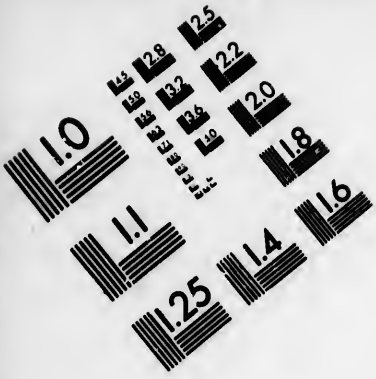

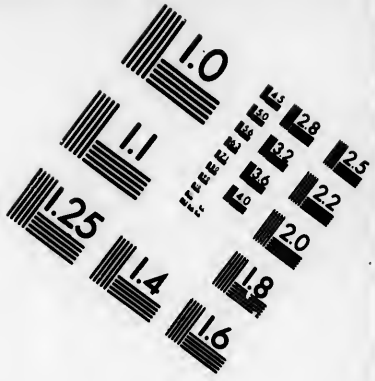

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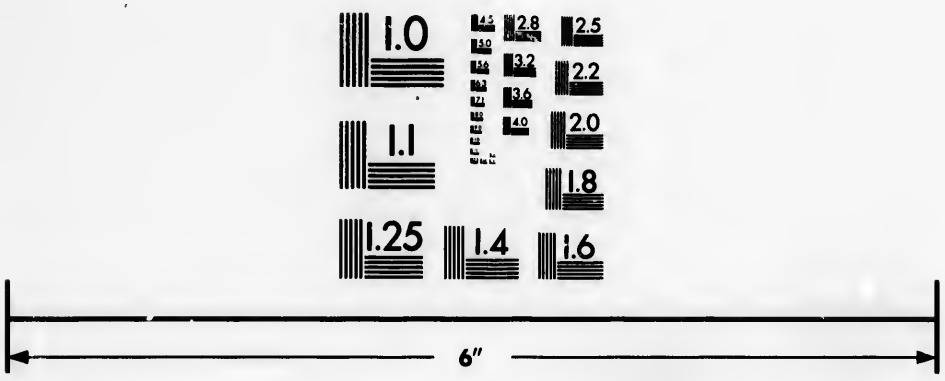

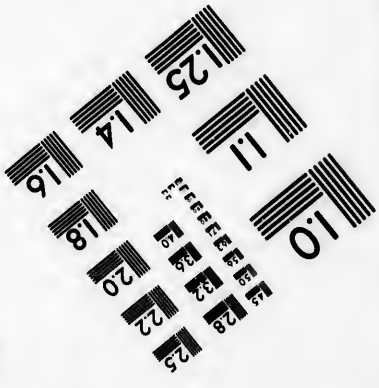

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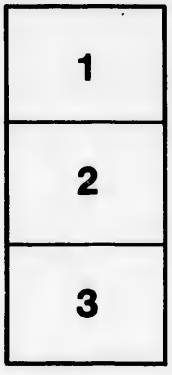

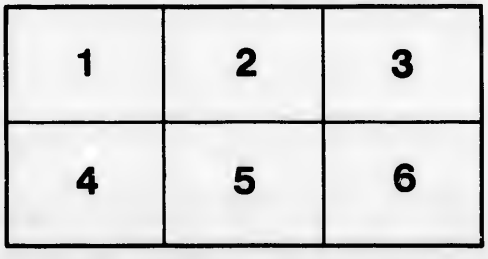

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Canadian Society of Civil Engineers.

INCORPORATED 1887.

ADVANCE PROOF—(*Subject to revision*)

THE COMPRESSIVE STRENGTH OF CONCRETE.

As determined by tests made at McGill University.

By W. B. Anderson, Stud. Can. Soc. C. E.

(To be read Thursday, March 2, 1899.)

Concrete, especially in the construction of piers and foundations, is coming every year into more extensive use. It is therefore desirable to determine its strength, and more particularly the resistance to crushing, as it is to a compressive force that it is most often subjected. The results of very few tests with this end in view are given in any of the treatises on Concrete or Building Materials, or in the Engineering Journals. A few results may be found, but they are scattered and very irregular, and little information can be obtained from them.

During the past three years a few tests have been carried on by the students of Civil Engineering at McGill University. The first series, two years ago, was to determine the effect of different percentages of water upon the strength, and the best percentage to use. This was found to be about 20 per cent. of the sand and cement. Last year tests were made comparing the strengths of concretes made respectively from an English Portland and a German one. This year tests were made upon sand cement in order to compare it with the Portlands, and also to determine the best proportions in which to mix it in making concretes.

This cement was "Cathedral" brand sand cement, made by the "St. Lawrence Portland Cement Co.," of Montreal. It is made of equal parts of Portland cement and kiln-dried pump sand. These are run together into a revolving cylinder half full of flint pebbles, where they are thoroughly mixed and ground to an impalpable powder.

The conditions under which the tests were made this year were the same as those of the first series (published in paper No. 117, Trans. Can. Soc. C. E.), except that the blocks were made 9x9x12-in. instead of 12-in. cubes, as the cubes were found, in some cases, to be too strong for the testing machine to break. The blocks were tested with their long edges vertical, and rested on a

steel plate which was on a ball and socket joint, the plate above the block being fixed. Sheets of rubber were inserted above and below the block to give a more uniform distribution of the load. The blocks were allowed to stand in the moulds for about two days, and were then removed and placed in water, where they were kept until the time of testing.

