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Pavement Strengthening by In-Situ Rehabilitation & Semi-Rigid Pavement Methods

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1. Introduction

1. To build **Stronger**, **Effective** and **Durable** pavements in **Fast**, **Green** and **Sustainable** manner, especially in South-East Asia with poor soil and reveres climatic conditions is a challenge.

2. In-situ rehabilitation (ISR), with appropriate chemical stabilizing binders for soils, stones, solid wastes and their mixtures to form the "Floating Semi-Rigid Platform" so as to strengthen the pavement, has been practiced for past 20 over years with confirmation to serve the purposes of better pavements.

3. Semi-rigid pavement (SRP) surface system has been also explored and applied, especially in Singapore and Malaysia for past more than 10 years, to provide better performances for surface areas with heavy wear/tear and various chemical attack; and this latest technological solution can well function like concrete but be maintained like asphalt concrete.

4. A total solution by combining the both ISR and SRP systems can build a complete well-performed pavement from bottommost sub-grade to surface wearing layer.

2. In-situ rehabilitation for base and sub-base

1. As traffic loading and frequency increase, the conventional method with natural materials and mechanical compaction can not meet higher technical requirements on various performances; while the poor soil sub-grade especially in South-East Asia can not also provide a satisfactory substrate to support pavements, while rich rainfall will quickly cause failure of pavements formed by bulk materials.

2. The pavement layers from upper layer of sub-grade to base course can be strengthened or stabilized by appropriate bio-chemical or chemical binders to form the "Floating Semi-Rigid Platform" especially over the soft or swampy ground so as to serve the purpose of building better and durable pavements.

3. To rehabilitate the in-situ soils, stones, some solid wastes and their mixtures using chemical stabilization method which can maximize the usage of local waste materials with faster construction rate is obviously green and sustainable. It is very useful for both quick road maintenance and new road construction.

4. In-situ rehabilitation mainly includes three simple steps: spreading binder; in-situ mixing binder with local materials and then compaction.

