PERFORMANCE OF THIN BONDED PORTLAND CEMENT CONCRETE OVERLAYS ON MILITARY AIRFIELDS

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The United States Air Force has more than 20 years of experience with thin bonded Portland cement concrete overlays--5.1 to 10.2 cm (2 to 4 in.) in thickness. The construction history and performance of 14 features (a feature being defined as a pavement cross-section of like construction) involving thin bonded overlays at four Air Force bases are discussed in this paper. The features range in age from 13 to 21 years and include both runways and aprons. Traffic on the thin bonded overlays ranged from high volume, lightweight fighter aircraft to moderate volume, very heavy cargo, tanker and bomber aircraft. The construction procedure followed for each of the thin bonded overlays was similar. The surface of the original pavement was scarified to a depth of not less than .6 cm (1/4 in.) and all loose material was removed. When necessary, the pavement was cleaned with a detergent, flushed, and then etched with muriatic acid. The surface was again flushed, and a grout .15 to .3 cm (1/16 to 1/8 in.) thick was applied to provide a bond. The overlay was then applied quickly before the grout could dry. In general, the overlays have performed quite satisfactorily. Condition surveys indicate that after 17 years most features are in VERY GOOD condition, and the remaining are in GOOD condition. Problems encountered with the overlays can be traced to faulty construction procedures. Most notably, allowing the grout to dry prior to overlay placement and failure to match joints in the overlay with the underlying pavement have resulted in loss of bond and reflection cracking, respectively.

Thin bonded Portland cement concrete (PCC) overlays have been used as a repair alternative for spalled and scaled rigid pavements for many years. The United States Air Force has used thin bonded overlays on taxiways for about 25 years. These overlays are particularly attractive on those portions of airfield pavements such as runway ends, hardstands, and aprons where bituminous resurfacing is subjected to damage by fuel spills, jet blast, and the turning and braking action of aircraft with high pressure tires. These overlays are applied to existing structurally sound pavement features to restore distressed surfaces to operational condition and include the secondary benefit of increased structural capacity. Thin bonded overlays 5.1 to 10.2 cm (2 to 4 in.) thick have been constructed in all parts of the continental United States at several Air Force installations. The overlays have experienced very different climatic conditions, and some have been subjected to light fighter and trainer aircraft traffic while others have supported heavy cargo, tanker and bomber aircraft.

This paper reports the performance of several of these thin bonded overlays with a view toward correlating performance with method of construction, climate, and traffic history where such data are available. For a number of case studies at varied geographical locations; e.g., Rickenbacker Air National Guard Base (ANGB), Ohio; Randolph Air Force Base (AFB), Texas; Selfridge ANGB, Michigan; and Grissom AFB, Indiana; the performance of thin bonded overlays is discussed in terms of qualitative and quantitative condition indicators which were in use at the time the condition surveys were made.

In this paper each thin bonded PCC overlay feature selected for discussion is examined beginning with the original construction of the base pavement. Factors such as soil classification and index properties of the subgrade, strength and thicknesses, and condition before overlay construction are discussed. Next, the thin bonded overlay itself is investigated, conditions affecting its installation and performance are discussed, and conclusions are drawn concerning correlation between performance, traffic volume and construction methods.

Selfridge Air National Guard Base, Michigan

Background

Selfridge ANGB is situated about 4.8 km (3 mi.) east of Mt. Clemens, Michigan and about 48 km (30 mi.) northeast of Detroit. It was originally developed as an all-turf airfield prior to World

Table 1. Summary of physical property data.

Feat. Nr.	Facility: Identification	Facility: Length (m)	Facility: Width (m)	Pavement: Overlay Thick. (cm)	Pavement: Orig. Thick. (cm)	Pavement: Flex. Str. (kPa)	Subbase: Thick. (cm)	Subbase: Description	Subbase: K (kPa/mm)	Subgrade: Description
					Selfridge Air Force Base, Michigan					
1	N-S Runway 0+00 to 5+00 85+00 to 90+00	153 each	46 each	7.6	53.3	4275	58	Silty Sand (SP-SM)	41	Clay (CL,CH) Silty Sand (SM)
2	N-S Runway 5+00 to 10+00 80+00 to 85+00	153 each	46 each	7.6	48.3	4275	64	Silty Sand (SP-SM)	41	Clay (CL,CH) Silty Sand (SM)
					Randolph Air Force Base, Texas					
3	West Runway 13+72 to 23+92	311	61	10.2	25.4	4206	20	Silty Gravel (GP-GM)	27	Clay (CH)
4	East Runway 68+24 to 70+00	54	61	5.1	21.6	3861	20	Silty Gravel (GP-GM)	95	Sandy Clay (SC)
5	East Runway 65+00 to 68+24	99	61	5.1	20.3	3861	20	Silty Gravel (GP-GM)	95	Sandy Clay (SC)
6	East Runway 60+00 to 65+00	153	61	5.1	20.3	3861	20	Silty Gravel (GP-GM)	95	Sandy Clay (SC)
7	East Runway 16+74 to 60+00	1319	61	5.1	20.3	3861	20	Silty Gravel (GP-GM)	95	Sandy Clay (SC)
8	East Runway 15+00 to 16+74	53	61	5.1	21.6	3861	20	Silty Gravel (GP-GM)	95	Sandy Clay (SC)
9	East Runway 3+00 to 15+00	366	61	5.1	25.4	3861	20	Silty Gravel (GP-GM)	95	Sandy Clay (SC)
10	East Runway 0+00 to 3+00	92	61	5.1	27.9	3861	20	Silty Gravel (GP-GM)	95	Sandy Clay (SC)
					Rickenbacker Air National Guard Base, Ohio					
11	ANG Apron	320	104	5.1	30.5	4689	15	Gravel (GW)	27	Clay (CL)
					Grissom Air Force Base, Indiana					
12	Reserve Apron	366	110	7.7	20.3	4068			16	Clay (CL)
13	NE-SW Runway 5+00 to 10+00	153	61	5.1	35.6	4413	61	Silty Sand (SM)	41	Clay (CL)
14	NE-SW Runway 0+00 to 5+00	153	61	5.1	35.6	4413	61	Silty Sand (SM)	41	Clay (CL)

