NACOE
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FINAL REPORT

Project Title: P30: Use of Bagasse Ash and Fibres in Pavement Construction
(Year 2 – 2015/16)

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P30: Use of Bagasse Ash and Fibres in Pavement Construction

SUMMARY

Queensland is one of the largest sugarcane producing regions in the world. The process of extracting sugar results in large quantities of a fibrous by-product known as bagasse, which is often incinerated to generate energy for the sugarcane processing plant and/or fed back to the municipal power grid. The residual by-product, bagasse ash, is currently considered a waste material requiring long-term storage in large stockpiles or disposal in landfills.

Bagasse ash and fibres are currently used in pavement construction in other sugar-producing countries, with the most common treatment being to blend bagasse into expansive subgrade soils to reduce shrinkage/expansion effects. This treatment will often require blending the bagasse ash with a traditional chemical stabilising agent such as lime. The vast quantities of excess bagasse ash and fibre present opportunities for an alternative treatment option for expansive subgrades while providing both environmental and economic benefits.

In the first year of study, a health and safety review found that the materials presented no additional risks that are not already taken into account for stabilisation products such as lime and fly ash.

The project has been funded (with a reduced budget) to sample and deliver high-plasticity fine-grained (blacksoil) materials to Sydney to facilitate the continuation of a laboratory testing program.

Laboratory testing at the University of Technology Sydney (UTS) found that bagasse ash, while not especially effective as a standalone treatment, when applied in a 3:1 blend with lime, did improve the performance of reactive blacksoils, both in terms of increased strength and in reduced linear shrinkage. The results were such that should this material be easy to source and show signs of being consistent in properties and performance, it could be used to offset a percentage of the lime currently used in subgrade stabilisation. This would likely lead to significant cost savings for comparable or superior performance.

This document constitutes the annual deliverable for this NACOE project. It summarises the key findings of the laboratory testing program, with the full research paper from University of Technology Sydney (UTS) included as Appendix A. This report also documents other outcomes of this project, including publications and presentations based on the laboratory data. The laboratory testing program is due to be finalised in 2017.

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1 SUMMARY OF UTS TESTING RESULTS

1.1 UTS Research Program

The following represents a broad outline of the bagasse ash and fibre research master schedule for the University of Technology Sydney (Table 1.1).

Table 1.1: Components for UTS research program (2014–17)

Task no.	Research component	Dates	Notes
1	Literature review on behaviour of untreated and treated expansive soils	Spring 2014 – Autumn 2017	In progress
2	Laboratory preparation (observations, samples preparation, setting up and running the trial testing apparatuses)	Spring 2014 – Autumn 2015	Complete
3	Conducting laboratory experiments on hydrated lime, bagasse ash and fibre treated and untreated expansive soil specimens to examine the mechanical properties of expansive soil	Autumn 2015 – Autumn 2017	In progress
4	Developing 2D & 3D numerical models proposed to simulate the performance of lime-fibre reinforced LTP and bagasse ash-lime columns supported highway embankments over expansive soil in terms of stress transfer mechanism, settlement, and variation of excess pore water pressure	Spring 2015 – Spring 2017	In progress
5	Validation of proposed numerical analysis results of the embankments with field observation data published in literature preview	Autumn 2016 – Spring 2017	Future task
6	Guidelines for practical applications of roads and railway networks constructed on lime-bagasse ash and fibre stabilised expansive soils	Autumn 2017 – Spring 2017	Future task
7	Publications (journal articles, conference papers etc.)	Spring 2015 – Spring 2017	In progress

1.2 Interim Test Results

The UTS study investigated the effects of various combinations of lime and bagasse ash on linear shrinkage, unconfined compressive strength (UCS), California bearing ratio (CBR) and free swell percentage.

