UNIAXIAL STRAIN RESPONSE OF A SAWDUST-SAND MIXTURE

Benjamin F. Wright, et al

Army Engineer Waterways Experiment Station
Vicksburg, Mississippi

June 1973

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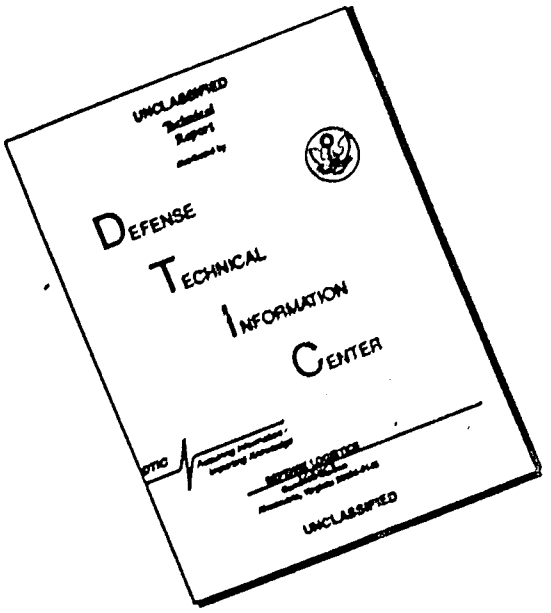

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UNIAXIAL STRAIN RESPONSE OF A SAWDUST-SAND MIXTURE

by

B. F. Wright, J. Q. Ehrgott

June 1973

Sponsored by Defense Nuclear Agency
Subtask SB209, Work Unit 06, "Experimental Studies of the Response of Soil and Rock to Ground Shock"

Conducted by U. S. Army Engineer Waterways Experiment Station
Soils and Pavements Laboratory
Vicksburg, Mississippi

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ABSTRACT

This report documents the results of a series of static and dynamic uniaxial strain tests conducted on a sawdust-sand mixture developed by Gulf Radiation Technology (GRT). The mixture was developed by GRT in an attempt to determine the response of tuff at extremely high stress levels (megabar range) by laboratory testing a material at a low-pressure range (0 to 70 bars). The purpose of the tests documented in this report was to determine the uniaxial strain loading and unloading response over the 0- to 70-bar stress range.

PREFACE

The material property investigation described in this report was performed for the Defense Nuclear Agency (DNA) as part of Subtask SB209, "Propagation of Ground Shock Through Earth Media." The sawdust-sand mixture used for the testing program was furnished to WES by Dr. Howard Kratz of Gulf Radiation Technology (GRT); Dr. Kratz also provided helpful comments and advice during the course of the study.

The investigation was conducted during the period April through October 1971 by personnel of the Soils and Pavements Laboratory (S&PL), U. S. Army Engineer Waterways Experiment Station (WES). Mr. B. F. Wright, Soil Dynamics Division (SDD), S&PL, performed the laboratory tests under the direction of Mr. J. Q. Ehrgott, SDD. Messrs. Wright and Ehrgott prepared this report.

The work was accomplished under the general supervision of Dr. J. G. Jackson, Jr., and J. P. Sale, Chiefs of SDD and S&PL, respectively.

Director of the WES was COL Ernest D. Peixotto, CE; Technical Director was Mr. F. R. Brown.

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CHAPTER 1

INTRODUCTION

The Defense Nuclear Agency (DNA) requested that the U. S. Army Engineer Waterways Experiment Station (WES) determine the uniaxial strain response of a special sawdust-sand mixture developed by Gulf Radiation Technology (GRT). This mixture had been developed at GRT under a DNA contract in an attempt to model the response of tuff at extremely high stress levels (megabar range) in laboratory tests at a low-pressure range (0 to 70 bars).

1.1 PURPOSE

The purpose of the WES study was to conduct controlled laboratory tests on the sawdust-sand mixture to determine its uniaxial strain loading and unloading response over the 0- to 70-bar stress range.

1.2 SCOPE

This report documents the results of 16 uniaxial strain tests conducted on two batches of the sawdust-sand mixture. The test series included six static tests (2 minutes to peak stress) and ten dynamic tests (50 msec to peak stress). In addition, several additional static tests were conducted on material in which the mixture proportions were parametrically varied.

CHAPTER 2

MATERIAL DESCRIPTION

The material, as described by GRT, is composed of redwood sawdust and plaster sand combined at a weight ratio of 354.4 grams of slightly moist sawdust to 1,460 grams of slightly moist plaster sand. When properly mixed, the material can be placed into a container and lightly pressed down by hand until a slight but definite resistance to further movement is detected. At that point, according to information furnished to WES by GRT, the density should be 0.8 gm/cm^3, which is the desired initial test condition.

2.1 DESCRIPTION OF FIRST BATCH

WES received four bags of the material, each bag containing approximately 1.8 kg of premixed material. Water content measurements of the material were taken as the bags were opened and the average water content (w) of the mixture was 1.9 percent. Although the contents of each bag were thoroughly mixed and portions of the mixture were carefully placed into the uniaxial strain device soil container according to the directions furnished by GRT, the minimum density attainable was 0.85 gm/cm^3. It was observed, however, that by removing small quantities of sand the density could be varied. Densities as low as 0.69 gm/cm^3 were attained by the removal of approximately 30 grams of sand (out of a total specimen weight of 260 grams). The sawdust-sand weight ratio for this material was not determined, since there was no apparent means of completely separating the premixed material.

2.2 DESCRIPTION OF SECOND BATCH

GRT was contacted and advised of the difficulty in remolding the premixed material to the 0.8 gm/cm^3 density. It was decided that GRT would send WES separate bags of the sawdust and of the sand in preweighed proportions. WES received eight bags, four of sawdust and four of sand, which were then mixed into four separate portions. Water content measurements of the mixed portions were taken immediately, and the

water content of the mixture was 3.2 percent. It was found that densities of 0.8 gm/cm^3 were easily obtained using placement procedures previously recommended by GRT.

2.3 COMPOSITION OF MIXTURE

The specimens molded from the mixture to a density of 0.8 gm/cm^3 were combinations of solids, air, and water. Four assumptions had to be made in order to determine the percent by volume that each component occupied in the mixture. Specific volumes of air voids have been found to correlate well with certain aspects of UX stress-strain curves for sands. Hence, it was desirable to determine if similar correlations existed for this mixture. To do this, the volume of air voids had to be obtained. This was done as follows:

1. First it was assumed that all the water present in the mixture was in or on the sawdust particles.

2. Then the actual proportion, by volume, of sawdust in the mixture could be calculated by assuming the sawdust consisted of solid particles having a specific gravity (grain density) equal to the dry bulk density of wood, which is the weight of a dry wood chip divided by the total volume of the dry chip.

3. Next it was assumed that the actual percentages of solid wood, air, and water in a sawdust chip could be calculated separately and then proportioned to the percentage of sawdust in the total mixture.

4. The last assumption made was that handbook values of specific gravity and bulk density for wood of 1.56 and 0.42 gm/cm^3, respectively, also apply to redwood sawdust. The specific gravity of sand is taken to be 2.65 gm/cm^3.

