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CLAY, AGGREGATE, AND CONCRETE

in cooperation with the
Department of Commerce
Bureau of Public Roads

RESEARCH REPORT 71-3 (Final)
STUDY 2-5-63-71
DELETERIOUS MATERIALS IN CONCRETE

CLAY, AGGREGATE, AND CONCRETE

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Deleterious Materials in Concrete
Research Study 2-5-63-71

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College Station, Texas

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LIST OF SYMBOLS

SE — The sand equivalent value.

LD — The loss by Decantation given as a percentage.

P — The decimal fraction of the minus no. 200 mesh material in a sample of sand.

A — The sand reading in inches in the sand equivalent test.

K — The ratio of the clay reading minus the sand reading and the sand reading in the sand equivalent test.

C — $\frac{K}{P}$.

LL — The liquid limit of the minus no. 200 mesh fraction.

K_1 — Adherence Factor, the ratio in percent between the fraction decanted in the loss by decantation test and the fraction of minus no. 200 mesh material actually present in an aggregate.

f^2 — Fundamental flexural frequency of vibration squared.

Introduction

Specifications for concrete aggregates represent a compromise between the desire for a perfect material and the necessity for using materials that are economically available. In many instances the engineer is faced with the problem of writing a specification to limit a certain property and finds that sufficient information concerning that property, or how to measure it is not available. These encounters have resulted in the use of such phrases as "harmful amounts," "excessive amounts" or in the assignment of some arbitrary quantitative measure. As experience is gained these arbitrary quantitative measures have been adjusted first in one direction then in another, resulting in serious loss of confidence in some specifications. One of the examples of this type of specification is in the area of cleanliness of concrete aggregates.

This research project was undertaken to strengthen the knowledge in this area. The specific objectives were:

1. To study methods of test for determining the clay content of concrete aggregates.

2. To determine the effects of clay content on the strength, shrinkage, and durability of concrete.

3. To relate these effects of clay on the properties of concrete to results of tests for determining clay content of the aggregates.

This research included a study of the existing test methods (sand equivalent and loss by decantation) used to detect clay in concrete aggregates, and a study of the effect of various amounts of clay with various liquid limits on the strength, shrinkage, and freeze-thaw durability of concrete. The work necessarily included the determination of clay fraction properties of concrete aggregates from pits within the state of Texas. The concrete testing program included one basic mix design with two coarse aggregates; a siliceous river gravel (all except B series mixes) and a crushed limestone (B series mixes). A siliceous river sand and one brand of Type I cement were used throughout the program.

Work on this project was conducted over a three-year period. The exact mix quantities and properties for each mix are given in Tables 7 through 12 in the appendix and the legends on curves indicate the mix series from which the data were taken.

Summary and Conclusions

The conclusions developed from this study are based on a limited number of aggregates and concrete batches. Care should be exercised in extending these conclusions to materials other than those studied.

It has been found that the activity as well as the amount of the minus no. 200 mesh fraction of concrete aggregates affects the properties of concrete. Both activity and amount are reflected in the sand equivalent value but not in the loss by decantation. Clay contaminants in concrete aggregate affect concrete properties primarily through their effect on water demand. Concrete strength and shrinkage correlate to a high degree with sand equivalent value and to a slightly lesser degree with water-cement ratio indicating the possibility that the sand equivalent test indicates properties of the aggregate that are not accounted for solely by the aggregates' water demand in concrete.

The basic reactions and mechanisms by which the clay components produced these observed effects are quite complex. Clay particles, being colloidial, are known to possess an adsorbed water layer, attracted and held by the negative electric charge on their surfaces. If this layer contains cations, such as calcium or sodium, it is referred to as the adsorption complex. The nature of this adsorption complex greatly influences the properties of the clay. The ability of a clay particle to attract water and cations and to increase in volume will act to influence the properties of the concrete. As the clay comes in contact with the batch water, water molecules are drawn into the layered clay particle causing an expansion and weakening the particle. The primary influence is apparently due to the increased water demand caused by the presence of these clay fines.

The freeze-thaw durability of the concretes studied is related to the sand equivalent value. Decreases in sand equivalent value bring about decreases in the freeze-thaw durability of the concretes. However, the mode of deterioration was different in the air entrained and non-air entrained concretes. The non-air entrained concretes exhibited structural failure as indicated by sonic modulus of elasticity determinations but in the air entrained concrete, attrition of the surface reflected by loss in weight was the primary indicator of deterioration.

The need for sufficient processing to produce a relatively clean aggregate can best be emphasized by considering the quantitative effects on the properties of the concrete. The data developed indicate that for a given fine aggregate, as the sand equivalent value changes from 60 to 80, the concrete properties will exhibit the following changes.

1. Gain in 7-day compressive strength of 15%.

2. Gain in 28-day compressive strength of 16%.

3. Gain in 7-day modulus of rupture of 13%.

4. Gain in 28-day modulus of rupture of 12%.

5. Increase in durability (according to ASTM C290) of *non*-air entrained concrete of 60%.

6. Insignificant change in durability of air entrained concrete (air content approximately 5%).

7. Decrease in relative 28-day shrinkage of 17%.

8. Decrease in relative 120-day shrinkage of 15%.

9. Decrease in concrete mixing water demand of 9%.

On the basis of concrete strength and shrinkage, the present Texas Highway Department sand equivalent specification minimum of 80 seems quite reasonable. The freeze-thaw durability test results emphasize the need for precise control of air entrainment where fine aggregates with sand equivalent values close to the specification limit are to be used.

The loss by decantation test was found to measure only the amount of minus 200 mesh material in an aggregate. It fails to distinguish between active clay material and durable, inert minerals. The sand equivalent test, on the other hand, indicates both amount and activity (as measured by the liquid limit) of the minus 200 mesh fraction and is a more desirable indicator of the quality of fine aggregate.

Sand Equivalent and Loss by Decantation Tests

The sand equivalent (Tex-203-F) and loss by decantation (Tex-406-A) test methods used in this program are given in the Appendix.

The sand equivalent test was developed by F. N. Hveem while he was serving as Materials and Research Engineer, California Division of Highways. It was to be used as a rapid means of quality control of fine aggregate for bases, subbases, bituminous mixtures, and portland cement concrete. The procedure developed by Hveem did not require that the sample be oven dried prior to testing and consequently results could be produced within 40 minutes.

The testing program was carried out in two phases—the first, a study of the relationship between the sand equivalent and loss by decantation tests, and the second, a more detailed investigation of the sand equivalent test. In the first phase, 15 samples of concrete sand from various locations in Texas were obtained. Values obtained from tests run on these samples are plotted in Figure 1 and are presented in Table 2.

In order to investigate the effect of liquid limit on the results of the two tests, artificially contaminated aggregates were blended and tested. The sand used was a high quality concrete sand which was washed in the laboratory with a detergent to remove all minus 200 mesh material. The contaminants used were: (1) pure silica flour with a liquid limit of zero, (2) a natural clay with a liquid limit of 35 percent, (3) a silica-montmorillonite mixture with a liquid limit of 200 percent, (4) a silica-montmorillonite mixture with a liquid limit of 400 percent, and (5) pure montmorillonite with a liquid limit of 640 percent. Results of tests performed on these sands are given in Table 2.

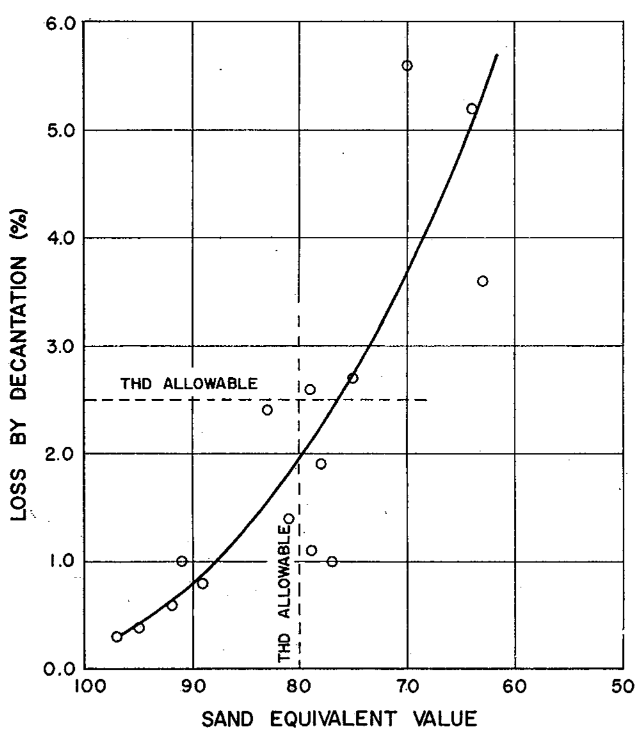


Figure 1. Relationship between loss by decantation and sand equivalent value for natural aggregate samples.

Figures 2 and 3 demonstrate the effect of liquid limit for two different percentages of contaminant on the results of the two tests. The sand equivalent values of Figure 3 are in close agreement with those reported by Clough and Martinez (4)*. It can be seen that the variation in liquid limit of the contaminant has little or no effect on loss by decantation results, but has a very pronounced effect on the sand equivalent value.

The relationship between loss by decantation and sand equivalent test values can be derived in the following manner. If the symbols of Figure 4 are used in the definition of the sand equivalent value, it can be written:

$$SE = 100A/(A + KA) \quad (1a)$$

or

$$SE = 100/(1 + K) \quad (1b)$$

For a given material the factor K can be written as another factor C times P, where P is the decimal fraction of the contaminant in the sample. Equation (1b) then becomes:

$$SE = 100/(1 + CP) \quad (2)$$

This equation can be written

$$C = (100\text{-}SE)/(SE)\ (P) \quad (3)$$

If values of C are plotted against values of the liquid limit (using the data from Table 2) and the data points fitted with a curve by the least squares method using $C = A_1\ (LL) + A_2$ as a model. The resulting equation is

$$C = 0.1318\ (LL) + 1.79 \quad (4)$$

Figure 2 shows the average value of the loss by decantation was 2.3 percent for 2.5 percent minus 200 mesh material. If these values are used in the equation,

$$LD = K_1P \quad (5)$$

the value of K_1 is found to be 92.

Equation (5) can now be written,

$$P = LD/92.0 = 0.01087\ LD \quad (6)$$

The relationship between sand equivalent (SE) and loss by decantation (LD) can be found by substituting

*Numbers in parentheses refer to corresponding numbers in the Bibliography.

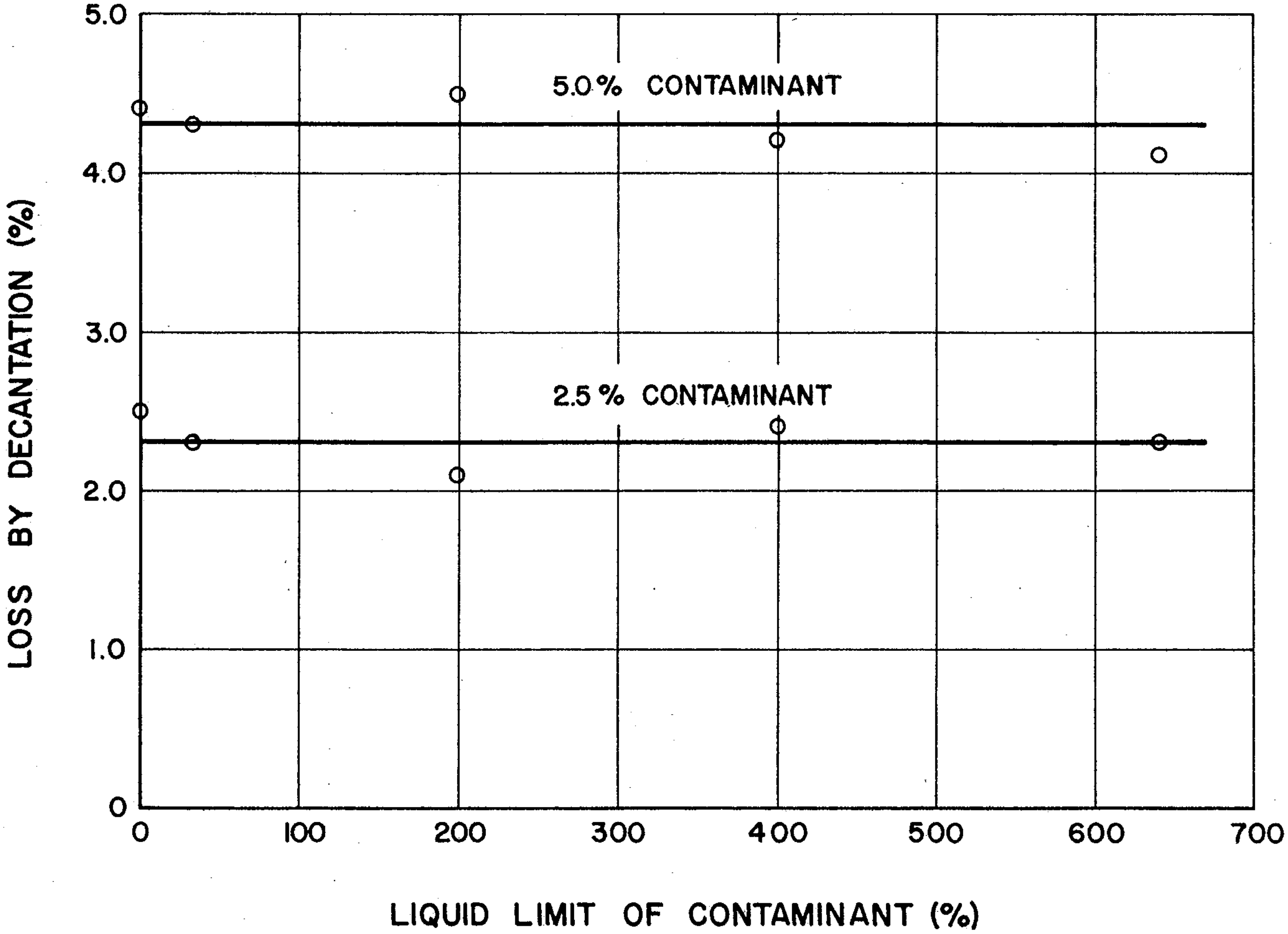


Figure 2. Relationship between loss by decantation and liquid limit of contaminant.

the expression for C from Equation (4) and the expression for P from Equation (5) into Equation (2). The resulting equation is

$$SE = \frac{100}{1 + \frac{LD}{K_1} (0.1318\ LL + 1.79)}$$

A comparison of calculated and measured values of sand equivalent for both the natural samples and manufactured samples is illustrated in Figure 5. The values for samples 106 through 110 compare very closely, but for samples 1 through 10 the calculated value is somewhat higher than the measured value.

There are several possible reasons for the smaller degree of correlation between calculated and measured sand equivalent values in the naturally occurring samples. First, the mode of occurrence of the clay, whether finely divided or as a coating, should influence the decantation loss creating a variable value of K_1. Second, properties of the sand, other than the minus no. 200 mesh fraction probably influence the sand equivalent value. Other researchers (3, 8) have shown that other properties of a sand are reflected in the sand equivalent value. Tests performed by Chamberlin (3) indicate that in a few sands a "generation of fines" takes place during the shaking operation of the sand equivalent test. It is very unlikely that this "generation of fines" takes place in the loss by decantation test due to the lack of any vigorous scrubbing action.

There are several opinions as to the meaning of the sand equivalent value, i.e., which of the various properties of sands are reflected in the sand equivalent value. Nevertheless, the fact remains that the test correlates quite well with the strength, shrinkage, and durability of the concretes tested in this program, and research conducted by the California Division of Highways (8) has resulted in a correlation between mortar shrinkage and sand equivalent value of natural sands.

