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16. Abstract

This report outlines the design, instrumentation and construction of a portland cement concrete pavement capable of evaluating nondestructive testing (NDT) equipment such as the Dynaflect and the Falling Weight Deflectometer. To test these devices, several variables that affect their output (i.e., deflection) will be recorded.

The variables that will be monitored at the test facility are subsurface moisture content, slab temperature gradient, voids, warping, and load transfer across a joint.

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Design and Construction of a Rigid Pavement Research Facility

by

Ron White
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Alvin H. Meyer
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Research Report Number 355-1

Construction of a Multipurpose Rigid Pavement Research Facility
Research Project 3-8-83-355

conducted for

Texas State Department of Highways
and Public Transportation

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

by the

Center for Transportation Research
Bureau of Engineering Research
The University of Texas at Austin

September 1984

PREFACE

This is the first report in a series that describes the work done in Research Project 3-8-83-355, "Design and Construction of a Rigid Pavement Research Facility. The findings of this study provide a "blueprint" that details the design and construction of a rigid pavement research facility. The project is supervised by Dr. W. R. Hudson and Dr. Alvin H. Meyer. Special thanks go to all of the members of the CTR staff that assisted in the research phase of this project and in the production of this report.

Ronald White
W. R. Hudson
Alvin H. Meyer

Austin, Texas
August 1984

LIST OF REPORTS

Report No. 355-1, "Design and Construction of a Rigid Pavement Research Facility," by Ronald White, W. R. Hudson, and Alvin H. Meyer, details the design construction and instrumentation of a rigid pavement research facility for evaluating nondestructive testing equipment. August 1984.

ABSTRACT

This report outlines the design, instrumentation and construction of a portland cement concrete pavement capable of evaluating nondestructive testing (NDT) equipment such as the Dynaflect and the Falling Weight Deflectometer. To test these devices, several variables that affect their output (i.e., deflection) will be recorded.

The variables that will be monitored at the test facility are subsurface moisture content, slab temperature gradient, voids, warping, and load transfer across a joint.

KEYWORDS: Rigid pavement design, rigid pavement construction, instrumentation, Dynaflect, Falling Weight Deflectometer.

SUMMARY

The Texas Highway Department uses the Dynaflect to estimate layer moduli in flexible and rigid pavements. Recently, Dynaflect deflection bowl data has been suspected of being erroneous on certain rigid pavements. The design and recommended construction procedures for a jointed reinforced concrete pavement that are outlined in this report will provide the information necessary to build a pavement research facility to solve this and other related problems.

The rigid pavement research facility to be built at Balcones Research Center, will make it possible to examine causes of the Dynaflect's inconsistencies by controlling numerous variables that influence deflection in pavements. Other deflection measuring devices, such as the Falling Weight Deflectometer (FWD), will also be tested at the facility.

The variables that will be monitored at the test facility are subsurface moisture content, slab temperature gradient, voids, warping and load transfer across a joint. A means measuring pavement deflection using DCDTs has been designed. The DCDT units will provide an independent measurement of the deflection bowls for comparison with data from non-destructive testing devices such as the Dynaflect and the Falling Weight Deflectometer.

IMPLEMENTATION STATEMENT

This document describes the design and subsequent construction of a rigid pavement research facility. This pavement will be capable of testing nondestructive pavement evaluation techniques such s the Dynaflect and the Falling Weight deflectometer.

TABLE OF CONTENTS

CHAPTER 4. INSTRUMENTATION

CHAPTER 5. CONSTRUCTION OF TEST PAVEMENTS

CHAPTER 6. RECOMMENDED TESTING AND FUTURE USES OF TESTING FACILITY

APPENDICES

CHAPTER 1. INTRODUCTION

BACKGROUND

A number of non-destructive deflection measuring devices are available for the structural evaluation of pavements. In the past, studies of these instruments have been comparative in nature, i.e., one device was checked against another device on an existing pavement. There has been little research to date specifically designed to test deflection measuring devices used today. The purpose of this project is to design and construct a pavement research facility with known properties to evaluate current and future non-destructive pavement evaluation devices such as the Dynaflect, Falling Weight Deflectometer (FWD), and Spectral-Analysis-of-Surface-Waves (SASW) (Ref 1).

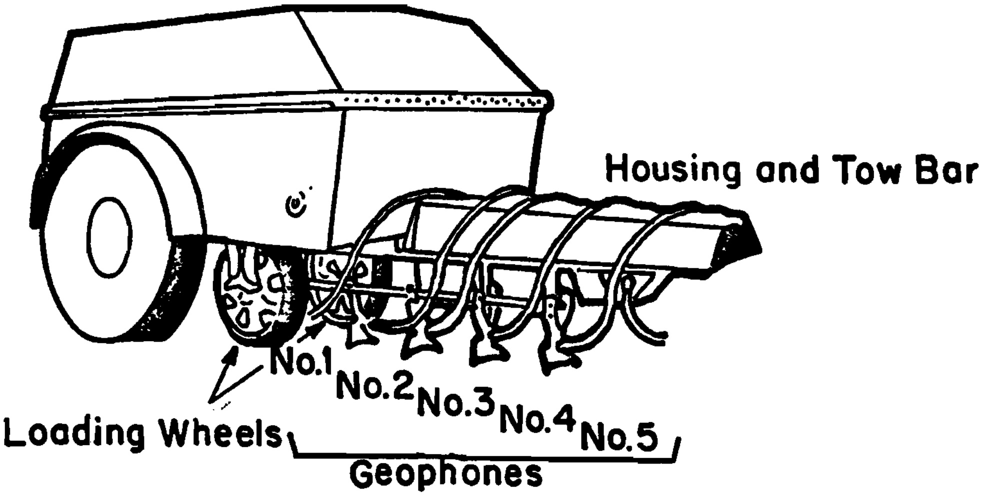
The structural evaluation of a pavement is a basic step in properly determining the present condition, predicting remaining life, and developing a meaningful rehabilitation strategy if one is needed. When the structural capacity of a pavement is unknown the engineer faces the risk of being too conservative, which may result in unnecessary costs, or of not being conservative enough, which may result in premature failure of a pavement section. Rarely is there a single "best solution" for rehabilitating a pavement with poor serviceability. However, by having the best input data possible, the engineer can reduce the number of unknown variables involved in pavement rehabilitation and can maximize the chance of selecting good design strategies.

Presently, the State Department of Highways and Public Transportation (SDHPT) uses the Dynaflect to evaluate the structural capacity of Texas roads. This device measures a deflection basin with a set of geophones positioned on a trailer at approximately one foot intervals (see Fig 1.1). The pavement surface is subjected to a dynamic load produced by two 100-pound eccentrically counter rotating masses (Ref 2). Data from deflection basin measurements are used to estimate the moduli of the various sublayers of a pavement system (Ref 3). The modulus is indicative of the amount of support the sublayers are providing to the surface layer. If the support is good the pavement will maintain good serviceability for some period of time. If support is poor the pavement will be susceptible to deterioration and require some form of rehabilitation.

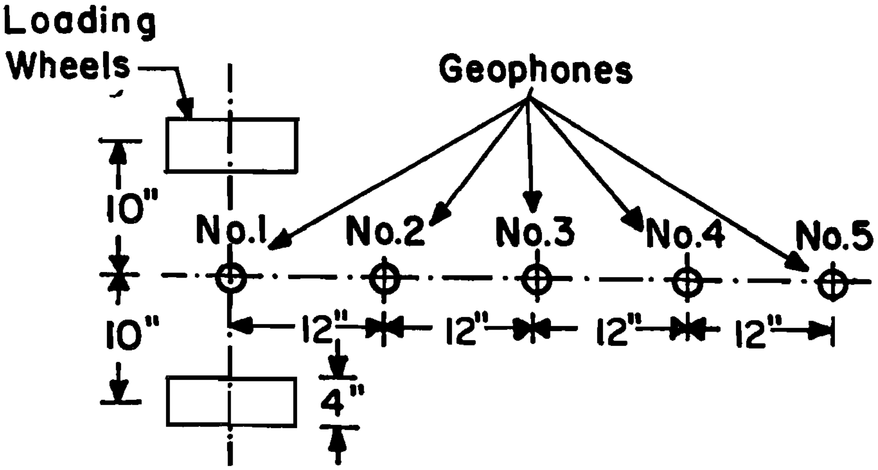
OBJECTIVES

The primary objective of this study is to design and construct a rigid pavement research facility for testing various aspects of Portland Cement Concrete (PCC) pavements including non-destructive testing devices such as the Dynaflect, the Falling Weight Deflectometer, Spectral Analysis of Surface Wave (SASW), and similar equipment under controlled conditions. Other potential uses of the pavement include the investigation of new design concepts in PCC and evaluation of potential or innovative rehabilitation methods, such as precast - prestressed PCC overlays and evaluation of precast joint assembly.

