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16. Abstract This report summarizes the research conducted during the past year as specified in the Center for Transportation Research Project 7-2941, "Long-Term Behavior of High Performance Concrete Bridges." In addition to the ongoing monitoring of sites at the Louetta Road Overpass on State Highway 249 in Houston, TX, and the North Concho River/US 87/South Orient Railroad (S.O.R.R.) Overpass on US 67 in San Angelo, TX, several new HPC bridges were examined for inclusion in this study. These additional sites will serve as monitoring points to build a HPC bridge database in which the behavior can be catalogued for study and comparison. It is the intent of this project to establish and maintain a database of HPC bridge sites throughout the state so the specific long-term effects of various HPC mix designs and strategies can be evaluated and improved.			
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Field Performance of Selected High-Performance Concrete Bridge Decks

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Report 2941-3

Research Project 7-2941
Long-term Behavior of High-Performance Concrete Bridges

Conducted for the
Texas Department of Transportation
in cooperation with the
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Federal Highway Administration
by the
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September 2002

Disclaimers

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Research performed in cooperation with the Texas Department of Transportation and the U.S. Department of Transportation, Federal Highway Administration.

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Field Performance
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Introduction

High Performance Concrete (HPC) is an engineered material enhanced to optimize properties associated with durability for the specific applications. Transportation structures have increasingly used the HPC concept to construct concrete decks with improved surface abrasion resistance, reduced chloride penetrability, and improved resistance to freezing and thawing damage. Although the benefits of these properties are apparent, it can be difficult to predict how much specific target properties result solely from concrete constituents, and how much those properties will be affected by other construction circumstances.

This report summarizes research conducted during the past year as specified in the Center for Transportation Research Project 7-2941, "Long-Term Behavior of High Performance Concrete Bridges." In addition to the ongoing monitoring of sites at the Louetta Road Overpass on State Highway 249 in Houston, Texas, and the North Concho River/US 87/South Orient Railroad (SORR) Overpass on US 67 in San Angelo, Texas, several new HPC bridges were examined for inclusion in this study.

These additional sites will serve as monitoring points to build aa HPC bridge database in which behavior can be catalogued for study and comparison. It is the intent of this project to establish and maintain a database of HPC bridge sites throughout the state so the specific long-term effects of various HPC mix designs and strategies can be evaluated and improved.

Background

The new bridges selected for study include several locations in Lubbock and Amarillo, Texas. In Lubbock, particular attention was focused on the 82nd St. overpass on US 82/62 (Figure 1), which exhibited visual evidence of cracking. Also, two recently constructed bridges which may be considered for future monitoring include Loop 289 and Frankford St., and the IH 27 New Deal Bridge. In Amarillo, the bridges of primary interest are also shown in Figure 1 and include the RM 1061 overpass on Loop 335 (3.4 mi. north of IH 40) and the Amarillo Creek Bridge on Loop 335 (1.8 mi. north of IH 40).

Figure 1. Map of US 82/62 Bridge in Lubbock, Texas

Annual Inspection
Lubbock - July 10, 2002
US HW 82/62 & FM 179

Currently, this bridge has no significant cracking that would warrant its inclusion in this study. A few observations of note include the use of permanent metal deck forms and irregular zip strips, which appear to be misaligned with the joints in the deck, and some slight stretch cracking on the east side of the eastbound bridge. Stretch cracking is a series of shallow longitudinal tears running orthogonally to the tine grooves. The cracks are thought to be the result of surface tears from the tining process after the surface of the concrete has begun to dry and lose it plasticity. The surface tears are exacerbated by plastic drying and shrinkage.

