University of Wisconsin-Extension

GEOLOGICAL AND NATURAL HISTORY SURVEY
3817 Mineral Point Road
Madison, Wisconsin 53705

M.E. Ostrom, State Geologist and Director

LABORATORY TESTS OF THE CEDARBURG DOLOMITE

by

G.T. Owen and E.F. Bean

Open-File Report 45-1
20 p.

This report represents work performed by the Geological and Natural History Survey, and is released to the open files in the interest of making the information more readily available. This report has not been edited or reviewed for conformity with Geological and Natural History Survey standards and nomenclature.

1945

LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title : LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

Project No.s : LS 64 (Rock Preparation); LS 25 (Laboratory Tests).

Supervisors : Mr. E.F. Bean, State Geologist, and Mr.R.R. Shrock.

Personnel: G.T.Owen, geologist.

Introduction:

This project consisted of (a) the preparation of rock specimens for laboratory tests to determine its suitability for building stone, and (b) the performance of the laboratory tests. The procedure given in the U.S. Bureau of Standards Technical Paper No. 123 was followed wherever practicable.

ROCK PREPARATION.

Types of Work Done:

A. Sawing the Specimens. Three blocks of quarry stone chosen in such a manner as to be representative of the quarry face were provided by the operators. These blocks had been roughly dressed by hammer and chisel at the quarry, and each was approximately 12"x 12" x 10" in size when received at the laboratory. The blocks were designated No.s 1, 2, and 3, and this classification was carried over to the smaller specimens. Lacking more specialized equipment, the blocks were quartered with an ordinary carpenter's cross-cut hand saw as shown in Diagram 1, cuts "a" and "b". Two slabs approximately 12" x 4" x 1" were secured from Block No.3, and one each from Blocks No.s 1 and 2 by cut "c". The average rate of cutting

1 NE side near barn
2 East Side
3 South Side
all in Groth Quarry

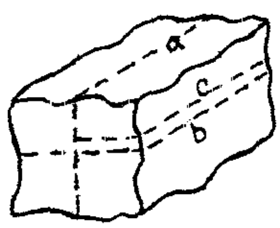

DIAGRAM I

by this method was about 1" per hour, exclusive of time spent in filing the saw, shoring up the stone on the work bench, and other activities incidental to the task. This cutting speed was said by employees of a local monument works to be about the same as that of similar work done in their shop. The shop price for such work is $1.50 per hour.

The "quarter-blocks" were next placed in a large power hack saw taking stock up to 6" x 6". Eight specimens 4"x4"x1" in size, and five specimens 2¼" x 2¼" x 2¼" were roughed out on this machine from each quarry block. Thirty to forty minutes were required to make a 4" to 5" cut by the 17" hacksaw blade running at 90 strokes per minute. These cuts were made as shown in Diagram 2 to obtain rock faces in the three planes of the block. The rough specimens from Block No. 3 were then placed in a crude mitre box and trimmed to size with the hand saw. The pieces from Blocks No.s 1 and 2 were trimmed to size on the power saw and on a coarse emery wheel

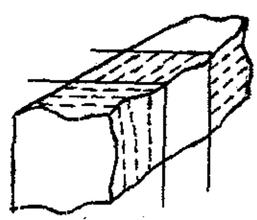

DIAGRAM 2.

at a considerable saving of time. Trouble was experienced in both the power and hand sawing from the fact that the stone sheared off consistently about ¼" to 1/8" from the bottom of the cut or kerf. This was not serious in the case of the 4" x 4" x 1" specimens (blocks for polishing) because only one true surface was wanted. In the case of the cubes, however, this breakage under the saw caused a considerable waste of stone and duplication of effort

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

because it was necessary to obtain all six faces as nearly true as possible. The difficulty was overcome by sawing in such a manner that the shearing produced a rough rim or lip at the bottom of the cut (Diagram 3), this lip subsequently being ground off flush on the emery wheel.

