INVESTIGATION OF METHODS OF PREPARING HORIZONTAL CONSTRUCTION JOINTS IN CONCRETE

TESTS OF JOINTS IN LARGE BLOCKS

TECHNICAL REPORT NO. 6-518

Report 2

July 1963

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

ARMY-MRC VICKSBURG, MISS.

ERRATA SHEET

INVESTIGATION OF METHODS OF PREPARING HORIZONTAL
CONSTRUCTION JOINTS IN CONCRETE

TESTS OF JOINTS IN LARGE BLOCKS

Technical Report No. 6-518, Report 2, July 1963

1. Substitute the attached for the abstract cards now included.

2. Page 13, par. 32, last line, for "95 percent confidence" read "two-sigma."

3. Page 14, par. 33, line 1, for "As shown in table 5, there are" read "There appear to be."

4. Table 5.

a. Headings of columns 8 and 13, for "95% Confidence Interval" read "Two-Sigma Limits."

b. Column 12
line 3, for "77" read "70"
line 6, for "90" read "58"

c. Column 13
line 3, for "186-494" read "200-480"
line 6, for "245-605" read "309-541"

THE CONTENTS OF THIS REPORT ARE NOT TO BE
USED FOR ADVERTISING, PUBLICATION,
OR PROMOTIONAL PURPOSES

PREFACE

The investigation reported herein was authorized by the Chief of Engineers (OCE) by first indorsement, dated 13 June 1960, to U. S. Army Engineer Waterways Experiment Station (WES) letter, dated 8 June 1960, subject, "Methods for Making Horizontal Construction Joints in Mass Concrete," and forms a part of CWI Item No. 617, "Improvements in Construction Practice," of the Civil Works Investigations Program of the Corps of Engineers. This work is supplementary to the laboratory investigation of methods of preparing horizontal construction joints in concrete that was conducted by the WES in 1958-1959, the results of which were reported in Technical Report No. 6-518, July 1959.

This work was conducted at the Concrete Division of the WES during the period 1960-1962, under the direction of Mr. Thomas B. Kennedy. Staff members actively concerned with the work include Messrs. James M. Polatty, W. O. Tynes, Kenneth L. Saucier (project leader), and W. B. Lee. This report was prepared by Mr. Tynes.

Directors of the WES during the investigation and preparation of this report were Col. Edmund H. Lang, CE, and Col. Alex G. Sutton, Jr., CE. Technical Director was Mr. J. B. Tiffany.

CONTENTS

	Page
PREFACE	iii
SUMMARY	vii
PART I: INTRODUCTION	1
Background	1
Scope and Purposes of Tests	2
PART II: MATERIALS, MIXTURES, SPECIMENS, AND TESTS	3
Materials	3
Mixtures	3
Preparation of Specimens	3
Cores and Types of Tests Used	5
Test Methods	6
PART III: DISCUSSION OF TEST RESULTS	9
Effect of Dry Versus Wet Surface	9
Effect of Mortar Between Lifts	10
Effect of Prolonged Drying of Lower Joint Surface	10
Effect of Broomed Versus Flowed Mortar	11
Effect of Thick Versus Thin Mortar	12
Relative Strength of Joints	12
PART IV: CONCLUSIONS	14
REFERENCES	15
TABLES 1-5	

SUMMARY

Three concrete blocks, 10 by 20 by 5 ft high, were cast in two 30-in.-high lifts. The 10- by 20-ft joint plane of each block was divided into four equal areas for testing different types of joint preparation. A series of strength tests (shear, tensile, and flexural) were made of cores drilled from several areas of each block to evaluate the various methods of preparing the horizontal construction joints. An analysis of the results indicated that there are no significant differences in effectiveness among the various joint treatments investigated in this program; therefore, it appears reasonable to select among the several treatments on the basis of cost.

INVESTIGATION OF METHODS OF PREPARING HORIZONTAL

CONSTRUCTION JOINTS IN CONCRETE

TESTS OF JOINTS IN LARGE BLOCKS

PART I: INTRODUCTION

Background

1. The first report[2*] of this series describes a laboratory investigation of various methods of preparing construction joints in concrete that provided information on the quality of joints in small concrete specimens made with small-aggregate (1-1/2-in. maximum size) concrete when the age of the old concrete to which the new concrete was joined was three days. In some cases the surface of the old concrete was allowed to room-dry before new concrete was placed, and the effect on joint quality of use or nonuse of a layer of mortar between the old, room-dried concrete and new concrete was evaluated. Approximately one-third of the old-concrete surfaces were cleaned by sandblasting before mortar or new concrete was placed thereon. The data indicated that: (a) absence of mortar resulted in generally greater joint strength; (b) joint cleanup by sandblasting markedly decreased permeability of the concrete at the joint; (c) when the surface to receive the concrete was dry, instead of wet as is customary in construction, the strength of the joint was improved in almost every case, and the permeability was reduced in every case; (d) no differences in quality of joint were evident as a result of smoothing the surface by floating prior to sandblasting as opposed to leaving the surface rough; and (e) maximum size of aggregate had no significant effect on the quality of the joint. The investigation reported herein was conducted to see if these findings are valid for joints in mass concrete formed under both similar and different conditions.

* Raised numerals refer to similarly numbered items in list of references at end of text.

Scope and Purposes of Tests

2. Three concrete blocks, 10 by 20 by 5 ft high, were cast in two 30-in.-high lifts, and shear, tensile, and flexural strength tests were made on specimens drilled from the joint plane to evaluate the effect on the quality of the horizontal construction joints of (a) short or prolonged drying of the old concrete surface, (b) wet or dry surface applications, (c) presence or absence of mortar at the joint, (d) mode of application of mortar, and (e) type of mortar. Concrete containing 1-1/2-in. maximum size aggregate was cleaned by sandblasting in the first investigation,[2] whereas 6-in. aggregate concrete was cleaned by air-water jet in this investigation.

