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STATIC FIELD TESTS OF KWIK-BOLT AND PHILLIPS STUD-TYPE CONCRETE ANCHORS

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ABSTRACT: Field tests were performed on Kwik-Bolt and Phillips stud-type concrete anchors to determine and compare the static capacities of the two anchors. Capacities of the two anchors were shown to be approximately equal. Capacities can be significantly increased by setting anchors deeper than manufacturer's suggested embedment. No tests were conducted involving impact testing.

KEY WORDS: anchor bolt, anchors, anchorages, expansion bolts, strength, studs, strength of materials.

STATIC FIELD TESTS OF KWIK-BOLT AND PHILLIPS STUD-TYPE CONCRETE ANCHORS

This test program was requested by the Committee for the Investigation of New Materials at its March 28, 1967 meeting. The purpose of this program was to determine the static capacities of Kwik-Bolt anchors and compare them with similar anchors produced by the Phillips Drill Co. The Committee reviewed this report on May 31, 1967 and approved the use of Kwik-Bolt and Phillips stud-type anchors of the sizes tested, subject to the load and embedment restrictions listed in the Recommendations section of this report. These recommendations require design study and analysis for particular applications, as has been the practice in the past when expansion anchors were specified. Departmental testing has been confined to static conditions, and prediction of pull-out strength under impact loading is not currently possible.

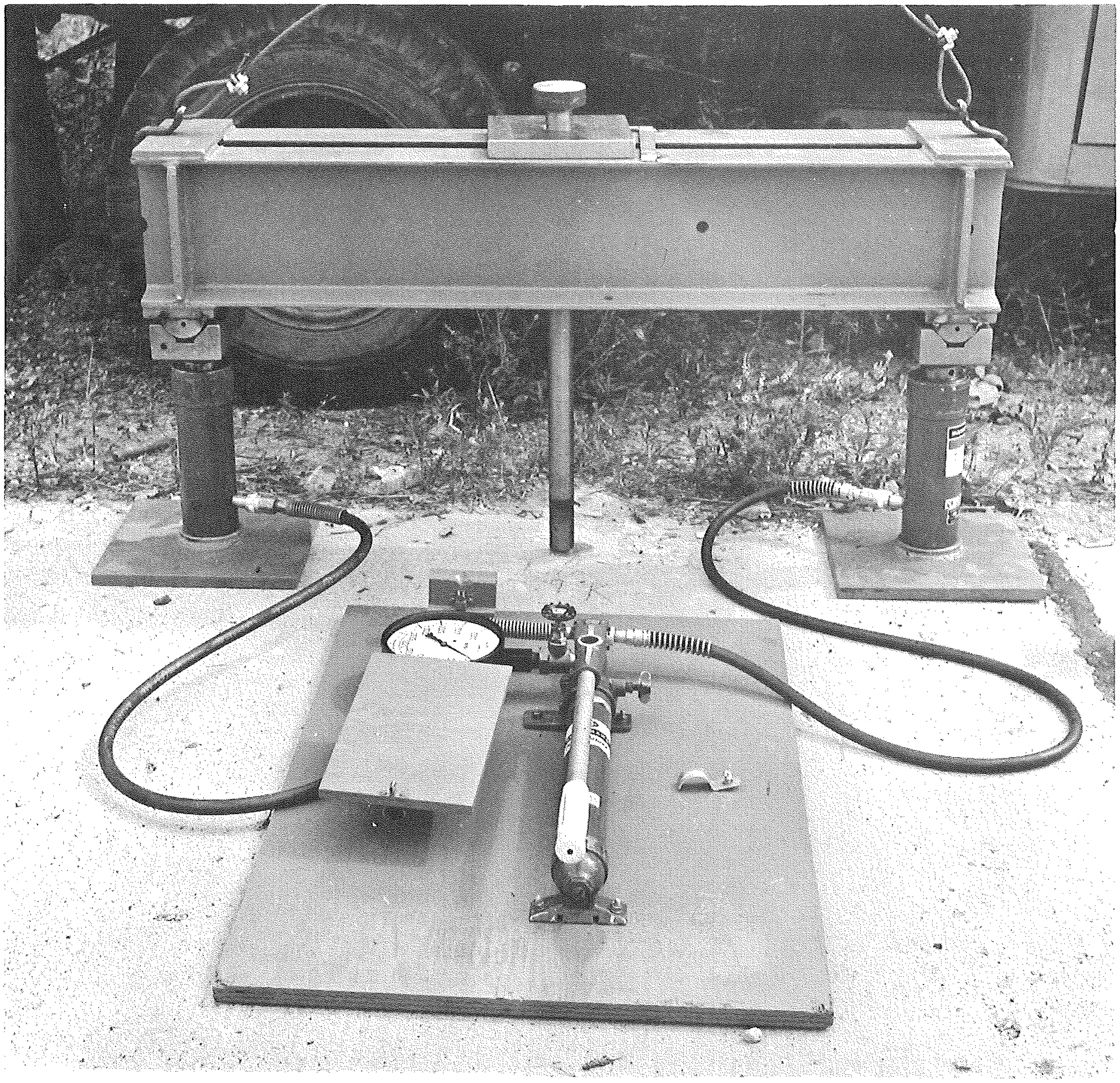
The 49 anchors used in the test were set in a 9-in. reinforced pavement slab at an abandoned weigh station near Fowlerville. Five cores were cut from the slab and tested in the laboratory, indicating compressive strengths of 4,300 to 5,600 psi, and averaging 5,200 psi.

