ALKALI-SILICA REACTION IN CONCRETE PAVEMENT AT GIMPO INTERNATIONAL AIRPORT – A MAINTENANCE CASE STUDY USING HMA OVERLAYS

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INTRODUCTION

In most cases, the deteriorated concrete pavements caused by alkali-silica reaction (ASR) need to be replaced to maintain their original function because it is easier than doing repairs on the pavements. To maintain a sustainable operation of the airport business, however, there are greater demands for using repair types in contrast to complete replacement and it can be conducted without any close pavement. In preparation for such demands, Korea Airports Corporation (KAC) has conducted test construction by milling 10 cm of existing concrete slabs and overlaying asphalt mixture and evaluated the pavement performance. The testing has been conducted on the 90m-long parallel taxiway at Gimpo International Airport in 2010. When the concrete pavement has been overlaid with 10 cm of asphalt mixture, it takes five years for the reflection cracking to occur and the spread of the cracks continue to create potholes. Therefore, KAC has conducted four different types of testing. Their types used asphalt mixture. After monitoring each types, it takes a result of which types can more effective on reducing the reflection cracking.

The list below, briefly explains how the test and evaluation of the pavement performance was conducted.

1) Pre-site survey(surface defects, HWD test)
2) Test construction
3) Site survey(distress defects, HWD test)
4) Analysis of survey data and monitoring of pavement performance
5) Evaluation of pavement performance
6) Repair of test construction

PAVEMENT CONDITIONS ON THE TESTING AREA

Concrete pavement at the threshold of the runway in Gimpo International Airport, was constructed in 1996 and the parallel taxiway concrete pavement that was completed in 1995 was found to have cracks caused by ASR (Alkali-Silica Reaction) in the pavement evaluation in 2009.

Figure 1. ASR occurrence site

Due to strong effect of ASR reaction, there are severe cracks occurring on most parallel taxiway pavement at which we are going to have a test. F.O.D resulted from longitudinal cracking influenced by ASR was occurring in the particular area of the wheel path, which required either the reconstruction of the entire pavement layer or repairs of the partial pavement layer on top of the existing pavement. Since partial repairs of the pavement area were not feasible, 4 types of milling and overlay methods by using asphalt mixture on top of the existing pavement were carried out in order to extend the pavement life.

A. Construction year
- Runway threshold concrete pavement: operated for 13 years from 1996, Thickness=40cm
- Taxiway threshold concrete pavement: operated for 14 years from 1995, Thickness=40cm

B. Pavement condition

Figure 2. Surface map-cracking

Figure 3. Surface longitudinal cracking

RESULTS OF INDOOR LABORATORY ASR TESTING

When evaluating the state of pavements, the following list was conducted in order to figure out the causes of their defects by observing the surface area and detecting the irregular and discoloring cracks from extracted cores.

- Data on damaged conditions collected through on-site investigation
- Analysis on lithological components in aggregates
- Investigation of the reaction product from extracted cores
- Microscope investigation inside pavement
- EDX(Energy Dispersive X-ray Spectroscopy) analysis on reaction product

The specimens of cores collected from the lithological analysis in the damaged area were found to be composed of metamorphic rock such as quartz feldspar gneiss, banded gneiss and garnet biotite gneiss. Most of the quartz was fine-grained ~ neutrality-grained crystal of the subhedral or oval shape, and showing undulatory extinction and suture texture. It will be suspected to be the principal reason for the ASR reaction. The Horizontal cracks were present and developed in 7 out of 8 cores, as demonstrated in Figure 4 and the reaction products were seen in the vicinity of the aggregate grains as in Figure 5 and also the white reaction product was found to exist within air-voids.

Figure 4. Surface and parallel crack

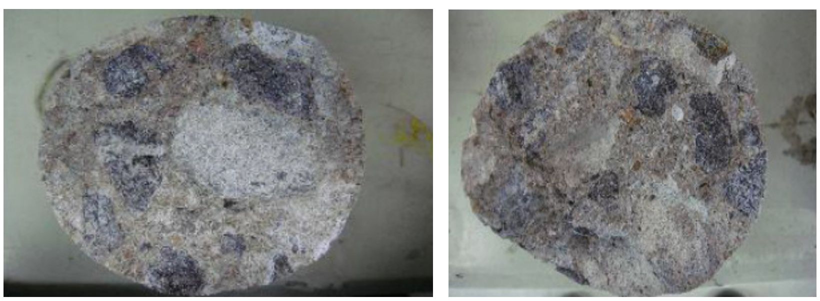


Figure 5. Chemical reaction in the parallel crack section

As a result of the microscopic observation into the concrete using the Phase-contrast microscope, the reaction product filled in air-void was found to be formed by the transparent gel around air-void in white shape as shown in Figure 6a. The white gel was formed on the boundaries between aggregate and cement material as shown in Figure 6b.