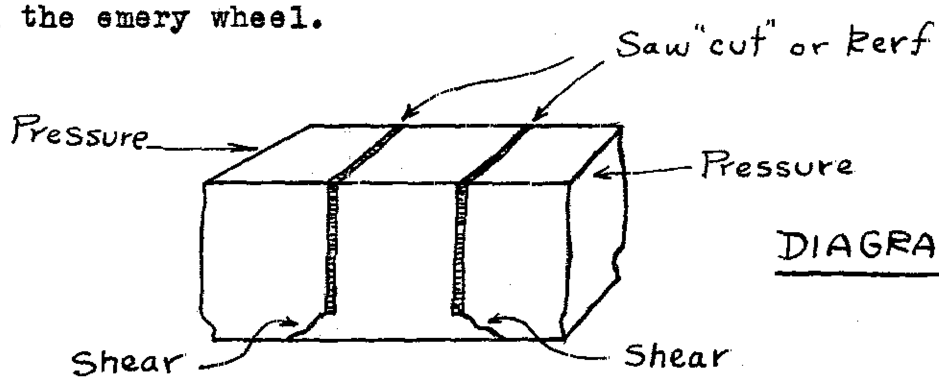

DIAGRAM 3

Information obtained from the Engineering Department of the University of Wisconsin indicated that cylindrical specimens would give better results in the compressive strength tests; hence two stone cylinders each 1 7/8" in diameter by 2" high were prepared from each quarry block. These cylinders or cores were drilled out with a tubular bit threaded for attachment to a drill press chuck and slotted so that glacial quartz sand wet to a semi-fluid condition could be fed to the cutting edge of the bit. The rough cores thus produced were then placed on the table of a grinding lathe and their ends ground off plane at right angles to the axis of the cylinders.

OBSERVATIONS

1. Blocks No.s 2 and 3 seemed quite hard under the saw and cut very slowly.
2. Block No. 1 seemed relatively soft under the saw and cut fairly rapidly.
3. The use of coarse carborundum under the saw blade did

not appreciably speed cutting.

4. Total time required to saw 24 specimens 4" x 4" x 1", 15 specimens $2\frac{1}{4}$" x $2\frac{1}{4}$" x $2\frac{1}{4}$", and 4 specimens 12" x 4" x 1" was about 180 hours. This includes all activities incidental to the sawing.

B. Grinding:

All the specimens with the exception of the 12" x 4" x 1" slabs were ground to smoothness on steel lap wheels. Six of the $2\frac{1}{4}$" cubes were prepared for compression strength tests; three cubes were prepared for absorption and apparent specific gravity tests. Twenty-three of the 4" x 4" x 1" ~~slabs~~ blocks were ground in preparation for polishing. Grinding technique for each type of specimen is described below.

1. Compression cubes: Each face of the cube was ground with coarse, medium, and fine grits on the lap wheel, then rubbed by hand in M 303 powder on a glass plate, and finally given a semi-polish by buffing on a smooth steel lap wheel lubricated with water. The two opposite faces which were most nearly parallel as determined by testing with outside calipers were then ground to a plane surface by testing on a glass plate until all edges rested in contact. The selected faces were marked so that they could be used as bearing faces in the compression tests.

2. Cubes for Absorption and Apparent Specific Gravity Tests: These cubes were prepared in exactly the same manner as were the compression specimens except that their edges were slightly rounded to prevent losses from chipping or crumbling during the tests.

3. Specimens for Polishing: The 4" x 4 x 1 blocks were

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: Laboratory Tests of the Cedarburg Dolomite.

ground with coarse, medium, and fine grits on the lap wheel. It was necessary to scrub the blocks with a stiff hand brush after each operation to remove as much of the grit from the pores as was possible. Even with this treatment there was slight discoloration of the stone by embedded grit. The edges of the blocks were rounded in preparation for later buffing on a linen-covered wheel. The specimens were then rubbed by hand in M303 powder on a glass plate.

4. Polishing: A No. 1, a No. 2, and a No. 3 block were polished by buffing in rouge on a steel lap wheel covered with coarse, unbleached linen. A good gloss was produced by the process, but embedded rouge discolored the stone badly. The use of rouge as a polisher was therefore discontinued. The surface of a No. 1 block was treated with Duco cement as a filler in an attempt to prevent the rouge from entering the pores of the stone, but without sucess.

Inability to obtain a suitable commercial polisher from local sources necessitated the use of questionable substitutes. Whiting (levigated and washed chalk) used on a linen-covered wheel and on a wheel to which a piece of wool-pile carpet had been shellacked did not produce a polish. A mixture of whiting, alum, and very fine emery powder produced a soft gloss without discoloring the stone. The polish was considerably intensified by the use of a good quality furniture wax in paste form. It was found that a pseudo-polish could be obtained by waxing the very smoothly ground specimens.

