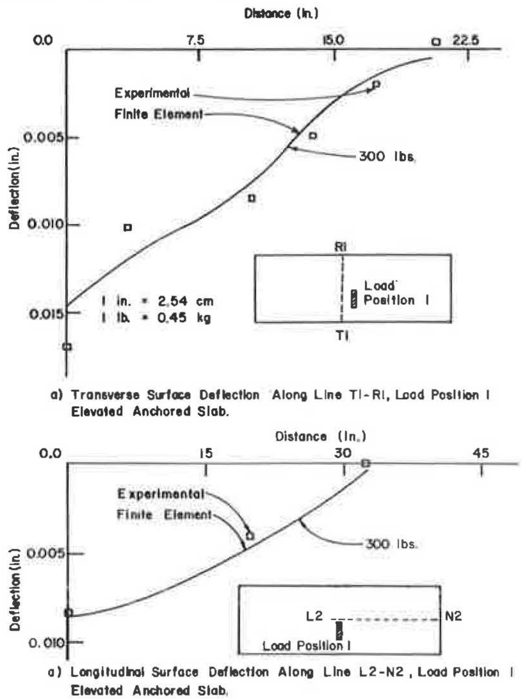
Figure 22. Transverse and longitudinal surface deflections along lines T1-R1 and L2-N2, load position 1, for ASLE.



model of the ASL for a 750-lb load are plotted as well as the experimentally observed points. The difference is about 11 percent. Figure 22 presents the transverse and longitudinal deflections and the experimental points for the ASLE for a 300-lb load at position 1. Although the longitudinal deflections show remarkable agreement, there is a difference of about 18 percent between observed and analytical values for the transverse deflections.

Although every effort was made to maintain the uniformity of the subgrade, human factors do cause nonuniformities. Keeping these factors in mind, it may be remarked that, in general, the trends of observed deflection of the model tests agree well with the analytical (finite-element) results. Although the paper presents results of only a few of the many experiments conducted, the inferences are based on a study of all experimental results.

CONCLUSIONS

The anchored slab offers two distinct advantages over the conventional slab. First, deflections are lower and more uniform. Second, stress in the soil is lower and distributed more widely by the rigid anchors. A significant portion of the pavement-distress mechanism arises from the subgrade, in which the soil is under greater confining stress (and as a result is stronger), and when moisture and temperature fluctuations are not acute, subgrade-related failure is less likely to occur.