Figure 6a. Reaction product within air-void (40X)

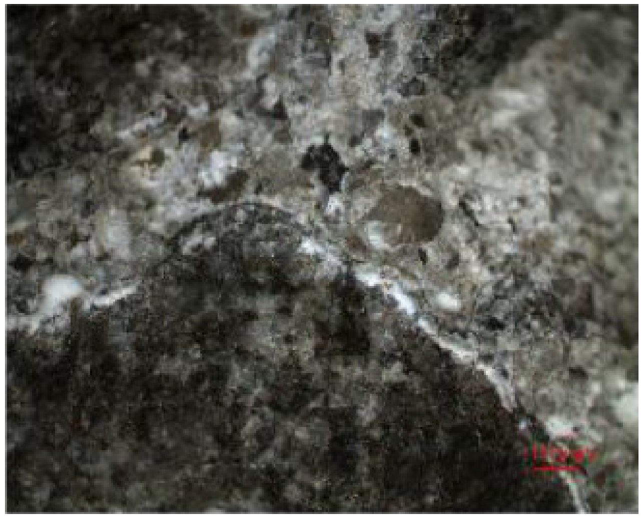


Figure 6b. Reaction product within aggregate boundaries (10X)

The reaction gel due to ASR was observed in SEM survey at the aggregation reaction product section and white product area. In EDX analysis, the spectrum of white product was analyzed to be ASR product in order of Si>K>O>Ca and therefore in this analysis we could recognize that this is the typical ASR product which were composed of Si and K

SITE CONSTRUCTION

The site construction was conducted on the concrete pavement of the parallel taxiway of the Gimpo International Airport. Although the construction normally makes of general HMA overlay, it is needed to consider the elevation differences between site construction area and the contacted existing taxiway pavement and milling and overlays was performed to adjust a elevation instead of overlay. And the surface of the concrete pavement weakened and was generating F.O.D. so it was also needed to remove in order to enhance adhesion between HMA overlay layers and the existing milling concrete slabs. And the test was consisted of 4 different types of replaced HMA overlays on top of the existing concrete.

- Total area of test construction: 2,700 m^2 (width 30m x length 90m)
- Period of test construction: 07/28/10 ~ 07/30/10

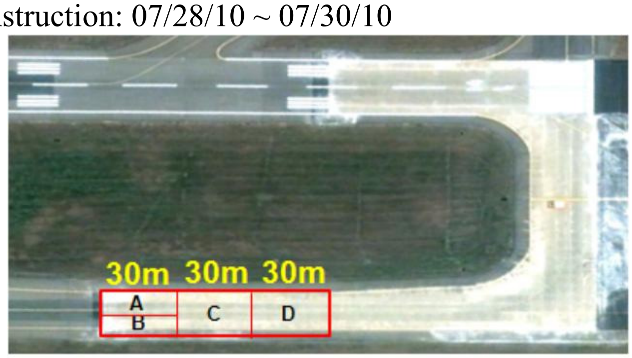


Figure 7. Test construction site

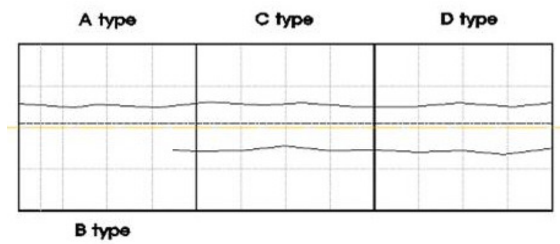


Figure 8. Longitudinal cracking

A-Type test construction was paved and compacted using the general asphalt mixture, adding T=5cm thick pavement twice after milling the existing concrete pavement less than 10cm depth and no additional reinforcing material was used. The airfield lighting was removed before the construction and reinstalled at the designated place after taking coring. B-Type used CRM (Crumb Rubber Modified) asphalt mixture and construction procedure is equal to the A-Type.

