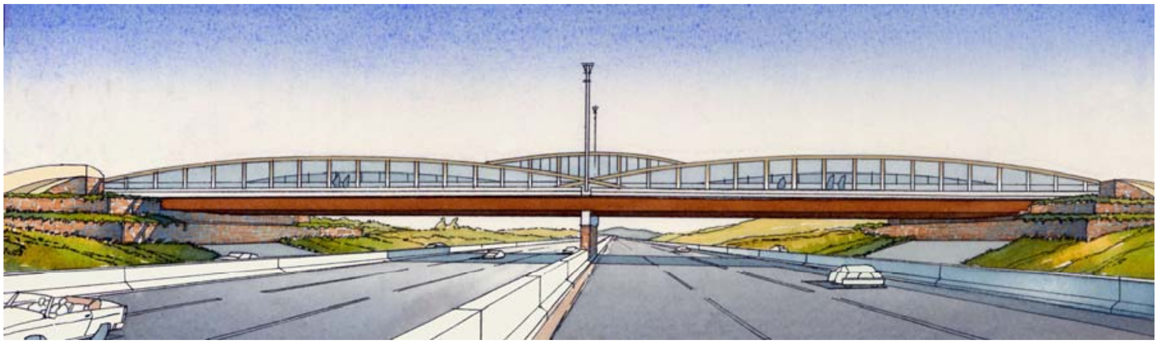
Laboratory Testing and Evaluation Report



24th Street Bridge over I80/I29, Council Bluffs, Iowa

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Prepared For

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1. Introduction

The Iowa Department of Transportation has plans to replace a bridge carrying 24th Street in Council Bluffs, IA over Interstate I80/29. Although not constructed, the design will include prestressed precast deck panels that are longitudinally post-tensioned on steel girders. This application of precast deck panels represents a step forward from a previous application of such a system in Iowa and strives to further improve the design concept.

Prior funding for the design, construction (which includes materials) and monitoring/evaluation of this project has been obtained through the Innovative Bridge Research and Construction (IBRC) Program sponsored by the FHWA. Additional funding has also been received through the Highways for Life program. The testing and evaluation proposed for this structure consists of two primary components: a laboratory component and a field component. The laboratory testing program was intended to help the Office answer specific design and construction questions such that they can be included in the final design. This report documents results from the laboratory phase of testing pertaining to this structure with the second phase is to be completed subsequently in the field. The successful implementation of this project has far reaching implications in the State of Iowa as it will allow for continuation of developmental work initiated through a previous IBRC project. This project directly addresses the IBRC goal of demonstrating (and documenting) the effectiveness of innovative construction techniques for the construction of new bridge structures.

2. Laboratory Testing Background

The current bridge design calls for shear studs to be welded to the top flange of the superstructure girders to provide composite action between the precast panels and the girders. These shear studs are to be placed in groups of six and those groupings will fall within a preformed deck panel “pocket”. There is concern whether or not there is sufficient room to weld the studs and to perform the required “bend” test. Thus, a mock-up was created to test the constructability of this detail. In addition, the stud pockets mentioned above are intended to be filled with either grout or concrete. There is concern whether this material will completely fill, with full consolidation, the area between the precast panels and the steel beam top flange (especially when the flange is 32 in. wide). This detail was fabricated and evaluated in the laboratory in conjunction with the bend test and the results of both presented subsequently.

In order to longitudinally post-tension the deck panels, ducts are installed in the deck panels which must then be connected in the field prior to stringing the post-tensioning strands. The current design requires that the ducts in adjacent precast panels be joined by a duct coupler and be sealed with some type of a waterproof covering. This coupler and covering serve the purpose of sealing the ducts from infiltration of grout when the transverse joints are cast. To test the integrity of this coupler and water-proof covering, a mock-up of the system was made and the performance verified.

