Plates With Anchors Post-Installed With Non-Shrink Grout

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Results of ten tension tests on post-installed plates with anchors utilizing non-shrink grout are presented. The plate anchors consisted of 1/2 in. (12.7 mm) diameter x 4 and 6 in. (102 and 152 mm) long headed studs and 1/2 in. (12.7 mm) diameter x 12 in. (305 mm) long deformed bar anchors. All plates were 8 x 8 in. (203 x 203 mm) with four anchors each. As a control, six plates with 4 and 6 in. (102 and 152 mm) headed studs were cast into the specimens and tested in tension. The results of the tests showed no distinction between failure tension loads or mode of failure for the cast-in and grouted-in plates with headed studs. The ratio of the tension loads for grouted-in plates with headed studs as compared to comparable cast-in plates ranged from 0.94 to 1.01. The grouted-in plates with deformed bar anchors all failed in tension by fracture of the reinforcing bar at a load corresponding to the specified minimum yield of 60 ksi (414 MPa) or higher. Due to the failure mode, no other tests on plates with deformed bar anchors were conducted.

Plates with headed studs or deformed bar anchors are commonly used in connections to precast concrete elements. The necessity to repair or replace these plates is also common. In this limited study, a method for installing plates is given as well as a method for evaluating the structural adequacy of plates with anchors post-installed with non-shrink grout.

With the use of welded connections in precast concrete construction, there are times when cast-in plates are missing or misaligned and need to be replaced with an equivalent plate. When plates anchored with headed studs are used for recessed, welded connections, it is necessary, and desirable, to replace the missing plate with a plate of similar capacity to the original cast-in unit. A solution to this problem is the installation of plates with headed studs and deformed bar anchors using non-shrink grout.

Design information for repairing this type of plate is not available. There are only limited reported test data on the capacity of stud groups, and none known to the author on stud

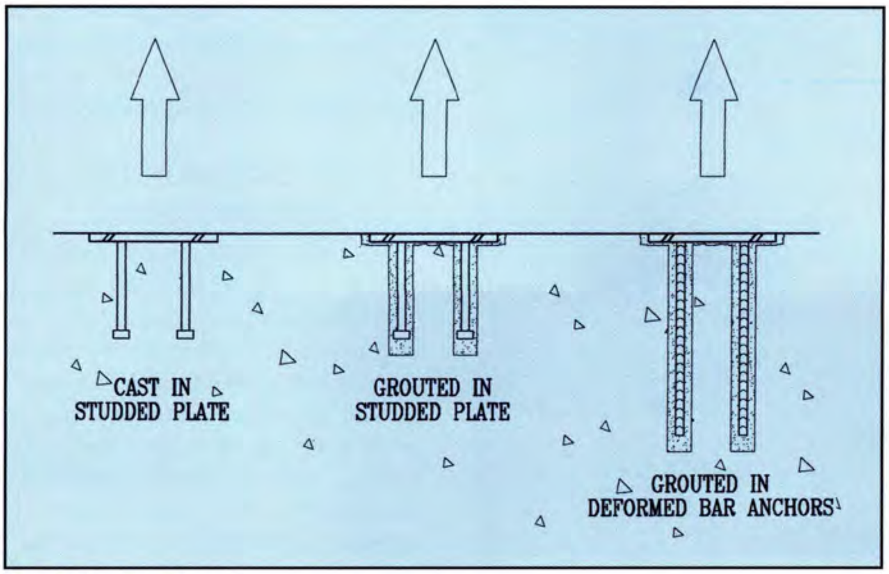


Fig. 1. Specimen types.

groups post-installed with non-shrink grout. Because this method of repair has been used in several applications, a limited test program was undertaken at Prestressed Casting Co. to verify the adequacy of the resulting connection.

The objective of the testing was to compare the tension capacity and the mode of failure of the post-installed plates with that of identical plates cast in the same specimen. This approach is limited to the evaluation and comparison of the post-installed plates vs. the cast-in plates, rather than concentration on the load capacity of each plate.

Only tension tests were made due to the limited scope of the program. The type of specimens tested are shown in Fig. 1.

