THESIS

PROPER AGGREGATES FOR CONCRETE

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1924

SUPPLEMENTARY
MATERIAL
IN BACK OF BOOK

[illegible] FOR [illegible]

A Report

Submitted to the Faculty of the

Michigan Agricultural College

by

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of

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It is a generally recognized fact that the aggregates found in Michigan are lacking in stone or coarse material. The proper proportioning of the aggregates requires much time in screening and then carefully measuring the quantities for the concrete. Especially on small jobs, the contractor can see no reason why he cannot add or subtract a certain amount of cement to the aggregate which he has available and have the concrete just as strong as though he had made the correct proportioning of the cement and the aggregate.

The object of this test is to determine the correct amount of cement to be added to any known mix of aggregate without proportioning the materials. It is clearly recognized that the aggregate from bank or stream-channel will vary considerably from time to time, and that tests should be made of the particular lots of aggregates; yet it is believed by us that the results given in this report will be of value in indicating approximately what may be expected from the various proportions of aggregates.

SPECIFICATIONS FOR AGGREGATES

Fine aggregate shall consist of natural sand or screenings from hard, tough, durable crushed rock or gravel, consisting of quartzite grains or other equally hard material graded from fine to coarse, with the coarse particles predominating.

Coarse aggregate shall consist of clean, tough, crushed rock or gravel, or slag of approved quality in graded sizes, free from vegetable or other deleterious matter and containing

no soft, flat or elongated particles. Both the fine and the coarse aggregate should meet the specifications of the A. S. M. I.

The proportioning of the aggregate was not up to the above specifications, but the proportions used will be fully described later in the report.

SOURCE OF MATERIAL

The aggregate was taken from the Cade Farm which is located two miles East of East Lansing.

The cement used was Huron Portland Cement.

The water was taken from the East Lansing supply.

TEST PIECES

This report covers compression tests of 6 by 12 in. concrete cylinders and wear tests on concrete blocks 8 in. square and 2 in. thick.

The 6 by 12 in. cylinders were molded in metal forms made of 12 in. in length of 6 in. inside diameter cold drawn steel tubing split along one element by means of a thin slotter. This form was enclosed by a circumferential band. Each form stood on a smooth concrete floor. A thin layer of oil was placed between the floor and the cylinder form to prevent the bonding between the floor and the test piece.

In molding the cylinders the concrete was puddled with a 5/8 in. steel bar about 20 in. long as small amounts were emptied into the form. The top was leveled off with a bricklayers trowel.

The metal forms of the wear blocks were made in gangs of three. The form was set on a piece of galvanized tin which

was first a steel mold, and laid directly on the floor. The top of the blocks were leveled off with the bricklayers trowel.

All test pieces were allowed to remain over night or approximately twenty- four hours in the forms and then immersed in water. The test pieces were allowed to remain in the water until twenty-four hours before they were tested. All aggregates larger than three-quarters inch were discarded.

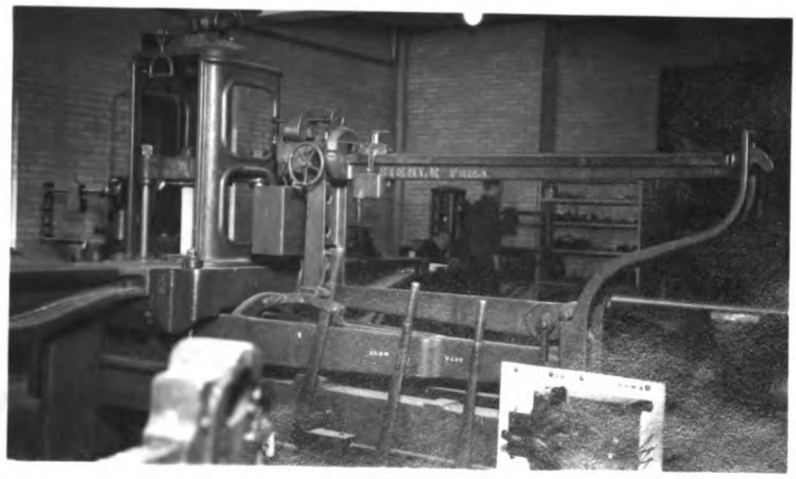
METHOD OF TESTING

The compression tests of concrete were made in a 100,000 lb. Riehle Universal Testing Machine. A universal bearing block was used on top of the cylinders.