PART II: MATERIALS, MIXTURES, SPECIMENS, AND TESTS

Materials

Portland cement

3. A type II portland cement from Alabama was used in this investigation. The chemical and physical properties are given in table 1.

Aggregates

4. The aggregates used were crushed limestone from Tennessee, graded to comply with OCE guide specifications.[3] Physical properties and gradings of the coarse and fine aggregates are shown in table 2.

Mixtures

Concrete

5. One air-entrained concrete mixture was proportioned with 6-in. maximum size aggregate, a cement factor of 2.5 bags per cu yd, and an air content of 6 ± 0.5 percent in the portion of the mixture passing the 1-1/2-in. sieve.

Mortar

6. Two mortar mixtures were proportioned with the same proportion of sand and cement as in the concrete, but with water-cement ratios changed to produce one thick and one thin mortar.

Preparation of Specimens

Concrete blocks and cylinders

7. As stated earlier, three concrete blocks, 10 by 20 by 5 ft high, were cast in two 30-in. lifts. The 10- by 20-ft joint plane of each of the blocks was divided into four equal areas for different types of joint preparation. The blocks were designated A, B, and C, and the four joint areas of each block were designated A1 through A4, B1 through B4, or C1 through C4.

8. To permit determination of the compressive strength of the concrete in the blocks, 6- by 12-in. cylinders were made from the concrete

used for the blocks after it had been wet-sieved through a 1-1/2-in. sieve. Six cylinders were made for each lift of each of the three blocks. Three of the six cylinders were cured in the field using the same procedure used for the test blocks, and the other three were cured using the standard laboratory method.

Joints

9. All joints were left rough as in actual dam construction. The concrete joint surface areas were cut by the use of an air-water jet applied at the proper time for cutting. All joints were cleaned immediately prior to placement of the second lift, the wet joints with air and water and the dry joints with air alone (see fig. 1).

Fig. 1. Joint surface after cutting and cleaning with air-water jet

10. The first lift of each block was wet-cured for 14 days. After this period of wet-curing, the surface of each bottom lift was further cured by one of the following methods: (a) allowed to dry for a period of 2 or 62 days, (b) allowed to dry for 62 days and then kept wet for 18 hr, or (c) kept wet for an additional 12 hr. The surfaces of the lifts were then divided into the four areas mentioned in paragraph 7, and one of the two types of mortar (thick or thin) was applied by one of two methods to each area, except for two areas on block A which were not treated. The two methods of mortar application were by (a) brooming it vigorously onto the cleaned surface or (b) allowing it to flow over the surface with a minimum amount of brooming. The procedures used in preparing each of the four areas on the surface of the lower half of each block are given on the following page. It will be noted that this constitutes an incomplete factorial experimental design in which only 12 of 20 possible relations were investigated.

Curing Condition	None	Thick Mortar Broomed	Thick Mortar Flowed	Thin Mortar Broomed	Thin Mortar Flowed
		Mortar Treatment			
Dry 62 days	A1	A2	*	*	*
Dry 24 hr	*	C1	C3	C2	C4
Dry 62 days, wet 18 hr	A3	A4	*	*	*
Wet additional 12 hr	*	B1	B3	B2	B4

* No test.

11. After the surfaces of the lower lifts had been treated as described above, the second lifts were placed and wet-cured for 14 days. Following this curing period the blocks were air-dried in the open 14 days or longer before the cores for the strength tests were drilled.

Cores and Types of Tests Used

12. Nine 10-in.-diameter by 60-in.-long cores were drilled from each quarter of each of the blocks (fig. 2) after the upper lift had reached

