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Chemical-Soil Stabilization for Sub-Grade Improvement

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Table of Contents

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1. Introduction

- The chemical-soil stabilization method is a classical and traditional engineering approach and has been used for past hundreds of years worldwide. It is technically effective for strengthening or stabilizing in-situ soils or mixtures as sub-grade, sub-base and even base courses of various pavements.

- The major functions and advantages of the chemical-soil stabilization are the volume stability; higher strengths and moduli; lower permeability; better durability; simple and fast construction; overall cost effectiveness and proven engineering solution. It is also remarkably green, environmental friendly and sustainable.

- One of the key successful factor for chemical-soil stabilization method is to incorporate with the appropriate chemical binders. As stabilization technique improves especially in quality binders and installation equipment, this method has been widely used in pavement construction in our tropical region for past 20 years.

- A series of polymer modified stabilizing binders and its projects are selected in this presentation because of its hundreds of proven engineering record in this region for past two decades.

1. Introduction

Construction Procedures

a) Spreading

b) In-Situ Mixing

c) Compaction

1) In-Situ Mixing/Recycling


a) Central Mixing Plant


b) Transport, lay & Compaction

2) Central Plant Mixing

2. "Floating" Semi-Rigid Platform Effect

Description

The chemically stabilized soil can function like **a continuous and jointless (weak) reinforced concrete slab over the soft ground**.

Basic Requirements

- Sufficient strengths and rigidity (stiff modulus with sufficient thickness)
- No cracking
- Lower permeability and minimum deformation
- No softening over the time (preferably with long-term cementation)
- Sufficient dimensions as comparing with pavement surface

2. "Floating" Semi-Rigid Platform Effect

Achievable Outcomes of the Effect

- Minimize or eliminate differential settlement of the pavement
- Reduce the total settlement
- Long-term working properties, even soaking in the water
- Consistent performances
- Less pavement maintenances
- Making the entire pavement working life longer

2. “Floating” Semi-Rigid Platform Effect

Project Examples

a) Public road over swampy area (1996, Brunei)

b) Road with higher water table (2002, Brunei)

2. "Floating" Semi-Rigid Platform Effect

Project Examples

c) Oil Field Road over Swampy Region (2003, Indonesia)

d) New Well Road Functioning as Stock Yard (2003, Indonesia)

2. “Floating” Semi-Rigid Platform Effect

Project Examples

e) Public road over paddy field (2012--, Malaysia)

f) Road with higher water table (2012--, Malaysia)

3. Performances and Durability

Commonly-Used Design Criteria for Soil Stabilization

- Sub-Grade and Sub-base (generally at 7-day):
  CBR ≥ 30 - 60%; and/or UCS ≥ 0.7 - 1.5 MPa
- Base (at 7-day):
  CBR ≥ 80 -120%, and/or UCS ≥ 1.5 - 5.0 MPa
- Achievable Resilient Modulus M_R and Modulus of Sub-Grade Reaction k (at 28-day)
  M_R:1,000 - 5,000 MPa, and k: 400 – 900 MPa/m
- Achievable Coefficient of Permeability (at 28-day)
  Range: 10E-7 – 10E-11 m/s
- Chemical Binder Dosage
  Range: 1.75 – 3.75% (based on the dry weight of the soil to be treated)

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3. Performances and Durability

ICAO Requirements on the Sub-Grade and Comparison

Designs	Flexible Pavement Sub-grade (CBR, %)				Rigid Pavement Sub-grade (k*, MN/m3 or MPa/m)				Remarks
Class	A 13 (>15)	B 10 (8-13)	C 6 (4-8)	D 3 (<4)	A 150 (>120)	B 80 (60-120)	C 40 (25-60)	D 20 (<25)	
Highest requirements	≥15	-	-	-	≥ 120	-	-	-	*k: modulus of sub-grade reaction.
Chemical-Soil Stabilization Method	≥30	-	-	-	≥ 300	-	-	-	Easily achievable based on the project data

3. Performances and Durability

A Public Road over Swampy Area (Brunei, 1995)

- Average CBR & UCS at 7-day
  100% & 2MPa
- Modulus of sub-grade reaction, k, at 28-day
  Range: 400 - 800 MN/m3 or MPa/m

Table 2. Average Testing Data for Chemilink Trial Project

M/P Test		Plate Loading Test			In-Situ CBR Test (%)	UCS Test (MPa)
No. of Blows	Depth of Penetration (mm)	Peak Pressure (MPa)	Settlement Recorded (mm)	Modulus Of S/R, K (MPa/m)		
300	6.3	1.72	7.44	522.62 (Max. 812.48)	100 (Max. 129)	2.04 (Max. 2.67)