First, considering only the sawdust, if the average water content of the mixture is 3.2 percent, then based on the actual weight proportions of the mixture and the assumption that all water is contained in the sawdust, the water content of the sawdust is 20 percent. Using the dry bulk density of a sawdust chip as the specific gravity of wood of 1.56 gm/cm^3 and the water content of 20 percent, then the calculated

percentage volumes of solids (V_s), water (V_w), and air (V_a) in the sawdust are:

$$V_s = 26.9\%$$
$$V_w = 8.4\%$$
$$V_a = 64.7\%$$

Next, using a weight ratio of 1 to 5.4, a dry density of 0.8 gm/cm^3, a specific gravity of 2.65 gm/cm^3 for the sand, a specific gravity of 0.42 gm/cm^3 for the "solid" sawdust chip, and a water content of 0 percent, the volumes of sawdust particles (V_{sd}), sand particles (V_s), and air (V_a) are:

$$V_{sd} = 29.8\%$$
$$V_s = 25.5\%$$
$$V_a = 44.7\%$$

But based on the assumptions above, the sawdust is composed, by volume, of 26.9 percent wood, 8.4 percent water, and 64.7 percent air; therefore, based on the same assumptions, the total mixture is actually composed of the following:

sand volume = 25.5%
wood volume = 8.0%
water volume = 2.5%
air volume = 64.0%

Because of the necessity of using the four assumptions to obtain these percentages, they represent approximate volumes. Nevertheless, they do indicate that there is a relatively large volume of air in the mixture. The mixture could undergo about 64 percent volumetric strain before all the air voids in the mixture are closed. The compressed density, or locked density, at 64 percent volumetric strain would be approximately 2.22 gm/cm^3, representing a density increase of approximately 2.7 times the initial density of 0.8 gm/cm^3.

CHAPTER 3

RESPONSE OF MATERIAL AT INITIAL DENSITY

3.1 TEST PROCEDURE

The uniaxial strain tests documented in this report were conducted in the WES 12.5-cm-diameter, dynamic uniaxial strain test device, which operates in conjunction with a 267-kilonewton-capacity dynamic ram loader (Dynapak). Load from the ram loader is applied to the test device through a piston assembly, which loads a fluid over the top of a specimen. In turn, the fluid transmits a uniform pressure to the top surface of the specimen. Transducers mounted in the test device monitor both axial stress and specimen top surface deflection continuously throughout the test. The specimen is restrained from radial expansion by a rigid steel boundary in the soil container. The uniaxial strain device soil specimen container used for these tests was 2.54 cm high and 12.7 cm in diameter. The specimen volume was approximately 321 cm^3.

The material, which was received from GRT in separate preweighed proportions, was thoroughly mixed. A portion was removed, weighed, and then carefully placed in the soil container. The material was pressed lightly until it offered some resistance to further compaction. A sharp straightedge was then used to level the top surface, and care was taken not to further disturb the specimen. The excess material was weighed, and density for the in-place specimen was then computed. Water content measurements were also made from the excess material.

The mixture had a tendency to segregate during placement, and several preliminary tests were conducted in order to improve placement techniques. Also, the specimen settled somewhat during the assembly procedure. The probable cause of this settlement is explained as follows. A disk attached to a rubber membrane that separates the fluid chamber from the specimen container is used to measure specimen deflection on the top surface of the specimen. It is, therefore, necessary for the disk to be properly seated on the specimen at the beginning of the test. The procedure used to insure seating of the footing was to

apply a slight vacuum through the soil container and partially evacuate air that was trapped under the membrane. It was during the evacuation procedure that the specimen settled. This settlement was monitored, treated as an increase in initial test density, and is reflected in the data presented. However, one static test was conducted in which the evacuation procedure was not used to provide a check on the test results obtained from specimens that were evacuated. No differences were observed that were greater than the data scatter in the tests started from the partially evacuated condition.

3.2 TEST PROGRAM

Five tests, two static and three dynamic, were conducted on the second batch of material received from GRT. The test specimens prepared from that batch were placed into the soil container at an average density of 0.8 gm/cm^3. As mentioned previously, settlement of the specimens was noted during the assembly procedure due to the evacuation technique used. Therefore, the actual average initial test density was 0.84 gm/cm^3. However, one of the static tests, GRT-16, was conducted without evacuating the air trapped under the membrane and its initial density was 0.81 gm/cm^3. The initial density, specimen settlement during chamber evacuation, test density, water content, and dry density for each of the five tests are listed in Table 3.1.

3.3 STATIC TEST RESULTS

Two static tests (2 minutes to peak stress) were conducted, and the test results are shown in Figure 3.1 as a plot of axial stress versus axial strain. Both specimens were loaded to approximately 56 bars and then unloaded. The results indicate that the stiffness of the material increases with increasing stress, i.e., there is a continuing stiffening up to an axial stress of 56 bars. The unloading response of the material appears to be extremely stiff when compared with the loading response. At very low pressures during the unloading, the test data indicate significant strain recovery of the material. It should be noted that the rubber membrane over the specimen was stretched due to

the great amount of deformation and it is likely that during unloading at low pressures the membrane could lift off the specimen surface. Since the axial deflection measurement system is attached through the membrane, the data could be in error in a direction that would indicate more recovery than that which actually occurred in the material.

The two statically tested specimens (Figure 3.1) had slightly different densities. However, the denser specimen, GRT-12, compressed more during loading than the lower density specimen, GRT-16. It is thought that some small specimen preparation variation occurred and that the results of the two tests can be averaged to produce a typical response for comparative purposes. The dashed curve shown in Figure 3.1 is such an average.

3.4 DYNAMIC TEST RESULTS

Figure 3.2 is a comparative plot of the results of the three dynamic tests. In addition to axial stress-axial strain curves for these tests, applied axial stress versus time curves are also shown. The densities of these specimens (GRT-13, -14, and -15) varied from 0.83 to 0.85 gm/cm^3. Results of two of the tests, GRT-14 and -15, generally agree, but Specimen GRT-13 appeared stiffer than the other two, i.e., it had less strain at any given stress. The time to peak stress for Tests GRT-14 and -15 was approximately 50 msec. Test GRT-13 had a faster loading rate time to peak stress (10 msec) and a hold time of 60 msec.

Using an axial stress of 34.5 bars as a reference, Specimen GRT-13 has an indicated axial strain of 23.6 percent, while Specimens GRT-14 and -15 indicate axial strains of 28.4 and 29.1 percent, respectively, at the same axial stress level. Since Specimen GRT-15 had approximately the same time to reach the reference stress level as did Specimen GRT-13, it is not believed that loading rate could explain the different results for Tests GRT-13, -14, and -15. The difference may have been caused by placement and/or some possible difference in the gradation of the sand particles of Specimen GRT-13. Another possible explanation is that the sawdust in Specimen GRT-13 might have been taken from previously tested material rather than from the fresh batch and, therefore,

may have been previously compressed. Variations in sawdust, such as being previously loaded and compressed, might cause a mixture containing such sawdust to compress less than a mixture containing fresh or undisturbed sawdust. It is not believed that Specimen GRT-13 was truly representative of the material at this density. Therefore, test results for this specimen were not used in the computation of the average curve, which is shown in Figure 3.2 as a dashed curve. Test GRT-15 was conducted to a higher axial stress level in an attempt to see if the response characteristics of the material differed at higher stress levels. The results indicate a continuously stiffening curve up to the 97-bar maximum stress level achieved. The unloading characteristics remain basically the same as those observed at lower stress levels.