In recent years, Dynaflect deflection basin data have sometimes been suspect on certain rigid pavements. The rigid pavement research facility at Balcones Research Center (BRC) will give researchers a chance to determine possible causes of any Dynaflect inconsistencies by monitoring numerous



(a) The Dynaflect system in operating position (Ref 26).



(b) Configuration of load wheels and geophones.

Fig 1.1. Configuration of Dynaflect load wheels and geophones in operating position.

variables that influence deflection in pavements. Other deflection measuring devices, such as the FWD, will also be tested at the facility to define the relative response of each instrument and its ability to provide the best pavement evaluation.

Experience and theory indicate that the magnitude of pavement deflection is a function of applied load and several other factors. Variables such as sub-surface moisture content, slab temperature gradient, type of shoulder, voids, and load transfer across a joint all influence deflection data measured by non-destructive devices.

VARIABLES

The variables to be monitored at the research facility slab were chosen because they have a significant impact on pavement deflection. These variables include sub-layer moisture, slab temperature gradient, load transfer, and curling. Two voids were added as a condition variable that will be monitored because they too influence pavement deflection. The effect of shoulders on pavement deflection will be studied in the future. Deflections of concrete pavements with continuous concrete shoulders are substantially less than of rigid pavements constructed with asphaltic concrete shoulders. This will be monitored at some future time in the study. A temporary crushed stone shoulder will be placed to provide normal shoulder support and access to the pavement surface.

SCOPE OF WORK

This report includes details regarding the design of a portland cement concrete pavement; instrumentation that can evaluate non-destructive testing equipment; and specifications that describe construction method necessary to build the pavement. The dimensions of the pavement are 10 inches thick, 12 feet 6 inches wide and 60 feet long, with a joint dividing the slab into a 20 and 40 foot section. The 40 foot section (Fig A.3) is designed with an end anchor (Fig A.6) to prevent slab movement. The 20 foot section is equipped with a loading frame and hydraulic rams so that the entire 20 foot slab can be moved longitudinally. The joint has been specially designed with tapered dowels to provide variable load transfer. The longitudinal movement between the slabs will generate a vertical gap in the dowels and thus a loss of load transfer. To measure the horizontal gap at the joint, mounting brackets for two dial gauges will be cast in place on both sides of the slab at the joint.

Thermocouples were manufactured in house and will be placed at specified locations within the slab to record the temperature gradient through the depth of the slab. Warping and curling of the slab will be monitored by a rod and level, making use of a nearby permanent bench mark. To measure deflection and load transfer, a series of DCDT gage head holding units will be cast in place at the locations specified on the plans (Fig A.5). These units will provide an independent measurement of the deflection basins for comparison with geophone measurements from non-destructive testing devices such as the Dynaflect and Falling Weight Deflectometer. They will also measure deflection basins induced in the pavement by static 18-kip single axle wheel loads. In addition to this instrumentation, a weather station belonging to the Texas State Department of Highways and Public Transportation (SDHPT) will be used as available to measure ambient weather conditions previous to and during testing at the facility.

CHAPTER 2. DESIGN OF TEST PAVEMENT

SITE SELECTION

The design of the test pavement required careful selection of a site that satisfied the needs of the project. In selecting a site for the construction of the rigid pavement research facility, project personnel considered several factors before making a final choice. These factors were (1) protection from surrounding property, (2) availability of utilities, (3) interference with other activities and (4) soil conditions on the site.

Protection from the surrounding property was an important consideration since a great deal of expensive and highly sensitive equipment will be stored at the site. Access to electricity was essential to power the equipment and instrumentation. A portable generator was considered but they are unreliable, particularly in cold weather. A generator also tends to give an irregular flow of electricity which would influence the output of the instrumentation.

The facility has no definite termination date. It may be funded for only one or two years, but it might be continued for extended use in the future. As a result, a site that could support this project for a long period of time had to be chosen. Finally the existing soil conditions had to be acceptable and preferably, typical of conditions that exist under concrete pavements built in Texas.

Several sites were considered as potential locations to construct the research facility. These included a State Department of Highways and Public Transportation (SDHPT) maintenance yard, the University of Texas Balcones Research Center (BRC) and somewhere on a state road right of way. The

Balcones Research Center was chosen because it fulfilled most of the site selection criteria. It is completely fenced in, giving the area excellent protection from outside influence. Utilities are available and there are no plans by the University to build other structures on the site at this time. The only problem associated with using this location is the soil conditions at Balcones Research Center.

Several sites at Balcones Research Center were considered by project personnel (Fig 2.1). After making exploratory borings, it was discovered that the subgrade became more shallow toward the north end of Balcones Research Center. This eliminated site number 2 to the north that had only 18 inches of subgrade. Site number 3 to the west of some nearby railroad tracks, was also rejected because there were no utilities available at this site and also, though still on University property, it did not lie within the protective fencing at Balcones Research Center. The subgrade at Balcones Research Center varies in thickness between one and three feet of soil. Beneath this shallow layer of earth lies a thick strata of bedrock. The presence of this rock formation could cause the pavement deflection basin to yield erratic results due to wave reflection. In addition, this rock layer could cause abnormally high soil support (k-psi) values resulting in lower than expected deflections. Finally, rigid pavements in Texas are typically not constructed over such stiff subgrade. To counter this potential reduction in deflection, seven feet of compacted soil and rock embankment will be placed over the subgrade to reduce the effects of the solid rock layer and increase pavement deflection. The fill material was obtained from local construction sites.

The site that was chosen and approved (site number 1 on Fig 2.1) has a subgrade depth of 36 inches. The final six inches of subgrade, adjacent to