The lap wheels upon which the fore-going materials were used in polishing have a speed of about 1100 R.P.M. This speed is too

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

high for best results with the latter type of polisher. In order to keep the polisher from being hurled from the plate by centrifugal force, it was necessary to reduce its water content to an amount which was insufficient to prevent a slight scorching of the paste by friction. This caused a slight yellowish discoloration of the polished surface.

The use of putty-powder(oxide of tin) and felt buffers run at slow to moderate speeds for considerable periods of time, as in marble polishing, will undoubtedly produce a good polish on this stone.

Observations

1. The semi-polished and polished surfaces of the stone show that it is very porous and that many small cavities are present. Most of the cavities are under ¼" in size, but a few openings up to 1" were noted. These cavities are of two types; one, the molds and casts of small, segmented crinoid stems; and two, small geodes which probably originated from fossil molds. The cavities are most numerous in Block No. 2; fairly numerous in Block No. 3; and relatively infrequent in Block No.1.

2. All three types of the stone are composed of tiny dolomite crystals cemented by calcite, dolomite, and possibly some limonite. The principal cement seems to be calcite as shown by the fact that the material binding the crystals effervesces freely in cold, dilute hydrochloric acid while the crystals themselves are attacked less readily. Incomplete filling of the interstices between the crystals produces the numerous pores and many of the small openings of macroscopic size. The crystals in Block

No. 1 are smaller than those in Blocks No.s 2 and 3, and the pores seem to be more numerous and more uniformly distributed; nevertheless this type of stone is much softer than the other two types.

3. Block No. 1 is a light buff in color, the stone having a dull and lifeless appearance to the eye. Embedded grit from the grinding operations produces a dirty, smudged appearance which is unpleasant. Block No. 2 is a mottled grayish-white to light cream in color. The mottled effect is due to the presence of dense, light colored areas occurring between the small cavities in the stone. The juxtaposition of these features creates an impression of high lights and shadows of soft intensity which give the stone life and a distinctly pleasing appearance. The slight amounts of embedded grit from the grinding operations tend to heighten the mottling, and the discoloration is therefore not injurious. Block No. 3 is a mottled light cream to buff in color, but the mottling is not as intense and conspicuous as in Block No. 2, and the the visual impression of the former is therefore slightly less pleasing.

4. Total time spent in grinding and in polishing the entire group of specimens was about 120 hours. This includes time spent in consulting library references, preparing equipment, and obtaining materials.

LABORATORY TESTS.

Under this heading are described the laboratory tests for

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

determining the apparent specific gravities, the true specific gravities, the porosities, the absorption values, the compressive strengths, the transverse strengths, and the weights per cubic foot of the three types of rock. These physical characteristics are of vital importance from the standpoint of the suitability of a stone for building purposes because they are an index to the ability of the stone to bear certain stresses and to resist the action of a number of destructive agents to which building stone is subjected in actual use. Details and purposes of the various tests are given under separate headings below.

Apparent Specific Gravity The apparent specific gravity of a stone is the specific gravity regardless of the pore spaces and air contained therein. "It is the weight in grams of a cubic centimeter of the dry stone".[1] This value is useful for (a) determining the weight per cubic foot of the stone, (b) to calculate the actual pore space, (c) to reduce the water absorption of a stone determined by weight to the volume ratio. The apparent specific gravity values of these specimens were determined on the cubes used for the absorption test, this procedure requiring only the additional operation of weighing the saturated cube suspended in water. An error is introduced if the wire of the suspending basket is not immersed to the same point when weighing the basket empty and with the stone. The error is eliminated by removing a volume of water from the beaker approximately equal to the volume of the cube during the operation of weighing the immersed spec-

1 U. S. Bureau of Standards Tech. Paper 123 See section on "Apparent Specific Gravity".

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

imens. The values are computed from the formula: G equals $\frac{W_1}{W_2 \text{ minus } W_3}$ in which G is the apparent specific gravity; W_1 is the weight of the dry cube; W_2 is the weight of the cube after soaking in water but dried on the surface with a towel; and W_3 is the weight of the soaked cube suspended in water. The weight of the dry stone is computed by multiplying the apparent specific gravity by 62.5