Note: 1 m = 3.28 ft., 1 cm = .394 in., 1 kPa = .145 psi, 1 kPa/mm = 3.68 psi/in.

War I. No pavements were constructed until 1932. Since then, new construction, reconstruction, and strengthening of pavements have been intermittently accomplished. Two pavement features constructed by the US Army Corps of Engineers during 1958-59 are considered: (#1) a 53.3 cm (21 in.) PCC pavement section designed for aircraft with 444.8 kN (100,000 lb.) gear loads that is located within the second 152.4 m (500 ft.) of each end of the N-S primary runway (1). Physical property data for these features are given in Table 1.

Considerable deterioration of these pavement features was observed even before the original construction was completed in 1959, and by 1963 the deterioration was judged to be extremely critical for aircraft operations. The deterioration was attributed to the presence of chert in the coarse aggregate used in the PCC mix. The chert created popouts in the surface varying from 7.6 to 15.2 cm (3 to 6 in.) in diameter and from 1.9 to 5.1 cm (0.75 to 2 in.) in depth (2).

Traffic

Military aircraft located at Selfridge ANGB subsequent to construction of these pavement features were the KC-97, F-106, T-33, and C-119 aircraft. Table 2 outlines the cycles of aircraft traffic per month where one cycle represents one takeoff and one landing for any particular aircraft.

Table 2. Cycles of aircraft traffic per month, Selfridge ANGB, Michigan

Aircraft	Cycles
KC-97	250
F-106	1050
T-33	270
C-119	150
Other (lighter aircraft)	800

Overlay

The thin bonded rigid overlay of the first 304.8 m (1000 ft.) of each end of the primary N-S runway at Selfridge ANGB was constructed during the summer of 1963. The thin bonded overlay was used as a resurfacing for the existing pavement and had a nominal thickness of 7.6 cm (3 in.)

The first step in preparing the old pavement for resurfacing was to remove paint and the bituminous sealing material used in the joints. Then the excess bituminous material adjacent to the joints was removed with a Tennant scarifying machine. The entire area was scarified to a depth of .2 to .6 cm (1/8 to 1/4 in.). After scarifying, the pavement was washed with a detergent where necessary to remove all traces of oil drippings and any other foreign matter. After washing, the detergent was flushed from the pavement using a tank truck equipped with a spray bar. The pavement was then etched with a commercial muriatic acid applied to the wet surface from a tank truck. After surface foaming ceased, the area which had been treated with the acid was again thoroughly flushed with water under pressure until the wet surface showed a neutral reaction. Prior to the concrete overlay placement, the surface was required to be damp but without evidence of free water. A grout consisting of equal parts of Portland cement and sand was then brushed in thoroughly with rattan street cleaning brooms, leaving a coating .15 to .3 cm (1/16 to 1/8 in.) thick. Special care was taken to synchronize the grouting and paving operations so that the overlay concrete could be spread before the grout dried. The concrete overlay was placed directly from two transit truck mixers dumping simultaneously on opposite sides of a 6.1 m (20 ft.) lane. The mix design of the concrete overlay was as follows:

Cement factor	5.8 sacks per m^3 (7.6 sacks per cu yd.)
Water-cement ratio	18.9 l (5.0 gal.) per sack cement
Aggregate by weight in concrete	40% dolomitic limestone, 60% sand
Maximum size aggregate	1.3 cm (1/2 in.)
Total air content	7 to 8%

A series of photographs showing the construction procedure for this project is shown in Figures 1 through 10.

Figure 1. Sand blasting to remove tire marks and paint.

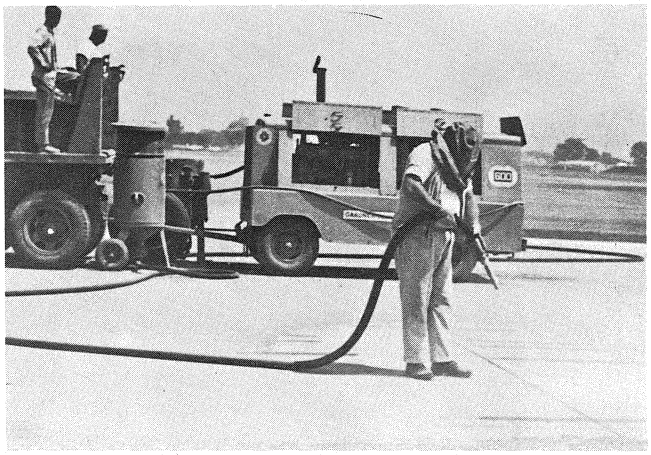


Figure 2. Scarifying runway prior to thin bonded PCC overlay.

