BONDED CONCRETE RESURFACING

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Successful thin bonded resurfacing of concrete pavements dates back to 1913. Following World War II, the U.S. Air Force and the Navy resurfaced a number of airport pavements with bonded techniques in an effort to repair and increase load bearing capacity of older pavements. Due to the lack of high production cost-effective equipment, little interest was seen for highway work. The development of slipform paving equipment and high speed milling machines in conjunction with the completion of the Interstate system and escalating asphalt prices created new interest in bonded resurfacings for the highway engineer. A 1973 research project in Iowa utilizing thin sections of fibrous reinforced resurfacing coupled with a successful program of bonded dense concrete bridge deck overlays led Iowa Engineers to believe they had come up with an alternate for the traditional bituminous restoration procedure. Numerous Iowa research and full scale Interstate contracts have since resulted in new techniques and design recommendations which make a thin bonded concrete resurfacing a viable and economical approach to the rehabilitation of concrete pavements.

Historical Background

Early History

This paper will cover bonded concrete resurfacing of old concrete pavements. The new concrete resurfacing is intentionally bonded to the old pavement so as to produce a new slab equivalent to the combined thicknesses. This method can, therefore, be used to increase the structural capacity of a pavement as well as to improve riding qualitites, skid resistance or other deficiencies.

Successful thin bonded resurfacings of concrete pavements dates back to the early 1900's. These early projects were resurfaced with concrete to correct surface distress in non-air-entrained concrete. Only projects constructed after 1950 had any type of intentional bonding preparation. The early projects included only sweeping or washing of the old pavement and in some cases an application of bonding grout was applied. A Highway Research Report by Roy W. Gillette (1) in 1965 states-"A safe assumption is that once bond is established, it will endure, as was the case for Market Street in Savannah, Missouri." The Savannah, Missouri, project was constructed in 1914 and surveyed by Gillette in 1953 when cores were taken from the pavement to determine thickness and bond strength.

Vacuum Processed Concrete Resurfacing. A few vacuum processed thin bonded resurfacings were made in the mid 1930's. This process was invented by Karl P. Billner in 1935 (2). The first applications of this process were thin resurfacings on deteriorated old concrete pavements in New York, Rhode Island and Pennsylvania.

In 1936, a 12.2 m (40 ft.) long, 3 m (10 ft.) wide, 5.08 cm (2 in.) resurfacing was placed on Route 85 just west of Albany, New York. In 1943, an inspection found no sign of scaling, disintegration or loss of bond (3).

Also in 1936, a 2 block section of North Lake Avenue in Albany, New York, was repaired with vacuumed processed concrete. Disintegrated concrete near joints was removed to a 5.08 cm (2 in.) depth. A grout coat was applied before the concrete was placed and vacuum processed. An inspection in 1943 showed the original concrete to be disintegrated as much as 5.08 cm (2 in.) below the patches which were unaffected. The edges of the patches were still sharp and remained as constructed even though this pavement was under heavy traffic (3).

Another project in 1936 was the resurfacing of a 12.2 m (40 ft.) long, 3 m (10 ft.) wide, 5.08 cm (2 in.) thick section of State Route 44, Putnam Pike, Providence, Rhode Island. A core of this pavement in 1938 showed absolute bond at the interface (4). An inspection in 1943 revealed no loss of bond or wearing of the grid pattern (3).

A 1953 report by the Portland Cement Association showed the resurfacing to be in excellent condition - no loss of bond (5).

Pennsylvania Route 59 (U.S. 322) 2.4 km (1½ mi.) northwest of Grampian, Pennsylvania, received a 5.08 cm (2 in.) resurfacing in 1938. This project was 975.6 m (3,200 ft.) long of 5.1 m (18 ft.) wide pavement and was built with form riding paving equipment. An inspection 10 years later showed no loss of bond. A Portland Cement Association study in 1953 showed considerable "D" cracking and distress due to failure of the underlying slab. There was, however, still

bond at the interface (5).

In 1970, the British Cement and Concrete Association and the City of Glasgow applied vacuum techniques to the main runway of the Glasgow Airport (6,7).

Conventional Bonded Resurfacing. In 1956, Earl J. Felt (8) presented a paper at the Highway Research Board which covered laboratory and field investigations of several concrete bonded resurfacing projects. Felt's studies investigated surface preparation including acid etching, the merits of bonding grout, specifications to be considered and cautions regarding construction procedures.

Two articles by W. G. Westall (9,10) give detailed description techniques used in constructing bonded concrete overlays.

Following World War II, the U. S. Army Air Force and the Corps of Engineers placed considerable emphasis on the rehabilitation and strengthening of old air field runways with bonded concrete resurfacing. Reports on projects at Randolph Air Force Base, Texas, were published by John B. Purinton, Jr. (11) and bonded resurfacings at Campbell Air Force Base, Kentucky, by the Corps of Engineers (12). These reports cover the construction of bonded resurfacing. Design and construction were covered in an ASCE paper by Ronald L. Hutchinson and Thurman R. Wathen (13) in 1961.

There was little, if any, highway activity in bonded resurfacings from the mid 1950's, also the beginning of the Interstate program, until the mid 1970's which coincided with that period in which the Interstate program was winding down and nearing completion. There were only a few scattered experimental or special resurfacing projects built during this period due to the emphasis on new construction.