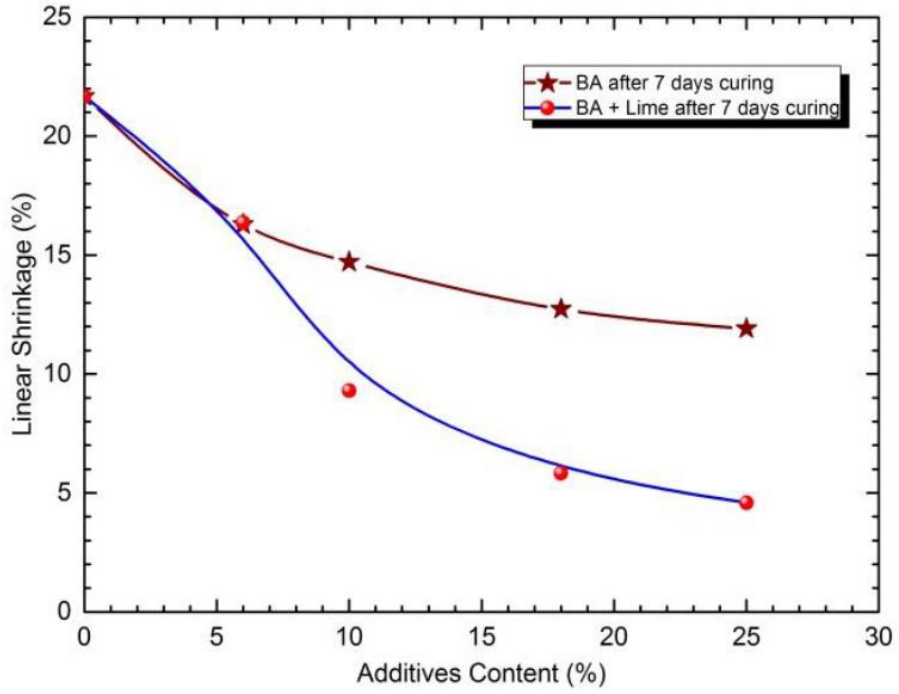
Details on the blacksoil and bagasse material properties are available in the full laboratory report from UTS (attached to this report as Appendix A). Select findings and graphs from the tests with bagasse ash and fibres, on their own and in combination with lime, are included in this section to illustrate the most significant findings.

1.2.1 Linear Shrinkage

The soil sample as tested without any additives, exhibited high linear shrinkage at around 22% (Figure 1.1). The addition of bagasse ash alone has a strong effect on linear shrinkage, dropping below 15% with 10% bagasse ash, however the largest gains are when used in conjunction with lime. It is unclear whether this shift would be sufficient to move the material into conformance with specifications.

It was noted that with this soil sample, there was little change in linear shrinkage for lime content of 1.5%, but a large reduction for lime content of 2.5%, with diminishing returns after this point. Similarly, with the bagasse/lime blend, a 2.5% lime and 7.5% bagasse blend reduced the linear shrinkage from 22% to under 10% after just three days curing. It does not appear as though a lime demand test was undertaken by the UTS laboratory.

Figure 1.1: Effect of bagasse ash and lime on linear shrinkage (7 days curing)



1.2.2 Unconfined Compressive Strength (UCS)

The addition of lime and bagasse to the natural blacksoil led to increased compressive strength, as measured using the UCS test. Much of this was due to the stabilising influence of the lime rather than the bagasse, as evidenced by the eventual drop-off in strength for a bagasse replacement content of 25% (Figure 1.2). A 2.5% lime and 7.5% bagasse ash blend led to a compressive strength increase from 138 kPa to around 350 kPa (Figure 1.3).