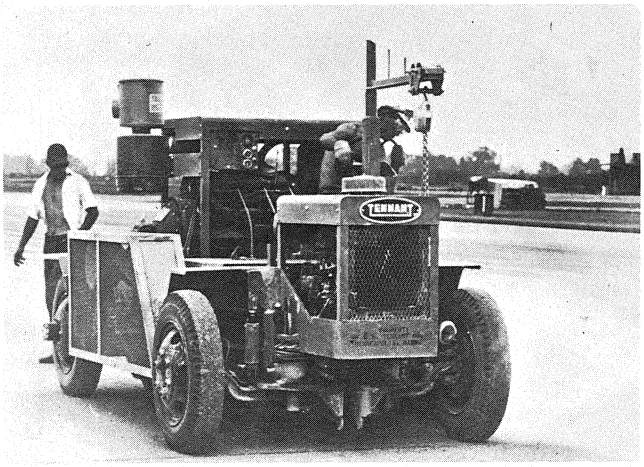


Figure 3. Finished scarified runway surface (note epoxy grout popout patches placed previously).



Figure 4. Looking south at PCC to AC transition prior to overlay.

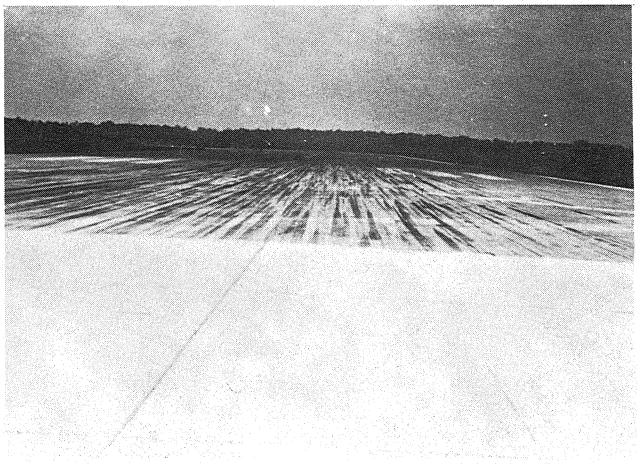


Figure 5. Acid etching subsequent to scarifying and prior to PCC overlay.

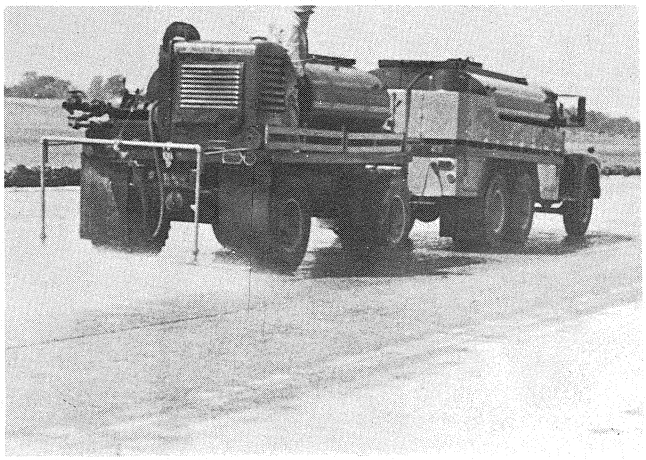


Figure 6. Water flush after acid etch.

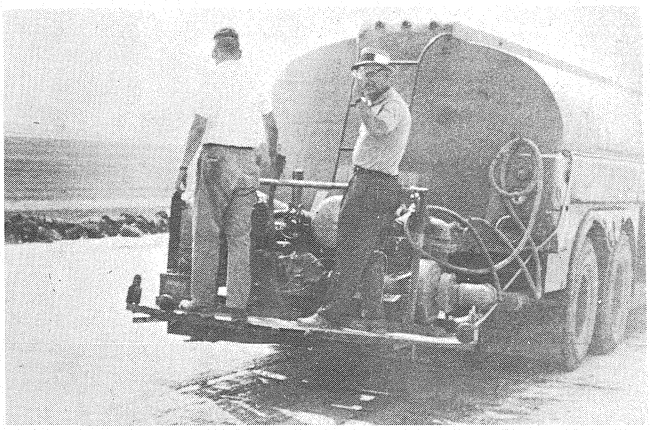


Figure 7. PCC overlay forms setting.



Figure 8. Placing PCC thin bonded overlay.

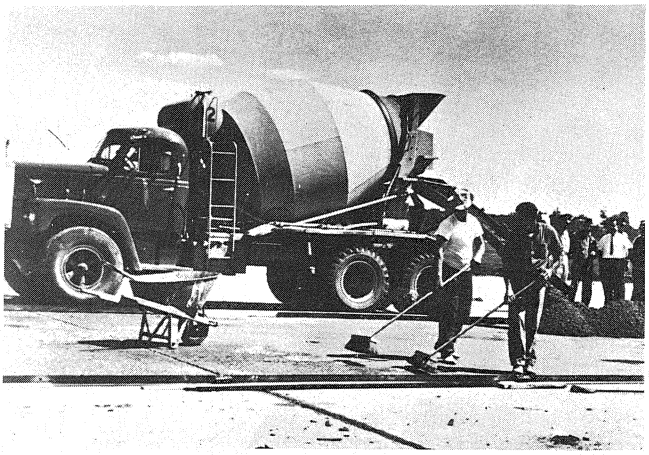


Figure 9. Edge of PCC overlay prior to placing adjacent lane.