Equipment

An electric roto-hammer was used to drill the test holes, with drill diameter equal to the bolt diameter. A fixture was used to hold the drill perpendicular to the pavement, and the holes were blown clear with air. Hole size was checked with a plug gage to be sure that manufacturer's suggested tolerance was maintained. Anchors were installed and loaded to failure, using the laboratory's 80,000-lb capacity load frame (Fig. 1).

Discussion of Test Results

The data accumulated by testing 37 Kwik-Bolt and 12 Phillips anchors are given in Table 1. The Phillips Anchors were of 1/2-in. diam only and were tested for comparison with Kwik-Bolt anchors of similar size and embedment. The smallest values of embedment and edge distance for each size anchor were equal to the Kwik-Bolt manufacturer's minimum specifications. Larger edge distances and embedments were tried in order to determine their effect on anchor capacity. Type of failure for each case is indicated in the table, and typical modes are shown in Figures 2, 3, and 4.



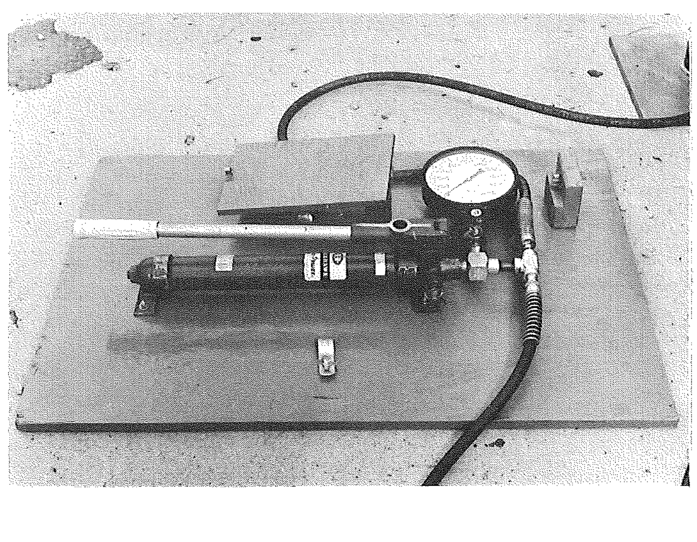
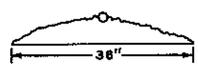
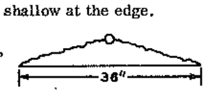


Figure 1. Reaction frame and hydraulic system.