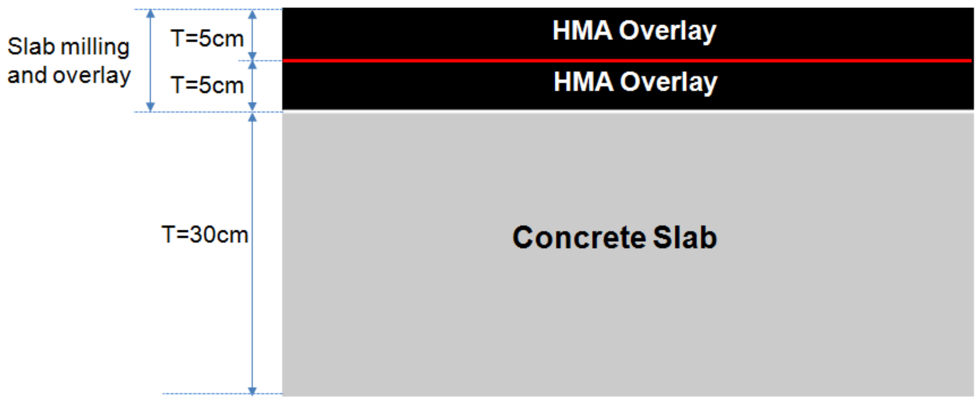


Figure 9. A-Type structure

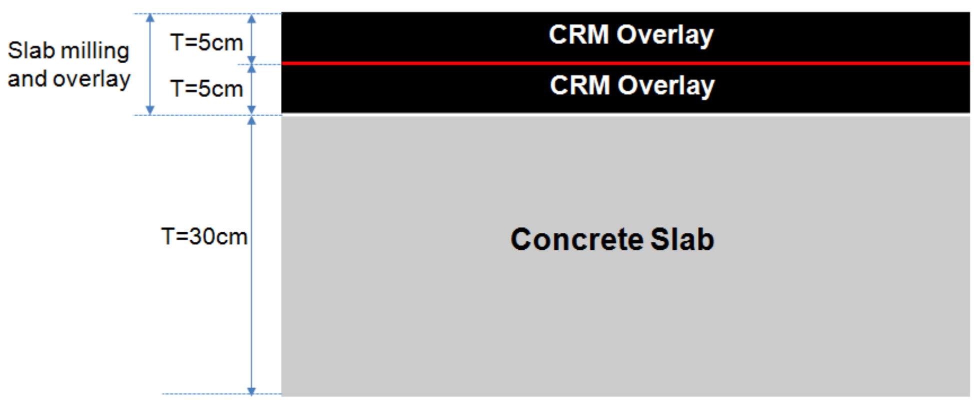


Figure 10. B-Type structure

C-Type test construction was paved and compacted using the general asphalt mixture, adding T=5cm thick pavement twice after milling the existing concrete pavement as much as 10cm depth and reinforcing material consisting of pavement fibers and waterproof adhesive were used. The C-Type procedures for removing the airfield lighting system, paving asphalt and compacting asphalt are not different from the ones of A-Type.