Initial investigations showed that the quality of concrete was affected by both amount and type of clay in the aggregates. It was felt that the quality of the concrete is also affected by the relative amount of the total clay content that occurs as a coating on the aggregate particles. In order to investigate such an effect, a means of detecting the relative amount of clay coating was desired. An attempt was made to modify the sand equivalent test procedure to detect relative amounts of clay coating. Two techniques were employed. First, a given sample was divided by quartering to yield four test specimens. A sand equivalent test was then run on each of these specimens—one specimen at zero shakes, another at 30, another at 60, and finally one at 90 shakes. The second technique used was to obtain a representative sample and run a sand equivalent test at zero shakes,

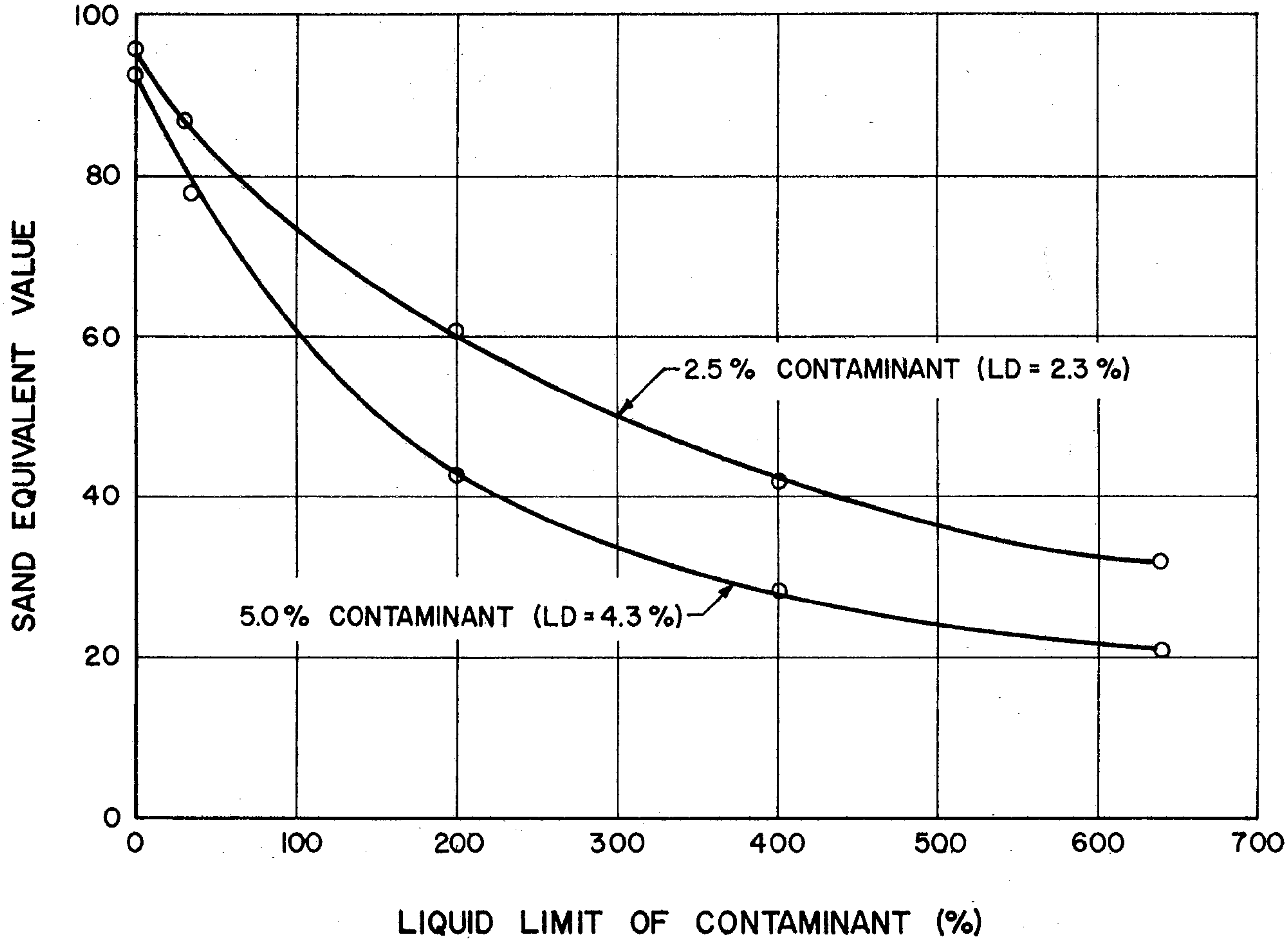


Figure 3. Relationship between sand equivalent and liquid limit of contaminant.

then siphon off the liquid down to the specified height for shaking and subject the specimen to 30 shakes. A second set of readings was taken. These siphoning and shaking operations were repeated at 30 shake intervals with readings taken after each shaking until a total of 90 shakes were imparted to the specimen. A number of tests were run up to 180 shakes.

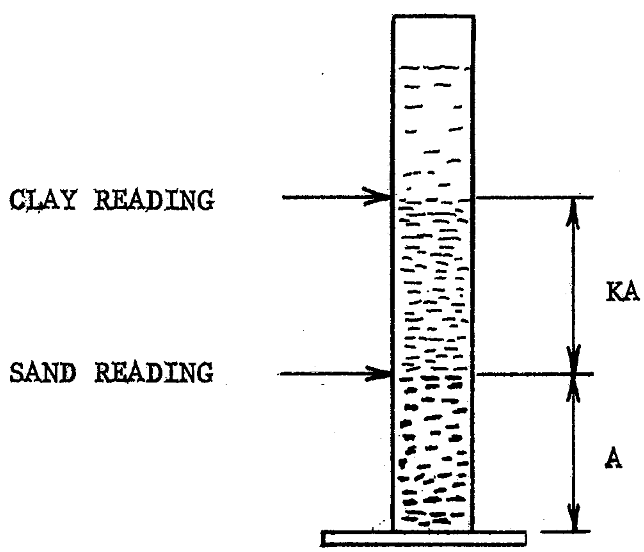


Figure 4. Illustration of clay and sand reading in sand equivalent test.

From these test results, a plot of sand equivalent against total number of shakes was made. It was thought that the shape of the curve relating sand equivalent value with number of shakes could be used as a measure of the relative amount of clay occurring as a coating.

Some 200 tests were run on 21 samples from various locations in Texas. Laboratory prepared samples were also tested in this phase. It was found that various preparations of laboratory samples using sand from a single source produced curves with various degrees of curvature. Quantitative measures of this curvature would indicate the relative ease with which a clay can be separated from the aggregate. Curves of the type desired are shown in Figure 6. Curves developed from commercially produced aggregates however, have a general downward trend and the curvatures artificially produced were not observed. Figure 7 illustrates two curves typical of those developed. No practical significance was discovered for the data developed in this area of the program except that the "generation of fines" phenomenon described by Chamberlin (3) seemed indicated by tests on some of the samples.

As stated earlier, this work included the determination of clay fraction properties of commercially produced

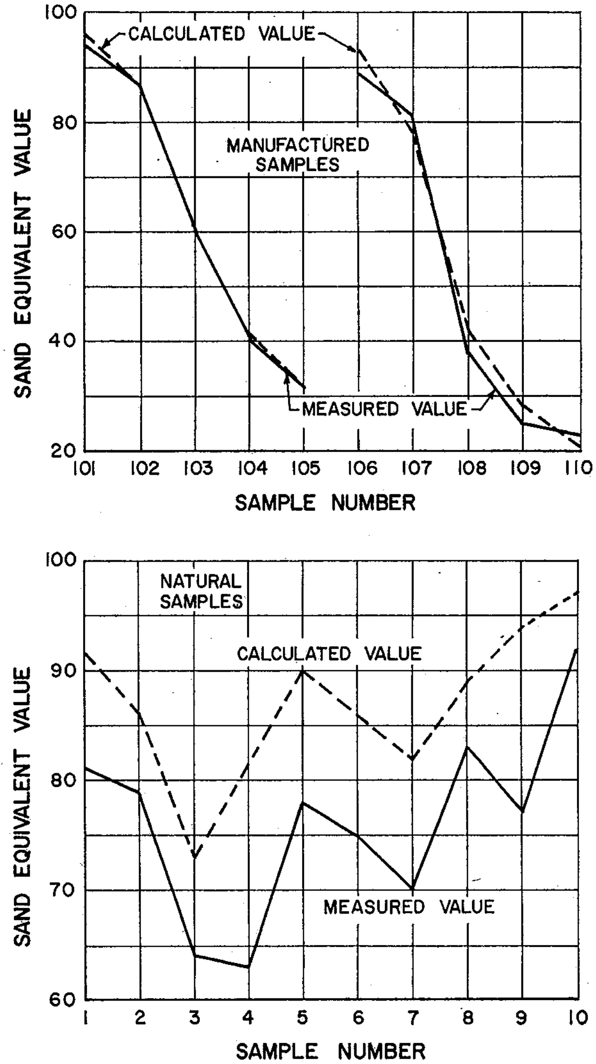


Figure 5. Correlation between calculated and measured sand equivalent value.

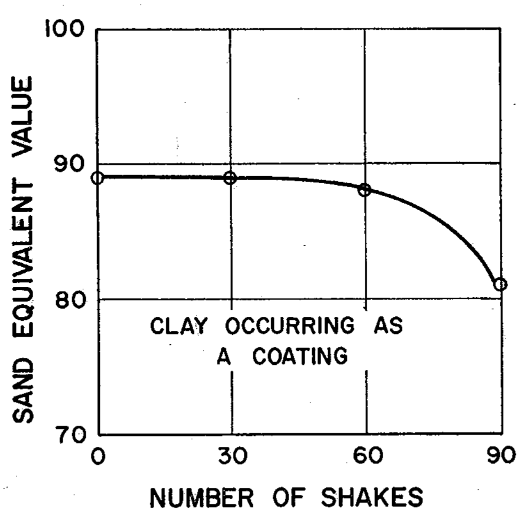


Figure 6 (a).

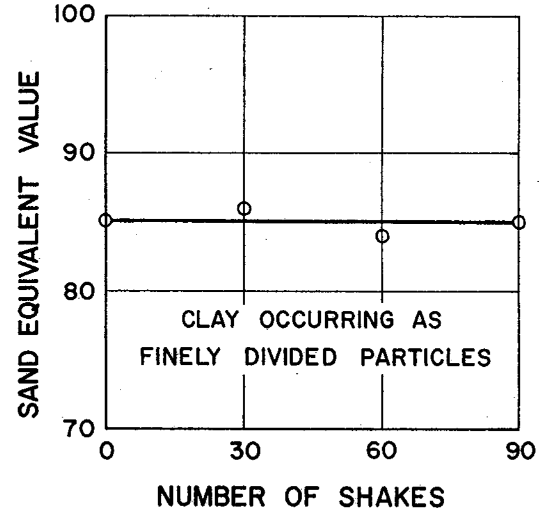


Figure 6(b). Typical curves indicated by preliminary tests and expected from natural samples.

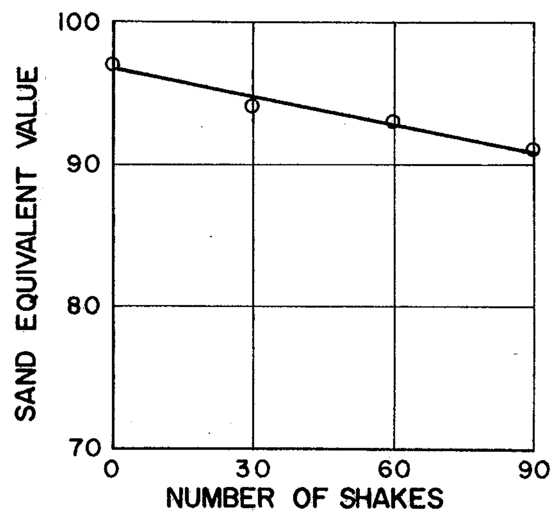


Figure 7 (a).

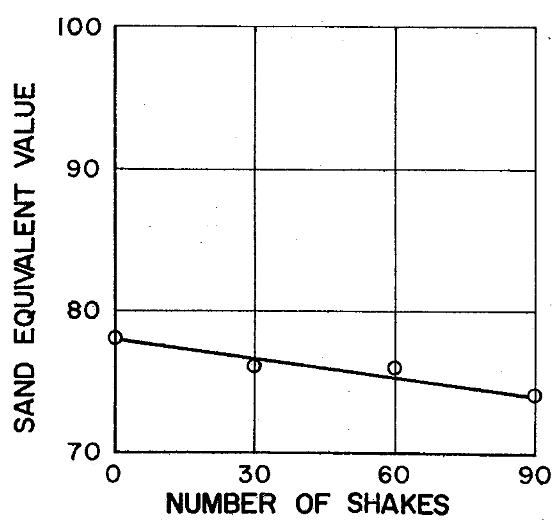


Figure 7(b). Typical curves relating sand equivalent value to number of shakes for natural samples.

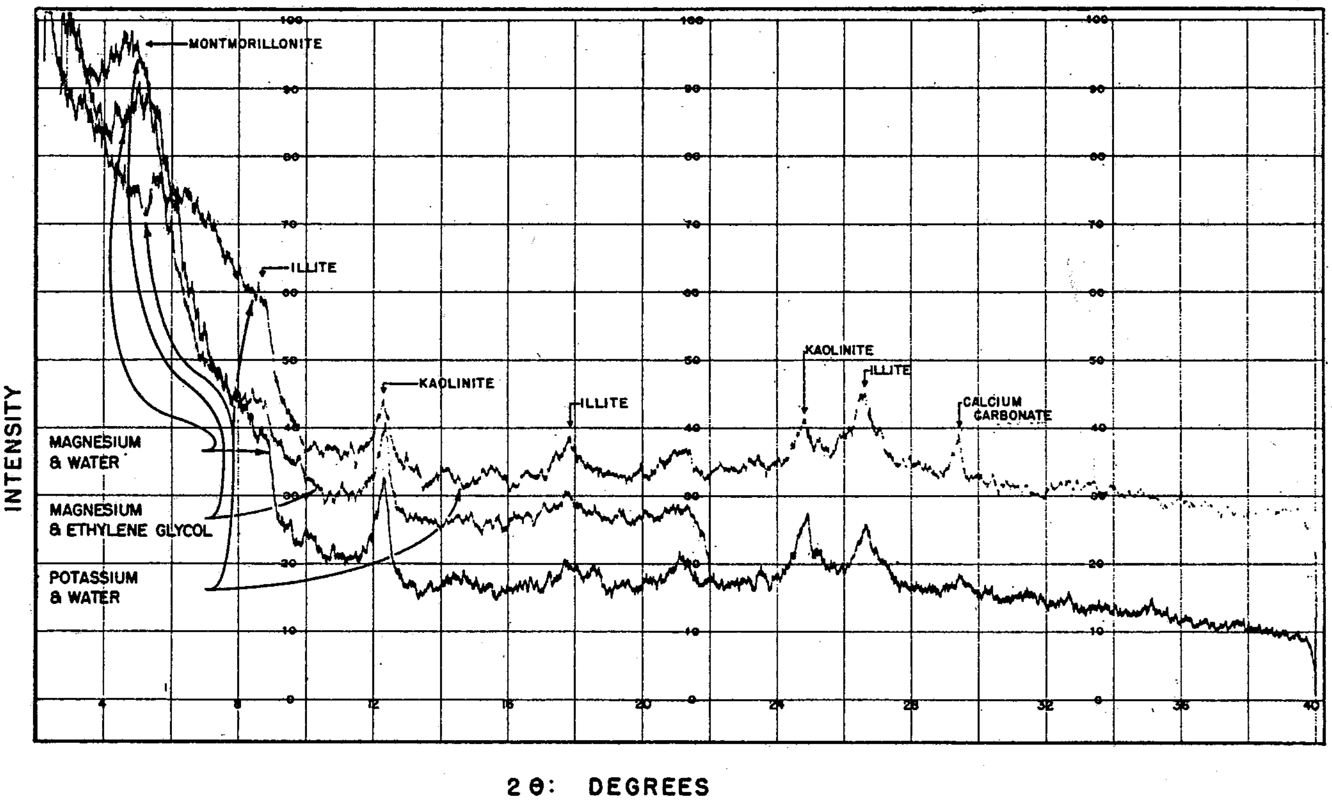


Figure 8. Typical X-ray diffraction pattern.

concrete aggregates. The clays were identified by x-ray diffraction, cation-exchange capacity, and exchangeable cation determinations which were performed by Dr. G. W. Kunze of the Texas A&M University Soil Physics Department. Figure 8 is a typical x-ray diffraction pattern obtained from one of the tests. Other related properties of the clays are given in Table 1. In general most of the clays are predominantly montmorillonite.

TABLE 1. ANALYSIS OF CLAYS

Sample Number	Type of Clay and Estimated Amount*	Cation Exchange Capacity in Milli-Equivalents per 100 gm.	Exchangeable Cations in Milli-Equivalents per 100 gms. Na	Ca	Mg	K
1	I2, M2, K2, Q3					
2	M1, I3, K3, Q3	17.3	0.24	calc.	3.2	0.37
3	M1, K2, I3, Q3	18.6	0.11	calc.	1.8	0.53
4	M1, I2, K2, Q3	7.5	0.10	calc.	0.94	0.18
5	M1, I2, K2, Q3	11.0	6.2	calc.	4.2	0.33
6	M1, K2, I2, Q3	13.5	0.44	calc.	1.8	0.29
7	M1, I2, K2, Q3	32.3	0.23	calc.	2.2	0.63
8						
9	M1, K2, I3, Q3	10.2	4.9	calc.	8.0	0.97
10	M1, K2, I3, Q3	9.6	0.58	calc.	1.2	0.29
11	I2, K2, M2, Q3	14.3	0.3	7.9	1.7	0.55
12	M1, I3, K3, Q3					
13	M2, I2, K2, Q3, F3					
14		7.7	0.22	calc.	1.4	0.20
15						
16	M1, K2, I3, Q3	17.1	1.2	15.5	5.7	0.75
17	M1, I2, K2, C3					
18	M1, K3, I3, Q3	8.3	0.39	calc.	0.58	0.25

*Abbreviations used are M-Montmorillonite, I-Illite, K-Kaolinite, Q-Quartz, F-Feldspar, C-Calcium Carbonate.

Numerical Code: 1—greater than 40 percent, 2—10 to 40 percent, 3—less than 10 percent. If several clay minerals have the same quantity code designation within a sample, they are arranged in order of descending magnitude.

Strength of Concrete

Initial testing conducted during the first year was aimed at determining the qualitative effects of contaminant liquid limit on the properties of concrete. Therefore a very wide range of liquid limit (0 to 640 percent) was employed. Contaminant percentages varied from 0 to 1.6 percent of the total aggregate by weight.

The effects of liquid limit of contaminant on the flexural and compressive strength is illustrated in Figures 9 through 12. In each case a significant reduction in strength is caused by increasing the liquid limit of the contaminant. The mixes included contaminants with very high liquid limits which were used to determine the relative importance of this factor.

The fact that concrete strength is influenced by both the amount and liquid limit of the contaminant indicated the need for more precisely defining these effects within the practical range found in concrete aggregates. Additional mixes (C and E series) were designed to accomplish this.

The data relating strength and shrinkage to sand equivalent value and water-cement ratio have been approximated by straight lines fitted by the least squares method (5). The control batch from each series of batches was used as the basis for calculating the relative strength and shrinkage for each particular series. The equation for each of the lines and the respective correlation coefficient are given on each figure. Dashed lines representing plus and minus 10 percent of the ordinate have been drawn on each figure to more clearly illustrate the degree of data scatter.

