DESIGN CRITERIA FOR CONTINUOUSLY REINFORCED CONCRETE OVERLAY BASED ON PERFORMANCE

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INTRODUCTION

The U. S. Interstate Highway system is almost 90% complete. Parts of the system, some only 10 years old, are showing serious deterioration. These sections have probably already carried heavy truck traffic equivalent to 20 year traffic volumes, not anticipated in design. The need is great to improve and strengthen these pavements.

Two major requirements must be met in all rigid pavement design. The pavement system must be adequate to support the applied wheel loads and withstand environmental forces. These requirements apply to resurfacing as well.

To counter the effect of temperature expansion and contraction in conventional concrete pavements, contraction joints are installed at short intervals, generally 15 ft. to 60 ft. (4.6m - 18.3m) and expansion joints are sometimes installed at greater intervals. Sealing of these joints are not effectively maintenance-free and may cause a rhythmic "bump" to vehicles, resulting in poor rideability.

Typical failures have occurred with jointed pavement in the form of diagonal cracks, usually at the corners formed by the pavement edge and transverse joint. Wheel load transfer from one slab to another is at best partial, and various load transfer devices are used. Small non-compressible particles tend to lodge in the open cracks between contracted slabs causing a gradual pavement "growth" with attendant spalling at joints and numerous blow-ups when "growth" becomes excessive. Water intrusion at joints and weak corners allows subbase degradation by the pumping action of the water as wheel loads are applied. Maintenance has been excessive in many cases.

These are some of the factors that encouraged state highway designers to use Continuously Reinforced Concrete Pavement (1, 2), or CRCP as it is called. This reasoning is as true today as it was 30 years ago although some of the conventional pavement problems encountered have been minimized by better load transfer devices, thicker pavement, and improved joint sealing methods. The cost has increased with improvements.

Survey of Existing CRC Overlays - 1975

From reports being received from many state highway departments, and personal road surveys by industry members, it was becoming obvious that some major reconstruction and highway improvements would be needed in the near future. Various possibilities existed for improvements. An Ad Hoc Committee for Concrete Overlays was formed in 1973 to investigate the feasibility of thinner overlays and elastic jointed CRC overlays, and to promote research in this field. The Ad Hoc Committee decided to perform a survey of existing CRC overlays since there were a number in service and this type seemed to offer the best available system for durability and long term economy. CRC overlays also utilize the investment in the original slab by halting further structural damage.

The Ad Hoc Committee consists of representatives of the following industries: the American Concrete Paving Association, the Associated Reinforcing Bar Producers-CRSI, the Portland Cement Association and the Wire Reinforcement Institute. Twenty-three highway projects in thirteen states, totaling 100 two-lane miles (161 Km), were surveyed in detail. (To date

the actual mileage of CRC overlays is 340 two-lane miles (547 Km) and includes airports.) Projects were divided among committee members to lessen time and travel required. Prior to each survey, design and construction details were obtained to incorporate into a report published in 1976 (3).

The inspections were made by first driving slowly along the shoulder, noting the general condition of the entire project and observing details such as transverse crack spacing, longitudinal cracking, wide cracks, closely spaced erratic cracks, failed areas and patched areas. This overall inspection was followed by a walking survey of random portions of each project to determine the effect of the surface characteristics on the condition of the resurfacing.

Photographs were taken to document the various surface characteristics. Finally, each project was reviewed in detail and given an overall rating ranging from excellent to poor.

The final result of the survey showed that 94% of the 100 two-lane miles (161 Km) were rated excellent to good and only 6% of this mileage was rated poor. (Table 4) The projects rated poor may be attributed to one or more of the following factors:

- Non-uniform thickness of the overlay where a leveling course was omitted and the base slab was irregular or settled.
- Poorly consolidated concrete resulting from improper vibration of concrete through closely spaced steel.
- Poor subgrade drainage; high water table with no provision for adequate edge drains.
- Poor non-uniform base pavement support and failure to stabilize original pavement in a known problem area.

Advantages of CRC Overlays

A CRC overlay offers many advantages for reconditioning older pavements or pavements showing early distress. Some of the major advantages are:

- Utilizes the existing pavement and avoids the cost of its removal.
- Increases structural capacity needed to offset heavier loads and traffic.
- Eliminates the need and difficult task of matching joints with those in the original jointed pavement during construction of the overlay.
- Crack reflection from the base pavement into the overlay is not critical because cracks remain tightly closed.
- Restores smooth riding qualities with no faulting joints or warped slabs.
- Restores coefficient of friction through surface texturing of new overlay.
- Performs satisfactorily for a long term with minimal maintenance.
- Economic both initially and on an annual cost basis.

Advantages of Leveling Course

Based on the Ad Hoc Committee survey previously discussed and extensive additional surveys prior to 1975, the following advantages of using a bond breaker such as a bituminous leveling course should be noted:

- CRC overlay thickness can be controlled accurately. This control results in more accurate bid prices.
- Since the overlay thickness is uniform, the stresses are more evenly distributed along the length of the overlay resulting in well spaced cracks and better performance.
- Reflective cracking is reduced to a minimum and, therefore, will not interfere with the normal crack formation.
- Constant friction factor with no keying at faulted areas, resulting in a pavement as designed.
- Uniform construction platform for paving equipment and accurate steel placement result in economies.
- Cross-sectional pavement contour may be easily changed as needed.
- Pavements with C values as low as 0.35 may be overlaid. In partially bonded cases, C values of 0.75 or greater are needed. (C values are discussed under Design.)

Factors that may overrule a leveling course:

- Cost may be increased to some extent because a sub-contractor is generally needed.
- Additional time is needed for construction.
- Total pavement build-up may reduce bridge clearance.
- Additional shoulder material is needed.

By comparison, it appears that using a leveling course may be the superior method. In two projects of the survey we noted more possible problem areas where a leveling course was not used. The Federal Highway Administration Program Manual (4) states "...evidence is not yet conclusive that partially bonded overlays will give adequate performance."

BASIS FOR DESIGN OF CONCRETE PAVEMENT

Thickness design is based on knowledge from several sources:

1. Theoretical studies of pavement slab behavior by Westergaard, Pickett and Ray and others.
2. Model and full-scale tests such as Arlington Test conducted by the Bureau of Public Roads and tests at PCA laboratories.
3. Experimental pavement subjected to controlled test traffic, such as the Bates Test Road, the Pittsburg, California Test Highway, the Maryland Road Test and the AASHO Road Test.
4. The performance of normally constructed pavements subjected to normal mixed traffic.

Knowledge available from these sources is important but pavement performance under normal existing conditions results in the most meaningful knowledge (12).

BASIS FOR DESIGN OF PCC OVERLAYS FOR PCC PAVEMENTS

While theoretical studies for rigid overlays are not as extensive as for rigid pavements, they provide some guide to design. Load tests were performed on overlays and experimental projects have been built and evaluated. Knowledge is also available from normally constructed CRC overlays subjected to normal mixed traffic. (Table 4)

Design procedures for determining thicknesses of CRC overlays are similar to the procedure used for designing rigid overlays over rigid pavements. Two modifications are used for CRC overlays which consist of a reduction factor, R, and a C value adjustment which are discussed later.

SEVERAL CURRENT METHODS FOR PCC OVERLAY DESIGN

Corps of Engineers Method

Possibly the original use of the formula $T^2 = T_o^2 + T_R^2$ was Older's "Highway Research in Illinois" in 1924. The formula had various modifications in 1948 by the Ohio River Div. Lab of the Corps of Engineers. Other agencies adopted or modified this procedure: PCA in 1956; Department of the Army, Corps of Engineers in 1958; ACI Committee in 1958 and updated in 1966; USN in 1959; and included in the AASHO Interim Guide for Design of Pavement Structures - 1972. Performance results of normally constructed pavements (3) have verified the validity of this procedure which is relatively easy to apply and will form the basis of this paper.

