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Utilisation of Eraring (NSW) Power Plant Fly Ash as Pavement Base Material

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Summary Fly ash, which is produced from the combustion of pulverised coal, is the principal waste product of thermal power stations. Only a small amount is utilised and the rest is stockpiled. Increasing amounts of stockpiled fly ash may cause environmental problems and is becoming a public concern. The purpose of this paper is to examine the use of fly ash as a full depth base material in road pavements. Fly ash may have different engineering and mechanical properties, depending on the source of the coal used in the power station, therefore each type should be investigated individually. As the material does not manifest desirable engineering properties by itself, it was therefore decided to stabilise the fly ash with cement and lime separately.

Cement and lime stabilised samples of fly ash with various percentages of stabilising agent up to 10% by weight were prepared and subjected to mechanical tests in the laboratory. Of the tests that have been done, UCS (Unconfined Compressive Strength) testing demonstrated an increase in strength response of the material for curing periods from 7 days to 1 year. Although this is a common test method, it has limited application to pavement design. Therefore, repeated load triaxial and indirect tensile modulus tests have been carried out in order to evaluate the elastic modulus which is an important material property used in the mechanistic pavement design method. Grading and moisture-density relationship of samples were also investigated.

The results showed that stabilised fly ash is a promising substitute material for conventional pavement materials under certain conditions.

1. INTRODUCTION

After combustion of coal in thermal power stations, the uncombusted remains are carried from the burners by gases and collected by electrostatic precipitators and cyclones. This accounts for 80 percent of the total waste product and is called fly ash (McLaren et al. 1987).

In 1992, there were 98 power stations in Australia. According to Electricity Australia, (1993), 26 out of 98 were thermal power stations and mostly located in NSW.

Consumption of 20 million tonnes of coal resulted in the production of nearly 4.5 million tonnes of fly ash in NSW (Beretka et al., 1994).

Currently more than 90% of the fly ash has accumulated as waste product in ash ponds. This method of disposal is unsuitable environmentally, especially in the long term.

Road and pavement construction is an area where high volumes of fly ash may be utilised. These applications include the use of fly ash as filler in asphaltic concrete, in blended cement for concrete pavements, for subgrade stabilisation, in

embankments and as backfill in retaining wall construction. Importantly, it is possible to use cement or lime stabilised fly ash without aggregate as pavement base course. Geomechanics in a changing world requires less common applications in order to increase waste utilisation. Therefore this application of fly ash is the main concern of this paper.

2. PAVEMENT DESIGN FOR STABILISED FLY ASH

Basically, there are two types of pavement design in current practice around the world. The empirical design method is based on experience and from the results of test roads. This method is not suitable for the design of stabilised fly ash pavements because there is virtually no experience accumulated and fly ash has unique engineering and related properties, depending on the source of the coal used in the power station.

The analytical (structural) design method which uses theoretical analysis, mechanical and engineering properties of materials is capable of dealing with the design of stabilised fly ash. The analytical design procedures for stabilised fly ash pavements require knowledge of the response of the

material to loading in terms of modulus and strains (Austroads, 1992).

Laboratory tests have been carried out to obtain the engineering and related properties of fly ash for the design procedure mentioned above.

3. GENERAL PROPERTIES OF FLY ASH

The fly ash used in this study was obtained from Pacific Power's Eraring power station. It is a fine grained, class F fly ash. The chemical composition and other related properties of the material may be found elsewhere (Lav and Kenny, 1996). The grading of fly ash is given in Figure 1.

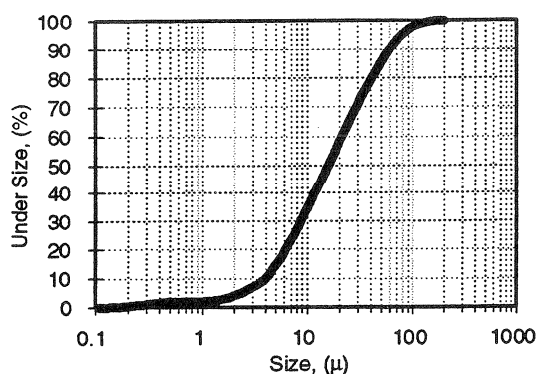


Figure 1. Grain size distribution of fly ash

4. ENGINEERING PROPERTIES OF STABILISED FLY ASH

In order to be used as a base course for a road pavements, fly ash should be mixed with a stabilising agent such as lime or cement in order to enhance its mechanical properties (GAI Consultants Inc., 1986). Therefore it was decided to stabilise fly ash with cement and lime separately. Stabilising agent content was 2%, 4%, 8%, 10% by weight respectively. The following tests were performed in the laboratory.