Figures 13 and 14 illustrate the effect of amount of clay contaminant at the 35% liquid limit level on the 7 and 28-day concrete compressive strength. The correlation coefficients for both lines (0.85 for 7-day and 0.89 for 28-day) are high, indicating a good correlation in each case. The plus and minus 10 percent lines include all but 5 out of 37 data points in each of the figures.

The relationship between modulus of rupture at 7 and 28 days and sand equivalent value is illustrated in Figures 15 and 16. The 7-day test data yield a lower correlation coefficient (0.74) than that found in the

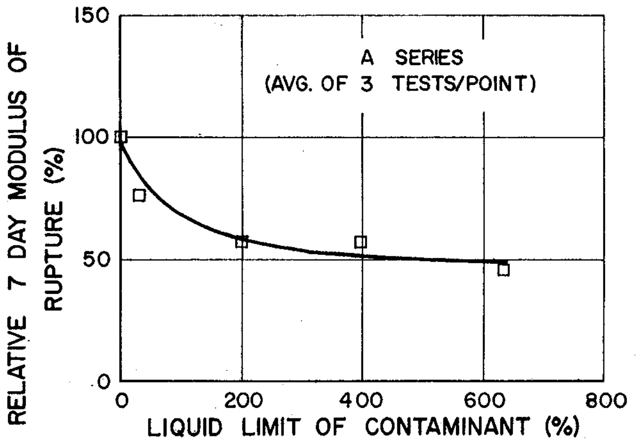


Figure 9. Influence of liquid limit of contaminant (nominally 1.6% clay) on 7-day modulus of rupture.

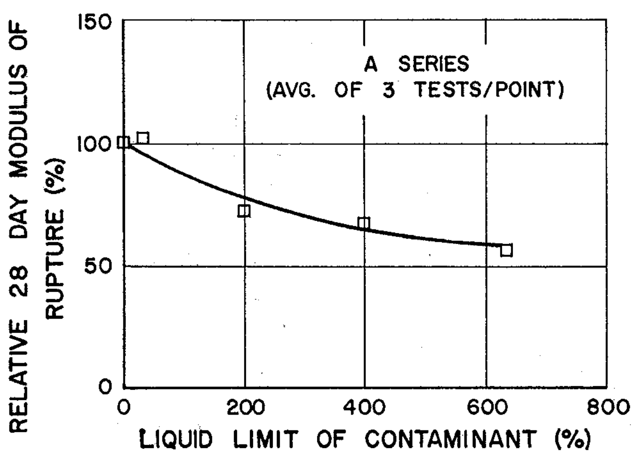


Figure 10. Influence of liquid limit of contaminant (nominally 1.6% clay) on 28-day modulus of rupture.

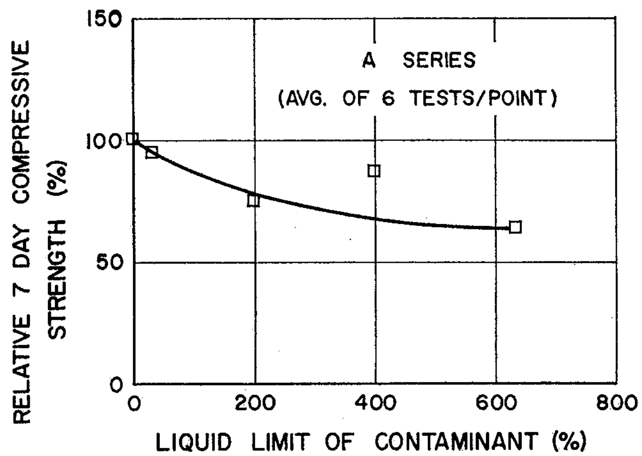


Figure 11. Influence of liquid limit of contaminant (nominally 1.6% clay) on 7-day compressive strength.

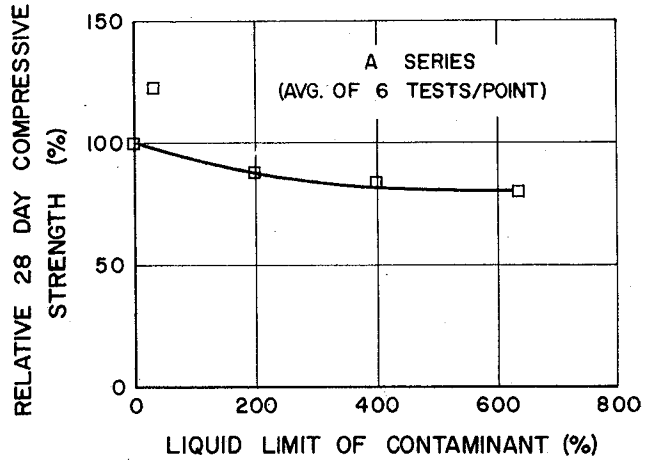


Figure 12. Influence of liquid limit of contaminant (nominally 1.6% clay) on 28-day compressive strength.

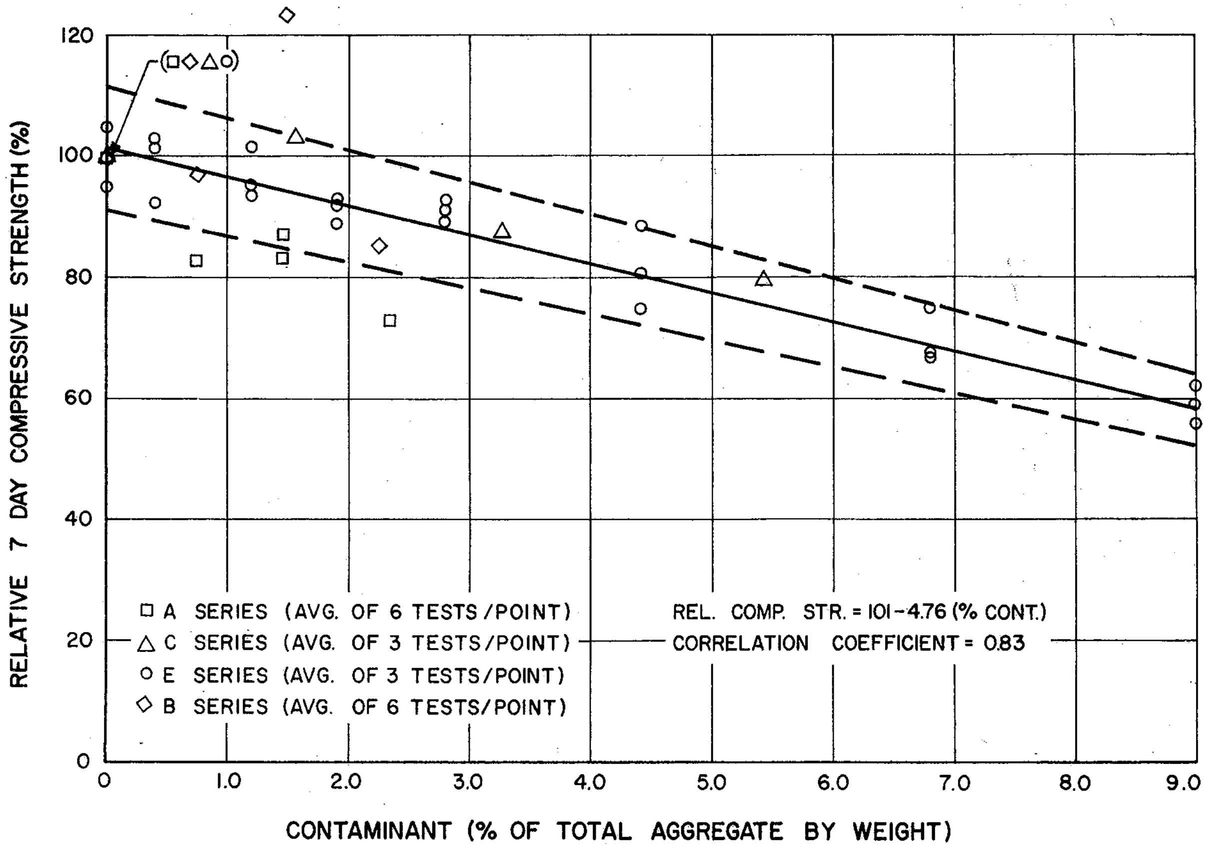


Figure 13. Influence of Amount of Contaminant (LL = 35%) on 7-day compressive strength.

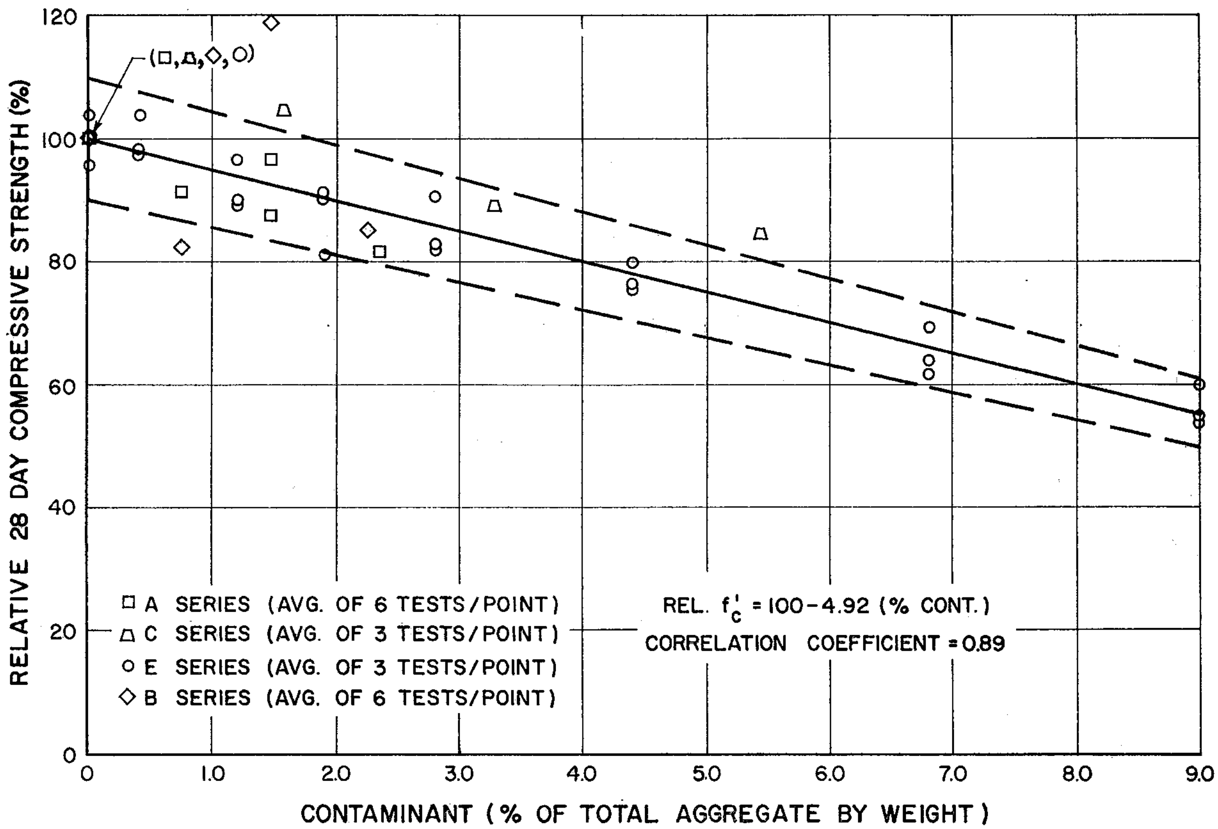


Figure 14. Influence of amount of contaminant (LL = 35%) on 28-day compressive strength.

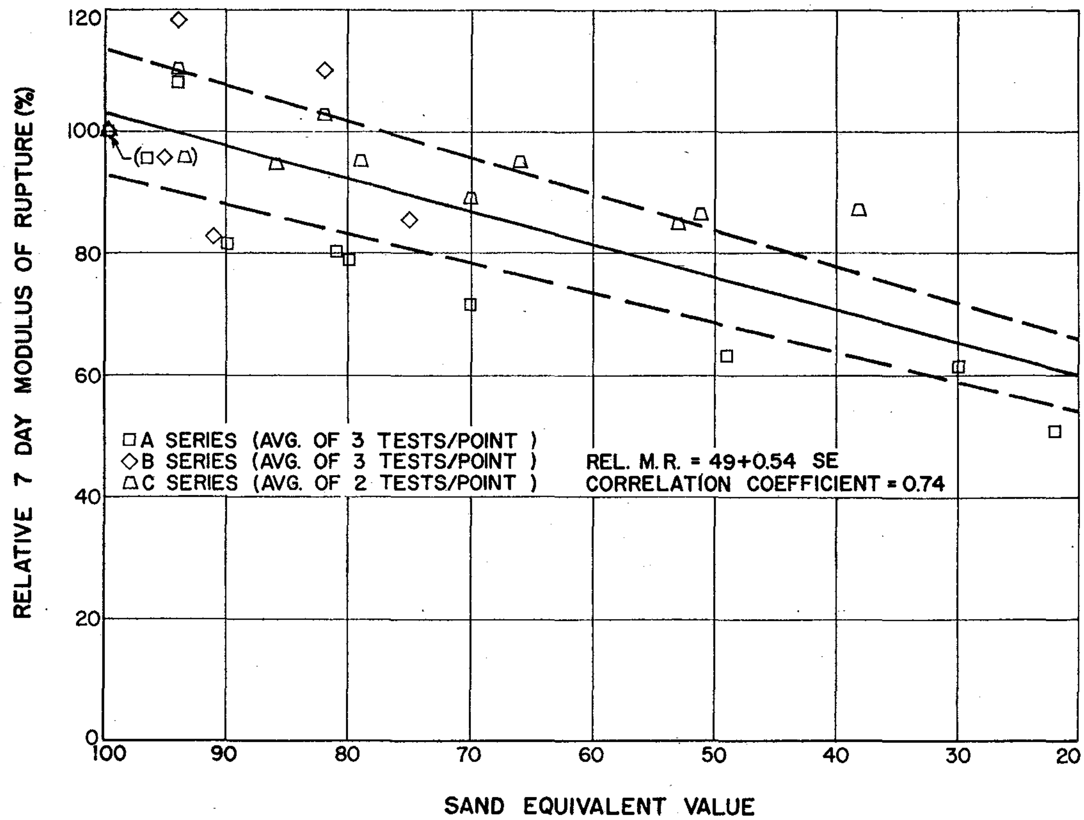


Figure 15. Relationship between 7-day modulus of rupture and sand equivalent value.

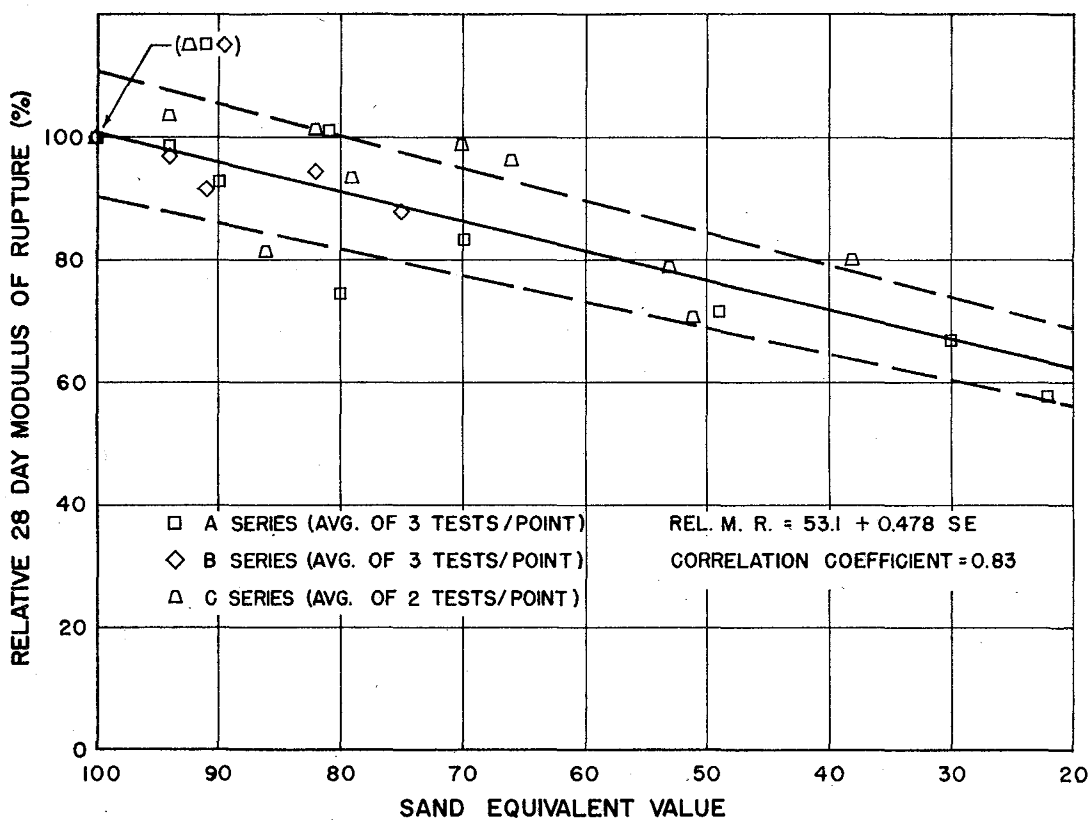


Figure 16. Relationship between 28-day modulus of rupture and sand equivalent value.

