Shearing Strength of Concrete

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PREFACE.

In this age of building and design, it is necessary that careful investigations and research be made as to the strength of materials that are used in construction. The methods for testing iron, steel, and wood have reached a high standard. The compressive and tensile strength of concrete have been well determined, but few series of tests have been made to determine its resistance to shear. Some shear tests have shown its ultimate shearing strength as low as 10%; others, as high as 97% of its compressive strength. The difference in these values is due to the different materials used in the concrete and the various methods of testing. At present there is a diversity of opinion as to its true shearing strength.

Shear may be defined as the action of two equal and opposed forces whose lines of action lie in adjacent parallel planes. For example, shearing stresses are produced in concrete beams, floor slabs, window lintels, foundation footings, bridge seats of bridge piers. In general, most classes of masonry construction are subjected to shearing stresses. As the shearing strength of concrete is lower than its compressive strength, provision must be allowed for it in concrete masonry design. But little reliable data for the shearing strength of concrete can be found in engineering records; it is necessary that valid values be derived. The purpose of this research made at the University of Kansas was to obtain values of shear that might be applied in the design of masonry.

R. F. Gallup.
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BIBLIOGRAPHY.

Bauschanger. In 1878, Herr Bauschanger conducted a series of tests on parts of concrete prisms that had been broken by flexure. He found concrete two years old to have an ultimate shearing strength of 1.5 times its tensile strength.

Falk. Falk gives the shearing of 1:3:5 concrete from 65# to 314# per square inch. From Falk's Cements and Mortars, page 95.

Feret. M. Feret's tests indicated the shearing value of concrete to be from 46% to 97% of its compressive strength. From Taylor and Thompson's Concrete, Plain and Reinforced, page 136.

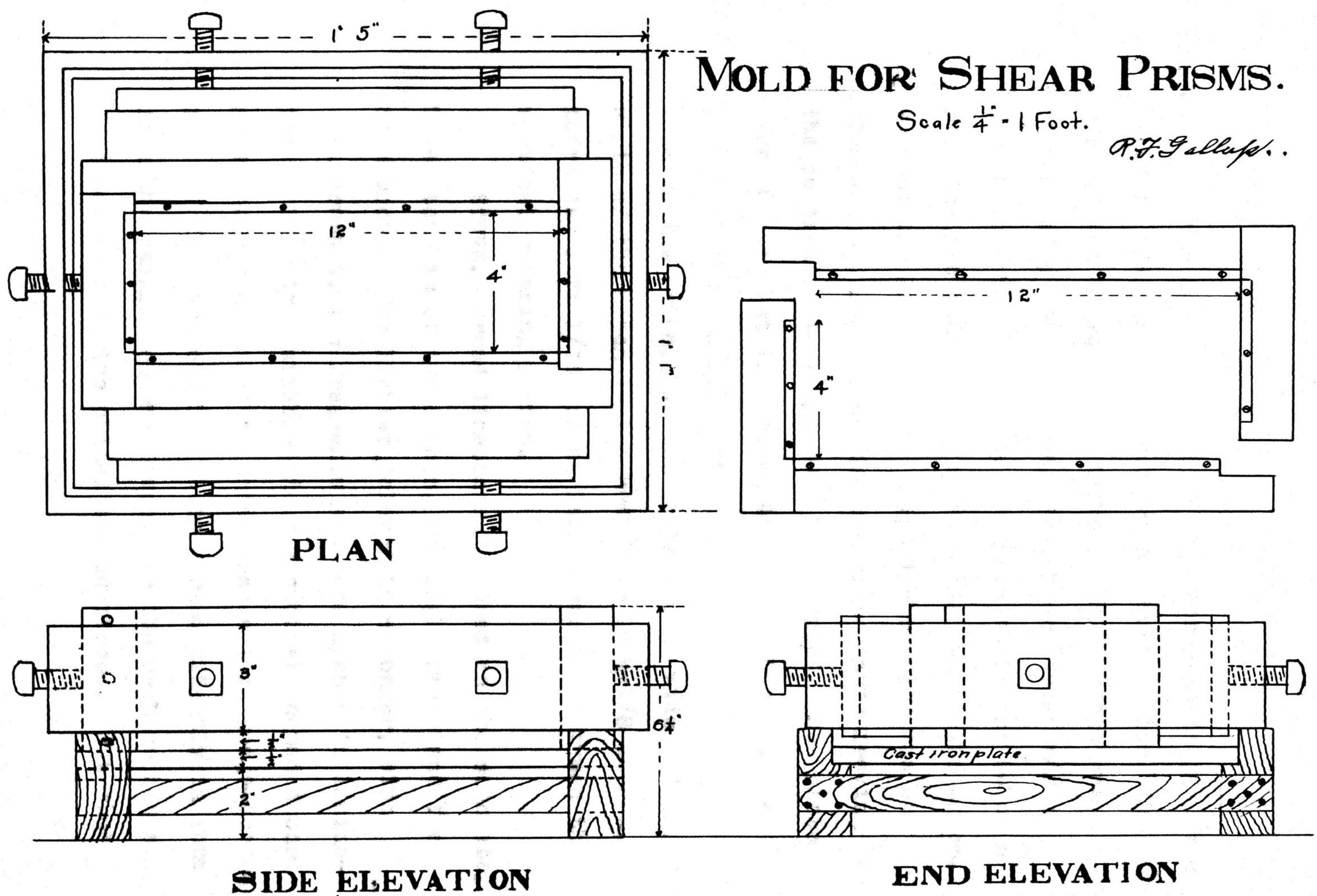
Zipkes. Zipkes found the shearing strength of concrete fifty days old to be 357# per square inch. From <u>Beton und Eisen,</u> January, 1906, page 15.

Prof. Swain. Recent shear tests on concrete have made under the general direction of Prof. Swain of the Massachusetts Institute of Technology, values are given in tables 12 and 13, pages 32 and 33.

Prof. Arthur N. Talbot. Prof. Arthur N. Talbot of the University of Illinois has found the shearing strength of concrete somewhat less than values as found by Prof. Swain. These values are given in tables 14 and 15, page

APPARATUS AND MATERIALS USED IN THE TESTS.