Wear tests were made in a casting rattler. The test pieces consist of blocks 8 in. square and 8 in. in thickness. The blocks were placed in the rattler without any definite arrangement. Since a comparative test only for wear was required in this case no definite arrangement of the blocks was necessary. Four blocks constituted a test. The removable section made it possible to seal the rattler.

The test consisted in exposing the concrete blocks to the wearing action of the inside faces or sides of the rattler. The rattler was run for a period of twenty minutes at the rate of thirty revolutions per minute. Each test block ineach set was weighed immediately before and after this test. The loss was then used as a comparison for wear in the different proportions.

CASTING RAPIER



RIEHLE UNIVERSAL TESTING MACHINE

Sample # 1. 1 : 2 : 4

Sample # 2. 1 : 2 : 4 25% coarse aggregate out.

Sample # 3. 1 1/8 : 2 : 4 25% coarse aggregate out.

Sample # 4. 1 1/4 : 2 : 4 25% coarse aggregate out.

Sample # 5. 1 3/8 : 2 : 4 25% coarse aggregate out.

Sample # 6. 1 : 2 : 4 50% coarse aggregate out.

Sample # 7. 1 1/8 : 2 : 4 50% coarse aggregate out.

Sample # 8. 1 1/4 : 2 : 4 50% coarse aggregate out.

Sample # 9. 1 3/8 : 2 : 4 50% coarse aggregate out.

Sample # 10. 1 : 3 : 5

Sample # 11. 1 : 3 : 5 25% coarse aggregate out.

Sample # 12. 1 1/8 : 3 : 5 25% coarse aggregate out.

Sample # 13. 1 1/4 : 3 : 5 25% coarse aggregate out.

Sample # 14. 1 3/8 : 3 : 5 25% coarse aggregate out.

Sample # 15. 1 : 3 : 5 50% coarse aggregate out.

Sample # 16. 1 1/8 : 3 : 5 50% coarse aggregate out.

Sample # 17. 1 1/4 : 3 : 5 50% coarse aggregate out.

Sample # 18. 1 3/8 : 3 : 5 50% coarse aggregate out.

Sample # 19. 1 : 1 1/2 : 3

Sample # 20. 1 : 1 1/2 : 3 25% coarse aggregate out.

Sample # 21. 1 1/8 : 1 1/2 : 3 25% coarse aggregate out.

Sample # 22. 1 1/4 : 1 1/2 : 3 25% coarse aggregate out.

Sample # 23. 1 3/8 : 1 1/2 : 3 25% coarse aggregate out.

Sample # 24. 1 : 1 1/2 : 3 50% coarse aggregate out.

Sample # 25. 1 1/8 : 1 1/2 : 3 50% coarse aggregate out.

Sample # 26. 1 1/4 : 1 1/2 : 3 50% coarse aggregate out.

Sample # 27. 1 3/8 : 1 1/2 : 3 50% coarse aggregate out.

The preceding tabulation is the complete description of the mixes. It should be remembered that where the 25% or the 50% of coarse aggregate has been removed that the same volume of fine aggregate was added.

The concrete was mixed by hand in the Concrete Laboratory of the Michigan Agricultural College. The specimens of each sample were taken from the same batch. The quantities of material were carefully measured in a metal pan. A slump test was taken for each batch, if the concrete settled one inch and not more than two inches when the cone was removed, the batch was considered O. K.

DESCRIPTION OF TEST

The tests included in this report consists of compression of 108 6 by 12 in. concrete cylinders and 108 wear tests on the two (2) in. cubes. The specimens were of the mixes previously specified. Also a test of the gradiation or a sieve analysis of the fine aggregate. The coarse aggregate consisted of pebbles from one-fourth to three-fourths inch in size. All pebbles above three-fourths inch were rejected. The curing conditions were ideal for the concrete, since the specimens were immerged in water.