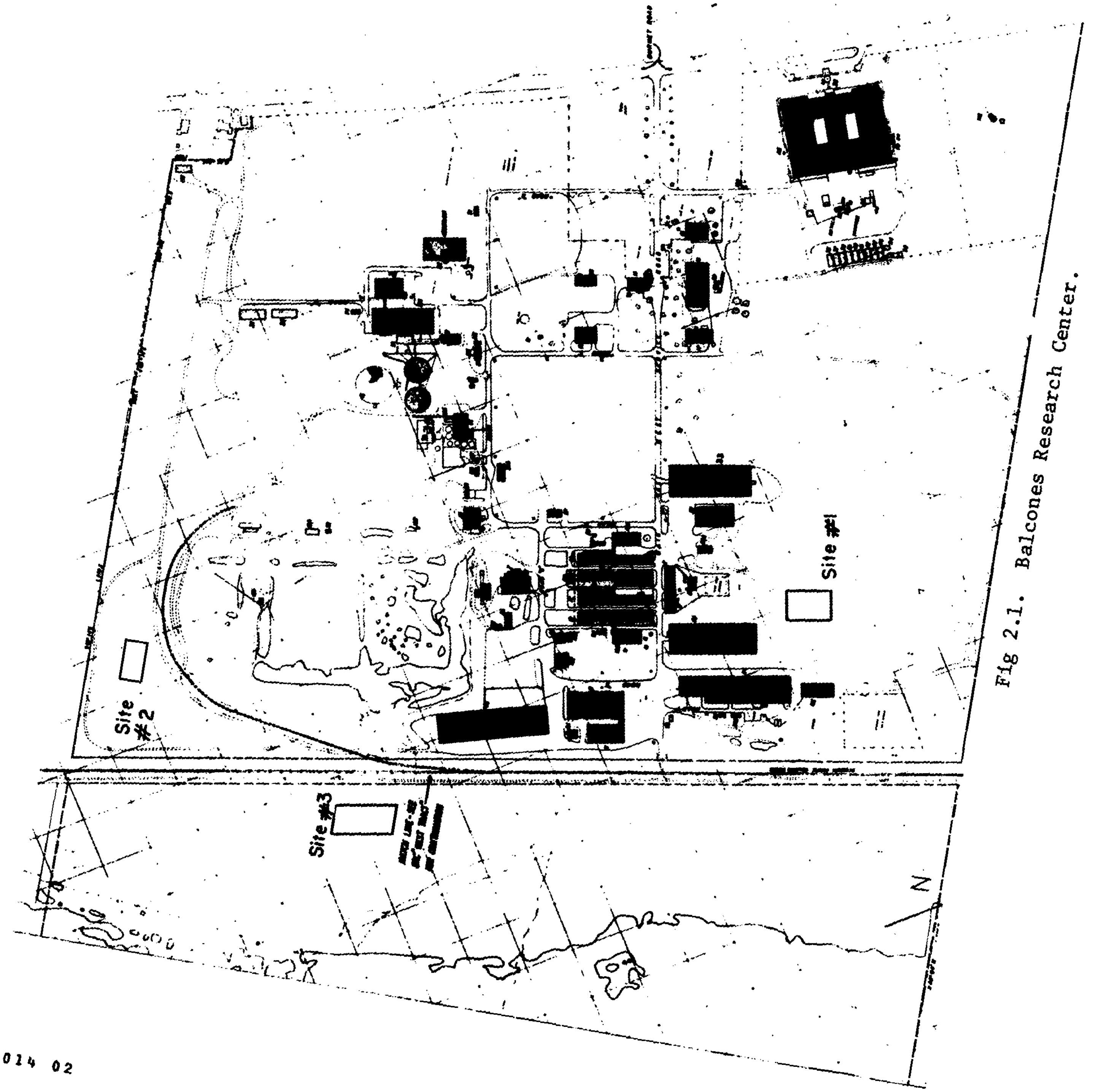


Fig 2.1. Balcones Research Center.

the bed rock, is composed primarily of broken rock mixed with the natural soil. The water content of the earth at this site is about 19 percent at a depth of 18 inches. The site is situated in a large field where other slabs can be constructed if it were desirable to expand the project at some later date.

PAVEMENT DESIGN

Earthwork

The pavement will be supported by a series of layers of known thickness and structural capacity. The thickness of each layer was chosen based on the requirements of the pavement.

Subgrade. The subgrade is very shallow at the site (approximately 3 feet deep). This will cause abnormally small deflections in the slab. To reduce the effects of the underlying rock layer, 7 feet of embankment was laid using readily available fill from a nearby source. The top 6 inches of the subgrade is mostly organic soil and was removed prior to placing the embankment. The remaining subgrade is mostly clay. The detailed properties of the subgrade will be described in the next report.

Embankment. The embankment was constructed as a result of an analysis using a layered system computer program called ELSYM5 (Ref 4). The data demonstrates that deflections in concrete pavements are reduced substantially when bedrock is close to the surface. The modulus of subgrade reaction (k-pci) increases significantly as the subgrade becomes more shallow.

Results of Computer Analysis

An analysis was using the ELSYM-5 computer program was conducted to assess the effect that layer thickness and layer modulus have on the deflection of a slab. Two data sets, one simulating a Dynaflect and the other simulating a Falling Weight Deflectometer (FWD) were used. The input data required to simulate the Dynaflect included the number of layers to be considered and, for each layer, the Poisson's ratio, modulus of elasticity, and thickness. The input for the FWD was essentially the same as for the Dynaflect, except the load was much higher.

The relative effect that each variable has on slab deflection is summarized in the following section.

Slab Thickness. The effect of slab thickness on pavement deflection is variable. For the FWD, deflection increases range from 16.5 to 33.0 percent when slab thickness is reduced from 10 to 8 inches. Deflection increases of 42 to 90 percent are observed when slab thickness is decreased from 10 to 6 inches. These numbers are approximately equal to those observed for the Dynaflect (Figs 2.2 to 2.5).

Subgrade Thickness. Subgrade thickness has a major effect on slab deflection though this effect is reduced as slab thickness decreases. For example, a 10-inch slab experiences an increased deflection of 90 percent when the subgrade is varied from 60 inches to 350 inches , but a deflection increase is 60 percent when the slab thickness is 6 inches. This same trend is noticed for both the Dynaflect and the FWD.

In addition to the preceding analysis, which considered a base thickness of 4 inches, deflections were also measured for a rigid pavement system with a base thickness of 1.5 inches (Figs 2.4 and 2.5). A comparison of these two analyses indicates that, when the base thickness is reduced from 4 to 1.5 inches, there is not an increase in deflections. Instead, there is a decrease in pavement deflection when the subgrade thickness is between 60 and 350 inches.

1K

Slab	ν	=	.15	E	=	6×10^6 psi
Base	ν	=	.35	E	=	0.5×10^6 psi
Subbase	ν	=	.35	E	=	0.1×10^6 psi
Subgrade	ν	=	.45	E	=	32,000 psi
Rock	ν	=	.10	E	=	1×10^{99} psi

Base Thickness = 4 inches
Subbase Thickness = 6 inches

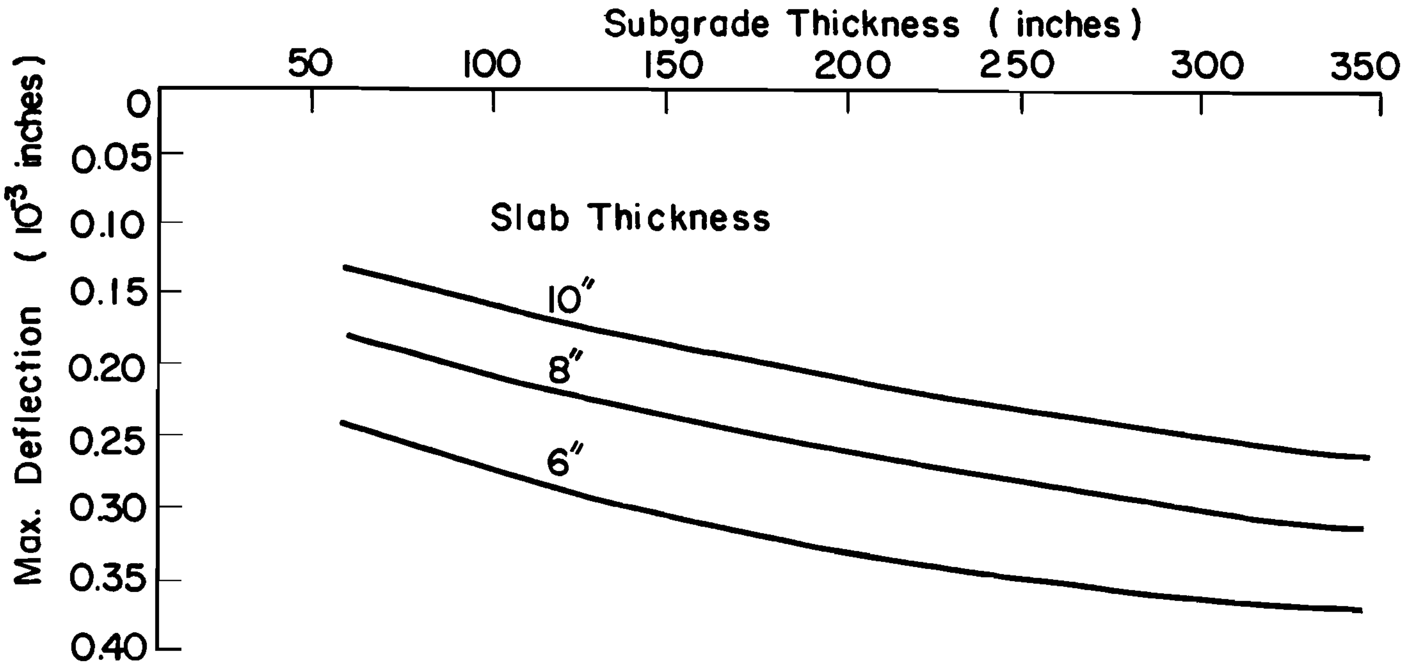


Fig 2.2. Effect of subgrade thickness on slab deflection (Dynaflect).