In making up the apparatus, considerable time was required. It consisted of stone screens, a water-tight box for determining percentage of voids in the aggregate, moulds and shears for testing the prisms. The rock screens are made of wire netting stapled to wooden frames, 24"x36"x4" deep. The coarser screen has 3/4" diamond mesh, and the smaller, 1/4" square mesh. A 1" square mesh was desired in place of the 3/4" diamond, but could not be obtained. The box for determining the percentage of voids was a water-tight galvanized iron box 12"x12" and 14" deep. A depth of one foot was graduated on the inside of the box and tested for a cubic foot by pouring in 62.5 pounds of water and seeing that the surface of the water coincided with the graduation. Wooden moulds lined with galvanized iron were made, in which to mould the prisms. The moulds were rectangular in shape and 4"x4"x12" inside dimensions. See Plate 1, page 6 Each mould was made of two sections and was held in place by set screws in iron clamping frames. The clamping frames



Mold for Shear Prisms.
Scale 1/4" = 1 Foot.
R. F. Gallup.
1' 5"
12"
4"
1' 1"
PLAN
12"
4"
3"
6 1/4"
2"
SIDE ELEVATION
Cast iron plate
END ELEVATION

Plate I

and surface plates were made from scrap castings. The drawings will show without further description, the arrangement of molds and frames. This design was found fairly satisfactory. The shears were made of cast iron. The bed-plate was faced above and below as were the two plates that clamped the top of the prism. A notch one inch deep by 4-1/8 inches wide was cut from the top surface of the bed plate, thus leaving the central part of the beam unsupported. See plate 2, page 8 A cast iron block 4"x2-1/2"x7" was placed on top of the central part of the beam to transmit the load to the prism. As the block was 4" wide and the width of the notch in the bed plate is 4-1/8 inches, there was left 1/16 of an inch clearance between the vertical shearing planes.

STONE. Oread limestone was used in the concrete. This stone is of two colors, the light brown and the dark brown. The lighter colored is stronger, since when crushed, its fragments are less liable to lamination. This is desirable since a cubical shaped stone gives more resistance to shear than a thin wedge-shaped piece. The hand crushed stone varies slightly in form from the machine crushed stone, as the machine has a tendency to form the chisel shaped pieces. But when

SHEARING MACHINE

Scale 4" = 1 Foot.

R.F. Galley.

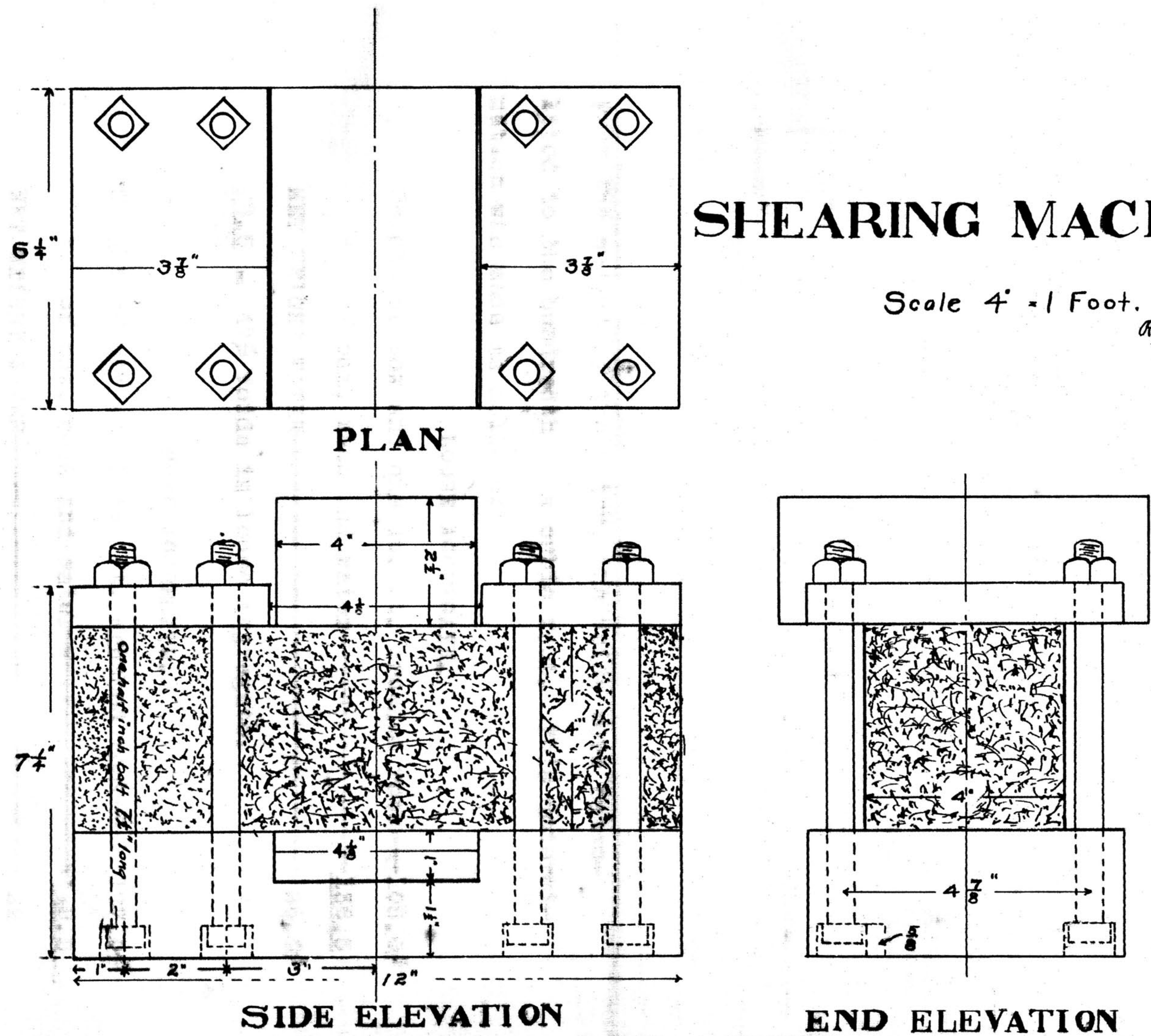


Plate 2

the two samples were compared, the difference was not considered sufficient to warrant the extra work of crushing by hand.

The limestone is carboniferous and is slightly crystalline. It exists in strata of varying thickness but is of too small dimensions for massive masonry. Table I on the opposite page gives the tests and analyses of the Oread limestone.

All the crushed rock was screened through a 3/4 inch "diamond mesh" and retained on a 1/4 inch sieve. The percentage of voids in the crushed rock was found by weighing the water required to fill them, the rock being first dampened to make allowance for absorption. From the weight of the water, the voids were calculated to the hundredth of a cubic foot. This determination was made as follows:

LOOSE AGGREGATE.

Weight of box and one cu. ft. crushed rock——108.0#

" of box, rock and water——————136.5

NET WEIGHT WATER—————————— 28.5#

$\frac{28.5}{62.5}$ = 47% voids in loose aggregate.

RAMMED AGGREGATE.