Before testing the cylinders for compression in the Riehle Universal Testing Machine they were set in plaster of paris.

All tests were made twenty- eight days after the concrete was poured. The specimens were removed from the water twenty-four (24) hours before being tested. In order to identify each cube after it had been in the rattler they were numbered with black paint before being placed in the rattler.

[illegible] OF THE FINE AGGREGATE

The gradation of the particles of the fine aggregate passing the one-quarter inch mesh sieve was determined by means of sand sieves of the following standard no. 4, 10, 14, 30, 30, 40, 50, 80, 100. All the fine aggregate used pased the 1/4 in. mesh screen. All the shaking was done by hand.

The results for this analysis are shown in Table 1 and the analysis curve is shown in Fig. 1. The sizes of grains as plotted represent the sizes of clear openings in the sieves used. The curve very clearly shows the relative sizes or gradations of grains of the fine aggregate of this material.

PROPORTIONING AND MIXING THE SAMPLES.

In the tests included in this report there were three mixes used. One was a 1 : 2 : 4 mix i.e. one part cement, two parts fine aggregate and four parts coarse aggregate. Another was a 1 : 3 : 5 mix., i.e. one part cement, three parts fine aggregate and five parts coarse aggregate. And the other was a 1 : 1 1/2 : 3 mix, i.e. one part cement, 1 1/2 parts fine aggregate and 3 parts coarse aggregate. Each one of these mixes was farther proportioned into two mixes. In one twenty-five (25) percent of the coarse aggregate was removed and the same amount of fine aggregate added. In the other mix fifty (50) percent of the coarse aggregate was removed and this amount replaced by fine aggregate. Then by varying the amounts of cement by 1/6 we were required to make a total of twenty-seven samples, four specimens for each test.

[illegible]

Table No. 1.

Sieves no.	Size in.	Amount Retained grams	Percentage by weight passing screen.
4.	.185	2.15	97,85
10.	.065	24.22	73.63
14.	.046	12.58	60.05
20.	.0328	10.83	50.07
30.	.0138	12.43	37.64
40.	.015	12.85	24.79
50.	.011	11.51	13.28
80.	.0069	8.70	4.58
100.	.0058	2.56	2.02
Passed the 100 mesh.		2.02	0.00

All the fine aggregate passed through the one-quarter inch mesh screen.

Mechanical Analysis Curve For
The Fine Aggregate

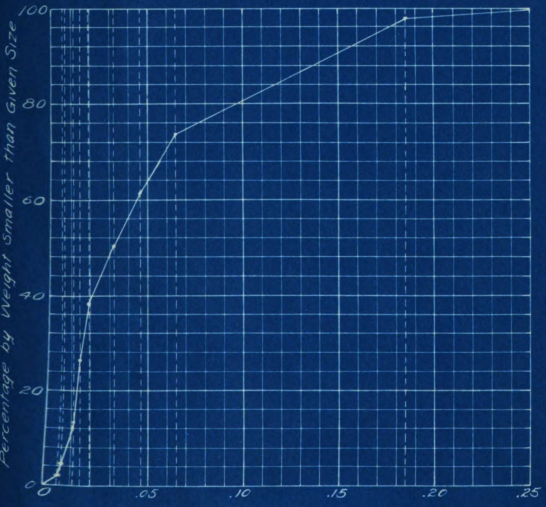
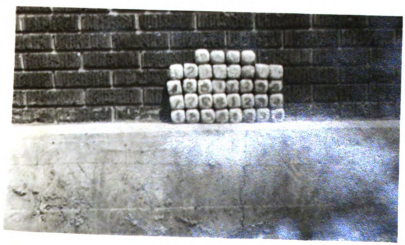


Figure No 1.