TABLE 1
SUMMARY OF TEST RESULTS

Test Number	Anchor Size and Type, in.	Distance From Edge, in.	Hole Depth, in.	Ultimate Load, kips	Remarks
1	1/2 by 5-1/2 Kwik-Bolt	3	2-1/4	9.5	Spalled to edge, spall 4-1/2 by 20 in., 2-1/4-in. deep at the bolt, 3-1/2-in. deep at the edge.
2	1/2 by 5-1/2 Kwik-Bolt	3	2-1/4	6.5	Cracked an area of concrete approximately 5-in. diam, bolt pulled out, sleeves remained in hole.
3	1/2 by 5-1/2 Kwik-Bolt	3	2-1/4	10.0	Surface spall 4 by 5 in., 2-1/4-in. deep at the bolt.
4	1/2 by 5-1/2 Kwik-Bolt	Far	2-1/4	8.5	Anchor pulled out, sleeves remained in hole, no spalling.
5	1/2 by 5-1/2 Kwik-Bolt	Far	2-1/4	9.5	Anchor pulled out, sleeves remained in hole, no spalling.
6	1/2 by 5-1/2 Kwik-Bolt	Far	2-1/4	8.5	Anchor pulled out, sleeves remained in hole, no spalling.
7	1/2 by 5-1/4 Phillips	Far	2-1/4	10.0	Anchor pulled out 1/4 in., surface spall 9- by 10- by 2-in. deep at the bolt.
8	1/2 by 5-1/4 Phillips	Far	2-1/4	9.5	Anchor pulled out 1 in., surface spall 4- by 7- by 1-in. deep at the bolt.
9	1/2 by 5-1/4 Phillips	Far	2-1/4	9.5	Anchor pulled out 3/4 in., surface spall 4-1/2- by 6- by 1-1/2-in. deep at the bolt.
10	1/2 by 5-1/2 Kwik-Bolt	Far	3-1/4	10.5	Anchor pulled out, sleeves remained in hole, no spalling.
11	1/2 by 5-1/2 Kwik-Bolt	Far	3-1/4	11.5	Anchor pulled out, sleeves remained in hole, no spalling.
12	1/2 by 5-1/2 Kwik-Bolt	Far	3-1/4	11.5	Anchor pulled out, sleeves remained in hole, no spalling.
13	1/2 by 5-1/4 Phillips	Far	3-1/4	11.5	Anchor pulled out 1 in., surface spall 9- by 9- by 1-1/2-in. deep at the bolt.
14	1/2 by 5-1/4 Phillips	Far	3-1/4	11.0	Anchor pulled out 3/4 in., surface spall 9- by 15- by 2-in. deep at the bolt.
15	1/2 by 5-1/4 Phillips	Far	3-1/4	12.5	Anchor pulled out 3/4 in., surface spall 7- by 11- by 2-in. deep at the bolt.
16	1/2 by 5-1/2 Kwik-Bolt	4-1/4	4-1/4	14.0	Anchor pulled out approximately 2 in. then it spalled to edge, spall 8-1/2- by 13- by 2-in. deep at bolt.
17	1/2 by 5-1/2 Kwik-Bolt	4-1/4	4-1/4	14.0	Anchor pulled out, sleeves remained in hole, no spalling.
18	1/2 by 5-1/2 Kwik-Bolt	4-1/4	4-1/4	11.5	Anchor pulled out, sleeves remained in hole, no spalling.
19	1/2 by 5-1/4 Phillips	4-1/4	4-1/4	11.5	Anchor pulled out, no spalling.
20*	1/2 by 5-1/4 Phillips	4-1/4	4-1/4	5.0	Anchor pulled out, no spalling. Not sufficiently expanded.
21	1/2 by 5-1/4 Phillips	4-1/4	4-1/4	11.5	Anchor pulled out approximately 2-1/2 in., surface spall 8-1/2-in. diam approximately 1-1/2-in. deep at bolt.
22	1/2 by 5-1/2 Kwik-Bolt	Far	4-1/4	12.5	Anchor pulled out, sleeves remained in hole, no spalling.
23	1/2 by 5-1/2 Kwik-Bolt	Far	4-1/4	14.0	Anchor pulled out, sleeves remained in hole, no spalling.
24	1/2 by 5-1/2 Kwik-Bolt	Far	4-1/4	14.0	Anchor pulled out, sleeves remained in hole, no spalling.
25	1/2 by 5-1/4 Phillips	Far	4-1/4	10.0	Anchor pulled out 2 in., surface spall 6- by 9- by 1-1/2-in. deep at the bolt.