Weight of box and 1 cu. ft. crushed rock———127.0#

" of box, rock and water——————149.5

NET WEIGHT WATER—————————— 22.5#

TABLE I. TESTS AND ANALYSES OF OREAD LIMESTONE

COUNTY	FORMATIONS	CRUSHING STRENGTH	WEIGHT PER CU. FT.	SPECIFIC GRAVITY	RATIO OF ABSORPTION	ANALYSES					
						Insoluable matter	Al_2O_3 & Fe_2O_3	Ca CO_3	Mg CO_3	Sulphates	Moisture.
Douglas	Carboniferous	11630	167.6	2.68	.007	3.53	1.07	94.18	1.16	00	00
"	"	10339	166.6	2.67	.01	2.29	1.79	95.02	0.79	"	"
"	"	11038	166.6	2.67	.01	8.02	2.05	88.54	1.29	"	"

$\frac{22.5}{62.5}$ = 36% of voids in aggregate.

The specific gravity of the rock was determined approximately with the same apparatus as was used for the void determination.

Weight of box------------------21.5#

Weight of box and rock--------127.0

WEIGHT OF ROCK---------------105.5#

As the percentage of voids of the aggregate is 36%, the absolute volume of the rock 64 of one cu. ft.

.64x62.5 40# of water displaced by .64 cu. ft. rock

$\frac{105.5}{40}$ 2.64, sp. g. Accurate determinations show the specific gravity as 2.67.

CEMENT. The portland cement used in the concrete was the "Sunflower brand," made by the Kansas Portland Cement Company of Iola, Kansas. The cement tests of Table 2, page. 11 , were made by B. B. Romig of the class of 1907.

SAND. Kaw River sand was used in all concrete. The sand was washed and afterward dried by roasting. Concrete that is mixed with dry roasted sand requires a definite proportion of water for mixing and in turn yields all mixtures of concrete of uniform consistency. All sand was screened through a 1/8 inch mesh screen and all pebbles and gravel retained on this sieve were

No. 2.

TESTS OF PORTLAND CEMENT

TIME OF SET

Initial	38 Min.
Final.	6 Hrs. 15 Min.

SPECIFIC GRAVITY	3.1
SOUNDNESS	O.K.

NORMAL CONSISTENCY.

Neat. —	21½% Water by wt.		
1:1	11 %	"	"
1:2	9½%	"	"
1:3	9%	"	"

TENSILE STRENGTH
Lbs. per sq. in.

Proportions of Cement to sand.	Age. 7 Days	Age 28 Days	Age 60 Days
1:0	685	783	
1:1	525	725	
1:2	425	485	
1:3	270	306	

rejected. The voids in this sand were found to average 35%. The analysis of this sand is given in Table 3, page   Test prisms No.'s 41 and 42 were mixed with fine river sand and No.'s 39 and 40 were mixed with graded river sand in the proportions of:

60% sand retained on No. 20 sieve.
37% " " " No.30 sieve
3% " " " No. 74 sieve.

See tables of comparative values of No.'s 39 and 40, 28 day test with 60 day tests for same mixture.

No 3

SIFTING TEST OF KAW RIVER SAND.

Percentage retained on No 200 Sieve		99.25
" " "	100 "	96.4
" " "	74 "	94.0
" " "	50 "	73.0
" " "	30 "	45.95
" " "	20 "	33.45

Percentage of Voids 34.7

Specific Gravity. 2.65

SIFTING TEST OF STANDARD SAND.

Percentage of Sand retained on No 200 Sieve		100.0
" " "	100 "	100.0
" " "	74 "	100.0
" " "	50 "	100.0
" " "	30 "	99.5

Percentage of Voids 49

Specific Gravity 2.65

Note: Standard sand was used only in tensile tests.

PROPORTIONING THE CONCRETE.

P R O P O R T I O N I N G O F M A T E R I A L S .

There are two methods for proportioning concrete. One is to fix the proportions of the ingredients so that the voids in the aggregate will be filled with mortar and that the cement will fill the voids in the sand. The second method is to adjust the proportions without reference to the percentage of voids in the rock or the sand, as for example, a mixture of concrete 1:2:4 is one part of cement, two parts of sand, and four parts of rock.

The correct proportions are those that make the concrete of maximum density, its density is represented by the total volumes of solid particles contained in a unit volume of concrete (exclusive of the water and air voids.) The elementary volumes in a unit volume of fresh concrete consist of the sum of the absolute volumes of rock, sand, cement, water, and air voids. Taylor and Thompson's test on Plain and Reinforced Concrete gives a very complete discussion in regard to proportioning concrete for maximum density.

Two of the four mixtures were proportioned with reference to the voids, one of the mixtures was figured to fill the voids in the aggregate with a 1:2 mortar, one other was estimated to fill 140% of the voids of the aggregate. These proportions were established as advised in "Barker's Masonary Construction," page 112 c. After having adopted these two proportions, we learned that the proportion as figured to fill 140% of the voids with a rich mortar does not always secure the densest concrete, for the lack of uniformity of the sand and of the aggregate does not necessarily yield a concrete of maximum density.

Two other proportions of concrete were used: 1:3:5 and 1:2:3. The 1:3:5 is used in the building of wing abutments, concrete arch culverts, foundations, and bridge piers, while the 1:2:3 concrete is used in the construction of foundations for high speed engines and vibrating machinery. All of the mentioned masonry constructions are subjected to shearing stresses.

MIXING THE CONCRETE.

The concrete was mixed on a metal storage pan from the cement laboratory. The dry sand and cement were mixed until the mixture was of uniform color. The rock was sprinkled before mixing it with the sand and cement, water was added and the concrete was turned until the aggregate was well covered with mortar. The molds were sponged with oiled waste before filling them. The concrete was tamped continously while the mold was being filled and a final tamping with a cast iron block flushed the projecting aggregate below the upper surface of the prism. The upper side of the prism was trowled down and numbered with a steel stencil. The prisms were numbered consecutively and the numbers recorded. This system of notation was found to be quite satisfactory as there was no chance for error in selecting the test prisms from the the storage tank. The new test prisms were placed on flat glass plates and stored under a damp cloth for two days. The stripping of the molds from the green concrete produced no appreciable distortion but it undoubtedly weakened it, and this in addition to the necessarily dry mixing has shown a lack of uniformity in the tests. All test specimens after two days' storing in air were put under water up to the time of testing.

On account of the lack of enough molds it was necessary to mix the concrete fairly dry as the molds were removed from the prisms about 20 minutes after molding. It was found that when the concrete was mixed with enough water for a "normal consistency" that the new molded prism when unsupported by the mold would fall to pieces.

The percentage of water used in mixing is shown in Table 4, page This percentage represents the ratio of the volume of the water used in mixing to the apparent volume of rammed concrete. A one-pint tin cup was adopted as the unit of volume. One mold was found to hold eight cups of crushed rock. On the basis that the yield of the concrete would be small, eight cups of rock were used in all mixtures, and the sand and cement were proportioned accordingly to the mixture required. In the richer mixtures there was generally a surplus of concrete, while with the lean mixtures when the measure fell short, a small batch of the same proportions was added.

Table 4, page 18 gives the Quantities of Ingredients required for the mixtures of concrete.