3.5 COMPARISON OF STATIC AND DYNAMIC TEST RESULTS

The two average curves of axial stress versus axial strain from the static and dynamic tests are shown in Figure 3.3. The results indicate that the material tends to be somewhat sensitive to loading rate at an average density of 0.83 gm/cm^3. Figure 3.3 indicates a dynamic to static axial stress ratio of 1.34 at 8 percent axial strain and 1.4 at 16 percent axial strain. At higher strain levels, the ratio is approximately 1.2. The unloading moduli do not appear to be influenced by any loading rate effects.

TABLE 3.1 COMPOSITION PROPERTIES OF THE MIXTURE TESTED AT 0.8 gm/cm^3

Test Number	Type Test	Initial Density	Volumetric Strain Due to Specimen Settlement	Calculated Test Density	Water Content	Dry Density
		gm/cm^3	percent	gm/cm^3	percent	gm/cm^3
GRT-12	Static	0.80	5	0.84	3.8	0.81
GRT-13	Dynamic	0.80	5	0.84	2.8	0.82
GRT-14	Dynamic	0.80	5.1	0.85	2.4	0.83
GRT-15	Dynamic	0.79	5.4	0.83	3.9	0.80
GRT-16	Static	0.81	0	0.81	3.2	0.78

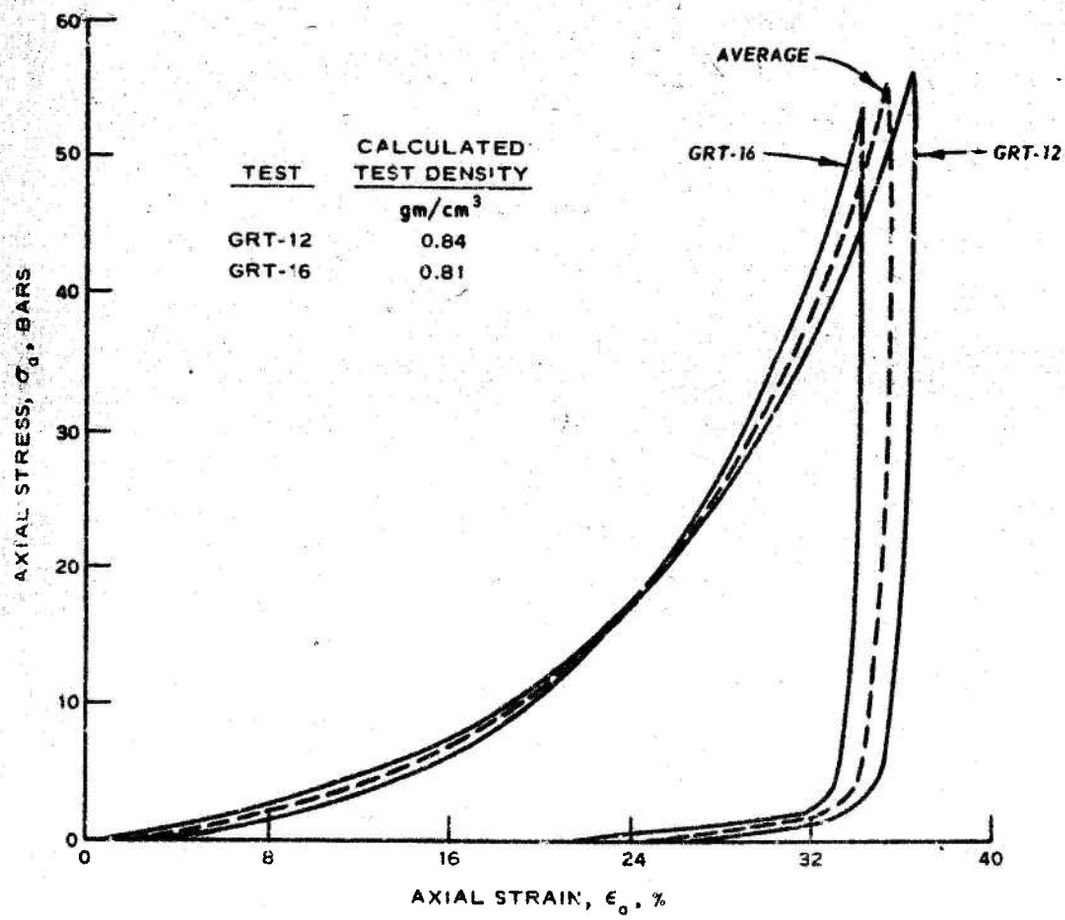

Figure 3.1 Static uniaxial strain test results (second batch materials).