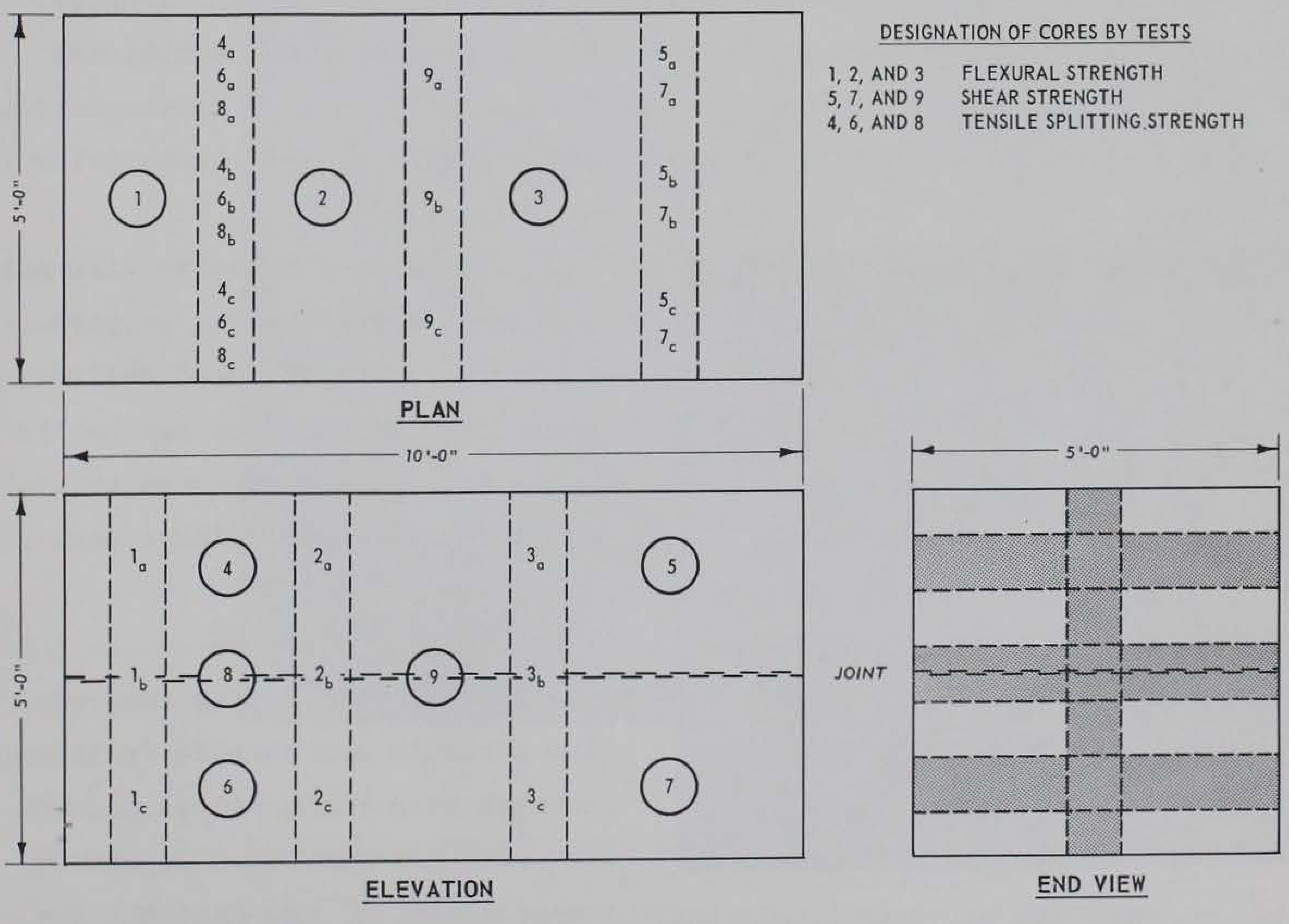

Fig. 2. Core layout for joint studies (one-quarter block)

28 days age. Cores 1, 2, and 3 were drilled vertically from top to bottom. Each was then tested in flexure in three places using third-point loading. One break was made at the joint plane using a 45-in. span length, and one break was made above the joint and one below the joint using a 24-in. span length. The tests above and below the joint provided "control" information on the strength of the concrete, or data with which to compare the strength of the joint between the two lifts. Cores 4, 6, and 8 were drilled horizontally through the block, and were used for tensile splitting tests. Core 8 was drilled through the joint plane, and cores 4 and 6 were drilled above and below the joint plane, respectively, for strength comparison. However, some of the joint planes of the No. 8 cores were far enough off-center to preclude tensile testing, and these specimens were tested in shear instead. Cores 5, 7, and 9 were drilled horizontally through the block and were tested in shear. Core 9 was drilled through the joint, and cores 5 and 7 were drilled above and below the joint plane.

13. All cores for shear testing were sawed into 10-in. lengths prior to testing; all tensile strength specimens were sawed to 20-in. lengths. The cores for flexural strength were tested as drilled. One additional core (No. 10) for flexural strength was drilled from each of block quarters A2 and C1. All of the cores for shear were capped with Hydrostone prior to testing.