THE CUBES BEFORE THE TEST



THE CUBES AFTER THE TEST

[illegible]

Sample #1.	Weight before.	Weight after.	in grams.
1.	348	312	
2.	330	307	
3.	346	315	
4.	329	295	
Sample # 2.			
1.	3[illegible]5	2[illegible]5	
2.	325	274	
3.	331	272	
4.	[illegible]	2[illegible]	
Sample #3.			
1.	331	291	
2.	321	290	
3.	329	2[illegible]	
4.	336	282	
Sample # 4.			
1.	342	301	
2.	326	291	
3.	336	293	
4.	000	000	
Sample # 5.			
1.	335	304	
2.	3[illegible]	297	
3.	327	296	
4.	330	295	
Sample # 6.			
1.	321	250	

[illegible]	[illegible]	[illegible] after gms.
2.	316	254
3.	325	258
4.	316	255
Sample # 7.		
1.	304	260
2.	304	260
3.	314	250
4.	321	257
Sample # 8.		
1.	325	276
2.	332	283
3.	336	282
4.	333	288
Sample # 9.		
1.	325	288
2.	326	289
3.	325	298
4.	322	2[illegible]
Sample # 10.		
1.	325	283
2.	307	274
3.	336	271
4.	332	280
Sample # 11.		
1.	330	278
2.	325	271
3.	320	268
4.	324	274

Sample # 1[illegible].	Weight before	Weight after, gms.
1.	[illegible]	[illegible]
2.	[illegible]	253
3.	316	247
4.	315	247
Sample # 13.		
1.	356	277
2.	344	281
3.	330	271
4.	347	278
Sample # 14.		
1.	341	291
2.	342	282
3.	353	301
4.	340	279
Sample # 15.		
1.	316	255
2.	302	220
3.	311	217
4.	316	239
Sample # 16.		
1.	319	244
2.	325	256
3.	320	239
4.	000	000
Sample # 17.		
1.	326	259
2.	322	251
3.	327	267
4.	322	257

Sample # 12.	[illegible]	[illegible] after, gms.
1.	[illegible]	[illegible]
2.	[illegible]	[illegible]
3.	[illegible]	247
4.	315	247
Sample # 13.		
1.	333	277
2.	344	281
3.	330	271
4.	347	278
Sample # 14.		
1.	341	291
2.	342	282
3.	333	301
4.	340	279
Sample # 15.		
1.	316	255
2.	[illegible]	280
3.	311	217
4.	316	259
Sample # 16.		
1.	319	244
2.	325	256
3.	320	259
4.	000	000
Sample # 17.		
1.	316	259
2.	322	251
3.	327	267
4.	322	257

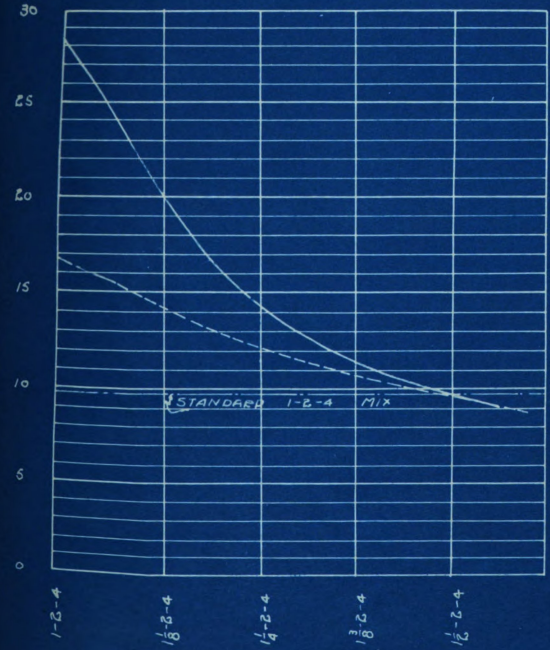
Sample # 18.	Weight before, gms.	Weight after, gms.
1.	332	273
2.	332	274
3.	325	269
4.	325	273
Sample # 19.		
1.	336	306
2.	341	303
3.	336	308
4.	000	000
Sample # 20.		
1.	330	276
2.	339	294
3.	331	284
4.	332	282
Sample # 21.		
1.	336	290
2.	331	289
3.	330	290
4.	331	289
Sample # 22.		
1.	332	301
2.	336	304
3.	336	29[illegible]
4.	340	299
Sample # 23.		
1.	331	290
2.	336	307
3.	330	303
4.	336	306

Sample # 24.	Weight before, gms.	Weight after, gms.
1.	319	301
2.	317	296
3.	322	303
4.	318	249
Sample # 25.		
1.	329	281
2.	319	269
3.	309	264
4.	321	270
Sample # 26.		
1.	344	307
2.	332	294
3.	327	297
4.	335	300
Sample # 27.		
1.	330	311
2.	329	314
3.	325	319
4.	323	316

RATTLER TEST FOR WEAR

----- 35% COURSE AGGREGATE OUT.