During this period, there were numerous Air Force projects constructed throughout the country. These varied in thickness from 2.54 cm (1 in.) to 17.78 cm (7 in.) and are covered in the paper by Gillette (14).

By today's standards, which have primarily been developed in Iowa, the projects constructed prior to 1970 were crude, labor intensive, low production and expensive. In spite of the lack of modern equipment and techniques, these early projects clearly illustrated that bonded concrete resurfacings were a viable method for rehabilitating or strengthening an old concrete pavement. Cores removed from the pavement showed that a bond strength of 14 km/cm^2 (200 psi) is adequate and that when such bond is obtained, it will endure. Bond loss occurs soon after placement with little or no growth in loss of bond area over a period of time and under traffic.

These early projects illustrated that it was essential to follow the recommended techniques and construction sequence and that adequate performance could be expected regardless of the thickness of resurfacing and the type and frequency of traffic.

Recent emphasis on the need to upgrade heavily trafficked pavements to increase structural capacity, safety and rideability along with the availability of funds for this purpose has focused new attention on concrete bonded resurfacing.

Airport Applications

The overlay design criteria used in the past for strengthening existing airport pavements was developed by the Corps of Engineers primarily for military airfields. During World War II, a large number of military airfields were constructed of pcc pavement in the 15.24 cm (6 in.) to 25.4 cm (10 in.) thickness range throughout the United States. With the gross weight of aircraft increasing from B-17 and B-24 to the B-47 and B-52 in the 1950's, it became necessary to strengthen these pavements. To do this, the Corps of Engineers embarked on a testing program. The overlay design criteria has been developed by the Corps of Engineers emperically from the results of full-scale traffic test tracks and adjusted where necessary based on actual performance data.

In developing the design criteria, full-scale test tracks were subjected to accelerated traffic, using the actual aircraft main gear loading. Among the test items included in this research were concrete overlays over concrete pavements, reinforced rigid overlays over flexible pavements and rigid overlays over composite pavements.

From the results of this research, the thickness design formulas were developed representing bonded, partially bonded (or direct) and non-bonded overlays.

The thickness design formula for the bonded overlay is simply:

$$T^r = T - T_0$$

The U. S. Army Corps of Engineers has developed a Specification for "Resurfacing of Rigid Pavements with Thin Bonded Rigid Overlays."

In 1971, a contractor slipformed 50,167 m^2 (60,000 sq. yds) of 15.24 cm (6 in.) plain concrete bonded resurfacing in less than 30 days at the Tampa International Airport. The overlay was on a taxiway, a runway end, and high speed turnouts. The project also includes the replacing of a runway with 40.64 cm (16 in.) plain concrete pavement on cement treated subbase.

In preparation for resurfacing, the existing pavement was cleaned by sandblasting and etched with acid. The acid, applied from a tank truck through a specially improvised spray bar, was spread by a CMI texturing machine with broom attachment and was thoroughly washed off after the foaming action stopped. Specifications required the existing slab to be kept wet for the 48 hours preceding paving to reduce the temperature differential between the old and new concrete. Just before paving, a neat cement bonding grout was spread on the existing surface to a depth of 1.59 - 3.175 mm (1/16 - 1/8 in.). This was normally accomplished by the texturing machine but in confined areas was done by a power broom.

Concrete mixed in a 6.9 m^3 (9 cu. yd.) Rex dual drum central mix plant was hauled in side dump trucks to a Maxon spreader which was followed by a CMI slipform paver and tube float. Curing compound was applied at the rate of 13.9 m^2/3.81 l (150 sq.ft./gal.), and after the joints were sawed additional cure was provided by covering the slab with wet burlap for a period of 24 hours. Joints were spaced to match those in the existing slab, generally at 7.6 m (25 ft.) transversely, and an intermediate longitudinal joint was sawed down the center of each 7.6 m (25 ft) wide slab. Longitudinal construction joints were also sawed. There are no keyways or tie bars in the overlay pavement. All joints were sealed with neoprene preformed compression seal. The taxiway received a burlap drag texture, but the runway was textured transversely by a wire comb.

The contractor had placed a similar bonded overlay on 609.6 m (2,000 ft.) of 22.9 m (75 ft.) wide taxiway at this airport a year before, using forms. Both the old and the new overlays were exceptionally smooth riding.

In 1978, the Consulting Engineering firm of Crawford, Murphy and Tilly, Inc., Springfield, Il-

linois, designed a bonded overlay for strengthening runway 4-22 at the University of Illinois Willard Airport in Champaign, Illinois. The consulting engineers determined through design analysis and competitive bidding that a bonded overlay was the most cost-effective method of strengthening the runway.

The project consisted of a 20.32 cm (8 in.) bonded overlay in the center 22.9 m (75 ft.) of the 45.7 m (150 ft.) wide runway with the remaining 11.4 m (37½ ft.) on either side placed as a direct or partially bonded overlay. The bonded overlay involved approximately 33,445 m^2 (400,000 sq. yds.).

The existing pavement was built in 1943 and 1944, and consisted of 20.32 cm (8 in.) pavement with a 22.86 cm (9 in.) thickness for a 152.4 m (500 ft.) length on each end of the runway. The pavement was placed on a 20.32 cm (8 in.) pit run gravel subbase. The existing pavement had doweled expansion joints at 36.58 m (120 ft.) spacing with transverse contraction joints at 6.1 m (20 ft.) spacing. The longitudinal joints consisted of keyed construction joints at 7.6 m (25 ft.) spacing and a longitudinal contraction joint at the center of each 7.6 m (25 ft.) lane.

