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Soil Stabilization-An Eco and Green Approaches for Pavement Construction

Daud
David_daud@chemilink.com

Dr Wu Dong Qing
wu@chemilink.com

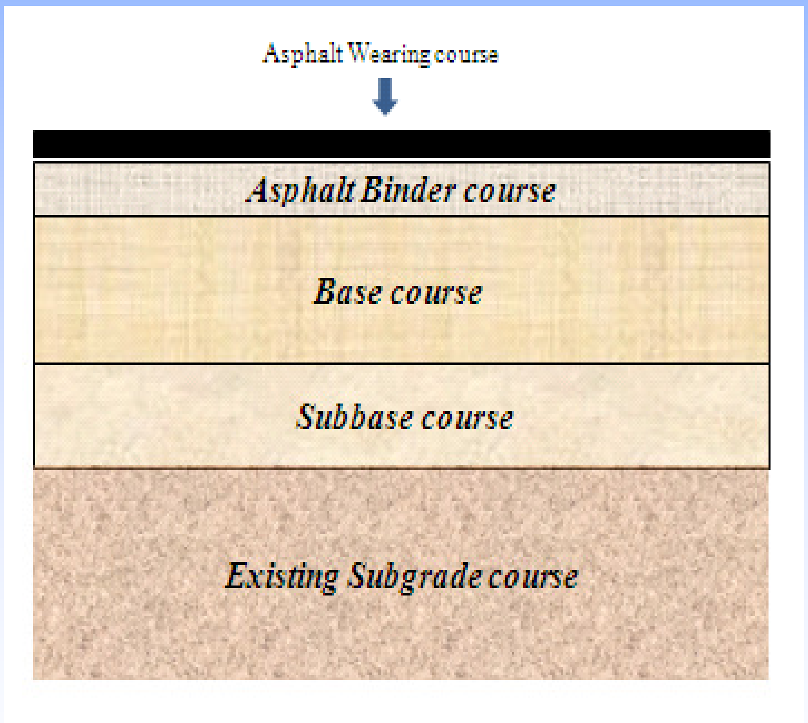
Tan Poi Cheong
poicheong_tan@chemilink.com

Chemilink Technologies Group, Singapore

Table of Contents

1. Introduction

Typical Conventional Road Profile



Pavement Construction Methods

a. Conventional (replacement method)→ Remove and replace the soft in-situ soil with **approved fill materials** as construction material.

b. Non-replacement method → Strengthen the engineering properties of in-situ soils which allows in-situ soils to be re-used as source of construction material.

1. Introduction

Estimated of selected fill to be used by replacement method

- Assume to construct1km length x 7m width of road
- To remove and replace the in-situ soil by selected fill material for Sub-grade, Sub-base and Base layer

Road layer	Material	Dimension of the road	Volume of approved fill materials (m^3)
Sub-grade layer	Approved fill materials	1km x 7m x 0.3-0.5m	2,100-3,500
Sub-base layer		1km x 7m x 0.3m	2,100
Base layer		1km x 7m x 0.25m	1,750
Total quarry material needed (m^3)			5,950-7,350
5.6million km of Unpaved Road in Developing Countries			**33,000-42,000 million**

Impact to Global Environments due to

Exploitation of natural resources and CO_2 emissions from mining and transportation of material

