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7. Author(s)
B. Frank McCullough, Harvey J. Treybig, and Ramesh K. Kher

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16. Abstract

Recent experiences with the performance of concrete pavements in Texas have been of major concern to design engineers, who have pointed out that greater thicknesses of pavements than those predicted by the current design manual should be used.

The report revises the current design manual and presents a new procedure for the design of portland cement concrete pavements. The procedure is based on information obtained from various research projects of the Texas Highway Department as well as the experience and ideas of THD design personnel.

The report summarizes the findings that may be implemented immediately by the Texas Highway Department. The draft of recommended revisions and design details has been prepared in a form in which they can be included in the design manual with a minimum of effort.

The recommended revisions provide an incremental step towards use of the Rigid Pavement System (RPS), developed for the Texas Highway Department under Project 1-8-69-123, since these revisions contain many of the concepts that are used in RPS.

17. Key Words
Rigid pavements, pavement design, pavements, performance, reliability, stochastic, concrete, Texas Highway Department.

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EVALUATION AND REVISION OF TEXAS HIGHWAY DEPARTMENT RIGID PAVEMENT DESIGN PROCEDURE

by

B. Frank McCullough
Harvey J. Treybig
Ramesh K. Kher

Research Report Number 502-1F

Evaluation and Revision of Texas Highway Department
Rigid Pavement Design Procedure

Research Project 3-8-71-502

conducted for

The Texas Highway Department

in cooperation with the
U. S. Department of Transportation
Federal Highway Administration
Bureau of Public Roads

by the

CENTER FOR HIGHWAY RESEARCH
THE UNIVERSITY OF TEXAS AT AUSTIN

November 1972

PREFACE

This is the first and the final report for Project 3-8-71-502, "Evaluation and Revision of Texas Highway Department Rigid Pavement Design Procedure."

The report presents a revised portland cement concrete pavement design procedure based on information obtained from previous research, observation of past performance of such pavements, and ideas developed by Texas Highway Department Design personnel, based on their past experience.

The recommended revisions and design details are written in a form that can readily be used by the Texas Highway Department for implementation. Procedure computations for the design details are also documented, for future reference.

The cooperation of the entire staff of the Center for Highway Research of The University of Texas at Austin is appreciated. The help of Mrs. Colleen Trlica, Mrs. Marie Fisher and Mr. Arthur Frakes, for their assistance with the manuscript, is appreciated.

Mr. Michael I. Darter is thanked for writing several concepts used in the preparation of revisions to the design manual.

District personnel are thanked for their ideas and valuable suggestions. Special thanks are due to Mr. Gerald Peck, Mr. James L. Brown and Mr. Billy Rogers for their guidance in this research study.

B. Frank McCullough
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ABSTRACT

Recent experiences with the performance of concrete pavements in Texas have been of major concern to design engineers, who have pointed out that greater thicknesses of pavements than those predicted by the current design manual should be used.

The report revises the current design manual and presents a new procedure for the design of portland cement concrete pavements. The procedure is based on information obtained from various research projects of the Texas Highway Department as well as the experience and ideas of THD design personnel.

The report summarizes the findings that may be implemented immediately by the Texas Highway Department. The draft of recommended revisions and design details has been prepared in a form in which they can be included in the design manual with a minimum of effort.

The recommended revisions provide an incremental step towards use of the Rigid Pavement System (RPS), developed for the Texas Highway Department under Project 1-8-69-123, since these revisions contain many of the concepts that are used in RPS.

KEY WORDS: rigid pavements, pavement design, pavements, performance, reliability, stochastic, concrete, Texas Highway Department.

SUMMARY

The report presents a review and revisions to the current portland cement concrete pavement design procedure used by the Texas Highway Department. The recommended revisions to the current design manual are based on the experience of district personnel, observations of past performance, utilization of information developed by other research projects, and various established design theories. Texas Highway Department concrete pavement design details have also been reviewed and revised.

The new design procedure, which provides an incremental step towards phasing the Rigid Pavement System into THD usage, is presented in a format similar to that of the current design manual to facilitate the implementation of the new procedure.

IMPLEMENTATION STATEMENT

The output from this study provides several items that may be or have been implemented by the Highway Design Division of the Texas Highway Department. Appendix B, "Revised Design Manual for Rigid Pavements," was prepared so that it could be included in the design manual with a minimum of effort, and the format used is that used in the manual. After appropriate review by the sections of the Highway Design Division, the Appendix could be distributed as an addendum to the manual.

The revised design details presented in Appendix C.1 are already in use by the Highway Design Division. For it no further action is required. The handwritten computations in Appendices C.2, C.3 and C.4 should be retained for future reference for revising the design details at a later date.

The utilization of the recommended revisions of the design manual will aid in implementing the Rigid Pavement System (RPS) developed previously. The recommended revisions contain many of the concepts that are used in RPS and, therefore, the manual will provide incremental phasing in RPS.

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CHAPTER 1. INTRODUCTION

In the past couple of years, there has been an intense concern among design engineers of the Texas Highway Department that additional pavement structure may be required for concrete pavements in certain areas of the state. There has been a special concern as to the thickness of continuously reinforced concrete pavement. Recent experiences with concrete pavement in the Gulf Coast area tend to validate this concern. In addition, many other pavement design details currently being used were in need of revision and documentation. Thus, Project 3-8-71-502, "Evaluation and Revision of Texas Highway Department Rigid Pavement Design Procedure," was initiated by the Highway Design Division, to fulfill these needs.

Objectives

The primary objectives of this study were as follows:

(1) Review and revise current portland cement pavement design procedures, based on discussions with district personnel, observations of past performance, utilization of information developed on other research projects, and established pavement design theories.

(2) Review and revise the current Texas Highway Department concrete pavement design details, taking into account the results of objective number one, and document their development for future reference and revision.

Background

During the period 1949-1950, several continuously reinforced concrete pavements were constructed in the Fort Worth area. The concrete pavement slabs were 8 inches thick and reinforced with 7/10 percent longitudinal steel. These pavements gave excellent performance under very high traffic volumes, and based on this experience the decision was made in 1958 to utilize continuously reinforced pavement as a standard construction item. Based on experience in other states and an extensive design analysis, it was felt these first pavements probably had an excessive amount of steel. Therefore, in order to make this pavement type competitive with other types, it was decided that a design detail should be developed utilizing what was deemed as an adequate amount on the basis of these studies.

In the latter part of the 1950's, the Texas Highway Department commenced building continuously reinforced pavement on an extensive scale. By 1971, over 2,800 miles of equivalent, two-lane miles of CRCP had been constructed. The background information on development of the design criteria for these pavements has been reported previously in a number of publications (Refs 1, 2, 3, and 4).

Basically, the design analysis required an 8-inch slab reinforced with 5/10 percent longitudinal steel on high volume highways. On secondary roads and some frontage roads, considerable mileage of 6 and 7-inch pavements, respectively, was constructed. The steel percentages, both longitudinally and transversely, remain the same for all pavements. In connection with this development, a new specification was developed for continuously reinforced concrete pavement that was eventually included in the standard specifications. The initial specification established a cement factor of four sacks of cement per cubic yard of concrete. This decision was based on satisfactory experience in the eastern part of the state with pavements where low cement factors were used. Thus, considering this successful experience and a desire to make this pavement type more competitive, what was considered as a minimum acceptable cement content was used.

During 1959 and 1960, distress manifestations of several types were observed on two of the earlier projects utilizing the new design standards. One of the distress manifestations was related to insufficient lapping of the longitudinal steel at transverse construction joints. This was corrected by requiring additional longitudinal bars at the construction joints (increased to approximately 1 percent), requiring the longitudinal steel to extend into the next day's placement a minimum of four feet, and a full lap staggering procedure. Another distress manifestation was extensive cracking on the down placement side of transverse construction joints that was a result of low density and poor quality concrete. Plan notes and specification required changes such as additional hand vibration at the construction joint and the addition of extra cement for the first few batches to compensate for that lost in coating the mixer walls during those batches. Although the concrete honeycombing problem was not completely eliminated, the incident rate was reduced sharply.

In 1963, an extensive performance study of CRCP was initiated on the pavements then in service on the Texas Highway System. The results of this study have been reported previously (Refs 5 and 6). Generally, with 1/2 percent longitudinal steel, it was found that under a wide range of environmental conditions the steel stresses were well below the maximum allowable working stress. Also, the deflection studies indicated that the previously established equivalency of 8 inches of CRCP to 10 inches of jointed concrete pavement was an acceptable criterion. The preliminary deflection studies showing pumping and high deflection with some granular subbases led to the widespread use of cement-stabilized, asphalt-stabilized, and lime-stabilized subbases.

The poor quality concrete and the greater surface deterioration experienced with pavements constructed with the low cement factor led to increasing the cement factor to 4-1/2 and finally 5 sacks of cement per cubic yard.

Considerable experience was gained with a number of experimental pavements with thickened edges, lightweight aggregate, lower steel percentages, preformed crack spacing, and various steel lapping procedures. The results of these studies have found their way into the design procedures and specifications over the development period.

Study Plan

The basic philosophy of this study was to gain as much information as possible from the previous research in this area and also from the experience and ideas developed by the Texas Highway Department design personnel in the Austin office and the Districts. First, a series of meetings were held with the Austin office design people. Next, field trips were made to Districts 2, 12, 15, 18, and 20 and the Houston-Urban Office to inspect the inservice pavements and to learn the ideas and experience of the field personnel.

Several research projects have previously developed information that was used in revising the design procedures. Project 1-8-63-46 provided essential information on performance studies as to deflection and steel stress. Project 3-5-63-56 provided analysis tools (Refs 7, 8, and 9) that could be used to extend the results of Project 1-8-63-46 to other conditions. Project 3-8-66-98 provided an extensive amount of information that was used to develop the subbase design procedures (Refs 10, 11, and 12). The terminal anchorage guidelines were developed from Project 1-8-63-39 (Refs 13,14, and 15).

The design procedure revisions to the Texas Highway Department manual recommended in Appendix B were developed for possible inclusion in the Rigid Pavement System being developed in Project 1-8-69-123 (Refs 16 and 17). If these revisions are included in the design manual in the near future, the design personnel will have an opportunity to achieve a familiarity with the concepts; thus, the implementation of the Rigid Pavement System for normal design will not involve the tremendous educational process and change that were experienced in the flexible pavement system implementation. The concept utilized in this study will provide a gradual change from one system to another without an extensive educational effort.

Scope

Chapter 2 summarizes the discussions with the Texas Highway Department field personnel about the design performance of CRCP. Chapter 3 presents background information on the recommended revisions to the design manual. Chapter 4 presents documentation information for the revisions and development of the concrete design details. Chapter 5 contains the primary conclusions and recommendations of this study.

Appendix A is a summary of the comments from each district. Appendix B contains the recommended revisions to the Texas Highway Department Design Manual that were developed in this study. Appendix C contains several subsections relative to the revision, revision checking, and documentation of the design details. Copies of the revised design details have previously been supplied to the Highway Design Division.

CHAPTER 2. SUMMARY OF CONSULTATIONS WITH DISTRICTS

Prior to developing possible revisions to the design manual, a visit was made to six Texas Highway Department Districts and the Houston-Urban Office to seek their ideas and experience as to a suggested course of action. The selected list, which included the Fort Worth, Houston, Houston-Urban, San Antonio, Dallas, and Beaumont districts, provided a variety of climatic traffic and soil conditions, hence establishing a more rational basis for revisions.

The procedure used in each district was to consult with the District Engineer, Design Engineer, Construction Engineer, and Maintenance Engineer, either individually or as a group. The principal investigators and representatives of the Highway Design Division met with each of the districts. The results of this survey are summarized in Table 1. In the following paragraphs, the pertinent points of the table are discussed in more detail.

General Performance

The general performance of CRCP in the six districts has been quite satisfactory, although each district has experienced various types of problems. Most of the districts expressed the qualitative opinion that the roughness level of CRCP was substantially lower than of jointed concrete pavement. Table 1 shows that three districts indicated an excellent performance record while two others rated the performance of CRCP as good and fair respectively. Districts 2, 15, and 18, all of which are in the region experiencing severe swelling clay problems, indicated that this pavement type has given a better performance than jointed pavement where swelling clays are present. The prevailing comment was that the CRCP tends to smooth out the heaves by giving a longer transition. It might also be hypothesized that the slabs' being tied together brings more mass into play, thus reducing the magnitude of heave.

Two of the districts mentioned they had experienced localized failures due to problem batches during the concrete placement, but the magnitude of this problem has been reduced as more slip form pavers and central mixing plants have been obtained on projects. Only District 20 reported distress that could

TABLE 1. SUMMARY OF COMMENTS FROM DISTRICT SURVEYS

Item	District 2 (Fort Worth)	District 15 (San Antonio)	District 18 (Dallas)	District 20 (Beaumont)	Houston-Urban
1. General performance	Excellent	Excellent	Good	Fair	Excellent
2. Thickness relative to present	Acceptable	Acceptable	Greater	Greater	Greater
3. Concrete mix design					
a. Min. cement factor	4.5	5.0	5.0	5.0	5.5
b. Max. coarse agg.	NC*	NC	NC	Smaller C.A.	Smaller C.A.
4. Steel design					
a. Use of transverse steel	Need	Need	NC	Need	Need
b. Present % of longitudinal steel	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
5. Subbase					
a. Require stability	Yes	NC	Yes	NC	Yes
b. Minimum thickness	NC	8"	NC	NC	6"
6. Pvt. terminals					
a. Require anchors	No	No	Yes	Yes	Yes
b. Problems	Slab lift up	Slab lift up	NC	Slab lift up	Expansion where no lugs
c. Joint seals	No problem	Not working	NC	NC	Not working
7. Construction & specifications					
a. Special problems	Extensive coring slip form & central mix	NC	Steel placement	NC	Eliminate long. float & surface requirements
b. Slip form & central mix	Prefer	NC	Prefer	NC	NC
c. Non-agitating trucks	Permit	NC	Permit		NC
8. Miscellaneous	Shoulder design on horizontal curves (drain 5')	NC	NC	NC	

* NC = No Comment

be attributed to structural inadequacy, and this seems to be more prevalent on CRCP than on jointed concrete pavement. Their problem seems to be one of excessive deflection. This is confirmed by the results of previous studies of CRCP where deflection in District 20 was found to be the highest in the state (Ref 5).

Pavement Thickness

Of the six districts interviewed, only two indicated that the present design criteria provided inadequate thicknesses. District 18 and the Urban Office stated a thickness in excess of 8 inches should be used on urban freeways, and both felt that 20 years was an inadequate design basis. A 30 to 40 year basis would be much more realistic. The impact of this point is emphasized when, watching the heavy flow of traffic on an urban freeway built in the late 1950's, one realizes that over one-half of the theoretical life has been used up.

Experience in District 20 indicates that the excessive deflection on CRCP could be reduced by thicker pavements. The experience in this district emphasizes the need for considering a maximum deflection as a criterion for design in addition to maximum stress.

Concrete Mix Design

Only District 2 stated that a cement factor of 4 1/2 sacks per cubic yard was satisfactory. Their experience has been excellent with this requirement and they obtain a 7-day flexural strength in excess of 700 PSI, so their stand is quite valid. In contrast, District 18 reported problems in obtaining adequate flexural strength with 4 1/2 sacks per cubic yard. Much of this may be attributed to the difference in aggregates used in the two districts. Three of the districts felt that the minimum cement factor should be 5 sacks per cubic yard in order to prevent excessive surface wear. District 15 had an unsatisfactory experience with soft aggregates in terms of skid resistance, and an increase in the cement factor provides a stronger cement aggregate matrix that is more polish resistant. The Urban Office recommends a mix of 5 1/2 sacks per cubic yard. It has progressively worked up to this value after starting with a cement factor of 4 sacks per cubic yard. In addition to the reasons expressed previously, the Urban Office indicates the uniformity of the concrete is improved and there is a greater safety factor against the possibility of losing cement during the mixing operations.

Two of the districts feel smaller coarse aggregates should be used, with the Urban Office recommending the maximum size, 1 inch. The smaller size, providing improved workability, is less inclined to produce honeycombing around the steel bars.

Steel Design

Four of the districts expressed a positive need for transverse steel in the CRCP. The consensus of opinion was that the transverse steel provided a continuity in areas where longitudinal cracks occurred due to deep soil movements among other reasons. District 2 and the Urban Office both had several examples in which large cracks occurred in the pavement; thus severe deterioration and slab faulting would have occurred if transverse steel had not been present.

Most of the districts felt the present percentage of longitudinal steel was satisfactory, although the Urban Office has increased the percentage to approximately 0.6. This increase was a result of the greater concrete strength expected with the increased cement factor that was discussed in a previous section and thus was not the result of unsatisfactory performance with the older designs.

Subbase Design

Three of the districts recommended the use of stabilized subbases with CRCP. District 18 specifically recommended that lime-stabilized materials not be placed directly beneath the CRCP slab. They feel that there should be an intermediate subbase layer of portland cement or asphalt-stabilized material. Previous experience had indicated that the edge pumping was experienced where lime-stabilized subbases were used. Although District 2 did not comment in general, they quoted an example in which poor performance was achieved with a 6-inch CRCP on a lime-treated subgrade. In this case both pumping and excessive deflections were the primary contributors to poor performance. It appears that lime stabilization does not prevent edge pumping, thus remedial procedures are required.

Minimum cement-stabilized subbase thicknesses of 6 and 8 inches were recommended by the Urban Office and District 15, respectively. The Urban Office had found through experience that a 4-inch cement stabilized subbase was undesirable, expecially for construction traffic, and therefore they were using a 6-inch thick subbase.

Treatment of Pavement Terminals

Three of the districts require lug anchors as per the CRCP (TA) design detail. Two of the districts have had excellent experience at the joints where lugs were not used. District 15 emphasized that in all cases they have observed only contractive movement, and thus they are using the H-beam joint. It should be emphasized that both Districts 2 and 15 have used surface treatments beneath their CRCP, and previous studies have indicated this is a high friction subbase, which reduces the magnitude of movement (Refs 14 and 15). It is interesting to note that the non-use of lugs occurs in the western-most districts interviewed and use was required in the eastern three districts. The Urban Office and District 20 both indicated use of two anchor lugs along with a 1-inch expansion joint was sufficient, but the Urban Office cited several instances where problems had developed when lugs were deleted.

Three of the districts stated major problems at terminals were in the vicinity of approach slabs, with Districts 2 and 15 definitely attributing the problem to swelling clay. District 20 has attributed its problem to concrete curling, since the uplift occurs on the pavement and not in the approach slab. (Five lugs were used in the cited cases.) District 2 has attempted to correct its problem by using less active materials (lower PI) in the embankment beneath the bridge approach slab and pavement terminal slab. This is generally in the form of a wedge section, with the maximum depth at the structure and tapering to zero two hundred to three hundred feet from the structure. In addition, it has used weakened-plane joints (inserts at the bottom of the slab), to allow the slab to crack and provide greater flexibility in adapting to the profile of the uplift. In an attempt to prevent the same type of problem, District 15 has used double layers of steel (2-1/2 inches from the top and bottom) in problem areas to provide a structural slab, but their experience has been inconclusive. As a remedial procedure, District 15 has used concrete grinding, although this is an expensive process.

Two of the districts reported that the expansion joint seal materials are not working. District 15 has primarily used two component polymer sealings, whereas the Urban Office has reported almost 100 percent failure with the Neoprene compression seals. The failures generally consist of the material being pulled out of the joint by the traffic action.

Construction

On the early CRCP, District 2 experienced some problems at the construction joint. These problems were generally with unconsolidated concrete on the new side of the joint, where it is difficult to achieve adequate vibration. To prevent the problem, it has required hand vibration and the concrete is cored in these areas to insure that a uniform consolidated concrete is achieved.

Several steel detailing comments that were made indicate that some design revisions may need to be considered or other construction techniques innovated. The spacing of tiebars was felt to be complicated and offered some problems with slip-form construction. Along with this problem was that of the overlapping of bent tiebars. The last comment about the tiebars was that the length should be a multiple of the longitudinal steel spacing.

The Urban Office has prohibited the use of a longitudinal float in the pavement train. It feels this equipment "over finishes" the concrete and brings the mortar to the surface, which reduces the uniformity of the concrete and provides a surface that is subject to disintegration under traffic. In addition to this step, it has eliminated the surface tolerance of 1/8-inch deviation in 10 feet. The rationale is that the shorter deviation is not the problem that causes an unsatisfactory ride, but rather that the longer wavelengths are the problem areas. Thus, the Urban Office has put special emphasis in laying a smooth grade line to avoid roughness due to longitudinal wavelength.

With reference to slip form pavers and central mixing plants, Districts 2 and 18 stated a preference for this type of construction, the consensus of opinion being that the central mixing plant produces a superior concrete in terms of uniformity and that in turn the slip form paver requires a more uniform product to prevent edge slump. Also the slip form paver gives a pavement with riding quality far superior to what was being achieved with a conventional form operation.

In the early stages of the development of the central mixing plants in Texas, there was a feeling that the use of nonagitating trucks might result in premature setting of the concrete. To avoid taking two steps at one time, the specifications were written to require agitating haul trucks with the early central mix concrete operations. After a successful experience with the central mix, several districts experimented with the use of nonagitating trucks. As a result of their experience, Districts 2 and 18 state a satisfactory product can be achieved with this practice.

Miscellaneous

District 2 has experienced failure with shoulder designs on CRCP in the area of super-elevated curves, due to bad drainage. To prevent this condition, the district has installed transverse French Drains 5 feet apart across the shoulder, with a minimum of three drains to a curve. This has prevented the collection of water, which tended to weaken the load-carrying capacity of the shoulder in the past. Performance with this change has been satisfactory thus far.

The Urban Office has built several experimental pavements using lightweight concrete. These pavements have served very heavy traffic for eight to ten years and have required no maintenance, and the performance has been excellent. It is the consensus of opinion among the personnel that lightweight concrete should be permitted.

A concrete overlay was placed by the Urban Office on a frontage road in Houston. This overlay is on an old concrete pavement built by the city. No bond breaker was used and the overlay is of varying thickness, 4 to 7 inches. Longitudinal cracks have formed in the overlay over the longitudinal cracks in the old pavement.

CHAPTER 3. BACKGROUND FOR RECOMMENDED REVISIONS TO DESIGN MANUAL

General

This chapter describes the basis for the recommended revisions to the rigid pavement portion of the design manual. The new method is based on the available state-of-the-art. Data and results from several studies conducted by the Texas Highway Department have been utilized in preparation of the recommended revisions.

An integrated approach to rigid pavement design has been utilized for this analysis. Unlike in the past, when slab, subbase, and reinforcement designs have been considered as separate problems, the revised design method considers the entire design process as one operation. Design of one component is dependent on the other so that output from one design operation becomes an input to the other.

Economic considerations are included in the analysis. During the design process, several design strategies are generated and analyzed from an economic point of view to obtain the most economical design meeting the specified requirements. This optimal design concept is similar in nature to that used in the Rigid Pavement Design System (Ref 17) developed for the Texas Highway Department under Project 1-8-69-123.

Various new concepts have been utilized for the design method presented in the manual. A concept of reliability is introduced whereby a designer can design a project at any level of reliability that is acceptable for his region. The concept of deflection as a design criterion has been utilized in this manual. Pavement design is restricted by a maximum allowable deflection. Subbase design has been extended to include the concept of considering the erodability of subbase materials during the lifetime of the pavement structure.

Details of the recommended design manual are given in Appendix B. This chapter describes the basis for revisions and sources of data to support the recommended revisions. For easy understanding, the main sections in this chapter are written to correspond to those given in Appendix B.

Analysis Period

Recommendations regarding the analysis period are given, based on a thorough study of the current considerations used by the field engineers. In urban areas, longer analysis periods are preferred to reduce high user costs involved in subsequent maintenance operations. Also, in urban areas maintenance and overlay operations create considerable public relations problems, especially when the traffic volumes are very high and alternate routes for detouring are unavailable. In contrast, low traffic volumes and availability of detours in rural areas make it desirable, in some instances, to allow shorter analysis periods and provide heavy maintenance at the end of such analysis periods.

A variable analysis period, rather than 20 years in all cases, has therefore been recommended for the design manual.

Design Traffic

Equivalent 18-kip single-axle load applications (18 KSA) are utilized for design. These applications are obtained by converting mixed traffic into a single statistic using the equivalency factors developed at the AASHO Road Test (Ref 18). Design traffic is determined using lane distribution factors as determined by traffic distribution studies reported in Ref 19.

Performance Level

The concept of serviceability-performance is used in the design procedure. The concept was first developed by Carey and Irick (Ref 20), based on the AASHO Road Test data.

The life history of a pavement depends on its initial as well as its minimum allowable serviceability index. The difference of the two indices, called the range of serviceability index, determines the level of pavement service. Estimates of initial and terminal serviceability indices are obtained from Ref 21. Information on a nationwide survey of pavement terminal serviceability modes conducted by Rogers et al (Ref 22) is also used as guidance to select the values for the minimum allowable serviceability index.

Material Evaluation

Subgrade. Since traffic loads are eventually transferred to subgrades through pavement structures, subgrade strength is used in every pavement design procedure in one form or another. Texas Triaxial class is one measure of such strength and is generally available in Texas for the subgrade materials. Therefore, Texas Triaxial class is used in design to account for the subgrade strength.

The correlations of Texas Triaxial class to the subgrade modulus value (k-value) are obtained from NCHRP Report 128 (Ref 19) and the THD design manual for controlled access highways (Ref 23).