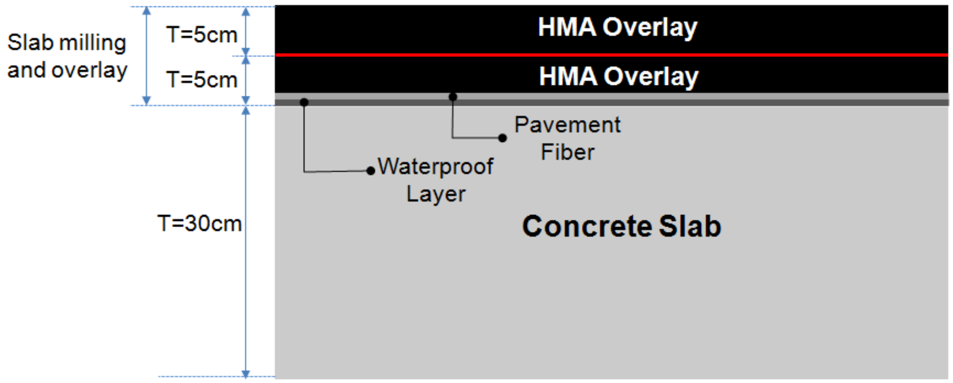


Figure 11. C-Type pavement cross section

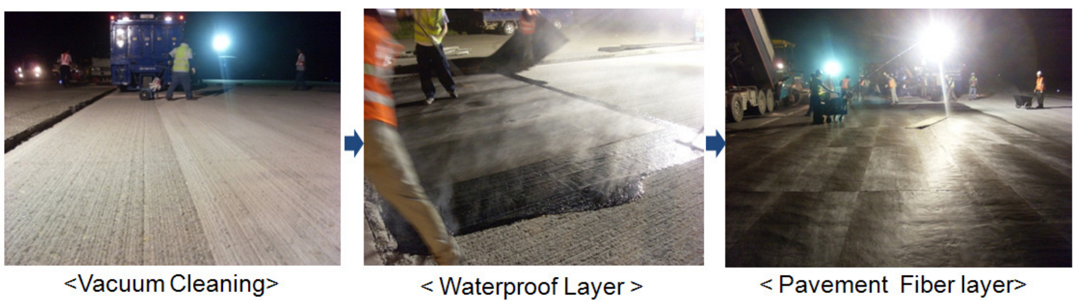


Figure 12. C-Type pavement construction process

D-Type test construction was paved with glass fiber Grid within the general asphalt mixture after milling as much as 10cm depth and paving and compacting the first 5cm lift of asphalt mixture and then covered with asphalt mixture and compacted as much as T=5cm pavement thickness. The procedures for removing the airfield lighting system, pave asphalt and compact asphalt are equal to the ones of A-Type.

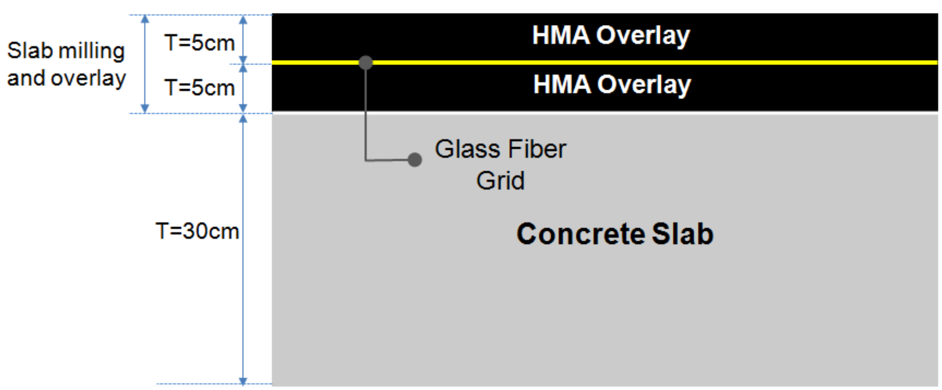


Figure 13. D-Type pavement structure

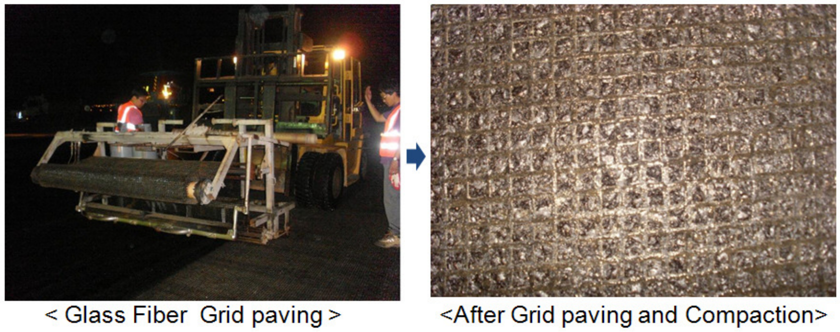


Figure 14. D-Type pavement construction process

MATERIAL PROPERTY TEST FOLLOWING THE TEST CONSTRUCTION

As for the result of material property test immediately following the test construction, Air void was a little high in B-Type and C-Type, both at little over 6%. In asphalt pavement, we manage the design air void of surface layer to be below 4.2%. And in general, manage air void right after construction to be below 6%. Since when air void reaches at design criteria right after construction, rutting could be able to occur because of traffic load. The field compaction density should be more than 96% of the theoretical maximum density. But most of them were less than it. The field compaction density was attributed to defected pavement.

