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APPLICATION OF THE TRI-AXIAL TYPE DIAGRAM TO THE STUDY OF CONCRETE MASONRY BATCH MIXES IN PLANT PRACTICE

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ABSTRACT

A study of the effects and results of using various combinations of a lightweight aggregate, Portland cement, and water on the properties of 8 by 8 by 16 inch masonry units was undertaken. For this work two series of tests were performed; on one series a Stearns No. 9 Joltcrete block machine was utilized and on the other a Besser Vibrapac. The aggregate gradation used was checked at each batch to note any variations. The triaxial method of plotting and organizing the batch compositions and data was employed for the study and proved to be an excellent means for correlating variations. Data indicate that there is an optimum water content which must be maintained for best overall results. At this water content the cement-aggregate proportions can be varied widely yet produce very satisfactory blocks. It was also noted that variations in water content affected block texture markedly. While the data presented could apply only to the particular aggregate studied, this method is suggested as an easy means for any block manufacturer to study mixes to work toward optimum conditions.

INTRODUCTION

The production of concrete masonry units has developed into an industry of major importance in the United States. Within the past few years the use of lightweight aggregates in such units has increased markedly. The increased production of lightweight units has resulted from a growing appreciation of the value of decreasing the overall weight in masonry structures and the desirability of better heat and sound insulation.

For a number of years large quantities of pumice and scoria, and some expanded shale aggregate have been shipped into Kansas for use in lightweight concrete masonry units. In the spring of 1952 the production of an expanded shale aggregate by Buildex, Inc., Ottawa, Kansas, and a sintered clay aggregate by Mineral Products, Inc., Kansas City, Kansas, greatly increased the supply of high-grade lightweight aggregate in this State (Plummer and Hladik, 1951).

Concrete masonry units made with lightweight aggregates vary greatly in yield, unit weight, workability, strength, and product color and texture. These variations are caused to a considerable extent by variations in the quantities of the batch components—lightweight aggregate, cement, and water. In general the method used to determine the optimum quantities of these materials have been haphazard, and in many cases the results have been unsatisfactory.

During the course of a study of the application of a sintered lightweight aggregate to concrete masonry units an investigation was undertaken wherein the effects of a systematic variation in the quantities of the materials making up the normal concrete masonry batch were observed. The tri-axial method of plotting and organizing the batch compositions and data was used.

In using the tri-axial diagrams three ingredients can be plotted so that the resulting batch compositions represent all possible combinations of these ingredients (Fig. 1). Each apex of the triangular grid represents 100 percent of one of the ingredients, and the base of the grid represents none (0 percent) of that same ingredient. The exact center of the triangular grid represents equal proportions of the three ingredients, or 33⅓ percent of each. The batches plotted may be spaced very closely on the grid to represent variations of less than 1 per cent, or spaced widely to represent larger variations. The selection of spacing depends on the significant differences in results produced by the variations represented by the spacing.

It is common practice to have wide variations in batch components plotted on the tri-axial diagram for the first series of test batches (Fig. 1). The first series of test batches will indicate a relatively small area in the tri-axial plot which contains all the mixes suitable for further testing. Within this relatively small area smaller step-by-step variations in composition are plotted in order to obtain more precise data on optimum mixes (Fig. 2.).

This method proved to be an excellent means for working out and correlating systematic variations, and should be a useful tool for the block manufacturer who wishes to study variations in mixes with the objective of determining the optimum quantities of materials to be used.

TESTS

Materials Used

The aggregate used was a sintered Kansas loess having a rather rounded particle shape and well-defined cell structure. This material, when sized for concrete masonry use, had a unit weight of 1,400 pounds per cubic yard in a loose dry condition. Normally this material when supplied to the customer contains 8 to 10 percent moisture which is added at the manufacturing plant to minimize dust and help prevent segregation. This added moisture is believed to improve mixing of the ingredients in batches. Using an aggregate compaction test described by the Housing and Home Finance Agency (1949, p. 6), this aggregate showed the compressive loads for indicated compactions as follows: 1 inch compaction, 3,000 psi, 1½ inch compaction, 10,000 psi. A representative screen analysis of the aggregate as furnished to the masonry manufacturers is given below.

Screen size	Percent retained
¼ inch	3.0
No. 4	12.0
8	30.0
16	18.0
30	10.0
50	7.0
100	6.0
pan	14.0
	100.0

The cements were regular Portland cement as used at the plants wherein tests were conducted.

