OVER-COMING DIFFERENTIAL SETTLEMENT IN SOFT GROUNDS USING 'FLOATING' SEMI-RIGID PAVEMENT

By

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ABSTRACT

With the current global climate change and rising tidal levels, high water tables and overflowing rivers in the wet seasons caused extensive damages to the coastal road network. To manage and to maintain these with a limited budget is an onerous task for the Malaysian Public Works, albeit the incessant public complaints.

Treatment in soft grounds involves the removal of unsuitable material and replacement with suitable material, vertical drains and embankment surcharge. This is to address long term consolidation and settlement, stability and bearing capacities for the foundation. Ironically, differential settlement persists, the root cause for periodic road repairs. A green, sustainable and cost-effective pavement technology is hereby tabled to address the issues of insufficient bearing capacities and differential settlement for roads in soft grounds. With case studies on road projects in the Public Works Department, State of Perak, Malaysia, Northport container terminal redevelopment, Port Klang, Malaysia, and Malaysian Senai International Airport runway and taxiway widening. This system has been applied in roads, seaports, and airfields in SE Asia, and facilities built and in service since 1994 with no major repairs, with proven performances and durability spanning 18 years.

Key Words: 'Floating' Semi-Rigid Pavement, Differential Settlement, Performance and Durability, Sustainable, Cost Effectiveness.

1. INTRODUCTION

In coastal towns, daily in-coming tides at 6 hours frequencies hamper drainage, causing water-logging in the drains in the low-lying coastal plains near to the sea level. In the granaries, rice field flooding for planting is common place, with extensive percolation and seepage, lowering the bearing capacities of pavement structures. During torrential downpours, the rivers overflow its banks, flooding and damaging the coastal road networks. Various soil improvements methods have been employed to build roads in these high water table areas such as vertical drains/consolidation, compaction, grouting, and geo-synthetics reinforcement but with limited success. (Mitchell and Katti, 1981). Chemical soil stabilization involves chemical reaction between chemical admixtures with soil particles to control soil properties such as its volume stability, strength and stress-strain properties, permeability and durability (Fang, 1990).

Cement (OPC) is widely used to treat granular soils, but difficult with cohesive soils as serious cracking renders less durability. Lime is used in clayey soil to improve its poor properties, but with low strength and durability. Bitumen is used to waterproof soils and aggregates, keeping moisture contents low and bearing capacity high, but is costs prohibitive and a potential environment hazard. Fly-ash, a by-product of coal fired power stations is 70% alumina and silica. A combination of cement, lime and fly-ash is used but not durable in high water table areas. Stabilizing agents in liquid form with various chemical bases is used for non-bearing purposes such as dust control and assistance in improving compaction degree through ionic exchange. With limited solid contents, the stabilized soils may only last for few months in high water tables or high rainfalls.

Polymer modified cementitious chemicals in fine powder form is very effective to improve and maintain the soaking strengths of stabilized soil, by decreasing the compressibility and permeability, provide anti-cracking effect, and reduce or eliminate potential damages due to swelling, shrinkage and seepage in a low-lying, high water table, flood prone and peat swamps environment (Suhaimi and Wu, 2003). This system is developed to treat sandy and clayey soils, with the capacity to create a 'platform effect' (as in Figure 1 below) with a certain tensile strength in stabilized soils, to reduce total settlements and minimize differential settlements; and to improve the long-term performance of soils. It is a proven system for past 18 years in airfield, seaport and highway construction (Wu, 2012)