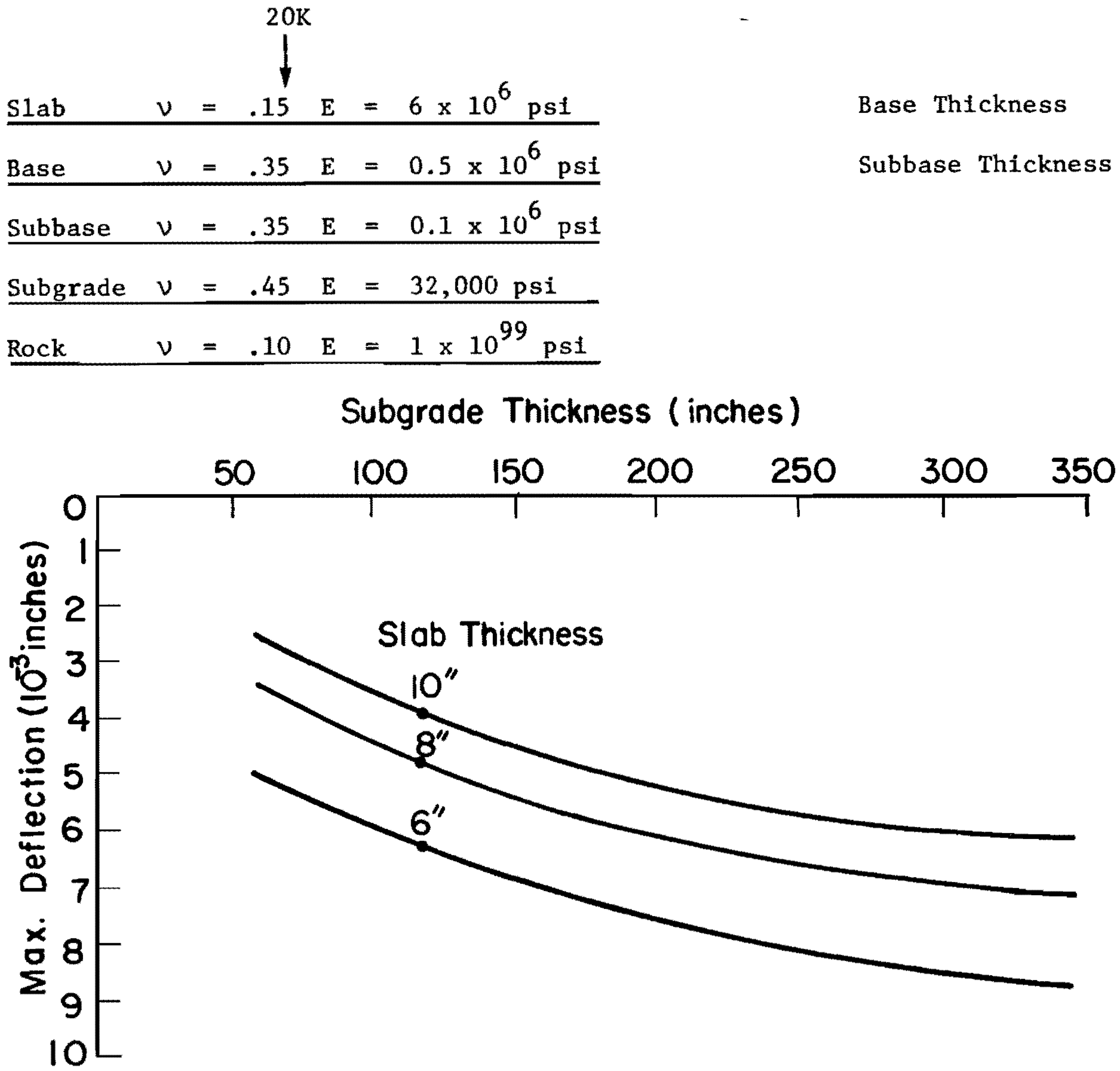


Fig 2.3. Effect of subgrade thickness on slab deflection (FWD).

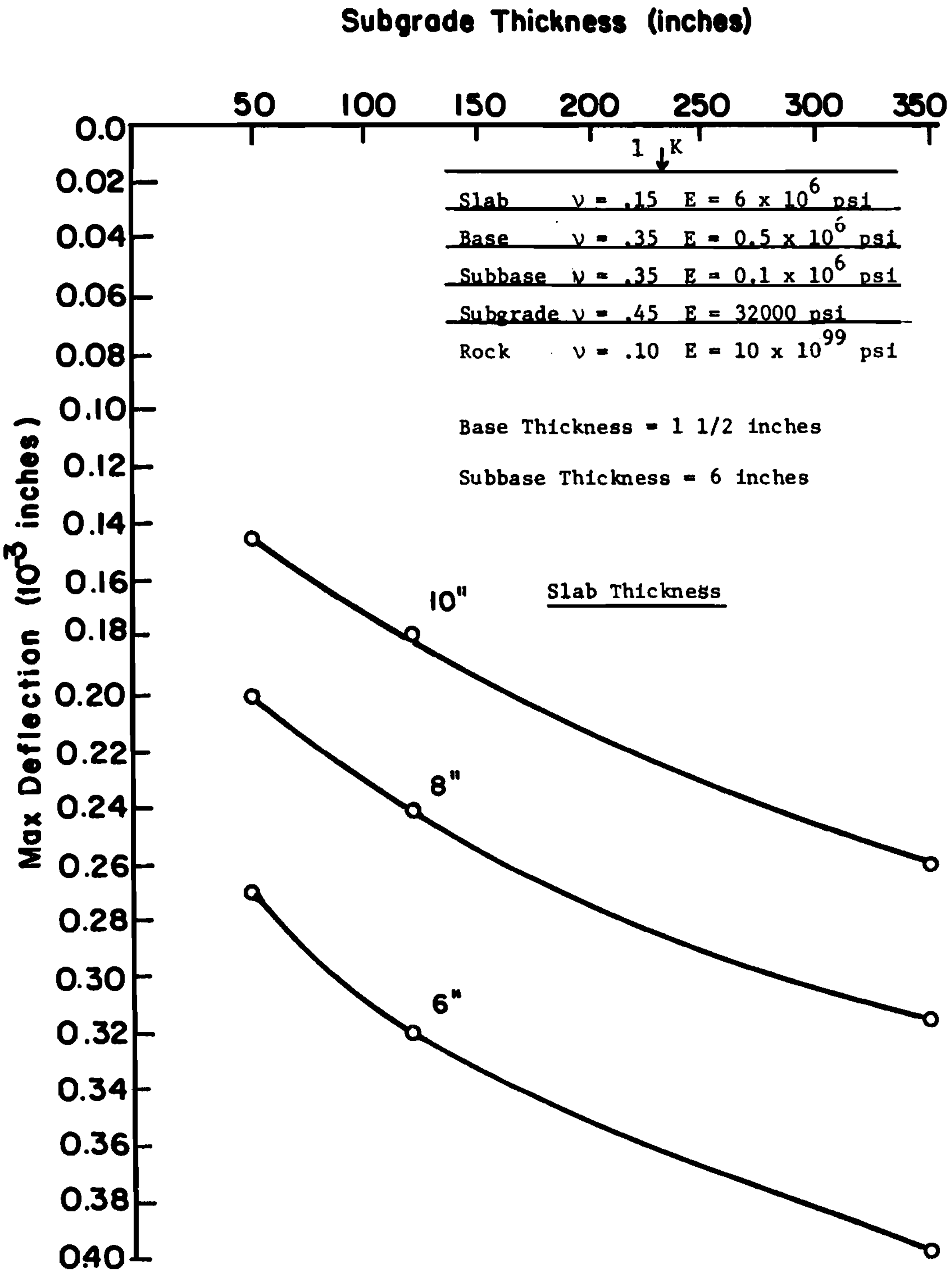


Fig 2.4. Effect of subgrade thickness on slab deflection (Dynaflect).

