

**A SANDBLAST ABRASION TEST FOR
SYNTHETIC AGGREGATE EVALUATION**

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PREFACE

The primary objective of the synthetic aggregate research being conducted by the Texas Transportation Institute is to develop a recommended acceptance criterion for synthetic aggregates for use in all phases of highway construction.

This is the eighth report issued under Research Study 2-8-65-81, one of the synthetic aggregate research studies being conducted at the Texas Transportation Institute in the cooperative research program with the Texas Highway Department and U. S. Bureau of Public Roads. The first seven reports are:

"Correlation Studies of Fundamental Aggregate Properties with Freeze-Thaw Durability of Structural Lightweight Concrete," by W. B. Ledbetter, *Research Report 81-1*, Texas Transportation Institute, August, 1965.

"Effect of Degree of Synthetic Lightweight Aggregate Pre-Wetting on the Freeze-Thaw Durability of Lightweight Concrete," by C. N. Kanabar and W. B. Ledbetter, *Research Report 81-2*, Texas Transportation Institute, December, 1966.

"Aggregate Absorption Factor as an Indicator of the Freeze-Thaw Durability of Structural Lightweight Concrete," by W. B. Ledbetter and Eugene Buth, *Research Report 81-3*, Texas Transportation Institute, February, 1967.

"Flexural Fatigue Durability of Selected Unreinforced Structural Lightweight Concretes," by J. C. Chakabarti and W. B. Ledbetter, *Research Report 81-4*, Texas Transportation Institute, July, 1967.

"Suitability of Synthetic Aggregates Made from Clay-Type Soils for Use in Flexible Base," by W. M. Moore, Richard S. van Pelt, F. H. Scrivner, and George W. Kunze, *Research Report 81-5*, Texas Transportation Institute, February, 1968.

"Performance Studies of Synthetic Aggregate Concrete," by C. E. Buth, H. R. Blank, and R. G. McKeen, *Research Report 81-6*, Texas Transportation Institute, March, 1969.

"Fundamental Factors Involved in the Use of Synthetic Aggregate Portland Cement Concrete," by W. B. Ledbetter, C. E. Sandstedt, and A. H. Meyer, *Research Report 81-7*, Texas Transportation Institute, November, 1969.

In addition, a special report has been published under this research study. The report is:

"A Recommended Synthetic Coarse Aggregate Classification System (Revised August, 1969)," by W. B. Ledbetter, B. M. Gallaway, W. M. Moore, and Eugene Buth, *Special Report*, Texas Transportation Institute, August, 1969.

The authors wish to thank all members of the Institute who assisted in this research. They would like to express special appreciation to Mr. M. B. Robertson who helped develop the test method described in this report, and to Dr. W. M. Moore, who supervised the acquisition of data for the series B tests.

The authors wish to acknowledge the guidance and assistance given by the advisory committee for this study. The members are as follows: (a) Texas Highway Department Personnel—Mr. Kenneth D. Hankins, Study Contact Representative and Research Area Representative; Mr. H. A. Sandberg, Jr., Materials and Tests Division Representative; and Mr. Louis White, Bridge Division Representative; (b) Bureau of Public Roads Personnel—Mr. Edward V. Kristaponis, Division Representative, and Mr. W. J. Lindsay, Regional Representative.

The opinions, findings, and conclusions expressed in this publication are those of the authors and not necessarily those of the Bureau of Public Roads.

ABSTRACT

The need for an aggregate abrasion test which effectively differentiates between the quality of aggregates of various unit weights prompted the development of a new test apparatus. The method selected uses air-driven sand as the abrading mechanism. Research findings based on tests of five natural and forty-seven synthetic aggregates tentatively indicate that the sandblast test is statistically reproducible and is characterized by improved differentiation between various aggregates when compared to results obtained with the Los Angeles test, ASTM C 131.

Key Words—abrasion, sandblast, porosity, thermal transformation, synthetic aggregate, testing.

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1. Introduction

1.1 Purpose and Scope

The over-all objective of this phase of the study is the development of a recommended synthetic aggregate classification system and performance standards for synthetic aggregate portland cement concrete.

The scope of this report is to describe the results from a new test for the evaluation of the abrasion resistance of synthetic aggregates. No attempt was made to compare these results with concrete made from these aggregates. That topic will be covered in a subsequent report.

1.2 Background

The need for an aggregate test which measures structural quality has been recognized for many years. This need is exemplified by the many different types of tests which have been developed to measure some quality delineating aspect of the structural integrity of aggregates.

Numbers in parentheses refer to references contained in Section 8.

gates of construction. A discussion by Woolf (1)¹ traces the history of the search for a satisfactory aggregate test and includes a description of the widely accepted Los Angeles abrasion test (ASTM C 131). Woolf described the Los Angeles method as an improvement on previous tests although it was subject to variation caused by aggregate particle shape.

Since the time of the general acceptance of the Los Angeles test, extensive use of lightweight aggregates has evolved with an even greater need predicted (2,3). In the routine testing of many of these lightweight aggregates some have noted that the Los Angeles abrasion test failed to show significant differences between various lightweight, easily crushed aggregates, and hard, dense natural aggregates (4). The relative ineffectiveness of the Los Angeles test for evaluation of lightweight aggregates is demonstrated by the efforts of several groups to improve the technique by various modifications (5,6). A definitive abrasion test of aggregates encompassing a wide range of particle densities was therefore desired. In an effort to meet this need, a new aggregate abrasion test was developed and is referred to as the Texas sandblast abrasion test for aggregates (7).

2. Description of Test

The use of sand as an abrasion mechanism for concrete testing has been tentatively standardized as ASTM C418-67T. However, the abrasion resistance of the aggregate within the concrete is difficult to accurately determine by such a test since the quality of the mortar greatly influences the results. It would seem that if the complicating influence of the mortar could be removed, a more meaningful comparison of different types of aggregates would result. Therefore, a technique using air-driven sand was developed for the abrasion testing of a sample consisting only of coarse aggregate particles. In this test the abrasion resistance of the aggregates is determined by measuring sample weight loss through abrasion and impact by air-driven sand.

