FIRED-CLAY AGGREGATES FOR USE IN FLEXIBLE BASES

by

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Synthetic Aggregate Research

Research Study Number 2-8-65-81

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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 twelfth 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 the U. S. Bureau of Public Roads. The first eleven 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 Eugene 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.

"A Sandblast Abrasion Test for Synthetic Aggregate Evaluation," by James T. Houston and W. B. Ledbetter, *Research Report 81-8,* Texas Transportation Institute, October 1969.

"Studies of the Thermal Transformation of Synthetic Aggregates Produced in a Rotary Kiln," by James T. Houston, H. R. Blank, and G. W. Kunze, *Research Report 81-9,* Texas Transportation Institute, November 1969.

"Effect of Synthetic Aggregate Thermal Transformation on Performance of Concrete," by James T. Houston and W. B. Ledbetter, *Research Report 81-10,* Texas Transportation Institute, November 1969.

"Evaluation of Shrinkage-Cracking Characteristics of Structural Lightweight Concrete," by R. G. McKeen and W. B. Ledbetter, *Research Report 81-11,* Texas Transportation Institute, October 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 author wishes to thank all members of the Institute who assisted in this research. He would like to express special appreciation to Mr. Frank H. Scrivner for his advice and assistance. His help throughout the study was particularly valuable. Special gratitude is also expressed to Messrs. C. H. Michalak and Rudell Poehl for their assistance in data reduction and report preparation and to Mr. Gene Schlieker for his assistance during the testing phases.

The author wishes 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; and (b) Bureau of Public Roads Personnel—Mr. Edward V. Kristaponis, Division Representative, and Mr. W. J. Lindsay, Regional Representative.

1. Introduction

This is a progress report on Phase 2 of a study entitled "Synthetic Aggregate Research" being conducted by the Texas Transportation Institute, sponsored by the Texas Highway Department and the Bureau of Public Roads. This phase deals specifically with synthetic aggregates for use in flexible base, and its primary objective is to develop acceptance criteria for such aggregates. It was initiated in 1966, after nonbloated, fired-clay aggregates had been used experimentally in flexible base on several Texas highways. To the author's knowledge, fired-clay aggregates are at present the only synthetic aggregates that are economically feasible for use in flexible base. Therefore, all research efforts so far have been directed toward evaluating this type of aggregate.

The first study done under this phase of the research was an investigation into the chemical and physical stability of laboratory produced aggregates. The results of this study were reported in Reference 1, which contained the following tentative conclusions:

"1. The clay minerals, montmorillonite, illite, and kaolinite, will not rehydrate under atmospheric conditions once they have been completely dehydrated (dehydroxylated); therefore, once they have been completely dehydrated, they become chemically stabilized for use as highway construction materials. Complete dehydration is accomplished by heating the clay and holding it at the elevated temperature for sufficient time to allow the dehydration to occur. A period of 15 minutes at 1400°F. was sufficient to completely dehydrate the clay present in the small, oven dry laboratory specimens made from the Texas soils investigated.

"2. Incomplete dehydration of aggregates made by dehydrating clay-type soils can be detected by a relatively simple laboratory test. The test procedure is given in Appendix 8.1 of Reference 1.

"3. Most (if not all) clay-type soils having a relatively high strength when air dried can be fired to produce hard, durable aggregates suitable for use in flexible base and asphaltic concrete."

The conclusions listed above were based almost entirely upon an evaluation of cylindrically shaped particles (1/2 inch diameter by 1 1/2 inches long) which had been fired in a laboratory muffle furnace (see Figure 1). Therefore, the next investigation initiated under this phase of the research was an evaluation of aggregates produced in a rotary kiln, and the development of acceptance criteria for such aggregates. The investigation included the production of aggregates in the Texas Transportation Institute rotary kiln, their evaluation, and a study of several synthetic aggregate flexible bases that had been in service in the vicinity of Houston, Texas, for several years.

