# A 10-Year Report on Performance of Bonded Concrete Resurfacings

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Approximately 15 small and large bonded concrete overlay projects constructed over the past 10 years on both highway and airfield pavements are described. Because techniques of constructing these projects have been amply covered previously, only performance of the overlays under ordinary usage is considered.

The performance of seven projects was surveyed in 1961. The survey method is outlined and information determined in the 1961 survey and in one made in 1964 of these and eight additional projects is given. Results are tabulated of tests of core samples and bond interface. Some areas of distress and of bond loss are pictured. Causes of bond loss and its effect on the performance of the overlay are discussed. Good bond must be the primary goal, but a loss of bond does not appear to impede the performance of a bonded concrete overlay in long-term continuous use.

•THE TECHNIQUE of resurfacing concrete with concrete was attempted as far back as 1910, and a bond was developed that was in existence over 30 years later. Additional early projects and later projects establish the fact that a permanent bond can be obtained when a new layer of concrete is placed on a previously existing layer of concrete. The parameters to be determined for bonded resurfacing were as follows:

1. What surface preparation, if any, must be done to the existing surface?
2. Is acid etching beneficial?
3. Should some type of bonding grout be used?
4. What specifications should be considered for the new concrete?
5. Would any special placing procedures be necessary?

These questions were investigated and published by Felt (1, 2). The publications cover both laboratory and field investigations of numerous projects where new concrete was bonded to old concrete using a portland cement grout and certain preparatory techniques. Two articles by Westall (3, 4) give complete details concerning the procedures for designing and constructing a bonded concrete resurfacing. Reports on specific projects were published by Purinton (5) and the U. S. Army Corps of Engineers (6). Design and construction criteria were covered by Hutchinson and Wathen (7) at the 1961 ASCE Convention. In 1962, the author presented a paper (8) on the performance of several small and large concrete resurfacing projects constructed before 1962.

The purpose of the present paper is to provide an up-to-date report on the performance of these projects and others constructed since 1961 and on the new knowledge that has been gained. Design and construction techniques will not be covered here since they have been amply described in numerous other papers and reports.

## REVIEW OF LABORATORY RESEARCH

In the early 1950's, a comprehensive study was undertaken at the Research and Development Laboratories of the Portland Cement Association under the direction of the late Earl J. Felt (1, 2). These studies established a procedure for obtaining good bond

Paper sponsored by Committee on Salvaging Old Pavements by Resurfacing.

TABLE 1

EFFECT OF SURFACE TREATMENT OF BASE SPECIMEN AND VARIOUS TYPES OF GROUT ON BOND[a]

| Surface Treatment and Type of Grout | Bond Strength (psi) | | | | | |
|---|---|---|---|---|---|---|
| | Damp Base | | | Dry Base | | |
| | Grout | | No Grout | Grout | | No Grout |
| | 1:1 | Neat | | 1:1 | Neat | |
| None (little laitance effect) | 216 | 239 | 254 | 264 | 253 | 308 |
| None (wood-float finish, laitance effect) | 136 | - | 152 | 153 | - | 140 |
| HCl | 339 | 232 | 295 | 625 | 408 | 353 |
| HCl not flushed and brushed | - | - | 93 | - | - | 106 |
| Tennant, shallow waffle | 415 | 345 | 336 | 388 | 410 | 543 |
| Tennant, deep waffle | - | - | - | - | 500 | - |
| HCl, 2% $CaCl_2$ in grout | 295 | 229 | - | 452 | 503 | - |
| HCl, retempered grout[b] | 620 | 317 | - | 517 | 403 | - |
| HCl, cement dust grout | - | 547 | - | - | 519 | - |
| HCl, grout sprayed at 26 psi | - | 392 | - | - | 564 | - |
| HCl, grout on surface 1½ hr before resurfacing | 353 | 259 | - | 440 | 437 | - |

[a] 9½ by 9½-in. prisms surfaced with 2-in. of 6-sk concrete consolidated by internal vibration; data average of at least three tests.
[b] Grout mixed, permitted to be undisturbed 1 hr, then remixed.

TABLE 2

EFFECT OF SURFACE TREATMENT, CONCRETE CONSISTENCY, AND PLACEMENT PROCEDURE ON BOND[a]

| Placement and Resurface Concrete | Bond Strength (psi) | | | | Type of Test Specimen |
|---|---|---|---|---|---|
| | Damp Base | | Dry Base | | |
| | 1:1 Grout | No Grout | 1:1 Grout | No Grout | |
| Surface vibration, 6 sk/cu yd, 3-in. slump, 6% air | 297 | 194 | 521 | 167 | Prisms |
| Internal spud vibration, 6 sk/cu yd, 3½-in. slump, 4½% air | - | - | 363 | 212 | Prisms |
| Compactor float, after hand tamping, | 579 | 397 | 593 | 0[b] | Prisms |
| 7 sk/cu yd, no slump | 640 | 468 | 687 | 0[b] | Cores |
| Internal spud vibration, compactor float, 2 hr later, 7 sk/cu yd, 2½-in. | 437 | 350 | 659 | 449 | Prisms |
| slump, 4% air | 620 | 430 | 816 | 657 | Cores |
| Shotcrete 1:3 mix, specimen | 289 | 434 | 428 | 301 | Prisms |
| vertical | 124[c] | 350 | 151[c] | 553 | Cores |
| Shotcrete 1:3 mix, specimen | 251 | 354 | 536 | 590 | Prisms |
| horizontal | 135 | 214 | 373 | 577 | Cores |
| Shotcrete 1:3 grout, 6 sk/cu yd, 1½-in. slump, 1½% air, internal | 477 | 269 | 574 | 481 | Prisms |
| vibration | 820 | 235 | 820 | 472 | Cores |
| Surface vibration followed by vac. process, 6 sk/cu yd, 3-in. slump, 6% air | 189 | 166 | 456 | 272 | Prisms |
| Internal spud vibration, 6 sk/cu yd air entrained; repeat of 2nd test above | - | - | 475 | - | Prisms |
| Same as above but surface sand-blasted | - | - | 391 | - | Prisms |
| | - | - | 468 | - | Prisms |
| Same as above, but sandblasted surface treated with HCl | - | - | 463 | - | Prisms |