TABLE 1 (Cont.)
SUMMARY OF TEST RESULTS

Test Number	Anchor Size and Type, in.	Distance From Edge, in.	Hole Depth, in.	Ultimate Load, kips	Remarks
26	1/2 by 5-1/4 Phillips	Far	4-1/4	11.5	Anchor pulled out 2 in., surface spall 17- by 20- by 2-in. deep at the bolt.
27*	1/2 by 5-1/4 Phillips	Far	4-1/4	1.5	Stone in side of hole caused deformation of bolt, could not be properly set.
28	3/4 by 4-1/4 Kwik-Bolt	4-1/2	3-1/4	6.5	Anchor pulled out approximately 2 in., surface spall 7 by 8 in., approximately 1-in. deep at bolt.
29	3/4 by 4-1/4 Kwik-Bolt	4-1/2	3-1/4	7.5	Anchor pulled out approximately 1-1/2 in., surface spall 9 by 12 in., approximately 1-1/2-in. deep at bolt.
30	3/4 by 4-1/4 Kwik-Bolt	4-1/2	3-1/4	9.5	Spalled to edge after anchor pulled out 1 in., spall 8- by 20- by 2-in. deep at the edge.
31	3/4 by 4-1/4 Kwik-Bolt	Far	3-1/4	9.5	Anchor pulled out 3/4 in., surface spall 9- by 12- by 2-1/2-in. deep at the bolt.
32	3/4 by 4-1/4 Kwik-Bolt	Far	3-1/4	7.5	Anchor pulled out 1-1/2 in., surface spall 10- by 11- by 1-in. deep at the bolt.
33	3/4 by 4-1/4 Kwik-Bolt	Far	3-1/4	9.5	Anchor pulled out 2 in., surface spall 6-in. diam 1-in. deep at the bolt.
34*	3/4 by 5-1/2 Kwik-Bolt	4-1/2	4-1/2	3.0	Anchor and sleeves pulled out, no spalling.
35	3/4 by 5-1/2 Kwik-Bolt	4-1/2	4-1/2	16.0	Anchor pulled out, sleeves remained in hole, no spalling.
36	3/4 by 5-1/2 Kwik-Bolt	4-1/2	4-1/2	11.5	Surface spall 3- by 4- by 1/2-in. deep, anchor pulled out, sleeves remained in hole.
37	3/4 by 5-1/2 Kwik-Bolt	Far	4-1/2	11.5	Anchor pulled out, sleeves remained in hole, no spalling.
38	3/4 by 5-1/2 Kwik-Bolt	Far	4-1/2	10.0	Anchor pulled out 3-1/2 in., small surface spall 5- by 5- by 1-in. deep at the bolt.
39	1 by 6 Kwik-Bolt	6	4-1/2	14.0	Cracked the slab to the edge, anchor pulled out. 
40	1 by 6 Kwik-Bolt	6	4-1/2	14.0	Spalled to edge, spall 9- by 27- by 3-1/2-in. deep at the edge, anchor pulled out.
41	1 by 6 Kwik-Bolt	6	4-1/2	12.5	Spalled to edge, spall 11- by 35- by 6-in. deep at the edge, anchor pulled out.
42	1 by 6 Kwik-Bolt	Far	4-1/2	17.5	Anchor pulled out 3/4 in., surface spall 16- by 18- by 3-1/2-in. deep at the bolt.
43	1 by 6 Kwik-Bolt	Far	4-1/2	17.0	Anchor pulled out 1 in., surface spall 18- by 30- by 3-1/2-in. deep at the bolt.
44	1 by 6 Kwik-Bolt	Far	4-1/2	15.0	Anchor pulled out, sleeves remained in hole, slight surface crack.
45	1 by 9 Kwik-Bolt	6	6	29.0	Anchor pulled out 1/2 in., surface spall 18- by 23- by 4-1/2-in. deep at the bolt, shallow at the edge.
46	1 by 9 Kwik-Bolt	6	6	22.5	Cracked the slab to the edge, anchor pulled out. 
47	1 by 9 Kwik-Bolt	6	6	20.0	Cracked the slab, anchor pulled out (near corner of slab).
48	1 by 9 Kwik-Bolt	Far	6	21.5	Anchor pulled out, sleeves remained in hole, no spalling.
49	1 by 9 Kwik-Bolt	Far	6	22.5	Anchor pulled out, sleeves remained in hole, no spalling.

* Denotes those anchors for which the low capacity could be explained by observation.

Figure 2. Concrete after extraction of Kwik-Bolt, where expansion sleeves remained in the hole and little concrete damage occurred.

