the joint and into the arch ribs – adding to more costly repairs or even total replacement of the bridge in the future. Based on the current level of deterioration of the longitudinal beam and continued intrusion of water and deleterious substances, it is estimated that in the absence of rehabilitation, significant deterioration could progress to a point where increases in maintenance costs and repairs reach a significant level in 5 to 10 years.

Repair of the longitudinal beam alone to limit water intrusion may not be sufficient to extend the life of the bridge significantly. A preferred method to limit water intrusion would be to replace the deck entirely and eliminate longitudinal and transverse joints all together. In addition, since the spandrel columns exhibit low compressive strength and several exhibit spalling and/or delamination, any bridge rehabilitation desiring increased lifespan would involve stripping the structure down to the arch ribs and rebuilding the spandrel columns, floorbeams, and deck.

For the arch ribs, the main load carrying members, the results of the concrete testing indicate that the concrete quality is generally good. However, the depth of carbonation and chloride content at some locations in the arch ribs at the level of the reinforcement is at a concentration consistent with the threshold for initiation of corrosion of the reinforcing bars. Although there is no definitive timeframe for further deterioration, it is likely that corroded reinforcing resulting in cracking and spalling of the concrete will progress over the next 3 to 5 years, resulting in increased maintenance cost, and eventually in deterioration requiring significant rehabilitation.

Any rehabilitation will require a structural analysis to determine whether the existing arch ribs have sufficient strength to support a new deck and floor system, especially if the deck is widened to accommodate pedestrian/bike lanes. A deck replacement scheme may require a stiffening element, such as continuous prestressed concrete box girders, to distribute loads more efficiently to the arches. Furthermore, any rehabilitation scheme would need to investigate and mitigate the effects of carbonation and chloride intrusion on the concrete and reinforcing steel.

PHOTOGRAPHS

Photo 9: Typical topside deck condition

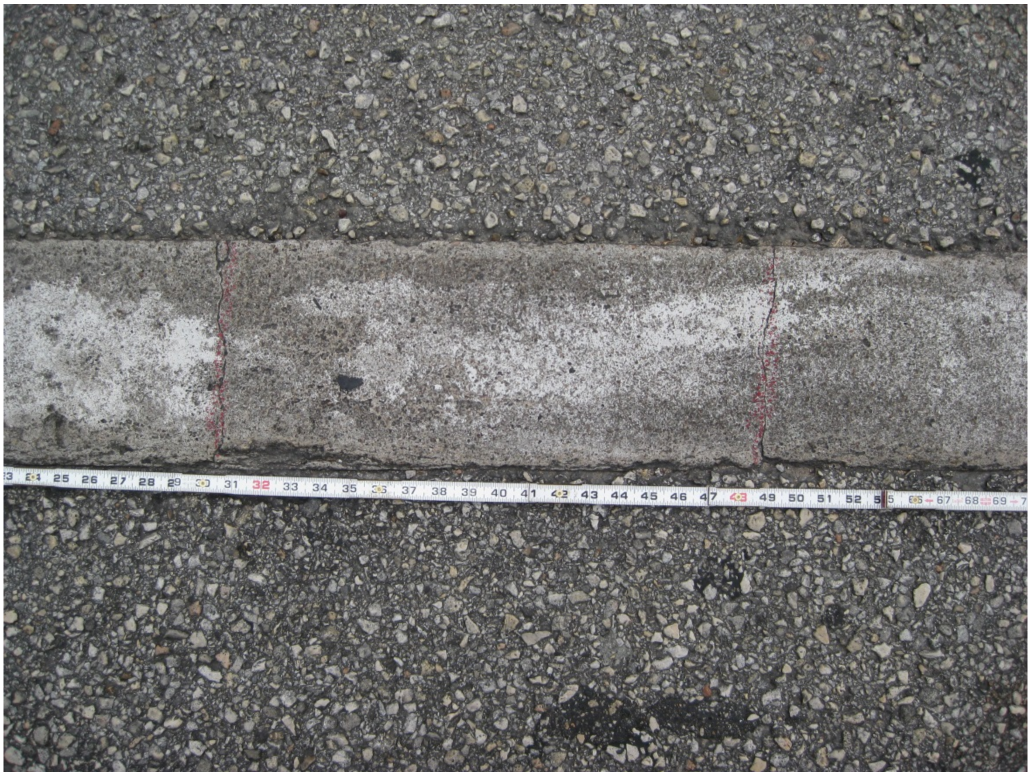


Photo 10: Typical cracking in concrete traffic stripe markers

Photo 11: Reflective cracking in centerline of bridge along longitudinal deck joint

Photo 12: Typical reflective cracking in transverse deck joint

Photo 13: Spall in concrete traffic stripe marker in South Structure deck


Photo 14: South Structure East Approach Transition

Photo 15: Imminent spall in southeast curb at the East Abutment

Photo 16: North Structure West Approach Transition


Photo 17: Exposed concrete deck at the North Structure West Approach Transition


Photo 18: Pothole at the North Structure West Approach Transition

Photo 19: Patch in the North Structure wearing surface near West Abutment

Photo 20: Pothole in North Structure wearing surface 72' east of the West Abutment


Photo 21: North Structure East Approach Transition

Photo 22: Crack in Span 1 south slab edge between Floorbeams 2 and 3 with greenish-black mold observed emanating from crack

Photo 23: Crack in Span 2 south slab edge between Floorbeams 9 and 10

Photo 24: Crack in Span 2 south slab edge between Floorbeams 11 and 12

Photo 25: Crack in Span 3 south slab edge between Floorbeams 16 and 17

Photo 26: Crack and spall in Span 3 south slab edge between Floorbeams 18 and 19

Photo 27: Crack in Span 3 south slab edge between Floorbeams 19 and 20

Photo 28: Spall in Span 1 underside of the deck above Arch Rib 4 near the expansion joint midway between Floorbeams 4 and 5

Photo 29: Spall in underside of Span 2 adjacent to expansion joint at longitudinal beam midway between Floorbeams 11 and 12

Photo 30: Spall in underside of Span 2 North Structure deck east of Floorbeam 11 midway between Arch Ribs 1 and 2

Photo 31: Spall in underside of Span 2 North Structure deck east of Floorbeam 11 directly over Arch Rib 2

Photo 32: Spall in underside of Span 2 North Structure deck east of Floorbeam 11 directly over Arch Rib 1

Photo 33: Spalls in underside of Span 2 North Structure deck between the longitudinal beam and Arch Rib 2 between Floorbeam 11 and 12

Photo 34: Spalls and delaminations in underside of Span 3 North Structure deck between the longitudinal beam and Arch Rib 2 between Floorbeam 14 and 15

Photo 35: Spalls and delaminations in underside of Span 3 North Structure deck between the longitudinal beam and Arch Rib 2 between Floorbeam 15 and 16

Photo 36: Rectangular hole in Span 3 of the North Structure deck underside above Arch Rib 1 between Floorbeams 15 and 16

Photo 37: Spall in Span 3 of the North Structure deck underside 2' north of the longitudinal beam and 1 ft. west of Floorbeam 19

Photo 38: Spall in Span 3 South Structure deck along the south lower edge at the expansion joint between Floorbeams 16 and 17

Photo 39: Edge spalls along expansion joint in Span 1 of the South Structure midway between Floorbeams 4 and 5

Photo 40: Edge spalls along expansion joint in Span 3 of the South Structure midway between Floorbeams 16 and 17

Photo 41: Mud dauber nests cover the superstructure

Photo 42: Typical Arch Rib 4 heavily stained with mold and dirt

Photo 43: Spall in south edge of Arch Rib 3 adjacent to the West Abutment Springing Line

Photo 44: Spall in north face of Arch Rib 3 in Span 1 between Floorbeams 3 and 4

Photo 45: Spall in top north corner of Arch Rib 2 in Span 2 just west of Floorbeam 10

Photo 46: Imminent spall on lower south corner of Arch Rib 3 in Span 2 below Floorbeam 12

Photo 47: Deterioration on south edge of the underside of Arch Rib 3 along cold joint at Span 2 Pier 2 Springing Line

Photo 48: Shallow surface defect in south face of Arch Rib 4 2' west of Floorbeam 12 in Span 2

Photo 49: Longitudinal crack and delamination of the north side of Arch Rib 2 below Floorbeam 16 in Span 3

Photo 50: Spall and cracking in lower south corner of Arch Rib 3 at the East Abutment Springing Line

Photo 51: Hairline cracking in the lower south edge of Arch Rib 4 at the East Abutment Springing Line

Photo 52: Close-up of hairline cracking in the lower south edge of Arch Rib 4 at the East Abutment Springing Line

Photo 53: Typical hairline crack at the cold joint between the arch rib and pier

Photo 54: Full width spall in underside of longitudinal beam in Span 1 adjacent to expansion joint at North Structure Floorbeam 4

Photo 55: Spalls in underside of longitudinal beam in Span 1 between Floorbeams 2 and 3

Photo 56: Spall with exposed rebar in lower south edge of longitudinal beam in Span 1 at Floorbeam 2

Photo 57: Spall with exposed rebar in underside of longitudinal beam in Span 2 immediately west of Floorbeam 11 of the South Structure

Photo 58: Spalls in lower south edge of longitudinal beam in Span 2 below the expansion joint between Floorbeams 11 and 12

Photo 59: Spall with exposed rebar and ties in lower south edge of longitudinal beam in Span 2 adjacent to expansion joint at the North Structure Floorbeam 11

Photo 60: Deterioration in lower south face and corner of longitudinal beam with exposed rebar in Span 2 between Floorbeams 13 and 14

Photo 61: Deterioration in lower south face and corner of longitudinal beam with exposed rebar in Span 2 between Floorbeams 13 and 14

Photo 62: Cracks in north face of longitudinal beam between North Structure Between Floorbeams 14 and 15

Photo 63: Deterioration in lower south face and corner of longitudinal beam with exposed rebar in Span 3 at North Structure Floorbeam 15

Photo 64: Deterioration in lower south face and corner of longitudinal beam with exposed rebar in Span 3 between North Structure Floorbeams 15 and 16

Photo 65: Deterioration on lower south face and corner of longitudinal beam with exposed rebar in Span 3 between North Structure Floorbeams 16 and 17

Photo 66: Deterioration of longitudinal edge girder at the expansion joint located at North Structure Floorbeam 17

Photo 67: Delamination in east face of Floorbeam 4 at Arch Rib 4

Photo 68: Delamination in east face of Floorbeam and Spandrel Column 4 at Arch Rib 3

Photo 69: Delamination in west face of Floorbeam 5 at Arch Rib 3

Photo 70: Delamination in east face of Floorbeam 5 at Arch Rib 3

Photo 71: Delamination in east face of Floorbeam 10 at Arch Rib 3

Photo 72: Delamination in east face of Floorbeam 12 at Arch Rib 3

Photo 73: Delamination in west face of Floorbeam 16 at Arch Rib 3

Photo 74: Delamination in east face of Floorbeam 16 at Arch Rib 4

Photo 75: Delamination in west face of Floorbeam and Spandrel Column 17 at Arch Rib 3

Photo 76: Delamination in east face of Floorbeam 17 at Arch Rib 3

Photo 77: Delamination in east face of Floorbeam 18 at Arch Rib 3

Photo 78: Delamination in lower west face of south cantilever of South Structure Floorbeam 17

Photo 79: Crack (up to 1/64") located in lower west face of south cantilever of South Structure Floorbeam 18

Photo 80: Cracks (up to 1/32") in south cantilever east face of South Structure Floorbeam 19

Photo 81: Typical minor deterioration of north end north cantilever of South Structure

Photo 82: Typical severe deterioration of north end north cantilever of South Structure

Photo 83: Delamination and spalling with exposed rebar on underside and east face of Floorbeam 3 between Arch Ribs 1 and 2

Photo 84: Delamination with shallow spalling on lower corner of east face of Floorbeam 4 on the north side of Arch Rib 1

Photo 85: Spall in underside of south cantilever of Floorbeam 3 at Arch Rib 2

Photo 86: Hairline crack on east and west faces of Floorbeam 8 located 6' south of Arch Rib 1 and continuing on the underside of the deck on either side of floorbeam

Photo 87: Spalling with exposed rebar in west face of south cantilever of North Structure Floorbeam 10

Photo 88: Spall with exposed rebar of underside of south cantilever of North Structure Floorbeam 17

Photo 89: Spall with exposed rebar in underside of north cantilever of North Structure Floorbeam 17

Photo 90: Spall in top edge of the east face of Floorbeam 18 over Arch Rib 2

Photo 91: Cracking and delamination of lower west edge of Floorbeam 17 on the south side of Arch Rib 1

Photo 92: Hairline diagonal crack visible on both east and west faces of Floorbeam 18 at Arch Rib 1

Photo 93: Spalling in northwest corner of Spandrel Column 5 over Arch Rib 3

Photo 94: Delamination in northeast corner of Spandrel Column 5 over Arch Rib 3

Photo 95: Delaminated pedestal at west face of Spandrel Column 10 over Arch Rib 3

Photo 96: Delamination in east face of upper collar of Spandrel Column 16 over Arch Rib 3

Photo 97: Spall on west face of Spandrel Column 18 over Arch Rib 3

Photo 98: Diagonal crack on north face of Spandrel Column 19 over Arch Rib 3

Photo 99: Crack in south sidewalk fascia beam at west side of South Structure Floorbeam 20

Photo 100: Typical condition of Pier 1 – east face shown

Photo 101: Typical condition of Pier 2 – west face shown

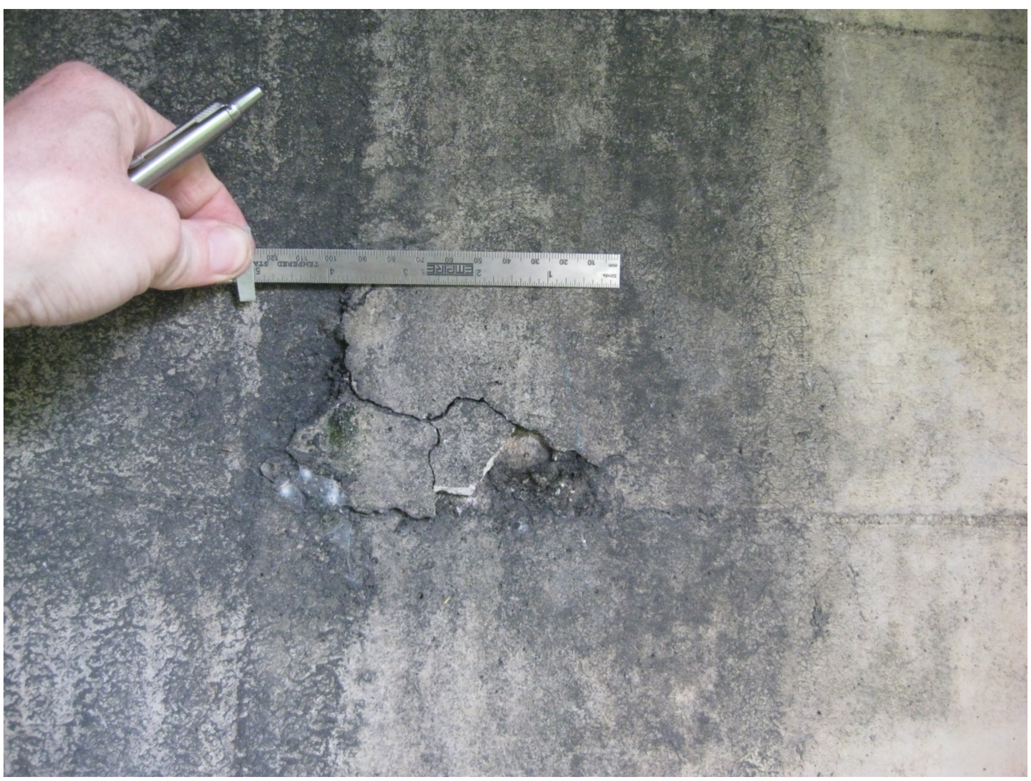


Photo 102: Delamination in West Abutment 35" north of Arch Rib 1

Photo 103: Spall in top of West Abutment Backwall 4' north of the North/South Structure joint

Photo 104: Spall with exposed rebar at West Abutment Backwall seat 28" north of Arch Rib 3

Photo 105: Expansion joint material at the North/South Structure joint at the West Abutment

Photo 106: Leaking utility pipe at the south end of the West Abutment

Photo 107: Spalls and delaminations in the North/South Structure joint cover at the East Abutment – bottom 15' shown

Photo 108: Spalls and delaminations in the North/South Structure joint cover at the East Abutment – top 15' shown

Photo 109: Delamination below the longitudinal edge girder at the East Abutment

Photo 110: Cracks in East Abutment backwall propagating from the delamination below the longitudinal edge girder

Photo 111: Cracks in East Abutment backwall propagating from the delamination below the longitudinal edge girder

Photo 112: Typical condition of West Abutment slope with erosion and bare slopes

Photo 113: Undermining of West Abutment below the North/South Structure joint cover

Photo 114: Undermining of West Abutment between Arch Ribs 3 and 4

Photo 115: Severe erosion and undermining of pedestrian path adjacent to the East Abutment

Photo 116: Erosion at the Northeast Wingwall

Photo 117: Sidewalk edge spall of the north sidewalk at the West Abutment joint

Photo 118: Spall in North Sidewalk curb 104'-4" east of the West Abutment

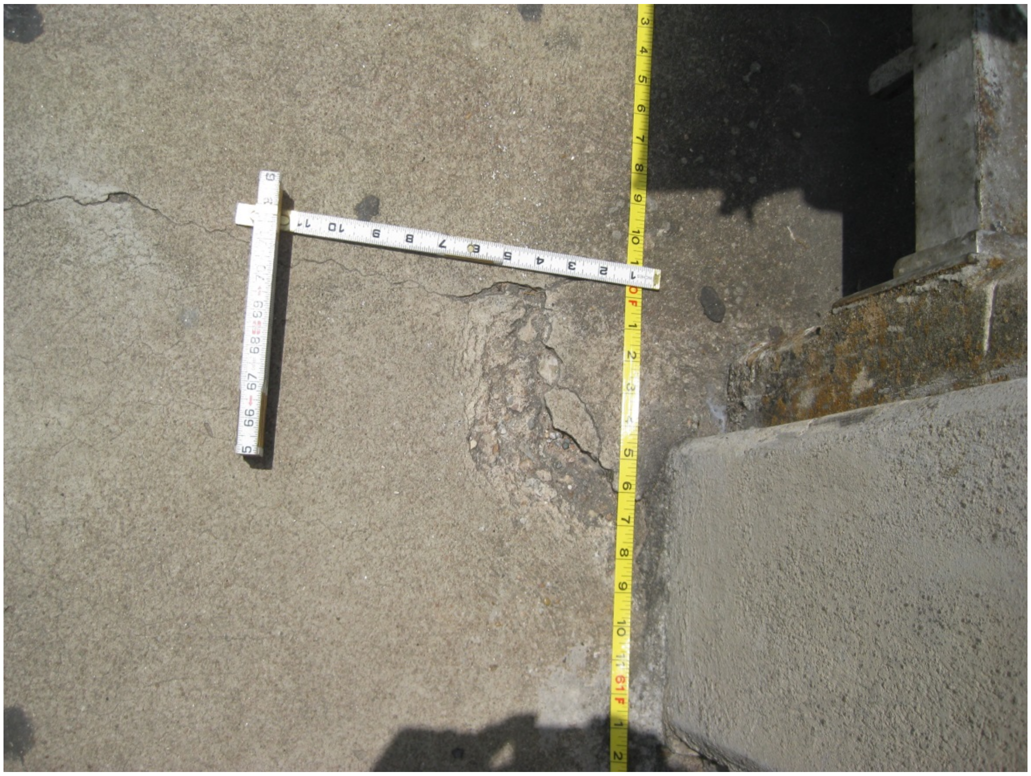


Photo 119: Spall in North Sidewalk153'-8" east of the West Abutment

Photo 120: Spall in North Sidewalk at the East Abutment joint

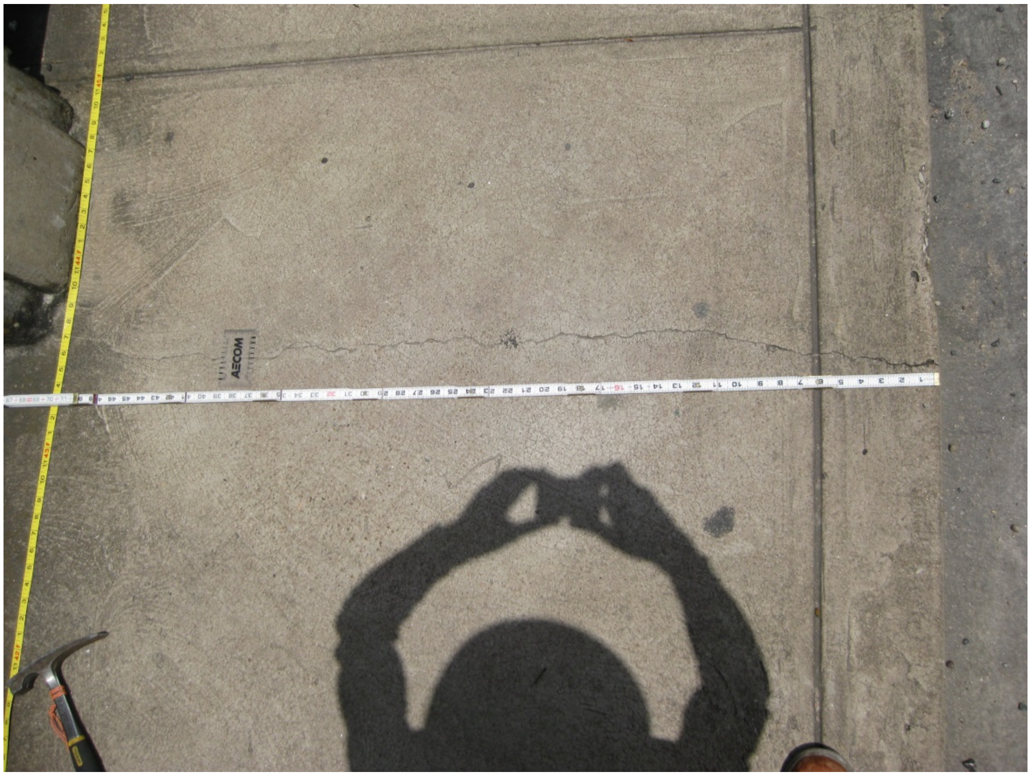


Photo 121: Typical full-width transverse cracks in the North Sidewalk located at transverse bridge expansion joints