20K

Slab ν = .15 E = 6 x 10^6 psi

Base ν = .35 E = .5 x 10^6 psi

Subbase ν = .35 E = .1 x 10^6 psi

Subgrade ν = .45 E = 32,000 psi

Rock ν = .10 E = 10 x 10^{99} psi

Base Thickness = 1.5 inches

Subbase Thickness = 6 inches

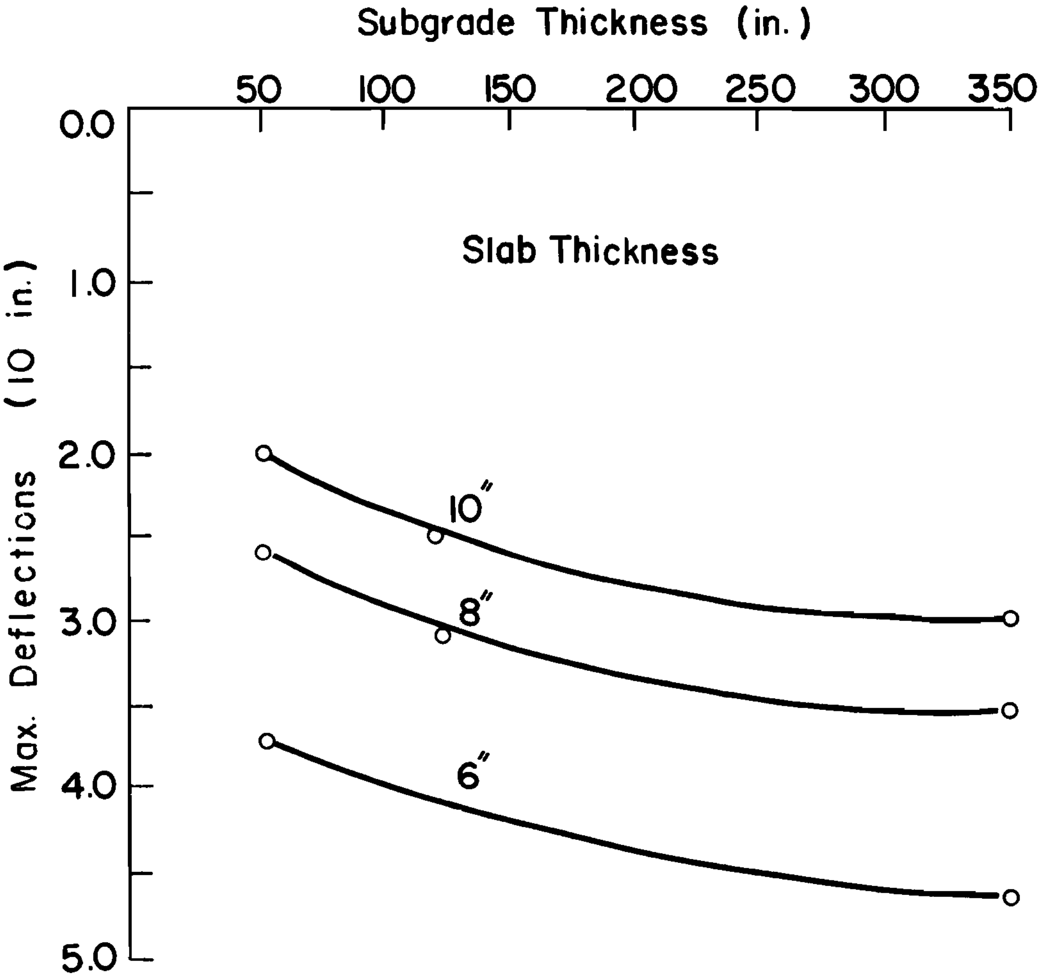


Fig 2.5. Effect of subgrade thickness on slab deflection (FWD).

of these two analyses indicates that, when the base thickness is reduced from 4 to 1.5 inches, there is not an increase in deflections. Instead, there is a decrease in pavement deflection when the subgrade thickness is between 60 and 350 inches.

When the subgrade approaches an infinite thickness, the pavement with a 1.5-inch base begins to experience slightly larger deflections than the pavement with a 4 inch base. This indicates that, for pavement systems with a shallow subgrade over bedrock, an increase in the thickness of asphaltic cement base will increase pavement deflection, while, for pavement systems with a deep subgrade, an increase in asphalt thickness will add strength to the pavement and reduce deflection.

Subbase Thickness. Six inches of crushed stone flexible subbase will be laid on top of the embankment to provide a working platform for slab construction and to help protect the embankment from rainfall and wind erosion. Type A, grade 1 material will be used as described in the Texas State Department of Highways and Public Transport 1982 Standard Specifications (Ref 5). A portion of the crushed stone (Fig A.1) will be covered with an asphaltic cement concrete (ACC) layer. The purpose of the ACC layer is to provide a uniform and stable surface upon which to build the slab. The ACC will also provide a smooth surface, on which to construct the pavement. A section of the crushed stone surface will remain uncovered for possible future testing of precast slabs on this type of material.

Once the pavement has been constructed, a six foot wide, ten inch deep, crushed stone shoulder will be placed on the west and north side of the slab to provide shoulder support for the pavement and access to the slab surface by loading vehicles and other testing equipment.

Summary. As a result of the analyses, a 7 foot embankment was built to minimize the effects of the shallow bedrock. Increasing the depth of the subgrade from 3 feet to 9 feet should result in a 65 percent higher deflection of the pavement. An embankment thick enough to increase these deflections by more than 65 percent would be prohibitively expensive and would provide only small increases in deflection. The properties of the embankment will be described in the next report.

Compaction. Compaction procedures for all layers adhere to the provisions set out in the State Department of Highways and Public Transportation 1982 Standard Specifications (Ref 5). Too much compaction can be as bad as not enough compaction. High compaction will reduce pavement deflection while incomplete compaction may allow unwanted voids to form under the pavement. The following compaction procedures will be followed for the various layers during construction in an effort to simulate conditions that exist in the field:

(a) Earthwork. No compaction will be performed on the existing ground surface. However, the top 6 inches of organic soil was removed.

(b) Embankment (0 - 5 feet). The first 5 feet of embankment will be compacted 85 to 90 percent of modified proctor, using a sheeps foot roller.

(c) Embankment (5 - 7 feet). The next 2 feet of embankment will be constructed with select fill and compacted under "ordinary compaction" procedures from 90 to 95 percent of modified proctor.

(d) Flexible Base. Six inches of crushed stone (flexible base) will be compacted under "density control" conditions from 95 to 100 percent of modified proctor.

(e) Asphaltic Concrete Cement. Three inches of ACC will be compacted to an optimum of 3 to 5 percent air voids.

Surface Concrete Layer

The Portland cement concrete slab design was based on the SDHPT Highway Design Division Operations and Procedures Manual (Ref 6, pg. A21) for jointed reinforced concrete pavement and the State Department of Highways and Public Transportation (SDHPT) 1982 Standard Specifications (Ref 5) .

Slab Thickness. Eight inch and 10 inch thicknesses were considered when the pavement was designed . A 10 inch thickness was chosen for this project because it is representative of most jointed pavements built in the state of Texas. In addition, there are abnormalities in the pavement due to special instrumentation. The resulting weakened planes might cause unwanted cracking in a 8 inch slab. One slab is designed to move; this movement will cause extraneous stresses that could cause cracking in a thinner pavement. A draw back of the 10 inch pavement thickness is deflection. As shown in the analysis earlier in this chapter, an 8 inch pavement will theoretically deflect 30 percent more than a ten inch pavement. Also, a 10-inch pavement will require a bigger loading frame to move the 20 foot slab because of the extra concrete weight. However, despite these short comings, a 10-inch slab was selected.

Reinforcement. Reinforcement type, size and spacing follow State Department of Highways and Public Transportation (SDHPT) 1982 Standard Specifications (Ref 5)and Highway Design Manual (Ref 6) criteria. The Highway Design Manual states that No. 3, No. 4 or No. 5 bars may be used for transverse and longitudinal reinforcement as long as an equivalent or greater area of steel is maintained and provided no bar spacing is greater than 36 inches. Based on this criterion two options were available for bar size and spacing. One option was a No. 4 bar size with 36 inch spacing in both the transverse and longitudinal directions. The second option specified a No. 3

bar size with 20 inch transverse bar spacing and 18 inch longitudinal bar spacing (Fig 2.6). The reinforcement for the No. 3 bar configuration is more evenly distributed through a cross-section of the pavement than the No. 4 bar configuration. An even distribution of steel will reduce the risk of cracking in the pavement. In the end, the No. 4 bar configuration was chosen because there is less chance of interference between the reinforcement and instrumentation.

Concrete. A standard concrete mix was used for the slab in accordance with State Department of Highways and Public Transportation (SDHPT) 1982 Standard Specifications Class A concrete (Ref 5). The mixture will be combined as follows:

Class	Min Sacks Cement per Cubic Yard	Min Comp Strength 28 days psi	Max W/C Ratio	Slump Range, inches	Fine Agg No.
A	5	3000	7.0	1-3	1

A special provision in the mix design stipulates a crushed limestone coarse aggregate rather than river gravel. This was done to minimize stresses due to thermal expansion and contraction.

Joint Design

An original requirement of this project was to examine the effects of variable load transfer across joint on output from non-destructive pavement evaluation devices. As a result, the joint for this slab required special design considerations that would allow full, partial, and zero load transfer to be interchangeable. Initially, a standard full joint keyway as shown in Fig 2.7, was considered the best way to provide variable load transfer.