Where,
1) M/P Test - Dynamic Mackintosh Probe Test
2) Modulus of S/R - The Modulus of Sub-grade Reaction
3) UCS Test - Unconfined Compressive Strength Test

- CBR & UCS at 10-year
  150-200% & 3-4 MPa

a) Stabilized soil samples at 7-d

b) Stabilized road (left) vs crushed stone road

c) Stabilized surface after 10 years

3. Performances and Durability

Batam Ship Yard (Indonesia, 1996)

- Area is > 200,000m2
- Average construction speed: 8,000m2/day/layer (300mm thick)
- The stabilized soils support reinforced concrete
- 1,000–2,000t ships directly sitting on the rails supported by the reinforced concrete

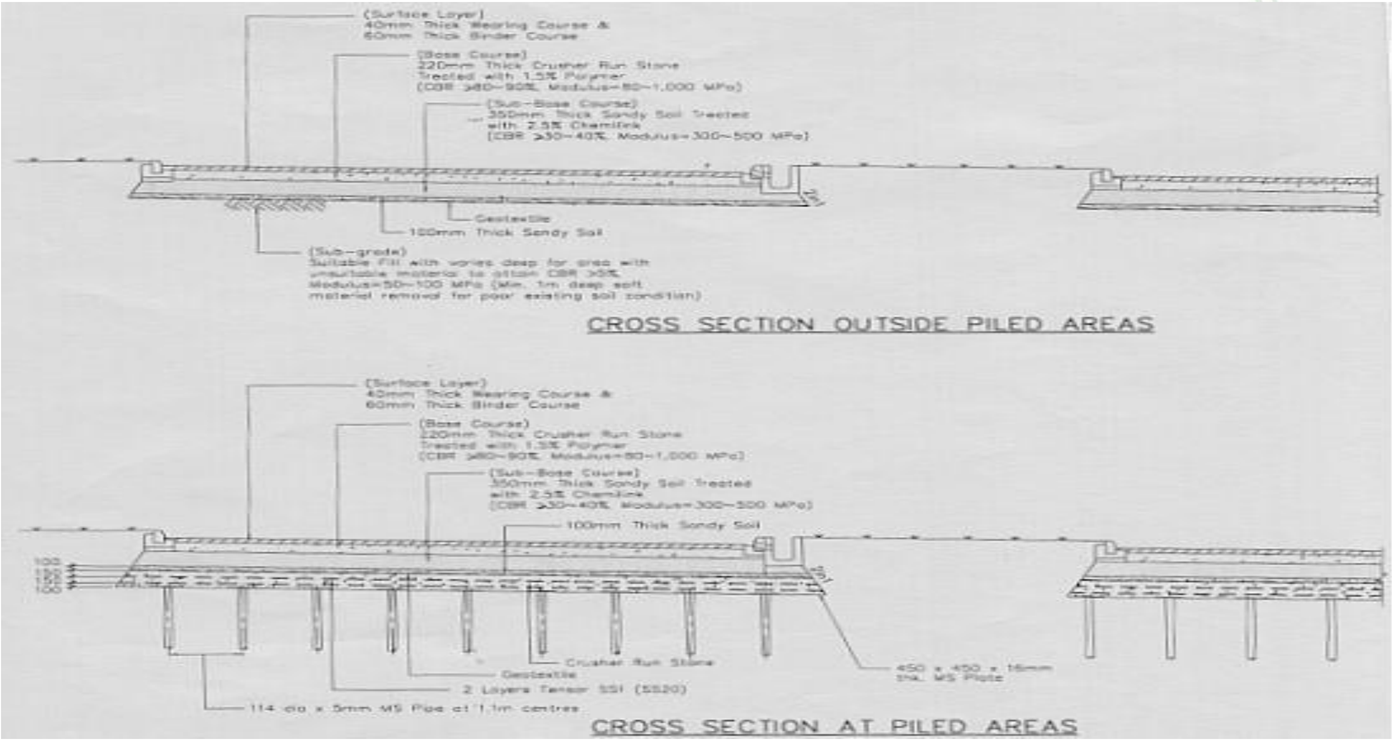
a) Stabilization in process

b) Completed surface of the stabilization

3. Performances and Durability

An Expressway over Swampy Area (1996–1999, Brunei)

- Stabilized soil as sub-base course (350mm)



A Typical Cross Section Design

3. Performances and Durability

Average Testing Data (2.5% binder with sandy soils)