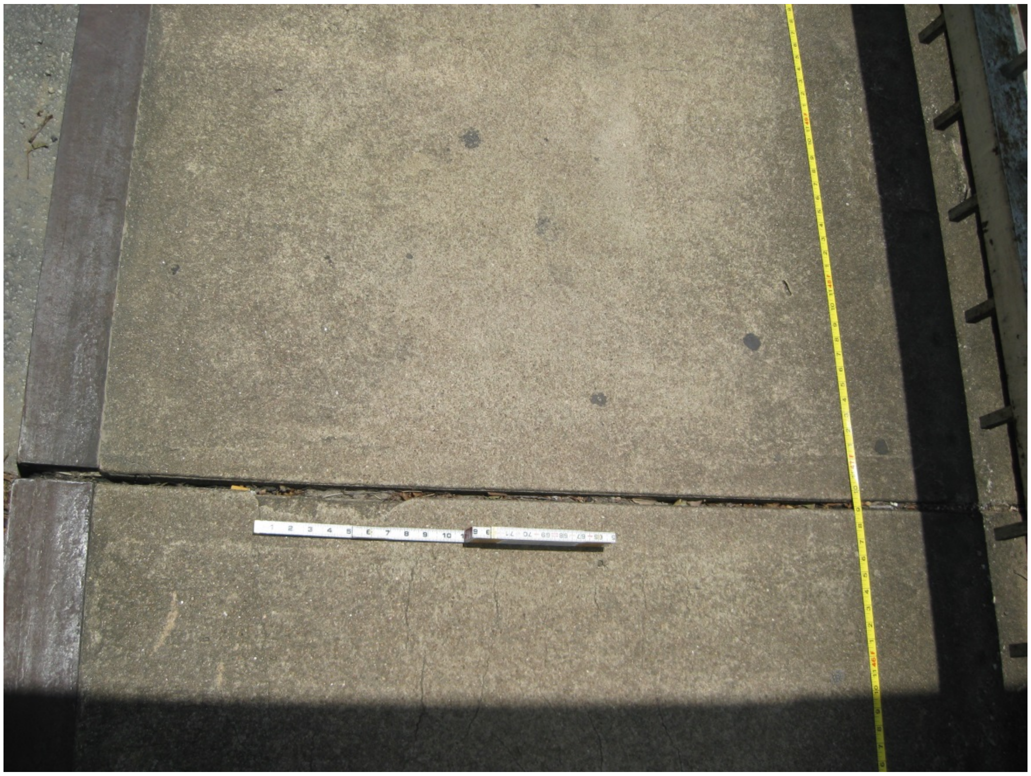


Photo 122: Spall in South Sidewalk overlay 47' east of the West Abutment

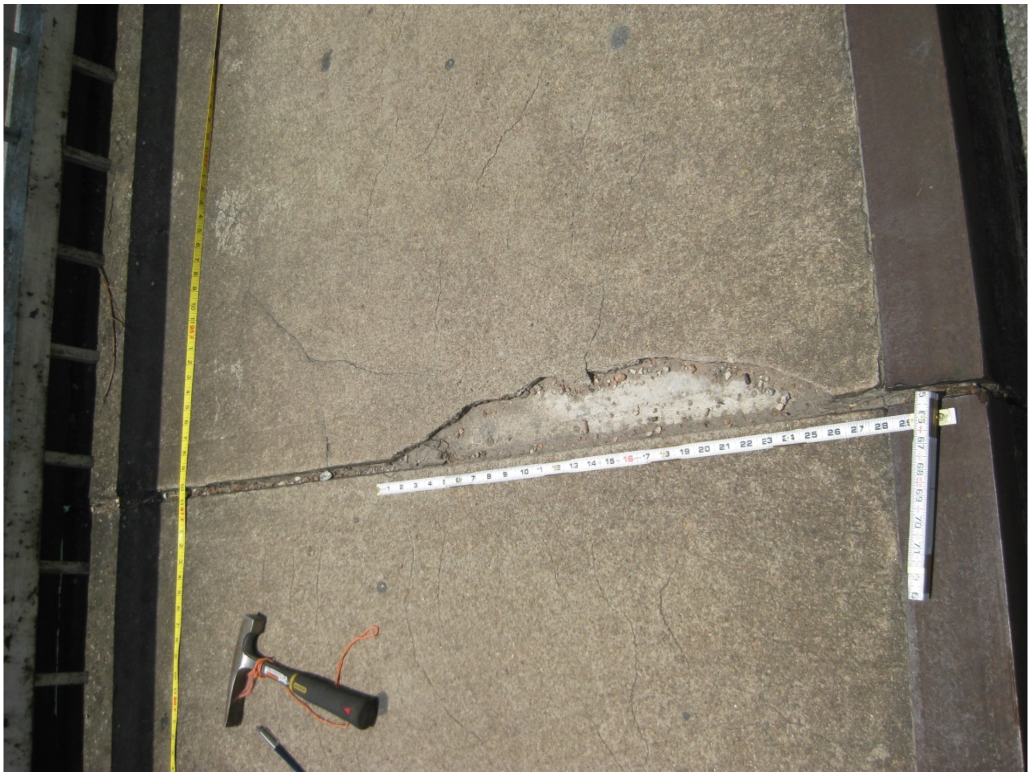


Photo 123: Spall in South Sidewalk overlay 97' east of West Abutment

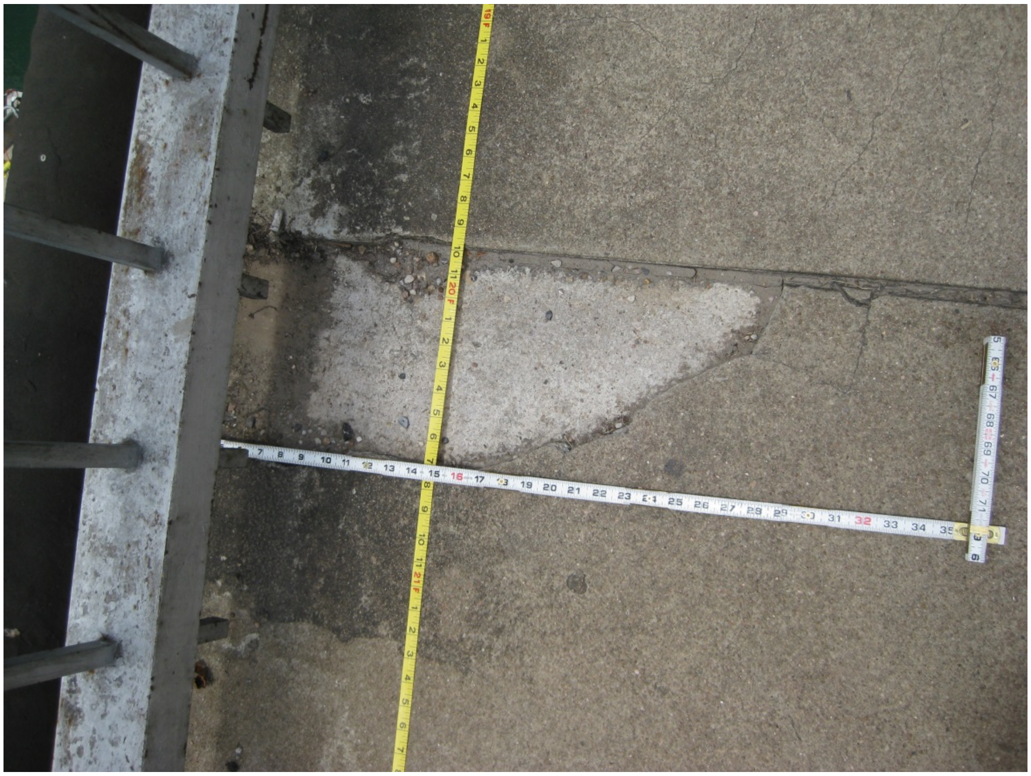


Photo 124: Spall in South Sidewalk overlay 117' east of West Abutment

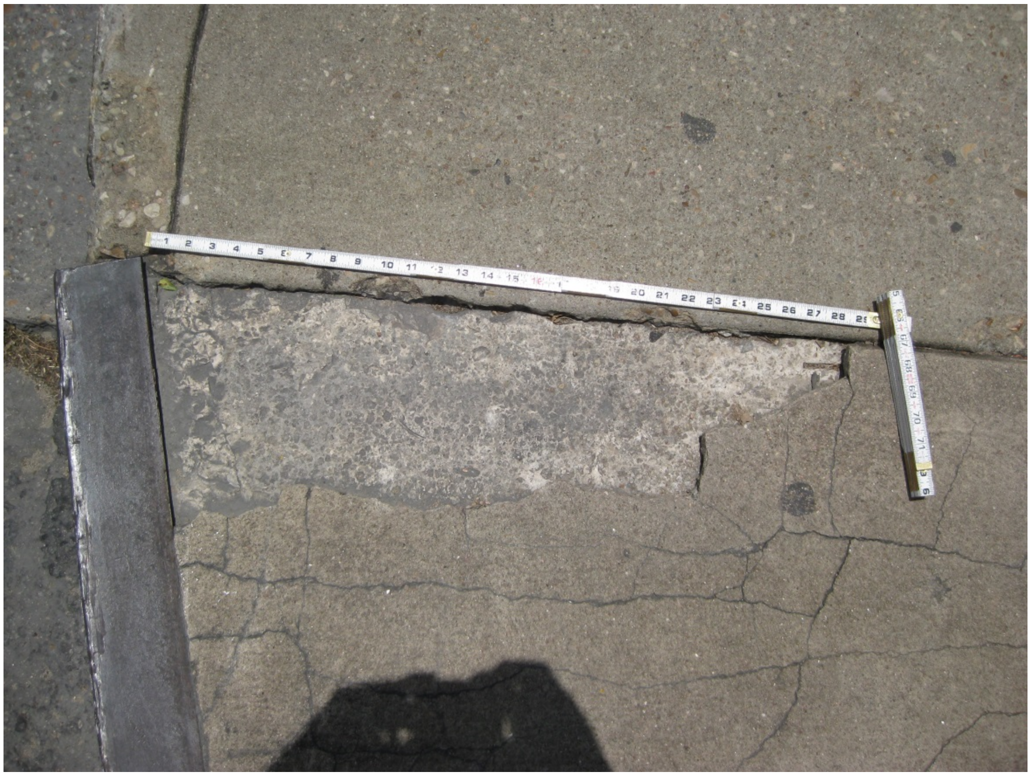


Photo 125: Spall in South Sidewalk overlay at the face of the East Abutment

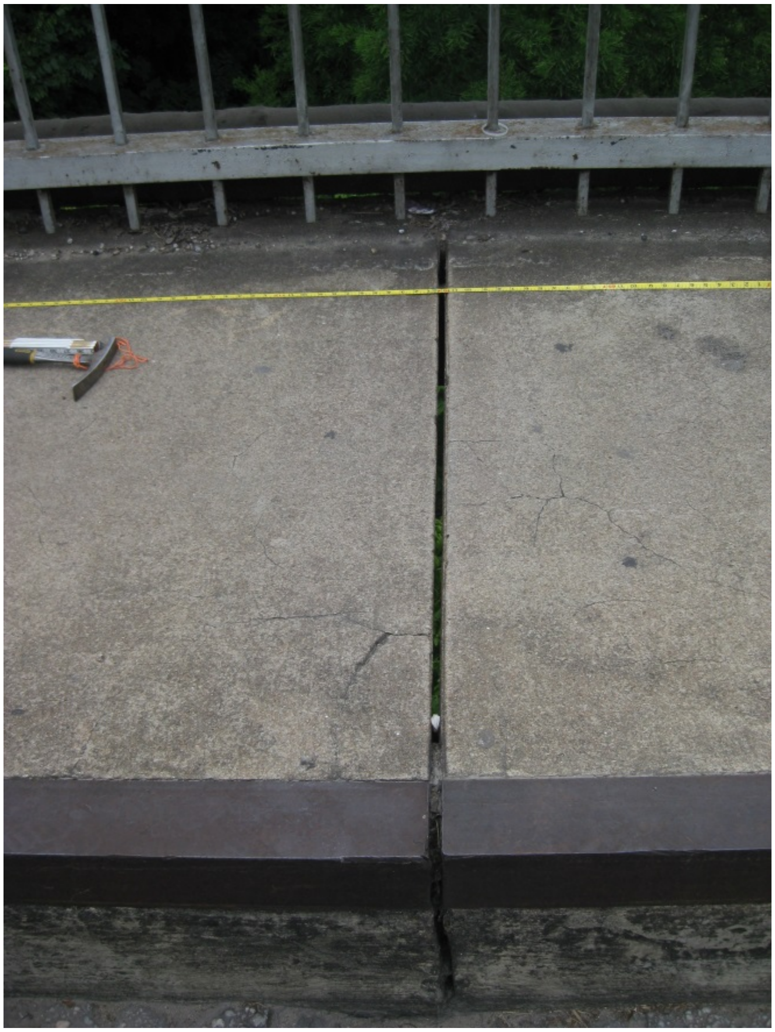


Photo 126: Missing expansion joint material in South Sidewalk 167' east of the West Abutment resulting in a 1/2" gap


Photo 127: Impact damage to the North Railing 139'-8" east from the West Abutment

Photo 128: Failed patch with cracking in the 7th pilaster from the west of the North Railing

STREAMBED PROFILES
AND
RADIAL SOUNDINGS

Form 2600
(03/16)

Texas Department of Transportation

CHANNEL CROSS-SECTION MEASUREMENTS RECORD

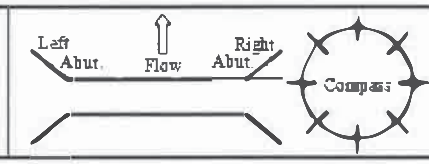
District: 14 County: 227 Control - Section: B002 - 26 Structure #: 001 Route: Barton Springs R

Feature Crossed: Barton Springs Creek

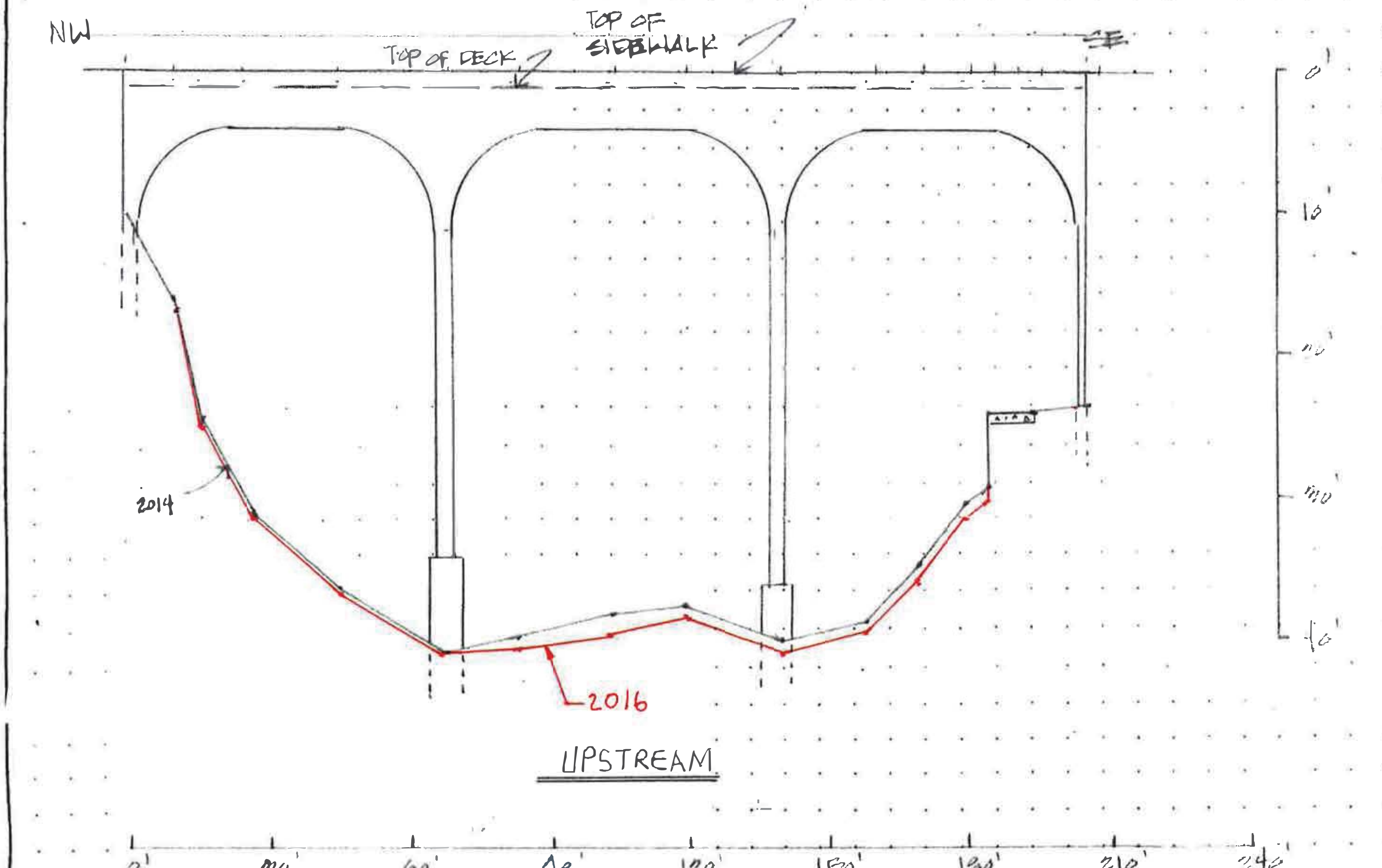
If measurements were taken with any device other than a drop line or tape measure, please describe method in comment section.
Please record any important comments on the reverse side.

Reference Features:

A. Top of Railing	B. Edge of Deck	C. Top of Curb	D. Top of Parapet
E. Sidewalk	F. Top of Cap	G. Water Surface	H. Channel
I. Rigid Rip-Rap	J. Rubble Rip-Rap	K. Top of Pipe	L. Top of Train



Bent #	Notes (Item 44)	Total Horiz. Dist.	AECOM				Company Name				Company Name				Company Name			
							Company Number				Company Number				Company Number			
			Date: 06/16/2016				Date:				Date:				Date:			
			☒ Upstream		☐ Downstream		☐ Upstream		☐ Downstream		☐ Upstream		☐ Downstream		☐ Upstream		☐ Downstream	
			Distance From Last Bent	Top Ref.	Bot. Ref.	Vertical Distance	Distance From Last Bent	Top Ref.	Bot. Ref.	Vertical Distance	Distance From Last Bent	Top Ref.	Bot. Ref.	Vertical Distance	Distance From Last Bent	Top Ref.	Bot. Ref.	Vertical Distance
1	SW Abut	0'	0'	K	L	10'												
		10'	10'	K	H	17'-2"												
		25'	25'	K	H	30'-5"												
		45'	45'	K	H	36'-4"												
2	Pier 1	68'	68'	K	H	41'-3"												
		83'	15'	K	H	40'-6"												
		103'	35'	K	H	39'-4"												
		118'	50'	K	H	38'-1/2"												
3	Pier 2	138'	70'	K	H	40'-8"												
		158'	20'	K	H	39'-7"												
		168'	30'	K	H	36'-2"												
		178'	40'	K	H	31'-7"												
		183'	45'	K	E	29'-9"												
		193'	55'	K	E	24'-6"												
4	SE Abut	206'	68'	K	H	23'-4"												



Texas Department of Transportation

Bridge Inspection and Appraisal Program

BRIDGE I.D.: 14-227-B002-26-001

ROUTE: BARTON SPRINGS RD

FEATURE X'ED: BARTON CREEK

INSPECTION DATE: 6-15-16 PAGE 1 OF 1

Texas Department of Transportation

CHANNEL CROSS-SECTION MEASUREMENTS RECORD

Form 2600
(03/16)

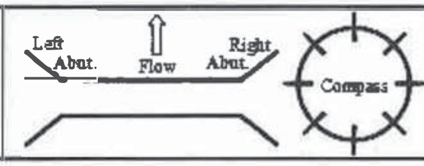
District: 14 County: 227 Control - Section: B002 - 26 Structure #: 001 Route: Barton Springs R

Feature Crossed: Barton Springs Creek

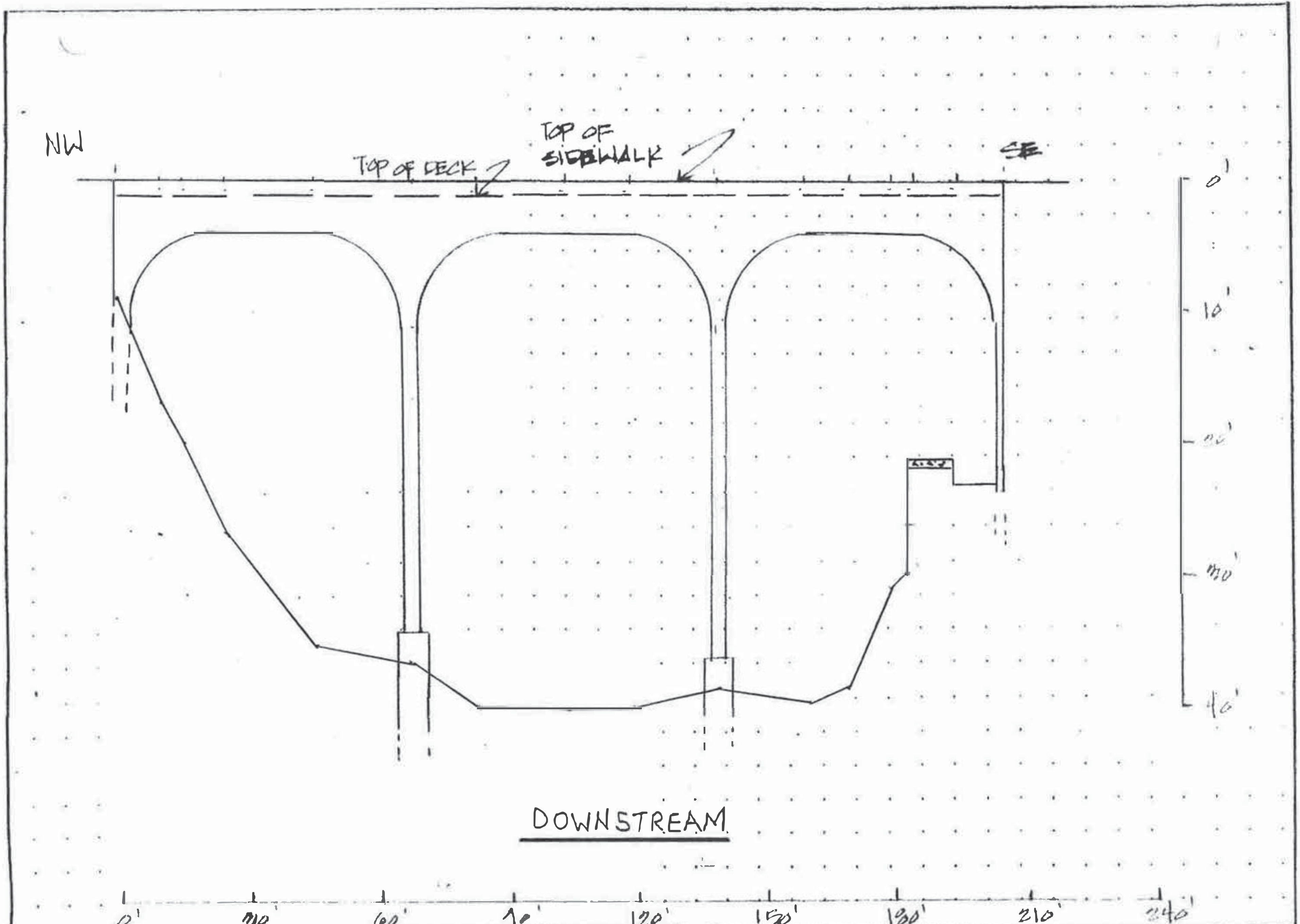
If measurements were taken with any device other than a drop line or tape measure, please describe method in comment section.
Please record any important comments on the reverse side.