The results of all the tests made in 1898, and the more striking ones of other years, are here presented in tabular form:—

RESULTS OF EXPERIMENTS ON THE COMPRESSIVE STRENGTH OF CONCRETE.

No. of Test.	Date of Test.	Brand of Cement.	Mixture.			Percentage of Water.	Weight in lbs. per cu. ft.	Breaking Load lbs. per sq. in.			Proportion of mortar to broken stone.	Relative amounts of Cement.	Relative Costs.	
			Cement.	Sand.	Broken Stone.			One week.	Four weeks.	Two months.			First Assumption.	Second Assumption.
1	1896	German Portland "Hemmoor" Brand.	1	2	4	20	139.5	746	626	507	60-80	157	174	126
2	"		1	2	5	"	.....	....	703	....	-100	137	152	121
3	"		1	2	6	"	.....	....	728	....	-120	122	135	116
4	1897		1	1	1	22½	142.3	×	×	....	60-30	367	407	206
5	"		1	1	2	"	146.7	1037	×	....	-60	275	305	175
6	"		1	1	3	"	148.0	×	×	....	-90	220	244	156
7	"		1	1	4	"	153.3	×	×	....	-120	183	204	144
8	"		1	1	5	"	151.2	×	×	....	-150	157	174	135
9	"	English Portland "Anchor" Brand.	1	2	2	20	143.5	494	565	....	60-40	220	259	150
10	"		1	2	3	"	146.0	611	555	....	-60	183	216	139
11	"		1	2	4	"	148.5	819	613	....	-80	157	185	131
12	"		1	2	5	"	150.5	581	680	...	-100	137	162	124
13	"		1	2	6	"	150.0	500	698	....	-120	122	143	120
14	"		1	3	3	"	139.5	333	205	....	60-45	157	185	122
15	"		1	3	4	"	139.0	....	306	....	-60	137	162	117
16	"		1	3	5	"	145.0	....	386	....	-75	122	143	113
17	"		1	3	6	"	147.0	....	357	...	-90	110	129	110
18	1898	Sand Cement "Cathedral" Brand.	1	3	5	"	146.5	144	274	400	-75	122	122	104
19	"		1	3	6	"	146.4	110	182	218	-90	110	110	102
20	"		1	3	7	"	150.3	210	322	....	-105	100	100	100
21	"		1	2	4	"	150.6	316	441	....	60-80	157	157	119
22	"		1	2	5	22	148.5	275	477	494	-100	137	137	114
23	"		1	2	6	20	154.0	521	639	670	-120	122	122	111
24	"		1	1½	3	"	149.8	412	490	....	60-72	200	200	134
25	"		1	1½	4	"	151.5	446	679	....	-96	169	169	126
26	"		1	1½	4½	"	153.5	536	741	....	-108	157	157	123
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

Blocks marked thus (×) remained unbroken under a load of 1,050 lbs. per square inch.

Column 13 shows the relative quantities of cement in the different mixtures, and some attempt has been made to estimate the cost of the different mixtures on this basis. The relative costs are compared on the following two different assumptions:—

First assumption:—Column 14 shows the relative costs if it is assumed that the sand and stone can be secured on the spot and their cost ignored. The cost of different brands of cement is taken as below.

Second assumption.—Column 15 shows the relative costs of the different mixtures and brands on the following assumed costs per cubic foot of materials.

English Portland	53 cents.
German Portland	50 "
Sand cement	45 "
Broken stone	8 "
Sand	2 "

The cost of labour is not taken into account, as it will be the same in every case, and these costs can at best be only a rough approximation.

The main requisite for an economic and good concrete is to have just enough cement to completely surround every grain of sand, and just enough of this mortar to fill every interstice between stones. Column 12 gives the proportion of mortar to stone, and it will be seen that with each different mortar the strength increases as the proportion of stone increases, or as the volume of interstices between the stones decreases, because the mortar is not so strong as the stone. The strength also increases with the richness of the mortar in cement, so that the strongest concrete will be one with very little sand and a great deal of stone. Those with the 1-1 mixtures of mortar are very much stronger, though also more expensive than the others. The sand cements are found to be weaker than similar mixtures of Portlands by from 12 per cent. to 40 per cent. The manufacturers claim that with a mortar, such as a 1-10, with a great deal of sand, this cement is stronger than the Portland. This remains to be determined.

If the concrete is desired to have very great strength, a Portland cement and a rich mortar might be used, but if weight is the main consideration, with only moderate strength required, a concrete of sand cement will be much cheaper and quite efficient. Of course, much cheaper mixtures than the ones tested can be made, but they will be weaker accordingly after a certain limit is passed, which limit has not been reached in these experiments. One of the cheapest and a fairly strong concrete is No. 23. This mixture would

seem to be the best one to use if excessive strength were not required.

The loads given in the table are the actual crushing loads. The blocks showed cracks or signs of failure before this load was reached, but it was thought better to make the comparison on this basis. For purposes of comparison it is best to take the results of the four-week tests, as the concretes then show more uniform results than at one week, and the two-month tests are not complete.

These tests are still very incomplete, and it might be profitable to make further tests with concretes containing more stone. The strongest of the sand cement mixtures is No. 26, and with this rich mortar it looks as if it would stand a good deal more stone, thus increasing both the strength and weight, and reducing the cost. Tests of this nature will likely be carried out at McGill University in future years.