- In-situ CBR at 7-day
  81.3%

- UCS
  i) 4-day soaked: 1.30 MPa
  ii) 7-day un-soaked: 1.66 MPa

- Compaction Degree
  97.5%

- Modulus of sub-grade reaction
  780 MPa/m

3. Performances and Durability

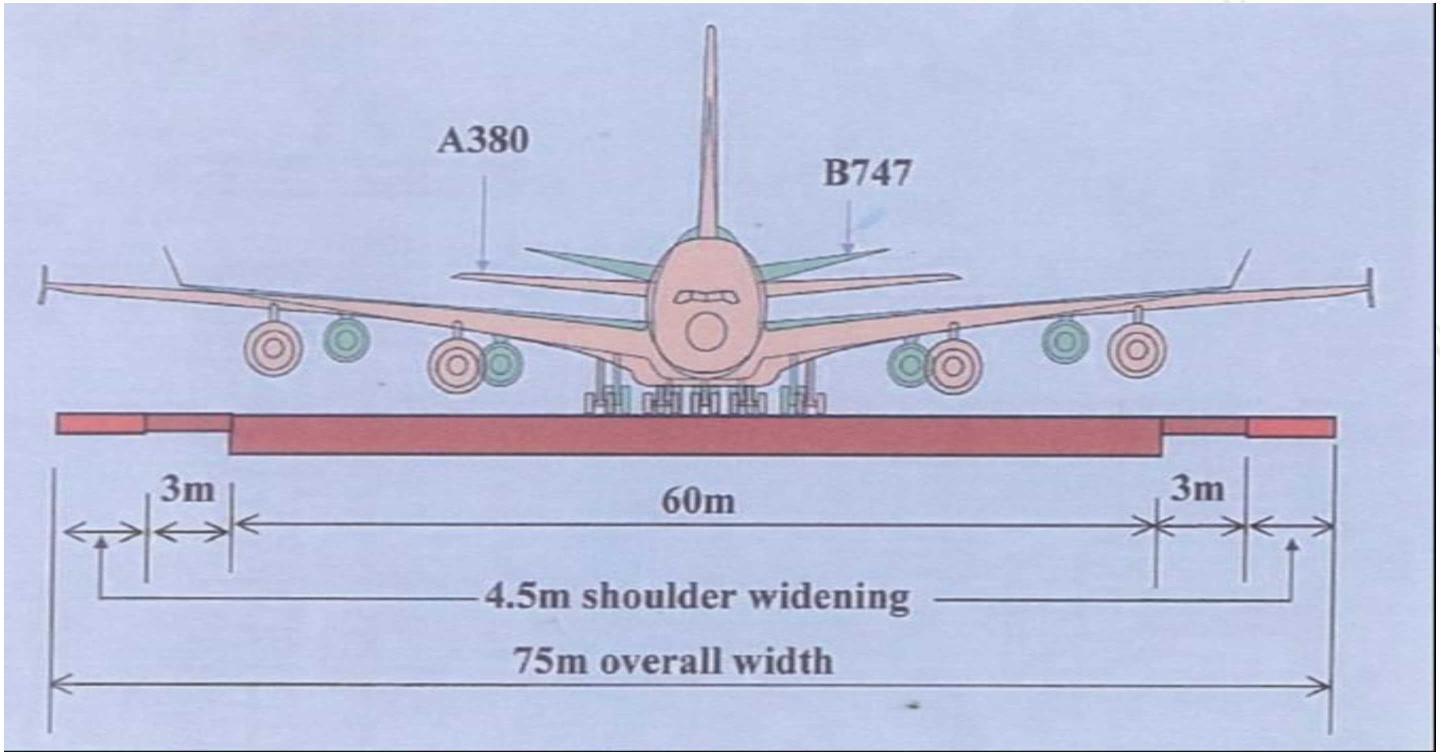
Confirmation

This expressway, somehow functioning like local central expressway, has well performed for **past 18-21 years** without any significant defects and major repairs.

4. Case Studies

4-1. Changi International Airport Runway Widening (2005)

Note: One of the 1st international airports to be ready for A380 and the construction video refers to Discovery Channel, "Man Made Marvels", Oct. 2008.