A drawing of the Texas sandblast abrasion test apparatus is shown in Fig. 1. The apparatus consists primarily of a sand feed-rate control device, a regulated air supply, and a rotating sample chamber.

The sand feed control device is an important component of any sandblast test apparatus. It must insure an accurate rate and quantity delivered for meaningful results. The method used here has both of these features. First, the quantity of sand used is controlled by the grading and weight. Ottawa sand (20-30 mesh) is accurately weighed for each test. The feed-rate is closely controlled by a gravity-fed, calibrated, glass funnel. This glass funnel was heated and drawn to the proper tip diameter to pass 600 grams/minute. A number of feed-rate calibrations has shown that the desired rate is reproducible, being well within current feed-rate specifications for the sandblast test of concrete (ASTM C 418-67T). The lower funnel seen in Fig. 1 has a relatively large

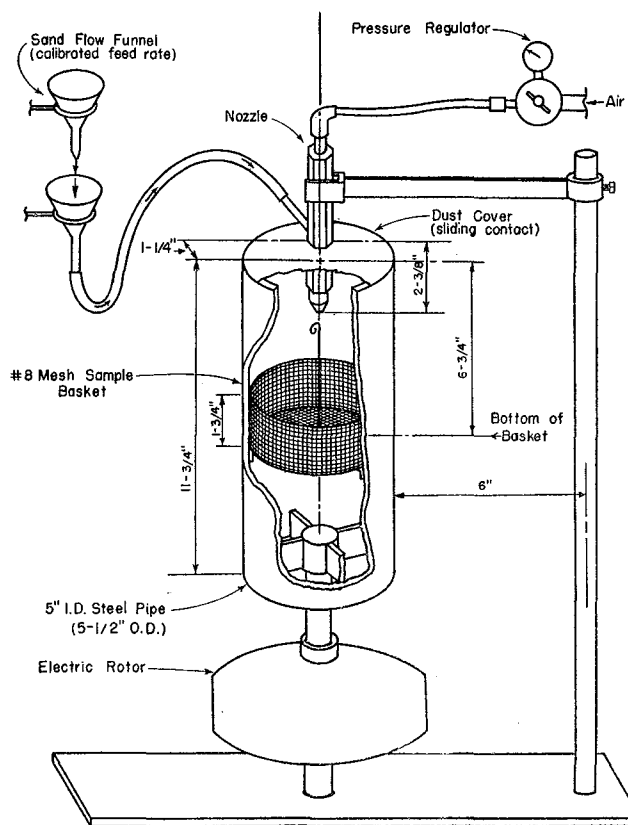


Figure 1. Texas sandblast abrasion test apparatus.

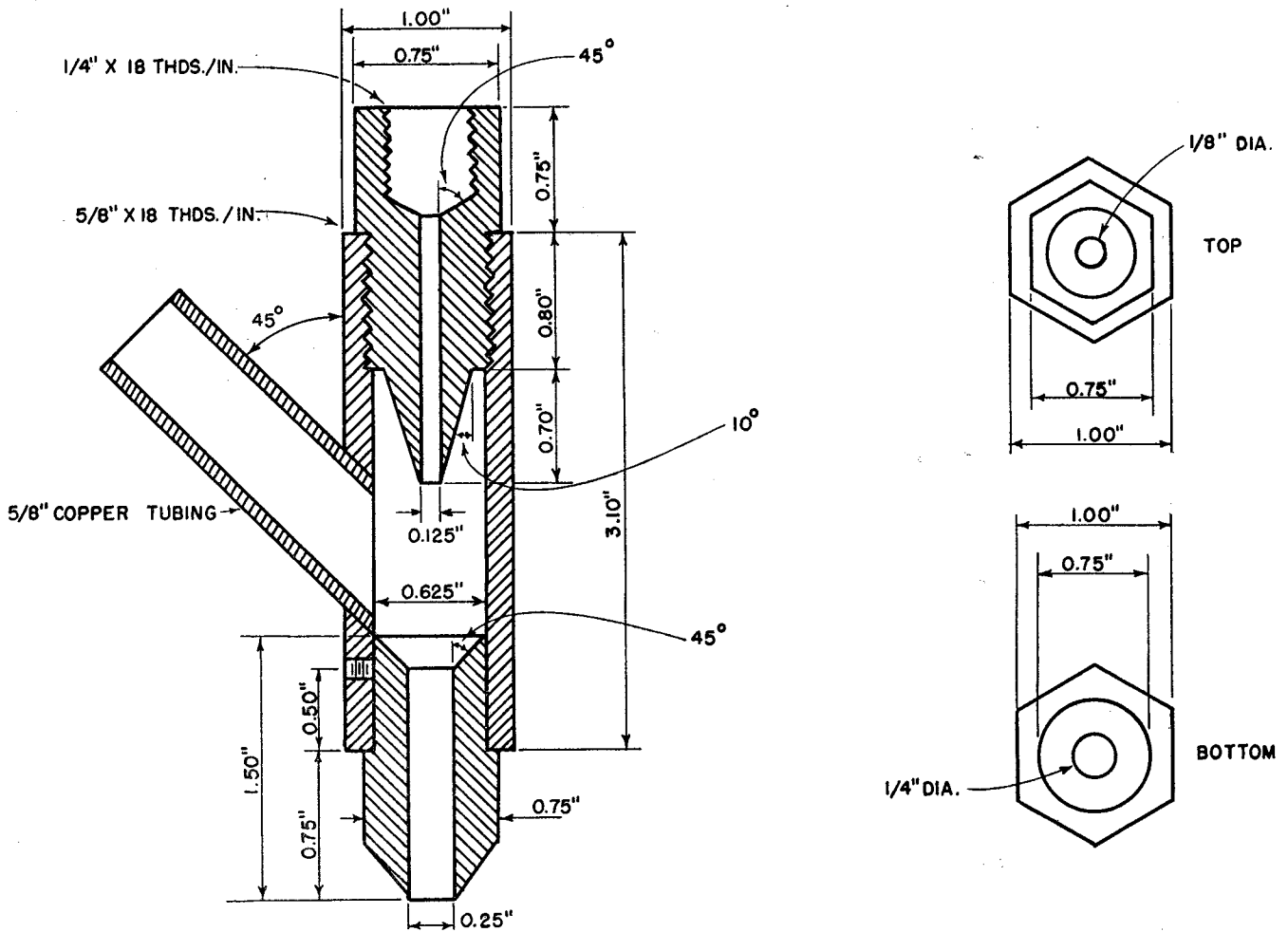


Figure 2. Nozzle for Texas sandblast abrasion test.

orifice and serves only to gather the falling sand for delivery to the suction line connected to the sandblast nozzle. This funnel is positioned several inches below the control funnel to prevent any suction interference with the rate control.