Methods and Equipment Used In Testing

Series of tests were performed at two different plants; one plant was equipped with a Stearns No. 9 Joltcrete, whereas the other plant had a Besser Vibrapac machine. It was noted that the intensity of all vibration applied to block forming by the Vibrapac machine was considerably greater than at the other plant. The effects of the greater vibration were quite pronounced.

The test procedure employed for each mix combination follows. (1) All the aggregate was weighed, the necessary corrections for moisture content were made, and it was fed into the mixer. (2) After the mixer had run for approximately 1 minute, a sample of the aggregate was taken for screen analysis. (3) All the water (either weighed or measured by volume) was added and the mixture run for 3 minutes. (4) All the cement (after weighing) was then added and the entire mixture stirred for 3 minutes. (5) Each batch was made into 8 by 8 by 16 inch standard three-cell units. (6) Three blocks from each batch were weighed directly from the block machine to determine yields. (7) All blocks were steam cured according to the standard practice at the respective plants.

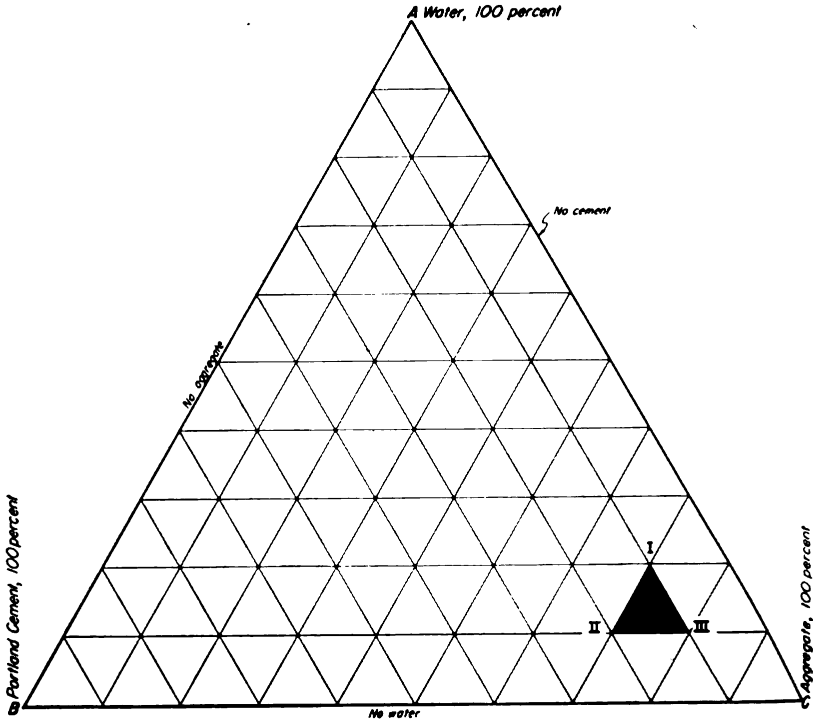

FIG. 1.—Tri-axial diagram showing location of field of study (triangular area I-II-III) in relation to a complete variation of composition from 100 percent of each of the ingredients.

TEST DATA

As a systematic scheme for proportioning the cement-aggregate-water combinations, the tri-axial type of plot was used. Each point thus selected represents some combination of the three component materials used in the study. Figure 1 shows the location of this particular field of study in relation to the points representing 100 percent of each of the ingredients. Proportions indicated are in percentages by weight and are based on dry aggregate. From this diagram it can be seen that the field studied lies in a triangle whose points represent the following batch compositions:

I Water, 20%	II Water, 10%	III Water, 10%
Cement, 10%	Cement, 20%	Cement, 10%
Aggregate, 70%	Aggregate, 70%	Aggregate, 80%

