

# **In-Situ Rehabilitation (ISR) Method for Pavement Strengthening**



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# 1. Introduction

- Frequent pavement repairs and upgrading are required worldwide due to increases of traffic loadings and frequencies. Such situations are even more serious for various pavements including airfield infrastructures over soft ground and swampy areas in tropical region.
- The ISR (In-Situ Rehabilitation) method can be technically capable and commercially effective to strengthen the in-situ materials especially the base course which generally formed by crushed stone (or called Crusher Run), cement treated base and so on.
- This solution is a remarkable green approach, which conforms to the historical trend of the time in today's world development.
- By incorporation with the maximized re-use and re-cycling of the in-situ or local stones or solid construction wastes, and with appropriate rehabilitation binders, ISR can quickly conduct pavement repair and maintenance works so as to minimize the construction time.

# 1. Introduction

- The **ISR Solution** with a series technological system has been proven in this region for past 20 over years in faster construction, superior technical performances, much longer durability and cost effectiveness, while it has exceptional advantages and benefits to airfield construction under heavy operational restrictions.
- More engineering practice and projects rather than theoretical statements have been selected in this presentation to highlight the **workability, reliability and durability** of this ISR solution for pavement construction from road, seaport to airfield.
- ISR is very similar to the chemical-soil in-situ stabilization especially in application process, including semi-rigid platform effect, while ISR can achieve much higher strength and modulus within a short time and so as to have much better performances to support the pavement surface layer and overall pavement structure.
- This presentation will concentrate on ISR applications in the base and sub-base courses mainly formed by crushed stones or equivalents.

## 2. Rehabilitation Design and New QC Criteria

### Standard Design Criteria for ISR with Crushed Stone or Equivalent

- Base (7-day):  
CBR  $\geq$  90 -120%, and/or UCS  $\geq$  3.0 - 6.0 MPa
- Achievable Stiffness Modulus (28-day):  
2,000 - 8,000 MPa
- Chemical Binder Dosage  
Range: 1.50 - 3.00% (based on the dry weight of the soil to be treated)

### New QC Criterial

- **CBR  $\geq$  120% within 24-hour** (key reason: to have QC assurance in works under time constrains)
- The rests are similar to those standard ones

## 3. ISR in Road Repair & Maintenance

### Base Strengthening of City Road (Brunei, 2000)

- Rehabilitated thickness: 300mm
- Working time: 10:00pm – 6:00am
- Rehabilitation sequence: lane by lane and night by night
- A purpose: to make road more even and prevent differential settlements



a) Rehabilitation in process



b) Immediate opening to traffic



c) Cored samples at site



### 3. ISR in Road Repair & Maintenance

#### Various Public Roads (2012-- , Malaysia)

- Road before and after ISR (300mm, Base)



### 3. ISR in Road Repair & Maintenance

#### Various Public Roads (2012--, Malaysia)

- Road before and after rehabilitation (300mm, base)
- Rehabilitation in process





### 3. ISR in Road Repair & Maintenance

#### Various Public Roads (2012-- , Malaysia)

- Before, in process and after ISR



### 3. ISR in Road Repair & Maintenance

#### Heavy-Duty City Road Junction (2017, Malaysia)

- 300mm ISR for base course
- 50-75mm Semi-Rigid Pavement (SRP) as surface wearing course



