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Comparative assessment of crushed aggregates and bound/unbound recycled asphalt pavement as base materials

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With the increased awareness of building sustainable transportation systems, recycled materials and industrial byproducts increasingly are being used in highway construction, especially as base materials. When compared to traditional base materials, such as crushed aggregate, recycled materials and industrial byproducts often display unique properties. However, the physical properties of recycled materials and industrial byproducts have yet to be fully characterised for the purpose of pavement design. This study evaluated the mechanical properties of a full-depth reclaimed pavement material (RPM) and RPM stabilised with high carbon/high calcium fly ash, and compared these with properties of a conventional crushed aggregate. It was found that RPM exhibited higher modulus than the traditional base course material (crushed aggregates) did. However, RPM also showed higher plastic strain than crushed aggregate, indicating a higher potential for rutting in RPM base. Adding high carbon/high calcium fly ash significantly increased the California Bearing Ratio (CBR) and resilient modulus and lowered plastic strain of RPM. The strength and stiffness of field-mixed RPM stabilised with fly ash was significantly lower than that of laboratory-mixed mixtures, as indicated by different measures, i.e., CBR, resilient modulus and unconfined compressive strength (UCS). Data obtained in this study, along with other data obtained from similar studies, indicate that there are good correlations between resilient modulus and CBR ($R^2 = 0.96$), as well as between resilient modulus and UCS ($R^2 = 0.94$) for recycled base materials stabilised with fly ash. However, there is still a need for more testing to further verify the proposed relationships. Nonetheless, the proposed relationships constitute the first such relationship proposed and can be useful in pavement design. Additionally, it is shown that flexural strength is about 20% of UCS as it is recommended for materials stabilised with other cementitious materials.

Keywords: recycled pavement material; crushed aggregates; high carbon fly ash; resilient modulus; flexural strength

Introduction

With the increased awareness of building sustainable transportation systems, recycled materials and industrial byproducts increasingly are being used in highway construction, especially as base course materials. For instance, deteriorated asphalt pavements could be reclaimed full depth and used as a base course material for a new pavement, as opposed to bringing in new base course materials. The full-depth reclaimed pavement materials, also known as recycled pavement materials (RPMs), may also be mixed with industrial byproducts, such as fly ash, to increase the stiffness of base materials (Wen *et al.* 2004, 2008, Li *et al.* 2007, Kootstra *et al.* 2010).

When compared to traditional base materials, such as crushed aggregates, recycled materials and industrial byproducts often have unique characteristics. For instance, previous studies have shown that RPM alone exhibited higher resilient modulus (Papp *et al.* 1998, MacGregor *et al.* 1999, Bennert and Maher 2005, Kim *et al.* 2007), but also higher permanent deformation, than the crushed aggregates did (Wen *et al.* 2007, 2008).

When these materials are used for pavement construction, properties such as resilient modulus and flexural strength (for bound materials only) have to be characterised as specified in the Mechanistic-Empirical Pavement Design Guide (MEPDG) (Applied Research Associates (ARA) 2004). In the MEPDG, resilient modulus (M_r) can be either directly measured for Level 1 input or correlated from simpler, routine tests such as California Bearing Ratio (CBR) for unbound materials or unconfined compressive strength (UCS) for materials stabilised by lime or cement (ARA 2004). Similarly, the flexural strength of stabilised materials (Level 1 property) can be estimated from UCS, which is a Level 2 property (ARA 2004). Equations (1) and (2) show the correlations between modulus and UCS for soil–cement and lime-stabilised soils, respectively (ARA 2004). It is noted that Equation (2) in MEPDG was based on English unit and

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was converted into a form in SI unit herein.

$$E = 1200\,\mathrm{UCS} \tag{1}$$

where E is the modulus of soil–cement in MPa and UCS is the unconfined compressive strength in MPa.

$$M_r = 0.124\mathrm{UCS} + 68.76 \tag{2}$$

where M_r is the resilient modulus in MPa and UCS is the unconfined compressive strength in kPa. For flexural strength of stabilised materials, the MEPDG uses 20% of UCS as an estimate of the flexural strength (ARA 2004).

