

CORPS OF ENGINEERS, U. S. ARMY

TESTS OF ANCHORS FOR MASS-CONCRETE FORMS



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PREFACE

Authority for this investigation is contained in a letter from the Office, Chief of Engineers, to the Director, Waterways Experiment Station, dated 3 April 1952, subject, "New Type Form Anchorage for Use in Low Strength Mass Concrete," and in the first indorsement, dated 18 March 1953, to a letter from the Waterways Experiment Station to the Chief of Engineers, dated 20 May 1952, subject, "Transmittal of Draft of Report, 'Tests of Form Anchors.'"

This investigation was performed for the Office, Chief of Engineers, by the Concrete Division of the Waterways Experiment Station under the supervision of Herbert K. Cook and Thomas B. Kennedy. This report was compiled by Thomas B. Kennedy and Walter O. Crawley.

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SUMMARY

The tests reported herein were intended to determine the holding strength of several designs of anchors for securing cantilever forms to mass-concrete surfaces. The investigation consisted of the fabrication of four blocks of low-strength, 6-in.-aggregate concrete in which a total of 48 anchors were embedded and tested at ages ranging from 24 to 72 hours. The results indicate that, under the test conditions used, adequate holding strength was developed in practically every case by the time the concrete was 3 days old.

TESTS OF ANCHORS FOR MASS-CONCRETE FORMS

PART I: INTRODUCTION

Purpose of Investigation

1. One of the limiting factors in early reuse of cantilever forms for mass concrete in large dams is the holding strength of the form anchors in the low cement-factor concrete used in such structures. The purpose of the investigation described herein was to obtain information on the holding strength of a variety of form anchors with the aim of determining how soon the forms can safely be removed for reuse.

Materials and Specimens

Anchors

2. The anchors and bolts that were tested were furnished by two companies. The laboratory designation and description of the anchors, and the numbers of the test series in which they were used are listed below; details of the anchors are shown in fig. 1.

<u>Designation</u>	<u>Anchor</u>	<u>Bolt Size</u>	<u>Test Series</u>
R-1	Ty-anchor	1-1/4-in. by 17-1/2-in.	1 - 2
R-2	Whirl-wind anchor	1-1/4-in. by 17-1/2-in.	1 - 2
R-3	Ty-anchor	1-1/2-in. by 24-in.	3
R-4	Whirl-wind anchor	1-1/2-in. by 19-1/2-in.	2 - 3
S-1	Special coil tie	1-1/4-in. by 15-1/2-in.	1
S-1a	Special coil tie	1-1/4-in. by 27-1/4-in.	2
S-2	Flared-coil loop	1-1/4-in. by 15-1/2-in.	1
S-2a	Flared-coil loop	1-1/4-in. by 30-in.	2
S-3	4-unit angle anchor	1-1/4-in. by 28-in.	3
S-4	Strut-coil rod anchor	1-1/4-in. by 23-1/2-in.	3

Concrete

3. The concrete in all three test series contained Type II cement, crushed limestone sand, and coarse aggregate graded up to the 6-in. size. Aggregates were graded within the limits of the Corps of Engineers "Standard Guide Specifications for Concrete for Civil Works." The