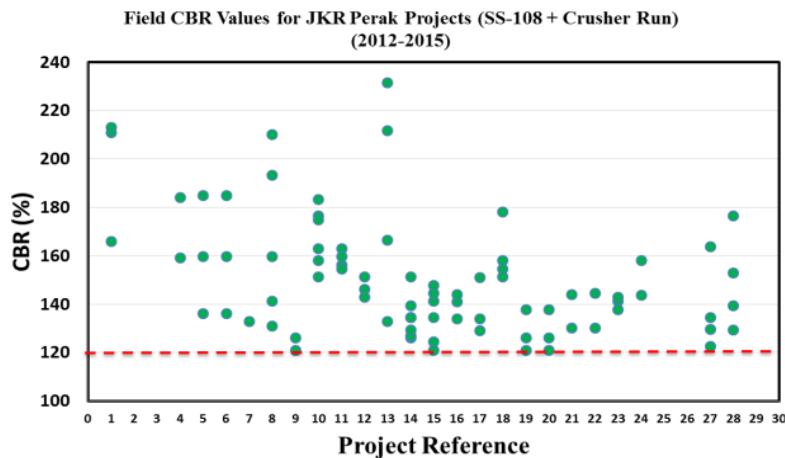
a) ISR for base course



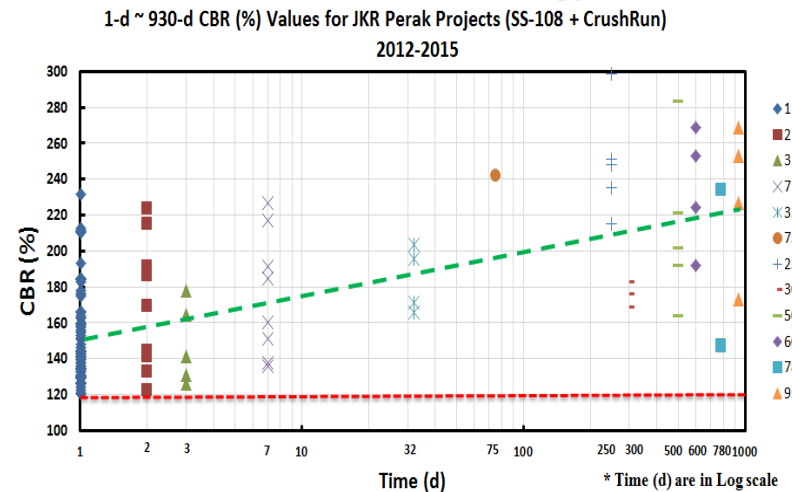
b) SRP as AC wearing course

## 4. Short- & Long-Term Performances of ISR

- The requirement of in-situ CBR  $\geq 120\%$  within 24-hour before laying AC surface has been exercised in Malaysia PWD road repair and maintenance works since 2012, where as a reference, the CBR value for well compacted graded stones or crusher runs is about 80-90%.
- Further studies on long-term CBR up to 930-day on the same roads were conducted and the CBR development trend is steadily increasing.