Reference Features:

A. Top of Railing	B. Edge of Deck	C. Top of Curb	D. Top of Parapet
E. Sidewalk	F. Top of Cap	G. Water Surface	H. Channel
I. Rigid Rip-Rap	J. Rubble Rip-Rap	K. Top of Railing	L. Top of Train



Bent #	Notes (Item 44)	Total Horiz. Dist.	AECOM				Company Name				Company Name				Company Name			
							Company Number				Company Number				Company Number			
			Date: 06/16/2016				Date:				Date:				Date:			
			☐ Upstream ☒ Downstream				☐ Upstream ☐ Downstream				☐ Upstream ☐ Downstream				☐ Upstream ☐ Downstream			
			Distance From Last Bent	Top Ref.	Bot. Ref.	Vertical Distance	Distance From Last Bent	Top Ref.	Bot Ref	Vertical Distance	Distance From Last Bent	Top Ref.	Bot. Ref.	Vertical Distance	Distance From Last Bent	Top Ref	Bot. Ref.	Vertical Distance
1	NW Abut	0'	0'	E	L	9'-1"												
		10'	10'	E	H	16'-10"												
		15'	15'	E	H	19'-11"												
		25'	25'	E	H	26'-10"												
		45'	45'	E	H	35'-3"												
2	Pier 1	68'	68'	E	H	36'-2"												
		83'	15'	E	H	39'-11"												
		103'	35'	E	H	40'-4"												
		118'	50'	E	H	40'-4"												
3	Pier 2	138'	70'	E	H	38'-2"												
		158'	20'	E	H	39'-5'												
		168'	30'	E	H	38'-8"												
		178'	40'	E	H	31'-0"												
		183'	45'	E	H	29'-5"												
		193'	55'	E	E	21'-2"												
4	NE Abut	206'	68'	E	H	23'-4"												



Texas Department of Transportation

Bridge Inspection and Appraisal Program

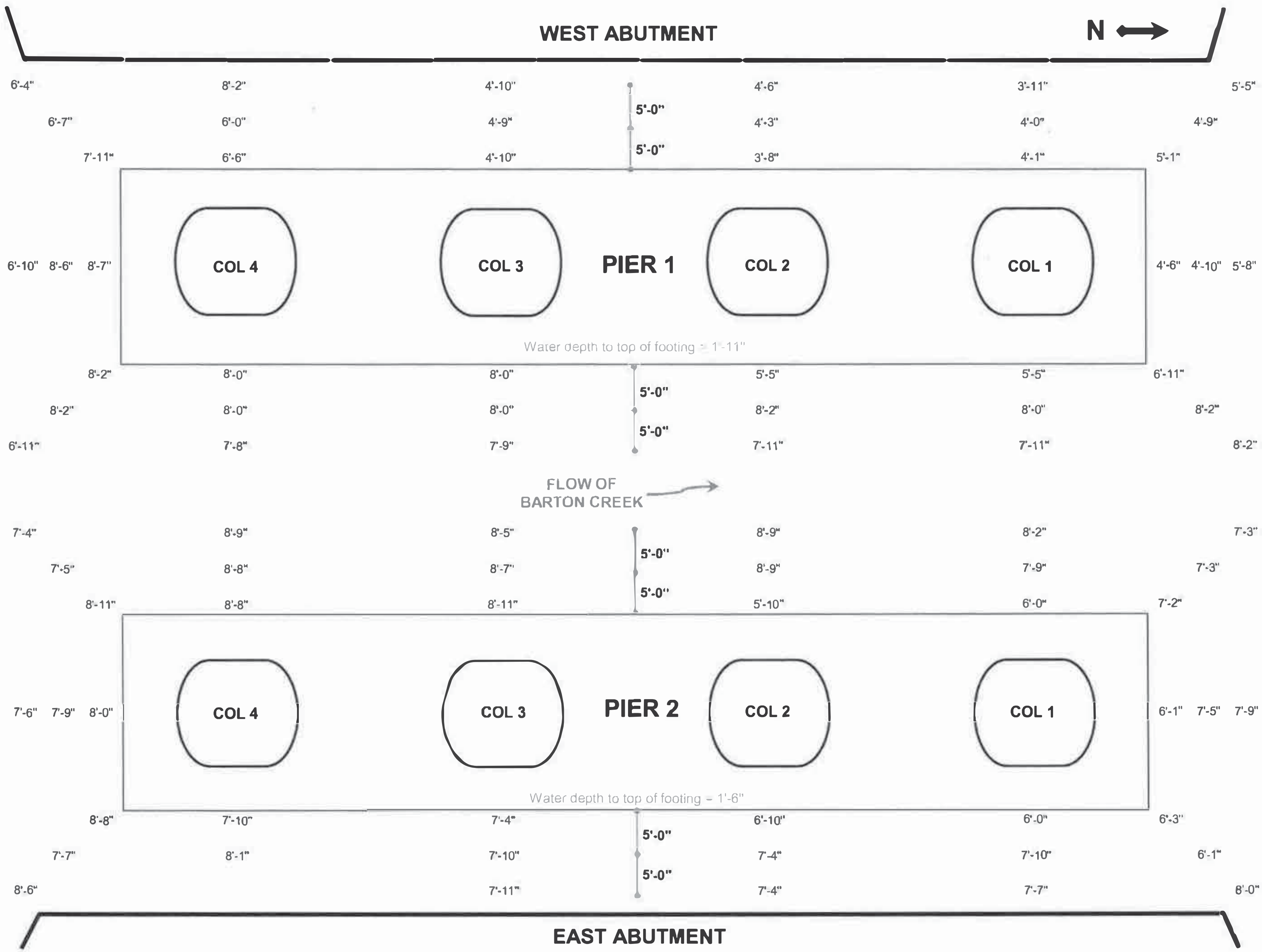
BRIDGE I.D.: 14-227-B002-26-001

ROUTE: BARTON SPRINGS RD

FEATURE X'ED: BARTON CREEK

INSPECTION DATE: 6-15-16 PAGE | OF |

Channel Soundings



APPENDIX A

Onsite Sampling and Laboratory Investigation of Concrete Cores

Austin, TX Office:
3737 Executive Center Drive, Suite 255
Austin, TX 78731-1633
P: 512-219-4075 F: 512-219-4077

September 9, 2016

Mr. Arnold Ashburn
AECOM
9400 Amberglen Blvd.
Austin, Texas 78729

Phone: 512-419-5173
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Summary Report
Onsite Sampling and Laboratory Investigation of Concrete Cores
Barton Springs Road Bridge, Austin, TX
CTLGroup Project No. 231599

Dear Mr. Ashburn:

As authorized by AECOM, CTLGroup has completed an on-site sampling and laboratory evaluation of concrete cores from the Barton Springs Road Bridge. The City of Austin requested a concrete materials study be performed on the Barton Springs Road Bridge and CTLGroup was retained by AECOM to assist with this study. CTLGroup was tasked to obtain concrete core samples from the bridge for laboratory testing. AECOM requested that laboratory testing be performed on the core samples to evaluate the concrete properties/characteristics, the concrete strength, and the reinforcement's susceptibility to corrosion. As a result, petrographic examination, chemical analysis, and compressive strength testing were performed on the core samples. This report summarizes CTLGroup's site visit and the laboratory testing results.

ONSITE EVALUATION

CTLGroup's site visit was conducted on June 15-17, 20 and 21, 2016. The following CTLGroup staff members were present during the site visit: Bradley East, P.E. (June 15 through 17, 20, and 21), Juan Carlos Araiza, Ph.D., P.E. (June 15 through 17 and 20), and Jon Poole, Ph.D., P.E. (June 20). During CTLGroup's site visit, AECOM representatives were present and traffic control and safety boats were provided.

The bridge was visually evaluated from street level, and pedestrian walkways that ran beneath the west and east ends of the bridge. The underside of the bridge was accessed using an Aspen A-62 Bridge Inspection Unit. Additionally, the bridge piers at water level were accessed using a boat.

GENERAL OBSERVATIONS

The structural framing of the bridge consisted of reinforced concrete. It was constructed in two half's (north half [downstream] and south half [upstream]). The south half was the original bridge. According to available bridge plans[1], the south half was constructed in the mid 1920's. In the mid 1940's, the bridge was widened and the north half of the bridge was constructed.

[1] Digital copies of the bridge plans were provided to CTLGroup by AECOM.

Both halves of the bridge are generally identical in layout. Each bridge consists of three spans (east, west and middle). The ends of the bridge are supported on abutments. The middle portion of the bridge that spans over Barton Creek is supported by piers. Additional reinforced concrete bridge elements include the following: arches, spandrel columns, floor beams, and deck. For reference purposes, an aerial image[2] and an elevation view of the bridge are shown in Figures 1 and 2, respectively, at the end of this report.

AECOM performed distress mapping and hammer sounding of the bridge to identify areas of delamination. Potential areas of delamination were identified and marked with chalk (Figure 3). Concrete cover was visibly spalled and the steel reinforcement was exposed at multiple locations (Figure 4). The steel reinforcement was corroded at these locations.

SAMPLING

Core sample locations were determined collaboratively with AECOM. The core locations are shown below in Table 1. The approximate locations of the cores are also shown on the bridge plans in Figures 5 and 6.

Table 1 – Core Sample Locations

Core	Bridge	Element	Location
C1	North	Pier	Downstream Pier, Upstream Face
C2		Pier	Upstream Pier, Downstream Face
C3		Arch	East Span, Downstream Arch, Upstream Face
C4		Arch	East Span, Upstream Arch, Upstream Face
C5		Arch	West Span, Upstream Arch, Upstream Face
C6		Arch	West Span, Upstream Arch, Upstream Face
C7		Column	West Span, Upstream Column, Upstream Face
C8		Beam	East Span
C9		Deck	East Span
C10	South	Pier	Downstream Pier, Upstream Face
C11		Pier	Downstream Pier, Downstream Face
C12		Arch	East Span, Upstream Arch, Upstream Face
C13		Arch	Middle Span, Upstream Arch, Upstream Face
C14		Arch	West Span, Downstream Arch, Upstream Face
C15		Arch	West Span, Downstream Arch, Downstream Face
C16		Column	Middle Span, Downstream Column, Downstream Face
C17		Beam	East Span
C18		Deck	East Span

Non-Destructive Testing

Ground Penetrating Radar (GPR) is a nondestructive test method that employs high-frequency electromagnetic energy that can assess a variety of characteristics when applied to concrete structures. GPR surveys performed on concrete elements allow for the detection of embedded objects (steel reinforcement, prestressing/post-tensioning strand, conduit, and other embedded items), material interfaces, and internal discontinuities such as voiding. The technique involves the use of a high-frequency radar antenna which transmits electromagnetic radar pulses along a

[2] Google, Inc., Google Earth (software), Version 7.1.5.1557

longitudinal scan at the surface of a structural element. Electromagnetic signals are optically reflected from material interfaces of varying dielectric constant along the propagation path of the wave. The reflected signals are collected by the antenna, amplified and displayed for subsequent interpretation.

GPR is commonly used to determine the location and depth of reinforcing bars in walls and other concrete structures. The contrast between the electromagnetic properties of embedded steel and that of cured concrete provides a distinct direct reflection from the reinforcing bars. The magnitude and phase of these reflections are analyzed to determine the location of the reinforcement.

During CTLGroup's site visit, GPR scans were performed at each core location to ensure that the embedded steel reinforcement was avoided during coring. A StructureScan Mini HR with a 2600 MHz antenna manufactured by Geophysical Survey Systems, Inc. (GSSI) was used on this project. Additionally, the depth and distribution of the lateral and longitudinal reinforcement were noted at most core locations to approximate the as-built conditions. A summary of the reinforcement depth and spacing is shown below in Table 2.

Table 2 – GPR Scan Results

Location	Reinforcement Orientation	Spacing (in.)	Average Cover (in.)
C1	Horizontal	12	Not Documented
	Vertical	17-22	Not Documented
C2	Horizontal	12	4.5
	Vertical	20-22	5
C3	Longitudinal	Top and Bottom	2.5
	Lateral	24	1.5
C4	Longitudinal	Top and Bottom	3
	Lateral	12-14	2
C6	Longitudinal	Top and Bottom	2.5
	Lateral	14	1.5
C7	Horizontal	12	1
	Vertical	2 Bars – 1 @ Each Corner	1.25
C8	Horizontal	Top and Bottom	3
	Vertical	10	1.5
C10	Horizontal	12	5+
	Vertical	Not Documented	5+
C12	Longitudinal	Top and Bottom	3
	Lateral	10	2
C13	Longitudinal	Top and Bottom	1
	Lateral	10-12	1.5
C15	Longitudinal	Top and Bottom	2
	Lateral	12	1.5
C16	Horizontal	4	1.5
	Vertical	Not Documented	Not Documented
C17	Horizontal	Top and Bottom	2
	Vertical	14	1

The above spacing and cover values are approximate. Additionally, the above results are only intended to be representative of the embedded reinforcement at the identified locations. CTLGroup did not calibrate the GPR results based on the dielectric properties of the concrete.

Concrete Coring

Cores samples were extracted from the bridge by Texas Cutting and Coring, L.P. at the locations shown in Table 1, and Figures 5 and 6. The cores were extracted in general accordance with ASTM C42[3]. Most cores measured nominal 4 in. diameter (3.75 in. actual diameter) and were removed from the bridge in a horizontal orientation. A summary of the size, orientation, and date the cores were extracted are shown below in Table 3.

Table 3 – Additional Core Details

Core	Nominal Diameter (in.)	Orientation	Date Extracted
C1	4 in.	Horizontal	June 17, 2016
C2	4 in.	Horizontal	June 17, 2016
C3	4 in.	Horizontal	June 20, 2016
C4	4 in.	Horizontal	June 20, 2016
C5	4 in.	Horizontal	June 21, 2016
C6	4 in.	Horizontal	June 17, 2016
C7	4 in.	Horizontal	June 17, 2016
C8	4 in.	Horizontal	June 20, 2016
C9	3 in.	Vertical (Overhead)	June 21, 2016
C10	4 in.	Horizontal	June 17, 2016
C11	4 in.	Horizontal	June 17, 2016
C12	4 in.	Horizontal	June 20, 2016
C13	4 in.	Horizontal	June 20, 2016
C14	4 in.	Horizontal	June 21, 2016
C15	4 in.	Horizontal	June 17, 2016
C16	3 in.	Horizontal	June 17, 2016
C17	4 in.	Horizontal	June 20, 2016
C18	3 in.	Vertical (Overhead)	June 21, 2016

At the request of AECOM, the concrete slurry created during coring was kept from dripping into Barton Creek. A funnel system using plastic sheeting, duct tape, and a 5-gallon bucket was used for this purpose (Figure 7).

With the exception of the vertical/overhead deck cores (C9 and C18), the core holes were patched after coring operations were completed. These core holes were patched by Texas Cutting and Coring, L.P. on June 21, 2016 using a non-shrink grout material (Figure 8). Jon Poole, Ph.D., P.E. and Bradley East, P.E. of CTLGroup returned to the site on July 27, 2016 to seal the vertical/overhead deck core holes (Figures 9 and 10). A liquid applied hydrostatic waterproof material was used for this purpose.

[3] ASTM C42 "Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete"

The concrete core samples were placed in plastic bags and packaged for shipment. The cores were shipped to CTLGroup's Skokie, IL Laboratory on June 23, 2016. Note that the time from when the cores were extracted to the time of testing varied from the requirements in C42 (testing no more than 7 days after extraction), due to developing and finalizing the testing plan. It is CTLGroup's opinion that this variance does not significantly affect the findings in this report.

SUMMARY OF LABORATORY TESTING

With input from AECOM, laboratory testing was identified for each core sample. This testing plan was communicated to AECOM in an email sent on July 7, 2016 and is summarized below in Table 4.

Table 4 – Summary of Lab Tests Performed on Each Core Sample

Core	Laboratory Test
C1	C856
C2	C856
C3	C856
C4	C39
C5	C856
C6	C39
C7	C39
C8	C39
C9	C856
C10	C856
C11	C856
C12	C856
C13	C856
C14	C39
C15	Modified C1556
C16	C39
C17	C39
C18	C856

COMPRESSIVE STRENGTH TESTING, PER ASTM C39

Compressive strength testing was performed on core samples C4, C6, C7, C8, C14, C16 and C17 in general accordance with ASTM C39[4]. Prior to testing, each core sample was capped with a sulfur capping compound (meeting requirements of ASTM C617), and placed in bags for 5 days. The results of the compressive strength testing were emailed on August 1, 2016 and can also be found in **Appendix A** at the end of this report.

The core strengths for the samples extracted from the spandrel columns (C7 and C16) were noticeably lower than the other cores tested. The spandrel column strengths measured 2,680 psi and 2,370 psi, whereas the other core strengths ranged from 4,040 psi to 6,670 psi.

[4] ASTM C39 "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens"

Regarding strength requirements for structural adequacy, ACI 318 5.6.5.4[5] states:

> *Concrete in an area represented by core tests shall be considered structurally adequate if the average of three cores is equal to at least 85 percent of fc' and if no single core is less than 75 percent of fc'.*

The above information is provided for reference purposes. CTLGroup was not asked to evaluate the structural adequacy of the bridge. Considering the age of the bridge, it is unlikely that the design strength of the concrete is known.

CHEMICAL ANALYSIS, MODIFIED ASTM C1556

Core sample C15 was evaluated for the depth, concentration, and profile of chloride concentration (chloride profile testing). The purpose of the test was to determine the chloride concentration in the sample at certain depth increments from the surface of the sample. This test method is based on a modified version of ASTM C1556[6]. Thin layers were ground off parallel to the exposed surface of the specimen. A total of 8 layers from 0-35 mm from the core surface were ground. Most layers were ground in 5 mm increments. The acid-soluble chloride content of each layer was then determined. For baseline/control purposes, the chloride content in the bottom 20 mm of the core sample was also determined. The results of the chloride profile testing were emailed on August 12, 2016 and can also be found in **Appendix B** at the end of this report.

The chloride concentration in the baseline/control was 0.015 percent by mass of concrete. The tested sample reached this baseline/control value at an approximate depth of 20-25 mm from the surface of the sample (less than 1 in.). For comparison purposes, the concrete cover measured during CTLGroup's site visit ranged from 1 in. to greater than 5 in.

Corrosion of steel will initiate when the concentration of chlorides at the level of the reinforcement reach a certain concentration (normally expressed as percentage of the concrete weight), if water and oxygen are also present at the steel. However, there is no single chloride threshold value where this corrosion will occur.[7] Studies have shown that chloride contents above 0.02 to 0.03 percent by mass of concrete, depending on cement content, can promote corrosion of embedded steel in non-carbonated concrete in the presence of sufficient moisture and oxygen. Levels below this threshold can accelerate corrosion in carbonated concrete. Major variables that control the rate of chloride ingress and time to corrosion initiation are the permeability of the concrete, the concrete cover over the reinforcing steel, and the degree of exposure to chlorides from the environment.

The actual threshold at which corrosion initiates could range from 0.02 to 0.07 percent (or greater), depending on the composition of the concrete, the effects of chloride binding in the hydrated cement paste, and other factors (such as availability of moisture and oxygen).

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[5] ACI 318-11: Building Code Requirements for Structural Concrete and Commentary, American Concrete Institute, Farmington Hills, MI, 2011

[6] ASTM C1556 "Standard Test Method for Determining the Apparent Chloride Diffusion Coefficient of Cementitious Mixtures by Bulk Diffusion"

[7] Angst, U., Elsener, B., Larsen, C. K., & Vennesland, Ø. (2009) "*Critical chloride content in reinforced concrete—a review*", Cement and Concrete Research, 39(12), 1122-1138.

Note that other factors may affect the chloride threshold. For example, the presence of the aluminate and ferrite phase (C_3A and C_4AF) in the cement can be beneficial for the reduction of chloride ingress, because the C_3A will combine with chlorides to form $3CaO{\cdot}Al_2O_3{\cdot}CaCl_2{\cdot}10H_2O$ (Friedel's salt).

PETROGRAPHIC EXAMINATION, PER ASTM C856

Petrographic examinations were performed on 10 concrete cores in general accordance with reference standard ASTM C 856[8]. The purpose of the examinations was to assess the general quality of the concrete, to determine if any deleterious reactions were occurring in the concrete, and to determine the depth of carbonation. The petrographic examination results were emailed on September 3, 2016 and can also be found in **Appendix C** at the end of this report.

Based on the results of the petrographic examination, notable cracking was only found in two (2) of the core samples, C12 and C13. The cracking is attributable to alkali-silica reaction (ASR); however, the ASR appeared localized. Additional information regarding this condition can be found in the petrographic examination report in Appendix C. Excluding the localized ASR cracking, the concrete in the remainder of cores C12 and C13 and the concrete in the other eight (8) cores was generally in good condition.

The depth of carbonation in the core samples varied from 0 to 43 mm (0 to 1.7 in.). For comparison purposes, the concrete cover measured during CTLGroup's site visit ranged from 1 in. to greater than 5 in.

Carbonation is the reaction between CO_2 in the air and the hydrated cement paste, generally the calcium hydroxide ($Ca(OH)_2$, or CH in cement chemistry notation). In dense, well consolidated and properly cured concrete, carbonation is a slow reaction that generally occurs over many years. This reaction converts the CH to calcium carbonate ($CaCO_3$), which reduces the pH of the concrete and can lead to the depassivation of the steel. Depassivation of the steel allows corrosion to occur.

CLOSING

Thank you for the opportunity to assist you on this project. Let me know if you have any questions or concerns, or need any additional information.

STATE OF TEXAS
BRADLEY L. EAST
107268
LICENSED
PROFESSIONAL ENGINEER
9-9-16

Bradley L. East, M.S., P.E.
Engineer
BLEast@CTLGroup.com
P. 512-220-2137
M. 512-971-3911

Attachments: CTLGroup Laboratory Testing Results

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[8] ASTM C856 "Standard Practice for Petrographic Examination of Hardened Concrete"

Figure 1 – Aerial view of subject bridge (highlighted in yellow)

Figure 2 – General view of bridge

Figure 3 – Delaminated area as identified by AECOM

Figure 4 – Concrete spall and exposed corroded reinforcement

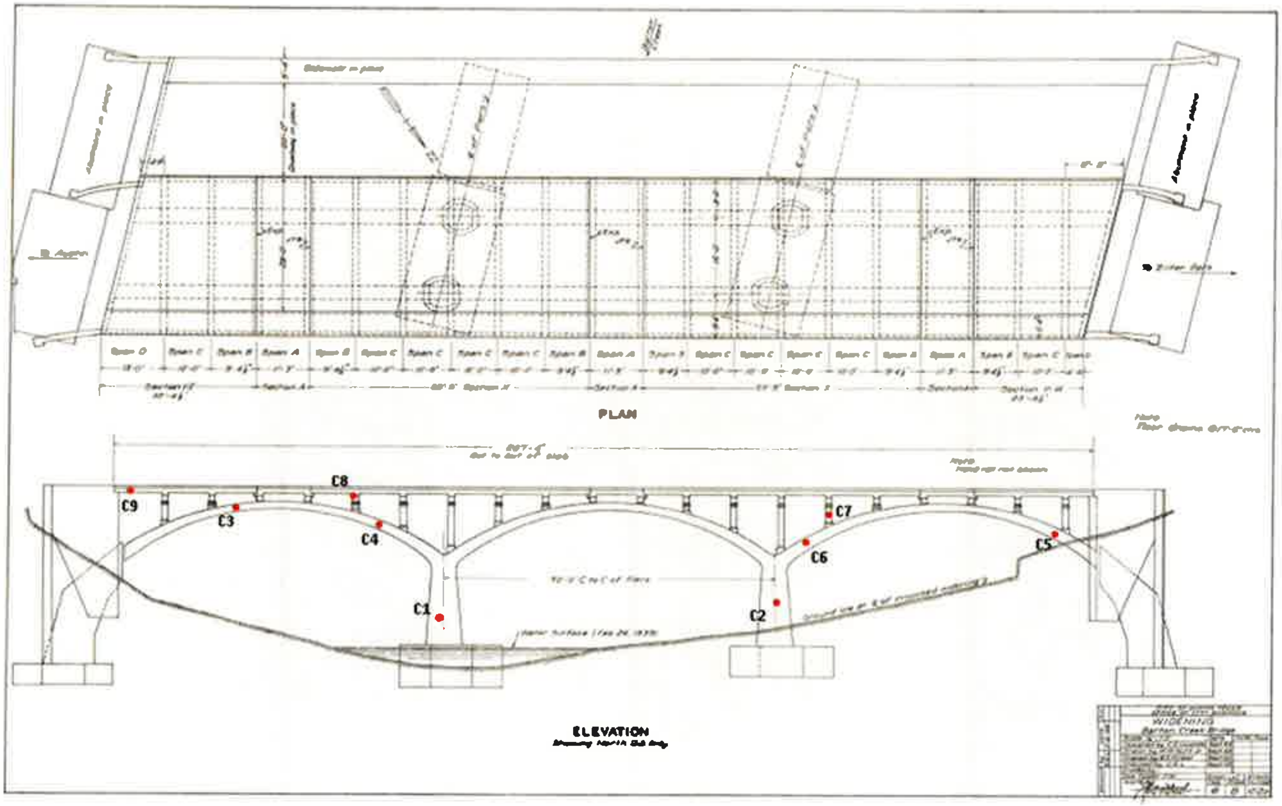


Figure 5 – Core locations (downstream bridge)

