Report to

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DRAFT

CINCINNATI / NORTHERN KENTUCKY INTERNATIONAL AIRPORT TAXIWAY K CONCRETE SCALING TESTS

by

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Submitted by

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- Samples were obtained from T/W K and from a reportedly older air-entrained concrete pavement section.

- Concrete cores were tested in accordance with American Society for Testing and Materials (ASTM) Designation: C666 *Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing.*

- Concrete blocks (T/W K) and cores (air-entrained) were tested in accordance with ASTM Designation: C672 *Standard Test Method for Scaling Resistance of Concrete Surfaces Exposed to Deicing Chemicals.*

- Two types of sealers, Hyrdozo Enviroseal 20 (Enviroseal) and ChemTec One (ChemTec), were evaluated in the rapid freeze-thaw and scaling test programs. Enviroseal is a water-based penetrating silane sealer and ChemTec is a soluble reactive silicate.

- Based on test performance data conceptual repairs were recommended.

- This report was prepared summarizing our test findings and recommendations.

4.0 FINDINGS AND RECOMMENDATIONS

Based on review of test data by others, surface distress surveys, brief inspections, and laboratory test data: the following findings and recommendations are made concerning taxiway K surface distress:

1. Taxiway K entrained air contents are poor to marginal. Overall air contents ranged from 0.9 to 4.7 percent. Reported air contents near the surface generally were less than 4 percent. Overall air contents were relatively higher in outer lanes than the center lanes. Air void spacing factors consistently exceeded the 0.008 in. recommended spacing for freeze-thaw durability.

2. Visual inspections and distress surveys in 1997 and 1998 indicate a progression of surface deterioration I the form of mortar flaking and scaling.

3. Samples from concrete with an estimated air content of 3 percent or less were subjected to laboratory freezing and thawing tests to evaluate the use of a silane sealer and the use of a soluble silicate sealer. Two types of tests were performed. The first set of tests conducted was a rapid freezing and thawing test to evaluate

susceptibility of concrete to surface scaling.

4. Based on the rapid freeze-thaw testing there are no conclusive advantages of using a sealer. While laboratory testing does not accurately simulate field performance, testing does indicate that the concrete is of sufficient quality where cracking due to freezing and thawing is not expected.

5. Both sealers did not perform well in preventing continued mortar flaking. The ChemTec soluble silicate sealer performed relatively better in delaying the surface mass loss than the Enviroseal silane sealer.

6. Although laboratory testing can not be directly correlated to field performance, in our opinion although the ChemTec significantly reduces mortar flaking, it will not give the desired durability for T/W K. Assuming that laboratory data can be correlated to field performance, the number of annual freezing-thawing cycles will continue at the same historical rate, and a terminal mass loss criteria of 0.3 lb/ft^2; the sealer would only be effective 2 to 4 more years.

7. Conceptual repairs were recommended. In our opinion the most feasible option is a combination of sealing the outer lanes (relatively higher air contents with smaller amounts of distress) with ChemTec and overlaying the keel section with asphalt (relatively lower air contents and greater distress).

5.0 DOCUMENT REVIEW

A review of reports and condition surveys to date was made. A condition survey by PBSJ, formerly Espey, Huston and Associates (Espey), Erlanger, KY was reviewed. Mortar flaking to light scaling was reported in 1997 in isolated areas east of T/W E and west of T/W F. As reported in the 1998 survey, the number of slabs exhibiting mortar flaking and light scaling in this are has significantly increased. Twenty-two slabs exhibiting no distress in 1997 now exhibit some mortar flaking. The number of slabs exhibiting mortar flaking has increased from 22 to 36. Reportedly deiced planes do not routinely use this part of the taxiway.

Distress between T/Ws F and J2 in the 1997 survey generally ranged from mortar flaking to medium scaling. As reported in the 1998 survey, the number of slabs exhibiting higher severity scaling in this are has significantly increased. Seventeen slabs exhibiting no distress in 1997 now exhibit some mortar flaking. The number of slabs exhibiting medium to severe scaling has increased from 30 to 48. Distress survey data are summarized in Table 1.

calculated coverage rate for the Enviroseal treated cores was 237 ft²/gal. The manufacturer recommended application rate is 125 to 200 ft²/gal.

The ChemTec treated cores were submerged for 45 minutes on consecutive days. Minimal weight gain was observed after the initial submersion. The calculated coverage rate for the ChemTec treated cores was 425 ft²/gal based. The manufacturer recommended application rate is 50 ft²/gal.

Specimens constantly submerged in water were subjected to approximately 300 freezing and thawing cycles. Mass loss and relative dynamic modulus were measured periodically throughout testing. As summarized in Table 2, all specimens performed well throughout the tests. Mass loss ranged from 0.3 to 1.3 percent at approximately 300 cycles. Loss in relative dynamic modulus ranged from 2 to 8 percent. Test data are detailed in the appendix. In our experience with rapid and freezing thawing tests with non-durable concrete, mass loss and change in relative dynamic modulus at 300 cycles can easily exceed 10 and 40 percent, respectively.