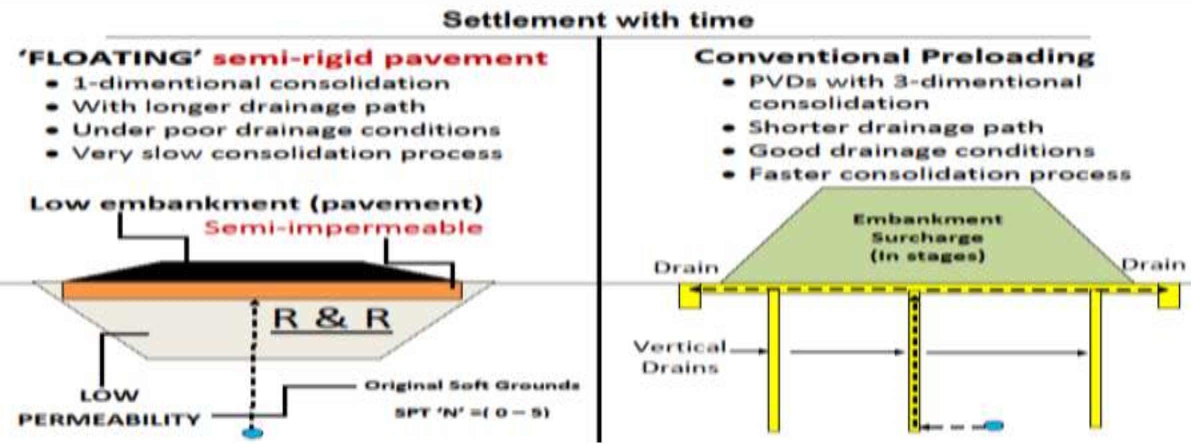

Fig 1: 'Floating' platform to reduce total settlement and minimize different settlement.

2. DESIGNS AND APPLICATIONS OF CHEMICAL STABILIZATION

The major design parameters are the Unconfined Compressive Strength (UCS) (7 days, cylinder sample testing) and California Bearing Ratio (CBR) for high grade pavements, thus

For sub-base	UCS = 0.75 – 1.50 MPa	CBR ≥ 30%
For base courses	UCS = 2.00 – 4.00 MPa	CBR ≥ 80% - 90%
For rural roads	UCS = 0.80 MPa	CBR = 80% for base course

In-situ mixing and/or recycling procedure consists of three (3) main steps, namely;

- SPREADING of the chemical agent on the soil layer to be stabilized
- MIXING the agent with soils with either a Stabilizer machine or a Rotavator
- COMPACTION of the mixture.


Mechanical Spreading

Mixing by Stabilizer


Compaction 1

Photo 1: In-situ mixing/recycling with a Stabilizer Machine for up to 400mm thick per layer.

3. CASE STUDIES

3.1 SENAI INTERNATIONAL AIRPORT, MALAYSIA

Senai International Airport runway (a half strength design) and taxiways (a full strength design) were widened in 2007-2008 after similar works done successfully in Singapore Changi Airport (Koh, et al, 2005). The local soils were nearly 100% clayey soil (liquid limit up to 88%, plastic index up to 46%, and moisture content up to 42%, about two times the OMC). With polymer modified cementitious chemical soil stabilization, these "unsuitable" clays were strengthened, met all the technical requirements, with no defect in any form detected during and after about 5 years in full operation. Average UCS is 2.1 MPa, CBR is 120%, Resilient modulus is 6,000 MPa, with 98% compaction. (Wu et al., 2008).

3.2 NORTHPORT CONTAINER YARD, PORT KLANG, MALAYSIA

Over the years, the deterioration of compacted crusher-run sub-base from seepage rendered the container stacking yard unserviceable. The in-situ crusher-run material was recycled using polymer modified cementitious chemicals stabilization in either two layers of 200 mm thick each or one layer of 300 mm thick layers. The project Phase- I was completed in 2011 and the average achieved UCS value (7-d) is 2.9 MPa (Specs > 2.0 MPa) and CBR is 140% (Specs > 120%). The overall performances are satisfactory to date (Tan et al, 2011). The Phase II works are still on-going, with target completion in 2013.

Photo 2: Phase I Northport, Malaysia.

Photo 3: Phase I in 9 months operation.