Table 1.

Design criteria

Property	A-Type (HMA)	B-Type (CRM)	C-Type (HMA+Water proof layer)	D-Type (HMA+Glass fiber grid)
Air Void(%)	2.8~4.2	3.0~5.0	2.8~4.2	2.8~4.2
Theoretical Maximum Density(g/cm³)	2.44	2.53	2.49	2.48

Table 2.

Material property test result

Property	A-Type (HMA)	B-Type (CRM)	C-Type (HMA+Water proof layer)	D-Type (HMA+Glass fiber grid)
Air Void(%)	5.51	6.23	6.71	5.85
Density(g/cm³)	2.30	2.36	2.32	2.33

LOAD TRANSFER EFFICIENCY TEST BY USING HWD

If overlay was conducted on the pavement, the reflection cracks develop inevitably and the reflection cracks is caused by the contraction and expansion slab due to both a pavement temperature change and the aircraft loads on the overlay above the concrete joint. And the reflection cracks and load transfer efficiency is related to each other. The change of load transfer efficiency is affected by milling slab and the pavement structural weakness. Therefore, load transfer efficiency test by using HWD was conducted to acknowledge its measurement value change when the reflection cracks develop and milling slabs weaken structurally. Load transfer efficiency and cracking is often related to each other. As mentioned previously, 4 types overlays is effective on the reflection cracks delay and It can be compared and evaluated with 4 types overlays. In order to measure the change of load transfer efficiency for each overlay type, HWD testing was implemented at the two slab lines on the wheel path. HWD data was obtained three times before (July 23th, 2010) and after (May 5th, 2011) test construction, and the time of pothole occurrence (August 17th, 2013).

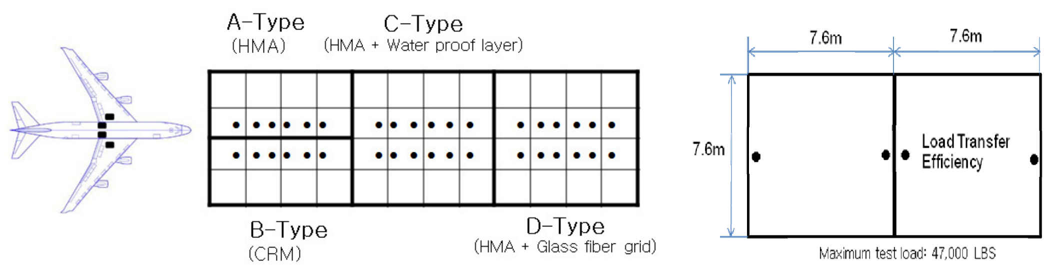


Figure 15. HWD test location

In this case study, the load transfer efficiency was determined by the ratio of deflection in the slab at both sides of a joint. Load transfer efficiency is one of the essential factors in evaluating structural capacity of concrete pavement. In a joint that lacks load transfer efficiency, traffic load will increase the difference in deflections in the slab at both sides of the joint, give excessive stress to only one side of the slab, which not only accelerates concrete degradation but can cause pumping or faulting and thus shorten the service life of the concrete pavement.

$$LTE(\%) = \frac{\Delta_{unload}}{\Delta_{load}} \times 100$$

where, LTE : Deflection ration caused by load transfer, %
Δ_{unload} : Deflection at the unloaded side of the slab joint
Δ_{load} : Deflection at the loaded side of the slab joint

MONITORING RESULTS OF PERFORMANCE

Generally, in the case of an HMA overlay on concrete pavement, reflective cracking first occurs by the contraction & expansion of concrete slab dependent on temperature change and vertical movement of concrete slabs caused by aircraft load. And then pothole occurs after rainfall infiltration into reflective cracking. In the case of 10cm HMA overlay thickness on concrete, it could be little variation according to region and traffic, generally reported that most reflective cracking occurs in 5 years from overlay. In the result of milling and overlay (T=10cm) on parallel taxiway at Gimpo airport, reflective cracking did not occur on any of the overlay types after three years. However, Potholes were found on wheel path areas on all overlay types. In the case of B-type, the potholes occurred less than the other types and alligator cracking of low severity occurred across the B-Type overlay areas. By these results, CRM (Crumb Rubber Modified) pavement can be strong against rutting but can fall slightly against the Top-Down cracking on the low temperature in winter season. It was assumed that hot mix production quality control is one of the other reasons for the alligator cracks