Subbase. The composite k-value at the top of the subbase layer must be determined in order to design pavement thickness. This requires estimation of modulus of elasticity for the subbase material. Methods to determine this modulus value have been developed in Project 3-8-66-98. The indirect tensile test method has been developed to determine material properties for stabilized materials. In case the test is not available, a table for guidance to select approximate modulus values for various stabilized materials has been prepared, based on the findings of this project.

The values of the composite modulus as determined at the top of the subbase are liable to change due to the instability caused by traffic and environmental factors during the lifetime of the pavement. Erosion, pumping, repetitive loadings, and freeze and thaw are some of these factors. Models to quantify the loss of support due to these factors have been developed in Report 123-5 (Ref 17) of Project 1-8-69-123. The loss of strength has been characterized by an erodability factor and the values of this parameter for various materials are given in the recommended manual.

The concept of determining the composite k-value and modifying it by the erodability factor has been developed with the help of pavement stress prediction models developed by Project 3-5-63-56 (Ref 24) and by elastic layered programs developed by Chevron Research Corporation (Ref 25).

Concrete. Two concrete properties used for pavement design use its 28-day third-point-loading flexural strength and its modulus of elasticity. The conversion factor to get this flexural strength from that obtained at the 7-day center-point loading is taken from the old AASHO interim design guide (Ref 1).

The guidance table for the selection of the modulus of elasticity of concrete has been prepared for the manual, utilizing the models developed by Pauw (Ref 26) and the Portland Cement Association (Ref 27) and the data presented in NCHRP Report 128 (Ref 19).

Rigid Pavement Design Criteria

Two new rigid pavement design criteria are used in the design manual: reliability concept and maximum allowable deflection. These two criteria indicate that in some cases thicker concrete pavements are required, as has been demanded by several districts. The sources of these new criteria are described below.

Reliability Concept of Pavement Design. The concept of reliability and designing a pavement structure at any desired level of confidence has been adopted from Project 1-8-69-123. Discussions of the variational properties of materials, and variations in design parameter and the design nomograph recommended for the manual have been taken from work done by Kher and Darter (Ref 28).

Deflection Criteria of Pavement Design. This is a completely new approach to rigid pavement design in the state of Texas. Experience in District 20 has indicated that excessive deflections have been experienced on CRCP and that they could be reduced by thicker pavements.

Little information exists on what an acceptable design deflection for rigid pavements should be. In the past six to eight years, the Texas Highway Department has sponsored a large field study of continuously reinforced pavement projects wherein deflections have been measured over a period of two years in the four seasons. These deflection data have been obtained from every continuously reinforced pavement design type which had been constructed to 1965 (Ref 5). Other information collected in this performance study of continuously reinforced pavements included serviceability index data and data at various points in time (Ref 6). The deflection and serviceability index data from the observed pavement test sections have been utilized to establish a desirable deflection. The deflections of pavements which have served well and provided good performance have been taken as a guide. Table 2 shows a list of such projects and their deflections and serviceability indices.* These deflection

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* This selection is based on a survey of CRCP in Texas conducted by Frank McCullough, Harvey Treybig, and Billy Rogers in the fall of 1970.

TABLE 2. DEFLECTION OF CRCP PROJECTS IN TEXAS WITH GOOD PERFORMANCE RATINGS*

Project Description	Deflection for Period					PSI** in 1966
	Oct - Dec 1963	Jan - March 1964	June-July 1964	March-April 1965	Average	
I35 Bexar County 17-10-1	.0113	.0121	.0112	.0086	.0108	3.85
I10 Colorado County 535-8-1	--	.0046	.0046	.0060	.0051	4.27
I45 Walker County 675-6-1	--	.0123	.0119	.0091	.0111	3.72
I45 Walker County 675-6-2	.0092	.0075	.0076	.0069	.0078	4.13
I45 Walker County 675-6-3	.0076	.0088	.0068	.0087	.0080	3.84
Average	.0094	.0091	.0084	.0079	.0086	3.96

*See THD Report 46-5 (Ref 30) for description of experimental measurements and test sections.

**PSI rated in 1966 as a part of Project 1-8-63-46 data indicate that an 8-inch continuously reinforced pavement which performed well had an average deflection of about 0.009 inch.

Table 3 contains a list of continuously reinforced pavement projects which have been observed to experience somewhat higher deflections. The serviceability index is slightly less than it was on the pavements with the lower deflections. The average deflection of the pavements listed in Table 3 is about 0.017 inch, considerably higher than of those pavements listed in Table 2.

The deflection design method has been developed using the procedures developed by Project 3-5-63-56, data gathered by Project 1-8-63-46, and the data obtained from the AASHO Road Test.

Joint Design. Joint design as recommended in the manual has been based on a comprehensive literature analysis of the theoretical and experimental work performed in the past as well as of the data reported for the performance of in-service jointed pavements. The table for design of dowels in contraction and expansion joints of concrete pavements as reported in the design manual has been taken from the recommendations of the ACI committee (Ref 29). Dowel diameter and length and the spacing of dowels have been recommended as a function of pavement thickness.

Reinforcement Design. Based on the survey conducted in the districts, reinforcement design as given by the old manual has been generally found to be satisfactory. The nomograph for longitudinal reinforcement design in CRC pavements has been simplified for use. The simplified nomograph was taken from NCHRP Report 128 (Ref 19).

Terminal Treatment. The design of anchor lugs has been extended for use with various subbase types and for two different amounts of end movement. Data from THD Project 1-8-63-39 and further research work have been used in the preparation of these recommendations.

TABLE 3. CRCP PROJECTS IN TEXAS WITH HIGH DEFLECTIONS*

Project Description		Deflection for Period					PSI** in 1966
		Oct - Dec 1963	Jan - March 1964	June-July 1964	March-April 1965	Average	
I820	Tarrant County 8-13-2	.0135	.0164	.0176	.0134	.0152	3.67
S183	Dallas County 94-7-1	.0139	.0156	.0144	.0146	.0146	3.78
I20	Kaufman County 95-4-1	.0150	.0169	.0128	.0130	.0144	3.33
I10	Jefferson County 739-2-4	.0225	.0283	.0207	.0194	.0227	3.78
I20	Smith County 495-4-1	.0222	.0164	.0205	.0082	.0168	3.91
	Average	.0174	.0187	.0172	.0137	.0167	3.69

*See THD Report 46-5 (Ref 30) for description of experimental measurements and test sections.

**PSI rated in 1966 as a part of Project 1-8-63-46

CHAPTER 4. REVISIONS AND DOCUMENTATION OF PAVEMENT DESIGN DETAILS

The Highway Design Division in finalizing P. S. & E. for concrete paving inserts special design details into the plans that provide pertinent construction information. In addition to using the design details for "blueprints" in the field, the contractor also uses the quantities for estimating purposes.

These design details have been prepared over a period of time and have been continually revised as special problems arise. Thus, it was felt that these details should be reviewed in light of the latest design procedures and that, in addition, the quantities, dimensions, etc., should be verified and documented for future reference.

As a part of this study, the following design details were reevaluated using Appendix B, and changes were made where applicable:

(1) CPCR (B)-71 (1)
(2) CPCR (B)-71 (2)
(3) CPJR (B)-71
(4) CPJR (F)-71
(5) CPJR (DW)-71
(6) CPCD - 71
(7) RC (CPCR)-71
(8) JS - 71

Following the general policy of the Highway Design Division, the last number of these details has been changed to 71 to reflect the year of their last major revision, i.e. 1971. A copy of each of these details is contained in Appendix C.1.

In the following sections, several of the major work items in the revisions are discussed.

Quantities

In Appendix C.2, the computation for quantities of steel reinforcement is presented. This section serves a two-fold purpose since no files were available in the Highway Design Division which documented how the steel quantities were arrived at and, as indicated earlier, the quantities required checking because they had been changed from time to time as revisions were made in the standards. All the steel details of each standard were evaluated and checked to document the method used to compute the quantities. The procedure used for each standard is presented in the appendix. Errors in the standards have been summarized and are presented.

Transverse Steel

In checking out the transverse steel design for each of the details, it was found that the design standard CPJR (B)-69 required an excessive amount of transverse steel. Computation documenting this work is presented in Appendix C.3. The basic change is a reduction in the amount of transverse steel. The design standard has been checked and evaluated and the changes made are indicated for future reference.

CPCR Thickness

As a result of the consultations with various district personnel and the new design criteria in Appendix B, it is evident that thicker slabs will be required for some pavement structures. Therefore, since slab thickness is a parameter that will be selected for each job, it was felt that a wide range of thicknesses should be included on the CPCR details.

Appendix C.4 presents the development of a series of 9 and 10-inch slabs. These additional thicknesses were included on the CPCR details. In addition, design details were prepared for two or three-lane pavements and also for four or five-lane pavements. This provides for a less complicated detail since the transverse steel requirements for the widths differ considerably. This complies with the recommendations of several districts that the transverse steel details should be less complicated.

Longitudinal Reinforcement

The consensus of opinion among the district personnel as indicated in Chapter 2 shows that the present longitudinal steel percentage of 0.5 percent is adequate in most situations. Therefore, the basic longitudinal steel percentages were not changed in this updating of the design details, although 0.6 percent was included for those desiring to select this steel percentage.*

Summary

A considerable portion of the project effort was expended in checking and documenting the design details. Since the finished product is a revised detail, the information in Appendix C.1 in reality reflects the effort in this area.

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* Manual states the use of 0.6 percent longitudinal steel if mean flexural strength greater than 625 psi is expected.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

On the basis of the work conducted in this study, several major conclusions and recommendations can be made. These reflect

(1) the inspection of approximately 1,000 miles of in-service CRCP,

(2) data and recommendations from eight Texas Highway Department research projects,

(3) two NCHRP research projects, and

(4) recommendations of personnel in six districts and the Texas Highway Department Highway Design Division.

It is felt that this study bridges the gap between developing research work and applying it in the field.

Conclusions

Following are the pertinent conclusions developed in this study:

(1) Inspection of the CRCP in the state and discussions with various Texas Highway Department personnel indicate that basically CRCP has provided excellent performance throughout the state. There have been problem areas, some in design but most associated with construction. The primary concern in the state pertains to providing adequate thickness for future traffic and wheel loads.

(2) Recommended revisions to the Texas Highway Department design manual are included in the appendix. The primary features contained in the recommended revisions are as follows:

   (a) consideration of longer analysis periods, especially in urban areas;

   (b) the use of a composite k-value that takes into account the subgrade and the subbase stiffness characteristics;

   (c) correction in the k-value to anticipate the degree of support expected during the lifetime of the facility;

   (d) a reliability concept that reflects the variability of material properties and a desired level of confidence in the design; and

   (e) a deflection criterion for selecting pavement thickness.

(3) The pavement structure must be designed as an integral unit since subbase thickness and pavement thickness are interdependent. The

recommended revisions to the design manual allow the designer to approach the design with a total concept.

(4) The greater the reliability the designer desires for his facility, the thicker the pavement structure required.

(5) The need for use of terminal anchorage lugs is still questionable; in some areas successful performance has been achieved without them while in other areas the anchor lugs are essential for the successful performance of CRCP at the terminals.

Recommendations

The report contains numerous recommendations in each of its chapters. Following are several pertinent recommendations pertaining to the project.

(1) The recommended revisions to the design manual are presented in Appendix B. These have been prepared in a format that allows them to be inserted into the design system after proper review with only a minimal amount of change.

(2) Utilization of the design manual will provide a transition stage between the present design practices and the implementation of the rigid pavement design system presently being developed in Project 123.

(3) Through the use of the revised design manual, the implementation of new research such as the indirect tensile test will become easy and desirable.

(4) In order to reduce the expense of terminal anchorage systems, it is recommended that the H-beam expansion joints developed by the CRCP group be utilized in areas where successful performance has been noted with two or less lugs.

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APPENDIX A.

SUMMARY OF COMMENTS FROM EACH DISTRICT

APPENDIX A. SUMMARY OF COMMENTS FROM EACH DISTRICT

INTRODUCTION

As part of the project, the project staff together with the technical contact representative from the Texas Highway Department met with Design, Construction, and Maintenance Engineers in six districts of the Texas Highway Department where rigid pavement is used extensively. These meetings included discussions of (1) current design practices, (2) problems on in-service pavements and solutions or attempted solutions, and (3) construction practices and techniques and a brief survey of particular pavements.

The following sections are a brief account of what was discussed in each of these meetings. These accounts serve to document the recommended revised rigid pavement design manual.

SUMMARY NOTES - MEETING WITH DISTRICT 15, SAN ANTONIO, SEPTEMBER 28, 1970

Three general pavement problems were found to exist in District 15:

(1) excessive pavement roughness from expansive soils,

(2) bridge approach-pavement end problems, and

(3) aggregate polishing.

Problems at pavement ends were at the ends of bridges first; then a bridge approach slab was used and tied to the abutment and the problem was transferred to the joint between the pavement end and the bridge approach slab. The problem is one of joint opening and slab lift-up or maybe curling. Remedial action has been grinding.

Other attempts made to solve the problem have been to lower continuous steel to 2-1/2 inches from the bottom of the slab at the end and also to place top steel about 2-1/2 inches from the surface, thus in effect making a structural slab. In areas where this has been done there has been no lift-up of slab ends, but these areas are not on very expansive soils.

Lug anchors are not used in the San Antonio District. The experience is that the pavements have not grown longer, but actually shortened.

The limestones in the San Antonio area are somewhat softer than others used for concrete aggregates. This has led to surface polishing and loss of skid resistance. For this reason, a cement factor of 5.0 sacks per cubic yard is being used.

SUMMARY NOTES - MEETING WITH DISTRICT 2, FORT WORTH, OCTOBER 5, 1970

In general, the Engineers of this district are satisfied with their rigid pavement designs and how they perform. For CRCP they support the 8-inch slab with a stabilized subbase. On bridge approaches, special care is made to provide good materials under the pavement end and the bridge approach slab to prevent action of expansive soils and the erosion due to pumping action.

The emphasis of the meeting was on the construction of rigid pavements and CRCP in particular. This district is probably the only one still using a cement factor of 4.5. They contend that this is good since concrete strengths average about 700 psi. They favor slip-form paving because of its required uniformity of concrete. For hauling central mix concrete they also use non-agitating trucks to their satisfaction. The concrete is cored at each header to insure uniformly consolidated concrete at these locations. The area at headers was a real problem on all early continuous pavements.

Two design features which were discussed were the use of weakened plane joints at the pavement end to insure desired cracking and the use of French drains in low or super-elevated areas. Surface failures in the shoulders have occurred with certain shoulder designs with CRCP in super-elevated sections. This has been a general problem that is not related to pavement type.

SUMMARY NOTES - MEETING WITH DISTRICT 18, DALLAS, OCTOBER 6, 1970

No particular pavement problems which are unique, i.e., non-existent in other districts, have been experienced in this district. From a design viewpoint, 8-inch CRCP may be too thin for urban freeways. For subbase design, either asphalt or cement layers must be used on lime-treated subgrade. A cement factor of 5.0 sacks per cubic yard is thought to be necessary in order to meet the minimum strength requirement. Anchor lugs are used to restrain pavement movement; for this, designs call for two lugs only. Designs include a bridge approach slab.

Specific mention was made of several items with regard to construction. Slip-form paving provides a product superior to that of conventional form-paving. As is done elsewhere, central mix concrete can be hauled in conventional dump trucks.

Several comments on steel detailing indicate that some design detail revisions need to be considered or other construction techniques innovated. The spacing of tiebars was thought to be complicated and offered some problems with slip-form construction. Along with this problem was that of the overlapping of bent tiebars. The last comment about the tiebars was that the length should be a multiple of the longitudinal steel spacing.

Another design comment discussed, which may or may not be related to pavement design, is the height of header bank fills. Designers in this district feel they should not be higher than 13 feet.

A significant pavement performance comment was that CRCP performs better on expansive soils than does jointed concrete pavement.

SUMMARY NOTES - MEETING WITH DISTRICT 12, HOUSTON
NOVEMBER 30, 1970

Rigid pavement in the Houston District is essentially all of the jointed type design. Several problem areas were cited and the worst problem has been spalling. Other problems which are of much less concern are longitudinal cracking and steel corrosion. Another problem which has caused pavement failures is that of improper concrete batch quantities. Expansion or growth of pavements has been noted on jointed as well as continuously reinforced type pavements.

Design practices include a redwood board for the joints in the 60-foot joint spacing design. Redwood has been selected because of unsatisfactory performance with other sealers. Dummy joints spaced at 20 feet are also used with the 60-foot spaced redwood board joints. Because of good performance of jointed pavement on the Gulf Freeway, which is serving very heavy traffic, the designers are satisfied with jointed type pavement; they also feel that continuous pavement as built, at a thickness of 8 inches, is too thin, and therefore continuous designs are not used.

Maintenance repairs to rigid pavement indicate that failures other than joint problems are largely a result of improper concrete batch quantities. Where sections of slab have been removed, stabilized subbases are still sound and do not need repairs.

SUMMARY NOTES - MEETING WITH HOUSTON URBAN OFFICE, HOUSTON, NOVEMBER 30, 1970

Rigid pavements built on the Houston expressway system by the Urban Project Office are essentially all continuously reinforced concrete designs. Pavement problems have been very minor, including some spalling, bad concrete batches, and some problems at pavement-bridge ends where no lug anchorages are provided.

The designers in this office feel very strongly about several CRCP design factors. The first is that pavements for urban freeways, such as in Houston, should not be designed for 20 years but for a more indefinite time. Some of the design practices used by the Houston Urban Office have set a precedent which has been followed by others. The Urban Office has shown design leadership by promoting thicker CRCP, heavier steel requirements, and a higher cement factor together with outstanding construction features. It is the feeling of this office that transverse steel in CRCP serves a very definite function and should not be removed.

The Houston Urban Office has built several experimental pavements using lightweight concrete. These pavements have served very heavy traffic for eight to ten years and have required no maintenance, and the performance has been excellent. That lightweight paving concrete should be permitted is the general feeling in this office.

A concrete overlay was placed on the frontage road of the South Loop (Homes Road). This overlay is on an old concrete pavement built by the city. No bond breaker was used and the overlay is of varying thickness, 4 to 7 inches. Longitudinal cracks have formed in the overlay over the longitudinal cracks in the old jointed pavement.

Experience with Neoprene joint seals on the urban freeways is that they are a 100 percent failure for pavements and a success about 50 percent of the time on bridges.

Other recommended design features included a stabilized subbase, 6 inches thick as a minimum. Also, based on experience, pavement end movement can be successfully controlled by using two lug anchors and several 1-inch joints between the pavement end and the bridge or bridge approach slab.

SUMMARY NOTES - MEETING WITH DISTRICT 20, BEAUMONT, DECEMBER 1, 1970

The weakest subgrades in the entire state of Texas are probably in the Beaumont District. Along parts of I10 in Jefferson County, the water table is about 1 foot beneath the top of the subgrade. Many failures have occurred on the 8-inch CRCP, and many of them can probably be attributed to the very weak subgrade. This has been substantiated by deflection measurements as well. In general, 10-inch unreinforced pavement has performed better than 8-inch CRCP.

Problems which have been encountered along with the already weak subgrade conditions include dirty concrete aggregates, lime-treated subbases, and severe pavement end movements.

The designers feel strongly about and use pavement lug anchors. They have reduced concrete aggregate size as have most other districts. Also they recommend and use a cement factor of five sacks per cubic yard.

APPENDIX B.

REVISED DESIGN MANUAL FOR RIGID PAVEMENTS

NOTE: The numbering of the parts, figures and tables in this appendix conforms to that of the Highway Design Division Operations and Procedures Manual. The references made are listed at the end of this appendix.

4-403 RIGID PAVEMENT STRUCTURES

4-403.1 INTRODUCTION

"Rigid Pavements" as used in this chapter includes three types of pavement structures that contain portland cement concrete: jointed unreinforced concrete pavement with load transfer devices at joints (CPCD), jointed lightly reinforced concrete pavement with load transfer devices at joints (CPJR), and continuously reinforced concrete pavement (CPCR). This section covers design traffic, materials evaluation, variability characterization, selection of thicknesses, reinforcement, joints, and terminal treatment. It is anticipated that future additions to this chapter will cover maintenance and economic considerations.

4-403.2 PAVEMENT STRUCTURE DESIGN

The intent of this manual is to bring about the selection of the most economical design which fulfills the requirements specified by the designer. A step-by-step procedure for accomplishing this objective is shown in Fig 4.1. Where applicable, the appropriate design chart is also listed. Necessary descriptions related to the development and use of these charts are given in subsections 4-403.3 through 4-403.10.

The design approach shown in Fig 4.1 is as follows:

(1) Evaluate subgrade modulus of the natural material.

(2) Select possible stabilization types.

(3) Ascertain the modulus of elasticity and erodability factors for the materials being considered for the subbase layer.

(4) Select a range of trial subbase thicknesses.

(5) Ascertain pavement design parameters such as level of service, pavement type, concrete properties, and traffic.

(6) Determine a composite k-value at the top of the subbase.

(7) Modify the composite k-value based on the erodability characteristics of the subbase material.

(8) Determine the required thickness for the concrete pavement.

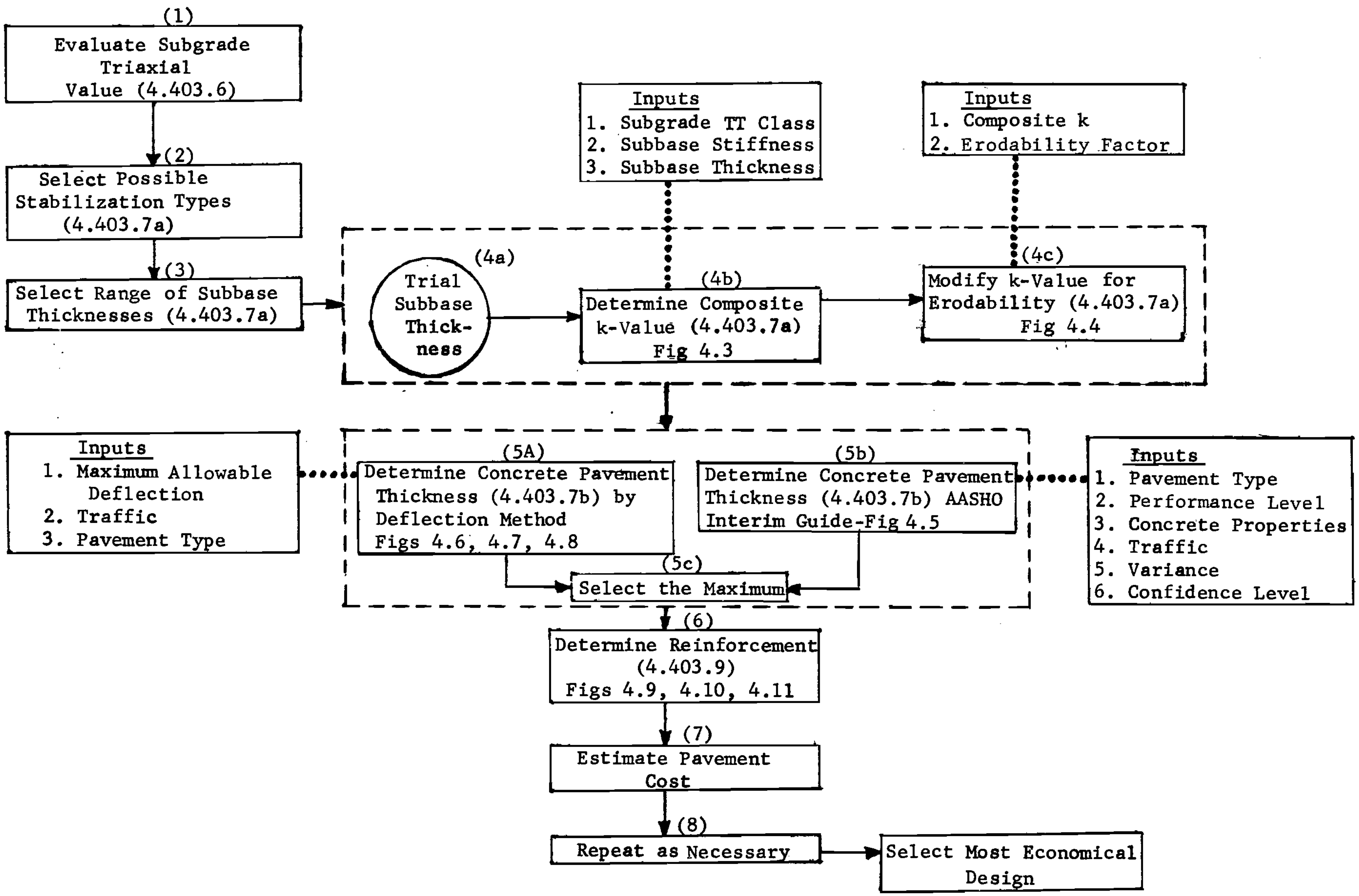


Fig 4.1. Procedure for pavement structure design.

(9) Design reinforcement for the concrete pavement.

(10) Estimate pavement cost for this design configuration.

(11) Repeat steps 5 through 10 for other design configurations.

(12) Compare the resulting costs of various design configurations and select the most economical design.

4-403.3 ANALYSIS PERIOD

The analysis period is the duration for which a pavement is designed, i.e., the time during which the pavement serviceability will reduce to an extent that an overlay will be required. In the past, the analysis period has always been taken as 20 years, i.e., all designs have been cited as being 20-year designs. This number, however, should be rationally evaluated for each facility and should not be arbitrarily selected.

The length of the analysis period depends upon several factors, such as

(1) location of a facility, i.e., urban or rural;

(2) additional vehicle operation costs incurred during pavement rehabilitation;

(3) accessibility of parallel lanes for handling traffic detours during overlay construction;

(4) surface drainage characteristics, i.e., whether or not inlets need to be raised with overlay construction; and

(5) other socio-economic and political reasons.