2. In-situ rehabilitation for base and sub-base

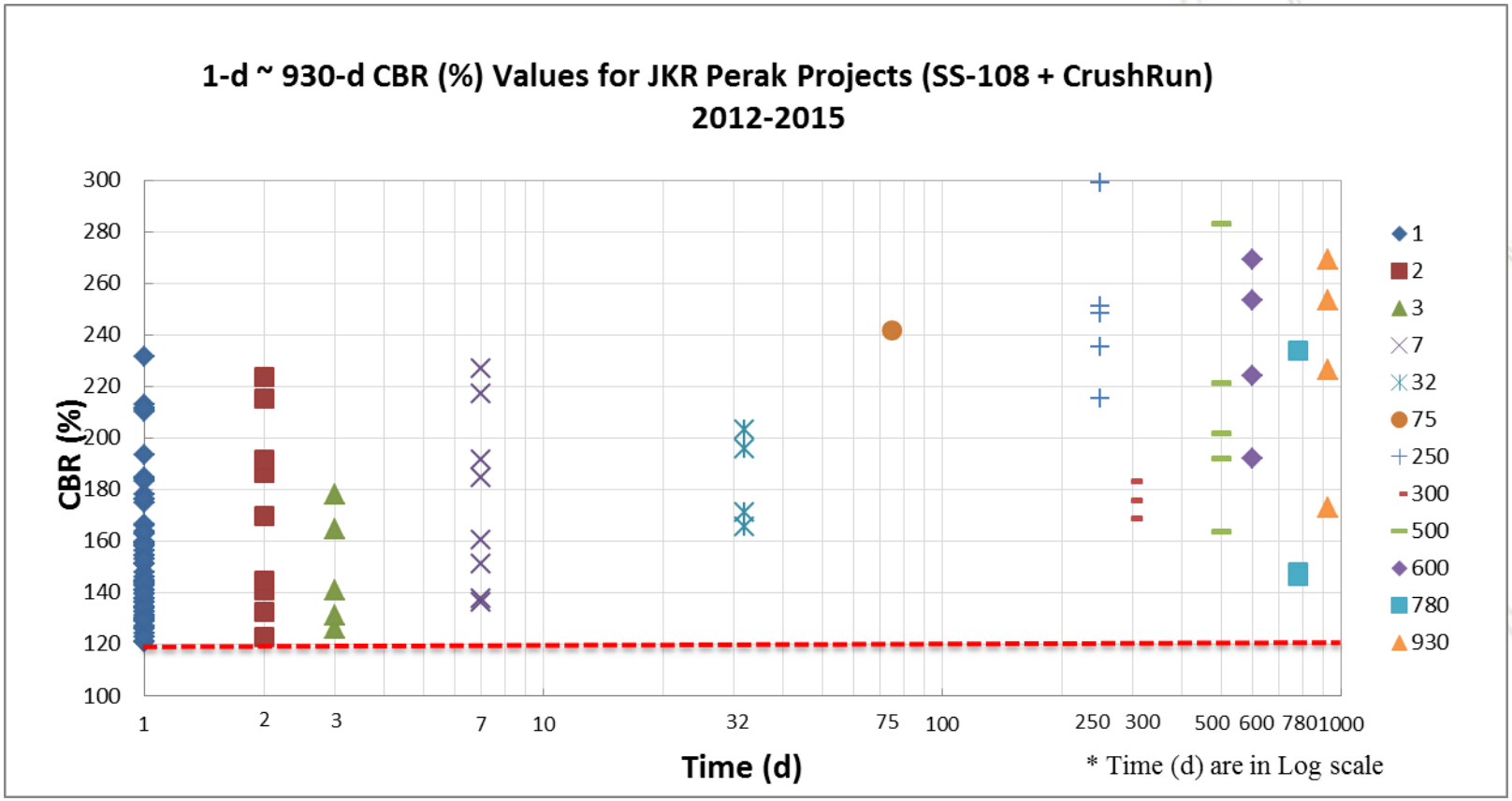

Figure A1. 1-d to 930-d In-situ CBR of Rehabilitated Base Achieved for Malaysia PWD Roads (2012-2015)

2. In-situ rehabilitation for base and sub-base

Falling Weight Deflectometer (FWD) Test Results for Perak JKR Roads – Federal JKR, Malaysia