<Pothole (initial)> <Defect spread and maintenance>

Figure 16. Maintenance status

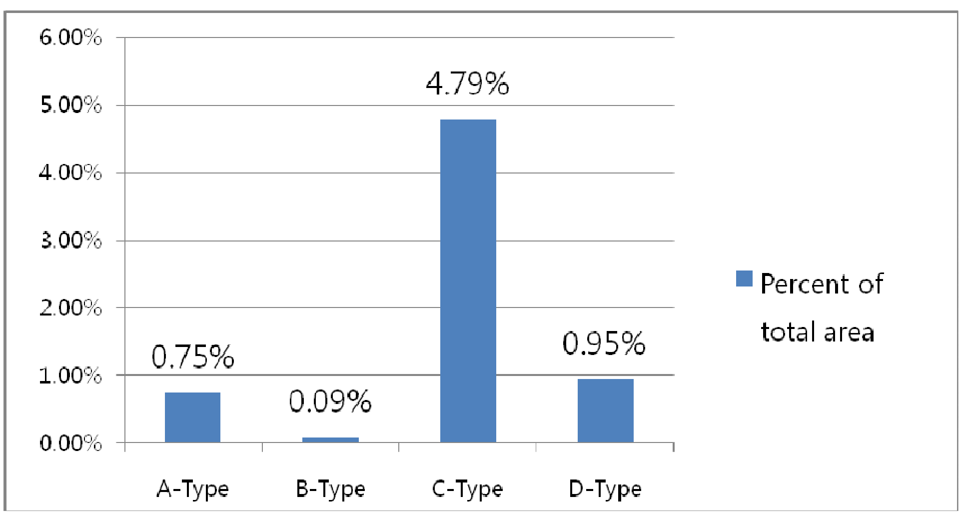


Figure 17. Maintenance area rate at each method within 36 months in service

As for the result of HWD test, Load transfer efficiency was decreased considerably in contrast to the before test construction. The decline of the C-Type and D-Type was larger than the other types, thus requiring a large number of repair works. The decline of B-Type was smaller than the other type, and this type required the least amount of maintenance. According to this result, it is estimated that the damaged slabs around the dowel bar at joints were assumed to be deteriorated further because of the ASR. The discovery that the dowels were too high in the pavement may have lost contact when the slabs were thinned.

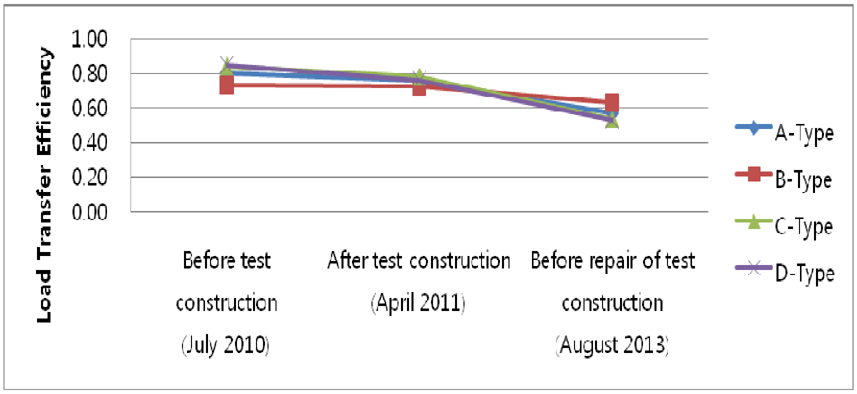


Figure 18. Decline of the load transfer efficiency

On the joints as shown in figure 18, the value of Do deflection measured before repair of test construction in 2013 increased far more than before test construction in 2010 after the repair of test construction 2013, B-Type deflection was recorded the highest as 16.15 mils when measuring in April 2011, but the lowest as 23.91 mils when measuring in August 2013. Also the A, C and D-Type recorded relatively high increase rate of deflection when measuring in August 2013 compared with other time. As a result of that, it is assumed that the structural weakened slabs were attributed to developing potholes. In fact B-type area had less longitudinal cracks than other types before the repair overlay.