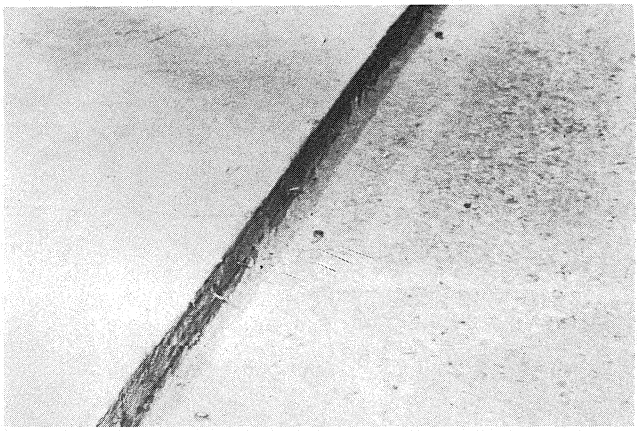
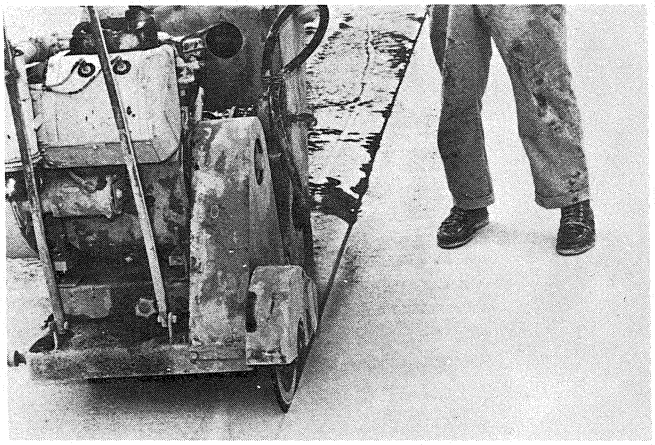


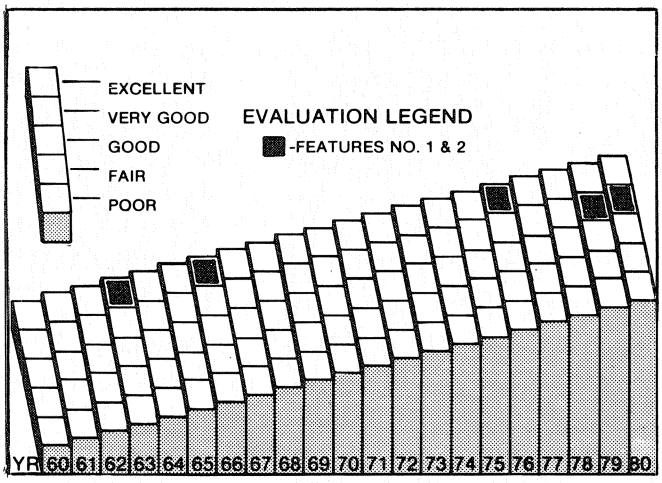
Figure 10. Sawing joints prior to sealing.



Condition Ratings

Condition survey reports for the years 1963, 1966, 1976 and 1979 are available. The overlay portions of the N-S Runway (features #1 and #2) were in EXCELLENT condition three years after construction. Minor unbonding was noted in approximately 10 percent of the slab corners that were sounded with an iron rod at the north runway end; however, complete bonding was detected by similar sounding at the south runway end. This survey was accomplished in 1966 (3). In May 1976, a USAF Pavement Evaluation Team conducted a condition survey and again judged the pavement to be in EXCELLENT condition after 16 years of service (4). Subsequently, in September 1979 the Air National Guard Support Center conducted an airfield pavement condition survey (5) and judged both pavement features to be in VERY GOOD condition after 19 years of active service. These pavement features are currently in service with a VERY GOOD condition rating after 20 years of active service. A summary of the above condition ratings are shown in Figure 11.

Figure 11. Condition history-Selfridge ANGB, MI.



Randolph Air Force Base, Texas

Background

Randolph AFB is located 16.1 km (10 mi.) Northeast of San Antonio, Texas. The original airfield pavements were flexible features constructed in 1931. Between 1943 and 1951 these pavements were replaced with PCC, and new pavements and runway extensions were constructed. The features under consideration (#3, 4, 5, 6, 7, 8, 9, and 10) comprise the east runway. The physical property data for the features are listed in Table 1.
The sandy clay subgrade has a great affinity for water and exhibits high volumeric changes with change in moisture content. In 1959 the east runway was judged to be in GOOD condition (6), but excessive roughness was detracting from operational safety. To correct this problem, a thin bonded PCC overlay, 5.1 cm (2 in.) minimum thickness, was placed in the spring of 1960.

Traffic

The aircraft at Randolph Air Force Base are comprised primarily of light trainer aircraft (T-37, T-38) and a small number of medium cargo and passenger aircraft (C-130, C-118) and light passenger aircraft (T-39). No aircraft with a gross weight of more than 37.8 kN (85,000 lb.) has been permitted to use the east runway except in abnormal circumstances. Table 3 provides a summary of traffic operations on these pavements for the decade 1964-1973. More recent traffic data are not available.

Table 3. Summary of traffic history, east runway, Randolph AFB, Texas.