Linear Elastic Layered Theory

A more sophisticated design method, the linear elastic layered principle, has recently come into use. The theory for this method was developed originally by Burmister, but applications of it have been impractical until the development of modern computers. A computer solution developed by B. F. McCullough and K. J. Bodecker now makes the method available for practical application. One weakness of the elastic-layered model is that joints and discontinuities in the slab cannot presently be considered. Some investigators have developed sophisticated analytical methods for recognizing the effect of these discontinuities in the slab. A more complete discussion of this method is given in other reports (6, 8).

Application of this method has been limited to one CRC overlay project - Palmdale Air Force Base in California, where overlay thickness varied from 8" to 14" (200mm - 350mm). Knowledge gained from performance is, therefore, also limited.

Rigid Overlays on Asphalt Pavement

PCC and CRC overlays have been successfully placed over original asphalt pavement. The thickness design procedure is equivalent to designing a new PCC or CRC pavement on an asphalt treated base with high support (k) values from regular concrete pavement design analysis (11, 12, 13).

CORPS OF ENGINEERS EQUATIONS FOR RIGID OVERLAYS OVER RIGID PAVEMENT*

The Department of the Army - Corps of Engineers (5) developed equations for rigid overlays over rigid pavement by the method of using existing subgrade (original pavement and base) to design a new slab. Because the overlay category implies that both overlay and existing pavement are of the same material (concrete), it is not necessary to use layer equivalencies between materials in the analysis (9).

Design equations are given for two conditions; partially-bonded and non-bonded. It should be noted that all the following equations are empirical.

For Partially Bonded Overlay: (A direct overlay--no attempt made to create or prevent bond)

$$T_R = \sqrt[1.4]{T^{1.4} - CT_o^{1.4}}$$

For C - 1.0 and 0.75 is applicable
0.50 is marginal
0.35 is not applicable

(Eq. 1)**

For Non-Bonded Overlay: (Bond breaker or separation course required)

$$T_R = \sqrt{T^2 - CT_o^2}$$

For C - 1.0, 0.75, 0.50 or 0.35

(Eq. 2)**

Where:

T_R = Thickness of overlay slab, inches
T = Thickness of new pavement from regular portland cement concrete design analysis, inches
T_o = Thickness of existing PCC pavement, inches
C = Condition Factor of existing pavement

Because layer equivalencies are unnecessary, the conversion factors for these design overlay situations only involve using pavement condition factors or C values in the basic equations, (Eq. 1) and (Eq. 2).

Partially Bonded Overlays are recommended only where existing pavement has a C value of 1.0 and 0.75. A C value of 0.5 may be marginal. When slabs are severely to moderately severely shattered, the overlay will be affected by discontinuities of the base slab and will not be able to act uniformly by virtue of the keying effect of the cracked slabs below (10).

CRC Reduction Factor

Because there are no joints in a CRC overlay, and full load transfer is obtained

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*Accepted method by the following agencies: USAF (C of E); USN; PCA; FAA; ACI; AASHO
**From AASHO Interim Guide for Design of Pavement Structures - 1972, $h_o = T_R$; $h_d = T$; $h = T_o$

across the tight cracks, the critical load is that at an interior position. On this basis it is reasonable to make some reduction in thickness from the results obtained from equations (1) and (2), which apply to rigid jointed overlay. By introducing a thickness reduction factor, R, these equations would become:

$$T_{CRC} = R\sqrt[1.4]{T^{1.4} - CT_o^{1.4}} \quad \text{for Partially-Bonded Overlay} \qquad \text{(Eq. 3)}$$

$$T_{CRC} = R\sqrt{T^2 - CT_o^2} \quad \text{for Non-Bonded Overlay} \qquad \text{(Eq. 4)}$$

Where: R = 0.8 and

T_{CRC} = Thickness of CRC Overlay (0.8 T_R)

A reduction factor of R = 0.8 may be considered adequate in most cases based on past performance studies by various agencies (6, 14 & 15). Figures 1, 2 and 3 are applicable to most highway pavement applications. In using the figures, thicknesses of the CRC overlay for highway pavements should be rounded off to the next higher ½ in. (13mm) of the value determined.

The equations may also be used to compute overlay thicknesses for heavier airport pavements. Performance results have shown that reduction factors may vary from R = 0.8 to R = 0.9 for airport pavements. By selecting a thickness to the next higher inch (25mm) of the value determined by computation, the reduction factor will result in a value of R between 0.85 and 0.90. Thus an adequate design thickness will have been achieved.

Condition Factor - C Value

Criteria have been established to determine C (5, 6 & 10). The definitions have been expanded for clarity by the author.

C = 1.0 Existing pavement is in good over-all structural condition. Stepping at joints 1/8" (3.2mm) or less. No excessive load cracking in existing slab. Visible transverse cracks (volume-change type) are infrequent in each slab. Exposure to studded tires has worn a groove in wheel paths. Overlay may be applied directly.

C = 0.75 Existing pavement has initial joint and corner cracks due to overloading, but no progressive structural distress or recent cracking. Stepping joints between 1/8" (3.2mm) and 1/4" (6.4mm) indicating minor pumping action. Slight to medium spalling of tight mid-slab cracks. Overlay may be applied directly after minor patching of local areas.

C = 0.50 Similar to 0.75 condition, but more severe in all categories. Jointed area may have severe deterioration, but remainder of slab may be generally sound. Many transverse or random cracks caused by volume change or heavy load applications in one slab. May or may not require leveling course for overlays.

C = 0.35 Existing pavement is generally badly cracked or shattered structurally. An excess of 10 discrete pieces in one slab. Stepping joints over 1/4" (6.4mm) in majority of pavement. General condition of slab shows full depth cracks in all directions. Generally past heavy maintenance. A leveling course is required before overlays.

In evaluating a length of pavement with varying C values, an overall average condition should be selected for pavement condition rating. Severe areas ($C \leqq 0.35$) that occur infrequently may be improved by replacement or repair to upgrade to higher C values determined by the average condition of the remaining sections. Evaluations

of C values are subjective and usually averaged for use in the equations. Similarly, interpolation may be applied to tabulated values. (Tables 1 & 2)

Drainage Effect on C Value

The value of C is based on the structural condition of the existing pavement. This does not take into account the amount of subbase deterioration or the support condition of the pavement. The presence of water in the substructure will tend to reduce values of C. A guide for adjustment for water conditions is suggested by the author.*

- No reduction in C value. Very good drainage. No water evident in subbase two days after rain. No pumping evident.
- Reduction of 0.10 in C value. Drainage fair. Slight amount of water retained in subbase two days after rain. Cross-drains still showing seepage. No pumping evident.
- Reduction of 0.20 in C value. Drainage fair. Slight amount of water retained in subbase one week after rain. Cross-drains still showing runoff. Occasional signs of pumping.
- Reduction of 0.30 in C value. Drainage poor. Water remains in subbase one week after rain. Drainage system not functioning. High water table or subsurface water intrusion. Evidence of strong pumping is prevalent during dry conditions.

STEEL REQUIREMENTS

Longitudinal Steel. The amount of longitudinal steel required for any type of CRC pavement should be that which will keep the transverse cracks very tight and maintain good aggregate interlock at all times, taking into account the shrinkage and temperature changes to which the pavement will be subjected.