Two Runways Widening Details

4. Case Studies

4-1. Changi International Airport Runway Widening (2005)

Construction Procedures for Two Runways

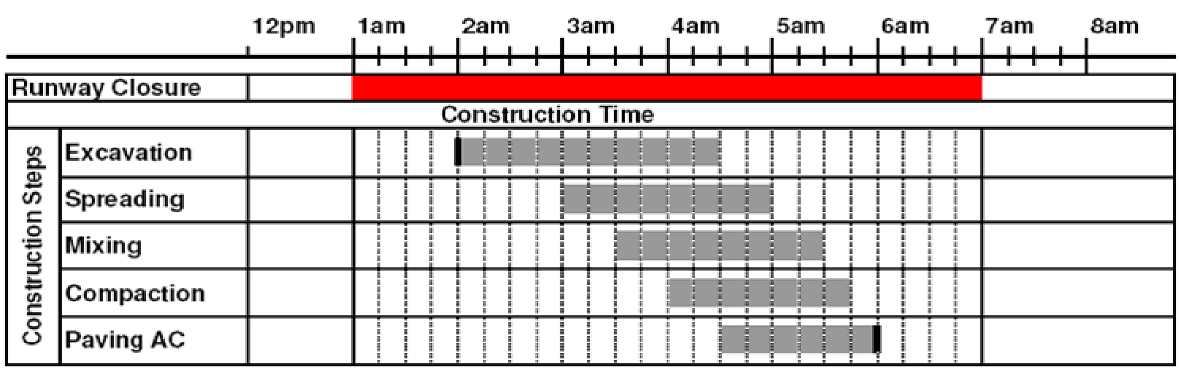
a) Spreading

b) In-Situ Mixing

c) Completion

- Completed in 60 working days
- Average 217m/w. day
- 3 months ahead the schedule

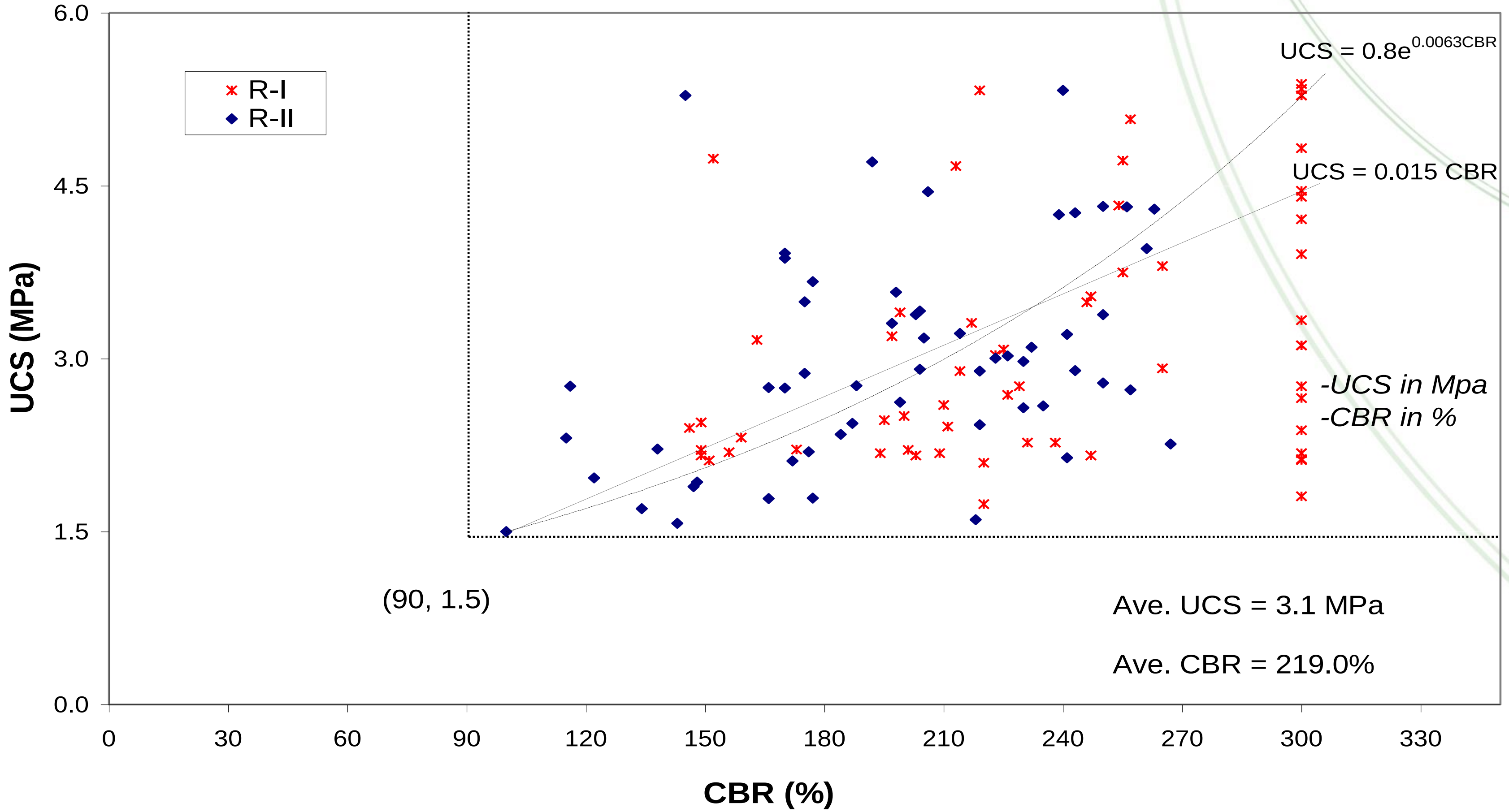
Construction Schedule for Runway Widening at Singapore Changi Airport