Year	Yearly Operations
64	139,295
65	98,838
66	182,361
67	157,122
68	143,131
69	212,810
70	185,296
71	136,950
72	137,101
73	114,043

Overlay

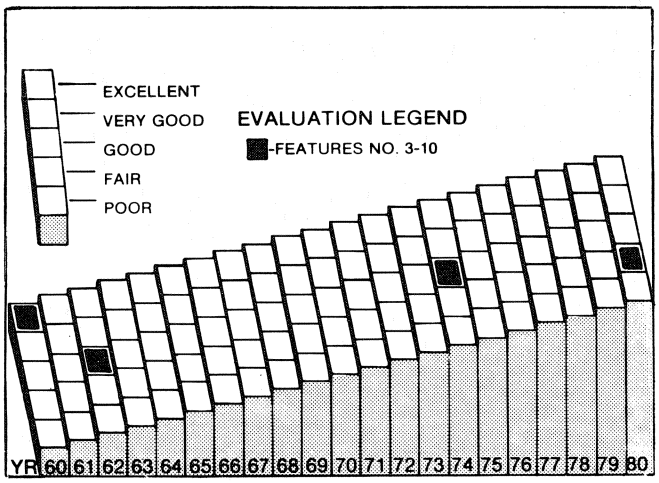
In the spring of 1960, a thin bonded PCC overlay of 5.1 cm (2 in.) minimum thickness was applied to the entire runway. To conform with the 3.8 by 4.6 m (12.5 by 15.0 ft.) base slabs, construction consisted of 7.6 m (25 ft.) paving lanes with sawed longitudinal and transverse joints. The base pavement was cleaned by sand blasting and acid etched with a dilute solution of muriatic acid. Residue from the acid reaction was removed from the pavement by flushing with water. A thin layer of grout was then applied to the damp pavement, and the concrete overlay was placed. The cement factor for the concrete overlay was 4.6 bags per m^3 (6 bags per cu yd.) and water content 18.9 l (5 gal.) per bag. Air entrainment was 3.5 percent of the volume of the concrete. Forms were left in place for approximately 72 hours, and joints were sawed within

six hours after the concrete was placed.

Condition Ratings

In the November 1962 report, the Ohio River Division, US Army Corps of Engineers (7) reported that the surface of the thin bonded overlay was in GOOD condition, but there was an appreciable loss of bond in the thin bonded overlay. During the period 1963 to 1968 this runway received a large amount of heavy passenger aircraft traffic (Boeing 707s). This traffic cracked the overlay which caused spalling and maintenance problems. Since 1968, it has been necessary to replace a portion of this deteriorated overlay each year. By February 1974, there was considerable distress in the overlay in the form of hairline cracks, with chunks becoming delaminated and resulting in a foreign object damage problem (8). These features were rated in GOOD condition, but because of the distress in the overlay, the allowable gross loads were reduced by 25 percent. The pavement features are currently in service with a GOOD condition rating after 20 years of active use. A summary of the condition ratings are shown in Figure 12.

Figure 12. Condition history-Randolph AFB, TX.



Rickenbacker Air National Guard Base, Ohio

Background

Rickenbacker ANGB (formerly Lockbourne AFB) is located in Franklin County, Ohio, approximately 17.1 km (11 mi.) southeast of Columbus. The airfield is located in the Columbus glacial plain and the overburden material is generally a glacier boulder clay with scattered lenses of moraine material. The subgrade soils are classified as a borderline material between a sandy and lean clay (CL) with occasional strata of fat clay (CH), and are frost susceptible.

The feature (#11) of interest is the 33,105.6 m^2 (39,600 sq yd.) Air National Guard apron constructed originally in 1954 by the Corps of Engineers. It consisted of a 30.5 cm (12 in.) uniform thickness PCC pavement designed for a 111.2 kN (25,000 lb.) single wheel gear load. It was placed on a 15.2 cm (6 in.) base course of well graded sandy gravel (GW), with a modulus of subgrade reaction (K) value of 27 kPa/mm (100 pci) and a frost K of 10 kPa/mm (35 pci). The evaluation flexural strength of the original PCC was 4689 kPa (680 psi) (9). Physical property data for the feature are given in Table 1.

In 1967 a 5.1 cm (2 in.) PCC thin bonded overlay was placed on this apron. The surface preparation and construction techniques were similar to those described for Selfridge ANGB. The condition of the original surface at the time of overlay was FAIR to POOR, with blowups and joints spalls constituting the major distresses. The condition rating subsequent to the overlay was judged to be EXCELLENT.

Traffic

No specific record of aircraft traffic using the ANG apron is available; however, it is known that only fighter and light load aircraft have been permitted on this feature.

Condition

The only condition rating available for the overlay was made in 1973 (10). A random check for delamination of the overlay was made and none was found. Small surface cracks were present along joints (see Figure 13) and at several slab corners (see Figure 14), probably as a result of reflections from corner breaks in the original PCC. The overall rating of the feature in 1973 was GOOD. This overlay is still functional with a GOOD condition rating after 13 years of active service. A history of the available ratings is depicted in Figure 15, and the present condition of the apron is shown in Figure 16.

Figure 13. Surface cracking along joints.