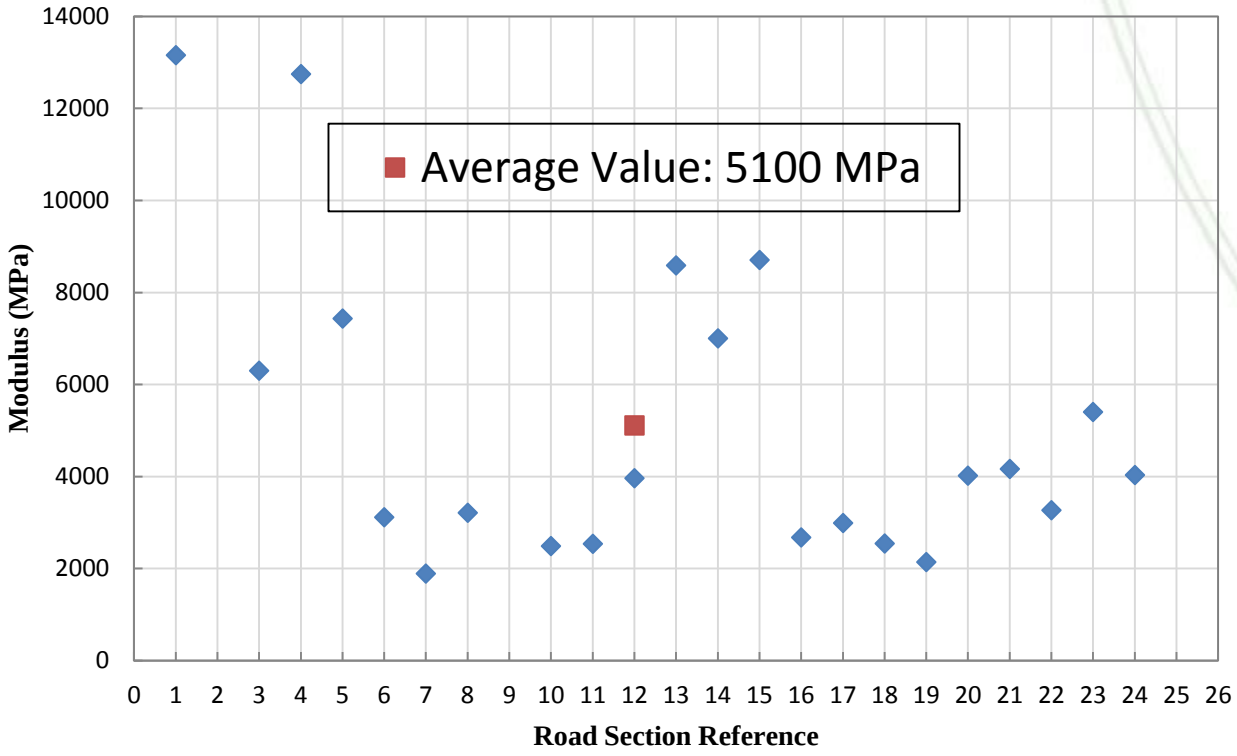

Figure A2. Stiffness Modulus of Chemilink Stabilized Base (1~3 Years)

2. In-situ rehabilitation for base and sub-base

a) Road partially closed from mid-night for maintenance

b) Road re-open for public early next morning

c) Cored samples of rehabilitated in-situ materials

Figure 1. A Rehabilitated City Road in 2000 (after Wu, 2011)