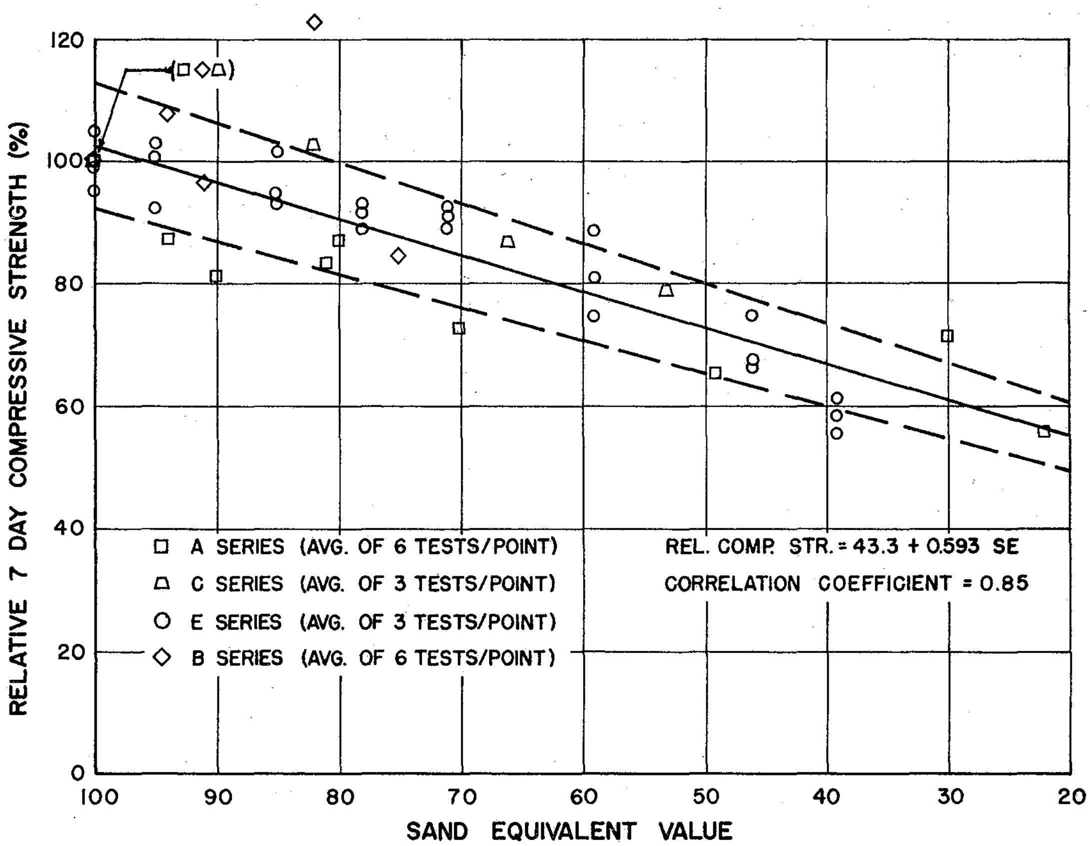


Figure 17. Variation in 7-day compressive strength with sand equivalent value.

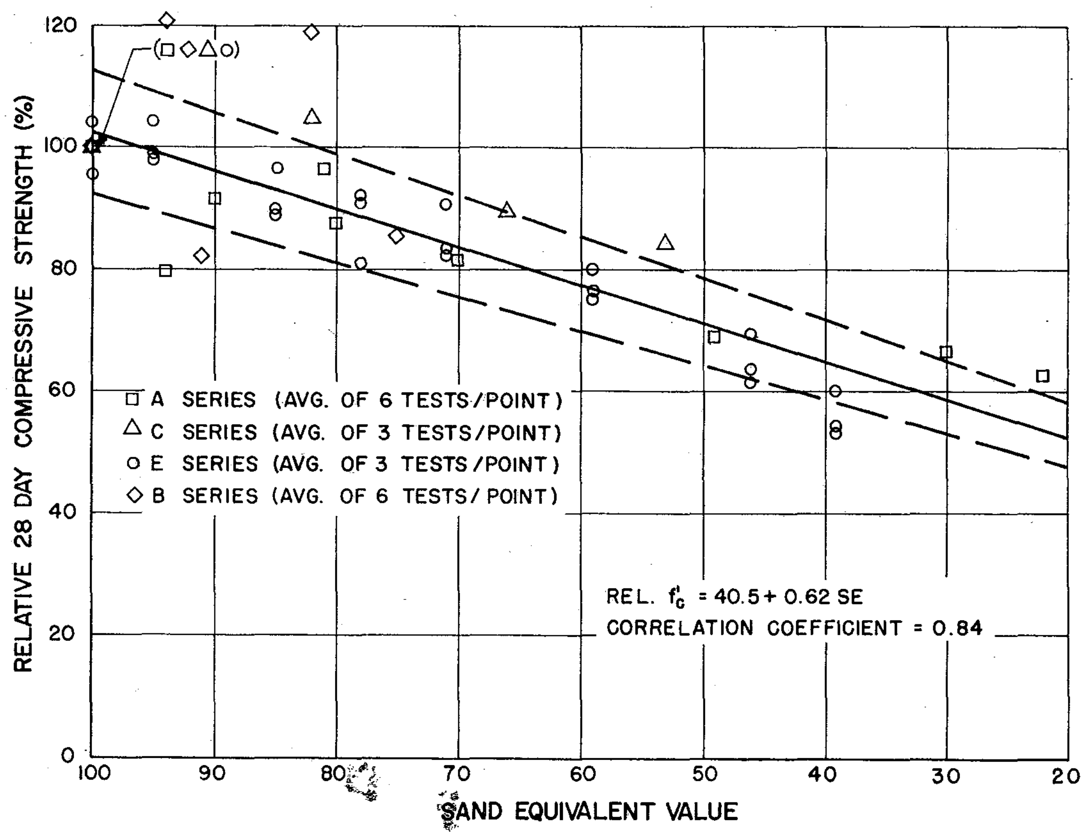


Figure 18. Variation in 28-day compressive strength with sand equivalent value.

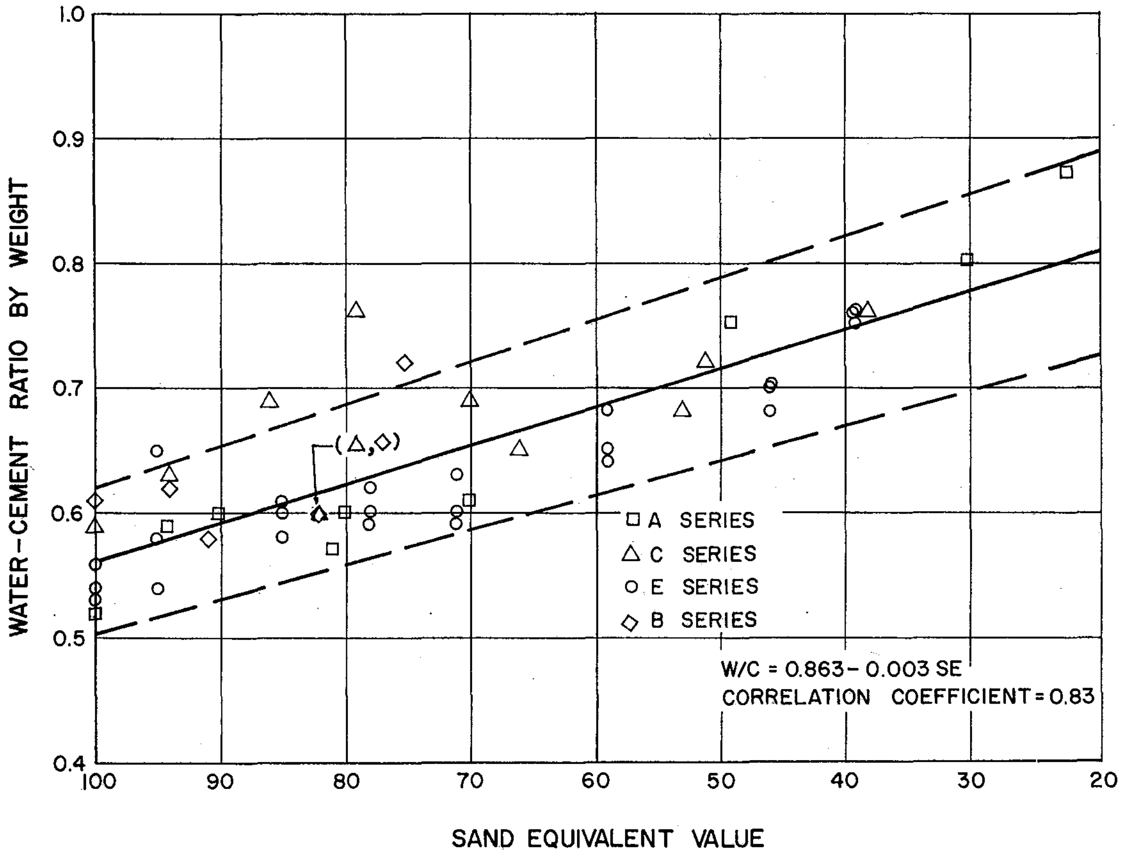


Figure 19. Effect of sand equivalent value on water-cement ratio for 5-sack mix with 3 in. slump.

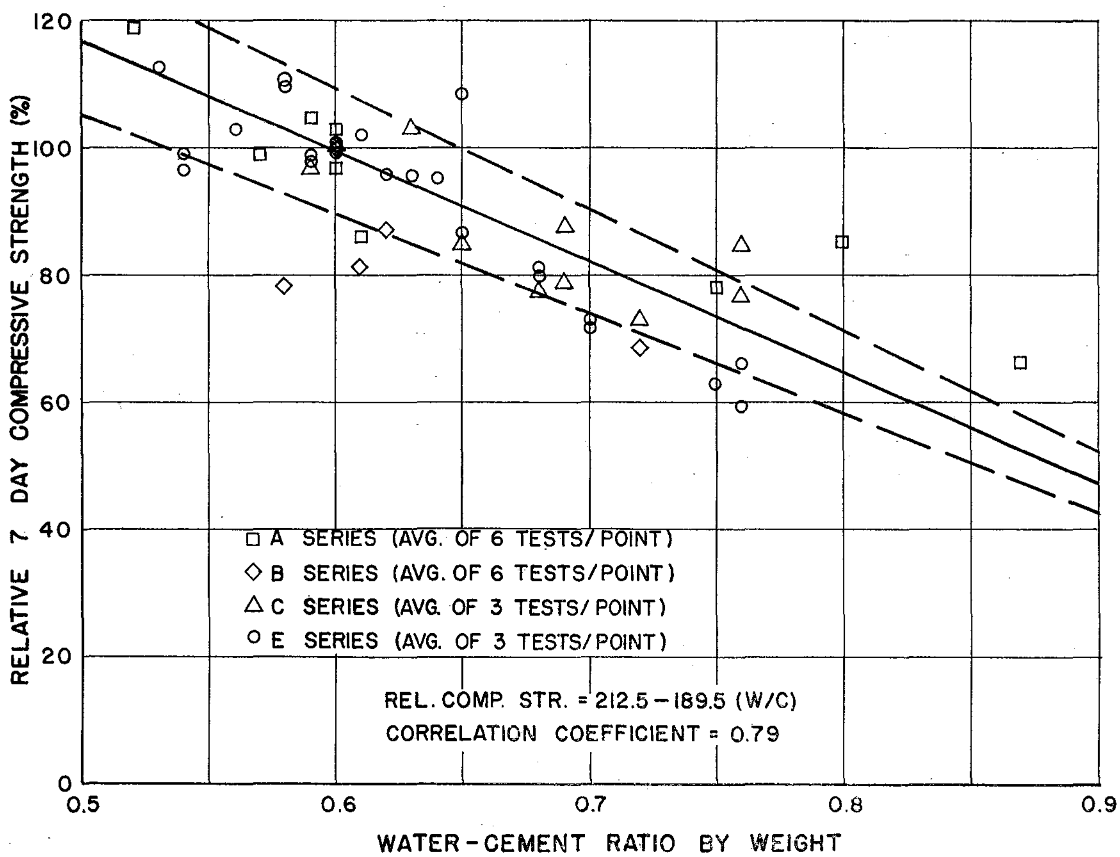


Figure 20. Relationship between 7-day compressive strength and water-cement ratio.

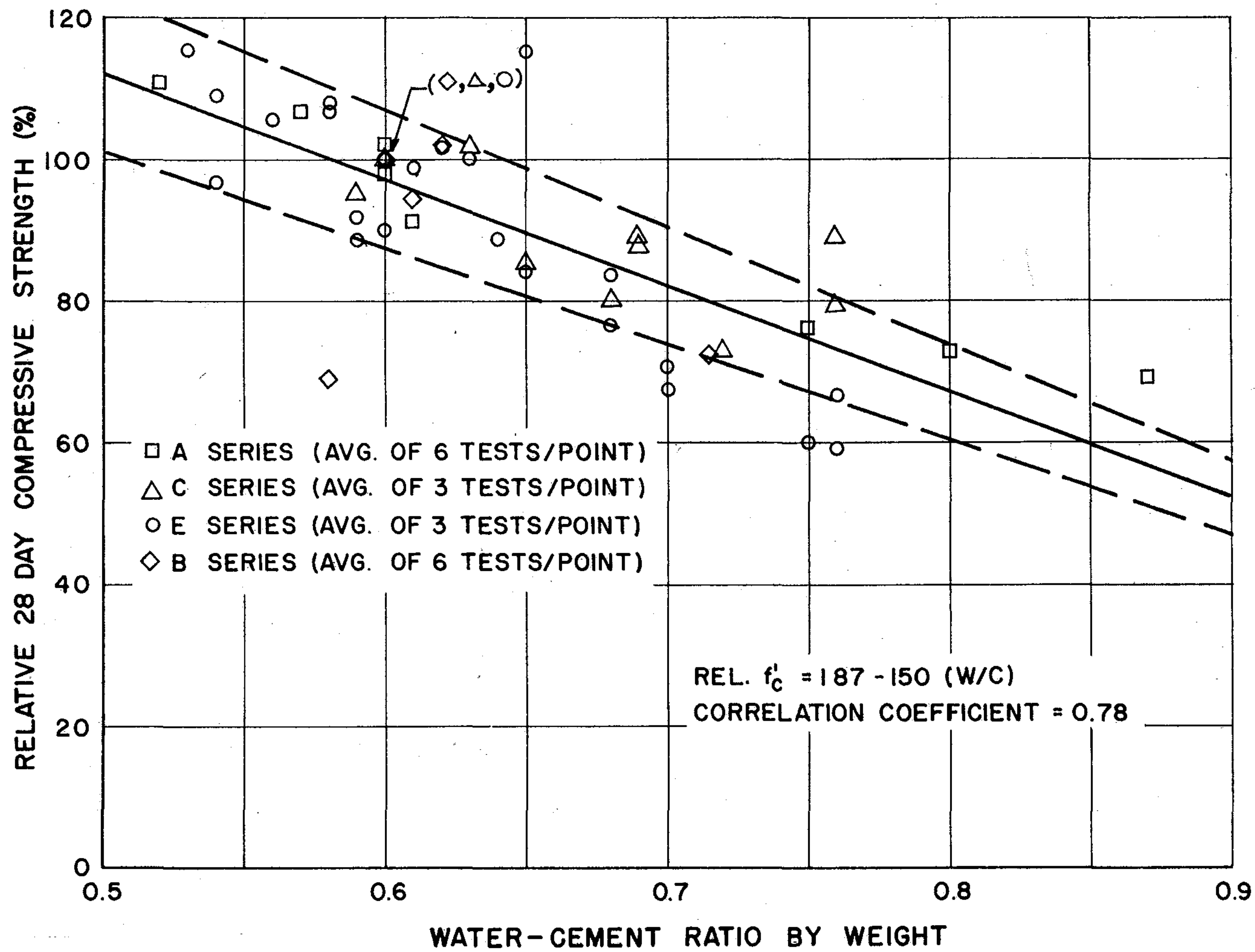


Figure 21. Relationship between 28-day compressive strength and water-cement ratio.

28-day test (0.84). Nevertheless both correlation coefficients are relatively high. A sand equivalent value of 80 indicates a reduction in modulus of rupture of about 10 percent when compared to mixes containing sands with a sand equivalent value of 100.

As in the case of modulus of rupture, the compressive strength correlates quite well with sand equivalent value as shown in Figures 17 and 18. Decreases in sand equivalent values cause a decrease in compressive strength. A decrease in compressive strength of about 11 percent can be expected if the sand equivalent value is changed from 100 to 80.

The water requirement for a given slump has been found to correlate quite well with sand equivalent value (correlation coefficient 0.83). This relationship is illustrated in Figure 19. The correlation of water-cement ratio with compressive strength is illustrated in Figures 20 and 21. Here and in Figures 24 and 25, batches with water-cement ratios of 0.6 were used as the control batches. The correlation coefficients for these two curves are slightly lower than those for the strength-sand equivalent correlations.

The fact that the correlation coefficient of the strength vs. sand equivalent value is only slightly higher than the strength vs. water-cement ratio indicates that almost all the variation in strength can be attributed to the increased water demand of the sands having lower sand equivalent values.

Test data obtained during the first two years did not make this relationship evident, but the accumulation of data during the last year has properly illustrated this relationship. The statement that fine aggregate affects the properties of concrete primarily through its effect on water requirement (3, 8) is supported by the data obtained from this study.

Shrinkage of Concrete

Shrinkage of the concretes studied correlates to some degree with water-cement ratio but to a higher degree with sand equivalent value as illustrated by Figures 22 through 25. In each case a decrease in sand equivalent value or an increase in water-cement ratio causes an increase in shrinkage.