Notes:
Runway Closure Time : 1:00am ~ 7:00am
Effective Construction Time : 2:00am ~ 6:00am
Average Area per 4 Working Hours: 250m by 4.5m or 225m2/hour

4. Case Studies

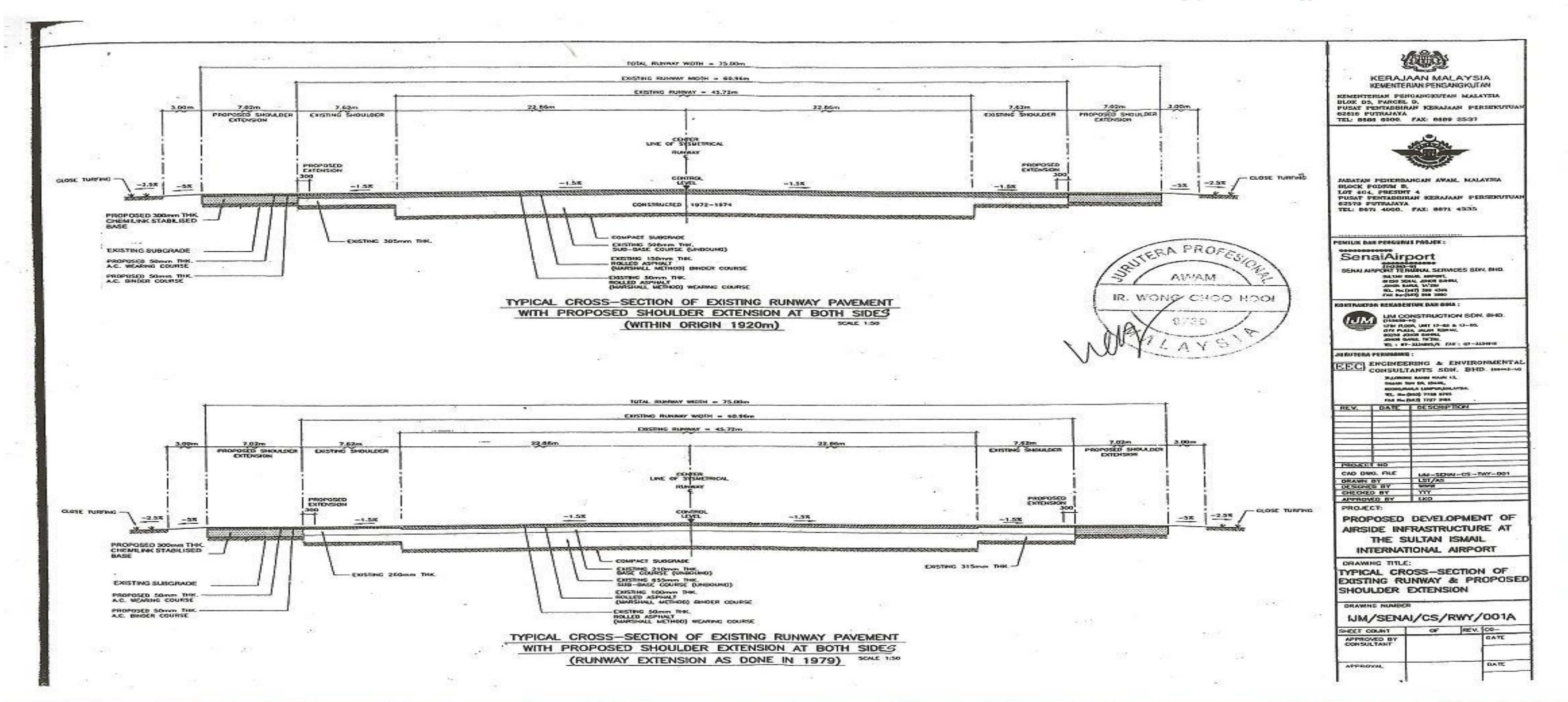
4-1. Changi International Airport Runway Widening (2005)