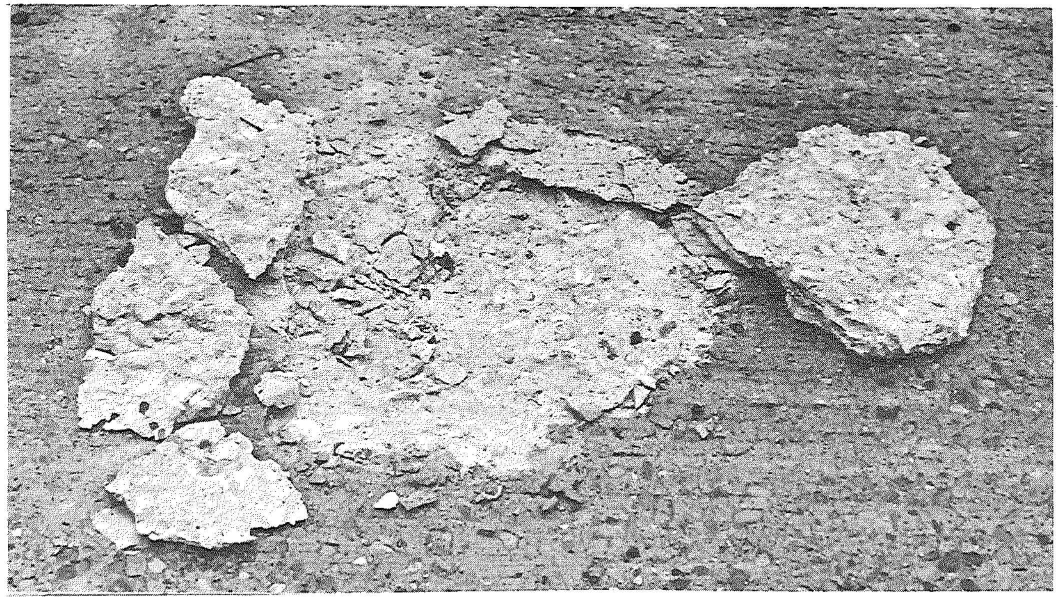


Figure 3. Typical surface spall failure.

Figure 4. Typical edge-spall failure.

Edge spall failures ordinarily are quite common when expansion anchors are set close to the edge of a slab. However, the expansion portion of the stud-type anchor is only as large as the bolt or stud, and they do not develop as much reaction as anchors that are designed to set in oversize holes. Therefore, the edge spall failure is not as prevelent or critical in stud-type anchors as in the other types for equal edge distances, especially in the smaller anchor sizes. Table 1 also shows that the 1/2- and 3/4-in. anchors that failed by spalling to the edge, developed about as much reaction as those that failed in other ways. The 1-in. diam anchors, set 4-1/2-in. deep, 6 in. from the edge, all failed by spalling to the edge at somewhat lower loads than were developed at locations far from the edge.

Table 2 is a portion of a report entitled "Field Tests of Epoxy Grout and Expansion Anchors"(1) which includes tests of Bethlehem 3/4-in. K-1 expansion anchors in order that they might be compared with the recently tested stud-type. It should be noted that the 3/4-in. diam Bethlehem anchors were set in 1-1/4-in. diam holes, 7-in. deep, and developed the strength of the bolt when set in the interior portion of the slab away from the pavement edge.

TABLE 2
FIELD TESTS OF BETHLEHEM 3/4-in. K-1 EXPANSION ANCHORS

Test No.	Description	Distance From Edge, in.	Hole Depth, in.	Ultimate Load, kips	Load at Time of Surface Spall	Type of Failure*
1	K-1	3-1/2	7	19	--	Concrete fracture to pavement edge, full depth.
2	K-1	3-1/2	7	18	--	Concrete fracture to pavement edge, full depth.
3	K-1	5-1/2	7	25-1/2	--	Concrete fracture to pavement edge, full depth.
4	K-1	5-1/2	7	23-1/2	--	Concrete fracture to pavement edge, full depth.
5	K-1	6	7	28	--	Pavement cracked from edge to nearby joint, loosening insert.
6	K-1	6	7	33	--	Bolt broken, concrete intact.
7	K-1	Far	7	33	--	Bolt broken, concrete intact.
8	K-1	Far	7	32-1/2	--	Bolt broken, concrete intact.

*In most cases, the inserts pulled out 1/2 to 3/4 in. before ultimate failure.

The comparison of 1/2-in. diam Phillips and Kwik-Bolt stud-type anchors indicated that their average failure loads were approximately equal. It was also found that increasing embedment depths beyond the manufacturer's suggested minimum resulted in significant increases in ultimate load capacity for all diameters tested.