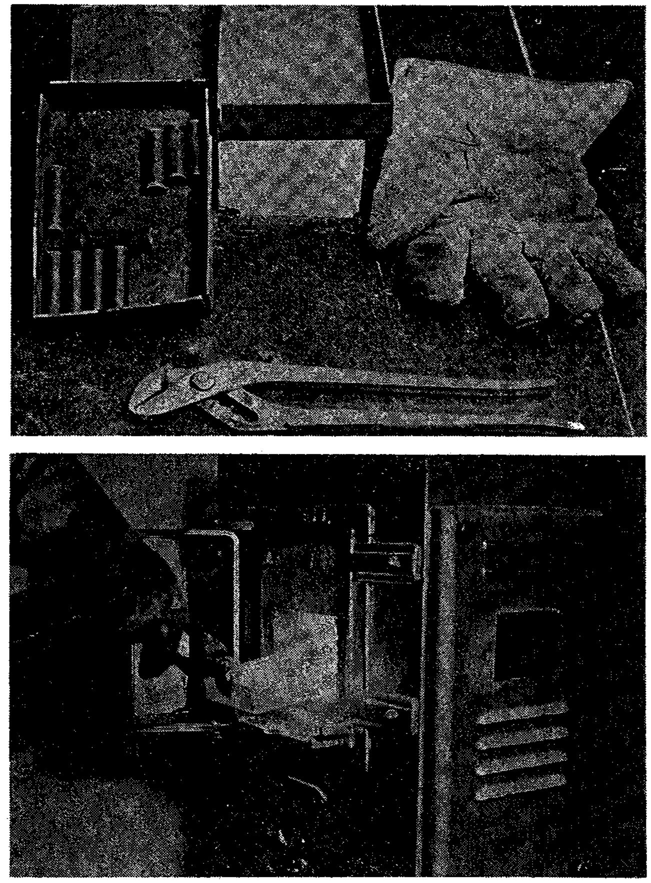

Figure 1. Preliminary findings in this research were based on molded specimens fired in a laboratory muffle furnace. The upper photograph shows specimens ready for firing; the lower shows them being removed from the furnace after firing.

All research results to date are favorable to the use of fired-clay aggregates in flexible base. The results indicate that these aggregates have great potential for use in highway construction in the many areas of the world where high quality aggregates no longer exist, but where the clays required for the production of synthetic aggregates are plentiful.

2. Materials

As a step in the development of a preliminary recommended criterion for the acceptance of flexible base aggregates, the Texas Transportation Institute's research rotary kiln (see Figure 2) was used to produce several samples of graded aggregates. The development of the research kiln and its capabilities are described in References 2 and 3.

Aggregate samples were produced from three plastic soils obtained from different sources in Brazos County, Texas. The Atterberg limits and gradations of the soils used are given in Table 1. Standard THD test procedures were followed in these determinations. Aggregates were made by firing each of the three soils at eight different temperatures; thus, twenty-four aggregate samples were available for testing. Each sample consisted of about 250 pounds of graded material, approximately 95% of which was sized between the one inch and the number 10 sieve.

In addition to aggregates made by the Texas Transportation Institute, four aggregate samples that had been produced in commercial rotary kilns for use in flexible base were obtained. Two of the four aggregates have been successfully used in flexible base by the Texas Highway Department. These are referred to herein as the Hopkin's aggregate, used by the Paris district, and the Wharton aggregate used by the Houston district. Two other samples, designated as the Madison 1 and Madison 2 aggregates, were obtained. These aggregates had been investigated by the Bryan district for possible future use in flexible base. The results of laboratory tests conducted by the Bryan district, which were reported in Reference 4, indicated that either of the two aggregates would be suitable for use in flexible base.

None of the above aggregates can be classified as "lightweight" synthetic aggregates. However, five samples of lightweight aggregate (unit weight of less than 55 pounds per cubic foot) produced commercially in Texas primarily for use in structural concrete, were also obtained. These aggregates are currently under investigation for Portland cement concrete application in Phase 1 of this study.

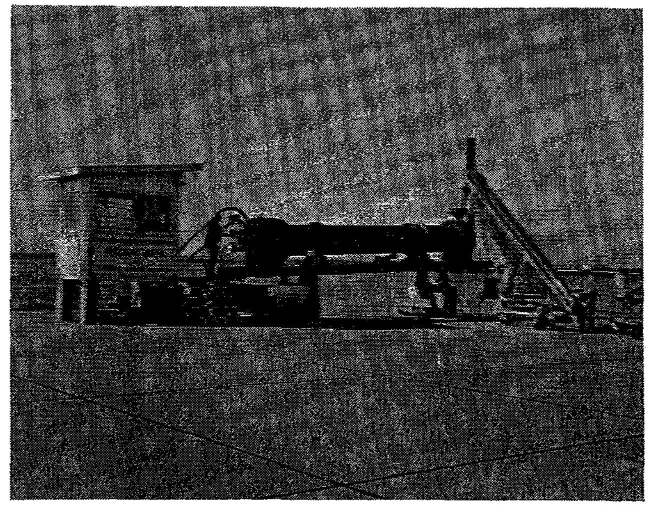

Figure 2. Aggregates are made for evaluation by firing air dried clays in the Texas Transportation Institute's research rotary kiln shown above.

In summary, thirty-three aggregate samples were investigated. Twenty-four of them were produced in the Texas Transportation Institute research kiln, two have been used successfully in flexible base on Texas highways, two have been investigated for possible similar future use, and the remaining five are lightweight aggregates that are available commercially in Texas.

TABLE 1. MATERIALS USED FOR RESEARCH AGGREGATE PRODUCTION

Raw Material	Liquid Limit	Plastic Limit	Plasticity Index	Gradation* Percent Sand	Percent Silt	Percent Clay
Red Clay	74	28	46	4	24	72
Gray Clay	67	23	44	5	41	54
Black Clay	53	19	34	13	34	53

*Determined by hydrometer analysis (MIT Classification: Sand—2 to .06mm; Silt—60 to 2 microns; and Clay—smaller than 2 microns).