The steel amount is usually expressed as a percentage of the cross-sectional area of the concrete slab. In general practice this may range from a minimum of about 0.5 percent in some southern states to a maximum of 0.7 in the northern states. Actually, the majority of states have used a value of approximately 0.6 percent. This percentage has become somewhat of an empirical standard due to the generally good experience with this amount of steel in most areas, and applies to CRC overlays as well as CRCP.

According to "CRCP-Design and Construction Practices of Various States" (16), four states specify 0.7% to 0.75%, 22 states specify 0.6% to 0.65 % and two states specify 0.5% to 0.585% longitudinal steel.

Once the percentage of steel is established, the area of steel required may be determined from the equation:

$$A_s = \frac{(BH)}{(100)} P_s \qquad \text{(Eq. 5)}$$

Where:

A_s = Cross sectional area of the steel in square inches
B = Width of overlay pavement in inches
H = Thickness of overlay slab in inches
P_s = Percentage of steel

*Note: Evaluation should not be made in the spring thaw period.

Example to Determine Number of Bars Required

Assume:

B = 144 in. (365.76cm)
H = 8 in. (20.32cm)
P_s = 0.6
Bar size = #5, Area = 0.31 in^2 ($2cm^2$)

Substituting values in (Eq. 5) gives:

$$A_s = \frac{144(8)0.6}{100} = 6.912 \text{ in}^2 \text{ steel required.} \quad (44.6\text{cm}^2)$$

To obtain the number of bars (N) required in a 12 ft. (3.6m) lane, divide A_s by the cross-sectional area of the bar (A_b) chosen and solve the equation:

$$N = \frac{A_s}{A_b} = \frac{6.912}{0.31} = 22.3 \text{ \#5 bars required.} \quad (\frac{44.6\text{cm}^2}{2\text{cm}^2} = 22.3)$$

Combining with (Eq. 5), the number of bars (N) may be obtained directly.

$$N = \frac{BHP_s}{100A_b} \qquad \text{(Eq. 6)}$$

N is rounded off to 23 bars to be above the minimum 0.6% steel requirement selected. The actual steel percentage will now be 0.62% using (Eq. 6) and solving for P_s.

Figures 4 and 5 may be used for determining #5 bars needed in a 24 ft. (7.3m) pavement. Table 3 gives suggested spacing for bars.

Again, extrapolating from Reference (16):

- For pavement thickness of 7" and 8" (180mm & 200mm) - Eight states specify #6 bars and 24 states specify #5 bars.

  For pavement thickness of 6" (150mm) - Three states specify #4 bars, seven states #5 bars and one state #6 bars.

- Most states follow the minimum longitudinal lap dimensions which should be 25 bar diameters.

- Most states specify wire ties. Four states allow an option for steel bands or clamps to secure splices. In the latter case, if two steel bands one inch wide are used, the lap splice must be increased by two inches because bond is lost on the smooth steel bands.

- Position of the steel below the surface is at least 2½ inches (64mm) in all states.

The tolerance for location of longitudinal steel for most states are realistic, but in some instances too severe. NCHRP Synthesis No. 16, Chapter 4 (17) states:

> "The longitudinal steel should be located vertically such that there will be at least 2½ in. (64mm) of cover, and the resulting placement should not be more than 1 in. (25mm) below mid-depth of the pavement. A variation of ±1 in. (25mm) in vertical and horizontal location does not appear to adversely affect pavement performance; therefore, steel placement tolerances should not be set so tight as to add to costs without significantly improving performance."

This must be qualified for overlays, however. The previous statement refers to

original CRC pavements generally 8 in. (200mm) to 10 in. (255mm) in thickness. Most overlays being built today are in the 5 in. (125mm) to 7 in. (180mm) range and tolerances must be kept somewhat tighter. It is suggested that a realistic tolerance of $\pm\frac{1}{2}$ inch (13mm) be adhered to.

Transverse Steel

Where transverse bars are used, with chairs, to support the longitudinal steel in position, such bars may serve as tie bars across the longitudinal joints and also to control any longitudinal cracking that may occur. Normally the use of #4 bars at 4 foot (1.2m) centers is adequate for all purposes where pavement widths do not exceed 4 lanes in width. Some states do not require the use of transverse steel, other than tie bars across longitudinal joints, where mechanical methods are used to place the longitudinal steel without the use of transverse bars and chairs. Methods are available, however, which permit placing both longitudinal and transverse steel mechanically.

Where pavements are two or more traffic lanes in width, transverse steel may be needed. When re-alignment is necessary, such that longitudinal joints in the overlay do not match those in the base, transverse steel must be used. If a separation course is used, reflective longitudinal cracks are usually eliminated. On a direct overlay, reflective cracks can be expected. Transverse steel will hold such cracks tightly together.

In this case, the amount of steel to be used may be computed in the same manner as for conventional jointed concrete pavement, utilizing the subgrade drag theory as expressed in the formula: (Ref. 6, 13)

$$A_s = \frac{fWL}{S_s} \quad * \qquad \text{(Eq. 7)}$$

Where:

A_s = Cross-sectional area of steel per foot length of overlay slab, sq. in.
W = Weight of overlay slab, lb./sq. ft. (12.5# X thickness of pavement in inches.)
L (for transverse steel) = Distance in feet from farthest point in a lane to nearest free longitudinal joint or free edge.
L (for tie bars) = Distance in feet from the joint to the nearest free longitudinal joint or free edge.
f = Coefficient of friction between overlay slab and base pavement.
S_s = Unit working stress of steel (usually assumed as 75% of yield strength)

From tests performed in Texas (18), a table gives suggested friction factors (f). For overlays, values for two applicable cases are given:

f = 1.8 for asphalt base slab or leveling course over rigid base - unbonded.
f = 2.0 to 2.2 for partially bonded cases depending on base pavement condition.

Suggested Steel Specifications

The 1975 FHWA Manual (4) suggests various criteria that should be observed. It can be reasonably assumed that projects deviating from these specifications would have to be justified on a case to case basis in order to obtain Federal matching funds. We quote directly:

"1. Minimum Percentage of Steel

The minimum percentage of steel should be .6 percent. Exceptions should

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*Note: "L" in Eq. 7 is equal to one-half the "L" of the AASHO equation $A_s = \frac{FLw}{2f_s}$ which refers to the full tied width of the pavement (11).

be made only where experience has shown that a smaller percentage of steel has given satisfactory service. In areas of large seasonal temperature changes or where periods of extreme low temperature occur, the use of .7 percent steel is encouraged.

2. Reinforcing Steel

The reinforcing steel should be deformed steel bars or deformed welded steel fabric that meet the requirements as set out in AASHO Specifications, Part I, AASHO M 31, M 42, M 53, M 54 or M 221. The tensile requirements for bars should conform to grade 60 for longitudinal bars and to either grade 40 or grade 60 for transverse bars.

a. Spacing and Size

Spacing of the longitudinal steel should not be less than 4 inches or greater than 9 inches. The minimum ratio of 0.03 square inches of bond area per cubic inch of concrete should be provided.

b. Position

The preferred position of longitudinal steel is at the mid-depth of the slab ±1 inch (25mm). Two and one-half inches (64mm) of cover should be considered a minimum.

3. Splices

Lap of the longitudinal steel should be a minimum of 25 diameters or 16 in. (400mm) with a recommended stagger or skew in the lap patterns. States are presently using laps from 16 in. (400mm) to 23 in. (585mm) in length. If a staggered pattern of splices is used, not more than one-third of the longitudinal members in a 24 ft. (7.3m) pavement width should terminate in the same vertical plane at right angles to the centerline and the minimum stagger of splices should be 4 ft. (1.2m). If a skewed pattern of splices is used, the minimum skew should be 12 ft. (3.6m) in a 24 ft. (7.3m) pavement.