Previous usage of similar precast panels has specified that transverse edges of the precast panels be “roughed” by sandblasting for shear resistance prior to grouting the transverse joints. Previously, a fabricator has proposed that the use of diamond plate formwork or chemical etching of the panel edge might provide sufficient “roughening” in this joint in place of the sandblasting. To evaluate these “roughening” alternatives, three shear specimens were cast per alternative to investigate the effectiveness of each. The alternatives considered were as follows: Control, Diamond Plate Form, Chemical Etching, Sandblasting. To establish a baseline for comparison, tests were conducted on specimens grouted without treating the concrete interface, the Control alternative. In this case, the forms create a smooth surface, which should provide the least amount of bonding area on the concrete interface, thus establishing the baseline. The second alternative consisted of using diamond plate steel as the form on the side of the concrete blocks used as a grout interface. The idea behind this alternative is that when the forms are removed there will be indentions left in the concrete from the diamond plate protrusions. These indentions will provide the shear interlock between the concrete and grout for load transfer. No other treatment is utilized on the concrete interface. The third alternative involved pre-treating the surface of the form (that creates the concrete interface to be grouted) with concrete retarder. This prevents the concrete on that interface from hydrating completely. Once the forms are removed, the surface is then power washed revealing a roughened concrete surface. The final alternative (called out in the plans) consisted of forming up the concrete block portion of the specimen as in the control, and then once the forms were removed, sandblasting the side which was to have the grout applied. Recommendations for surface treatment are made based on these test results.

3. Test Results

3.1 Shear Stud Pocket Investigation – Bend Test and Concrete Flowability

To investigate the ability to perform the necessary bend test in the specified stud pocket, a mock-up of two successive stud pockets was created out of plywood with a piece of plate steel simulating the beam top flange. This mock-up was also used to investigate the ability of concrete to flow through the stud pockets and into the haunch between the precast panels and the steel girder top flanges. Figure 3.1 and 3.2 illustrate the dimensions and make-up of the mock stud pockets and haunch, which were taken as the worst case scenarios from the plans (i.e., the haunch was taken as the minimum allowable haunch, 15/16in., combined with the maximum girder top flange width, 32 in). Six studs, 3 – 6in. studs and 3 – 7in. studs were welded to the plate steel as specified in the plans in the arrangement shown in Fig. 3.2.

Once the shear studs were installed and the pockets and haunch created, the contractor was allowed to investigate the setup and evaluate the ability to install the studs with their equipment. The contractor saw no difficulty in installing the shear studs in the pockets as they were called out on the plans, so testing continued with the bend test. No difficulty was found in bending the four studs in the corners of the stud pocket using just a straight pipe. However, bending of the center two studs was a bit more arduous. However, with a pipe pre-bent into an “S” shape at one end, these studs may also be easily bent in the stud pockets.

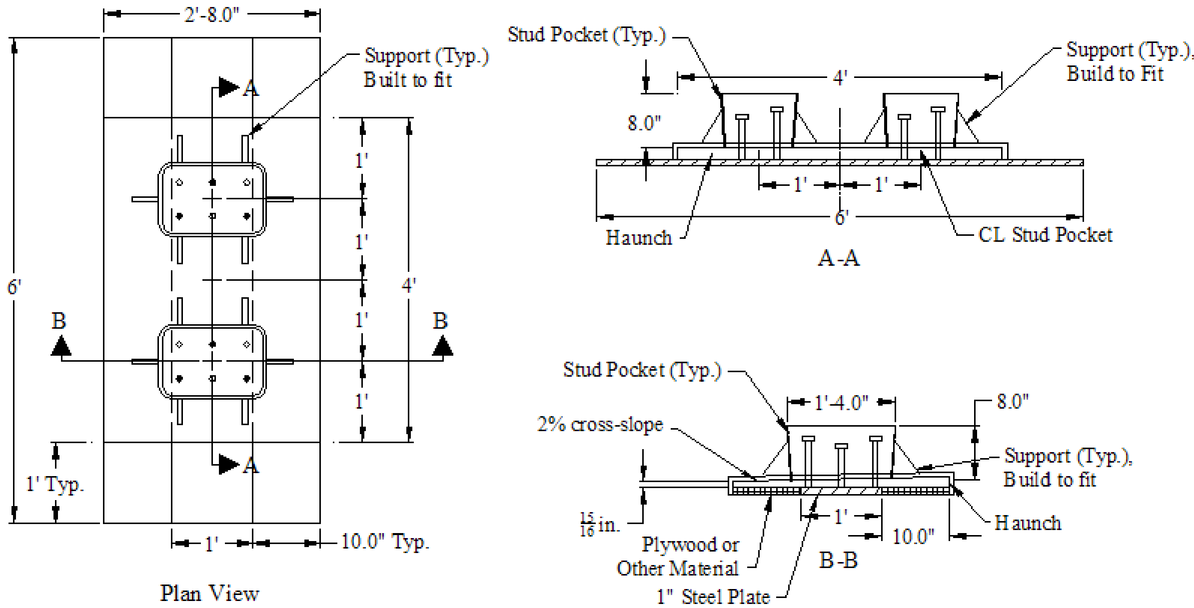


Figure 3.1. Shear Stud/Grout Flow Mock-Up Dimensions.

