Introduction

- Basecourse failure heavily associated with pavement failure
- Is it feasible to achieve laboratory densities (95-98%) in the field?
- Are we getting what we want from laboratory compaction and basecourse tests?
Overview

Objectives
- Background - Repeated Load Triaxial Test
- Laboratory Methods of Basecourse Compaction
  - Vibratory Hammer and Kneading
- Variables Monitored
  - Particle Size Distribution (PSD)
  - Dry Density
  - Repeatability
- Results
- Conclusion

Objectives – Compaction Study

- Undertake Literature Survey
  - Identify common compaction methods
  - Determine their applicability to RLT specimen compaction
- Develop Compaction Gear and Methodology
- Compaction of M/4 and Permeable basecourse using:
  - Vibratory Hammer Compaction, and
  - Kneading Compaction
- Determine Ideal Mode of Compaction of M/4 and Permeable Basecourse
Background – Repeated Load Triaxial (RLT) Test

Small Scale RLT
- 150mmΦ by 300mm high specimen
- Literature suggests removing 19mm+ aggregates (Shackel 2006, Molenaar 2010)
- Vibratory compaction
- Aggregate degradation
- Saturation, frequency and aggregate to specimen size not relating to field condition

Large Scale RLT
- University of California, Berkeley
- 250mmΦ by 625mm high specimen
- Allows for full NZ M/4 basecourse spectrum to be tested
- Vibratory and Kneading compaction
- Saturation, frequency and aggregate to specimen size is comparable to field condition

Laboratory Methods of Basecourse Compaction

- Vibratory Hammer Compaction
  - Most common method of basecourse compaction. Due to:
    - High energy output
    - Ease of use
    - Availability of compactor
  - Achieves high dry densities
  - NZS 4402 : Test 4.1.3
  - Target density rather then maximum energy output
Laboratory Methods of Basecourse Compaction – Vibratory Hammer Compaction

- Aggregate degradation affects reproducibility
- Problems with reproducibility can be associated with (Investigation of the Variability in the Results of the NZ Vibrating Hammer Compaction Test (Shahin (2011))):
  - Operator learning
  - Operator error,
  - Hammer energy,
  - Oversized particles, and
  - Aggregate degradation and segregation
- Reproducibility of specimens significant for RLT testing
- Enough variation to make it unsuitable for RLT specimen compaction?

Laboratory Methods of Basecourse Compaction – Kneading Compaction

- Made in early 1970’s by Dr Do Van Toan (Toan 1975)
- Compacts in layers
- Foot Pressure of 1000 kPa
- Dwell time of 2 seconds

Compaction Foot
Variables Monitored

- Basecourse compaction in the lab should replicate field compaction so that field basecourse performance can be predicted in the lab
- This involves replicating:
  - Field densities, and
  - Particle Size Distribution (PSD)
- Failure to do so often results in unpredictable basecourse performance in field then as perceived in the lab
- Difficult to replicate in the lab due to compaction method and rigidity of the mould

Small Scale Vibratory Compaction

PSD’s

M/4 Post Vibratory Compaction PSD

- Test 1
- Test 2
- Test 3
- Test 4
- Test 5
- Test 6
- Test 7
- Test 8
- Upper Limit
- Lower Limit
- Pre Compaction
Small Scale Vibratory Compaction
PSD’s

Permeable Mix Post Vibratory Compaction PSD @ varying MC
(Post MDD Tests)

The University of Auckland
New Zealand
28 March 2014

Large Scale Kneading Compaction
PSD’s

Kneading Compaction of M/4 Basecourse at 4% WC

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New Zealand
28 March 2014
Large Scale Vibratory Compaction
PSD’s

Vibratory Compaction of M/4 Basecourse at 4% WC

Density of Specimens

<table>
<thead>
<tr>
<th>Dry Density (kg/m³)</th>
<th>Compaction Type</th>
<th>M/4 Basecourse</th>
<th>Permeable Basecourse</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kneading</td>
<td>2043</td>
<td>1853</td>
<td></td>
</tr>
<tr>
<td>Vibratory</td>
<td>2070</td>
<td>1961</td>
<td></td>
</tr>
</tbody>
</table>

- Similar density for M/4 basecourse
- Vibratory compaction achieved higher density for permeable basecourse
- Field correlation / Plateau testing
- MDD of M/4 basecourse material approximately 2350 kg/m³ - achieved through compaction in smaller mould ((The effect of grading on the performance of basecourse aggregate)(Arnold, Werkmeister and Alabaster (2007)))
- 95% of MDD is 2232 kg/m³
- Over compaction in field / small scale densities too high?
Conclusions

- Compaction energy needs to be controlled in order to avoid aggregate degradation.
- The small RLT mould can lead to the degradation of aggregates.
- The larger RLT mould reduces aggregate degradation.
- Aggregate size to specimen diameter ratio of at least 1:6 must be adhered to when compacting basecourse aggregate in the laboratory.
- Failure to do so will result in non-representative densities and aggregate degradation in the laboratory that are unrealistic in terms of setting a specification target for field density.
- Field compaction to laboratory compaction calibration should be considered.

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THANK YOU
Large Scale Vibratory Compaction PSD's

Vibratory Compaction of Permeable Basecourse @ 1% WC

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Layer 1</th>
<th>Layer 2</th>
<th>Layer 3</th>
<th>Layer 4</th>
<th>Lower Limit</th>
<th>Upper Limit</th>
<th>Pre Compaction</th>
<th>Entire Specimen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Limit</td>
<td></td>
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<td>Entire Specimen</td>
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<tr>
<td>Upper Limit</td>
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<td>Pre Compaction</td>
<td>Entire Specimen</td>
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<tr>
<td>Cumulative % Passing</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>Pre Compaction</td>
<td>Entire Specimen</td>
</tr>
</tbody>
</table>

Equipment Used

Vibratory Hammer Compactor
- 85 sec maximum compaction duration per layer

Kneading Compactor
- 1000 kPa foot pressure
- 2 sec dwell time
- 25 tamps per layer
Methodology

- Specimens split using rifle box
- Water Content of M/4 raised to 4% (OWC 4-5%); Permeable compacted at NWC of 1%
- Compaction
  - Vibratory hammer for 85 seconds per layer for 6 layers
  - Different from targeting the density of each layer / specimen
  - Kneading for 6 layers
  - Controlled energy output
- 6 layers dried separately in oven overnight
- Dry sieving to determine PSD of each layer and thus the entire specimen