3.3 CULVERT CROSSINGS AT KM 561.60, FT 05, HILIR PERAK, MALAYSIA

A 300 mm thick platform of polymer modified cementitious chemicals stabilized crusher run to distribute traffic loads evenly across the culvert over 100 m is constructed to eliminate the effects of the 'culvert hump', a safety hazard to motorist.

Photo 4: Culvert 'hump' at culvert crossing.

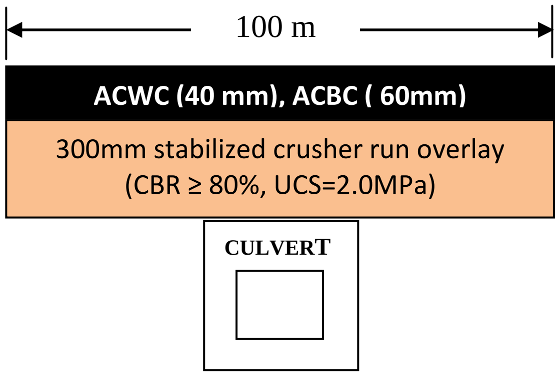

Fig 2: Floating platform over culvert.

3.4 MAJOR ROAD REPAIRS AT A104, PARIT BUNTAR, PERAK, MALAYSIA

This is a heavily trafficked 2 lane single carriageway located in the coastal Kerian rice granary. The road is 'sinking' with no end, with repetitive major road repairs incorporating geo-synthetics reinforcement but results are unsatisfactory. A 'floating' platform is created by re-cycling 300 mm thick in-situ road base crusher run, and road monitoring is on-going.

Photo 5: Road keep 'sinking' with no end.

Fig 3: Floating semi-rigid platform

3.5 ROAD UPGRADING AT A145, TELUK INTAN, PERAK, MALAYSIA

The standard design consists of 300 mm thick crusher run base and a 250 mm thick sand sub-base. A 'floating' platform system consists of stabilized sub-base (200mm) and stabilized road base (200mm) with a 100 mm thick crusher run top-up to minimize differential settlement between old and new in deep marine clays.

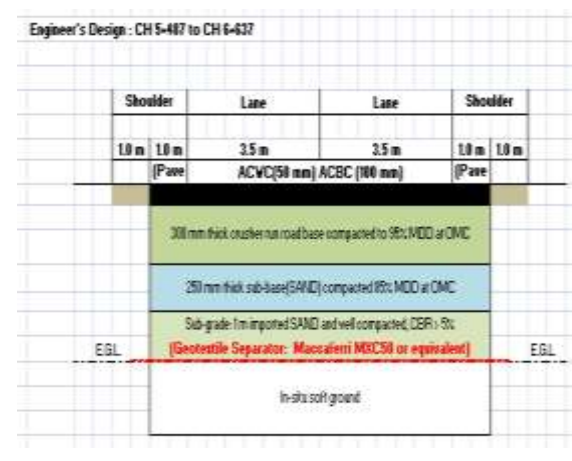

Fig 4: Standard design

Fig 5: Floating platform proposal

4. QUALITY ASSURANCE AND QUALITY CONTROL

Based on the established international practice and local engineering experience, the detailed QAQC regulations and requirements with testing methods, targets and tolerances, minimum checking frequencies and recording manners for Cement, Bitumen, Polymer-base and the modified cementitious chemical stabilizations can be found in "General Specification for Pavement Stabilization (GS 07:1999)" published by Brunei PWD in 1999.

5. CONCLUSIONS

- In low-lying, high water tables and flood prone areas, loss of bearing capacities mainly due to seepage and lower soaked strengths in the road base 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, Nov 30, 2012.

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7. ACKNOWLEDGEMENT

The authors wish to thank the invaluable insights and contributions from fellow colleagues from the Public Works Department, Perak, Malaysia in particular to **Meor Mohamed Haris Bin Meor Hussein, Mohd. Yusup Bin Zahidin, Abdul Rani Bin Harun, Mohd. Salehhuddin Bin Othman, Ahmad Roslan Bin Bidin, Norizan Bin Tan Sali.**