Quality Control Tests (7-day)

4. Case Studies

4-2. Senai International Airport Runway & Taxiways Widening (2007-2008)



Typical Widening Cross Sections for

1) **Runway (300mm base, half strength, 2007); and**
2) **Taxiway (300mm sub-base, full strength, 2008)**

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4. Case Studies

4-2. Senai International Airport Runway & Taxiways Widening (2007-2008)

Technical Challenges

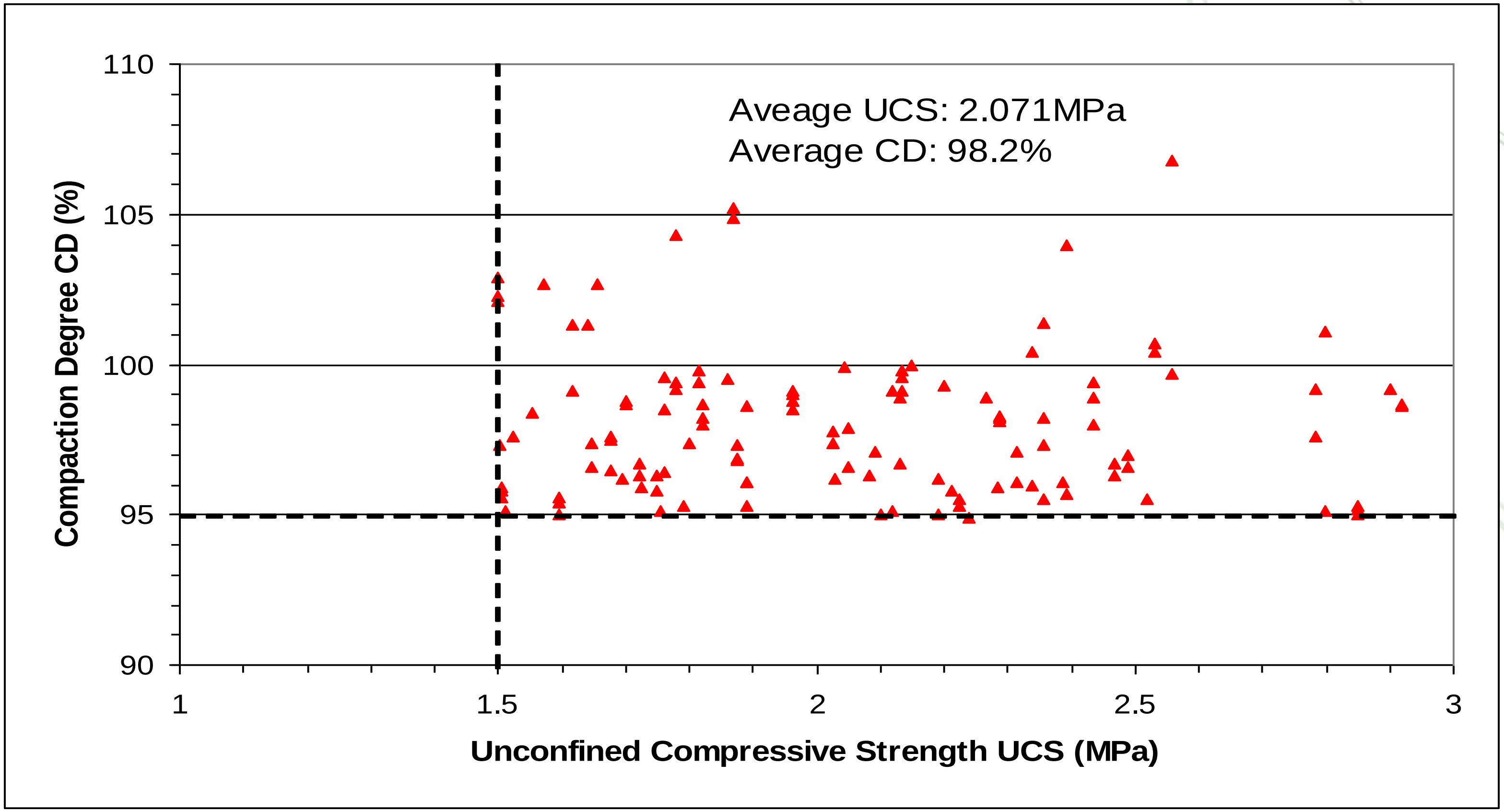
- Higher clay/silt content (> 80%)
- Higher LL (up to 88%) & PI (up to 46%)
- Higher in-situ moisture content (up to 2 x OMC)