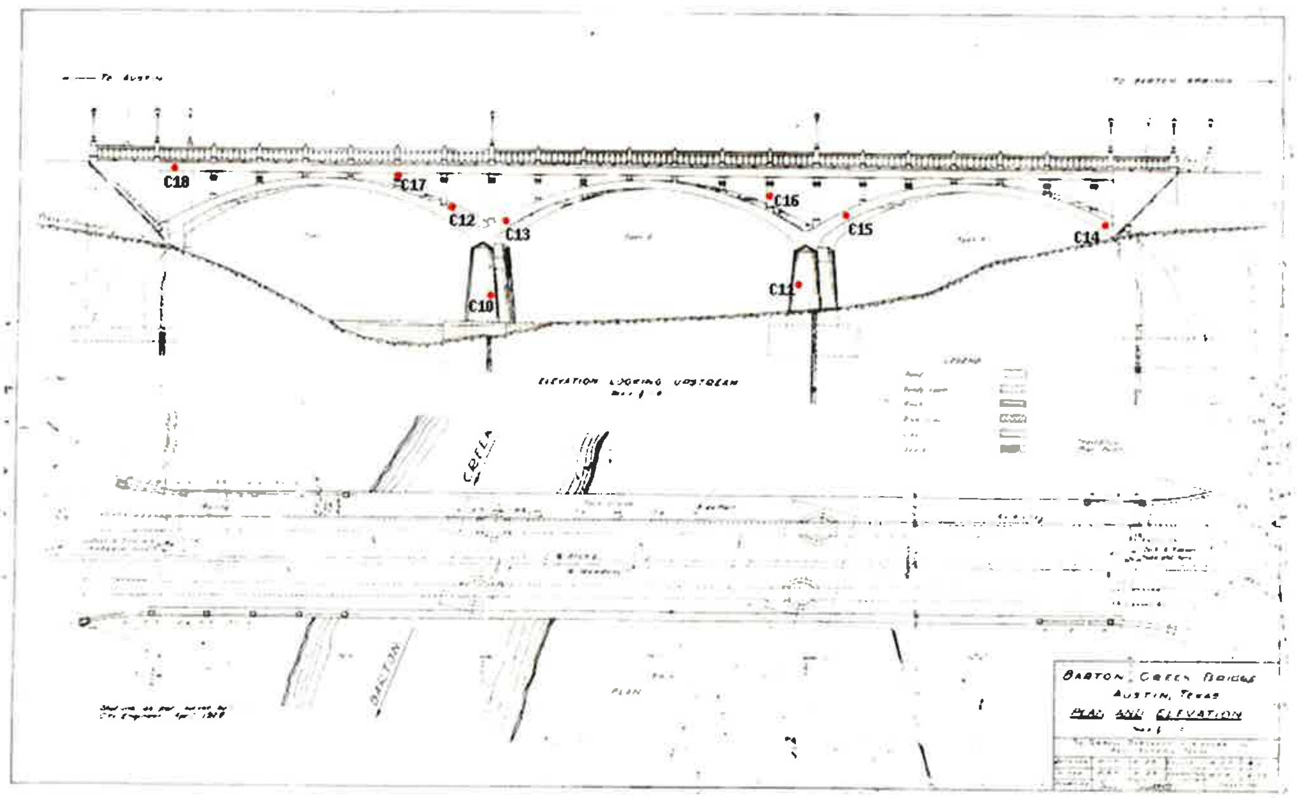


Figure 6 – Core locations (upstream bridge)

Figure 7 – Funnel system used to capture core slurry

Figure 8 – Core hole patching

Figure 9 – Sealed core hole at C9

Figure 10 – Sealed core hole at C18

Appendix A

Compressive Strength Testing Report

CTLGROUP

Client:	**AECOM**	CTLGroup Project No.:	**231599**
Project Name:	**Barton Springs Road Bridge Concrete Evaluation.**	CTLGroup Project Mgr.:	**Bradley East**
		Analysts:	**B. Szczerowski, C. Arboleda**
Contact:	**Arnold Ashburn**	Approved by:	**J. L. Jones**
Submitter:	**Arnold Ashburn**	Date Analyzed:	**July 27, 2016**
Date Received:	**July 20, 2016**	Date Reported:	**July 29, 2016**

ASTM C42 Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
Section 7: Cores for Compressive Strength

Specimen Identification

CTLGroup Identification	4267904	4267906	4267907
Client Identification	C4	C6	C7
Date Core Obtained from the Field	7/20/16	7/20/16	7/20/16
Date end preparation was completed and core was placed in sealed bag	7/22/16	7/22/16	7/22/16
Date Core was Tested	7/27/16	7/27/16	7/27/16

Concrete Description

Nominal Maximum Aggregate Size, in.	3/4	3/4	3/4
Concrete Age at Test	Not Stated	Not Stated	Not Stated
Moisture Condition at Test	Per ASTM C42	Per ASTM C42	Per ASTM C42
Length of Core, As Drilled, in.	6 1/2	6 3/4	7
Orientation of Core Axis in Structure	Not Stated	Not Stated	Not Stated
Cylinder End Preparation	Capped	Capped	Capped

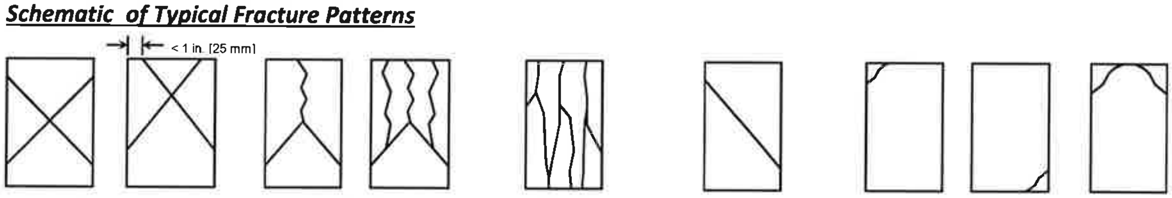
Concrete Dimensions

Diameter 1, in.	3.71	3.70	3.70
Diameter 2, in.	3.70	3.70	3.70
Average Diameter, in.	3.71	3.70	3.70
Cross-Sectional Area, in^2	10.81	10.75	10.75
Length Trimmed, in.	5.9	5.8	6.2
Length Capped, in.	6.0	6.0	6.4
Density, pcf	143	143	142

Compressive Strength and Fracture Pattern

Maximum Load, lb	47,206	48,614	29,324
Uncorrected compressive Strength, psi	4,370	4,520	2,730
Ratio of Capped Length to Diameter	1.63	1.62	1.74
Corrected Compressive Strength, psi	4,240	4,380	2,680
Fracture Pattern	Type 1	Type 1	Type 1

Schematic of Typical Fracture Patterns



Type 1
Reasonable well-formed cones on both ends, less than 1 in. [25 mm] of cracking through caps

Type 2
Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end

Type 3
Columnar vertical cracking through both ends, no well-formed cones

Type 4
Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type I

Type 5
Side fractures at top or bottom (occur commonly with unbonded caps)

Type 6
Similar to Type 5 but end of cylinder is pointed

Notes:
1. This report may not be reproduced except in its entirety.

CTLGroup

Client:	**AECOM**	CTLGroup Project No.:	**231599**
Project Name:	**Barton Springs Road Bridge Concrete Evaluation.**	CTLGroup Project Mgr.:	**Bradley East**
		Analysts:	**B. Szczerowski, C. Arboleda**
Contact:	**Arnold Ashburn**	Approved by:	**J. L. Jones**
Submitter:	**Arnold Ashburn**	Date Analyzed:	**July 27, 2016**
Date Received:	**July 20, 2016**	Date Reported:	**July 29, 2016**

ASTM C42 Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
Section 7: Cores for Compressive Strength

Specimen Identification

CTLGroup Identification	4267908	4267914	4267916
Client Identification	C8	C14	C16
Date Core Obtained from the Field	7/20/16	7/20/16	7/20/16
Date end preparation was completed and core was placed in sealed bag	7/22/16	7/22/16	7/22/16
Date Core was Tested	7/27/16	7/27/16	7/27/16

Concrete Description

Nominal Maximum Aggregate Size, in.	3/4	3/4	3/4
Concrete Age at Test	Not Stated	Not Stated	Not Stated
Moisture Condition at Test	Per ASTM C42	Per ASTM C42	Per ASTM C42
Length of Core, As Drilled, in.	6	7	7
Orientation of Core Axis in Structure	Not Stated	Not Stated	Not Stated
Cylinder End Preparation	Capped	Capped	Capped

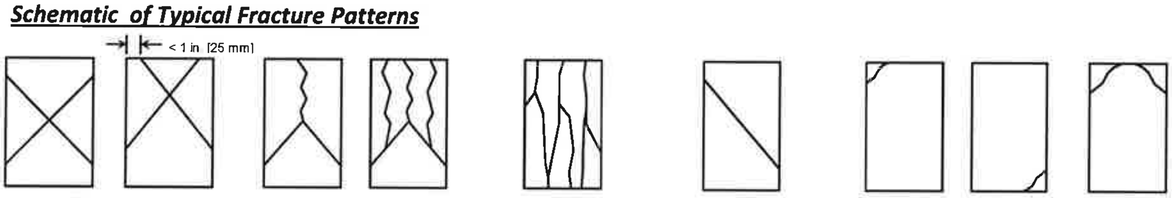
Concrete Dimensions

Diameter 1, in.	3.69	3.74	2.79
Diameter 2, in.	3.70	3.74	2.74
Average Diameter, in.	3.70	3.74	2.77
Cross-Sectional Area, in^2	10.75	10.99	6.03
Length Trimmed, in.	5.4	6.3	5.1
Length Capped, in.	5.5	6.4	5.4
Density, pcf	143	143	141

Compressive Strength and Fracture Pattern

Maximum Load, lb	46,811	74,872	14,295
Uncorrected compressive Strength, psi	4,350	6,810	2,370
Ratio of Capped Length to Diameter	1.50	1.72	1.94
Corrected Compressive Strength, psi	4,180	6,670	2,370
Fracture Pattern	Type 2	Type 1	Type 1

Schematic of Typical Fracture Patterns



Type 1
Reasonable well-formed cones on both ends, less than 1 in. [25 mm] of cracking through caps

Type 2
Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end

Type 3
Columnar vertical cracking through both ends, no well-formed cones

Type 4
Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type I

Type 5
Side fractures at top or bottom (occur commonly with unbonded caps)

Type 6
Similar to Type 5 but end of cylinder is pointed

Notes:
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CTLGroup

Client:	**AECOM**	CTLGroup Project No.:	**231599**
Project Name:	**Barton Springs Road Bridge Concrete Evaluation.**	CTLGroup Project Mgr.:	**Bradley East**
		Analysts:	**B. Szczerowski, C. Arboleda**
Contact:	**Arnold Ashburn**	Approved by:	**J. L. Jones**
Submitter:	**Arnold Ashburn**	Date Analyzed:	**July 27, 2016**
Date Received:	**July 20, 2016**	Date Reported:	**July 29, 2016**

ASTM C42 Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
Section 7: Cores for Compressive Strength

Specimen Identification

CTLGroup Identification	4267917
Client Identification	C17
Date Core Obtained from the Field	7/20/16
Date end preparation was completed and core was placed in sealed bag	7/22/16
Date Core was Tested	7/27/16

Concrete Description

Nominal Maximum Aggregate Size, in.	3/4
Concrete Age at Test	Not Stated
Moisture Condition at Test	Per ASTM C42
Length of Core, As Drilled, in.	6 1/4
Orientation of Core Axis in Structure	Not Stated
Cylinder End Preparation	Capped

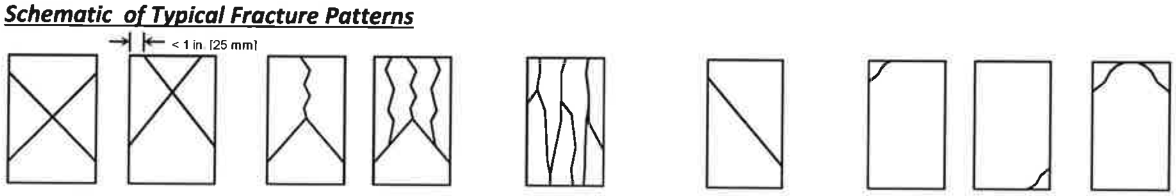
Concrete Dimensions

Diameter 1, in.	3.72
Diameter 2, in.	3.70
Average Diameter, in.	3.71
Cross-Sectional Area, in^2	10.81
Length Trimmed, in.	5.7
Length Capped, in.	5.9
Density, pcf	142

Compressive Strength and Fracture Pattern

Maximum Load, lb	45,120
Uncorrected compressive Strength, psi	4,170
Ratio of Capped Length to Diameter	1.59
Corrected Compressive Strength, psi	4,040
Fracture Pattern	Type 1

Schematic of Typical Fracture Patterns



Type 1 — Reasonable well-formed cones on both ends, less than 1 in. [25 mm] of cracking through caps

Type 2 — Well-formed cone on one end, vertical cracks running through caps, no well-defined cone on other end

Type 3 — Columnar vertical cracking through both ends, no well-formed cones

Type 4 — Diagonal fracture with no cracking through ends; tap with hammer to distinguish from Type I

Type 5 — Side fractures at top or bottom (occur commonly with unbonded caps)

Type 6 — Similar to Type 5 but end of cylinder is pointed

Notes:

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Appendix B

Chemical Analysis Report

CTLGroup

Client:	**AECOM**	CTL Project No:	**231599**
Project:	**Barton Springs Road Bridge Concrete Evaluation.**	CTL Project Mgr.:	**Bradley East**
		Analyst:	**Manny Hailemariam**
Contact:	**Arnold Ashburn**	Approved:	Meg Schroeder
Submitter:	**Arnold Ashburn**	Date Analyzed:	**11-Aug-16**
Date Received:	**20-Jul-16**	Date Reported:	**11-Aug-16**

REPORT of ACID-SOLUBLE CHLORIDE

Sample Identification CTL ID	Client ID		Description	Determined Chloride (wt% sample)	(ppm Cl)
4267915-02	C15	0-1mm (Core Top)	Concrete	0.042	420
4267915-03	C15	1-5mm	Concrete	0.030	300
4267915-04	C15	5-10mm	Concrete	0.024	240
4267915-05	C15	10-15mm	Concrete	0.022	220
4267915-06	C15	15-20mm	Concrete	0.019	190
4267915-07	C15	20-25mm	Concrete	0.016	160
4267915-08	C15	25-30mm	Concrete	0.016	160
4267915-09	C15	30-35mm	Concrete	0.020	200
4267915-01	C15	20mm Core Bottom (Control)	Concrete	0.015	150

Notes:

1. This analysis represents specifically the samples submitted as received.
2. Analysis by potentiometric titration with silver nitrate. (ASTM C1152-04(2012)^{e1})
3. This report may not be reproduced except in its entirety.

Appendix C

Petrographic Examination Report

Copy No. 1

Report for
AECOM
9400 Amberglen Boulevard, Austin, Texas 78729

CTLGroup Project No. 231599

Petrographic Examination of Concrete Cores from Barton Springs Road Bridge Concrete Evaluation Project, Austin, Texas

September 2, 2016

Submitted by:
Jaclyn Ferraro
Jean L. Randolph

COA# F-3849

5400 Old Orchard Road
Skokie, Illinois 60077-1030
(847) 965-7500

Austin, TX • Bradenton, FL • Chicago, IL • Horsham, PA
Naperville, IL • Washington, DC • Doha, Qatar

www.CTLGroup.com

REPORT OF PETROGRAPHIC EXAMINATION

Date: September 2, 2016

CTLGroup Project No.: 231599

Petrographic Examination of Concrete Cores from Barton Springs Road Bridge Concrete Evaluation Project, Austin, Texas

Ten concrete cores, identified as C1, C2, C3, C5, C9, C10, C11, C12, C13, and C18 (Figs. 1 through 10), were received on June 27, 2016, from Mr. Bradley East, CTLGroup Engineer, on behalf of AECOM, Austin, Texas.

The following information was reported to the CTLGroup Petrographic Laboratory: The concrete cores were obtained from different areas of the Barton Springs Road Bridge, constructed in the 1920s, in Austin, Texas (Table 1). The south half of the bridge is the original bridge. The bridge was then widened in the 1940s to construct the north half of the bridge. Both halves of the bridge are identical in layout and each half consists of an east, west, and middle span. The middle portion is supported by piers, and the ends are supported by abutments.

Table 1 – Core Sample Locations

Core	Bridge	Element	Span
C1	North	Pier	N/A
C2		Pier	N/A
C3		Arch	East
C5		Arch	West
C9		Deck	East
C10	South	Pier	N/A
C11		Pier	N/A
C12		Arch	East
C13		Arch	Middle
C18		Deck	East

Petrographic examination, ASTM C856, of the ten cores was requested to evaluate properties and condition of the concrete, as well as to evaluate for any possible deterioration, specifically in the form of spalling and corrosion.

This report presents the details and results of the petrographic examination of the ten concrete cores.

FINDINGS AND CONCLUSIONS

Of the 10 cores, only Cores C12 and C13 exhibit notable cracking. In Core C12 the cracking is attributed to alkali-silica reaction (ASR), which has occurred between a random particle of glass and the alkalis in the cement paste. Although the ASR appears localized to the one glass particle, a few glass particles are present in the core, suggesting the possibility for other localized areas of ASR in the surrounding concrete. In Core C13, 2 cracks are present, parallel to each other and approximately 3 inches apart. The cause for these cracks was not discerned petrographically.

Excluding the above-described cracks, the concrete in the remainder of Cores C12 and C13 and the concrete in the other 8 cores is in generally good condition. A few microcracks are present in the cores, generally located in the outer regions of the concrete; however, they do not appear to be of notable consequence. No freeze-thaw deterioration, other areas of ASR, or other deleterious mechanisms are observed. No spalling or incipient spalling is observed in any of the cores. A small amount of shallow scaling or abrasion is present on the outer surface of Core C9; however, it is relatively insignificant and is not associated with corrosive processes.

The paste quality in the concrete is not optimum. It is generally moderate to moderate soft, with generally a moderately weak to weak bond to the aggregate. Depth of carbonation is generally fairly deep, commonly extending deeper than 1 in. from the outer core surface. Still, very little deterioration is observed to the paste, excluding the cracking in Cores C12 and C13 described above. Because of the age of the concrete, the water/cement ratio (w/c) of the concrete is not estimated.

No reinforcement steel is present in any of the 10 cores. No corrosion product is observed in any of the cores.

The concrete in each core consists of a natural gravel coarse aggregate and a natural sand fine aggregate uniformly distributed within a non-air-entrained portland cement paste. The aggregate types appear similar among the 10 cores. The air content is estimated to be less than 1.5% in each core. The paste appears relatively similar among the 10 cores.

Other notable features among the 10 cores include the following:

- Core C5. The outer concrete surface is covered with a gray coating.
- Core C9. The outer concrete surface exhibits a small amount of scaling or abrasion, to a depth of approximately 1 mm.
- Core C11. A large limestone chunk is present in the midportion of the core.
- Core C12 (core with the observed ASR). The outer concrete surface is covered with a thin (less than 2-mm-thick) mortar-like coating.
- Core C13. Part of the outer concrete surface is covered with a thin mortar-like coating, which is coated with a brown sealer.

Table 2, following the signature page, presents a summary of the concrete constituents and properties.

All information obtained in the examination is presented in the petrographic data forms at the end of this report.

Photographs illustrating the cores and notable features are presented in the corresponding petrographic data forms at the end of this report.

METHODS OF TEST

Petrographic examination of Cores C1, C2, C3, C5, C9, C10, C11, C12, C13, and C18 was performed in accordance with ASTM C856-14, "Standard Practice for Petrographic Examination of Hardened Concrete." The cores were visually inspected and photographed as received. The cores were saw-cut in half longitudinally, and one of the resulting saw-cut surfaces of each core was ground (lapped) to produce a smooth, flat, semi-polished surface. Lapped and freshly broken surfaces of the concrete were examined using a stereomicroscope at magnifications up to 45X. Application of India ink was used to accentuate certain details of the concrete.

For thin-section study, a small rectangular block was cut from the outer 36 mm (1.4 in.) of each core, and one side of each block was lapped to produce a smooth, flat surface. The blocks were cleaned and dried, and the prepared surfaces were mounted on ground glass microscope slides with epoxy. After the epoxy hardened, the thickness of the mounted blocks was reduced to approximately 20 μm (0.0008 in.). The resulting thin sections were examined using a polarized-light (petrographic) microscope at magnifications up to 400X to study aggregate and paste mineralogy and microstructure.

Depth and pattern of paste carbonation was initially determined by application of a pH indicator solution (phenolphthalein) to freshly cut or fractured concrete surfaces. The solution imparts a deep magenta stain to high pH, non-carbonated paste. Carbonated paste does not change color. The extent of paste carbonation was confirmed in thin-section.

Jaclyn Ferraro
Petrography Group

Jean L. Randolph
Senior Petrographer and Group Manager
Petrography Group

JMF/JLR/

Attachment

Notes: 1. Results refer specifically to the samples submitted.
2. This report may not be reproduced except in its entirety.

TABLE 2 SELECTED PROPERTIES AND CONSTITUENTS OF ALL TEN PROVIDED CORES

	C1	C2	C3	C5	C9
Outer core surface	Somewhat worn, fairly flat, formed concrete surface.	Somewhat worn, fairly flat, formed concrete surface.	Mostly flat slightly worn, formed concrete surface.	Mostly flat, possibly formed, concrete surface covered with a gray coating.	Mostly flat, formed concrete surface, with small amount of shallow scaling or abrasion.
Reinforcement	None present.	None present.	None present.	None present.	None present.
Paste properties:					
• **Hardness**	Moderately soft to moderate throughout paste.	Moderately soft throughout.	Moderately soft throughout paste, but local to moderate.	Outer 3.5 to 1.5 mm (0.1 to 0.6 in.) is moderate to moderately hard. Remainder is moderate.	Moderate to moderately hard throughout paste.
• **Bond to aggregate**	Weak to moderately weak.	Weak.	Weak.	Moderately weak to weak.	Moderately tight to moderate.
• **Depth of carbonation**	28 to 30 mm (1.1 to 1.2 in.).	26 to 33 mm (1.0 to 1.3 in.).	37 to 43 mm (1.5 to 1.7 in.).	0 to 2 mm (0 to 0.08 in.).	28 to 31 mm (1.1 to 1.2 in.).
Air-void system	Not air entrained. Air content estimated at 1.5% or less.	Not air entrained. Air content estimated at 1.5% or less.	Not air entrained. Air content estimated at 1.5% or less.	Not air entrained. Air content is estimated at 1.5% or less.	Not air entrained. Air content is estimated at 1.5% or less.
Aggregate types	**Coarse:** Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of other rock types. Particles are rounded to subangular in shape. **Fine:** Natural sand composed of a wide variety of rock and mineral types, mainly including quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, and a few other mineral types.				
Aggregate top size	1.2 in.	0.8 in.	0.9 in.	1.1 in.	0.7 in.
Cracks	None present.	None present.	None present.	None present.	None present.
Microcracks	Very few microcracks with no general orientation occur throughout the core, extending around all aggregate particles.	A few microcracks mainly within the outer 1.2 in. of the core, extending around all aggregate particles.	Several microcracks with no general orientation occur throughout the core, but mainly present in the outer 1.8 in. of the core, extending around all aggregate particles.	A few microcracks with no general orientation occur throughout the core, but mainly located within the outer 2.0 in. of the core, extending around all aggregate particles.	Very few microcracks with no general orientation present within outer 1.2 in. of core, extending around all aggregate particles.
Notable deterioration or other notable features	--	--	--	Gray surface coating.	Shallow surface scaling or abrasion.