As the percentage of voids in the aggregate was found to be .36% the quantities of a 1:2 mortar required to fill the voids has been calculated. 8x.36=2.88

cups of mortar. Therefore 1.44 cups of cement, 2.88 cups of sand, 8.00 rock are required for a mixture as figured to fill the voids in the aggregate. This mixture is in reality a 1:2:5.6 concrete. The tests of two standard mixtures were made with the object to acquire practical tests. The two mixtures 1:3:5 and 1:2:3 are commonly used in construction and it was quite necessary to give them a careful investigation.

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TABLE 4

Quantities of Ingredients required for mixtures of Concrete.

Mixture	Cups of			Percentage of Water by Vol.
	Cement	Sand	Rock	
1:3:5	1.6	4.8	8.00	11.5
1:2:3	2.66	5.32	"	12.0
1:2:5.6	1:44	2.88	"	11.0
1:2:4	2.02	4.03	"	11.5

DESCRIPTION OF TESTS AND VALUES OF SHEAR.

TESTING MACHINE.

The shears were operated with the 100,000 pound Olsen's tension and compression machine in the testing laboratory. Brick No. 34 was the trial test but the rate of application of the load was too great for the machine could not be held under control. A counter shaft was used in connection with the driving shaft of the machine to reduce the rate of loading. The slowest rate of descent of the compression block on the machine as is used for the testing of steel and iron is a rate of .037 inch per minute but with the use of the countershaft the speed was reduced to a rate of .008 of an inch per minute. This rate of loading brought the machine under control and applied an average beam load of 3500 pounds per minute.

PREPARING PRISM FOR TESTING.

When preparing a brick for testing, its number, age and mixture were recorded. All test prisms were placed in the shears in the same relative position as the concrete was placed in the molds. The bottom of the prism that was surfaced with the surfaced plate of the mold was put on the base-plate of the shears, and the shearing block was placed on top of the prism. Plaster of Paris was used to give the test prisms a good bearing surface in the shears. Care was given to plastering the prisms and the shears were well cleaned before bedding each test piece. The stucco was mixed wet. The bottom of the prism was plastered and placed in the shears. By tapping the brick after placing it in the shears, the stucco would ooze from its edges, thus insuring a good uniform bearing. The top of the test piece was plastered and the clamps were brought into place by the bolts.

The prism and the shears were placed in the testing machine and the shearing block was set in a fresh batch of stucco. The center line of the block was placed approximately at the center of the test piece and was immediately centered with a small try square. The centering required much care for equal clearances of 1/16 of an inch between shearing planes is required. When the block was centered a load of nearly 1000# was applied to it and retained until the plaster had set. It was necessary to place the block in the soft plaster in order to secure a uniform distribution of the load to the area in contact. Slow setting Plaster of Paris was made to set in less time by the addition of a small quantity of salt.

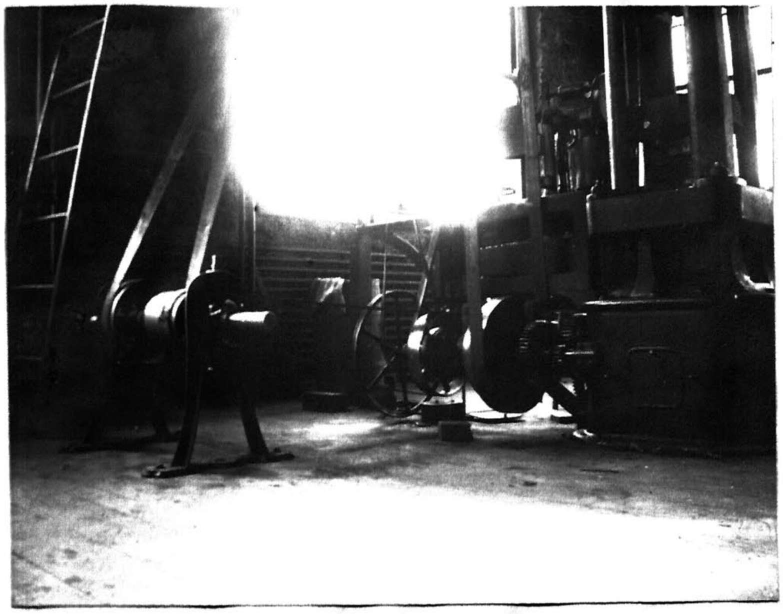
TESTING.

The initial beam readings averaged about 600#. During the test, one minute readings were taken and recorded. The clerk kept close watch of the test prism and noted its behavior while undergoing the test.

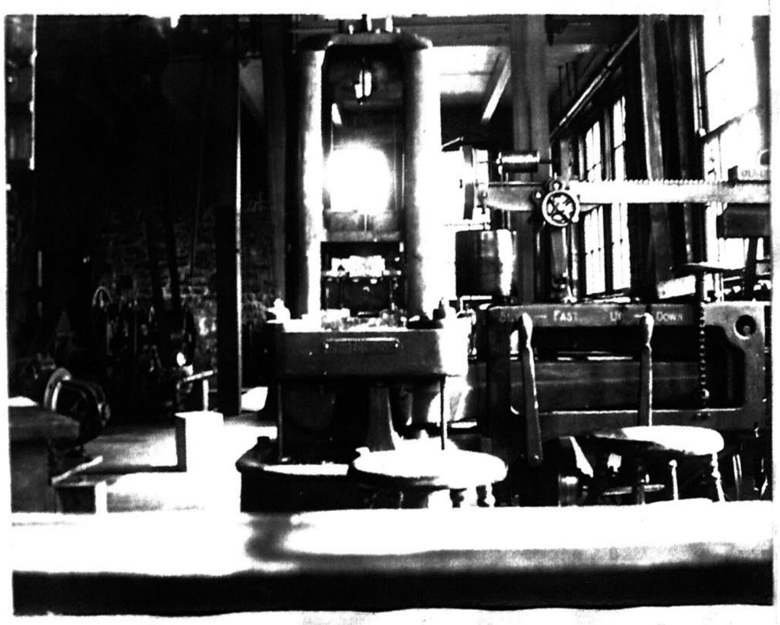
In general, it failed first as a simple beam loaded at the middle. The first sign of failure was generally by a small crack at the bottom of the test piece. This crack generally occurred at about 3/4 of the ultimate strength of the concrete. At this point of failure the beam of the testing machine generally responded by a slight poising, but soon picked up and withstood the same rate of loading as before the crack occurred. Soon after the crack appeared at the middle of the beam, small diagonal lines appeared near the vertical shearing plane and ran outward and downward at an angle of 45 degrees with the vertical plane. The first of these cracks generally occurred at the inner edge of the shear bed plate and gradually increased in number until the two shearing planes were pierced from top to bottom with small diagonal lines. In some tests of the lean concrete no diagonal cracks appeared but the concrete sheared vertically. When such failures occurred as last mentioned, no poising of the beam of the testing machine was noticed before the ultimate failure of the prism. The elastic limit of the concrete was sought but could not satisfactorily be determined. Table 5, page 22, is a copy of the data as taken during the tests.