From the lower funnel the sand passes through rubber tubing to the sandblast nozzle. The nozzle shown in Fig. 2 is basically designed according to the nozzle specifications given in ASTM C 418-67T. As specified in the ASTM method, the nozzle tip is replaced at regular intervals.

As the sand enters the nozzle housing, it is driven by a stream of high-pressure air through the nozzle tip onto the aggregate sample. The aggregate sample is held in the rotating drum in a No. 8 mesh wire basket. The nozzle tip is located in a position halfway between the vertical center line and inside surface of the rotating drum so that as the drum turns, the sample surface is uniformly exposed to the air-driven sand. A photograph of the nozzle and the sample basket containing the aggregate is given in Fig. 3.

The drive for rotating the sample chamber is an electric motor with a speed of 1½ rpm (other rotation speeds are currently being investigated). The total abrasive charge of sand used is 1200 grams fed at 600 grams/minute. Consequently, the sample is abraded for two minutes (a total of three revolutions).

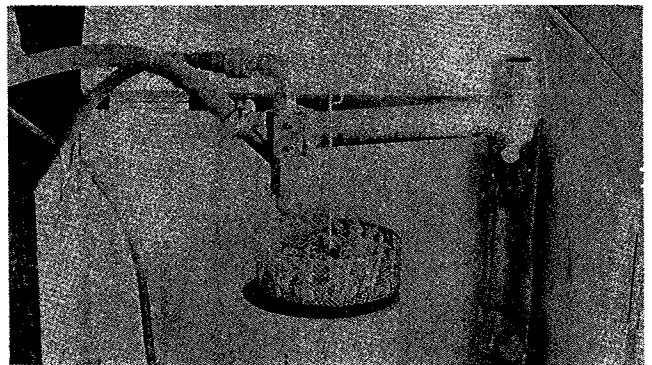


Figure 3. Sandblast nozzle and sample basket.

3. Test Procedure

The entire testing procedure including sample preparation and calculation of results is given in the following list.

3.1 Sample Preparation

1. Secure a representative coarse aggregate sample of approximately $\frac{1}{2}$ cubic foot.
2. Screen the sample over 1, $\frac{3}{4}$, $\frac{1}{2}$, and $\frac{3}{8}$ in. sieves.
3. Select the sample grading according to the maximum size of aggregate used.

Grading 1

($-\frac{3}{4}$ in. + $\frac{1}{2}$ in.) 60 pieces

($-\frac{1}{2}$ in. + $\frac{3}{8}$ in.) 120 pieces

Grading 2

(-1 in. + $\frac{3}{4}$ in.) 15 pieces

($-\frac{3}{4}$ in. + $\frac{1}{2}$ in.) 30 pieces

($-\frac{1}{2}$ in. + $\frac{3}{8}$ in.) 60 pieces

The samples are proportioned so that in each aggregate size range for a particular grading, approximately the same aggregate surface area is available for abrasion testing. Four samples corresponding to grading 1 or 2 are subjected to the abrasion test for each aggregate type evaluated.

4. Oven dry the samples to constant weight and then weigh to the nearest 0.1 grams.

3.2 Sand Preparation

An appropriate number of 1200-gram samples of 20-30 mesh Ottawa sand are prepared. This sand should be dry (storage at about 50 percent relative humidity is sufficient).

3.3 Sandblast Testing (refer to Fig. 1)

1. Place the thoroughly mixed aggregate sample in the sample basket so that the particles form a relatively level surface.
2. Place the sample and basket in the sample chamber and position the dust cover and sandblast nozzle.
3. Cover the funnel tip and fill the funnel with 1200 grams of Ottawa sand.
4. Turn on the chamber rotation.
5. Turn on the air supply (preset at 80 psi regulated pressure) and immediately release the sand. Monitor the pressure during the test and adjust if necessary to hold 80 psi (± 3 psi).
6. After the funnel is empty, wait approximately 10 seconds, then turn off the air supply and rotation.
7. Carefully remove the sample basket and transfer the contents to a No. 10 mesh sieve. Vibrate the sample for approximately 30 seconds to remove any trapped sand particles.
8. If a dry air system is used, the sample can be weighed immediately. If not, it is necessary to oven dry the samples to constant weight before final weighing.

3.4 Calculation of Abrasion Losses

The abrasion loss is calculated as the weight lost during the abrasion testing expressed as a percent of the initial oven-dry weight of the sample. The average of four such calculations is used for the characteristic value of each aggregate type.

4. Experimental Results-Series A

4.1 Results

A total of 14 different aggregates in Series A were subjected to compositional analyses and engineering evaluations. Twelve were lightweight aggregates produced by processing two types of crushed shale in a 25-ft. long by 2-ft. inside diameter research rotary kiln (7). Specific gravities and dry loose unit weights for all 14 aggregates are given in Table 1. The processing parameters² and photographs showing the pore and surface texture of these twelve research kiln aggregates are given in Figs. 4 and 5. One commercially produced synthetic aggregate with a good field performance record was also

tested and is shown in Fig. 6. The final aggregate tested was a naturally occurring, predominantly siliceous gravel (Hearne) with a good field performance record.