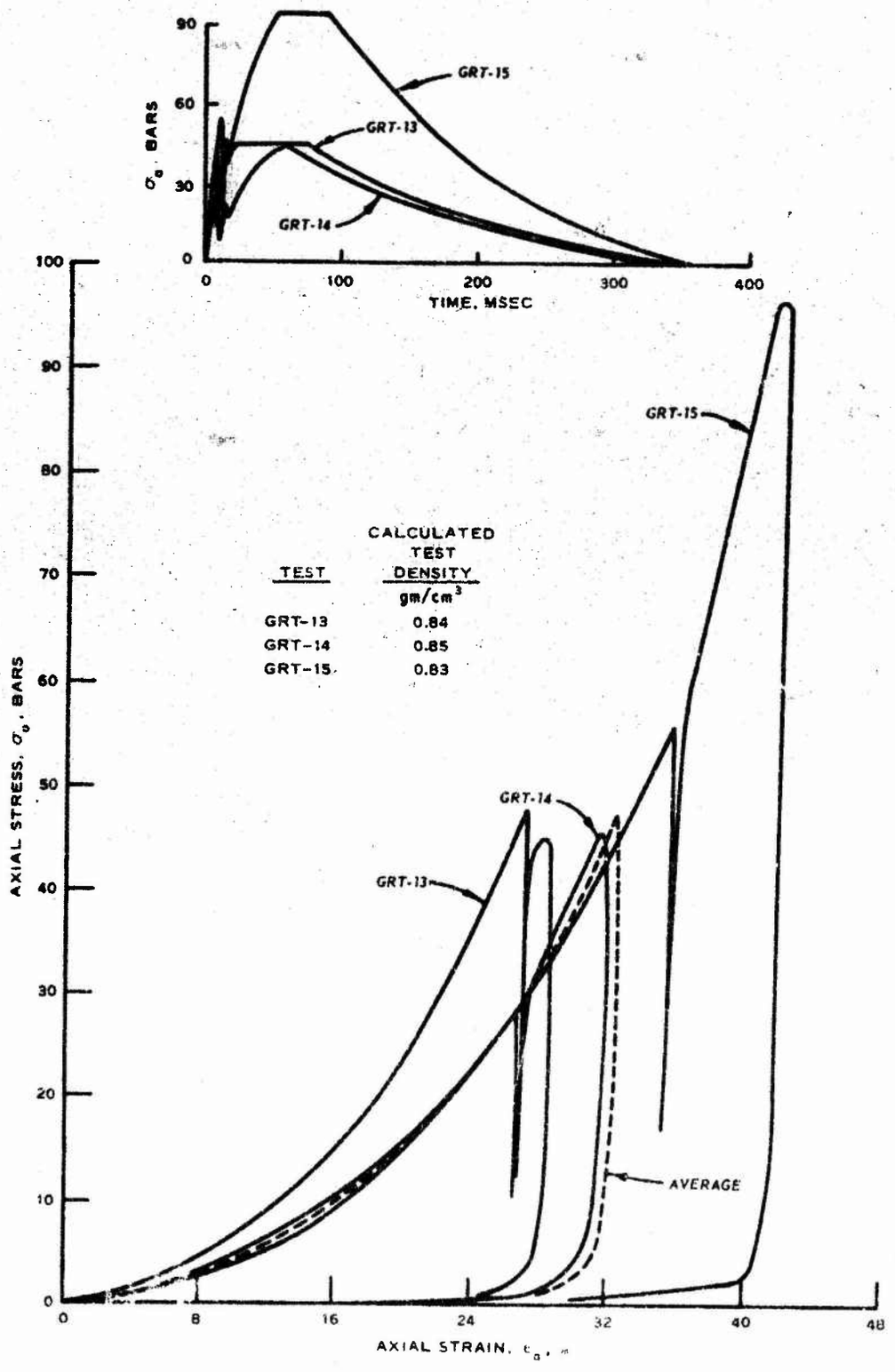

Figure 3.2 Dynamic uniaxial strain test results (second batch materials).

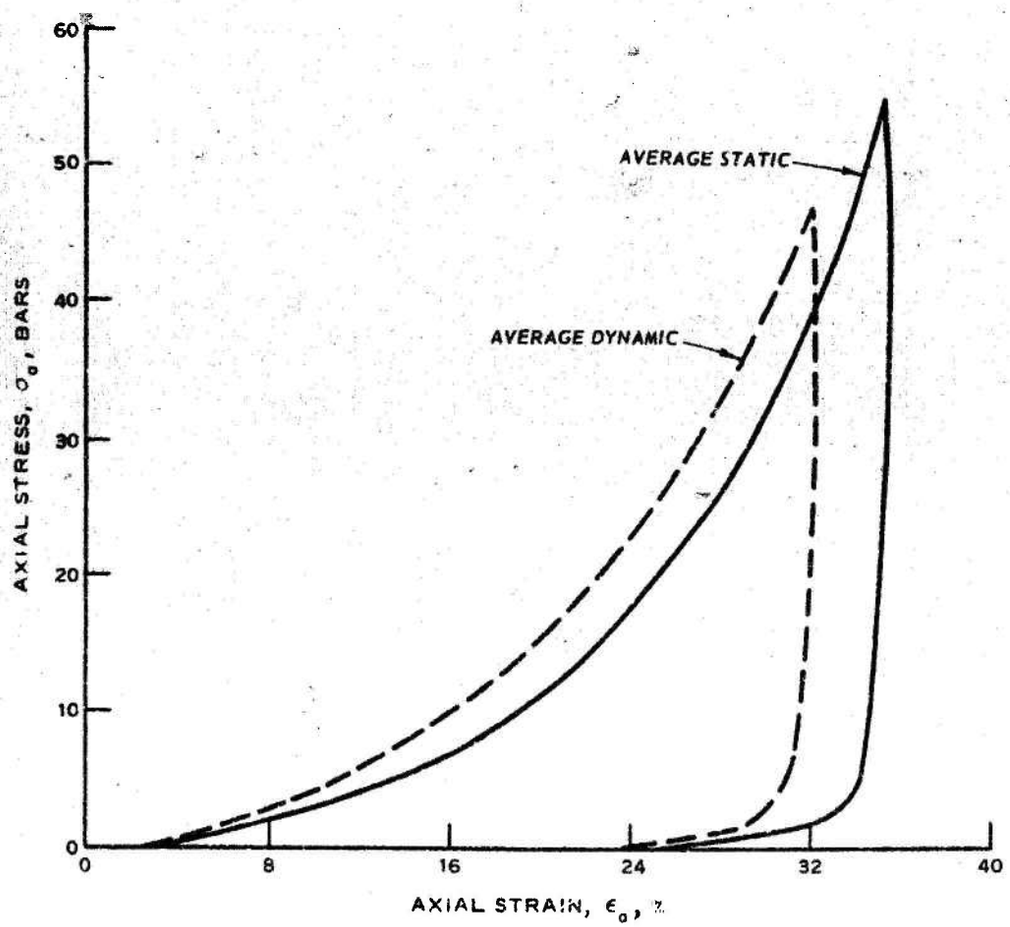

Figure 3.3 Comparison of average static and dynamic uniaxial strain test results.

CHAPTER 4

EFFECT OF VARIATION IN MIX PROPORTIONS

As might be expected, the material segregated readily during handling and placement. When the desired mixed quantity was poured into a container, the sand would generally separate from the sawdust, resulting in an apparent low mixture density at the top of the container (due to less sand) and a higher mixture density at the bottom (due to the additional sand). It was therefore believed that additional tests should be conducted on the material with slight variations in mix proportions to establish some bounds on the response characteristics.

4.1 TEST PROGRAM

The first batch of material received by WES was used for this study. A bag of the material was thoroughly mixed and separated into several portions. The portions were then thoroughly mixed prior to placement in the soil container. The placement of the material and assembly of the uniaxial test device have been described in Chapter 3. The compaction effort was held constant and density was varied by adding or removing only a slight amount of sand. The maximum amount removed was approximately 30 grams.

Eleven uniaxial strain tests were conducted on the material, with initial test densities ranging from 0.64 to 0.90 gm/cm^3. The tests consisted of four static tests (2 minutes to peak stress) and seven dynamic tests (50 msec to peak stress). Table 4.1 presents a list of all the tests and the densities obtained for each test.

Since the weight of sawdust was held constant and the amount of sand was varied, the percent by volume of the various components also varied and could also be calculated as was done in Chapter 2. For densities of 0.7 and 0.9 gm/cm^3, the volumes of sand, wood, water, and air were:

Component	Volume for 0.7-gm/cm^3 mixture	Volume for 0.9-gm/cm^3 mixture
	pct	pct
Sand	21.7	29.3
Wood	8.0	8.0
Water	2.5	2.5
Air	67.8	60.2

If, however, the weight proportions had been held as specified by GRT for the given densities, the volumes would have been:

Component	Volume for 0.7-gm/cm^3 mixture	Volume for 0.9-gm/cm^3 mixture
	pct	pct
Sand	22.3	28.7
Wood	7.0	9.0
Water	2.2	2.8
Air	68.5	59.5

As can be seen from the tabulations above, slight differences in the volume percentages result from alteration of the mix proportions.

4.2 STATIC TEST RESULTS

Figure 4.1 shows a comparison of the results of the four static uniaxial strain tests. The membrane in the uniaxial test device broke during the loading portion of Test GRT-1, and the test was terminated at that point. Test GRT-2 was conducted on a specimen of approximately the same density as Specimen GRT-1 in an attempt to substantiate the results of the loading portion of GRT-1 and also to check the unloading characteristics at this density. This was accomplished by adding a small quantity of sand to an "as is" portion of the premixed material. There was good agreement between the results of the two tests.