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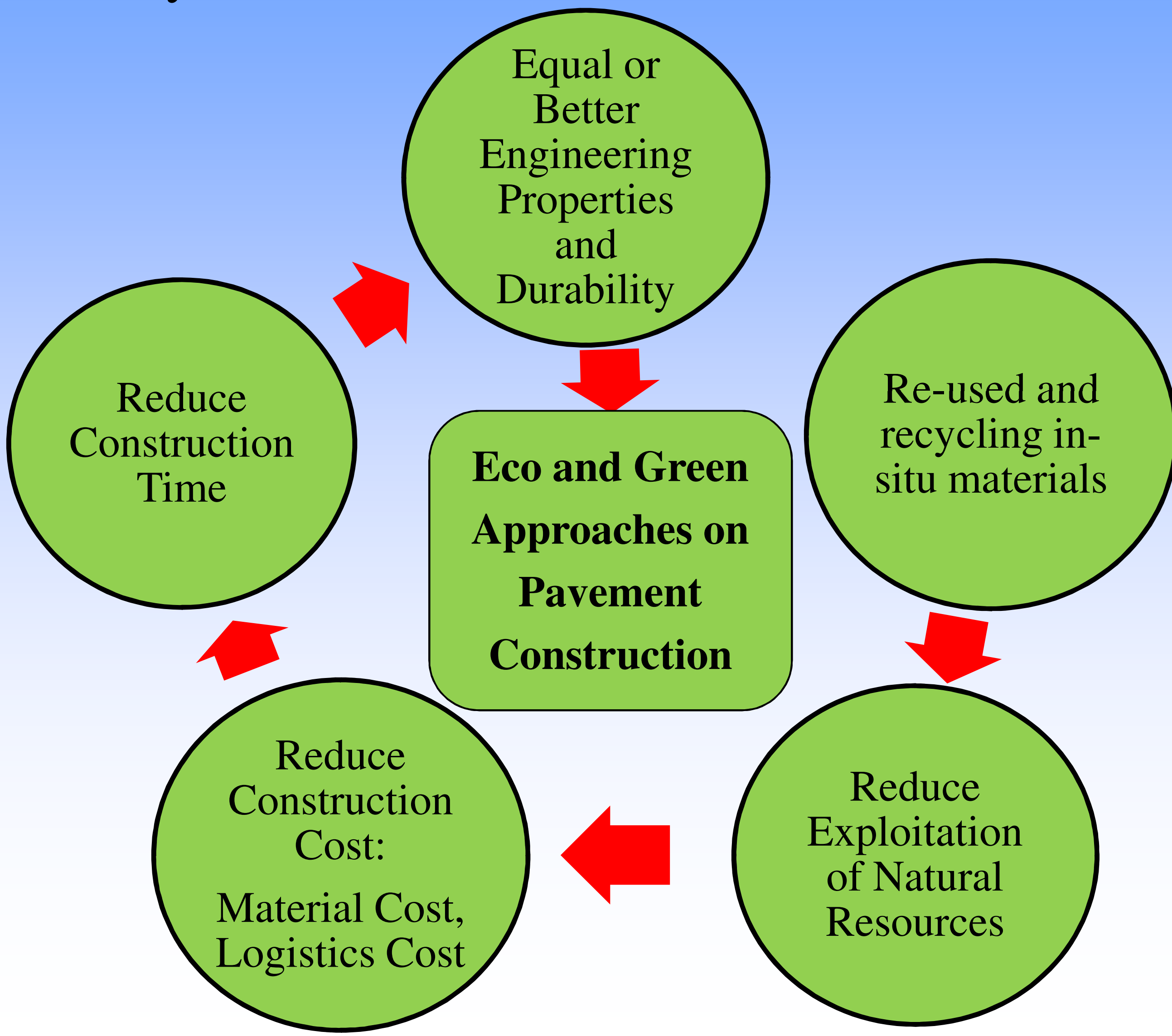
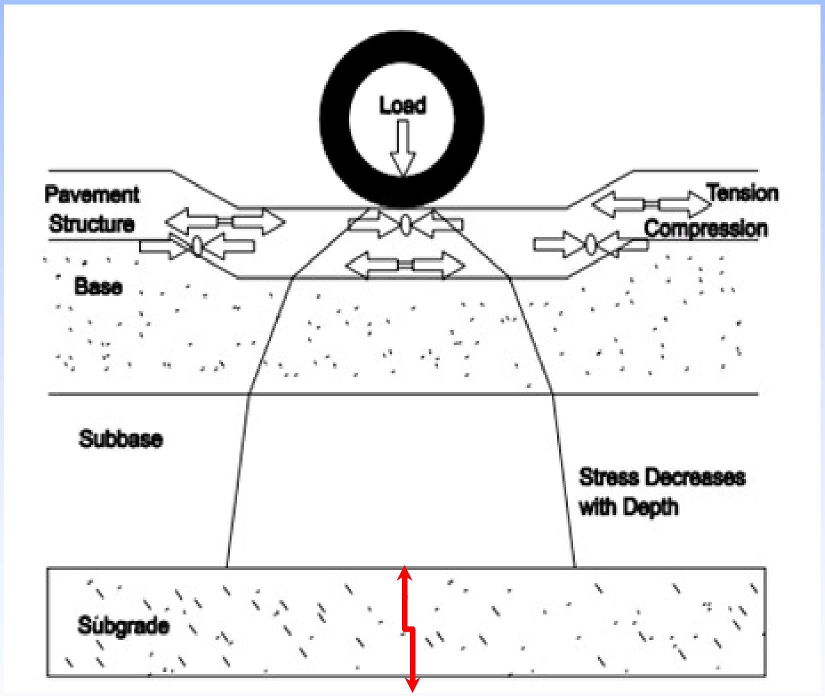
Eco and Green Approaches Concept on Pavement Construction by Chemical Soil Stabilization Method