With traffic volumes as they exist today, longer analysis periods in urban locations are imperative, i.e., the 20-year design is no longer adequate, while in rural locations an analysis period of less than 20 years may be acceptable. Experience and engineering judgement must be applied by the designer in selecting the appropriate number. It is emphasized that the longer the analysis per period and the greater the terminal serviceability, the greater the initial pavement thickness.

4-403.4 DESIGN TRAFFIC

In addition to the provisions in this section, general instructions in section 4-402.4 pertaining to acquisition of design traffic data are applicable.

Traffic evaluation for rigid pavement design is based upon an analysis of the total traffic which the pavement will serve in its analysis period. The

Planning Survey Division (D-10) of the Texas Highway Department will furnish the designer with the number of equivalent 18-kip single axle load applications (18 KSA) based upon the mixed traffic in the direction of interest.

The 18 KSA for rigid pavements varies with the thickness of the concrete pavement. When requesting 18 KSA from D-10, the designer should request output for all possible thicknesses that might be selected. As an example, if it is anticipated that a project will require 7 or 8 inches of continuously reinforced concrete pavement, the traffic request should be for 18 KSA for 6, 8, and 10-inch rigid slabs. (Linear interpolation or extrapolation for 5, 7, 9, or 11-inch slabs should be accurate enough for use.)

Design 18 KSA is estimated as follows:

$$18\ \text{KSAD} = (18\ \text{KSA}) \times \text{LDF}\ ,$$

where

18 KSAD = design 18 KSA

18 KSA = total equivalent 18-kip axles in one direction

LDF = lane distribution factor, the ratio between the traffic in the lane of interest and the one-directional traffic

On freeway facilities where more than two lanes are used in each direction, a lane distribution factor will be required and will depend upon the number of lanes. For a two-lane roadway, the factor is 1.0. For facilities with more than two lanes, the lane distribution factor can be taken from Table 4.1 (Ref 6 at the end of Part 4-403).

Design traffic to be obtained from D-10 should be that expected in the first analysis period, as established in Section 4-403.3.

4-403.5 PERFORMANCE LEVEL

The designer can select any performance level for a facility by establishing a change in serviceability during the analysis period. Figure 4.2 illustrates the concept of serviceability index versus pavement life. In the design nomograph presented here, the designer must select the values of the initial and

TABLE 4.1. LANE DISTRIBUTION FACTORS FOR MULTILANE ROADWAYS (after Ref 6)

Total Number of Lanes, One Direction	Lane Distribution Factor
2	1.0
3	0.8 - 1.0
3+	0.4 - 0.6

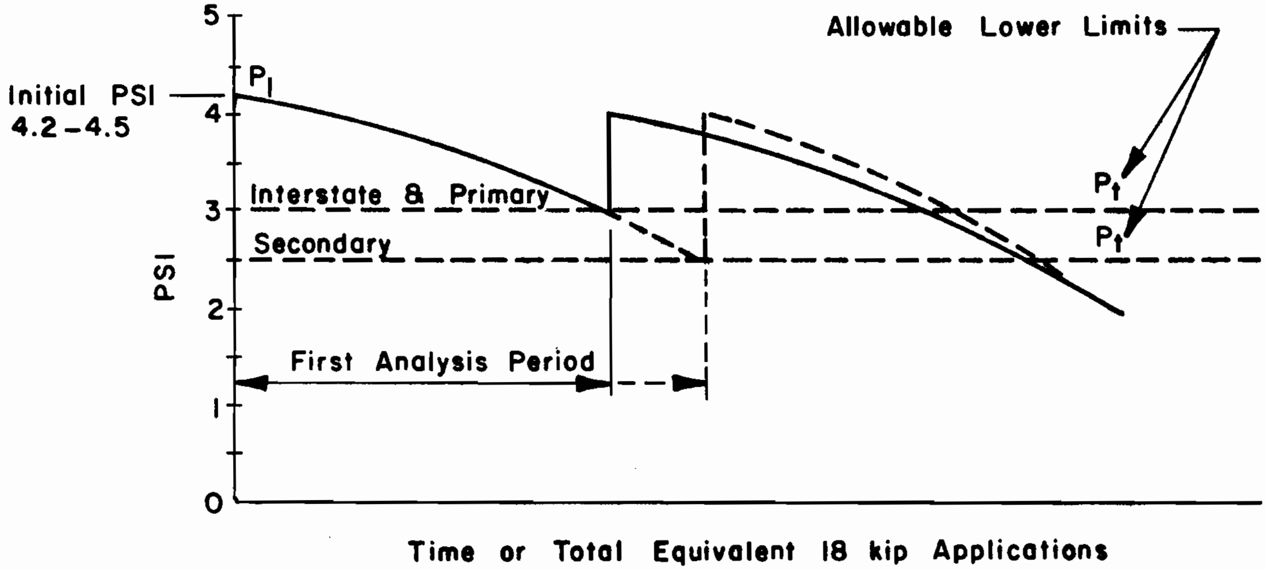


Fig 4.2. Illustration of serviceability versus pavement life.

the terminal serviceability indices. In this section, guidance is given for establishing the values of initial and terminal serviceability indices.

The initial serviceability index of a pavement when its construction is completed is referred to as P_1. An average value for Texas pavements has been cited as 4.2 (Ref 7 at the end of Part 4-403), while at the AASHO Road Test the average initial serviceability index was 4.5. A design value of 4.2 is recommended unless experience is such that a value greater than this is validated by field measurements of some kind, i.e., by Mays Road Meter or by some other such serviceability index measuring device.

Terminal serviceability index of a pavement P_t refers to the level of service when rehabilitation of the pavement will be required. More traffic can be carried if the designer is willing to accept a lower level of terminal serviceability index. Based on past experience in Texas, interstate and primary highways are generally upgraded before their serviceability index drops to a level of 3.0, while the lesser traveled secondary highways normally fall to a serviceability index of about 2.5 before their surfaces are upgraded to a satisfactory serviceability level.

4-403.6 MATERIALS EVALUATION

The designer must evaluate and characterize the properties of the subgrade material, the subbase material and the paving concrete. In the following sections, guidance is given for characterization of the materials for each of the layers for use in determining the pavement structure thickness in section 4-403.6. In some cases, the designer may have two or more materials to characterize for each of the layers. The charts presented are based on the assumption that the materials are prepared in accordance with standard specifications.

Subgrade Evaluation. In order to determine the pavement thickness, a subgrade modulus (k-value) must be determined for the subgrade. Plate load tests have proven too cumbersome for determining this value; therefore, Texas Triaxial class of the subgrade should be used.

A plot of triaxial classification versus station number should be prepared. This plot should be divided into design sections observing the plot and noting where obvious changes of soil properties occur. Next, a weighted mean triaxial class value should be computed using the length of each section as the weighting factor.

Subbase Evaluation. The design of subbase to provide a relatively permanent structural foundation for the concrete pavement must be coordinated with the pavement thickness design. This requires that a k-value at the top of the subbase layer be determined. The desirable evaluation would be after the subbase is in place, but for pavement design purposes a value will have to be estimated before the subbase is constructed. Subbase evaluation will consist of determining a modulus of elasticity and an erodability factor for the subbase material. The erodability factor is defined as an index which represents the loss of subbase support during the life of the pavement.

During the mix design phase, the modulus of elasticity characterization can be performed. For granular materials, the stress-strain data from the triaxial test can be used, and for chemically stabilized materials the characterization can be made by the indirect tensile test (Refs 8, 9, and 10 at the end of Part 4-403). If these tests are not available, the modulus values can be estimated as outlined in Table 4.2. Although the values given in Table 4.2 are rough estimates, their use will be better than an oversight.

Table 4.3 gives guidance in selecting the erodability value for a subbase. For fine-grained and granular materials, the larger the proportion of fine grains, the higher the erodability factor will be. For chemically stabilized layers, a general guide would be to reduce the erodability factor as the proportion of stabilizing agent increases. The third classification will be for special conditions where a one or two-course surface treatment is applied over the subbase layer. The designer should recognize that the selection of the erodability factor is also dependent on the amount of heavy truck traffic and the amount of water penetrating the pavement structure. Generally, higher erodability factors should be associated with higher traffic and larger availability of water to the subbase.

The k-value at the top of the subbase used in design should represent the support conditions during the life of the pavement, not just the initial conditions. Uniform support conditions beneath the slab are generally lost during the life of the pavement due to various reasons. Any change in soil type, compaction, moisture, and factors such as loss of support, erosion, and pumping

TABLE 4.2. TYPICAL SUBBASE MODULI

Material	Stiffness Range, psi
Granular	8,000 - 20,000
Cement-stabilized base	500,000 - 1,000,000
Cement-stabilized soil	400,000 - 900,000
Asphalt-treated base	350,000 - 1,000,000
Asphalt-emulsion treated	40,000 - 300,000

TABLE 4.3. ERODABILITY VALUES FOR VARIOUS SUBBASE MATERIALS

Material	Erodability Value
(1) Granular materials	
(a) Fine-grained	3.0
(b) With large percentage of coarse aggregates	2.0-2.5
(2) Bituminous-treated materials	
(a) With amount of bitumen less than optimum	1.0
(b) With optimum amount of bitumen	0
(3) Cement-treated materials	
(a) With cement less than 3 percent by weight	0.5
(b) With optimum cement content	0
(4) Lime-treated materials	1.0-2.0

cause variations in foundation support along a project during numerous seasonal cycles in the design life of a pavement. Estimation of possible variations in k-values suggests that a coefficient of variation of about 35 percent should be expected on a pavement project. This number is used in the development of the design nomograph in Section 4-403.7.

Concrete Evaluation. The engineering properties of the portland cement concrete required for slab thickness design are modulus of elasticity and 28-day flexural strength obtained by third-point loading of a standard test beam as specified in ASTM-Designation-T-97.

For flexural strength, the Texas Highway Department uses tests with center-point loading at an age of seven days. This strength should, therefore, be transformed to 28-day third-point loading strength. The following equation should be used:

$$S'_c = 1.107 \, S_c$$

where

S_c = mean flexural strength of concrete at seven days by center-point loading tests, psi;

S'_c = mean flexural strength of concrete at 28-days by third-point loading tests, psi.

According to several studies (Ref 11 at the end of Part 4-403), concrete flexural strength is the most important variable affecting the concrete pavement thickness. The mean flexural strength value should be determined as closely as possible by analyzing the beam tests performed on other projects where similar concrete has been used.

The modulus of elasticity can be determined by using a static compression test on concrete cylinders (TEX-418-A). Experience has shown that the modulus of elasticity can be roughly categorized into two groups: concrete with siliceous gravel aggregates and concrete with crushed limestone aggregates. The modulus of elasticity of concrete made with crushed limestone aggregates has a value very near to that of lightweight concrete or concrete made with synthetic aggregates.

Concrete containing siliceous gravel aggregates usually has a modulus of elasticity of about 5.5 million psi, whereas concrete with crushed stone or synthetic aggregate has a value of about 2 million psi. The concrete modulus is also dependent on the flexural strength of concrete. Modulus values for various concretes and flexural strengths are tabulated in Table 4.4.

Concrete properties generally have large variations associated with them. The causes of these variations are attributed to two major factors; nonhomogeneous ingredients and nonuniform concrete production and placing. Property variations due to ingredients arise from changes in types and quantities of aggregates, cement, and water during concrete pavement construction. Variations due to concrete production occur during batching, mixing, transporting, placing, finishing, and curing of concrete. Nonuniform concrete placing produces such effects as nonhomogeneous distribution of concrete air content, which gives rise to localized spalling areas during freeze and thaw cycles.

The plots of standard deviations versus average compressive or flexural strengths show a general increase in standard deviation as a function of average strength. The estimate of possible variations in flexural strengths as obtained from data on actual projects indicates a coefficient of variation of about 10 percent. The same coefficient of variation is also observed in the modulus of elasticity of concrete. This value is used for these concrete properties in the development of the design nomograph in Section 4-403.7.

4-403.7 PAVEMENT COMPONENTS

(a) Subbases

General. The subbases under concrete pavements are provided to serve the following functions:

(1) improving the foundation strength,

(2) providing a workable platform upon which to construct the concrete slab, and

(3) providing a stable structural foundation for reasons such as pumping, frost action, shrinkage and drainage.

Subbase Stabilization. Using knowledge of materials and costs in a particular locality, the designer should select one or more subbase types. The choice will depend on the availability of local materials as well as the cost

TABLE 4.4. MODULUS VALUES FOR VARIOUS CONCRETES

Material	Modulus Value
Siliceous gravel aggregate	5.5×10^6 psi
Lightweight aggregate	2×10^6 psi

MODULUS VALUES BASED ON CONCRETE FLEXURAL STRENGTH

Flexural Strength, psi	Modulus Value, psi ($\times 10^6$)
500	3
550	3.3
600	3.6
650	3.9
700	4.2
750	4.5
800	4.8
850	5.1
900	5.6

of stabilizing agents and materials processing, such as selective grading for natural subbases or mixing for stabilized materials.

The mix design for cement should satisfy Texas Test Method Tex 120-E with the compressive strength recommended therein being considered a minimum (Ref 5 at the end of Part 4-403). If asphalt stabilization is selected, the mix designer should remember that except when carrying construction traffic, durability is more important than stability.

Design of the subbase to act as an adequate working platform becomes simply a separate structural pavement design problem in which the traffic is the construction traffic. Unless the specifications prohibit batch trucks from hauling on the subbase, it should be designed as recommended in Texas Test Method 117-E (Ref 5 at the end of Part 4-403). A design wheel load of 10-kips and a load frequency design factor of 0.65 are recommended as minimum loads.

Subbase Thickness. To provide a reasonably permanent foundation for the concrete slab, the subbase should be resistant to the hydrodynamic forces that may be applied. It is required as a minimum that the top 4 inches of the subbase be stabilized with asphalt or cement to insure that a nonerosive subbase is obtained.

For obtaining a most economical overall design, several subbase thicknesses should be selected. This range should be based on minimum and maximum thicknesses derived from construction limitations, agency administrative requirements, engineering judgements, etc.

Composite Modulus. The composite k-value at the top of the subbase is required for design of concrete pavement thickness. This value should be obtained from Fig 4.3, using the Texas Triaxial value of subgrade as determined in Section 4-403.6, the modulus of elasticity of the subbase material selected from Table 4.2, and the thickness of the subbase as specified. The k-value thus obtained should be modified according to Fig 4.4 to take into account the influence of material erodability. Figure 4.4 gives the modified k-value using the initial k-value and the erodability factor as established by Table 4.3.

(b) Concrete Pavement

Concrete pavement thickness should be designed by two methods, the Modified AASHO Interim Guide method and the deflection method. The higher of

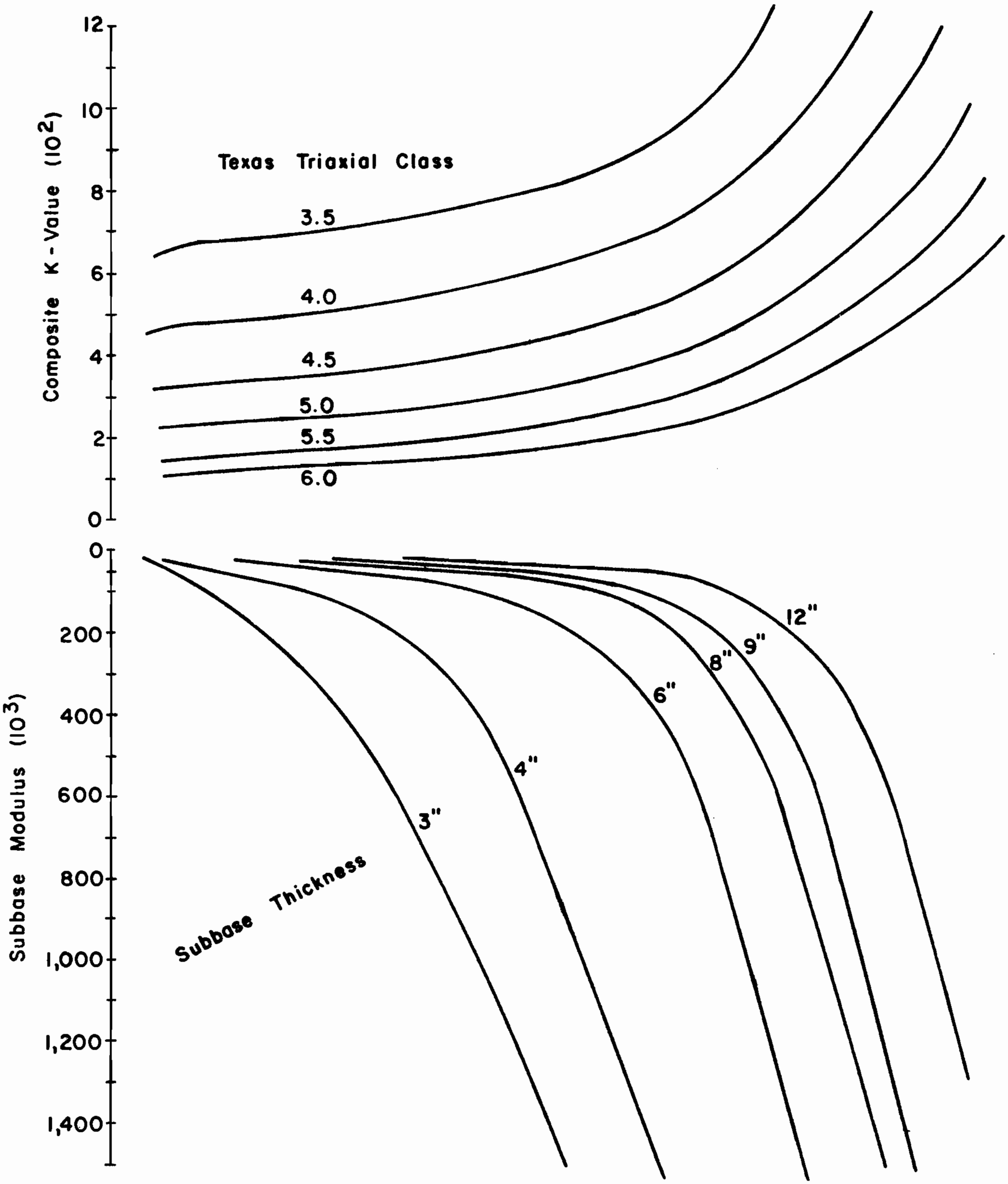


Fig 4.3. Composite k-value chart.

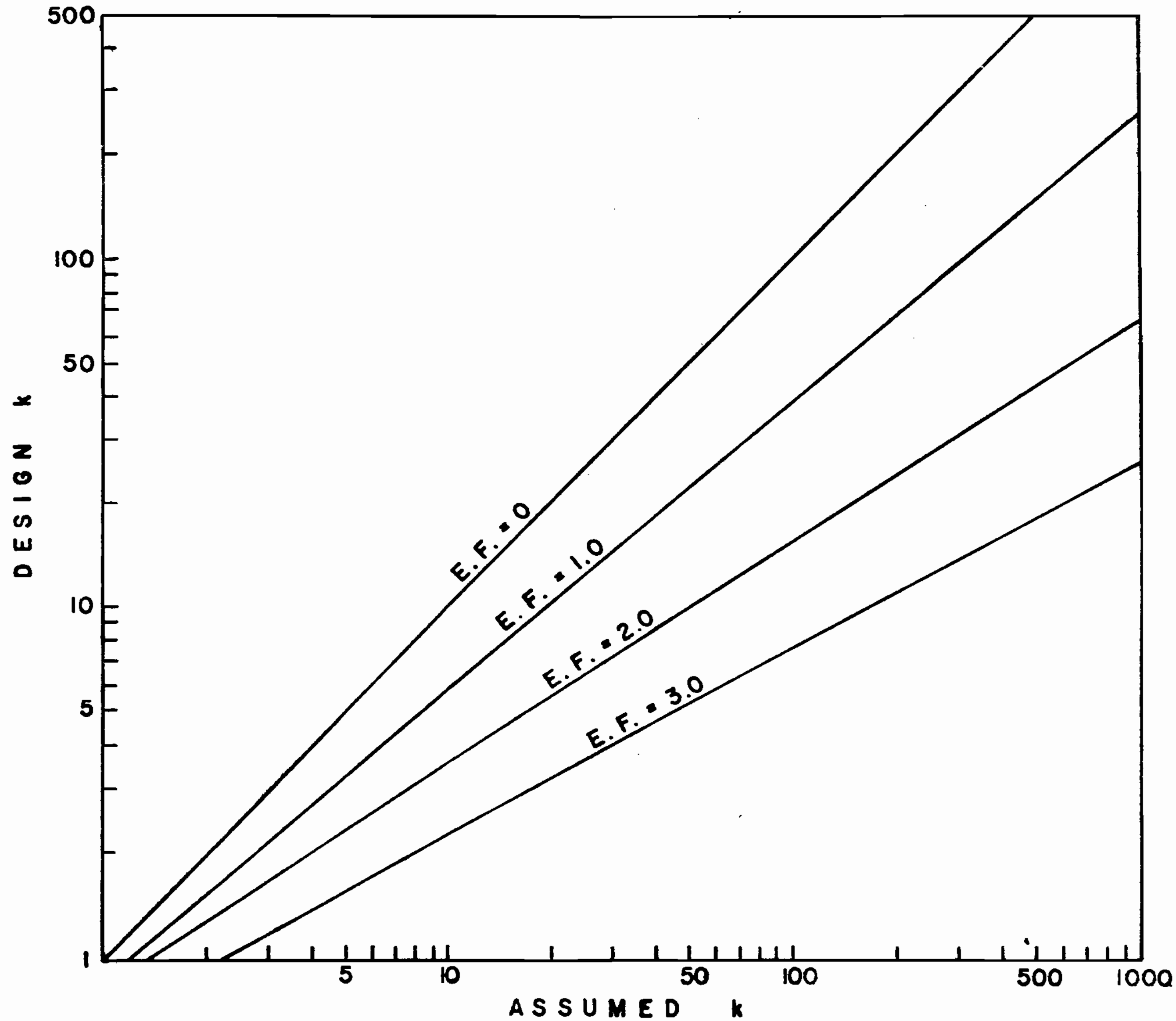


Fig 4.4. Modified k-value due to erodability of subbase.

the two values thus obtained should be considered as the design pavement thickness. The two methods are described in the following sections.

Modified AASHO Interim Guide Method. The procedure presented here makes it possible to design a pavement thickness at any level of reliability taking into account the uncertainties associated with various parameters. The design thickness bears a promise that it will last the required number of applications with the reliability for which it is designed. Pavement design procedure is taken from a research study conducted to upgrade the AASHO interim design guide (Ref 11 at the end of part 4-403). The procedure takes into account the average conditions of variabilities in material properties and other design parameters. Concrete pavement thickness should be established by taking the following steps:

Step I. Determine the overall variance in pavement performance (VAR) by the following method:

(1) Select a variance value from Table 4.5 (an initial estimate of the required thickness will be needed to use this table) called V_p.

(2) Add to V_p the variance V_T due to traffic prediction error by using the following equation:

$$V_T = \left[\frac{\log(\text{twice 18 KSAD}) - \log(\text{half 18 KSAD})}{4}\right]^2 \times 1000$$

Step II. Estimate the design reliability level based on experience and judgement. The design reliability should depend upon the "consequence of failure" in order to provide an adequate performance throughout the design period. The consequence of failure should be judged by user delay and accident costs during rehabilitation operations and other socio-economic-political effects. Thus the design reliability level should be selected based upon consideration of all these factors, not only the initial construction cost. As a rough guideline, the original AASHO interim design guide exercised a design reliability of 90 to 95 percent on the pavement thickness designed by that nomograph.

TABLE 4.5. VARIANCE (V_p) VALUES

Concrete Flexural Strength, psi	Foundation Modulus, psi	JCP Without Load Transfer Devices: 6	8	10	12	JCP With Load Transfer Devices: 6	8	10	12	CPCR: 6	8	10	12
600	25	775	718	684	661	866	809	775	752	935	879	845	822
	100	779	722	688	664	870	813	779	755	940	883	849	825
	300	821	742	700	673	912	833	791	764	982	903	861	834
	600	918	777	719	685	1009	868	810	776	1078	938	880	846
700	25	775	718	684	661	866	809	775	752	936	879	845	821
	100	778	721	687	664	869	812	778	755	938	882	848	824
	300	810	737	698	671	901	828	788	762	971	898	858	832
	600	886	766	714	682	977	857	805	773	1047	927	874	843
800	25	775	718	684	661	866	808	775	752	936	879	845	821
	100	776	720	687	663	867	811	778	754	937	881	847	824
	300	803	734	696	670	894	825	787	761	964	895	856	830
	600	865	759	710	679	956	850	801	770	1026	920	870	840
900	25	776	718	684	661	867	809	775	752	937	879	845	821
	100	776	720	686	663	867	811	777	754	936	881	847	824
	300	797	731	694	669	888	823	785	760	958	892	855	829
	600	849	753	706	677	940	844	797	768	1010	914	867	838

<u>Step III</u>. Select the concrete thickness from the nomograph in Fig 4.5 in the following manner.

(1) Join "Reliability" and "Variance" to intersect at TL 1.

(2) Draw a line through "Traffic" and the point established on TL 1 above to intersect TL 2.

(3) Go to TL 3 from TL 2 through "Minimum Allowable Serviceability Index."

(4) Go to TL 4 from TL 3 through "Joint and Crack Load Transfer Coefficient."

(5) Go to TL 5 from TL 4 through "Concrete Flexural Strength" (do not use any safety factor).

(6) Start now on the extreme right hand side of the nomograph and draw a line through "Gross Foundation Modulus" and "Concrete Modulus of Elasticity" to intersect TL 6.