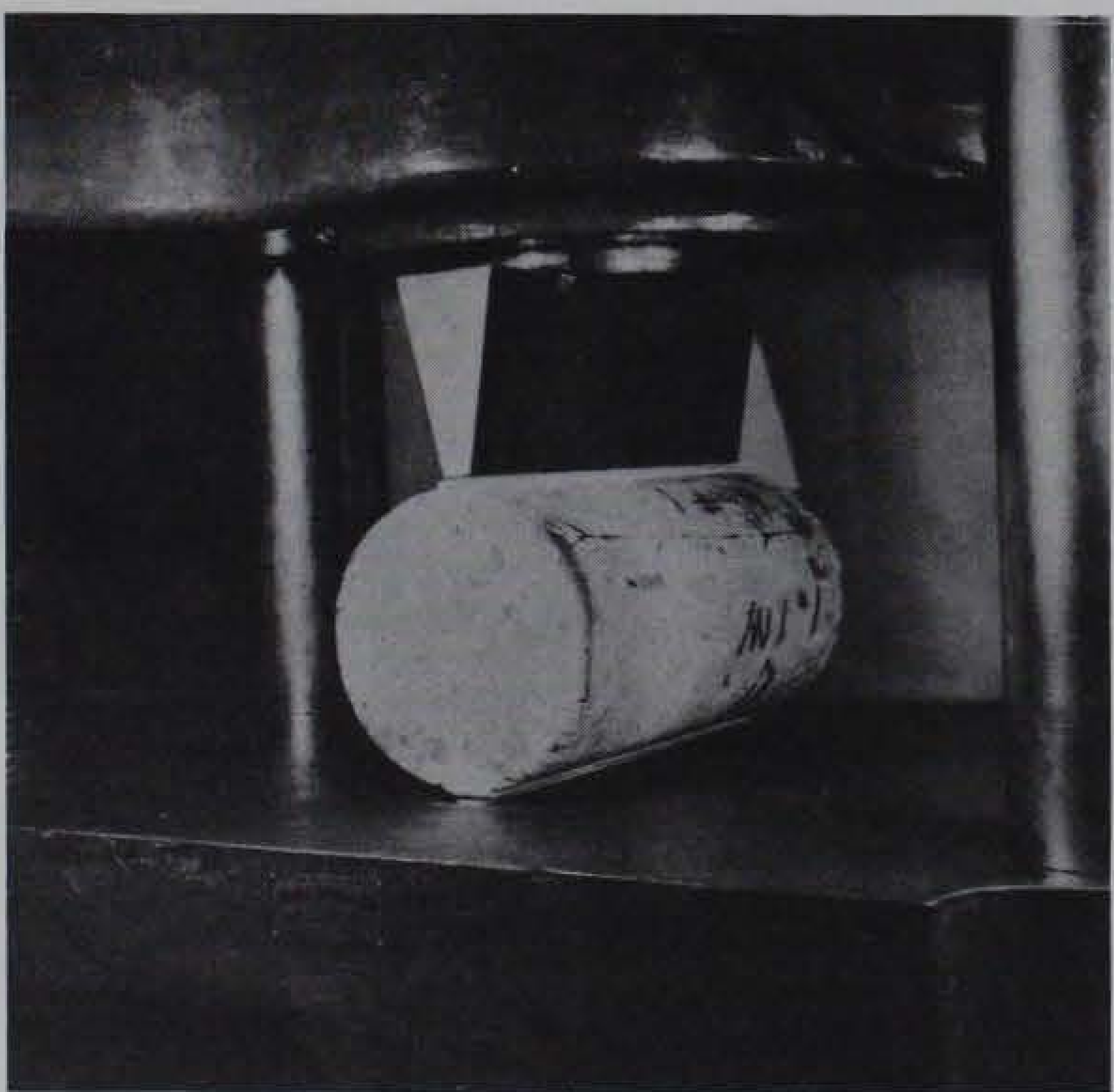

Fig. 3. Specimen in testing machine for tensile splitting test

14. The compressive strength specimens were described in paragraph 8. The field-cured cylinders were tested at the same age as the cores; the laboratory-cured cylinders were tested at 28 days age.

Test Methods

15. The tests for compressive strength and tensile splitting strength were conducted in accordance with Methods CRD-C 14 and 77, respectively, of the Handbook for Concrete and Cement.[1] Fig. 3 shows

a specimen in the testing machine used for the tensile splitting strength test.

16. The methods used for the shear and flexural strength tests are not included in the handbook; therefore, they are described below.

a. Vertical shear strength test. This test involved determination of the strength in shear on a vertical plane through a cylindrical concrete specimen. The test was conducted using a testing machine as described in CRD-C 14 and an apparatus (shown in fig. 4) in which one-half of a 10- by 10-in. core was placed, with the section to be sheared off extending out over the baseplate. The load was applied at a rate of 100 psi per min. The shear strength was calculated by dividing the maximum load by the vertical cross-sectional area of a section normal to the loading face, and was expressed to the nearest 5 psi. The test described really measures a combination of stresses, and the values reported should not be taken as the true shear strength of the concrete.

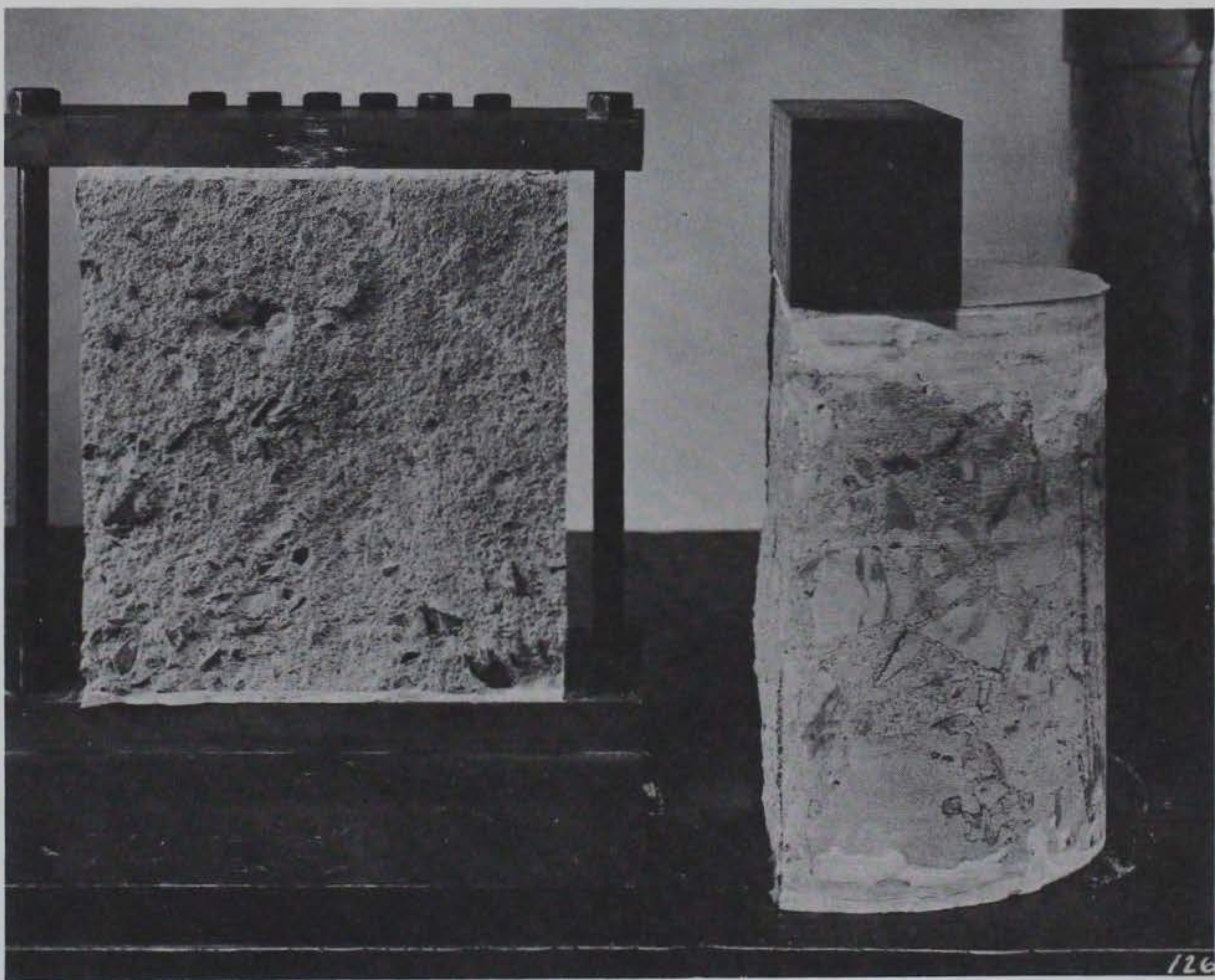

Fig. 4. Shear specimen after testing

b. Flexural strength test of cylindrical specimens using third-point loading. This test method was similar to Method CRD-C 16 except that cylindrical instead of rectangular