Using an axial stress of 34.5 bars as a reference, the results indicate axial strains of 24.1 and 24.2 percent for Tests GRT-1 and -2, respectively. Both tests had a calculated test density of 0.92 gm/cm^3. Using an axial stress of 34.5 bars as a reference, these tests indicate approximately 22 percent less strain than that of the average static curve for tests on samples with densities of 0.81 and 0.84 gm/cm^3 (shown in Figure 3.1).

Test GRT-9 was conducted to investigate the response of the material at the estimated lower bound of variation in mix proportions. This was accomplished by the random removal of a slight amount of sand from an "as received" portion. Specimen GRT-9 had a calculated test density of 0.76 gm/cm^3. At an axial stress reference of 34.5 bars, axial strain of 33.1 percent was recorded. Using the average curve from Figure 3.1 and the same stress reference, results of Test GRT-9 indicate approximately 7 percent greater strain than that of the average curve.

Test GRT-10 was conducted using a portion of the premixed material "as received" from GRT, and the results indicate an axial strain of 29.2 percent for a stress of 34.5 bars. Using the average curve from Figure 3.1 again, Test GRT-10 has approximately 6 percent less strain. Specimen GRT-10 had a calculated test density of 0.91 gm/cm^3.

4.3 DYNAMIC TEST RESULTS

Figure 4.2 is a comparative plot of stress-strain curves for the seven dynamic uniaxial strain tests showing the effect of variations in mix proportions. The average rise time to peak stress for these tests was 50 msec. Specimen GRT-3 had a calculated test density of 0.89 gm/cm^3 and an axial strain of 27.6 percent at an axial stress of 34.5 bars. Specimen GRT-4 had a calculated density of 0.92 gm/cm^3 and an axial strain of 24.3 percent at a stress of 34.5 bars. Specimen GRT-6 had a calculated density of 0.69 gm/cm^3 and an axial strain of 30.6 percent at the 39.5-bar stress level. Specimen GRT-7 had a calculated density of 0.70 gm/cm^3 and an axial strain of 34.1 percent. Specimen GRT-8 had a calculated density of 0.77 gm/cm^3 and an axial strain of 28 percent. Specimen GRT-11 had a calculated density of 0.91 gm/cm^3 and

an axial strain of 25.5 percent at the 34.5-bar axial stress level.

4.4 COMPARISON OF STATIC AND DYNAMIC TEST RESULTS

A comparison was made of the results of the static and dynamic tests to determine if the same rate effects existed as in the first test series. Figure 4.3 is a plot of the results of dynamic Test GRT-8 and static Test GRT-9, which were conducted on specimens of approximately the same initial density (0.76 gm/cm^3). The comparison plot indicates a dynamic to static stress ratio as high as 1.6. Figure 4.4 presents a comparison of the results of the static and dynamic tests conducted on the specimens that all had an approximate density of 0.91 gm/cm^3. Tests GRT-4 and GRT-11 were dynamic, and Tests GRT-2 and GRT-10 were static. Results of the two dynamic tests agree favorably with each other, but those for the two static tests are considerably different. It is believed that a positive conclusion regarding the rate effects on these specimens cannot be made with the available data.

4.5 COMPARISON WITH THE RESULTS OF THE FIRST TEST SERIES

The results of both the static and dynamic tests tend to suggest the same general trend as was observed with the first test series; the stress-strain curve for the material stiffened as axial stress increased. The unloading characteristics were approximately the same for all densities. In each case, a very stiff unloading curve was observed, with the greatest portion of the strain recovery occurring at low stresses. The effect of increasing the percentage of sawdust in the mixture was to increase the amount of strain during loading at the stress levels studied. The effect of more sand in the mixture was to decrease the amount of strain. There was some scatter in all the test results, but scatter was more prevalent in the tests on the specimens with variations in mix proportions. It should be noted, however, that the test results from the second series (in which mix proportions were varied) indicate trends only and were never intended to be quantitive results since the mix proportions were varied from those specified by GRT.

Since for each test the change in specimen height was measured, it

was possible to calculate specimen density at each increment of applied stress. Figures 4.5 and 4.6 show the results of each test plotted as axial stress versus density. Based on the previously presented calculation of percent air volume, the lowest densities at which the air could be totally compressed would be as follows:

Density	
Initial	Minimum Locked
gm/cm^3	gm/cm^3
0.7	2.17
0.8	2.22
0.9	2.26

The results in Figures 4.5 and 4.6 tend to indicate that relatively high stress levels (i.e. >140 bars) would be required to obtain the calculated locked densities. However, the slopes of the curves do, in general, show little effect of initial test density at the stress levels investigated. This is reasonable considering the great amount of density change required to cause lockup. Also, if the sawdust in some of the mixtures had been previously compressed, the air content would also have been less, resulting in a lower lockup density than that calculated.

TABLE 4.1 COMPOSITION PROPERTIES OF THE MIXTURE TESTED AT VARIOUS DENSITIES

Test Number	Type Test	Initial Density	Volumetric Strain Due to Specimen Settlement	Calculated Test Density	Water Content	Dry Density
		gm/cm^3	percent	gm/cm^3	percent	gm/cm^3
GRT-1	Static	0.89	3	0.92	1.8	0.90
GRT-2	Static	0.90	3	0.92	1.7	0.91
GRT-3	Dynamic	0.85	4	0.89	1.7	0.87
GRT-4	Dynamic	0.88	3.5	0.92	1.7	0.90
GRT-5	Dynamic	0.90	3	0.93	2.1	0.91
GRT-6	Dynamic	0.64	6.5	0.69	2.8	0.67
GRT-7	Dynamic	0.65	6.3	0.70	2.8	0.68
GRT-8	Dynamic	0.73	5.6	0.77	1.5	0.76
GRT-9	Static	0.71	6	0.76	1.3	0.75
GRT-10	Static	0.88	3.5	0.91	1.9	0.89
GRT-11	Dynamic	0.88	3.5	0.91	1.9	0.89