Absorption Tests The absorption tests as carried out in this investigation consisted of determinations of the amount of water absorbed by a dry cube of the stone. The absorption value shows the probable effects of weathering on the stone. Absorbed water softens a stone and carries into it atmospheric gases which may produce deleterious solutions. Considered in connection with the porosity of the stone, the absorption value is an index to the possible effects of freezing , for according to Hirshwald's theory, a stone whose absorption value is more than nine-tenths of the pore space, ~~the stone~~ will be damaged by freezing. This is based on the fact that water expands by one-tenth of its volume as the temperature is lowered from 4degrees C to the freezing point. Thus if a stone is more than nine-tenths filled with water, there is not enough space to allow for expansion and the stone will be subjected to internal stresses of destructive force. Buckley states that the size of the pores is an important factor which may render the theory invalid in certain instances.[1]

The preparation of the cubes used in the absorption tests has already been described. Procedure for the test is as follows: the

---

Buckley, E.R. . Building and Ornamental Stones, Wis Geol and Nat Hist Survey, Bull IV, 1898 Pp 21, 22, 23.

cubes are dried in an electric oven at 110 degrees Centigrade for 48 hours; cooled; weighed to the nearest 0.01 of a gram; then placed in a shallow tray containing about 1" of water. Small amounts of water (distilled) are added until the specimens are immersed. After 48 hours the cubes are taken out one at a time, carefully dried on the surface with a cloth, and immediately weighed. The increase in weight is the amount of water absorbed. The absorption value is computed from the ratio of the volume of water absorbed to the volume of the specimen, viz. divide the weight of the absorbed water in grams by the volume of the cube in cubic centimeters. This value multiplied by 100 gives percentage ratio of absorption. The volume of the test piece is obtained by subtracting the immersed weight(apparent specific gravity determination) from the weight of the soaked cube, assuming that 1 cc of water equals 1 gram. A second method of determining the absorption value is by determining the ratio of the weight of water absorbed to the weight of the dry stone. This method disregards the factor of specific gravity and an unfair value may be obtained; i.e. a specimen of high specific gravity may appear to have absorbed less than one of low specific gravity, even though the contrary be true. The true absorption value may be obtained by multiplying the value determined by the weight method by the apparent specific gravity of the stone. Both weight and volume values of absorption for the specimens under test are given in the table, page .

True Specific Gravity True specific gravity is the specific gravity of the solid stone material,or the weight in grams of a cubic centimeter of the stone having the pores filled with solid

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

material of the same composition. In this investigation the true specific gravity was obtained by reducing the stone to a powder passing a 200 mesh screen and determining the specific gravity of the particles by means of a pycnometer or specific gravity bottle. A 50 cc. pycnometer adjusted at 20 degrees C. was used, and the readings were taken at room temperature which approximated 20 derees C. True specific gravity was computed from the formula G equals $\frac{\text{B minus A}}{\text{D plus B minus A minus C}}$, where A is the weight of the pycnometer, B is the weight of the pycnometer and the powdered mineral, C is the weight of the pycnometer and mineral plus distilled water(flask filled), and D is the weight of the pycnometer filled with distilled water.

In order to obtain accurate determinations by this method, great care must be used in the procedure. It is absolutely necessary that trapped air(air film on the mineral particles and air in the interstices) be exhausted from the bottle in obtaining weight C; otherwise an erroneous value will result. The text-book procedure of suspending the flask in boiling water is not adequate to exhaust trapped air in a sample of powdered mineral under test. An aspirator or faucet air pump having a suction sufficient to lower a column of mercury to approximately 6 cm. or a pressure of one-twelfth of an atmosphere was used in this investigation with excellent results in this connection. Frothing of the sample under suction with a consequent loss of mineral is a complication of this method. This can be overcome by (a) first exhausting the air in the distilled water used , and (b) barely saturating the powder and applying suction and then gradually filling the bottle between intervals of suction. The reduced pressure must be attained gradually.

Six to ten determinations for each type of the stone under test were made. The individual samples varied between 10 and 20 grams in weight. Results of the tests are tabulated on page .