4. Transverse Steel

Transverse bars may be included or omitted at the option of the State. In those cases where transverse steel also performs the function of tie bars, omission of transverse steel would call for the use of tie bars."

TERMINAL JOINTS AND END ANCHORAGES

As in regular CRCP, special treatment is required for a CRC overlay at structures. Normally a wide flange beam terminal joint (Burdell) is used to allow for expansion at bridges. The Burdell joint provides a smooth junction and good load transfer between abutting pavements and requires little seasonal maintenance. Normal practice has been to install a series of three conventional doweled expansion joints on the approach slab between the end of the CRCP and the structure. The Burdell joint allows approximately one inch of free movement of the CRCP.

Normal practice is to install the Burdell joint in a sleeper slab. With a CRC overlay, the base pavement could act as the sleeper slab, and the wide flange beam may be imbedded and grouted into the prepared base slab. The method used would be a matter of engineering judgement. Reference (13) covers the subject in more detail.

Experience has shown that it is only the end 300 feet to 400 feet of a CRC pavement, no matter how long, that moves due to changes in moisture and temperature. With a CRC overlay that is partially bonded to the old slab, we can expect less movement. From available information, end anchors or lugs will not restrain end movements by more than one half.

Where the road approaches an overpass, a solution for bridge clearance is removal of the old pavement for a sufficient distance to establish a new grade on either side of the structure. A new CRC pavement may then be placed and tied into the CRC overlay. However, various other options are available to the engineer regarding pavement replacement. Generally, overpasses are not so frequent in rural areas to present much concern.

CONCRETE SHOULDERS

When concrete overlays are placed, a shoulder build-up is necessary. Concrete shoulders should be considered. They may be reinforced or plain but tied to the main line pavement to eliminate separation. Concrete shoulders have been removed from the experimental classification by the Federal Highway Administration.

A useful pamphlet on this subject was published by the Portland Cement Association (19). Some advantages may be listed:

1. Support is furnished to the mainline pavement, and stiffness and continuity of the total pavement system is increased. Researchers at the University of Texas in 1972 showed that a tied shoulder with the same design as the adjacent roadway pavement (8" CRCP) reduced deflections at the roadway pavement edge by one-half.

2. Separation between pavement and shoulder is eliminated preventing wide joint openings and vertical displacement.

3. Water intrusion at the joint is insignificant, eliminating problems caused at pavement edges such as pumping.

4. Resealing of shoulder joints and replacing eroded shoulder material is eliminated.

5. Costs of concrete shoulders are competive with other paved shoulder types which require maintenance.

EXPERIMENTAL CRC OVERLAYS

Georgia

Some of Georgia's highways are showing signs of deterioration and some type of resurfacing had to be considered that would be both economical and durable. With these goals in mind, an experimental project was built on I-85 near Atlanta in November, 1975. The project was approximately one mile (1.6Km) long, 24 ft. (7.3m) wide and constructed in the southbound lanes. Each of the four sections listed below were 1300 feet in length with transitions between sections:

1. - 3 in (75mm) thickness of CRC overlay reinforced with deformed welded wire fabric (WWF) with CRC shoulders.

2. - 4½ in. (114mm) thickness of CRC overlay reinforced with bars (longitudinal and transverse) with tied plain concrete shoulders.

3. - 6 in. (150mm) thickness of CRC overlay reinforced with longitudinal bars and tied plain concrete shoulders.

4. - 6 in. (150mm) thickness of plain portland cement concrete with tied plain concrete shoulders. Joints were matched to base slabs and dowels required at these joints. Intermediate contraction joints required no dowels.

Bond was broken by using two applications of curing compound. Repairs were made to the base pavement where necessary prior to placing overlays.

Iowa

In Green County a concrete overlay project was constructed in 1973 on a badly shattered county road. Part of this total project consisted of 3 in. (75mm) and 4 in. (100mm) CRC overlay. Two short sections are conventional 3 in. (75mm) and 4 in. (100mm) CRC overlays--partially bonded. Two other sections are CRC overlays using the elastic joint concept and are unbonded. Steel percentage (WWF) was 0.45.

The elastic joint method used a crack initiator placed on the base pavement at 8 ft. (2.4m) intervals. The longitudinal steel was coated with asphalt to break bond for 16 in. (400mm) in the area of the induced crack. The steel was smooth to further reduce bond.

This project is still being monitored and was rated excellent in the 1975 survey. There has been one localized failure, 6 ft.^{2} (0.56m^2) in size, in the 4 in. (100mm) thick section which occurred directly over an asphalt patch in the old pavement.

Florida

A composite type pavement is to be paved in February, 1977, on U.S. 41 north of Fort Myers. The base throughout is a 9 in. (230mm) thick "Econocrete", a low strength concrete utilizing locally available aggregates. Numerous surfacings which include asphalt, fibrous concrete, plain concrete and CRC are incorporated.

The two CRC sections are a regular 3 in. (75mm) CRC overlay which is unbonded and 3 in. (75mm) elastic joint section fully bonded except at the crack induced area. This elastic joint concept has been used successfully in Europe which encouraged Florida to build a test section.

CONCLUSIONS AND RECOMMENDATIONS

1. Added structural capacity of the existing pavement can be easily achieved with an overlay to handle today's higher volumes and increased loadings, and anticipated future traffic volumes and loads.

2. A maintenance-free pavement may be approached but has not been achieved. The record of CRC overlays built to date indicates the feasibility of building CRC overlays nearly maintenance-free.

3. A simple guide for the design of CRC overlays based on knowledge gained from performance is proposed which designers may have confidence in using.

4. Costs of CRC overlays, as compared to equivalent resurfacing types, are very competitive, based on bid prices monitored in all states.

5. Improved maintenance-free performance and extended service life can be attained by use of leveling courses prior to CRC overlay.

6. From a practical standpoint, a thickness design should not use tolerances that cannot be achieved by available construction equipment.

7. Longitudinal steel should generally be 0.6% for most areas. Grade 60 should be specified. Northern states having extreme low temperatures and heavy salting policies should use 0.7% steel and #6 bars if suitable. For the same percentage of steel, #6 bars have 16% less corrosion surface than #5 bars. Placement tolerances are more easily attained and consolidation is improved using #6 bars.

8. Transverse steel is required when the overlay is wider than the base or realigned to one side or the other.

9. Concrete shoulders tied to CRC overlays provide additional edge support and eliminate the edge loading condition of a pavement system.

