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RESILIENT MODULUS OF BASE COURSE CONTAINING RECYCLED ASPHALT PAVEMENT

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ABSTRACT

A total of 20 resilient modulus (M_R) tests were conducted for specimens with different ratios of recycled asphalt pavement (RAP) and aggregate to investigate the effect on material stiffness. Specimens were prepared by a gyratory compactor instead of a vibratory hammer because the density of a gyratory compacted specimen was closer to the field density. Moisture content and density were estimated before and during the tests following the NCHRP 1-28A protocol requirements. M_R data were evaluated by the quality control / quality assurance (QC/QA) criteria such as the angle of rotation, signal-to-noise ratio and coefficient of variance, and about 95% of the sequences passed the QC/QA criteria. Specimens with 65% optimal moisture contents were stiffer than the specimens with 100% optimal moisture contents at all confining pressures. The 50% aggregate – 50% RAP specimens developed stiffness equivalent to the 100% aggregate specimens at the lower confining pressures; at higher confinement, the RAP specimens were stiffer. However, from the tracking of axial displacement during the conditioning sequence, it appeared that the specimens with RAP exhibited greater permanent deformation than the 100% aggregate material.

Keywords: Resilient modulus, Recycled asphalt pavement, Full depth reclamation

INTRODUCTION

Full-depth reclamation (FDR) is a recycling technique in which all of the existing pavement section and all or a portion of the underlying aggregate materials are processed to produce a well compacted based course *(1)*. FDR has been proposed as a viable alternative in road construction, where material and transportation costs are reduced because recycling eliminates the need for hauling new material and disposing of old material *(2)*. The mixture of recycled asphalt pavement (RAP) and crushed aggregate, produced from FDR, has the potential to have engineering properties that exceed those of a 100% aggregate base material, although little data are available to substantiate the claim *(3)*.

The resilient modulus (M_R) test is a commonly conducted laboratory test to define stiffness of base material. In this research, M_R tests were conducted on the laboratory compacted specimens with various ratios of RAP and crushed aggregate to determine the effect of RAP and moisture content on the M_R values.

The reclaimed materials were obtained from the road sites in Minnesota and were prepared for various blends. Gyratory and Proctor compaction tests for the selected mixtures were performed, and index properties and associated parameters (maximum dry density and optimum moisture content) were determined. Then, M_R tests, generally following the National Cooperative Highway Research Program (NCHRP) 1-28A protocol *(4)*, were conducted on 20 specimens: five different blend types at one density, two moisture contents and one set of replicates. From the tests, M_R at different combinations of confining pressures and deviator stresses were calculated. In addition, M_R data were evaluated by the quality control / quality assurance (QC/QA) criteria such as the angle of rotation, signal-to-noise ratio, and coefficient of variance.

SAMPLE PREPARATION

The reclaimed materials were obtained from County Road (CR) 3 in central Minnesota. An in-situ blend, the mixture of RAP and crushed aggregate, was taken during FDR. In addition, pure RAP and pure aggregate materials from CR 3 were sampled separately, and various blended mixtures with different ratios of RAP and aggregate base were produced in the laboratory (% RAP/aggregate): 0/100, 25/75, 50/50, 75/25. RAP and aggregate materials were poured into a splitter, according to the specified ratio by mass, and mixed several (4-6) times until the materials were visually well-mixed. The gradation curves are shown in Figure 1; the samples with more RAP are more granular and have less fines content. Finally, the five different blended mixtures, one in-situ and four laboratory samples, were prepared for M_R testing at one density (maximum) and two moisture contents (65% and 100% optimal moisture content) and one set of replicates.

A second site was selected to evaluate laboratory and field compaction. Trunk Highway (TH) 5 near St. Paul, Minnesota provided an opportunity to compare densities in the field estimated by the sand cone method with those measured by standard Proctor and gyratory compaction. An in-situ blend (the mixture of RAP and crushed aggregate) was sampled during FDR.

COMPACTION TESTS

The Proctor compaction test is typically performed to determine the density-moisture relation of soils. However, compaction by the drop of a mass has been questioned as the appropriate procedure for simulating field compaction of granular materials, with the additional concern being that moisture can escape from a Proctor mold. For these reasons, gyratory compaction was investigated for determining the maximum dry density and optimum moisture content. Both standard Proctor and gyratory compaction tests were performed for the six mixtures and the results were compared with each other.

Proctor Compaction Tests (PCT)

Proctor compaction tests (PCT) were performed following Method C from the American Association of State Highway and Transportation Officials (AASHTO) T99, which specifies a 101 mm mold size, materials smaller than 19 mm, and 3 layers of 25 blows each *(5)*. Representative samples (5400 g) for each material were prepared for PCT and those particles larger than 19 mm were replaced by equal mass of -19 mm, +4.75 mm materials. From the PCT, density at different moisture contents were measured, and the maximum dry density and optimum moisture content for each different mixture were estimated. Moisture content was determined by obtaining about 500 g of material from the center of the mold and drying in an oven at 40^{o}C for 48 hours.