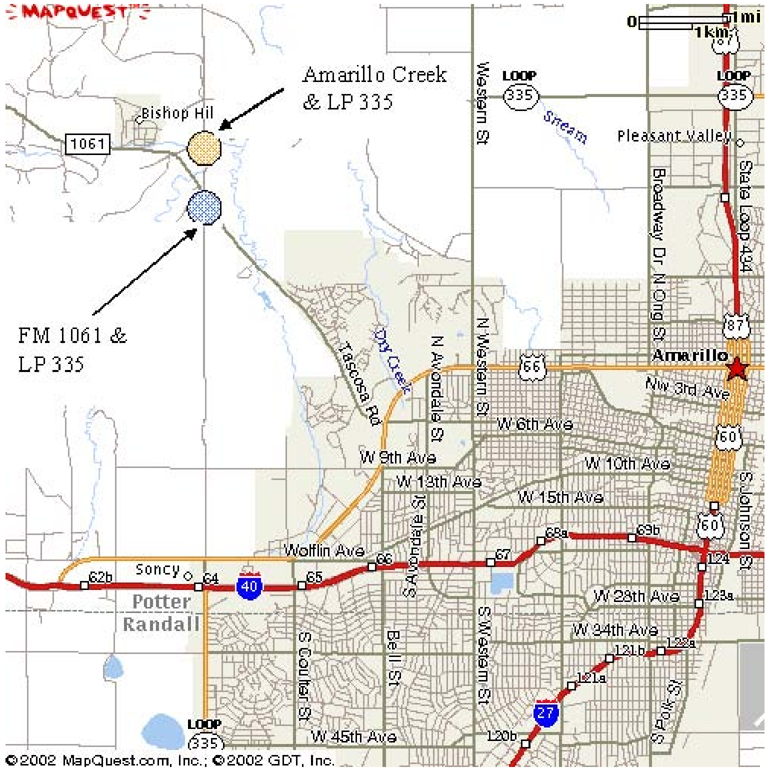

Figure 2. Map of Bridges in Amarillo, Texas

US HW 82/62 & 82nd St.

This structure presented the most visual evidence of cracking and merits inclusion in this HPC deck study. Cores were drilled from the deck upon a subsequent visit to further examine chloride content and permeability. The cast-in-place (CIP) deck is supported with precast deck panels and has a slight negative camber. There is minor stretch cracking that appears to be induced by tining and plastic shrinkage. The most serious problem with this deck is several large transverse cracks in areas located over the supports. Figure 2 shows a cracked region of the deck that was cored to determine the chloride content along the crack surface.

Figure 3. Region of Cracked HPC Deck Used for Chloride Determination

LP 289 & Frankford St.

This newly constructed bridge was inspected to determine if there were any early signs that would suggest inclusion in the study. However, at this early point in time in the bridge service life, there are no distress symptoms such as visible signs of cracking that indicate any potential problems.

New Deal

During the first inspection of this structure, the northbound direction had been completed and was carrying both directions of traffic while the southbound bridge was being constructed. At the time, no signs of serious cracking in the completed deck were observed. However, there have been recent reports of cracking since the last visit, and researchers will check again to see if this bridge should be included in the database.

Figure 4. Transverse Cracks in the LP 335 & FM 1061 Bridge in Amarillo

Amarillo - July 11, 2002
335 & RM 1061 - 3.4 Mi. N. of IH 40

There are several regions of this deck with a moderate amount of transverse cracks that would warrant its inclusion in the database. Approximately 51 ft. from the southern end is an area with several significant cracks. A typical representation of the transverse cracks is shown in Figure 3. Also in this area are a few longitudinal cracks located mid-span.

LP 335 & Amarillo Creek - 1.8 Mi. N. of IH 40

The most significant cracking in this HPC deck appears to be longitudinal, located primarily in the thickened CIP sections over the bents. Figure 4 shows a crack typical of the longitudinal patterns observed in this deck. The cracking is not severe in this deck, but, due to the fact that the cracking is longitudinal, rather than transverse as in other HPC decks, this bridge will be included in the database for comparison.

Figure 5. Longitudinal Cracks in the Amarillo Creek Bridge

Houston - September 26, 2002
SH 249 & Louetta Rd.