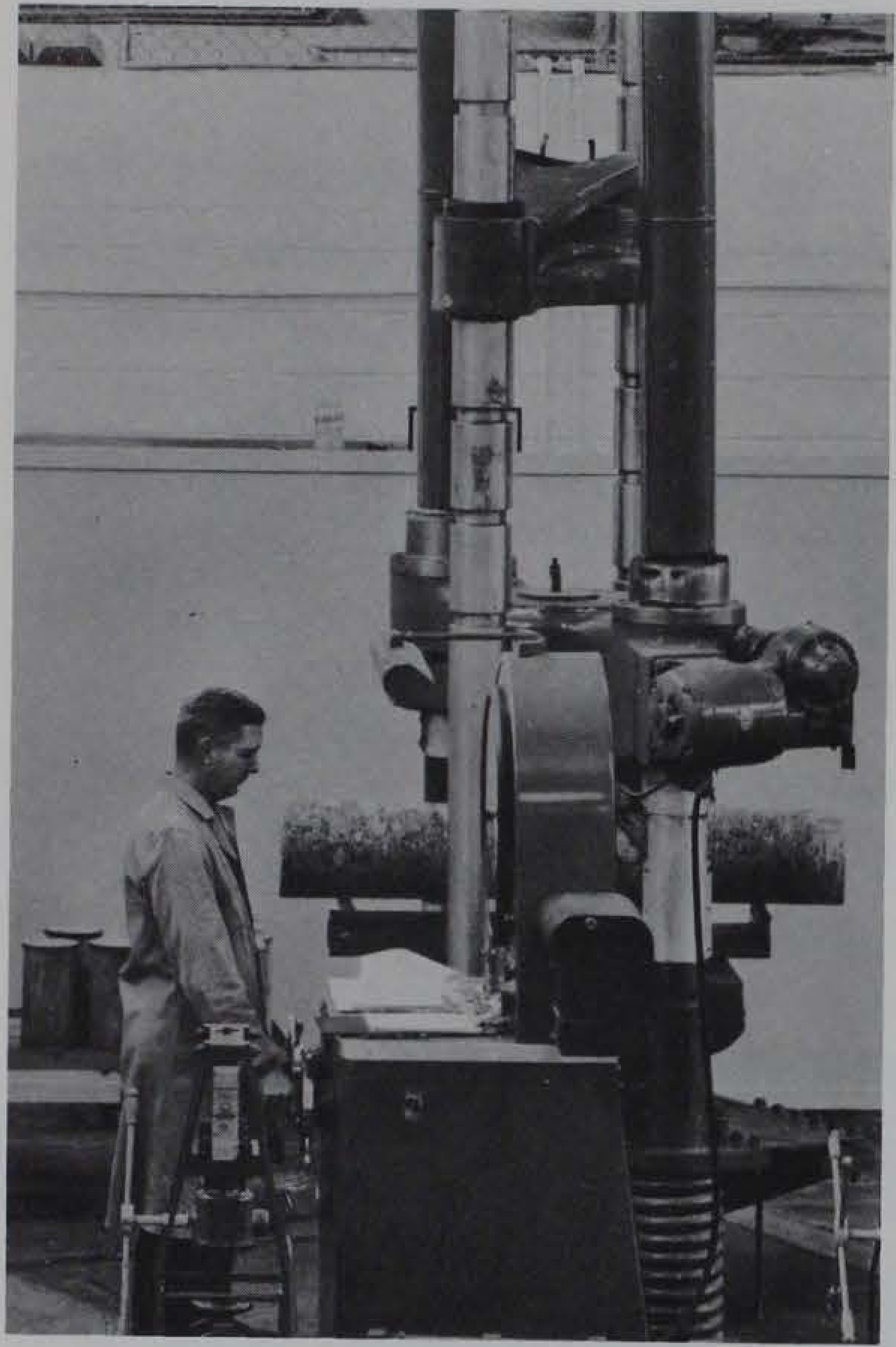

Fig. 5. Specimen in testing machine for flexural test

specimens were used (fig. 5). The load was applied at a rate of 150 psi per min, and the flexural strength was calculated using the formula shown below.

$$R' = \frac{16PL}{3\pi D^3}$$

where

R = modulus of rupture, psi

P = maximum applied load indicated by the testing machine, lb

L = span length, in.

D = diameter of specimen, in.

17. All strength tests of the cores were made when the specimens from the second lift were approximately 370 days old; the concrete in the lower lift was then approximately 400 days old.

PART III: DISCUSSION OF TEST RESULTS

18. The results of each individual test for strength in shear, tensile splitting, flexure, and compression are presented in tables 3 and 4. These data are included for record purposes only, because the large range in test values for each of the tests prevents valid comparisons between individual results for different methods of joint preparation. However, it is believed that the average values, which are also shown in tables 3 and 4, indicate consistent trends and can be used to draw conclusions.

19. As stated earlier, several of the joint cores designated for tensile splitting were tested in shear because the joint plane was off-center. Therefore, because of the sparsity of the tensile splitting data, they were not considered in the analysis.

Effect of Dry Versus Wet Surface

20. The effect on joint strength of allowing the surface of the hardened concrete to dry before the new concrete was placed, as compared with placement on a wet surface, is shown in the following tabulation (values taken from table 3):

Block Quarter	Surface Treatment	Condition of Joint Plane	Strength of Joint, psi	
			Shear	Flexure
A3	None	Dry 62 days, wet 18 hr	340	440
A1	None	Dry 62 days	405	285
Ratio, dry to wet			1.2	0.6
A4	Mortar, thick	Dry 62 days, wet 18 hr	395	385
A2	Mortar, thick	Dry 62 days	335	345
Ratio, dry to wet			0.8	0.9

If only the shear data are considered, when mortar was used, wet surfaces showed higher strength; when mortar was not used, dry surfaces showed higher strength. The highest average value of the shear test results when the surface was dry agrees with the previous studies[2] and with the findings of Waters.[4]

Effect of Mortar Between Lifts

21. The average data relating the effect on joint strength of a layer of thick mortar between the hardened lift and the fresh concrete are tabulated below (complete data are given in table 3).