TABLE 2 CONTINUED SELECTED PROPERTIES AND CONSTITUENTS OF ALL TEN PROVIDED CORES

	C10	C11	C12	C13	C18
Outer core surface	Mostly flat, somewhat worn, formed concrete surface with some shallow abrasion.	Mostly flat, slightly worn, formed concrete surface.	Mostly flat concrete surface covered with a thin mortar-like coating.	Mostly flat, partially medium brown and partially medium beige. Sealer is present on the medium brown area and worn off of the medium beige area.	Slightly worn, formed concrete surface.
Reinforcement	None present.	None present.	None present.	None present.	None present.
Paste properties:					
• **Hardness**	Moderately soft throughout paste.	Outer 3 to 5 mm (0.1 to 0.2 in.) is moderate. Remainder is moderate to moderately soft, but varies locally to moderately hard in some small areas.	Outer 0.6 in. is moderate to moderately hard. Following 1.1 in. is moderately soft to moderate. Remainder is moderate to moderately hard.	Outer 0 to 0.2 mm (0 to 0.008 in.) is very soft. Following 1 to 5 mm (0.04 to 0.2 in.) is hard. Remainder moderate to moderate.	Outer 13 to 29 mm (0.6 to 1.1 in.) is moderate to moderately soft. Remainder is moderately soft.
• **Bond to aggregate**	Weak.	Moderate.	Moderate.	Moderately weak to weak.	Moderately weak to moderate.
• **Depth of carbonation**	12 to 39 mm (0.5 to 1.5 in.).	3 to 10 mm (0.1 to 0.4 in.).	12 to 16 mm (0.5 to 0.6 in.).	15 to 27 mm (0.6 to 1.1 in.).	14 to 29 mm (0.6 to 1.1 in.).
Air-void system	Not air entrained. Air content estimated at 1.5% or less.	Not air entrained. Air content estimated at 1.5% or less.	Not air entrained. Air content estimated at 1.5% or less.	Not air entrained. Air content estimated at 1.5% or less.	Not air entrained. 1.5% or less.
Aggregate types	**Coarse:** Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of other rock types. Particles are rounded to subangular in shape. **Fine:** Natural sand composed of a wide variety of rock and mineral types, mainly including quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, and a few other mineral types.				
Aggregate top size	0.8 in.	0.6 in.	0.9 in.	0.8 in.	1.0 in.
Cracks	None present.	Core received cracked partially around a large limestone chunk; crack assessed to be a result of the coring.	Two random cracks present within a core depth interval of 2.6 to 4.9 in, passing through and around aggregate particles.	Two cracks present, somewhat parallel to each other, at angled core depths of 0.8 to 1.9 in. and 3.6 to 4.7 in., passing mainly around aggregate particles.	None present.
Microcracks	One forked microcrack on core outer surface extends to a depth of 0.8 in., extending around all aggregate particles.	Very few microcracks occur with no general orientation within the outer 1.5 in. of the core, extending around all aggregate particles. A microcrack occurs around a large limestone chunk.	Many microcracks with no general orientation occur throughout the core, but mainly between depths of 1.5 to 5.0 in., extending around all aggregate particles. Significant microcracking stems from and within a glass particle at a depth of 3.9 in.	Many microcracks splaying from the 2 cracks. Very few other microcracks with no general orientation occur within the outer 0.8 in. of the core, extending around all aggregate particles.	Few microcracks with no general orientation occur within the outer 1.1 in. of the core, extending around all aggregate particles.
Notable deterioration or other notable features	--	A large (4-in. in size) limestone chunk is present in the midportion of the core.	Thin mortar surface coating. A few random particles of glass present within the concrete. ASR has occurred between one of the glass particles and the alkalis in the cement, resulting in the 2 random cracks and much associated microcracking.	Two significant cracks present, somewhat parallel to each other, approximately 3 in. from each other.	--

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge
DATE RECEIVED: June 27, 2016
LOCATION: Austin, Texas
EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C1.

CTLGroup Identification: 4267901.

Overview of Core: Core taken from a pier of the north bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 150 to 166 mm (5.9 to 6.6 in.); partial concrete thickness.

Outer Core Surface: Somewhat worn, fairly flat and striated, formed concrete surface.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly around aggregate particles.

Cracks, Joints, Large Voids: None observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 31 mm (1.2 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (very few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 9 to 18 mm (0.4 to 0.7 in.) of the core is light beige with a slight tinge of extremely light orange. Paste in the remainder of the core is light beige.

Hardness: Moderately soft to moderate throughout the paste.

Luster: Dull to subvitreous.

Paste-Aggregate Bond: Weak to moderately weak. When struck with a geology hammer in the laboratory, the concrete fractured mostly around, but through only a couple, coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 28 to 30 mm (1.1 to 1.2 in.) from concrete outer surface.

Calcium Hydroxide*: No calcium hydroxide present in thin section, due to paste carbonation.

Residual/Relic Portland Cement Clinker Particles: Estimated at 1 to 5%.

Supplementary Cementitious Materials: None observed.

Secondary Deposits: None observed.

MICROCRACKING: Very few, generally short microcracks observed, with no general orientation, throughout the core. Microcracks extend around all aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste

C1-1a. **Core (concrete) outer surface. The surface is a somewhat worn, fairly flat and striated, formed concrete surface.**

C1-1b. **Side view of core.**

Photo C1-1 **Core C1, as received for testing.**

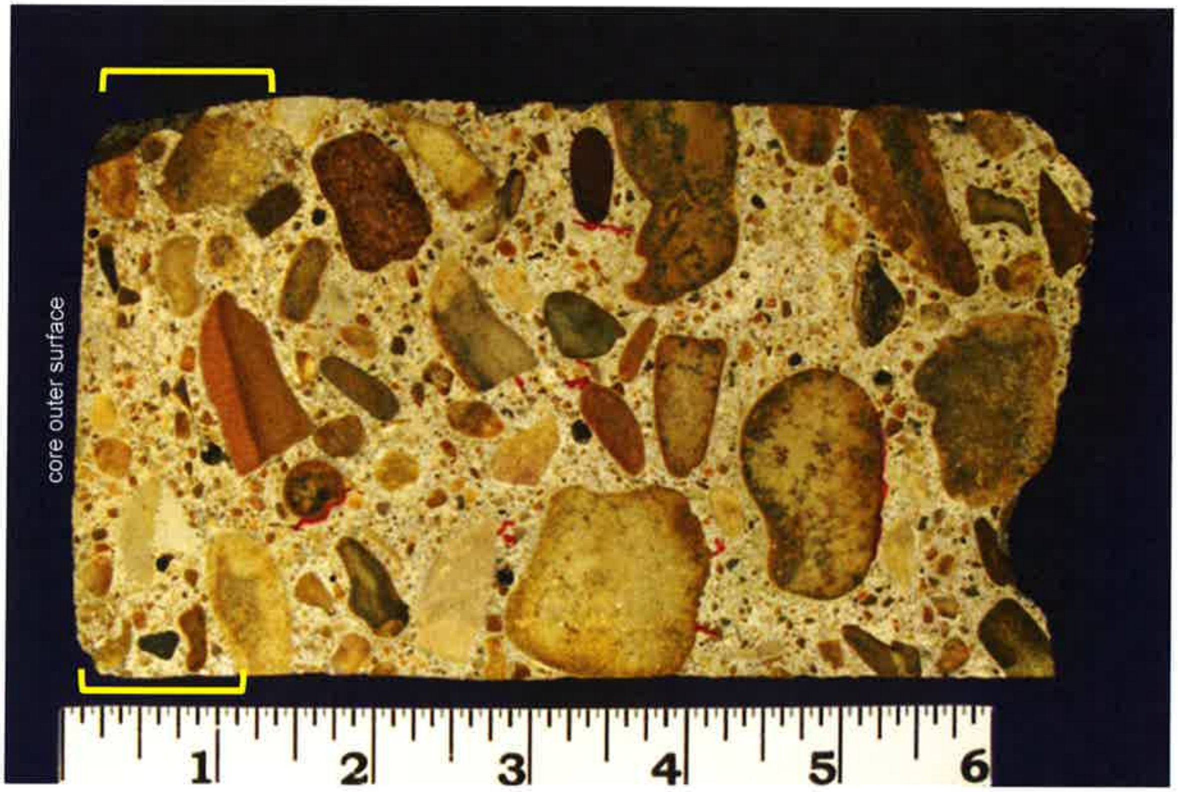
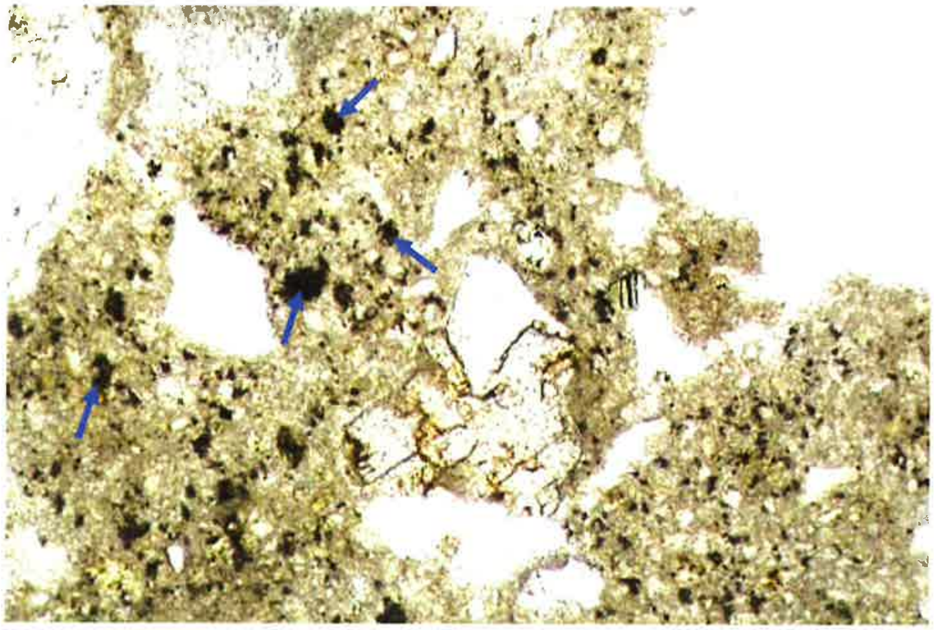


Photo C1-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C1.**

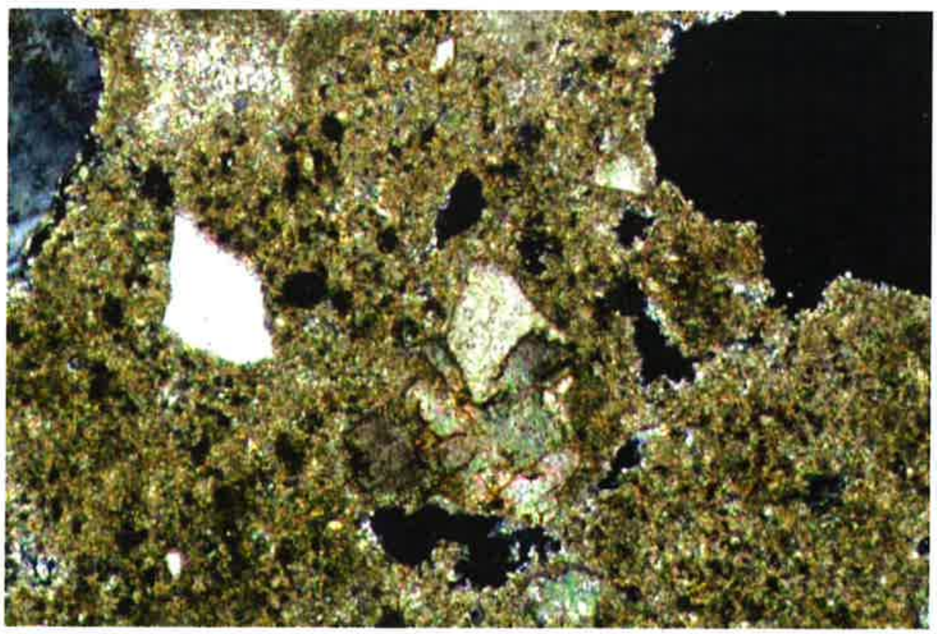
Paste carbonation is to a depth of 1.2 in. (yellow brackets) from the outer concrete surface.

The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains very few microcracks with no general orientation, throughout the core. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 1.2 in., is rounded to subangular in shape, and uniformly distributed in the concrete.



C1-3a. **Plane-polarized light. Blue arrows depict several residual/relic portland cement grains.**



C1-3b. **Cross polarized light. Paste is completely carbonated, shown by its bright tan/brown color.**

Photo C1-3. **Thin section photomicrographs of Core C1, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).**

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

LOCATION: Austin, Texas

DATE RECEIVED: June 27, 2016

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C2.

CTLGroup Identification: 4267902.

Overview of Core: Core taken from a pier of the north bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 154 to 169 mm (6.1 to 6.7 in.); partial concrete thickness.

Outer Core Surface: Somewhat worn, fairly flat and striated, formed concrete surface.

Bottom Core Surface: Fractured and rough concrete surface, extending equally through and around aggregate particles.

Cracks, Joints, Large Voids: None observed.

Reinforcement: None observed.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 21 mm (0.8 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (very few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 12 to 16 mm (0.5 to 0.6 in.) of the core is light beige with a slight tinge of extremely light orange. Paste in the remainder of the core is light beige.

Hardness: Moderately soft throughout the paste.

Luster: Dull to subvitreous.

Paste-Aggregate Bond: Weak. When struck with a geology hammer in the laboratory, the concrete fractured essentially around all coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids. 1000pts

Depth of Carbonation: 26 to 33 mm (1.0 to 1.3 in.) from concrete outer surface.

Calcium Hydroxide*: No calcium hydroxide present in thin section, due to paste carbonation.

Residual/Relic Portland Cement Clinker Particles: Estimated at 1 to 3%.

Supplementary Cementitious Materials: None observed.

Secondary Deposits: None observed.

Limestone Fines: Common throughout paste.

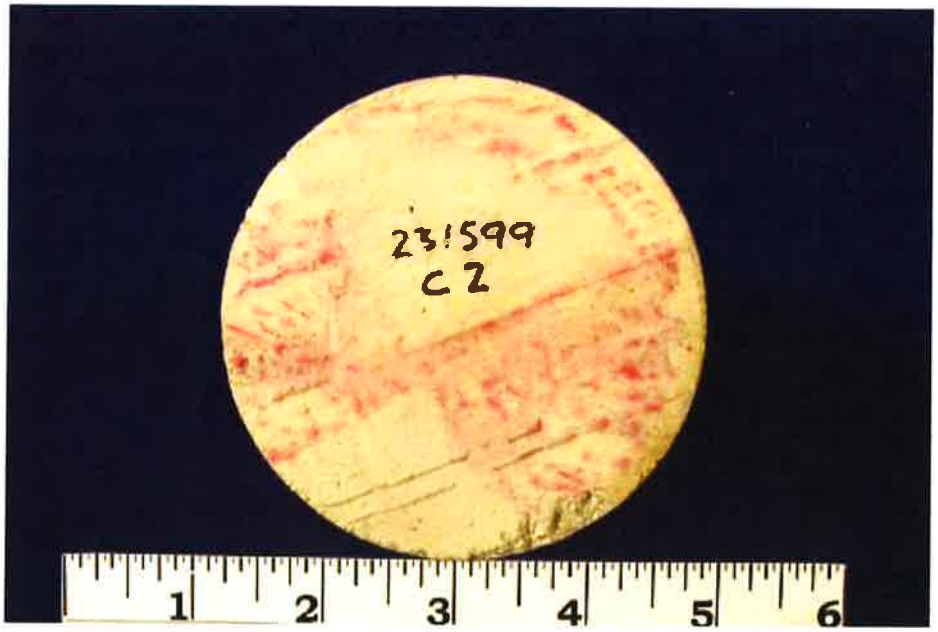
MICROCRACKING: A few microcracks, mostly oriented perpendicular to the outer core surface, mainly present within the outer 31 mm (1.2 in.) of the core. Microcracks extend around all aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste



C2-1a. **Core (concrete) outer surface. The surface is a somewhat worn, fairly flat and striated, formed concrete surface.**

C2-1b. **Side view of core.**

Photo C2-1 **Core C2, as received for testing.**

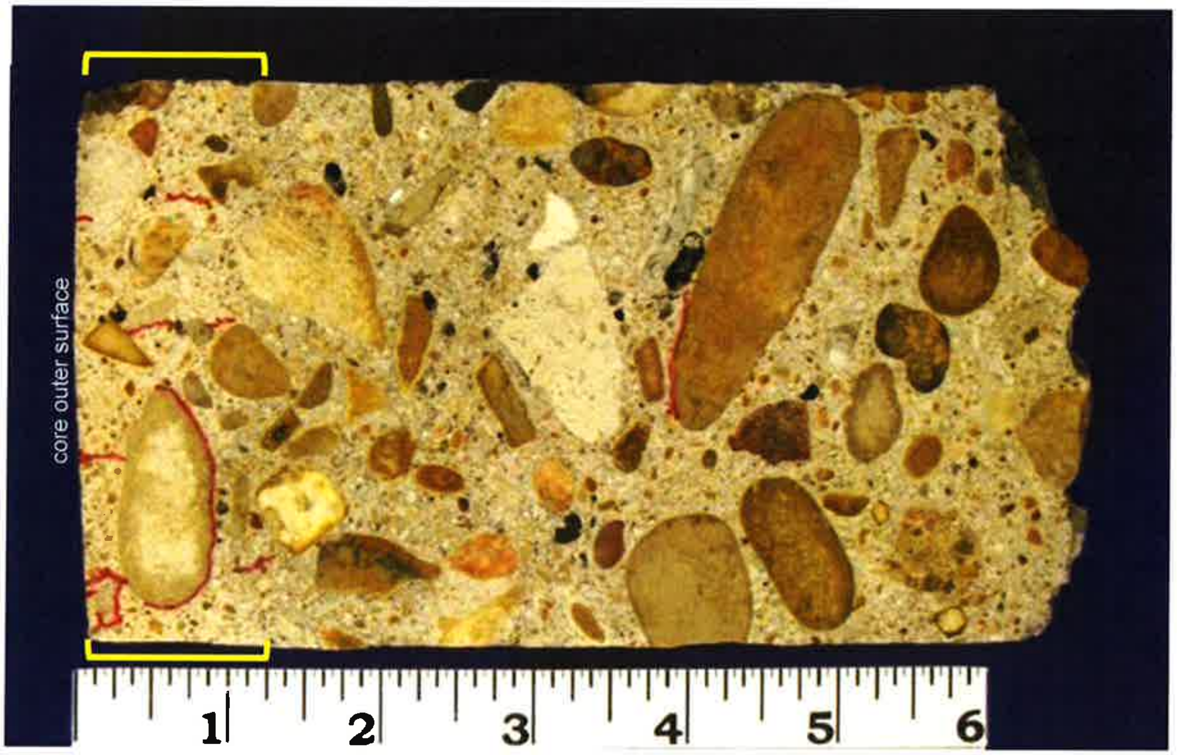
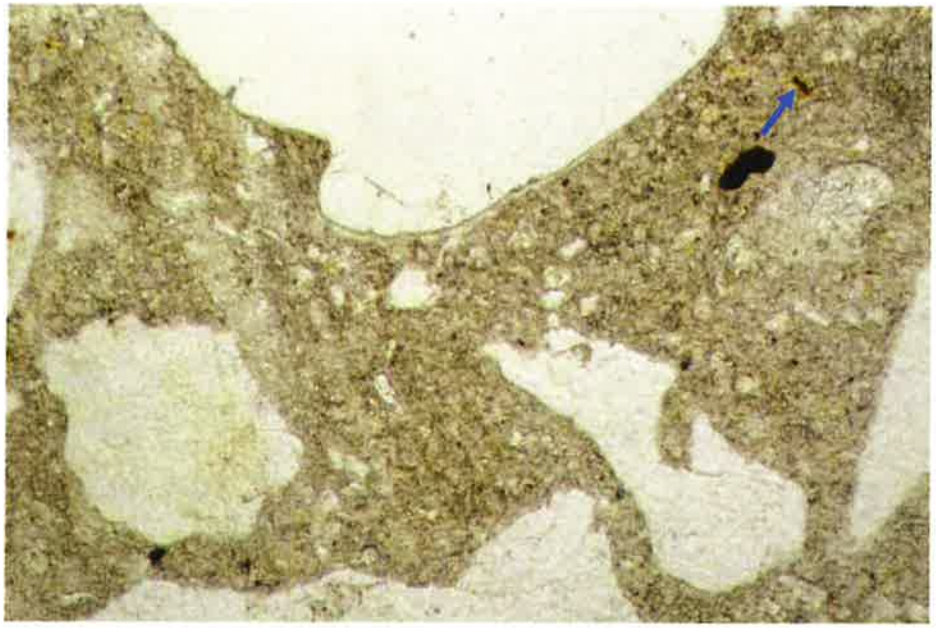


Photo C2-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C2.**

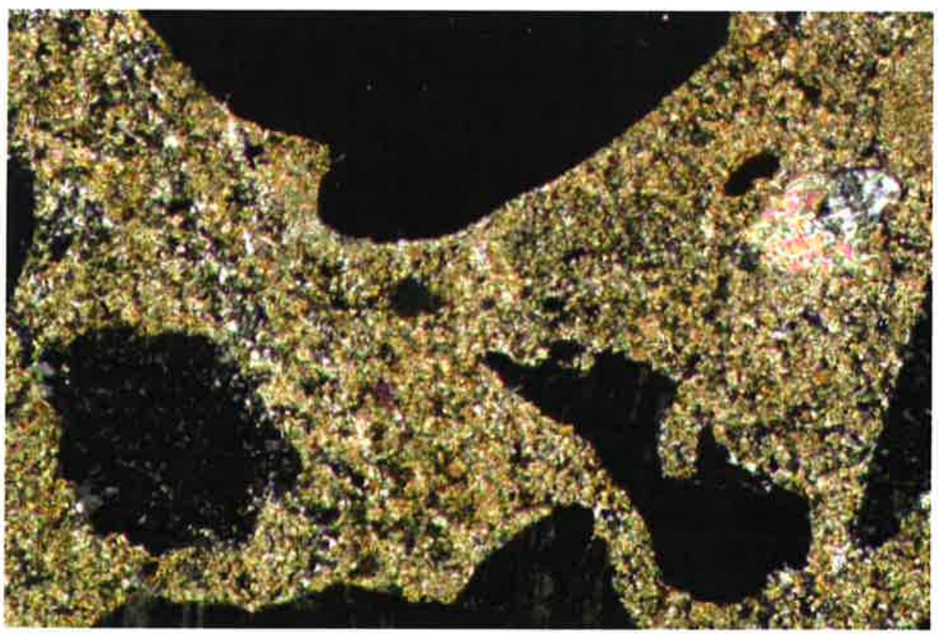
Paste carbonation is to a depth of 1.0 to 1.3 in. (yellow brackets) from the outer core surface.

The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains a few microcracks throughout the core, mainly present within the outer 1.2 in. of the core. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 0.8 in., is rounded to subangular in shape, and uniformly distributed in the concrete.



C2-3a. Plane-polarized light. Very few residual/relic portland cement grains (blue arrow) are observable.



C2-3b. Cross polarized light. Paste is completely carbonated, shown by its bright tan/brown color.

Photo C2-3 Thin section photomicrographs of Core C2, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

DATE RECEIVED: June 27, 2016

LOCATION: Austin, Texas

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C3.

CTLGroup Identification: 4267903.

Overview of Core: Core taken from an east arch of the north bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 162 to 179 mm (6.4 to 7.0 in.); partial concrete thickness.

Outer Core Surface: Mostly flat, slightly worn and striated, formed concrete surface. Some small air voids are also exposed.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly around aggregate particles.

Cracks, Joints, Large Voids: None observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 24 mm (0.9 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (very few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 37 to 43 mm (1.5 to 1.7 in.) of the core is very light beige. Paste in the remainder of the core is light beige.

Hardness: Moderately soft throughout paste, but locally to moderate.

Luster: Dull to subvitreous.

Paste-Aggregate Bond: Weak. When struck with a geology hammer in the laboratory, the concrete fractured mostly around essentially all coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 37 to 43 mm (1.5 to 1.7 in.) from concrete outer surface.

Calcium Hydroxide: No calcium hydroxide present in thin section, due to paste carbonation.

Residual/Relic Portland Cement Clinker Particles: Estimated at 1 to 4%.

Supplementary Cementitious Materials: None observed.

Secondary Deposits: None observed.