3. *Evaluation of Aggregates*

The simple testing procedure developed during the initial laboratory studies is illustrated in Figure 3. Basically it consists of the cooking of specimens under water in a common kitchen-type pressure cooker, and then observing the effect of such treatment upon the particles. This procedure works quite well for laboratory produced cylindrical specimens because deterioration caused by the treatment is readily apparent on the smooth surface of the particles. It was initially thought that the same procedure would yield significant changes in the gradation of kiln produced aggregates if they were not sufficiently dehydroxylated; however, this was found not to be the case. Only minor changes in gradation were observed after the cooking treatment for many aggregates obviously unsuitable for use in flexible base —after the cooking treatment, these aggregate samples could be easily crumbled with the fingers.

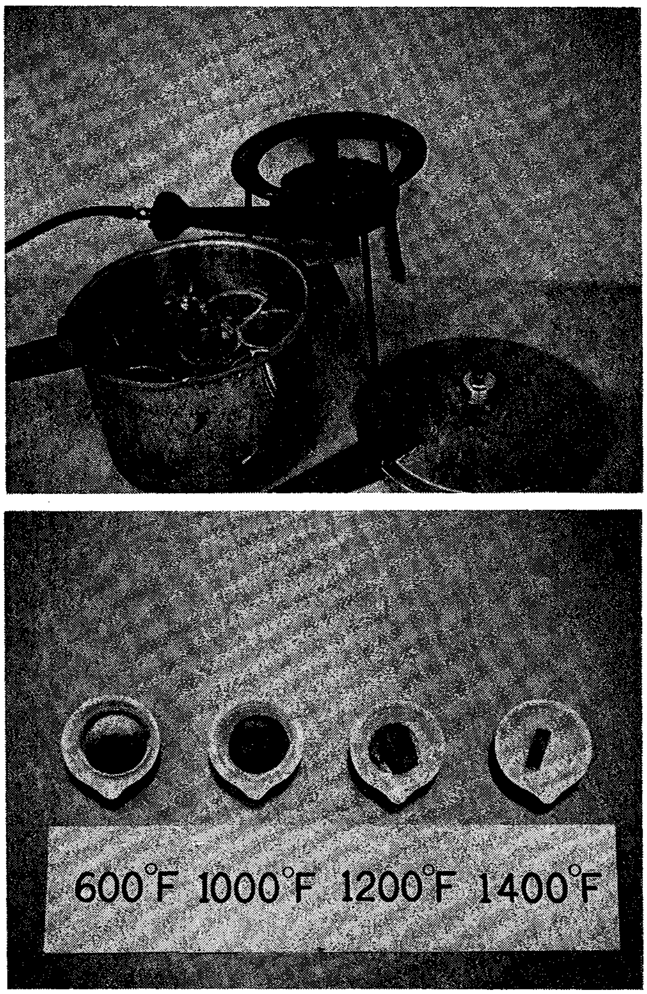

Figure 3. An evaluation test developed early in the study consisted of cooking specimens in a pressure cooker (upper) and observing the effect visually (lower). This was called the "slaking test."

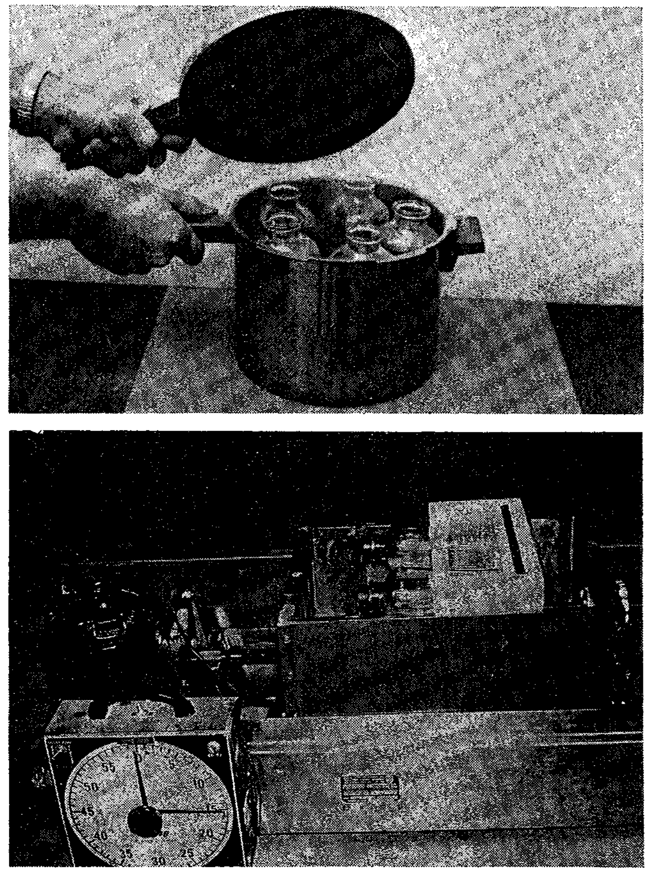

Figure 4. In a later modification to the evaluation test, kiln produced aggregates—after cooking (upper)—are subjected to severe agitation in water by a laboratory heavy duty shaker (lower). This is referred to as the "pressure slaking test."