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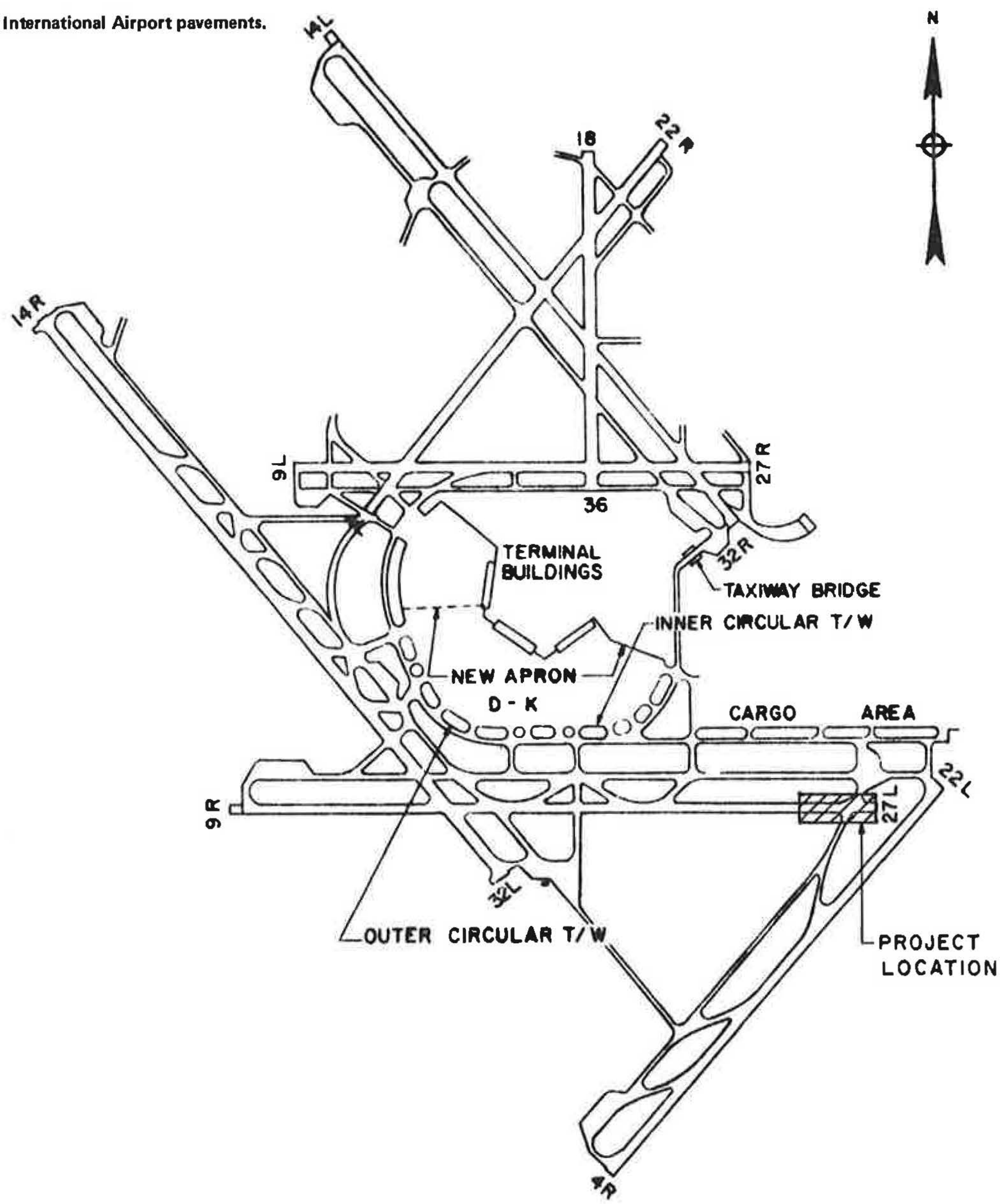
Prestressed Concrete Overlay at O'Hare International Airport: In-Service Evaluation

DONALD M. ARNTZEN

A 240-m (800-ft) prestressed concrete overlay was placed on the 27L end of runway 9R-27L at Chicago O'Hare International Airport. The overlay consisted of two 120 x 46-m (400 x 150-ft) sections 20 or 23 cm (8 or 9 in) thick. The pavement was posttensioned by using a fully bonded bar system. Conventional paving and tensioning equipment was used, and the cost and time of construction were comparable with those of conventional paving systems of portland cement concrete.

At 10:00 a.m., Sunday, August 24, 1980, runway 27L at Chicago O'Hare International Airport was reopened for traffic after completion of a prestressed concrete overlay. This overlay of the threshold 240 m (800 ft) long was another step in the ongoing program to rehabilitate and upgrade the airfield pavement system.

Figure 1. Layout of Chicago O'Hare International Airport pavements.



BACKGROUND

Chicago O'Hare International Airport has six primary runways and one secondary runway, which amounts to 814 954 m^2 (974 825 yd^2) of pavement. The taxiway system amounts to 1 104 930 m^2 (1 321 687 yd^2) and the apron system amounts to 633 278 m^2 (757 510 yd^2). This totals 2 553 162 m^2 (3 054 022 yd^2) of airfield pavement, which equals 349 km (217 miles) of pavement 7.3 m (24 ft) wide. The airport pavement layout is shown in Figure 1.

The original runways 4L-22R, 9L-27R, 14L-32R, and 18-36 built in 1942 consisted of 18-cm (7-in) portland cement concrete (PCC) on 30.5 cm (12 in) of gravel. Subsequent construction of runways, taxiways, and aprons has included 30.5-cm PCC and continuously reinforced concrete pavement (CRCP), 38.4-cm (15-in) PCC, 35.6-cm (14-in) CRCP, 45.7-cm (18-in) PCC, and 53.3-cm (21-in) PCC.