The MEPDG does not, however, address the use of many recycled materials and industrial byproducts, such as fly ash stabilised base materials. The correlations between Level 1 and Level 2 properties, which were developed for traditional materials, such as soil–cement or clay–lime, need to be verified before these correlations are used on recycled materials and industrial byproducts for proper pavement design. Moreover, the default values of properties (Level 3 input) of fly ash stabilised recycled materials, such as flexural strength, have to be determined for use in the MEPDG.

In addition, past studies on fly ash stabilised materials have been focusing on the laboratory-mixed samples of primarily sub-grade soils. However, laboratory-mixed samples might not be representative of the field mixtures as indicated by Mitchell and Freitag 1959, Wang 1968, Keshawarz 1985, Bin-Shafique *et al.* 2004 and Hatipoglu *et al.* 2008 for stabilised soils due to differences in mixing and curing conditions that exist between laboratory and field. Therefore, there is a need to evaluate the properties of field-mixed samples and compare to those of laboratory-mixed samples for the recycled materials.

This study aimed to evaluate the properties of two emergent base materials used at the Minnesota Road (MnROAD) testing facility, located at Otsego, MN: RPM, and RPM stabilised with high carbon and high calcium fly ash (SRPM) to be compared with conventional crushed aggregate. The properties of these materials are characterised for three purposes: (1) direct measurement of Level 1 properties of unbound and fly ash stabilised recycled materials, such as resilient modulus and flexural strength; (2) measurements of Level 2 properties, such as CBR and UCS (for stabilised materials only), to correlate with the Level 1 properties; and (3) development of correlations between the Level 1 and Level 2 properties for fly ash stabilised materials.

Materials

Cementitious high carbon fly ash

The fly ash used in this study to stabilise the RPM is a high carbon content fly ash (carbon content of 16.35% based on loss on ignition (LOI)) that cannot be used in concrete production and is not extensively investigated for the purpose of soil and base course stabilisation. However, due to air quality control requirements, such fly ashes are becoming more prevalent. It was produced by the Riverside Power Station Unit No. 8 of Xcel Energy in St. Paul, MN. It is a self-cementing fly ash with a calcium oxide (CaO) content of 22.37%. At the presence of moisture, this fly ash, in a form of fine powder, hydrates and serves as binder. The chemical composition of Riverside 8 fly ash is summarised in Table 1.

Crushed aggregates

The Minnesota Department of Transportation (MnDOT) Class 6 crushed granite aggregate was used as the control base material for comparison with the recycled materials at MnROAD test sections. The crushed aggregate is classified as well-graded gravel (GW) and A-1-a in accordance with the Unified Soil Classification System (USCS) and American Association of State Highways and Transportation Officials (AASHTO) soil classification methods, respectively. This material has a maximum grain size of 25 mm and 2% fines. Particle size distribution for Class 6 crushed aggregate is shown in Figure 1. The optimum moisture content was 5.2% and the maximum dry density was 2220 kg/m^3, based on the compaction using the modified Proctor procedure.

Recycled pavement material

The RPM samples were collected at MnROAD during the construction of the test sections. The RPM was generated by pulverizing the existing asphalt layer (100-mm thick) and then mixing with the underlying base layer consisting of 100-mm thick MnDOT Class 5 crushed aggregate. Particle size distribution of RPM is also shown in Figure 1.

RPM is classified, based on its grain size distribution characteristics, as a well-graded, silty sand (SW-SM) and A-1-a in accordance with the USCS and AASHTO soil classifications, respectively. RPM has a maximum grain size of 25 mm. The optimum moisture content of the RPM was 4.9% and the maximum density was 2044 kg/m^3 in accordance with the modified Proctor procedure.