Since anchors of each size were set at more than one depth, it was possible to compare static capacities for anchors of different sizes set at approximately the same depth. Such a comparison for Kwik-Bolt stud anchors of 1/2-, 3/4-, and 1-in. diam set at depths of 4-1/4-, 4-1/2-, and 4-1/2-in., respectively, gave average capacities of 13.5, 11.0, and 16.5 kips. The average capacity for the 3/4-in. bolts was based upon two, rather than three tests, due to stripped threads in the drawbar. The results show, however, that little if any capacity is gained by the use of larger diameter anchors if the depth of embedment is kept constant.

Three of the 49 anchors failed at loads that were abnormally low due to improper functioning of the expansion sleeves or insufficient expansion. These failures were obvious during the test, and are noted by asterisks in Table 1. Excluding the three low values noted above, the capacities of the anchors are quite uniform, especially in the interior of the slab. If the ratio of the lowest to the highest capacity for any given size and embedment is expressed in percent, the resulting average value was about 90 percent for tests conducted in the interior of the slab, and 80 percent for tests conducted near the edges.

Figure 5 shows the type of failure that occurs when an expansion anchor is set near the pavement edge and close to a transverse joint. This fact should be kept in mind when selecting locations for such anchors near joints or corners. Previous experience has indicated that a 3/4-in. Bethlehem anchor, set 6 in. from the edge, should not be less than about 2 ft from an adjacent joint or corner. Since the stud-type anchors have lower ultimate capacity than the K-1 shell, the minimum corner distance could probably be decreased.

The manufacturers of both Phillips and Kwik-Bolt stud-type anchors suggest embedment depths of slightly more than 4 diameters. Table 3 shows the results of the recent tests at the suggested embedments, extracted from Table 1, for comparison with the advertised capacities from manufacturer's sales literature. These capacities were taken from manufacturer's pamphlets, Kwik-Bolt Form No. KB 167, and Phillips Form No. F 500-P. Test results presented are averages of three individual tests and all values are reported to the nearest 500 lb. It should be noted again that better results were obtained with deeper embedments, as Table 1 indicates. Although the two types of stud anchors tested are similar in general appearance, the technique of expansion and resulting concrete grip are different. Phillips anchors are expanded by driving against the cone in the bottom of the hole. The Kwik-Bolt anchors, however, are inserted into the hole and expand or "set" by the sleeves sliding on the cone when