Several variations of the initial test were tried. A procedure found to be adequate is given in Appendix A. It is called the "pressure slaking test" to distinguish it from the "slaking test" (now considered obsolete) described in Appendix 8 of Reference 1, and from the slaking procedures often used in the preparation of soil samples for laboratory testing. Basically the pressure slaking test consists of the same under-water pressure cooking, but an additional treatment of severe agitation in water is inserted between the cooking and the gradation change measurement. The agitation is accomplished using a standard laboratory heavy duty shaker (see Figure 4). Typical results of cooking and gradation are illustrated in Figure 5. One can observe in this figure the relative amounts of disintegration resulting from the test.

Results of the pressure slaking test and the Los Angeles abrasion test for the 24 aggregates produced by the Texas Transportation Institute, as well as the nine aggregates produced commercially, are given in Table 2 and plotted in Figure 6. From the figure it is clear

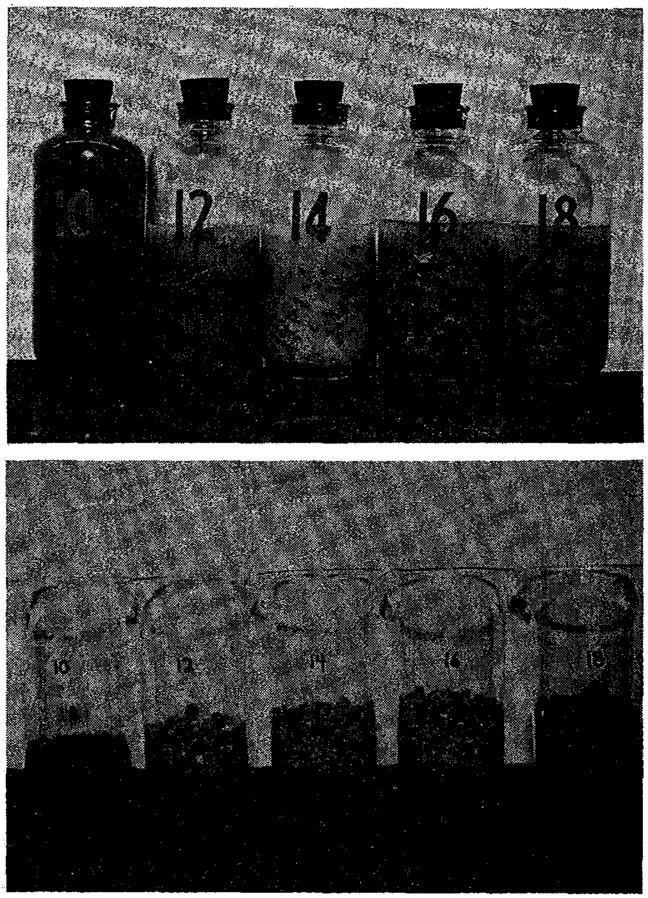

Figure 5. The top photograph shows complete samples immediately after cooking and subsequent agitation in water; the lower shows fraction retained on the No. 40 sieve. The numbers refer to the approximate firing temperature in hundreds of degrees, F.

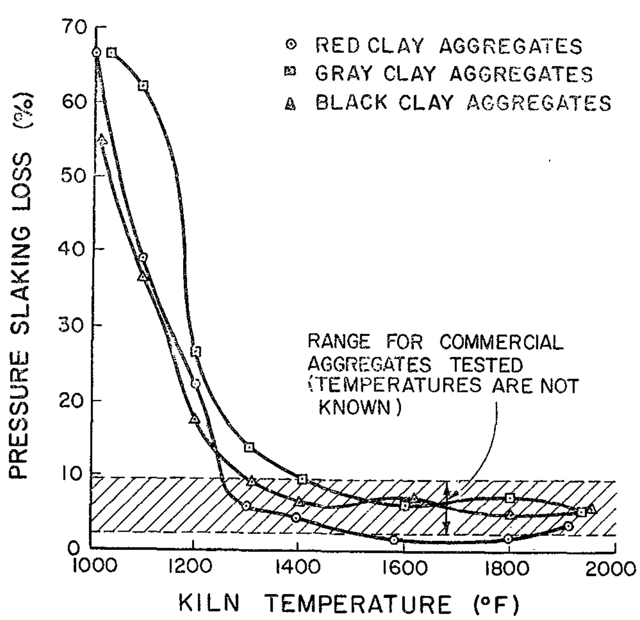

Figure 6. Pressure slaking loss versus maximum kiln temperature for research aggregates made from three clays.