METHOD OF INSTALLING PLATES

The method used for installing plates with non-shrink grout is as follows:

1. Chip away the concrete to a depth slightly greater than the thickness of the plate. Chip an area enclosed approximately 1/2 in. (12.7 mm) around all edges of the plate to be used. Mark the location of the studs and drill holes at each location slightly larger than the head of the stud (see Figs. 2 and 3). The sizes shown in Fig. 2 are typical for an 8 in. (203 mm) square plate with four 1/2 in. (12.7 mm) diameter x 6 in. (152 mm) headed studs.

2. Clean the chipped and drilled area with vacuum or forced air. Soak the area with water for 12 to 24 hours when possible. When pre-soaking is not practical, the area to be grouted should be thoroughly saturated prior to placing the grout. The saturation should be such that the concrete at the interface does not suck the water from the fluid grout.

3. Prior to placement of grout, remove all excess water from the prepared area. This can be done with forced air or vacuum.

4. Mix the grout according to the manufacturer's instructions for conditions to produce a liquid state. The mixing time and the amount of water is critical to a proper grout mix. The grout is then placed into the area where the plate is to be set. Place sufficient grout to cause the void to be slightly overfilled when the plate with anchors is positioned. The plate is then set in the grout filled void and tapped with a hammer to help consolidate the grout around the studs and under the plate (see Figs. 4a, 4b and 4c).

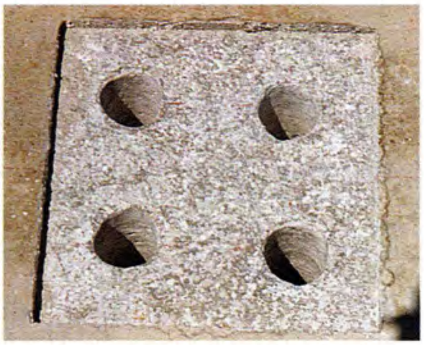


Fig. 3. Completed chipped and drilled concrete area for plate.

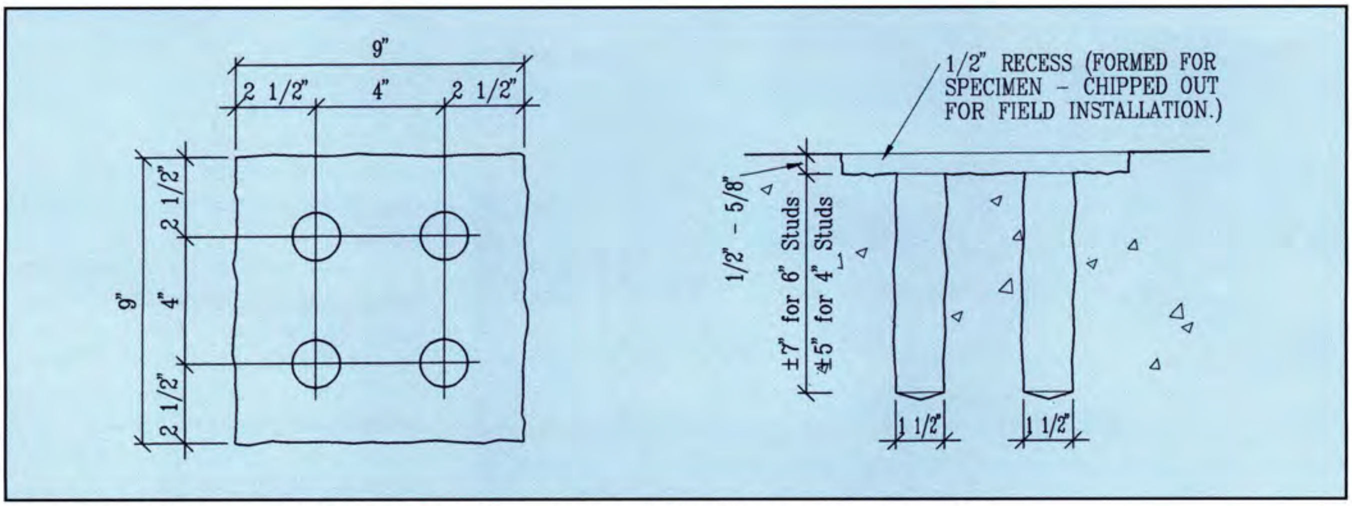


Fig. 2. Typical chipped and drilled concrete area for 8 x 8 in. (203 x 203 mm) plate with studs.