Figure 1.2: Effect of bagasse ash on compressive strength of blacksoil

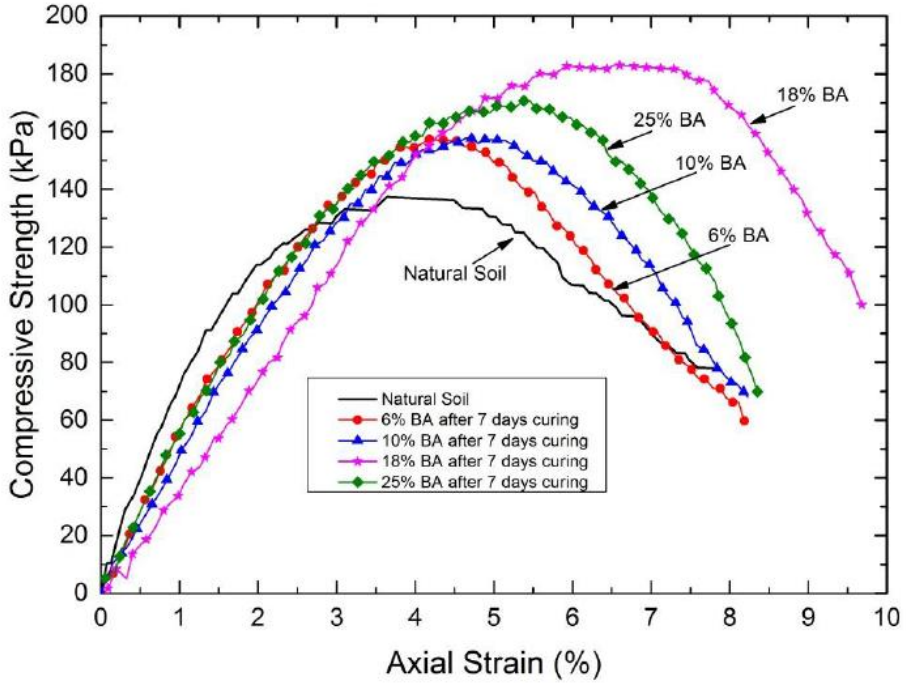
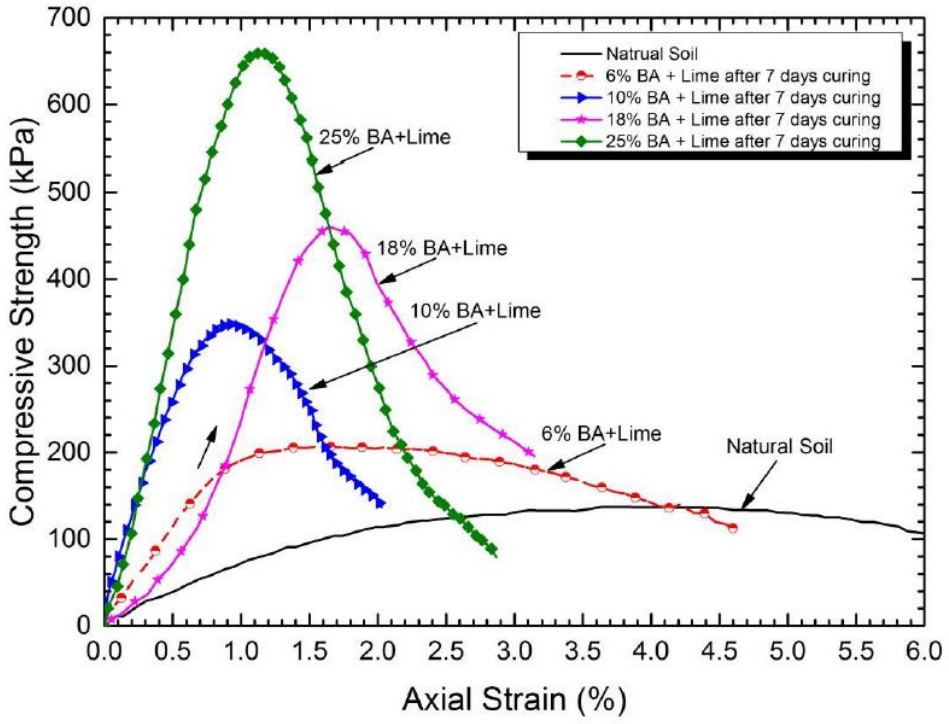
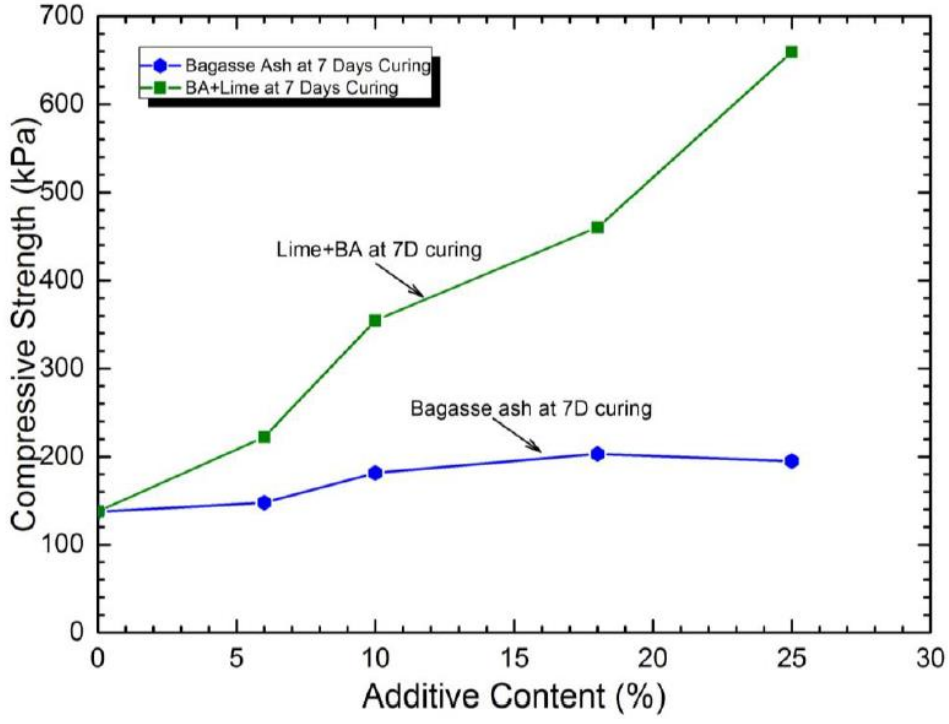


Figure 1.3: Effect of lime/bagasse ash blend on compressive strength of blacksoil



When assessed as a comparison between the compressive strength and additive content (Figure 1.4), the impact of the bagasse itself is clearly minimal, although it does not appear to be leading to a reduced compressive strength. Lime/bagasse blends lead to large strength gains, particularly at 2.5% lime and above.