TABLE 2. TEST RESULTS FOR RESEARCH AGGREGATES AND AGGREGATES PRODUCED IN COMMERCIAL KILNS

Aggregate Type	Sample Designation	Pressure Slaking (% Loss)	L. A. Abrasion (% Wear)
	RC-1000	66.6	64.2
	RC-1100	38.9	61.3
Red Clay	RC-1205	20.5	56.6
Nonbloated	RC-1295	6.2	50.2
Produced by TTI	RC-1390	4.5	42.8
	RC-1585	2.2	36.1
	RC-1800	2.5	36.8
	RC-1910	2.8	33.9
	GC-1030	66.4	62.2
	GC-1095	61.7	66.6
Gray Clay	GC-1200	25.6	55.2
Nonbloated	GC-1305	13.8	61.5
Produced by TTI	GC-1400	9.8	62.8
	GC-1600	6.1	49.4
	GC-1800	5.8	52.7
	GC-1930	4.0	39.6
	BC-1010	55.9	71.3
	BC-1100	37.4	67.0
Black Clay	BC-1205	16.8	64.9
Nonbloated	BC-1310	9.3	60.1
Produced by TTI	BC-1395	6.7	56.8
	BC-1610	6.5	51.7
	BC-1800	4.2	37.4
	BC-1940	4.2	37.0
	Hopkins	8.3	35.0
Nonbloated	Wharton	9.7	43.6
Produced Commercially	Madison 1	6.9	33.3
	Madison 2	7.7	38.3
	R	2.7	27.5
Bloated (Lt. Wt.)	S	4.9	22.5
Produced Commercially	C	5.7	40.4
	E	2.5	25.2
	D	5.0	23.1

Notes: The four-digit numbers shown in some sample designations refer to the maximum kiln temperature measured during sample production. Each pressure slaking loss value is the average of three tests performed in accordance with Appendix A. Each L. A. abrasion value is the result of a single test (ASTM C-131).

that the research aggregates made at about 1000°F would not be suitable for use in flexible base, while all those made at firing temperatures of 1400°F and higher compare favorably with the synthetic aggregates produced commercially.

4. *Evaluation of Field Samples*

During the period 1963-64 the Houston district of the Texas Highway Department constructed several projects, totaling about fifteen miles in length, utilizing synthetic aggregate flexible base. The base material consisted of a mixture of approximately seventy percent of aggregate produced from clay in a rotary kiln, and thirty percent field sand. The Wharton aggregate—shown in Table 2 for comparison with the research aggregates—was used in at least one of these projects. The field sand, taken from several sources, was required to have a liquid limit of less than 35 and a plasticity index of less than 10. In one of the projects, the base material was stabilized with lime. According to local engineers all of the projects are still in good shape. One short section has been reworked—necessitated by a bridge grade change—and the synthetic aggregate flexible base in this section was salvaged and reused.

In the summer of 1968, at six different locations several miles apart, sections of these synthetic aggregate flexible bases were sampled and field tested (see Figure 7). Samples from five of these locations were prepared for laboratory testing in accordance with standard Texas Highway Department testing procedures.

Figure 7. Synthetic flexible bases that had been in service for several years in the Houston area were sampled for laboratory testing.

As may be seen from the gradations given in Table 3, the amount of soil binder (fraction finer than No. 40 sieve) in the five samples prepared for laboratory testing varied from 22 to 34 percent and averaged 28 percent. When one considers that the kiln produced aggregates had from 2 to 5 percent soil binder, and that the construction specifications required that they be mixed with 30 percent of a field sand with 99 percent soil binder, it appears that there has been no significant disintegration of synthetic aggregates during the five to six years they have been in service.

The pressure slaking tests (Table 3) were made on aggregate samples separated from the base samples by washing over the No. 10 sieve. The loss values obtained varied from 8.3 to 15.5 percent and averaged 11.0 percent, as compared to a range of 6.9 to 9.7 percent and an average of 8.2 percent for the four commercial flexible base aggregates sampled from stockpiles (see Table 2). Thus, the material samples from the roadway had a somewhat greater range and a higher average loss than was the case for the materials sampled from stockpiles. According to the general trend shown in Figure 6, it appears that the synthetic aggregates taken from the roadway probably were produced at temperatures slightly lower than those taken from stockpiles.

In summary it can be said that all of the synthetic aggregate bases appear to have performed satisfactorily to date. The laboratory tests made on the samples that had been in service for several years indicate that these aggregates had not undergone any significant disintegration. Thus, it can be concluded—at least for the Houston, Texas environment—that synthetic aggregates suitable for use in flexible base can be produced by firing highly plastic clays. Such aggregates may or may not be suitable for use in more severe environments.

In the opinion of the author, ten percent loss determined by the pressure slaking test (Appendix A) is a safe and reasonable upper limit for an acceptance criterion for flexible base synthetic aggregates in Texas to insure that the aggregates have been fired sufficiently to remain stable in their intended use.

TABLE 3. TEST RESULTS OBTAINED ON SAMPLES OF SYNTHETIC AGGREGATE FLEXIBLE BASES TAKEN FROM HIGHWAYS NEAR HOUSTON, TEXAS

Section No.	Moisture Percent	Dry Density (pcf)	(Percent retained—sieve size) ¾ In.	No. 4	No. 10	No. 40	Pressure Slaking Test
2	13.5	111.2	0	29	50	66	12.6
7	15.8	105.9	1	32	60	78	10.0
8	15.9	90.6	0	28	54	71	8.7
9	15.8	90.8	2	34	58	73	15.5
14	15.7	111.4	1	24	49	72	8.3
15*	16.4	107.0					

*Base material was stabilized with lime and could not be tested.