High traffic volume in both directions limited the inspection of the deck to visual observations from the outer shoulder lanes. There is a moderate concentration of cracks throughout the deck, particularly in the areas above the skewed bents. Some of the cracks appear to have been routed or sawed and had accumulated in some of the wider cracks. Figures 5 and 6 show two of the larger cracks observed from the shoulder.

The research team observed some minor cracking from below the bridge in a couple of beams and panels. A few of the beams showed some structurally insignificant cracking, but the most noticeable instance is shown in Figure 7 where a large crack starts in the top flange and continues vertically through one of the web faces of the U-beam. Although this larger crack does not appear to present any structural implications at this time, it should be closely inspected and reported every year. Another non-structural beam anomaly was observed, where the underside had a "honeycombing" pattern of cracking, resulting from poor consolidation in the form bottom.

The deck panels with cracks seemed to be located in areas over the skewed bents. In these deck panels the cracks were oriented diagonally from the main axis of the roadway, an example of which is presented in Figure 8. Additionally, the soffits on both edges of the deck had several occurrences of very obvious cracking, which are presented in Figure 9.

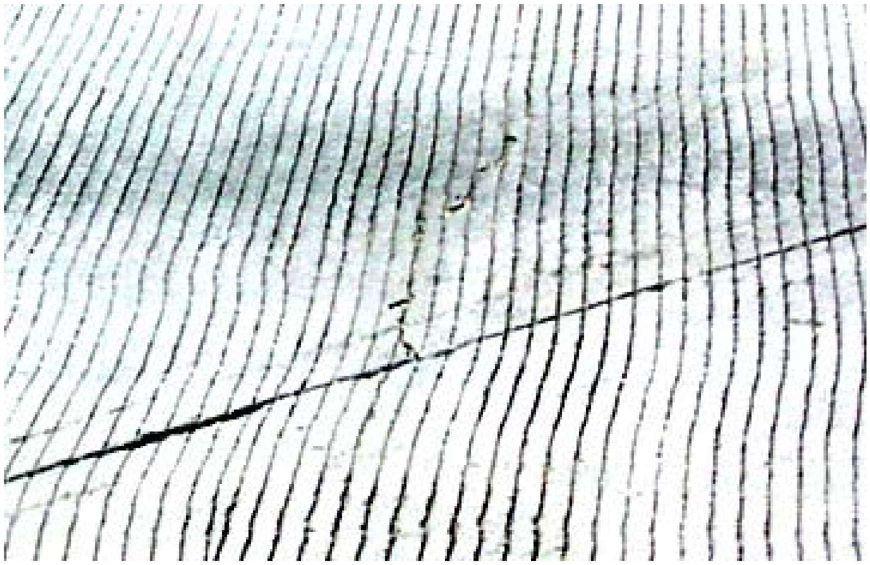

Figure 6. Large Transverse Cracking in the Louetta Bridge Deck (Contrast Increased to Highlight Crack)

San Angelo, September 24, 2002
US 87 & N. Concho River Bridge

At the time of inspection, the eastbound bridge was closed due to unrelated construction in the area. This facilitated the observation of that entire deck. However, due to the high volume of traffic passing over the westbound bridge, it was not possible to observe this deck during this trip. TxDOT area engineers did not want to close down traffic on the one bridge not in the construction traffic control plan, so another inspection trip will be necessary in the future. There is some cracking located in the eastbound bridge deck over the bents. There are both transverse and longitudinal cracks, with a few regions of bisecting cracks. With the exception of this one moderately cracked region, the majority of the deck was problem free. No significant cracking or other problems in the beams or precast panels were observed when viewing the underside of the bridge.