(7) Join the two points established in Steps 5 and 6 on TL 5 and TL 6 respectively. This joining line will pass through "Concrete Design Thickness" and will intersect it at the required design concrete thickness.

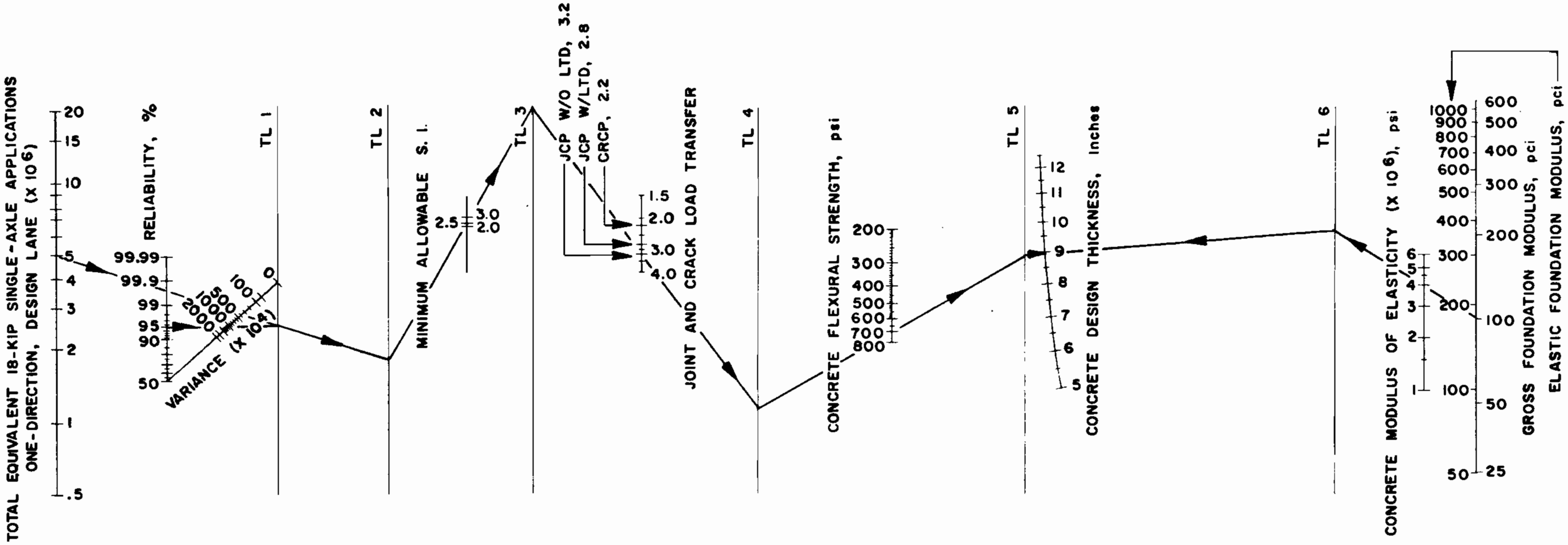
<u>Deflection Method</u>. The use of deflection as a rigid pavement design criterion is a new approach in the state of Texas. This criterion limits the pavement slab deflection from exceeding the specified maximum value. The procedure is described in the following steps:

<u>Step I</u>. Using Fig 4.6, estimate the maximum allowable deflection for the pavement structure based on total number of equivalent 18-kip axle loads.

<u>Step II</u>. Using the deflection obtained in Step I, select the required concrete pavement thickness with the help of Figs 4.7 and 4.8 for jointed reinforced and continuously reinforced pavements, respectively.

4-403.8 JOINT DESIGN

Joints that are used in portland cement concrete pavement include transverse contraction, transverse expansion, transverse construction, longitudinal grooved, and longitudinal construction joints. The joints should be in accordance with the design details. (See Standard Design Details listed in Appendix A at the end of the manual.)



EXAMPLE PROBLEM

Traffic = 5,000,000 single-axle equivalent 18-kip applications
Variance = 1,000 (corresponds to average quality control)
Minimum Allowable Serviceability Index = 2.5
Joint and Crack Load Transfer Coefficient = 3.2 (JCP w/o load transfer device - LTD)
Concrete Flexural Strength = 700 psi
Concrete Modulus of Elasticity = 4,000,000 psi
Gross Foundation Modulus = 100 pci

REQUIRED CONCRETE THICKNESS

Reliability	90	95	99	99.9	99.99
Thickness, inches	8.6	8.9	9.7	10.4	11.5

Concrete thickness required by original interim design guide using working flexural stress of .75 × 700 = 8.75 inches (corresponds to 92.5 percent reliability)

Developed by
M. I. Darter
R. K. Kher
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Fig 4.5. Nomograph for concrete pavement design at desired reliability level.

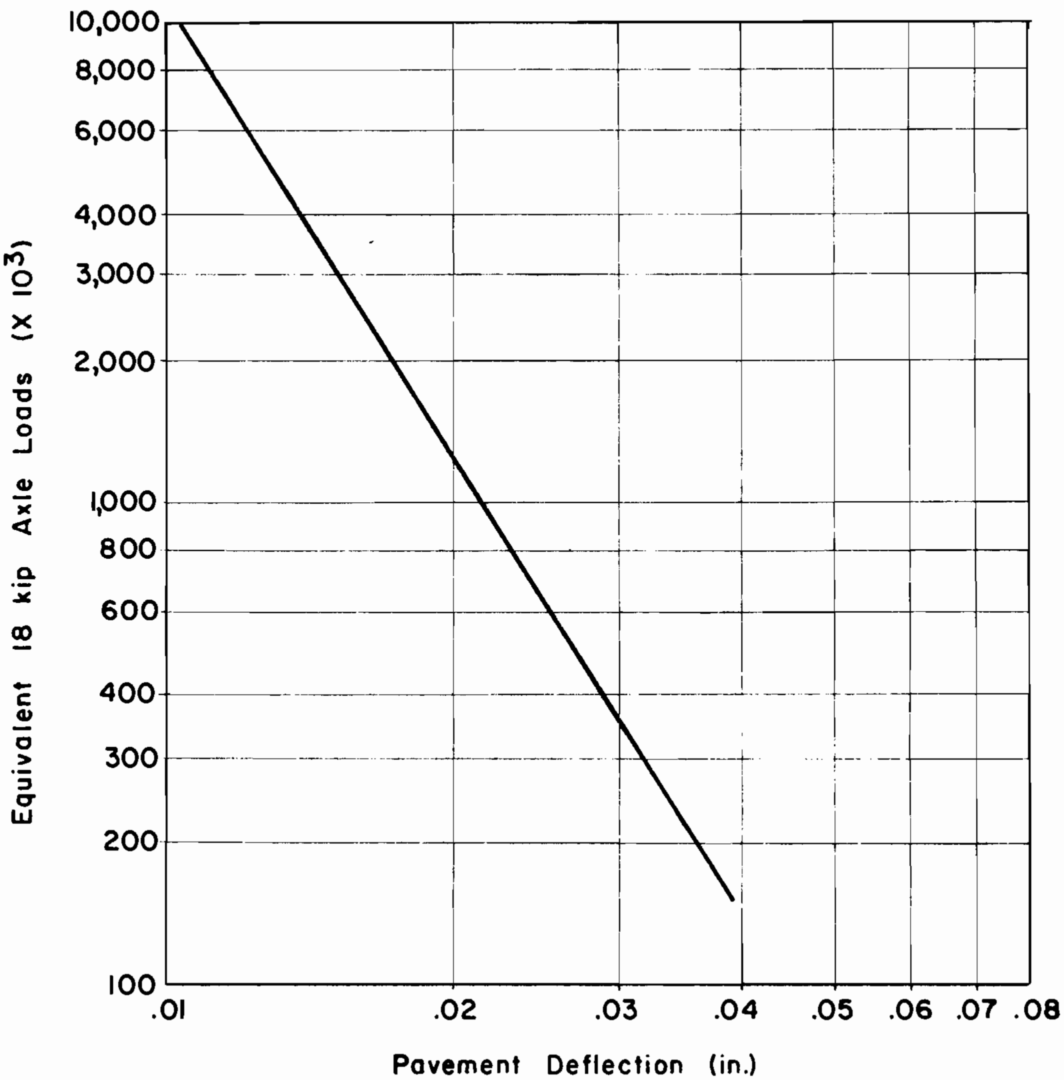

Fig 4.6. Maximum allowable pavement deflection.

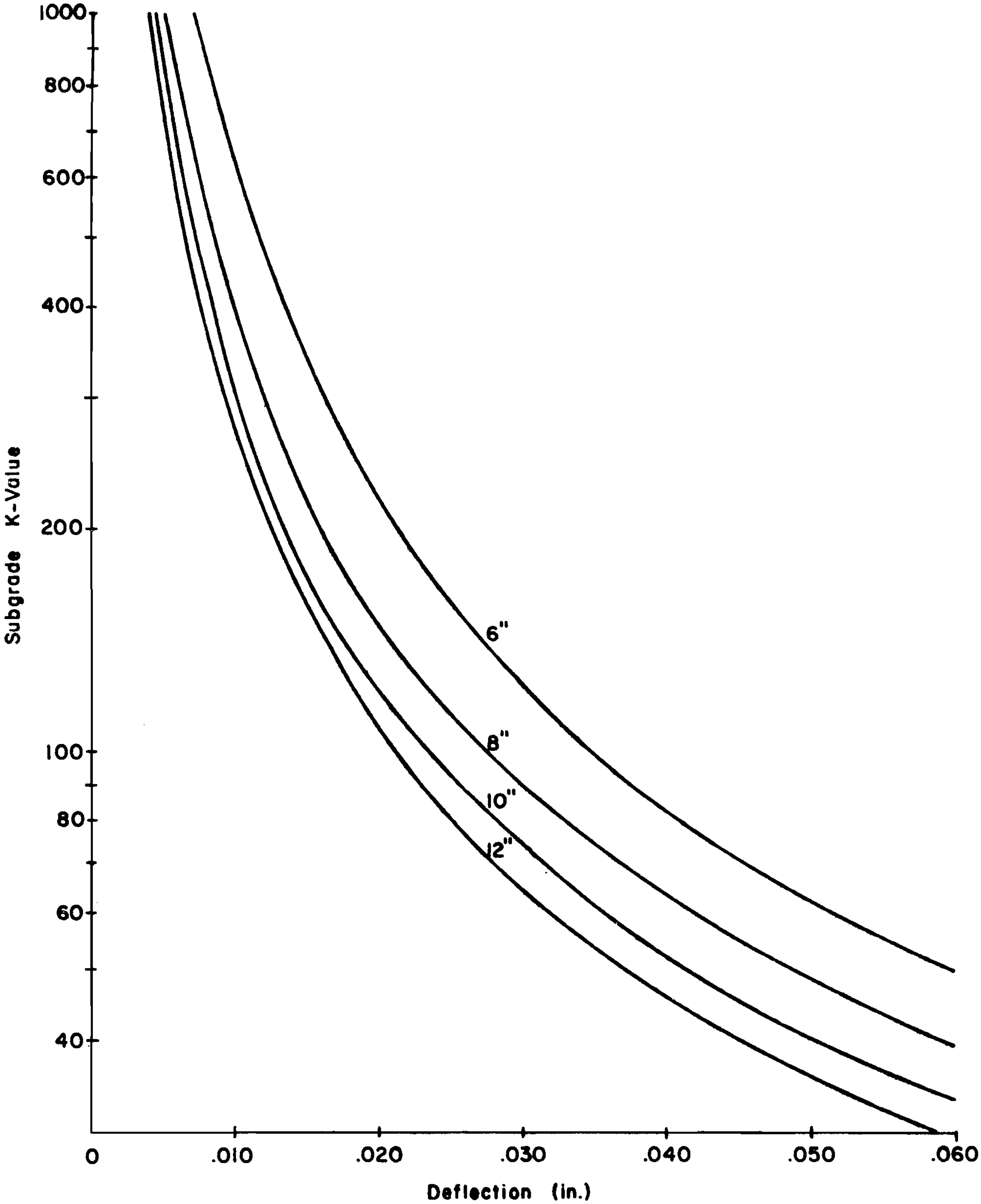

Fig 4.7. Pavement thickness design by deflection criteria, jointed pavements.

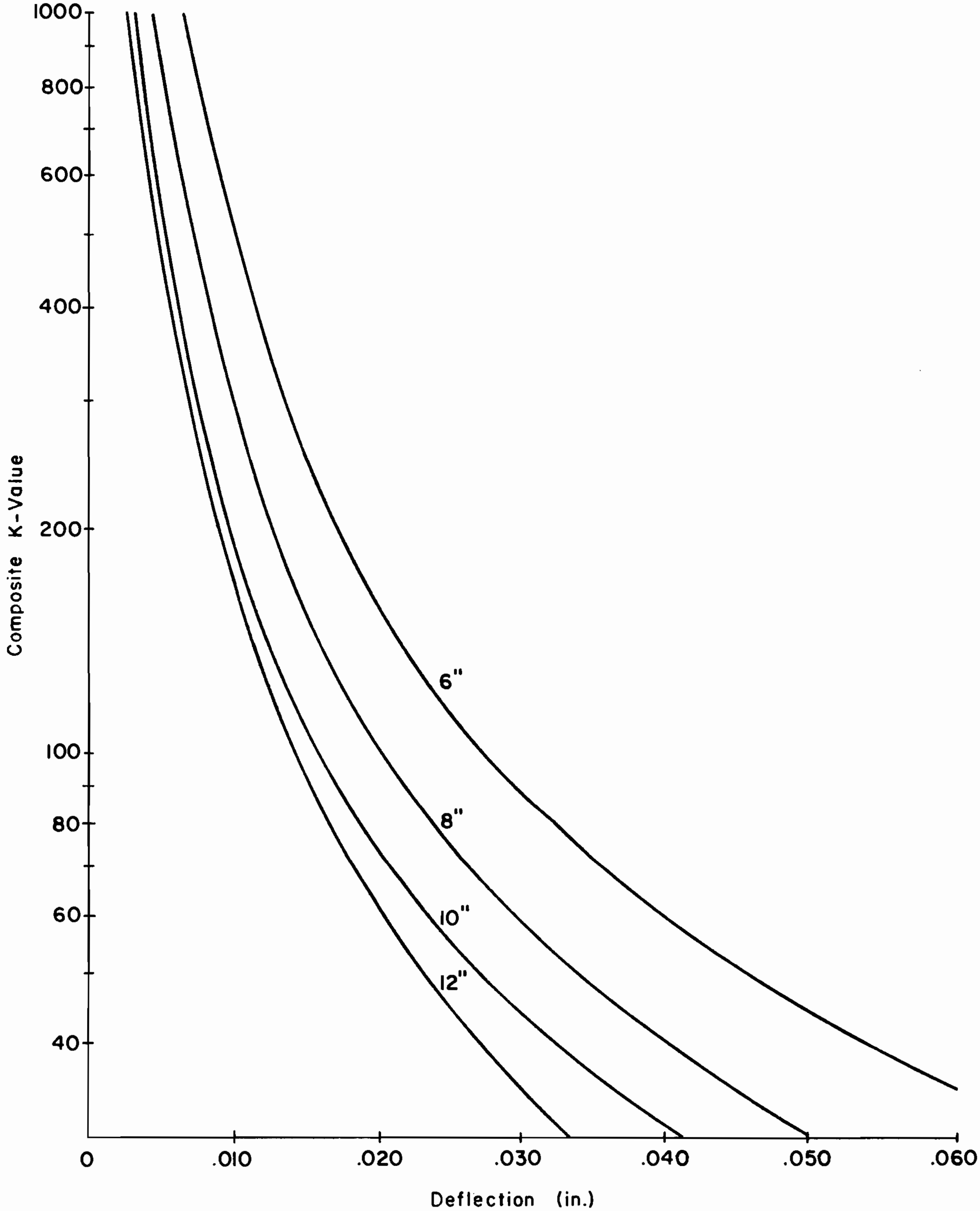

Fig 4.8. Pavement thickness design by deflection criteria, CPCR.

Load transfer in all longitudinal construction joints should be maintained by the use of tiebars. The transverse steel through longitudinal joints should be equivalent in load carrying capacity to that in the slab. The length of the tiebar should be a minimum of 60 diameters with one-half of the bar length on each side of the joints.

Load transfer in all transverse joints should be developed by the use of round steel dowels. The design of dowels is based on recommendations of the American Concrete Institute (Ref 12 at the end of Part 4-403). Table 4.6 lists the required diameter, length, and spacing of dowels as a function of pavement thickness. Great care in installation is needed to assure that dowels are properly aligned and installed to insure satisfactory performance.

Details for recommended joint seals are shown in Standard Design Details listed in Appendix A.

4-403.9 REINFORCEMENT

(a) Continuous Reinforcement

The selection of continuous longitudinal steel is based on Vetter's analysis of reinforced concrete (Ref 4 at the end of Part 4-403). The nomograph in Fig 4.9 shows a graphical solution for percentage of longitudinal steel. The longitudinal steel detail shown in Continuously Reinforced Concrete Pavement Standard Design Details (see Standard Design Details listed in Appendix A) has been selected from Fig 4.9. Figure 4.10 can be used to select the bar spacing. When 7-day concrete flexural strengths greater than 625 psi are expected, the higher of the two percentages of longitudinal steel shown on the design standards should be specified unless experience has shown that the lower percentage of steel has provided satisfactory service.

The transverse steel requirement in continuously reinforced concrete pavement is based on the subgrade drag theory (Ref 3 at the end of Part 4-403). Figure 4.11 can be used to determine the percentage needed. This method is reflected in the transverse steel details shown in the Design Details (see Standard Design Details listed in Appendix A).

The percentage of longitudinal steel should not be less than 0.4 percent for concrete made with conventional coarse aggregates even though Fig 4.9 may indicate less. Deflection studies on in-service pavements have shown that the

TABLE 4.6. RECOMMENDED DOWEL REQUIREMENTS FOR EXPANSION OR CONTRACTION TRANSVERSE JOINTS IN HIGHWAY CONSTRUCTION

Pavement Thickness, in.	Dowel Diameter, in.	Dowel Length, in.	Dowel Spacing, in.
6	3/4	18	12
7	1	18	12
8	1	18	12
9	1-1/4	18	12
10	1-1/4	18	12

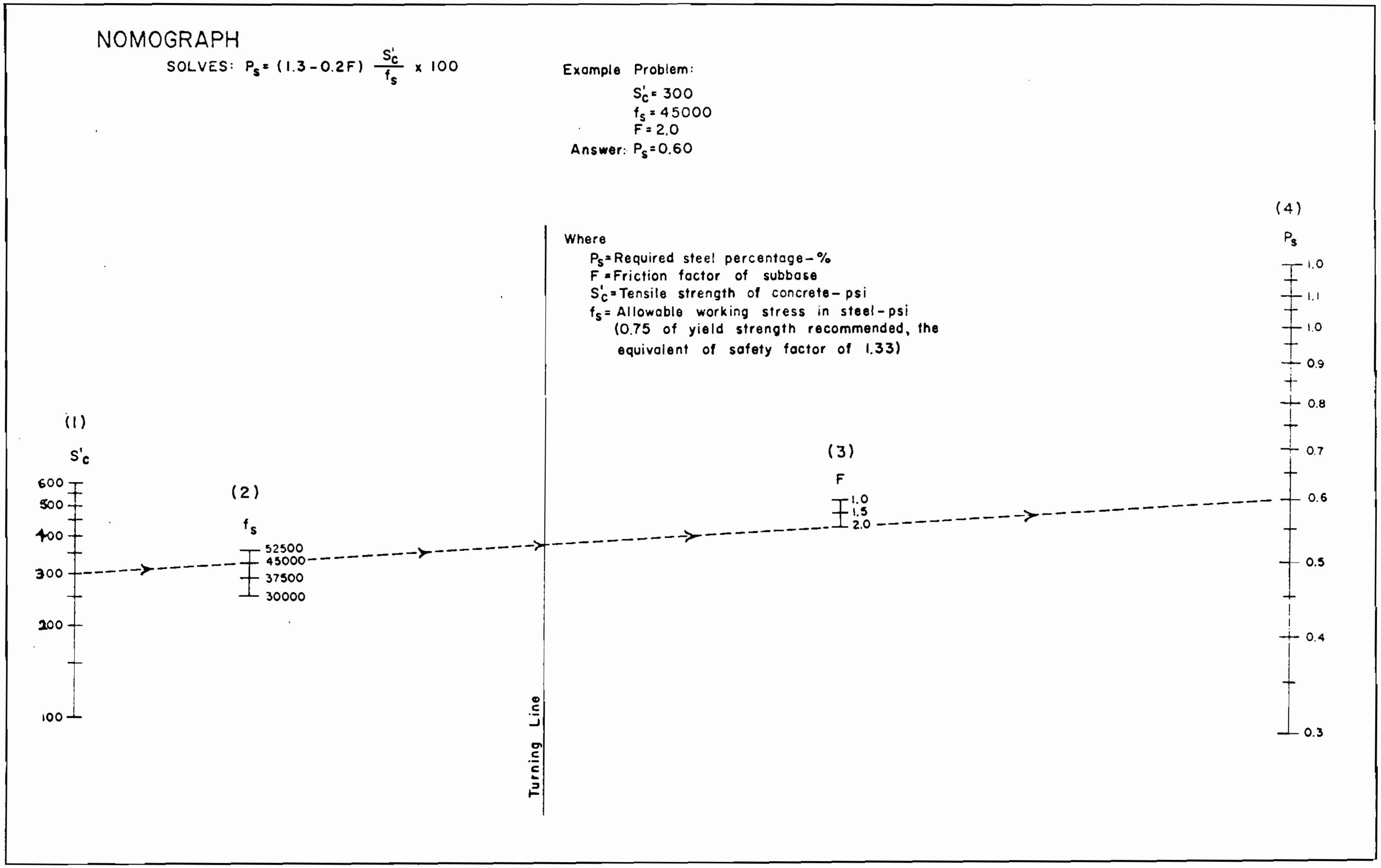

Fig 4.9. Longitudinal steel for CPCR.

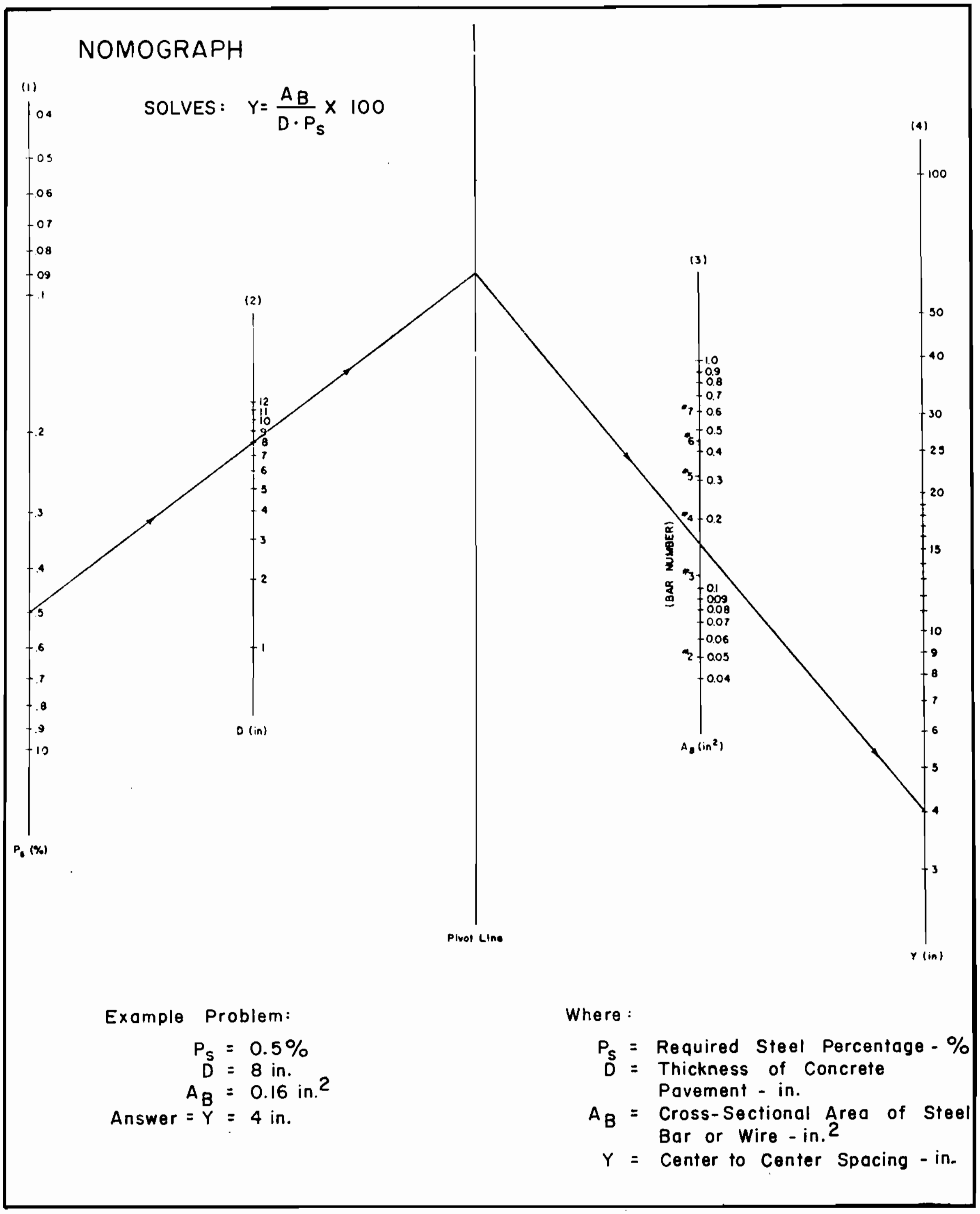

Fig 4.10. Bar spacing design.

continuity condition across a transverse crack (full load transfer) is lost when the percentage of longitudinal steel decreases below 0.4 percent. Pavements with less than 0.4 percent have stayed in service for extended periods, but not without problems. In special cases, where the concrete coarse aggregate has a thermal coefficient of from 2×10^{-6} to 4×10^{-6} in/in/^{o}F, the minimum allowable longitudinal steel can be reduced to 0.35 percent.