Table 1. Chemical composition of Riverside unit 8 fly ash.

Fly ash	Strength activity at 7 days, min (%)	LOI (%)	CaO (%)	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)
Riverside 8	87	16.35	22.37	18.96	13.96	5.93

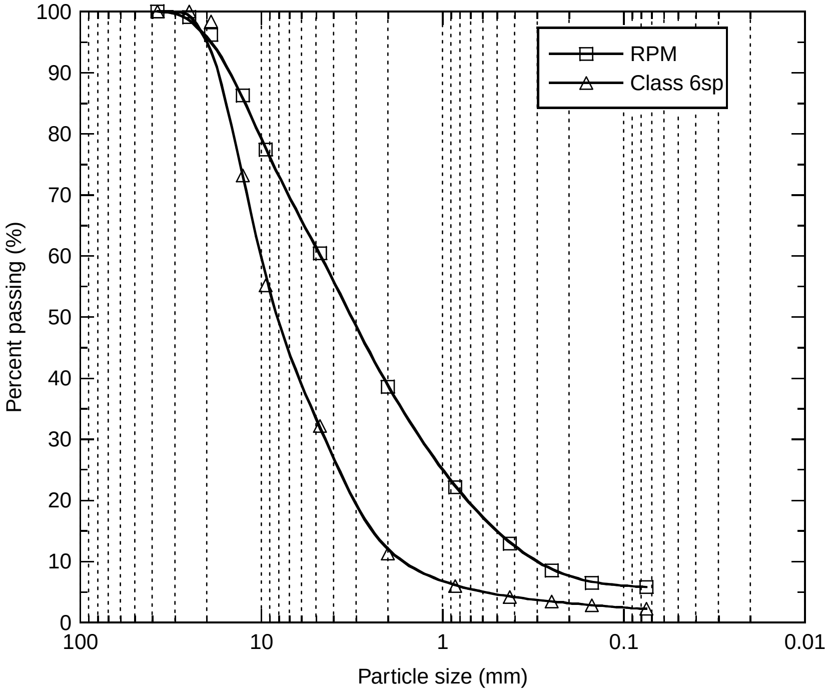

Figure 1. Particle size distribution for RPM and crushed aggregates.

Stabilised recycled pavement material

In another test section at MnROAD, the RPM was stabilised with the fly ash described above at 14% application rate by the dry weight of RPM. The fly ash SRPM had an optimum moisture content of 6.5% and a maximum dry density of 2111 kg/m^3 in accordance with the modified Proctor procedure. The compaction characteristics and classifications of the Class 6, the RPM, and the SRPM are given in Table 2.

Experimental methods

Crushed aggregate, RPM and fly ash each were sampled during construction and used to fabricate specimens in the laboratory. During the MnROAD construction, the moisture content and dry densities of the compacted base layers (crushed aggregate, RPM and SRPM) were measured using a nuclear density gauge in accordance with the ASTM D 6938, ‘Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods’, immediately after field compaction. The density was controlled by the number of roller passes. The moisture was controlled by adding water to the base materials as needed. The mean dry densities of the crushed aggregate, RPM and SRPM were 2080, 1998 and 2059 kg/m^3 in the field, respectively. These values were used to prepare the specimens for laboratory tests so that the moisture content and dry densities were the same between the laboratory samples and the field mixtures.

Laboratory-mixed fly ash-RPM mixtures were prepared by adding 14% fly ash (by the dry weight of RPM) to RPM (the same percentage as specified in the field construction). Modified Proctor compaction for the laboratory-mixed specimens was carried out one hour after fly ash was mixed with RPM to simulate the compaction delay in the field (Li *et al.* 2007).

Furthermore, fly ash-RPM mixed by the field equipments was also sampled before field compaction started. The field-mixed samples were compacted in a mould on site to the field densities and transported to the laboratory for curing

Table 2. Summary of compaction characteristics[a] and classification of Class 6 aggregate, RPM and SRPM.