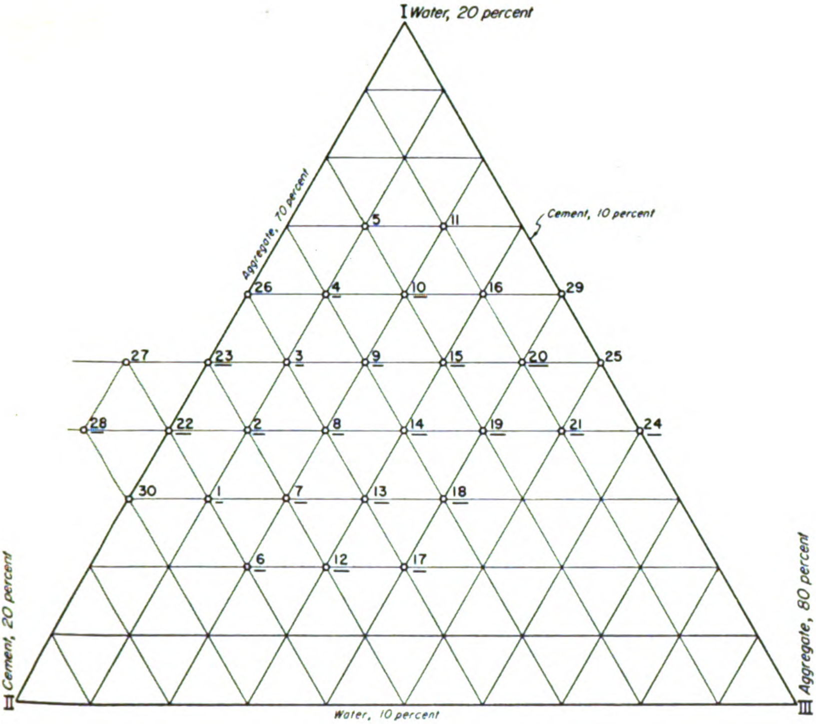

FIG. 2.—Tri-axial diagram showing the composition of the various batches in the area of mixes investigated. This diagram is an enlargement of triangle I-II-III shown in Figure 1. Underscored numbers indicate mixes tested.

It is clearly shown also that the field of workable mixes occurs within fairly narrow limits.

Figure 2 is an enlargement of the area of mixes investigated showing the composition of the various batches. These figures are based on dry aggregate; consequently corrections in water and aggregate batch weights are necessary when moisture is present in the aggregate.

Table 1 summarizes the data assembled from the test runs on the batches formed on the Stearns No. 9 Joltcrete. The data are shown graphically in Figure 3. It was possible to run all the batches, as indicated from the data summary, on this machine. However, above 15 percent water the blocks slumped quite badly when removed from the die box and were badly smeared. The

TABLE 1.—*Summary of data obtained on 8x*[illegible]

Mix no.	Percent by weight, dry basis: Lt. wt. aggre.	Water	Cement	2-Sack batch weights, dry basis, pounds: Lt. wt. aggre.	Water	Cem.	Total	Mixer batch, 9.6 percent water in aggregate: Lt. wt. aggre., pounds	Water, pounds	Cement, pounds	Cu yd aggre at 1444 lbs dry
1	71	13	16	830	152	188	1170	906	76.5	188	0.574
2	71	14	15	890	176	188	1255	971	94.5	188	0.615
3	71	15	14	950	202	188	1345	1038	114	188	0.656
4	71	16	13	1025	232	188	1445	1120	137	188	0.707
6	72	12	16	840	141	188	1175	915	66	188	0.580
7	72	13	15	910	163	188	1255	992	81	188	0.629
8	72	14	14	965	188	188	1345	1050	93	188	0.666
9	72	15	13	1040	216	188	1445	1135	121	188	0.716
10	72	16	12	1130	252	188	1570	1230	152	188	0.780
12	73	12	15	915	151	188	1255	1000	66	188	0.653
13	73	13	14	980	174	188	1345	1070	84.5	188	0.678
14	73	14	13	1050	202	188	1445	1145	107	188	0.725
15	73	15	12	1140	235	188	1570	1245	130	188	0.786
17	74	12	14	995	161	188	1345	1090	66	188	0.688
18	74	13	13	1070	188	188	1445	1170	88	188	0.738
19	74	14	12	1165	220	188	1570	1270	115	188	0.803
20	74	15	11	1270	256	188	1710	1380	146	188	0.875
21	75	14	11	1280	239	188	1710	1400	119	188	0.882
22	70	14	16	820	165	188	1175	895	90	188	0.566
23	70	15	15	875	188	188	1255	955	103	188	0.605
24	76	14	10	1425	263	188	1880	1560	128	188	0.983

* Average 3 specimens.

green weights of the blocks as received from this machine were relatively low.

All the mixes containing 14 percent water gave indications of having the best all-around workability regardless of the relative amounts of cement and aggregate. Increasing or decreasing the water content by only 1 percent from 14 percent affected the workability of the mix and the appearance of the block markedly. This variation in water content had more effect on the color and texture of the finished block than any variation that might be ascribed to aggregate gradation variations.