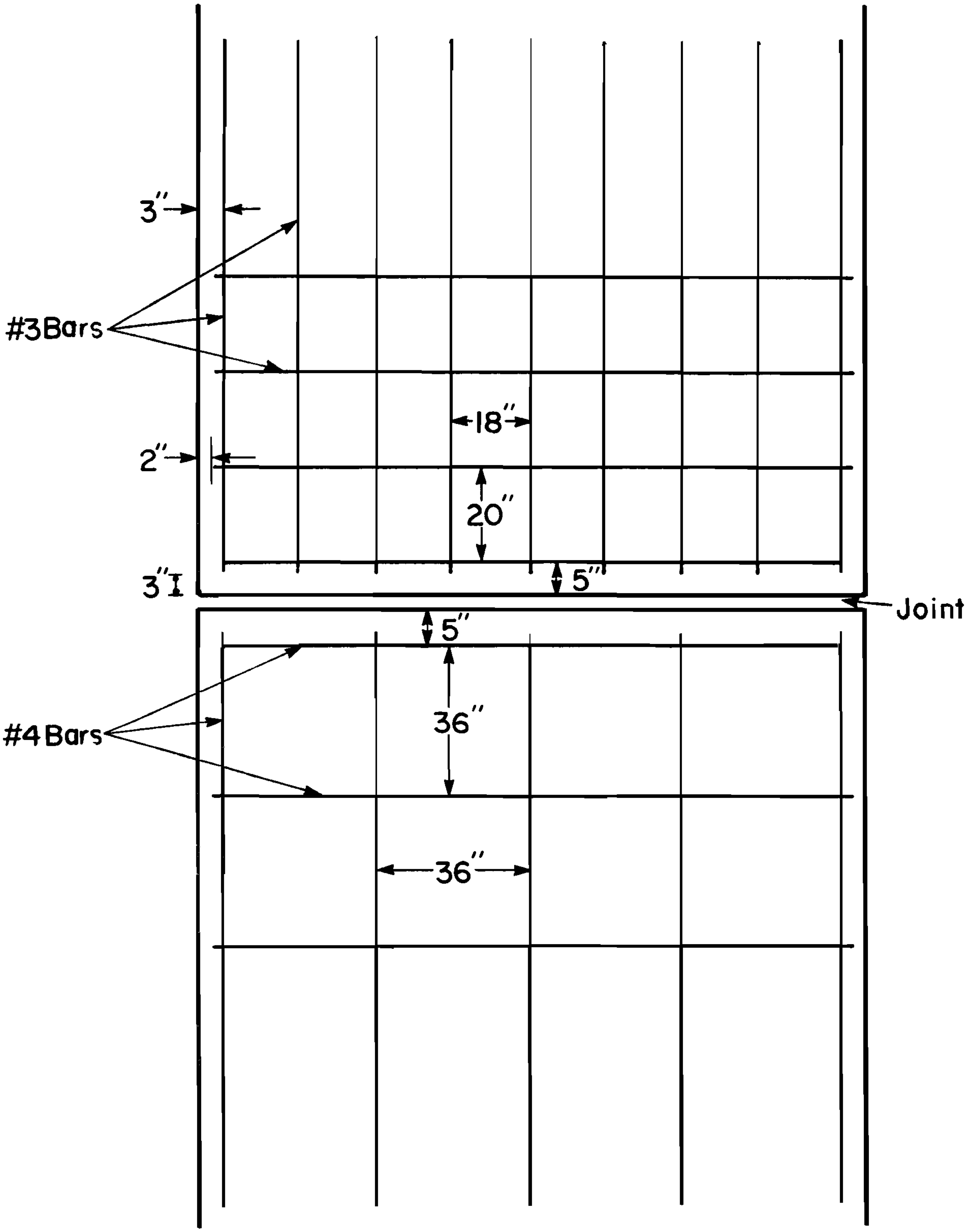


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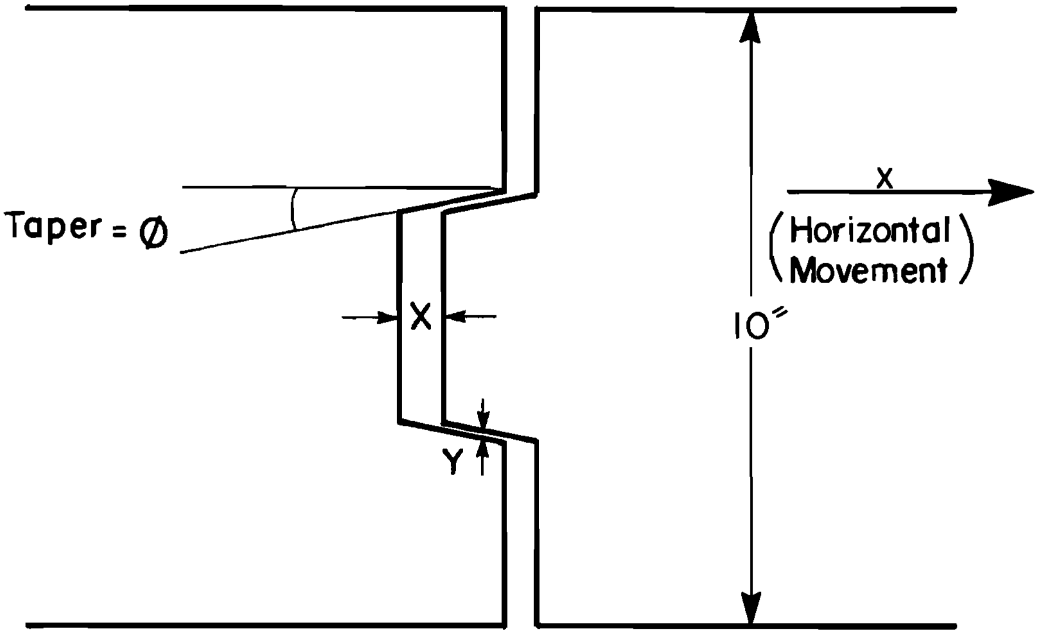
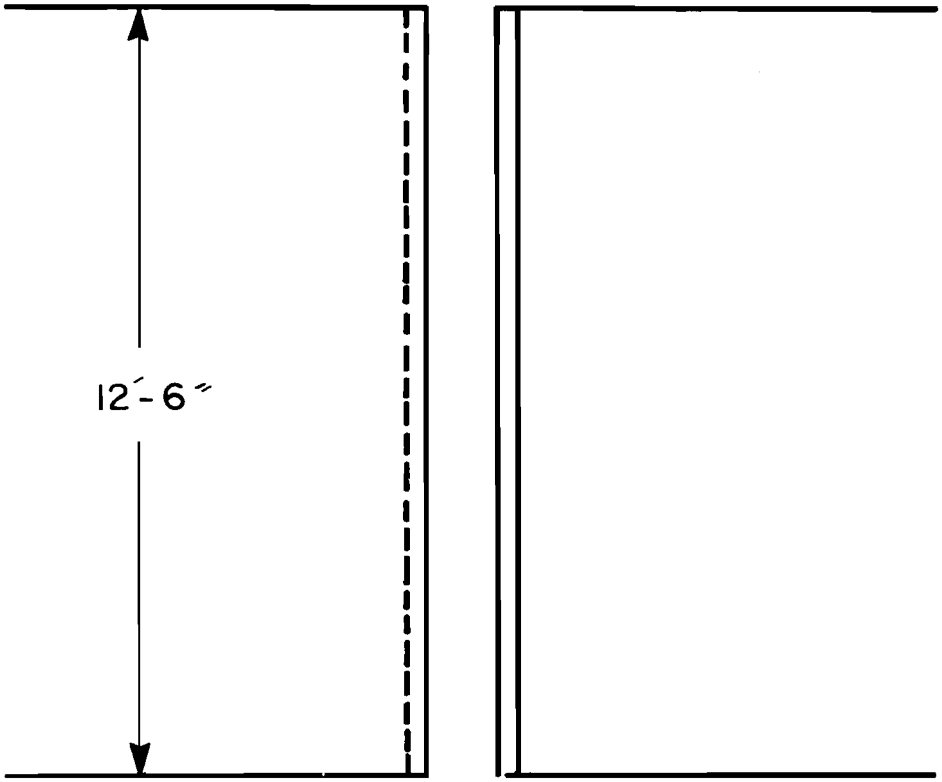
Fig 2.6. Slab steel requirements (Highway Department Manual).



(a) Elevation.



(b) Plan view.

Fig 2.7. Keyway joint design.