The photographs and properties listed for the synthetic aggregates indicate that a wide range in processing parameters was employed in the manufacture of these materials. Therefore, a technique combining X-ray diffraction, differential thermal analysis, effluent gas analysis and gas chromatography was utilized to provide a relative measure of the degree to which the raw materials have been transformed during kiln processing (5). Those thermally induced reactions which were studied included clay mineral dehydroxylation, development of high temperature crystalline phases, gas evolution, decomposition, and oxidation reactions.

It is of interest to note that except for aggregates Z-2 and Z-4, the transformation study indicated that the

²For processing parameters the following abbreviations apply:

T_m—maximum aggregate temperature as determined by optical pyrometer.

R.T.—aggregate retention time within kiln (minutes).

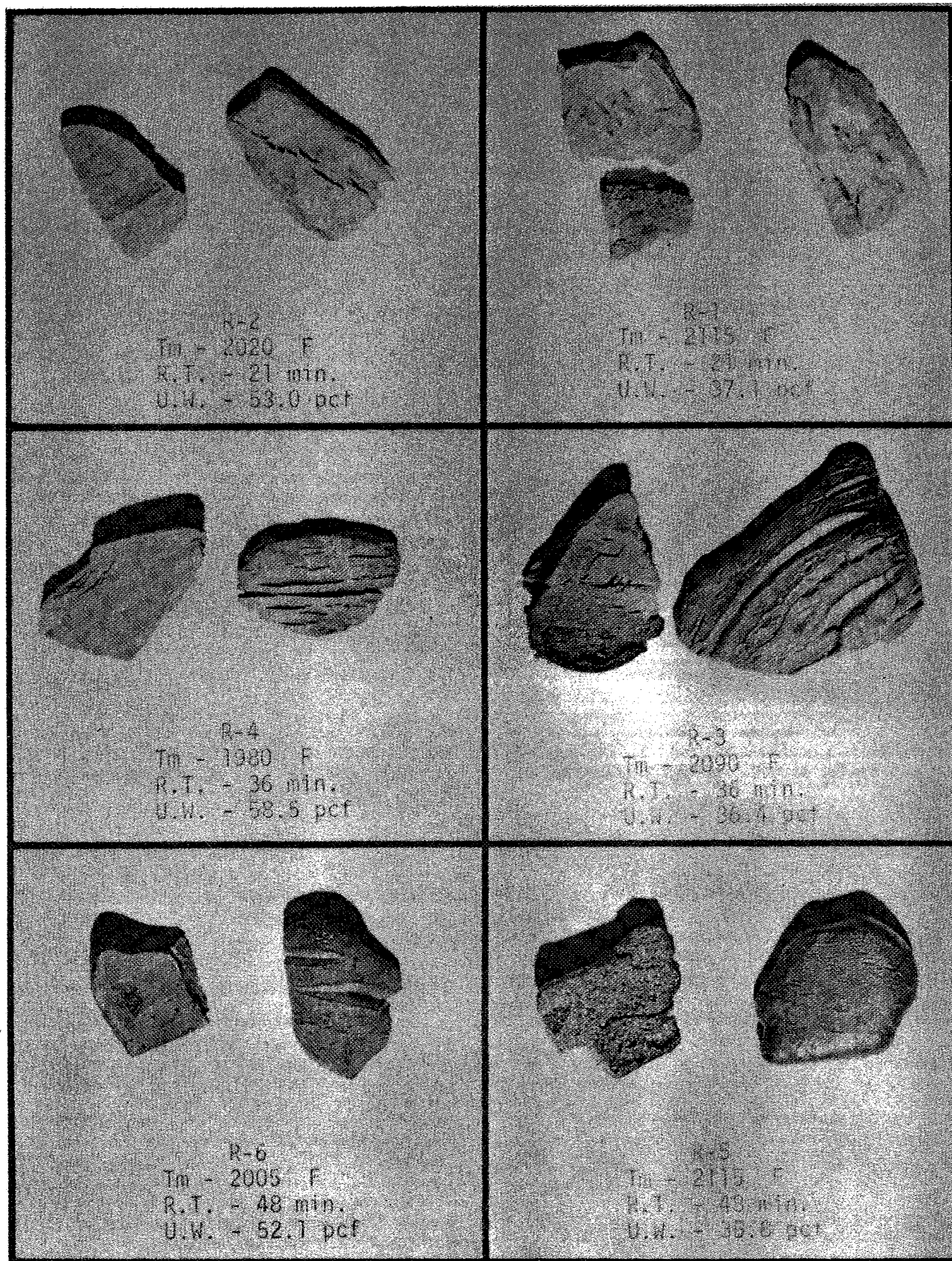


Figure 4. Surface and pore characteristics of pilot kiln aggregates R.