Table 2 summarizes data collected on the test runs performed using a Besser Vibrapac block machine. The data are shown graphically in Figure 4. The effects of the increased vibration intensity are very marked, resulting in lower yields, heavier blocks, and increase in compressive strengths. It was impossible to run mixes having more than 15 percent water on this machine: the material for the most part would not vibrate into the feed box and any block that was formed was very badly smeared.

inch lightweight blocks made on Stearns 9 Joltcrete

Block weight at machine, pounds per block	Calculated yield, blocks			Average cured block weights and compressive strengths*							
				3 days		7 days		15 days		28 days	
	Per batch	Per sack	Per cu yd. aggre.	Comp. load	Wt.	Comp. load	Wt.	Comp. load	Wt.	Comp. load	Wt.
25.5	45.8	22.9	79.8	342	24.6	418	24.6	467	24.2	412	23.7
26.9	46.5	23.2	75.6	476	25.6	536	24.8	718	25.6	678	24.6
29.0	46.3	23.1	70.6	627	26.5	718	26.9	759	27.5	752	26.8
32.2	44.4	22.2	62.8	494	30.4	805	30.9	690	28.3	719	28.2
25.6	44.1	22.0	76.0	358	25.8	285	24.0	350	24.2	304	23.7
25.6	49.0	24.5	78.0	381	24.9	357	24.1	363	23.4	449	23.9
26.9	50.0	25.0	75.2	464	25.2	610	25.6	594	25.1	752	25.6
28.6	50.5	25.2	70.6	521	27.1	675	27.0	631	25.7	747	26.1
33.3	47.2	23.6	60.6	525	29.7	631	29.7	649	28.4	689	28.3
26.7	47.0	23.5	71.0	284	25.1	233	23.9	221	23.2	310	23.7
27.2	49.4	24.7	72.8	289	23.6	397	24.4	384	24.1	527	24.8
28.3	51.0	25.5	70.5	353	24.8	481	24.7	481	24.2	646	25.3
28.6	54.8	27.4	69.8	432	26.6	668	26.4	626	25.7	790	27.8
25.5	52.7	26.3	76.7	182	25.0	255	25.4	140	23.7	290	24.6
26.2	55.1	27.5	74.8	126	24.5	253	24.9	376	24.9	261	23.6
27.0	58.0	29.0	72.2	635	26.7	629	26.6	392	24.3	447	23.7
29.9	57.2	28.6	65.5	799	28.9	898	28.7	674	26.0	757	26.0
26.8	63.8	31.9	72.4	531	25.8	565	25.0	514	24.2	635	24.0
27.3	43.0	21.5	76.0	765	26.7	1018	27.2	905	26.5	720	24.7
28.9	43.4	21.7	71.8	701	27.3	832	27.4	831	26.6	830	26.5
25.9	72.5	36.2	73.7	522	26.1	553	26.1	379	24.0	428	23.6

Figures 3 and 4 are detailed plots of these data to analyze the effects brought about by relative variations in the three batch ingredients—i.e., cement, aggregate, and water. Study of these curves points up the following trends.

(1) *Constant cement; increasing aggregate with decreasing water content.* (a) Yield of blocks per sack and blocks per cubic yard of aggregate decrease; (b) compressive load-bearing ability decreases markedly.

(2) *Constant aggregate; water increasing with decreasing cement.* (a) Yield of blocks per sack increases whereas the yield per cubic yard of aggregate decreases. (b) Strength in compression of the block tends to increase with increasing water content up to 14 to 15 percent water and then to fall off.

(3) *Constant water; increasing aggregate with decreasing cement.* (a) Yield of blocks per sack increases with yield of blocks per cubic yard of aggregate decreasing. (b) Block compressive strengths show an increase to a maximum, then drop;

