A Green and Effective Approach for Pavements in Tropical Region

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1. Introduction

Difficulties of Pavement Construction in Tropical Region:

- Swampy & soft ground, and lower land.
- Reverse climate conditions like rich rainfall and high water table.
- Poor geotechnical properties of in-situ soils, such as peaty and problematic soils.
- Lack of suitable construction sites and quarry materials.

Conventional Methods

- Engaging a large quantity of quarry materials.
- Lower technical performances and durability.

* Eco & environmental issues and higher CO_2 emission.

1. Introduction

Soil Stabilization Method

- Maximizing the usage of in-situ & local soils as well as solid construction wastes.
- Eco & environmental friendly with much less CO_2 emission.
- Higher technical performances.
- Longer durability.
- Cost effectiveness.
- It has been proven for past 20 years in South East Asia.

2. Soil Stabilization Agent and Green Solution

• Soil stabilization: "To mix proper chemical or bio-chemical admixtures (or called Stabilizing Agent) with soils or solid construction wastes so as to significantly improve and increase the geotechnical properties of the stabilized materials in shallow base foundations".

• Conventional stabilizing agents, such as cement, lime, fly-ashes and bituminous materials, have various limitations in tropical region in aspects of:
  * Technical performances
  * Application workability
  * Environmental pollutions

• A commonly used stabilizing agent --- Chemilink SS-108 sub-series products in South East Asia

• Chemilink systematic green solutions for pavements
  * Designs
  * Materials
  * Application methodologies

2. Soil Stabilization Agent and Green Solution

Total Green Concept ---

Green Product: A substantial percentage of its raw materials include recycled waste materials such as agricultural bio-mass and mining wastes.

Green Process: The application of the stabilizing agents is green because the process reuses in-situ soils and/or waste materials, and thus minimizes the demand on fresh quarry materials and also reduces the removal of the soil as a waste. Besides quality performances with faster construction speed and longer durability, disturbance to natural environment and public is lesser.

Green Result: The stabilized soil is physically and chemically stable under the specified usage and therefore creates no environmental issues, which has been proven for past years too.

3. Design and Installation of Soil Stabilization

Typical Achievable Results ---

- CBR (California Bearing Ratio, %) : 30 ~ 200 or more (7-day)
- UCS (Unconfined Compressive Strength, MPa) : 0.75 ~ 6.00 (7-day)
- M_R (Resilient Modulus, MPa) : 1,000 ~ 10,000 (7- to 28-day)

Installation Process ---

1) In-situ mix

a) Spreading

b) In-situ Mixing

c) Compaction

Photo. 1. Typical In-Situ Mixing Process of Soil Stabilization
(Photos source: Singapore Changi Airport Runway Widening)

2) Plant Mix

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3. Design and Installation of Soil Stabilization

Premier and Unique Engineering Models, such as ---

- ***"Floating" Semi-Rigid Platform*** over swampy and soft ground.
  (15-year highways/roads in swampy areas without major repairing)

- ***Anti-Cracking Performance*** for high-grade flexible pavements.
  (Examples: airport runways and taxiways with stabilized base & sub-base courses)

- ***Excellent Workability*** for quick build and repair airport infrastructures under heavy operational limitations.
  (Iconic project: Singapore Changi International Airport runways widening, featured by Discovery Channel in "Man Made Marvels" program and broadcasted since 2008)

4. Advantages and Benefits

Higher Technical Performances to form the semi-rigid platform

Longer Pavement Lifespan as proven by numerous projects for past 20 years

Green Approach in recycling/rehabilitation with lower CO_2 emission

Faster Construction to complete projects even under various limitations

Overall Cost Effectiveness for both direct cost and long-term maintenance cost

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5. Case Studies

5.1 **Airfields** – Singapore Changi International Airport Runways Widening (2005)

Background: 1st airport widening for A380; airport on reclaimed land with various filling materials; 4 working hours per night (day); total 16km by 4.5m; completion in 60 working days; no defects reported in past 6 years.

Key Technical Merits: Super fast and super strong; pioneer trial; to prove workability and performances of the systematic solution under extremely heavy operational conditions.

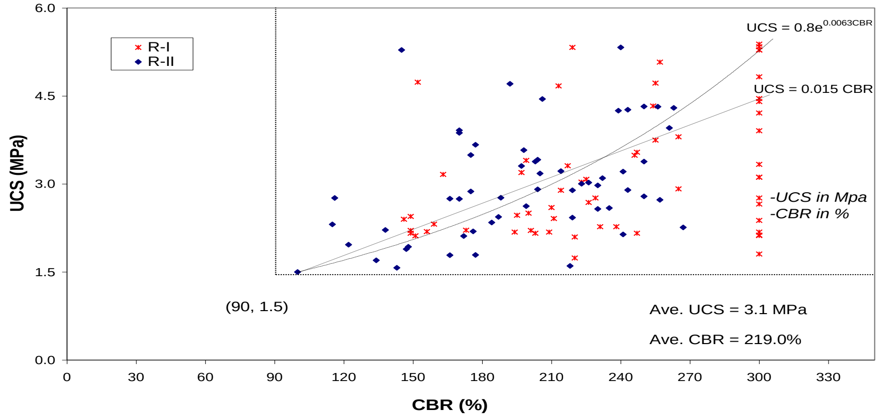


Fig. 1. UCS and CBR Results in Singapore Airport Runways Widening Project

5. Case Studies

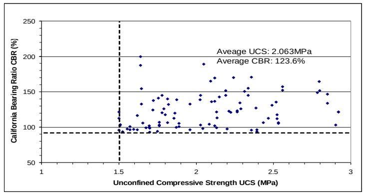
5.1 **Airfields** – Malaysia Senai International Airport Runway & Taxiway Widening (2007 & 2008)

Background: airport on lower land and soft ground; 4 working hours per night/day; total 8km by 7.5m; no defects including cracking reported in past years.