The construction techniques followed those developed in Iowa for bonded overlays. The pavement to receive the bonded overlay was cold planed with a CMI Roto Mill followed by high pressure water blasting. Prior to placing the bonded overlay, a grout of thick cream consistency is spread on the dry prepared surface. The surface of the prepared pavement is specified to be dry to improve bond between the old pavement and the overlay.

The pavement was placed with a CMI Slipform Paver. Concrete was deposited directly in front of the paver by dump trucks. The grout was also mixed in the central mix plant and brought to the paving site in an agitor truck. The pavement was placed in alternate lanes starting from the runway edge. On two passes the pavement consists of 3.8 m (12½ ft.) of fully bonded and 3.8 m (12½ ft.) of partially bonded or direct overlay. No surface preparation is required for the partially bonded overlay except sweeping and dampening prior to placing the concrete.

The jointing system in the overlay consisted of butt joints for all longitudinal joints and sawed contraction joints matching all existing contraction and expansion joints. A longitudinal joint at the center of the 7.6 m (25 ft.) wide lane of the overlay will also be sawed. New full depth expansion joints 5.08 cm (2 in.) wide were also cut at selected locations, generally about 213.5 m (700 ft.) apart.

Highway Market

Equipment Developments

The slipform paver along with equipment to provide proper surface preparation has permitted thin bonded concrete resurfacing to become a viable alternate for concrete pavement rehabilitation.

The ability of slipform equipment to extrude a concrete pavement of any thickness desired and to do so efficiently with minor variation in the underlying pavement is the principal reason concrete resurfacing is economical and competitive. The expensive forming cost related to thin bonded overlays was just not compatible with high production cost-effective highway resurfacing for concrete. The slipform paver can produce a thin concrete section providing adequate vibration to give a dense concrete meeting the desired riding qualities and still correct for minor deviations in profile.

Surface Preparation

Proper preparation of the surface of the old concrete is the most important step in securing a satisfactorily bonded overlay. Research has shown that adequate bond can be achieved by the following methods or combination of methods for surface preparation:

Milling and Scarifying Equipment. This equipment consists of the CMI Roto Mill machine, Gallion Miller, Barber-Greene, Barco, Reconoco or similar machine. It is capable of uniformly scarifying or removing the old surface to the depths and cross section required. This machine can be used to remove concrete near bridge approaches, intersections and vertical clearance for structures.

Sandblaster. The high production portable sandblasters have sufficient force and duration to uniformly remove all surface film, laitance, and other materials that may impede the bond of the subsequent overlay.

High production sandblasting equipment may or may not require dust abatement.

High-Pressure Waterblasting. The high pressure waterblaster is capable of producing pressure in excess of 422 kg/cm^2 (6,000 psi) and has the capability to clean the existing concrete surface free of oil, dirt, paints and other contaminants.

The hardness and type of coarse aggregate used in the old pavement may dictate the type of surface preparation based on economics. Research has shown the highest bond strengths have been obtained using both milling and sandblasting. However, adequate bond strengths have been obtained with only sandblasting or Blastracing. The type of surface preparation should be determined by the materials in the old pavement.

The surface preparation is necessary to clean the old concrete of all tire rubber, dirt, oil drippings, and old lane line paint. It is extremely important to keep the pavement clean and dry until the overlay is placed in order to obtain a good bond.

Development of Market

This new equipment and the recent techniques developed by contractors are a direct result of two historical events. The first being the completion of the Interstate program.

Concrete paving contractors spent huge sums of money investing in modern equipment to meet the challenge of the Interstate program. The completion of this program and the lack of funds for new construction has left these same contractors with large equipment inventories and a nucleus of experienced personnel. They needed a new market area to utilize this equipment and experienced manpower. Available Federal funds were being directed to restoring and upgrading the many miles of neglected primary and secondary systems. Also in need of repair is some of the earlier constructed Interstate system which has been subjected to far greater traffic than ever anticipated. It is only logical that these contractors should look to the concrete resurfacing market.

The second event which has enhanced the concrete resurfacing market is this nation's dependence on foreign oil. The crude oil used in the production of liquid asphalt is basically Mid East (OPEC) crude. Most U.S. crude is too high in sulfur, thus very little goes into asphalt production (15). Asphalt pavements use huge quantities of oil.

Asphaltic cement prices have increased sharply since 1973. It is predicted by the National Asphalt Pavement Association that the price of asphaltic cement will be $260/907 kg (ton) by the end of 1981. This would be a 45% increase in 1981.

Along with this escalating price in asphalt comes the very realistic possibility of less crude being available to the asphalt industry. Last April, Ashland Oil, Inc., announced a major breakthrough in the refining process called "reduced crude conversion". This process will extract more than 70% gasoline rather than the 50% usually extracted from a barrel of oil by treating the 25% of a barrel usually sold as lower priced boiler fuel or made into asphalt. Ashland Oil is spending $70 million on a refinery addition which by early 1982 will produce gasoline from the heavy, leftover end of the barrel of crude oil (16).

Our dependence on OPEC oil, the escalating cost of asphalt, the realisitic possibility of less asphalt along with equipment developments and new techniques have made concrete pavement resurfacing a very competitive alternate on an initial cost basis. If we consider life cycle cost based on performance, concrete resurfacing has a definite advantage.