Based on the rapid freeze-thaw testing there are no conclusive advantages of using a sealer. While laboratory testing does not accurately simulate field performance, testing does indicate that the concrete is of sufficient quality where cracking due to freezing and thawing is not expected.

7.2 Deicer Scaling Tests

Marginally air-entrained slab sections from T/W K were sawed into nominal 12-in.-square by 4-in.-deep blocks. A cursory examination indicated that the concrete was marginally air-entrained throughout the body of concrete with estimated air contents on the order of 3 percent or less. Air-entrained samples for scaling tests were 6-in.-diameter cores. Slab specimens were treated by brushing the sealers onto concrete surfaces with Enviroseal or ChemTec at the manufacturers recommended application rate of 125 ft²/gal and 50 ft²/gal, respectively. ChemTec was applied over a two-day period with 60 percent of the recommended application applied on the first day and the remaining 40 percent applied on the second. Uniform applications of the products were achieved and efforts were made not to allow ponding on the sample surfaces.

A total of six T/W K specimens were treated with Enviroseal, ChemTec, or nothing (control). Closed-cell rigid insulation dikes were installed around the specimen surface perimeters to allow approximately ¼ in. ponding of water or 50 percent ethylene glycol and 50 percent water solution. Three of the specimens were subjected to freezing and thawing in water and

water solution. Thirteen of the nominal 6-in.-diameter cores were subjected to water and 12 subjected to the glycol-water deicer solution. Specimens were subjected to approximately 14 hours of freezing (0 ± 5 deg. F) and approximately 10 hours of thawing (73 ± 3-deg. F) thawing. Specimens were flushed and ponded with fresh solution every five cycles. Surfaces were rated for scaling and mass loss recorded from decanted solutions. Scaling ratings vary from zero with no scaling to 5 severe scaling. Test data are detailed in the appendix.

As summarized in Table 2, deterioration with the ethylene glycol solution was negligible for all specimens up through 50 freezing and thawing cycles. No significant amount deterioration was measured or observed since the ponded glycol solution did not freeze at the very top surface. Concrete temperatures measured one inch below the surface averaged approximately 3 deg. F. The glycol ponded specimens were therefore terminated at the end of 50 cycles.

Water ponded specimens tended to deteriorate in thin layers as mortar disintegrated exposing some of the near surface coarse aggregates. As listed in Table 2, the ChemTec performed significantly better through 80 cycles than specimens with no treatment or treated with Enviroseal. Average cumulative mass loss through 80 freezing and thawing cycles was zero for air-entrained concrete, 0.30 lb/ft^2 for no treatment, 0.33 lb/ft^2 with the Enviroseal treatment, and 0.11 lb/ft^2 with the ChemTec treatment. Typical conditions of slab surfaces initially and at the end of 80 cycles are shown in Figures 1 through 6 for T/W K concrete treated with nothing, ChemTec, and Enviroseal.

To evaluate the effectiveness of the ChemTec sealer on previously scaled concrete, the Enviroseal specimens were allowed to air dry for five days at the end of 80 cycles, wire brushed to remove loose deteriorated concrete, and re-coated with ChemTec. After five days of curing the re-coated Enviroseal (ChemTec) specimens were again subjected to freezing and thawing for an additional 30 cycles. The original ChemTec specimens were subjected to an additional 25 freezing and thawing cycles. As summarized in Table 3, both the ChemTec and re-coated Enviroseal specimens continued to deteriorate. The rate of deterioration for the ChemTec specimens increased from 0.0011 lb/ft^2 between 50 and 80 cycles to 0.0107 lb/ft^2 between 80 and 105 cycles. Conversely, the rate of deterioration decreased for the re-coated Enviroseal specimens from 0.0074 lb/ft^2 between 50 and 80 cycles to 0.0029 lb/ft^2 between 80 and 110 cycles. Average terminal cumulative mass was 0.41 lb/ft^2 for the Enviroseal treatment (re-coated with ChemTec) and 0.15 lb/ft^2 for the ChemTec treatment. Typical conditions of slab surfaces initially and at the end of testing are shown in Figures 7 and 8 for T/W K concrete treated with ChemTec and Enviroseal (re-coated with ChemTec).

flaking. Existing air-entrained concrete did not loose any mass through 80 freezing and thawing cycles. The Enviroseal did not provide any long-term protection relative to the no sealer treatment. The Enviroseal was only effective in delaying deterioration through approximately 35 to 40 cycles. As the number of cycles increased the Enviroseal treated specimens deteriorated as rapidly or more rapidly than specimens with no treatment.

The ChemTec was more effective in delaying surface deterioration. The average cumulative mass loss for the ChemTec specimens of 0.15 lb/ft^2 at 105 cycles was reached in approximately 40 cycles when no treatment was used. This corresponds to an increase in life of approximately 2.5 times. Tests on the Enviroseal specimens re-coated with ChemTec also indicate that the rate of deterioration can be reduced but not eliminated if applied to deteriorated surfaces. Reductions in mass loss rates between 50 and 80 cycles and between 80 and 105 cycles averaged approximately 61 percent.

