Louisiana

LIGHTWEIGHT AGGREGATE ABRASION STUDY

Highway Research

LOUISIANA DEPARTMENT OF HIGHWAYS

STATE OF LOUISIANA UNION JUSTICE CONFIDENCE

LIGHTWEIGHT AGGREGATE ABRASION STUDY

by
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LIGHTWEIGHT AGGREGATE ABRASION STUDY

Introduction

The rapid increase in the use of lightweight aggregates in Structural concrete has created a number of problems for the Materials Engineer in evaluating this type aggregate. Exhaustive studies are being made of a number of properties of lightweight aggregates. This report covers only one phase of the nation-wide search for information.

The Los Angeles abrasion test, ASTM Method: C 131, does not make any provision for the density of aggregates in that it requires a certain sample size, by weight, regardless of the weight-volume relationship of the material. Consequently, when the aggregate is lighter, the resulting volume charged into the drum is larger. With very light aggregates, this may affect the results, due to the cushioning effect of the additional volume, giving an erroneous lower abrasion loss.

Furthermore, all aggregates, during the abrasion test, will break to smaller sizes. This breakage does not necessarily increase the percentage of material passing a No. 12 sieve. Nevertheless, when two different aggregates are tested and one shows a higher breakage on larger sieves, both aggregates may show the same standard loss. Consequently, the value of this test in the evaluation of the wear characteristics of lightweight aggregate has been quite questionable.

This investigation was designed to evaluate the behavior of different lightweight aggregates at various stages of the abrasion test and a charge corrected to furnish samples of approximately the same bulk volume. Additional tests were run to compare the results of the Los Angeles test with the Deval Abrasion Test. In addition to the lightweight aggregate, two reference gravels were also included.

Aggregates

The three lightweight aggregates used in this investigation were of the expanded clay type produced in Louisiana. For purposes of identification, they will be referred to as A, B and C. Aggregate A is manufactured by the sintering process and crushed to produce both coarse and fine aggregate. Aggregates B and C are both produced by the rotary kiln process. In both cases, some crushing is necessary to produce the fine aggregate, but generally these aggregates can be graded to a No. 50 sieve without crushing.

The two reference gravels used were from two different producers in the State. The gravel identified as D exhibits the highest Los Angeles Abrasion loss available in Louisiana and gravel E shows the lowest.

Test Procedures

The test procedures used in this study were as follows:

Los Angeles Abrasion Test - The Standard Method of Test for Abrasion of Coarse Aggregate by Use of the Los Angeles Machine, ASTM Designation C 131 (for the gradings utilized in this project, ASTM C 131 and AASHO T 96 Methods are the same), Grading B, was used with modifications as required to handle the variables to be studied in this project.

The number of revolutions used were 50, 100, 250 and 500. The aggregates were tested both in an oven dry and a "saturated" condition. Saturation was considered to have been obtained after the aggregate had been immersed in water for 24 hours prior to use.

After saturation, the samples were placed in the abrasion machine without surface drying.

Two different aggregate weights were established as follows:

(a) The standard charge of 5,000 grams with an abrasive charge of 4584 $\pm$ 25 grams.

(b) An adjusted weight to give a volume of lightweight aggregate equal to the volume of gravel used in the standard test. The same abrasive charge was used as in paragraph (a).

The method used to determine the aggregate charge for the volumetric method was as follows:

Assuming the lightweight aggregate weighed 35 lbs/cu.ft. dry loose, and the gravel weighed 97 lbs/cu.ft. dry loose, the weight of material to be used in the test would bear the same relation to the 5,000 gram standard as the unit weight of the lighter material would bear to that of a standard material. That is,

$$\frac{X}{5000 \text{ grams}} = \frac{35 \text{ lbs. per cu.ft.}}{97 \text{ lbs. per cu.ft.}}$$

$$X = 1802 \text{ grams}$$

This 1,802 gram sample is then broken down in the same manner as the 5,000 gram standard sample. That is, 50 per cent of the sample is composed of aggregate passing the 3/4 inch sieve and retained on the 1/2 inch sieve, and the remaining half is aggregate which passes the 1/2 inch sieve and is retained on the 3/8 inch sieve.

The method described in paragraph (a) will be referred to hereafter as the "weight method" and that in paragraph (b) will be the "volume method" for the sake of simplicity.

In addition to the requirements of the test method, and in an effort to determine the extent of breaking for all aggregate sizes, a complete sieve analysis was made on each sample. This, of course, will give the complete picture of the changes that occur during the abrasion test.

A minimum of three tests was performed and the results averaged for each value reported. Whenever any one of the three results varied by more than 5 per cent from the other two, an additional test was run. It may be interesting to note, that throughout the study, only one test had to be repeated due to a variation of more than 5 per cent.

For saturated material, the required amount of dry aggregate was weighed and immersed in water for 24 hours. It was removed from the container immediately prior to the test and placed in the abrasion machine without surface drying.

Deval Abrasion Test - In addition to Los Angeles Abrasion Test, a series of tests were made using "Standard Method of Test for Abrasion of Gravel by Use of the Deval Machine," AASHO Designation T 4-35 using samples having grading B as required for the Los Angeles Test Method. Two series of tests were conducted in this case:

a. Using a dry aggregate charge, as required by the method

b. Saturated aggregate charge

The quantity of aggregate to be used was determined in the same manner as described above under paragraph (b) for Los Angeles Abrasion Test and referred to as the volume method. After the testing was started it was observed that the aggregate, when used in a saturated condition, caked around the cylinder and did not give satisfactory results. Consequently, a modification was effected whereby the saturated aggregate would be placed in the abrasion machine and the cylinder filled with water. This method gave very satisfactory results and was used for all tests for the saturated material.

Discussion of Test Results

Los Angeles Abrasion Test - Results of tests conducted in this investigation are given in the appendix.