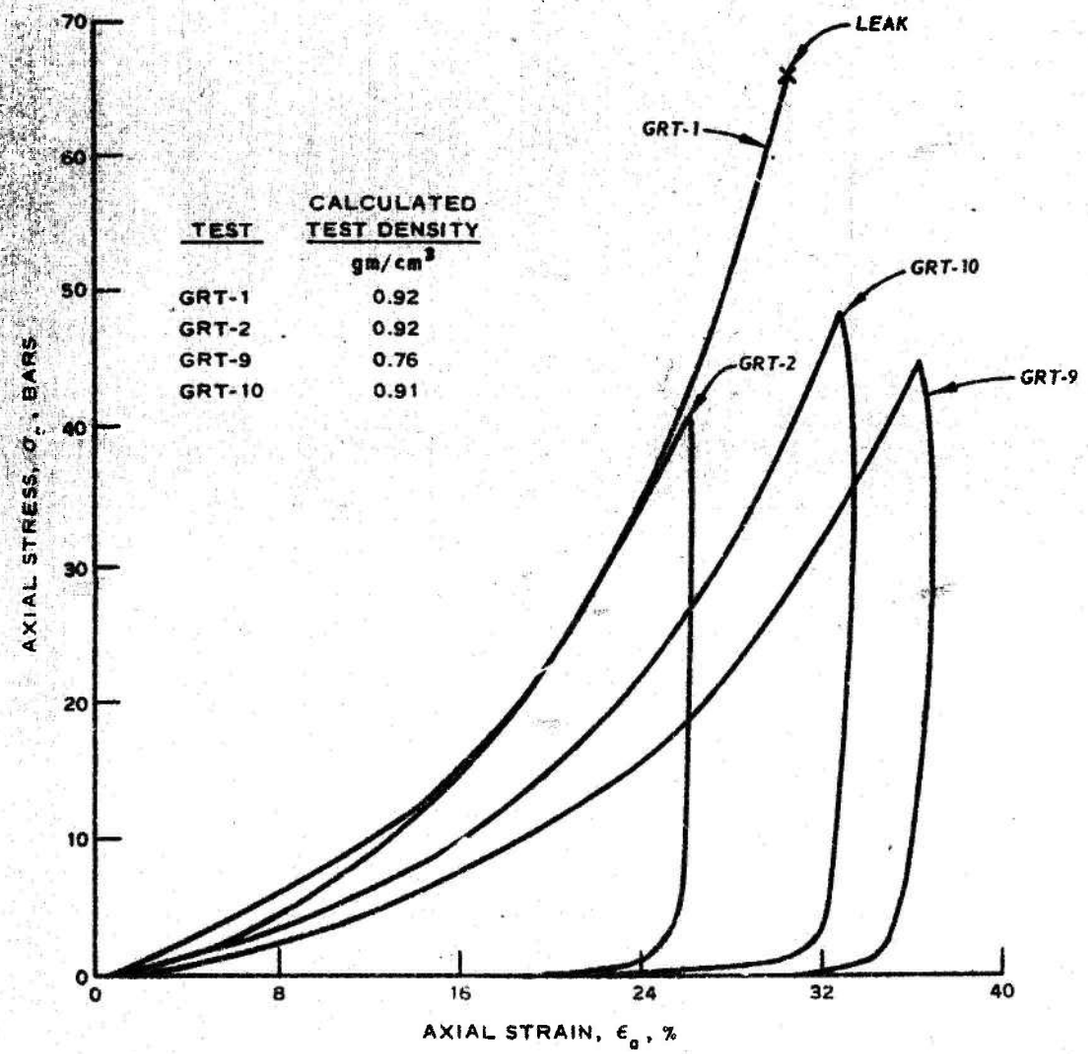

Figure 4.1 Static uniaxial strain test results (first batch materials).

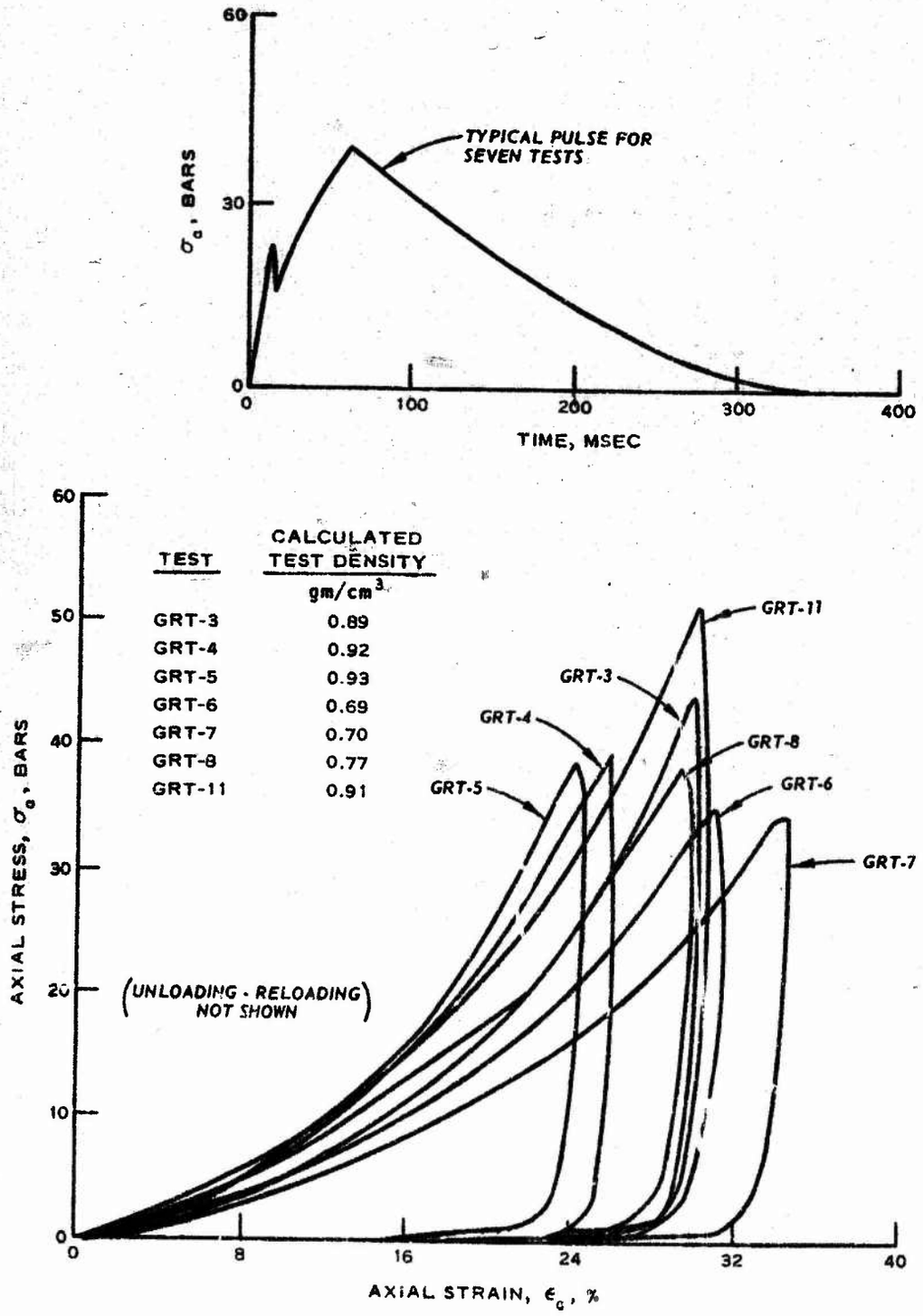

Figure 4.2 Dynamic uniaxial strain test results (first batch materials)