Fiber Reinforced Concrete Overlays

No discussion of concrete overlay would be complete without some mention of fiber reinforced concrete. There have been several experimental highway resurfacing projects using steel fibers. The fibers may be rectangular, in cross-section (approximately 10 x 20 mils) or round with a diameter of approximately 20 mils. They range in length from 2.54 cm (1 in.) to 6.35 cm (2½ in.). A newer type of fiber is actually deformed. This Bekaert fiber is made from hard drawn steel wire. They have a tensile strength of 11,764 kg/cm^2 (170,000 psi). The ends are hooked to mechanically anchor them to the concrete. The steel fibers which are generally shipped in cardboard boxes are added to the concrete at a rate of about 1-2% by volume (about 59.3 - 118.6 kg/m^3 [100 - 200 lbs. per cu. yd]). Generally smaller size coarse aggregate with fly ash is used and a slightly higher cement factor to provide adequate mortar to coat all fibers and insure bond. Fiber reinforced concrete has excellent physical properties in laboratory tests - high strengths, toughness and resistance to cracking, spalling, and crack growth.

Several demonstration or experimental projects have been built, mostly resurfacing of existing pavements. The largest fibrous projects as of 1972 was placed on a heavily traveled arterial street (8 Mile Road) in Detroit. Two lanes of the old slab were built in 1922 and in 1954 and one new one in 1972. The fibrous concrete overlay designed to be a 7.62 cm (3 in.) minimum thickness was placed by a slipform paver directly on the old pavement. Half of the experiment contained 71.18 kg (120 lbs.) of fiber per m^3 (cu. yd.) and the other half 118.6 kg (200 lbs.). Nine sacks of cement were used and slag coarse aggregate with 1.27 cm (½ in.) maximum size. Transverse joints were sawed at 15.2 m (50 ft.) intervals in part of the project and 30.4 m (100 ft.) for the balance. Cracks developed between joints and in some cases the overlay shattered due to lack of bond at corners and several areas failed requiring removal of approximately 3/4 of the project. The inside turning lane is in excellent condition (17).

In 1973 Minnesota built an experimental resurfacing project to correct surface profile. A heavy traffic arterial, Snelling Avenue near Minneapolis, had been subjected to studded tire traffic for several years before Minnesota banned the use of studs. The highway department was seeking a method for constructing a thin resurfacing to fill the tire ruts and to restore transverse drainage and skid resistant texture. The Minnesota project included methods for developing bond between the new layer and the old slab. They tried sandblasting to provide a clean textured surface and then three different methods of bonding. Epoxy cement was applied in some test sections. Cement sand grout in some and others were simply direct applications of the new steel fibers, fiberglass fibers, and normal concrete. Thicknesses were 7.62 cm (3 in.) for the plain concrete and 5.08 & 7.62 cm (2 & 3 in.) for the two fiber reinforced concrete mixtures (18).

Early Iowa Research

Background

Iowa's experience in attempting to place portland cement concrete resurfacing on top of existing pc concrete pavements began with a project in West Brulington, Iowa, on U. S. 34 in 1954 (19). This was a research project involving mesh-reinforced concrete, 2.54 - 7.62 cm (1 to 3 in.) thick, that was bonded with a .64 cm (¼ in.) layer of cement-sand grout. The grout was applied pneumatically, using a jet-crete type of machine.

As noted in the report (19), the contractor had considerable difficulty in controlling the water content of the grout. The grout was placed as much as 12.2 m (40 ft.) ahead of the concrete placement and it was noted the bonding course had begun to whiten or dry before concrete placement was finished.

A major problem on the project was failure of the bond. It is believed the jet-crete grout layer contributed to the bonding failure because of the drying that was experienced. In areas where the grout was not used the bond was in fact better.

It is interesting to note the pavement cleaning that was done. After dry brooming, the pavement was vigorously scrubbed with a detergent, flushed with water and then etched with muriatic acid. The pavement was then washed and allowed to dry prior to applying the grout.

One of the recommendations coming from this research report was for the grout to have a consistency resembling paint and that it should be of proportions of one-to-one; that is, one part sand to one part cement.

Nearly 20 years later, on Old U. S. 30 in Greene County, Iowa, (just east of the town of Jefferson) another concrete overlay project was constructed (20). This was the largest and most comprehensive research project of a fibrous concrete overlay that had been undertaken to that time. The project was three miles long and included 33 test sections of fibrous concrete, four sections of CRCP, two sections of mesh reinforced concrete and two sections of dowel-reinforced concrete. This research project, constructed in 1973, involved different types of bonding for the various overlay sections. The bonding conditions required by the research project were as follows:

1. Fully bonded, which consisted of a cement paste bonding agent on the wetted surface. This was accomplished by wetting down the old roadway surface after broom cleaning and then sprinkling on dry cement and brushing it around on the surface.
2. Partially bonded, in which the old pavement was swept and the cracks cleaned prior to overlay

and the surface wetted.

3. Unbonded, which consisted of a double thickness of polyethylene sheet on top of the old pavement.

The research project was reviewed in depth in October, 1978, and a report made on those observations (21). In that inspection it was noted that the bonded sections seemed to be performing better than either the partial bond or unbonded sections.