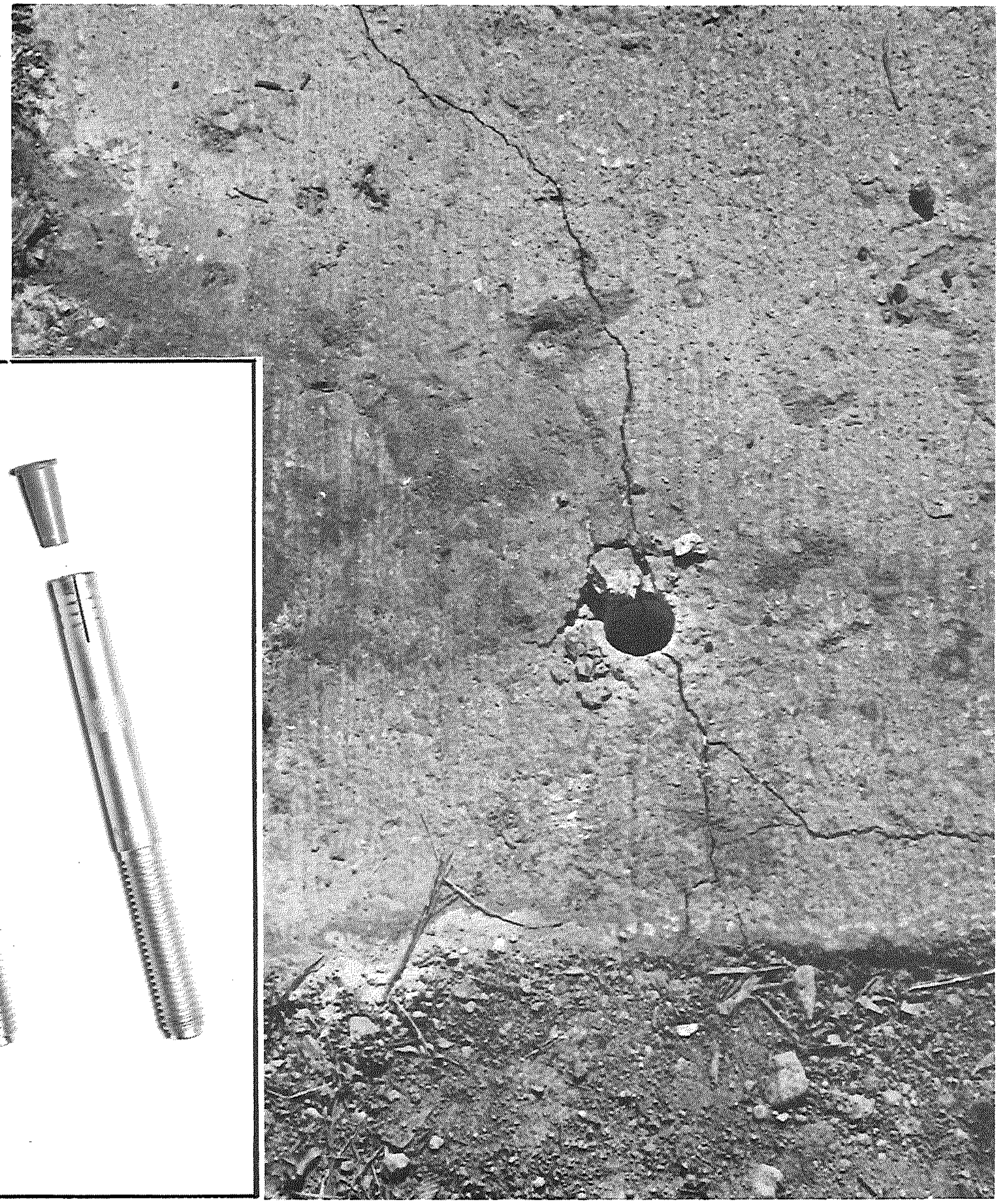


Figure 5. Corner fracture caused by extraction of Kwik-Bolt anchor.

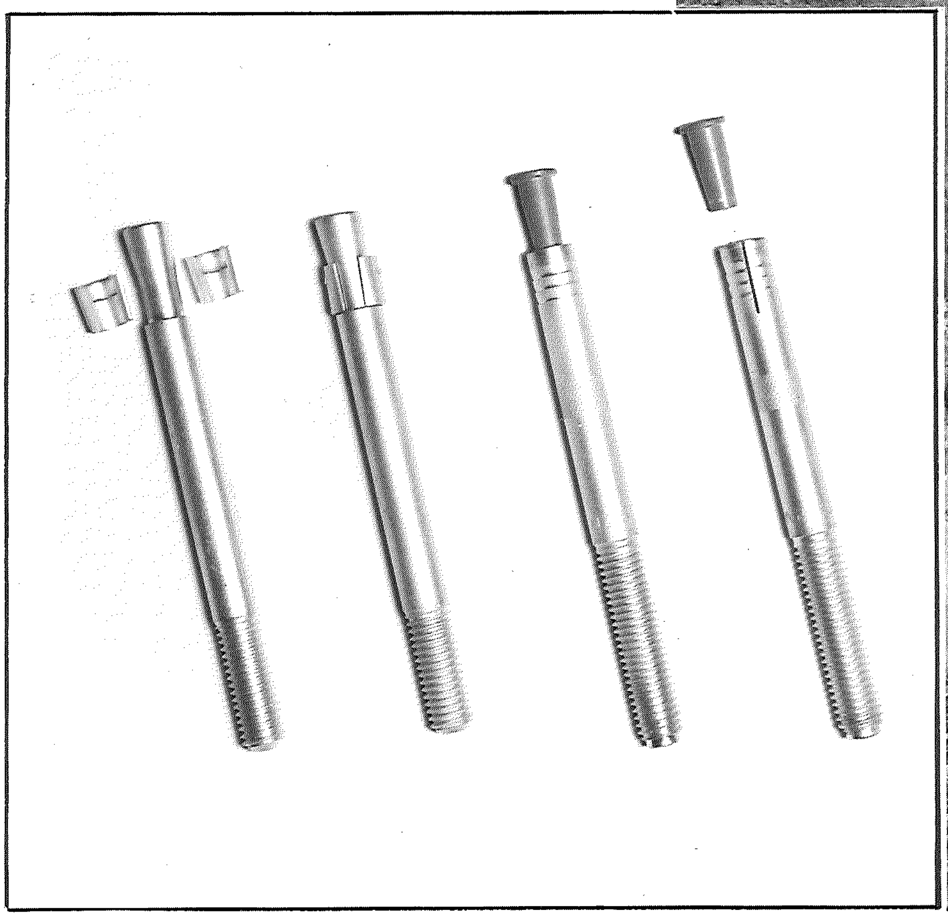


Figure 6. Typical stud-type expansion anchors. Note that the expansion cone is part of the stud in the Kwik-Bolt anchor (left), and is a separate part of the Phillips anchor (right).