Block Quarter	Surface Treatment	Condition of Joint Plane	Strength of Joint, psi	
			Shear	Flexure
A4	Mortar	Wet	395	385
A3	None	Wet	340	440
Ratio, no mortar to mortar			0.9	1.1
A2	Mortar	Dry	335	345
A1	None	Dry	405	285
Ratio, no mortar to mortar			1.2	0.8

These data indicated that in one test the mortar gave the best result and in the other test the best result was obtained without mortar. These findings do not completely agree with those of the previous laboratory work[2] in which the absence of mortar slightly increased the strengths when the surface was wet. However, the data indicate no definite superiority of joints made with mortar, which agrees with the findings of Wuerpel.[5]

Effect of Prolonged Drying of Lower Joint Surface

22. The effect of allowing the joint to dry 62 days as compared with allowing it to dry 1 day or less is shown in the tabulation below (see tables 3 and 4 for complete data).

Block Quarter	Surface Treatment	Condition of Joint Plane	Strength of Joint, psi	
			Shear	Flexure
A2	Mortar, thick	Dry 62 days and broomed	335	345
C1	Mortar, thick	Dry 1 day and broomed	375	360
Ratio, 1 day to 62 days drying			1.1	1.0
A4	Mortar, thick	Dry 62 days, wet 18 hr, and broomed	395	385
B1	Mortar, thick	Wet additional 12 hr and broomed	430	370
Ratio, 0 to 62 days drying			1.1	1.0

These data indicate that there was no appreciable difference between joint strength after 1 day or no days drying and after 62 days drying of the joint surface.

Effect of Broomed Versus Flowed Mortar

Wet joint surfaces

23. The effect on joint strength of mortar vigorously broomed versus mortar flowed onto wet joint surfaces is shown below.

Block Quarter	Surface Treatment	Condition of Joint Plane	Strength of Joint, psi Shear	Strength of Joint, psi Flexure
B3	Mortar, thick	Wet and flowed	425	320
B1	Mortar, thick	Wet and broomed	430	370
Ratio, wet, broomed to flowed			1.0	1.2
B4	Mortar, thin	Wet and flowed	400	485
B2	Mortar, thin	Wet and broomed	560	470
Ratio, wet, broomed to flowed			1.4	0.9

Apparently there was no appreciable difference between the broomed and flowed application of the mortar on the wet joint surfaces.

Dry joint surfaces

24. The effect on joint strength of mortar vigorously broomed versus mortar flowed onto dry joint surfaces is shown below.

Block Quarter	Surface Treatment	Condition of Joint Plane	Strength of Joint, psi Shear	Strength of Joint, psi Flexure
C3	Mortar, thick	Dry and flowed	355	415
C1	Mortar, thick	Dry and broomed	375	360
Ratio, dry, broomed to flowed			1.1	0.9
C4	Mortar, thin	Dry and flowed	570	460
C2	Mortar, thin	Dry and broomed	545	485
Ratio, dry, broomed to flowed			1.0	1.1

Apparently there was no appreciable difference between broomed and flowed application of the mortar on the dry joint surfaces.

Effect of Thick Versus Thin Mortar

Wet joint surfaces

25. The effect of thick and thin mortar characteristics on wet surfaces is shown in the tabulation below.

Block Quarter	Surface Treatment	Condition of Joint Plane	Strength of Joint, psi	
			Shear	Flexure
B1	Mortar, thick	Wet and broomed	430	370
B2	Mortar, thin	Wet and broomed	560	470
Ratio, thin to thick mortar, wet and broomed			1.3	1.3
B3	Mortar, thick	Wet and flowed	425	320
B4	Mortar, thin	Wet and flowed	400	485
Ratio, thin to thick mortar, wet and flowed			0.9	1.5

These data indicate that there is a very slight advantage in the use of thin mortar on wet joint surfaces

Dry joint surfaces

26. The effect of thick and thin mortar characteristics on dry surfaces is shown in the data below.

Block Quarter	Surface Treatment	Condition of Joint Plane	Strength of Joint, psi	
			Shear	Flexure
C1	Mortar, thick	Dry and broomed	375	360
C2	Mortar, thin	Dry and broomed	545	485
Ratio, thin to thick mortar, dry and broomed			1.5	1.3
C3	Mortar, thick	Dry and flowed	355	415
C4	Mortar, thin	Dry and flowed	570	460
Ratio, thin to thick mortar, dry and flowed			1.6	1.1

These data indicate that there is a very slight advantage in the use of thin mortar on dry surfaces.

Relative Strength of Joints

27. An analysis was made of only the flexural and shear data from tables 3 and 4, and the results are shown in table 5. Relative results were compared with directly comparable results of control tests (see paragraph 12); therefore, in some cases only the results of two tests were used.

28. An analysis of the data in table 5 is shown below.

Surfaces of Lower Lift			Relative Strength of Joint as % of Strength of Concrete				
			No	Thick Mortar		Thin Mortar	
Condition	Age	Strength	Mortar	Broomed	Flowed	Broomed	Flowed
Dry	Old	Flexure	74	78	--	--	--
		Shear	71	71	--	--	--
		Avg	72.5	74.5	--	--	--
	Young	Flexure	--	72	88	90	86
		Shear	--	56	59	90	97
		Avg	--	64	73.5	90	91.5
Wet	Old	Flexure	83	94	--	--	--
		Shear	67	59	--	--	--
		Avg	75	76.5	--	--	--
	Young	Flexure	--	96	64	85	94
		Shear	--	66	64	79	62
		Avg	--	81	64	82	78

29. The strongest joint in flexure was obtained with thick mortar broomed onto a wet surface of young concrete. The strongest joint in shear (with a value of 97 percent) was obtained with thin mortar flowed on a dry surface of young concrete; this joint was also strongest when the average relative strengths in flexure and shear were taken together.