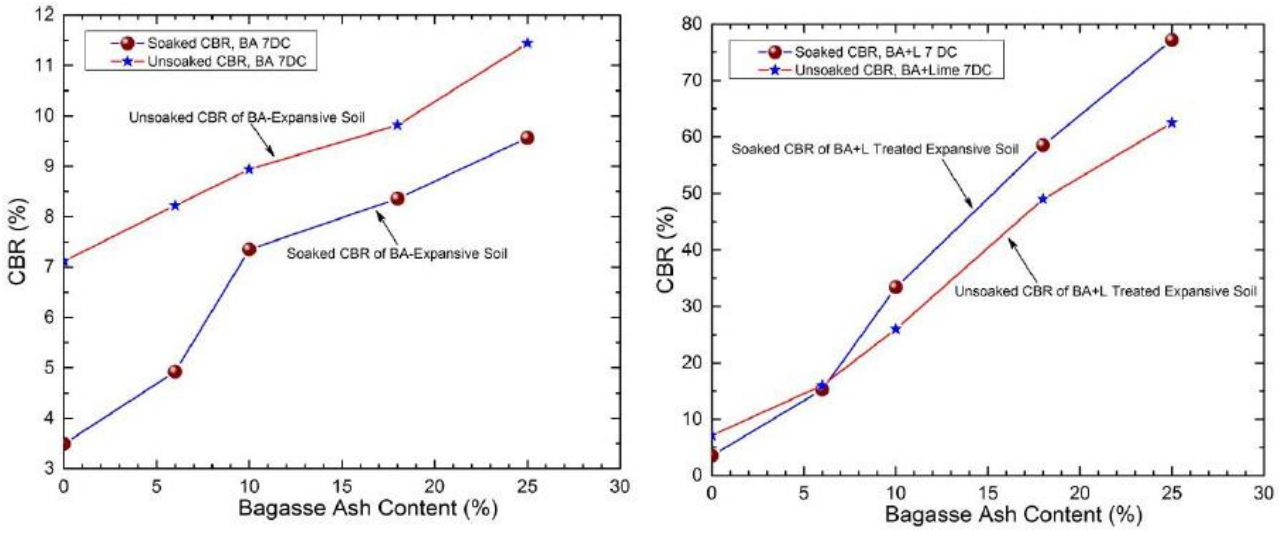
Figure 1.4: Unconfined compressive strength of blacksoil after 7 days curing with bagasse ash and lime/bagasse blends



1.2.3 California Bearing Ratio (CBR)

Bagasse ash alone had a small effect on soaked CBR values of the blacksoil, increasing CBR from 3.5% to just over 7% at 10% bagasse ash content (Figure 1.5). However, when combined with lime, the impact is much more substantial. The 2.5% lime and 7.5% bagasse ash blend had a CBR ratio of 33% after 7 days curing.

Figure 1.5: Effect of bagasse ash and lime/bagasse blend on soaked and unsoaked CBR of blacksoil