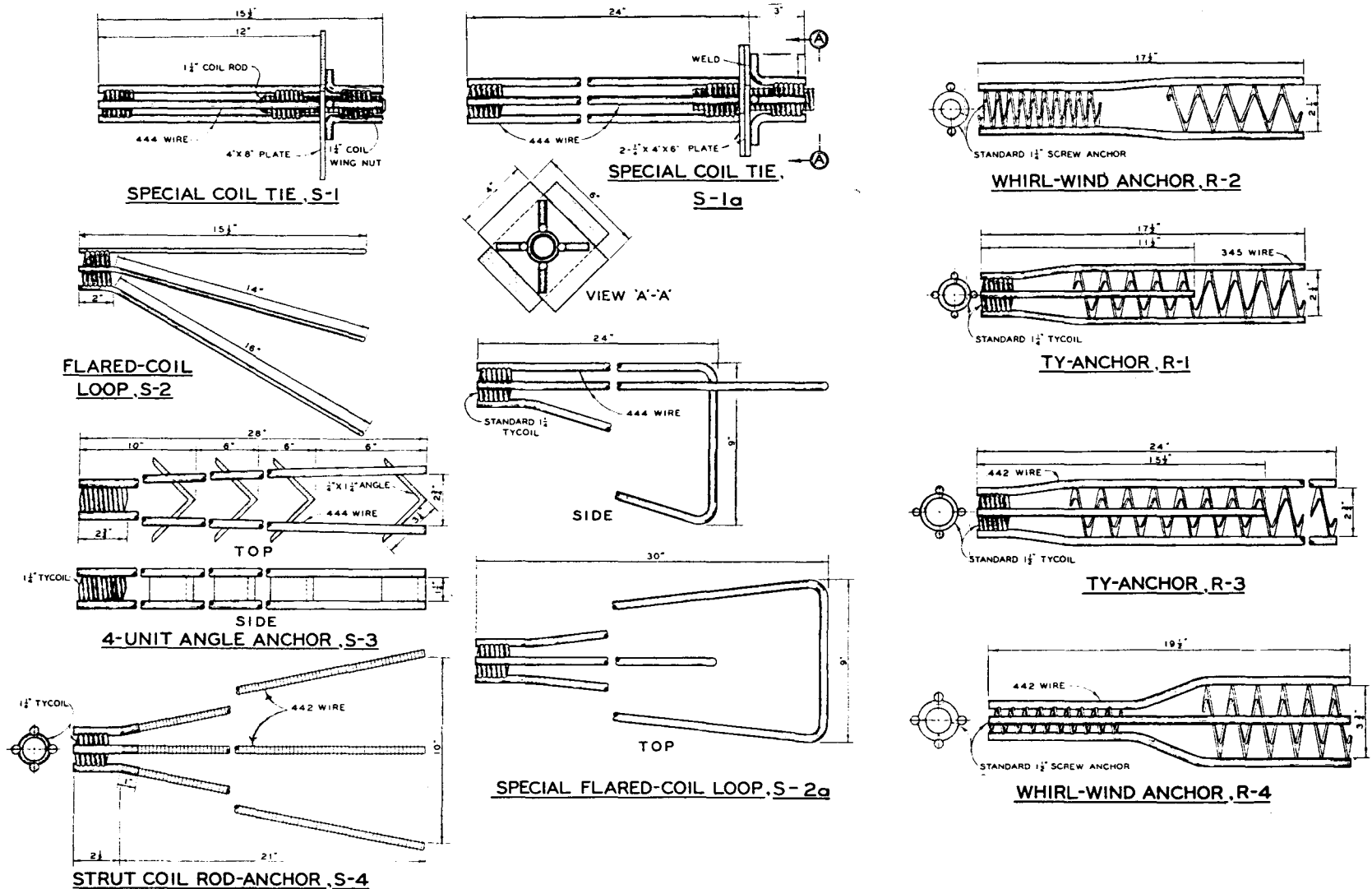


Fig. 1. Form anchors for cantilever forms

nominal cement factor was 2.5 bags per cu yd, sand factor 25 per cent by volume of total aggregate, water-cement ratio approximately 0.8 by weight, slump approximately 2-1/2 in., and air content 5 to 7 per cent in that portion of the mixture passing the 1-1/2-in. sieve.

4. The concrete used in test series 1 was mixed and placed in the laboratory using a laboratory rocking-tilting 10-S mixer. The concrete in series 2 and 3 was batched and mixed in the Waterways Experiment Station 2-cu-yd concrete plant and the test blocks were cast out-of-doors.

5. Compression test cylinders for each series were made of concrete wet-sieved through the 3-in. sieve. The cylinders were covered with damp burlap and allowed to remain in their molds alongside the test blocks until the time at which the anchors were tested. Test ages given are within ± 2 hr.