In 1974, a systematic program of pavement rehabilitation began with the bituminous concrete overlay of runways 9R-27L, 14R-32L, and 14L-32R. In subsequent years, runways 9L-27R and 4L-22R along with numerous taxiways were also overlaid with bituminous concrete. The runway overlays were expected to perform for five years before additional surfacing was required; consequently, a staged program was adopted whereby the total overlay was not installed initially. By now, 53 percent of the runways have been overlaid with bituminous concrete.

ECONOMICS

The 53.3-cm PCC on 15 cm (6 in) of bituminous asphaltic mixture, adopted as a standard for O'Hare, was selected after completion of the Airfield Pavement Demonstration-Validation Study (1). Although the 53.3-cm standard section is the most economical, the cost of removal and replacement has risen to $110/$yd^2$. Because of grade differentials, it is necessary to remove the existing pavement, which contributes to the cost and the length of time of construction. The cost of delays has also risen dramatically, and a Delay Task Force Study (2) was completed in July 1976 for Chicago O'Hare International Airport. This report indicates that the annual cost of aircraft delays that could occur without optimized runway use is $27.6 million. This does not infer that all runway construction will affect operations equally; however, even occasional disruptions are costly. Because of these delay costs, airline representatives are advocating nighttime construction.

PRESTRESSED CONCRETE PAVEMENT

At the 1979 International Air Transportation Conference in New Orleans, Louisiana, Richard Heinen presented a paper on prestressed concrete pavement design and described the various installations in Europe and South America (3). At that time, 3 261 300 m² (3 900 050 yd²) had been placed since 1956, and it was reported that these pavements were performing satisfactorily. The thickness of the prestressed pavements varied from 14 to 18 cm (5.5-7 in), and they were used by all types of aircraft, including the Boeing 747.

Members of the American Society of Civil Engineers' Airfield Pavement Committee inspected the prestressed pavements at Amsterdam's Schipol Airport, the Cologne-Wahn Airport at Cologne, and the Manching NATO/German Air Force Base near Munich and concluded that an in-service evaluation in the United States was warranted. Of particular interest was the possibility of using prestressed pavement as an overlay, which would provide a maintenance-free pavement that would have minimal grade changes. This concept was approved by the city of Chicago and the Federal Aviation Administration, and the project to rehabilitate the 27L end of runway 9R-27L was selected for the evaluation.

DESIGN CONSIDERATIONS

The prestressed concrete overlay was to be patterned after the successful installations inspected in Europe. Major structural failures in the existing CRCP such as punchouts or base failures would be repaired. Normal transverse cracking or longitudinal construction joints would not be reinforced. The pavement would be designed for a 20-year service life by using the finite-element model with edge loading for maximum stress. Verification of the design would be determined by using instrumentation and actual aircraft loading.

DESIGN CRITERIA AND RUNWAY DATA

The installation was not to be experimental but was to be patterned after the systems installed in Europe and South America. Consequently, a posttensioned, fully bonded bar system was used. The design aircraft was to be the Boeing 747, which has a wheel loading of 22 197 kg (49 000 lb). The spacing of the main gear wheel is 147 cm (58 in) longitudinally and 112 cm (44 in) transversely. The reaction of the modulus of the base course on the surface of the 31-cm CRCP was assumed to be 51.09 kN/cm³ (700 lbf/in³). The 14-day compressive stress of the concrete was specified to be 34 500 kN/m² (5000 lbf/in²). The concrete was to be air-entrained and the surface grooved. Centerline lights were to be installed, and provisions for future touchdown lights were to be made.

Runway 9R-27L is 3065 m (10 140 ft) long and 46 m (150 ft) wide and has 8-m (25-ft) shoulders. It is one of the preferential runways in the optimized runway-use plans and consequently is subject to heavy traffic. Annual operations at O'Hare have exceeded 700 000 arrivals and departures. In addition to extensive use for arrivals and departures, the runway threshold is used by aircraft that taxi from runway 4R-22L. This cross traffic is one of the causes of the failure of the threshold.

PAVEMENT DESIGN

The pavements previously installed in Europe were 14-18 cm thick. The 18-cm pavements had been subjected to B747 loadings in international operations; however, these loads were not so frequent as those at O'Hare. These pavements were stressed at each end, which required a gap for jacking filled by using a gap slab. Also, each transverse joint was laid on a sleeper slab.