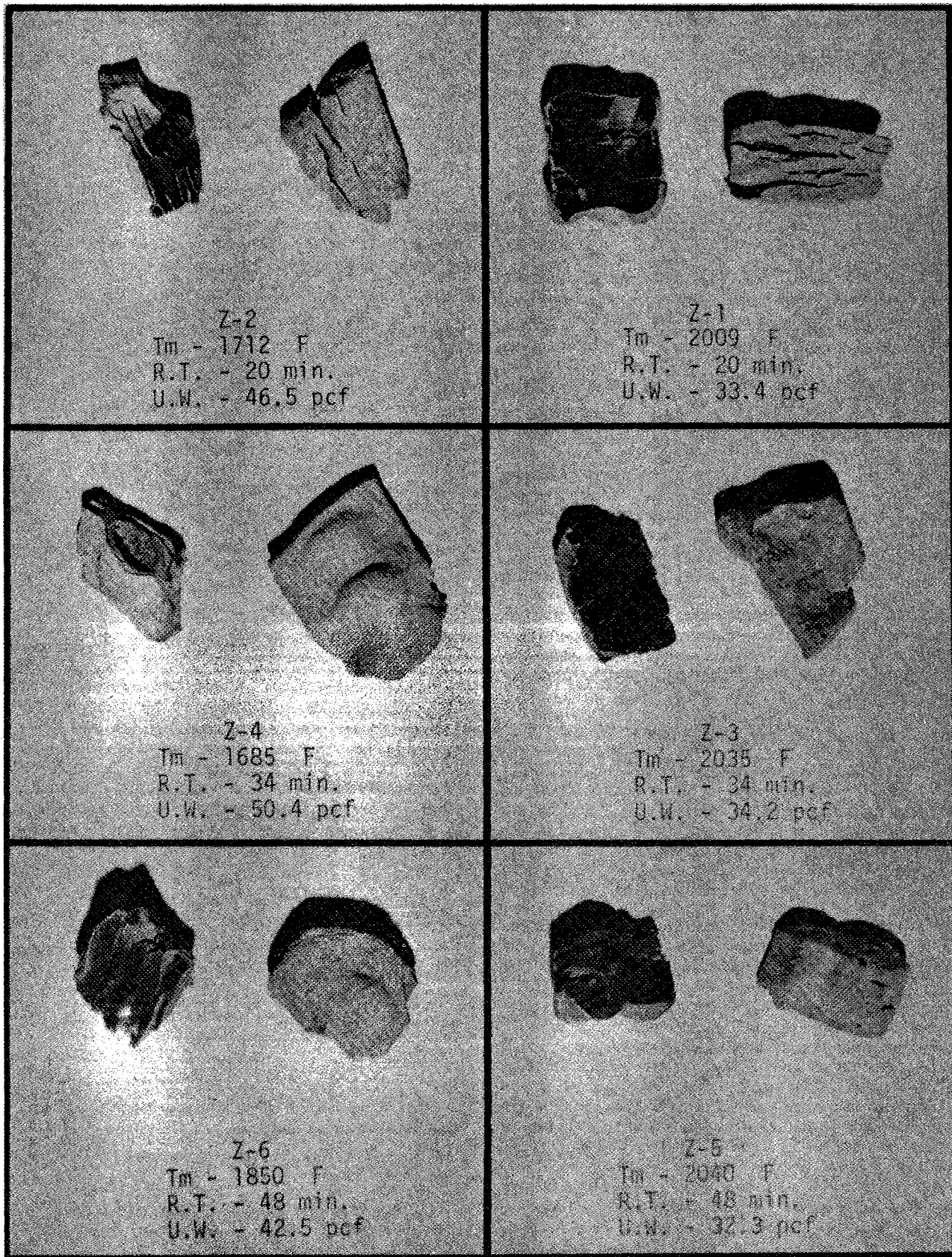


Figure 5. Surface and pore characteristics of pilot kiln aggregates Z.

TABLE 1. AGGREGATE PROPERTIES FOR SERIES A

Aggregate Type	Dry Bulk Sp. Gr. ^a	Absolute Sp. Gr. ^b	Unit Weight, ^c (U.W.)—pcf
R-1	1.16	2.05	37.1
R-3	1.10	1.90	36.4
R-5	1.03	1.86	35.8
R-2	1.66	2.23	53.0
R-4	1.73	2.26	58.5
R-6	1.53	2.18	52.1
R-comm.	1.43	2.17	48.1
Z-1	1.15	2.19	33.4
Z-3	1.10	2.12	34.2
Z-5	1.03	2.05	32.3
Z-2	1.67	1.94	46.5
Z-4	1.77	2.00	50.4
Z-6	1.44	2.24	42.5
Hearne	2.64	2.66	100.5

^aDetermined by a pycnometer technique developed by Bryant (8).

^bDetermined by saturating aggregates under 1200 psi water pressure in a volumetric pycnometer.

^cTested according to ASTM C 29-67T (loose method).

rotary kiln produced aggregates had been converted to essentially stable materials consisting of amorphous glass, α -quartz, and small amounts of high temperature minerals such as spinel, cristobalite and mullite. On the other hand, the thermal transformation of aggregates Z-2 and Z-4 was found to be less complex. Analyses of these two burned aggregates indicated an incomplete formation of the high temperature crystalline phases, and the probable presence of only partially dehydrated clay minerals, measurable quantities of organic matter, and carbonate. The incompleteness of transformation of these two aggregates raises a question as to their suitability for structural applications and places emphasis on the need for effective testing techniques of practical utility.

Comparison of Los Angeles and Texas Abrasion Tests

The results of the Los Angeles abrasion test (ASTM C 131) and the Texas sandblast abrasion test for all 14 aggregates in Series A are given in Table 2 and by the bar graph of Fig. 7. An exception to the specified Los Angeles procedure was that the plus No. 12 material was not washed. For a more convenient presentation, two different vertical scales were selected as shown.

Perhaps the most striking difference between the two sets of abrasion loss data is the greater differentiation between aggregates provided by the Texas test. One of the shortcomings of the Los Angeles test is that it frequently fails to show significant increases in the abrasion loss for easily crushed lightweight aggregates in comparison to dense, strong, natural aggregates. This specific problem is exemplified by the data shown in Fig. 7. In general, the abrasion losses obtained by the Los Angeles test differ only slightly, even though the aggregates tested are characterized by very different properties as shown by Figs. 4, 5, 6 and Table 1. Especially notice for the Los Angeles test that the highly bloated, easily crushed synthetic aggregates (R-1, R-3, R-5, Z-3, Z-5) compare favorably with the Hearne siliceous aggregate. Also note that the Los Angeles abrasion losses for the relatively strong, less bloated aggregates R-2, R-4, and R-6 are approximately equal to those of the highly bloated, easily crushed aggregates R-1, R-3,

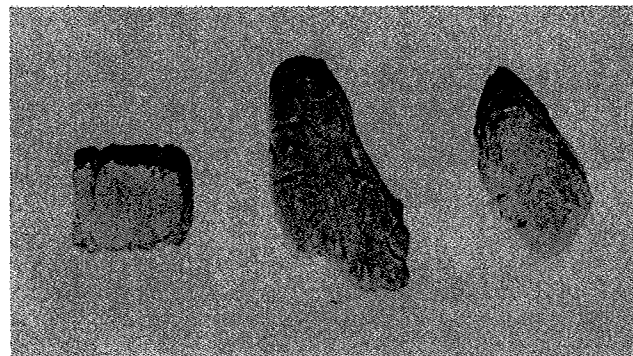


Figure 6. Surface and pore characteristics of commercial aggregate R.

and R-5. It is this type of behavior which has led to questions about the application of results obtained from the Los Angeles abrasion test when performed on lightweight aggregates.