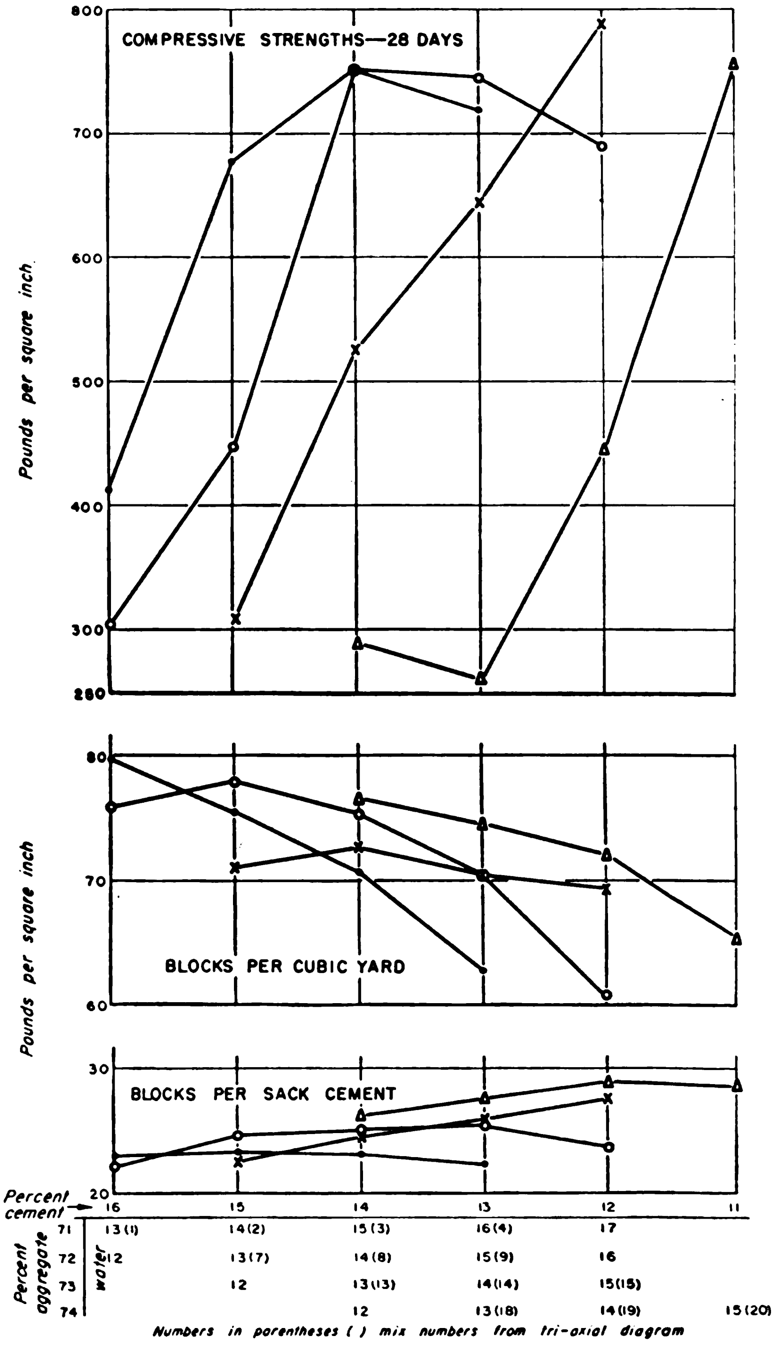

FIG. 3.—Graph showing changes in properties with variations in composition of standard 3-cell blocks manufactured on a Stearns Joltcrete machine.