Gyratory Compaction Tests (GCT)

Gyratory compaction tests (GCT) were performed with a 152 mm diameter specimen mold, and the base rotated at a constant 30 revolutions per minute during compaction with the mold positioned at a compaction angle of 1.25 degrees *(6, 7)*. A compaction pressure of 600 kPa with 50 gyrations was selected based on the research from the University of New Hampshire *(8)*. By comparing field density and moisture content, and comparing the resilient modulus of specimens compacted by 50 and 75 gyrations, 50 gyrations was recommended for the specimen compaction. Therefore, 5400 g of the representative samples (+12.5 mm particles were replaced with -12.5 mm, +4.75 mm particles for material homogeneity) with different moisture contents were compacted by 50 gyrations, and the maximum dry density and optimum moisture content for each different mixture were estimated. Moisture content was determined by obtaining about 200 g of material from the center of the mold and drying in an oven at 40^{o}C for 6 days *(8)*. The moisture contents did not change significantly after the first 48 hours.

Results from Compaction Tests

Six different mixtures, including their identification letters, descriptions, maximum dry densities and optimum moisture contents from two different compaction methods (Proctor and gyratory), are contained in Table 1. Results from the gyratory compaction tests showed somewhat larger change in maximum dry densities (32 – 128 kg/m^3) and slightly smaller change in optimum moisture contents (1.2 – 1.9%). Also, the optimum moisture contents for the CR 3 materials decreased as percentage of RAP material increased. With gyratory compaction, maximum dry densities did not change as RAP content varied, but optimal moisture decreased slightly. The increased asphalt content may be responsible for the decrease in optimal moisture constant as %RAP increased.

TEST PROCEDURE

Resilient Modulus (M_R) and NCHRP 1-28A Protocol

Achieving a proper modulus of an unbound base course is important for pavement performance. One commonly used parameter to define material stiffness is the resilient modulus (M_R), which is similar to Young's modulus based on the recoverable axial strain $\Delta\varepsilon_a^r$ under an imposed axial (deviator) stress $\Delta\sigma_a$:

$$M_R = \frac{\Delta\sigma_a}{\Delta\varepsilon_a^{\ r}} \tag{1}$$

The M_R test is conducted in the laboratory by maintaining constant confining pressure within a conventional triaxial cell and applying a cyclic axial stress to simulate traffic loading. Two test protocols are commonly used: (a) Long Term Pavement Program (LTTP) P46 by the Strategic Highway Research Program *(9)*, and (b) National Cooperative Highway Research Program (NCHRP) 1-28A *(4)*. In both protocols, repeated cycles of axial stress are applied to a specimen at a given confining pressure. Each cycle is 1 s in duration, consisting of a 0.1 or 0.2 s haversine pulse followed by a 0.9 or 0.8 s rest period for coarse- and fine-grained soils, respectively.

The NCHRP 1-28A test protocol was used to establish the 30 loading sequences, but the protocol was modified to include three displacement transducers (not two as specified by 1-28A). The loading involves conditioning, which attempts to establish steady state or resilient behavior, through the application of 1000 cycles of 207 kPa deviator stress at 103.5 kPa confining pressure. The cycles are then repeated 100 times for 30 loading sequences with different combinations of deviator stress and confining pressure. The M_R is calculated as the mean of the last five cycles of each sequence from the recoverable axial strain and cyclic axial stress.

Test Control

A total of 20 M_R tests were conducted: five different blend types at one density, two moisture contents and one set of replicates. Each specimen was labeled "letter_number1_number2," where the letter represents the sample identification, number1 indicates the moisture content, and number2 shows whether it is the first or second test. Dry densities from gyratory compaction were chosen as the target densities (100% maximum), and the target moisture contents were 100% and 65% of optimum (Tables 1 - 3).

Moisture Content Control

NCHRP 1-28A protocol specifies that the moisture content of the specimens should be within ±0.5% from the target moisture content. As seen from Table 2, all 20 specimens had moisture contents within ±0.5% from the target. Moisture contents were also measured after testing, and did not show much difference with the moisture contents before testing.

Selection of Compaction Process

Compaction by a vibratory hammer following the maximum dry density from the standard Proctor test is suggested by the M_R testing protocols. However, as mentioned previously, compaction by the drop of a mass has been questioned as the appropriate procedure for simulating field compaction of granular materials. For example, both standard Proctor and gyratory compaction tests were performed for the TH 5 in-situ blend material, and the results were compared with the field sand cone (4 in. and 6 in.) test values. From Figure 2, the maximum dry density and optimum moisture content obtained from a gyratory compaction test were closer to the field compaction values compared to the values from a standard Proctor test. The variability in the field values was due to the difficulty of performing the sand cone test in the RAP base course. Nevertheless, gyratory compaction seemed to better simulate field conditions.

To compare the effect of the different laboratory compaction methods on M_R, two tests were conducted on the specimens from TH 5 in-situ blend material compacted by the two different methods, vibratory hammer and gyratory compaction. The results showed that the specimen compacted by the vibratory hammer using the maximum dry density from a standard Proctor test did not provide sufficient density; the specimen was stiffening (an increase of the tangent modulus) with increasing deviator stress and significant permanent deformation was recorded (Figures 3 and 4). It appeared that compaction was not complete and density changes produced an increase in modulus. With gyratory compaction, the specimen response was typical of well-compacted granular soil (Figures 3 and 4). From Figure 3, it was noticed that the nonlinear and relatively soft response due to incomplete compaction was changed to a stiffer response with the gyratory compactor. From Figure 4, note that the permanent deformation due to incomplete compaction was reduced with gyratory compaction. Therefore, it was decided to use a gyratory compactor.