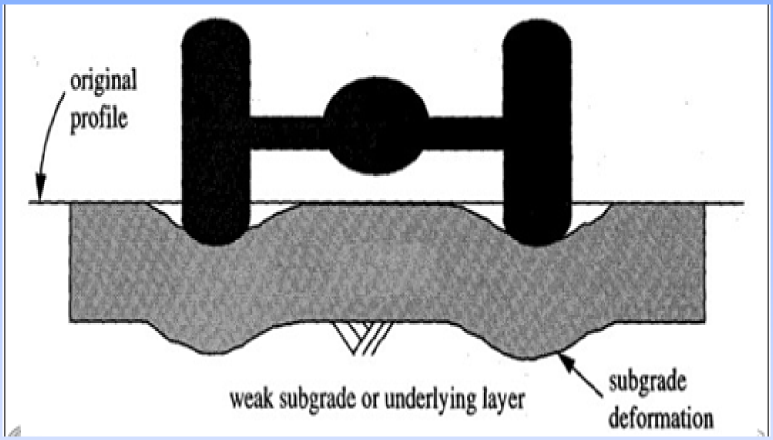
2. Soil Stabilization for Road Construction

Common Pavement Distress Due to Weak Base or Sub-grade Layer

Load distribution of pavement



Vertical compressive stress and strain at the top of sub-grade layer



Permanent deformation of weak base or sub-grade layer

2. Soil Stabilization for Road Construction

- Soil stabilization:

  The alteration or preservation of one or more soil properties to improve the engineering characteristics and performance of a soil.

- Purposes of soil stabilization:

  a. Soil properties improvement:

     → Reduction of plasticity index (PI), swelling potential

     → Increase in durability and strength.

  b. Thickness reduction of pavement layer

     → Improved the strength and stiffness of the soil layer

     → Permit the reduction design thickness of the stabilized layer compared with un-stabilized or unbound layer.

  c. Effectively utilize of locally available soils and other materials as road construction material.

2. Soil Stabilization for Road Construction

❖ Soil stabilization methods:

a. Mechanical stabilization

Altering the soil properties by:

- ✓ Changing the gradation through mixing with other soils
- ✓ Densifying the soils using compaction efforts
- ✓ Undercutting the existing soils and replacing with granular material

Common remedial procedure for soft sub-grade, sub-base and base layer:

Cover with granular material or partially remove and replace the wet soil with granular material → Conventional pavement construction method.

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2. Soil Stabilization for Road Construction

b. Chemical Admixtures or Stabilizing Agents:

- ✓ Blending and mixing suitable **chemical admixtures** or **stabilizing agents** with in-situ soils to improve/strengthen the certain properties through chemical reactions for engineering purposes.
- ✓ Common chemical reaction involved: Cementation, Hydration, Ion Exchange, Flocculation, Precipitation Polymerisation, Oxidation and Carbonation.
- ✓ Types of **stabilizing agents** that commonly used for Soil stabilization:
  a. Cement
  b. Lime: Hydrated lime, Quicklime.
  c. Fly ash: Class C and Class F fly ash.
  d. Bituminous materials: Asphalt binder, Cutback asphalt and Asphalt emulsions.
  e. Polymer modified cementitious chemical – Chemilink soil stabilization products