Hveem and Tremper (8) reported a correlation coefficient of 0.66 between drying shrinkage of mortar and sand equivalent value of commercially produced concrete sands. However, when the absorption of the sand was included the correlation was significantly improved (correlation coefficient 0.83). Chamberlin (3) reports "... Interestingly, sand equivalents of the experimental aggregates also correlate with drying shrinkage and to a rather high degree ...

"The relative contribution of aggregate elasticity and clay content (as measured by sand equivalent) to the observed shrinkage cannot be distinguished by statistical methods alone. This is because the two factors correlate significantly with one another (coefficient of 0.80), that is, sands with low elastic moduli tend also to have low sand equivalents and both, therefore, would be expected to influence shrinkage in the same direction and in unison ..."

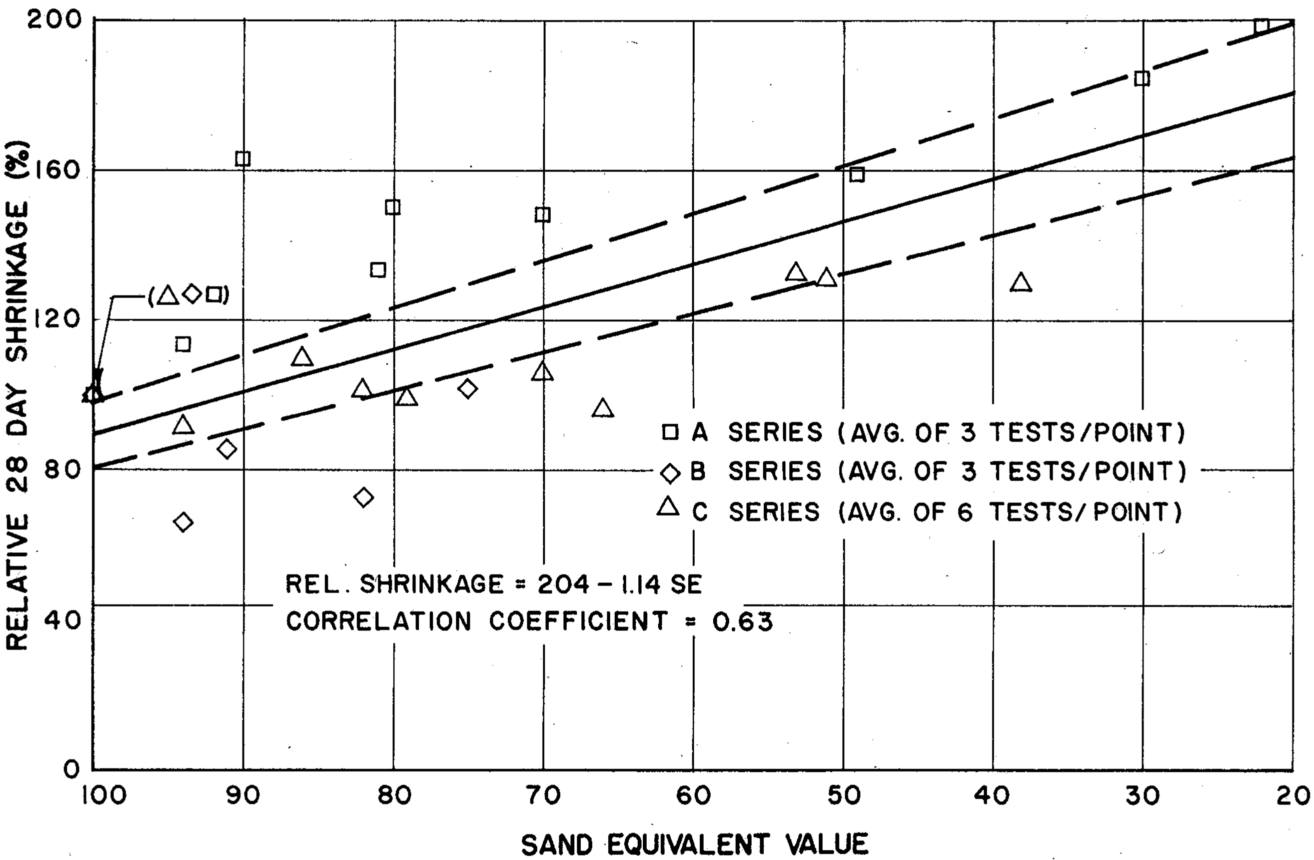


Figure 22. Relationship between 28-day shrinkage and sand equivalent value.

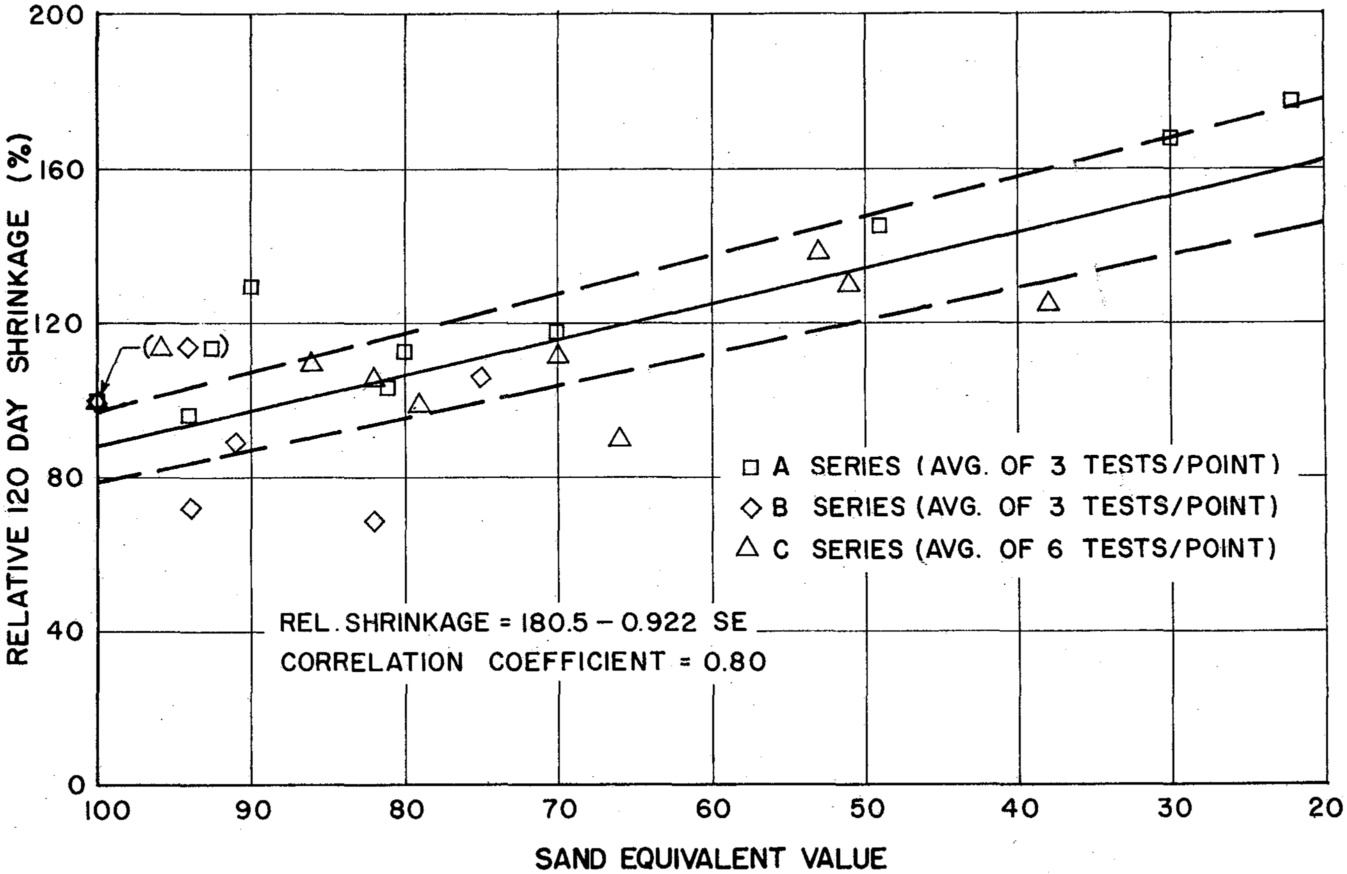


Figure 23. Relationship between 120-day shrinkage and sand equivalent value.

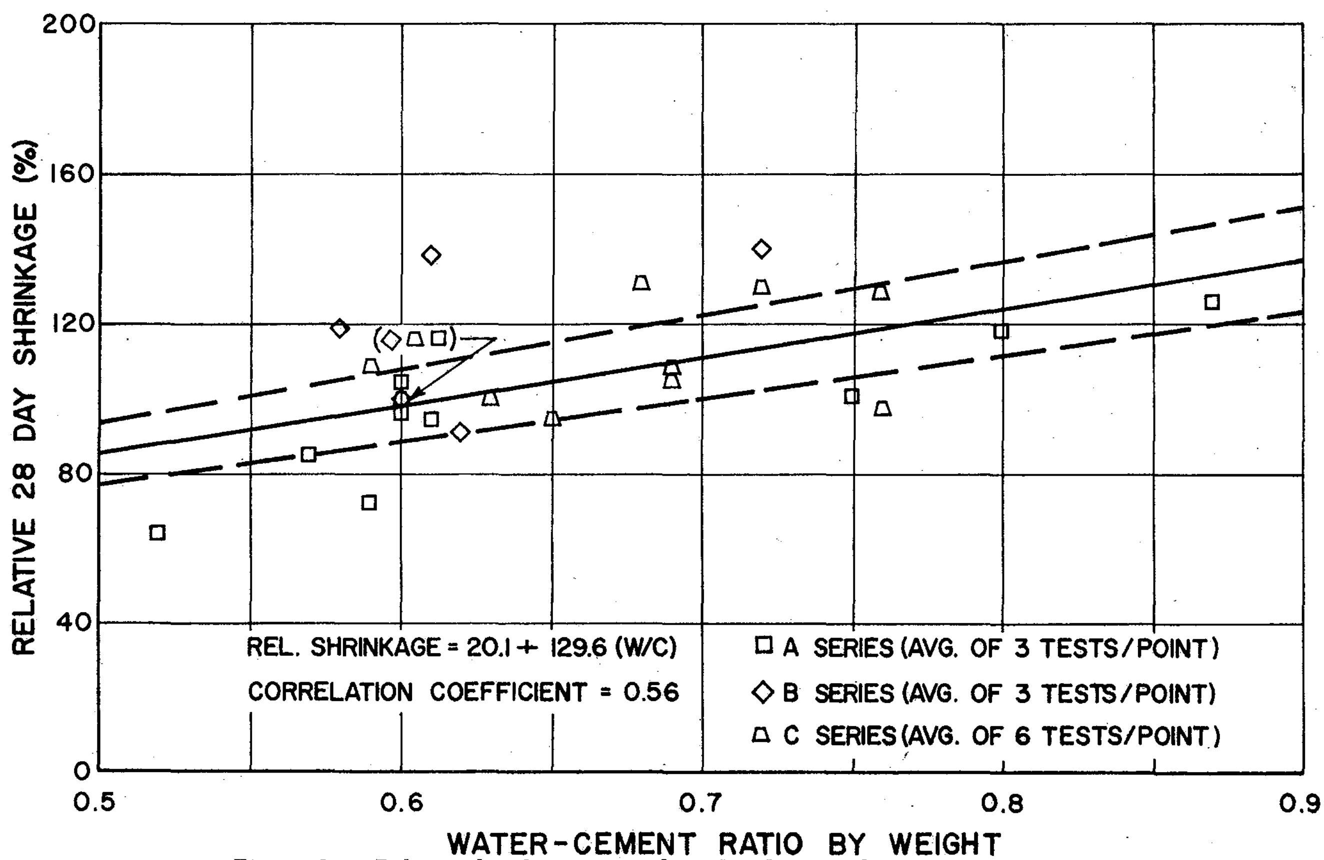


Figure 24. Relationship between 28-day shrinkage and water-cement ratio.

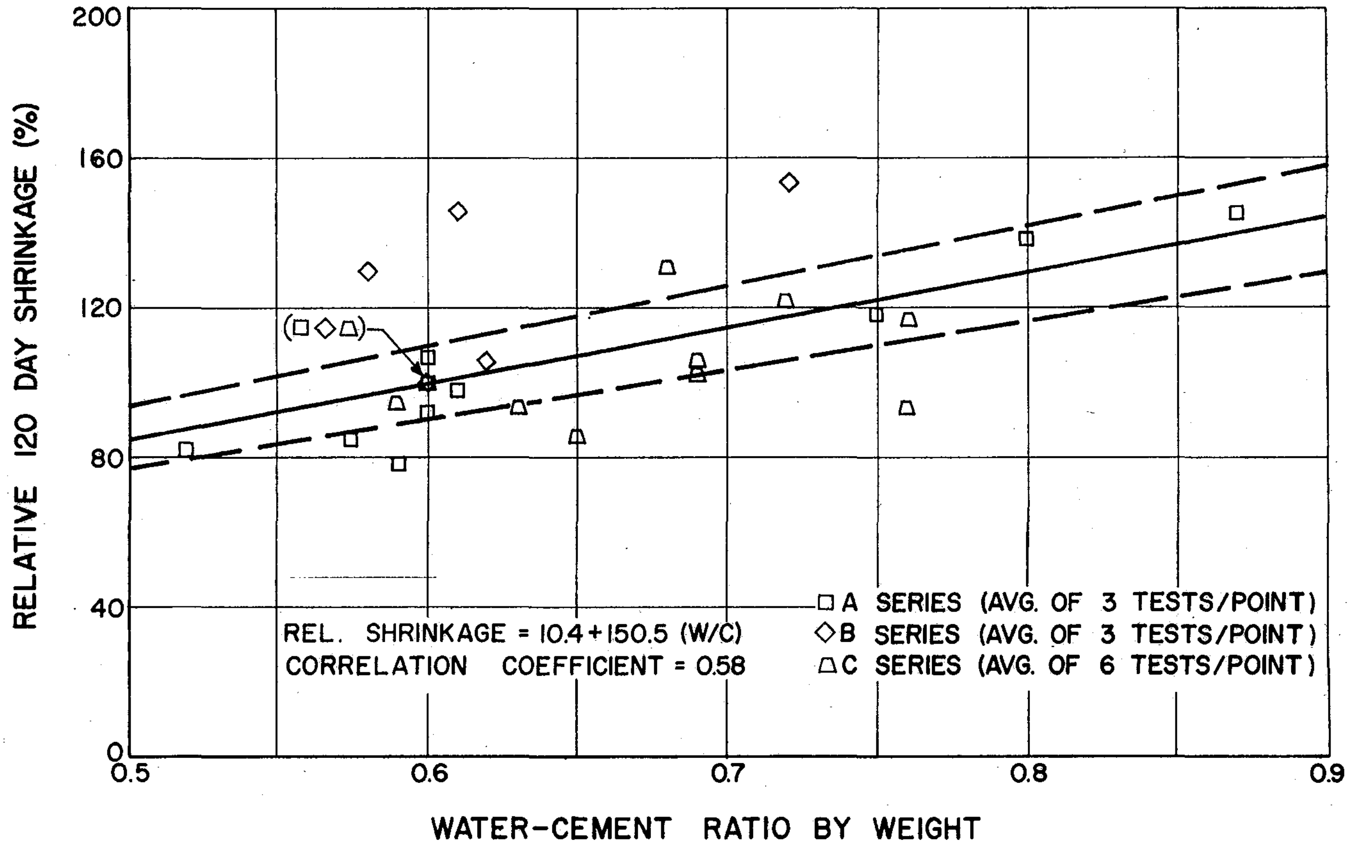
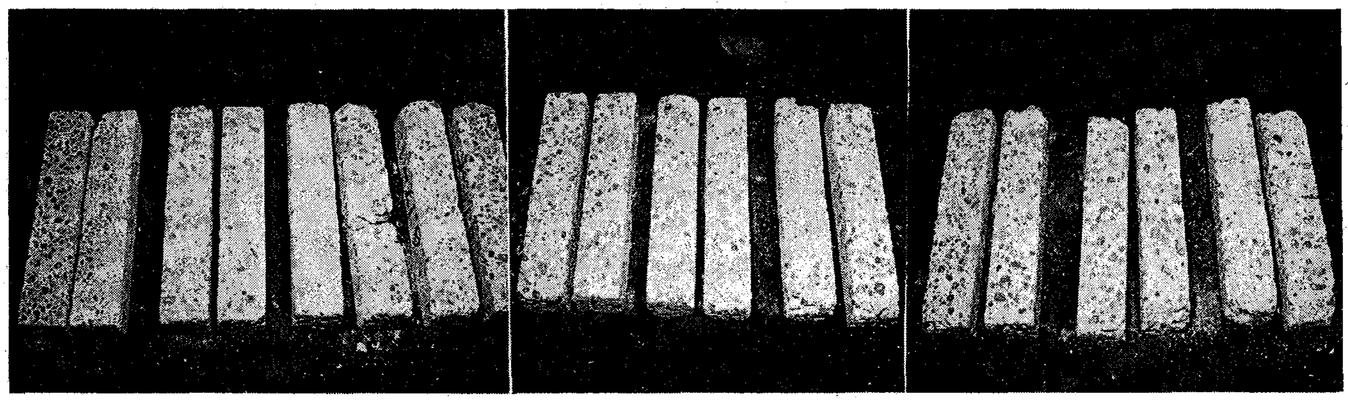


Figure 25. Relationship between 120-day shrinkage and water-cement ratio.