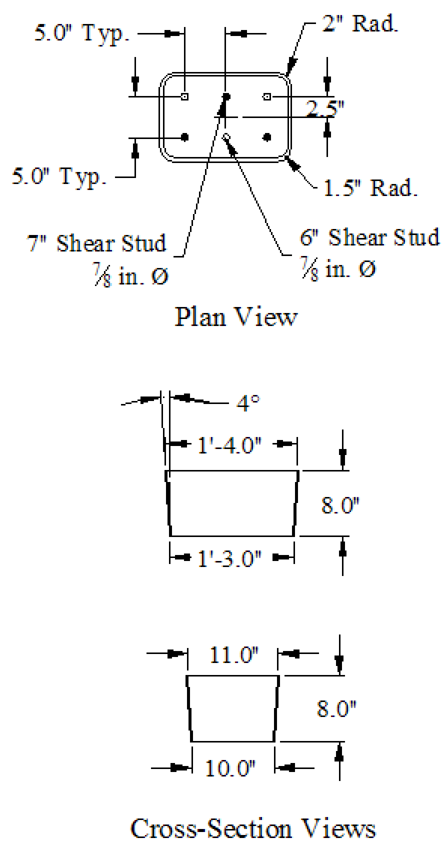


Figure 3.2. Stud Pocket Dimensions.

Once installation and the ability to test the studs were deemed sufficient, testing continued with the investigation of the flow of concrete through the stud pockets into the girder haunch. For testing, a 5 ft^3 batch of concrete was made consisting of 122.2 lbs of cement, 30.6 lbs of slag, 53.7 lbs of water, 254.2 lbs fine aggregate, 249 lbs coarse aggregate (3/8" washed limestone), and 170 mL of high range water reducer (ADVA 190, High Range Water Reducing Admixture). After mixing, a slump of 9.5in. was measured. This exceeded the allowable slump, so the drum was allowed to run for another 15-20 min. at which point an acceptable slump of 7.5in. was measured. The concrete was then placed into the two stud pockets in the mock-up and agitated with an electric vibrator. Figures 3.3, 3.4 and 3.5 show the mock-up filled with concrete before and after removal of the forms, respectively.

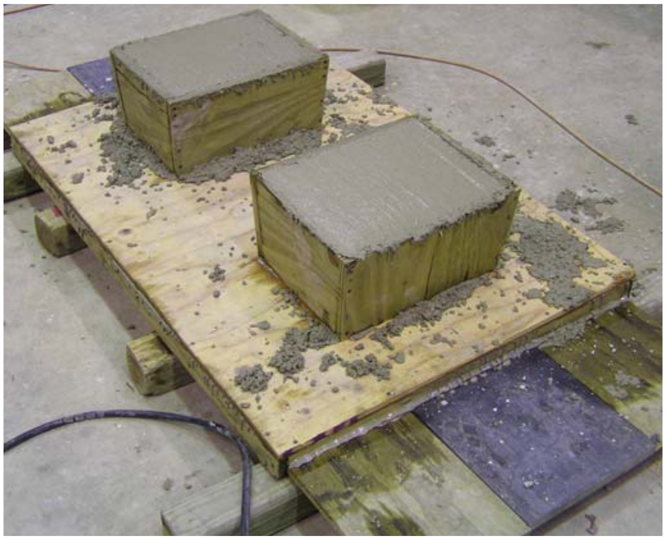


Figure 3.3. Stud pocket and haunch mock-up prior to form removal.

Figure 3.4. Stud pocket and haunch mock-up after form removal.

Figure 3.5. Haunch cross-section after form removal.

Figures 3 through 5 clearly indicate that concrete can sufficiently flow through the stud pockets and into the haunch area in the specified dimensions. Small voids did exist on the top of the haunch as a result of trapped air in the forms, however, the concrete still reached full depth in all areas.