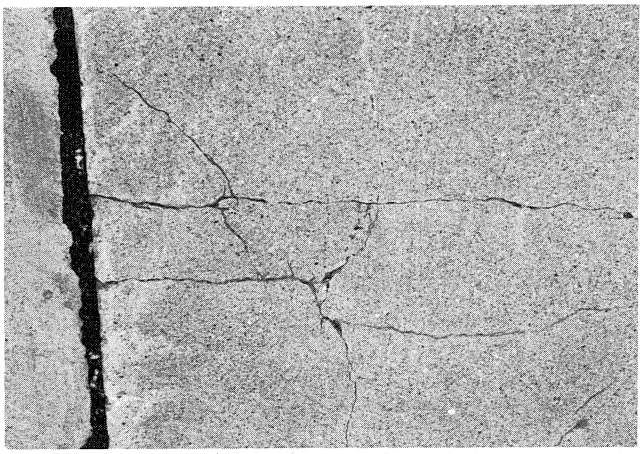


Figure 14. Corner break repair.

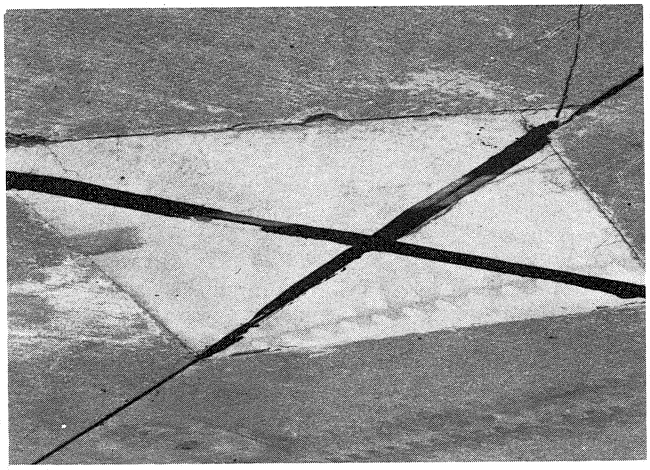


Figure 15. Condition history-Rickenbacker ANGB, OH.

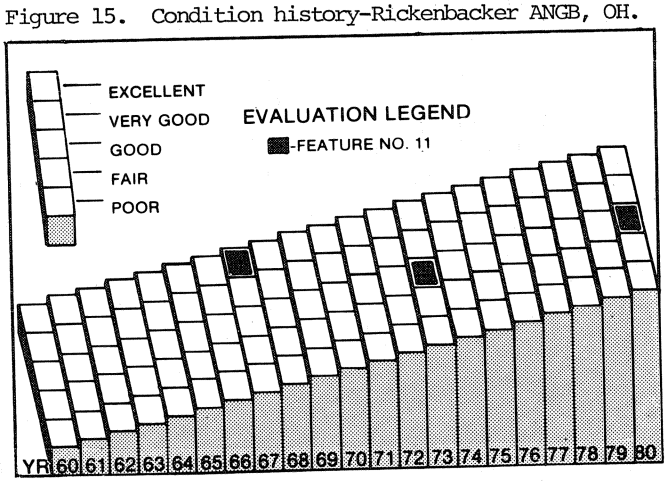


Figure 16. ANG Apron present condition.



Grissom Air Force Base, Indiana

Background

Grissom AFB (formerly Bunker Hill AFB) is located about 14.5 km (9 mi.) south of Peru and 112.7 km (70 mi.) north of Indianapolis in north central Indiana. Originally a Naval Air Station, Grissom AFB was redesignated as an Air Force Base in 1954. The naval station was constructed during World War II but records of the original construction are not available. All primary pavement features at the base have been constructed or strengthened since 1954 and post 1954 construction records exist.

Grissom AFB is a Strategic Air Command (SAC) base and is used by heavy cargo and bomber aircraft. Detailed traffic data are not available but the base handles about 2500 cycles a month. In recent years the primary heavy aircraft using the airfield has been the KC-135 (average gross takeoff weight of 1112 kN (250,000 lb.) of which there are about 5000 cycles per year. Prior to being phased out of the Air Force inventory, B-47 and B-58 aircraft made extensive use of the Grissom facilities.

Grissom AFB has one main NE-SW runway (4-22) and a parallel taxiway. There are three features of particular interest at Grissom: (#12) a 20.3 cm (8 in.) pavement section comprising a 40,128 m^2 (48,000 sq yd.) parking apron; (#13) a 35.6 cm (14 in.) pavement section making up the second 152.4 m (500 ft.) of the northeast end of the runway; and (#14) a 35.6 cm (14 in.) pavement section at the first 152.4 m (500 ft.) of the northeast end of the runway. Features #13 and #14 have a base consisting of 40.6 cm (24 in.) of silty sand (SM) with a modulus of subgrade reaction of 41 kPa/mm (150 pci) overlying a clay subgrade (CL). These features were constructed during 1954-1955. Feature #12 was placed directly on the subgrade material where k = 16 kPa/mm (60 pci) and was constructed in 1942 when Grissom AFB was a naval training base.

To correct surface irregularities in the parking apron, pavement feature #12 was overlayed during the summer of 1959 (11). Features #13 and #14 were overlayed in 1965 to correct surface irregularities and to strengthen the existing pavement. The deterioration was caused primarily by popouts.