The design analysis for 27L by using sector analysis and the finite-element model resulted in a 20-cm (8-in) pavement thickened to 23 cm (9 in) at the longitudinal joint adjacent to the taxiways. It was decided that if prestressed concrete was to be effective as an overlay, it would be desirable to eliminate the sleeper slab and the gap slab. Consequently, two thicknesses were selected as shown in Figure 2, and a sleeper slab was used only at the joint between the 20-cm and the 23-cm slabs. The east and west ends were poured directly on the existing concrete, which had a PCC leveling course 5 cm (2 in) thick by 61 cm (24 in) wide bonded to it. The balance of the pavement was overlaid with an asphaltic concrete leveling course 2.5-5 cm (1-2 in) thick. Stressing of the tendons both longitudinally and transversely was to be from one end only, i.e., the east, west, or south end of the completed overlay.

CONSTRUCTION

The successful low bidder was Milburn Brothers, Inc., of Mt. Prospect, Illinois, and construction began on June 24, 1980. After the sleeper slab had been placed, major failures in the 30-cm CRCP had been repaired, and the asphaltic leveling course had been placed, standard metal forms lined with planking were installed. Two layers of polyethylene were laid on top of the asphalt, and then the conduits for the tendons, the light bases, and the electrical conduits were installed. The 2.5-cm longitudinal tendons were installed, and paving of the 8-m lanes proceeded by using a conventional paving train except that internal vibrators were not permitted. The contractor elected to use a superplasticizer to facilitate placement around the conduits and light bases. Burlap curing for seven days was specified; in the 39°C (101°F) environment, this proved beneficial in cooling the concrete during curing. In addition to the high temperatures encountered, more than 12.7 cm (5 in) of rainfall was recorded in this period. Because this operation was an overlay, it caused only minor interruptions in use of the airport, and the contractor did not request a time extension.

Prestressing in the longitudinal direction was performed at 12 h, at 36 h, and when the concrete had achieved 80 percent of its design strength. Prestressing in the transverse direction was performed after all lanes had been poured. PCC transition beams 1.22 m (4 ft) wide doweled into the existing pavement were placed adjacent to the taxiways and the runway asphaltic concrete overlays.

After prestressing had been completed, an expansive grout was pumped into the conduits to fully bond the tendons. The tendons were deformed bars, and the grout specified required a pullout test of 6900 kN/m² (1000 lbf/in²). The concrete was a 6.5-bag mix that included a limestone coarse aggregate [maximum size, 2 cm (0.75 in)], which was specified to decrease the potential of D-cracking. At other locations at O'Hare, conventional 38-cm PCC pavements have failed due to D-cracking. These pavements had gravel as a coarse aggregate.

Grooving of the pavement was accomplished by us-

Figure 2. Plan of prestressed concrete overlay on runway 27L.