The saturated aggregate did not show any significant improvement in the test results for all tests and, therefore, will not be discussed any further. All discussions will be based on dry aggregate.

Figures 1 through 4 graphically illustrate these results and give a comparison of the weight and volume methods. A preliminary analysis of the data indicated that the most significant sieves were No. 12, No. 4 and 3/8 inch. Therefore, these were used as a basis of comparison.

It will be noted that the weight method does not give a true indication of the wear characteristics of the aggregate in the test, in that, whenever the volume method is used, there is a significant difference in the percentage of loss between hard and soft aggregates. To illustrate this point; aggregate B, which weighs approximately 32 pounds per cubic foot, dry loose, shows a smaller abrasion loss than gravel D (soft gravel) when the standard method is used. However, whenever a correction is made for weight, and the same volume of charge is used in both cases, there is a significant difference between the losses obtained on these two materials. This observation is noted in all test results on this study. Therefore, in order to evaluate

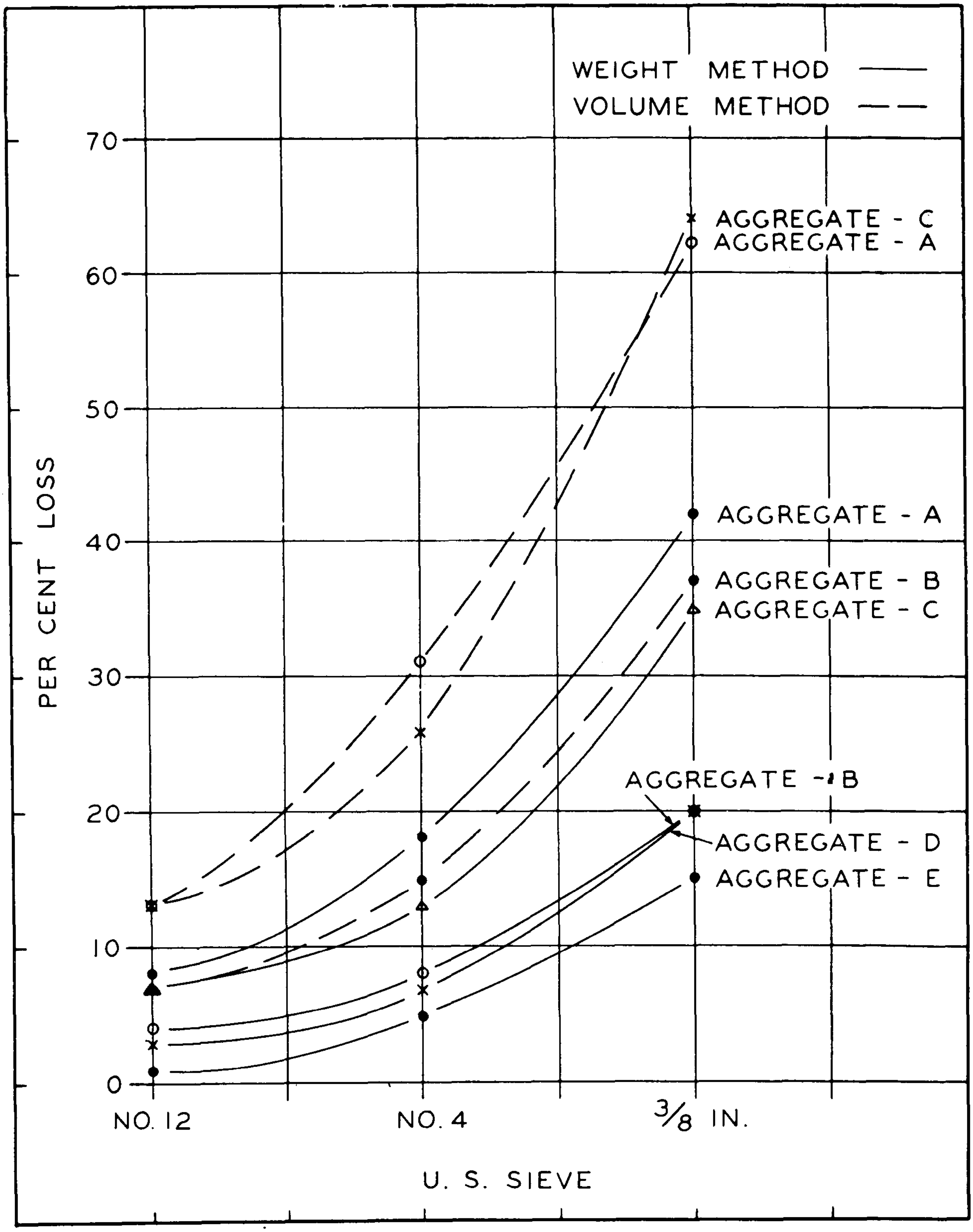

FIGURE 1 - LOS ANGELES ABRASION TEST
LOSS AT 50 REVOLUTIONS
CONDITION OF AGGREGATE - DRY

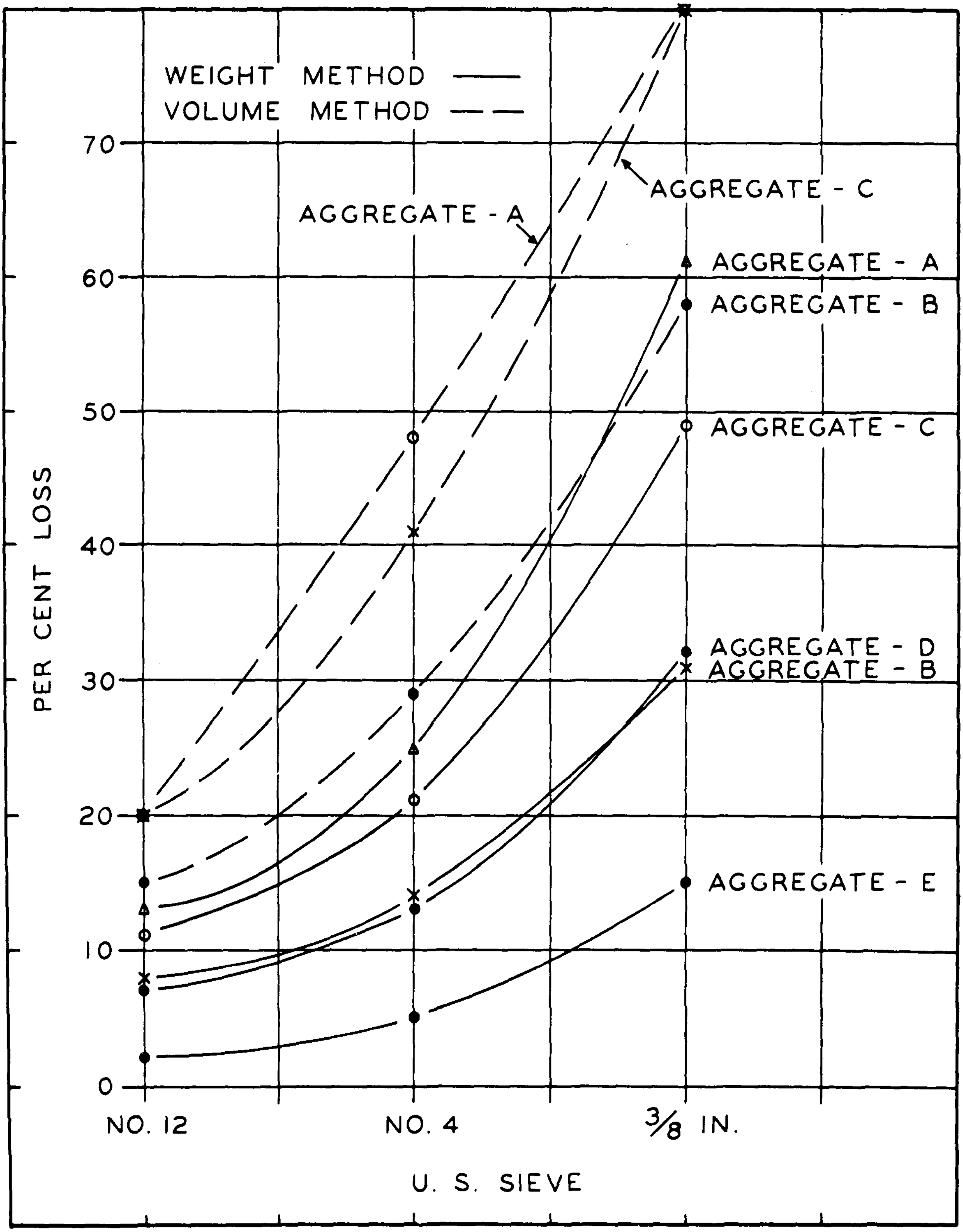

FIGURE 2 - LOS ANGELES ABRASION TEST
LOSS AT 100 REVOLUTIONS
CONDITION OF AGGREGATE - DRY

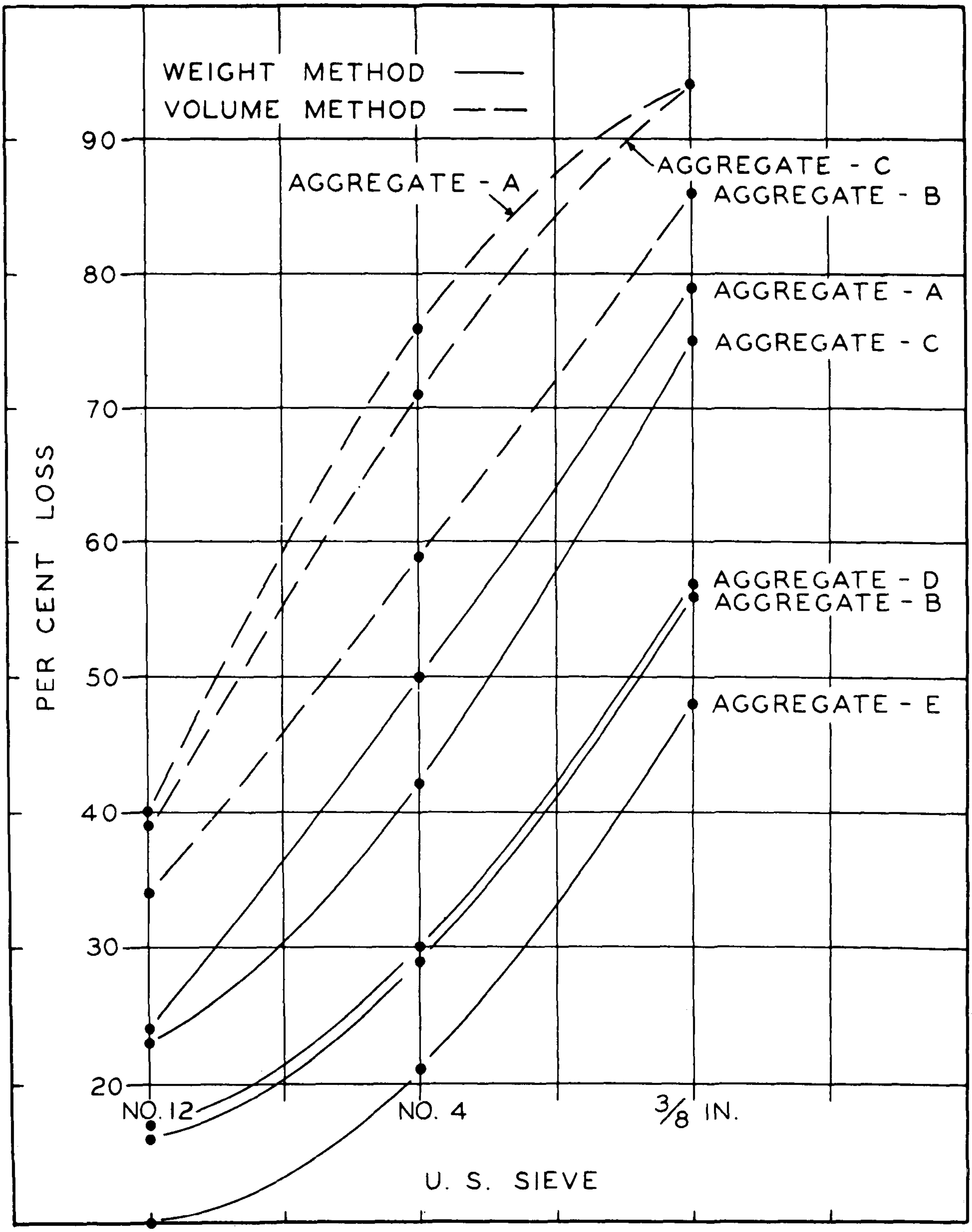

FIGURE 3 - LOS ANGELES ABRASION TEST
LOSS AT 250 REVOLUTIONS
CONDITION OF AGGREGATE - DRY

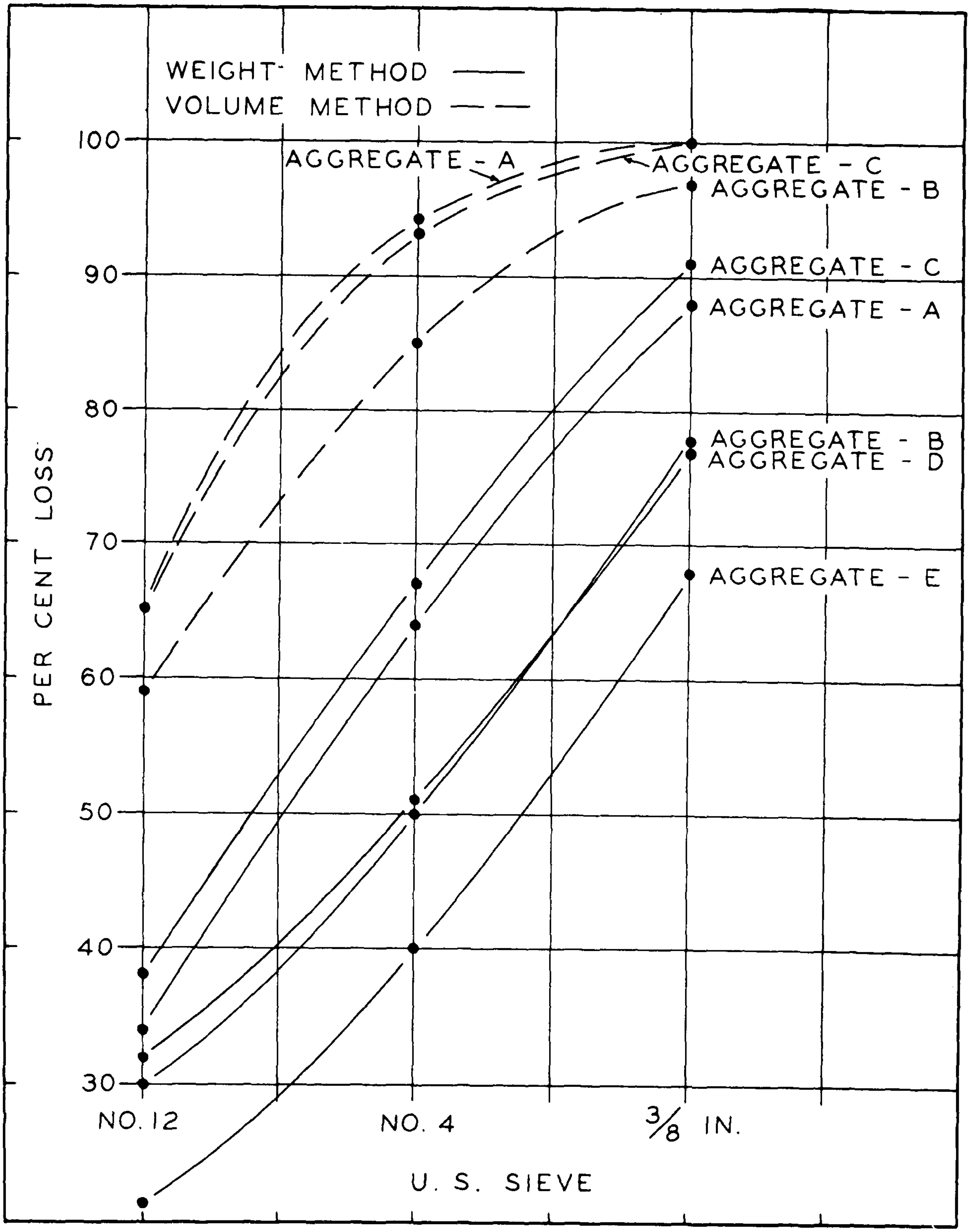

FIGURE 4 - LOS ANGELES ABRASION TEST
LOSS AT 500 REVOLUTIONS
CONDITION OF AGGREGATE - DRY

aggregates of lighter weight on the same basis as those of heavier weight, a correction should be made to compensate for the difference in the resulting volume.

The next objective of this investigation was to establish the sieve size to be used for the determination of losses. All aggregates, generally during the abrasion test, break to smaller sizes. Nevertheless, when the loss is based on a No. 12 sieve, the extent of this breakage is not indicated in the results and some softer aggregates will show the same loss as those of higher wear resistance. This, of course, is illustrated in Figures 1 through 4 where on a No. 12 sieve the maximum difference between the three lightweight aggregates tested is approximately 6 per cent with aggregates A and C giving almost identical results. When a 3/8 inch sieve is used, aggregates A and C again exhibit similar percentages of loss, whereas, using a No. 4 sieve the losses obtained for 100 revolutions are 48.1 per cent for aggregate A, 28.6 per cent for aggregate B, and 40.8 per cent for aggregate C, a minimum difference of approximately 8 per cent and a maximum difference of 20 per cent. This, of course, should permit better evaluation of wear characteristics of these three materials. Therefore, a No. 4 sieve is recommended for use to determine the loss.