(b) Jointed, Light Reinforcement

The distributed steel reinforcement requirement for lightly reinforced jointed concrete pavements can also be obtained from Fig 4.11. Recommended reinforcement details for jointed concrete pavements are reflected in Standard Design Details for Contraction Design & Jointed Reinforced Design with Steel Bars and Welded Wire Fabric (see Standard Design Details listed in Appendix A).

4-403.10 TERMINAL TREATMENT

(a) Anchorage Systems

The termini or ends of portland cement concrete pavements may require special treatment in order to reduce the detrimental effects of pavement movement. The use of anchor lug systems is optional, depending upon the district's experience with such pavement growth. Table 4.7 is a table of terminal treatment showing the number of end anchorages required for different subbase types to combat a 100^{o} F temperature change. The number of end anchorages may be determined by entering the table with the subbase type and the allowable movement for the expansion joint sealer material proposed for use.

For an anchorage system containing five anchor lugs, design details are shown in Standard Design Details listed in Appendix A.

The recommended anchor lug details for jointed concrete pavement are shown in Standard Design Details listed in Appendix A.

(b) Bridge Approach Slabs

The bridge approach slab is a heavily reinforced slab placed between a bridge and a pavement end. The approach slab is designed to perform as an unsupported slab over a short length. The use of approach slabs is optional

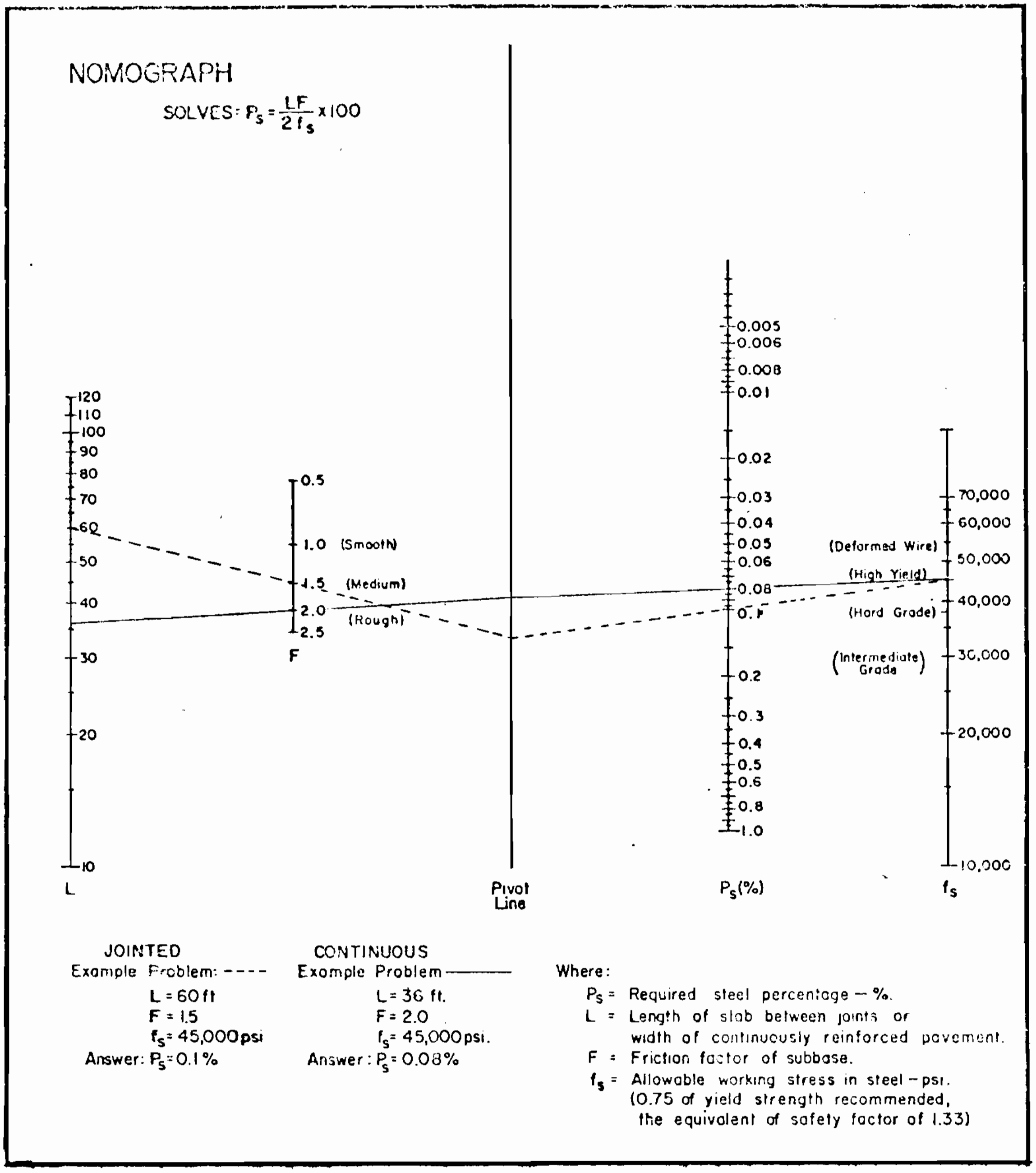

Fig 4.11. Distributed steel for jointed concrete pavement and transverse steel for continuous concrete pavement.

TABLE 4.7 RECOMMENDED NUMBER OF ANCHOR LUGS FOR SUBBASE TYPE AND ALLOWABLE JOINT MOVEMENT

Subbase Type*	Number of Lugs for Allowable Joint Movements of	
	± 1/2 in.**	± 1/4 in.**
Surface treatment (chip seal)	0	0
Lime stabilization	0	2
Asphalt stabilization	0	2
Cement stabilization	0	2
River gravel	0	2
Crushed stones	0	2
Sandstone	2	4
Natural soil	3	6

Notes:

These recommendations were derived from a field study in Texas.

* The material that the CPCR is resting directly on should be used in this analysis.

** The number of terminal anchor lugs required to restrict the end movement to variation indicated.

depending upon experience in the locality. Recommended design details are shown in Standard Design Details listed in Appendix A.

REFERENCES USED IN APPENDIX B

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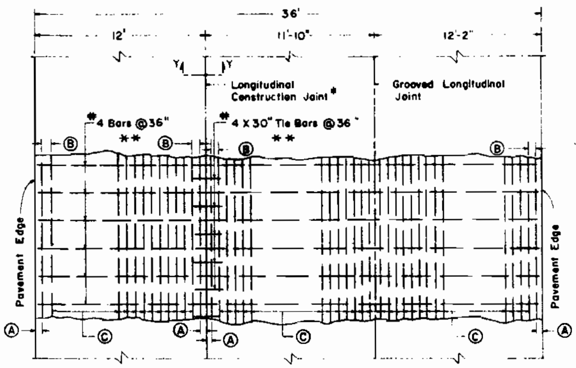
APPENDIX C.1

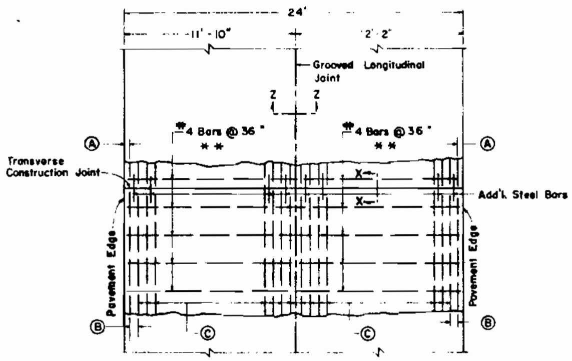
REVISED
TEXAS HIGHWAY DEPARTMENT RIGID
PAVEMENT DESIGN STANDARDS



THREE LANE PAVEMENT PLAN

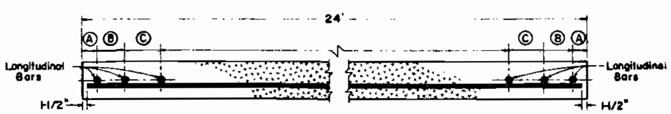
(12ft. and 24ft. Placement)

* WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUDINAL JOINT.



TWO LANE PAVEMENT PLAN

(24ft. Placement)*

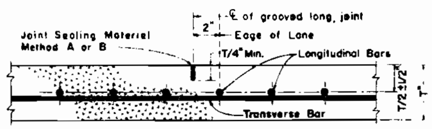


TYPICAL SECTION

(24ft. Placement)

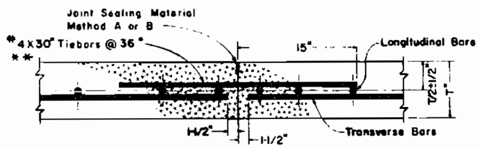
*LANE WIDTHS ARE FOR ILLUSTRATIVE PURPOSES ONLY AND SHOULD NOT BE USED IF IN CONFLICT WITH TYPICAL CROSS SECTIONS SHOWN ELSEWHERE IN THE PLANS.

Per Cent Long Steel	Pavement Thickness "T" in.	Bar Size	24 ft. Placement Width: Spacing c-c (A) in	(B) in	(C) in	No. of Bars	Steel #/sy (1)	12 ft. Placement Width: Spacing c-c (A) in	(B) in	(C) in	No. of Bars	Steel #/sy (1)	Add'l Steel @ Trans. Const. Jt.: Size	(2) No. per 24' place. width	(2) No. per 12' place. width	Weight #/ft, based on 12' placement
0.5	10	No.6	3	5	8.5	35	21.72	3	5.25	8.5	18	22.28	3/4"ø x36"	18	9	3.38
	9	No.5	3	4.5	6.5	45	19.60	3	4	6.5	23	20.00	5/8"ø x36"	22	11	2.87
	8	No.5	3	6	7.5	39	17.26	3	5.25	7.5	20	17.65	5/8"ø x36"	20	10	2.61
	7	No.5	3	5	8.5	35	15.69	4	8.5	8.5	17	15.30	5/8"ø x36"	18	9	2.35
	6	No.4	3	4.5	7	42	12.53	3	6	7	21	12.53	1/2"ø x36"	20	11	1.84
0.6	10	No.6	3	7	7.25	40	24.53	3	7.25	7.25	20	24.53	3/4"ø x36"	20	10	3.76
	9	No.6	3	5	8	37	22.84	3	5	8	19	23.41	3/4"ø x36"	19	10	3.76
	8	No.5	3	6.25	6.25	46	20.00	3	3.5	6.25	24	20.78	5/8"ø x36"	23	11	2.61
	7	No.5	3	7	7.25	40	17.65	3	7.25	7.25	20	17.63	5/8"ø x36"	20	10	2.61
	6	No.5	3	5	8.5	35	15.69	3	5.25	8.5	18	16.08	5/8"ø x36"	18	9	2.38



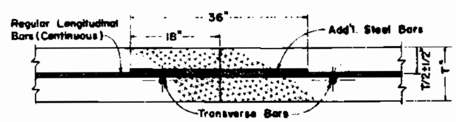
GROOVED LONGITUDINAL JOINT

Section Z-Z



LONGITUDINAL CONSTRUCTION JOINT

Section Y-Y



TRANSVERSE CONSTRUCTION JOINT

Section X-X

(REV.)

** SEE DESIGN DETAIL RC(CPCR)-71A FOR STEEL REQUIREMENTS FOR RAMP CONNECTIONS.

GENERAL NOTE

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. WITHIN ANY AREA BOUNDED BY TWO FEET OF PAVEMENT LENGTH MEASURED PARALLEL TO THE CENTERLINE AND TWELVE FEET OF PAVEMENT WIDTH MEASURED PERPENDICULAR TO THE PAVEMENT CENTERLINE, NOT OVER 33% OF THE REGULAR LONGITUDINAL STEEL SHALL BE SPLICED.
5. LONGITUDINAL AND TRANSVERSE BARS SHALL BE STEEL CONFORMING TO ASTM A-615 OR ASTM A-616 (GRADE 60) AS NOTED IN THE SPECIFICATIONS.
6. SPLICES SHALL BE A MINIMUM OF 24 TIMES THE NOMINAL DIAMETER OF THE BAR.
7. BARS OF ASTM DESIGNATIONS: A-615 OR A-616, GRADE 60 STEEL SHALL NOT BE BENT. IF THE CONTRACTOR ELECTS TO BEND THE TIEBARS, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, AND SPACED AT 24" C-C.
8. AT TRANSVERSE CONSTRUCTION JOINTS THE REGULAR LONGITUDINAL BARS SHALL EXTEND BEYOND THE JOINT SO THAT THE BAR SPLICES FOR THE REGULAR LONGITUDINAL BARS SHALL BE A MINIMUM OF FOUR FEET FROM THE CONSTRUCTION JOINT. AT LONGITUDINAL CONSTRUCTION JOINTS IF THE CONTRACTOR ELECTS TO CONTINUE THE REGULAR TRANSVERSE STEEL THROUGH THE JOINT- THE #4 ØTIEBARS SHOWN HEREON MAY BE DELETED. VIBRATION WITH HAND MANIPULATED MECHANICAL VIBRATORS WILL BE REQUIRED ADJACENT TO ALL TRANSVERSE CONSTRUCTION JOINTS.
9. WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.
10. THE CHAIRS USED TO SUPPORT THE BAR MAT SHALL BE OF SUFFICIENT STRUCTURAL QUALITY AND NUMBER TO HOLD THE MAT WITHIN THE PLACEMENT HEIGHT TOLERANCES, AND SHALL BE OF A TYPE APPROVED BY THE ENGINEER.
11. IN THE NORMAL 36" PLACEMENT FOR THE TRANSVERSE BARS, CHAIRS SHALL BE PLACED UNDER EVERY TRANSVERSE BAR. THE TRANSVERSE SPACING SHALL BE A 36" MAXIMUM. PLACEMENT MAY BE STAGGERED SO THAT CHAIRS IN ALTERNATE ROWS ARE CENTERED BETWEEN THE CHAIRS IN ADJACENT ROWS.
12. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
13. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE-TWELFTH OF THE SPACING SHOWN HEREON.
14. WHEN MACHINE PLACING OF STEEL REINFORCEMENT IS USED, THE USE OF CHAIRS SHALL NOT BE REQUIRED, AND THE TRANSVERSE STEEL MAY BE PLACED EITHER ABOVE OR BELOW THE LONGITUDINAL STEEL.

NOTE: THE SPACINGS (B) SHOWN IN THE ABOVE PLACEMENT TABLE ARE THE MAXIMUM ALLOWABLE SPACINGS. WHERE THE PROPOSED PLACEMENT WIDTHS VARY FROM THE BASIC DESIGN WIDTH SHOWN, THE SPACING (B) AND THE ADJACENT SPACING (C) SHALL BE ADJUSTED TO ACCOMMODATE A REINFORCEMENT ARRANGEMENT EQUAL TO OR SLIGHTLY HEAVIER THAN THAT SHOWN AS DIRECTED BY THE ENGINEER.

(1) INCLUDES BOTH REGULAR LONGITUDINAL AND TRANSVERSE BARS BASED UPON 1 FOOT PAVEMENT LENGTHS FOR THE WIDTH INDICATED. ALL TRANSVERSE STEEL IS #4 BARS AT 36" CENTERS. **

(2) THIS SHALL BE THE MINIMUM NUMBER OF ADDITIONAL STEEL BARS TO BE PLACED PER LANE. THE SPACING OF THE ADDITIONAL STEEL BARS SHALL BE VARIED AS DIRECTED IN ORDER TO PROVIDE A MINIMUM CLEARANCE OF 1-3/4" FROM EACH REGULAR LONGITUDINAL REINFORCING BAR.

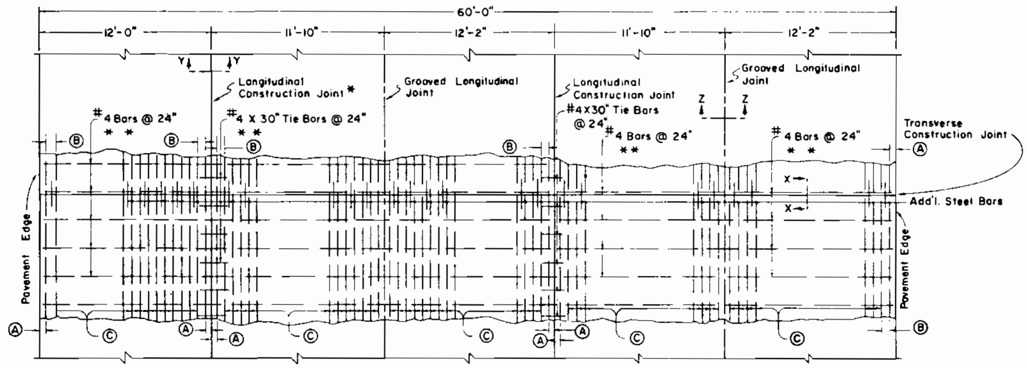
TEXAS HIGHWAY DEPARTMENT

CONCRETE PAVEMENT DETAILS CONTINUOUSLY REINFORCED

STEEL BARS

CPCR (B)-71 (1)

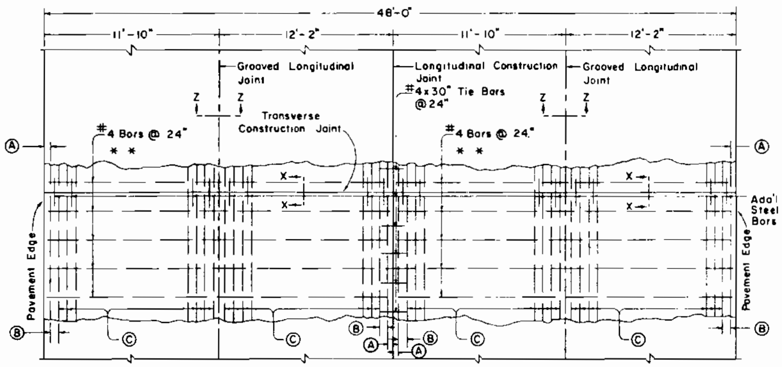
	DRAWING	DATE
DN.		
CK.DN.	ORIGINAL	FEB. 1969
DW.	REVISED	DEC.1, 1969
CK.DW.		
TR.		
CK.TR.		



FIVE LANE PAVEMENT PLAN

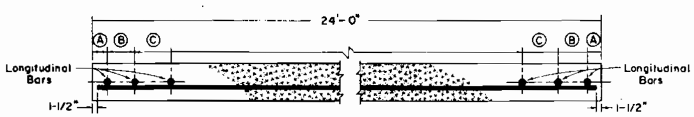
(12 ft. and 24 ft. Placement)

*WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUDINAL JOINT.



FOUR LANE PAVEMENT PLAN

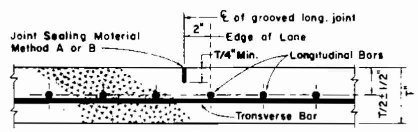
(24 ft Placement)



TYPICAL SECTION

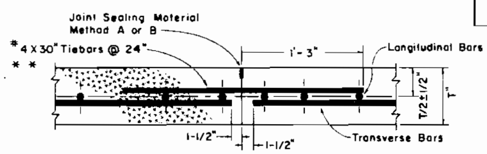
(24 ft. Placement)

*LANE WIDTHS ARE FOR ILLUSTRATIVE PURPOSES ONLY AND SHOULD NOT BE USED IF IN CONFLICT WITH TYPICAL CROSS SECTIONS SHOWN ELSEWHERE IN THE PLANS.



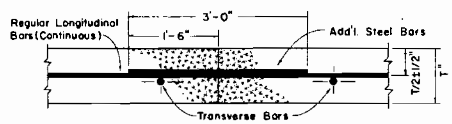
GROOVED LONGITUDINAL JOINT

Section Z–Z



LONGITUDINAL CONSTRUCTION JOINT

Section Y–Y



TRANSVERSE CONSTRUCTION JOINT

(Bar) Section X–X

** SEE DESIGN DETAIL RC(CPCR)-71 FOR STEEL REQUIREMENTS NEAR RAMP CONNECTIONS.

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS
2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT, REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. WITHIN ANY AREA BOUNDED BY TWO FEET OF PAVEMENT LENGTH MEASURED PARALLEL TO THE CENTERLINE AND TWELVE FEET OF PAVEMENT WIDTH MEASURED PERPENDICULAR TO THE PAVEMENT CENTERLINE, NOT OVER 33% OF THE REGULAR LONGITUDINAL STEEL SHALL BE SPLICED.
5. LONGITUDINAL AND TRANSVERSE BARS SHALL BE STEEL CONFORMING TO ASTM A-615 OR ASTM A-616 (GRADE 60) AS NOTED IN THE SPECIFICATIONS.
6. SPLICES SHALL BE A MINIMUM OF 24 TIMES THE NOMINAL DIAMETER OF THE BAR.
7. BARS OF ASTM DESIGNATIONS; A-615 OR A-616, GRADE 60 STEEL SHALL NOT BE BENT. IF THE CONTRACTOR ELECTS TO BEND THE TIEBARS, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATIONS: A-615, GRADE 40 AND SPACED 22" C-C, FOR 37' TO 60' PAVEMENT WIDTHS.
8. AT TRANSVERSE CONSTRUCTION JOINTS THE REGULAR LONGITUDINAL BARS SHALL EXTEND BEYOND THE JOINT SO THAT THE BAR SPLICES FOR THE REGULAR LONGITUDINAL BARS SHALL BE A MINIMUM OF FOUR FEET FROM THE CONSTRUCTION JOINT. AT LONGITUDINAL CONSTRUCTION JOINTS IF THE CONTRACTOR ELECTS TO CONTINUE THE REGULAR TRANSVERSE STEEL THROUGH THE JOINT, THE #4 TIEBARS SHOWN HEREON MAY BE DELETED. VIBRATION WITH HAND MANIPULATED MECHANICAL VIBRATORS WILL BE REQUIRED ADJACENT TO ALL TRANSVERSE CONSTRUCTION JOINTS.
9. WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.
10. THE CHAIRS USED TO SUPPORT THE BAR MAT SHALL BE OF SUFFICIENT STRUCTURAL QUALITY AND NUMBER TO HOLD THE MAT WITHIN THE PLACEMENT HEIGHT TOLERANCES, AND SHALL BE OF A TYPE APPROVED BY THE ENGINEER.
11. IN THE NORMAL 24" PALCEMENT FOR THE TRANSVERSE BARS, CHAIRS SHALL BE PLACED UNDER EVERY TRANSVERSE BAR. THE TRANSVERSE SPACING SHALL BE A 48" MAXIMUM. PLACEMENT MAY BE STAGGERED SO THAT CHAIRS IN ALTERNATE ROWS ARE CENTERED BETWEEN THE CHAIRS IN ADJACENT ROWS.
12. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
13. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE-TWELFTH OF THE SPACING SHOWN HEREON.
14. WHEN MACHINE PLACING OF STEEL REINFORCEMENT IS USED, THE USE OF CHAIRS WILL NOT BE REQUIRED, AND THE TRANSVERSE STEEL MAY BE PLACED EITHER ABOVE OR BELOW THE LONGITUDINAL STEEL.

*Per Cent Long Steel	Pavement Thickness "T" in.	Bar Size	24 ft. Placement Width: Spacing c-c (A) in	(B) in	(C) in	No. of Bars	Steel #/sy (1)	12 ft. Placement Width: Spacing c-c (A) in	(B) in	(C) in	No. of Bars	Steel #/sy (1)	Add'l Steel @ Trans. Const. Jt.: Size	(2) No. per 24' place. width	(2) No. per 12' place. width	Weight #/ft, based on 12' place.
0.5	10	No.6	3	5	8.5	35	22.72	3	5.25	8.5	18	23.28	3/4"ø x36"	18	9	3.38
	9	No.5	3	4.5	6.5	45	20.61	3	A	6.5	23	21.00	5/8"ø x36"	22	11	2.87
	8	No.5	3	6	7.5	39	18.26	3	5.25	7.5	20	18.65	5/8"ø x36"	20	10	2.61
	7	No.5	3	5	8.5	35	16.70	4	8.5	8.5	17	16.30	5/8"ø x36"	18	9	2.35
	6	No.4	3	4.5	7	42	13.53	3	6	7	21	13.53	1/2"ø x36"	20	11	1.84
0.6	10	No.6	3	7	7.25	40	25.52	3	7.25	7.25	20	25.52	3/4"ø x36"	20	10	3.76
	9	No.6	3	5	8	37	23.85	3	5	8	19	24.41	3/4"ø x36"	19	10	3.76
	8	No.5	3	6.25	6.25	46	21.00	3	3.5	6.25	24	21.78	5/8"ø x36"	23	11	2.87
	7	No.5	3	7	7.25	40	18.65	3	7.25	7.25	20	18.65	5/8"ø x36"	20	10	2.61
	6	No.5	3	5	8.5	35	16.70	3	5.25	8.5	18	17.09	5/8"ø x36"	18	9	2.35

NOTE: THE SPACINGS (B) SHOWN IN THE ABOVE PLACEMENT TABLE ARE THE MAXIMUM ALLOWABLE SPACINGS. WHERE THE PROPOSED PLACEMENT WIDTHS VARY FROM THE BASIC DESIGN WIDTH SHOWN, THE SPACING (B) AND THE ADJACENT SPACING (C) SHALL BE ADJUSTED TO ACCOMMODATE A REINFORCEMENT ARRANGEMENT EQUAL TO OR SLIGHTLY HEAVIER THAN THAT SHOWN AS DIRECTED BY THE ENGINEER.