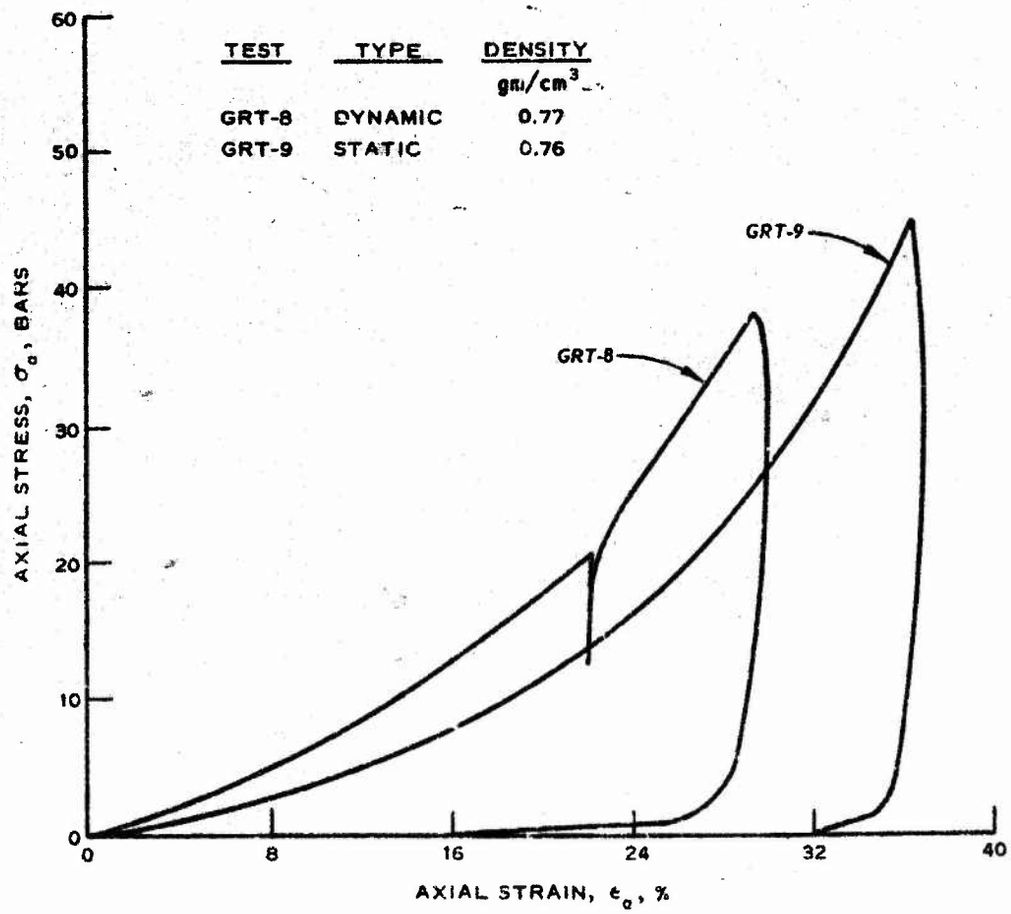

Figure 4.3 Comparison of results of dynamic Test GRT-8 and static Test GRT-9.

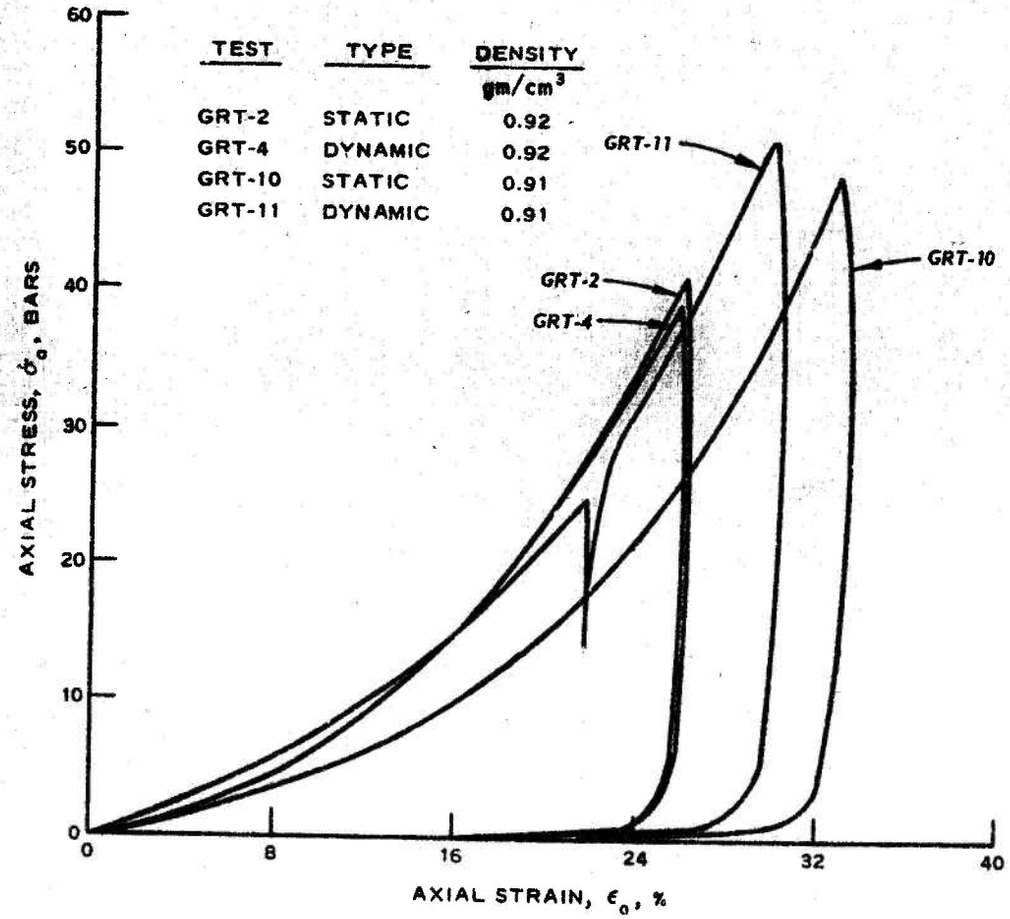

Figure 4.4 Comparison of results of static and dynamic uniaxial strain tests of Specimens GRT-2, -4, -10, and -11.