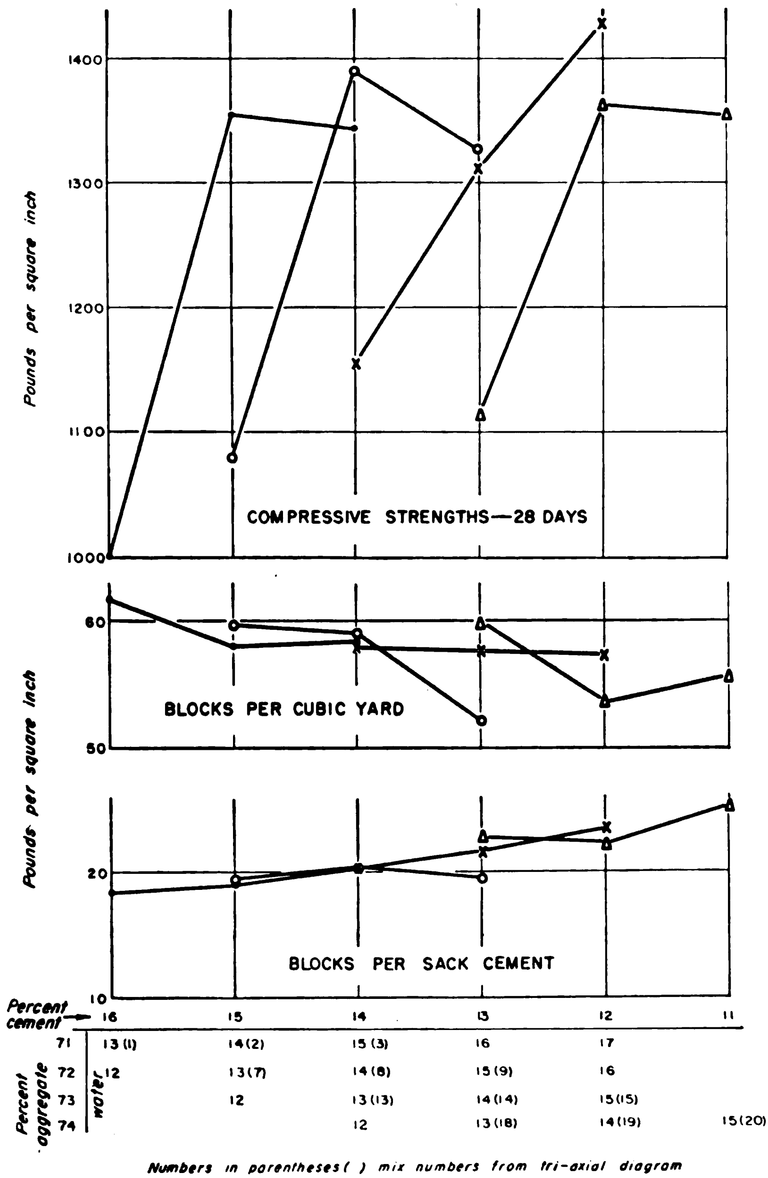

Fig. 4.—Graph showing changes in properties with variations in composition of standard 3-cell blocks manufactured on a Besser Vibrapac machine.

TABLE 2.—*Summary of data obtained on 8x8x16*

	Percent by weight, dry basis			3-Sack batch weights, dry basis, pounds				Mixer batch, 11.0 percent water in aggregate			
Mix no.	Lt. wt. aggre.	Water	Cement	Lt. wt. aggre.	Water	Cement	Total	Lt. wt. aggre., pounds	Water: Pounds	Water: Gallons	Cement, pounds
1	71	13	16	1255	229	282	1765	1390	94	11.3	282
2	71	14	15	1385	263	282	1880	1535	113	13.6	282
3	71	15	14	1480	302	282	2010	1640	142	17.1	282
7	72	13	15	1355	244	282	1880	1505	94	11.3	282
8	72	14	14	1450	282	282	2010	1610	122	14.7	282
9	72	15	13	1565	326	282	2170	1735	156	18.7	282
13	73	13	14	1470	261	282	2010	1620	101	12.1	282
14	73	14	13	1585	304	282	2170	1760	129	15 5	282
15	73	15	12	1715	352	282	2350	1900	167	20.1	282
18	74	13	13	1610	282	282	2170	1785	107	12.9	282
19	74	14	12	1740	329	282	2350	1930	139	16.7	282
20	74	15	11	1895	384	282	2560	2100	179	21.5	282
21	75	14	11	1920	358	282	2560	2130	148	17.8	282
24	76	14	10	2140	394	282	2820	2370	164	19.7	282
25 A	75	15	10	2140	422	282	2820	2370	192	23.1	282
22	75	12.5	16.5	1230	247	282	1765	1365	82	9.8	282
23A	71	14.7	14.2	1410	282	282	1980	1565	137	16.4	282
26	70	16	14	1410	321	282	2010	1560	171	20.5	282
27	69	15	16	1220	264	282	1765	1350	134	16.1	282
28	69	14	17	1140	232	282	1660	1265	107	12.8	282
29	74	16	10	2080	450	282	2820	2310	220	26.4	282
23	70	15	15	1320	282	282	1880	1465	137	16.4	282

* Average 3 specimens.

this trend is true for all water contents. Greatest strengths occur at 14 percent or more water content.

It is also interesting to note that for this aggregate, at a content of 73 percent aggregate there seems to be generally less variation in yield and strength plus a more uniform rise in strength with decreasing cement and increasing water.

At or near a water content of 14 percent the greatest number of satisfactory blocks were produced with regard to texture. Below this percentage the blocks tended to be smooth as though the aggregate was of a very fine size; their appearance was definitely "dry." When more than 14 percent water was used, especially where the cement content was the highest, smearing became evident and where the vibration was particularly intense the blocks were entirely smoothed over so that no texture was visible. The so-called "dry" textured blocks were also quite dark in color, having a very unpleasing appearance regardless of cement and aggregate proportions.