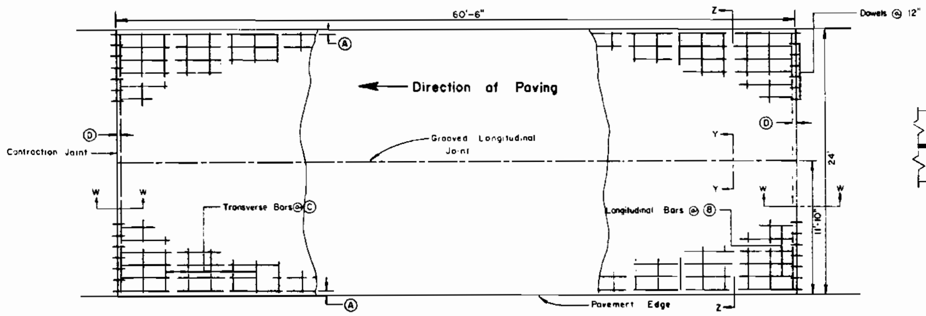
1. INCLUDES BOTH REGULAR LONGITUDINAL AND TRANSVERSE BARS BASED UPON 1 FOOT PAVEMENT LENGTHS FOR THE WIDTH INDICATED. ALL TRANSVERSE STEEL IS #4 BARS AT 24" CENTERS.**
2. THIS SHALL BE THE MINIMUM NUMBER OF ADDITIONAL STEEL BARS TO BE PLACED PER LANE. THE SPACING OF THE ADDITIONAL STEEL BARS SHALL BE VARIED AS DIRECTED IN ORDER TO PROVIDE A MINIMUM CLEARANCE OF 1-3/4" FROM EACH REGULAR LONGITUDINAL REINFORCING BAR.

TEXAS HIGHWAY DEPARTMENT

CONCRETE PAVEMENT DETAILS CONTINUOUSLY REINFORCED

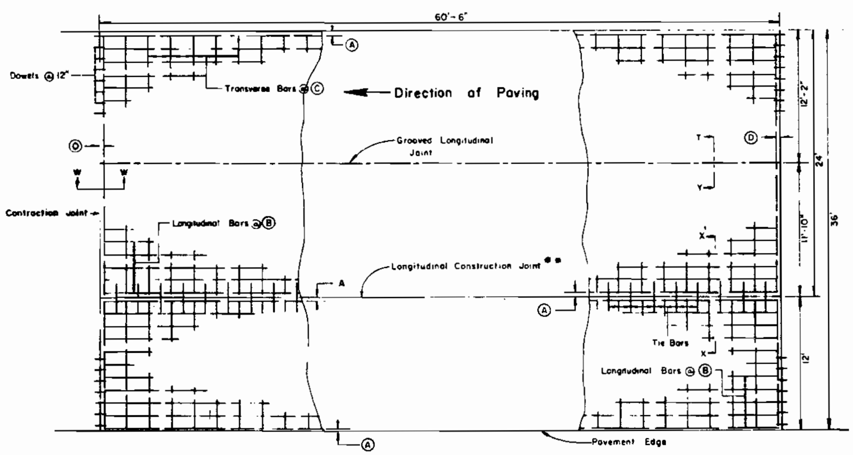
STEEL BARS

CPCR (B)-71 (2)



TWO LANE PAVEMENT PLAN

(24 ft. Placement)*

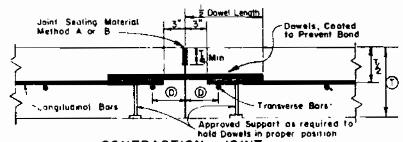


THREE LANE PAVEMENT PLAN

(12 ft. and 24 ft. Placement)*

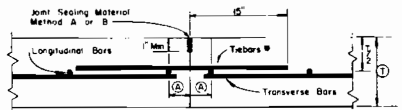
**WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUDINAL JOINT.

*Lane widths are for illustrative purposes only and should not be used if in conflict with typical cross sections shown elsewhere in the plans.



CONTRACTION JOINT

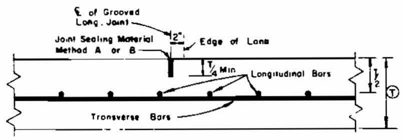
Section W—W



*WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.

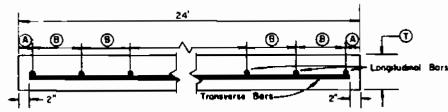
LONGITUDINAL CONSTRUCTION JOINT

Section X—X



GROOVED LONGITUDINAL JOINT

Section Y—Y



TYPICAL SECTION

Section Z—Z

GENERAL NOTES

1. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
2. CONSTRUCTION JOINTS MAY BE FORMED BY THE USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.
3. TREATMENT OF PAVEMENT ENDS AT STRUCTURES OR AT FIXED OBJECTS WILL BE SHOWN ELSEWHERE IN THE PLANS.
4. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
5. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
6. LONGITUDINAL AND TRANSVERSE BARS SHALL BE OF STEEL CONFORMING TO ASTM DESIGNATIONS; A-615 OR ASTM A-616 (GRADE 60) AS NOTED IN THE SPECIFICATIONS. THE SIZE AND SPACING SHALL BE IN ACCORDANCE WITH TABLE SHOWN BELOW.
7. BARS OF ASTM DESIGNATION: A-615 OR A-616, GRADE 60, SHALL NOT BE BENT. IF THE CONTRACTOR ELECTS TO BEND THE TIE BARS, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION; A-615, GRADE 40, AND SPACED AT 24" C-C.
8. IT IS THE INTENT OF THIS DESIGN THAT THE LONGITUDINAL STEEL BE AT THE CENTER OF THE SLAB. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO TAKE ALL NECESSARY PRECAUTIONS TO INSURE THAT THE FINAL POSITION OF THE STEEL IS WITHIN 1/2 INCH OF THE SLAB CENTER.
9. CONCRETE SHALL NOT BE DISCHARGED FROM THE MIXER DIRECTLY ON TOP OF OR ON THE SIDES OF THE JOINT ASSEMBLY.
10. ANY APPROVED METAL CHAIR TYPE OR DESIGN, WHICH WILL SATISFY THE REQUIREMENTS NOTED HEREON WILL BE PERMITTED. CHAIR SPACINGS SHALL NOT BE GREATER THAN 60" C-C MEASURED PARALLEL TO THE PAVEMENT CENTER LINE AND 30" C-C MEASURED PERPENDICULAR TO THE PAVEMENT CENTER LINE. ADDITIONAL CHAIRS SHALL BE USED IF NECESSARY TO MEET THE STEEL PLACEMENT REQUIREMENT.
11. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.
12. SEE RC(CPCR)-71(REV.) FOR STEEL PLACING REQUIREMENTS IN THE AREA OF CONFLUENCE AT RAMP TERMINALS.

TABLE OF REINFORCING STEEL SIZES, SPACINGS AND ESTIMATED QUANTITIES

ALTERNATE DESIGNS ①	PAVEMENT THICKNESS Ⓣ (INCHES)	24' PLACEMENT WIDTH: LONGITUDINAL BAR #	SPAC Ⓐ (IN.)	SPAC Ⓑ (IN.)	TRANSVERSE BAR #	SPAC Ⓒ (IN.)	SPAC Ⓓ (IN.)	② STEEL #/SY	12' PLACEMENT WIDTH: LONGITUDINAL BAR #	SPAC Ⓐ (IN.)	SPAC Ⓑ (IN.)	TRANSVERSE BAR #	SPAC Ⓒ (IN.)	SPAC Ⓓ (IN.)	② STEEL #/SY	DOWELS (SMOOTH BARS) SIZE	AVG SPAC (IN.)	WT #/FT OF JT	TIE BARS (DEFORMED ③) SIZE	AVG SPAC (IN.)	WT #/FT OF JT
L	10	3	5½	10¼	4	36	3	5.96	3	5½	10¼	4	36	3	5.94	1¼" x 22"	12	7.65	#4 x 30"	36	0.56
	9	3	6	11½	4	36	3	5.54	3	3	11½	4	36	3	5.66	1⅛" x 20"	12	5.63	#4 x 30"	36	0.56
	8	3	5	13¾	4	36	3	5.12	3	5¾	13¾	4	36	3	5.11	1" x 18"	12	4.01	#4 x 30"	36	0.56
H	10	3	4½	7¾	4	24	3	8.17	3	2¼	7¾	4	24	3	8.26	1¼" x 22"	12	7.65	#4 x 30"	30	0.67
	9	3	6	8⅝	4	26¼	5¼	7.32	3	3	8⅝	4	28½	5¼	7.42	1⅛" x 20"	12	5.63	#4 x 30"	30	0.67
	8	3	4½	9⅝	4	30	3	6.61	3	4½	9⅝	4	30	3	6.56	1" x 18"	12	4.01	#4 x 30"	30	0.67

NOTE:

① One of the alternate designs must be crossed out
  a. L alternate—to be used with subbases having a low friction factor.
  b. H alternate—to be used with subbases having a high friction factor.

② Steel weights are for contractor's use only and include weights of longitudinal and transverse bars.

③ Spacings shown are for ASTM Designation: A-615 or A-616, Grade 60 Tiebars

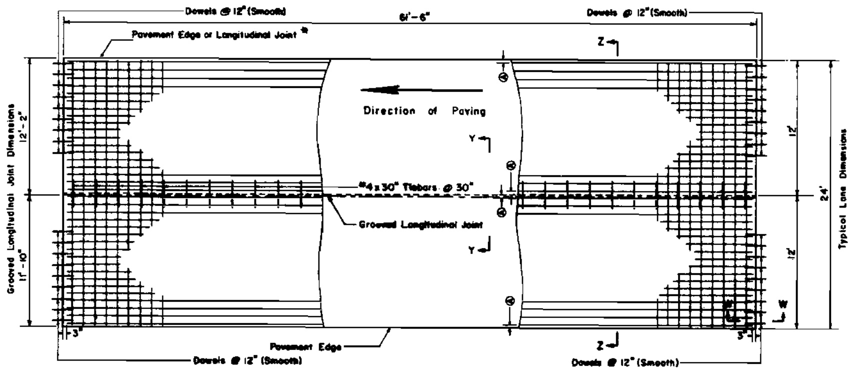
TEXAS HIGHWAY DEPARTMENT

CONCRETE PAVEMENT DETAILS

JOINTED REINFORCED

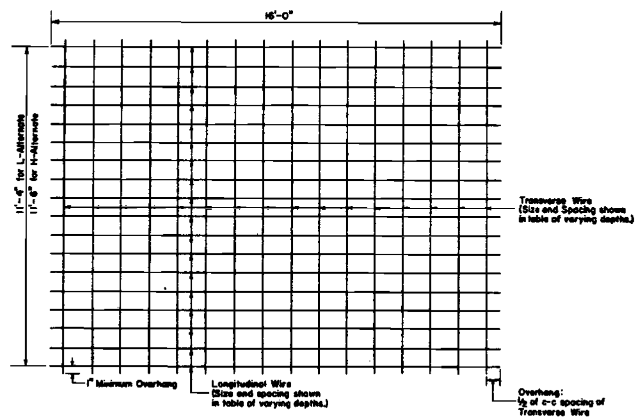
STEEL BARS

CPJR (B) — 71 (REV.)



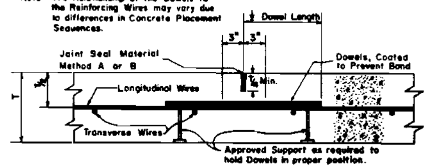
PAVEMENT PLAN

*WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUDINAL JOINT.



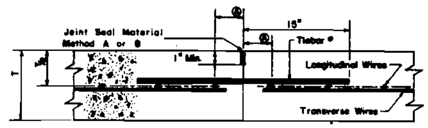
TYPICAL SHEET OF WELDED WIRE FABRIC

Note: The Relationship of the Dowels to the Reinforcing Wires may vary due to differences in Concrete Placement Sequences.



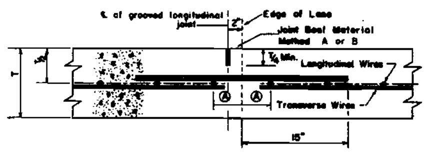
CONTRACTION JOINT

Section W-W



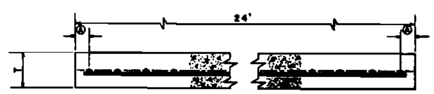
*WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM YIELD FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.

LONGITUDINAL CONSTRUCTION JOINT



GROOVED LONGITUDINAL JOINT

Section Y-Y



TYPICAL SECTION

Section Z-Z

GENERAL NOTES

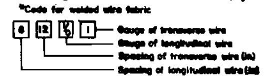
1. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
2. CONSTRUCTION JOINTS MAY BE FORMED BY THE USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE
3. TREATMENT OF PAVEMENT ENDS AT STRUCTURES OR AT FIXED OBJECTS WILL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
5. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
6. THE MINIMUM TRANSVERSE LAP OF THE WELDED WIRE FABRIC SHALL BE 12 INCHES LONG. THE MINIMUM LONGITUDINAL LAP, IF USED, SHALL BE EQUAL TO THE CENTER TO CENTER SPACING OF THE LONGITUDINAL WIRE.
7. IT IS THE INTENT OF THIS DESIGN THAT THE LONGIDUTINAL STEEL BE AT THE CENTER OF THE SLAB. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO TAKE ALL NECESSARY PRECAUTIONS TO INSURE THAT THE FINAL POSITION OF THE STEEL IS WITHIN 1/2 INCH OF THE SLAB CENTER.
8. CONCRETE SHALL NOT BE DISCHARGED FROM THE MIXER DIRECTLY ON TOP OF OR ON THE SIDES OF THE JOINT ASSEMBLY.
9. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.
10. SEE BC (CPCR)-71 (REV.) FOR STEEL PLACING REQUIREMENTS IN THE AREA OF CONFLUENCE AT RAMP TERMINALS.

TABLE OF VARYING DEPTHS

Alternate Designs [1]	(T) Pavement Thickness (inches)	Steel Welded Wire Fabric # Style No.	Edge Spacing Ⓐ	Weight [2] #/sy	Dowels (Smooth Bars) Size	Average Spacing (in.)	Weight #/lin. ft.	Tiebars [3] (Deformed Bars) Size	Average Spacing (in.)	Weight #/lin. ft.
L	10	812-2/0 1/0	4	6.35	1¼" x22"	12	7.65	#4 x30"	30	0.67
	9	812-2/0 1/0	4	6.35	1⅛" x20"	12	5.63	#4 x30"	30	0.67
	8	812-1/0 1	4	5.44	1" x18"	12	4.01	#4 x30"	30	0.67
H	10	66-2/0 1/0	3	8.90	1¼" x22"	12	7.65	#4 x30"	30	0.67
	9	66-2/0 1	3	8.39	1⅛" x20"	12	5.63	#4 x30"	30	0.67
	8	66-1/0 2	3	7.21	1" x18"	12	4.01	#4 x30"	30	0.67

1. One of the alternate designs must be crossed out.
   a. L alternate – to be used with subbases having a low friction factor.
   b. H alternate – to be used with subbases having a high friction factor.
2. Steel weights are for contractors information only.

#Code for welded wire fabric

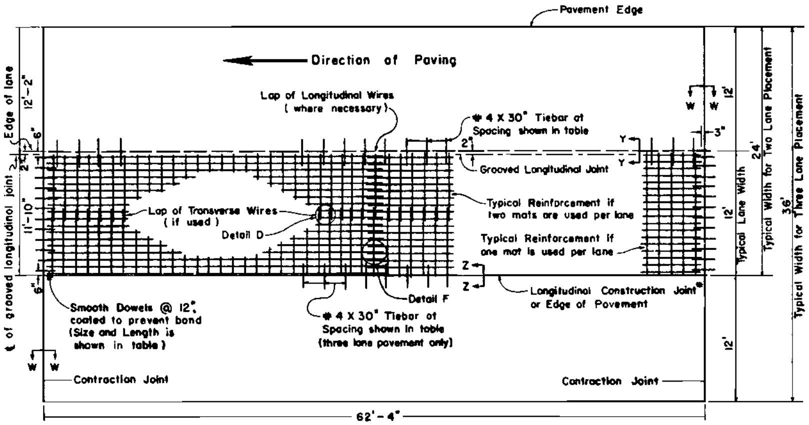


3. Spacings shown are for ASTM Designation: A-615 or A-616, Grade 60, tiebars. If tiebars are to be bent, they shall be steel conforming to ASTM Designation: A-615, Grade 60, and spaced at 24" C-C.

TEXAS HIGHWAY DEPARTMENT

CONCRETE PAVEMENT DETAILS
JOINTED REINFORCED
WELDED WIRE FABRIC

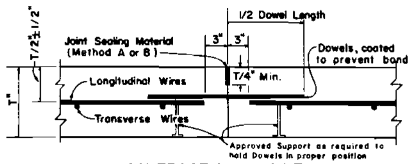
CPJR (F) – 71 (REV)



PAVEMENT PLAN SHOWING TYPICAL REINFORCEMENT PATTERN FOR ONE LANE

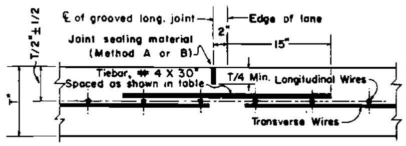
NOTE: LANE WIDTHS ARE FOR ILLUSTRATIVE PURPOSES ONLY AND SHOULD NOT BE USED IF IN CONFLICT WITH TYPICAL CROSS SECTIONS SHOWN ELSEWHERE IN THE PLANS.

*WITH THE APPROVAL OF THE ENGINEER, THE CONTRACTOR MAY PLACE THE PAVEMENT THE FULL ROADWAY WIDTH AS ONE PLACEMENT. IF SO PLACED, THE LONGITUDINAL CONSTRUCTION JOINT SHOWN SHALL BE REPLACED BY THE GROOVED LONGITUNINAL JOINT.



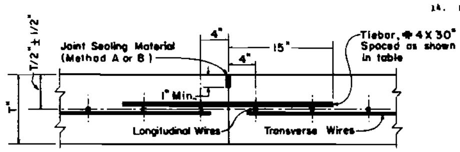
CONTRACTION JOINT

SECTION W-W



GROOVED LONGITUDINAL JOINT

SECTION Y-Y



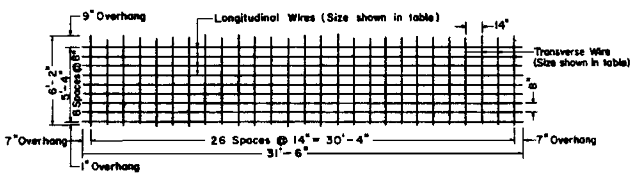
LONGITUDINAL CONSTRUCTION JOINT

(with tiebars)

SECTION Z-Z

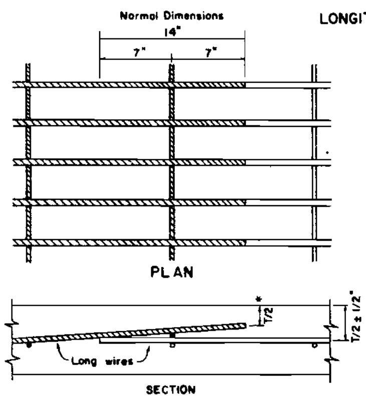
GENERAL NOTES

1. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
2. CONSTRUCTION JOINTS MAY BE FORMED BY THE USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.
3. TREATMENT OF PAVEMENT ENDS AT STRUCTURES OR AT FIXED OBJECTS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
4. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".
5. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.
6. THE MINIMUM LAP OF THE LONGITUDINAL WIRES SHALL BE EQUAL TO THE CENTER TO CENTER SPACING OF THE TRANSVERSE WIRES AS SHOWN IN DETAIL "F".
7. IT IS THE INTENT OF THIS DESIGN THAT THE LONGITUDINAL STEEL BE AT THE CENTER OF THE SLAB. IT SHALL BE THE RESPONSIBILITY OF THE CONTRACTOR TO TAKE ALL NECESSARY PRECAUTIONS TO INSURE THAT THE FINAL POSITION OF THE LONGITUDINAL STEEL IS WITHIN 1/2 INCH OF THE SLAB CENTER EXCEPT THAT THE TOLERANCE SHOWN ON THE LONGITUDINAL LAP DETAIL SHALL GOVERN AT THAT POINT. TRANSVERSE WIRES MAY BE PLACED ON TOP OR BOTTOM.
8. CONCRETE SHALL NOT BE DISCHARGED FROM THE MIXER DIRECTLY ON TOP OF OR ON THE SIDES OF THE JOINT ASSEMBLY.
9. DOWELLS LOCATED AT TRANSVERSE JOINTS SHALL BE UNIFORMLY COATED TO PREVENT BOND AS DIRECTED BY THE ENGINEER.
10. SLIGHT VARIATIONS IN MAT DIMENSIONS MAY BE ABSORBED IN THE EDGE SPACINGS.
11. TRANSVERSE AND LONGITUDINAL STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.
12. ADJACENT MATS SHALL BE SECURELY FASTENED TOGETHER IN A MANNER TO PRECLUDE SEPARATION OF THE STEEL DURING CONCRETE PLACEMENT AND FINISHING OPERATIONS.
13. SPACINGS SHOWN FOR TIEBARS ARE FOR ASTM DESIGNATION; A-615 OR A-616, GRADE 60, TIEBARS WHICH SHALL NOT BE BENT. IF TIEBARS ARE TO BE BENT THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, SPACED AT 24 INCHES C-C.
14. SEE RC(CPCR)-71 (REV.) FOR STEEL PLACING REQUIREMENTS IN THE AREA OF CONFLUENCE AT RAMP TERMINALS.



TYPICAL MAT DESIGN *

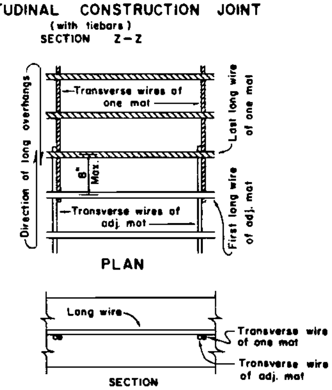
* NOTE: REINFORCEMENT MATS MAY BE FURNISHED IN THE WIDTH SHOWN OR IN THE FULL LANE WIDTH (11'-6") AT THE OPTION OF THE CONTRACTOR. ANY LENGTH MAY BE USED EXCEPT THAT NO MAT LESS THAN 16'-4" MAY BE USED WITHOUT THE PERMISSION OF THE ENGINEER. MINIMUM LAPS SHALL BE 10 INCHES FOR TRANSVERSE WIRES AND 14 INCHES FOR LONGITUDINAL WIRES AS SHOWN IN DETAILS "D" AND "F" RESPECTIVELY.



* NOTE: AT LONGITUDINAL LAPS OF MATS THE CENTERLINE OF THE BOTTOM LAYER OF LONGITUDINAL STEEL SHALL BE LOCATED WITHIN 1/2" OF THE SLAB CENTER. THE CENTERLINE OF THE UPPER LAYER OF LONGITUDINAL STEEL SHALL BE WITHIN 1 1/2" OF THE SLAB CENTER.

DETAIL F

TYPICAL LAP OF LONGITUDINAL WIRES



DETAIL D

TYPICAL LAP OF TRANSVERSE WIRES

Alternate Designs [1]	Pavement Thickness (inches)	Wire Size [2]		Weight [3] #/sy	Dowels (Smooth Bars)			Tiebars (Deformed Bars)		
		Long.	Transv.		Size	Average Spacing (inches)	Weight #/ft.-jt.	Size	Average Spacing (inches)	Weight #/ft.-jt.
L	10	D-7.6	D-7.6	5.46	1¼" X 22"	12	7.65	#4X30"	30	0.67
	9	D-6.8	D-6.8	4.88	1⅛" X 20"	12	5.63	#4X30"	30	0.67
	8	D-6.0	D-6.0	4.31	1" X 18"	12	4.01	#4X30"	30	0.67
H	10	D-10.0	D-10.0	7.18	1¼" X 22"	12	7.65	#4X30"	30	0.67
	9	D-9.0	D-9.0	6.46	1⅛" X 20"	12	5.63	#4X30"	30	0.67
	8	D-6.0	D-8.0	5.74	1" X 18"	12	4.01	#4X30"	30	0.67

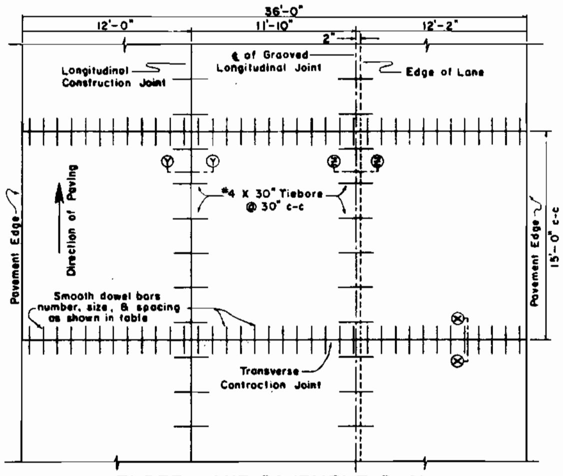
1. ONE OF THE ALTERNATE DESIGNS MUST BE CROSSED OUT.
   a. L ALTERNATE - TO BE USED WITH SUBBASES HAVING A LOW FRICTION FACTOR.
   b. H ALTERNATE - TO BE USED WITH SUBBASES HAVING A HIGH FRICTION FACTOR.
2. NUMBERS DESIGNATING WIRE SIZES GIVE THE NOMINAL AREA OF THE WIRE IN HUNDREDTHS OF AN INCH.
3. STEEL WEIGHTS ARE BASED ON 12 FT. LANE WIDTH AND LENGTH OF 62'-4" WITH ONE LONGITUDINAL AND ONE TRANSVERSE LAP. STEEL WEIGHTS ARE FOR CONTRACTORS INFORMATION ONLY.