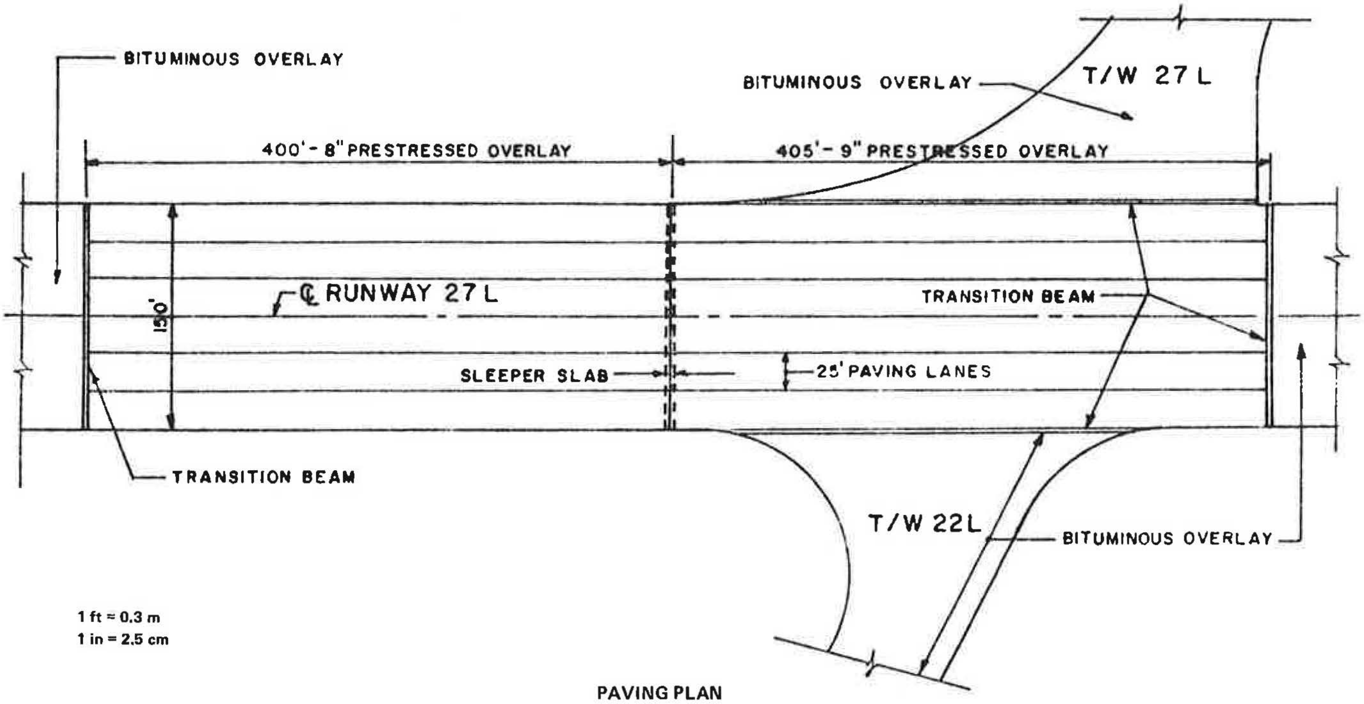
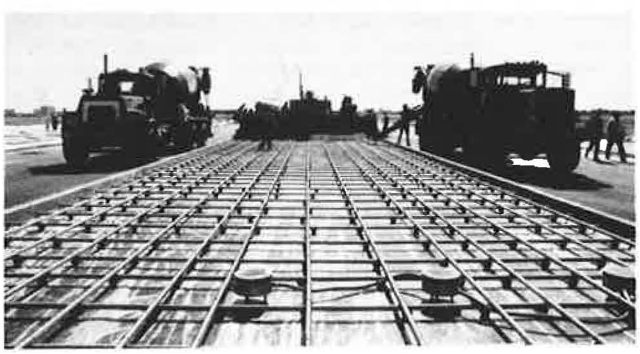


Figure 3. Paving train in operation.

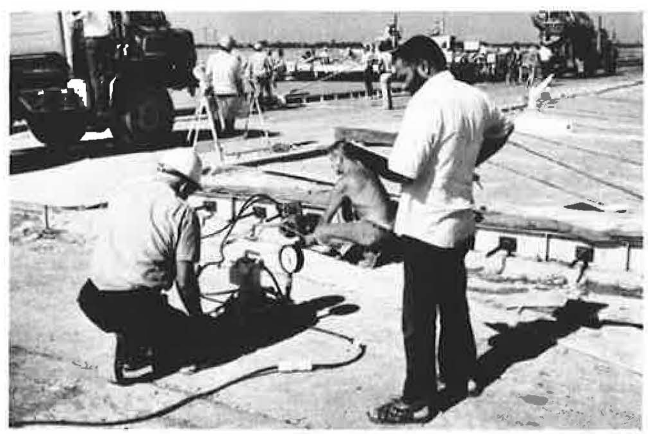
Figure 4. Conduits and lighting fixtures in place.



ing a wet diamond-sawing process.

Test sections for deflection were installed at six locations. On Sunday, August 24, 1980, from 7 to 8 a.m., a United Airlines B 727-200 that weighed 59 362 kg (131 000 lb) was positioned over the test locations in the 23-cm and in the 20-cm overlays. Prior to the test, calculations had been made for various subgrade moduli so that field measurements could be interpreted as they were taken. The results obtained during the test indicated that the subgrade moduli were significantly in excess of those used in the design and that the edge that did not have a sleeper slab was more than adequate.

Figure 5. Tensioning longitudinal tendons.