5. Pressure Slaking Test (Mod. 1)

In order to utilize existing equipment in Texas Highway Department district laboratories, a modification of the pressure slaking procedure described in Appendix A was undertaken. The modified procedure is called the "Pressure Slaking Test (Mod. 1)," and is described in Appendix B. Basically it consists of the same procedure used in the pressure slaking test except that it employs a Tyler sieve shaker, shown in Figure 8, for accomplishing the agitation in water, instead of the heavy duty shaker (Figure 4). Comparative test results obtained using the two different procedures on the 24 aggregate samples produced by Texas Transportation Institute are given in Table 4. One can note from this data that results obtained using the modified test are always lower than those obtained using the original procedure.

Comparative analyses of variance for the data obtained from the two test procedures indicate that the repeatability of the two is about the same. A plot of comparative values is shown in Figure 9. From this it is clear that there is a strong correlation between the tests; thus, the two are essentially measuring the same property. Specifically, it can be said that the recommended acceptance criterion of ten percent loss based on the pressure slaking test is equivalent to a loss of four percent based on the modified test.

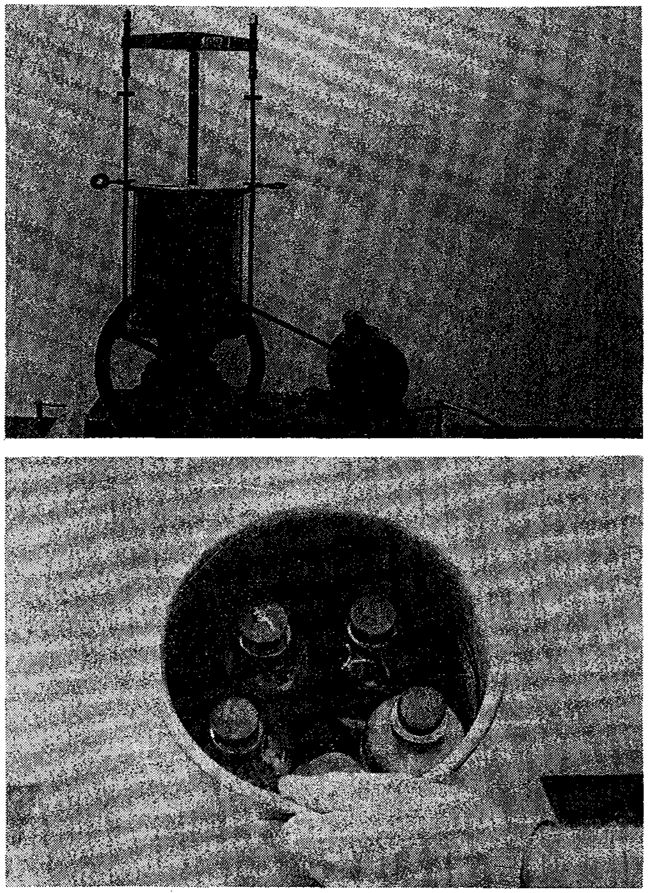

Figure 8. The Tyler sieve shaker (upper photograph) is used in the "Pressure Slaking Test (Mod. 1)" instead of the heavy duty shaker shown in Figure 4. Lower photograph shows container designed to fit shaker. Five samples can be agitated simultaneously.

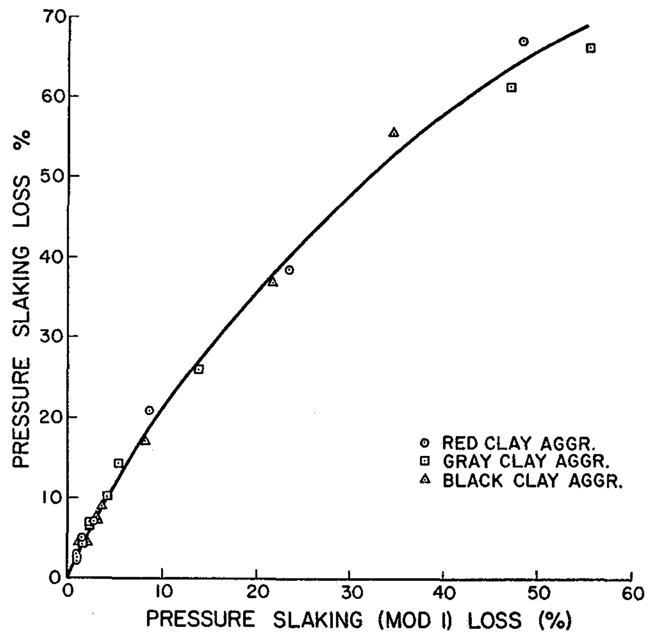

Figure 9. Comparison between original and modified pressure slaking test results.