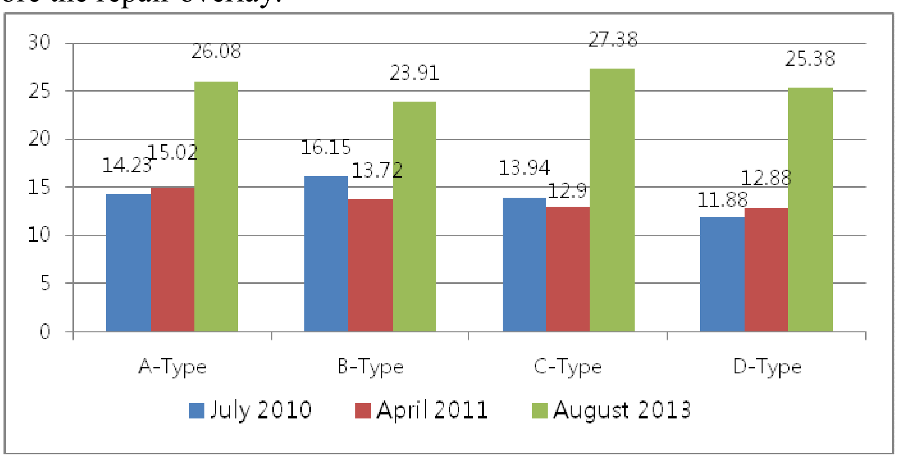


Figure 19. D_0 deflection data (load : 45,399LBS, unit : mils)

REPAIR OF THE TEST CONSTRUCTION AREA

As for the main reason of the premature defects, it is estimated that there is a limit for HMA overlay to protect rainfall infiltration. And especially, milling and overlay method on the impermeable concrete slabs will make the occurrence of premature defects inevitable such as the parallel delamination and potholes on the high tire pressure of the aircraft. Therefore, repair work was implemented by using Polymer Modified SMA in September 2013. The Polymer Modified SMA(Stone Mastic Asphalt concrete) can be effective in preventing rutting while reducing air void. The second test construction was paved and compacted using SMA, adding T=5cm thick pavement twice after milling the existing overlay pavement of 10cm depth. The second overlay was each consisted of 13mm and 10mm maximum size of coarse aggregate.

- Asphalt binder: SBS Polymer Modified Asphalt(PG 76-22)
- maximum size of coarse aggregate: 13mm (t=5cm) + 10mm(t=5cm)
- Repair area: width 16m of the wheel path area that have potholes