On the other hand, the Texas abrasion losses relate well to the physical characteristics of the lightweight aggregates. For example, a comparison of all the aggregates on the basis of physical appearance and density leads one to predict that the natural hardrock aggregate would be the most abrasive resistant material; and according to the Texas test this is shown to be the case for one aggregate tested. In addition, note that the hard, dense aggregates R-2, R-4, and R-6 are shown to be more abrasive resistant than the highly bloated, easily crushed aggregates R-1, R-3, R-5, Z-1, Z-3, Z-5.

The results of the Los Angeles test might indicate that aggregates Z-2, Z-4 and perhaps Z-6 and Z-1 would be unacceptable in an abrasive environment because of high abrasion loss. However, if the data given for the Texas test are used, aggregates Z-2, Z-4, and R-5 would possibly be rejected. These inconsistencies obviously relate to the basic differences between the two tests. Fortunately, both methods predict that aggregates Z-2 and Z-4 are the least abrasive resistant, and this agrees well with their expected behavior based on the thermal transformation analysis mentioned previously (7).

TABLE 2. NUMERICAL DATA FOR LOS ANGELES ABRASION AND TEXAS SANDBLAST ABRASION TESTS—SERIES A AGGREGATES

Aggregate Designation	L.A. Abrasion Loss - Percent Grade B (ASTM C 131)	Average Texas Sandblast Loss - Percent
R-Comm (Shipment 3)	30.3	6.7
R-2	29.2	3.9
R-4	28.8	3.3
R-6	28.2	3.9
R-1	24.6	6.9
R-3	27.9	8.6
R-5	28.9	10.1
Z-2	42.7	14.0
Z-4	40.6	10.5
Z-6	33.3	7.2
Z-1	33.5	8.1
Z-3	28.3	7.3
Z-5	26.9	7.4
Hearne	23.9	0.6

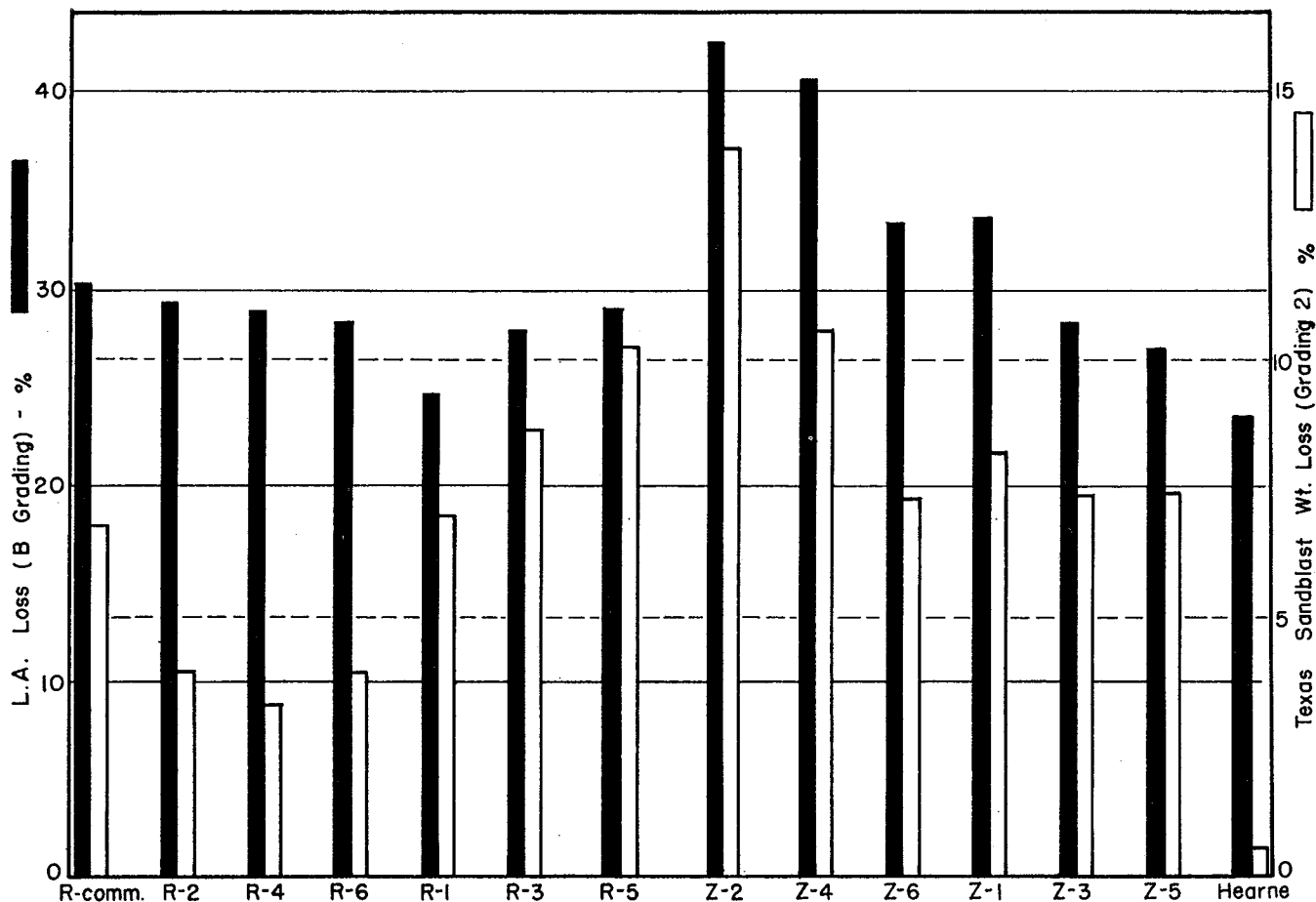


Figure 7. Comparison of Los Angeles abrasion and Texas sandblast abrasion tests.