MICROCRACKING: Several microcracks are present, with no general orientation, throughout the core, but mainly in the outer 45 mm (1.8 in.) of the core. Microcracks extend around all aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste

C3-1a. Core (concrete) outer surface. The surface is a mostly flat and smooth, slightly worn, surface with remnants of a striated finish and some exposed small air voids.

C3-1b. Side view of core.

Photo C3-1 Core C3, as received for testing.

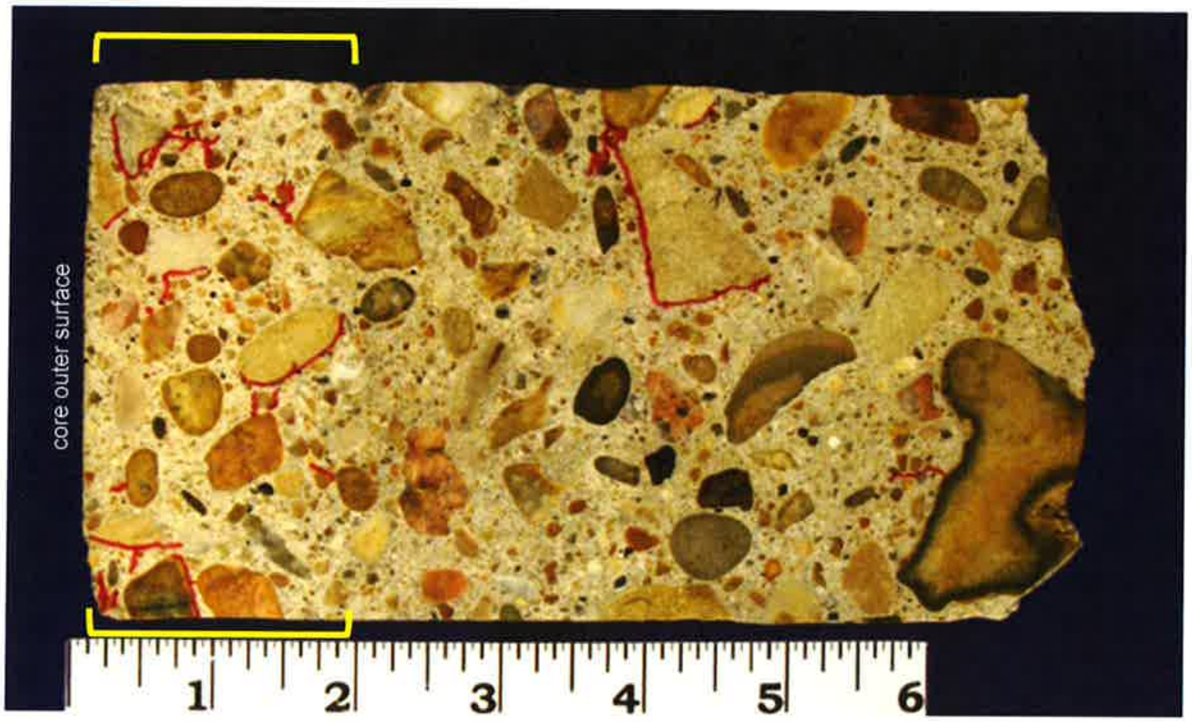


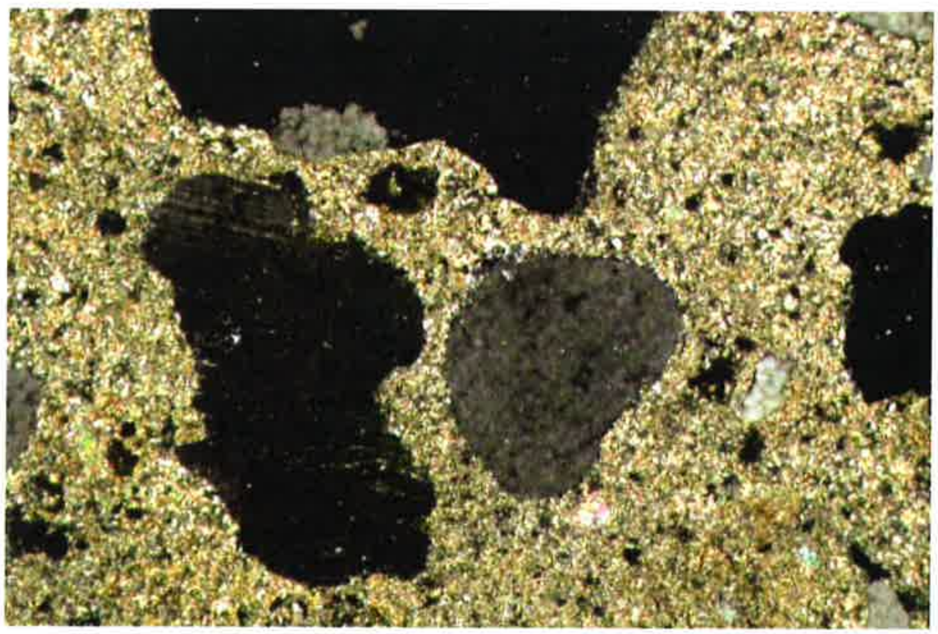
Photo C3-2 **Lapped, cross-sectional concrete surface of Core C3.**

Paste carbonation is to a depth of 1.5 to 1.7 in. (yellow brackets) from the outer core surface.

The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains several microcracks with no general orientation, throughout the core, but mainly within the outer 1.8 in. of the core. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 0.9 in., is rounded to subangular in shape, and uniformly distributed in the concrete.

C3-2a. Plane-polarized light. Blue arrows depict several residual/relic portland cement grains.



C3-2b. Cross polarized light. Paste is completely carbonated, shown by its bright tan/brown color.

Photo C3-2 Thin section photomicrographs of Core C3, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

LOCATION: Austin, Texas

DATE RECEIVED: June 27, 2016

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C5.

CTLGroup Identification: 4267905.

Overview of Core: Core taken from a west arch of the north bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 211 to 214 mm (8.3 to 8.4 in.); partial concrete thickness.

Outer Core Surface: Mostly flat concrete surface with remnant striations, possibly formed surface, covered by gray coating.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly around aggregate particles.

Cracks, Joints, Large Voids: None observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 28 mm (1.1 in.).

Shape, Texture, Distribution: Coarse- Rounded and subangular, equant (very few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 0.1 to 0.3 mm (0.004 to 0.01 in.) of the core is medium gray. Paste in the following 0.1 mm (0.004 in.) of the core is very light beige. Paste in the following 3.5 to 15.5 mm (0.1 to 0.6 in.) of the core is light orange-beige. Paste in the remainder of the core is light beige.

Hardness: Paste in outer 3.5 to 15.5 mm (0.1 to 0.6 in.) of the core is moderate to moderately hard. Paste in remainder of the core is moderate.

Luster: Paste in the outer 0.1 to 0.3 mm (0.004 to 0.01 in.) of the core is subvitreous. Paste in the following 3.5 to 15.5 mm (0.1 to 0.6 in.) of the core is subvitreous to dull. Paste in the remainder of the core is dull to subvitreous.

Paste-Aggregate Bond: Moderately weak to weak. When struck with a geology hammer in the laboratory, the concrete fractured mostly around, but through a very few, coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 0 to 2 mm (0 to 0.08 in.) from concrete outer surface.

Calcium Hydroxide*: Estimated at 15 to 20%; coarse to fine crystallinity. Small patches line coarse aggregate particles.

Residual/Relic Portland Cement Clinker Particles: Estimated at 3 to 6%.

Supplementary Cementitious Materials*: None observed.

Secondary Deposits: None observed.

Limestone Fines: Present in moderate amounts, possibly from the aggregate.

MICROCRACKING: Several microcracks occur, with no general orientation, throughout the core, but mainly within the outer 51 mm (2.0 in.) of the core. Microcracks extend around all aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste

C5-1a. Core (concrete) outer surface. The surface is a mostly flat surface covered by gray paint layer.

C5-1b. Side view of core.

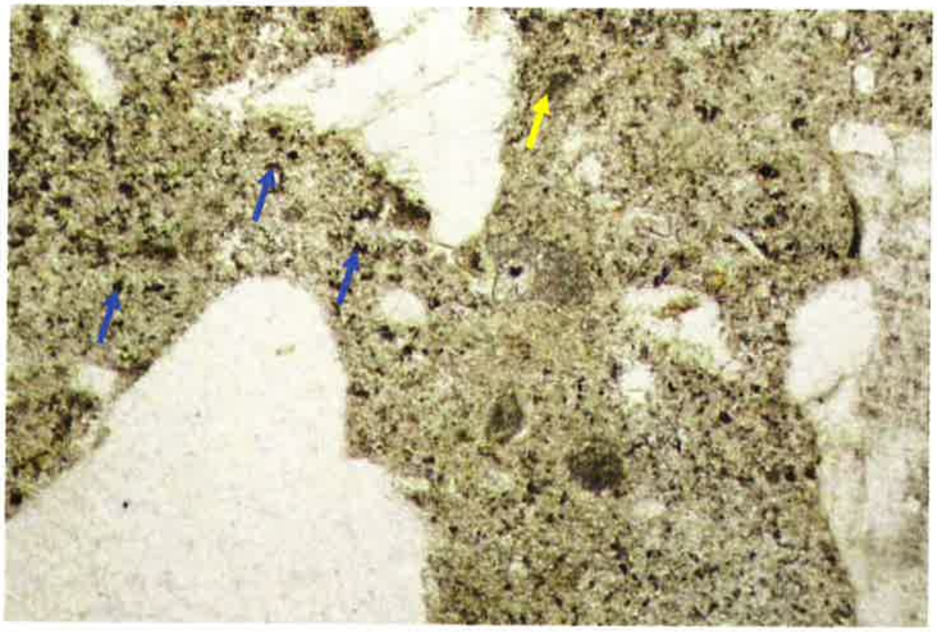
Photo C5-1 Core C5, as received for testing.

Photo C5-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C5.**

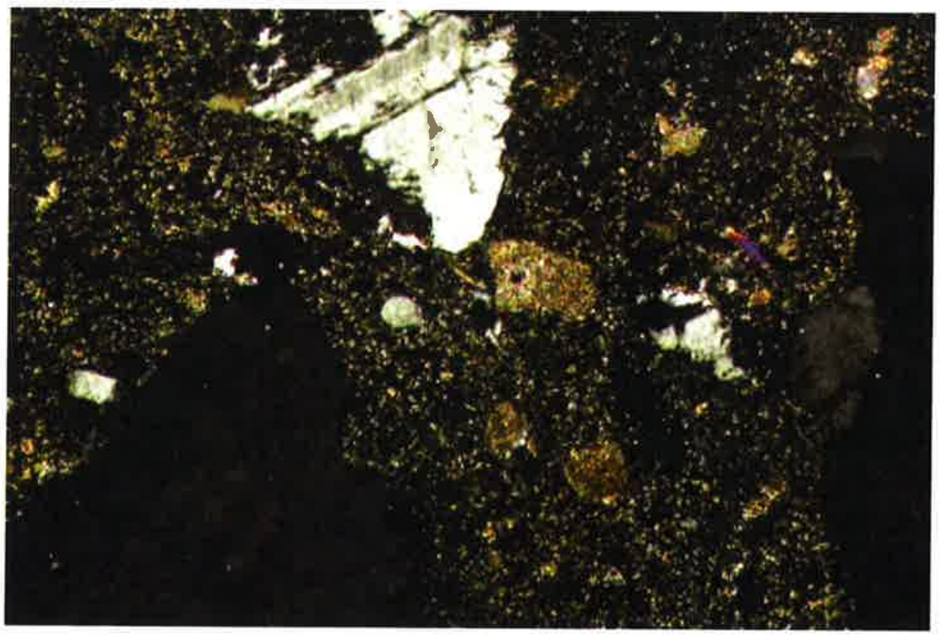
Paste carbonation is to a depth of 0 to 0.08 in. (2 mm) (yellow brackets) from the outer core surface.

The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains several microcracks with no general orientation, throughout the core, but mainly within the outer 2.0 in. of the core. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 1.1 in., is rounded to subangular in shape, and uniformly distributed in the concrete.



C5-3a. **Plane-polarized light. Blue arrows depict several residual/relic portland cement grains.**



C5-3b. **Cross polarized light.**

Photo C5-3 **Thin section photomicrographs of Core C5, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).**

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

DATE RECEIVED: June 27, 2016

LOCATION: Austin, Texas

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C9.

CTLGroup Identification: 4267909.

Overview of Core: Core taken from an east deck of the north bridge.

Dimensions: Core diameter = 70 mm (2.8 in.). Core length = 124 to 136 mm (4.9 to 5.4 in.); partial concrete thickness.

Outer Core Surface: Mostly flat, somewhat worn, striated, formed concrete surface, which exhibits a small amount of scaling or abrasion that exposes fine aggregate particles. Scaling or abrasion is to a depth of approximately 1 mm (0.04 in.).

Bottom Core Surface: Fractured and rough concrete surface, extending mostly around aggregate particles.

Cracks, Joints, Large Voids: None observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 18 mm (0.7 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (very few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 20 to 30 mm (0.8 to 1.2 in.) of the core is light orange-beige. Paste in the remainder of the core is light beige.

Hardness: Moderate to moderately hard throughout the paste.

Luster: Dull to subvitreous.

Paste-Aggregate Bond: Moderately tight to moderate. When struck with a geology hammer in the laboratory, the concrete fractured mostly through, but around some, coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 28 to 31 mm (1.1 to 1.2 in.) from concrete outer surface.

Calcium Hydroxide*: As observed in thin section, most of the paste is carbonated. In the small amount that is not carbonated, the paste is amorphous: the calcium hydroxide crystals have been leached out.

Residual/Relic Portland Cement Clinker Particles: Estimated at 3 to 6%.

Supplementary Cementitious Materials*: None observed.

Secondary Deposits: Small amounts of ettringite present.

Limestone Fines: Present in moderate amounts, possibly from the aggregate.

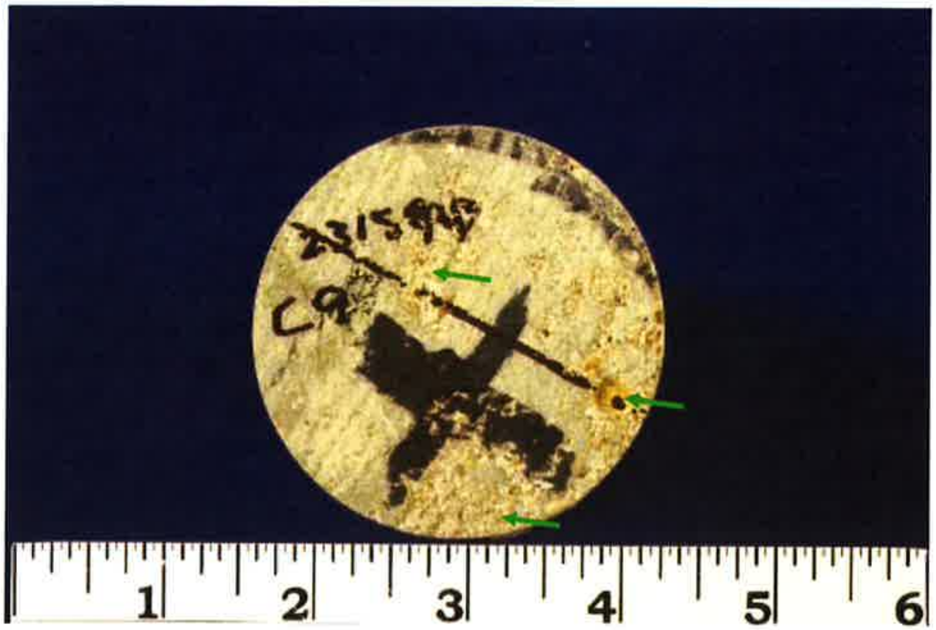
MICROCRACKING: Very few microcracks occur, with no general orientation, within the outer 31.5 mm (1.2 in.) of the core. Microcracks extend around all aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste



C9-1a. **Core (concrete) outer surface. The surface is a mostly flat, somewhat worn and striated, formed concrete surface, with shallow scaling or abrasion (green arrows) that exposes fine aggregate particles.**

C9-1b. **Side view of core.**

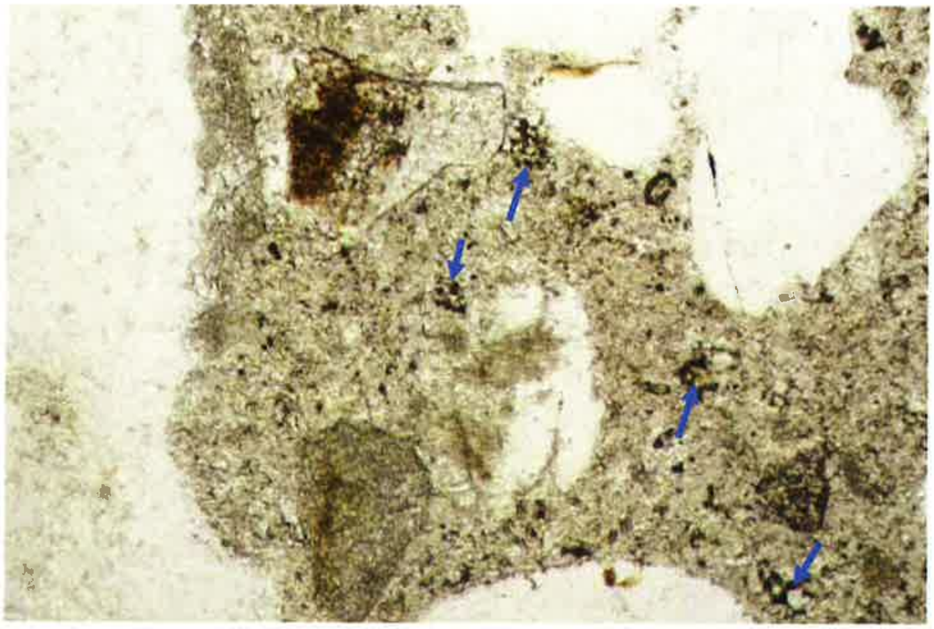
Photo C9-1 **Core C9, as received for testing.**

Photo C9-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C9.**

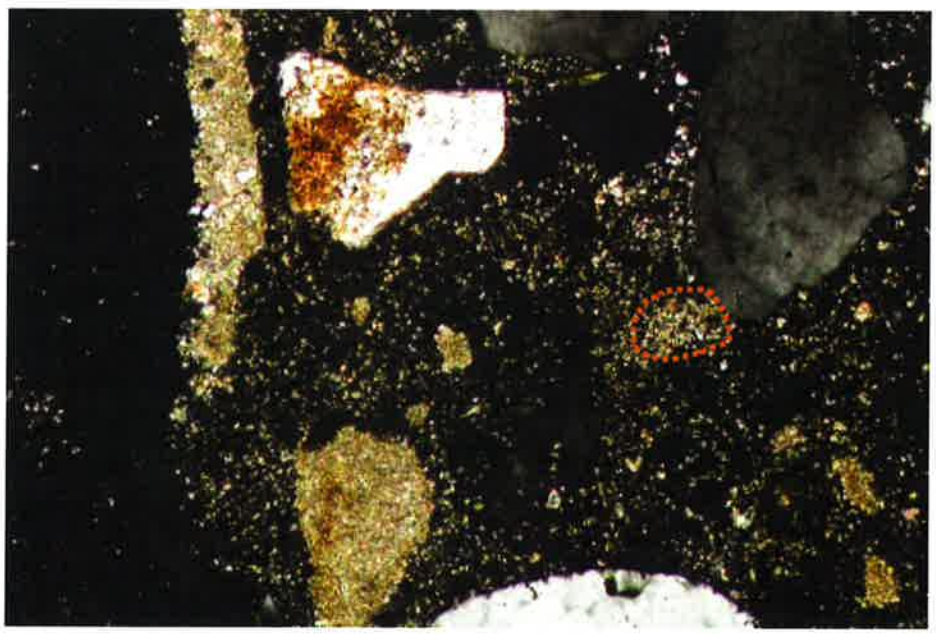
Paste carbonation is to a depth of 1.1 to 1.2 in. (yellow brackets) from the outer core surface.

The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains very few microcracks with no general orientation, within the outer 1.2 in. of the core. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 0.7 in., is rounded to subangular in shape, and uniformly distributed in the concrete.



C9-3a. **Plane-polarized light. Blue arrows depict several coarsely ground residual/relic portland cement grains.**



C9-3b. **Cross polarized light. The paste is amorphous: calcium hydroxide particles have been leached out of the paste. Bright colored speckles are limestone dust and fines (orange encirclement).**

Photo C9-3 **Thin section photomicrographs of Core C9, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).**

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

DATE RECEIVED: June 27, 2016

LOCATION: Austin, Texas

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C10.

CTLGroup Identification: 4267910.

Overview of Core: Core taken from a pier of the south bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 163 to 180 mm (6.4 to 7.1 in.); partial concrete thickness.

Outer Core Surface: Mostly flat, somewhat worn, formed concrete surface with some shallow abrasion that exposes fine aggregate particles.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly around aggregate particles.

Cracks, Joints, Large Voids: None observed.

Reinforcement: None observed.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains. One metal particle,1.5-mm (0.06-in.) side, is located 20 mm (0.8 in.) from the concrete outer surface.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 21 mm (0.8 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 3 to 39 mm (0.1 to 1.5 in.) of the core is very light orange-beige. Paste in the remainder of the core is light beige.

Hardness: Moderately soft throughout the paste.

Luster: Dull to subvitreous.

Paste-Aggregate Bond: Weak. When struck with a geology hammer in the laboratory, the concrete fractured mostly around essentially all coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 12 to 39 mm (0.5 to 1.5 in.) from concrete outer surface.

Calcium Hydroxide*: Estimated 8 to 13%; coarse to fine crystallinity. Small patches line coarse aggregate particles.

Residual/Relic Portland Cement Clinker Particles: Coarsely ground and estimated at 4 to 7%.

Supplementary Cementitious Materials*: None observed.

Secondary Deposits: None observed.

Limestone Fines: Present in moderate amounts, possibly from the aggregate.

MICROCRACKING: One forked microcrack is present on the core outer surface, extending to a core depth of 21 mm (0.8 in.). The microcracks extend around and through aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste

C10-1a. Core (concrete) outer surface. The surface is a mostly flat, somewhat worn, formed concrete surface, which exhibits some shallow abrasion that exposes exposed fine aggregate particles.

C10-1b. Side view of core.

Photo C10-1 Core C10, as received for testing.

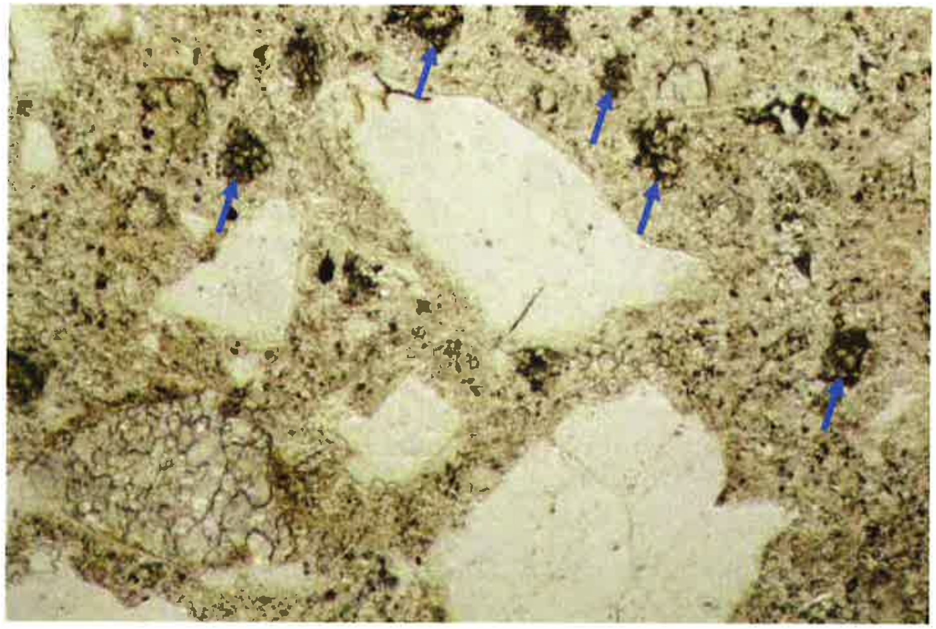
Photo C10-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C10.**

Paste carbonation is to a depth of 0.5 to 1.5 in. (yellow brackets) from the outer core surface.