30. For old dry or old wet concrete the two conditions tested showed only a small difference in joint strength. For young dry concrete the condition of flowed thin mortar was strongest, as noted in paragraph 29 above. For young wet concrete the broomed thin and thick mortar gave maximum strength, but there was a large difference between relative flexural and relative shear strengths. The strength of joints in young concrete without mortar was not studied in this investigation.

31. The weakest joints were those made with thick mortar flowed on young wet concrete and broomed onto young dry concrete. These had an average relative strength of 64 percent; all of the other ten conditions studied had average relative strengths in excess of 72 percent.

32. The data in tables 3 and 4 for flexural and shear strengths were subjected to statistical analysis. The calculated standard deviations and 95 percent confidence limits are given in table 5.

PART IV: CONCLUSIONS

33. As shown in table 5, there are no significant differences in the effectiveness of any of the various joint treatments investigated in this program. Since in some conditions the test results tended to favor one type of joint treatment but in other conditions favor another type of joint treatment, and since the volume of available data was rather limited, it may be concluded that there are no significant differences in the effectiveness of the various treatments investigated in this program. Therefore, within the limits of the data presented, the most economical joint treatment is as effective as any that are more costly.

REFERENCES

1. U. S. Army Engineer Waterways Experiment Station, CE, Handbook for Concrete and Cement, with quarterly supplements. Vicksburg, Mississippi, August 1949.

2. __________, Investigation of Methods of Preparing Horizontal Construction Joints in Concrete. Technical Memorandum No. 6-518, Vicksburg, Mississippi, July 1959.

3. U. S. Army, Office, Chief of Engineers, Standard Guide Specifications for Concrete. CE-1401.01, October 1953, pp 6-7.

4. Waters, T., "A study of the tensile strength of concrete across construction joints." Magazine of Concrete Research (December 1954), pp 151-153.

5. Wuerpel, Charles E., "Tests of the potential durability of horizontal construction joints." Proceedings, ACI Journal, vol 35 (January 1939), pp 181-186.

Table 1

Results of Chemical and Physical Tests of

Type II Portland Cement (RC-474)

Test	Results
Chemical Data	
SiO_2, %	22.15
Al_2O_3, %	4.20
Fe_2O_3, %	3.31
CaO, %	62.96
MgO, %	3.06
SO_3, %	2.00
Ignition loss, %	1.15
Insoluble residue, %	0.36
Na_2O, %	0.20
K_2O, %	0.39
Total alkalies as Na_2O, %	0.46
C_3S, %	49.0
C_3A, %	6.0
Heat of hydration, cal/g	
7 days	75.8
28 days	87.0
Physical Data	
Specific gravity	3.15
Air permeability fineness, sq cm/g	3447
Normal consistency, water, %	27.2
Initial set, Gillmore, hr:min	4:00
Final set, Gillmore, hr:min	6:00
Autoclave expansion, %	0.07
Air content, %	7.7
Compressive strength, psi	
3 days	2502
7 days	3769
28 days	5215

Table 2

Physical Properties and Gradings of

Crushed Limestone Aggregates

Test	Fine VICKS-3 MS(16)A	Coarse, Sieve Size No. 4 to 3/4-in. VICKS-3 G-1(23)	3/4- to 1-1/2-in. VICKS-3 G-1(22)	1-1/2- to 3-in. VICKS-3 G-1(24)	3- to 6-in. VICKS-3 G-1(18)
		Physical Properties			
Bulk specific gravity, saturated surface dry	2.66	2.68	2.68	2.70	2.71
Absorption, %	1.1	0.9	0.9	0.5	0.5
		Percent Passing Standard Sieves			
Sieve:					
6-in.					100
5-in.					77
4-in.					37
3-in.				100	10
2-in.				44	2
1-1/2-in.			100	12	
1-in.			53		
3/4-in.		100	7		
1/2-in.		83	2		
3/8-in.		51			
No. 4	100	6			
8	88				
16	63				
30	35				
50	19				
100	11				

Table 3

Effect on Joint Strength of Use or Nonuse of Thick Grout Broomed onto Wet or Dry Lower Joint Surface*

Block A

Batch	Concrete: Air Content %	Concrete: Slump in.	Concrete: As-Mixed Temp, °F Concrete	Concrete: As-Mixed Temp, °F Air	Concrete: Bleeding, %		Concrete: Compressive Strength, psi 28 d	Concrete: Compressive Strength, psi 400 d	Block Quarter	Joint Condition		Strength, psi, of Cores from Block: Flexure Lift 1st	Flexure Lift 2nd	Flexure Joint	Tensile Lift 1st	Tensile Lift 2nd	Tensile Joint	Shear Lift 1st	Shear Lift 2nd	Shear Joint
Lift 1									Joint Not Grouted											
1	3.6	2-3/4	63	72	5.8		2210	3430	A3	Wet		530	430	230	315	260	245	610	515	420
							1790	2790				---	---	---	390	215	320	540	435	320
							1930	3270				570	590	650	350	---	320	530	400	285
						Avg	1980	3160			Avg	550	510	440	350	240	295	560	450	340
3	4.5	4-1/4	63	72					A1	Dry		185	365	305	305	320	**	500	500	555 410
												430	610	230	395	200	**	615	605	310 345
8	4.2	2	65	74								360	375	320	---	170	**	510	695	415 405
											Avg	325	450	285	350	230		540	600	405
Lift 2									Joint Grouted											
1	4.5	2-3/4	50	58	3.4		2130	2680†	A4	Wet		380	405	290	320	325	---	740	905	335
							1930	3430†				335	400	385	295	365	**	690	635	385 240
							2570	4070†				475	460	485	245	280	**	560	535	400 605
						Avg	2210	3390			Avg	400	420	385	285	325		660	690	395
3	5.8	3	51	59					A2	Dry		355	515	395 315	300	315	305	525	475	325
												535	520	360	335	330	360	415	485	365
8			52	63								300	425	305	280	230	340	420	475	320
											Avg	400	490	345	305	290	335	455	480	335

* Lower joint surface cleaned on all block areas.