				Classification	
Material	Fly ash content (%)	Optimum water content (%)	Max. dry density (kg/m^3)	AASHTO	USCS
Class 6	0	5.2	2220	A-1-a	GW
RPM	0	4.9	2044	A-1-a	SW-SM
SRPM	14	6.5	2111	–	–

[a] In accordance with the ASTM D1557, ‘Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort’.

and testing. The purpose was to verify the effects of mixing and curing fly ash-RPM mixtures in the field on material properties by comparing to the properties of the laboratory-mixed specimens for which the mixing well controlled. Both laboratory-mixed and field-mixed fly ash SRPM specimens were cured for 7 and 28 days before testing so that their curing conditions were similar. Because laboratory-mixed and field-mixed specimens were controlled to have the same moisture content and dry densities, the air voids in both types of specimens would be the same. The difference in material properties between laboratory-mixed specimens and field-mixed specimens thus is expected to result from the construction practices, such as uniformity of mixing.

Resilient modulus (M$_r$)

Resilient modulus is a fundamental property for a pavement design. Resilient modulus tests were performed on RPM, crushed aggregates and fly ash SRPM, in accordance with the National Cooperative Highway Research Program (NCHRP) 1-28A test protocol (NCHRP 2004). Three replicates were used for each test. Resilient modulus was computed in accordance with the NCHRP 1-28A and was modelled using Equation (3) (NCHRP 2004).

$$M_{\mathrm{r}} = k\cdot{}_1\cdot p_a\left(\frac{\sigma_b - 3k_6}{p_a}\right)^{k_2}\cdot\left(\frac{\tau_{oct}}{p_a}+k_7\right)^{k_3} \tag{3}$$

where M_{r} is the resilient modulus; k_1, k_2, k_3, k_6 and k_7 are constants; p_{a} is the atmospheric pressure, τ_{oct} is the octahedral shear stress; and σ_{b} is the bulk stress.

The summary resilient moduli (SRM) were reported at a bulk stress (σ_{b}) of 208 kPa and octahedral stress (τ_{oct}) of 48.6 kPa for base materials in accordance with the NCHRP 1-28A. The accumulated permanent deformations of the specimens after the M_{r} tests were used as an index of plastic behaviour of the materials.

Unconfined compressive strength

UCS is the most common property to characterise stabilised materials. Unconfined compression tests were conducted on SRPM specimens. All stabilised specimens were loaded at a strain rate of 0.21% per minute in accordance with the ASTM D 5102, 'Standard Test Method for Unconfined Compressive Strength of Compacted Soil-Lime Mixtures'. These samples were cured for 7 and 28 days and tested to determine the effects of curing period on the unconfined compression strength of these materials.

California bearing ratio (CBR)

Resilient modulus test can be conducted on both stabilised and unstabilised materials. However, it is a time-consuming test. Only few simple tests exist to directly compare the properties between stabilised and unstabilised materials. The CBR test was selected to compare the properties between stabilised and unbound materials and to determine the effects of stabilisation on the material properties over time. In addition, CBR is a Level 2 property in the MEPDG.

The unsoaked CBR tests were conducted on all specimens in accordance with the ASTM D 1883, 'Standard Test Method for CBR (California Bearing Ratio) of Laboratory-Compacted Soils'. CBR tests on RPM and crushed aggregates were performed immediately after compaction, whereas specimens with fly ash were tested after 7-day and 28-day curing, respectively. A surcharge of 4.54 kg was used during CBR testing.

Flexural strength

Flexural strength of SRPM was determined using a third-point bending beam method as described in the ASTM D 1635, 'Standard Test Method for Flexural Strength of Soil-Cement Using Simple Beam with Third-Point Loading'. Rectangular beams had dimensions of 76 mm × 102 mm × 406 mm. RPM was mixed with fly ash, compacted into the mould (3 lifts of equal mass and thickness) to the desired density, using a hammer, and cured for 7 and 28 days. SRPM beams were loaded at a constant rate of 138 kPa/min until failure in accordance with the ASTM D 1635. The beams had span lengths of 356 mm between the two supports. All these tests were conducted at room temperature (about 20°C).