TABLE 4. COMPARATIVE RESULTS, PRESSURE SLAKING TEST VERSUS PRESSURE SLAKING TEST (MOD. 1)

Aggregate Designation	Pressure Slaking—Percent Loss Test 1	Test 2	Test 3	Avg.	Pressure Slaking (Mod. 1)—Percent Loss Test 1	Test 2	Test 3	Avg.
RC-1000	60.3	60.4	79.0	66.6	53.6	47.3	43.3	48.1
RC-1100	37.4	33.2	46.0	38.9	21.9	26.7	23.1	23.7
RC-1205	22.9	18.7	20.0	20.5	9.4	7.6	9.8	8.9
RC-1295	5.9	5.6	7.0	6.2	2.1	2.2	2.5	2.3
RC-1390	4.0	4.4	5.0	4.5	1.5	1.6	1.3	1.5
RC-1585	1.8	1.9	3.0	2.2	1.3	1.0	0.8	1.0
RC-1800	2.4	2.1	3.0	2.5	1.2	0.8	1.0	1.0
RC-1910	2.3	2.1	4.0	2.8	0.9	1.2	0.6	0.9
GC-1030	66.6	65.5	67.2	66.4	54.3	60.3	52.6	55.7
GC-1095	62.7	60.7		61.7	51.6	46.0	44.6	47.4
GC-1200	27.5	26.2	23.1	25.6	13.0	12.8	14.1	13.3
GC-1305	12.7	14.9		13.8	5.8	4.8	5.6	5.4
GC-1400	10.2	9.2	10.0	9.8	3.9	3.7	4.5	4.0
GC-1600	6.9	5.5	6.0	6.1	1.9	1.9	2.5	2.1
GC-1800	6.4	5.1	6.0	5.8	2.0	2.1	2.1	2.1
GC-1930	4.0	3.1	5.0	4.0	1.9	1.4	1.0	1.4
BC-1010	51.6	52.2	64.0	55.9	35.2	36.1	32.4	34.6
BC-1100	36.0	36.3	40.0	37.4	23.9	22.7	19.5	22.0
BC-1205	17.4	16.1	17.0	16.8	7.0	7.4	9.0	7.8
BC-1310	8.9	10.0	9.0	9.3	4.1	3.6	3.2	3.6
BC-1395	6.5	7.0	6.5	6.7	2.2	2.2	2.8	2.4
BC-1610	6.1	6.4	7.0	6.5	2.5	2.7	2.6	2.6
BC-1800	3.3	4.3	5.0	4.2	1.4	1.6	1.8	1.6
BC-1940	4.1	4.6	4.0	4.2	0.9	1.1	1.4	1.1

Analysis of Variance:
Within sample std dev—3.1
Within sample CV—16.0%

Analysis of Variance:
Within sample std dev—1.8
Within sample CV—14.5%

6. Conclusions

Listed below are the findings reached as a result of the investigation described in this report:

1. Synthetic aggregates suitable for use in flexible base in Texas can be produced in rotary kilns from highly plastic clays. These aggregates may or may not be suitable for use in locations having more severe environment than Texas, e.g. locations subjected to deep frost penetration.

2. Incomplete dehydration of synthetic aggregates made by firing clays can be detected by two relatively simple tests. The procedures for these tests are given in Appendices A and B.

3. Test results and service records to date indicate that these aggregates have great potential for use in highway construction in the many areas of the world where high quality aggregates no longer exist, but where the clays required for the production of synthetic aggregates are plentiful.

7. Implementation Statement

Based on the results of this investigation, it is recommended that synthetic aggregates for use in Texas flexible bases have a loss measured by the pressure slaking test (Appendix A) of less than ten percent or a loss measured by the pressure slaking test (mod. 1) (Appendix B) of less than four percent.

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

8. References

1. Moore, W. M., Van Pelt, Richard, Scrivner, F. H. and Kunze, George W., "Suitability of Synthetic Aggregates made from Clay-type Soils for Use in Flexible Base," Research Report 81-5, Texas Transportation Institute, Texas A&M University, February, 1968.

2. Houston, James T. and Ledbetter, W. B., "Development of a Rotary Kiln for Synthetic Aggregate Research," Pit and Quarry, November, 1967, pp. 110-112.

3. Houston, James T. "Development of a Research Rotary Kiln and a Study of the Effects of Degree of Thermal Transformation on Selected Properties of Synthetic Aggregates," Ph.D. Dissertation, Texas A&M University, January, 1969.

4. Long, R. E., "A Summary of Base and Subgrade Testing for IH45," Unpublished Report, District Laboratory, District 17, The Texas Highway Department, Bryan, Texas, 1963.

Appendix A

PRESSURE SLAKING TEST

Scope. The test method described here is intended to be used to evaluate the amount of dehydration that has occurred in the production of synthetic aggregates fired in a rotary kiln. This procedure is a modification of the procedure previously reported in Reference 1.

Apparatus. The apparatus shall consist of the following:

(a) Pressure Cooker (common kitchen-type with 6 quart capacity with 15 psi pressure regulator).

(b) Centrifuge Bottles—500 ml. Pyrex.

(c) Balance—A balance with 3000 gm. capacity having a sensitivity of 0.1 gm.

(d) Heavy Duty Reciprocating Laboratory Shaker (Precision Scientific Cat. No. 5855 or equivalent).

(e) Sieves (¾", No. 10 and No. 40 sieves which meet the requirements of ASTM Designation E-11 Specification).

(f) Drying Oven—An oven capable of heating to 105°C (220°F).