Design Requirements on UCS for Cement Stabilized Soils in Various Countries

Country	Curing Time (day)	Curing Condition	UCS (MPa)	Road Grade / Function	Remarks
Australia	7	-	3.0	-	
Brunei	7	Wet-air: 6d Soaking: 1d	2.0 0.7 ~ 1.5	All/Base All/Sub-base	Or per design
Canada	7	Soaking	2.1	-	
China	7	Wet-air: 6d Soaking: 1d	3.0 ~4.0 2.0 ~ 3.0 2.0 1.5	High/Base Low/Base High/Sub-base Low/Sub-base	UCS=5~6 for high road grade with more or very heavy loading
Ex-SU	28	Soaking	7.5 6.0 4.0 2.0	Highest/Base High/Base Low/Base All/Sub-base	
France	7	-	4.0 ~5.0 1.5	M./Base M./Sub-base	M. — Medium
Germany	-	-	3.0 ~ 10.0	-	
Japan	7	Wet-air: 6d Soaking: 1d	3.0 ~ 4.0 2.5 1.5 ~ 2.0 0.7 ~ 1.3	Highest/Base High/base Low/base All/Sub-base	
New Zealand	7	-	1.72	-	
Spain	7	-	6.0 2.5	All/Base All/Sub-base	
UK	7	-	4.5 ~ 15.5	-	
California Washington - US	7	Wet-air -	5.2 5.8	- -	

2. Soil Stabilization for Road Construction

- Chemilink soil stabilization agent:
  - ✓ Polymer modified cementitious chemical agent in fine powder form.
  - ✓ Designed for soil stabilization especially for sandy and clayey soils under tropical conditions and environment.
- Typical Technical Design:
  - ✓ Key component → Dosage Design

Layer to be stabilized	CBR (7-day)	UCS (7-day)	Resilient Modulus (M_R)-28 day
Base Course	≥ 80%	≥ 2MPa	3000MPa ~ 20000MPa
Sub-base Course	≥ 30%	0.7-1.5MPa	

Note:

Data shown above are typical technical performance achievable for different applications