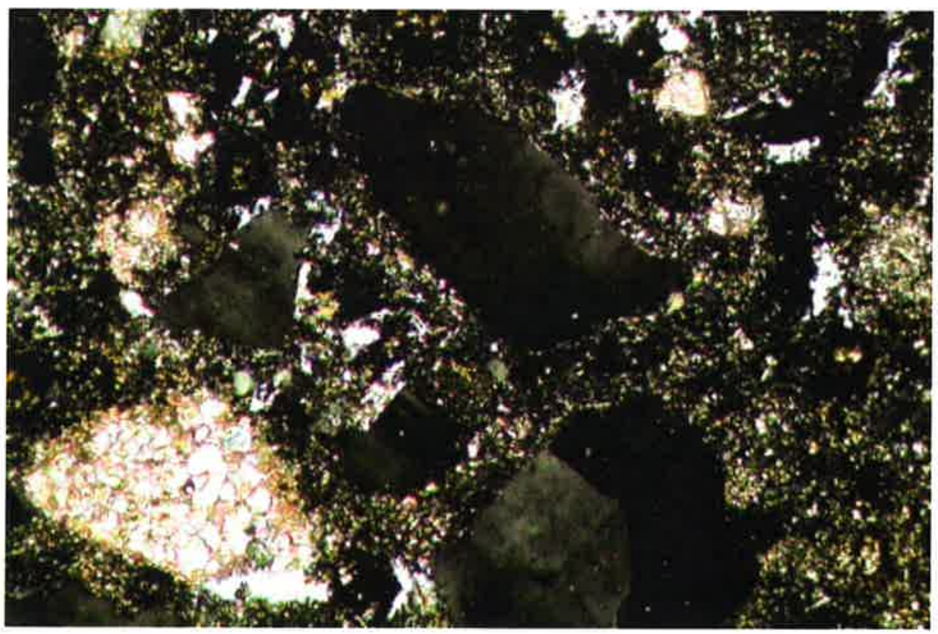
The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains one splayed microcrack, perpendicular to the outer core surface, extending to a core depth of 0.8 in. The microcracks extend around and through aggregate particles.

The natural gravel coarse aggregate has an observed top size of 0.8 in., is rounded to subangular in shape, and uniformly distributed in the concrete.

Green arrow points to one small metal particle in the concrete. No associated corrosion product observed.



C10-3a. Plane-polarized light. Blue arrows depict several coarsely ground residual/relic portland cement grains.



C10-3b. Cross polarized light.

Photo C10-3 Thin section photomicrographs of Core C10, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

DATE RECEIVED: June 27, 2016

LOCATION: Austin, Texas

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C11.

CTLGroup Identification: 4267911.

Overview of Core: Core taken from a pier of the south bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 160 to 177 mm (6.3 to 7.0 in.); partial concrete thickness.

Outer Core Surface: Mostly flat, slightly worn and striated, formed concrete surface with remnants of a striated finish.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly around aggregate particles.

Cracks, Joints, Large Voids: Core was received cracked or fractured partially around a large limestone chunk; fracture is assessed to be a result of the coring. No joints or large voids observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles. One large (101 mm, 4.0 in.) limestone chunk is present in the midportion of the core.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 14 mm (0.6 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (very few elongate) in shape; slightly irregular texture; mostly uniform distribution, excluding the large limestone chunk. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 3 to 5 mm (0.1 to 0.2 in.) of the core is light brown-beige. Paste in the remainder of the core is light beige.

Hardness: Paste in the outer 3 to 5 mm (0.1 to 0.2 in.) of the core is moderate. Paste in the remainder of the core is moderate to moderately soft, but varies locally to moderately hard in some small areas.

Luster: Paste in the outer 3 to 5 mm (0.1 to 0.2 in.) of the core is subvitreous to dull. Paste in the remainder of the core is dull to subvitreous.

Paste-Aggregate Bond: Moderate. When struck with a geology hammer in the laboratory, the concrete fractured through approximately half and around approximately half of the coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 3 to 10 mm (0.1 to 0.4 in.) from concrete outer surface.

Calcium Hydroxide*: Estimated 5 to 10%; coarse to fine crystallinity. Small patches line coarse aggregate particles.

Residual/Relic Portland Cement Clinker Particles: Coarsely ground and estimated at 6 to 9%.

Supplementary Cementitious Materials*: None observed.

Secondary Deposits: None observed.

Limestone Fines: Present in moderate amounts, possibly from the aggregate.

MICROCRACKING: Very few microcracks observed, with no general orientation, within the outer 38 mm (1.5 in.) of the core. A microcrack (as well as a crack, fracture) occurs along the interface between a large limestone chunk and the concrete. Microcracks extend around all aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste

C11-1a. **Core (concrete) outer surface. The surface is a mostly flat, slightly worn and striated, formed concrete surface, with some shallow abrasion present.**

C11-1b. **Side view of core. Core was received fractured (red arrows) partially around a large limestone aggregate chunk (large tan object in the center portion of the core); fractured is assessed to be due to the coring.**

Photo C11-1 Core C11, as received for testing.

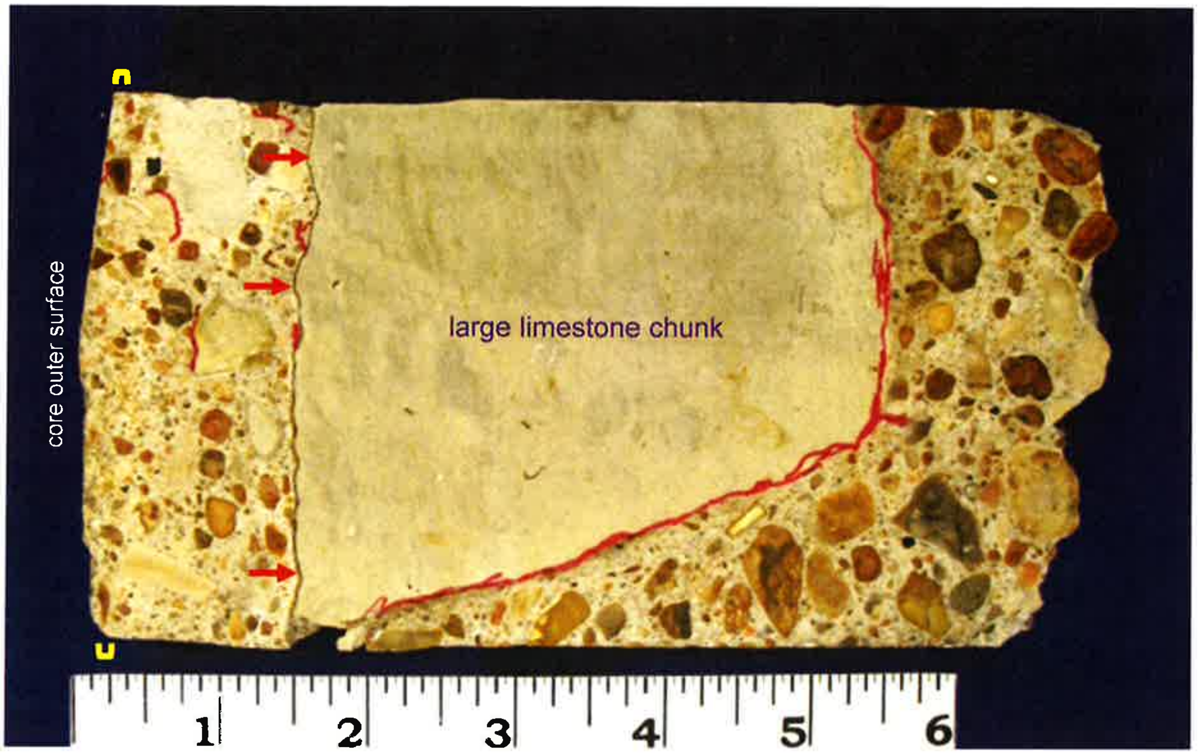
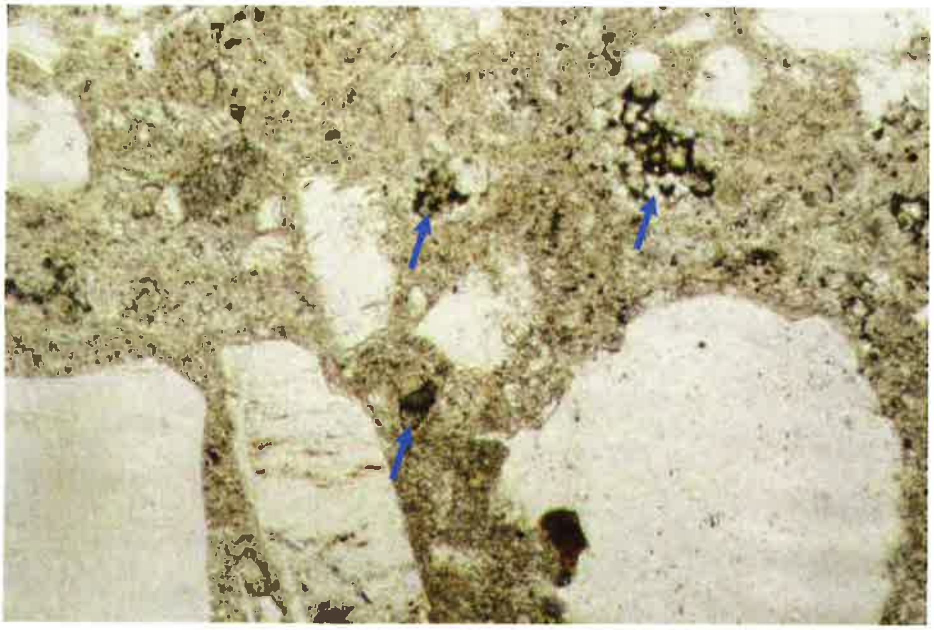


Photo C11-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C11.**

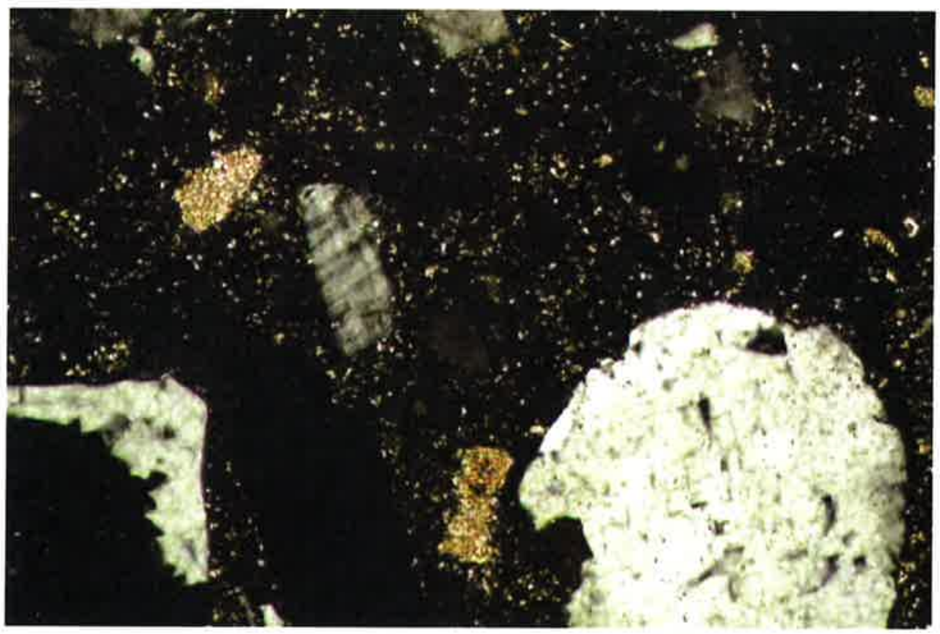
Paste carbonation is to a depth of 0.1 to 0.4 in. (yellow brackets) from the outer core surface.

The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains very few microcracks with no general orientation, within the outer 1.5 in. of the core. A microcrack occurs along the interface between a very large limestone particle and the concrete; the outer portion of the limestone-concrete interface is a cracked or fractured surface (red arrows), assessed to be a result of the coring. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 0.6 in., is rounded to subangular in shape, and mostly uniformly distributed in the concrete, excluding the one large limestone chunk.



C11-3a. Plane-polarized light. Blue arrows depict several coarsely ground residual/relic portland cement grains.



C11-3b. Cross polarized light.

Photo C11-3 Thin section photomicrographs of Core C11, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

DATE RECEIVED: June 27, 2016

LOCATION: Austin, Texas

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C12.

CTLGroup Identification: 4267912.

Overview of Core: Core taken from an east arch of the south bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 142 to 162 mm (5.6 to 6.4 in.); partial concrete thickness.

Outer Core Surface: Mostly flat concrete surface covered with a thin (less than 2-mm-thick, 0.08-in.-thick) mortar-like coating.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly around aggregate particles.

Cracks, Joints, Large Voids: Two random cracks, 0.25 mm (0.01 in.) wide, are present within a core depth interval of 67 to 125 mm (2.6 to 4.9 in.), passing through and around aggregate particles. No joints or large voids observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles. A few random particles of glass are present.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 24 mm (0.9 in.).

Shape, Texture, Distribution: Coarse- Rounded to angular, equant (very few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 0.1 mm (0.004 in.) of the core is white. Paste in the following 0.5 to 1.5 mm (0.02 to 0.06 in.) of the core is medium gray. Paste in the following 11.5 to 15 mm (0.5 to 0.6 in.) of the core is very light orange-beige. Small patches of the very light orange-beige are present in the following 9 mm (0.4 in.) within a light beige paste. Paste in the following 12 to 20 mm (0.5 to 0.8 in.) of the core is light beige. Paste in the remainder of the core is medium-light beige.

Hardness: Paste in outer 16.5 mm (0.6 in.) of core is moderate to moderately hard. Paste in the following 29 mm (1.1 in.) of the core is moderately soft to moderate. Paste in remainder of concrete is moderate to moderately hard.

Luster: Paste in the outer 1.5 mm (0.06 in.) of the core is subvitreous. Paste in the following 11.5 to 15 mm (0.5 to 0.6 in.) of the core is subvitreous to dull. Paste in the following 21 to 29 mm (0.8 to 1.1 in.) of the core is dull to subvitreous. Paste in the remainder of the core is subvitreous to dull.

Paste-Aggregate Bond: Moderate. When struck with a geology hammer in the laboratory, the concrete fractured around approximately half and through approximately half of the coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 12 to 16 mm (0.5 to 0.6 in.) from concrete outer surface.

Calcium Hydroxide*: Estimated 10 to 15%; coarse to fine crystallinity. Small patches line coarse aggregate particles.

Residual/Relic Portland Cement Clinker Particles: Coarsely ground; estimated at 6 to 9%.

Supplementary Cementitious Materials*: None observed.

Secondary Deposits: None observed.

Limestone Fines: Present in moderate to significant amounts, possibly from the coarse aggregate.

MICROCRACKING: Many microcracks occur, with no general orientation, throughout the core, but mainly between core depths of 38 to 128 mm (1.5 to 5.0 in.) Microcracks extend around almost all aggregate particles. Significant microcracking stems from and occurs within a glass particle at a core depth of 99.5 mm (3.9 in.).

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

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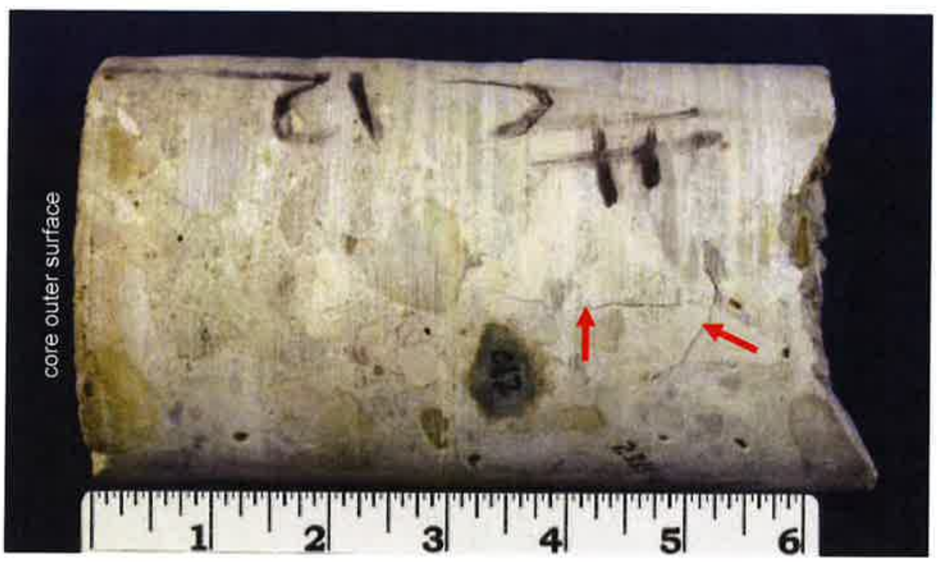
*percent by volume of paste

C12-1a. **Core (concrete) outer surface. The surface texture is a mortar-like coating over the underlying concrete.**



C12-1b. **Side view of core. Red arrows point to two random cracks.**

Photo C12-1 Core C12, as received for testing.

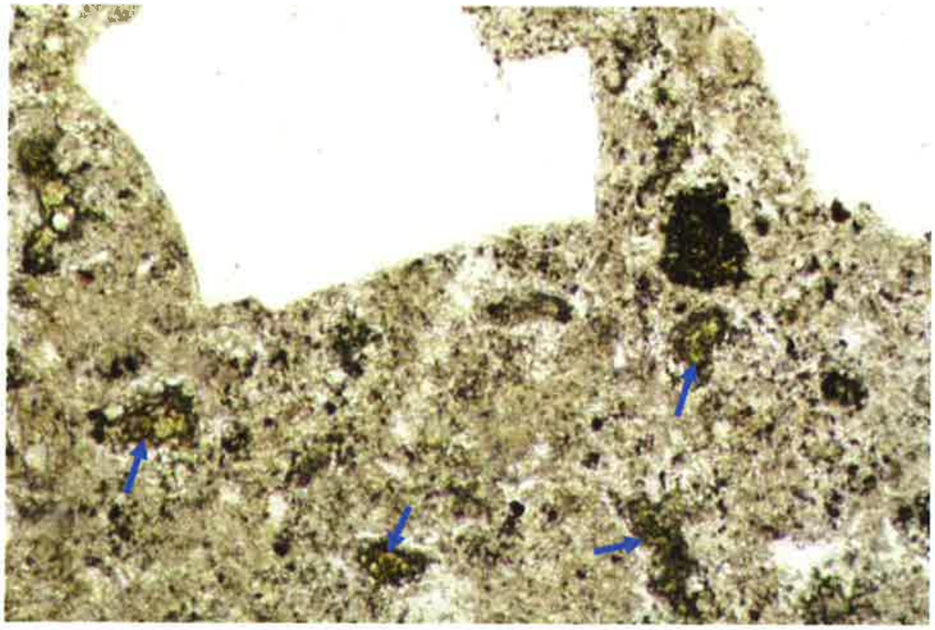
Photo C12-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C12.**

Paste carbonation is to a depth of 0.5 to 0.6 in. (yellow brackets) from the outer core surface.

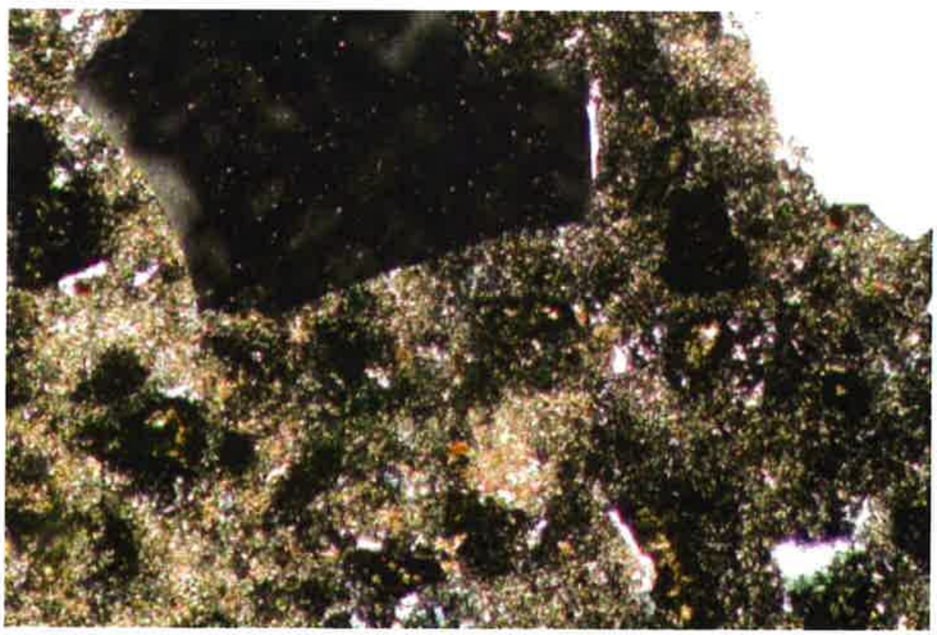
The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains many microcracks with no general orientation, throughout the core, but mainly between core depths of 1.5 to 5.0 in. Microcracks extend around almost all aggregate particles. Significant microcracking stems from and occurs within a glass particle at a core depth of 3.9 in. (purple arrow); these microcracks are assessed to be ASR microcracks.

Another glass particle (green and encircled green) is present on the lapped concrete surface.

The natural gravel coarse aggregate has an observed top size of 0.9 in., is rounded to subangular in shape, and uniformly distributed in the concrete.



C12-3a. Plane-polarized light. Blue arrows depict several coarsely ground residual/relic portland cement grains.



C12-3b. Cross polarized light. Paste is mostly carbonated, shown by its bright tan/brown color.

Photo C12-3 Thin section photomicrographs of Core C12, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

LOCATION: Austin, Texas

DATE RECEIVED: June 27, 2016

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C13.

CTLGroup Identification: 4267913.

Overview of Core: Core taken from a middle arch of the south bridge.

Dimensions: Core diameter = 95 mm (3.7 in.). Core length = 167 to 177 mm (6.6 to 7.0 in.); partial concrete thickness.

Outer Core Surface: Mostly flat, partially medium brown and partially medium beige, surface. Part of the surface is concrete and part is a thin mortar-like coating. A sealer is present on the part of the mortar-like surface that is medium brown, and worn off of the medium beige area. When water is applied to the area with the sealer, it beads up very readily and is not absorbed for an extended amount of time. When water is applied to the area without a sealer, water is readily absorbed.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly through aggregate particles.

Cracks, Joints, Large Voids: One crack, 0.1 to 0.4 mm (0.004 to 0.2 in.) wide, parallel/slight angle to the core outer surface, occurs between depths of 21 to 48 mm (0.8 to 1.9 in.). One full fracture (crack separates the core in two segments, somewhat parallel to the overlying crack, between depths of 91 to 120 mm (3.6 to 4.7 in.). The cracks extend mostly around aggregate particles. No joints or large voids observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 21 mm (0.8 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 0 to 0.2 mm (0.008 in.) of the core is medium orange-brown. Paste in the following 1 to 5 mm (0.04 to 0.2 in.) of the core is medium gray. Paste in the following 14 to 40 mm (0.6 to 1.6 in.) of the core is very light orange-beige. Paste in the remainder of the core is light beige.

Hardness: Paste in the outer 0 to 0.2 mm (0.008 in.) of the core is very soft. Paste in the following 1 to 5 mm (0.04 to 0.2 in.) of the core is hard. Paste in the remainder of the core is moderate.