2. In-situ rehabilitation for base and sub-base

a) Singapore Airport Runway

b) Malaysia Airport Taxiway

Figure 2. ISR for Widening of Runway and Taxiway

2. In-situ rehabilitation for base and sub-base

a) Taxiway-A

b) Taxiway-B

c) Runway

Figure 3. Damaged Runway and Taxiways

2. In-situ rehabilitation for base and sub-base

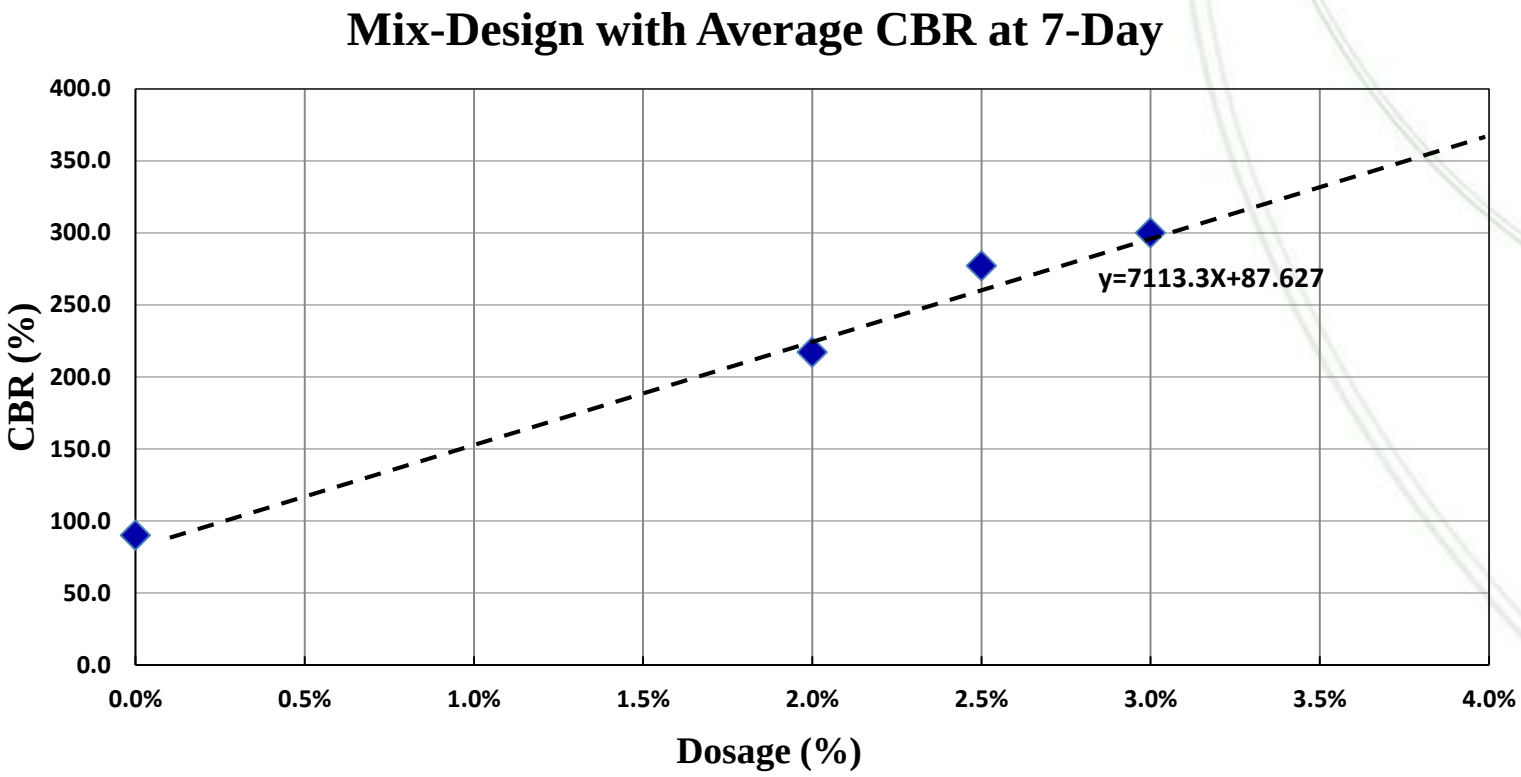

Figure A3. Mix-Design with Average CBR at 7-Day

2. In-situ rehabilitation for base and sub-base

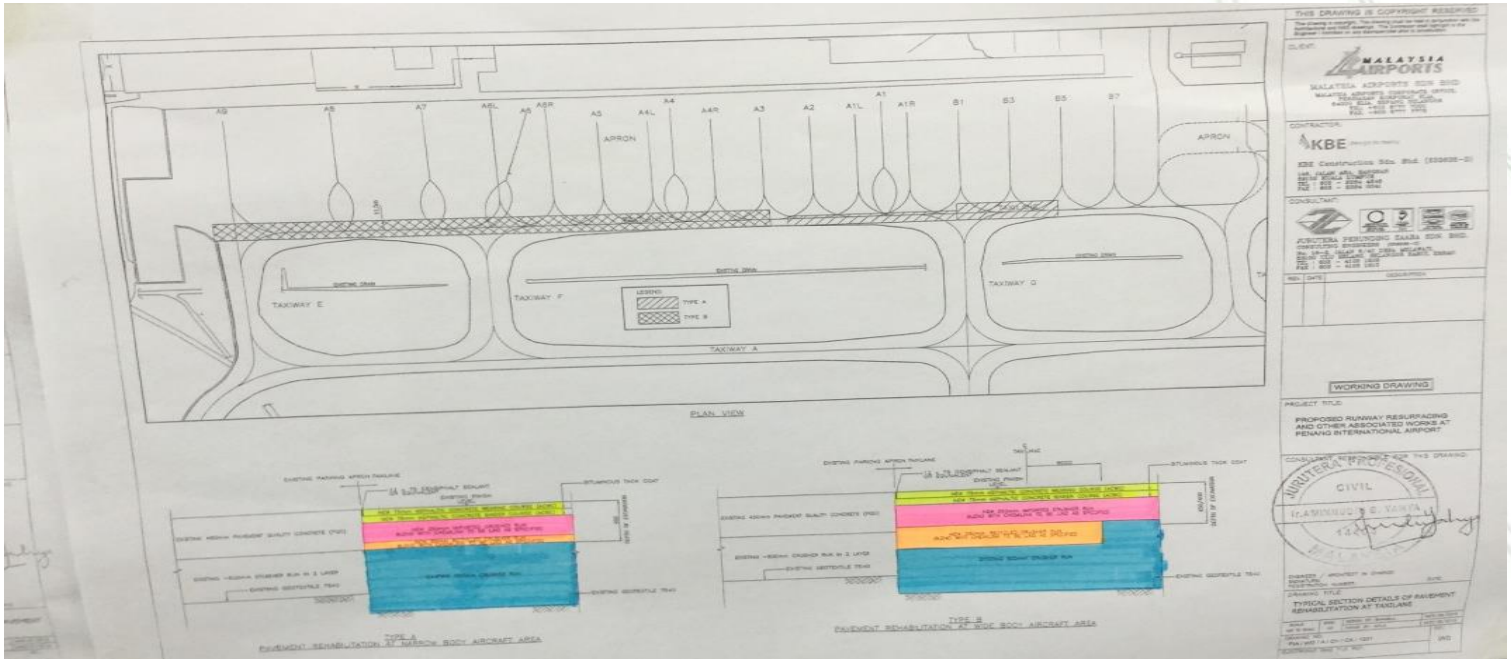

Figure 4. Design Drawing of ISR for Damaged Pavement Sections (Full-Strength)

