Over-coming differential settlement in soft grounds using ‘Floating Semi-Rigid Pavement’

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Objectives

- Sustainable road construction
  - Building durable roads with proven performance in soft grounds

- Improved bearing capacities
  - By maintaining the soaking strength against possible damages due to swelling, shrinkage and seepage.

- Minimize differential settlement
  - Creating a platform effect to reduce total settlement and minimize differential settlement, even under long term soaking conditions.
Peat: Water-logging and acidic conditions
Road on piled foundation in peaty soils
Coastal towns and high tides
Roads under constant soaking conditions
Differential settlement
Perennial flooding for planting in the granaries
Background

Deep marine clay.
High tidal levels.
Serious settlement.
Operation capacity far below designed.

Key Technical Merits

Pavement rehabilitation
By re-cycling in-situ crusher run below existing pavement to form a Semi-Rigid Platform to eliminate differential settlement and upgrade container stacking capacity.
Typical Container Yard

20 Tons each container ⇒ 20 × 6 = 120 Tons

0.4m CRUSHER RUN - 105 kN/m²
0.4m LEAN CONCRETE - 70 kN/m²
0.8m CRUSHER RUN - 105 kN/m²
## Bounded (stabilized) structure vs Unbounded

<table>
<thead>
<tr>
<th>Pavement Structure</th>
<th>100 mm heavy duty inter-locking pavers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400 mm thick Grade 15 concrete slab</td>
</tr>
<tr>
<td></td>
<td>800 mm compacted crusher run (semi-rigid sub-base)</td>
</tr>
<tr>
<td>Sub-grade</td>
<td></td>
</tr>
</tbody>
</table>
In service 9 months after construction (Phase I, 2011)

QC Testing Results:

Ave UCS (7-d) = 2.9MPa (spec > 2.0MPa)
Ave CBR (7-d) = 141.5% (spec > 120%)
**Background**

1. Airport runway and taxiway widening to meet Airbus A380 operational requirements.
2. Re-cycling in-situ soil with high clay content (80%), high LL: 80%, PI: 45%, high natural moisture content (2 x OMC)
3. UCS: 2.0 Mpa, CBR: 120%, Degree of compaction: 98%

### SENAI AIRPORT RUNWAY SHOULDER WIDENING
Soil Investigation Summary

<table>
<thead>
<tr>
<th>NO</th>
<th>LOCATION</th>
<th>DEPTH (mm)</th>
<th>INSITU OMC (%)</th>
<th>OMCE (Mg/m³)</th>
<th>MDD (Mg/m³)</th>
<th>LL (%)</th>
<th>PI (%)</th>
<th>CLAY&amp;SILT (%)</th>
<th>SAND (%)</th>
<th>GRAVEL (%)</th>
</tr>
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<tr>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>6</td>
<td>P6</td>
<td>350</td>
<td>23.59</td>
<td>15.00</td>
<td>1.74</td>
<td>73</td>
<td>36</td>
<td>54.80</td>
<td>32.40</td>
<td>12.80</td>
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<tr>
<td>7</td>
<td>P7</td>
<td>350</td>
<td>30.08</td>
<td>22.00</td>
<td>1.49</td>
<td>88</td>
<td>37</td>
<td>78.80</td>
<td>19.20</td>
<td>2.00</td>
</tr>
<tr>
<td>8</td>
<td>P8</td>
<td>350</td>
<td>41.63</td>
<td>18.00</td>
<td>1.54</td>
<td>76</td>
<td>31</td>
<td>70.40</td>
<td>2.60</td>
<td>27.00</td>
</tr>
<tr>
<td>11</td>
<td>P11</td>
<td>350</td>
<td>27.38</td>
<td>19.00</td>
<td>1.68</td>
<td>62</td>
<td>33</td>
<td>66.80</td>
<td>33.20</td>
<td>0.00</td>
</tr>
<tr>
<td>12</td>
<td>P12</td>
<td>350</td>
<td>38.74</td>
<td>19.00</td>
<td>1.55</td>
<td>79</td>
<td>46</td>
<td>82.70</td>
<td>17.20</td>
<td>0.10</td>
</tr>
</tbody>
</table>
200 mm thick access – Caltex Petroleum, Indonesia, 2002

Subgrade Condition

200 mm thick stabilized road floating over peat and in use after 3 months construction
Jalan Lamunin, JKR Brunei, 2002
Platform on eroded embankment
Soil stabilization using chemical binders

A polymer modified cementitious chemical binder in fine powder form

1. To improve/maintain soaking strength of soils through chemical binding of soil particles.
2. To decrease compressibility and permeability of soils, and to provide anti-cracking effect, thereby eliminate potential damages due to swelling, shrinkage and seepage.
3. To improve long term performance of soils.
4. To create ‘platform-effect’ to reduce total settlement and minimize differential settlement.