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FIGURE 1. C VALUE OF 0.75 AND R = 0.8

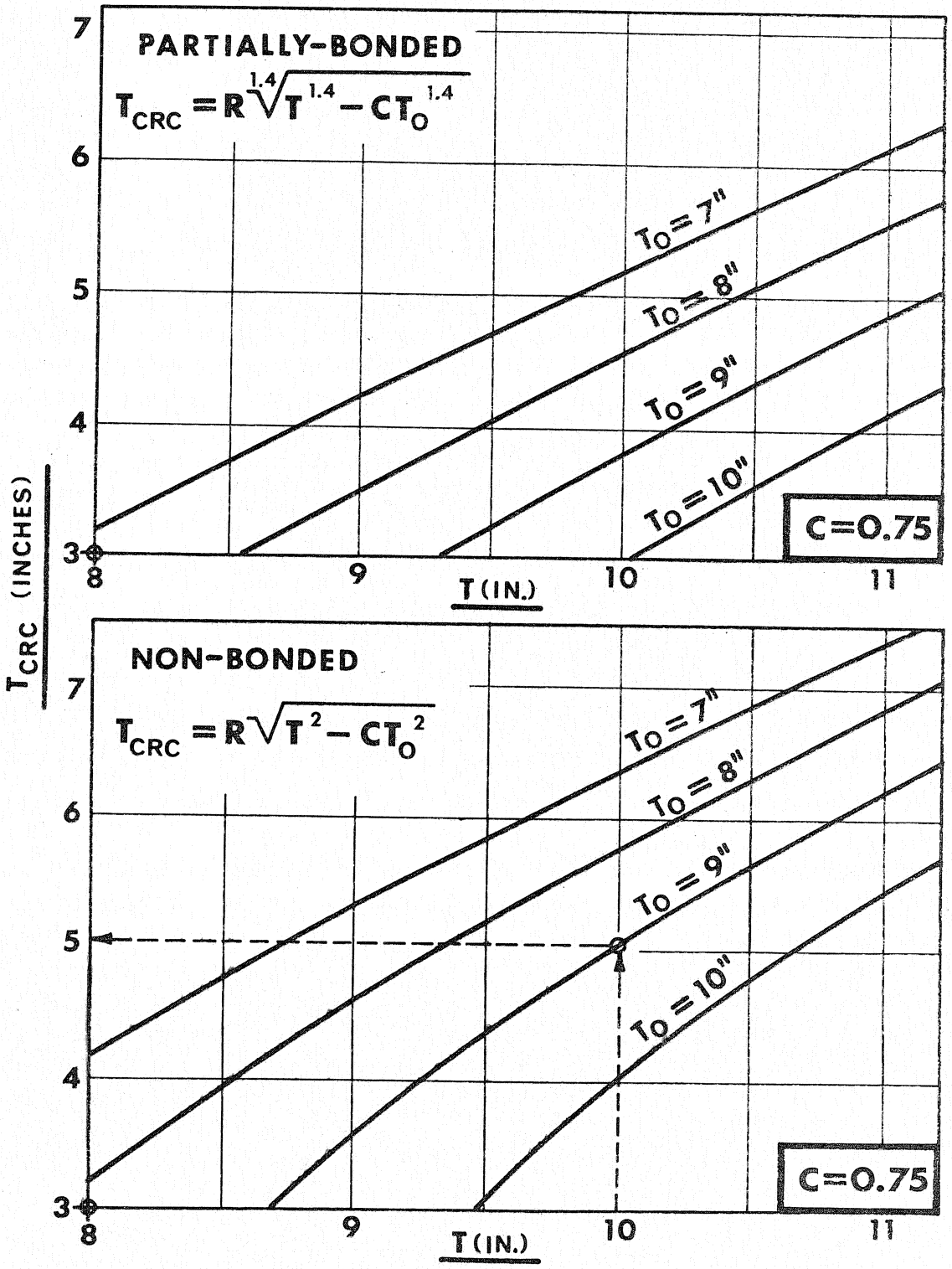


FIGURE 2. C VALUE OF 0.50 AND R = 0.8

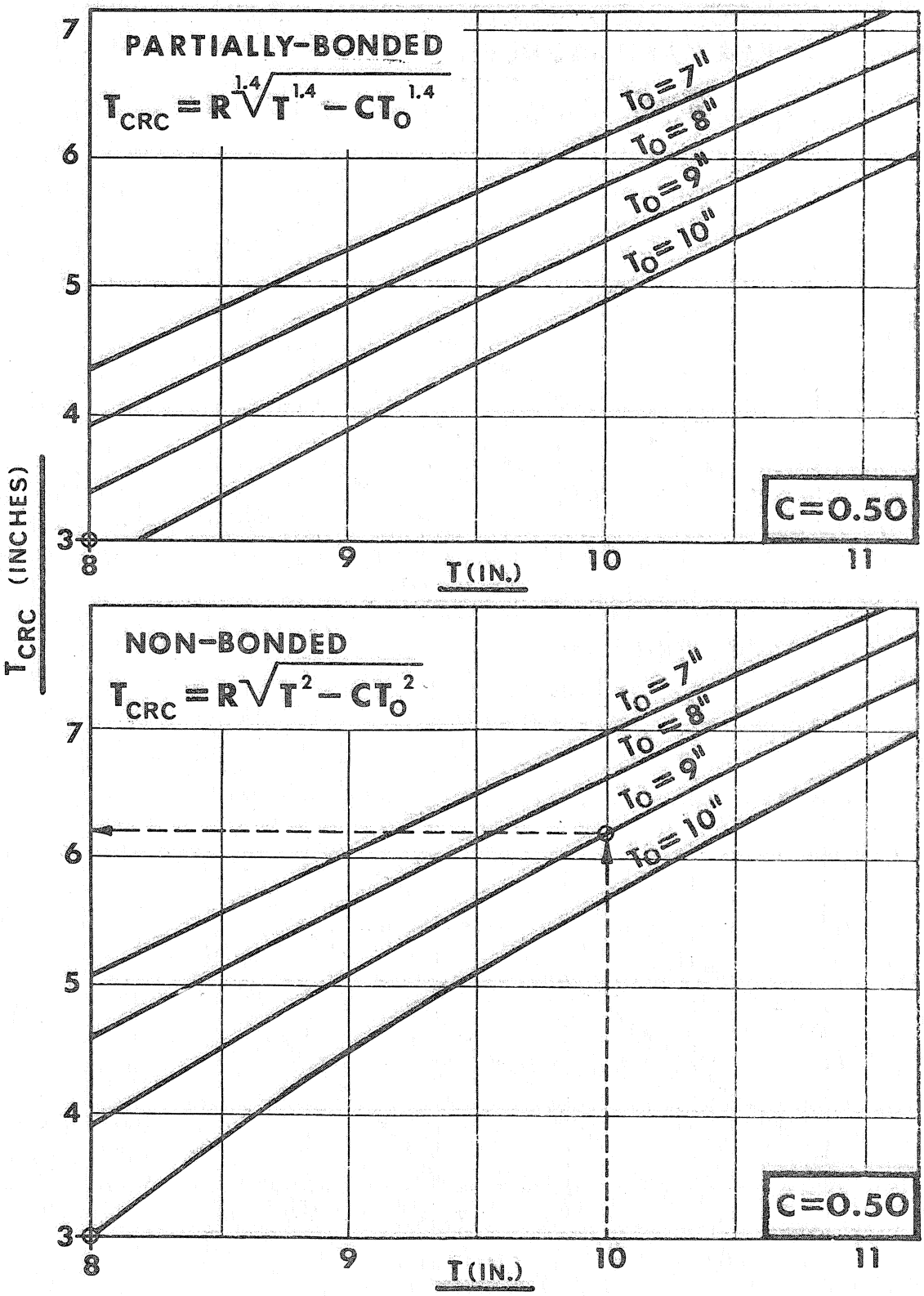
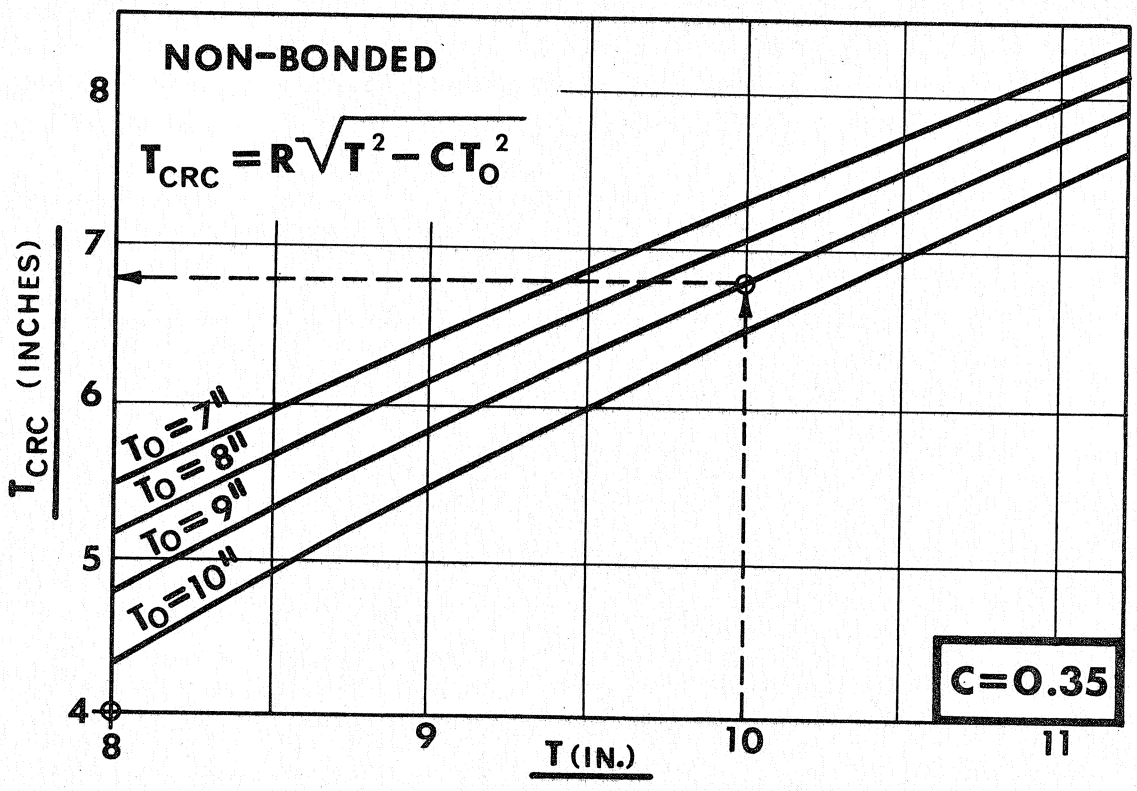