[a] 16 x 40-in. slabs treated with HCl (except as noted) and surfaced with 2 in. of concrete; data average of tests on two 8-in. cores or two 8-in. prisms cut from the slabs, except on four prisms where no data shown for cores.
[b] Resurface came off during sawing and coring.
[c] Sand pockets apparent in concrete.

TABLE 3

EFFECT OF SURFACE TREATMENT OF OLD CONCRETE ON BOND[a]

| Surface Treatment[b] | Bond Strength (psi) | |
|---|---|---|
| | 1:1 Grout | No Grout |
| HCl | 301 | 228 |
| HCl, internal vibration | 363 | 212 |
| Glacial acetic acid | 52 | 68 |
| Brushed and washed with water | 21 | 4 |
| Sandblasted, torpedo sand, shotcrete gun | 102 | 88 |
| Sandblasted, silica sand, commercial gun | 48 | 64 |
| Tennant machine, shallow waffle | 283 | 326 |
| Electric chisel, light chipping | 163 | 162 |
| HCl, 7 sk/cu yd concrete internally vibrated[c] | 525 | 327 |
| HCl, 11 sk/cu yd concrete internally vibrated | 425 | 418 |
| HCl, 7 sk/cu yd concrete[d] | 358 | - |
| Tennant machine, 7 sk/cu yd[d] | 407 | - |

[a]Slabs, 16 by 40 in. sawed from 25-yr-old pavement, surfaced with 2-in. of 6-sk air-entrained concrete consolidated by surface vibration except as noted; data average of tests on four 8-in. prisms.
[b]Of old base slabs in air-dry condition.
[c]Base concrete for tests above this entry from different source and weaker than base concrete for remaining tests.
[d]Scaled but soundbase.

TABLE 4

SUMMARY OF BOND STRENGTHS OF CORES REMOVED FROM EARLY PROJECTS IN SERVICE[a]

| Project Name | Resurfacing | | | Surface Preparation[b] |
|---|---|---|---|---|
| | Date Built | Nominal Thickness (in.) | Bond Strength (psi) | |
| Ilene St., Detroit, Mich. | 1950 | 1/2 | 256 | 1, 2 |
| Tennant Co., Minneapolis, Minn. | 1952 | 1 | 316, 424, 596 | 3, 1, 4, 5 |
| Themis St., Cape Giradeau, Mo. | 1922 | 5 | 0, 291 | Unknown |
| Market St., Savannah, Mo. | 1914 | 3 | 0, 86, 208 | Unknown |
| First St., Hastings, Neb. | 1948 | 4 | 0, 308, 348 | 1, 5 |
| Seventh St., Hastings, Neb. | 1948 | 4 | 0, 186 | 1, 5 |
| South St., Hastings, Neb. | 1949 | 4 | 0, 168 | 1, 5 |
| Bus Stop, Rochester, N.Y. | 1942 | 4 | 444, 480 | 3, 1, 4, 5 |
| Meadowbrook Rd., Rochester, N.Y. | 1942 | 1 1/2 | 0, 120, 396, 520 | 3, 1, 4, 5 |
| Suffolk Co., US 27, N.Y. | 1947 | 6 | 500, 504, 524 | Unknown |
| Dublin Bridge, Ohio | 1945 | 1 | 448 | 1, 4, 5 |
| Stratford Bridge, Ohio | 1949 | 3 | 210, 356, 416 | 1, 4, 5 |
| Warsaw St., Toledo, Ohio | 1913 | 1 1/2 | 188, 320, 484 | 1, 4, 5 |
| Clearfield Co., US 322, Pa. | 1938 | 2 | 348, 364, 500 | 3, 2, 1, 4, 5 |
| Providence, Rt. 44, R.I. | 1936 | 2 | 484, 640 | Unknown |

[a]Cores drilled during summer and fall of 1953.
[b]Numbers signify the following: 1 = broom cleaned, 2 = blown clean with compressed air, 3 = scarified or other surface removal, 4 = dampened, 5 = bonding grout or cement applied to wet surface, and 6 = acid etched.