Specially designed to stabilize
- Clayey soils
- Silty and sandy soils
- Crusher run
- Their mixtures

Stabilization process
- Spreading
- Mixing
- Compaction
Road repairs: 300mm stabilized road base

1. Pot holes on existing road

2. Ensure chemical agent are delivered, stacked and properly covered on site

3. Lay 300 mm crusher run road base on existing pavement

4. Setting out road center line and road edge lines
Road repairs: 300mm stabilized road base

5. 1 ton jumbo bags distributed

6. Spreading chemical on road base

7. Even out spreading using labor

8. Stabilizer machine for mixing
Road repairs: 300mm stabilized road base

9. Dry mixing for 1\textsuperscript{st} run.

10. 2\textsuperscript{nd} mixing in opposite direction, add water if required.

11. Check moisture content.

12. Lightly compact, level and grade before final compaction.
Road repairs: 300mm stabilized road base

13. Final compaction; 8 runs

14. Completed lane opened to traffic, and chemical spread on other lane.

15. Dry mixing on the other lane

16. Minimum 300mm construction joint lapping between old and new works
Road repairs: 300mm stabilized road base

17. Road base stabilization process repeated till completion

18. Binder course is laid immediately and road opened to traffic

19. In-situ C.B.R. testing

CBR RESULTS (B.S. 1377: Part 9: 1990-4.3)

Jalan A123, KM 20, Bagan Datoh, Perak
1. C.B.R. value: 168 % (7 day)
2. C.B.R. value: 146 % (7 day)

Jalan A104, KM 6, Tanjong Piandang, Perak
1. C.B.R. value: 103 % (7 day)
2. C.B.R. value: 111 % (7 day)
3. C.B.R. value: 111 % (7 day)
Including following aspects and elements

1) Preparations
   Properties of in-situ/imported materials to be stabilized
   Chemical stabilizing agents to be used

2) Construction
   Spreading quality  ❖  In-situ moisture control
   Mixing depths and widths  ❖  Compaction Controls

3) Finishing
   Level controls  ❖  Surface finishing tolerances

4) Technical Results
   UCS, CBR, Resilient Modulus and etc
Quality Assurance and Quality Control

- Spreading Rate Check
- Preparation of Specimens
- UCS Test
- CBR Test
- Nuclear Density Test
- Resilient Modulus Test
### JKR Brunei: GS 7: 1999
### General Specifications for Pavement Stabilization

#### Table 5
Quality Control Requirements for Chemical Stabilisation of Sub-Grade

<table>
<thead>
<tr>
<th>Element</th>
<th>Test Method</th>
<th>Target</th>
<th>Minimum Frequency</th>
<th>Record</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suitability of using existing material</td>
<td>CBR tests to BS 1377</td>
<td>5%</td>
<td>as required with change in soil conditions</td>
<td>Test Report</td>
</tr>
<tr>
<td>Depth of stabilisation</td>
<td>Measurement</td>
<td>1.4 times designated thickness</td>
<td>every 50 meters</td>
<td>Daily Report</td>
</tr>
<tr>
<td>Dosage and spreading</td>
<td>Weighing and visual inspection</td>
<td>Not less than specified value</td>
<td>every 40 meters</td>
<td>Daily Report</td>
</tr>
<tr>
<td>Overlapping - Minimum Lengths</td>
<td>Measurement</td>
<td>Long: 0.3m</td>
<td>every 50 meters</td>
<td>Daily Report</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lateral: 1.0m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resultant strength</td>
<td>CBR and 28-Day UCS tests according to BS 1377</td>
<td>&gt; 30% and 0.7-2.5 MPa</td>
<td>every 50 meters or a determined by RE</td>
<td>Test Report</td>
</tr>
</tbody>
</table>
Settlement with time

‘FLOATING’ semi-rigid pavement
- 1-dimensional consolidation
- With longer drainage path
- Under poor drainage conditions
- Very slow consolidation process

Conventional Preloading
- PVDs with 3-dimensional consolidation
- Shorter drainage path
- Good drainage conditions
- Faster consolidation process

Low embankment (pavement)
Semi-impermeable

Embankment Surcharge (In stages)

Original Soft Grounds
SPT ‘N’ = (0 – 5)

PERMEABILITY

Drain

Vertical Drains
Total Settlement = \( f(e_3 - e_0) \)
Conclusion and recommendations

- In soft grounds with high water table, seepage and subsequent loss in bearing capacities is the major cause for pavement failures.
- Various contemplations to strengthen the pavement structure using cement, lime, soil stabilizers in liquid form and geo-synthetics reinforcement are always unsatisfactory.
- Polymer modified cementitious chemicals soil stabilization system is green, sustainable and cost-effective to improve and maintain the soaking strength of pavement structures against possible damages due to swelling, shrinkage and seepage.
- It has certain tensile strength and anti-cracking properties to create a platform effect even under a long-term soaking condition to reduce total settlement and minimize differential settlement.
- With numerous engineering applications in airfields, seaports and roads, the performances and durability are proven since 1994, with no major repairs up to date.