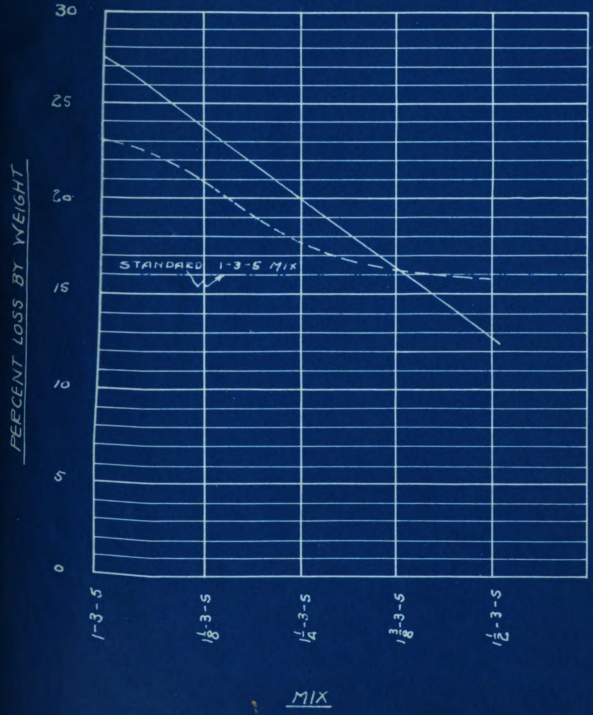
——— 50 % COURSE AGGREGATE OUT



RATTLER TEST FOR WEAR

----- 25% COURSE AGGREGATE OUT

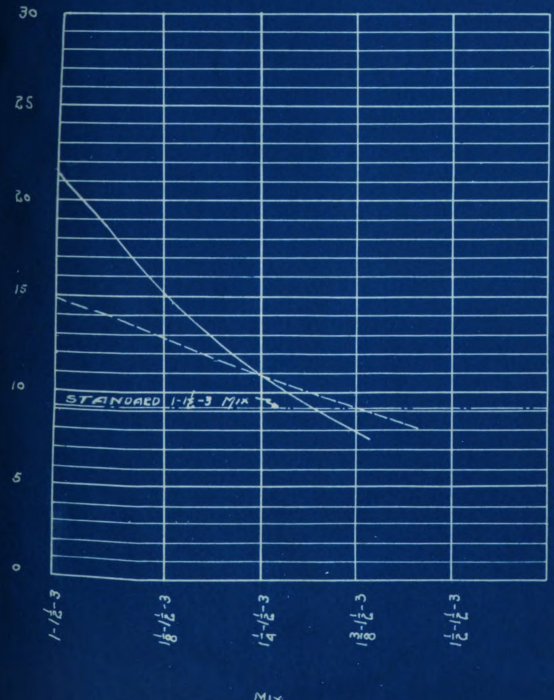
—— 50 % COURSE AGGREGATE OUT



RATTLER TEST FOR WEAR

----- 25 % COURSE AGGREGATE OUT

——— 50 % COURSE AGGREGATE OUT



THE CYLINDERS BEFORE THE TEST.

A CYLINDER AFTER THE TEST.

The following data is given in pounds per cylinder and the cross sectional area of a cylinder is 33.5 sq.in. and from this the pounds per sq. in. can be determined.

Sample # 1.

1.	47,700 *
2.	64,200
3.	64,300
4.	63,900

Sample # 2.

1.	63,200
2.	65,700 *
3.	60,000
4.	63,500

Sample # 3.