The next objective of this investigation was to evaluate the number of revolutions to be used for lightweight aggregate. Figure 5 shows the relationship between percentage of loss and varying numbers of revolutions for the three lightweight aggregates used in the study for a No. 4 sieve. It will be noted that 500 revolutions are excessive for this type material,

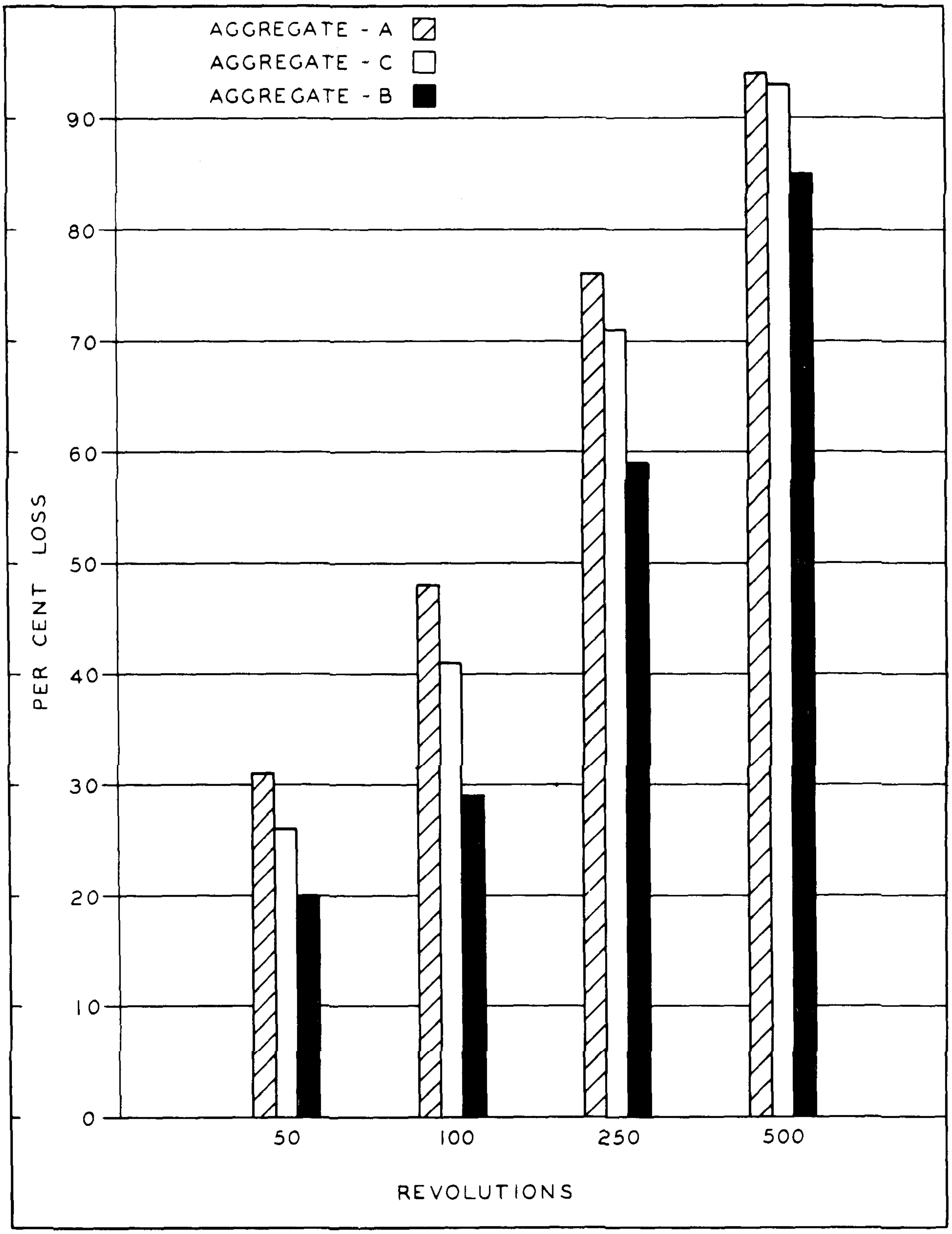

FIGURE 5 - LOS ANGELES ABRASION TEST
LOSS USING NO. 4 SIEVE
VOLUME METHOD - AGGREGATE DRY

and that the differential loss for the three aggregates illustrated is very low. These data indicate that for the conditions tested, 100 revolutions appear to provide a better evaluation of the relative abrasion resistance of these three materials.

Deval Abrasion Test - Results of tests of this series are given in the appendix and are graphically illustrated in Figures 6 and 7. Since this test method employs the principle of volume correction, a comparison was not made with the weight method. Nevertheless, the correction table given in AASHO Method T 4-35 does not cover the specific gravity as low as normally found in lightweight aggregates. For this reason, as previously discussed, the same correlation method was used for the test.

As discussed previously, aggregates were tested in a dry and immersed state. The results of the dry test (Figure 6) do not distinguish between gravel and lightweight aggregates for a No. 12 and No. 4 sieve. On a 3/8 inch sieve there is a satisfactor distinction between gravels and lightweight aggregates. However, all three lightweight aggregates are very close. When tested in an immersed state in water, a well defined separation of results between the gravels and also between the lightweight aggregates is obtained (Figure 7). It will be noted that in this case, again, the No. 4 sieve gives the optimum results under the conditions tested with a well pronounced separation between all five aggregates.