Fig. 4a. Filling void with fluid grout.

Fig. 4b. Placing plate in grout-filled void.

Fig. 4c. Tapping of plate to eliminate air voids.

5. Allow the grout to cure for 12 to 48 hours (depending on the curing temperature and curing conditions) before making the welded attachment.

FABRICATION OF TEST SPECIMENS

The test specimens consisted of three 24 x 24 in. (610 x 610 mm) x 14 ft (4.27 m) rectangular members, as shown in Fig. 5. Half of the plates were cast-in on one face of the member and the second half post-installed on the opposite face of the specimen. This process was intended to eliminate the concrete strength and the member geometry as parameters when comparing the results.

Specimens 1 and 2 were fabricated prior to any load tests. The spacing of the plates in the specimen was based on a failure cone at 30 to 45 degrees to the beam surface. The failure cones for concrete pull-out spread enough to cause two plates in each specimen face to be unusable.

The fabrication of the specimens was done by field personnel in order to be representative of actual applications.

The number of specimens was limited to three with a total of 13 tests of plates with headed studs and three with deformed bar anchors. The test plates all had $^1/_2$ in. (12.7 mm) diameter studs or deformed bar anchors. Details of the test specimens are given in Tables 1, 2 and 3.

Specimen 1 was made with all the cast-in plates in the top surface and the grouted-in plates in the bottom of the member. In the remaining specimens (Specimens 2 and 3), some cast-in and grouted-in plates were located on opposite faces, as shown in Table 3. For installation of the grouted-in plates on the bottom face of the specimens, the member was rotated 180 degrees and all grouting was done into a horizontal surface.

The concrete used for the specimens was a structural grade concrete normally used in plant production with a 28-day design strength of 5000 psi (34.5 MPa). The actual concrete strengths are given in Table 4.

The grouts used were commercial products which met ASTM C 1107-Type C Specifications. These Specifi-

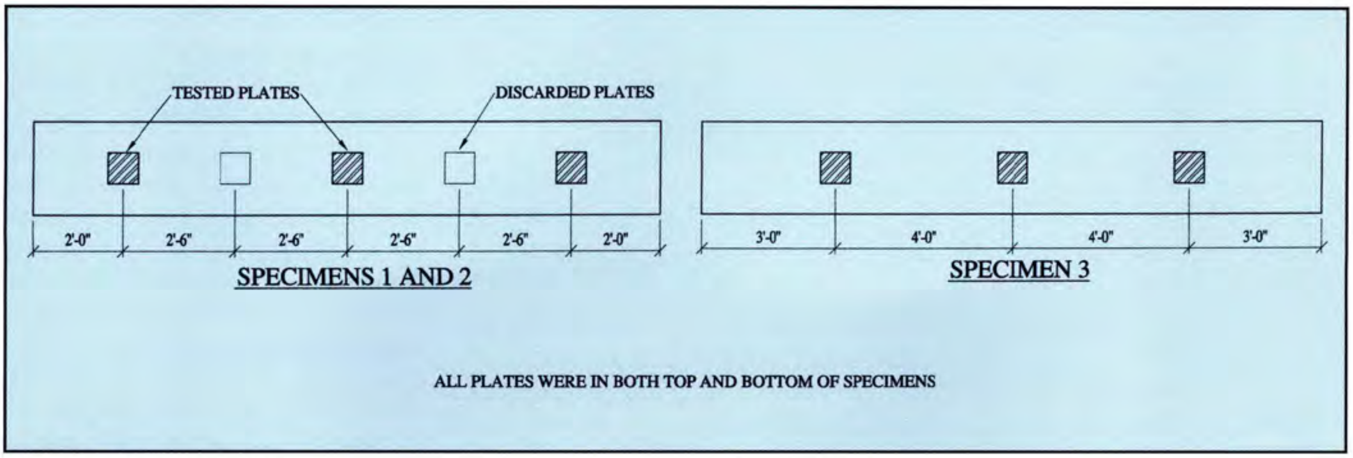


Fig. 5. Specimen geometry.