1.	61,100
2.	60,850
3.	55,070
4.	73,920 *

Sample # 4.

1.	65,250
2.	64,050
3.	60,900 *
4.	65,700

Sample # 5.

1.	90,800
2.	90,100
3.	93,900
4.	96,00

* Data not used.

Sample [illegible].

1. [illegible]
2. 80,000 *
3. [illegible]
4. 68,700

Sample # 7.

1. 67,000
2. 78,400
3. 79,000 *
4. 70,540

Sample # 8.

1. 67,000
2. 82,000 *
3. 74,010
4. 72,130

Sample # 9.

1. 74,100
2. 76,000
3. 78,100
4. 70,000

Sample # 10.

1. 40,000
2. 52,000
3. 50,000 *
4. 49,000

Sample # 11.

1. 51,340
2. 48,300
3. 51,000
4. 54,000

Sample # 12.

1. [illegible]

2. 58,000

3. 57,600

4. 60,900 *

Sample # 13.

1. 58,500

2. 58,300

3. 60,400

4. 54,600

Sample # 14.

1. 5[illegible],900

2. 56,[illegible]40

3. 61,[illegible]0

4. 47,400 *

Sample # 15.

1. 54,470

2. 55,130

3. 54,000

4. [illegible],340

Sample # 16.

1. 44,070

2. 40,300

3. 52,400

4. 50,500

Sample # 17.

1. 46,500

2. 46,3[illegible]0

3. 49,000

4. 51,200

Sample # 18.

1. 53,300

2. 52,000

3. 55,600

4. 59,900 *

Sample # 19.

1. 66,760

2. 66,840

3. 67,000

4. 65,790

Sample # 20.

1. 64,210

2. 66,550

3. 70,300

4. 68,600

Sample # 21.

1. 79,350

2. 79,000

3. 75,000

4. 79,000

Sample # 22.

1. 68,500

2. 62,700

3. 64,100

4. 75,900 *

Sample # [illegible].

1. [illegible]
2. [illegible]
3. [illegible]
4. [illegible] *

Sample # 24.

1. 44,370 *
2. 31,700
3. 35,300
4. 31,130

Sample # 25.

1. 71,310
2. 71,110
3. 75,000
4. 65,0[illegible] *

Sample # 26.

1. 79,300
2. 75,300
3. 70,750
4. 80,300 *

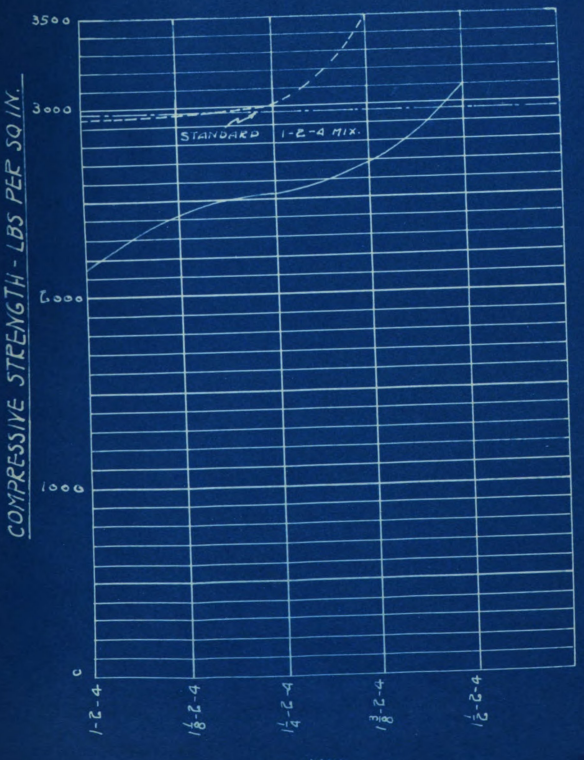
Sample #27.