Specimen Compaction Control

The gyratory compaction pressure ranged from 500 – 700 kPa, and up to 150 gyrations (for the dry of optimum specimens) were used to produce the desired dry densities (Table 3). Two specimens around 140 mm in height were placed one on top of the other; the surfaces in contact between the two specimens were scratched, and the joined specimens were compacted again by a vibratory hammer to achieve a specimen height of 280 mm. The interface between the two 140 mm specimens was not pronounced, and no separation was noticed during any of the tests. Although a 305 mm height is required by the NCHRP 1-28A protocol to achieve a 2:1 (length:diameter) ratio, the gage length of 152 mm was used to measure axial deformation so that it is anticipated that the slightly (< 10%) short specimen had no effect on the M_R.

For the lower moisture content specimens, more compaction energy was required (Table 3). However, with the highest compaction pressure (700 kPa) and number of gyrations (150), it was still difficult to produce a 100% gyratory dry density specimen at the lower moisture content; around 97.5% of the target dry density was achieved instead of 100% (Table 3). The lower moisture content specimens could not satisfy the NCHRP 1-28A protocol for the variation (±1%) in dry density.

Displacement Measurements

Because the M_R is calculated from recoverable axial strain, and the recoverable axial strain is determined from recoverable axial displacement, it is important to measure accurately the axial deformation. In this work, *three* Linear Variable Differential Transformers (LVDTs) were used at equi-angular positions; two LVDTs, as specified by 1-28A, are not sufficient to evaluate the uniformity of axial deformation *(10)*. Two parallel aluminum collars were attached to the specimen; on the lower collar, columns were mounted below the LVDTs as contacts for the spring-loaded tips of the LVDTs. This arrangement allowed the two collars to move independently of each other. Spacers maintained a parallel distance between the collars while the apparatus was placed on the specimen *(11)*.

The LVDT system had a 152 mm gage length. Although the NCHRP 1-28A protocol specified the LVDT minimum stroke range requirement as ±6.3 mm, a ±2.5 mm range was used for the tests for more accurate data with less noise effects. LVDT ranges were always checked before the tests to make sure that all three LVDTs were within range. Also, when the LVDTs were about to reach their limit during the resilient modulus tests, the loading was stopped and the LVDTs were re-zeroed. For the last sequence, the displacement was so large that the LVDTs sometimes reached the range limit, even though the LVDTs were re-zeroed before the sequence.

RESULTS

Resilient Modulus Data

M_R data for the 100% aggregate and the 50% aggregate – 50% RAP specimens are shown in Figures 5 and 6. Replicate tests showed very similar M_R values. Typical of granular materials, the M_R increased with increase of confining pressure and decreased with increase of deviator stress, although the confining effect was more pronounced; the spread in the data at a constant confining pressure represents the M_R at various deviator stresses. The specimens with 65% optimal moisture contents were stiffer than the specimens with 100% optimal moisture contents at all confining pressures. For example, at a confining pressure of 22 kPa, the M_R values were 50% larger for the dry of optimum specimens even though the lower moisture content specimens could not reach 100% gyratory dry density (actually 97.5% gyratory dry density).

Figures 5 and 6 also show that the 50% aggregate – 50% RAP specimens developed stiffness equivalent to the 100% aggregate specimens at the lower confining pressures; at higher confinement, the RAP specimens were stiffer. However, from the tracking of axial displacement during the conditioning sequence, it appeared that the specimens with RAP exhibited greater permanent deformation than the 100% aggregate material, although further work is needed to quantify the degradation effect *(12)*.

A summary of the results is presented in Figures 7 and 8, for the different mixtures at 65% optimal moisture content and 100% optimal moisture content, respectively. M_R data from replicate tests were averaged. Note that the specimens with more RAP content were stiffer, with the effect increasing at higher confining pressures. The 25% aggregate – 75% RAP material had the largest values of M_R. In addition, the blend produced from the reclaimer during FDR behaved similar to the 50% aggregate – 50% RAP specimens.

Quality Control of Resilient Modulus Data

M_R data from a test should represent element response at a given density and moisture. However, due to imperfections of the specimen and test equipment, some error occurs. Therefore, it is important to control the quality of the data through various criteria. M_R data were checked for angle of rotation, signal-to-noise ratio and coefficient of variance, and those data that failed to pass the limits set by the Minnesota Department of Transportation were withdrawn.

Rotation

During load application, some rotation may occur and the displacement values from the three LVDTs can vary. However, it can be shown that the mean of the three LVDT displacement readings is equal to the displacement from the axial stress *(10)*. Furthermore, the ratio of the maximum and minimum displacement does not provide an objective evaluation of uniformity, but it is reasonable to limit the angle of rotation *(10)*:

$$\cos\theta = \frac{\frac{3}{4}D}{\sqrt{\delta_1^2 + \delta_2^2 + \delta_3^2 - \delta_1\delta_2 - \delta_1\delta_3 - \delta_2\delta_3 + \frac{9}{16}D^2}} \tag{2}$$

where θ = angle of rotation, δ_i = axial displacement (LVDTi), and D = diameter of specimen. Angle of rotation of the last five cycles of the 30 sequences of all 20 specimens were analyzed, and those cycles that failed to pass the maximum limit of 0.04° were withdrawn.

Signal-to-Noise Ratio

Because stiffness and stress state may require the LVDTs to measure very small amount of displacement, noise acting during a resilient modulus test can seriously affect the results. Therefore, a coefficient called the signal-to-noise ratio (SNR), which compares the peak displacement to the standard deviation (SDev) of the noise, was introduced:

$$SNR = \frac{Peak}{3 \times SDev(Baseline)} \tag{3}$$

An SNR value of 3 was chosen as the minimum limit for each LVDT at each cycle. Also, an SNR value of 10 was used for each loading cycle. Those cycles that failed to pass the limits were withdrawn.