FIGURE 3. C VALUE OF 0.35 AND R = 0.8



Not Applicable For Partially-Bonded

FIGURE 4

Number of No. 4 deformed reinforcing bars required in 24-ft. pavement for various percentages of longitudinal steel

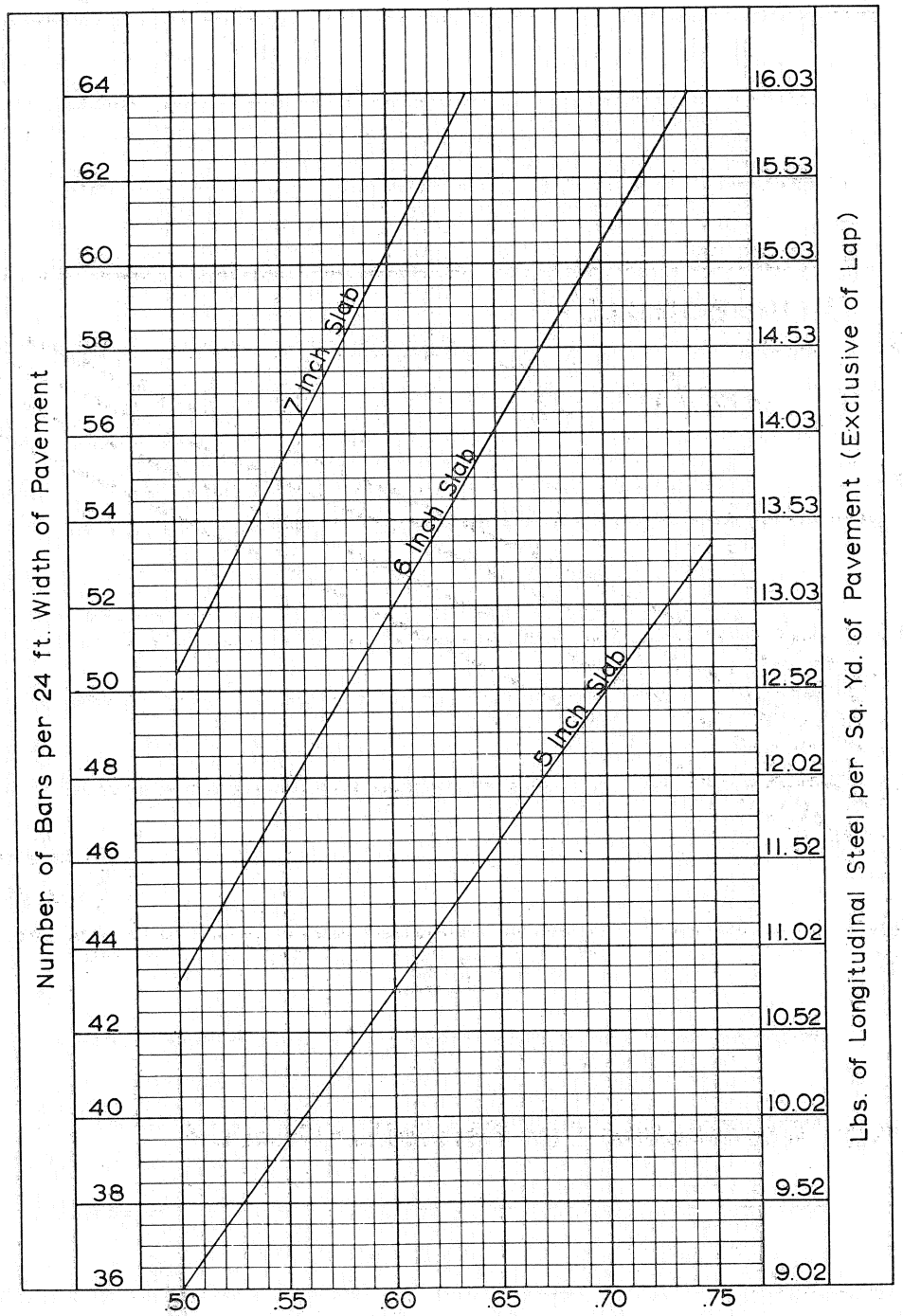
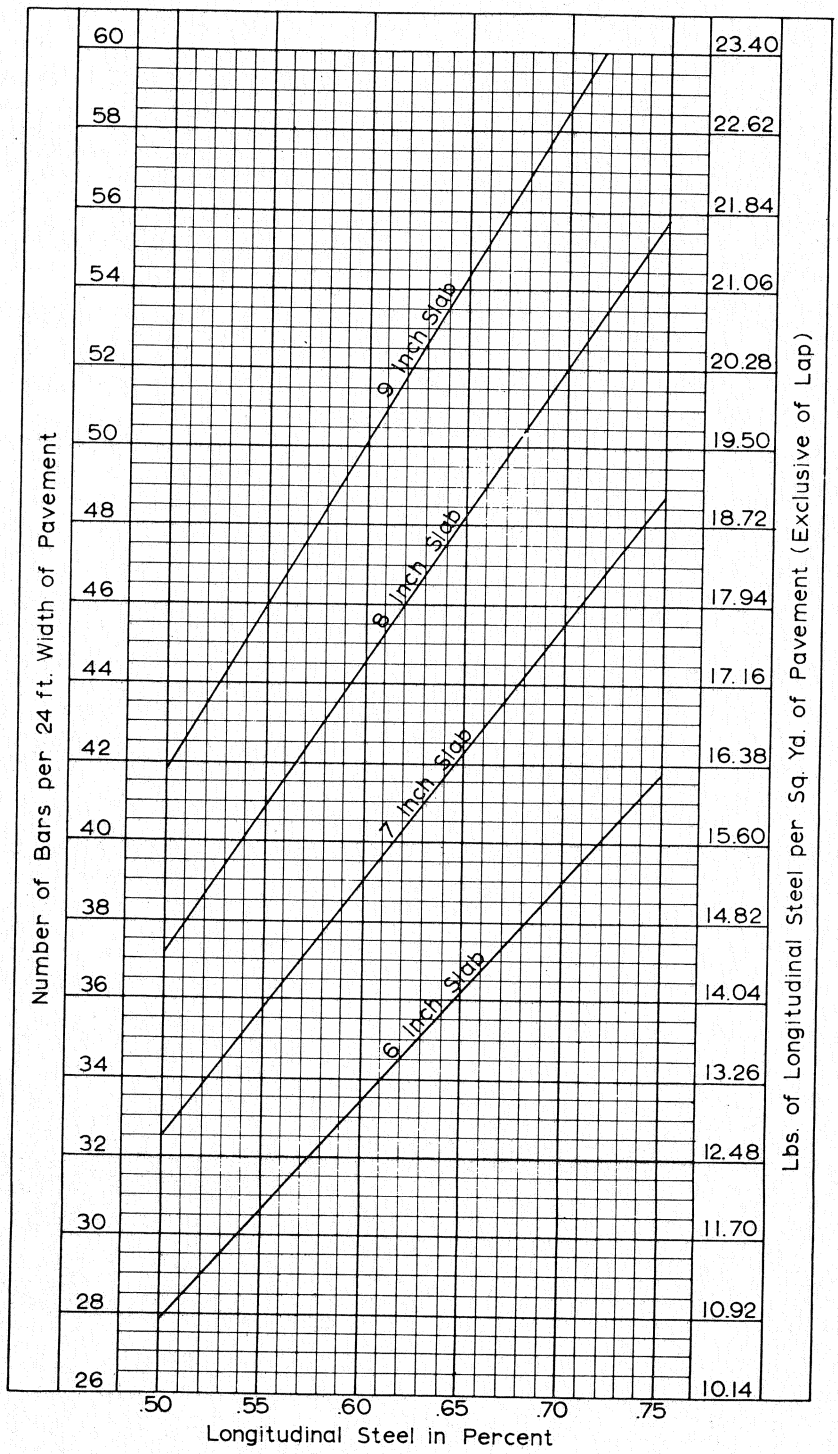