SENAI AIRPORT RUNWAY SHOULDER WIDENING
Soil Investigation Summary

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

4. Case Studies

4-2. Senai International Airport Runway & Taxiways Widening (2007-2008)



Achievable Compaction Degree (CD)

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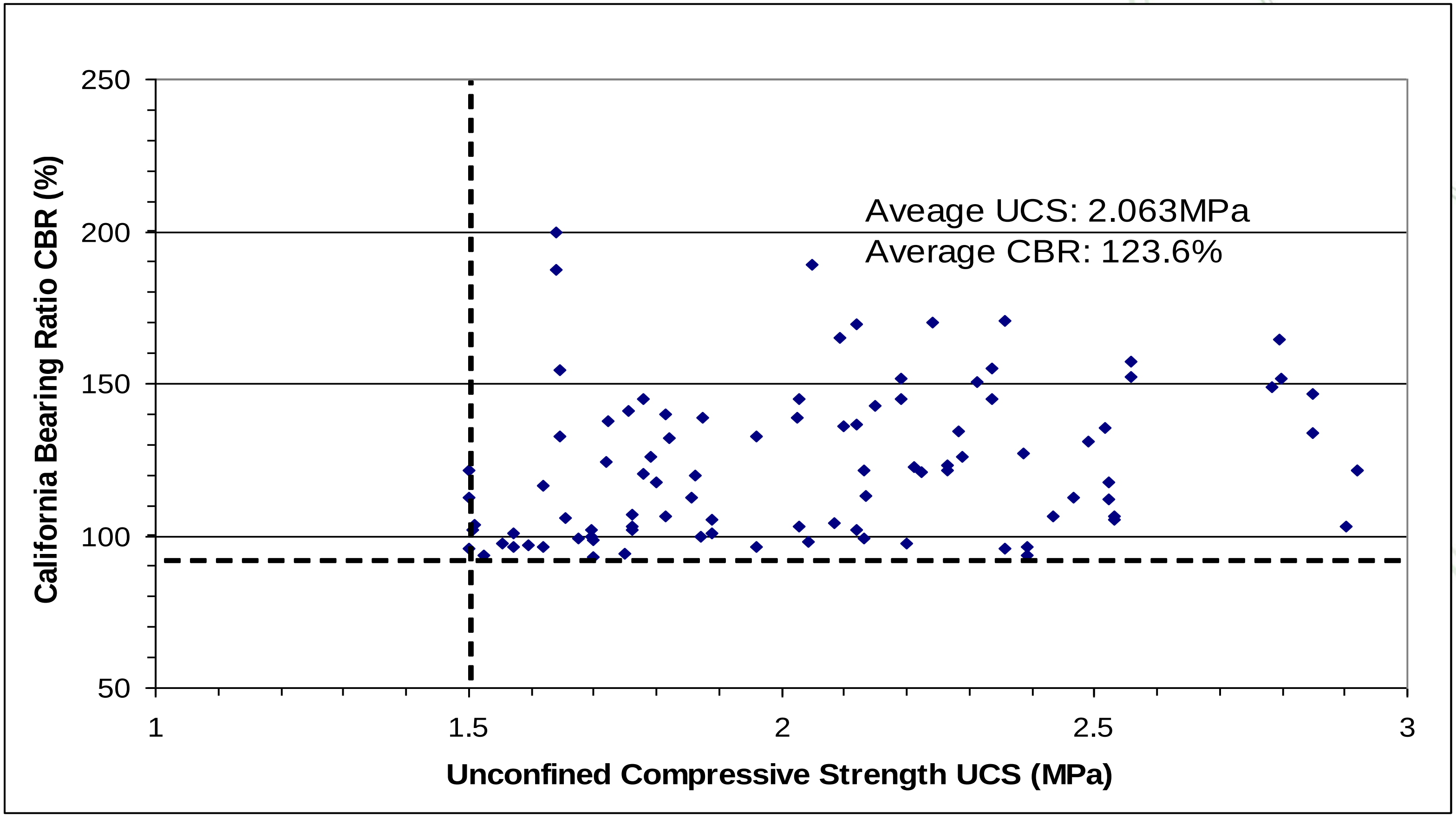
4. Case Studies

4-2. Senai International Airport Runway & Taxiway Widenings (2007-2008)



CBR and UCS Testing Results (7-day)