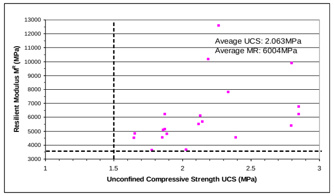
Key Technical Merits: technical challenges on poorer soil conditions.

NO	LOCATION	DEPTH (mm)	INSITU MC (%)	OMC (%)	MDD (Mg/m³)	LL (%)	PI (%)	CLAY & SILT (%)	SAND (%)	GRAVEL (%)
		150~450 mm	depth at 350mm							
6	P6	350	23.59	15.00	1.74	73	36	54.80	32.40	12.80
7	P7	350	30.08	22.00	1.49	88	37	78.80	19.20	2.00
8	P8	350	41.63	18.00	1.54	76	31	70.40	2.60	27.00
11	P11	350	27.38	19.00	1.68	62	33	66.80	33.20	0.00
12	P12	350	38.74	19.00	1.55	79	46	82.70	17.20	0.10
13	P13	350	21.37	17.00	1.71	56	23	62.20	30.60	7.20

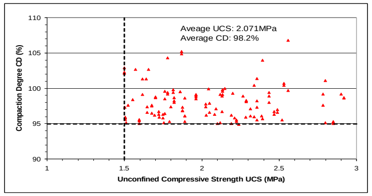
Table. 1. Typical Soil Investigation for Senai Airport Widening



a)UCS & CBR



b)UCS & MR



c)USC & CD

Fig. 2. Testing Results in Senai Airport Widening Projects

5. Case Studies

5.2 **Seaport Facilities** – Indonesia Batamas Shipyard (1997)

Background: stabilized sub-base below reinforced concrete as the surface

Key Technical Merits: average construction rate - 8,000m^2/day.

a) Manually Spreading

b) In-Situ Mixing and Compaction

Photo. 4. Soil Stabilization in Progress in Shipyard

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5. Case Studies

5.2 **Seaport Facilities** – Malaysia Port Klang Container Yard Upgrading (2010)

Background: the biggest port in Malaysia; serious settlements; operational capacity far below the designed.

Key Technical Merits: to form semi-rigid platform by in-situ rehabilitation to eliminate differential settlement and minimize the total settlement rate.

a) Before Upgrading

b) Before and after Stabilization

c) Upgraded Yard Operations

Photo. 5. Upgrading of Port Klang Container Yard

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5. Case Studies

5.3 **Highways & Roads** – Brunei Jalan Tutong, Phase III (1997-1999)

Background: typical swampy area with peaty soils down to 30-50m deep; lower land next to a big rival; the original design with 100% pilling.

Key Technical Merits: to prove "Floating" Semi-Rigid Platform in both technical performances and durability; to eliminate differential settlement between non-settlement and free-settlement zones; no major repairing be done for past 12 years.

Fig. 3. Typical Cross Sections at Free- and Non-Settlement Zones

5. Case Studies

5.3 **Highways & Roads** – Brunei Jalan Tutong, Phase III (1997-1999)

a) Opened Cross Section after 2 Years

b) Road after 12 Years

Photo.6. Jalan Tutong, Phase III

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5. Case Studies

5.3 **Highways & Roads** – City Road Maintenance (2000)

Key Technical Merits: to complete road repairing by in-situ rehabilitation from middle night and to the next early morning to minimize the impacts to users.

a)Road Partially Closed during Night for Maintenance

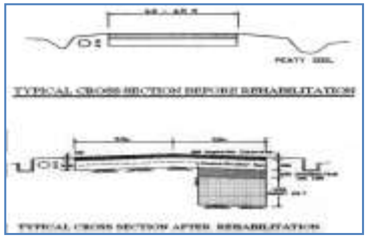
b)Road Opened for Use in Next Morning

c)Cored Samples with Recycled In-Situ Materials

Photo. 7. City Road Quick Maintenance

5. Case Studies

5.3 **Highways & Roads** – Roads over Swampy and Soft Ground (1994 - 2011)



a) Typical Road Cross Section

b) Road after Years

Photo. 8. Widening of Junjungang Road

Photo. 10. A Stabilized Road at Low-Lying Area (2004)

a)Oil Field Road in Use

b) Sub-Grade Conditions

Photo.11. A Stabilized Oil Road Access Under Heavier Loads (2002)

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6. Conclusions

1) Soil stabilization with appropriate stabilizing agents of chemical or bio-chemical admixtures, incorporated with proper designs and applicable methodologies, is a green and effective approach for pavement construction in tropical region.

2) The stabilization with green product, green process and green result, can maximize the usage of in-situ or local soils and some construction wastes so as to obviously minimize the impacts to natural environment and significantly reduce the CO_2 emission.

3) Based the comprehensive case studies, the systematic solution of soil stabilization introduced in the paper has been proven for past 20 years to deliver higher technical parameters and performances with fast construction and thus to provide longer pavement lifespan and overall cost effectiveness.

4) This well-proven system has presented premier, innovative and leading models especially in “floating” semi-rigid platform over swampy ground; anti-cracking quality for high-grade pavements; and excellent workability and performances under exceptionally heavy operational airport activities.



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Thank You for Your Attention!