6. Average compressive strengths of the cylinders were as follows:

<u>Test Age, hr</u>	<u>Compressive Strength, psi</u>		
	<u>Series 1</u>	<u>Series 2</u>	<u>Series 3</u>
24	415*	150*	-
41	765*	-	-
48	-	300*	-
72	-	440*	1150**

* Average of six tests on 8- by 16-in. cylinders.

** Average of four tests on 10- by 20-in. cylinders.

Test blocks

7. The size of the blocks containing the anchors varied. In series 1, two prisms, each 2 ft wide by 10 ft long by 2 ft high, were made. In series 2, one block 20 ft long by 10 ft wide by 5 ft high was made, and in series 3, one block 15 ft long by 10 ft wide by 5 ft high was made.

8. All anchors were set a clear distance of 2-1/2 in. from the inside vertical faces of the forms with a minimum spacing of 4 ft between anchors. All anchors were set either 6 in. below the top or 6 in. above the bottom of the test blocks. This setting provided the minimum practicable coverage and depth of embedment and resulted in a severe test condition for the anchors. The anchor bolts protruded 12 in. from the surface of the concrete at time of test.

PART II: TESTS AND RESULTS

Tests

9. The anchors were stressed by means of an H-beam and jack device shown schematically in fig. 2. Slip and elongation of the anchors, as

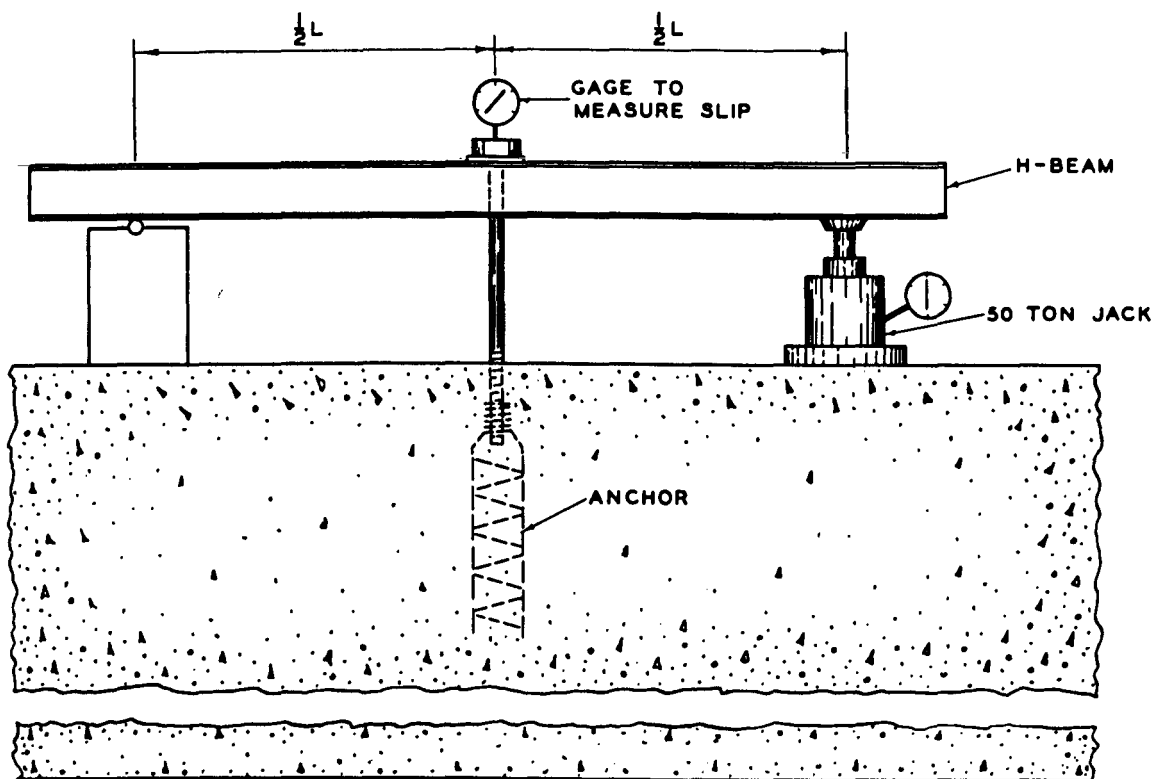


Fig. 2. Schematic plan view of device to test form anchors

evidenced by movement of the head of the anchor bolt, was measured to 0.0001 in. with a dial gage separately mounted from the pulling rig. Failure was judged to have occurred when the concrete cracked or a movement of 1/16 (0.0625) in. was observed on the gage.