a) At 1-day

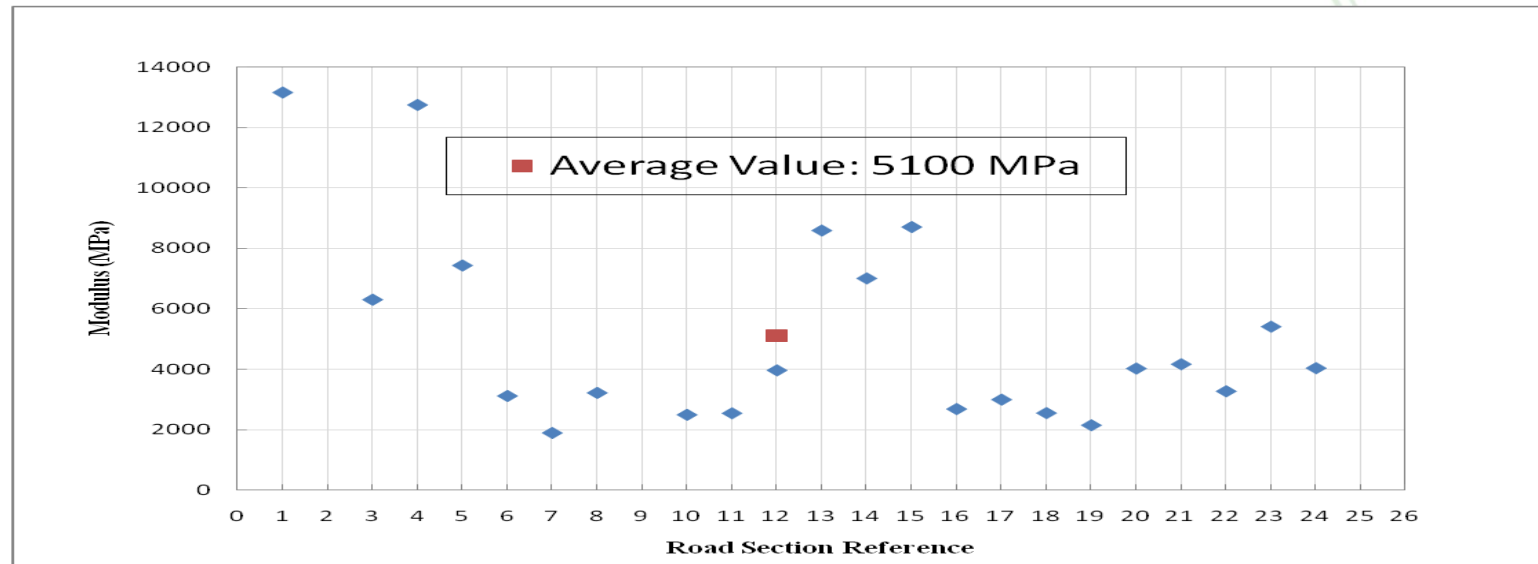


b) At 1-day to 930-day

### Selected In-Situ CBR Values of ISR Base from 28 Public Roads

## 4. Short- & Long-Term Performances for ISR

- Malaysia Federal PWD conducted HWD tests (2016) on 24 public road sections along the west coast used for past years (2012-2015) to investigate the stiffness moduli of ISR bases over soft ground or swampy areas.
- Typical road design: **110mm AC, 300mm ISR base and 200-300mm sub-base.**
- The average value of Stiffness Moduli is **5,100MPa (min. 2,000MPa).**
- Road life prediction: At least another **10 years.**



**Stiffness Moduli of ISR Base from 24 Malaysia Public Roads**



## 5. ISR in Seaport Re-Construction

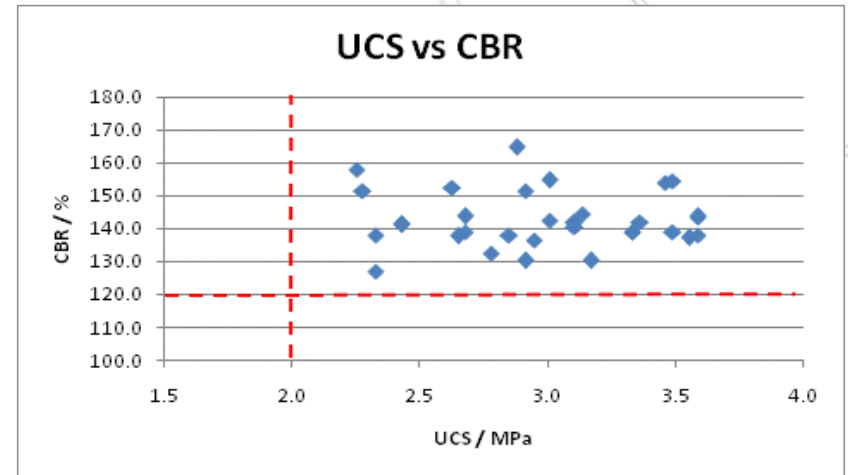
### Port Klang's Container Yard (2010-2013, Malaysia)

- Before and after ISR, phase by phase





- Design and QC Tests



## QC Test Results (7-day)

- 350mm Concrete
- 300-400mm ISR Base/Sub-base
- 100-300mm in-situ CR with compaction

## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

#### Penang International Airport (09/2015-06/2016, Malaysia)

- The original pavement design before rehabilitation is generally as follows:
  - 500-600mm CR;
  - 450mm CTB or CR
  - 120mm Bituminous Macadam
  - 100-150mm AC

(Note: typical PWD road: 110mm AC, 300mm ISR base and 200-300mm sub-base.)

- Selected stiffness moduli of the existing base by Heavy Weight Deflectometer Test
  - Section Runway 04-22 - 233 - 475MPa
  - Sections Taxiways A-J & Taxi-lane - 33 - 683MPa
- In consideration of the stiff modulus of min. 2,000MPa for the ISR road base, the taxiways have to be strengthened and upgraded.

## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

- Visual investigations were conducted immediately before the strengthening project started.
- The observations tally with the full investigation report and thus the strengthening designs were quickly adjusted and **ISR Solution** were engaged.



a) Section 1



b) Section 2



c) Section 3

### **Selected Damaged Sections of Taxiways**

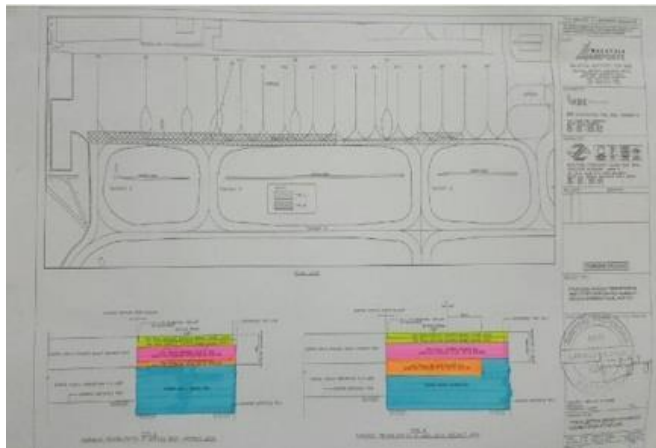
## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

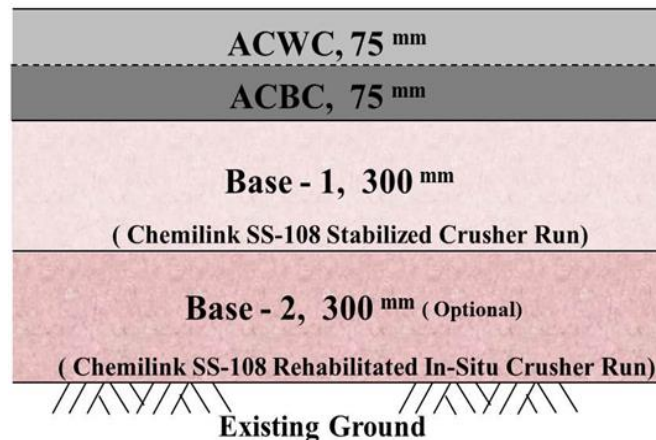
#### Designs for both Taxiways & Runway

**Case 1.** Both Base-2 and Base-1, when  $\text{CBR} \geq 30\%$ -60% on the original top of Base-2 after excavation.

**Case 2.** Base-1 only (also prepared for some of Runway Strengthening in Phase-2)



a) Typical Section Details



b) Cross Section Design

#### Typical Cross Section Designs of Pavement Rehabilitation at Taxiways

## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

- 3 Key ISR Processes
  - **Spreading**
  - **Mixing**
  - **Compaction**



a) Spreading



b) Mixing



c) Compaction

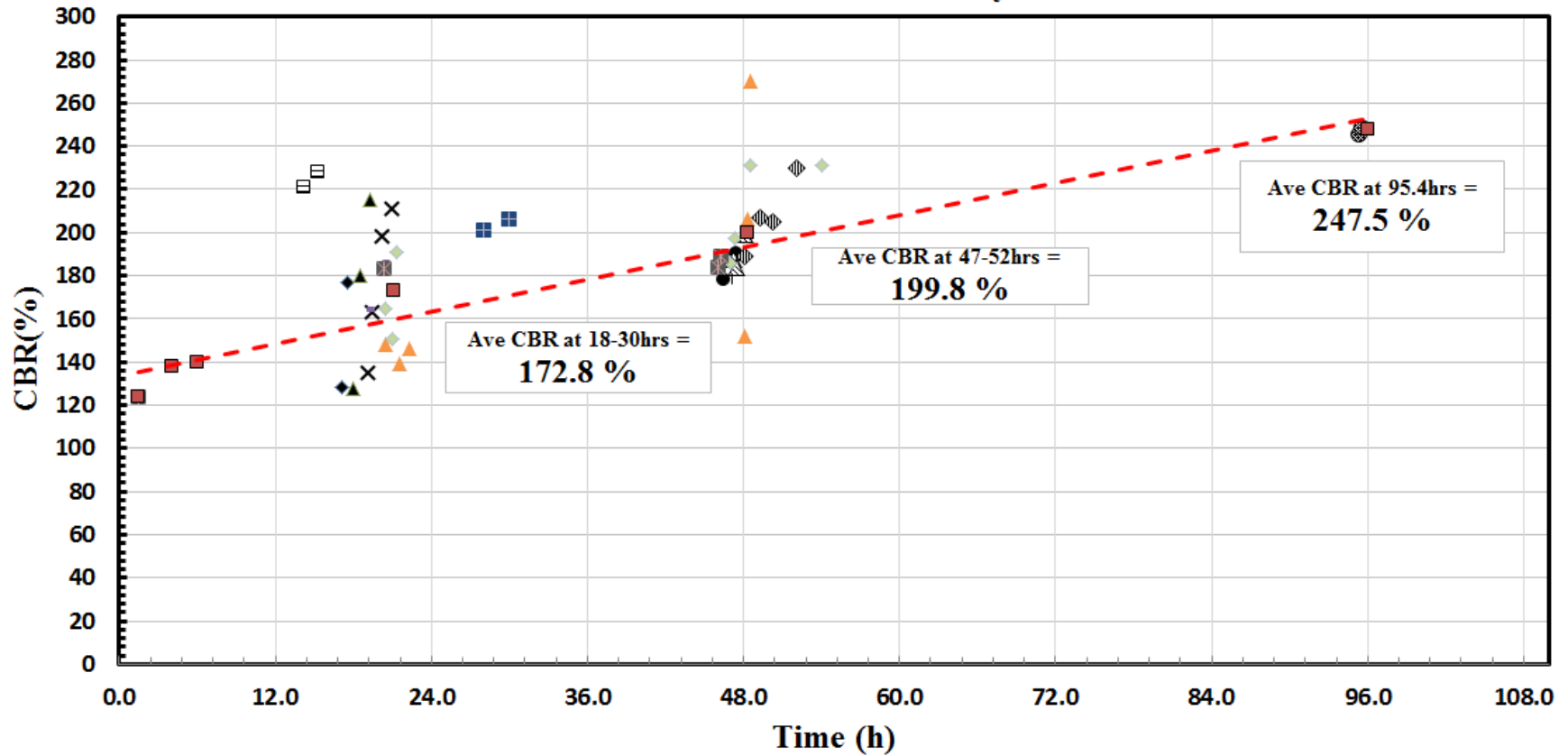
### ISR in Process



## 6. ISR in Strengthening of Airport Taxiways

--- Penang International Airport

All CBR Data Library



In-Situ CBR Test Results for ISR of Taxiways

## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

- Immediate Re-Opening to Airport Operations