Figure 7. Another Large Crack in Louetta Bridge Deck
(Contrast Increased to Highlight Crack)

Chloride Content and Permeability Evaluation

Core samples were collected in the Lubbock US 82/62 & 82nd St. bridge and the two Amarillo bridges on LP 335. At each site, two cores were selected with cracks for use in determining the chloride content along the crack face at varying depths. Two additional uncracked specimens were collected to evaluate the permeability of each HPC deck.

A 3/8-in. drill bit was used to extract the sampling material from the cracked cores. For each core, the chloride content was determined at depths of 0-1/4 in. and 1/4-1/2 in. Samples were drilled from the top surface of each core and from the crack faces. A diagram is presented in Figure 10 showing the location of each sampling location for this test. Enough material was collected so that two separate 1.5-g samples could be tested at each location. Tests were conducted using a James Instruments CL-500 meter, according to ASTM C 1152, except for the smaller sample size specified by the manufacturer of this equipment.

The percent Cl values were determined using the CL-500 test calibration graphs and graphed in Figure 11. For clarification, the prefix for each group indicates the core from which the sample was retrieved, and the suffix lettering indicates the two samples collected at each core.

Figure 8. Large Crack in Flange and Web of Louetta U-Beam

Figure 9. Underside of Cracked Panel in Louetta Bridge

Figure 10. Cracked Soffit Section on Westbound Deck

As should be expected, the highest chloride concentrations are found at the surface readings. For several of the samples the chloride content is higher at the locations along the crack face than the readings 1/4-1/2 in. at the surface. This is important to note, as it strengthens the hypothesis that the cracks serve as a more important vehicle to transporting the chloride ions than the permeability of the concrete matrix.

Later, it was determined that chloride content readings should also be recorded at depths closer to the rebar at the cracked section face, and compared with the equivalent depth in an uncracked portion of the deck. In this second procedure, samples were collected 1/2 in. above the rebar depth both inside the cracked surface and the exterior circumference of the core. Furthermore, samples were collected 1/2 in. from the top surface inside the crack face as well as the exterior. A diagram showing the location of these tests is presented in Figure 13 and the results can be found in Figure 14.

It should be mentioned that the first sampling process with our limited number of specimens left the cores from the RM 1061 bridge too badly damaged to drill material with the required confidence of location and contamination to conduct the ASTM C 1152 chloride evaluation test procedure. The impact rotary drill disintegrated portions of these cores and made it impossible to say with certainty which locations were 1/2 in. above the rebar and 1/2 in. from the surface.

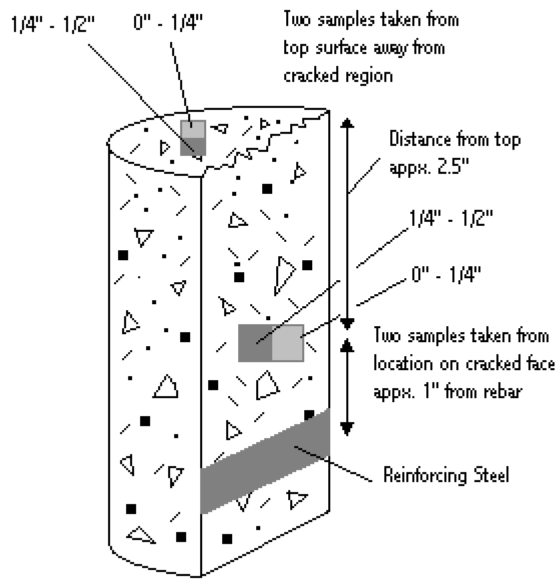

Figure 11. Drill Locations for Sampling Procedure 1

In order to evaluate the permeability of each HPC deck, the concrete cores were cut to provide 2-inch thick slices from the top of each core for testing. The circumferential surface of each slice was coated with rapid setting epoxy, that was allowed to cure and then placed into a desiccator for three hours. Then, each specimen was place in a plastic tray and filled with de-aerated water. The specimens were then soaked under vacuum pressure for an additional hour. After the pressure treatment, the samples soaked for 18 hours. Following the 18-hour period, silicone was applied around each end plate and fastened to the exposed surfaces of each core. One cell (-) was filled with 3% NaCl solution, and the other cell (+) was filled with 0.3-N NaOH solution. The lead wires were attached to banana posts, and automated scanning using a computer-integrated data logger was enabled for 6 hours, with readings taken every 30 minutes. This test was conducted according to AASHTO T 277-93 (ASTM C1202-91).