3.2 Evaluation of Duct Splicing Performance

The 1in. x 3in. duct splice connection detail was evaluated to determine if grout or moisture would seep into the duct at the connection locations and thusly causing future problems when post tensioning the strands and grouting the ducts. To evaluate the performance of the duct splices, two mockup duct splices were constructed and placed in grout. One duct splice was constructed of Polyken waterproof duct tape. This splice was constructed with one duct tape strip placed along the longitudinal seam of the coupler, then three 12in. strips of tape were wrapped around both joint interfaces of the duct and coupler, as shown in Fig. 3.6a. The second splice mockup was constructed with 12in. long x 1/16in. thick x 1 1/2in. wide butyl rubber strips wrapped around the joint interfaces of the duct and coupler. The longitudinal joint of the coupler was sealed with a strip of Polyken duct tape, as shown in Fig. 3.6b.

a. Waterproof duct tape

b. Butyl rubber and duct tape

Figure 3.6. Mockup splice connections for 1”x3” P-T duct.

After constructing the connections, the ends of the ducts were sealed with butyl rubber and duct tape to assure that no grout would seep in from the ends. The ducts were then placed in a small beam form and a flowable grout mixture was placed around the duct. Approximately 3in. of grout was placed above the top of the duct. Scrap concrete pieces were used as ballast to prevent the duct from floating out of the grout mixture. The cured beam and ballast can be seen in Fig. 3.7.

Figure 3.7. Mockup duct embedded in grout beam.

After allowing the grout to cure for 5 hours, the beam was broken apart with a sledge hammer to examine the embedded ducts and couplers. The splice connections were cut apart and the interior of the ducts were visually examined for any traces of grout or moisture. Both connection types were found to have no grout or moisture in the interior of the duct. The interior of the ducts can be seen in Fig. 3.8. The waterproof duct tape and the butyl rubber methods of grout proofing the splices were both found to be acceptable.

a. Waterproof duct tape b. Butyl rubber and duct tape

Figure 3.8. Interior of duct splices after embedded in grout.

3.3 Evaluation of the Influence of Surface Treatment on Transverse Joint Shear Transfer

Below are the results from testing and evaluation of the following four surface "roughening" alternatives: Control (i.e. no roughening), Diamond Plate forms, Chemical Etching, and Sandblasting. For each alternative, three specimens were tested, each specimen consisting of a 6in. by 6in. by 6in. grout cube sandwiched between two concrete cubes of similar dimensions (see Fig. 3.9). Push-out tests were performed on each of the specimen as illustrated in Fig. 3.10. For the Diamond Plate and Sandblasting specimens, the concrete and grout strength were 5.6 ksi and 10ksi, respectively. For the Control and Chemical Etching specimens, the concrete and grout strengths were 4.0ksi and 10ksi, respectively.

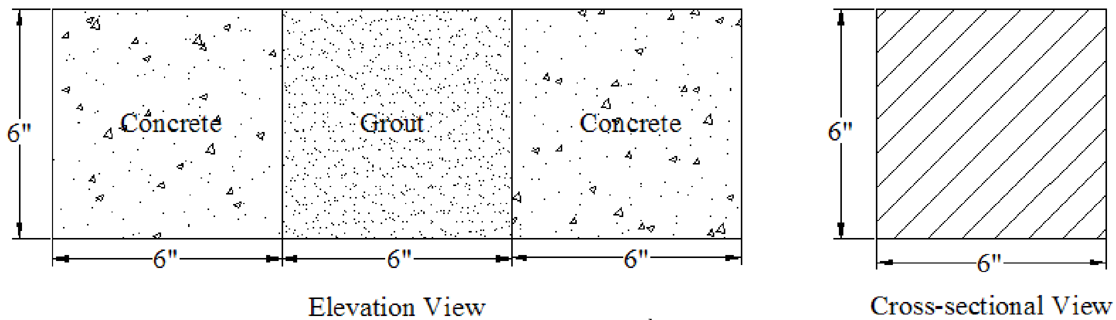


Figure 3.9. Approximate dimensions for 24th St. Bridge Shear Specimens.