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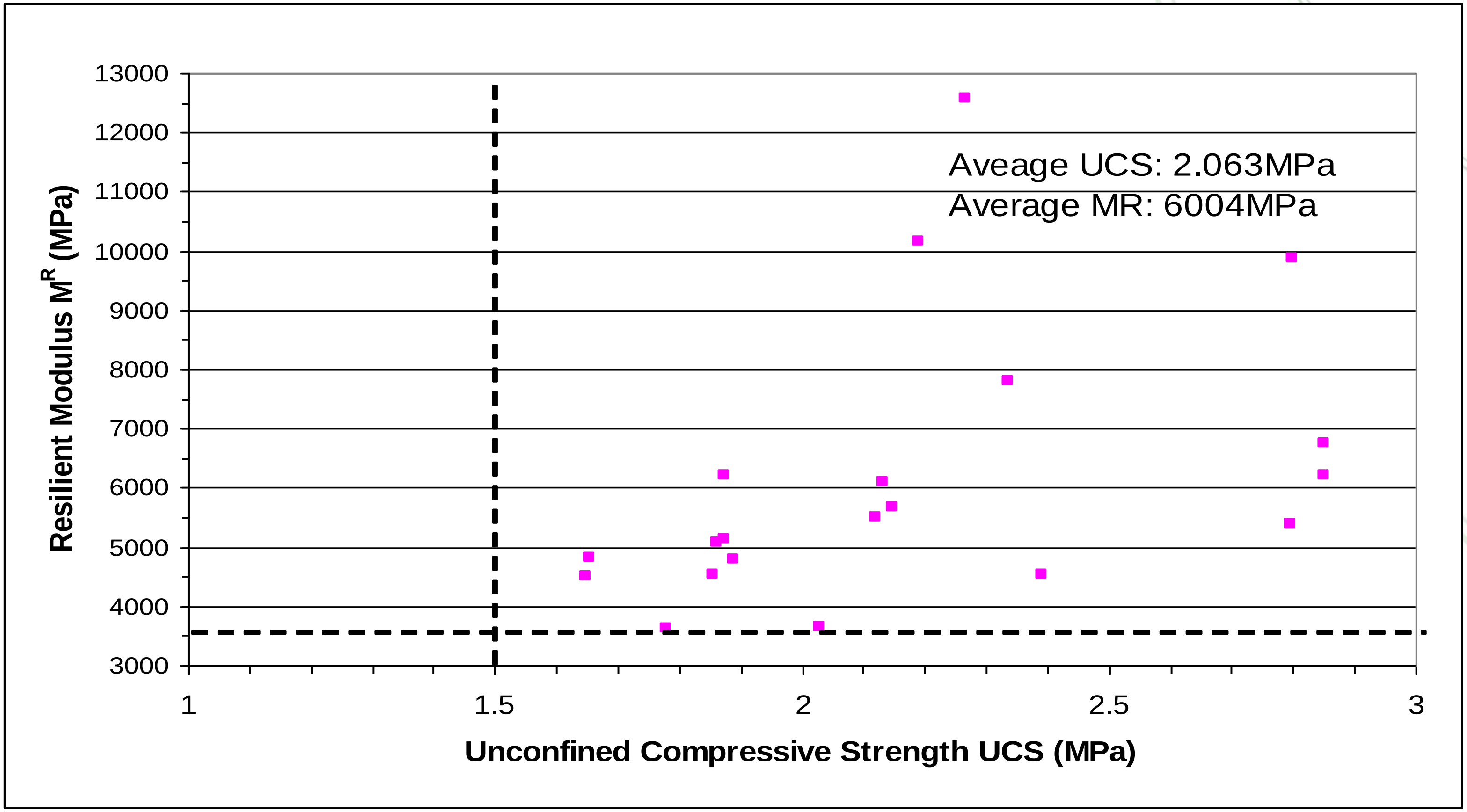
4. Case Studies

4-2. Senai International Airport Runway & Taxiway Widenings (2007-2008)



Achievable Resilient Modulus Results (28-day)

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6. Conclusions

1) Chemical-soil stabilization method is a proven engineering solution for pavement construction in tropical region. Stabilized soils can be used as sub-grade, sub-base and even base for various pavements.

2) This method is remarkably green, environment-friendly and sustainable.

3) It can achieve superior construction quality and higher technical properties and performances as comparing with conventional ways.

4) Past more than 20 years engineering practice has confirmed that this method with the appropriate binders can be very much durable, even over soft ground or swampy area with high water table.

5) This construction approach is very suitable for airfield infrastructural construction under airport operational constrains.

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Thank You!