FIGURE 5

Number of No. 5 deformed reinforcing bars required in 24-ft. pavement for various percentages of longitudinal steel



$$T_R = \sqrt[1.4]{T^{1.4} - CT_O^{1.4}} \; *$$

For: Partially Bonded Rigid Overlay

T_O = 7"			R = 0.8	T_O = 8"			R = 0.8	T_O = 9"			R = 0.8	T_O = 10"			R = 0.8
T	C	T_R inches	T_{CRC} inches	T	C	T_R inches	T_{CRC} inches	T	C	T_R inches	T_{CRC} inches	T	C	T_R inches	T_{CRC} inches
8"	.75	3.99	3.19	8"	.75	———	———	8"	.75	———	———	8"	.75	———	———
	.50	5.46	4.36		.50	4.88	3.90		.50	4.23	3.39		.50	3.52	3.—
9"	1.00	3.78	3.02	9"	1.00	———	3.—	9"	1.00	———	———	9"	1.00	———	———
	.75	5.27	4.22		.75	4.37	3.50		.75	3.34	3.—		.75	———	———
	.50	6.60	5.28		.50	6.07	4.86		.50	5.49	4.39		.50	4.84	3.88
10"	1.00	5.13	4.11	10"	1.00	3.91	3.13	10"	1.00	———	3.—	10"	1.00	———	———
	.75	6.48	5.18		.75	5.66	4.53		.75	4.75	3.80		.75	3.72	3.—
	.50	7.72	6.18		.50	7.22	5.78		.50	6.68	5.34		.50	6.09	4.88
11"	1.00	6.40	5.12	11"	1.00	5.30	4.24	11"	1.00	4.03	3.22	11"	1.00	———	3.—
	.75	7.65	6.12		.75	6.89	5.51		.75	6.06	4.85		.75	5.13	4.10
	.50	8.82	7.06		.50	8.35	6.68		.50	7.84	6.27		.50	7.29	5.83

*Corps of Engineers

T_R - Resurfacing T - Required Slab
T_O - Existing C - Condition factor

Note: 1. CRC overlays of less than 5 in. have only been used in experimental projects.

2. A condition factor C of 0.5 is shown but is marginal and a non-bonded overlay should be considered

Table 1. Shows PCC overlay (T_R) thickness and conversion to CRC overlay (T_{CRC}) thickness using 0.8 T_R

T_0 = 7" R = 0.8				T_0 = 8" R = 0.8				T_0 = 9" R = 0.8				T_0 = 10" R = 0.8			
T	C	T_R inches	T_{CRC} inches	T	C	T_R inches	T_{CRC} inches	T	C	T_R inches	T_{CRC} inches	T	C	T_R inches	T_{CRC} inches
8"	1.00	3.87	3.10	8"	1.00	——	——	8"	1.00	——	——	8"	1.00	——	——
	.75	5.22	4.18		.75	4.00	3.20		.75	——	——		.75	——	——
	.50	6.28	5.03		.50	5.66	4.53		.50	4.85	3.88		.50	3.74	3.—
	.35	6.84	5.48		.35	6.45	5.16		.35	5.97	4.78		.35	5.39	4.31
9"	1.00	5.66	4.53	9"	1.00	4.12	3.30	9"	1.00	——	——	9"	1.00	——	——
	.75	6.65	5.32		.75	5.74	4.60		.75	4.50	3.60		.75	——	3.—
	.50	7.52	6.01		.50	7.00	5.60		.50	6.36	5.09		.50	5.57	4.45
	.35	7.99	6.39		.35	7.66	6.12		.35	7.26	5.80		.35	6.78	5.43
10"	1.00	7.14	5.71	10"	1.00	6.00	4.80	10"	1.00	4.36	3.49	10"	1.00	——	——
	.75	7.95	6.36		.75	7.21	5.77		.75	6.26	5.01		.75	5.00	4.00
	.50	8.69	6.95		.50	8.25	6.60		.50	7.71	6.17		.50	7.07	5.66
	.35	9.10	7.28		.35	8.81	7.05		.35	8.46	6.77		.35	8.06	6.45
11"	1.00	8.49	6.79	11"	1.00	7.55	6.04	11"	1.00	6.32	5.06	11"	1.00	4.58	3.67
	.75	9.18	7.34		.75	8.54	6.84		.75	7.76	6.21		.75	6.78	5.43
	.50	9.82	7.86		.50	9.43	7.55		.50	8.97	7.18		.50	8.43	6.74
	.35	10.19	8.15		.35	9.93	7.94		.35	9.63	7.70		.35	9.27	7.42