4.1. Moisture-Density Relationship

The standard compaction test was performed comprising the RTA test method T130 for the cement stabilised samples and the RTA test method T140 for the lime stabilised samples. The moisture-density results are shown in Figure 2.

All the samples in this study were compacted in accordance with the results obtained in Figure 2.

4.2. Strength Development Within Time

The unconfined compressive strength (UCS) test has been commonly used to determine the relative response of materials to cement and lime stabilisation (NAASRA, 1986).

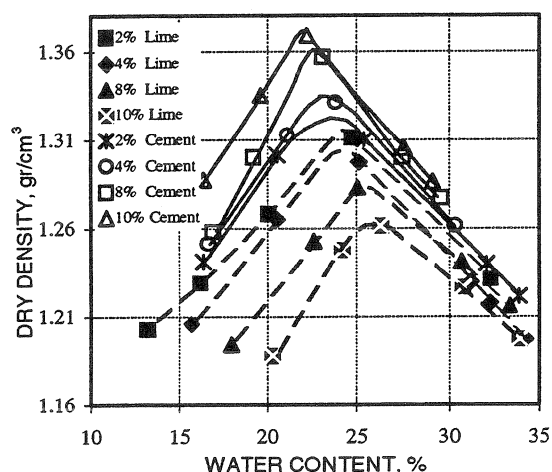


Figure 2. Moisture- density relationship of stabilised fly ash samples

The UCS samples were prepared and tested according to the RTA test method T131 for the cement stabilised samples and T141 for the lime stabilised samples. Cylindrical samples having a diameter of 105 mm and a height of 115 mm. The samples were wrapped in plastic bags and cured in a fogged room until the test date. Before being tested, the samples were cured for 7 days, 14 days, 28 days, 90 days and 360 days. The test results are shown in Figure 3 for lime stabilised samples and Figure 4 for cement stabilised samples.

4.3. Texas Triaxial Test

The Texas triaxial test is an undrained triaxial shear test which measures the deformation resistance of pavement base materials (Lay, 1985).

Two sets of samples each containing 2% cement and 2% lime were prepared. In order to compare the stabilisation effect between lime and cement, the tests were carried out after 7 days of preparation. There were 4 samples in each set and each sample was tested at different confining stress, (10 kPa, 30 kPa, 60 kPa, 90 kPa) until failure. The Coulomb failure envelopes of the four samples tested were then compared to the standard envelopes to assign a "Texas triaxial classification number" which is 1.4 for cement stabilised fly ash and 3.1 for lime stabilised fly ash.

4.4. Flexural Strength Test

Samples were prepared and tested for determining the flexural strength of stabilised fly ash in accordance with AS 1012.11. The samples were compacted in a purpose-build steel mould which has a length of 350 mm, a height of 100 mm and a depth of 100 mm. During the test, the load was applied to