Another important aspect and influence on Iowa's present pc concrete resurfacing procedures began in the early 1960's. At that time the deteriorating condition of Iowa's concrete bridge decks was becoming a major subject of concern. Due to the many applications of salt for snow and ice control, the corrosion of reinforcing bars and the accompanying bridge deck spalling were widespread. The bridge deck deterioration and the resulting poor ride characteristics were becoming a serious problem.

In the summer of 1964 an experimental research project was awarded to resurface a bridge on Iowa 196 in Sac County. This work consisted of removing the unsound concrete and placing a 2.54 cm (1 in.) thick pc concrete wearing surface over the entire bridge deck.

Because of the success of that project, Iowa embarked on a bridge deck repair and overlay program that is still continuing. This system of low slump, dense concrete (LSDC) is also known as the Iowa Method or the Iowa System of dense concrete bridge deck repair (22).

Essentially, the system used on those first bridges, and still being used today, is:

1. The surface is removed or scarified to a depth of approximately .64 cm (¼ in.) to provide a clean surface with which to bond an overlay. The scarifying will remove the road oils, dirt and other minor surface imperfections that the bridge deck may have.

2. The unsound concrete detected by sounding with hammers of chain drags and by electrical corrosion measurements, is removed down to at least the top of the reinforcing bars. The concrete is removed down to and around the reinforcing bar, and below the bar if continued deterioration is present.

3. After all unsound concrete is removed, the entire area is sand blasted for final cleaning.

4. A layer of sand-cement grout (at a 1:1 proportion with enough water to give it a thick, cream consistency) is then broomed across the prepared surface just prior to placement of the low slump concrete.

The low slump concrete, today as in the beginning of Iowa's program of bridge deck repair, consisted of .95 cm (3/8 in.) top size, high quality crushed limestone coarse aggregate, 377.4 k (832 lbs.) of cement (8 3/4 bags), with a 1.9 cm (3/4 in.) slump as a desired target. A plus 1.9 cm (3/4 in.) tolerance is allowed. This procedure has continued, and from 1965 through 1978 approximately 450 bridges in Iowa have been repaired and/or overlayed using this system of low slump dense concrete.

Iowa's design standard for new bridges, effective in January, 1974, called for a two-course deck. The top course was a 5.08 cm (2 in.) layer of low slump, dense concrete bonded to the underlaying course. Since December, 1976, the standard has required epoxy coating of the top mat of reinforcing steel and 6.35 cm (2½ in.) of clear cover.

In the mid 1970's, while the national and the local trend was shifting from building new highways to restoring and rehabilitating the existing highways, Iowa again gave thought to the need of a long-lasting, durable resurfacing for concrete pavements. Up until that time the restoration process of portland cement concrete pavements involved the resurfacing with bituminous material. Bituminous resurfacing, while providing the various governmental agencies with a method of extending the surface life, had a relatively short life. After approximately eight to ten years, additional resurfacing was needed.

Having had the experience with thin-lift resurfacing on the fibrous concrete project and the thin-lift overlays on the bridge deck repair system, as well as considering the increasing cost and limited availability of the asphalt involved with bituminous resurfacing, Iowa began the planning and consideration for a portland cement concrete resurfacing project.

Considering the satisfactory performance of the bridge deck repair system, Iowa looked at ways this procedure could be adapted to pavement resurfacing. However, the procedures used in bridge deck repair were much too slow to be considered practical. A higher production rate was necessary in order for the pcc resurfacing concept to be economically feasible. The ability to place a thin lift of concrete, using existing conventional paving equipment, was considered sufficiently demonstrated by the 1973 fibrous concrete research project in Greene County.

The availability of two new systems was influential in the decision to consider a bonded thin lift pcc resurfacing project in 1976:

1. High production pavement scarifying equipment such as the CMI Roto-Mill, and

2. The advent of the super plasticizing admixtures.

To successfully construct a thin lift nominal 5.08 cm. (2 in.) thickness of pc concrete resurfacing, it was felt the majority of the procedures and techniques used in bridge deck repair should be applied to such a project. Thus, the need for scarifying (cleaning the roadway) was apparent. The Roto-Mill type machine provided a high speed, .1-.2 m/s (20-40 ft./min.) in limestone aggregate with a 2.7 m (9 ft.) wide head, method of scarifying the existing surface of the concrete pavement.

Due to the very satisfactory performance of the bridge deck overlay there was a strong desire to use a similar high cement content, low slump mix. However, it was not considered practical to use the slow-moving, slow-production rate bridge finishing machine on a resurfacing project. Therefore, the use of super plasticizing admixtures was considered desirable in order to provide the necessary workability and placeability to a concrete mixture which would allow its placement with existing, conventional paving equipment.

Projects

Waterloo. This then led to the bonded, thin-lift portland cement concrete resurfacing project on U.S. 20 in Black Hawk County, Iowa, in October of 1976. (23) This roadway was a 25.4 cm (10 in.) plain, pc concrete pavement with 15.2 m (20 ft.) joint spacing, constructed in 1958. There was some spalling at the joints due to "D" cracking deterioriation.

The objectives of that project were to:

1. Determine the feasibility of proportioning, mixing, placing and finishing a thin-lift approximately 5.08 cm (2 in.) of a bonded, dense, non-reinforced, portland cement concrete using a conventional ready-mix porportioning plant and slipform paving equipment;

2. To determine if an adequate bond between the existing pavement and overlay of thin lift concrete could be obtained;

3. To determine the economics, longevity and maintenance performance of a bonded, thin lift pc concrete resurfacing as a viable alternate to bituminous resurfacing of concrete pavements; and

4. To determine the feasibility and performance of partial depth concrete repair of deteriorated transverse joints on concrete pavements.