a) Passenger aircraft taxiing



b) Cargo B747 arriving



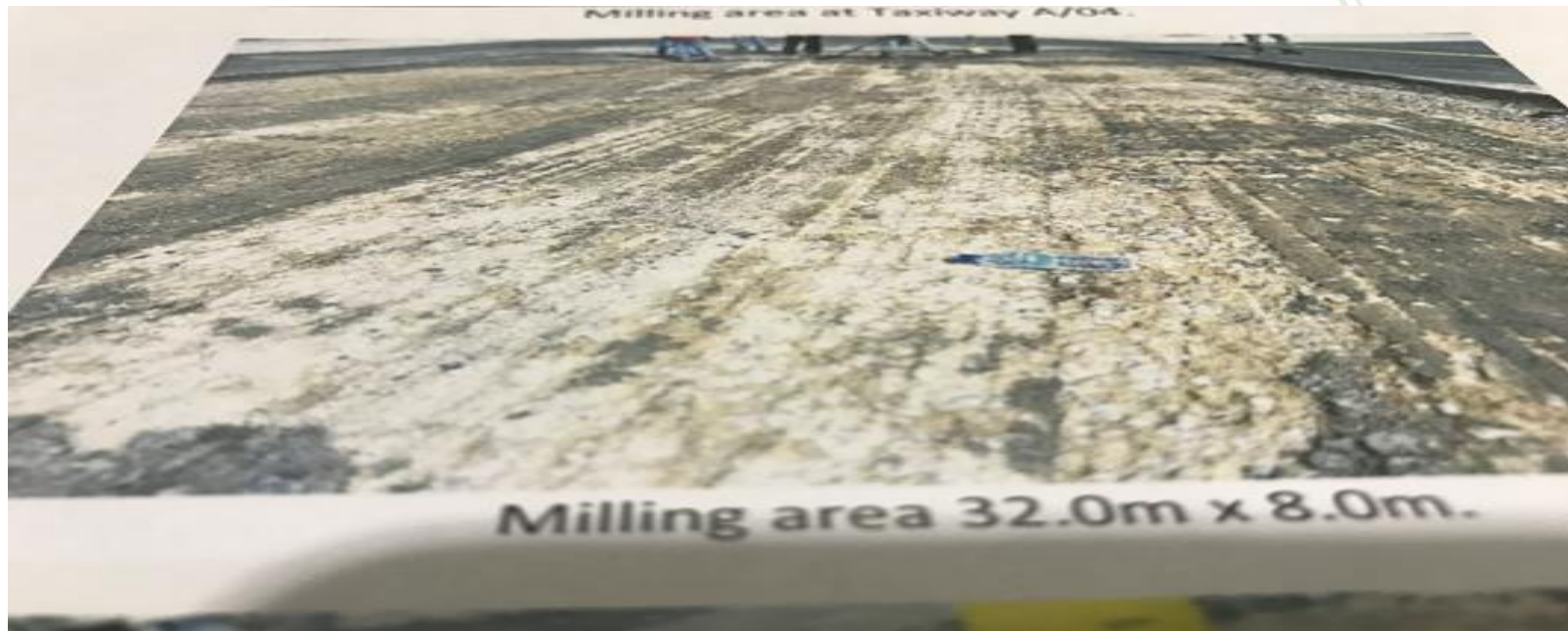
c) Aircrafts to be taking-off

**Immediate Opening to Airport Operations**

## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

- In about 18 months after completion, AC layers in a section of 32m by 8m were completely removed and the surface of ISR base was carefully investigated.
- No defects like cracking, deforming, softening and etc. had been found there at all.



### Investigation on ISR Base Quality after 18 Months

## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

- About two years later upon completion, the AC layers in selected sections were completely removed to investigate the ISR base and no defects directly related to ISR, like cracking, deforming, softening and etc., had been found.



### Investigation on ISR Base Quality after 24 Months



## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

- For past 15-24 months, **no defects** directly related to ISR have been found so far.
- Penang International Airport is in **smooth operations**.



**Airport in Smooth Operations after Strengthening with ISR**



## 6. Conclusions

- The in-situ rehabilitation (ISR) method has been applied in strengthening of the various pavement base courses, especially for quick repairing and maintenances under operational conditions in tropical region for past many years .
- An innovative design and QC criteria of the in-situ CBR $\geq$ 120% within 24-hour for ISR in quick repairing and maintenance works has been employed to promptly ensure the quality and reliability of pavement construction. The workability of this revolutionary change has been also proven to be effective in many full-scale PWD roads and Penang international airport project under operations and thus unnecessary disruptions to road/airport operations and other risks related to the construction have been minimized or eliminated.
- Specific advantages and benefits using the ISR method indicate the adaptation, practicability and reliability of this ISR Solution not only in technical performances but also in commercial/operational aspects.
- Technical performances of the projects listed in this presentation with various ISR base courses to-date are still satisfactory and no major defects have been found so far, though those pavements have been in operations for past many years.

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**Thank You for Your Attention!**





## 6. ISR in Strengthening of Airport Taxiways

### --- Penang International Airport

- About two years later upon completion, the AC layers in selected sections were completely removed to investigate the ISR base and no defects directly related to ISR, like cracking, deforming, softening and etc., had been found.



**Investigation on ISR Base Quality after 24 Months**