Luster: Paste in the outer 0 to 0.2 mm (0.008 in.) of the core is vitreous to subvitreous. Paste in the following 1 to 5 mm (0.04 to 0.2 in.) of the core is subvitreous. Paste in the remainder of the core is subvitreous to dull.

Paste-Aggregate Bond: Moderately weak to weak. When struck with a geology hammer in the laboratory, the concrete fractured mostly around, but through a very few, coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 15 to 27 mm (0.6 to 1.1 in.) from concrete outer surface.

Calcium Hydroxide*: Estimated 10 to 15%; coarse to fine crystallinity. Small patches line coarse aggregate particles.

Residual/Relic Portland Cement Clinker Particles Coarsely ground and estimated at 4 to 7%.

Supplementary Cementitious Materials*: None observed.

Secondary Deposits: Some ettringite observed.

Limestone Fines: Present in moderate amounts, possibly from the aggregate.

MICROCRACKING: Many microcracks occur splaying from the crack and from the full fracture/crack. Very few other microcracks are observed, with no general orientation, located within the outer 20 mm (0.8 in.) of the core. Microcracks extend around all aggregate particles.

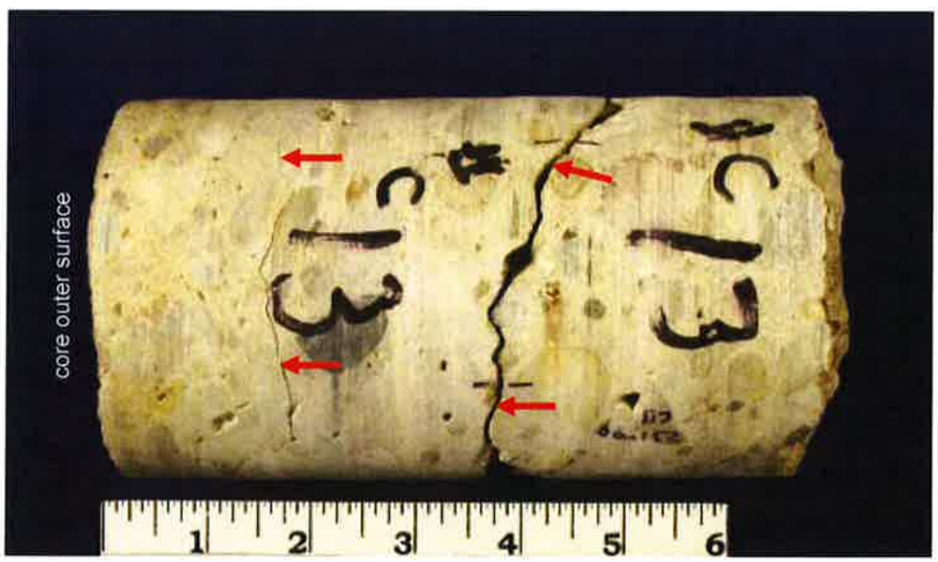
ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

---

*percent by volume of paste

C13-1a. Core (concrete) outer surface. The surface is a mostly flat, partially medium brown and partially medium beige, surface. A sealer is present on the part of the surface that is medium brown (purple arrow).



C13-1b. Side view of core.

Photo C13-1 Core C13, as received for testing.

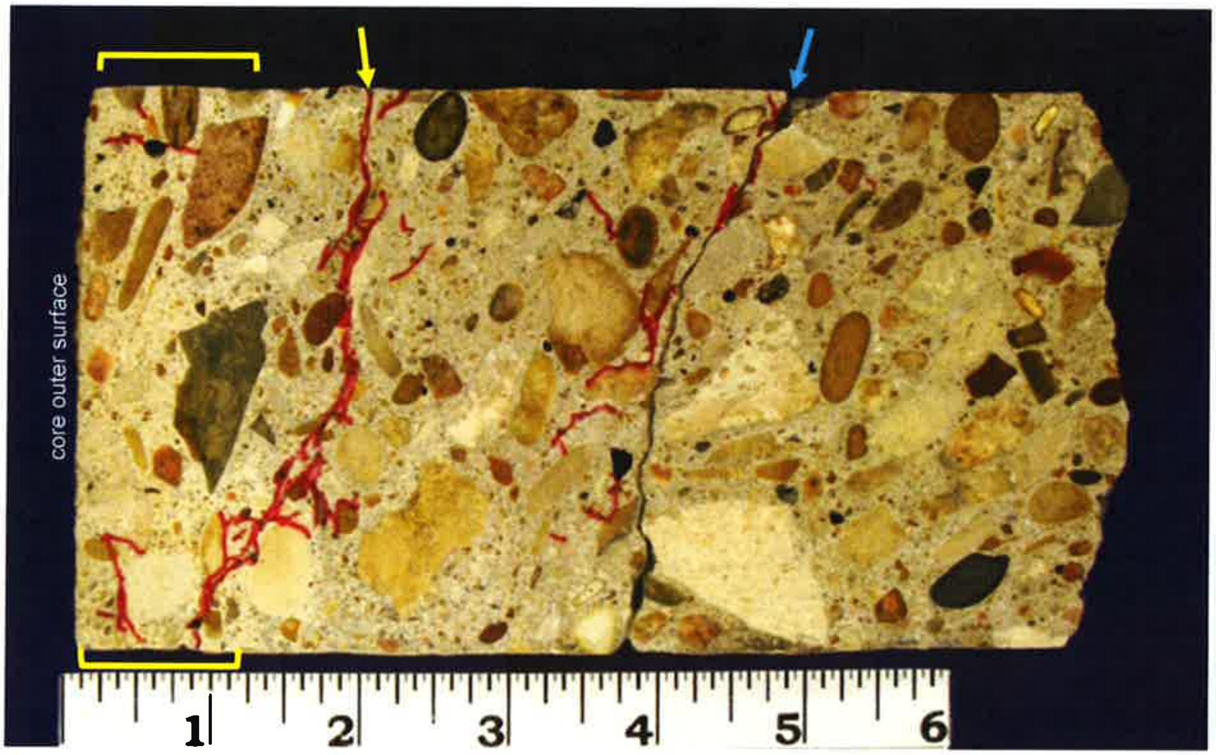
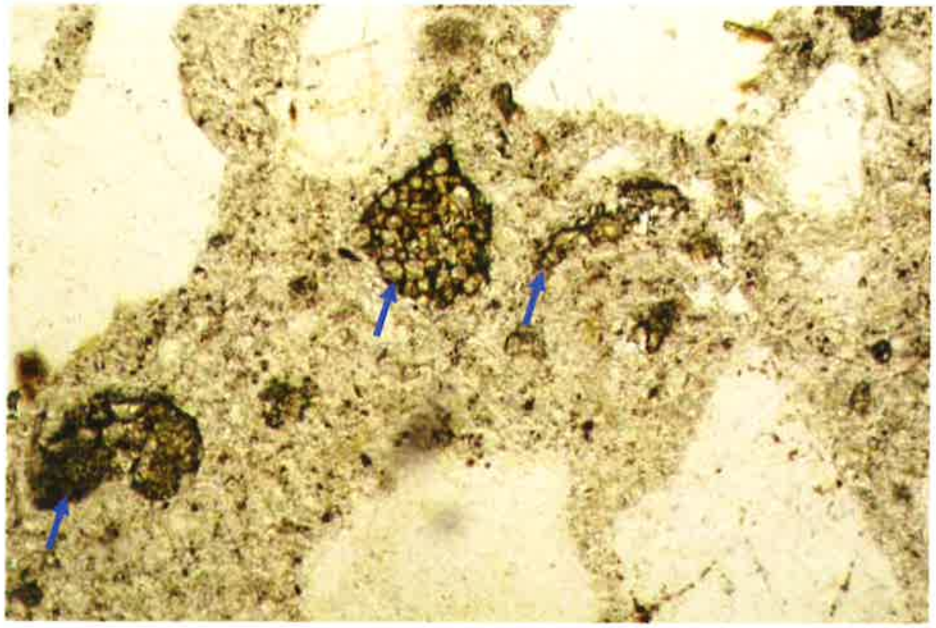


Photo C13-2 **Lapped, cross-sectional (longitudinal) concrete surface of Core C13.**

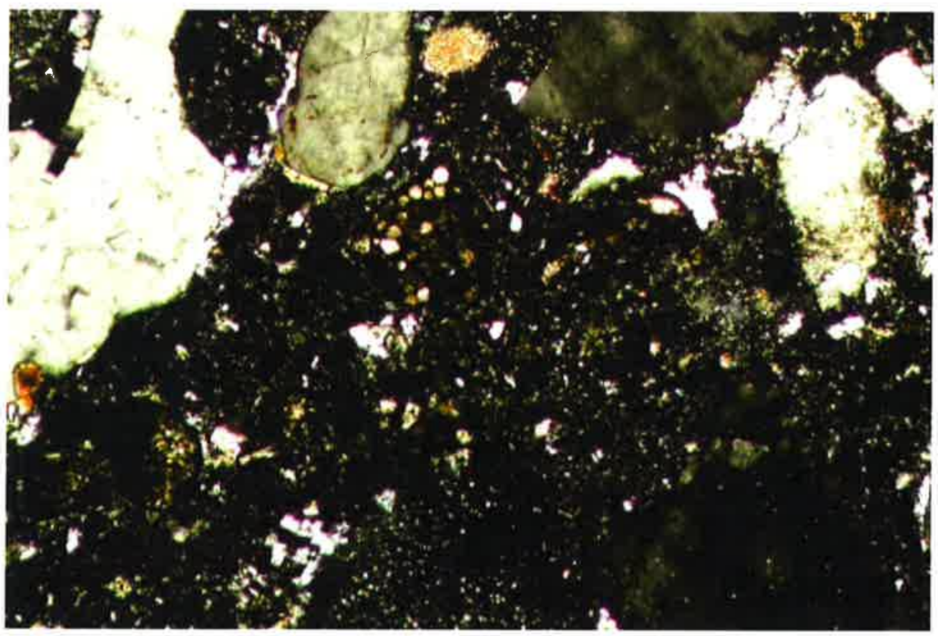
Paste carbonation is to a depth of 0.6 to 1.1 in. (yellow brackets) from the outer core surface.

Cracks and microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains many microcracks occur splaying from the crack (yellow arrow) and full fracture/crack (blue arrow). Very few other microcracks with no general orientation are present within the outer 0.8 in. of the core. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 0.8 in., is rounded to subangular in shape, and uniformly distributed in the concrete.



C13-3a. Plane-polarized light. Blue arrows depict several coarsely ground residual/relic portland cement grains.



C13-3b. Cross polarized light.

Photo C13-3 Thin section photomicrographs of Core C13, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).

PETROGRAPHIC EXAMINATION OF HARDENED CONCRETE, ASTM C856

STRUCTURE: Road Bridge

LOCATION: Austin, Texas

DATE RECEIVED: June 27, 2016

EXAMINED BY: Jaclyn Ferraro

SAMPLE

Client Identification: C18.

CTLGroup Identification: 4267918.

Overview of Core: Core taken from an east deck of the south bridge.

Dimensions: Core diameter = 70 mm (2.8 in.). Core length = 138 to 144 mm (5.4 to 5.7 in.); partial concrete thickness.

Outer Core Surface: Slightly worn, partially flat, and partially unevenly spaced striated, formed concrete surface.

Bottom Core Surface: Fractured and rough concrete surface, extending mostly through, but around some aggregate particles.

Cracks, Joints, Large Voids: None observed.

Reinforcement: None present.

AGGREGATES

Coarse: Natural gravel composed of a variety of rock types, mainly including limestone; with lesser amounts of quartzite and chert and/or chalcedony; and lesser amounts of granite, as well as several other igneous rock particles and a few sandstone particles.

Fine: Natural sand composed mainly of quartz grains and feldspar grains; with lesser amounts of limestone and chert and/or chalcedony; and even lesser amounts of granite, sandstone, calcite grains, and amphibole grains.

Gradation & Top Size: Visually appears evenly graded to an observed top size of 25 mm (1.0 in.).

Shape, Texture, Distribution: Coarse- Rounded to subangular, equant (very few elongate) in shape; slightly irregular texture; uniform distribution. Fine- Rounded to angular; uniform distribution.

PASTE

Color: Paste in the outer 14 to 29 mm (0.6 to 1.1 in.) of the core is medium orange-beige. Paste in the remainder of the core very light beige.

Hardness: Moderate, to locally moderately hard.

Luster: Paste in outer 14 to 29 mm (0.6 to 1.1 in.) of core is dull to subvitreous. Paste in remainder of core is dull.

Paste-Aggregate Bond: Moderately weak to moderate. When struck with a geology hammer in the laboratory, the concrete fractured mostly around, but through several, coarse aggregate particles.

Air Content: Estimated at 1.5% or less. The hardened concrete is considered not air-entrained, based upon the scarcity of air voids.

Depth of Carbonation: 14 to 29 mm (0.6 to 1.1 in.) from concrete outer surface.

Calcium Hydroxide*: 5 to 10%.

Residual/Relic Portland Cement Clinker Particles: Coarsely ground and estimated at 8 to 12%.

Supplementary Cementitious Materials*: None observed.

Secondary Deposits: None observed.

Limestone Fines: Present in few to moderate amounts, possibly from the aggregate.

MICROCRACKING: A few microcracks, with no general orientation, are present within the outer 27 mm (1.1 in.) of the core. Microcracks extend around all aggregate particles.

ESTIMATED WATER-CEMENT RATIO: Not estimated, due to reported age of concrete.

CORROSION: None observed.

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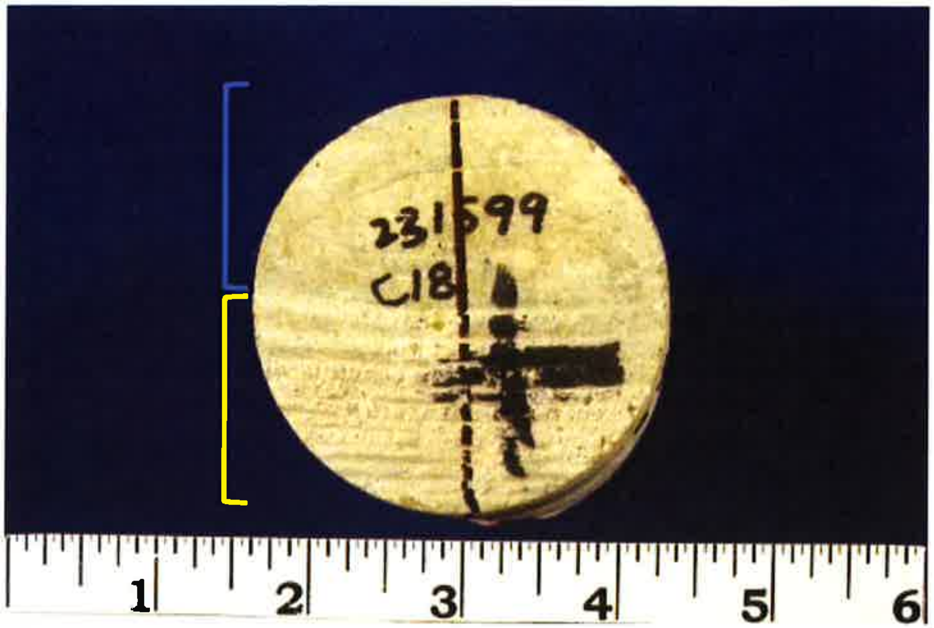
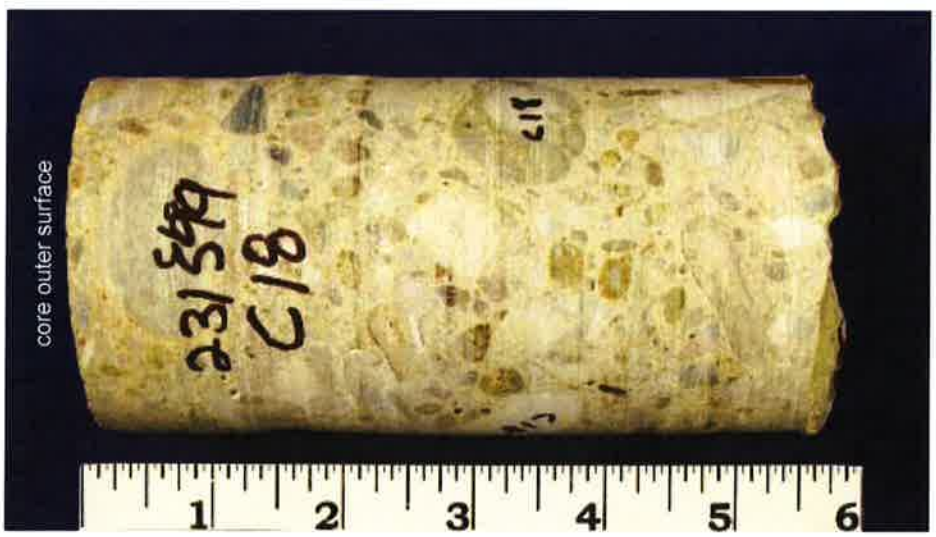
*percent by volume of paste



C18-1a. **Core (concrete) outer surface. The surface is a slightly worn, partially flat (blue bracket area), and partially unevenly spaced striated (yellow bracket area), formed concrete surface.**



C18-1b. Side view of core.

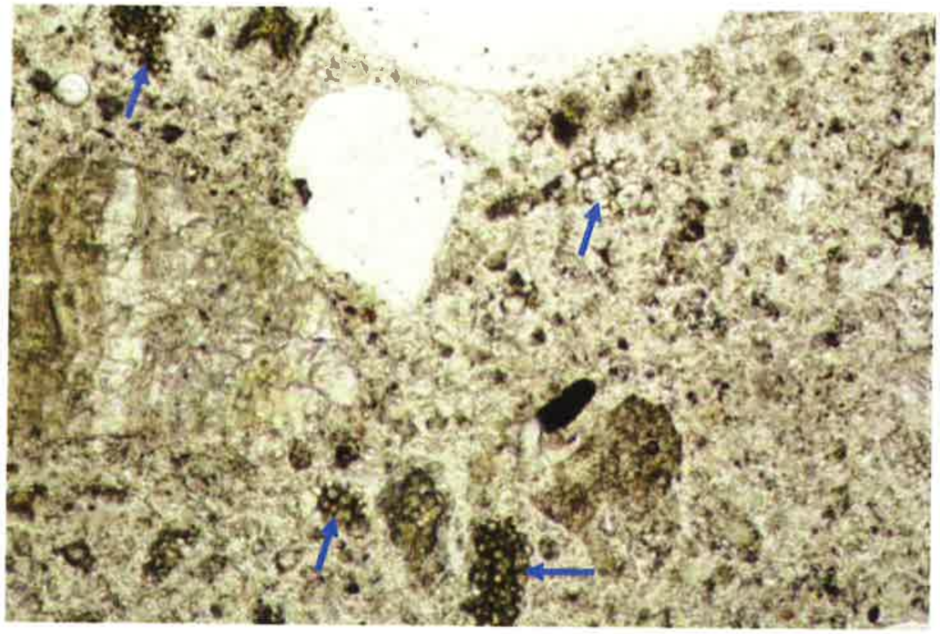
Photo C18-1 Core C18, as received for testing.

Photo C18-2 Lapped, cross-sectional concrete surface of Core C18.

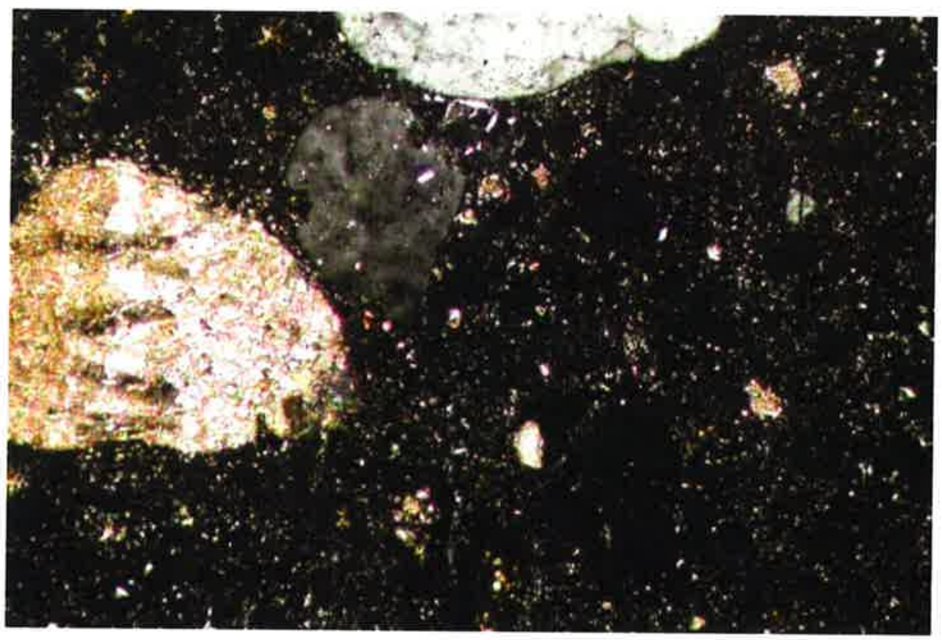
Paste carbonation is to a depth of 0.6 to 1.1 in. (yellow brackets) from the outer core surface.

The microcracks in the concrete are highlighted with red marker to depict their visibility in the image; the actual microcracks are much narrower. The concrete contains a few microcracks with no general orientation, located within the outer 1.1 in. of the core. Microcracks extend around all aggregate particles.

The natural gravel coarse aggregate has an observed top size of 1.0 in., is rounded to subangular in shape, and uniformly distributed in the concrete.



C18-3a. Plane-polarized light. Blue arrows depict several coarsely ground residual/relic portland cement grains.



C18-3b. Cross polarized light.

Photo C18-3 Thin section photomicrographs of Core C18, illustrating features in the paste. Both images show the same field of view but under different lighting. Length of field, left to right, is approximately 0.78 mm (0.03 in.).

APPENDIX B

Condition Rating Guidelines

From Chapter 4 of Federal Highway Administration's Publication *FHWA-NHI-16-013, Bridge Inspectors Reference Manual* of the bridge and component condition ratings eventually reflect the overall condition of the component. If the approach is to consider both the severity and extent of a component's deterioration in rating each component at the time of inspection (or up to 90 days after the inspection as required by the NBIS), there cannot be any assumptions about future improvements made to a localized area. Only if an improvement is made, the rating should then be raised as appropriate. If the improvement is made within 90 days of the inspection, there is no need to consider the localized deterioration in the rating.

The following general component condition rating guidelines (obtained from the 1995 edition of the *FHWA Coding Guide*) are to be used in the evaluation of the deck (Item 58), superstructure (Item 59), and substructure (Item 60):

Code	Description
N	NOT APPLICABLE
9	EXCELLENT CONDITION
8	VERY GOOD CONDITION - no problems noted.
7	GOOD CONDITION - some minor problems.
6	SATISFACTORY CONDITION - structural elements show some minor deterioration.
5	FAIR CONDITION - all primary structural elements are sound but may have minor section loss, cracking, spalling, or scour.
4	POOR CONDITION - advanced section loss, deterioration, spalling, or scour.
3	SERIOUS CONDITION - loss of section, deterioration, spalling, or scour have seriously affected primary structural components. Local failures are possible. Fatigue cracks in steel or shear cracks in concrete may be present.
2	CRITICAL CONDITION - advanced deterioration of primary structural elements. Fatigue cracks in steel or shear cracks in concrete may be present or scour may have removed substructure support. Unless closely monitored it may be necessary to close the bridge until corrective action is taken.
1	"IMMINENT" FAILURE CONDITION - major deterioration or section loss present in critical structural components, or obvious vertical or horizontal movement affecting structure stability. Bridge is closed to traffic but corrective action may put bridge back in light service.
0	FAILED CONDITION - out of service; beyond corrective action.

The component condition rating guidelines presented above are general in nature and can be applied to all bridge components and material types.

Structural capacity is defined as the designed strength of the member. However, structural capacity is different than load-carrying capacity. Load-carrying capacity refers to the ability of the member to carry the legal loads of the highway system of which the bridge is a part. Therefore, a bridge could possibly have good structural capacity yet be load posted because it is unable to carry the legal loads.