Coefficient of Variance

For a specimen at a given sequence, M_R values for each cycle should be very similar. However, there will be some variance in M_R between the cycles and it is important to control the maximum amount for each sequence. Therefore, the coefficient of variance (COV), defined as

$$COV(\%) = \frac{SDev}{Average} \tag{4}$$

must be less than 10%. The M_R values from last five cycles were analyzed by this criterion. Those sequences that failed to pass the maximum COV limit (10%) were withdrawn.

LVDT Range

As mentioned previously, LVDT ranges were checked before the tests to make sure that all three LVDTs were within the stroke range. Also, when the LVDTs were about to reach their limit during a test, the loading was stopped and the LVDTs were re-zeroed. However, for some sequences (usually sequence 30), the displacement was so large that the LVDTs sometimes reached the limit even though it was re-zeroed and checked before the sequence. If at least one of the LVDTs reached its range limit, those cycles were withdrawn.

Results

The M_R data were analyzed using the QC/QA criteria (LVDT range, angle of rotation, SNR and COV), and those that failed to pass the limit were withdrawn. The summary of % passing rate for each criterion and total % passing rate of all 20 specimens are shown in Table 4. Those sequences that failed to pass the LVDT range and rotation limit were usually higher loading sequences (sequences 29 and 30), and those sequences that failed to pass the SNR limit were usually lower loading sequences (sequences 1 and 2).

CONCLUSIONS

A total of 20 resilient modulus (M_R) tests were conducted for specimens with different ratios of recycled asphalt pavement (RAP) and aggregate to investigate the effect on material stiffness. Specimens were prepared by a gyratory compactor instead of a vibratory hammer because the density of a gyratory compacted specimen was closer to the field density. Moisture content, density and displacement transducer range were measured before and during the tests following the NCHRP 1-28A protocol requirements. M_R data were evaluated by the quality control / quality assurance (QC/QA) criteria such as the angle of rotation, signal-to-noise ratio and coefficient of variance, and about 95% of the sequences passed the QC/QA criteria. From the M_R tests, specimens with 65% optimal moisture contents were consistently stiffer than the specimens with 100% optimal moisture contents. The 50% aggregate – 50% RAP specimens developed stiffness equivalent to the 100% aggregate specimens at the lower confining pressures; at higher confinement, the RAP specimens were stiffer. However, from the tracking of axial displacement during the conditioning sequence, it appeared that the specimens with RAP exhibited greater permanent deformation than the 100% aggregate material, although further work is needed to evaluate this phenomenon.

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LIST OF TABLES

LIST OF FIGURES

TABLE 1 Compaction Test Results.

Soil Identification Letter	Description	Proctor		Gyratory	
		Maximum Dry Density (kg/m^3)	Optimum Moisture Content (%)	Maximum Dry Density (kg/m^3)	Optimum Moisture Content (%)
S	In-situ Blend from CR 3	1984	9	2032	7.8
T	100% Aggregate from CR 3	2000	10	2032	8.8
U	75% Aggregate - 25% RAP from CR 3	2000	10	2032	8.7
V	50% Aggregate - 50% RAP from CR 3	1952	9.5	2032	8.0
W	25% Aggregate - 75% RAP from CR 3	1920	8.5	2032	7.2
X	In-situ Blend from TH 5	1984	8.5	2112	6.6

TABLE 2 Moisture Content Control.

Specimen ID	Description	Target MC (%)	Actual MC (%)	ΔMC (%)
S_5.1_1	CR3_Blend_65%OMC_1	5.1	5.1	0.0
S_5.1_2	CR3_Blend_65%OMC_2	5.1	4.9	-0.2
S_7.8_1	CR3_Blend_100%OMC_1	7.8	7.4	-0.4
S_7.8_2	CR3_Blend_100%OMC_2	7.8	7.7	-0.1
T_5.7_1	CR3_100%A_65%OMC_1	5.7	6.0	0.3
T_5.7_2	CR3_100%A_65%OMC_2	5.7	6.2	0.5
T_8.8_1	CR3_100%A_100%OMC_1	8.8	9.1	0.3
T_8.8_2	CR3_100%A_100%OMC_2	8.8	9.1	0.3
U_5.7_1	CR3_75%A-25%R_65%OMC_1	5.7	6.1	0.4
U_5.7_2	CR3_75%A-25%R_65%OMC_2	5.7	6.0	0.3
U_8.7_1	CR3_75%A-25%R_100%OMC_1	8.7	8.3	-0.4
U_8.7_2	CR3_75%A-25%R_100%OMC_2	8.7	8.8	0.1
V_5.2_1	CR3_50%A-50%R_65%OMC_1	5.2	5.1	-0.1
V_5.2_2	CR3_50%A-50%R_65%OMC_2	5.2	5.7	0.5
V_8_1	CR3_50%A-50%R_100%OMC_1	8.0	8.4	0.4
V_8_2	CR3_50%A-50%R_100%OMC_2	8.0	8.0	0.0
W_4.7_1	CR3_25%A-75%R_65%OMC_1	4.7	4.5	-0.2
W_4.7_2	CR3_25%A-75%R_65%OMC_2	4.7	4.3	-0.4
W_7.2_1	CR3_25%A-75%R_100%OMC_1	7.2	7.3	0.1
W_7.2_2	CR3_25%A-75%R_100%OMC_2	7.2	7.7	0.5

TABLE 3 Compaction Control (Target Dry Density = 2032 kg/m^3).