10. The loads to which form anchors are subjected are indeterminate, because of the weight of the form and tightening of the bolts. Allowances were made for these loads of 10,000 lb in series 1 and 8,000 lb in series 2 and 3. For these loads it is believed that the 8,000-lb figure is probably ample as a zero load from which to start measurement of movement for all but the most unusual conditions.

11. In series 1, a zero reading was taken at 10,000-lb pull, and movement of the bolt was observed at each additional 10,000-lb increment of load. The distance between the bolt and jack was progressively shortened from 24 to 19 to 11 in. to reduce the bending moment in the block caused by the loading of the anchors.

12. In series 2 and 3, a zero reading was taken at 8,000-lb pull and movement of the bolt was observed at each additional 2,000-lb increment of load. In these two series the distance between the bolt and jack was 24 in. in every case.

Results

13. The size and type of anchor and the test results are given in tables 1, 2, and 3 for series 1, 2, and 3, respectively.

Series 1

14. The depth of section of the blocks in which the anchors were tested in this series was insufficient to prevent failure of the blocks because of bending when the anchors were pulled, except for the flared-coil loops, even with the test span reduced to 11 in. The flared-coil loops all failed by excess movement.

Series 2

15. Tests at 24 hr. Four anchors near the top and four near the bottom were tested at the 24-hr age. One anchor took a 1-1/2-in. bolt, the others took 1-1/4-in. bolts.

16. The concrete holding two of the top anchors cracked before the 8,000-lb load, the starting point for measurement of slip, had been applied. The concrete holding the two other top anchors cracked at loads of 10,000 and 14,000 lb. Movements of 1/16 in. did not occur in either case.

17. The strength of the concrete around the bottom anchors was somewhat higher than around the top anchors, and their behavior was better. Movements of 1/16 in. occurred at approximately 27,000, 30,000, and 30,000 lb for two whirl-winds and a special coil tie anchor, respectively. The second whirl-wind required a 1-1/2-in. bolt. Movement of 1/16 in.

occurred at a pull of approximately 15,000 lb on the special flared-coil loop anchor. Cracking was observed at 28,000 lb around one whirl-wind anchor bolt and at 36,000 lb around the special coil tie anchor bolt.

18. Tests at 48 hr. Six anchors near the top and four near the bottom were tested at the 48-hr age. Nine took 1-1/4-in. bolts and one a 1-1/2-in. bolt.

19. All the top anchors failed by movement or cracking at loads ranging from 12,000 to 28,000 lb.

20. The performance of the bottom-positioned anchors was better than that of the top positioned. One anchor withstood a pull exceeding 40,000 lb, and one a pull of 32,000 lb before allowing a movement of 1/16 in. Cracking was observed around the bolt for another anchor at a load of 28,000 lb with a movement of 0.0492 in. The remaining anchor bolt (special flared-coil loop anchor) moved more than 1/16 in. at somewhat less than 22,000 lb.

21. Tests at 72 hr. Two anchors near the top and four near the bottom were tested at the 72-hr age. All required 1-1/4-in.-diameter bolts.

22. The concrete surrounding one top anchor bolt cracked at 26,000 lb and the other at 16,000 lb. Cracking occurred in both cases before a movement of 1/16 in. was experienced.

23. A movement of 1/16 in. occurred for two of the bottom anchors at approximately 32,000 lb. Another anchor withstood a pull of 38,000 lb, when the concrete was observed to be cracked, without moving 1/16 in. The remaining anchor, a special flared-coil loop, showed 1/16 in. movement at a pull of approximately 26,000 lb.