Durability of Non-Air Entrained Concrete

A series of ten concrete batches were mixed for this determination of relative durability. The amount of contaminant ranged from 0 to 5.25 percent of the total aggregate by weight with three levels of liquid limit (0, 35, and 70 percent) used for each amount of contaminant. Material quantities and properties of the plastic concrete for these mixes are given in Table 11. Two 3″ by 3″ by 16″ prismatic specimens were cast from each mix and moist cured at 72 ± 2° F for 14 days prior to testing. These specimens were then subjected to freeze-thaw durability testing in accordance with ASTM C290.

These concretes proved to be quite susceptible to freeze-thaw deterioration. Deterioration of the concretes manifested itself in surface scaling and loss of structural



D10	D11	D12	D13	D14	D15	D16	D17	D18	D19
No Clay	1.62% Clay	1.61% Clay	1.66% Clay	3.15% Clay	3.32% Clay	3.43% Clay	4.77% Clay	5.25% Clay	4.95% Clay
SE = 100	0% LL	35% LL	70% LL	0% LL	35% LL	70% LL	0% LL	35% LL	70% LL
	SE = 94	SE = 82	SE = 70	SE = 89	SE = 66	SE = 51	SE = 84	SE = 55	SE = 43

Figure 26. Photograph of specimens from D series batches after completion of freeze-thaw testing by ASTM C290.

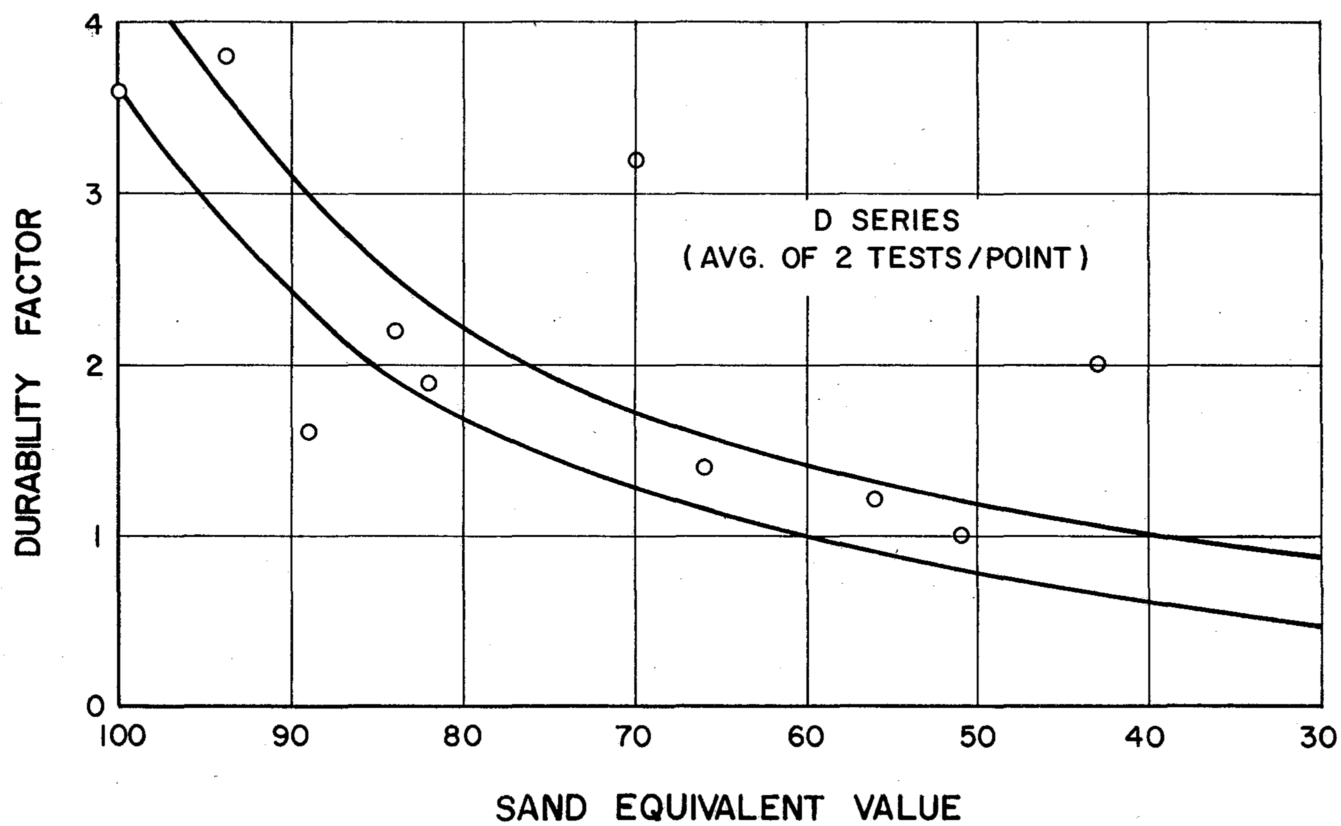


Figure 27. Relationship between freeze-thaw durability of non-air entrained concrete and sand equivalent value.

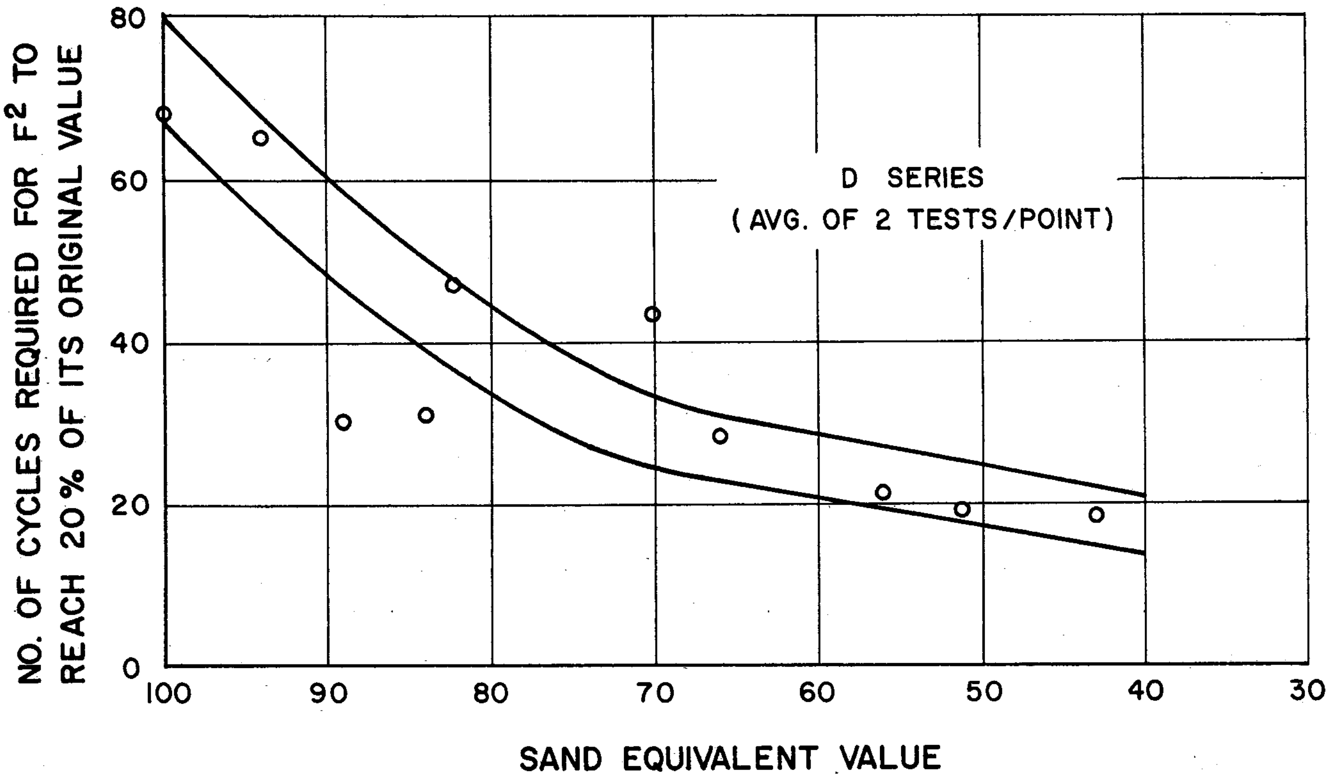


Figure 28. Relationship between no. of freeze-thaw cycles for fundamental flexural frequency squared to reach 20 percent of its original value and sand equivalent value.

integrity as indicated by sonic modulus of elasticity determinations. Figure 26 shows the specimens after testing was terminated at 300 cycles.

Figure 27 shows the batch durability factors plotted as a function of sand equivalent value. The durability factor was calculated as outlined in ASTM C290 using 300 cycles and 60% relative dynamic modulus of elasticity. With the exception of two errant points a very definite trend is produced—a decrease in sand equivalent value is accompanied by a very significant decrease in durability factor. The two excessively high points are not believed to be representative and were not considered in establishing the data trend. This opinion is supported somewhat by Figure 28 where the relative fundamental flexural frequency of vibration squared has been carried to 20 percent. The two high data points are now more in line with the previously assumed data trend. It can be seen that aggregates meeting sand equivalent specification limits of 80 can result in a 50% loss in durability in non-air entrained concrete.

Durability of Air Entrained Concretes

Specimens from batches A13 and A15 through A19 were subjected to 400 cycles of slow freezing and thawing in a chest type freezer. Results of these tests were inconclusive and only very slight surface deterioration was observed. The specimens were stored until a later date when they were subjected to freeze-thaw testing according to ASTM C290. Deterioration of most of these specimens was not indicated by fundamental frequency determinations but did show itself in changes in weight due to surface deterioration. The exceptions were the specimens containing 640 liquid limit contaminant (batch A19). These specimens completely disintegrated after 40 cycles and were removed from testing. Figure 29 presents the weight loss after 300 cycles (except for batch A19) of ASTM C290 testing, and Figure 30 shows these specimens after completion of testing.

The tests indicate an insignificant loss in durability of specimens containing fine aggregates with contaminant liquid limits of 35% or less (sand equivalent values of 80 or above) when the proper amount of air is entrained in the concrete.

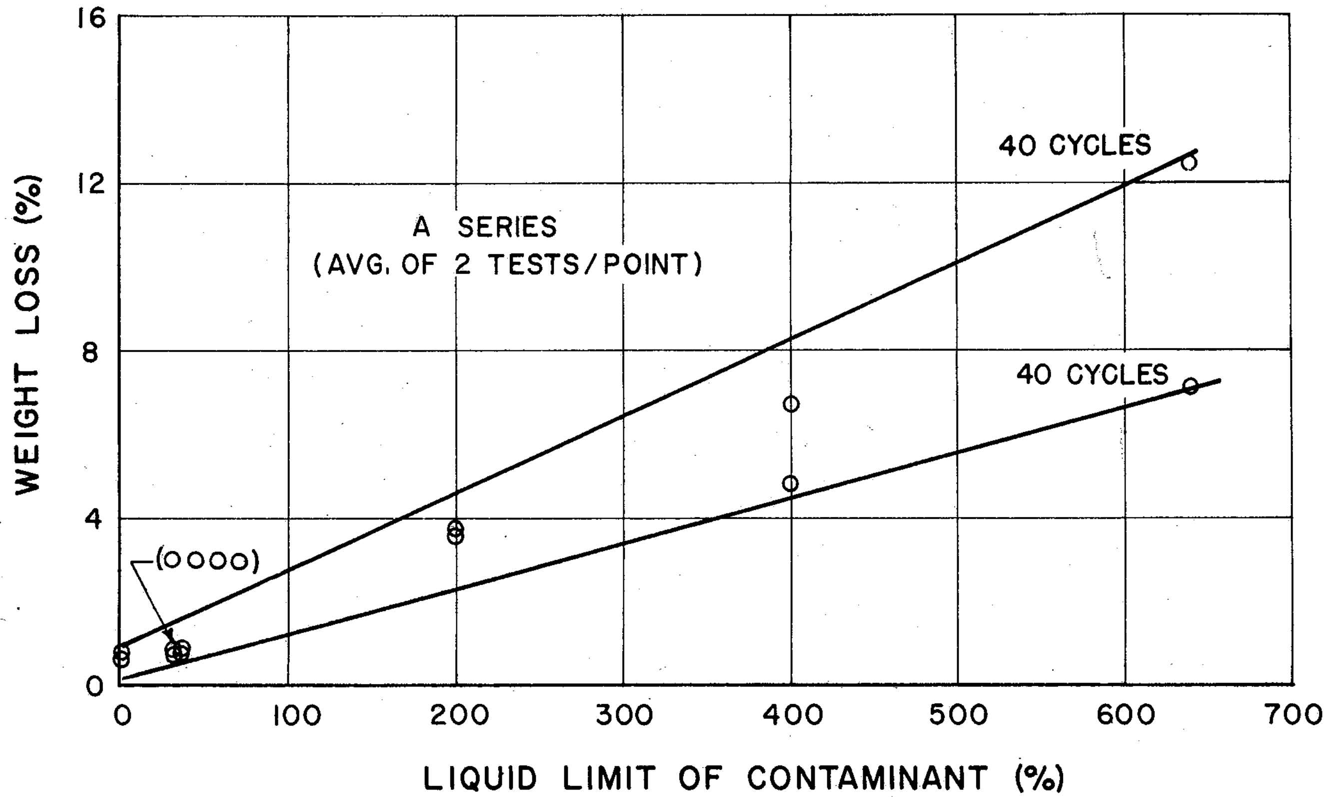


Figure 29. Relationship between weight loss of freeze-thaw specimens and liquid of contaminant after 300 cycles of ASTM C290.

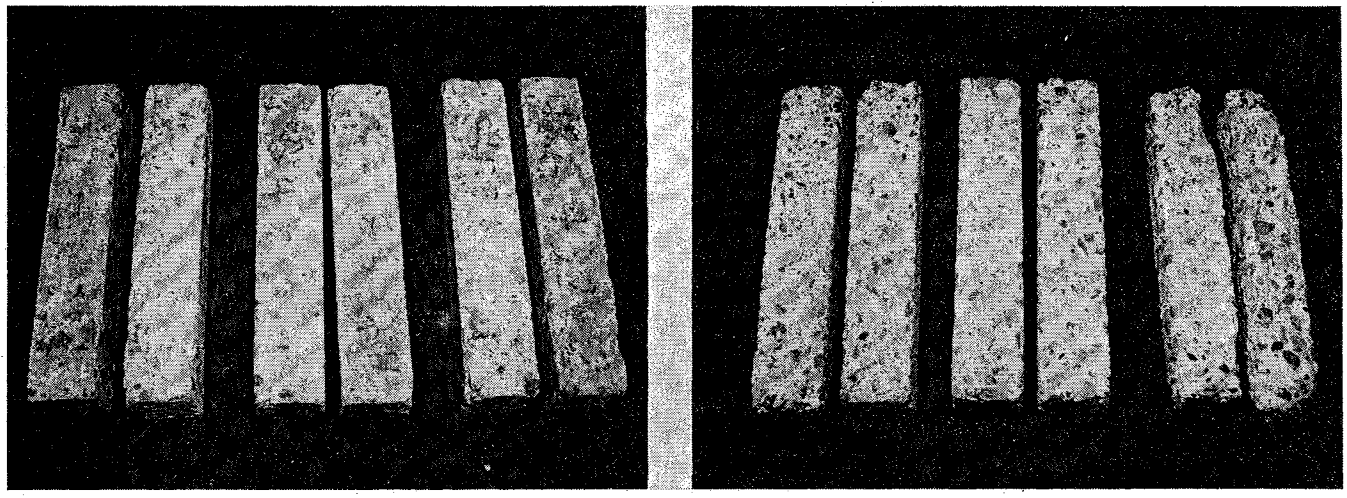


Figure 30. Photograph of specimens from A series batches after completion of freeze-thaw testing by ASTM C290.

A15	A16	A13	A17	A18	A19
1.42% Clay	1.48% Clay	1.48 Clay	1.50% Clay	1.57% Clay	1.60% Clay
0% LL	35% LL	35% LL	200% LL	400% LL	640% LL
SE = 94	SE = 81	SE = 80	SE = 49	SE = 30	SE = 22

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Appendix

TABLE 2. MEASURED AND CALCULATED DATA FOR AGGREGATE SAMPLES

Sample Number	Loss by Decan-tation	Measured Sand Equivalent Value	Liquid Limit	Calculated Sand Equivalent Value
1	1.4	81	29.7	92
2	2.6	79	33.1	86
3	5.2	64	36.2	73
4	3.6	63	30.1	82
5	1.9	78	27.8	90
6	2.7	75	30.5	86
7	5.6	70	36.2	72
8	2.4	83	25.8	89
9	1.0	77	33.6	94
10	0.6	92	24.2	97
11	0.8	89	*	
12	0.4	95	*	
13	0.3	97	*	
14	1.0	91	*	
15	1.1	79	*	
101	2.2	94	0.0	96
102	2.3	87	34.0	87
103	2.1	61	200.0	61
104	2.4	41	400.0	42
105	2.3	32	640.0	32
106	4.4	89	0.0	93
107	4.3	81	34.0	78
108	4.5	38	200.0	43
109	4.2	25	400.0	29
110	4.1	23	640.0	21

*There was not enough minus number 200 mesh material in this sample for a liquid limit determination.