cations define the grout expansion by a vertical expansion test of ASTM C 1090 for grout with fluid consistency. The two different grout products used in the tests had the following expansion values listed by the manufacturer:

	3 days	28 days
Grout 1	0.05 percent	0.14 percent
Grout 2	0.09 percent	0.13 percent

In all cases, the values of grout expansion listed by the manufacturers continued to increase with time. Because bonding of the grout to the surface of the drilled hole was felt to be critical, the expansion characteristics of the grout were the primary consideration for the grout selection. The grout strength was not a primary concern so long as it remained greater than the strength of the surrounding concrete. The grout cube strengths are listed with the test results in Table 4.

The concrete for all specimens was cured for a minimum of 28 days prior to testing. The grout for the first four tests of grouted-in plates with headed studs (Specimens GI4S-1, GI4S-2, GI4S-3, GI6S-1) was at 28 days while the remainder (Specimens GI6S-2, GI6S-3, GI6S-4, GI12B-1, GI12B-2, GI12B-3) were at 19 days of age.

TEST PROGRAM

The tests were conducted in a precast plant environment. The loading head had a clear distance between supports of 27 in. (686 mm). The spacing of the support legs had little effect on the concrete failure cone. The test setup can be seen in Fig. 6. The attachment to the specimen was by a

Table 1. Number and description of tests.

Anchor type	Cast-in headed studs	Grout-in headed studs	Grout-in deformed bar anchors
1/2 in. diameter x 4 in. studs	3	3	
1/2 in. diameter x 6 in. studs	3	4	
1/2 in. diameter x 12 in. deformed bar anchor			3

Note: 1 in. = 25.4 mm.

Table 2. Specimen notation for testing.

Cast-in headed studs	Grouted-in headed studs	Grouted-in deformed bar anchors
CI4S-1	GI4S-1	GI12B-1
CI4S-2	GI4S-2	GI12B-2
CI4S-3	GI4S-3	GI12B-3
CI6S-1	GI6S-1	
CI6S-2	GI6S-2	
CI6S-3	GI6S-3	
	GI6S-4	

CI – cast-in
GI – grouted-in
4S – 4 in. (102 mm) long studs
6S – 6 in. (152 mm) long studs
12B – 12 in. (305 mm) long deformed bar anchors

Table 3. Specimen and plate installation.

Specimen/ Surface	Cast-in studs		Grouted-in studs		Grouted-in bars	
	Top	Bottom	Top	Bottom	Top	Bottom
1	CI4S-1 CI4S-2 CI4S-3			GI4S-1 GI4S-2 GI4S-3		
2	CI6S-1 CI6S-2	CI6S-3		GI6S-1		
3			GI6S-2 GI6S-3 GI6S-4			GI12B-1 GI12B-2 Gi12B-3

Table 4. Summary of test results.

Specimen	f'_c concrete (psi)	f'_c* grout (psi)	N_{test} (kips)	N_{ave} (kips)	$\frac{N_{test}}{N_{ave}}$	Mode of failure
CI4S-1	6120	—	29.0	31.13		C.C.
CI4S-2	6120	—	32.2	31.13		C.C.
CI4S-3	6120	—	32.2	31.13		C.C.
GI4S-1	6120	7280	30.2		0.97	C.C.
GI4S-2	6120	7280	30.2		0.97	C.C.
GI4S-3	6120	7280	30.2		0.97	C.C.
CI6S-1	5540	—	43.6	44.33		C.C.
CI6S-2	5540	—	41.6	44.33		C.C.
CI6S-3	5540	—	47.8	44.33		C.C.
GI6S-1	5540	9590	43.6		0.98	C.C.
GI6S-2	5520	9590	41.6		0.94	M.C.C.
GI6S-3	5520	9590	44.6		1.01	M.C.C.
GI6S-4	5520	9590	44.6		1.01	M.C.C.
GI12B-1	5520	9590	57.0			S.Y.
GI12B-2	5520	9590	51.0			S.Y.
GI12B-3	5520	9590	52.0			S.Y.