Series 3

24. Eight anchors were tested in this series, all at the 72-hr age, and all positioned 6 in. from the top edge of the block. Four anchors required 1-1/4-in.-diameter bolts and four 1-1/2-in.-diameter bolts.

25. Generally, cracking of the concrete around the anchors was observed to begin at a load on the bolt of approximately 30,000 lb. Movement at 28,000 lb, the observed load immediately before cracking was noticed, was quite low for all the anchors tested and ranged from 0.0138

to 0.0265 in. At 40,000 lb, the highest load at which movement for all anchors can be compared, the movement ranged from 0.0288 to 0.0547, all less than $1/16$ in. The least amount of movement per unit load was experienced with the special coil tie anchor; however, the movement was quite small for all anchors tested.

PART III: DISCUSSION OF RESULTS

Cracking

26. An examination of the data shows that cracking was observed in most cases before a movement of $1/16$ in. was measured. The cracking occurred on the surfaces of the concrete normal to the axis of the anchor and bolt and outlined an area of spalling varying in radius from 9 to 42 in. on each side of the bolt, but of lesser extent below the bolt. Typical cracking of this type is shown in fig. 3. The cracking

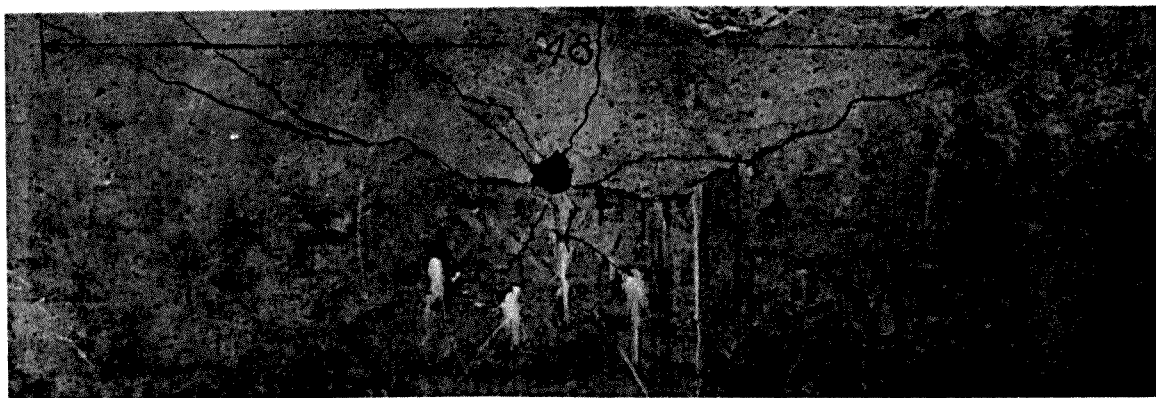


Fig. 3. Typical spalling caused by overloading a form anchor

associated with spalling extended to a relatively shallow depth varying from approximately 6 to $8\frac{1}{2}$ in., as nearly as could be observed, and appeared to originate from movement due to elongation of the bolt or fore part of the anchor (or both) under load, rather than to slip of the anchor. Another type of crack was observed in one case on the top surface of the test block. A single crack was observed parallel to the axis of the bolt and anchor extending away from the face of the block to the full length of the anchor. This crack may have been caused by wedging action of the anchor as it moved under load.

27. The cracking, when first noticed, was slight and very fine. Anchors were pulled excessively after the cracks appeared in order to develop the extent and pattern of the cracking. Such cracking would probably never be experienced in actual practice except in the case of a severe form failure.

Load on Anchors in Prototype

28. It is practically impossible to predict the load that will be put on an anchor in actual use, but assuming an extreme condition of a 5-ft hydraulic head of concrete weighing 150 lb per cu ft, with form supports on 6-ft centers, anchor bolts 6 in. below the lift surface, and the stiffleg end of the form support extending 4 ft below the bolt head, then a load of approximately 17,000 lb might be exerted against the anchor by the concrete. This load plus possibly 8,000 lb for impact of bucket against forms, or other accidental loading, indicates that the safe capacity for an anchor might be 25,000 lb.