CONCLUSIONS

Based on the bids received and time of construction, it is apparent that prestressed concrete overlays are competitive with other PCC paving systems. From observations of the progress of the construction, the equipment used, and the lighting installation, there are no apparent problems associated with using standard paving trains or standard posttensioning equipment (Figures 3, 4, and 5). The load testing indicated that the system could span joints or cracks and that sleeper slabs were not required. Also, varying thicknesses of prestressed pavement could be placed.

Long-term observations will be necessary to document maintenance costs and possible design modifications to improve on the construction and performance of a prestressed overlay system.

It is strongly recommended that qualified, experienced personnel be employed in the design, construction, and quality assurance of prestressed concrete pavements.

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Bonded Portland Cement Concrete Resurfacing

JERRY V. BERGREN

The experiences of the state of Iowa in developing and refining the process of resurfacing concrete pavements by using portland cement concrete (PCC) are described. The methods of evaluating the condition of the underlying pavement and determining the thickness of the resurfacing layer are discussed. Several projects that used PCC resurfacing to satisfy different roadway needs are described. Several methods of surface preparation, the methods of bonding, and the bond test results are included and discussed. It is concluded that bonding a layer of PCC 50-75 mm (2-3 in) thick to an existing concrete pavement is a viable alternative to bituminous resurfacing for the rehabilitation and restoration of concrete pavements.

Iowa has more than 12 000 miles of portland cement concrete (PCC) primary and Interstate highways, secondary or county roads, and city streets. Approximately 15 percent of these streets and highways have been in service more than 40 years and have had little or no surface maintenance and no additional wearing surface. Many, however (especially those that carry high volumes of traffic), need surface attention at this time. The serviceability (rideability) is approaching, and in some cases has arrived at, the point at which surface restoration or reconstruction is imminently needed.

Nationally and locally, the trend has shifted from building miles of new pavement to restoring and rehabilitating the existing pavement. This has been for the most part due to financial, environmental, and ecological restrictions.

Historically, the restoration process on PCC roads and streets has usually involved resurfacing by using bituminous materials to provide an acceptable riding surface. The bituminous-resurfacing process has provided city, county, and state government agencies with a viable method of extending the service life of PCC pavement at a considerably lower cost than that of reconstructing or replacing the facility.

Since 1976, this nation has been made aware that petroleum and products derived from petroleum are becoming more and more expensive. Further, and more important, is the forecast that this nation's supply of crude oil is quite limited and may be exhausted before the turn of the century. Thus, there is a stong emphasis on the search for substitute fuels, products, and methods that are not dependent on petroleum.

Various types of PCC overlays, which include plain, nominally reinforced, and continuously reinforced overlays, have been demonstrated on concrete pavements as well as a few cases on bituminous pavements. For example, since 1959, 13 different states, including Iowa (Greene County), have had projects that used continuously reinforced concrete overlays (1).

In 1973, a research project was conducted in Greene County that used 50- and 75-mm (2- and 3-in) thicknesses of fibrous reinforced concrete in various conditions of bonding: unbonded (two layers of polyethylene), partially bonded (wet interface), and bonded (dry cement broomed over wetted surface). Also, in the fall of 1954, PCC resurfacing was placed on US-34 in West Burlington, Iowa. This was reinforced by using steel mesh, and most of the project was bonded by using a nominal 6 mm (0.25 in) of cement-sand grout (2).

Although there is a variety of designs and construction procedures available, the projects mentioned above demonstrated the practicability of concrete for resurfacing in rehabilitating old concrete pavements. In previous attempts at full bonding of overlays, the information available indicates that complete bonding was not obtained.

A definite need existed for a high-strength, durable, skid-resistant, long-lasting, and economical resurfacing course for PCC pavements. Such a resurfacing course, completely bonded to the existing pavement, would provide additional support for the ever-increasing traffic loads and volumes on our roads and streets.

Iowa has had considerable success in the use of thin, bonded, dense concrete overlays used in the repair of deteriorated bridge decks (3). This process involves the removal of unsound concrete down to and around the top layer of steel reinforcement. The entire remaining area of the bridge-deck surface is removed to a nominal depth of 6 mm. This removal is most generally accomplished by using scarifying equipment.

The existing surface is scarified to remove road oils, linseed oil, etc., as well as the surface concrete that has the highest concentration of chloride ions from the interface. The entire surface is