As can be observed from Figure 7, the curves on Aggregate C and B cross each other between the No. 12 and No. 4 sieves. This was the only instance where the results were not consistant with the results received from all other tests. These points were

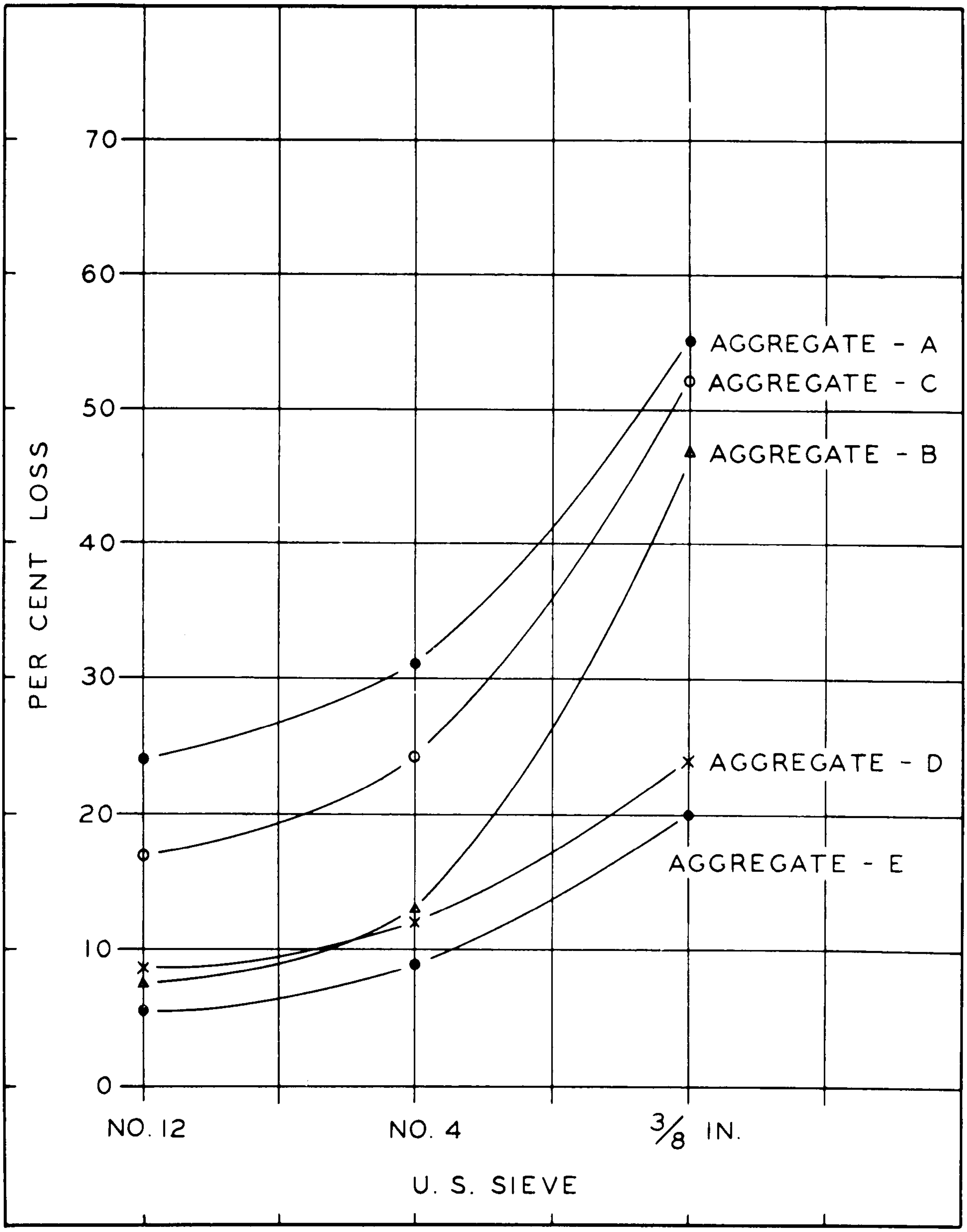

FIGURE 6

DEVAL ABRASION TEST - AGGREGATE DRY

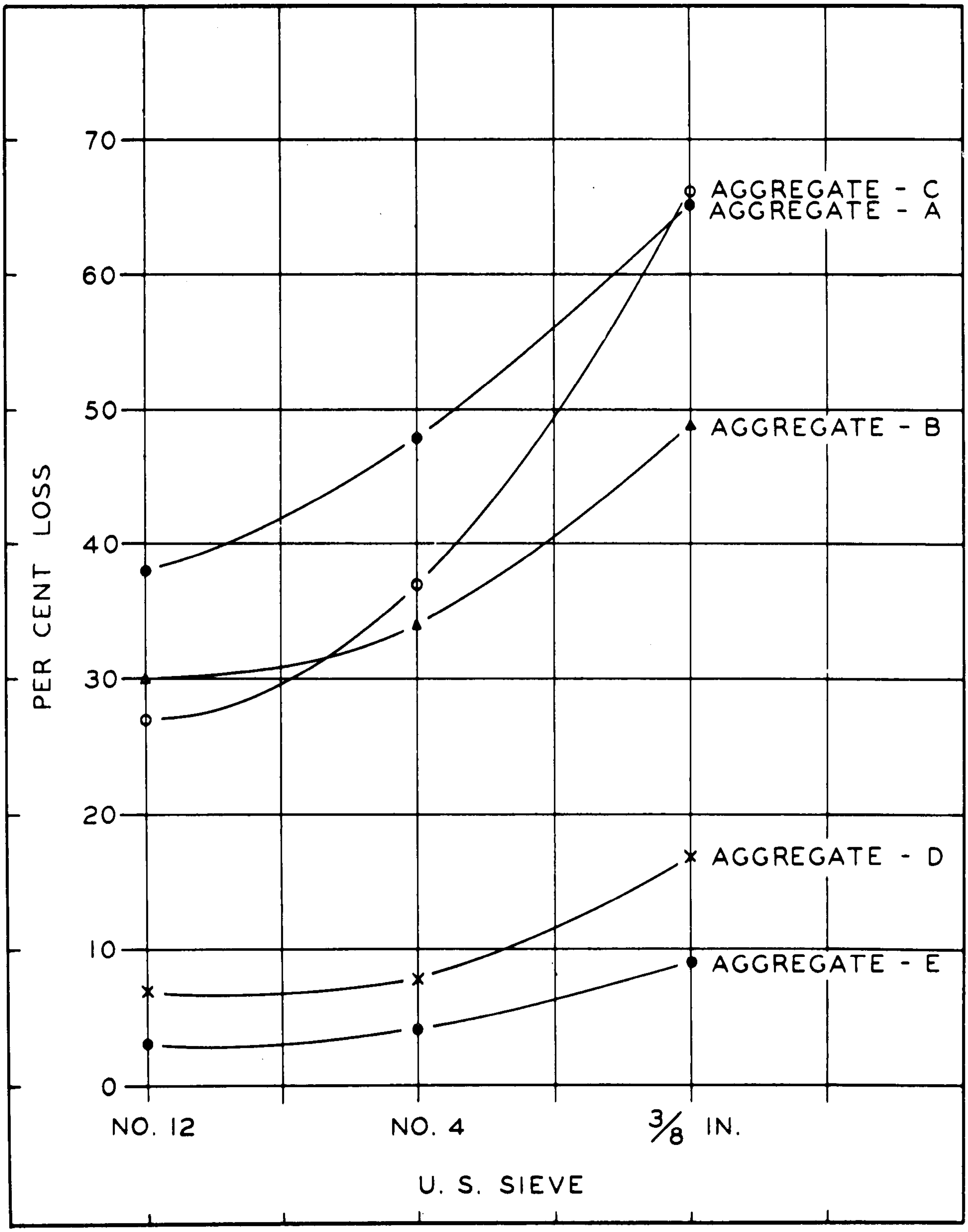

FIGURE 7

DEVAL ABRASION TEST - AGGREGATE IMMERSED checked and found to be correct so it can only be assumed that by immersing the aggregates in water, aggregate B abraded, while aggregate C merely broke into smaller pieces

Conclusions

The results of the investigation of these particular aggregates warrant the following conclusions:

1. The Deval Abrasion Test (AASHO Designation T 4-35), modified to use a No. 4 sieve for determining loss and using the aggregate in a saturated condition and immersed in water at the time of test, will give better results than the Los Angeles Abrasion Test as modified below.

2. The Los Angeles Abrasion Test will also give satisfactory results with the following modifications:

   a. A No. 4 sieve should be used for the determination of loss.

   b. One hundred revolutions be used in lieu of 500.

   c. The dry aggregate charge be determined by using the same volume of lightweight aggregate as is used for gravel and stone.

Remarks

Even though the Deval test gives a better distinction between hard and soft aggregates, the time element is a considerable drawback in that 10,000 revolutions take approximately five hours and could create a problem in routine testing; whereas, the Los Angeles Abrasion Test, when modified as described above with only 100 revolutions, could be completed in approximately 3 minutes with the exception of the preparation time which would be again considerably less.