29. The data obtained in series 1 are limited in value because of the insufficient section of the test blocks.

30. Examination of the data for series 2, table 2, shows that no top-positioned anchors withstood a pull of 25,000 lb at the 24-hr age, but three of the four bottom-positioned anchors did. At 48 hr, one of six top-positioned anchors and all three of the bottom-positioned anchors resisted a pull of 25,000 lb. At 72 hr, one of two top-positioned and all four bottom-positioned anchors withstood a pull of 25,000 lb.

31. In series 3 all the anchors successfully withstood a pull exceeding 25,000 lb.

Effect of Diameter of Anchors

32. The effect of increased diameter of anchor and bolt was not determined because the strength of the concrete at the early ages at which the anchors were tested was so low that failure almost invariably occurred in the concrete. The yield point of the steel of even the 1-1/4-in.-diameter anchor bolts, and objectionable movement of the anchors were not reached before the concrete failed.

PART IV: CONCLUSIONS

33. Based on the tests reported herein all the anchors except the two flared-coil loop designs caused cracking in the concrete before sufficient movement was observed to be classed as failure of anchor. The flared-coil loops permitted slippage that might be objectionable in some circumstances.

34. The low cement-factor mass concrete used in these tests developed sufficient strength by the time it was 3 days old to permit safe use of the anchors.

Table 1
Load and Movement of Anchors
Series 1

Total Load $lb \times 10^{-3}$	Movement of Anchor, in. $\times 10^4$							
	Anchors 6 in. from Top				Anchors 6 in. from Bottom			
	Ty- anchor	Whirl- wind	Special Coil Tie	Flared- coil Loop	Ty- anchor	Whirl- wind	Special Coil Tie	Flared- coil Loop
<u>24 \pm 2-hr Tests, Compressive Strength: 415 psi</u>								
	<u>R-1 16</u>	<u>R-2 1</u>	<u>S-1 14</u>	<u>S-2 3</u>	<u>R-1 2(b)</u>	<u>R-2 15</u>	<u>S-1 4(d)</u>	<u>S-2 13</u>
10	0	0	0	0	0	0	0	0
14	---	---	---	---	---	---	(a)	---
20	43	205	0	212	122	151	---	110
30	124	305	34	462	300(a)	383(a)	---	340
38	---	---	---	957(c)	---	---	---	---
40	444(a)	530	94(a)	---	---	---	---	830(c)
42	---	(a)	---	---	---	---	---	---
<u>41 \pm 2-hr Tests, Compressive Strength: 765 psi</u>								
	<u>R-1 6</u>	<u>R-2 9</u>	<u>S-1 8</u>	<u>S-2 11</u>	<u>R-1 10</u>	<u>R-2 5</u>	<u>S-1 12</u>	<u>S-2 7</u>
10	0	0	0	0	0	0	0	0
20	78	47	77	47	12	80	90	90
28	---	(a)	---	1170+(c)	---	---	---	---
30	200	---	219	---	1132+(a)	210	325	242
40	412	---	559(a)	---	---	360	605	1095+(c)
48	---	---	---	---	---	---	1095+(c)	---
52	---	---	---	---	---	960(a)	---	---
54	902+(e)	---	---	---	---	---	---	---

Note: Bolts 1-1/4 in. in diameter; span between jack and bolt 11 in., except as noted.

(a) Block failed in flexure.

(b) Span between jack and bolt 19 in.

(c) Failure through excess movement of anchor.

(d) Span between jack and bolt 24 in.

(e) Failure through excess movement due to failure of weld in anchor.