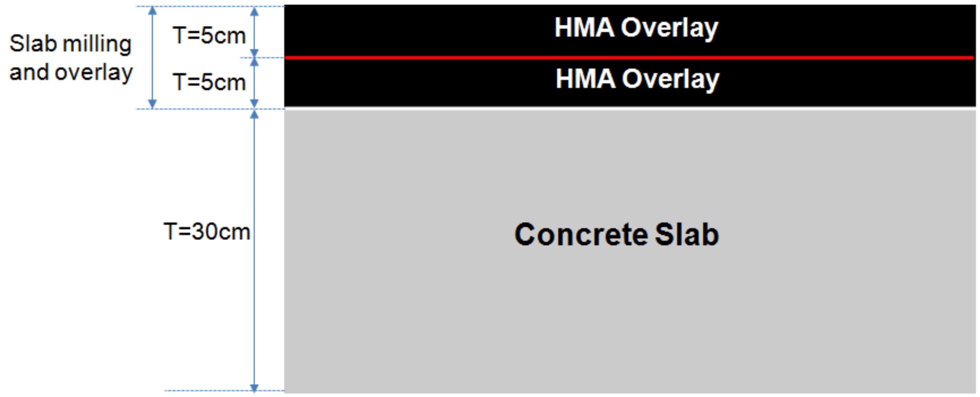


Figure 20. Second Repair pavement structure

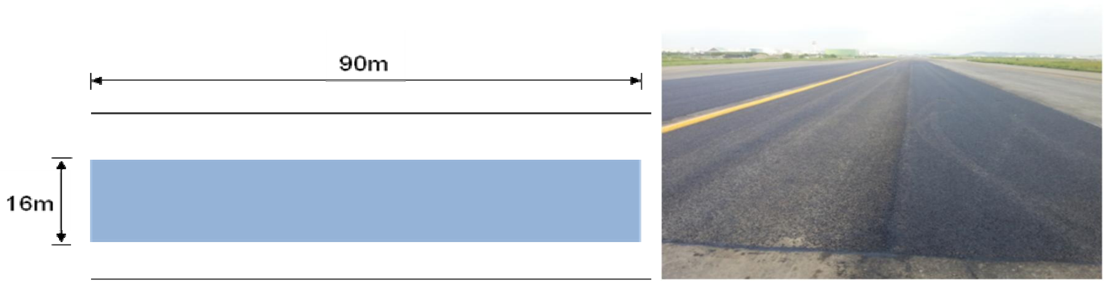
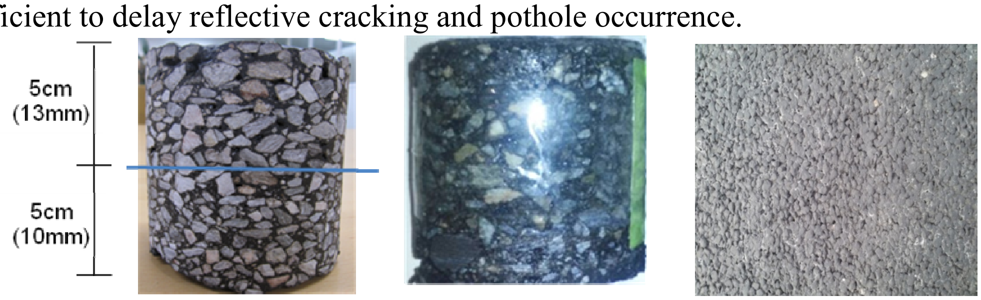


Figure 21. Repair size and photograph after repair work

RESULT OF MATERIAL PROPERTY TEST AFTER SECOND REPAIR

In the result of material property test after 3 months of performance period, void of upper SMA 13mm layer was 5.1~6.6% and void of the under layer SMA 10mm was 3.3~3.8%. This result shows that the basic characteristic of SMA material is more resistant to rutting and better prevents rain infiltration from beginning of the construction. Therefore SMA is expected to be more efficient to delay reflective cracking and pothole occurrence.



SMA 13mm+10mm HMA 19mm Surface of SMA

Figure 22. Comparison of core sample with SMA and HMA

Table 3.
Polymer Modified SMA

Air Void(%)	13mm	5.1~6.6
	10mm	3.3~3.8
Density(G/cm3)	13mm	2.33~2.36
	10mm	2.35~2.36
Maximum Theoretical Density(g/cm3)	13mm	2.496
	10mm	2.446
Asphalt content(%)		5.53

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

In general, it has often been assumed that when a concrete pavement has been overlaid with 10cm of HMA, it will take about four to five years for reflection cracks to fully form and the reflection cracks will eventually form pothole. However in the case of the test construction, Potholes have occurred in the aircraft wheel-paths after 3 years of performance period and reflection cracks did not occur.

As the cause of the premature defects, it is estimated that the deterioration of the structure damage due to ASR and existing longitudinal cracks accelerated the defects. And damaged slabs were deteriorated further as a result of milling of the slab. Therefore we recommend carrying out overlay instead of milling and overlay, provided that there is no problem with the final elevations. According to load transfer efficiency result, it is estimated that the damaged slabs around the dowel bar at joints were assumed to be deteriorated further because of the ASR. The discovery that the dowels were too high in the pavement may also affect to deteriorate the pavement when the slabs were thinned. As for the main reason of the premature defects, there is a limit for HMA overlay to protect rainfall infiltration. Under the air void of HMA, milling and overlay method on the impermeable concrete slab will make the occurrence of premature defects by factors such as rainfall infiltration and high tire pressure of the aircraft.

Therefore the management of the air voids in the overlay right after construction is important factor and it is desired to use asphalt mixtures which air void can be reduced to minimize water infiltration while raising its stability. And it needs to study further so that we define an exact boundary or range of the air voids that result in suitable performance

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