Results and analysis

The tests results of laboratory-mixed and field-mixed specimens are shown in Table 3. The results therein presented correspond to the mean value of three test specimens for each laboratory test, and the corresponding coefficients of variation are presented in Table 4. As for the field tests, 6 and 8 test specimens were used for CBR tests and 3 and 4 specimens for UCS tests at 7 and 28 days, respectively. These results are interpreted from two aspects: comparison of recycled materials (RPM in this case) with and without an industrial byproduct binder (fly ash) to a traditional base material (crushed aggregate in this case), and correlations between Level 1 properties and Level 2 properties.

Comparison of characteristics of RPM and SRPM to class 6 aggregate

Resilient modulus

The average summary resilient modulus (at a bulk stress (σ_{b}) of 208 kPa and octahedral stress (τ_{oct}) of 48.6 kPa) of untreated RPM was 257 MPa, which is 17% higher than

Table 3. Summary of mean field and laboratory test results.

Material	Curing time (days)	CBR (%)	Summary resilient modulus (MPa)	Plastic strain[a] (%)	Flexural strength (kPa)	UCS (kPa)
Crushed aggregate	0	133	220	0.71	–	–
RPM	0	19	257	2.8	–	–
Laboratory-mixed SRPM	7	129	2984	0.58	150	1160
	28	176	4334	0.56	320	1380
Field-mixed SRPM	7	62	–	–	–	350
	28	94	–	–	–	480

Note: The dash mark '–' indicates not applicable or not available.

[a] Accumulated plastic strain at the end of the resilient modulus test.

the SRM of crushed aggregate, 220 MPa. The accumulated permanent deformations of the specimens at the end of the resilient modulus test were used to determine the plastic strain, which is viewed as an index of the permanent deformation. It was found that RPM exhibited higher plastic strain (2.77%) than the crushed aggregate (0.71%) after the same loading history. This indicates that resilient modulus tests alone may not capture the behaviour of unstabilised materials, specifically rutting potential.

Adding fly ash to RPM significantly increased the SRM from 257 MPa to 2984 and 4334 MPa (nearly 17 folds higher than unstabilised RPM) after 7-day and 28-day curing, respectively. Adding fly ash also lowered the plastic strains from 2.77% to 0.58% and 0.56% (nearly fivefolds) after 7-day and 28-day curing, respectively. Thus, the self-cementing fly ash, even if it has high carbon content, improved the stiffness and reduced the plastic strain of RPM.

CBR characteristics

The average CBR value of RPM without fly ash in this study was 19, which is about 86% lower than that of crushed aggregate, 133. This is not consistent with the results of resilient modulus tests. The SRM of RPM was higher than that of crushed aggregate. A similar observation was also reported by Wen *et al.* (2007, 2008). It is believed that the asphalt might form bonds between the RPM particles under compaction, which increases the resistance to smaller strain level deformation in the resilient modulus test. The bonding (or healing) of asphalt, upon contact, is a well-known phenomenon in the asphalt area (Kim and Little 1989, 1990). However, during the CBR test, which induces large strains and is destructive, these bonds are likely to break and the soft asphalt relative to the friction between aggregate particles leads to reduced resistance to large stresses. For unbound materials, the resilient modulus tests simulate the field traffic conditions involving smaller strains and are more representative than the large-strain conditions of the CBR test. Therefore, resilient modulus is more appropriate to characterise the materials for pavement design. There is a general correspondence of modulus and strength for natural earthen materials; however, it is noted that RPM does not conform to this general observation due to its particle characteristics.