Tables 6, 7 and 8 give the shearing values obtained from the shear tests made at Kansas University.

Table No. 9, page, gives the summary of the shear tests made at Kansas University.



ARRANGEMENT OF BELTING FOR REDUCTION OF SPEED



SPECIMEN IN TESTING MACHINE

TABLE 5. SHOWING DATA TAKEN IN BREAKING BRICKS.

READING NO	TIME	BEAM READING	REMARKS
1	10 - 02	1200	BRICK NO. 4
2	03	4700	1:3:5 Mixture
3	04	8700	4 Months Old.
4	05	11700	
5	06	17300	
6	07	22900	
7	08	28600	
8	09	35100	
9	10	42100	
10	11	48600	
11	12	54000	
12	13	60000	First Crack
13	14	66000	
14	15	69300	
15	16	73000	Maximum Strength
16	17		Failure
			$\frac{73000}{32} = 2280$ #/in²

TABLE 6.

RESULTS OF SHEAR TESTS MADE AT KANSAS UNIVERSITY.

Reference Number	Kind of Concrete	Method of Storing	Age in Days	Sq. in. Shearing Area	Load in Pounds		Shearing Strength Lbs. Per sq. in.	Rate of Loading Lbs. sq. in. Per min.
					First Crack	Ult. Strength		
35	1:3:5	Water	28	32.0		31500	984	158
36	1:3:5	"	"	"	21400	28840	901	60.9
34	1:3:5	"	"	"	21300	23640	727	72.7
38	2:4:6	"	"	"	49400	50800	1590	155.0
37	2:4:6	"	"	"	52000	57000	1781	144.0
41	1:2:4	"	"	"	40800	42000	1312	155.0
42	1:2:4	"	"	"	44300	50000	1562	152.0
39	1:2:5.6	"	"	"	33000	34000	1062	133.3
40	1:2:5.6	"	"	"	38000	39200	1225	152.0

TABLE 7.

RESULTS OF SHEAR TESTS MADE AT KANSAS UNIVERSITY.

Reference Number	Kind of Concrete	Method of Storing	Age in Days	Shearing Area Sq. ins.	Load in Pounds		Shearing Strength Lbs. Per sq. in.	Rate of Loading Lbs. sq. in Per min
					First Crack	Ult. Strength		
13	1:2:4	Water	60	32.0	43800	52500	1641	113
14	"	"	"	"	26700	32000	1000	112
15	"	"	"	"	39000	39000	1220	116
16	"	"	"	"	26750	27400	856	104
24	1:2:5.6	"	"	"	38300	38300	1197	134
23	"	"	"	"	46000	47000	1469	147
22	"	"	"	"	37900	41000	1281	142
21	"	"	"	"	48400	51600	1612	147
32	1:3:5	"	"	"	31000	31000	972	100
30	"	"	"	"	35400	36800	1150	144
29	"	"	"	"	48600	52700	1647	165
31	"	"	"	"	34800	34800	1088	145
6	2:4:6	"	90	"	48450	85000	2656	156
7	"	"	"	"	45880	73000	2281	151
5	"	"	"	"	32200	69000	2156	133
8	"	"	"	"	38800	53000	1656	137

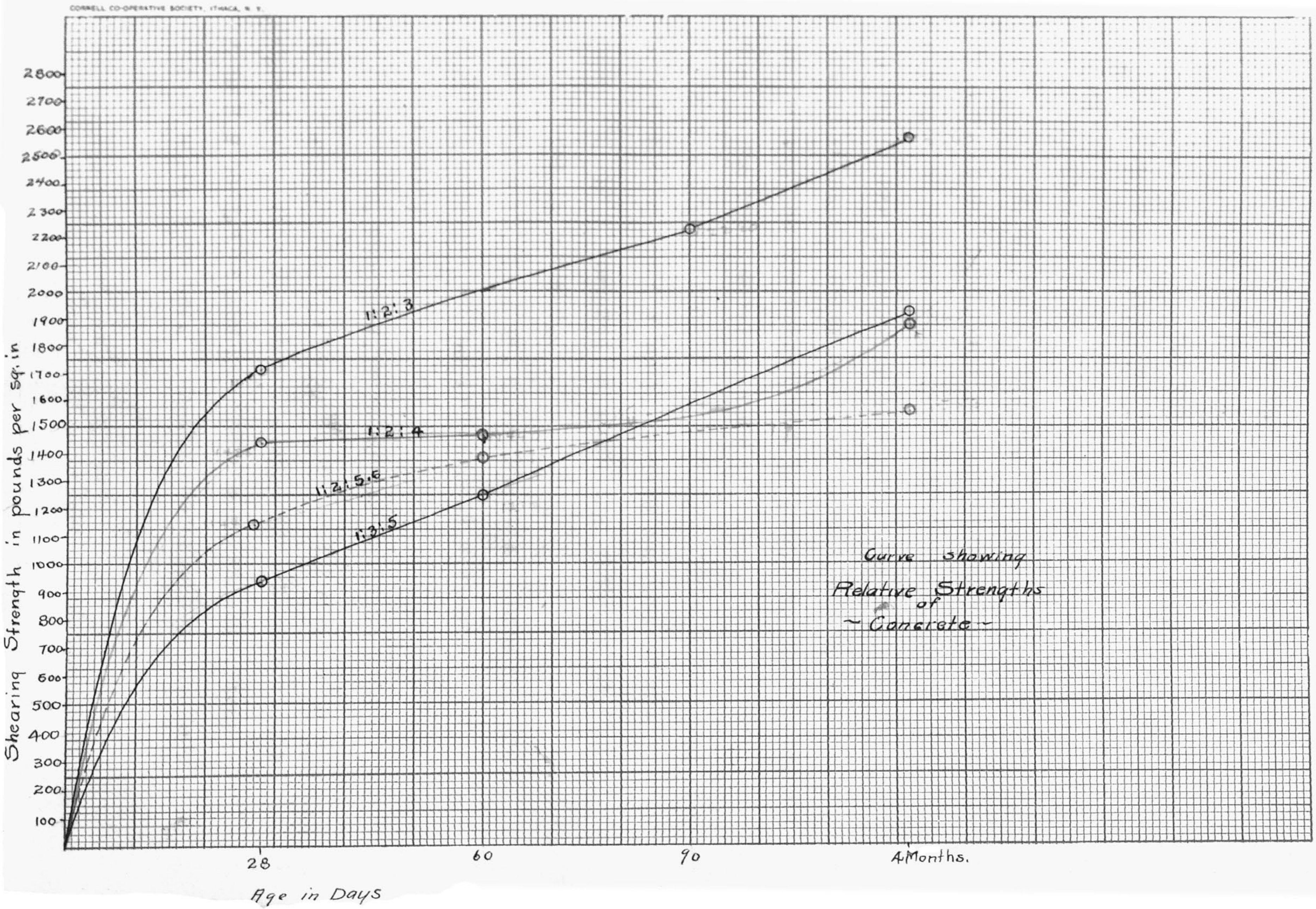
TABLE 8.