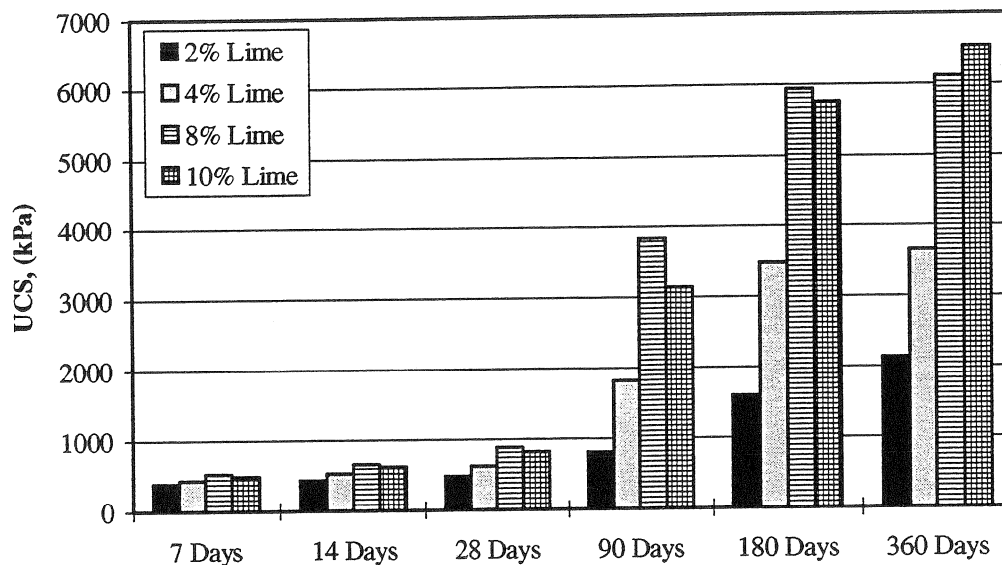


Figure 3. UCS Results of Lime Stabilised Fly Ash Samples

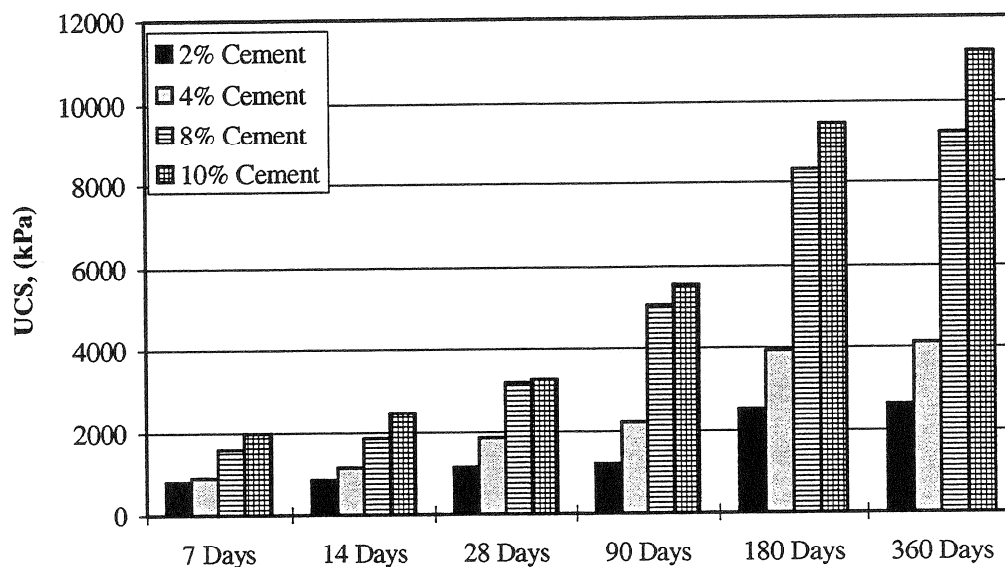


Figure 4. UCS Results of Cement Stabilised Fly Ash Samples

the sample through a frame which has two parts. The upper part consist of two loading rollers and lower part consist of two supporting rollers. The span length of the samples between the supporting rollers were 300 mm. The load were increased continuously at 1 Mpa/min until the failure. The test results are given in Table 1.

Table 1. Flexural Strength Test Results

Sample Type	Load at failure (N)	Flexural strength (kPa)
2% Cement	430	126.6
4% Cement	915	266.1
8% Cement	1970	577.7
10% Cement	2500	726.7
10% Lime	430	124.2

4.5. Indirect Tensile Modulus Test

The structural analysis of road pavements requires the determination of modulus as a crucial part of the process. Of the several methods for determination of modulus, indirect tensile strength test may be used for this purpose, (Austroads, 1992).

The cylindrical samples having a diameter of 105 mm were prepared. The length of the samples varies between 51.5 mm and 70.5 mm. In the test, 5 consecutive loading force were applied to the samples along the vertical diametral plane. The average of force applied and the average of strain from the perpendicular axes to the force applied measured for modulus calculation.