For laboratory-mixed specimens, adding 14% fly ash to RPM increased the CBR of RPM from 19 to 129 (7-day of curing) and 176 (28-day of curing). The mean CBR of field-mixed SRPM (6 specimens), however, was only 62 and 94 after 7 and 28 days of curing, respectively.

The CBRs of field-mixed fly ash-RPM were 52% and 47% lower than that of laboratory-mixed fly ash-RPM after 7 and 28 days of curing, respectively. Li *et al.* (2007) reported similar differences in CBR for fly ash-RPM mixed in the field and in the laboratory. They reported that CBRs of field-mixed specimens were 66% lower than that of laboratory-mixed specimens. Bin-Shafique *et al.* (2004) reported similar reductions of CBR for silty clay and Class C fly ash mixtures. They reported that UCS of field

Table 4. Coefficient of variation for test results.

Material	Curing time (days)	CBR (%)	M_r (%)	Plastic strain (%)[a]	Flexural strength (%)	UCS (%)
Crushed aggregate	0	5	4	6	–	–
RPM	0	22	3	5	–	–
Laboratory-mixed SRPM	7	10	9	17	34	14
	28	6	5	3	43	12
Field-mixed SRPM	7	29	–	–	–	8
	28	41	–	–	–	38

Note: The dash mark '–' indicates not applicable or not available.

[a] Accumulated plastic strain at the end of the resilient modulus test.

specimens was two thirds of that of the laboratory specimens. The reduction in CBR of field-mixed specimens is believed to be due to uniform mixing achieved in the laboratory under controlled conditions as opposed to mixing in the field.

Unconfined compressive strength

In this study, the laboratory-mixed SRPM had UCS of 1160 and 1380 kPa after 7 and 28 days of curing, respectively. The field-mixed SRPM had lower UCSs (70% and 65%) than the laboratory-mixed SRPM after 7 and 28 days of curing, respectively. Li *et al.* (2007) reported that the UCS of field-mixed specimens was less than one half of the laboratory-mixed specimens for RPM stabilised with 10% Class C fly ash. Bin-Shafique *et al.* (2004) reported similar reductions of UCS for silty clay and Class C fly ash mixtures. They reported that UCS of field specimens ranged from one half to two thirds of that of the laboratory specimens. Since the moisture content, dry densities and curing conditions of both laboratory-mixed specimens and field-mixed specimens were same, it is again believed that the difference is due to the efficiency of mixing in laboratory field.

The strength/stiffness of field-mixed SRPM was significantly lower than that of laboratory-mixed SRPM, in terms of three different measures, i.e., CBR, SRM and UCS. These findings indicate that tests on laboratory-mixed fly ash-RPM mixtures are not representative of the materials in the field. It is suggested that the test results of laboratory-mixed fly ash-RPM be corrected to values for field-mixed fly ash-RPM as MEPDG input, which would provide a more realistic prediction of pavement performance. However, there may be additional discrepancies in SRPM properties due to the laboratory and field curing conditions, which are not investigated herein. However, in the longer term, the strength gain can be expected to be complete if sufficient moisture is provided during field mixing for hydration reactions.

Correlations between Levels 1 and 2 properties for fly ash stabilised base materials

In the MEPDG, the correlations between Level 1 and Level 2 properties are provided for lime or cement stabilised materials. In this study, the relationships between summary resilient modulus and Level 2 properties, such as UCS and CBR, specifically for fly ash stabilised materials were developed for use in the MEPGD. However, due to the limited number of tests available in this study, the test results of fly ash stabilised materials in previous studies by the co-authors of this paper (Wen *et al.* 2007, Camargo 2008) were combined with the test results of this study to cover a wider range of materials.

Camargo (2008) studied another RPM and road surface gravel (RSG) stabilised with Class C fly ash (10% and 15% by dry weight) after 7, 28 and 56 days of curing, respectively. Wen *et al.* (2008) studied RPM stabilised with 10%, 14% and 18% Riverside 8 fly ash for 7 days of curing. Wen *et al.* (2007) also studied the RPM stabilised with two high carbon cementitious fly ashes at different fly ash contents (6%, 10% and 14%) and curing periods (7, 28 and 56 days). The test data from these studies were combined to examine the correlation between M_r and other parameters, such as CBR and UCS.