Note: 1 psi = 6.895 kPa; 1 kip = 4.448 kN.
* 2 x 2 in. (51 x 51 mm) cube strength
C.C. – concrete cone pull-out
M.C.C. – modified concrete cone pull-out
S.Y. – steel yield-steel fracture
N_{ave} – average value for pull-out capacity of cast-in plate

Fig. 6. Test setup.

second X-shaped plate welded to the cast/grouted-in test plate with a pin connection to a rod that passed through a center hole ram.

A groove in the concrete approximately 1/16 in. (1.6 mm) deep was made around the edge of the plate to allow for expansion during the welding process. The welded-on X-shaped plate was oriented on the cast/grouted-in plate to load directly into the studs, eliminating plate bending. The pin connection to the loading rod helped to minimize the loading eccentricity.

The load was applied with a 100 kip (445 kN) hydraulic ram and load readings were taken from a pressure gauge. The ram-pressure gauge combination was calibrated in a testing machine with the ram generating the load and the testing machine acting as a load cell. The results were very consistent with a linear relationship between the loads and the gauge readings.

The loading rate was consistent for all tests:

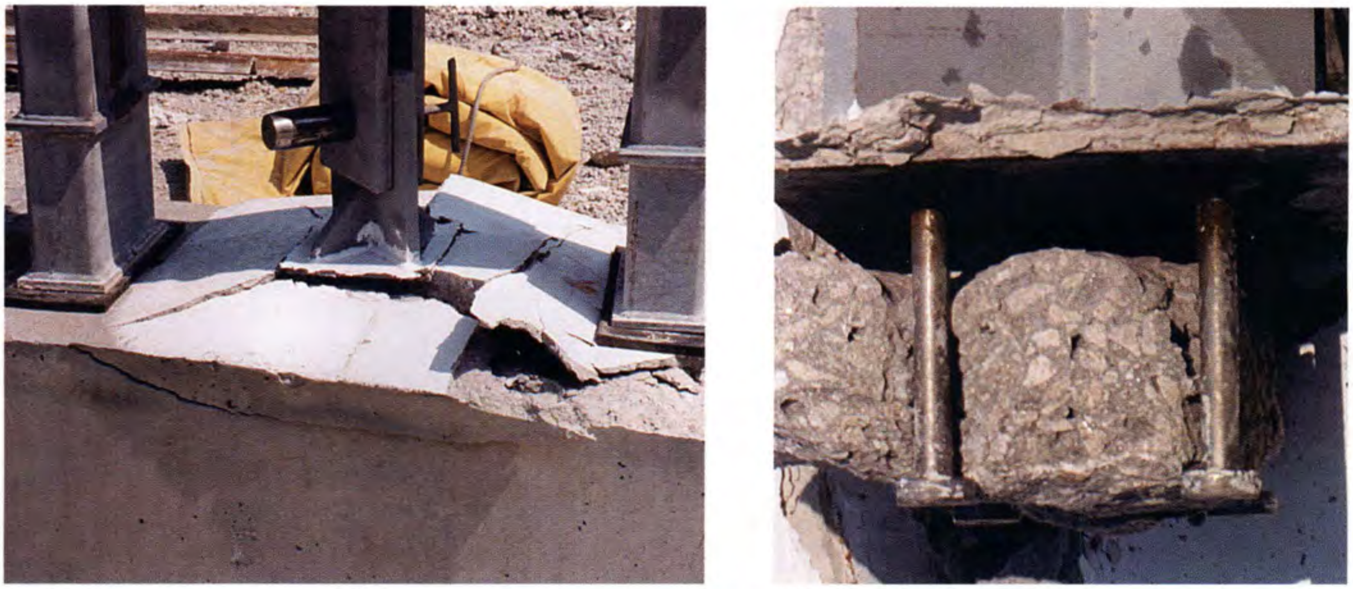
4.0 kips (18 kN) per minute to initial cracking

2.0 kips (9 kN) per minute from initial cracking to failure

The load was applied in increments corresponding to either 4.0 or 2.0 kips (18 or 9 kN) and maintained for the one-minute period.