TABLE 5

SUMMARY OF BOND STRENGTHS OF CORES REMOVED FROM PROJECTS IN SERVICE[a]

| Project Name | Resurfacing Statistics | | | | Approx. Year Base Constructed | Surface Preparation[b] |
|---|---|---|---|---|---|---|
| | Date | Reason | Nominal Thickness (in.) | Core Bond Strengths (psi) | | |
| Bunker Hill AFB, Ind. | 1959 | Strengthen and correct surface irregularities. | 3 | 750<br>627 | 1943 | 3, 4, 5 |
| Standiford Field, Louisville, Ky. | 1959 | Strengthen and improve grade. | 4 | 343<br>321 | 1944 | 3, 4, 5 |
| Glenview NAS, Ill. (Phase I) | 1961 | Strengthen and repair. | 5 | 468<br>224 | 1943 | 3, 4, 5<br>4, 5 |
| Glenview NAS, Ill. (Phase II) | 1963 | Strengthen and repair. | 5 | No cores tested | 1943 | 3, 4, 5 |
| Randolph AFB, Texas | 1960 | Improve surface smoothness. | 2½ | No cores obtained | 1944 | 5, 6 |
| Ft. Campbell Army Air Base, Ky. | 1957 | Repair construction deficiency. | 2 | 468<br>525 | 1957 | 3, 4, 5 |
| Selfridge AFB, Mich. | 1956 | Correct surface irregularities. | 1 | No cores obtained | 1929<br>1942 | 3, 4, 5 |
| Sections of Pennsylvania Turnpike, Pa. | 1954 | Correct surface irregularities. | ½, 1, 2 | No cores obtained[c] | 1940 | 3, 4, 5 |
| Andrews AFB, Md. | 1961 | Improve surface smoothness. | 2 | No cores tested[d] | 1941 | 4, 5, 6 |
| Kellogg Field, Battle Creek, Mich. | 1962 | Correct surface irregularities. | 2 | 312<br>460 | 1939 | 3, 4, 5 |
| Detroit Metropolitan Airport, Mich. | 1963 | Correct surface irregularities. | 2 | 406<br>320 | mid-1930's<br>1941 | 3, 4, 5 |
| Sections of Ohio Turnpike | 1955 | Correct construction deficiencies. | 3-6 | No cores tested[e] | 1955 | 3, 4, 5 |

[a]Cores drilled during summer of 1964.
[b]Numbers signify the following: 1 = broom cleaned, 2 = blown clean with compressed air, 3 = scarified or other surface removal, 4 = dampened, 5 = acid etched, and 6 = sandblasted.
[c]See Figure 6.
[d]See Figure 7.
[e]See Figure 8.

between old and new concrete. Although the laboratory studies indicated that a better bond is obtained on a dry surface, large projects indicate that a damp (but not wet) surface, free of standing water, gives better construction control. A damp surface brings the old surface closer to the temperature of the plastic concrete, prevents rapid drying of the bonding grout, and prevents rapid hydration of the cement in the resurfacing (Tables 1, 2, and 3). In addition it was found that the base surface must be sound and that all loose or unsound concrete must be removed. There are a number of methods which can be used to remove unsound material (Table 3).

Other variables to consider were whether acid etching of the prepared sound surface was desirable, if a bonding grout is needed, and whether the method of concrete placement had an effect on the degree of bond (Tables 1, 2, and 3). A decision was tentatively made that a bond strength of 200 psi or higher indicated adequate bond between the old and new concrete (Tables 1, 4, and 5).

## CONSTRUCTION TECHNIQUE

Small and large bonded resurfacing projects over the past 10 years have resulted in the determination and acceptance of specifications for obtaining a good bond. Contractors have learned that a dampened base pavement is easier to work with than a dry one, especially in summer.

As reported by Westall, Purinton, Hutchinson and Wathen, and Adams (9), the following techniques have been used as a construction sequence for bonded resurfacing projects:

1. Prepare surface: scarification and acid etching, sandblasting and acid etching, or acid etching only;

2. Place forms;
3. Dampen base concrete and place bonding grout;
4. Place-finish-cure concrete resurfacing; and
5. Form and/or saw and seal joints.

A proper understanding of each step is necessary to insure optimum results. As pointed out by Felt, the base concrete must be brushed and flushed after acid etching to insure a clean surface free of residue and loose particles. The base concrete must be damp but free of standing water. The grout should have a thick paint-like consistency so it can easily be broomed into the surface. The presence of free water on the pavement surface, or a thin grout with excess water from the resurfacing concrete, could lead to a weak mortar layer at the bond interface.

Proper placement of the resurfacing concrete must include adequate consolidation, finishing, and curing, along with a satisfactory method of joint construction. It is important to match joints in the base pavement.

## EARLY PROJECTS

Felt's paper (1) reported that shear tests on cores from older projects showed varying bond strengths (Table 4). Most of these projects were constructed to correct some surface distress in old non-air-entrained portland cement concrete due to scaling or weathering. It is noteworthy that only the projects after 1950 had any intense preparation for bonding. The majority of projects before 1950 included only sweeping or washing the base concrete; not all had bonding grout applied (Table 4). Of the 37 cores taken, 26 (70 percent) show bond strengths of 200 psi or more and only six show no bond at all. A safe assumption is that once bond is established it will endure, as was the case for Market Street in Savannah, Mo.

## RECENT PROJECTS

The majority of these projects have been constructed since 1954. The first of the smaller projects and most of the larger projects will be discussed. These are projects where a definite effort was made to obtain a bond between the old and new concrete; all are on highway or airport pavements.