Further study is needed to correlate the results of these two test methods as modified above. However, one of the aggregates used in this study, believed to be of questionable quality, may justify a tentative recommended maximum loss. A loss of 40 per cent for the Deval test and 45 per cent for the Los Angeles Abrasion Test, as modified above, could tentatively be used. It should again be mentioned that further study is needed before a commitment can be made in this respect.

A P P E N D I X

LOS ANGELES ABRASION TEST RESULTS

AGGREGATE - A

METHOD USED-WEIGHT

TOTAL WEIGHT OF MATERIAL USED - 5000 GRAMS

PER CENT PASSING

	Dry Aggregate				Saturated Aggregate			
Rev.	50	100	250	500	50	100	250	500
U. S. Sieve								
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2	78.1	87.2	93.3	96.6	80.0	86.2	94.5	98.9
3/8	41.5	60.7	79.1	87.8	39.2	55.9	79.3	95.0
No. 4	17.9	24.9	50.1	64.0	16.0	25.6	47.7	72.3
No. 8	9.0	15.4	28.8	41.5	7.7	12.6	25.5	43.1
No. 12	7.6	12.6	23.6	33.9	6.3	10.1	20.8	34.9

METHOD USED-VOLUME

TOTAL WEIGHT OF MATERIAL USED - 2224 GRAMS

PER CENT PASSING

	Dry Aggregate				Saturated Aggregate			
Rev.	50	100	250	500	50	100	250	500
U. S. Sieve								
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2	88.7	94.4	98.7	100.0	89.2	93.5	98.7	100.0
3/8	62.2	80.1	93.6	99.1	57.7	75.4	95.1	99.4
No. 4	30.6	48.1	76.1	94.3	25.5	41.8	77.8	96.1
No. 8	15.7	24.8	47.6	74.7	11.7	20.9	46.3	72.8
No. 12	12.7	20.2	39.7	64.8	9.5	16.8	38.1	61.3

AGGREGATE - B

METHOD USED-WEIGHT

TOTAL WEIGHT OF MATERIAL USED - 5000 GRAMS

PER CENT PASSING

	Dry Aggregate				Saturated Aggregate			
Rev.	50	100	250	500	50	100	250	500
U. S. Sieve								
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2	70.1	75.0	88.6	96.1	64.6	72.8	89.1	95.8
3/8	19.5	30.7	55.7	78.1	15.8	26.2	52.4	77.9
No. 4	7.8	13.5	28.8	50.3	5.7	10.2	24.2	45.6
No. 8	5.1	8.6	18.6	34.1	3.2	5.5	13.6	28.2
No. 12	4.3	7.5	16.4	30.2	2.9	4.8	11.8	24.5