2. In-situ rehabilitation for base and sub-base

a) In-Situ Mixing in Progress

b) Newly Rehabilitated Taxiway in Use

Figure 5. In-Situ Rehabilitation for Full-Strength Taxiways

2. In-situ rehabilitation for base and sub-base

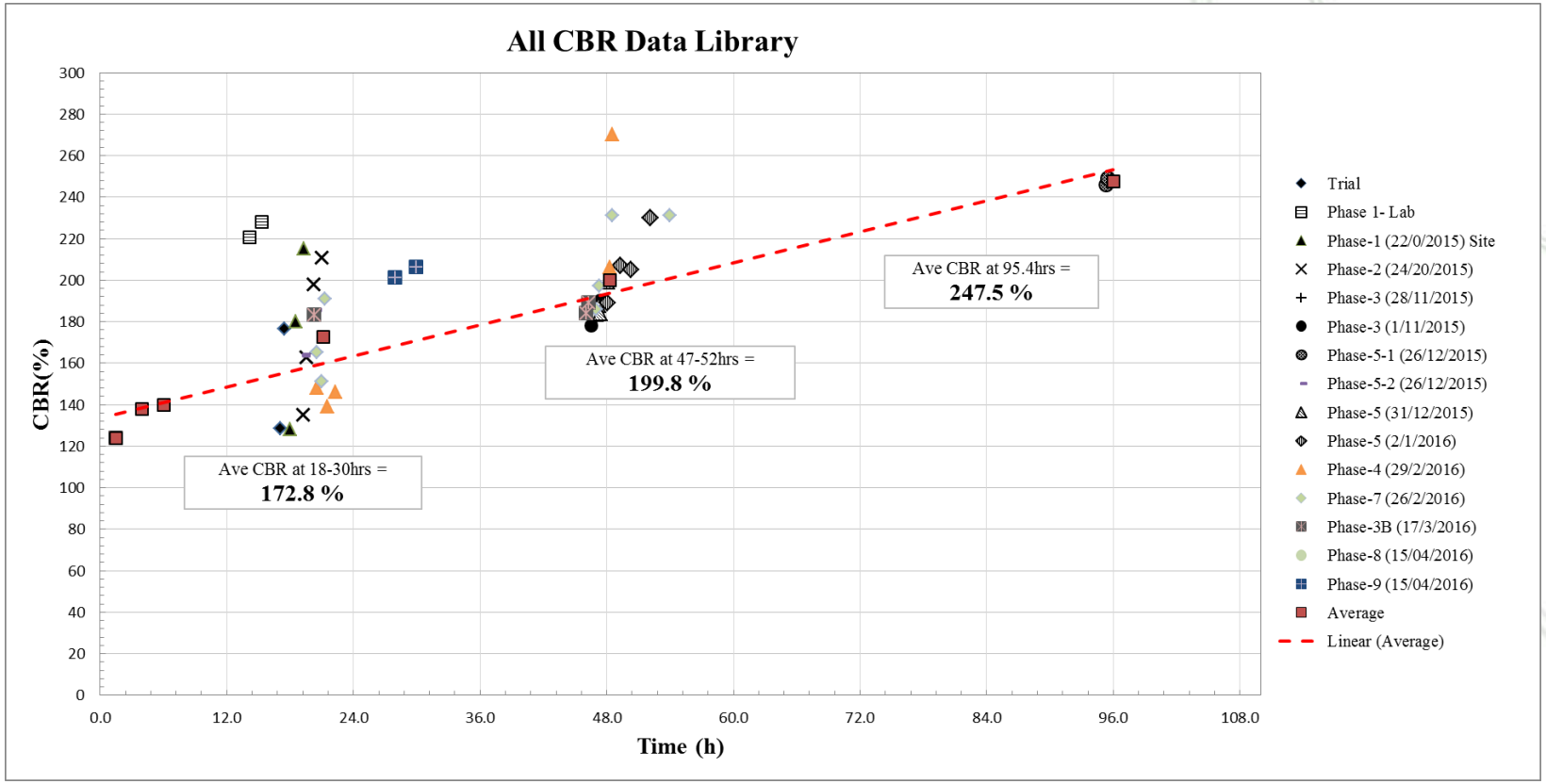

Figure A4. Field Test Results for ISR.

3. Semi-rigid pavement for surface

* Semi-Rigid Pavement (SRP) has been used for wearing course of pavement

* SRP formed by Porous (or Open) Asphalt Concrete fully filled by Polymer Modified Cement Mortar (or called Grout material)

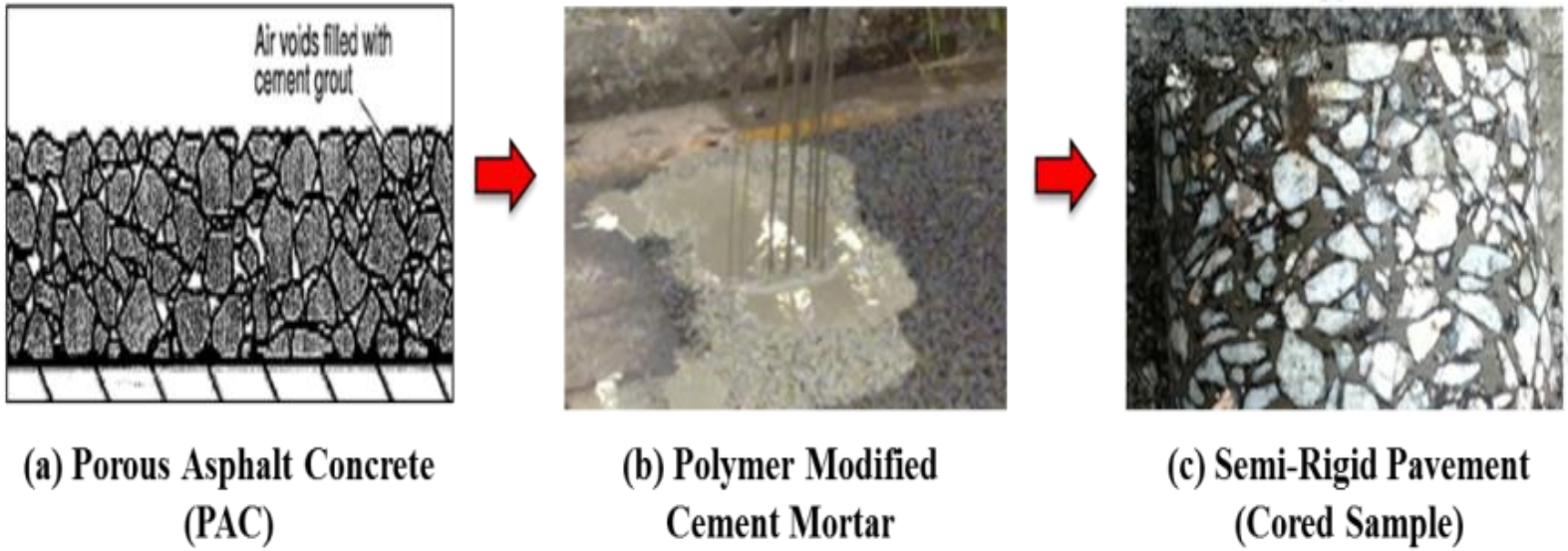

Figure 6. Composition of Semi-Rigid Pavement (SRP)