Some of the projects were surveyed in 1960-61 and again in 1964. The 1960-61 survey (8) consisted of a complete visual inspection; all cracks, spalls, and scaled areas, if any, were mapped. In addition, a careful sounding of the pavement surface along joints and reflective cracks was made with a steel rod to determine areas of bond failure. Wherever a hollow sounding area was located, additional soundings were made to determine the extent of bond loss and this area was plotted on the plan of the pavement. Cores taken from these areas substantiated the fact that a loss of bond existed. In addition to soundings, close surveillance was made of any surface irregularities and these areas were also plotted.

Bonded resurfacing projects at the following locations were surveyed in 1960-61: Bunker Hill Air Force Base, Ind.; Standiford Field, Louisville, Ky.; Ft. Campbell Army Air Base, Ky.; Selfridge Air Force Base, Mich.; Little Rock Air Force Base, Ark.; section of Pennsylvania Turnpike; and US 34 near West Burlington, Iowa. In 1964 a follow-up survey was made of bonded resurfacing projects at the following locations: Bunker Hill Air Force Base, Ind.; Standiford Field, Louisville, Ky.; Glenview Naval Air Station, Ill. (Phase I in 1961 and Phase II in 1963); Randolph Air Force Base, Tex.; Ft. Campbell Army Air Base, Ky.; Selfridge Air Force Base, Mich.; section of Pennsylvania Turnpike; Andrews Air Force Base, Md.; Kellogg Field, Battle Creek, Mich.; Detroit Metropolitan Airport, Mich.; and sections of Ohio Turnpike.

The 1964 survey, when possible, consisted of a complete visual survey of the pavement, including random soundings along joints and reflective cracks and also in the center of slabs. Since the 1960 survey established that small unbonded areas can be expected along joints, this survey was not specifically oriented toward discovering unbonded areas. The primary purpose was to observe the performance of the pavements where bond loss has occurred. The old survey sheets were examined and soundings were taken to determine if unbonded areas had increased in size, spalling had occurred, or other distress could be seen.

Figure 1. Coring operations.

Figure 2. Laboratory jig for shearing cores.


Figure 3. Core showing break in base pavement at Detroit.


Figure 4. Cores showing breaks in base pavements at (l. to r.) Detroit Metropolitan Airport; Bunker Hill Air Force Base, Ind.; Fort Campbell, Ky.; and Kellogg Field, Mich.

In addition to the visual survey and the random soundings, two 4-in. diameter cores were taken (Fig. 1) from each project where it was possible to do so. In addition, several 2-in. diameter cores were taken at random to verify the existence of bond wherever a solid area was indicated by sounding.

The 4-in. diameter cores were taken to the Portland Cement Association's Research and Development Laboratories where they were placed in a special jig and sheared at the bond interface (Fig. 2). All cores fractured in the old base concrete indicating an excellent bond (Figs. 3 and 4, Table 5). The 2-in. cores indicated a satisfactory bond although they were not sheared in the laboratory. Several 4-in. cores were taken in unbonded areas to try to determine the reason for the loss of bond.

Since each project differed in some respects, such as in thickness, area, or surface preparation each project surveyed in 1964 is discussed individually in the Appendix.

## CONCLUSIONS

Bonded concrete resurfacing has performed in an excellent manner as a means of strengthening old concrete pavement, providing a new smooth surface, repairing surfaces which have pop-outs, or repairing and patching spalls, scaled areas, etc.

Since adequate bond can be obtained with normal construction equipment and materials, chemical adhesives are not necessary. Cores obtained from projects using various methods of surface preparation indicate that a bond strength of 200 psi is adequate and that when such bond is obtained, it will endure.

Evidence shows that wherever loss of bond occurs, it probably developed soon after construction; little or no growth in the loss of bond area occurs over a period of time and under traffic. A few unbonded areas, especially at corners, show evidence of needing removal and replacement in the future. Certain information has been accumulated which is common to practically every project. Here, in brief, are some of the findings.

1. It is essential to follow the recommended techniques and construction sequence to assure a successful project;

2. Thin watery grout or free water left standing on the surface of the base paveme tends to weaken the bond;

3. An adequate bond strength can be obtained, using the techniques outlined by Westall (3, 4). When such bond is obtained, shear tests cause a break in the base pavement in practically every core tested (Fig. 4);

4. Some loss of bond was found on practically every project with most areas being small in size along longitudinal construction joints;

5. Loss of bond areas can only be found by sounding the pavement and show little or no deterioration;

6. No distress was observed along longitudinal construction joints which could be attributed to lack of load transfer;

7. Joints in the base pavement will reflect through the resurfacing and should be matched whenever possible; and

8. Cracks in the base pavement will also reflect through the resurfacing in most cases.

The evidence gathered shows that adequate performance can be expected regardless of the thickness of the resurfacing and the type and frequency of traffic.