Specimen ID	Description	Gyration1 (kPa-#)	Gyration2 (kPa-#)	Height (mm)	Actual Dry Density (kg/m^3)	Actual / Target (%)
S_5.1_1	CR3_Blend_65%OMC_1	700-150	700-150	292	1966	96.8
S_5.1_2	CR3_Blend_65%OMC_2	700-150	700-150	291	1995	98.2
S_7.8_1	CR3_Blend_100%OMC_1	600-150	600-150	282	2032	100.0
S_7.8_2	CR3_Blend_100%OMC_2	500-150	500-120	282	2043	100.6
T_5.7_1	CR3_100%A_65%OMC_1	700-150	700-150	290	1963	96.6
T_5.7_2	CR3_100%A_65%OMC_2	700-150	700-150	290	1961	96.5
T_8.8_1	CR3_100%A_100%OMC_1	500-90	500-90	281	2041	100.5
T_8.8_2	CR3_100%A_100%OMC_2	500-140	500-150	282	2035	100.2
U_5.7_1	CR3_75%A-25%R_65%OMC_1	700-150	700-150	287	2001	98.5
U_5.7_2	CR3_75%A-25%R_65%OMC_2	700-150	700-150	283	1958	96.4
U_8.7_1	CR3_75%A-25%R_100%OMC_1	600-83	600-90	287	2051	100.9
U_8.7_2	CR3_75%A-25%R_100%OMC_2	600-67	600-75	281	2049	100.9
V_5.2_1	CR3_50%A-50%R_65%OMC_1	700-150	700-150	285	1996	98.3
V_5.2_2	CR3_50%A-50%R_65%OMC_2	700-150	700-150	288	1964	96.7
V_8_1	CR3_50%A-50%R_100%OMC_1	500-97	500-92	282	2048	100.8
V_8_2	CR3_50%A-50%R_100%OMC_2	500-110	500-115	283	2049	100.9
W_4.7_1	CR3_25%A-75%R_65%OMC_1	700-150	700-150	284	2000	98.4
W_4.7_2	CR3_25%A-75%R_65%OMC_2	700-150	700-150	286	1987	97.8
W_7.2_1	CR3_25%A-75%R_100%OMC_1	500-80	500-95	279	2052	101.0
W_7.2_2	CR3_25%A-75%R_100%OMC_2	500-150	600-75	281	2032	100.0

TABLE 4 Quality Control of Resilient Modulus Data.

% Passing					
LVDT Range	Rotation <0.04°	SNR >3	SNR F >10	COV <10%	Total
98.3	98.7	98.1	100	100	95.2

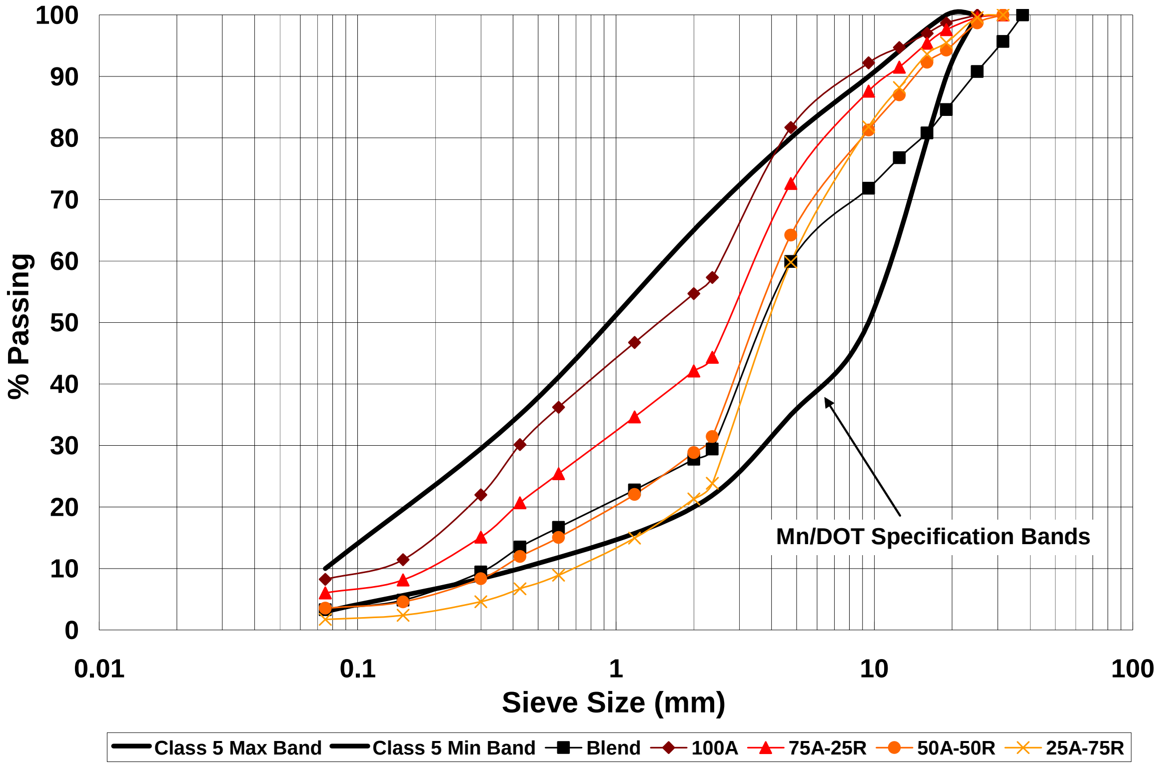

FIGURE 1 Gradation Curves for CR 3 Materials.