TABLE 3. DESCRIPTION OF BLENDED AGGREGATE SAMPLES

Sample Number	Type of Material
101	Washed sand with 2½% silica flour
102	Washed sand with 2½% natural clay (liquid limit = 35%)
103	Washed sand with 2½% silica-montmorillonite (liquid limit = 200%)
104	Washed sand with 2½% silica-montmorillonite (liquid limit = 400%)
105	Washed sand with 2½% montmorillonite (liquid limit = 640%)
106 through 110	Same as 101 through 105 but with 5% contaminant

TABLE 4. PHYSICAL PROPERTIES OF AGGREGATES A AND B SERIES

	Siliceous Coarse Agg.	Siliceous Fine Agg.	Crushed Lime-stone Coarse Agg.
Unit weight in lb./cu. ft. (dry loose)	93.0	98.5	88.0
Specific Gravity (SSD)	2.61	2.62	2.64
Absorption (% of dry wt.)	1.2	0.8	1.4
Sieve Analysis Cumulative Percent Retained on			
¾ in.	0.0		0.0
½ in.	35.0		35.0
⅜ in.	60.0		60.0
#4	100.0	0.24	100.0
#8		10.10	
#16		26.21	
#30		41.21	
#50		83.29	
#100		98.62	
#200		100.00	

TABLE 5. PHYSICAL PROPERTIES OF AGGREGATES C, D, AND E SERIES

	Siliceous Coarse Aggregate	Siliceous Fine Aggregate
Unit weight in lb./cu. ft. (dry loose)	98.0	100.0
Specific Gravity (SSD)	2.64	2.63
Absorption (% of dry wt.)	1.2	0.8
Sieve Analysis Cumulative Percent Retained on		
¾ in.	0.0	
½ in.	35.0	
⅜ in.	60.0	
#4	100.0	0.76
#8		15.20
#16		33.22
#30		54.28
#50		89.60
#100		98.42
#200		100.00

TABLE 6. CALCULATED SAND EQUIVALENT VALUES FOR AGGREGATES USED IN CONCRETE MIXES*

Batch	Sand Equivalent Value	Batch	Sand Equivalent Value
A11	100	D10	100
A12	90	D11	94
A13	80	D12	82
A14	70	D13	70
A15	94	D14	89
A16	81	D15	66
A17	49	D16	51
A18	30	D17	84
A19	22	D18	55
		D19	43
B11	100		
B12	91	E10, 20, 30	100
B13	82		
		E11, 21, 31	95
B14	75		
B15	94	E12, 22, 32	85
C10	100		
C11	94	E13, 23, 33	78
C12	82		
		E14, 24, 34	71
C13	70		
C14	86	E15, 25, 35	59
C15	66		
		E16, 26, 36	46
C16	51		
C17	79	E17, 27, 37	39
C18	53		
C19	38		
C20, 30, 40	100		
C21, 31, 41	94		

*Calculated by the equation $SE = \frac{100}{1+P(0.1318\ LL + 1.79)}$

TABLE 7

CONCRETE MIX DATA
A AND B SERIES
QUANTITIES PER CUBIC YARD OF CONCRETE

Batch	Aggregate		Type I Cement		Water lbs.	Contaminant			Air %	Slump in.	Wet Unit Wt. lbs./cu. ft.
	Coarse lbs.	Fine lbs.	sks.	lbs.		Type[1]	Liquid Limit	% of total Agg. Wt.			
A11	1840	1300	5.02	472	247			0.00	6.1	3 ½	143.0
A12	1810	1290	5.07	477	287	NC	35	0.74	5.0	3 ¼	144.3
A13	1960	1160	5.11	480	287	NC	35	1.48	4.5	3	146.0
A14	1960	1080	5.26	495	300	NC	35	2.36	4.1	3	145.0
A15	1820	1360	5.07	477	282	S	0	1.42	3.0	2 ¾	147.5
A16	1810	1280	5.05	475	273	S-M	35	1.48	4.9	2 ¾	144.0
A17	1780	1220	4.97	467	352	S-M	200	1.50	2.9	3 ¼	142.9
A18	1840	1100	5.11	480	386	S-M	400	1.57	3.0	3	142.9
A19	1700	1110	4.95	465	406	M	640	1.60	3.3	3	138.8
B11	1670	1490	4.97	467	287			0.00	4.1	3	145.0
B12	1680	1380	5.00	470	271	NC	35	0.74	6.0	3 ½	141.0
B13	1720	1380	5.11	480	289	NC	35	1.49	3.0	3	145.0
B14	1670	1330	4.97	467	334	NC	35	2.25	4.2	2 ¾	143.0
B15	1700	1400	5.05	475	296	L	0	1.48	3.1	3	145.5

[1]NC—Natural Clay; S—Silica flour; S-M—Silica-montmorillonite mixture; M—Montmorillonite; L—Limestone fines.

TABLE 8

CONCRETE PROPERTIES
A AND B SERIES

Batch	Dynamic Modulus of Elasticity 10^{-6} lb./sq. in. ASTM C215		Modulus of Rupture Center point 3x4x16" prisms lb./sq. in.		Comp. Strength ASTM C116 lb./sq. in.		Shrinkage[1] μ in./in.	
	7 day	28 day	7 day	28 day	7 day	28 day	28 day	120 day
A11[2]	5.86	6.25	810	780	3300	3670	235	435
A12	5.61	6.31	660	720	2690	3370	383	565
A13	5.79	5.99	640	580	2850	3220	353	490
A14	5.26	6.64	580	650	2390	3000	347	518
A15[2]	6.40	6.46	880	770	2890	2920	265	420
A16	5.48	6.00	650	790	2750	3530	312	450
A17	4.81	5.16	510	560	2160	2520	373	630
A18	4.58	4.72	500	520	2370	2430	433	730
A19	3.96	4.33	410	450	1840	2290	465	768
B11	5.76	6.22	700	830	2900	3210	432	628
B12	5.44	5.64	580	760	2790	2640	370	560
B13	5.35	5.95	770	790	3570	3810	312	430
B14	5.14	5.38	600	730	2450	2750	440	665
B15	5.52	5.84	830	810	3120	3890	285	455

[1]ASTM C157 except specimens had 4 in. x 4 in. cross section and were internally vibrated. Specimens were moist cured for 3 days then dried at 50 ± 5% R. H. and 72 ± 2° F.

[2]Control batch.

TABLE 9

CONCRETE MIX DATA
C SERIES
QUANTITIES PER CUBIC YARD OF CONCRETE

Batch	Aggregate		Type I Cement		Water lbs.	Contaminant		Air %	Slump in.	Wet Unit Wt. lbs./cu. ft.
	Coarse lbs.	Fine lbs.	sks.	lbs.		Liquid Limit	% of total Agg. Wt.			
C10	1770	1400	5.04	474	278		0.00	4.7	3	145.2
C11	1760	1350	4.99	469	297	0	1.59	5.3	3	145.6
C12	1800	1350	5.04	474	283	35	1.59	4.2	3	146.5
C13	1770	1290	4.98	468	224	70	1.61	4.4	3 ½	144.5
C14	1790	1270	4.99	469	321	0	3.24	5.2	3 ¼	144.8
C15	1790	1230	4.99	469	304	35	3.29	4.0	3 ½	144.0
C16	1790	1150	5.01	471	338	70	3.38	4.5	3	142.4
C17	1810	1080	5.05	475	359	0	5.55	5.2	3 ½	144.0
C18	1780	1140	4.97	467	319	35	5.43	4.8	3	142.8
C19	1800	1060	5.02	472	357	70	5.59	4.0	3	142.4
C20	1760	1400	4.93	463	253		0.00	6.2	2 ½	143.2
C30	1750	1340	4.89	460	267		0.00	7.2	4	141.2
C40	1800	1330	5.05	475	284		0.00	5.0	3 ½	144.6
C21	1780	1310	4.99	469	265	0	1.66	6.5	3 ½	142.4
C31	1800	1350	5.05	475	255	0	1.64	5.0	3	145.6
C41	1790	1410	5.02	472	222	0	1.61	5.0	3 ¼	145.2

TABLE 10

CONCRETE PROPERTIES
C SERIES

Batch	Dynamic Modulus of Elasticity 10^{-6} psi ASTM C215			Modulus of Rupture psi ASTM C78			Compressive Strength psi ASTM C39			Shrinkage[1] μ in./in.	
	7 day	14 day	28 day	7 day	14 day	28 day	7 day	14 day	28 day	28 day	120 day
C10[2]	6.21	6.45	6.54	620	630	660	4500	4730	4990	355	520
C11	5.60	6.49	6.78	680	695	685	4800	5230	5310	325	510
C12	5.62	6.46	6.73	635	675	670	4620	4900	5240	360	550
C13	5.89	5.99	6.26	550	625	650	4070	4310	4580	375	580
C14	6.02	5.49	6.31	585	585	540	3680	4210	4700	390	570
C15	6.02	6.08	6.26	590	615	635	3910	4150	4480	340	475
C16	5.38	5.39	5.63	535	460	465	3400	3810	3860	470	675
C17	6.03	6.27	6.35	590	585	620	3930	4340	4700	350	510
C18	5.46	5.46	5.61	525	490	520	3590	3820	4220	470	720
C19	5.36	5.55	5.77	540	515	530	3560	3950	4160	460	645
C20							3580	4210			
C30							2980	3820			
C40							3450	4140			
C21							3280	4120			
C31							3660	4620			
C41							3540	4250			

[1]ASTM C157 with specimens being moist cured for 7 days, then dried at 50 ± 5% R. H. and 72 ± 2° F.
[2]Control batch.

TABLE 11

CONCRETE MIX DATA
D SERIES
QUANTITIES PER CUBIC YARD OF CONCRETE

Batch	Aggregate		Type I Cement		Water lbs.	Contaminant		Air %	Slump in.	Wet Unit Wt. lbs./cu. ft.
	Coarse lbs.	Fine lbs.	sks.	lbs.		Liquid Limit	% of total Agg. Wt.			
D10[1]	1810	1380	5.11	480	304		0.00	2.5	3	147.6
D11	1800	1340	5.07	477	310	0	1.62	3.0	3 ½	147.2
D12	1810	1360	5.11	480	298	35	1.61	2.2	3	148.0
D13	1830	1300	5.16	485	321	70	1.66	1.6	3	147.6
D14	1770	1400	5.00	470	275	0	3.15	2.5	3	148.4
D15	1820	1250	5.13	482	318	35	3.32	1.6	3	147.2
D16	1840	1180	5.18	487	333	70	3.43	1.5	3	146.4
D17	1750	1350	4.95	465	278	0	4.77	2.7	3 ¼	148.0
D18	1850	1120	5.20	489	340	35	5.25	1.7	3 ½	147.2
D19	1740	1230	4.90	461	350	70	4.95	1.4	4	145.2

[1]Control batch.

TABLE 12

CONCRETE MIX DATA AND COMPRESSIVE STRENGTHS
E SERIES
QUANTITIES PER CUBIC YARD OF CONCRETE

Batch	Aggregate		Cement		Water lbs.	Contaminant[1]		Air %	Slump in.	Wet Unit Wt. lbs./cu. ft.	Compressive Strength	
	Coarse lbs.	Fine lbs.	lbs.	sks.		lbs.	% of total Agg. Wt.				7 day psi	28 day psi
E10[2]	1730	1370	455	4.84	244	0	0	8.5	4	140	3050	3570
E20[2]	1800	1440	475	5.05	251	0	0	5.4	2	146	3590	4280
E30[2]	1740	1430	458	4.87	255	0	0	5.2	2 ¾	144	3260	3920
E11	1770	1360	466	4.96	304	12.6	0.4	5.5	2 ¾	144	3440	4270
E21	1770	1360	466	4.96	253	12.6	0.4	6.2	3 ¼	143	3150	4030
E31	1770	1360	466	4.96	268	12.6	0.4	6.0	3 ½	144	3520	4010
E12	1760	1330	463	4.93	282	36.3	1.2	5.4	3 ¼	144	3240	3650
E22	1760	1330	463	4.93	277	36.3	1.2	5.9	3 ½	143	3190	3670
E32	1780	1340	469	4.99	272	36.8	1.2	5.9	3 ¼	144	3480	3940
E13	1770	1310	466	4.96	278	60.4	1.9	5.1	3	144	3170	3700
E23	1770	1310	466	4.96	287	60.4	1.9	4.5	3	144	3040	3760
E33	1760	1300	463	4.93	273	60.0	1.9	6.1	3	143	3130	3320
E14	1770	1290	466	4.96	292	84.4	2.8	4.5	3 ½	144	3040	3720
E24	1770	1290	466	4.96	280	84.4	2.8	5.2	3 ¼	144	3150	3360
E34	1760	1280	463	4.93	273	83.9	2.8	5.5	3 ¼	143	3110	3400
E15	1760	1230	463	4.93	303	131.7	4.4	5.0	3	144	2750	3120
E25	1770	1200	466	4.96	315	132.3	4.4	4.5	3 ½	144	2540	3100
E35	1770	1200	466	4.96	299	132.3	4.4	5.0	3 ¼	144	3020	3280
E16	1790	1080	472	5.02	321	194.9	6.8	4.5	3 ½	143	2550	2840
E26	1780	1070	469	4.99	326	193.7	6.8	5.5	3 ¼	142	2320	2610
E36	1760	1060	463	4.93	322	191.4	6.8	5.2	3 ¼	141	2280	2510
E17	1760	1010	463	4.93	350	250.6	9.0	4.4	3 ¼	142	2100	2460
E27	1750	1010	460	4.89	348	248.9	9.0	5.1	3 ¼	141	1900	2190
E37	1780	960	469	4.99	354	253.2	9.0	4.5	3 ½	142	1990	2220

[1]Liquid Limit of contaminant is 35 percent.

[2]Control batches.

TEXAS HIGHWAY DEPARTMENT
MATERIALS AND TESTS DIVISION

Sand Equivalent Test

Scope

This test method, which is a modification of California Test Method No. 217-C, provides a means for determining the relative proportion of detrimental fine dust or clay-like particles in soils or fine aggregates (that portion of the aggregate passing the No. 4 sieve).

Apparatus

1. A transparent plastic graduate cylinder 1¼-inch inside diameter, about 17 inches in height, and graduated up to 15 inches in intervals of one-tenth inch starting at the base. A rubber stopper to fit the mouth of the graduated cylinder, Figure 1.

2. An agitator tube—a brass, stainless steel, or copper tube of ¼-inch outside diameter approximately 20 inches in length with one end closed to form a wedge-shaped point. Two holes (drill size 60) are drilled laterally through the flat side of the wedge near the point.

3. A weighted foot assembly, for measuring the height of sand in the cylinder, consists of a metal rod connected to a foot, with flat, smooth surface, at lower end and an attached weight at upper end sufficient in size to give the assembly a total weight of 1000 grams. The foot has a conical upper surface and three small screws to center it loosely in the cylinder. A cap to fit the top of cylinder is bored to fit loosely around the rod and serves to center the weighted foot assembly in the cylinder. See Figure 1A for detail dimensions of parts.

4. A 1-gallon glass bottle equipped with siphon assembly consisting of a 2-hole rubber stopper and pieces of glass or copper tubing.

5. A 4-foot length of plastic or rubber tubing with pinch clamp to control flow of liquid. The flexible tubing connects the open end of agitator tube with siphon assembly of bottle placed on a shelf three feet above the work surface. The tubing should fit snugly on siphon and agitator tube and be of convenient working length.

6. A No. 4 sieve with square openings

7. A 3-ounce measuring can

8. A wide-mouth funnel for transferring material into plastic cylinder

9. A watch or clock reading in minutes and seconds.

10. Graduate—a 100 cc. glass cylinder graduated in increments of 2 cc. or less.

Note: The equipment listed above with the exception of the graduate is shown in Figure 1.

Materials

1. Stock solution. Prepare the stock solution with the following:

454 grams (1 pound) tech. anhydrous calcium chloride, or 601 grams dihydrate, or 896 grams of hexahydrate calcium chloride

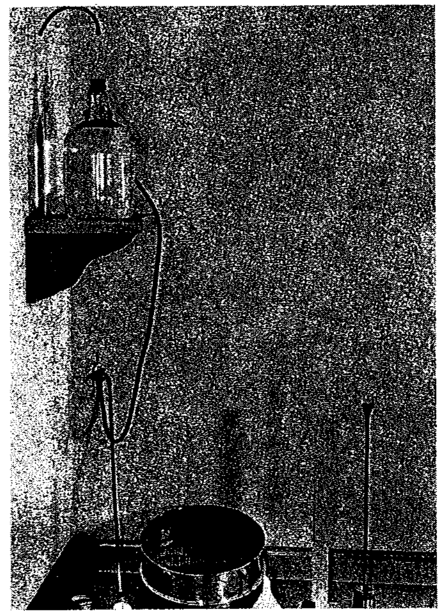


Figure 1.

2050 grams (1640 cc.) U.S.P. glycerine
47 grams (45 cc.) formaldehyde (40 percent by volume)

Dissolve the 454 grams calcium chloride in ½-gallon of distilled or demineralized water. Cool the solution and filter it through a Whatman No. 12, or equivalent, filter paper. Add the 2050 grams of glycerine and 47 grams of formaldehyde to the filtered solution, mix well and dilute to one gallon with distilled or demineralized water.

2. Working calcium chloride solution. Prepare the working solution by diluting 88 cc. of the stock calcium chloride solution to one gallon of distilled or demineralized water. A good quality tap water may be used if the purity is such that it does not affect the test results.

Test Record Forms

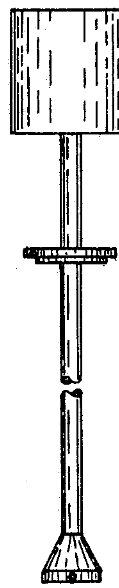
Record test data on work sheet, Form No. D-9-F7.

Preparation of Sample

1. Select a representative sample of material and dry to constant weight at a temperature of 200° to 230° F.

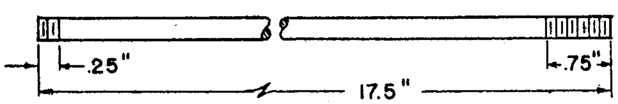
2. Use the No. 4 sieve with square openings and separate the sample into two portions, breaking up lumps which consist of particles obviously finer than the No. 4 sieve.