nch lightweight blocks made on Besser Vibrapac

Cu. yds. aggre. at 1444 lbs., dry	Block weight at machine, pounds per block	Calculated yield, blocks			Average cured block weights and compressive strengths*					
					7 days		18 days		28 days	
		Per batch	Per sack	Per cu. yd. aggre.	Comp. load	Wt.	Comp. load	Wt.	Comp. load	Wt.
0.896	31.7	55.5	18.5	61.8	902	29.9	924	29.4	1001	30.6
0.990	32.8	57.4	19.1	58.0	1155	31.1	1208	30.4	1356	31.4
1.055	32.7	61.5	20.5	58.3	1135	31.3	1311	30.9	1344	31.1
0.967	32.5	57.8	19.3	59.8	973	31.4	1050	30.1	1080	30.9
1.035	32.9	61.0	20.3	59.0	1208	31.6	1383	31.6	1391	31.7
1.120	37.2	58.3	19.4	52.0	1284	33.4	1558	32.9	1328	32.1
1.050	32.9	61.0	20.3	58.0	1087	31.3	1187	30.6	1155	30.8
1.133	33.2	65.5	21.8	57.8	1199	32.0	1321	30.8	1312	31.4
1.225	33.3	70.5	23.5	57.5	1167	32.5	1354	31.7	1431	32.5
1.150	31.4	69.0	23.0	60.0	932	30.1	1062	30.0	1116	30.4
1.245	35.1	67.0	22.3	53.9	1170	31.2	1208	30.1	1361	31.2
1.355	33.9	75.5	25.2	55.7	1341	32.8	1374	31.4	1354	32.1
1.370	35.5	72.0	24.0	52.5	1113	31.0	1195	30.8	1262	31.3
1.530	35.7	79.0	26.3	51.5	1091	30.9	1228	30.6	1301	31.0
1.530	33.2	85.0	28.3	55.5	1067	31.7	1233	30.6	1278	31.7
0.878	31.7	55.7	18.6	63.5	746	29.9	885	30.2	959	30.2
1.010	33.0	60.0	20.0	59.5	1228	31.7	1399	30.7	1479	31.6
1.010	Too wet; not weighed									
0.872	Too wet; not weighed									
0.815	31.8	52.2	17.4	64.2	1285	32.0	1309	30.9	1321	30.8
1.485	Omitted									
0.943	Too wet, not weighed									

Assuming, as the data illustrate, that the best all-around results for this particular aggregate are achieved at 14 percent water, Table 3 summarizes the results with regard to yield, strength, and weight of 8 by 8 by 16 inch masonry units of this study.

The screen analyses of the aggregate samples taken at each batch show fairly uniform gradation. There is little, if any, correlation between the slight gradation variations of the various mixes and the final block properties; other factors were strongly overriding. An outstanding example is the smooth-textured block produced by lack of water in the run which is entirely independent of the gradation as it was for these studies. Within the limits of practicality it is entirely reasonable to assume that the results that have been illustrated herein have not been influenced by the slight aggregate gradation variations. Table 4 gives screen analyses of the aggregates used in the batch mixes.

TABLE 3.—*Data on mixes containing 14 percent water*

Material proportions, dry basis, percent			Yields			
Aggregate	Water	Cement	Blocks per sack cement	Blocks per cu. yd. aggregate	Compressive load to failure, psi, 28 days	Weight per block
I Type machine for forming: Stearns Joltcrete						
70	14	16	21.5	76.0	720	24.7
71	14	15	23.2	75.6	678	24.6
72	14	14	25.0	75.2	752	25.6
73	14	13	25.5	70.5	646	25.3
74	14	12	29.0	72.2	447	23.7
75	14	11	31.9	72.4	635	24.0
76	14	10	36.2	73.7	428	23.6
II Type machine for forming: Besser Vibrapac						
70	14	16	18.2	62.0	1108	30.6
71	14	15	19.1	58.0	1356	31.4
72	14	14	20.3	59.0	1391	31.7
73	14	13	21.8	57.8	1312	31.4
74	14	12	22.3	53.9	1208	31.2
75	14	11	24.0	52.5	1262	31.3
76	14	10	26.3	51.5	1301	30.6
III Type machine for forming: Besser Vibrapac (decreased vibration intensity)					(7 day)	
69	14	17	18.0	66.5	1230	28.9
70	14	16	18.8	64.5	1330	30.1
72	14	14	22.9	66.0	1080	28.0
73	14	13	23.3	62.0	1190	29.2
74	14	12	25.0	60.5	1020	28.7
75	14	11	27.5	60.0	1060	28.8

CONCLUSIONS

Although only one specific type of aggregate was used for the tests summarized in this report, it is reasonable to assume that any tests involving systematic variations in the proportions of aggregate, cement, and water will give comparable results. The results of the above tests indicate that the water content is by far the most important of the three variables. For example, 14 percent water was shown to produce optimum results, whereas an increase to 15 percent water markedly lowered the quality of the block. Batches in which the cement content was constant, the aggregate used in increasing amounts, and the water in decreasing amounts showed decreasing yields in blocks per sack of cement and per cubic yard of aggregate. Batches in which the aggregate remained constant, with increasing water and decreasing cement, showed increasing yields of blocks per sack of