Porosity Percentage of the total pore space of the stone under test is calculated from the results of the true and apparent specific gravity tests. The difference between the apparent specific gravity value(weight in grams of the actual stone) and the true specific gravity(weight in grams of a cubic centimeter of solid stone) is the amount of solid stone required to fill the pores of the actual stone. Percentage of pore space is determined by the formula $\frac{t \text{ minus } a}{t} \times 100$, where t is the true specific gravity and a is the apparent specific gravity. Porosity values for the stone under test are given in the table on page

.

Transverse Strength Tests The transverse strength of each type of the dolomite was obtained by breaking 4 bars on an Olson testing machine in the Materials Laboratory of the College of Engineering. The bars are placed on adjustable knife-edges on the bed of the machine and the load is applied by means of a third knife edge at the center of the span. The breaking load is recorded and the unit of strength is computed from the formula R equals $\frac{3\,W\,l}{2\,b\,d^2}$, where R equals the modulus of rupture in cross-breaking, W equals the breaking load, l equals the length between the supporting edges,or span, b equals the breadth of the test piece, and d equals the depth of the test piece.

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

The modulus of rupture represents the maximum unit strength of the material when used as a beam. It is useful in determining the load to which the stone should be subjected when used in arches, sills, and caps. Blocks cut perpendicular to the bedding show greater transverse strength than do blocks cut parallel to the bedding. The plane of the bedding was not known for the quarry blocks from which the test pieces used in this investigation were sawed; hence this factor was not known for the specimens tested. It is believed that the wide variation in transverse strengths obtained in one or two of the specimens may be the result of this factor. The results of the tests are tabulated on page of this report.

Compressive Strength Tests The compressive strength of a stone is determined to find what loads it will support in structures. Knowing the compressive or crushing strength of a stone, it can be classified as fit or unfit for certain types of construction such as piers, columns, arches, abutments, trusses, walls, etc. A high compressive strength has commonly been regarded as an evidence of great durability, but such is not necessarily the case. Stones of low compressive strength may have other physical characteristics which render them more resistant to decay and disintegration than stones of high compressive strength. "The compressive strength of a stone is nearly always sufficient for the requirements of ordinary structures."[1]

The compressive strength values of the Cedarburg Dolomite were determined by crushing cubes and cylinders of the stone on a

---

Quoted from U.S. Bureau of Standards Tech. Paper No. 123, "Properties of Marble".

CIVIL WORKS ADMINISTRATION PROJECT

UNIVERSITY OF WISCONSIN

Title: LABORATORY TESTS OF THE CEDARBURG DOLOMITE.

Riehle Bros., 2-screw, testing machine of 100,000 pounds capacity in the Materials Laboratory of the College of Engineering. Compression specimens cut perpendicular to the bedding usually show a higher crushing strength than do specimens cut in the plane of or "with" the bedding. The test pieces used in this investigation were cut in both these planes of the quarry blocks, but since the bedding was not known for the rough stock, it was not possible to make this distinction in crushing the specimens. This factor is probably responsible for the marked variations in crushing strength obtained for a singlr type of the stone.The results of the compressive strength tests are tabulated on page   of this report.

Compression specimens which have been saturated with water usually show a marked loss in crushing strength. The three cubes which had been used in the absorption tests were crushed while in a saturated condition to determine the effect of excessive moisture upon the stone. The results of this test are given on page   . It should be pointed out that while this single determination may be regarded as indicative, it should not be taken as conclusive evidence because a single test is not sufficient to establish the true value of the effect of saturation on the strength of the stone.

CONCLUSIONS

The various tests to which the Cedarburg Dolomite was subjected in this investigation shows that the stone has physical characteristics which justify its classification as a building and ornamental stone. The stone can be polished, and the resultant product is pleasing. The type of stone represented by Block No.2 is the most satisfactory, that represented by Block No. 3 slightly less so, and that represented by Block No. 1 is probably unsatisfactory from the standpoint of beauty and general appearance. All three types are suitable where hand-finished stone rather than the polished product is required. The uniform color (i.e., lack of stains and other discolorations) is a favorable characteristic.

The purely physical tests show that the stone is very porous and relatively soft. These characteristics probably obviate its general use in outside walls, for foundation work, or for any type of construction which would cause it to be subjected to abrasion. It is believed that the most satisfactory results would be obtained by restricting the use of the stone to interior construction such as interior trim, wall panels, casings,etc. The tables of compressive and transverse strengths should be of value to architects and designers in determining the exact uses for which the stone is suited.