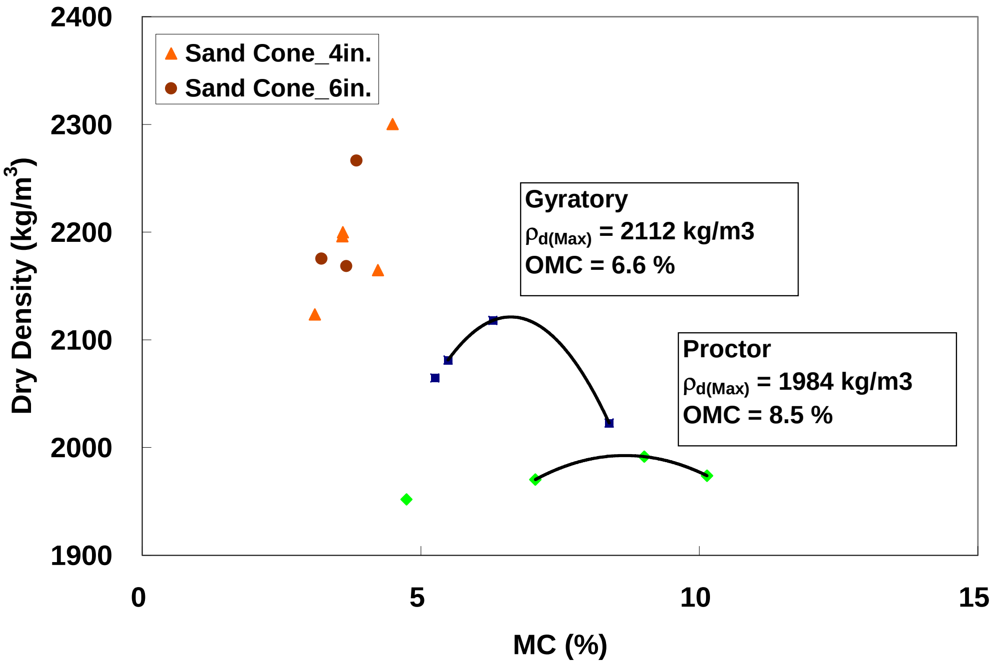

FIGURE 2 Compaction Method Comparison: TH 5 In-situ Blend Material.

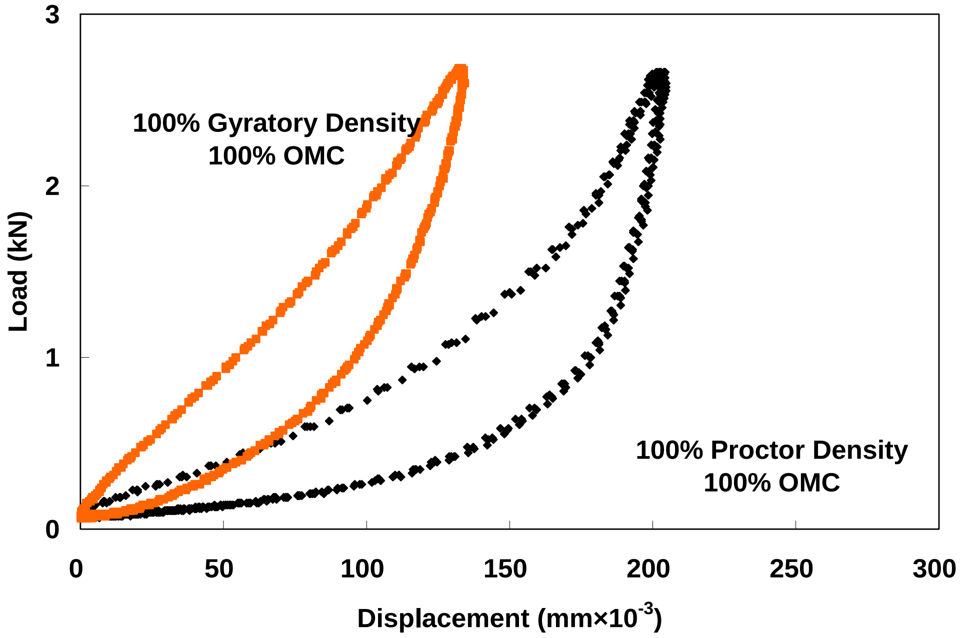

FIGURE 3 Load vs Displacement, Last Five Cycles, Sequence 26 (20.7 kPa confinement): TH 5 In-situ Blend Material.