TEXAS HIGHWAY DEPARTMENT

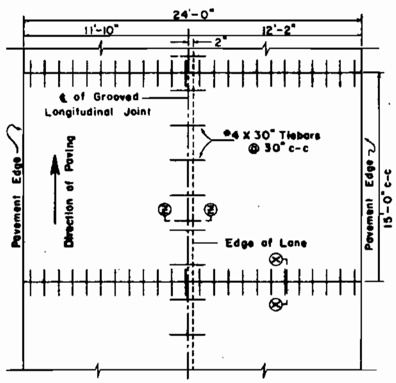
CONCRETE PAVEMENT DETAILS
JOINTED REINFORCED

DEFORMED WIRE FABRIC

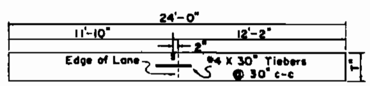
CPJR (DW) — 71 (Rev.)



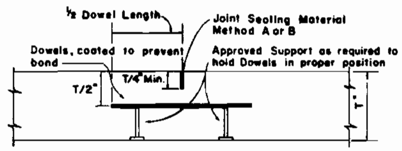
THREE LANE PAVEMENT PLAN
(12 ft. & 24 ft. Placement)*



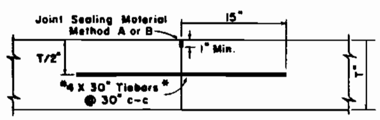
TWO LANE PAVEMENT PLAN



TYPICAL SECTION
(24 ft. Placement)*

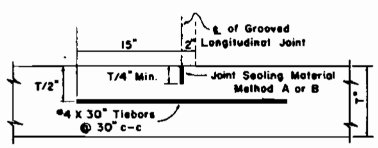


TRANSVERSE CONTRACTION JOINT
Section X-X



LONGITUDINAL CONSTRUCTION JOINT
Section Y-Y

*WITH THE APPROVAL OF THE ENGINEER, MULTIPLE PIECE TIEBARS (THREADED COUPLING OR OTHER ADEQUATE DEVICE) MAY BE USED TO FACILITATE CONSTRUCTION PROVIDED THE SYSTEM DEVELOPS A FORCE EQUAL TO 1 1/2 TIMES THE MINIMUM FORCE OF THE TIEBAR SHOWN. THE SPACINGS FOR THE SYSTEM SHALL BE LESS THAN OR EQUAL TO THE SPACING ALLOWED FOR BARS OF SIMILAR YIELD STRENGTH.



GROOVED LONGITUDINAL JOINT
Section Z-Z

* Lane widths are for illustrative purposes only and should not be used if in conflict with typical cross sections shown elsewhere in the plans.

GENERAL NOTES

1. NO EXPANSION JOINTS WILL BE USED EXCEPT AT STRUCTURE ENDS OR FIXED OBJECTS AS SHOWN ELSEWHERE IN THE PLANS.

2. FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND LOAD TRANSFER DEVICES REFER TO THE GOVERNING SPECIFICATIONS FOR "CONCRETE PAVEMENT".

3. DETAILS AS TO PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS-SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.

4. JOINT GROOVE AND SEAL DETAILS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.

5. TIEBARS SHALL BE SECURED PARALLEL TO THE PAVEMENT SURFACE AND PERPENDICULAR TO THE CENTERLINE BY:

   (a) USE OF BAR CHAIRS
   (b) ACCURATELY PLACED IN POSITION ON THE SCREEDED CONCRETE BY MEANS OF AN APPROVED TEMPLATE AND FORCED TO THE PROPER POSITION WITH A SUITABLE TOOL, OR
   (c) BY ANY OTHER MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.

6. DOWEL BARS SHALL BE SECURED PARALLEL TO THE PAVEMENT SURFACE AND CENTERLINE BY A DOWEL BAR CHAIR.

7. WHEN WORK IS STOPPED DUE TO BREAKDOWN OR OTHER CAUSE, CONCRETE SHALL BE REMOVED BEYOND LAST CONTRACTION JOINT IN PLACE AND A HEADER INSTALLED.

8. WHERE A MONOLITHIC CURB IS SPECIFIED, THE JOINT IN THE CURB SHALL COINCIDE WITH PAVEMENT JOINTS AND MAY BE FORMED BY ANY MEANS WHICH, PRIOR TO ITS USE, HAS BEEN APPROVED BY THE ENGINEER.

9. CONSTRUCTION JOINTS MAY BE FORMED BY USE OF METAL OR WOOD FORMS EQUAL IN DEPTH TO THE NOMINAL DEPTH OF THE PAVEMENT, OR BY OTHER MEANS WHICH HAVE BEEN APPROVED BY THE ENGINEER PRIOR TO THEIR USE.

10. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.

11. THE TIEBAR SPACINGS SHOWN ARE FOR ASTM DESIGNATIONS: A-615, OR A-616, GRADE 60, TIEBARS, WHICH SHALL NOT BE BENT. IF TIEBARS ARE TO BE BENT, THEY SHALL BE STEEL CONFORMING TO ASTM DESIGNATION: A-615, GRADE 40, WITH A CENTER TO CENTER SPACING OF 24 INCHES.

12. SEE RC (CPCR)-71 (REV.) FOR STEEL PLACING REQUIREMENTS IN THE AREA OF CONFLUENCE AT RAMP TERMINALS.

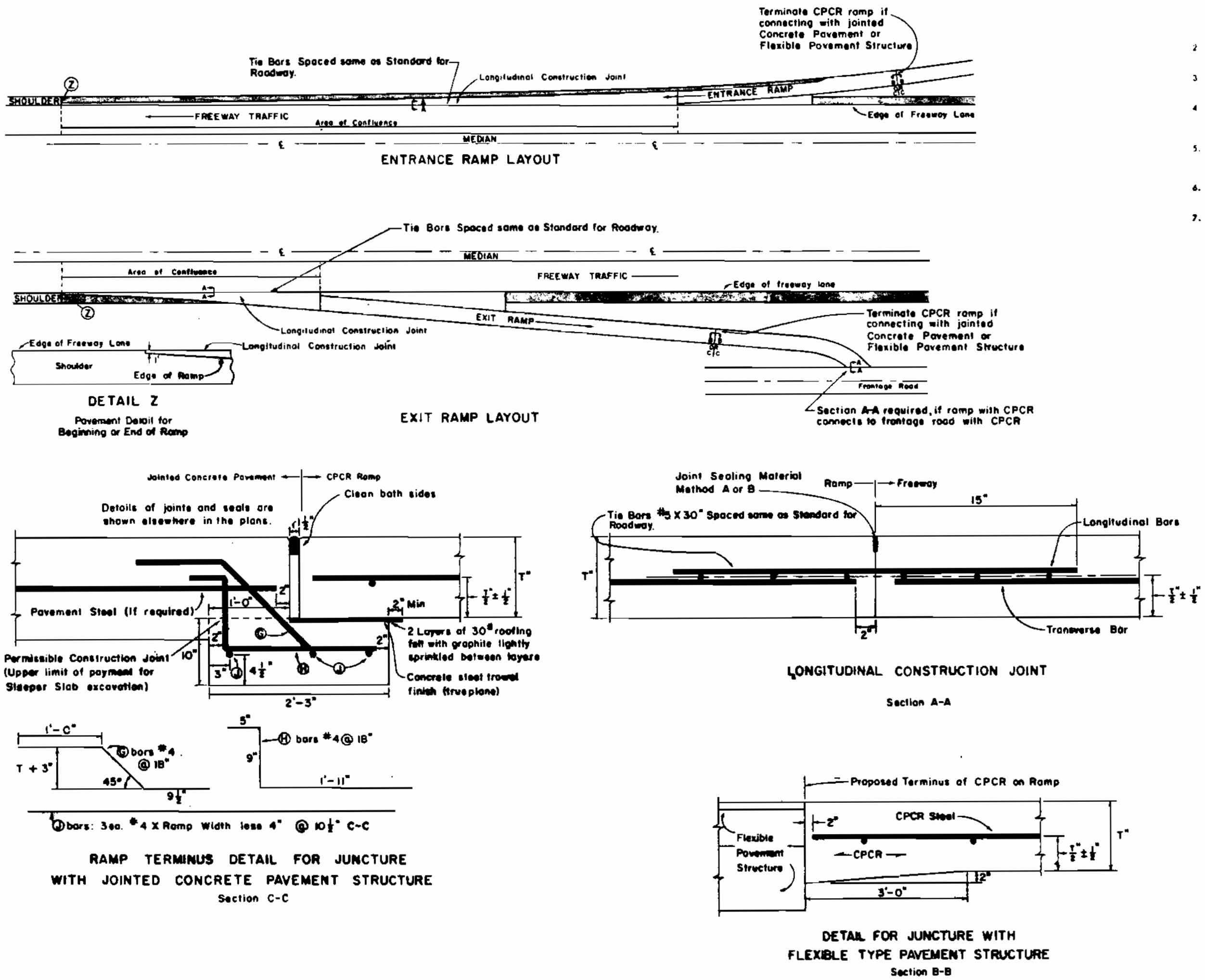
DEPTH OF PAVEMENT (INCHES)	DOWELS (SMOOTH BARS)		
	SIZE AND LENGTH	AVERAGE SPACING (INCHES)	WEIGHT PER FOOT OF JOINT (LBS.)
8	1" X 18"	12	4.01
9	1⅛" X 20"	12	5.63
10	1¼" X 22"	12	7.65
11	1⅜" X 24"	12	10.10

TEXAS HIGHWAY DEPARTMENT

CONCRETE PAVEMENT DETAILS

CONTRACTION DESIGN

CPCD-71 (Rev.)



GENERAL NOTES

FOR FURTHER INFORMATION REGARDING THE PLACEMENT OF CONCRETE AND REINFORCEMENT REFER TO THE GOVERNING SPECIFICATION FOR CONCRETE PAVEMENT.

2 RAMP DETAILS ARE TYPICAL ONLY. GEOMETRIC DETAILS AS TO ALIGNMENT, PAVEMENT WIDTH, PAVEMENT THICKNESS, AND THE CROWN CROSS SLOPE SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.

3 THE DESIGN REQUIREMENTS FOR THE PAVEMENT STRUCTURE, I.E. BAR SPACING, BAR SIZE, LAP REQUIREMENTS, ETC., SHALL BE AS SHOWN ON THE APPROPRIATE CPCR DESIGN DETAIL.

4 IF THE CONTRACTOR ELECTS TO CONTINUE THE REGULAR TRANSVERSE STEEL THROUGH THE JOINT AT THE LONGITUDINAL CONSTRUCTION JOINTS, THE NUMBER 5 ROUND TIEBAR AS SHOWN HEREON MAY BE DELETED. THE LOCATION OF THE RAMPS SHALL BE AS SHOWN ELSEWHERE IN THE PLANS.

5. THE SEQUENCE OF OPERATION IN PLACING THE RAMP SHALL BE AS DIRECTED BY THE ENGINEER. THE LONGITUDINAL STEEL SHALL BE PLACED IN A DIRECTION APPROXIMATELY PARALLEL TO THE DIRECTION OF THE RAMP.

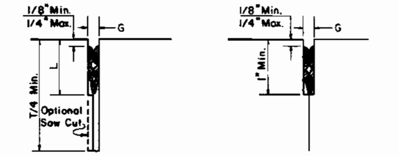
6. LONGITUDINAL AND TRANSVERSE STEEL SPACING SHALL NOT VARY MORE THAN ONE TWELFTH OF THE SPACING SHOWN HEREON.

7. IN THE AREA OF CONFLUENCE TRANSVERSE BARS AND TIE BARS (MAIN LANES AND RAMPS) WILL BE #5 BARS WITH SPACING SAME AS THAT IN STANDARD FOR ROADWAY.

TEXAS HIGHWAY DEPARTMENT

RAMP CONNECTIONS FOR CONCRETE PAVEMENT CONTINUOUSLY REINFORCED

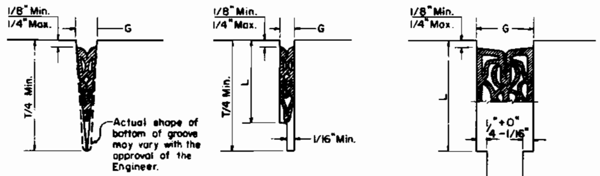
RC (CPCR)-71 (REV)



GROOVED LONGITUDINAL JOINT (TYPES L-1 or L-2)

LONGITUDINAL CONSTRUCTION JOINT (TYPE L-2)

LONGITUDINAL JOINT SEALS

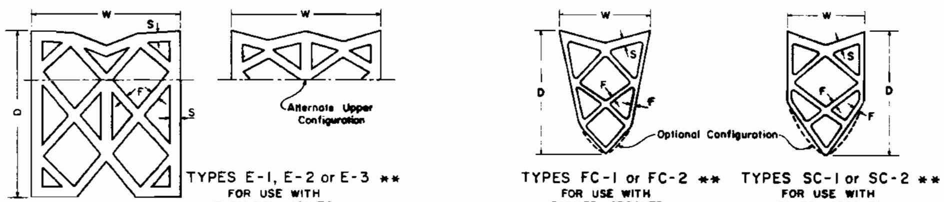


FORMED CONTRACTION JOINT (TYPES FC-1 or FC-2)

SAWED CONTRACTION JOINT (TYPES SC-1 or SC-2)

EXPANSION JOINT (TYPES E-1, E-2 or E-3)

TRANSVERSE JOINT SEALS



TYPES E-1, E-2 or E-3 ** FOR USE WITH EXPANSION JOINTS

TYPES FC-1 or FC-2 ** FOR USE WITH FORMED GROOVES

TYPES SC-1 or SC-2 ** FOR USE WITH SAWED GROOVES

PREFORMED COMPRESSION SEAL TYPES

** See General Note No. 6

METHOD A: PREFORMED COMPRESSION SEALS

JOINT TYPE	JOINT GROOVE		MINIMUM JOINT SEAL SIZE TO BE USED 2							SEAL DESIGNATION & TYPE
	WIDTH G (in.)	DEPTH 1 L (in.)	WIDTH W (in.)	DEPTH D (in.)	MAX. WID.LAT. COMP.	THICK. S (in.)	TOLER. 3 S (in.)	THICK. F (in.)	TOLER. 3 F (in.)	
LONGITUDINAL JOINT	1/8 -0 +1/16	7/8	5/16	5/8	1/8	0.040	-0.005	0.040	-0.005	L-1
	1/4 ± 1/32	1	7/16	23/32	7/32	0.062	-0.005	0.040	-0.005	L-2
SAWED TRANSVERSE CONTRACTION JOINT	1/4 -0 +1/16	1-1/2	11/16	1-1/8	1/4	0.080	-0.012	0.040	-0.009	SC-1
	3/8 -0 +1/16	1-3/4	13/16	1-1/8	5/16	0.080	-0.012	0.040	-0.009	SC-2
FORMED TRANSVERSE CONTRACTION JOINT	3/8	N/A	13/16	1-1/8	5/16	0.080	-0.012	0.040	-0.009	FC-1
	5/8	N/A	1-1/4	1-1/2	5/8	0.080	-0.012	0.080	-0.012	FC-2 **
EXPANSION JOINTS	1 *	2-1/8	1-5/8	1-5/8	7/8	0.094	-0.016	0.080	-0.012	E-1
	1-1/4 *	2-3/4	2	2	1	0.125	-0.016	0.110	-0.016	E-2
	1-5/8 *	3-3/8	2-1/2	2-3/4	1-1/4	0.187	-0.016	0.125	-0.016	E-3

* THIS GROOVE WIDTH IS FOR SUMMER CONCRETE PLACEMENT. WHEN CONCRETE IS PLACED DURING THE WINTER SEASON, THIS GROOVE SHALL BE INCREASED 1/8".

1. DUE TO SMALL VARIATIONS IN SEAL SIZES, THIS DIMENSION MAY HAVE TO BE MODIFIED SLIGHTLY TO ENSURE PROPER INSTALLATION. THIS DIMENSION IS APPLICABLE ONLY WHEN A STEPPED GROOVE IS USED. N/A: NOT APPLICABLE.

2. THESE DIMENSIONS ARE MINIMUM DIMENSIONS. DIMENSIONS GREATER THAN THOSE SHOWN MAY BE USED IF APPROVED BY THE ENGINEER AND IF THEY PERMIT INSTALLATION IN A WORKMANLIKE MANNER AT NO EXTRA EXPENSE TO THE STATE.

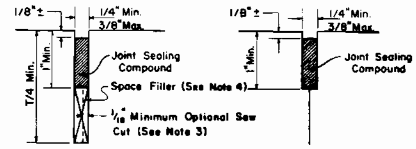
3. ONLY MINIMUM TOLERANCES ARE SHOWN. ANY REASONABLE OVERSIZE WILL BE ACCEPTED PROVIDED PROPER INSTALLATION IS POSSIBLE.

GENERAL NOTES FOR METHOD "A"

1. A SAMPLE OF EACH SIZE AND TYPE OF SEAL PROPOSED FOR USE SHALL BE APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.
2. THE SEALS SHOWN AS METHOD "A" OR METHOD "B" MAY BE USED AT ANY JOINT REQUIRING A SEAL, HOWEVER, THE SAME SEAL SHALL BE USED THROUGHOUT THE PROJECT UNLESS OTHERWISE AUTHORIZED BY THE ENGINEER.
3. LONGITUDINAL JOINTS SHALL BE SAWED STRAIGHT AND TRUE TO LINE AS DETAILED IN THE STANDARD SPECIFICATIONS.
4. TRANSVERSE JOINTS MAY BE SAWED OR FORMED AND SHALL BE PLACED AS SHOWN ELSEWHERE IN THE PLANS.
5. THE SEALS DESIGNATED L-1 AND L-2 SHALL HAVE A CONFIGURATION SIMILAR TO THE TYPE FC OR SC.

** 6. OTHER INTERIOR CONFIGURATIONS MAY BE USED PROVIDED THE MATERIAL MEETS ALL OF THE REQUIREMENTS OF THE SPECIFICATIONS AND AS OTHERWISE SHOWN HEREON OR ELSEWHERE IN THE PLANS. THE NUMBER OF INTERIOR CELLS AND/OR THE THICKNESS OF THE EXTERIOR AND INTERIOR WALLS SHALL BE SUCH AS TO PROVIDE AN ADEQUATE COMPRESSIVE FORCE TO MAINTAIN A POSITIVE SEAL.

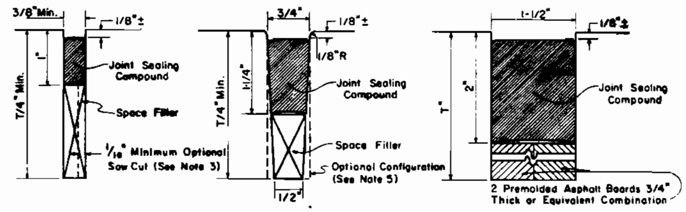
7. UNLESS OTHERWISE SPECIFIED, THE SIDES OF THE FORMED CONTRACTION JOINT MAY BE FORMED PARALLEL, BUT IF SO FORMED, THE SEAL SHALL BE AN APPROPRIATE TYPE SC SEAL APPROVED BY THE ENGINEER.
8. UNLESS THE GROOVE AND SEAL COMBINATION IS SPECIFICALLY DESIGNATED ELSEWHERE IN THE PLANS, ANY GROOVE AND SEAL COMBINATION SHOWN IN THE TABLE FOR A PARTICULAR TYPE JOINT MAY BE USED, BUT MUST BE APPROVED BY THE ENGINEER.



GROOVED LONGITUDINAL JOINT

LONGITUDINAL CONSTRUCTION JOINT

LONGITUDINAL JOINT SEALS



SAWED CONTRACTION JOINT

FORMED CONTRACTION JOINT

EXPANSION JOINT

TRANSVERSE JOINT SEALS

METHOD B: JOINT SEALING COMPOUND

GENERAL NOTES FOR METHOD "B"

1. LONGITUDINAL JOINTS MAY BE SAWED OR FORMED AS DETAILED IN THE STANDARD SPECIFICATIONS.
2. TRANSVERSE JOINTS MAY BE SAWED OR FORMED AND SHALL BE PLACED AS SHOWN ELSEWHERE IN THE PLANS.
3. A SUITABLE SPACE FILLER SHALL BE USED WHERE SHOWN AND THE JOINT SEAL COMPOUND POURED TO THE DEPTH INDICATED EXCEPT THAT IF THE MINIMUM SAW CUT IS USED, THE SPACE FILLER MAY BE DELETED.
4. AT THE OPTION OF THE CONTRACTOR, THE SPACE FILLER MAY BE OMITTED IN THE LONGITUDINAL JOINT ONLY AND THE JOINT SEALING COMPOUND POURED FULL DEPTH.
5. UNLESS OTHERWISE SPECIFIED, THE SIDES OF THE FORMED CONTRACTION JOINT MAY BE FORMED PARALLEL AT THE OPTION OF THE CONTRACTOR.
6. UNLESS OTHERWISE SHOWN IN THE PLANS, EITHER METHOD "A" OR METHOD "B" MAY BE USED.

TEXAS HIGHWAY DEPARTMENT

CONCRETE PAVING DETAILS
JOINT SEALS
JS-71

APPENDIX C.2

COMPUTATIONS FOR
QUANTITIES OF STEEL REINFORCEMENT

A CHECK OF ALL RIGID PAVEMENT
DESIGN STANDARDS

Concrete Pavement Details - Reinforcing Steel Checks

A. Longitudinal and Transverse Reinforcement

CPCR (DW) - 69

Calculations based on 32-foot cover length and indicated width (12 or 24 feet). Longitudinal reinforcement, transverse reinforcement, and splices are included. Calculate the number of longitudinal and transverse wires needed per placement area. Determine longitudinal, transverse, and splice lengths from details. Multiply the numbers of wires times their respective lengths times their respective weights and divide by the placement area in square yards.

CPJR (F) - 69

Calculations based on "Typical Sheet of Welded Wire Fabric" detail. Calculate the number of longitudinal and transverse wires per sheet of fabric. Determine lengths of longitudinal and transverse wires, multiply the number of each wire type times its respective length times its respective weight, add them together, and divide by the placement area in square yards.

CPJR (DW) - 69

Calculate the number of longitudinal and transverse wires per foot (12"/ bar spacing, inches). Add together and multiply times 9 to obtain the number of wire-feet per square yard. Multiply this times wire weight. If wire weights are different for longitudinal and transverse steel bars, calculate the number of wires per foot for each, multiply each number times its respective weight, add together, and then multiply times 9.

CPJR (B) - 69

Calculations based on 60.5-foot length and 12-foot or 24-foot width. Calculate the number of longitudinal and transverse wires per placement area based on 60.5-foot length, indicated width, and indicated spacings. Take into account all edge spacings. Multiply the number of wires times their respective lengths times their respective weights, add, and divide by the placement area in square yards.

B. Miscellaneous Details

Tiebars or Tie Wires

Find the number of bars per foot (12 inches/bar spacing, inches), multiply times bar length times bar weight.

Dowels

Find the number of bars per foot (12 inches/bar spacing, inches), multiply times bar length times bar weight.

Additional Steel Transverse Construction Joint

Divide number of wires per lane by the lane width, multiply times wire length times wire weight.