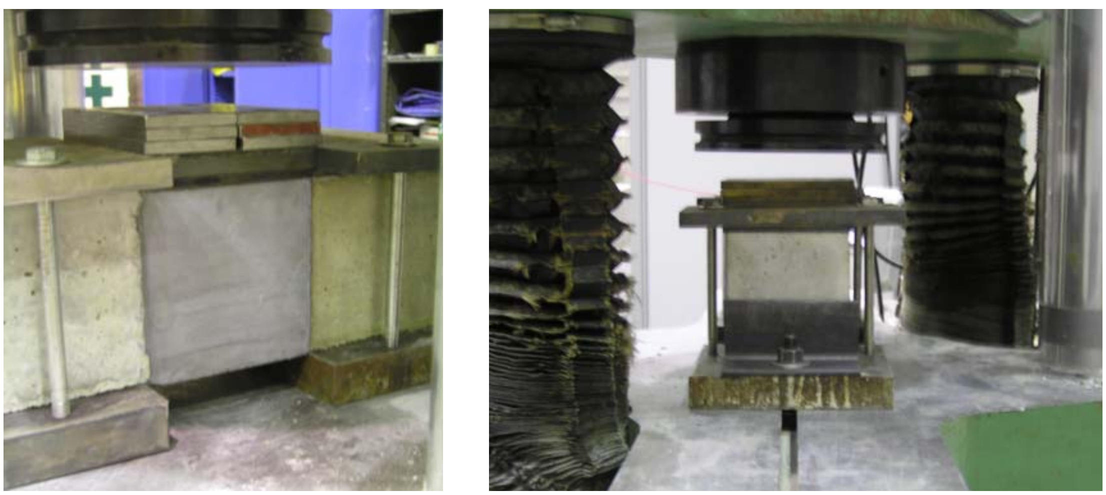


Figure 3.10. Test setup for shear specimens.

Loading of the specimen was deflection controlled and applied at the rate of 0.06 in./min. To ensure loading in pure shear, measures were taken in the setup and testing of the specimen to eliminate as much bending in the specimens as possible. Illustrated in Fig. 3.11 is a typical deflection vs load curve for a test specimen. As seen in Fig. 3.11, two drops in load are typically observed. The first drop typically corresponded to the initial cracking of the specimen at one of the bond interfaces. However, because the concrete blocks were restrained from moving outward, the specimen continued to hold load until the second bond interface cracked, resulting in the second load drop shown in Fig. 3.11.

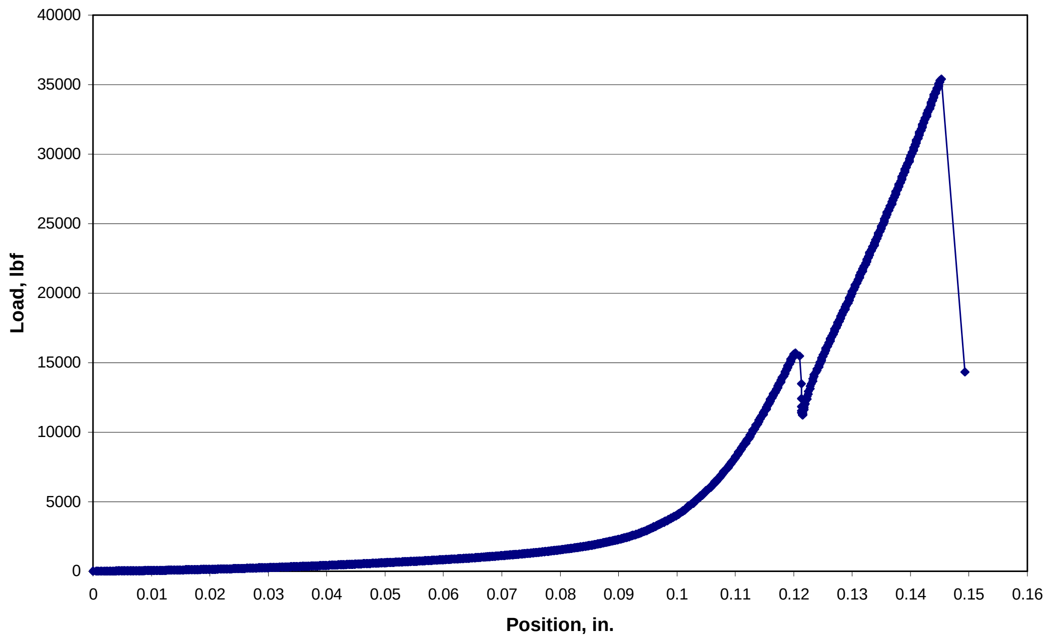


Figure 3.11. Deflection vs Load plot for Sandblasted Specimen #3.