1. 90,[illegible]
2. 80,735
3. 80,000
4. 91,700

COMPRESSION TEST

----- 25% AGGREGATE OUT

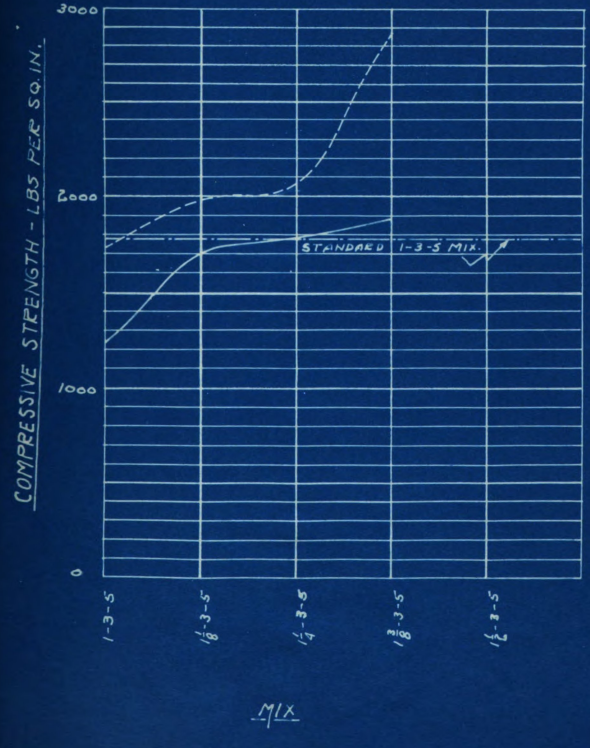
——— 50% AGGREGATE OUT



COMPRESSION TEST

----- 25% AGGREGATE OUT

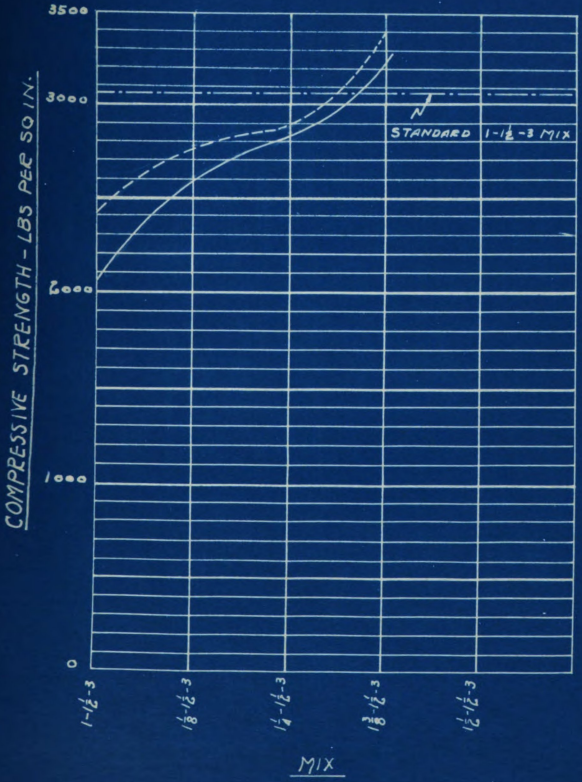
——— 50% AGGREGATE OUT



COMPRESSION TEST

----- 25% AGGREGATE OUT

—— 50% AGGREGATE OUT



Conclusion

From the curves the desired compressive strength of concrete can be obtained by knowing the proportion of the mix and then adding the correct amount of cement.

It can be readily seen by comparing the curves on wear and compression that with a high compressive strength there is very little wear and where the compressive strength is low the wear is great.

The curves show that at all times with just 50 percent of the coarse aggregate cut and its volume replaced by fine aggregate that the compressive strength is greater than that of concrete where the mix is such that 50 percent of coarse aggregate is cut and its volume replaced by fine aggregate.

By interpolation of the curves it can be determined what amount of cement should be added to the aggregate on hand to obtain the desired compressive strength and wear.

The authors wish to express their thanks to the following men for their help and advice which was carefully given in the preparation of this report.

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Prof. C. L. Allen

Prof. H. J. Woods

J. A. Eicher

[redacted]

[redacted]

Pocket has:
7 Suppls.