2. Soil stabilization for road construction

Application Method of Chemical Soil Stabilization

1. In-situ recycling method

Spreading → **Mixing** → **Compaction**

By Mechanical

By Stabilizer

By Compactor

By Manual

By Rotovator

By Compactor

2. Soil stabilization for road construction

Application Method of Chemical Soil Stabilization

2. Central-plant mixing method

Central Mixing Plant

Mixture after Compaction

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

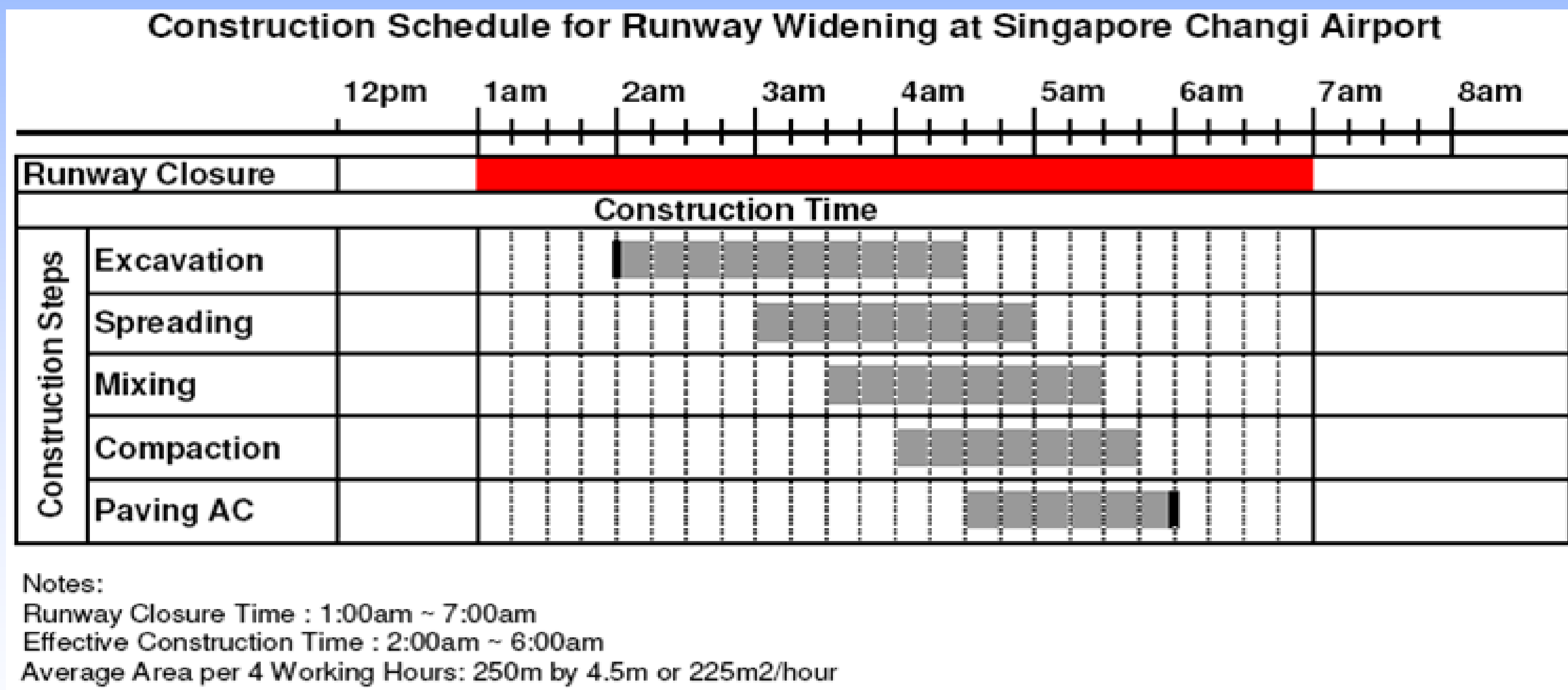
A. Singapore: Runway shoulders widening of Singapore Changi International Airport (2005) for Airbus A380.

- In-situ soil condition:
  - a. Inorganic clay (CL) → LL=48%, PI=28%
  - b. High plasticity clay (CH) → LL=88%, PI=55%
  - c. Beach sands, Crushed stones and Their mixtures (Reclaimed land)
- Design and construction considerations:
  - a. Minimize the period of risks and impact of inconveniences caused by construction activities.
  - b. Avoid extensive excavation and backfilling to reduce the negative impact on the environment
  - c. Cost effectiveness

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

- Construction schedule: Closing time: 1:00am-7:00am → 6 hours

  Effective pavement construction time: 2:00am-6:00am → 4 hours



By Conventional construction method is difficult to achieved those design considerations and construction schedule

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

- Proposed design by Chemilink soil stabilization method: stabilized **300mm** of in-situ soils as **Base Course**

a) Spreading

b) In-situ Mixing

c) Compaction

Completion of Runway Widening in Changi International Airport Runway II (after 3 years)

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

- Average values:

Testing items	Chemilink soil stabilization	Specification. requirement
CBR-7 days	219%	≥90%
UCS-7days	3.10MPa	≥1.5MPa
Resilient Modulus (M_R)-28 days	12,000MPa	≥3000MPa

- Construction results by Chemical soil stabilization method:
  a. High construction speed → Completed in 60 working days which completion time is 6 months
  b. Low construction cost → Do not need extensive earthworks
  c. Less disruptions to airport operations and environmental friendly
  d. Good quality of engineering properties

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

B. Brunei Darussalam:

Jalan Tutong Widening, Phase III (1997-1999).

- Brunei Highway design
- In-situ soil condition: Backfilled Sandy Soils/Swampy area.
- Original design:

  100% of Pilling foundation and Geogrid system as Base and Sub-base course → serious differential settlements after few years by previous highway construction
- Design consideration:

  Eliminate differential settlement and allow total settlement within the control limits

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

- Proposed design by Chemilink soil stabilization method:

a. 30% of piling foundation for important crossroad cable and pipes

b. Stabilized 350mm of in-situ soil as Sub-base course and stabilized 220mm of Crusher run as Base course

a. Opened road cross section

b. Road after 2-year completion

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

Jalan Tutong Widening, Phase III (1997-1999).