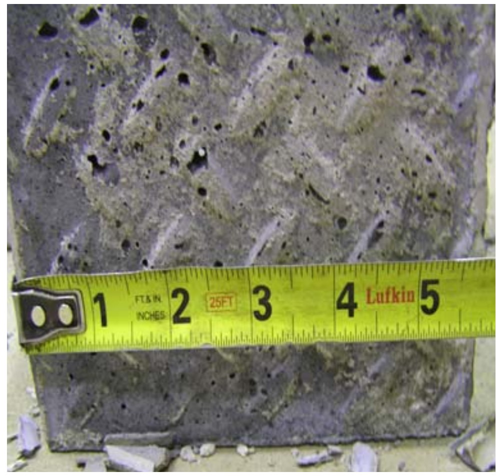
Listed in Table 3.1 are the test results from all twelve specimens. The load at '1st Crack' (i.e. initial drop in load) and 'Failure' (i.e. maximum applied load) are listed for each specimen as well as the shear bond in pounds per square inch (psi). Note that the shear bond is calculated by dividing the maximum load in pounds by the total surface area loaded in shear.

From Table 3.1, a progression in higher shear bond strength is evident as one moves downward in the table. Visual inspection of all four alternatives grout surfaces prior to grout application could have nearly anticipated these results. The Control specimens grout interfaces were relatively smooth with only a few voids from air pockets. These voids from air pockets are likely what provided most of the shear resistance for this alternative as little to no concrete was removed with the grout. This suggests little to no bond between the concrete and grout. The overall interface left by the Diamond Plate was smooth as well. However, the indentions left by the 'diamond' treads in the concrete provided numerous small shear keys for the grout to adhere to and increase the resistance to load compared to the Control. In terms of appearance, the Chemical Etching and Sandblasting appeared to have similar levels of "roughening"; however, they differed significantly in terms of performance for resistance to shear. Based on the results presented in Table 3.1, Sandblasting appears to be the most effective surface treatment for resistance to pure shear. See Fig. 3.12 for photos illustrating the shear interface of each alternative after testing was completed.

Table 3.1. Shear interface testing results for 24th St. Bridge.

	Load			Shear Bond, psi	
	1st Crack	Failure	Area, in^2	1st Crack	Failure
Control					
#1	3497	4867	69,000	50.7	70.5
#2	1267	2173	66,375	19.1	32.7
#3	1646	7281	64,010	25.7	113.7
			Average	31.8	72.3
Diamond Plate					
#1	4287	7647	66,000	65.0	115.9
#2	5850	2173	71,200	82.2	93.9
#3	5012	5991	71,200	70.4	84.1
			Average	72.5	98.0
Chemical Etching					
#1	12736	23649	67,375	189.0	351.0
#2	7989	13337	65,285	122.4	204.3
#3	3715	5991	66,220	56.1	117.3
			Average	122.5	98.0
Sandblasting					
#1	25681	47820	71,920	357.1	664.9
#2	-	-	71,920	-	-
#3	15477	35385	71,920	215.2	492.0
			Average	286.1	578.5

Control



Diamond Plate Form

Chemical Etching

Sandblasting

Figure 3.12. Shear interfaces after testing for each alternative.

4. Conclusion

Three primary laboratory tests were conducted to evaluate specific design and construction issues for the 24th Street Bridge in Council Bluffs, Ia. The three tests consisted of evaluating the shear stud pockets, (including the stud bend test and concrete flowability), evaluation of duct splicing performance, and the influence of surface treatment on transverse joint shear transfer. In general the following conclusions were made from the laboratory testing:

1. No difficulty in installing the shear studs in the precast panel pockets were foreseen by the contractor or encountered by the research team.
2. Conducting the bend test on the four studs in the corners of the precast panel pockets was easily done with a straight pipe. Bending the center two studs was more difficult than the corner studs; however, the studs can be easily bent if a pipe pre-bent in an “S” shape is used.

3. Concrete with the proposed slump can sufficiently flow through the stud pockets into the haunch areas. It is anticipated that air will remain entrapped in these areas. The impact of the voids is not known.
4. The waterproof duct tape and butyl rubber methods of grout proofing the duct splices were both found to be acceptable.
5. Sandblasting the surface of the concrete /grout joint was the most effective surface treatment for resistance to shear.