ABSORPTION TESTS.

EFERENCE IUMBER	TESTS MADE	AVERAGE PER CENT OF ABSORPTION	
		By Weight	By Volume
1	3	6.23	12.92
2	3	3.83	8.53
3	3	3.96	8.41

SPECIFIC GRAVITY TESTS

REFERENCE NO.	TRUE SPECIFIC GRAVITY				APPARENT SPECIFIC GRAVITY				PERCENTAGE of POROSITY	WEIGHT PER CUBIC FOOT.
	TESTS MADE	HIGHEST	LOWEST	AVERAGE	TESTS MADE	HIGHEST	LOWEST	AVERAGE		
1	4	2.8862	2.8704	2.875	3	2.120	2.105	2.110	26.6	131.8
2	4	2.8896	2.8860	2.887	3	2.240	2.236	2.238	21.4	139.8
3	6	2.8785	2.8581	2.867	3	2.238	2.223	2.231	22.1	139.4

COMPRESSIVE STRENGTH TESTS.

REFERENCE NUMBER	TYPE OF SPECIMEN	AVERAGE STRESSED AREA, IN SQUARE INCHES	COMPRESSIVE STRENGTH			REMARKS.
			Total Load	Compressive strength, in pounds per square inch.	AVERAGE for Type of Stone	
1	Cube	4.5	29,160	6,480		Explosive break, oppose pyramids.
1	Cube	3.5	17,110	4888		Quiet break; pyramid below, wedge above.
1	Core	2.7	13,660	5059	5429	Explosive break, inverted and upright pyramids.
1	Core	2.7	14,290	5292		Quiet break; upright and inverted cones incipient.
2	Cube	4.0	16,280	4070		Slight explosive break; pyramid below, wedge above.
2	Cube	5.0	38,630	7726		Quiet break; wedge fractures.
2	Cube	4.8	35,730	7443	5581	Explosive break; pyramid below, wedge above.
2	Core	2.7	10,680	3955		Gradual crumbling followed by single shear.
2	Core	2.7	12,725	4713		Explosive break; inverte and upright cones, one shear plane pronounced.
3	Cube	4.5	35,590	7908		Explosive break; wedge above, pyramid below.
3	Cube	4.5	17,680	3928	5931	Quiet break, pyramids above and below.
3	Core	2.7	12,150	4500		Quiet failure; uprigh and inverted cones
3	Core	3.1	22,905	7388		Explosive break; opposed cones.

TRANSVERSE STRENGTH TESTS.

REFERENCE NO.	LENGTH OR SPAN, in inches	AVERAGE SECTIONAL DIMENSIONS in inches		BREAKING LOAD in pounds.	MODULUS OF RUPTURE	REMARKS.
		BREADTH	DEPTH			
3	7	4.125	1.093	418	895	Broke by tension crack starting on under side of slab 1" from center.
3	7	4.125	1.0	241	613	Tension crack ½" from center.
1	7	4.031	1.0	192	500	Fine, hair-crack of tensional origin ½" from center.
2	7	4.0	1.0	342	872	Failed at center by tension crack
1	4	4.0	1.0	307	460	Tension crack at center of span.
3	4	4.0	1.0	652	978	Failed suddenly with moderate violence, diagonal tension crack starting at center of span.

COMPRESSION STRENGTH TESTS ON WATER-SOAKED SPECIMENS.

REFERENCE NUMBER	AVERAGE STRESSED AREA, in square inches	COMPRESSIVE STRENGTH OF SATURATED SPECIMEN		AVERAGE STRENGTH OF DRY STONE. Pounds per square inch.	STRENGTH DIFFERENCE Average strength dry minus strength wet.	HIGHEST STRENGTH OF DRY STONE Pounds per square inch	STRENGTH DIFFERENCE Highest strength dry minus strength wet	REMARKS
		Total Load	Pounds per square inch					
Cube 1	4.2	16,950	4035	5429	−1394	6480	−2445	The saturated cube failed with a fairly sharp break. Pyramids above and below developed — upper pyramid most perfect
Cube 2	4.5	29,160	6480	5581	+899	7726	−1246	The saturated cube failed with a moderately quiet break. Pyramid above and below fairly well developed.
Cube 3	4.2	16,090	3830	5931	−2101	7908	−4078	Cube failed quietly. Two sets of shears well developed.