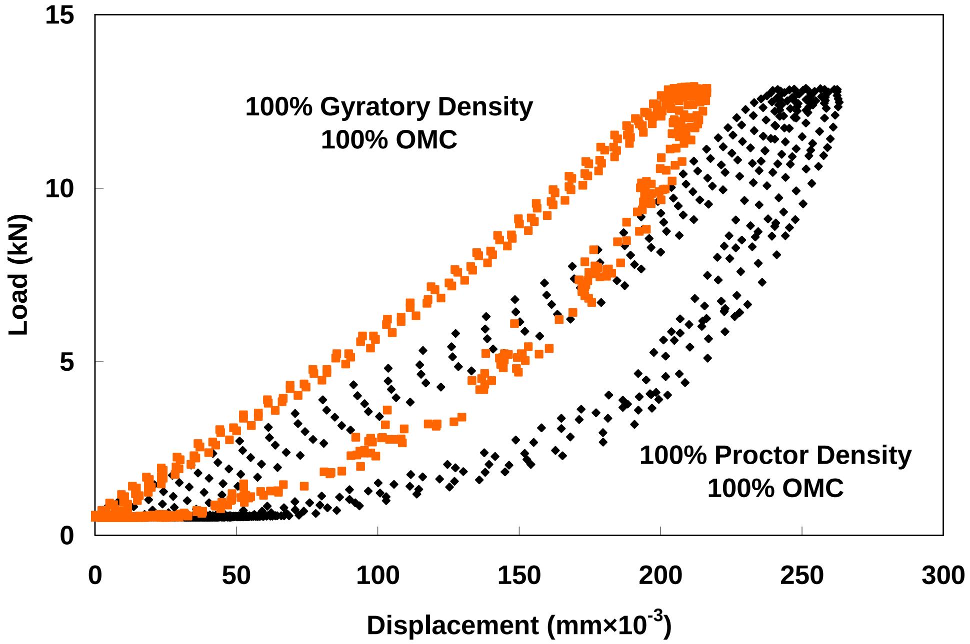

FIGURE 4 Load vs Displacement, Last Five Cycles, Sequence 25 (128 kPa confinement): TH 5 In-situ Blend Material.

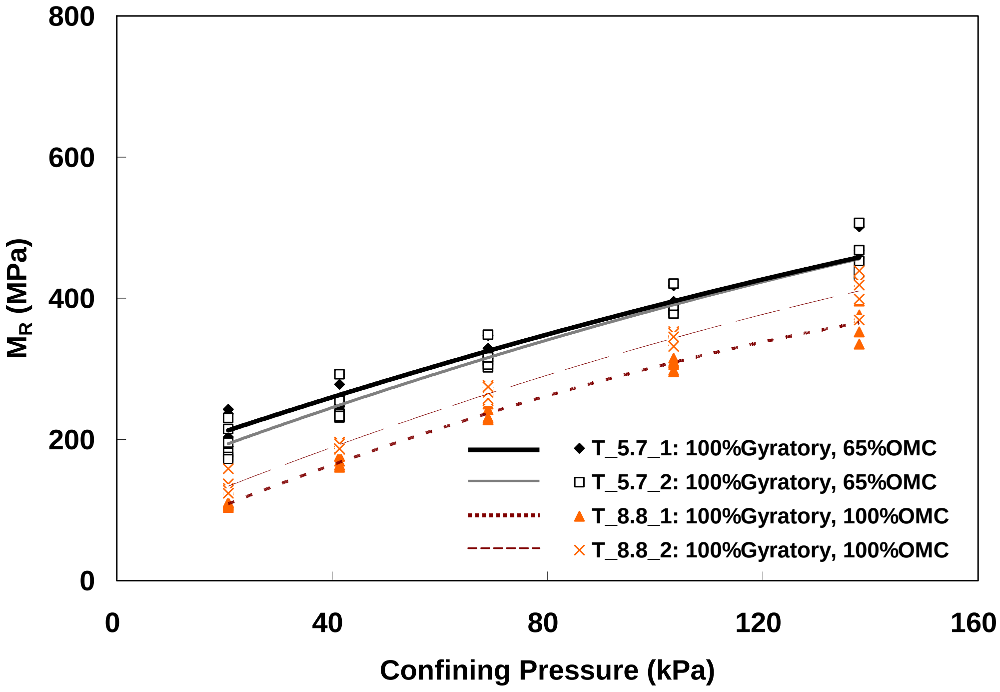

FIGURE 5 Resilient Modulus of CR 3 100% Aggregate Material
(Sample T, 100% Gyratory = 2032 kg/m^3, 100% Optimal Moisture Content (OMC) = 8.8%,
65% OMC = 5.7%).

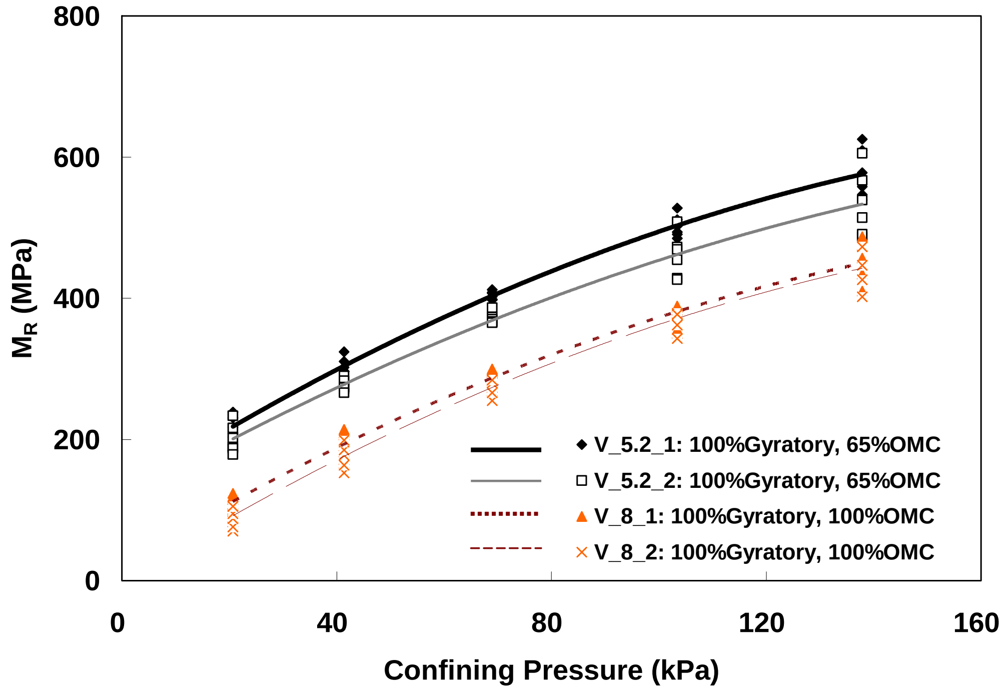

FIGURE 6 Resilient Modulus of CR 3 50% Aggregate – 50% RAP Material
(Sample V, 100% Gyratory = 2032 kg/m^3, 100% Optimal Moisture Content (OMC) = 8.0%,
65% OMC = 5.2%).