withdrawal is begun. The Kwik-Bolt cone is an integral part of the bolt (Fig. 6). If the sleeves also slip along the interior wall of the hole, the resulting final anchorage resistance may be concentrated quite close to the surface. The surface concrete can then spall at relatively low loads. This may explain the failures of 3/4- and 1-in. diam anchors at approximately the same loads as the 1/2-in. diam anchors that were set at almost the same depth. Since spall resistance increases rapidly with depth of embedment, these anchors should be set considerably deeper than the suggested minimum for more effective bolt strength utilization.

TABLE 3
COMPARISON OF TEST RESULTS
WITH MANUFACTURER'S ADVERTISING CAPACITIES

Anchor Type	Stud Diameter, in.	Hole Depth, in.	Manufacturer's Advertised Capacities		Test Results	
			Average Pull-Out Strength, lb	Concrete Compression Strength, psi	Average Pull-Out Strength, lb	Concrete Compression Strength, psi
Kwik-Bolt	1/2	2-1/4	9,633	5,500	9,000	5,200 avg
Phillips	1/2	2-1/4	5,620	3,985 avg	9,500	5,200 avg
Kwik-Bolt	3/4	3-1/4	28,400	5,550	9,000	5,200 avg
Kwik-Bolt	1	4-1/2	32,933	5,500	16,500	5,200 avg

It was also discovered that the tests that were the basis for the advertised Kwik-Bolt capacities were made with a hollow hydraulic ram. This results in compressive loading of the concrete immediately surrounding the anchors. This prevents spalling and can lead to overly optomistic results.

Conclusions

The field tests showed that Kwik-Bolt and Phillips 1/2-in. stud-type anchors have approximately equal capacities. Although none of the anchors tested developed the strength of the bolt, resulting load capacities should be sufficient for many applications, especially where the factor of identical bolt and drill size would be advantageous, or where extremely high loads are not anticipated. Capacities can be significantly increased by setting anchors deeper than the embedment suggested in the manufacturer's literature.

Recommendations

Based on the results of the field tests, it is recommended that stud-type expansion anchors of the types tested be set with depth-to-diameter ratios of 6 to 8. Edge distance should be at least equal to the depth of embedment, and corner distances of 1, 1-1/2, and 2 ft should be maintained for the 1/2-, 3/4-, and 1-in. diam stud anchors set in concrete with a compressive strength in the range of the field test values. Weaker concrete would require greater clearance.

Pending any evidence to the contrary, it appears that a correction factor of about 1/2 should be applied to the values for pull-out capacity of 3/4- and 1-in. diam Kwik-Bolt anchors as published by the manufacturer, in addition to the above mentioned change in embedment depths. The manufacturer's recommended safe working load of 25 percent of the average pull-out load seems reasonable if applied to the corrected pull-out load. Manufacturer's recommendations on a drill and hole size should be followed exactly since oversize holes can weaken the anchorage considerably.

The Phillips Co. has published pull-out capacities, determined by laboratory tests similar to the recent field tests, that are far more conservative than the Kwik-Bolt results. Although Phillips anchors were tested in only one size and in a stronger concrete, the results were considerably higher than the company's published values. Therefore, no correction factor is suggested for Phillips literature. The above mentioned limitations on embedment depth, edge, and corner distances would still apply. Phillips also recommends working loads at 25 percent of average pull-out load, which should lead to safe results.

A proposal has been submitted by the Research Laboratory for a project involving impact testing of several types of anchorages including expansion anchors. If approval is received, work could begin on the project soon and possibly be completed during this year. Until this or some similar study is completed, expansion anchors are not recommended for applications where the primary loading application is by impact, such as in anchorage of posts for bridge or guard rail.

REFERENCE

1. Arnold, C. J. and Brown, M. G., "Field Tests of Epoxy Grout and Expansion Anchors: Supplement to Research Report No. R-579." Michigan Department of State Highways Research Report No. R-619, January 1967.