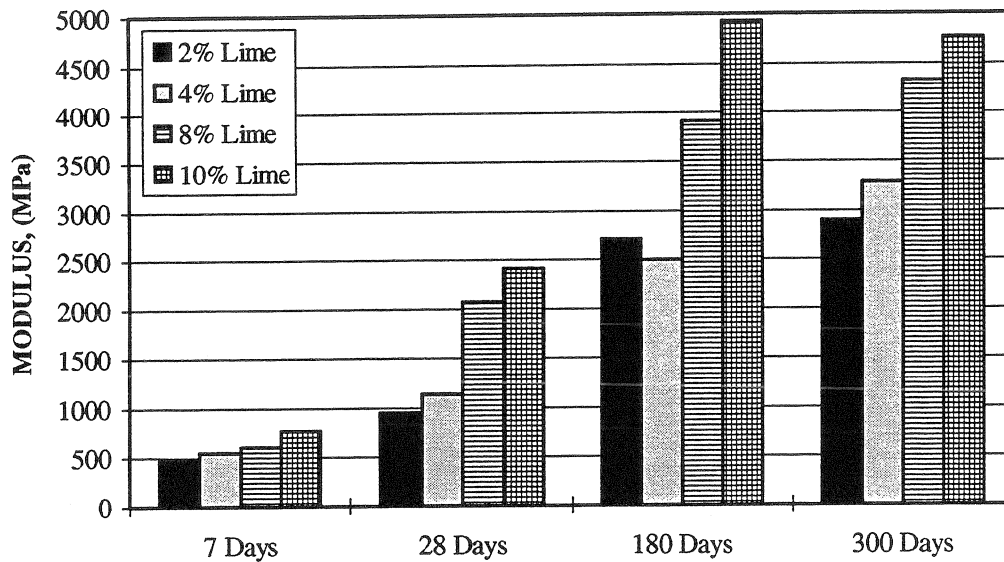


Figure 5. Indirect Tensile Modulus of Lime Stabilised Fly Ash Samples

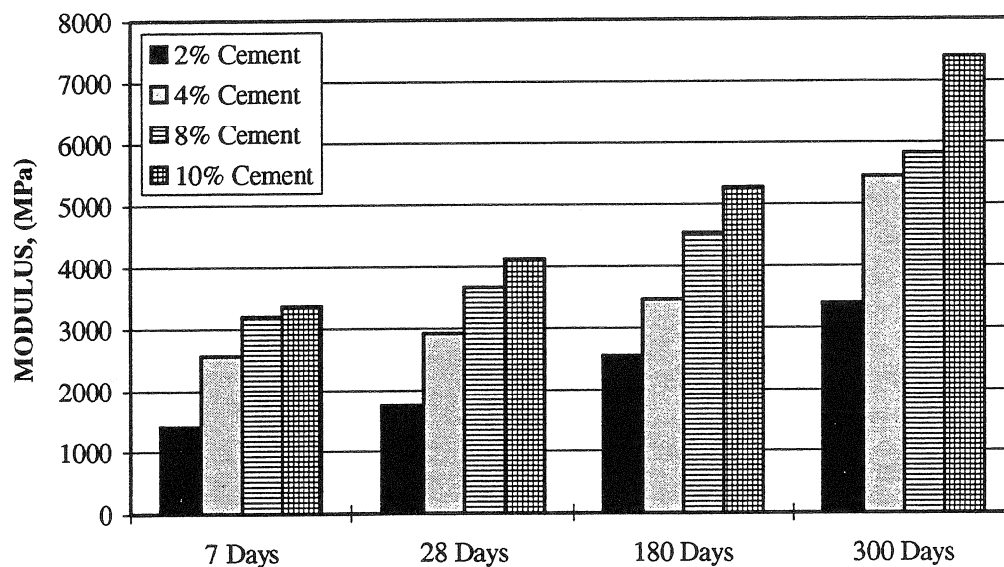


Figure 6. Indirect Tensile Modulus of Cement Stabilised Fly Ash Samples

The test was carried out for 7 days, 28 days, 180 days and 300 days samples. The results are given in Figure 5 for lime stabilised samples and Figure 6 for cement stabilised samples.

4.6. Repeated Load Triaxial Test

The repeated load triaxial testing method has been extensively used to characterise the stress-strain behaviour of pavement materials. The repeated load triaxial machine was used by Grainger and Lister, (1962), as early as sixties to characterise the performance of soils and unbound pavement materials.

Until recently, it was not the favourable method of assessing the mechanical behaviour of cemented material. In 1993, Vic Roads roads suggested that

the triaxial apparatus may be used for determining of the resilient modulus of the cemented material.