8.0 REHABILITATION STRATEGIES

Although there are no standards as to what constitutes scaling failures, some Department of Transportation agencies consider 0.3 lb/ft^2 as a terminal value. With aircraft operations and foreign object debris (FOD) risks, the terminal mass loss may be even less. Assuming a terminal mass loss of 0.3 lb/ft^2, existing mass loss of 0.151 lb/ft^2, and continued mass loss rate of 0.0017 lb/ft^2/cycle; the ChemTec treated specimens would fail in another 88 cycles (total of approximately 193 cycles). Assuming the ChemTec is applied to fairly extensively damaged surfaces, terminal mass loss of 0.3 lb/ft^2, existing mass loss of 0.151 lb/ft^2, and continued mass loss rate of 0.0029 lb/ft^2/cycle (Enviroseal treated specimens re-coated with ChemTec); the ChemTec treated specimens would fail in another 51 cycles (total of approximately 156 cycles).

Although laboratory testing can not be directly correlated to field performance, in our opinion although the ChemTec significantly reduces mortar flaking, it will not give the desired durability for T/W K. The annual number of concrete freeze-thaw cycles was estimated from historical air temperatures in the Cincinnati area since there was no temperature instrumentation data from T/W K. It was assumed that when the average air temperature was below freezing that it constituted one freezing cycle and when the average air temperature was above freezing that it constituted one thawing cycle. Using these criteria, the average number of freezing and thawing cycles in the Cincinnati area for 1995 and 1996 was 17. Assuming that laboratory data can be correlated to field performance, the number of annual freezing-thawing cycles will continue at the same rate, and a terminal mass loss criteria of 0.3

surface. The wearing course would prevent the potential for a FOD problem if the concrete surface were properly prepared. We recommend that all loose and damaged mortar/concrete be removed by grinding or shotblasting. The most severely scaled slabs should be removed and replaced prior to preparation for the overlay. We recommend that joints be sawed and sealed in the overlay to minimize reflective cracking from the concrete through the asphalt. Advantages include keeping existing elevations of electric utilities and transitions to other taxiways. The rate of scaling deterioration beneath the overlay should be decreased although not be eliminated. A feasible rehabilitation would be to periodically seal the outer taxiway lanes with the ChemTec sealer and overlay the keel section. Based on the latest PBSJ distress survey we recommend that the entire keel section be overlayed. Without repairing and with continued freezing and thawing, the west end of the taxiway will continue to exhibit surface distress.

6. Bonded Concrete Overlay – An air-entrained bonded concrete overlay to minimize the existing concrete from becoming critically saturated is another rehabilitation alternative. The joint sealant would be removed, existing surface would be diamond ground to provide mechanical bond, surface cleaned, bonding grout applied, and a dense concrete overlay bonded to the existing substrate before the bonding grout skims and dries. Joints in the overlay and substrate would be matched to minimize reflective cracking and resealed. Calculations will be necessary to determine the overlay thickness to minimize surface water saturation of the substrate as well as reduce the number of freeze-thaw cycles. The overlay thickness may be on the order of four inches, which would require elevation grade transitions to existing intersecting taxiways and possibly redirecting surface water drainage.

9.0 CONCLUDING REMARKS

A laboratory freeze-thaw testing program was conducted on concrete samples from Taxiway K at the Cincinnati-Northern Kentucky International Airport. Tests were conducted to evaluate the use of surface sealers to minimize freeze-thaw durability distress. Conclusions are found in the section "FINDINGS AND RECOMMENDATIONS" of this report.

Table 2 - Summary of ASTM C666 Rapid Freezing and Thawing Tests

Concrete	Surface Treatment	No. of Cores	Average Mass Change, percent	Relative Dynamic Modulus, percent
T/W K	none	5	0.55	92
T/W K	ChemTec	6	0.29	94
T/W K	Enviroseal	6	1.29	92
air-entrained	none	4	0.70	98

Table 3 - Summary of ASTM C672 Scaling Tests

Concrete	Surface Treatment	Ponding Solution	Average Mass Loss, lb/ft²			Average Loss rate, lb/ft²/cycle		
			50 Cycles	80 Cycles	105 Cycles	0 to 50	50 to 80	80 to 105
T/W K	none	water	0.190	0.301	....	0.0040	0.0034	....
		glycol	0.015	....	....	0.0003	....	....
T/W K	ChemTec	water	0.074	0.108	0.151	0.0015	0.0011	0.0017
		glycol	0.016	....	....	0.0003	....	....
T/W K	Enviroseal	water	0.105	0.328	0.414	0.0021	0.0074	0.0029
		glycol	0.010	....	....	0.0004	....	....
air-entrained	none	water	0	0	0	0.0000	0.0000	....
		glycol	0	....	....	0.0000	....	....

NOTES:

1. 50 percent ethylene glycol and 50 percent water deicer solution.
2. Deicer specimen testing terminated at 50 cycles.
3. Enviroseal specimens recoated with ChemTec at 80 cycles and terminated at 110 cycles.
4. ChemTec specimens terminated at 105 cycles.