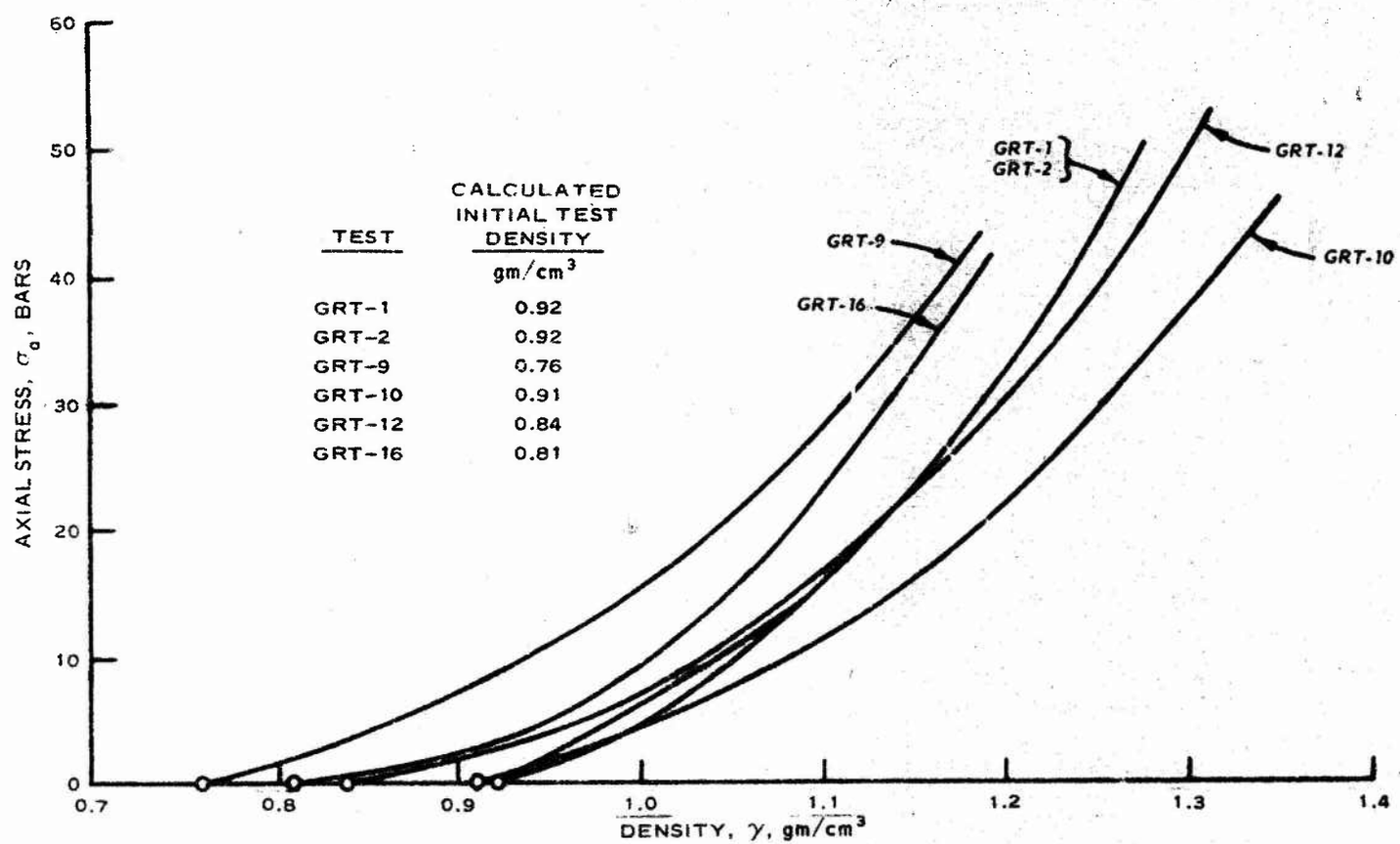

Figure 4.5 Static uniaxial strain test results plotted as axial stress versus density.

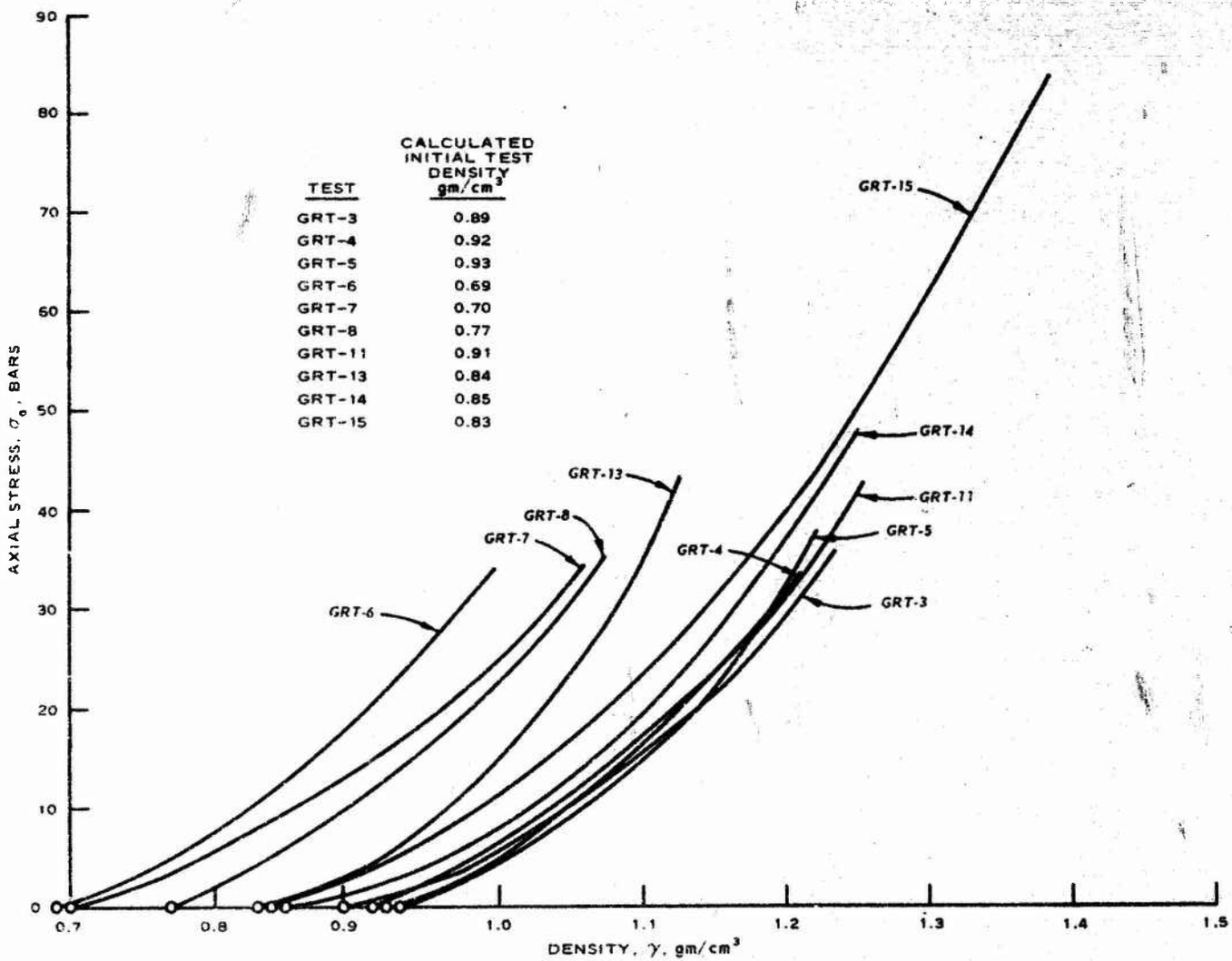

Figure 4.6 Dynamic uniaxial strain test results plotted as axial stress versus density.

CHAPTER 5

SUMMARY

Sixteen uniaxial strain tests were conducted on two batches of material received from GRT. Static (2 minutes to peak stress) and dynamic (approximately 50 msec to peak stress) loadings were applied, with peak axial stress levels ranging from 34.5 to 97 bars. The test results showed some experimental variations. This is thought to be, at least in large part, due to inevitable variations in the mixture occurring during placement of the specimens. The material segregated during handling and placement, and this required that special care be taken in specimen preparation.

It is believed that the first batch of material received by WES was not of the correct sawdust to sand ratio since the density specified by GRT (0.8 gm/cm^3) was unattainable. The material was used, however, to indicate the effect of mix variation since the density of the mixture could be easily varied by adding or removing small quantities of sand. Densities from 0.64 to 0.9 gm/cm^3 were attained in this manner. The general effect of the variation on the uniaxial strain test response was to decrease the amount of axial strain, at a given stress level during loading, as the amount of sand in the mix was increased. Little difference in the unloading moduli was noted.

The second batch of the material was of the correct mix proportions. The test results indicated a continually stiffening loading stress-strain curve and a stiff unloading stress-strain curve with very little rebound of the material except at low stress levels (i.e., 1.4 bars). This material did appear to have some rate-of-loading effects. Dynamic to static axial stress ratios ranging from 1.34 to 1.4 for strain levels ranging from 8 to 16 percent were noted. At higher strain levels, the ratio was approximately 1.2.