*Corps of Engineers

T_R - Resurfacing
T_0 - Existing
T - Required Slab
C - Condition factor

Note: 3" to 5" CRC overlay - Trial projects only

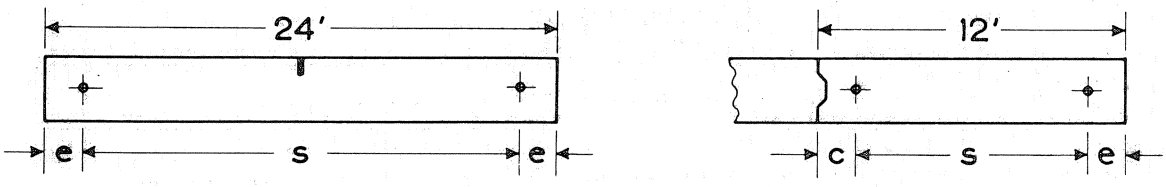
Table 2. Shows PCC overlay (T_R) thickness and conversion to CRC overlay (T_{CRC}) thickness using 0.8 T_R

$$T_R = \sqrt{T^2 - CT_0^2}\ *$$

For: Non-Bonded Rigid Overlay

TABLE 3

Suggested spacing of bars for pavement width as shown



No. of Bars	Spacing in Inches for 24' Width			No. of Bars	Spacing in Inches for 12' Width		
	e	s	e		c	s	e
30	2 @ 4½	27 @ 10	2 @ 4½	15	1 @ 5	13 @ 10	2 @ 4½
32	1 @ 4½	31 @ 9	1 @ 4½	16	1 @ 4½	15 @ 9	1 @ 4½
34	1 @ 3¾	33 @ 8½	1 @ 3¾	17	1 @ 4¼	16 @ 8½	1 @ 3¾
36	1 @ 4	35 @ 8	1 @ 4	18	1 @ 4	17 @ 8	1 @ 4
38	1 @ 2 15/16	37 @ 7⅝	1 @ 2 15/16	19	1 @ 3 13/16	18 @ 7⅝	1 @ 2 15/16
40	1 @ 2⅝	39 @ 7¼	1 @ 2⅝	20	1 @ 3⅝	19 @ 7¼	1 @ 2⅝
42	1 @ 3 1/16	41 @ 6⅞	1 @ 3 1/16	21	1 @ 3 1/16	20 @ 6⅞	1 @ 3 1/16
44	1 @ 4¼	43 @ 6½	1 @ 4¼	22	1 @ 3¼	21 @ 6½	1 @ 4¼
46	1 @ 3⅜	45 @ 6¼	1 @ 3⅜	23	1 @ 3⅛	22 @ 6¼	1 @ 3⅜
48	1 @ 3	47 @ 6	1 @ 3	24	1 @ 3	23 @ 6	1 @ 3
50	1 @ 3⅛	49 @ 5¾	1 @ 3⅛	25	1 @ 2⅞	24 @ 5¾	1 @ 3⅛
52	1 @ 3¾	51 @ 5½	1 @ 3¾	26	1 @ 2¾	25 @ 5½	1 @ 3¾
54	1 @ 4⅞	53 @ 5¼	1 @ 4⅞	27	1 @ 2⅝	26 @ 5¼	1 @ 4⅞
56	1 @ 3 1/16	55 @ 5⅛	1 @ 3 1/16	28	1 @ 2 9/16	27 @ 5⅛	1 @ 3 1/16
58	2 @ 3¼	55 @ 5	2 @ 3¼	29	1 @ 2½	27 @ 5	2 @ 3¼
60	1 @ 3⅞	59 @ 4¾	1 @ 3⅞	30	1 @ 2⅜	29 @ 4¾	1 @ 3⅞

CRCP HIGHWAY OVERLAY PROJECTS

TABLE 4

			OVERLAY					BASE PAVEMENT			REMARKS
State	Route	Location	Area, sq.yd. Length, mi.	Year built	Thickness, in.	Interlayer	Condition 1975	Type	Year built	Design	
Arkansas	I-55	W. Memphis	24,000 1.7	1972	6	Bitum. leveling course	Excellent	PCC	1951	9 in. reinforced	
Connecticut*	I-86	Near Mass. line	152,000	1975-76	6	Bitum. leveling course		PCC			Under construction
Georgia	I-75	N. of Macon, Monroe County	191,000 13.5	1971	7, 8	None—partially bonded	Excellent	PCC	1954	8 in. plain	
Georgia*	I-85	N. of Hamilton Mill Road, southbound	10,000 0.7	1975	3, 4.5, 6	Curing compound		PCC		9 in. plain	Constructed Nov. 1975
Iowa	Greene County E-53	E. of Jefferson	4,600 0.3	1973	3, 4	Curing compound	Excellent	PCC	1921-22	8½ in. reinforced 4 in. widening 1973	
Illinois	I-70	W. of Pocahontas, westbound	54,000 3.8	1967	6, 7, 8	Bitum. leveling course	Excellent	PCC	1939	10-8-10 in. reinforced	
Indiana	I-69	N. of Indianapolis	13,000 1	1970	6	None—partially bonded	Poor	PCC	1955	9 in. reinforced	
Indiana	I-69	N. of Indianapolis	52,000 4	1971	6	Polyethylene	Poor	PCC	1955	9 in. reinforced	
Maryland	I-70	3 projects W. of Baltimore	366,000 13.5	1972-74	6	Bitum. leveling course	Good	PCC		Reinforced	3 projects
Maryland	I-83	S. of Penn. border	43,000 3.1	1973	6	Bitum. leveling course	Good to fair	PCC		Reinforced	
Mississippi	I-20	Vicksburg	30,000 2.1	1971	6	Bitum. leveling course	Excellent	PCC	1955	9 in. reinforced	
North Dakota	I-29	Near Manvel, southbound	59,000 4.2	1972	6	Bitum. leveling course	Good	PCC	1958	8 in. plain	
North Dakota	I-29	Near Grafton, N. & southbound	101,000 4.7	1974-75	6	Bitum. leveling course	Excellent	PCC	1958	8 in. plain	
Oregon	I-5	4 projects S. of Portland	1,247,000 28.3	1969-75	7-9 variable	Bitum. leveling course	Excellent	Flexible	Prior to 1959		4 projects
Oregon	I-205	E. of Portland	34,000 2.4	1973	7-9 variable	Bitum. leveling course	Excellent	Flexible	Prior to 1959		Traffic light since I-205 not completed
Oregon*	I-80	Near Ladd	66,000 2	1971	7-9 variable	Bitum. leveling course		Flexible	Prior to 1959		
Pennsylvania*	I-90	Erie County, Sec. B-10	558,000 19	1975-76	7	Bitum. leveling course		PCC	1960	10 in. reinforced	Under construction
Pennsylvania*	I-90	Erie thruway, Sec. B-20	12	Awarded 1975	7	Bitum. leveling course		PCC	1960-62	10 in. reinforced	Under construction
Texas	I-35	N. of Eddy	15,000 0.9	1959	7	3½ in. AC overlay	Fair to poor	PCC	1934	9-6-9 in. reinforced	
Texas	I-35	Near Schertz, southbound only	30,000 2.1	1965	6	1½ in. AC (1934) ¾ in. leveling	Excellent	PCC	1934	9-6-9 in. reinforced	
Texas	I-35W	S. of Burleson, southbound	102,000 6.6	1965	6	2 in. AC (1947) 1 in. leveling (1957)	Excellent	PCC	1936	9-6-9 in. reinforced	
Texas	I-40	W. of Bushland	68,000 7.2	1972	8	Bitum. leveling course	Excellent	Flexible	1953	16 in. base and AC surface	
Wisconsin	US-16	Heartland—Pewaukee	16,000 1.2	1973	7 average	Polyethylene	Excellent	PCC	Early 1950's	9 in. plain	

*Not included in 1975 survey.