Sample. An unwashed representative sample of sufficient volume to one half fill the centrifuge bottle should be chosen. The sample material is that which passes a ¾ in. sieve and is caught on a No. 10 sieve. Any material retained on the ¾ in. sieve should be crushed to pass this sieve using a minimum amount of crushing. Since synthetic aggregates vary widely as to specific gravity, a volumetric measure of the sample is used rather than weight.

Procedure.

1. Place the sample into the centrifuge bottle, and add 200 ml. of distilled water. It is not necessary to determine the initial weight of the sample. (Repeat for any number of samples up to as many as can be conveniently placed in the pressure cooker.)

2. Place the centrifuge bottles containing the aggregates into the pressure cooker, adding approximately ½ in. of distilled water to the pressure cooker and seal the lid tightly.

3. Heat the pressure cooker with a large Bunsen burner until full pressure is indicated by the pressure regulator.

4. Adjust the flame to allow only a slight escape of steam and maintain pressure for 15 minutes. Remove the Bunsen burner, release the pressure, and remove the centrifuge bottles.

5. After cooling to approximately 100°F, place corks in the centrifuge bottles and place the bottles in the laboratory shaker. Shake the aggregates for 15 minutes.

6. Upon removing the bottles from the shaker, wash the sample over a No. 40 sieve, taking care not to lose any of either −40 or +40 material.

7. Dry both −40 and +40 material to a constant weight at 105°C (220°F). Due to rehydration, the final total weight of the sample may be greater than the initial weight.

Calculations.

The pressure slaking loss is expressed as the percent passing the No. 40 sieve and is calculated by the following equation:

$$\text{Percent Loss} = \frac{\text{Weight of minus 40 mesh material}}{\text{Total weight of material}} \times 100.$$

Appendix B

PRESSURE SLAKING TEST (MOD. 1)

Scope. This procedure is a modification of the pressure slaking test procedure given in Appendix A. The modification was made to better utilize existing equipment in the Texas Highway Department district laboratories.

Apparatus. The apparatus shall consist of the following:

(a) Pressure Cooker (common kitchen-type with 6 quart capacity with 15 psi pressure regulator).

(b) Centrifuge Bottles—500 ml. Pyrex.

(c) Tyler Sieve Shaker (Soiltest Model No. C1-305A or equivalent, cpm = 285 ±10, throw = 1¾ ± ¼ in.).

(d) Balance—A balance with 3000 gm. capacity having a sensitivity of 0.1 gm.

(e) Stainless Steel Bucket (fits Tyler sieve shaker)—Bain Marie pot with cover and beaker without pourout (8 ¼ quart, 8" body dia., 9¾" depth, 8¾" over bead dia.). Available from Texas Highway Department D-4 stock.

(f) Spacer (7¾" dia. × 2" thick), rubber cushion (7¾" dia. × ⅛" thick) and miscellaneous rubber sheeting or rags.

(g) Sieves (¾", No. 10 and No. 40 sieves which meet the requirements of ASTM Designation E-11 Specification).

(h) Drying Oven—An oven capable of heating to 105°C (220°F).

Sample. An unwashed representative sample of sufficient volume to one half fill the centrifuge bottle should be chosen. The sample material is that which passes a ¾ in. sieve and is caught on a No. 10 sieve. Any material retained on the ¾ in. sieve should be crushed to pass this sieve using a minimum amount of crushing. Since synthetic aggregates vary widely as to specific gravity, a volumetric measure of the sample is used rather than weight.

Procedure.

1. Place the sample into the centrifuge bottle, and add 200 ml. of distilled water. It is not necessary to determine the initial weight of the sample. (Repeat for any number of samples up to as many as can be conveniently placed in the pressure cooker.)

2. Place the centrifuge bottles containing the aggregates into the pressure cooker, adding approximately ½ in. of distilled water to the pressure cooker and seal the lid tightly.

3. Heat the pressure cooker with a large Bunsen burner until full pressure is indicated by the pressure regulator.

4. Adjust flame to allow only a slight escape of steam and maintain pressure for 15 minutes. Remove the Bunsen burner, release the pressure, and remove the centrifuge bottles.

5. After cooling to approximately 100°F, place corks in the centrifuge bottles and place the bottles vertically in the stainless steel bucket. (The rubber cushion should be placed beneath the bottles and the rubber sheeting or rags inserted between the bottles to press them firmly against the side of the bucket.)

6. Place the spacer over the rubber corks in the bottles and fasten the cover to press the bottles against the bottom of the bucket.

7. Lock the stainless steel bucket in the Tyler sieve shaker and shake the aggregates for 15 minutes.

8. Upon removing the bottles from the shaker, wash the sample over a No. 40 sieve, taking care not to lose any of either −40 or +40 material.

9. Dry both −40 and +40 material to a constant weight at 105°C (220°F). Due to rehydration, the final total weight of the sample may be greater than the initial weight.

Calculations.

The pressure slaking (Mod. 1) loss is expressed as the percent passing the No. 40 sieve and is calculated by the following equation:

$$\text{Percent Loss} = \frac{\text{Weight of minus 40 mesh material}}{\text{Total weight of material}} \times 100.$$