Effect of Aggregate Void System and Degree of Transformation

In a number of research studies concerning the properties of fused silicates, ceramists have noted that the properties of compressive strength and modulus of rupture vary as a function of absorption and porosity (9,10). Phase transformation and fusion have also been mentioned as parameters controlling the strength of fired shale products (11). Although these research studies were primarily concerned with evaluating the properties of brick, the similarities in raw materials and thermal processing suggest corresponding relationships for the strength-related properties of synthetic aggregates. It is assumed here that the abrasion resistance of the aggregates is a strength-related property and, as such, should in some way be related to porosity and phase-transformation characteristics.

A measure of the degree of bloating, i.e. porosity, was needed for use with the synthetic aggregates. For this purpose aggregate porosity was defined as the volume of voids saturated at 1200 psi water pressure,³ expressed as a percent of the bulk volume of the aggregate. By this definition the aggregate properties of dry bulk specific gravity and absolute specific gravity were

³Assumed to accomplish complete saturation of all voids.

used to determine the aggregate porosity in the following manner:

$$\begin{aligned} \text{Volume of Voids} &= \text{Bulk Volume} - \text{Volume of Solids} \\ &= \frac{\text{Dry Weight}}{\text{Bulk Specific Gravity}} - \frac{\text{Dry Weight}}{\text{Absolute Specific Gravity}} \\ \therefore \text{Volume of Voids} &= \text{Dry Wt.} \left[\frac{1}{\text{Bulk Sp. Gr.}} - \frac{1}{\text{Absolute Sp. Gr.}} \right] \quad [1] \end{aligned}$$

If equation [1] is divided by the expression for bulk volume, i.e. by

$$\text{Bulk Volume} = \frac{\text{Dry Weight}}{\text{Bulk Sp. Gr.}}, \text{ it becomes}$$

$$\frac{\text{Volume of Voids}}{\text{Bulk Volume}} = \left[1 - \frac{\text{Bulk Sp. Gr.}}{\text{Absolute Sp. Gr.}} \right]$$

whence by the foregoing definition of porosity:

$$\text{Porosity} = \left[1 - \frac{\text{Bulk Sp. Gr.}}{\text{Absolute Sp. Gr.}} \right] \times 100 \text{ percent.} \quad [2]$$

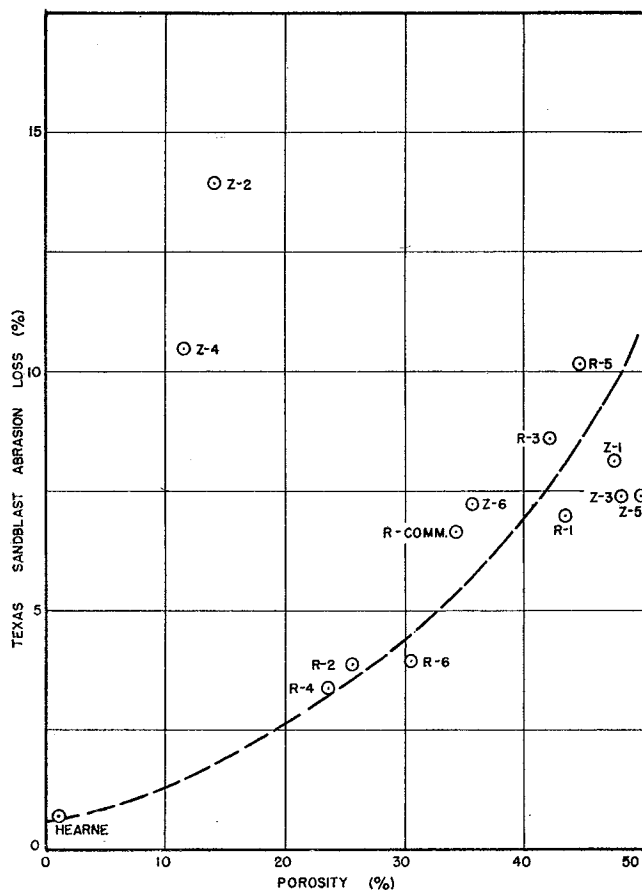


Figure 8. The influence of porosity and thermal transformation on abrasion resistance of Series A aggregates.

This equation [2] was employed for the calculation of the porosities of all 14 aggregates, and the results of this determination were plotted in Fig. 8 as a function of the Texas sandblast abrasion loss. From Fig. 8 it is apparent that for all the aggregates except Z-2 and Z-4, a general relationship exists between the Texas abrasion loss and porosity. This relationship implies that as the aggregates become more highly bloated, a corresponding increase in abrasion loss results.

In contrast, aggregates Z-2 and Z-4 have relatively low porosities, and yet they exhibit high abrasion losses. This behavior is certainly a marked exception to the general relationship of Fig. 8. However, when the additional variable of degree of thermal transformation is considered, the position of these two data points is perhaps understandable. According to the results of the transformation analysis, aggregates Z-2 and Z-4 were definitely the least thermally transformed of all materials of this study. In short, these two aggregates were not completely transformed into fused masses of inert components.

These results would seem to indicate that a general relationship such as shown in Fig. 8 presents a logical correlation of abrasion resistance and porosity. Also, for synthetic aggregates, major deviations from such a relationship tend to imply that a lack of thermal transformation may be the intervening factor.

4.2 Statistical Accuracy of Method

In order to determine some measure of the reproducibility of the sandblast test method, a statistical study was made of the data obtained from four tests on each of 14 aggregates in Series A. An indication of the reliability of the method is given by these results of the statistical study:

Average coefficient of variation = 9.2 percent
(determined by averaging 14 separate computations for the coefficients of variation within each aggregate type).

Variance—between observations and within aggregate type for all aggregates = 0.51
(determined by the statistical method of calculating the pooled variance between grouped observations).