The results from the rapid-ion permeability test are presented in Table 1. Tests of two cylinders had to be stopped before the experiment was scheduled to be completed, because these specimens reached the 190-degree maximum temperature. These cylinders are indicated with an (*) in the results shown in Table 1. According to the T 277-93 test standard, a charge passed greater than 4000 columbs is categorized as being high, and a charge between 2000 and 4000 is categorized as being moderate.

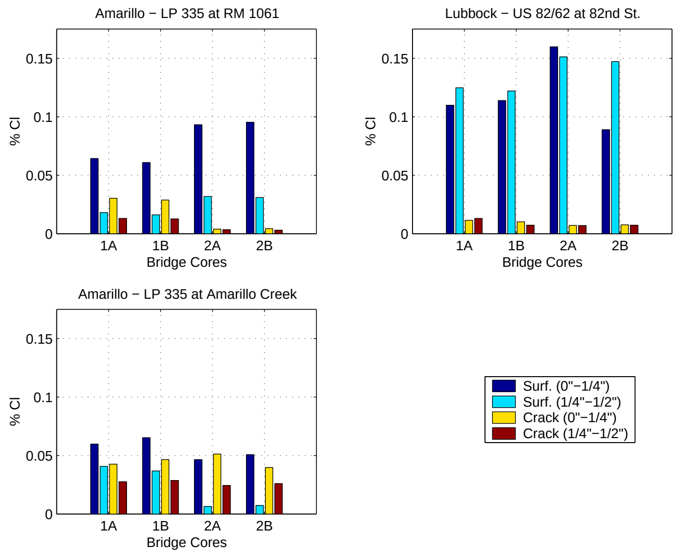

Figure 12. Chloride Content Evaluation Number 1

Monitoring Equipment

In addition to making visual observations on the condition of the HPC bridge decks and beams, one of the goals was to report on the status of the monitoring equipment being used at the San Angelo and Houston sites. The objective of this site visit was to access the data collection stations, examine the monitoring equipment for any problems, and reestablish a connection between the modem and the local computers in Austin.

The bridge in San Angelo has three data acquisition stations (DAS), indicated in the diagram in Figure 14. The DAS monitoring the westbound span had a connection problem between the data module and the solar panel source. After checking the solar panel source with a voltmeter, it appeared that no power was being transmitted to the module. The research team was unable to make a connection between the data module and the data logging software on the laptop computer in the field, so the module was removed and replaced for further examination in Austin.

Table 1. Results from Rapid-Ion Permeability Test

* Tests terminated prematurely due to excessive temperature

Time	Lubb1	Lubb2	Am 1061 1	Am1061 2	Am Creek 1	Am Creek 2
1	0.00311	0.00329	0.00206	0.002	0.00129	0.00092
2	0.00403	0.00449	0.00247	0.00244	0.00144	0.00104
3	0.00514	0.00527	0.00261	0.00287	0.00146	0.00114
4	0.00611	0.00592	0.00273	0.0032	0.00153	0.00125
5	0.00701	0.00633	0.00307	0.00362	0.00165	0.00139
6	0.00773	0.00666	0.00307	0.00362	0.00165	0.00139
7	0.00827	0.00703	0.00317	0.00374	0.0017	0.00142
8	*	*	0.00318	0.00387	0.00175	0.00147
9	*	*	0.0032	0.00399	0.00178	0.0015
10	*	*	0.00316	0.00404	0.0018	0.00156
11	*	*	0.00312	0.00415	0.00184	0.00159
12	*	*	0.00297	0.00462	0.0018	0.00162
13	*	*	0.00288	0.00473	0.0018	0.00165
Charge Passed in Columbs						
	6430	6090	6320	7800	3580	2900