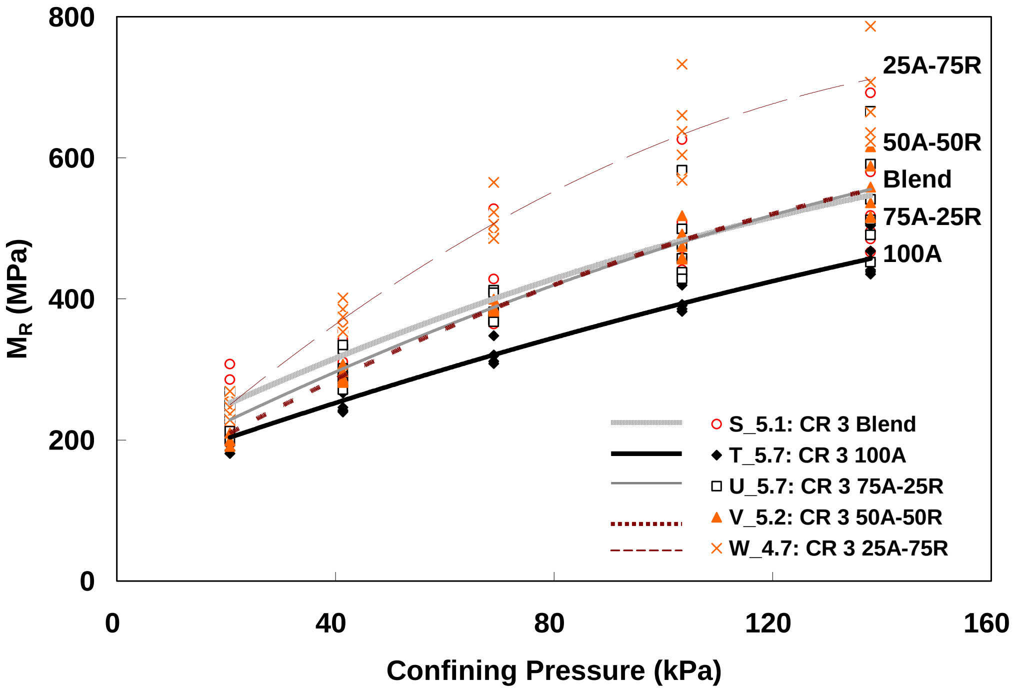

FIGURE 7 Resilient Modulus of CR 3 Materials at 65% OMC.

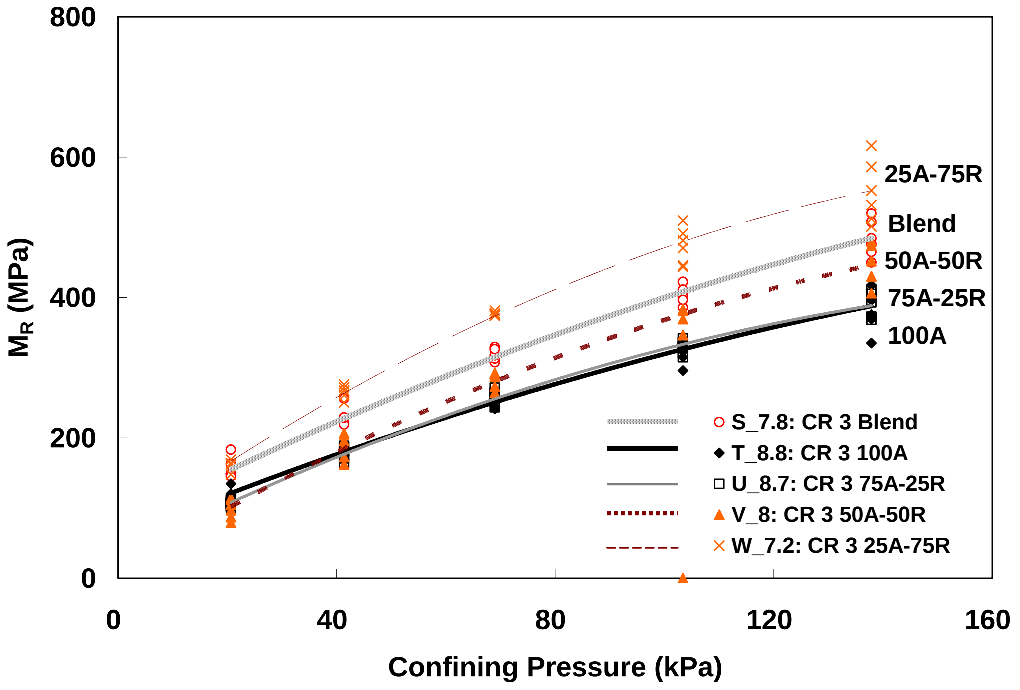

FIGURE 8 Resilient Modulus of CR 3 Materials at 100% OMC.