** Subjected to shear test because joint plane was off-center in core.

† Tested at 370 days age.

Table 4

Effect on Joint Strength of Thick and Thin Grout

Applied by Different Methods to Wet and Dry Lower Joint Surfaces

Blocks B and C

Concrete								Block	Grout	Strength, psi, of Cores from Blocks								
Batch	Air Content %	Slump in.	As-Mixed Temp, °F Concrete	As-Mixed Temp, °F Air	Bleeding, %	Compressive Strength, psi 28 d	Compressive Strength, psi 400 d	Quarter	Type	Flexure Lift 1st	Flexure Lift 2nd	Flexure Joint	Tensile Lift 1st	Tensile Lift 2nd	Tensile Joint	Shear Lift 1st	Shear Lift 2nd	Shear Joint
Block B, Wet Lower Joint Surface																		
Lift 1								Grout Applied by Flowing										
1	4.2	2-1/4	45	48	2.6	2580	4300	B3	Thick	510	490	265	---	---	*	655	565	400 435
						2400	4430			735	405	265	---	---	*	740	650	415 510
						2300	2930			365	---	420	---	---	*	750	590	335 445
						Avg 2430	3890			Avg 535	450	320				715	600	425
3	3.8	2	47	48				B4	Thin	550	695	575	---	---	*	660	610	510 335
										470	385	380	---	---	*	620	770	435 420
8	5.3	2-3/4	47	47						470	510	495	---	---	*	740	440	455 240
										Avg 495	530	485				675	605	400
Lift 2								Grout Applied by Brooming										
1	3.8	3			2.1	2140	2950†	B1	Thick	365	385	420	330	420	235	675	670	450
						2230	3570†			---	470	345	335	365	220	620	520	410
						2390	3390†			305	405	345	305	350	220	740	665	430
						Avg 2250	3300			Avg 335	420	370	325	380	225	680	620	430
4	3.8	2						B2	Thin	875	590	495	---	---	*	740	715	555
										405	670	495	400	330	255	610	675	685**
8	5.0	1-3/4								345	430	420	420	405	195	680	820	435
										Avg 540	565	470	410	370	225	675	735	560
Block C, Dry Lower Joint Surface																		
Lift 1								Grout Applied by Brooming										
1	5.0	3	70	68	2.2	2410	3460	C2	Thin	510	570	495	---	---	*	535	630	740 575
						2270	3450			---	570	535	---	---	*	690	590	515 545
						2590	3550			570	510	420	---	---	*	720	475	275 610
						Avg 2420	3490			Avg 540	550	485				650	565	545
3	4.5	2-1/2	71	78				C1	Thick	530	530	230 480	---	---	*	720	570	705 140
										530	450	305	---	---	*	750	600	440 180
8	5.0	2	72	78						405	530	420	455	300	315	765	640	405
										Avg 490	505	360	455	300	315	745	605	375
Lift 2								Grout Applied by Flowing										
1	3.0	1-1/2			2.9	2490	4000†	C4	Thin	430	590	575	280	275	265	685	490	415
						2490	3750†			590	530	380	360	395	275	720	475	515
						2040	2800†			510	550	420	---	---	*	535	610	675 665
						Avg 2340	3520			Avg 510	555	460	320	335	270	645	525	570
4	3.2	2-1/2						C3	Thick	365	630	380	---	---	*	535	605	550 310
										365	470	495	---	---	*	735	610	310 190
7	5.7	2-3/4								430	550	375	---	---	*	625	520	385 375
										Avg 385	550	415				630	580	355

* Subjected to shear test because joint plane was off-center in core.
** Broke around large rock.
† Tested at 370 days age.

Table 5

Strength of Horizontal Construction Joints, Mass Concrete

			Flexure					Shear				
			Average			Joint		Average			Joint	
Block Quarter	Condition of Joint Plane	Mortar and Application	Control psi	Joint psi	Relative %	Standard Deviation psi	95% Confidence Interval psi	Control psi	Joint psi	Relative %	Standard Deviation psi	95% Confidence Interval psi
Cured 14 Days, 1st Lift Dried 62 Days Before 2d Lift Cast												
A4	Wet 18 hr	Thick, broomed	410	385	94	97	191-579	675	395	59	133	129-661
A2	Dry	Thick, broomed	445	345	78	42	261-429	470	335	71	25	285-385
A3	Wet 18 hr	None	530	440	83*	297	0-1034	505	340	67	77	186-494
A1	Dry	None	385	285	74	48	189-381	570	405	71	84	237-573
Wet, 1st Lift 14 Days Old When 2d Lift Cast												
B1	Wet additional 12 hr	Thick, broomed	380	370	96	43	284-456	650	430	66	20	390-470
B3	Wet additional 12 hr	Thick, flowed	500	320	64	89	142-498	660	425	64	90	245-605
B2	Wet additional 12 hr	Thin, broomed	550	470	85	43	384-556	705	560	79	125	310-810
B4	Wet additional 12 hr	Thin, flowed	515	485	94	98	289-681	640	400	62	96	208-592
Dry, 1st Lift 14 Days Old When 2d Lift Cast												
C1	Dry 24 hr	Thick, broomed	500	360	72	112	136-584	675	375	56	227	0-829
C3	Dry 24 hr	Thick, flowed	470	415	88	68	279-551	605	355	59	119	117-593
C2	Dry 24 hr	Thin, broomed	545	485	90	58	369-601	605	545	90	151	243-847
C4	Dry 24 hr	Thin, flowed	535	460	86	103	254-666	585	570	97	125	320-820

Note: Relative results are based on the average of three tests except where shown differently.
* Based on the average of only two tests.