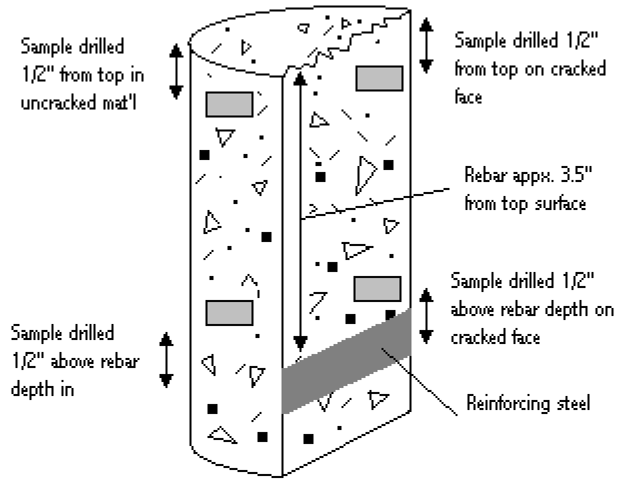

Figure 13. Drill Locations for Sampling Procedure 2

The data acquisition stations located on the eastbound bridge appeared to be functioning properly, in-so-far as there were audible indications of a periodic and regular timer sending data to the storage modules. However, there were similar difficulties in achieving a connection between the module and the laptop in the field. The full modules were replaced with fresh ones and transported to Austin for data retrieval.

A few of the PVC pipes used to encase the exposed wires were originally connected with duct tape. Exposure to the elements caused many of the fittings to separate, revealing the cables inside. The research team noted that in a future trip, more permanent means of sealing the PVC pipes will be considered.

In Houston, one of the noticeable problems with the DAS on the northbound bridge was the absence of an antenna. In the future, an antenna will need to be added for any modem connection to be established. Similarly, the storage modules were swapped out for data retrieval at the lab in Austin.