- Average Site testing results:

Testing items	Chemilink Soil Stabilization	Specification. Requirement
CBR-7 days	80%	≥90%
UCS-7days	1.60MPa	≥1.5MPa
Modulus of sub-grade reaction (k)-28days	780MPa/m	≥3000MPa
Degree of compaction	>97%	>95%

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

C. Malaysia:

(1) Runway/Taxiway widening of Sultan Ismail International Airport of Malaysia (2007).

- In-situ soil condition:

  Clay content > 80%, LL=70-90%, PI=40-50%, water content=40%

- Proposed design by Chemilink soil stabilization method:

  Stabilized **300mm** of in-situ soil as **Base/Sub-base course**.

- Construction speed:

  1.5months ahead from construction schedule (4months)

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

Runway/Taxiway widening of Sultan Ismail International Airport of Malaysia (2007).

- Average Site testing results:

Testing items	Chemilink Soil Stabilization	Specification. Requirement
CBR-7 days	120%	≥90%
UCS-7days	2MPa	≥1.5MPa
Resilient Modulus (M_R)-28 days	6,000MPa	≥3000MPa
Degree of compaction	~97%	>95%

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3. Case Studies by Chemical Soil Stabilization Method for Road Construction

Runway/Taxiway widening of Sultan Ismail International Airport of Malaysia (2007)

a) Excavation

b) Spreading

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

Runway/Taxiway widening of Sultan Ismail International Airport of Malaysia (2007)

c) In-Situ Mixing

d) Compaction

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

Runway/Taxiway widening of Sultan Ismail International Airport of Malaysia (2007)

e) Paving Asphalt Concrete

f) Completion of Widening

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

C. Malaysia:

(2) FELDA Plantation Access (2009)

- In-situ soil condition: Swampy and High water table areas

Before stabilization

After stabilization

3. Case Studies by Chemical Soil Stabilization Method for Road Construction

E. China: Low cost rural road in Xizang, Tibet (2007)

- Local condition: High altitude, extreme of temperature and humidity.
- Construction consideration: Limited of natural resources as road construction materials and long transportation distances to the job-site.

Road in Use

General comparison by different aspects between Conventional and Soil stabilization method for roads construction

a. Impact to environments

Comparison Items	Conventional Method	Soil stabilization Method
a. Quantities of quarry materials required	Very high	Limited to None
b. Disturbances to public	More	Less
c. Non-toxic, environmental safe and stable	Yes	Yes
d. Carbon emissions due to mining and transportation of quarry material	Very high	Less

b. Construction

Comparison Items	Conventional Method	Soil stabilization Method
Construction cost (Materials, Transportation, Waste disposal)	Higher	Lower
Construction speed	Slower	Faster

General comparison by different aspects between Conventional and Soil stabilization method for roads construction

c. Applications

Comparison Items	Conventional Method	Soil stabilization Method
a. On good sub-grades	Yes	Yes
b. On swampy or weak sub-grades	No	Yes
c. Applicable soil types	---	Normal soils such as sandy, silty and clayey soils

4. Conclusion

a. By using chemical soil stabilization method for road construction

→Decrease the dependence of approved fill materials (especially for those region or countries with limited of natural resources)

→Decrease the global environment impact in term of CO_2 emissions due to less mining and transportation aspects.

b. Benefits of using soil stabilization for road construction:

✓ In-situ soil properties improvement → Strength and Stiffness of soil layer.

✓ Improve the long-term durability of road compared with un-stabilized or unbound layer

✓ Reduce the construction cost and time of road due to effectively utilize of locally available soils and other materials as road construction material.

4. Conclusion

c. With chemical stabilization method, many technical difficulties, especially the total and differential settlements, at clayey, swampy or low-lying land areas with peaty soils have successfully been resolved.

d. Chemilink soil stabilization has technically and commercially been proven to be the effective and durable method especially for road and airfield construction in this region, based on the performance and durability of numerous projects with Chemilink soil stabilization method.

e. Wide ranges of Chemilink soil stabilization method application for road construction, from high profile projects (airfield and highway construction) to low cost rural road.

THANK YOU
FOR YOUR ATTENTION