## ACKNOWLEDGMENTS

This survey and paper would not have been possible without the assistance and cooperation of the following individuals and unit offices: the personnel of the Directorate of Civil Engineering, U. S. Air Force; Martin L. Cawley, Airfield Engineer, Portland Cement Association; Eugene W. Meeker and F. C. Staib, Ohio Turnpike Commission; Lt. Col. D. O. Fishbeck and Maj. R. D. Bartholomew, Michigan Air National Guard; Charles R. Dillon, Base Civil Engineer's Office, Andrews AFB; Engineering Office, Pennsylvania Turnpike Authority; Col. Gregory J. Hobbs and the personnel of the Base Civil Engineer's Office, Randolph AFB; Cmdr. John B. Adams, Cmdr. James C. Pierce, and the personnel of the Public Works Office, Glenview NAS; Wendell B. Ealy, Base Civil Engineer's Office, Bunker Hill AFB; the personnel of the Post Engineer's Office, Ft. Campbell, Ky., Foster V. Jones, Henry P. Julliard, and George A. Brown, Louisville and Jefferson County Airboard; and the District and Field Engineers of the Ohio, Michigan, Kentucky, Texas, Pennsylvania, and Indiana Districts of the Portland Cement Association. In addition I wish to thank Frank M. Mellinger, Director of the Ohio River Division Laboratories of the U. S. Corps of Engineers, and members of his staff for making their survey reports available and for their valuable advice and suggestions.

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# *Appendix*

## PROJECTS SURVEYED IN 1964

Bunker Hill Air Force Base, Ind.

Type of pavement: aircraft parking apron
Date of construction: summer 1959
Date of survey: summer 1960 and spring 1964

This 48,000-sq yd, 3-in. resurfacing was placed on an 8-in. World War II concrete pavement. The 3-in. bonded resurfacing was chosen as a means of correcting surface irregularities, mostly pop-outs, and to add additional strength to the parking area to facilitate the parking of heavier aircraft. For three years, fighter-type aircraft used the resurfaced area for parking and for the past year it has been used for parking by much heavier aircraft, including the C-135, C-130, and C-133.

The survey conducted in 1960 indicated that loss-of-bond areas were small and rather localized at the edge of certain longitudinal construction joints. Very few loose areas were found along transverse joints. One fairly large area approximately 100 sq ft in the center of the slab was located. At this time, no surface evidence of the loss-of-bond areas could be seen. There were a few longitudinal cracks developing where joints were not constructed over joints in the base pavement. The entire resurfaced area was rated excellent.

In 1962, the Ohio River Division Laboratories of the Corps of Engineers conducted a thorough visual and sounding survey (10) of the resurfaced area and reached the following conclusions:

> There has been a slight increase in the number of slabs showing loss of bond and spalling on the thin bonded overlay on the ADC apron, but this deterioration has not been excessive. The thin bonded overlay continues to be in excellent condition and in full operational use. Most of the increase of the unbonded areas in the thin bonded overlay has occurred along the joint abutting the box drains.

The 1964 survey indicated a small increase in the number of small spalls along the box drains. Random sounding with a rod showed no increase in size of the unbonded areas and no surface indication of the unbonded areas was evident. The pavement is in excellent condition. Two 4-in. diameter cores were taken at random locations (Table 5, Fig. 5). One 4-in. core was taken in the large unbonded area, mentioned earlier, and the apparent cause of bond failure was due to a ¼-in. layer of grout that had apparently dried before the placement of the new concrete.

Standiford Field, Louisville, Ky.

Type of pavement: end of runway
Date of construction: summer 1959
Date of surveys: summer 1960 and spring 1964

This was the first major project constructed at a civil airport and was one of the thickest resurfacings constructed using the acid etch, bonding grout technique. The resurfacing was 4 in. in thickness and consisted of 8,300 sq yd at the end of a primary runway. The 4-in. resurfacing was placed on a 6-in. resurfacing constructed in 1944 on an old 9-6-6-9-in. concrete base pavement (Fig. 5). This 4-in. resurfacing was

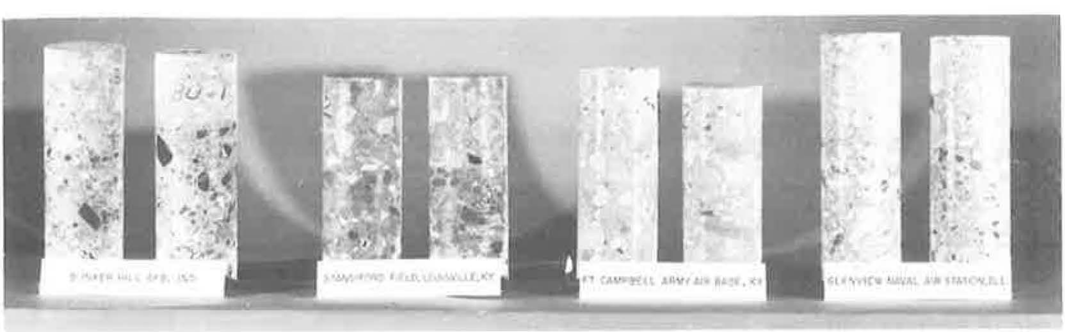

Figure 5. Four-inch cores taken at Bunker Hill Air Force Base, Ind.; Standiford Field, Louisville, Ky.; Fort Campbell Army Air Base, Ky.; and Glenview Naval Air Station, Ill.

constructed to strengthen the base pavement, correct surface irregularities and to insure a proper grade for the runway end since a bituminous overlay was to be placed in the interior of the runway.