The relationship between summary M_r and CBR is shown in Figure 2. In this figure, 'L-SRPM' is the laboratory-mixed stabilised RPM; in this study; 'SRPM' is the Class C fly ash stabilised RPM (Camargo 2008) and 'SRSG' is the Class C fly ash stabilised RSG (Camargo 2008). A strong correlation exists between M_r and CBR ($R^2 = 0.96$) for base materials stabilised with different fly ashes at different percentages, which suggests that M_r can be estimated from CBR for fly ash stabilised base materials. This relationship is given as:

$$M_r = 31.5\text{CBR} - 464 \tag{4}$$

where M_r is in MPa and CBR is in percent.

A similar relationship exists between M_r and UCS ($R^2 = 0.94$), as shown in Figure 3. This relationship can be described as:

$$M_r = 3.45\text{UCS} - 481 \tag{5}$$

where M_r is in MPa and UCS is in kPa. It is important to note that this relationship is quite different from the relationships for other additives (i.e. lime, cement or the mixture of lime-cement and fly ash) used for soil

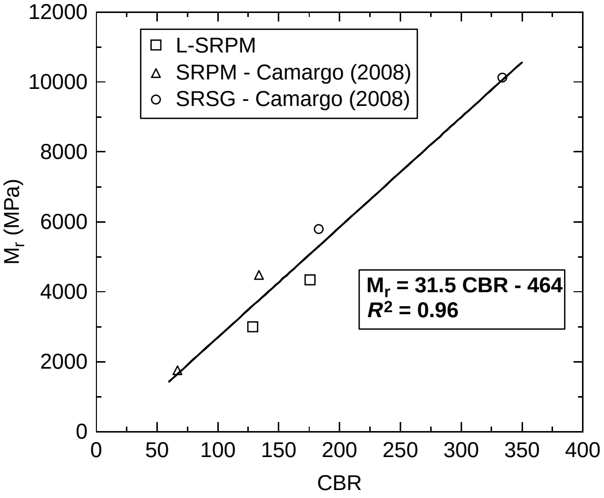

Figure 2. Relationship between resilient modulus and CBR of fly ash stabilised base course materials.

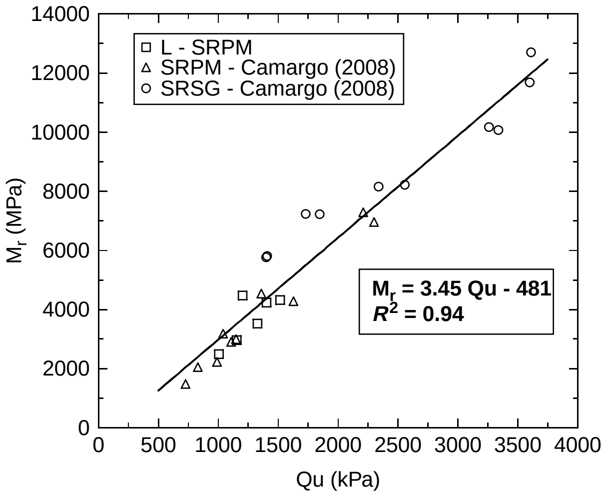

Figure 3. Relationship between resilient modulus and UCS for fly ash stabilised base course materials.

stabilisation by the MEPDG, as shown in Equations (1) and (2).