METHOD USED-VOLUME

TOTAL WEIGHT OF MATERIAL USED - 1638 GRAMS

PER CENT PASSING

	Dry Aggregate				Saturated Aggregate			
Rev.	50	100	250	500	50	100	250	500
U. S. Sieve								
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2	81.8	90.8	98.1	99.9	78.1	89.6	97.9	100.0
3/8	37.1	58.4	85.8	97.4	35.5	58.0	86.6	99.3
No. 4	15.4	28.6	58.6	84.9	13.8	26.4	55.0	93.5
No. 8	9.3	17.3	39.0	65.4	7.8	14.7	32.6	71.7
No. 12	7.8	14.9	34.3	58.9	6.9	12.6	28.4	63.6

AGGREGATE - C

METHOD USED-WEIGHT

TOTAL WEIGHT OF MATERIAL USED - 5000 GRAMS

PER CENT PASSING

	Dry Aggregate				Saturated Aggregate			
Rev.	50	100	250	500	50	100	250	500
U. S. Sieve								
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2	72.8	80.7	89.9	96.2	74.3	84.3	95.0	98.7
3/8	35.4	49.1	74.9	90.5	33.2	49.7	81.0	94.6
No. 4	13.0	21.4	42.3	66.5	12.0	20.1	43.2	68.5
No. 8	7.6	12.8	25.6	42.0	6.4	10.9	23.6	40.0
No. 12	6.7	11.2	23.2	38.2	5.5	9.2	20.3	33.4

METHOD USED-VOLUME

TOTAL WEIGHT OF MATERIAL USED - 1824 GRAMS

PER CENT PASSING

	Dry Aggregate				Saturated Aggregate			
Rev.	50	100	250	500	50	100	250	500
U. S. Sieve								
3/4	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1/2	89.2	94.5	98.4	99.9	88.7	95.1	99.1	99.9
3/8	63.5	80.4	93.9	99.4	61.2	80.1	96.6	99.6
No. 4	26.4	40.8	71.2	93.0	22.9	41.3	80.0	97.3
No. 8	15.4	23.7	46.3	73.0	11.7	22.4	52.1	81.0
No. 12	13.3	19.9	39.3	64.7	9.5	18.6	43.6	71.5

AGGREGATE - D

METHOD USED-WEIGHT

TOTAL WEIGHT OF MATERIAL USED - 5000 GRAMS

PER CENT PASSING

	Dry Aggregate			
Rev.	50	100	250	500
U. S. Sieve				
3/4	100.0	100.0	100.0	100.0
1/2	59.6	68.8	81.9	92.8
3/8	19.8	31.9	56.6	77.1
No. 4	7.4	13.3	30.0	51.3
No. 8	4.6	8.0	19.1	35.2
No. 12	4.1	7.1	17.0	31.5

AGGREGATE - E

METHOD USED-WEIGHT

TOTAL WEIGHT OF MATERIAL USED - 5000 GRAMS

PER CENT PASSING

	Dry Aggregate			
Rev.	50	100	250	500
U. S. Sieve				
3/4	100.0	100.0	100.0	100.0
1/2	56.3	62.4	75.3	84.9
3/8	14.7	24.8	47.5	67.7
No. 4	4.9	8.8	21.1	40.0
No. 8	2.7	4.7	12.0	25.1
No. 12	2.2	3.9	10.0	21.7

DEVAL ABRASION TEST RESULTS

AGGREGATE - A

TOTAL WEIGHT OF MATERIAL USED - 2224 GRAMS

Dry Aggregate U. S. Sieve	Per Cent Passing	Saturated Aggregate U. S. Sieve	Per Cent Passing
3/4	100.0	3/4	100.0
1/2	84.9	1/2	82.1
3/8	55.2	3/8	65.0
No. 4	31.2	No. 4	47.8
No. 8	28.5	No. 8	40.6
No. 12	24.4	No. 12	38.3

AGGREGATE - B

TOTAL WEIGHT OF MATERIAL USED - 1638 GRAMS

Dry Aggregate U. S. Sieve	Per Cent Passing	Saturated Aggregate U. S. Sieve	Per Cent Passing
3/4	100.0	3/4	100.0
1/2	74.2	1/2	90.1
3/8	46.5	3/8	49.2
No. 4	12.7	No. 4	33.5
No. 8	8.5	No. 8	30.1
No. 12	7.7	No. 12	29.5

AGGREGATE - C

TOTAL WEIGHT OF MATERIAL USED - 1824 GRAMS

Dry Aggregate U. S. Sieve	Per Cent Passing	Saturated Aggregate U. S. Sieve	Per Cent Passing
3/4	100.0	3/4	100.0
1/2	83.4	1/2	87.0
3/8	51.9	3/8	66.2
No. 4	23.6	No. 4	37.1
No. 8	17.6	No. 8	29.3
No. 12	16.5	No. 12	27.7

AGGREGATE - D

TOTAL WEIGHT OF MATERIAL USED - 5000 GRAMS

Dry Aggregate		Saturated Aggregate	
U. S. Sieve	Per Cent Passing	U. S. Sieve	Per Cent Passing
3/4	100.0	3/4	100.0
1/2	59.1	1/2	54.8
3/8	23.5	3/8	16.5
No. 4	11.7	No. 4	7.8
No. 8	9.2	No. 8	6.7
No. 12	8.8	No. 12	6.6

AGGREGATE - E

TOTAL WEIGHT OF MATERIAL USED - 5000 GRAMS

Dry Aggregate		Saturated Aggregate	
U. S. Sieve	Per Cent Passing	U. S. Sieve	Per Cent Passing
3/4	100.0	3/4	100.0
1/2	56.8	1/2	51.9
3/8	20.4	3/8	8.9
No. 4	8.8	No. 4	3.7
No. 8	6.3	No. 8	3.1
No. 12	5.8	No. 12	2.8