TABLE 4.—*Screen analyses of aggregate used for tests*

Batch no.	Percent material retained on screen							
	¼-inch	No. 4	No. 8	No. 16	No. 30	No. 50	No. 100	Pan
			Blocks formed on Joltcrete machine					
1	3.6	11.7	31.9	17.8	9.2	6.5	4.6	14.7
2	3.7	12.2	31.5	17.2	9.1	6.8	4.1	15.4
3	3.7	12.6	30.7	17.8	9.6	7.1	4.2	14.3
4	3.7	10.9	32.4	17.4	9.4	6.9	3.9	15.4
6	2.0	10.6	31.0	19.2	10.1	7.0	4.1	16.0
7	3.1	9.1	31.4	19.1	10.1	7.3	4.1	15.8
8	4.2	11.3	31.8	17.3	9.3	6.7	3.8	15.6
9	6.2	17.8	31.4	14.5	7.2	5.3	3.1	14.5
10	6.3	14.7	33.3	15.9	7.1	4.7	2.8	15.2
12	3.5	11.3	32.5	17.8	8.6	5.7	3.7	16.9
13	3.9	12.7	35.3	16.8	7.6	4.9	3.2	15.6
14	3.8	10.6	35.3	17.1	7.9	5.4	3.6	16.3
15	4.7	16.7	36.7	14.5	6.2	4.1	2.8	14.3
17	2.7	8.4	27.5	19.4	11.1	7.2	4.4	19.3
18	2.3	6.7	23.6	21.0	13.1	8.5	5.6	19.2
19	3.5	9.7	26.9	19.9	11.2	6.5	4.2	18.1
20	3.6	10.8	29.9	19.1	10.2	6.0	3.8	16.6
21	3.3	9.9	31.5	18.3	9.4	5.3	3.5	18.8
22	4.6	14.1	29.9	16.6	8.7	4.9	3.5	17.7
23	5.4	12.4	29.3	18.3	9.4	5.4	3.7	16.1
24	2.7	10.5	33.7	19.4	8.8	5.1	3.6	16.2
			Blocks formed on Besser Vibrapac machine					
1	4.3	15.4	31.8	15.6	7.8	4.4	3.6	15.9
2	2.4	11.2	30.2	18.3	10.1	6.4	5.2	16.3
3	1.6	8.8	28.2	19.6	12.0	7.7	6.6	16.7
7	1.5	8.8	28.8	19.8	11.4	7.2	5.9	16.7
8	1.6	8.0	26.2	19.8	12.1	7.9	6.8	17.6
9	1.8	8.3	29.0	19.6	11.4	7.3	6.6	17.1
13	1.5	8.1	28.4	19.5	11.5	7.5	6.4	18.3
14	1.3	10.3	27.6	18.5	10.9	7.2	6.5	17.7
15	1.7	12.4	29.0	17.9	10.4	6.5	6.3	16.0
18	2.5	13.8	30.3	17.4	9.6	6.3	5.8	14.6
19	2.4	12.4	29.9	18.2	9.9	6.6	6.2	14.4
20	2.3	12.4	29.5	17.9	10.2	6.6	6.5	14.6
21	1.3	11.5	29.4	18.6	10.5	6.5	6.4	15.7
22	2.3	12.2	31.6	18.2	9.9	6.2	6.1	13.6
23	2.6	9.8	29.2	18.2	11.1	8.2	7.2	13.8
24	3.5	11.1	29.2	17.6	9.7	6.3	6.3	16.3
25	3.5	14.1	29.6	16.6	8.9	5.7	5.7	16.1
22A	4.3	18.3	34.9	14.6	7.0	4.4	4.5	12.2
23A	3.2	14.0	32.5	16.7	9.0	6.1	5.9	12.8
22B	4.1	17.3	32.6	15.5	8.0	4.9	4.8	13.1
26	2.2	11.3	28.8	18.0	10.6	7.2	6.7	15.1
27	2.2	12.2	31.0	17.8	10.1	6.6	6.6	13.4
28	3.3	17.4	32.8	15.2	8.0	5.5	5.2	12.7

cement and decreasing yields in blocks per cubic yard of aggregate. The strength of the blocks tended to increase with increasing water content (and decreasing cement) up to 14 to 15 percent water. In the case of batches in which the water content was kept constant and the aggregate was increased with a decreasing cement content, the yield of blocks per sack of cement increased and the yield per yard of aggregate decreased. The compressive strengths increased to a maximum and then decreased. This is a result obviously to be expected because a composition containing no cement and all aggregate and water was being approached.

The important result of these tests was not so much the determination of optimum proportions of aggregate, cement, and water for block manufacture, but the proof that the systematic investigation of varying proportions by means of the tri-axial type diagram yields easily interpreted results.

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