This 460 m (1,500 ft.) long demonstration project was done in cooperation with the members of the Iowa Concrete Paving Association. They contributed men and equipment in order to allow the Iowa Department of Transportation to make a demonstration project of this new procedure.

The mixture was proportioned and mixed in a ready-mix plant, transported in transit mix trucks, deposited directly on the slab in front of a conventional slipform paver, and was placed, spread, consolidated, finished, textured and cured with existing conventional paving equipment.

The scarifying equipment performed very well and accomplished two things:

1. Profiled (leveled) the existing roadway; and

2. Provided a clean scarified surface on which to bond the overlay course.

The super plasticizing admixture provided a workability of concrete in the range that finishers and paving equipment were accustomed to, as well as providing a very low-water cement ratio (0.3±) of concrete mixture. This provided for very high compressive and flexural strengths.

The bond obtained by manually brooming a grout, like that used in bridge deck repairs, across the pavement was considered excellent. However, the method of spreading the grout using manual labor and brooms obviously is not the most efficient way of spreading a grout layer on a pavement.

Clayton County. The first project of bonded, thin lift pc concrete resurfacing placed in Waterloo demonstrated the feasibility of the system. This led to a major research project on a secondary road in Clayton County in 1977. (24) The need and objective of the Clayton County project was not to repair a deteriorated pavement so much as it was to increase the section. The original pavement was 15.24 cm (6 in.) thick. Shortly after it was constructed in 1968, a large silica sand plant was opened as well as a nearby grain terminal resulting in a large number of heavily loaded trucks traveling over this slab. The slab was starting to break up as a result of these loads and the county was experiencing a large amount of costly repairs.

The possibility of effectively increasing slab thickness, and thus its load carrying capacity, by utilizing the bonded, thin lift concrete resurfacing approach was very appealing to the officials of Clayton County.

The objectives of this research project were:

1. To determine if the proportioning and mixing of the mixture using super plasticizers could be performed in a conventional central mix plant;

2. To determine the economics, longevity, and maintenance performance of a bonded thin lift concrete resurfacing produced both with and without a super plasticizing admixture (in other words, conventional concrete paving mixture); and

3. To determine if an adequate bond could be obtained by using surface preparation methods other than scarification.

Approximately one-half of the 2.08 km (1.3 mi.) long project was constructed with concrete using a super plasticizing admixture. The mixing and proportioning was performed quite satisfactorily in a conventional central drum mix plant. The other half of the project was constructed with a conventional Iowa primary road concrete paving mixture utilizing only a conventional water reducing admixture.

The surface preparation consisted of a small amount of scarification using one of the motorized scarifying units - in this case a Gallion Road Planer. The remainder of the existing roadway was prepared in the following two ways:

1. The surface was sand blasted with a self-propelled sand blasting unit; and

2. The surface was cleaned with a high pressure, self-propelled water blast unit. The water blaster was able to achieve a pressure of approximately 421.96 kg/cm^2 (6,000 psi.) through a small spray bar. The shortcoming of the water blast cleaning was its failure to remove the traffic paint lines. It was considered desirable, and later proven by bond testing, that the paint lines must be removed in order to secure an adequate bond. The water blaster was not able to sufficiently remove the paint.

This project was completed in October of 1977 and was considered a success. The bond test results of the differently prepared surfaces indicated that sufficient bond could be obtained whether or not the surface was scarified, and by either the sand blasting or high pressure water blasting method. The conventional mixing plant equipment was able to satisfactorily mix the proportions when a super plasticizing admixture was used and the conventional paving and texturing equipment was able to satisfactorily place and finish both mixtures at a nominal 5.08 cm (2 in.) thickness.

Sioux City. With the satisfactory bond and other test results of the paving mixtures used in the Clayton County research project on the various types of surface preparation, the Iowa Department of Transportation was more confident that the procedure was a viable method of providing a durable, long-lasting, smooth riding, skid-resistant surface for concrete pavements. In the spring of 1978 approximately .8 km (.5 mi.) of a four-lane divided pavement in Sioux City on U.S. 20 was considered for a bonded overlay because of a unique problem. This was a downhill section of pavement in a relatively high speed zone of 72.41 km/h (45 m/h) with several traffic signals. This section had an ADT of 21,100, with 8 percent trucks. The large amount of truck traffic decelerating for the traffic signals was causing the existing buitminous resurfacing to "washboard". This problem had been present for several years and heater-planing had been performed more than once without any lasting success.

A project of removing the existing 7.62 cm (3 in.) bituminous overlay and replacing it with a bonded concrete resurfacing was constructed in the early spring of 1978. The existing roadway was removed by the Roto-Mill type of scarifying equipment, the surface was scarified with the same equipment, sand blasted and followed by the grouting and paving operation. A conventional concrete paving mix proportion was used on this project.

This project was constructed without incident and again reinforced Iowa's feeling and opinion that a thin lift layer of bonded pc concrete was a viable approach to restoration and rehabilitation of a concrete pavement. This led to the design and letting of the first bonded concrete resurfacing project to be done on Iowa's Interstate system.