After all welding on the plate was completed, and the groove around the plate was filled with patching mortar, the area was coated with white lacquer, allowing initial cracking in the concrete and mortar to become visible. The initial cracking was a hairline crack in the mortar around the perimeter of the plate. There was no recognizable change in the load at initial cracking. However, at that point, the loading rate was reduced to allow better determination of the failure load. No deformation measurements were made during the tests.

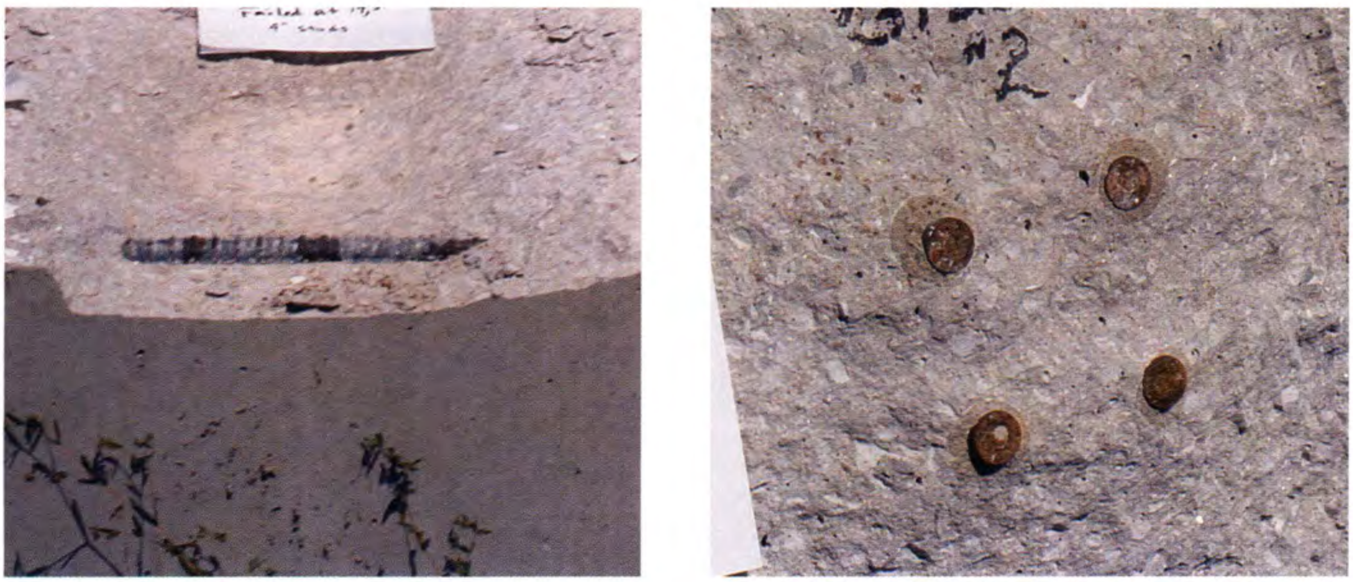
All specimens were loaded to failure. The failure mode for all plates with studs was concrete pull-out, which was sudden and easy to determine from the load. At the failure load, the cracking of the concrete was visible. The cracking shown in Figs. 7, 8, 10 and 11 shows the failure plane development. The plate was pulled until



(a) Cracking pattern at concrete failure.

(b) Failure plane in concrete.

Fig. 7. Failure of cast-in plates with four $^1/_2$ in. (12.7 mm) diameter x 4 in. (102 mm) studs.



(a) Area after concrete failure cone was removed.

(b) Bottom surface of failure cone at the studs.

Fig. 8. Failure cone of grouted-in plate with four $^1/_2$ in. (12.7 mm) diameter x 4 in. (102 mm) studs.

the failure plane of the concrete was exposed, as shown in these figures.