Overlays

An overlay on apron feature #12 consisting of a minimum 7.6 cm (3.0 in.) of Portland cement concrete bonded to the existing 20.3 cm (8 in.) pavement over an area 109.7 by 365.8 m (360 by 1200 ft.) was put down in 1959. Prior to placing the overlay, the base pavement was thoroughly cleaned, acid etched, and washed. A thin layer of grout was then applied to the damp pavement and the concrete overlay placed. Paving lanes of the overlay were 6.0 m (20 ft.) wide with the centerline sawed to conform to the base slabs which were 3.0 by 6.1 m (10 by 20 ft.) (11).

In June 1960 a pavement survey of the apron was conducted, and bond quality was determined. By sounding the slabs with a small iron pipe, loss of bond was determined by the hollow sounds. Each hollow sounding area was further sounded until the extent of the unbonded area was determined (12). A similar survey was conducted in 1962, and of 1539 slabs sounded, 14 percent indicated bond loss compared to seven percent in 1960. In 1962, four percent of the slabs showed evidence of spalling whereas less than one percent did in 1960.

The 1962 survey did not show any significant increase in the size of the unbonded areas as compared to the previous survey (11). Most of the newly discovered unbonded areas were located on either side of a box drain located within the thin bonded overlay pavement. The number of patches where loss of bond was indicated on the apron had increased from 16 in 1960 to 34 in 1962. Gillette (12) reported that bond failure in a large unbonded area was due to a 6 cm (1/4 in.) layer of grout that had apparently dried prior to the placement of the new concrete. Also, reflection cracking from longitudinal joints in the underlying pavement appeared in the overlay where joints in the overlay were not matched with the base pavement.

A less extensive survey was carried out in 1975 (13) and the condition of the apron pavement was EXCELLENT. A recent inspection of this feature indicated it was in VERY GOOD condition. Several areas of delamination have occurred, particularly near the lateral drain, but all had been well patched. Condition ratings for feature #12 have been plotted versus time in Figure 17.

An overlay (features #13 and #14) consisting of a nominal 5.1 cm (2 in.) of Portland cement concrete (3.8 cm (1 1/2 in.) minimum, 6.4 cm (2 in.) maximum) was placed in the northeast end of the runway in the summer of 1965. The overlay was put down on an existing 35.6 cm (14 in.) PCC pavement constructed in 1954-1955 by the Navy to correct surface irregularities caused primarily by popouts. Both features are 152.4 m (500 ft.) long and 61 m (200 ft.) wide.

In preparation for the placement of the overlay, the surface of the existing pavement was scarified to a depth not less than .6 cm (1/4 in.) to expose sound, unweathered concrete. The loose material was then removed by sweeping and blowing with compressed air. Joint sealing and expansion joint material were removed flush with the prepared surface. The remainder of the construction procedure was very similar to that described previously for Selfridge ANGB.

Condition

The 1975 condition survey found numerous popouts that had been repaired by coring to the depth of the popout and filling with either epoxy or cement. Both features were described as being in EXCELLENT condition. An inspection performed in May 1980 revealed that the features had deteriorated to a GOOD condition some 15 years after their construction. The condition histories for features #13 and #14 are shown schematically in Figure 17, and several photographs depicting the present condition of each feature are presented in Figures 18 through 26.

Figure 17. Condition history-Grissom AFB, IN.

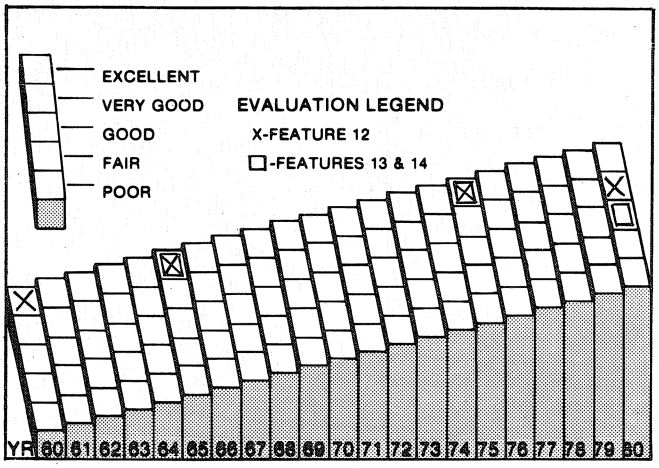


Figure 18. Feature #12. Overlay repairs on apron.

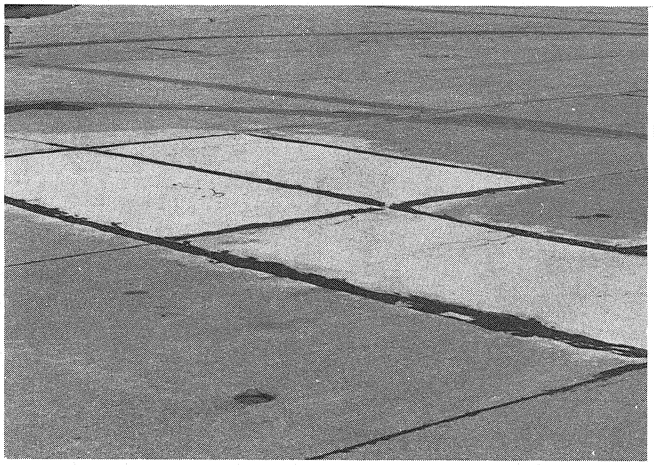


Figure 19. Feature #12. Loss of bond at slab corner.



Figure 20. Feature #12. Corner spall at slab corner.