RESULTS OF SHEAR TESTS MADE AT KANSAS UNIVERSITY.

Reference Number	Kind of Concrete	Method of Storing	Age in Days.	Shearing Area Sq. ins.	Load in Pounds. First Crack.	Load in Pounds. Ult. Strength	Shearing Strength Lbs. Per Sq. in.	Rate of Loading. Lbs per Sq. in per min.
1	1:3:5	Water	4 Months	32.0	57600	57600	1796	150
2	"	"	"	"	48000	55000	1720	156
3	"	"	"	"	58000	61000	1905	147
4	"	"	"	"	60000	73000	2280	163
9	2:4:6	"	"	"	72500	75100	2350	
10	"	"	"	"	80000	82300	2570	
11	"	"	"	"	81300	81300	2545	
12	"	"	"	"		91200	2850	
17	1:2:5.5	"	"	"	51200	56800	1780	120
18	"	"	"	"	37000	42300	1325	125
19	"	"	"	"	25600	26000	810	82
20	"	"	"	"	30000	32800	1025	101
25	1:2:4	"	"	"	52200	55000	1720	127
26	"	"	"	"	61000	65500	2050	173
27	"	"	"	"	56500	59600	1860	135
28	"	"	"	"	45000	50400	1575	125

Note!

The proportions 1:2:4 were figured to fill 100% of voids of aggregate
" " 1:2:5.55 " " " " 140% " " " "


CORNELL CO-OPERATIVE SOCIETY, ITHACA, N. Y.
Shearing Strength in pounds per sq. in
2800
2700
2600
2500
2400
2300
2200
2100
2000
1900
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
1:2:3
1:2:4
1:2:5.6
1:3:5
28
60
90
4 Months.
Age in Days
Curve showing
Relative Strengths of
~ Concrete ~

COMPARISON OF VALUES AND THE DIFFERENT METHODS OF TESTING FOR THE SHEARING STRENGTH OF CONCRETE.

FERET:--

M. R. Feret, Director of the Laboratory of Bridges at Boulogne, has investigated the shearing strength of concrete and has found it to be from .16 to .20 of the compressive strength. Feret tested his prisms in single shear and as a result of this method of testing the low values that he obtained, are probably nearer the tensile values then of shear. Fig. 1 of Plate 4 shows his method of testing. This method may be criticised for the small bearing surface of the shearing block produced high cutting stresses at the small area in contact.

Table 10, page 29, gives Feret's values for the shearing strength of Portland Cement Mortars.

MESNAGER:--

M. Mesnager, Director of the School of Bridges and Roads at Paris, gives as a result of his experiments that the shearing strength of concrete is from 1.2 to 1.3 times its tensile strength. These values agree very well with the research made by Herr

COMPARATIVE METHODS OF TESTING THE SHEARING STRENGTH OF CONCRETE.

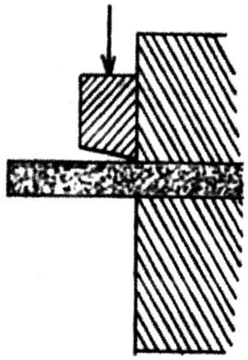


FIG. 1.
FERET

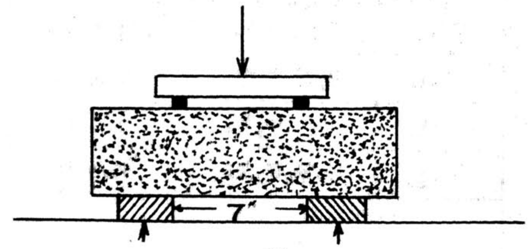


FIG 2.
FALK.

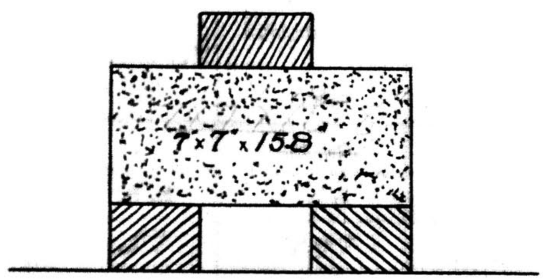


FIG 3
ZIPKES.

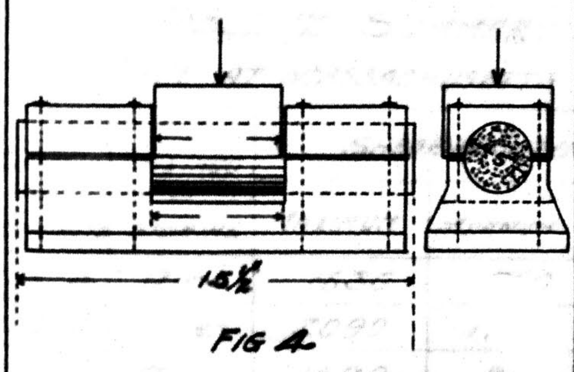


FIG 4
MASS. INST. TECH.

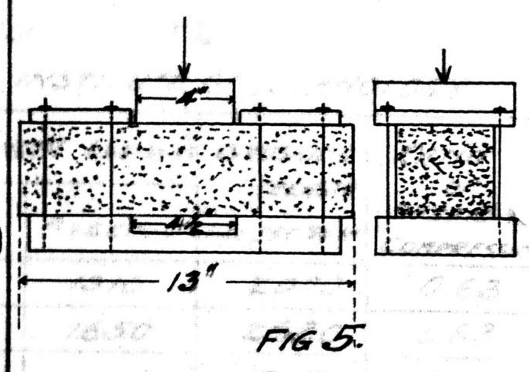


FIG 5.
ILL. UNIVERSITY.

PLATE 4

TABLE 10.

STRENGTH OF PORTLAND CEMENT MORTAR AS FOUND BY FERET.						
ITEM	APPROXIMATE PROPORTION BY WEIGHT.		SHEARING STRENGTH — #per sq. in.			Ratio of Shear to Comp.
	CEMENT	SAND	SHEAR	TENSION	COMPRESSION	
32	1	3.0	3100	450	4010	.77
15	1	3.1	1810	320	2720	.67
33	1	2.0	3070	518	4810	.64
17	1	2.0	2650	415	4380	.61

TABLE 11.

SHEARING STRENGTH OF 1:3:5 CONCRETE - FALK.