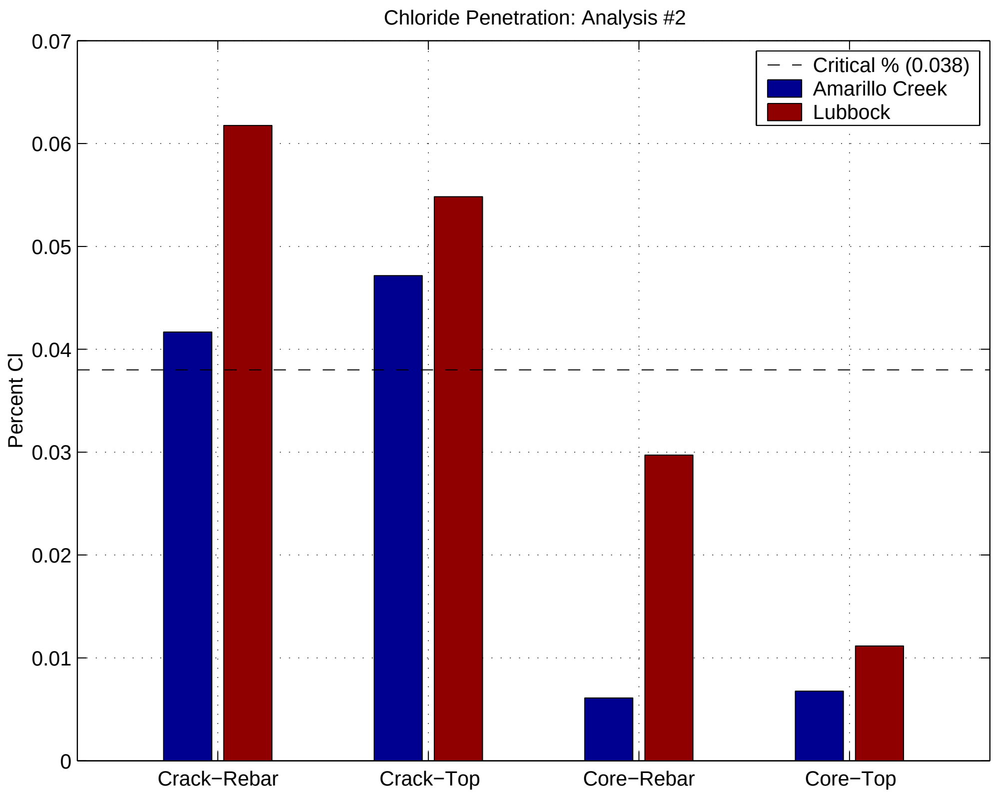

Figure 14: Chloride Content Evaluation Number 2

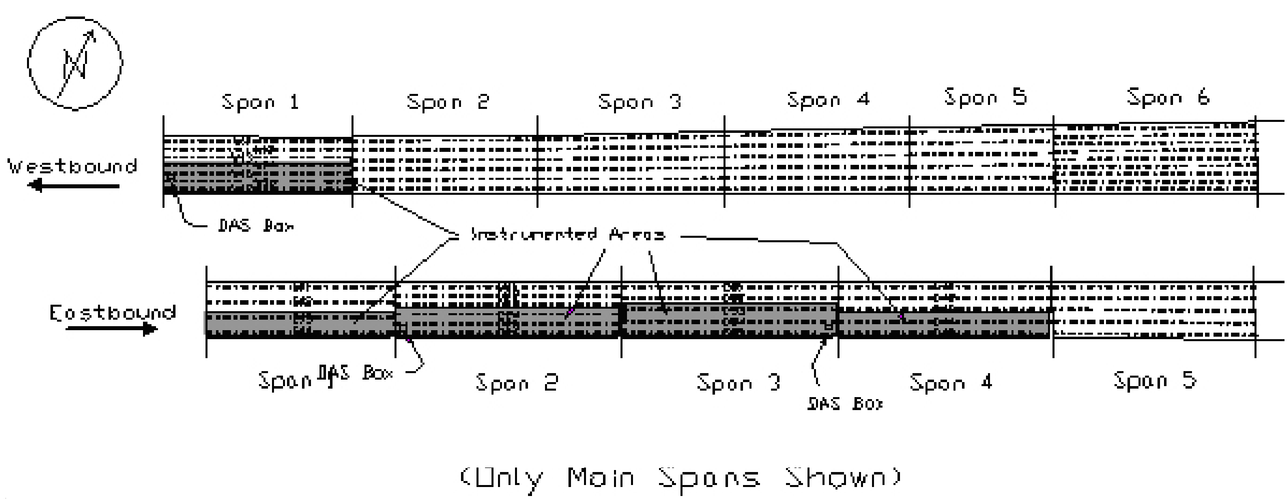

Figure 15: Diagram of Data Acquisition Stations on San Angelo N. Concho River Bridge

Recommendations and Conclusions

Having identified the additional HPC bridges in Lubbock and Amarillo, the next step in preparing the database will include contacting each district for any and all relevant construction and materials data. Researchers will repair remote download problems in Houston and San Angelo and continue to annually monitor the selected HPC decks for further symptoms. More cores will be collected from each bridge every four or five years to monitor significant changes in the permeability and chloride content near the steel reinforcement.

With the data modules in the research team's possession at the lab, the next major step in evaluating the condition of the monitoring stations and the ability to engage the remote access capability will be two-fold. First, verification must be made to see exactly what, if any, data is successfully being stored in each module. Second, confirm that the modems are still properly connected and powered, and attempt to connect with each station from remotely.