As the slab is moved slightly a distance (X) with respect to the other slab, the taper in the keyway causes a vertical gap (Y) to occur between the two sides of the slabs. When the two slabs are pushed together so that no horizontal gap exists at the joint, full load transfer should occur. As the horizontal gap is increased, the vertical gap will increase until large loads cannot deflect the pavement enough to close the space in the joint between the two slabs. Then, zero load transfer conditions exist. The keyway joint was abandoned for several reasons. First, it would be extremely difficult to fabricate the keyway with the necessary precision. Second, this type of joint, though used in the past, is not commonly used in jointed pavements built today. Third, the keyway would be susceptible to breaking under heavy loads and thermal stresses.

A system of dowel bars was designed to replace the keyway as a means of providing variable load transfer (Fig 2.8). The bars are tapered and will provide variable load transfer exactly as the tapered keyway would have. the joint will consist of 13 dowel units spaced at one foot intervals (Fig A.5). Each dowel unit consists of two stainless steel bars (Fig A.5). One bar (the male bar) is one inch in diameter and tapered at a specified angle on one end into a slight conical shape. The other bar (the female bar) is 1-1/4 inches in diameter with one end reamed out at the same taper as the male dowel so that the two bars fit snugly together. The dowel unit, when together, is 2 feet long. The male bar is 13 1/2 inches long and the female bar is 12 inches long. There is an overlap of 1-1/2 inches where the male bar fits inside the female bar.

The taper selected for the dowels was based on an analysis of the maximum and minimum deflections that are expected during testing. It was assumed that the minimum deflection would occur at an interior loading

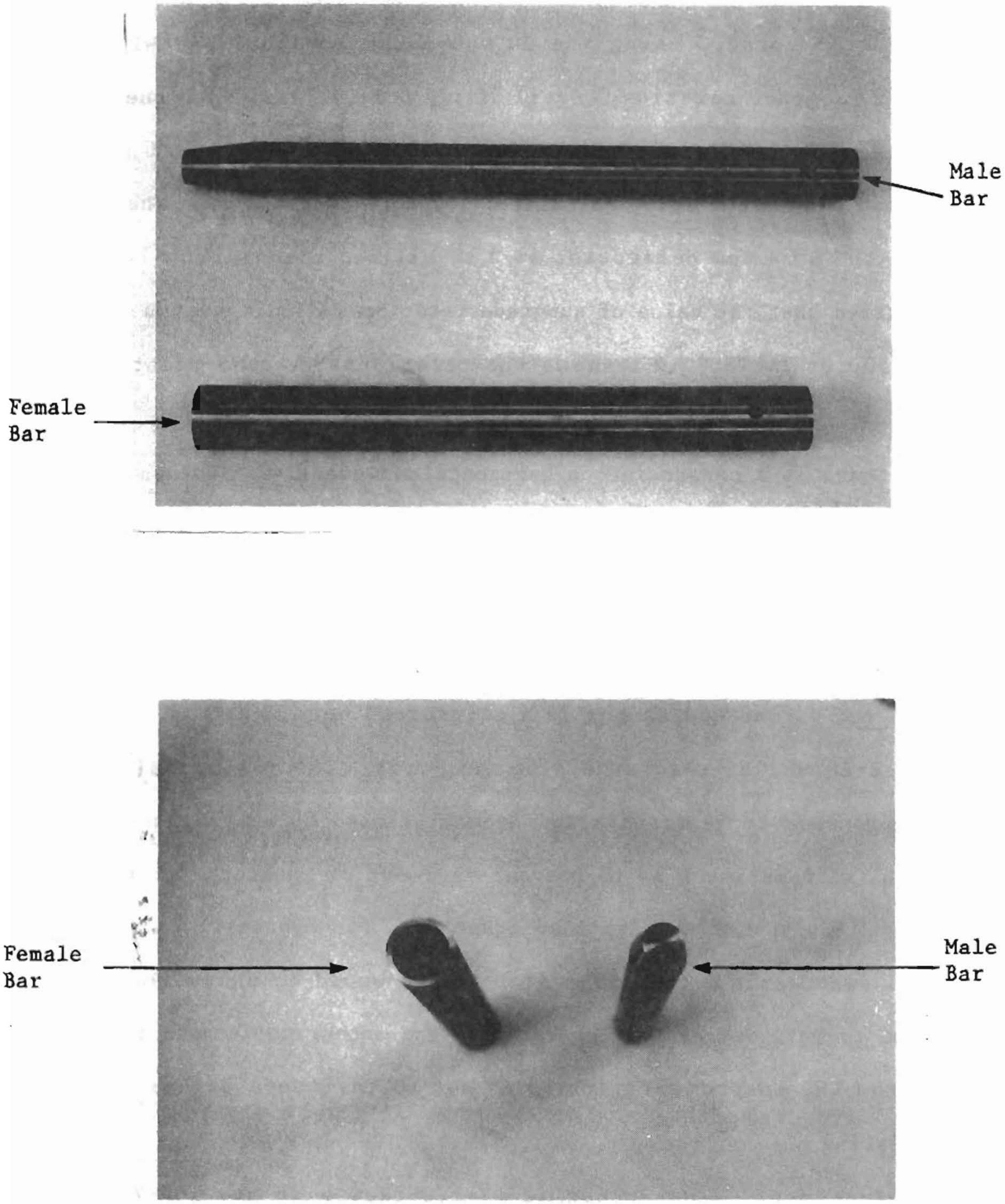


Fig 2.8. Dowel bars.

condition using the Dynaflect and that the maximum deflection would occur at an unsupported corner using the 20,000-pound load of the FWD. When a modulus of subgrade reaction (k-pci) of 500 pci is input into the computer program SLAB49 (Ref 7) a minimum deflection of 0.49 mil and a maximum deflection of 16.0 mils were calculated for a 10 inch slab. When k equals 1500 pci, the minimum deflection is 0.19 mil and the maximum is 5.46 mil. It is expected that the value of subgrade reaction will lie somewhere between 500 and 1500 pci. Table 2.1 shows the relationship of horizontal gap and vertical gap for various degrees of dowel taper ranging from one to ten degrees. There is a constraint on horizontal movement of 3/4 inch for the 20 foot slab. Based on this data, and leaving some room for error, a dowel taper of 7 degrees was chosen.

Terminal Anchorage

Purpose. The end anchor is a reinforced beam, cast in place 5 feet from the free end of the large slab (Fig A.6). Though typically used on bridge approaches to restrain slab movement caused by thermal stresses, its purpose in the experiment is to prevent movement of the large slab while the small slab is adjusted to vary load transfer. Two hydraulic rams will push the small slab against the large slab and it would be undesirable for the large slab to move during this operation. The anchorage is cast in place far enough from the instrumentation so as not to influence pavement response during testing.

Reinforcement. The anchor is 12-1/2 feet wide and 3-1/2 feet deep (excluding slab depth) and is reinforced according to the Highway Design Division Operations and Procedures Manual for terminal anchors (Ref 6).

TABLE 2.1. VERTICAL GAP GENERATION (INCHES X 10^{-3})

Horizontal Movement (inches)	Angle (degrees)									
	10	9	8	7	6	5	4	3	2	1
1.0	176.33	158.38	140.54	122.78	105.10	87.49	69.93	52.41	34.92	17.96
0.75	132.25	118.79	105.41	92.01	78.83	65.62	82.45	39.31	26.19	13.07
0.50	88.16	79.19	70.27	61.39	52.55	43.74	34.76	26.20	17.45	8.73
0.25	44.08	39.60	35.14	30.70	26.28	21.87	17.48	13.10	8.73	4.36
0.15	26.45	23.76	21.08	18.42	15.77	13.12	10.49	7.86	5.24	2.62
0.10	17.63	15.84	14.05	12.28	10.51	8.75	6.99	5.24	3.49	1.75
0.05	8.82	7.92	7.03	6.14	5.26	4.37	3.80	2.62	1.75	.87
0.01	1.76	1.58	1.41	1.28	1.05	.87	.70	.52	.35	.17

Load Frame

Purpose. The purpose of the load frame is to provide a method of moving the 20 foot slab laterally, as shown in Fig 2.9. The resulting joint opening will yield variable load transfer.