The 1960 survey indicated that 35 to 40 percent of the slabs in the resurfacing had small unbonded areas along joints and at corners. In practically every case, the unbonded areas were 1 sq ft or less in area and were more numerous along certain longitudinal construction joints and in one lane. At this time, the pavement had been in service for 1 year and there was no surface indication of the unbonded areas.

In 1962, the Ohio River Division Laboratories of the Corps of Engineers conducted a survey (11) which was similar to the one the author conducted in 1960 but much more comprehensive. The conclusions were as follows:

1. The 4-in. portland cement concrete overlay pavement at the north end, 19, of the N-S Runway is in excellent condition.
2. No appreciable deterioration of the overlay pavement has occurred since 1960 under traffic by commercial aircraft.
3. The small areas where the overlay is unbonded near the slab joints and corners have produced no appreciable effects on the surface of the pavement.
4. Based on performance at Standiford Field, the placing of thin bonded overlays for improved surfacing of concrete pavements appears to be good construction practice.

The 1964 survey confirmed the Corps of Engineers' report that an increase in unbonded areas exists but there is no surface indication of the loss-of-bond areas. A few corners do show hairline cracks but the pavement is intact. Approximately five unbonded corners show evidence of additional cracking and it is anticipated that small repairs will be necessary in the future.

The present condition of the pavement is excellent and it is performing well under the traffic of commercial jets (707's and DC-8's), Electras, DC-7's and other commercial aircraft.

Glenview Naval Air Station, Ill. (Phase II)

Type of pavement: aircraft parking apron
Date of construction: summer 1961
Date of surveys: fall 1963 and summer 1964

In the summer of 1961, the U. S. Navy awarded a contract for approximately 78, 000 sq yd of 5-in. bonded concrete resurfacing at Glenview Naval Air Station, Ill. The resurfacing was placed on 6- and 7-in. portland cement concrete constructed during World War II. Severe scaling of the old non-air-entrained concrete and the anticipation of heavier aircraft were the primary considerations for smoothing the apron surface and increasing the load-carrying capacity of the old 6- and 7-in. pavement.

Since a 5-in. resurfacing is difficult to sound with a rod and determine unbonded areas, a survey was conducted by the author in 1963 by walking and mapping all surface defects. This survey indicated that some cracks in the base pavement had reflected through the resurfacing. No evidence of any loss of bond was evident on the surface.

In 1964, both 4- and 2-in. cores (Fig. 5) were removed from this project and all showed an excellent bond between the surface and the base pavement. A walking survey of this area at this time showed additional reflective cracks and one area of spalled concrete near a drop inlet along the edge of the apron. The overall area is in excellent condition.

Glenview Naval Air Station, Ill. (Phase I)

Type of pavement: aircraft parking apron
Date of construction: summer 1963
Date of surveys: summer 1964

This 1963 resurfacing project was an extension of the initial project constructed in 1961. A walking survey in 1964 showed that the pavement was in excellent condition with only a few reflective cracks. An attempt was made to obtain 4- and 2-in. cores. The coring bit available was $11\frac{1}{2}$ in. in length, so attempts to snap the cores in the 14-in. pavement broke the cores in the old pavement less than 1 in. below the bond interface. Since all cores were intact after drilling, and since they all snapped in the base pavement, it can be assumed the bond was excellent.

Randolph Air Force Base, Texas

Type of pavement: aircraft runway
Date of construction: summer 1960
Date of surveys: winter 1961 and fall 1964

In the summer of 1960, an average $2\frac{1}{2}$-in. thick bonded resurfacing was placed on a runway 200 ft wide and 7,000 ft long. Because of surface irregularities and uneven slab construction, the 8-in., 16-year-old concrete pavement was too rough for high-performance jet aircraft. This project of 155,600 sq yd resurfacing is one of the largest in scope yet built; it utilized sandblasting instead of scarification for surface preparation.

In December 1961, a survey was made after approximately 200,000 aircraft operations. As in other projects, some loss of bond was found along joints but no surface distress was evident. A follow-up survey in the fall of 1964 was made which indicated large areas of unbonded resurfacing but very little cracking and practically no spalling. Because of aircraft operations, no cores were obtained. Most cores taken during the construction phase showed an excellent bond, but several showed a bond failure due to a residue left on the surface of the base slab after the acid application.

In 1962, a survey by the Ohio River Division Laboratories of the Corps of Engineers (12) concluded:

a. The surface of the thin bonded overlay on the East Runway is in good condition. However, it should be noted that no freezing or thawing conditions, and no heavy traffic by heavy aircraft have been applied to this pavement.
b. Cracks in the overlay are not open or spalled and do not detract appreciably from the serviceability of the runway pavement.

Ft. Campbell Army Air Base, Ky.

Type of pavement: aircraft parking hardstands
Date of construction: summer 1957
Date of surveys: summer 1960 and spring 1964

Due to surface irregularities during construction, the top 2 in. of a 17-in. portland cement concrete hardstand were removed and replaced with 1,400 sq yd of a nominal 2-in. bonded resurfacing in 1957.

When surveyed in 1960, only a minor area of bond loss was found. The surface was in excellent condition. In 1962, a survey by the Ohio River Division Laboratories of the Corps of Engineers (13) concluded:

a. The 2-in. portland cement concrete overlay of the 17-in. base pavement of hardstands #4 and #5 is in excellent condition.
b. No deterioration of the overlay has resulted under use of the hardstands for the parking of cargo and fighter aircraft since the 1960 pavement inspection.