NO.	ULTIMATE CRUSHING STGTH		ULTIMATE SHEARING STGTH		Ratio of Shear to Compression
	6" cube Lbs. per sq. in.	Age in days	Lbs. per sq. in.	Age in days.	
1	1870	177	195	169	.10
5			314	165	
6	1246	164	166	164	.13
8	1196	157	187	157	.15
10	863	151	158	151	.18
22	922	128	104	128	.11
23	600	128	65	128	.11

TABLE 12.

TABLE 12. SUMMARY OF SHEAR TESTS MADE AT MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

KIND OF CONCRETE	METHOD OF STORING	SHEARING STRENGTH Lbs-sq. in.			CRUSHING STRENGTH Lbs. per sq. in.	RATIO OF SHEAR TO COMPRESSION
		MAXIMUM	MINIMUM	AVERAGE		
1:2:4	air	1630	960	1310	2070	0.63
1:2:4	Water	2090	1180	1650	2620	0.63
1:3:5	air.	1590	890	1240	1310	0.94
1:3:5	Water	1380	840	1120	1360	0.32
1:3:6	air.	1450	950	1180	950	1.25
1:3:6	Water.	1200	1030	1120	1270	0.88

Baushinger who states that the ultimate shearing strength of concrete four months' old is 1.25 and at two year, 1.5 times its tensile strength. Baushinger's tests were made in the year of 1878. Neither Baushinger's or Mesnager's methods of testing were available for reference.

(From Reid's Concrete and Reinforced concrete Construction, page 197.)

FALK:--

Falk found the shearing values of concrete from 65# to 314# per square inch. His method of testing the shearing strength of concrete is shown in Plate 4, Fig. 2. The small bearing surfaces of the shearing block produced high cutting and web stresses. This method of testing can not be said to have determined the true shearing strength of concrete.

Falk's values for shear are found in Table 11, page 29

(From Falk's Cements and Morters, page 95.)

ZIPKES:--

Zipkes gives the shearing values of concrete as 375# per square inch for concrete fifty days old. His test prisms were 7"x7"x15.8" long, and when tested were supported at the ends on surfaced blocks. See Plate 4, Fig. 3. The load was applied at the top of the test specimen, the ends of the beam were supported but not clamped and as a result they failed as a simple beam loaded at the middle.

(From Beton und Eisen, Jan. 1906, page 115.)

PROF. SWAIN:—

In the years of 1904 and 1905, a series of shear tests on concrete were made by Prof. Charles Spofford and in 1906 by Prof. F. P. McKibben. The tests were under the general direction of Prof. Swain, professor of Civil Engineering at the Massachusetts Institute of Technology. The test pieces were 5" in diameter by 15-1/2 inches long, and in testing were held in cylindrical bearings 5-1/2" apart. The load was applied at the top through a semi-cylindrical bearing 5-7/16 long, thus making a clearance between shearing planes of 1/32 of an inch. The tests were made on some specimens which had been stored in air. Others were stored in water. The air stored specimens were sprinkled with water for six days after being removed from the molds. The specimens were made of standard brands of Portland cement, a mixture of equal volumes of Plum Island and Ipswich Island sands, the stone was composed of a mixture of one volume of 1/2" rock and two volumes of 1-1/2 Waltham trap rock. In some tests Roxbury pudding stone was used in place of the Waltham trap rock. Fig. 4, plate 4 shows Prof. Swain's method of testing.

Table 12, page 29 , gives the summary of shear tests made at the Massachusetts Institute of Technology.

Table 13, page 33 also gives shearing values of concrete made with graded stone of three parts of one inch with one part of 1/4 inch stone. The proportions of this concrete were based on a barrel of 3.5 cubic feet volume.

Prof. Arthur N. Talbot:--

Shear tests on concrete have been made recently at the University of Illinois under the general direction of Prof. Arthur N. Talbot, Professor of Municipal and Sanitary Engineering, and in charge of Theoretical and applied Mechanics. The test prisms were 4"x4"x13" long and in testing were clamped to the bed plate of the shears. The bearings were 4-1/8" apart and the load was applied at the top through a rectangular block 4" wide, thus leaving 1/16 of an inch between shearing planes. The design of shears is similar to that used at the University of Kansas. Tables No.'s 14 and 15 give his shearing values of concrete.

Fig. 5, plate 4, shows Prof. Talbot's methods of testing concrete for shear.

TABLE 13. By C. M. Spofford.

SHEARING STRENGTH OF CONCRETE AND MORTAR.

PROPORTIONS	NUMBER OF SPECIMENS	AGE IN DAYS	SHEARING STRENGTH Lbs. Per sq. in	AGE IN DAYS	STRENGTH IN COMPRESSION
1:0	3	53	2753	40	4778
1:2	5	29	1331	33	4000
1:3	5	27½	839	38	1716
1:2:4	9	27	1082	33	2457
1:3:5	10	23½	560	34	1225
1:3:6	9	27½	612	27	1104

TABLE 14

SHEARING STRENGTH OF RESTRAINED BEAMS
1:3:6 A.N. Talbot.

REFERENCE NUMBER	METHOD OF STORING	AGE IN DAYS	SHEARING AREA	LOAD IN POUNDS		SHEARING STRENGTH Lbs per sq. in.
				AT FIRST CRACK	ULTIMATE	
1	DAMP SAND	60	34.0		40500	1190
2	"	60	34.0	41200	48000	1371
3	"	61	35.0	46000	46500	1368
4	"	59	34.0	33300	45000	1324
AVERAGE						1313
5	"	60	34.0	34000	34700	1020

TABLE 15

SHEARING STRENGTH OF RESTRAINED BEAMS.
1:2:4 A.N. Talbot.

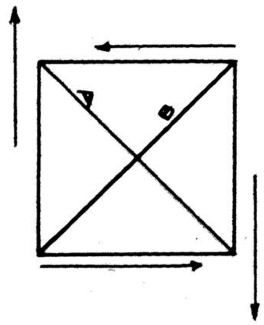
REF. NO.	METHOD OF STORING	AGE IN DAYS.	SHEARING AREA	LOAD IN POUNDS		SHEARING STRENGTH Lbs – in. sq.
				AT FIRST CRACK	ULTIMATE	
6	DAMP SAND	59	35.0		54000	1543
7	"	59	34.0	31500	44000	1295
8	"	58	34.0	46400	58400	1718
9	"	59	34.0	33400	49300	1450
10	"	57	34.5	29800	45800	1327
AVERAGE						1418

HOW HIGHER VALUES OF SHEAR MAY BE OBTAINED.

All designs of shearing machines thus far have been defective for the test specimens in testing are subjected to tensile and web stresses, and a uniform distribution of shearing stress has not been transmitted to the area in shear.