Thus, both CBR and UCS could be used for estimating the M_r of fly ash stabilised materials. In addition, CBR can also be used for estimating the UCS of stabilised recycled materials ($R^2 = 0.83$), as shown in Figure 4 and Equation (6).

$$\mathrm{UCS} = 10.8\mathrm{CBR} - 421 \tag{6}$$

where UCS is in kPa and CBR is in percent. It can be seen that in Figure 4, the data are more scattered ($R^2 = 0.83$) when compared to Figures 2 and 3. The reason was that more data sources were used in Figure 4. Nonetheless, a fairly good correlation was found between UCS and CBR values.

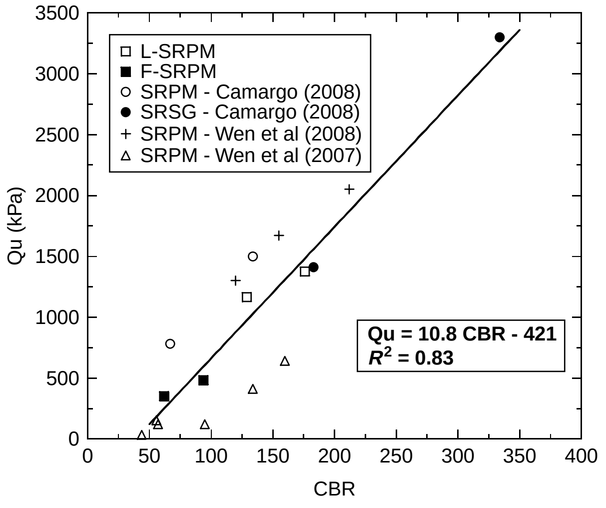

Figure 4. Relationship between CBR and UCS of fly ash stabilised base course materials.

Flexural strength

The MEPDG includes typical values of flexural strength of materials stabilised by cement or lime and indicates that flexural strength of these stabilised materials can be estimated to be about 20% of UCS (ARA 2004). However, no typical values or estimates of flexural strength of fly ash stabilised materials are included in the MEPDG. Flexural strengths for laboratory-mixed fly ash-RPM after 7 and 28 days of curing were 150 and 320 kPa, respectively. In this study, flexural strengths for laboratory-mixed fly ash-RPM were 13% and 23% of UCSs after 7 and 28 days of curing, respectively.

Conclusions and recommendations

This paper presents the results of the characterisation of an RPM with and without fly ash stabilisation, as a base material for pavement construction, and compared to the properties of traditional crushed aggregates, in terms of Level 1 and Level 2 properties in the MEPDG and their correlations.

The conclusions of this study are summarised as follows:

(1) Unstabilised RPM exhibited a higher modulus in the order of about 17% than the conventional natural base course material (i.e., crushed aggregate); however, RPM showed a higher plastic strain, indicating a higher potential for rutting by unstabilised RPM.
(2) The CBR of unstabilised RPM is significantly lower than that of the crushed aggregate (about 86%). Stabilizing RPM with a high carbon/high calcium fly ash, however, significantly increased the CBR and the M_r and lowered the plastic strain of this material (nearly fivefolds).
(3) The strength and stiffness of field-mixed RPM stabilised with fly ash was significantly lower than that of laboratory-mixed mixtures, in terms of three different measures, namely CBR, resilient modulus and UCS. It is suggested that the test results based on laboratory-mixed specimens should be corrected for input into the mechanistic-empirical pavement design procedure.
(4) Data obtained in this study, along with other data obtained from similar studies, indicate that there are good correlations between resilient modulus and CBR ($R^2 = 0.96$), as well as between resilient modulus and UCS ($R^2 = 0.94$) for RPM mixed with fly ash. However, there is a need for further testing to verify the proposed relationships due to the limited number of tests performed. Nonetheless, the proposed relationships constitute the first such relationships proposed and can be useful in pavement design.

(5) The flexural strengths for laboratory-mixed fly ash-RPM were 13% and 23% of their UCSs after 7 and 28 days of curing, respectively. It is suggested that the flexural strength of RPM stabilised with fly ash can be estimated as 20% of its UCS as proposed for other chemically stabilised materials in MEPDG.

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Notes

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