These measures of the test's reliability suggest that the method is statistically reproducible. In addition, the test can be performed easily and rapidly. However, the most significant attribute of this technique is that the results of the tests performed thus far indicate that the method realistically differentiates between lightweight aggregates of varying quality and unit weight.

5. Experimental Results-Series B

5.1 Results

In order to more fully evaluate the statistical reliability of this method, another series of Los Angeles Abrasion and Texas sandblast tests was conducted on various synthetic aggregates which were *not* bloated—produced both in the TTI research kiln and commercially. In addition, four naturally occurring aggregates were subjected to the Texas sandblast test. All of the aggregates tested in series B are being investigated for potential

use as base materials in another phase of this study (see *Research Report 81-5*).

The results of the Texas sandblast tests and the Los Angeles abrasion tests on the nonbloated aggregates are given in Table 3. Such aggregate properties as porosity, degree of thermal transformation, and specific gravity have not been determined. Thus, any direct comparison between any Texas sandblast loss and the corresponding Los Angeles abrasion loss could be misleading (see Chapter 4) as these aggregates are largely nonbloated.

TABLE 3. NUMERICAL DATA FOR LOS ANGELES ABRASION AND TEXAS SANDBLAST ABRASION LOSSES—SERIES B AGGREGATES

Aggregate Designation	Firing Temp. °F	Los Angeles Abrasion Loss - Percent (ASTM C131) (Grade B)	Average ^a Texas Sandblast Loss - Percent
Series B-1 . . . Commercially Produced Synthetic Lightweight Aggregates ^b			
R-Comm			
(Shipment 2)		21	4.0
E-6			4.4
E-7		24	5.2
D-3			5.5
S-2		30	7.7
S-3			9.8
Series B-2 . . . Commercially Produced Synthetic Aggregates ^c			
Hopkins			7.9
Wharton		60 (44 ^d)	9.2
Landrum		(33 ^d)	11.6
Yegua		(38 ^d)	12.2
Series B-3 . . . TTI Produced Synthetic Aggregates			
GEW	1030	62	9.0
	1095	67	14.9
	1200	55	6.8
	1305	62	10.9
	1400	63	17.8
	1600	49	12.2
	1800	53	20.9
	1930	40	11.9
RGH	1000	64	16.4
	1100	61	13.5
	1205	57	10.9
	1295	58	10.0
	1390	43	7.0
	1585	36	7.7
	1800	37	9.7
	1910	34	9.9
BA	1010	71	11.2
	1100	67	11.4
	1205	65	9.1
	1310	60	6.9
	1395	37	6.5
	1610	52	18.4
	1800	37	8.1
	1940	37	13.3
Series B-4 . . . Conventional Aggregates			
ZEM-1			2.3
ZEM-2			0.8
Cr. Ls.			2.8
Soft Sandstone			53.9

^aEach data point is the average of four tests.

^bFor a complete description of each aggregate, see *Research Report 81-3 (13)*.

^cFor a complete description of each aggregate, see *Research Report 81-5 (12)*.

^dASTM C131—Grade C.

In addition, caution should be exercised in attempting to draw any conclusions in terms of the effects of firing temperature on either sandblast abrasion or Los Angeles abrasion. As pointed out in the series A tests (Chapter 4), the sandblast loss was a function of many factors including degree of thermal transformation and porosity. And neither thermal transformation nor porosity necessarily is a sole function of firing temperature.

However, certain conclusions can be made. First, the Texas sandblast test delineated differences between soft sandstone and high quality conventional aggregates. Second, there were significant differences in Texas sandblast abrasion losses between different aggregates, which substantiates the conclusions reached in the Series A tests. Third, more data and field experience records are needed before the Texas sandblast test can be fully verified as a suitable test. And fourth, the statistical accuracy of the Texas sandblast test was fully substantiated as discussed in the next section.

5.2 Statistical Accuracy of Method

The statistical analyses of the Series B Aggregate data are given in Table 4. The analyses were based on four replications of each of the 38 different aggregates tested. Note that the within set standard deviations and coefficients of variation are quite low, further substantiating the repeatability and reliability of the test as discussed in Section 4.2.

TABLE 4. STATISTICAL ANALYSES OF SERIES B AGGREGATE DATA

Series	Aggregate Type	Within Set ^a Standard Deviation	Within Set ^a Coefficient of Variation-Percent
B-1	Commercially Produced Lightweight Aggregate	0.45	7.3
B-2	Commercially Produced Synthetic Aggregate	0.89	8.8
B-3	TTI Produced Synthetic Aggregate	1.48	13.0
B-4	Conventional Aggregate	0.77	5.2
B	All Aggregates	1.26	11.6

^aA "set" as used herein is the set of four test results obtained for a single aggregate.

6. Conclusions and Recommendations

1. The Texas sandblast abrasion test provided an evaluation technique which realistically differentiated

between lightweight synthetic aggregates of various unit weights and degrees of transformation.

2. When evaluating the abrasion resistance of synthetic aggregates which were not lightweight, wide variations in results occurred, indicating that firing temperature, by itself, might not be a good indicator of degree of transformation.

3. Statistical analyses of the fifty-two aggregates tested strongly indicates the test is repeatable and reliable.

4. The initial test results of the technique justify continued research with emphasis on the correlation of field performance and sandblast abrasion loss. Studies of highway skid resistance and aggregate polishing characteristics may be particularly suited to evaluation by the Texas sandblast test.

7. Implementation Statement

It is suggested that the implementation of this test include an evaluation program by the Materials and Tests Division, comparing it with standard abrasion tests and field performance, as well as evaluating it in terms of test variation of the Departmental personnel running the test. Special attention should be given to comparing test results with tests on highway skid resistance and polishing characteristics of aggregates.

It is suggested that periodic review of these data be

instituted by the researchers and Highway Department personnel. It is further suggested that a Type B Research Project be considered which would be designed to assist in the "follow up" evaluation and implementation.

The above statement represents the combined opinions of the study contact representative and the authors and should not be construed as departmental policy.

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