3. Semi-rigid pavement for surface

Table 1. Comparison of Three Typical Types of Pavements

Compared properties (selected properties)	Flexible Pavement	Rigid Pavement	Semi-Rigid Pavement (SRP)
1. Resistance to rutting/deformation	Poor	Good	Good
2. Skid resistance properties	Good	Poor	Good
3. Resistance to petroleum products, oil and chemical	Poor	Good	Good
4. Resistance to moisture damage	Poor	Good	Good
5. Maintenance and repair	Easy	Difficult	Easy
6. Life span	Short	Long	Long
7. Flexural strength properties	Low	High	High
8. Expansion joint	Not required	Required	Not required
9. Installation and open to traffic	Within hours	0.5-3.0 months	Within 24 hours
10. Construction and maintenance costs	Lower const. cost; High maint. cost	Higher const. cost; Low maint. cost	Low const. cost; Low maint. cost

3. Semi-rigid pavement for surface

Figure 7. Installation Procedure of SRP

3. Semi-rigid pavement for surface

Airport Parking Apron

Airport Runway Entry Section
75mm x 2 layers

Road Junction

Heavy Loading Road

Expressway Entry Section

Turning Zone for Heavy
Loading Vehicles

Parking Area for Heavy
Loading Vehicles

SRP at 50,75,100mm thick

Figure 8. Selected Typical Applications of SRP in Singapore (2006~2015)

3. Semi-rigid pavement for surface

Figure A5. Singapore Tuas MRT/Bus Depot Using SRP System (100mm thick, 2016)

4. Recommendations

Table 2. Recommended Quick Pavement Strengthening Patterns

Pattern No	Existing Conditions	Key Description	Estimated Construction Rate	Remarks
1	General damaged; heavy operational road	#1 Rehabilitate base (300mm)	500mX(3.5~6.0)m per 12 working hours	Most common case
2	Similar to No. 1 but existing base is hardly to be rehabilitated	#1 Top-up CR as new base and stabilize it (300mm), while converting existing base as sub-base	350mX(3.5~6.0)m per 12 working hours	CR: Crusher Run. Road level increased
3	Foundation is very weak or with higher water table; Updating road grade	#1 Rehabilitate existing base as sub-base (300mm); #2 Top-up CR as new base and stabilize it (250~300)mm	250mX(3.5~4.5)m per 12 working hours	Road level increased
4	Serious damaged; Others similar to No. 3	#1 Make existing surface rough; #2 Top up CR as sub-base and stabilize it (300mm); #3 Top up CR as base and stabilize it (250~300)mm	200mX(3.5~4.5)m per 12 working hours	Using existing road as sub-grade; Road level increased
5	Damaged surface materials recyclable; Higher water table	#1 Rehabilitate existing surface materials together with new CR (300mm)	400mX(3.5~6.0)m per 12 working hours	Purposely increase pavement elevation
6	Surface sudden drop between non- & free settlement zones; On embankment and/or week soils	#1. Rehabilitate existing sub-base over through both zones (250~300)mm; #2 Rehabilitate the back-filled existing base materials over through both zones (250~300mm)	200mX(3.5~4.5)m per 12 working hours	Preferably incorporated with grouting system for long-term performance