During the spring of 1964, this project was again inspected and both 4- and 2-in. cores were obtained. All cores showed an excellent bond and no surface evidence of distress could be seen (Fig. 5, Table 5).

Selfridge Air Force Base, Mich.

Type of pavement: aircraft parking apron
Date of construction: summer 1956
Date of surveys: summer 1959 and 1960 and fall 1961

This project of 47,000 sq yd of 1-in. bonded concrete resurfacing was the first large project and established methods and techniques which are now standard for this type of work. Approximately 37,000 sq yd of this apron consisted of 14-year-old 10-in. concrete base pavement and the remaining area consisted of 27-year-old 6-in. portland cement concrete pavement. The resurfacing was placed to correct scaling, popouts and joint raveling.

A survey in 1961 indicated a loss of bond along some joints and at corners. Some small corners had been repaired and much of the unbonded areas showed no surface distress.

A survey by the Ohio River Division Laboratories of the Corps of Engineers in 1962 (14) concluded:

> 1. There has been an increase in the number of slabs showing a loss of bond on the thin bonded overlay portion of the ADC operational apron. The predominant areas where loss of bond is occurring are along longitudinal joints.

Unfortunately, cores could not be obtained on this area but a visual inspection from time to time indicates that the poor surface condition of the base slab and unfamiliar construction techniques contributed to the loss of bond areas. All cores but one, taken from the project after construction was completed, broke in the base pavement when they were subjected to the shear test.

Eastbound Lane, 18 Mi East of Allegheny Tunnel, Pennsylvania Turnpike

Pavement: highway pavement
Date of construction: 1954
Dates of survey: fall 1961 and summer 1964

This highway project was constructed on a 700-ft section, 24 ft wide, of the eastbound lane. The base pavement was 9-in. reinforced concrete, 14 years old. The resurfacing consisted of sections of varying thicknesses ranging from ½ to 2 in., all in separate sections. The 2-in. section contained wire mesh reinforcement and the landing grout was pneumatically placed.

Due to the heavy volume of traffic only a visual inspection and spot sounding could be made during the 1961 and 1964 inspection surveys. At both times, the resurfacing was in excellent condition, considering the traffic, and very few areas of bond loss were found. Actual surface distress was observed in three small areas along one joint and two cracks. The majority of bond loss showed no surface distress. Some cracking and small spaces are evident and several cracks above the mesh strands were observed.

Unfortunately it was impossible to obtain any cores from this project. In the fall of 1964, this section of pavement was removed because of the construction of a parallel tunnel. Portions of the resurfaced pavement were obtained and samples were sawed out showing the varying resurfaced thicknesses (Fig. 6).

Andrews Air Force Base, Md.

Pavement: aircraft runway
Date of construction: summer 1961
Date of survey: summer 1964


Figure 6. Pavement sections cut from Pennsylvania Turnpike.

In 1961 a 2-in. bonded concrete resurfacing of approximately 83,400 sq yd was placed on a 150 by 5,000-ft area of a 20-year-old concrete runway. The old concrete, although in good condition, was too uneven and rough for present-day jet aircraft. The resurfacing was placed to give the old pavement a smooth, even surface and at the sar time provide additional strength.

A survey and cores taken in the summer of 1964 showed the pavement to be in excellent condition with all cores showing excellent bond (Fig. 7). The same condition of small bond loss along joints was found with a few small spaces having been patched. This project also utilized sandblasting for surface preparation instead of scarification.

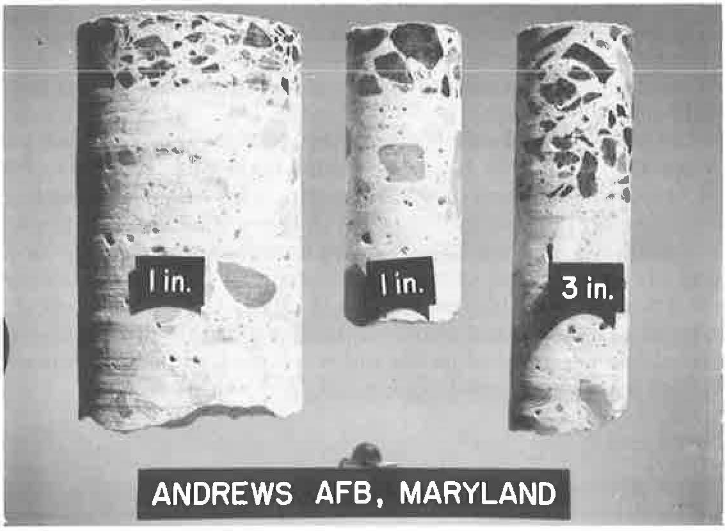


Figure 7. Cores from Andrews Air Force Base, Md.

Kellogg Field, Battle Creek, Mich.

Pavement: aircraft parking apron
Date of construction: summer 1962
Date of survey: summer 1964

In the summer of 1962, a 20-year-old 8-in. concrete apron belonging to the Michigan Air National Guard received a 2-in. bonded resurfacing totaling 38,620 sq yd. Scaling and surface popouts plus the desire for additional strength were the reasons for this resurfacing project.