I-80 Iowa. The Iowa Department of Transportation put to good use its expertise in bonding concrete in 1979, resulting in a new lease on life for 7.2 km (4.5 mi.) of I-80, west of Des Moines. The project is the first major use of the bonding technique on an Interstate pavement and represents the first time that work of this magnitude has been applied to continuously reinforced concrete.

Koss Construction Company of Des Moines was the successful low bidder on this $1,465,800 resurfacing project.

In addition to the 56,674 m^2 (63,000 $yd.^2$) of resurfacing, the project includes 14,300 m (47,000 ft.) of drainage and tiling work. Approximately 460 m^2 (550 $yd.^2$) of existing pavement was patched, and 9,197 m^2 (11,000 $yd.^2$) of the surface of the present pavement was ground down 2.54 cm (1 in.) to eliminate any deteriorated concrete. Resurfacing the shoulders with 8,924,800 kg (8,400 tons) of asphaltic concrete completed the project.

During the concrete paving project, the north half of I-80 was used for both eastbound and westbound traffic.

The I-80 project brought together all of the important lessons learned from previous experiments. A further challenge existed in that concrete aggregates in this area of the southwest Iowa are of questionable quality, and their use in the pavement to be resurfaced had resulted in some "D" cracking. A bonded layer of concrete was felt to be the most successful method of restoration for this type of deterioration.

The base pavement on the I-80 project was 20.3 cm (8 in.) continuously reinforced concrete, placed in 1966 on a 10.2 cm (4 in.) granular subbase. The extent of deterioration on this section was considered typical of other pavements of this design in the state. The project also included resurfacing a 640 m (2,100 ft.) length of adjacent 25.4 cm (10 in.) conventionally reinforced pavement with mesh and doweled joints spaced at 23.3 m (76.5 ft.) intervals. Traffic is nearly 13,000 vehicles per day, and 25 percent of it is commercial (3,200 trucks). The estimated 5,200 trucks per day by the year 2000 would require a concrete thickness of 26.7 cm (10½ in.). Iowa designers specified a 7.6 cm (3 in.) bonded overlay addition to the 20.3 cm (8 in.) base pavement after taking into account the depth of concrete removal during surface preparation.

Iowa requires a durable, crushed limestone aggregate meeting a gradation of an AASHTO 67 or that of the bridge deck overlay gradation, which is a minus 1.27 cm (½ in.) materials. The concrete mixture required is the conventional concrete paving mix proportions that would be used on any primary paving. The exception is that a conventional water reducing admixture is required (in "normal" concrete paving the use of a water reducing admixture is optional with the contractor).

Based on past experience, as well as the existing condition of the surface of I-80, it was decided to require the entire surface to be prepared by the nominal .64 cm (¼ in.) scarifying. In addition, in areas that had apparent (visible) "D" cracking surfaces as well as the road oils, chlorides, etc. that exist at or near the surface. It would also provide a more sound concrete face with which to bond the overlay.

The repair considerations are the same as for any conventional resurfacing project. Those areas requiring full-depth pavement repair were repaired prior to the concrete resurfacing. However, due to favorable previous experience, areas of partial-depth concrete repair were also allowed. This was for areas where deterioration was of a lessor degree and not considered sufficient to require a full-depth repair. The concrete was removed down to or near the level of the reinforcement. On jointed pavement these would be areas at or near transverse joints where the deterioration was readily apparent, such as where some minor spalling exists, but where there was no evidence of crushing damage of punchouts.

When constructing full depth repairs on the CRCP, no effort was made to maintain or restore the coninuity of the reinforcement. It was felt that if a portion of the reinforcement, in this case approximately 22.9 cm (9 in.), was left on either side of the repair area, load transfer would exist across this joint between the existing pavement and the new patch. This was considered sufficient and the continuity of the continuous reinforcement was not considered necessary. This conclusion was reached due to past experience where the pavement reinforcement was severed with a wheel saw in order to provide some expansive relief near bridge abutments. The resulting satisfactory performance indicated that maintaining the continuity of the continuous reinforcement was not necessary.

The concrete placement operations were conventional. The surface, after scarifying, was sand blasted. This is for cleaning, and for removing small areas that may be partially fractured but would not be removed by air blasting. As a final cleaning the entire surface was air blasted just prior to the grouting - paving operation. The subcontractor used modern sandblasting equipment incorporating a .66 m^3/s (1400 cfm.) compressor, a 1,269 kg. (14 ton) sand storage tank, and swinging nozzles on a self-contained 13.4 m (44 ft.) trailer.

Pressure relief joints 10.16 cm (4 in.) wide were cut full depth through the old roadway and through the resurfacing at 305 m (1,000 ft.) spacing. Through experience it was felt that these joints would provide some relief from the expansion-contraction pressures that will exist subsequent to resurfacing, and will hopefully prolong the life of the resurfacing.

When paving over any jointed paving - and this includes the joints that will exist at the full depth pavement repairs in the CRCP - it would be desirable to saw the full depth of the resurfacing over each joint. On past Iowa projects they sawed one-half the thickness of the resurfacing over the joints. It was felt that sawing full depth through the resurfacing course would provide some room for expansion due to temperature changes and thus prolong the life of the surface course.

The texturing was what is conventionally required on concrete paving in Iowa, an astrograss drag followed by transverse tining formed in the plastic concrete. The liquid curing compound was applied at 1½ times the specified rate for normal concrete paving. The reason for the additional curing compound is due to the importance of the cure, especially on a thin course of concrete. It was felt that an additional application rate would be beneficial.