3. Secure the sand equivalent test sample from the portion passing the No. 4 sieve by carefully reducing the amount of material to laboratory test size. Split or quarter the material to obtain enough to fill the 3-ounce measuring can (approximately 110 grams). To insure representative samples when working with a material that is

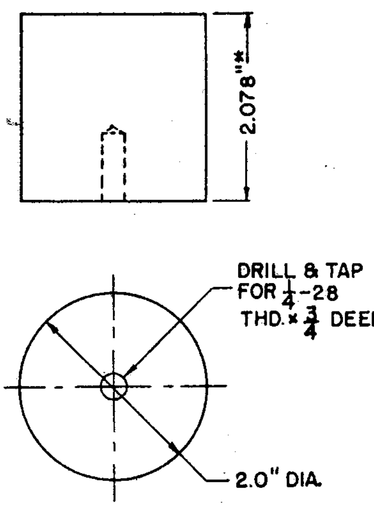


WEIGHT FOOT ASSEMBLY

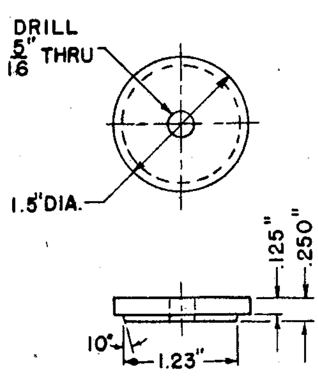
Adj. Screws-R.Hd.	1/4" × 3-48	Brass
Foot	1" Dia. × .75"	Bronze
Guide	1.50" Dia. × 1/4"	Brass
Weight *	2" Dia. × 2.078	C.R. Stl.
Rod	Dia. × 17.5"	Brass
*Weight Foot Assy. minus Guide = 1 Kg. ± 5g.		



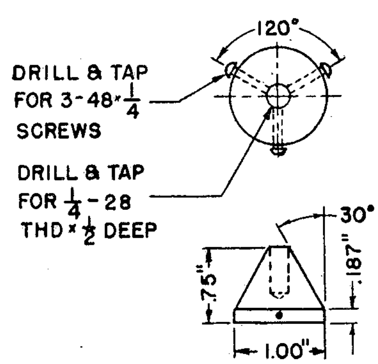
ROD



WEIGHT



GUIDE



FOOT

half scale

Figure 1A.

predominantly coarse (No. 4 to No. 10 material), the sample should be separated into No. 4 to No. 10 and minus No. 10 sizes, then recombined in proper proportions to produce a uniform sample.

Procedure

1. Shake the bottle of working calcium chloride solution well and siphon about 4 inches of the solution into the plastic cylinder. Check the agitator tube to be certain that the solution flows freely.

2. Use the small funnel and transfer the sample from the measuring can into the plastic cylinder, Figure 2. Stopper the cylinder. Tap the bottom of the cylinder on the heel of the hand several times to remove air bubbles and promote the thorough wetting of the sample. Remove stopper. Using a minimum amount of solution wash the particles clinging to wall of cylinder down into the mixture.

3. Allow the cylinder with contents to stand undisturbed, free of any vibration, for ten minutes plus or minus one minute.

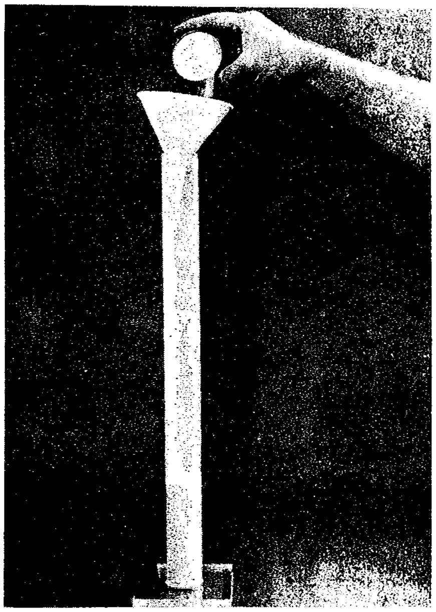


Figure 2.

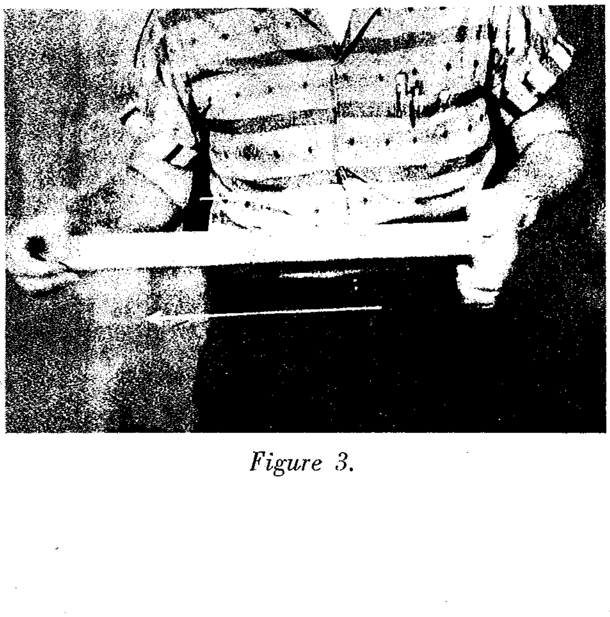


Figure 3.

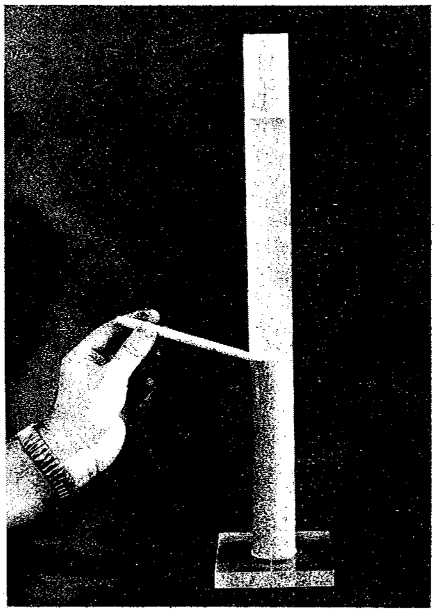


Figure 4.

4. At the end of the soaking period place the stopper in end of cylinder, partially invert the cylinder and simultaneously shake it to dislodge the material from the bottom. After loosening the material, hold the cylinder in a horizontal position and shake it vigorously by alternately throwing the contents of the cylinder from end to end (9″ plus or minus 1″ throw) as illustrated in Figure 3. Make 90 cycles in approximately 30 seconds; a cycle consists of a complete back and forth motion.

5. Following the mixing operation, place the cylinder on the work table, remove stopper and wash down the cylinder wall with the agitator tube. Then force the agitator through the material to the bottom of the cylinder by gently twisting and shoving while the solution flows from the tip of the tube. Continue smoothly jabbing the agitator tube up and down with a gentle twisting motion while slowly rotating the cylinder in a vertical position to flush the fine clay-like material up into suspension above the coarse sand particles.

6. Continue the operation until the cylinder is filled to the 15-inch mark. Then slowly remove the agitator tube without shutting off the flow so that the level of the liquid is maintained at about 15 inches. Regulate the flow of the solution and adjust the level of solution to 15 inches when the agitator tube is entirely withdrawn.

7. Allow the cylinder and contents to stand undisturbed for a period of 20 minutes plus or minus 15 seconds. Start the timing immediately after the removal of the agitator tube.

8. After the 20-minute sedimentation period, read and record the level of the top of the clay suspension to the nearest 0.1 inch, Figure 4.

9. Gently lower the weighted foot assembly in the cylinder until it comes to rest on top of the sand. Keep one of the centering screws in contact with the cylinder wall near the graduation marks so that it can be seen. When the weighted foot has come to rest, read the level

of the centering screw and record as the sand reading to nearest 0.1 inch (Figure 5).

Should either reading in Steps 8 or 9 fall between two divisions on the graduated cylinder, the reading should be raised to the higher reading. (Example: 8.68 = 8.7″, 6.21 = 6.3″)

Calculations

Calculate the sand equivalent value to the nearest 0.1 using the following formula:

$$SE = \frac{\text{Sand Reading}}{\text{Clay Reading}} \times 100$$

Reporting Test Results

Report the sand equivalent test results as a whole number. For example:

$$SE = \frac{3.2}{6.9} \times 100 = 46.4, \text{ report the value as } 47.$$

References

Test Method No. Calif. 217-C.

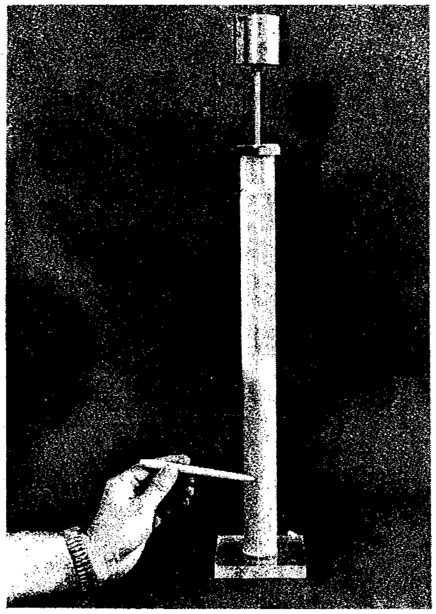


Figure 5.

Decantation Test for Concrete Aggregates

Scope

This test method describes a procedure for determining the amount of clay and silt in concrete aggregates. The procedure provides a means for measuring the percentage loss in terms of absolute volume which is equal to the percentage loss by weight, assuming that all of the particles have the same specific gravity.

Part I

Laboratory Method for Coarse Aggregate

Apparatus

1. Balance with 5000 gram capacity sensitive to 0.1 gram
2. Drying oven maintained at 230° F
3. Graniteware milk pan 12 inches in diameter and 5 inches deep
4. Sieve—a standard U. S. No. 200 sieve
5. Sample splitter or quartering cloth

Test Record Forms

Record test data on Form D9-A-3 and report results on Form No. 272 or Field Laboratorv Aggregate Sieve Analysis Report Form No. 310.

Procedure

1. Obtain a representative sample of the coarse aggregate and reduce the material to laboratory test size, a sufficient quantity to yield approximately 3000 grams when dry, by means of the sample splitter or quartering cloth.

2. Dry the aggregate to constant weight at a temperature of 230° F. and obtain the dry weight of the sample to the nearest 0.1 gram.

3. Place the coarse aggregate into a graniteware pan, cover with tap water and allow to soak for 24 hours.

4. After the aggregate has been thoroughly saturated to allow the clay particles to disintegrate, use the hands to vigorously agitate the material and then decant the wash water over the No. 200 sieve. Add water and repeat washing and decanting until the wash water is clear. Recover any of the aggregate that spilled onto and retained on the No. 200 sieve.

5. Dry the washed material to constant weight in an oven at a temperature not to exceed 230° F., weigh and record the net weight of the washed aggregate.

Calculations

Calculate the percentage of clay and silt or loss from the following expression:

$$\text{Percent loss} = \frac{W_1 - W_2}{W_1} \times 100 \text{ (Decantation)}$$

Where:

W_1 = Original dry weight of aggregate
W_2 = Dry weight of aggregate after washing

Part II

Field Method for Concrete Aggregates

Also

Laboratory Method for Fine Aggregate

Apparatus

1. Scale or balance with 5000 grams capacity, sensitive to 1 gram.
2. Wide-mouth funnel
3. Calibrated pycnometer, Figure 1, Test Method Tex-403-A
4. Sieve—Standard U. S. No. 200 sieve. (Required in laboratory, optional in field)
5. A watch or clock with second hand
6. Sample splitter or large pan
7. Towel or lint-free cotton cloth

Test Record Forms

Record test data on Work Sheet Form D9-A-3 and report test data on Form 272.

Procedure

1. Thoroughly mix the representative sample and secure a portion weighing approximately 1200 grams. The sample need not be weighed and the moisture content of the material is not considered since these factors have no bearing upon the test values.

2. Place the sample into the half-gallon pycnometer jar and cover with water.

(a) If the material is no drier than saturated, surface-dry, proceed immediately to Step 3 below.

(b) If the moist condition of the material is in doubt, or if the material is drier than saturated, surface-dry, allow to stand undisturbed for at least 24 hours.

3. Then fill the jar with water to within ½ inch of the rim, screw the pycnometer cap on the jar until the match marks coincide and then fill completely with water. Stop the hole in the cap with finger and roll the pycnometer to free all entrapped air. Raise and lower the jar in such a manner that the material will flow back and forth in the jar while it is being rolled. Set the pycnometer on work bench and refill the cap to remove any air bubbles. Take precautions to prevent loss of fine material while removing the entrapped air. Use the towel to dry the outside of the pycnometer, fill level full with water and weigh. Record the weight to the nearest 0.1 gram as Z_1.

4. When testing sand, close the opening in the cap with the finger or thumb and agitate the contents of the pycnometer by rolling the pycnometer with a swinging motion. When testing coarse aggregate, the pycnometer

should be rolled gently in order to avoid breaking the jar. Place the jar in an upright position and allow the very fine particles to settle for 15 seconds. Remove the cap from the jar and slowly pour out the liquid, taking care to lose none of the fine material. Only the material in suspension should be decanted. Repeat the above operation until the water above the fine aggregate is reasonably clear after a 15 second settling period.

Note: As a precaution against loss of material, it is recommended that the water be decanted into a No. 200 sieve.

5. Recover any material which may be retained on the No. 200 and return to the pycnometer. Screw the pycnometer cap on the jar and fill with water. Dry the outside of the pycnometer and complete filling the cap level with water. Weigh and record the weight as Z_2.

Calculations

Calculate the percent loss by decantation as follows:

$$\text{Percent loss} = \frac{Z_1 - Z_2}{Z_1 - Y} \times 100$$

Where:

Z_1 = weight of pycnometer containing sample and water to fill, before washing

Z_2 = weight of pycnometer containing sample and water to fill, after washing

Y = weight of the pycnometer filled with water at approximately the same temperature at which Z_1 and Z_2 were determined.

Notes

The percentage by weight of material lost by decantation is equal to the percentage by absolute volume, assuming that the specific gravity of the material lost to be the same as that of the particles remaining. In actual practice, the difference is negligible.

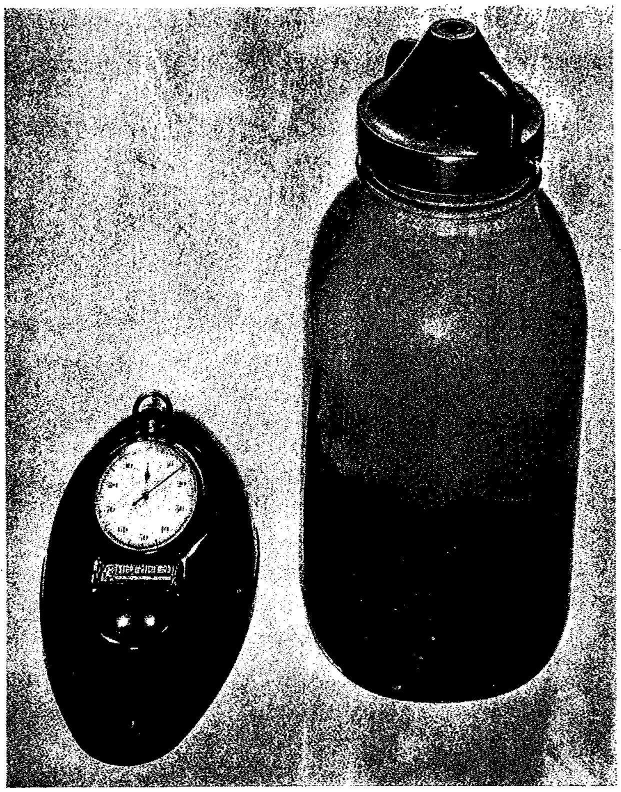


Figure 1.

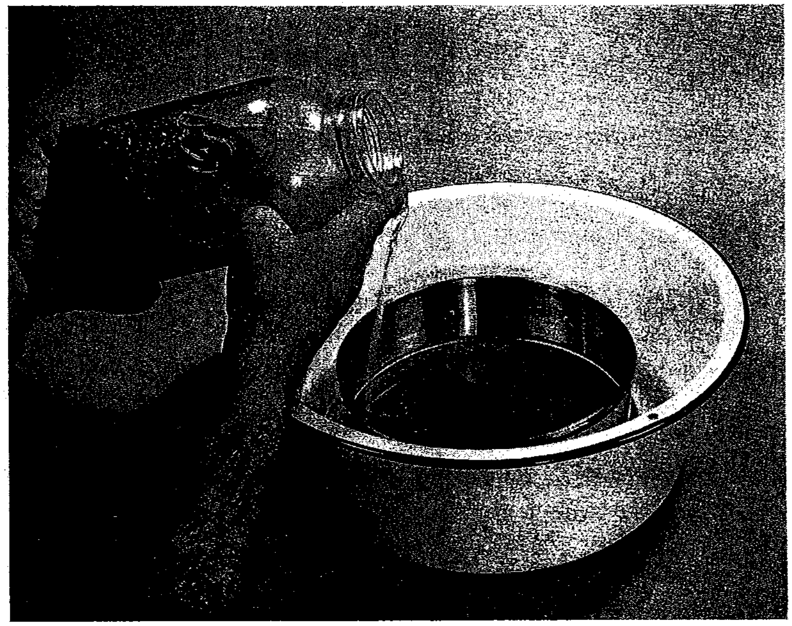


Figure 2.