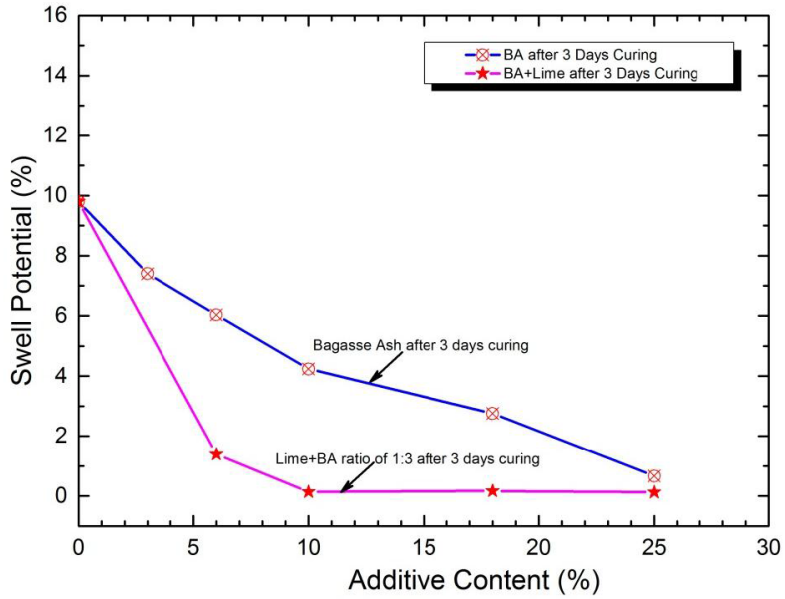


1.2.4 Free Swell Percentage

The swell percentage of the blacksoil dropped from around 10% to negligible levels with the 2.5% lime and 7.5% bagasse ash blend (Figure 1.6). There was also a significant drop for the 'bagasse only' mixes, but in a more linear fashion (potentially suggesting this was due to replacing material).

Bagasse ash alone does appear to reduce swell, but remains at a level at which stabilising or adding cover over the subgrade would still likely be required.

Figure 1.6: Effect of bagasse ash and lime/bagasse blend on swell potential of blacksoil



1.2.5 Tests on Bagasse Fibres

While not a primary objective of the initial TMR investigations into bagasse in expansive soil, UTS has also looked at the impact of bagasse fibres (before being burned) on shrinkage and strength when added to blacksoil.

Adding 1% bagasse fibre to natural blacksoil did in fact have a strong effect on shrinkage, with linear shrinkage dropping from 22% to around 13% after 7 days curing. A combination of lime (2.5%) and bagasse fibres (0.5%) had a strong effect, with the linear shrinkage dropping to 10% (while lime alone was only enough to bring linear shrinkage down to 13%).

There were also significant strength increases when treating blacksoil with bagasse fibres, and with a combination of bagasse fibres and lime. Laboratory testing with bagasse fibres is ongoing.

1.3 Publications and Presentations

The University of Technology Sydney has published a number of reports based on the testing conducted to date. This research was made possible by the support for this work under the NACOE program and the supply of materials by the Australian sugarcane industry. Completed and upcoming publications include:

- Dang, L 2016, *Enhancing the Engineering Properties of Expansive Soil Using Bagasse Ash, Bagasse Fibre and Hydrated Lime,* PhD Candidature Assessment Report - University of Technology Sydney – School of Civil and Environmental Engineering (see Appendix A).
- Dang, L, Dang, C, Fatahi, B & Khabbaz, H 2016, *Numerical Assessment of Fibre Inclusion in Load Transfer Platform for Pile-Supported Embankments over Soft Soil*, GeoChina 2016, Shandong, China.
- Dang, L, Hasan, H, Fatahi, B, Jones, R & Khabbaz, H 2016, *Enhancing the Engineering Properties of Expansive Soil Using Bagasse Ash and Hydrated Lime*, International Journal of GEOMATE, Vol.11, No.25, pp.2447–54.
- Dang, L, Hasan, H, Fatahi, B & Khabbaz, H 2015, *Influence of Bagasse Ash and Hydrated Lime on Strength and Mechanical Behaviour of Stabilised Expansive Soil*, GEO Québec 2015, eds J. Côté & M. Allard, Québec City, Canada.
- Dang, L, Khabbaz, H, Fatahi, B & Hasan, H 2016, Geotechnical Characteristics of Expansive Soil Stabilised with Bagasse Ash and Hydrated Lime.
- Hasan, H 2015, *Adverse Effects of Expansive Soils on Infrastructure and Evaluation of Remediation Techniques,* Doctoral Assessment Report - University of Technology Sydney – School of Civil and Environmental Engineering.
- Hasan, H, Dang, L, Khabbaz, H, Fatahi, B & Terzaghi, S 2016, *Remediation of Expansive Soils Using Agricultural Waste Bagasse Ash,* Advances in Transportation Geotechnics 3 - The 3rd International Conference on Transportation Geotechnics (ICTG 2016), Procedia Engineering, Volume 143, pp.1368–1375.

1.4 Future Work

The UTS testing program is due for completion sometime during 2017. At this time, it would be worthwhile assessing the potential of this material in treating expansive blacksoil in Queensland. Should further work be warranted, field trials could be considered.

APPENDIX A UTS TESTING REPORT

Attached is a copy of the candidature assessment report for PhD candidate Liet Chi Dang, one of the UTS researchers into the performance of bagasse ash and fibres in blacksoil.

This report is only to be circulated between the stakeholders of the bagasse research program, as it represents a progress report on the background to the research, the testing completed to date and plans for future testing.