A survey conducted in the summer of 1964, during which 4- and 2-in. cores were taken, showed the apron to be in excellent condition. This project contains a very minor amount of bond loss and the bond is excellent. A few cracks exist where the joints on the base pavement were not matched, but these are tight and are not raveling.

Detroit Metropolitan Airport, Detroit, Mich.

Pavement: aircraft parking apron
Date of construction: summer 1963
Date of survey: summer 1964

This parking apron was resurfaced in 1963 with a 2-in. bonded resurfacing. The total project approximated 75,000 sq yd placed on 9-in. concrete. A portion of the old pavement was built in the mid 1930's and the balance in 1941.

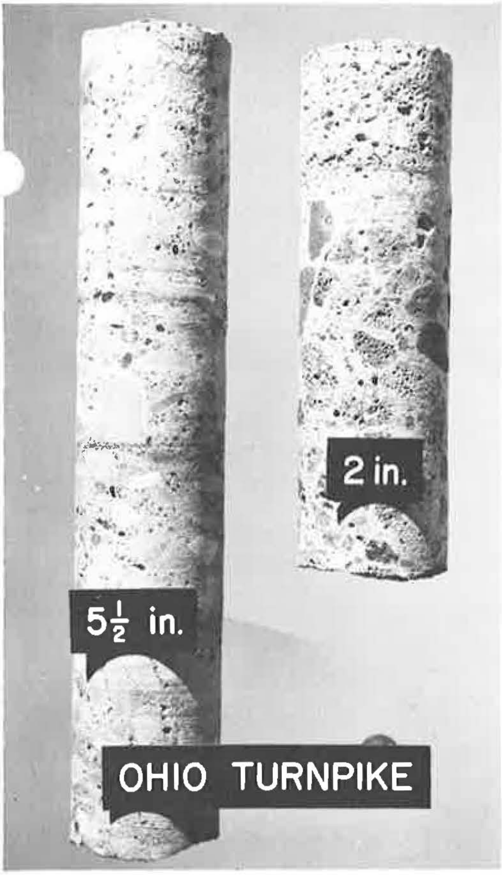


Figure 8. Cores from Raccoon Creek Bridge resurfacing and from patch on Tinkers Creek Bridge on Ohio Turnpike.

The entire area was surveyed and cored in the summer of 1964 and is in excellent condition (Fig. 3). There are some small unbonded areas and some small spalls along transverse joints due to construction difficulties with a paper joint insert. Several cracks are evident due to misplacement of joints in the resurfacing which do not match the joints in the base pavement.

Ohio Turnpike

Pavement: Raccoon Creek Bridge deck, milepost 97.9
Tinkers Creek Bridge deck, milepost 185.5
Date of construction: May 1955
Date of survey: summer 1964

The entire maintenance procedure for all pavement on the Ohio Turnpike is accomplished using the procedures outlined in previous papers and articles and by which bonded resurfacings are constructed. Two projects were chosen to survey and core, the Raccoon Creek Bridge deck and the Tinkers Creek Bridge deck.

Raccoon Creek.—This bridge was resurfaced in 1955 because of construction deficiencies. The bridge is approximately 170 ft long and 32 ft in width. The bonded resurfacing consists of 3- to $6\frac{1}{2}$-in. concrete, with mesh, placed using the previously mentioned bonding procedures. Attempts were made to obtain 4-in. cores but the structural steel in the base pavement made this impossible. However, a series of 2-in. cores was taken, so as to miss the steel, and all showed an excellent bond (Fig. 8). These cores were taken in the right-hand lane on the eastbound section of the bridge at approximately milepost 97.9. After 9 years the resurfacing is in excellent condition with no evidence of scaling, cracking or distress of any kind.

Tinkers Creek.—This bridge deck was patched approximately 1½ years ago using the aforementioned bonding techniques. The patching was necessary to replace concrete which had spalled above the steel in the deck. Several 2-in. cores were taken between steel bars and all showed an excellent bond (Fig. 8). The patches are in excellent condition and none sounded loose.

## Other Projects

A number of other bonded concrete resurfacing projects have been constructed and should be mentioned. A few of these are as follows:

| Year Built | Location | Sq Yd | Nominal Thickness (in.) |
|---|---|---|---|
| 1954 | US 34, Burlington, Iowa | 3,000 | 1, 2, 3 |
| 1955 | Little Rock AFB, Ark. | 1,700 | 1 |
| 1957 | Seymour-Johnson AFB, N. C. | 100 | 2 |
| 1957 | Ladd AFB, Alaska | 3,200 | 2 |
| 1957 | Lake Charles AFB, La. | 600 | 2 |
| 1957 | Lincoln AFB, Neb. | 1,400 | 2 |
| 1961 | Forbes AFB, Kan. | 1,800 | 2 |
| 1961 | Otis AFB, Mass. | 51,000 | 7 |
| 1962 | Otis AFB, Mass. | 48,800 | 7 |
| 1962 | Rock Island Bridge, Ill. | 5,366 | 2 |
| 1964 | Laredo AFB, Tex. | | |

It is impossible to report on each of these projects, but the author did survey the projects at Little Rock AFB, Seymour-Johnson AFB, and Rock Island Bridge and found all in excellent condition.