In this study, triaxial samples which have a diameter of 100 mm and a height of 200 mm were prepared and tested at various stress paths. Constant confining pressures, namely, 250 kPa, 200 kPa, 100 kPa and 50 kPa were applied respectively. Air was used as confining pressure. For each confining pressure, increasing deviator stress, namely, 50 kPa, 100 kPa, 150 kPa and 200 kPa was applied consecutively. The axial strains were measured until six consecutive identical strains obtained. Otherwise, 200 hundred vertical pulses were applied for each stress path. The wave shape of loading was haversine with a loading time of 0.1 seconds and a loading frequency of 1 Hz. The intended stress

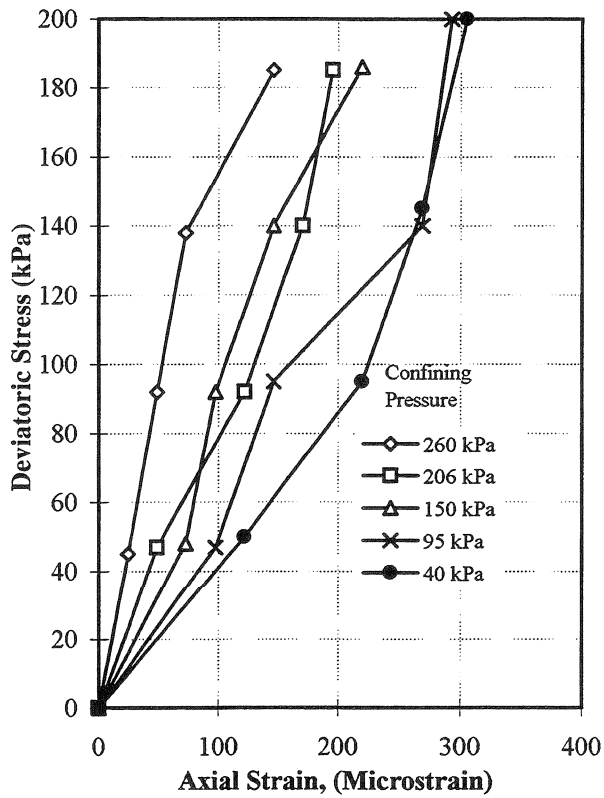


Figure 7. Repeated Load Triaxial Test Results of 2% Cement Stabilised Fly Ash Samples

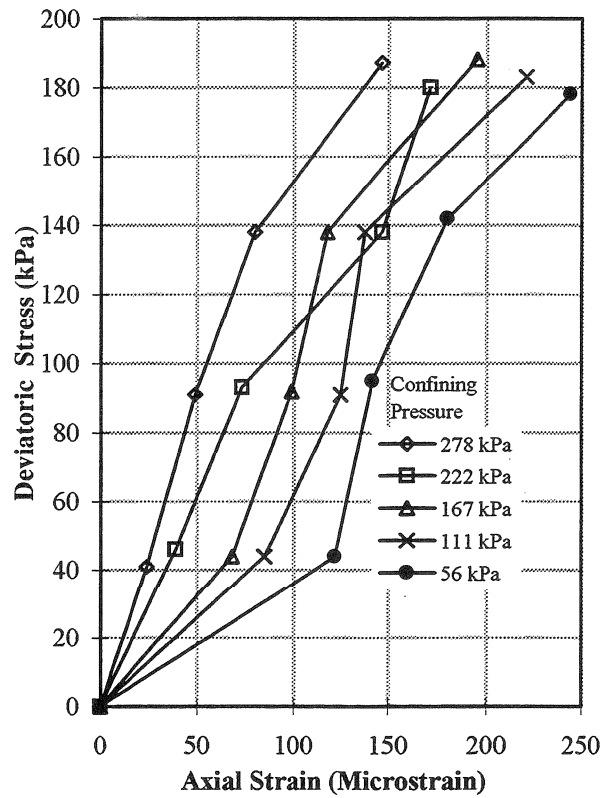


Figure 8. Repeated Load Triaxial Test Results of 8% Cement Stabilised Fly Ash Samples