Table 2
Load and Movement of Anchors
Series 2

Movement of Anchor, in. x 10 ⁴											
Total Load lb x 10 ⁻³	Anchors 6 in. from Top					Anchors 6 in. from Bottom					
	Ty- anchor	Whirl- wind	Whirl- wind (1-1/2 in.)	Special Coil Tie	Special Coil Tie	Special Flared- coil Loop	Ty- anchor	Whirl- wind	Whirl- wind (1-1/2 in.)	Special Coil Tie	Special Flared- coil Loop
24 ± 2 hr Age											
Compressive Strength: 145 psi						Compressive Strength: 160 psi					
	R-1 10	R-2 12	R-4	S-1a 1	S-1a	S-2a 11	R-1	R-2 17	R-4 19	S-1a 20	S-2a 18
8	*	0		0		*	0		0		0
10		144**		1			1		33	15	59
12		294		6			12		69	46	263
14				80**			57		134	83	536
16				201			100		168	90	779
18							162		203	143	944
20							208		237	197	
22							325		339	296	
24							427		412	367	
26							585		485	466	
28							715		545**	548	
30									693	651	
32										757	
34										872	
36										962**	
38										1117	
48 ± 2 hr Age											
Compressive Strength: 300 psi						Compressive Strength: 360 psi					
	R-1 6	R-2 8	R-4 2	S-1a 5	S-1a 9	S-2a 7	R-1 23	R-2 21		S-1a 24	S-2a 22
8	0	0	0	0	0	0	0	0		0	0
10	23	8	19	110	26	51	10	16		12	32
12	80**	32	433	299**	79	179	30	37		33	94
14		61	628**	482	115	342	51	57		74	153
16		116			170	416**	74	89		121	245
18		185**			203	705	101	116		174	325
20		395			267		135	263		238	453
22					313		165	295		302	657
24					372		195	353		354	854
26					420		226	409		414	919**
28					474**		260	492**		456	
30					526		298			518	
32							343			584	
34							400				
36							448			684**	
38							508				
40							590				
42							690				
44							808**				
72 ± 2 hr Age											
Compressive Strength: 430 psi						Compressive Strength: 460 psi					
		R-4 4			S-2a 3		R-1 15	R-2 13		S-1a 16	S-2a 14
8		0			0		0	0		0	0
10		2			26		25	2		2	12
12		22			139		32	11		18	25
14		50			269		50	36		39	38
16		109			470**		76	76		92	59
18		147					96	107		141	96
20		219					129	170		192	176
22		278					153	222		237	286
24		347					181	296		288	401
26		460**					217	366		346	528
28		467					257	443		392	763**
30							284	492		484	
32							358	606		595	
34							417	697**		704**	
36							495			852	
38							587**			1053	

Note: Bolts for anchors were all 1-1/4 in. in diameter except where shown differently.
 * Concrete cracked before load of 8,000 lb was applied.
 ** Concrete cracked.

Table 3

Load and Movement of Anchors

Series 3

72 \pm 2 hr Age, Compressive Strength: 1150 psi								
Movement of Anchor, in. $\times 10^4$								
Total Load lb $\times 10^{-3}$	1-1/2-in.-diam bolts				1-1/4-in.-diam bolts			
	Ty- anchor R-3 1	Ty- anchor R-3 5	Whirl- wind R-4 2	Whirl- wind R-4 7	4-unit Angle Anchor S-3 3	4-unit Angle Anchor S-3 8	Strut Coil Rod Anchor S-4 4	Strut Coil Rod Anchor S-4 6
8	0	0	0	0	0	0	0	0
10	1	19	27	10	23	19	1	1
12	16	35	59	26	49	35	2	3
14	25	57	83	46	75	53	16	17
16	39	76	101	62	104	73	31	29
18	56	98	123	81	125	94	46	47
20	73	118	139	102	150	121	62	60
22	102	143	166	123	174	146	86	79
24	117	170	194	144	200	172	105	98
26	143	198	224	168	228	206	140	118
28	163	230	265	187	253	232	166	138
30	188	260*	306	210	283	270	201	162
32	213	286	347	233	311	294	231	186
34	238	315	383	252*	332	320	261	206
36	262	341	427	276	371	350	295*	231
38	298	376	484*	300	391	379	341	259
40	345*	401	547	328	410*	411	386	288*
42	394	428	622	354	440	436*		317
44	432	468	677	371	464	474		348
46	514	498		388	494	509		378
48	548	539		418	525	540		417
50	606	570		456	559	567		455
52		607		538				499

* Concrete cracked.

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