4. Recommendations

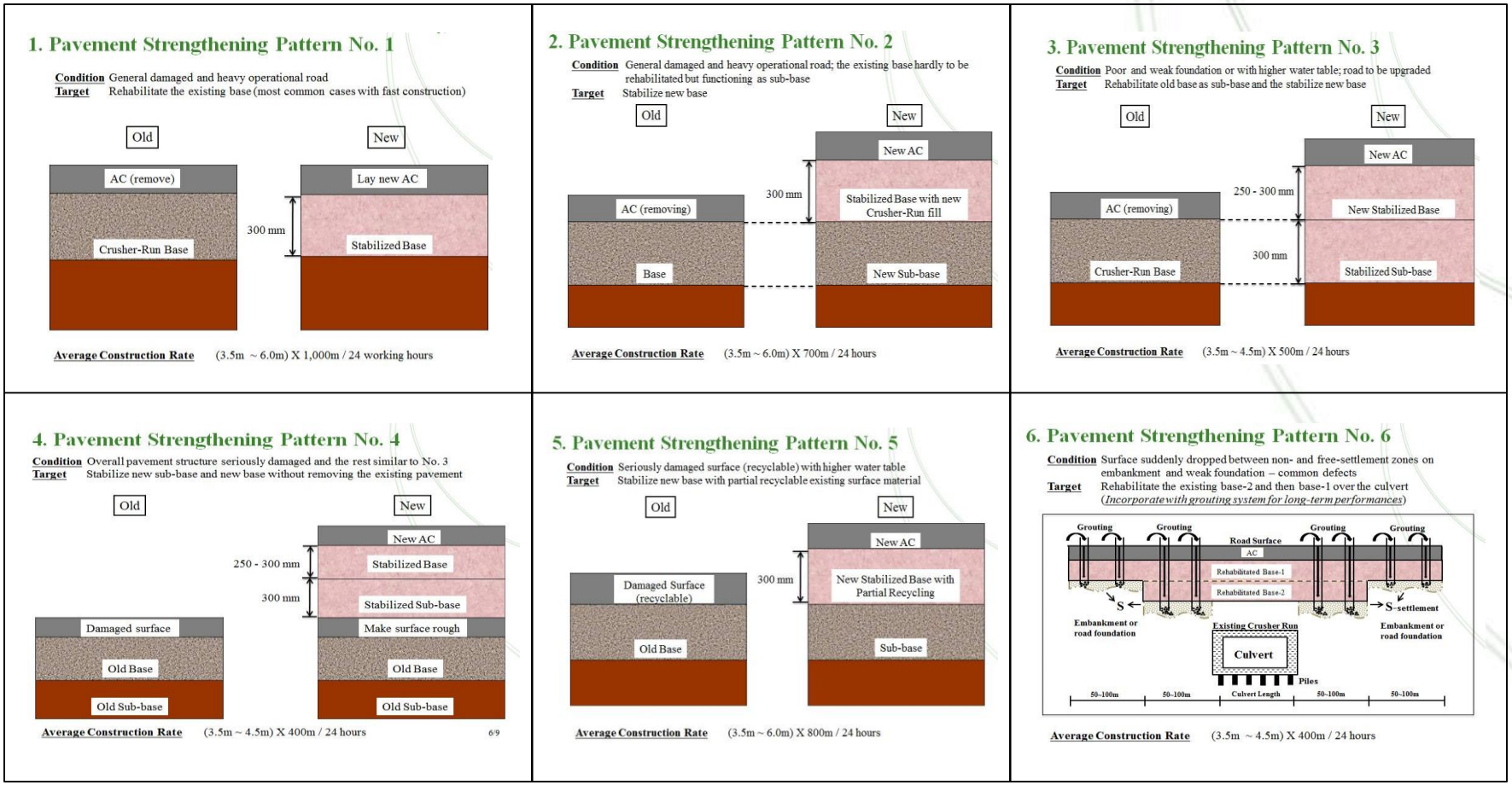

Figure A6. Six Quick Strengthening Patterns

4. Recommendations

Table 3. Recommended Typical Thicknesses for SRP Applications

No	SRP Thickness	Application Scope	Remarks
1	50mm	Most commonly used; road junction, heavy loading road section; bus lane and stop; parking apron	Minimum SRP thickness; 1 layer only
2	75mm	Heavier loading zone; parking apron;	1 layer only
3	100mm	Permanent heavier loading/chemical-attack zone; bus depot/terminal;	1 layer of 100mm or 2 layers of 50mm each
4	150mm	Specially strengthening area; taxiway turning section; runway initial taking-off section	2 layers of 75mm each

5. Conclusions

- **In-Situ Rehabilitation (ISR) or Stabilization is a proven engineering approach in quickly strengthening pavements and it is remarkably green and sustainable, which indicates a developing direction in new construction and maintenances/repair of various existing pavements.**

- **Semi-Rigid Pavement (SRP) is a high effective wearing course in increasing surface performances and lifespan, which has fully combined advantages of both rigid and flexible pavements.**

- **Typical applications with appropriate quick strengthening patterns for ISR and in different thicknesses for SRP have been recommended and more engineering exercises could be conducted based on the local conditions.**

- **This paper provides a workable total solution for quick strengthening various pavements from bottommost sub-grade to surface wearing layer, deduced from numerous proven engineering practices for past 10 to 20 years in South-East Asia.**

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