Indianola Streets. The streets surrounding the city square in Indianola, Iowa, were originally paved with portland cement concrete in 1949. Even without the benefit of air entrainment, which was not a common practice at that time, the pavement has served for 30 years. Gradual deterioration of the surface from deicing chemicals caused the city to decide in 1978 on a thin-bonded concrete resurfacing layer as the best means of restoring a durable surface to the pavement. City officials were also interested in retaining the esthetic characteristics and low maintenance costs of the original pavement.

The project was bid in 1979. The Duit Construction company of Iowa Falls, Iowa, was contractor for the resurfacing. They paved the two outer 4.8 m (16 ft.) lanes of the 18.3 m (60 ft.) wide resurfacing using a Gomaco Slipform Paver. The center 8.5 m (28 ft.) section was slipformed by the Central Paving Corporation of Indianola. Their equipment included a Rex slipform paver and Rex central-mix concrete plant.

Surface scarification of the old pavement was done primarily by sandblasting. A grader-mounted grinder and pneumatic scabbler were also used to remove scaled concrete, oil spots, and other areas of the surface where bond might have been inhibited. Some small-area scarification was done experimentally with a machine that employs centrifugal force (rather than an air jet) to drive metal abrasive pellets against the surface to be cleaned. The machine, manufactured by the Wheel-A-Brator Frye Corporation, also recovers the abrasive pellets for reuse and has a dust collector system to keep air pollution to a minimum.

After the scarified surface was blown clean with compressed air, bonding grout was applied and spread by brooms and rubber squeegees. All grout for the project was batched and mixed in a Concrete-Mobile on the site, using the Iowa Department of Transportation recommended 50-50 mix where a sand-cement grout mixture is specified.

Slipforming of the 5.08 cm (2 in.) thick concrete followed immediately. The center section was paved first, with the 4.9 m (16 ft.) outer lanes paved to the curb in subsequent operations. An astrograss texture was applied to the finished surface, and curing was accomplished with white-pigmented liquid spray cure. Transverse joints were sawed to match the joints in the base pavement. Where irregular joints were present in the base slab, a rolling joint former or trowel was used to impress a joint above them to prevent reflection cracking. Expansion joints in the base pavement were cleaned by compressed air jet and filled with sand prior to resurfacing. A temporary expansion space was made in the fresh concrete above the joint with the cutter or trowel. After the concrete hardened, the expansion space was widened with parallel sawcuts above the outer limits of the joint below. Concrete between the sawcuts was removed by air hammer, and the expansion space in the resurfacing layer filled with a hot-poured expansion joint sealant.

Bond Strength. The bond strengths referred to in this text and in other discussions of Iowa's bonded pc concrete resurfacing are the result of testing cores in shear. (25)

In essence, a core is taken through the resurfacing and into, or through, the underlying pavement. The core is then placed in the testing jig with the interface lined up between the two sliding parts of the testing device. The resurfacing course is then sheared off.

From the work of others (Portland Cement Association), it is assumed that any bond strength, in shear, at 14.1 kg/cm^2 (200 psi) and above is sufficient and adequate.

The laboratory evaluation of sprayed and brushed on water/cement grouts vs. the previously used sand/cement/water grouts for the I-80 Project is as follows:

The specimens for test were prepared by filling a flexural test beam mold half full with a concrete paving mixutre. The surface was roughened slightly by scratching with a wire brush and a screwdriver (to simulate a scarified surface). After seven days curing, the grout was applied and the mold filled with concrete. 10.16 cm (4 in.) diameter cores were then drilled through the beams, and after 23 days curing in the moist room, the bond (shear) testing was performed with the water/cement grout - sprayed resulting in the highest bond strength - 42.9 kg/cm^2 (610 psi).

After evaluating the results, the Iowa Department of Transportation elected to approve the contractor's request to apply a water/cement grout at a .28 kg/kg (0.62 lb/lb) water/cement ration (26.5 l [7 gal.] per bag) by spraying.

It was anticipated that this method would provide the contractor a labor savings in the grouting operation. This will then reflect in a cost savings on subsequent projects of this type.

Economics. Using a 30 year analysis period, M. J. Knutson, Iowa Concrete Paving Association, (26) shows a 5.08 cm (2 in.) bonded resurfacing to be $273,695 per 1.6 km (1 mi.), and a 7.62 cm (3 in.) asphalt overlay to be $352,094 per 1.6 km (1 mi.). On the I-80 project considering a 12.2 m (40 ft.) width, including the shoulders, the actual initial cost for the 7.62 cm (3 in.) resurfacing was $177, 295 per 1.6 km (1 mi.).

Projection and Conclusion

The I-80 project, which was inspected by some 500 highway officials throughout the country at an Open House, created considerable interest. A number of State agencies now have thin-bonded resurfacing projects in the planning or design stage. The thin-bonded method of concrete pavement rehabilitation is economically feasible based on its excellent performance. Competition in the construction of overlays on road, street and airport system is essential to our economy. Concrete resurfacings are the ideal solution in this era of expensive and limited energy. It makes possible conservation of energy by utilizing local materials, thus reducing the cost of transportation and dependence on an unreliable source for the main ingredient. It minimizes natural resources required to provide a pavement facility and it extends the life and load carrying capacity of the existing pavement structure. Thin-bonded concrete resurfacing will give the maximum performance, the lowest in maintenance requirements, and the longest service life.

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