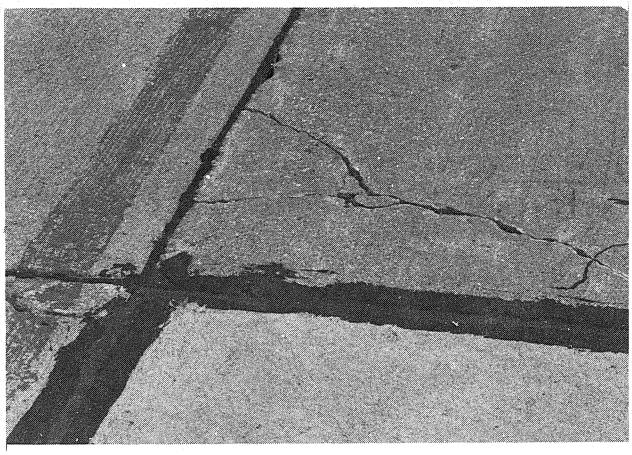


Figure 21. Feature #12. Transverse crack with spalling.

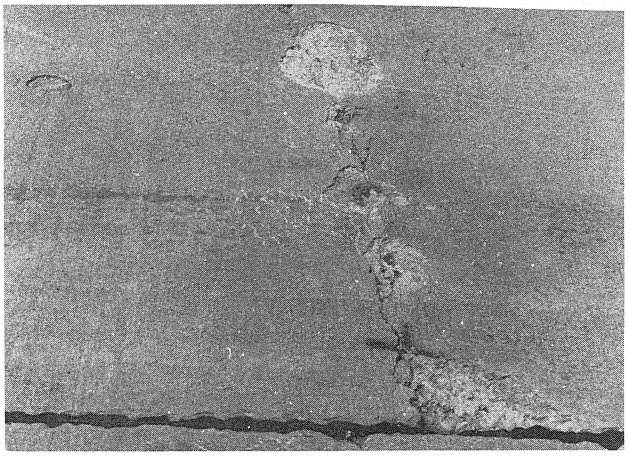


Figure 22. Feature #13. Repaired transverse joint with evidence of D-cracking.



Figure 23. Feature #13. Loss of bond at slab corner.

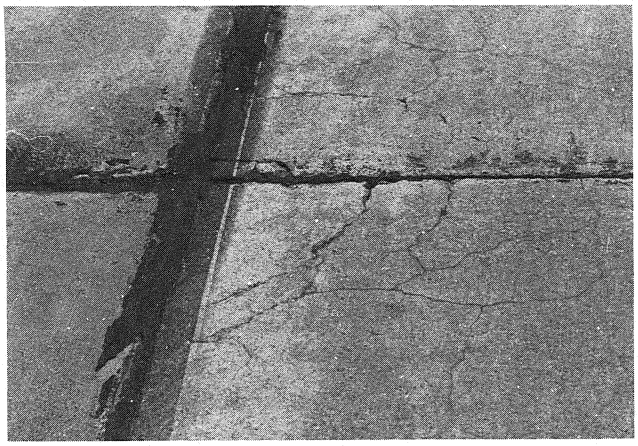


Figure 24. Feature #13. Severe spalling after loss of bond along longitudinal joint.

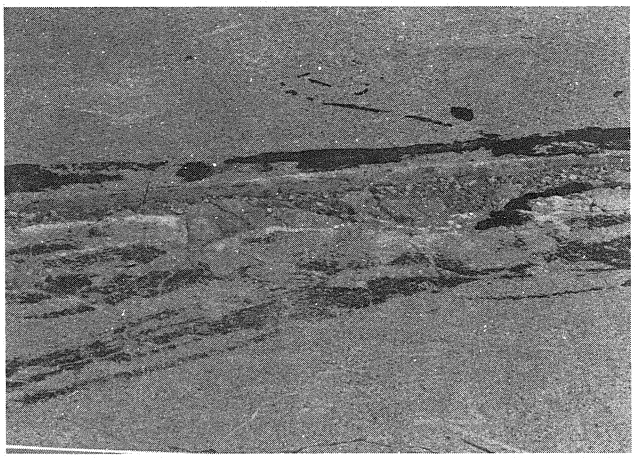


Figure 25. Feature #14. Area of widespread loss of bond on runway showing severe distress.



Figure 26. Feature #14, Corner slab failures due to loss of bond and overload.



Summary and Recommendations

The pavement features under consideration were constructed during 1959, 1960, 1963, 1965, and 1967 in four geographical locations throughout the United States. The air bases at which the thin bonded overlays were constructed have very different missions. Therefore, climatic conditions, volume, and type of traffic at the four bases varied widely. The 14 features have performed successfully over an average period of more than 18 years and all of them have a current condition rating of at least GOOD.

Air Force experience with the thin bonded PCC overlays indicates that these overlays perform satisfactorily if careful surveillance of the construction procedure has been maintained. Lack of bond between the old surface and the PCC overlay is a problem with some of the features studied. The bonding problem is probably due to premature drying of the grout which bonds the layers together before the thin PCC overlay was applied. This problem is eliminated by coordinating the grouting and paving operations. Reflection cracking was observed in some pavement features because of failure to match joints in the thin bonded PCC overlay with those in the underlying pavement. When the recommended procedure for constructing thin bonded PCC overlays (14) has been closely followed, Air Force experience with these overlays is satisfactory and indicates that thin bonded overlays are a viable alternative in upgrading pavement surfaces.

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