TEST RESULTS

The test results are summarized in Table 4. Without the benefit of deflection instrumentation, only the magnitude of loads was measured. Failure tension loads from the grouted-in plates were compared with the average of the tension failure loads for comparable cast-in plates.

The mode of failure of all the plates with headed studs (see Figs. 7, 8, 10 and 11) was typically a concrete failure cone. It is interesting to note that

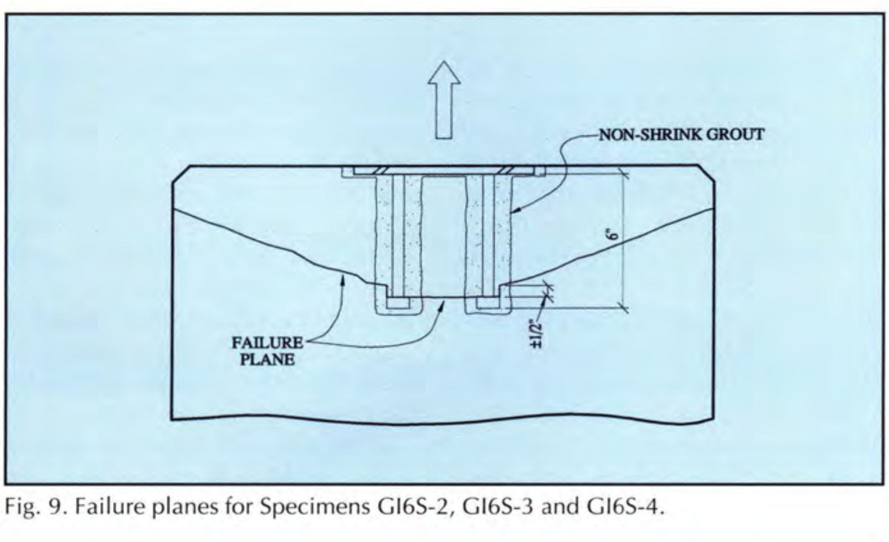


Fig. 9. Failure planes for Specimens GI6S-2, GI6S-3 and GI6S-4.

(a) Cracking pattern at concrete failure.

(b) Failure plane in concrete.

Fig. 10. Failure of first specimen with grouted-in plate with four $^1/_2$ in. (12.7 mm) diameter x 6 in. (152 mm) studs.


(a) Cracking pattern at concrete failure.

(b) Modified failure plane in concrete.

Fig. 11. Typical failure of grouted-in Specimens GI6S-2, GI6S-3 and GI6S-4 plate with four $^1/_2$ in. (12.7 mm) diameter x 6 in. (152 mm) studs.

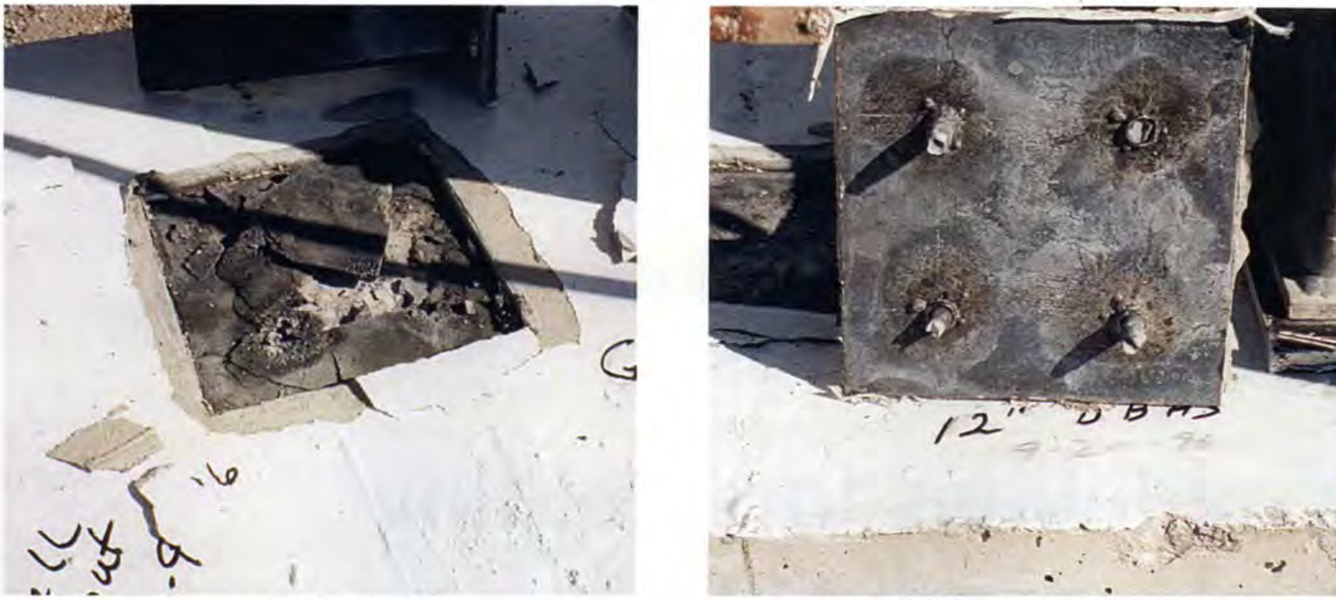
none of the failure planes were at angles as sharp as any of the present theories. In fact, for a headed stud group with a 10 in. (254 mm) edge distance and 4 in. (102 mm) embedment length, the failure plane still progressed through the sides of the specimen approximately 2 in. (51 mm) down from the top surface. In addition, the longitudinal progression of the cone was limited by the leg of the loading apparatus, which had 27 in. (686 mm) between edges of supports, or the end of the specimen for the end plate.