The resistance of concrete to shear depends partly on the strength of the aggregate. Compare the values of shear as obtained at the Massachusetts Institute of Technology with those made recently at the University of Kansas. Although the two methods of testing were practically the same, the concrete of trap rock aggregate gave higher shearing values than that with the Oread limestone.

As to the significance of the diagonal cracks at the vertical shearing planes, it is difficult to say, but they probably show that the concrete has partially failed by diagonal tension. From the law in mechanics, a section of a beam subjected to vertical shear is at the same time subjected to a horizontal shearing stress of equal intensity. In the figure, the horizontal sides of the figure represent the resistance to horizontal shear while the vertical sides represent the vertical shear. As a resultant of the couple of



these forces, the diagonal A is brought into tension while diagonal B is brought into compression. As the tensile strength of concrete is less than its compressive stength, the cement probably failed partly by diagonal tension. It is therefore difficult to determine the actual shearing strength on account of the existence of the diagonal fractures at the shearing plane.

This series of tests has in general shown a lack of uniformity, a part of which can well be eliminated. As previously stated, the ingredients were proportioned by volume. In this way of proportioning, it is impossible to measure definite proportions: in some volumes the material is packed while in others it is loose. It is better to establish a given weight for a given volume and weigh out all ingredients. Because of the lack of molds the concrete was necessarily mixed dry enough to hold its own shape after standing in the molds twenty minutes. As a result of the dry mixing and removing of the molds, the test prisms were appreciably weakened. For example, the 1:2:4 concrete 28 days old was mixed fairly wet and left in the molds two days and had an average shearing strength of 1438# per square inch, while the 60 day concrete of the same mixture.

averaged 1440# per square inch. Similar tests have shown the importance of mixing the concrete wet and leaving it in the molds until set.

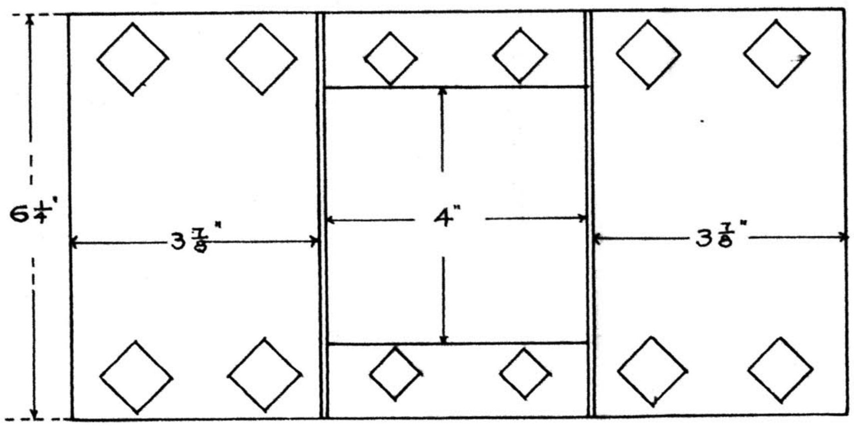
A coarser and stronger aggregate would have given higher shearing values--graded aggregate would have been better. We would suggest the use of an aggregate of sizes ranging from 1-1/2" to 1/4" in the proportions of two parts of the coarser to one part of the 1/4".

Plate 5, page 37 shows a design of shear that could be built to test the same size test prisms as were used in our tests. The principle difference in this machine from the one described in Plate 2 is in the design of the shearing block. This design of block will restrain the middle third of the beam from bending and will prevent the occurrence of the crack at the middle. By this method of testing, higher shearing values can be obtained than those given in Table 9.

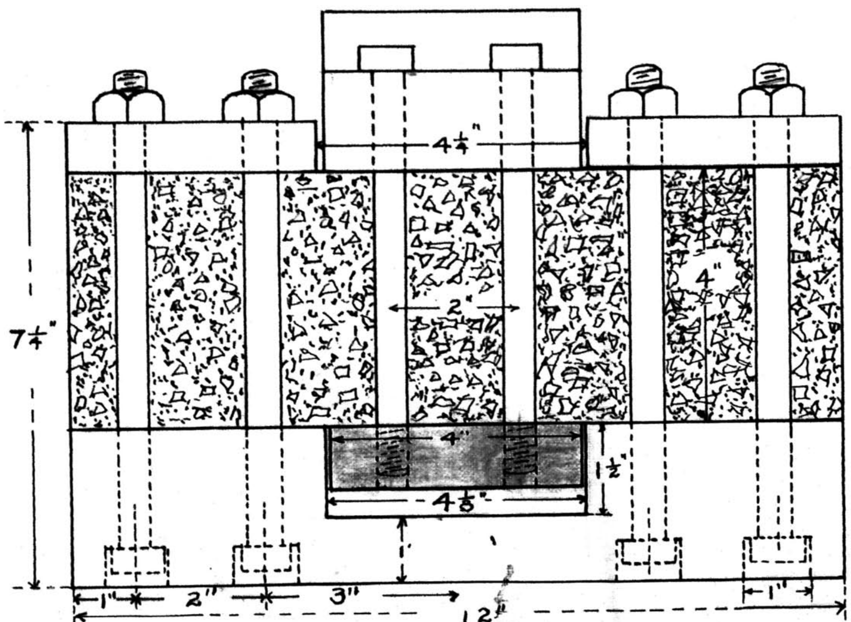
In conclusion this series of shear tests is but a continuation of other tests that have been made, but by a different method in testing. As a matter of fact, very little reliable data as to the shearing strength of concrete can be found, and we hope that the Civil Engineering Department of the University of Kansas will continue these tests, improve the methods of testing, and attain standard shearing values of concrete that will be adopted by prominent engineers.

PROPOSED DESIGN OF SHEARING MACHINE

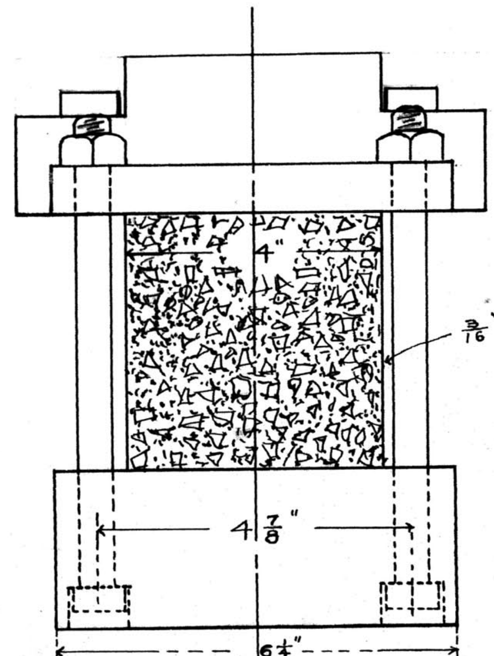
Scale 4" = 1 Foot.



PLAN



SIDE ELEVATION



END ELEVATION

R. F. Dollup