CPJR (F) -69

Pavement Thickness	Weight Standard	Weight 502	Weight Diff.	Dowels Standard	Dowels 502	Dowels Diff.	Tiebars Standard	Tiebars 502	Tiebars Diff.
10	6.35	6.37	+.02	7.89	7.89	—	0.67	0.67	—
9	6.35	6.37	+.02	5.67	5.67	—	0.67	"	—
8	5.44	5.46	+.02	4.01	4.01	—	0.67	"	—
10	8.90	8.79	-.11	7.89	7.89	—	0.67	"	—
9	8.39	8.30	-.09	5.67	5.67	—	0.67	"	—
8	7.21	7.13	-.08	4.01	4.01	—	0.67	"	—

CPJR (DW) -69

Pavement Thickness	Weight Standard	Weight 502	Weight Diff.	Dowels Standard	Dowels 502	Dowels Diff.	Tie bars Standard	Tie bars 502	Tie bars Diff.
10	5.46	5.47	+.01	7.89	7.89	—	0.67	0.67	—
9	4.88	4.90	+.02	5.67	5.67	—	"	"	—
8	4.31	4.33	+.02	4.01	4.01	—	"	"	—
10	7.18	7.21	+.03	7.89	7.89	—	"	"	—
9	6.46	6.49	+.03	5.67	5.67	—	"	"	—
8	5.74	5.77	+.03	4.01	4.01	—	"	"	—

CPCD -69

Pavement Thickness	Dowels Standard	Dowels 502	Dowels Diff.
8	4.01	4.01	—
9	5.67	5.66	-.01
10	7.89	7.89	—
11	10.63	10.63	—

CPCR (DW) -69

Pavement Thickness	24' Stand.	24' 502	24' Diff.	12' Stand.	12' 502	12' Diff.	Add'l. Steel Stand.	Add'l. Steel 502	Add'l. Steel Diff.	Tie Wires Stand.	Tie Wires 502	Tie Wires Diff.
8	16.51	16.51	—	16.40	16.40	—	2.65	2.65	—	0.450	.450	—
7	14.40	14.40	—	14.30	14.30	—	2.60	2.60	—	0.361	.361	—
6	12.36	12.35	-.01	12.28	12.27	-.01	2.61	2.60	-.01	0.282	.280	-.02

CPJR (B) -69

Pavement Thickness	24' Stand.	24' 502	24' Diff.	12' Stand.	12' 502	12' Diff.	Dowels Stand.	Dowels 502	Dowels Diff.	Tie Bars Stand.	Tie Bars 502	Tie Bars Diff.
10	6.33	6.37	+.03	6.30	6.33	+.03	7.89	7.89	—	0.67	0.67	—
9	5.92	5.95	+.03	6.02	6.05	+.03	5.67	5.67	—	"	"	—
8	5.50	5.53	+.03	5.47	5.49	+.02	4.01	4.01	—	"	"	—
10	8.17	8.21	+.04	8.26	8.31	+.05	7.89	7.89	—	"	"	—
9	7.32	7.36	+.04	7.42	7.46	+.04	5.67	5.67	—	"	"	—
8	6.61	6.64	+.03	6.58	6.61	+.03	4.01	4.01	—	"	"	—

CPCR (B) - 69 (1)

Pavement Thickness	24' Stand.	24' 502	24' Diff.	12' Stand.	12' 502	12' Diff.	Add'l. Stand.	Add'l. 502	Add'l. Diff.
9	20.01	20.00	-.01	20.40	20.40	—	2.61	2.61	—
8	17.66	17.66	—	18.05	18.05	—	2.61	2.61	—
7	16.09	16.09	—	15.70	15.70	—	2.61	2.61	—
6	12.93	12.93	—	12.93	12.93	—	1.67	1.67	—
9	23.21	23.24	—	23.81	23.81	—	3.00	3.00	—
8	20.40	20.40	—	21.18	21.18	—	2.61	2.61	—
7	18.05	18.05	—	18.05	18.05	—	2.61	2.61	—
6	16.09	16.09	—	16.49	16.48	-.01	2.09	2.09	—

CPCR (B) - 69 (2)

Pavement Thickness	24' Stand.	24' 502	24' Diff.	12' Stand.	12' 502	12' Diff.	Add'l Stand.	Add'l 502	Add'l Diff.
9	20.31	20.61	+.30	21.00	21.00	—	2.61	2.61	—
8	18.26	18.26	—	18.65	18.65	—	2.61	2.61	—
7	16.70	16.70	—	16.30	16.30	—	2.61	2.61	—
6	13.52	13.53	+.01	13.52	13.53	+.01	1.67	1.67	—
9	23.85	23.85	—	24.41	24.41	—	3.00	3.00	—
8	21.00	21.00	—	21.78	21.78	—	2.61	2.61	—
7	18.65	18.65	—	18.65	18.65	—	2.61	2.61	—
6	16.70	16.70	—	17.09	17.09	—	2.09	2.09	—

APPENDIX C.3

DESIGN REVISION AND CHECK

CPJR (B) - 69

Check Percent Steel CPJR (B) - 69

$$P_s = 100 \times \frac{\text{Area Steel}}{\text{Area Concrete}}$$

Longitudinal Steel (Low Friction)

$$P_s = 100 \times \frac{10 \text{ bars} \times \text{area/bar}}{10 \text{ barspaces} \times \text{spacing} \times \text{thickness}}$$

$t = 10$ in $\quad P_s = \dfrac{100 \times 10 \times 0.2}{10 \times 10.25 \times 10} = \dfrac{200}{1025} = 0.195\ \%$

$t = 9$ in $\quad P_s = \dfrac{100 \times 10 \times 0.2}{10 \times 11.5 \times 9} = \dfrac{200}{1034} = 0.193\ \%$

$t = 8$ in $\quad P_s = \dfrac{100 \times 10 \times 0.2}{10 \times 13.25 \times 8} = \dfrac{200}{1060} = 0.189\ \%$

Longitudinal Steel (High Friction)

$t = 10$ in $\quad P_s = \dfrac{100 \times 10 \times 0.2}{7.75 \times 10 \times 10} = 0.258\ \%$

$t = 9$ in $\quad P_s = \dfrac{100 \times 10 \times 0.2}{8.625 \times 10 \times 9} = 0.258\ \%$

$t = 8$ in $\quad P_s = \dfrac{100 \times 10 \times 0.2}{9.625 \times 10 \times 8} = 0.262\ \%$

Transverse Steel (Low Friction)

$$P_s = 100\,\frac{\text{Area Steel}}{\text{Area Concrete}} = 100\,\frac{\text{Area 1 bar}}{\text{bar spacing} \times \text{thickness}}$$

$t = 10\text{ in} \qquad P_s = \dfrac{100(0.2)}{30 \times 10} = 0.0667\ \%$

$t = 9\text{ in} \qquad P_s = \dfrac{100(0.2)}{30 \times 9} = 0.074\ \%$

$t = 8\text{ in} \qquad P_s = \dfrac{100(0.2)}{30 \times 8} = 0.0834\ \%$

Transverse Steel (High Friction)

$t = 10\text{ in} \qquad P_s = \dfrac{100(0.2)}{24 \times 10} = 0.0834\ \%$

$t = 9\text{ in} \qquad P_s = \dfrac{100(0.2)}{26.5 \times 9} = 0.0839\ \%$

$t = 8\text{ in} \qquad P_s = \dfrac{100(0.2)}{30 \times 8} = 0.0834\ \%$

Compute P_s values for transverse steel if its spacing is changed to 36 in. for the low friction factor

t = 10 in. $\quad P_s = \dfrac{100 \times 0.20}{36 \times 10} = 0.0556$

t = 9 in. $\quad P_s = \dfrac{100 \times 0.20}{36 \times 9} = 0.0618$

t = 8 in. $\quad P_s = \dfrac{100 \times 0.2}{36 \times 8} = 0.0695$

Compute P_s required for smooth subbase

For 5 lane, 60 ft. pavement

L = 60

F = 1.0

f_s = 45,000 (High yield) 0.75 × 60,000

$P_s = \dfrac{LF}{2 f_s} \times 100 = 0.067\,\%$

OK, but 10 & 9 in. designs above slightly less ∴ 36 in. spacing not satisfactory for 5 lane pvt.

For 36 ft., 3 lane pvt

F = 1.0

f_s = 45,000 psi

P_s = 0.040 %

Check Intermediate Grade tiebars

36-ft slab (2 lane, 1 lane joint)

$W = 24$ ft

$F = 1.0$

$f_s = 30{,}000$ $(0.75 \times 40{,}000)$

$$P_s = \frac{24 \times 1.0 \times 100}{2 \times 30{,}000} = 0.04\ \%$$

$\therefore$ for tiebars 0.04 % intermediate grade steel is required

transverse bars or tiebars spaced @ 36 in. in 8, 9, 10 in. slabs yield steel percentages greater than 0.04 %, $\therefore$ for 3 lane pvt 36 in. trans steel & tiebar spacing is ok.

Compute weights of Steel for CPJR(B)-69 if transverse steel spacing is increased to 36 in. for low friction subase.

24-Ft placement width

$$\frac{24\text{ Ft} \times 60.5\text{ ft}}{9\text{ ft}^2/\text{sy}} = 161.333\ \text{S.Y.}/\text{Panel}$$

Steel wts: $\#3 = 0.376\ \text{lb}/\text{ft}$

$\#4 = 0.668\ \text{lb}/\text{ft}$

10-in. slab

24 ft - 11 in. = $(23'1'')(12'')/10.25'' = 27.024$,

$\therefore$ 28 long bars

$60'6'' - 6'' = (60')(12'')/36'' = 20$, $\therefore$ trans bars

$(0.376)(28)(60) = 631.680$ lb (Longitudinal)

$(0.668)(21)(23.667) = 332.001$ lb (Transverse)

$\Sigma = 963.681$

$W_s = 963.681/161.333 = 5.973\ \#/\text{sy}$

9-in. slab

$$24'\text{-}12'' \Rightarrow (23')(12'')/11.5 = 23.989,$$

$\therefore$ 25 long. bars also 21 trans. bars

$$(0.376\ \#/ft)(25\ \text{bars})(60') = 564.000 \quad (\text{long.})$$
$$(0.668\ \#/ft)(21\ \text{bars})(23.667') = 332.001 \quad (\text{trans})$$

$$\Sigma = 896.001\ \#$$

$$W_s = \frac{896.001\ \#}{161.333\ sy} = 5.554\ \#/sy$$

8-in. slab

$$24'\text{-}10'' \Rightarrow (23'2'')(12'')/13.25 = 20.981,$$

$\therefore$ 22 long. bars also 21 trans. bars

$$(22\ \text{bars})(0.376\ \#/ft)(60') = 496.320 \quad (\text{long.})$$
$$(21\ \text{bars})(0.668\ \#/ft)(23.667) = 332.001 \quad (\text{trans.})$$

$$\Sigma = 828.321$$

$$W_s = \frac{828.321\ \#}{161.333\ sy} = 5.134\ \#/sy$$

12-ft Placement Width

$$\frac{12\,ft \times 60.5\,ft}{9} = 80.667 \text{ S.Y.}$$

10-in. slab

$12'\text{-}11'' \rightarrow (11'\text{-}1')(12'')/10.25 = 12.975$, $\therefore$ 14 long. bars

$60'\text{-}6' \rightarrow (60')(12'')/36 = 20$, $\therefore$ 21 trans. bars

$(14 \text{ bars})(0.376\ \#/ft)(60') = 315.840\ \#$

$(21 \text{ bars})(0.668\ \#/ft)(11.667) = 163.6647\ \#$

$\Sigma = 479.505$

$$W_s = \frac{479.505\ \#}{80.667\ sy} = 5.944\ \#/sy$$

9-in. slab

$12'\text{-}6'' \rightarrow (11'\text{-}6'')(12'')/(11.5) = 12$, $\therefore$ 13 long. bars

$(13 \text{ bars})(0.376\ \#/ft)(60') = 293.280$

$(21 \text{ bars})(0.668\ \#/ft)(11.667) = 163.665$

$\Sigma = 456.945$

$$W_s = \frac{456.945}{80.667} = 5.6645\ \#/sy$$

8-in. slab

$$12' \text{-} 11.5'' \Longrightarrow (11'\ 1/2'')(12'')/13.25 = 10,$$

$\therefore$ 11 long. bars

$$(11 \text{ bars})(0.376\ \#/\text{ft})(60') = 248.160\ \# \quad \text{(long.)}$$
$$(21 \text{ bars})(0.668\ \#/\text{ft})(11.667) = 163.665\ \# \quad \text{(trans.)}$$

$$\Sigma = 411.825\ \#$$

$$W_s = \frac{411.825\ \#}{80.667\ \text{sy}} = 5.1052\ \#/\text{sy}$$

APPENDIX C.4

DESIGN COMPUTATIONS FOR SERIES OF 10-IN. SLAB CPCR DESIGNS

AND

REVISION OF CPCR (B) - 69 - (1) REVISED AND CPCR (B) - 69 (2)

Design Computations for 10-in. CPCR

0.5 Percent Longitudinal Steel

(1.) try #5 bars @ 6 in.

$\therefore$ spacing (B) = 6 in. ; (A) = 3 in.

10 sp @ 6 in.
depth = 10 in.

$$P_s = 100 \frac{A_s}{A_c}$$

$$P_s = 100 \frac{10 \times 0.31}{60 \times 10} = 100 \frac{3.1}{600} = \frac{3.1}{6.0}$$

$$P_s = 0.517$$

(2.) try #6 bars @ 8 in.

$$P_s = 100 \frac{10 \times 0.44}{8 \times 10 \times 10} = 100 \frac{4.4}{800} = \frac{4.4}{8.0}$$

$$P_s = 0.550$$

(3.) try #6 bars @ 8.5 in.

$$P_s = 100 \frac{4.4}{85 \times 10} = \frac{4.4}{8.5}$$

$$P_s = 0.518$$

0.6 Percent Longitudinal Steel

(1.) try #6 bars @ 7 in.

$$P_s = 100 \frac{4.4}{70 \times 10} = \frac{4.4}{7.0}$$

$$P_s = 0.629$$

(2.) try #6 bars @ 7.5 in.

$$P_s = 100 \frac{4.4}{75 \times 10} = \frac{4.4}{7.5}$$

$$P_s = 0.586$$

(3.) try #6 bars @ 7.25 in.

$$P_s = 100 \frac{4.4}{72.5 \times 10}$$

$$P_s = 0.607$$

Additional Steel at Transverse Construction Joints

10-in. CPCR

Design No.	Additional Bars for Width		N	Avg	Wt/ft
	2 lanes	1 lane	(Design)	Spacing	
1	24	12	12	12	4.17
2	18	9	9	15	3.38
3	20	10	10	14	3.76
4	20	10	10	14	3.76
5	20	11	11	13	4.13

Computations for Weights of Steel / sy

CPCR-(B)-69(2) ~ 10-in. slab

24-ft Placement With

trans. Steel

$$①^{*} \quad W_s = \left[\frac{48 \text{ bars}}{24 \text{ ft}} \times 1.043 \frac{\text{lb}}{\text{bar/ft}} + 0.334\right] 9.000 = 21.780$$

$$② \quad W_s = \left[\frac{35}{24} \times 1.502 + .334\right] 9.000 = 22.716$$

$$③ \quad W_s = \left[\frac{40}{24} \times 1.502 + .334\right] 9.000 = 25.524$$

$$④ \quad W_s = \left[\frac{39}{24} \times 1.502 + .334\right] 9.000 = 24.975$$

$$⑤ \quad W_s = \left[\frac{42}{24} \times 1.502 + .334\right] 9.000 = 26.667$$

12-ft Placement Width

$$① \quad W_s = \left[\frac{24}{12} \times 1.043 + 0.334\right] 9.000 = 21.780$$

$$② \quad W_s = \left[\frac{18}{12} \times 1.502 + 0.334\right] 9.000 = 23.283$$

$$③ \quad W_s = \left[\frac{20}{12} \times 1.502 + 0.334\right] 9.000 = 25.524$$

$$④ \quad W_s = \left[\frac{20}{12} \times 1.502 + 0.334\right] 9.000 = 25.524$$

$$⑤ \quad W_s = \left[\frac{21}{12} \times 1.502 + 0.334\right] 9.000 = 26.667$$

* These numbers refer to attached summary table

CPCR · (B) · 69(1)   10-in. slab

24-ft Placement Width

① $W_s = \left[\frac{48}{24} \times 1.043 + 0.2672\right] 9.000 = 21.179$

② $W_s = \left[\frac{35}{24} \times 1.502 + 0.2672\right] 9.000 = 22.118$

③ $W_s = \left[\frac{40}{24} \times 1.502 + 0.2672\right] 9.000 = 24.934$

④ $W_s = \left[\frac{39}{24} \times 1.502 + 0.2672\right] 9.000 = 24.372$

⑤ $W_s = \left[\frac{42}{24} \times 1.502 + 0.2672\right] 9.000 = 26.061$

12-ft Placement Width

① $W_s = \left[\frac{24}{12} \times 1.043 + 0.2672\right] 9.000 = 21.179$

② $W_s = \left[\frac{18}{12} \times 1.502 + 0.2672\right] 9.000 = 22.682$

③ $W_s \left[\frac{20}{12} \times 1.502 + 0.2672\right] 9.000 = 24.934$

④ $W_s \left[\frac{39}{24} \times 1.502 + 0.2672\right] 9.000 = 24.934$

⑤ $W_s \left[\frac{21}{12} \times 1.502 + 0.2672\right] 9.000 = 26.061$

Steel Weight ~ CPCR(B) - 69(1) Revised
(Trans Steel @36")

Steel Bars

24' Placement Width

#5 Bars

$$W_s = \left(N/24 \times 1.043 + 0.2227\right) 9000 \qquad \#/sy$$

N	45	39	46	40
W_s	19.6047	17.258	15.693	17.649

#4 Bars

$$W_s = \left(42/24 \times 0.668 + 0.2227\right) 9.000$$

$$W_s = 12.5253 \quad \#/sy$$

#6 Bars

$$W_s = \left(37/24 \times 1.502 + 0.2227\right) 9.000 = 22.844 \quad \#/s.y.$$

$$W_s = \left(35/24 \times 1.502 + 0.2227\right) 9.000 = 21.7179 \quad \#/s.y.$$

$$W_s = \left(40/24 \times 1.502 + 0.2227\right) 9.000 = 24.5331 \quad \#/s.y.$$

12' Placement

#5 Bars

$$W_s = \left(N/12 \times 1.043 + 0.2227\right) 9.0000 \qquad \#/s.y.$$

N	23	20	17	24	18
W_s	19.9953	17.649	15.302	20.778	16.0848

#4 Bars

$$W_s = \left(21/12 \times 0.668 + 0.2227\right) 9.000$$

$$W_s = 12.5253 \quad \#/s.y.$$

#6 Bars

$$W_s = \left(19/12 \times 1.502 + 0.2227\right) 9.000$$

$$W_s = 23.407 \quad \#/s.y.$$

$$W_s = \left(18/12 \times 1.502 + 0.2227\right) 9.000 = 22.2813 \quad \#/s.y.$$

$$W_s = \left(20/12 \times 1.502 + 0.2227\right) 9.000 = 24.5331 \quad \#/s.y.$$

Additional Steel Bars at Transverse
Construction Joint CPCR(B)-69(1)

N = number of additional bars

For Even number of lateral spaces greater than 5 inches

$$N = \frac{\text{No. spaces}}{2} + 1$$

For Odd number of lateral spaces greater than 5 inches

$$N = \frac{\text{No. spaces} - 1}{2} + 1$$

$$\text{Average spacing per lane} = \frac{\text{lane width} - 2\,Ⓐ^{*}}{N}$$

Weight of steel :

$$\frac{N \text{ bars}}{12 \text{ ft}} \times \frac{\text{weight of bar}}{\text{foot of bar length}} \times \frac{36 \text{ in. length}}{12 \text{ in/ft}} = \frac{N}{4} \times \frac{\text{wt. of bar}}{\text{ft}}$$

*This value from table on design standard, barspacing

Additional Steel at Construction Joint
CPCR(B)-69(1)

Percent Steel	Thickness	Bar Size	Additional Bars (N) 12 ft Width	Additional Bars (N) 24 ft Width	N Use on Design Std.	Avg. spacing (in)	Wt/ft lb/ft
0.5	9	5	11	22	11	12	2.87
	8	5	10	20	10	14	2.61
	7	5	9	18	9	15	2.35
	6	4	11	20	10	14	1.67
0.6	9	6	10	19	10	14	3.76
	8	5	11	23	11	12	2.87
	7	5	10	20	10	14	2.61
	6	5	9	18	9	15	2.35

DESIGN COMPUTATIONS FOR WEIGHTS OF STEEL FOR CPCR(B) 69(1) REVISED FOR 36-IN. SPACING OF TRANSVERSE STEEL INCLUDING PROPOSED 10-IN. SLAB DESIGNS USING THE FOLLOWING FORMULA.

$$\text{WT.} = \left[\frac{\text{NO. BARS}}{\text{PLACEMENT WIDTH (FT)}} \times \text{LONGITUDINAL BAR WT./FT.} + \frac{12 \text{ IN} \times \text{TRANSVERSE BAR WT/FT}}{\text{TRANSVERSE BAR SPACING}} \right] 9 \ \text{FT.}^2/\text{YD.}^2$$

		NO. OF BARS													
		PLACEMENT WIDTH 12-FT.							PLACEMENT WIDTH 24-FT						
% STEEL	BAR SIZE	17	18	19	20	21	23	24	35	37	39	40	42	45	46
0.5	4					12.53							12.53		
	5	15.30			17.65		20.00		15.69		17.26			19.60	
	6		22.28						21.72						
0.6	5		16.08		17.65			20.78	15.69			17.65			20.00
	6			23.41	24.53					22.84		24.53			

CPCR (B) – 69(2)
10-INCH DESIGNS

DESIGN NO.	PERCENT LONGITUDINAL STEEL	PAVEMENT THICKNESS	BAR SIZE #	24-FT. PLACEMENT WIDTH: SPACING C-C (IN) A	B	C	NO OF BARS	STEEL #/SY	12-FT. PLACEMENT WIDTH: SPACING C-C (IN) A	B	C	NO. OF BARS	STEEL #/SY	ADD'L. STEEL @ CONST. JOINT: SIZE	AVG SPAC	NO. PER LANE	WT. #/FT.
1	.517	10	5	3	6	6	48	21.78	3	6	6	24	21.78	5/8" ϕ x 36"	12	12	4.17
2	.517	10	6	3	5	8.5	35	22.72	3	5.25	8.5	18	23.28	3/4" ϕ x 36"	15	9	3.38
3	.607	10	6	3	6.88	7.25	40	25.52	4	6.38	7.25	20	25.52	3/4" ϕ x 36"	14	10	3.76
4	.586	10	6	3	6	7.5	39	24.98	3	5.25	7.5	20	25.52	3/4" ϕ x 36"	14	10	3.76
5	.629	10	6	3	4.5	7.0	42	26.67	3	6	7.0	21	26.67	3/4" ϕ x 36"	13	11	4.13

24-INCH SPACING OF TRANSVERSE STEEL

CPCR(B) - 69(1)
10-INCH DESIGNS

DESIGN NO.	PERCENT LONGITUDINAL STEEL	PAVEMENT THICKNESS	BAR SIZE #	24-FT. PLACEMENT WIDTH					12-FT. PLACEMENT WIDTH					ADD'L STEEL @ CONST. JOINT			
				SPACING C-C			NO. OF BARS	STEEL #/SY	SPACING C-C			NO OF BARS	STEEL #/SY	SIZE	AVG. SPAC.	NO. PER LANE	WEIGHT #/FT.
				A	B	C			A	B	C						
1	.517	10	5	3	6	6	48	21.18	3	6	6	24	21.18	5/8"φ X 36"	12	12	4.17
2	.518	10	6	3	5	8.5	35	22.12	3	5.25	8.5	18	22.68	3/4"φ X 36"	15	9	3.38
3	.607	10	6	3	6.88	7.25	40	24.93	4	6.38	7.25	20	24.93	3/4"φ X 36"	14	10	3.76
4	.586	10	6	3	6	7.5	39	24.37	3	5.25	7.5	20	24.93	3/4"φ X 36"	14	10	3.76
5	.629	10	6	3	4.5	7.0	42	26.06	3	6	7.0	21	26.06	3/4"φ X 36"	13	11	4.13

30 INCH SPACING OF TRANSVERSE STEEL

TABLE OF REINFORCING STEEL SIZES, SPACINGS, AND ESTIMATED QUANTITIES

ALTERNATE DESIGNS (1)	PAVEMENT THICKNESS (T) (INCHES)	24' PLACEMENT WIDTH							12' PLACEMENT WIDTH							DOWELS (SMOOTH BARS)			TIEBARS (DEFORMED) (3)		
		LONGITUDINAL			TRANSVERSE			(2) STEEL	LONGITUDINAL			TRANSVERSE			(2) STEEL						
		BAR #	SPAC (A) (IN.)	SPAC (B) (IN.)	BAR #	SPAC (C) (IN.)	SPAC (D) (IN.)	#/SY	BAR #	SPAC (A) (IN.)	SPAC (B) (IN.)	BAR #	SPAC (C) (IN.)	SPAC (D) (IN.)	#/SY	SIZE	AVG. SPAC (IN.)	WT. #/FT. OF JT.	SIZE	AVG. SPAC (IN.)	WT. #/FT. OF JT.
L	10	3	5½	10¼	4	36	3	5.97	3	5½	10¼	4	36	3	5.94	1¼" x 22"	12	7.65	#4 x 30"	36	.56
	9	3	6	11½	4	36	3	5.55	3	3	11½	4	36	3	5.66	1⅛" x 20"	12	5.63	#4 x 30"	36	.56
	8	3	5	13¼	4	36	3	5.13	3	5¾	13¼	4	36	3	5.11	1" x 18"	12	4.01	#4 x 30"	36	.56
H	10	3	4½	7¾	4	24	3	8.17	3	2¼	7¾	4	24	3	8.26	1¼" x 22"	12	7.65	#4 x 30"	30	0.67
	9	3	6	8⅝	4	26½	5¼	7.32	3	3	8⅝	4	26½	5¼	7.42	1⅛" x 20"	12	5.63	#4 x 30"	30	0.67
	8	3	4½	9⅝	4	30	3	6.61	3	4½	9⅝	4	30	3	6.58	1" x 18"	12	4.01	#4 x 30"	30	0.67

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THE AUTHORS

B. Frank McCullough is an Assistant Professor of Civil Engineering at The University of Texas at Austin. His engineering experience includes work with the Texas Highway Department and the Center for Highway Research at The University of Texas at Austin. His current research is concerned with (1) systematic pavement design and (2) the evaluation and revision of the Texas Highway Department rigid pavement design procedure. He is the author of numerous publications and a member of several professional societies.

Harvey J. Treybig is currently associated with Austin Research Engineers, Inc. While at the Center for Highway Research at The University of Texas at Austin he was involved in the application and implementation of rigid pavement design. Prior to this, he was involved in continously reinforced concrete pavement design and research at the Texas Highway Department.

Ramesh K. Kher is a Research Engineer at the Center for Highway Research at The University of Texas at Austin. He has had experience as an engineering consultant in India and as an Assistant Professor of Civil Engineering at Punjab University. His area of teaching interest there was in the fields of soil mechanics and structural design. His current research efforts are primarily concerned with (1) analysis and design of pavement management systems, (2) rigid pavement design, and (3) expansive clays. He is the author of several other publications.