Two observations can be made regarding the grouted-in plates with headed studs which relate to the mode of failure:

1. For tests with Specimens GI4S-1, GI4S-2, GI4S-3, the failure cone started from the top of the head of the studs in an identical manner to that of the cast-in plates. In Figs. 7 and 8, it can be seen that the grout-concrete areas are without discontinuity while the grout areas are quite visible.

2. For tests with Specimens GI6S-2, GI6S-3, GI6S-4, the failure cones were similar to the cast-in plates except that the concrete cone did not start at the head of the stud. The cone started approximately $^1/_2$ in. (12.7 mm) above the head on the exterior of the stud group and at the top of the head between the studs. This failure plane is illustrated in Fig. 9 and shown in Fig. 10.

The tests of the grouted-in plates with deformed bar anchors, Tests GI12B-1, GI12B-2, GI12B-3, each resulted in loading of all bars to a level above the specified minimum yield of the bars at 60 ksi (414 MPa). At that point, one or two bars fractured at or near the weld of the bar to the plate.



(a) Concrete in the area of the failed plate. (b) Plate with failed deformed bar anchors.

Fig. 12. Failure of grouted-in plate with four 1/2 in. (12.7 mm) diameter x 12 in. (305 mm) deformed bar anchors.

There was a minimum of plate movement prior to the initial bar fracture, which would indicate a reasonable distribution of load between the bars.

The loading was continued until all the bars were fractured so the mode of failure could be examined. A failed plate with deformed bar anchors is shown in Fig. 12. Due to the type of failure (steel controlled), no additional tests with deformed bar anchors were scheduled.

CONCLUSIONS

The objective of the test program was to evaluate the tension load capacity of plates with headed studs and deformed bar anchors, post-installed with non-shrink grout, as compared to that of comparable plates cast-in concrete.

Based on the results of the investigation, the following observations can be made:

1. Plates with headed studs and deformed bar anchors can be post-installed with non-shrink grout without a reduction in tension capacity. With proper installation, there appears to be no recognizable difference in the performance of the post-installed and the cast-in plates.

2. The modes of failure were identical for all the plates with headed stud anchors. It is of interest to note that the failure modes for all these tests were concrete tension failures. However, with a sufficient increase in embedment length or decrease in stud diameter, a steel failure should occur. Evaluation of this latter mode was outside the scope of this study.

3. The mode of failure for the reinforcing bar anchors was fracture of the reinforcing steel. With a large enough decrease in embedment length, a concrete failure should occur. Evaluation of embedment length variation was also outside the scope of this study.

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