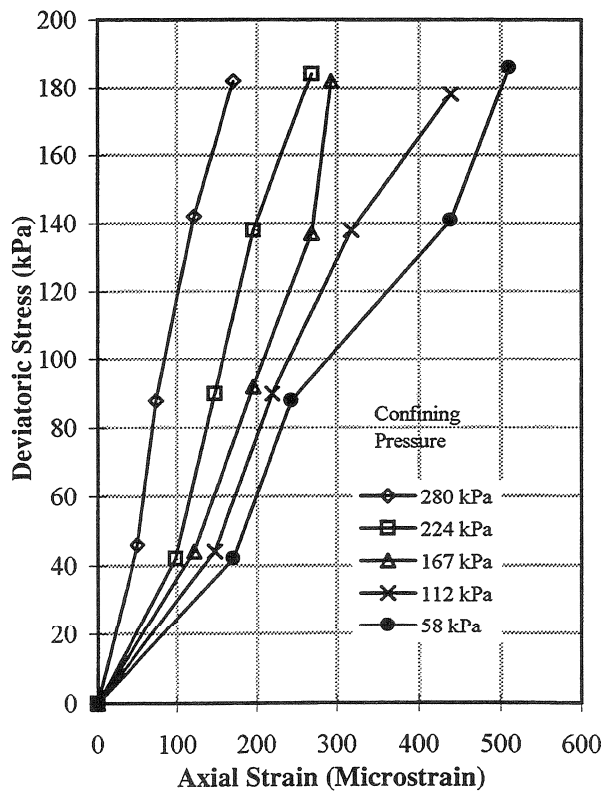


Figure 9. Repeated Load Triaxial Test Results of 2% Lime Stabilised Fly Ash Samples

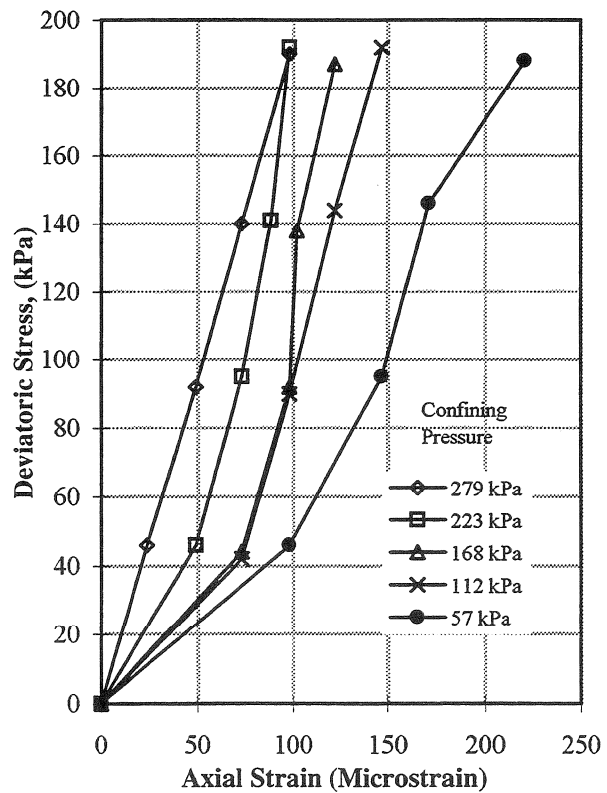


Figure 10. Repeated Load Triaxial Test Results of 10% Lime Stabilised Fly Ash Samples

paths mentioned above could not be achieved exactly due to the difficulty of keeping air pressure at desired level. But the tests were completed successfully achieving close pressures to the target stress paths. This has no negative effect on further analytical studies. The results are shown from Figure 7 to Figure 10.

5. CONCLUSIONS

Moisture-density relationship of all samples are close to each other because of relatively low additive content. Therefore the behaviour of fly ash dominates in the compaction process. But it was observed that lime stabilised fly ash requires more moisture than cement stabilised fly ash due to the chemical behaviour of lime. As can be seen from Figure 2, this trend increases with lime content. For that reason compaction operation should be completed within one hour.

The strength gain of both cement and lime stabilised fly ash are adequate. It should be noted that the strength gain increases over time. The reason is not only additive hydration but also pozzolanic reactivity of the fly ash because of its fineness and low loss of ignition (LOI).

The indirect tensile modulus values also increase over time. Also there is correlation between the UCS and modulus results. According to Austroads Pavement Design Manual, the modulus values are acceptable within the range for a base material.

Texas triaxial tests revealed that the material is suitable to use as a base course in terms of its shear resistance.

Flexural strength of stabilised fly ash gives initial data for dynamic testing of the material which is an important part of assessing the fatigue relationship with loading.

Repeated load triaxial test results (Figure 7 to 10) show the nonlinear behaviour of the material. This will be used in the nonlinear structural design of stabilised fly ash pavements. It was noticed that the stress-strain behaviour of the material changes significantly under different loading time and loading frequency. At the moment this case is being investigated.

In conclusion, according to the initial test results presented, cement and lime stabilised fly ash may be used as pavement base material.

6. ACKNOWLEDGMENTS

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