Design. The loading frame consists of a 2-foot wide, 3-foot deep and 12-1/2 foot long reinforced concrete beam. A sleeper slab is situated between the beam and the PCC pavement to prevent the soil from shoving at this location (Figs A.4 and A.7). Anchor bolts that will hold two steel flanges will be cast in place in the concrete. The flanges will provide the reaction for two hydraulic rams to push and pull against when moving the test slab. The rams will be connected to the pavement by means of two 4 foot support bars and two 9 inch long collars (Fig 2.9). Two 15 foot long anchor bolts 1 inch in diameter will be cast into the small slab and extend 5 inches from the free end of the small slab. The collar will thread on to the 5 inches of anchor bolt that extend from the small slab. These collars serve as a coupling device from the 5 inch threaded extension of the slab anchor bolts to the 4 foot support bars, which in turn support the rams (Fig 2.9). This configuration can provide 2 inches of horizontal movement in the slab. The reinforcement in the load frame is designed to prevent tensile failure in the concrete. Assuming a friction factor of 1.5 and a unit weight of concrete of 150-pounds, the maximum load the system will have to push or pull is approximately 22 tons. Three sheets of 4 mil polyethylene will be laid under the 20 foot slab to help reduce friction between the asphaltic base and the Portland cement concrete layer.

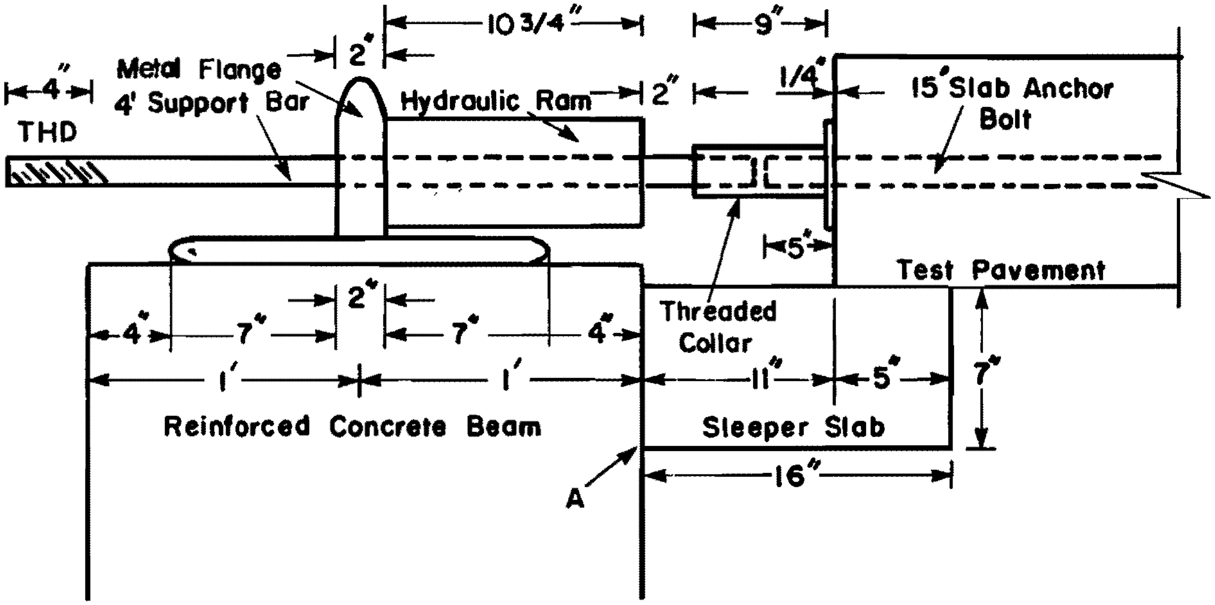


Fig 2.9. Joint gap adjustment hardware.

CHAPTER 3. PILOT SLAB

INTRODUCTION

It was decided that a laboratory scale test pavement would be useful in testing some of the design concepts planned for the large slab. The pilot slab was designed and constructed to (1) test the tapered dowels' ability to vary load transfer, (2) test installation of DCDT holding units, and (3) test the use of the Berry Strain Gage unit.

DESIGN AND CONSTRUCTION

The pilot slab was 2-1/2 feet wide, 6 feet long and 10 inches thick, with a transverse joint splitting the slab into two 3 foot slabs. No. 3 reinforcing bars were spaced as shown in Fig 3.1 and set just above mid-depth in the slab. Three dowel bars were placed precisely at mid-depth in the slab. The dowel bars had a circular cross-section, and a 2-1/2 degree taper and were located at 1 foot centers across the joint with 3 inches of concrete cover on each side (Fig 3.1). The joint gap was adjustable by means of a loading frame, so that load transfer could be varied as shown in Fig 3.2. Eight adjustment nuts were used to open and close the joint, thereby varying load transfer.

The two slabs were cast in place on top of 2 inches of rubber that simulated a subbase. Two sheets of polyethylene were placed between the slab and the subbase to reduce friction.

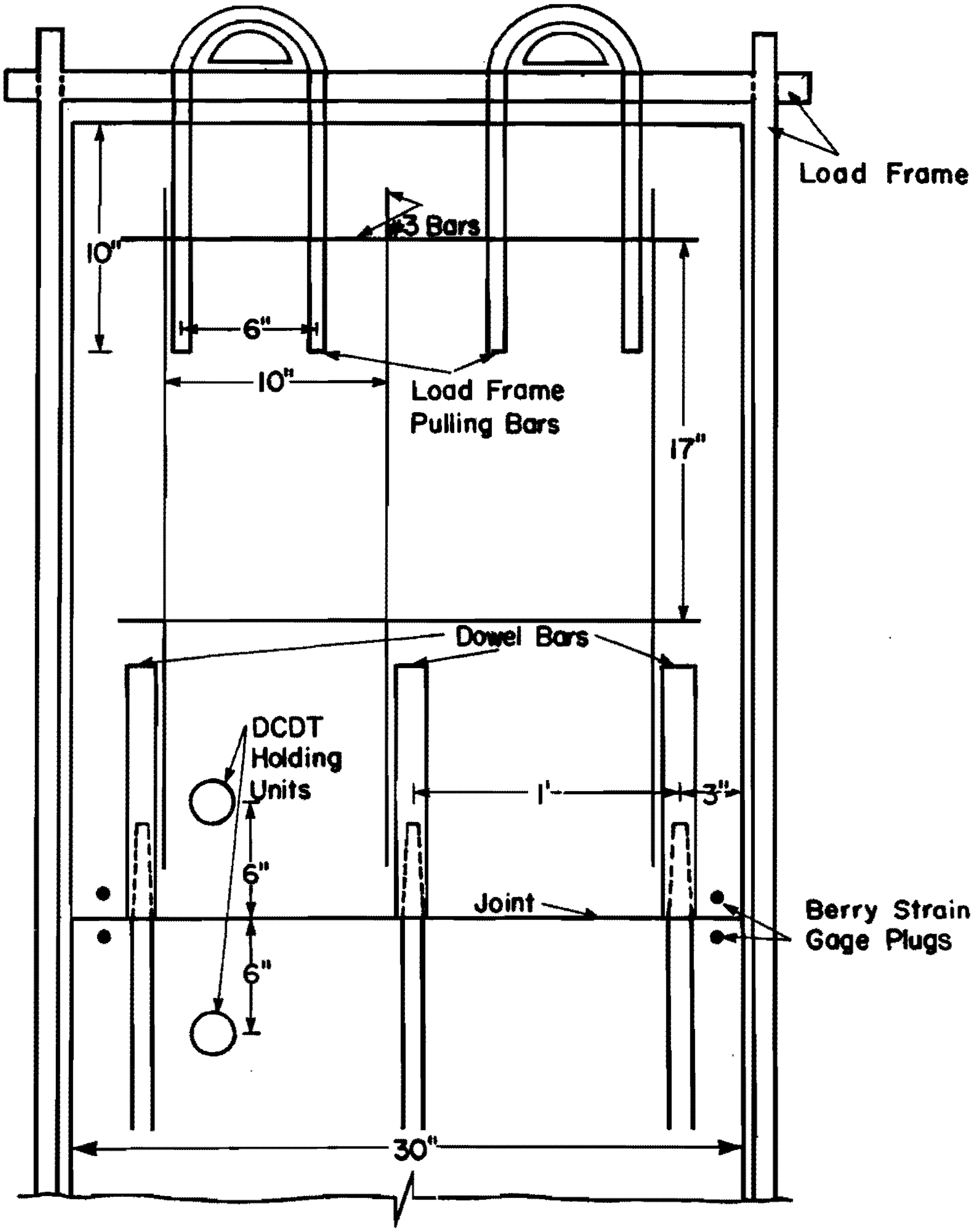


Fig 3.1. Pilot slab reinforcing.

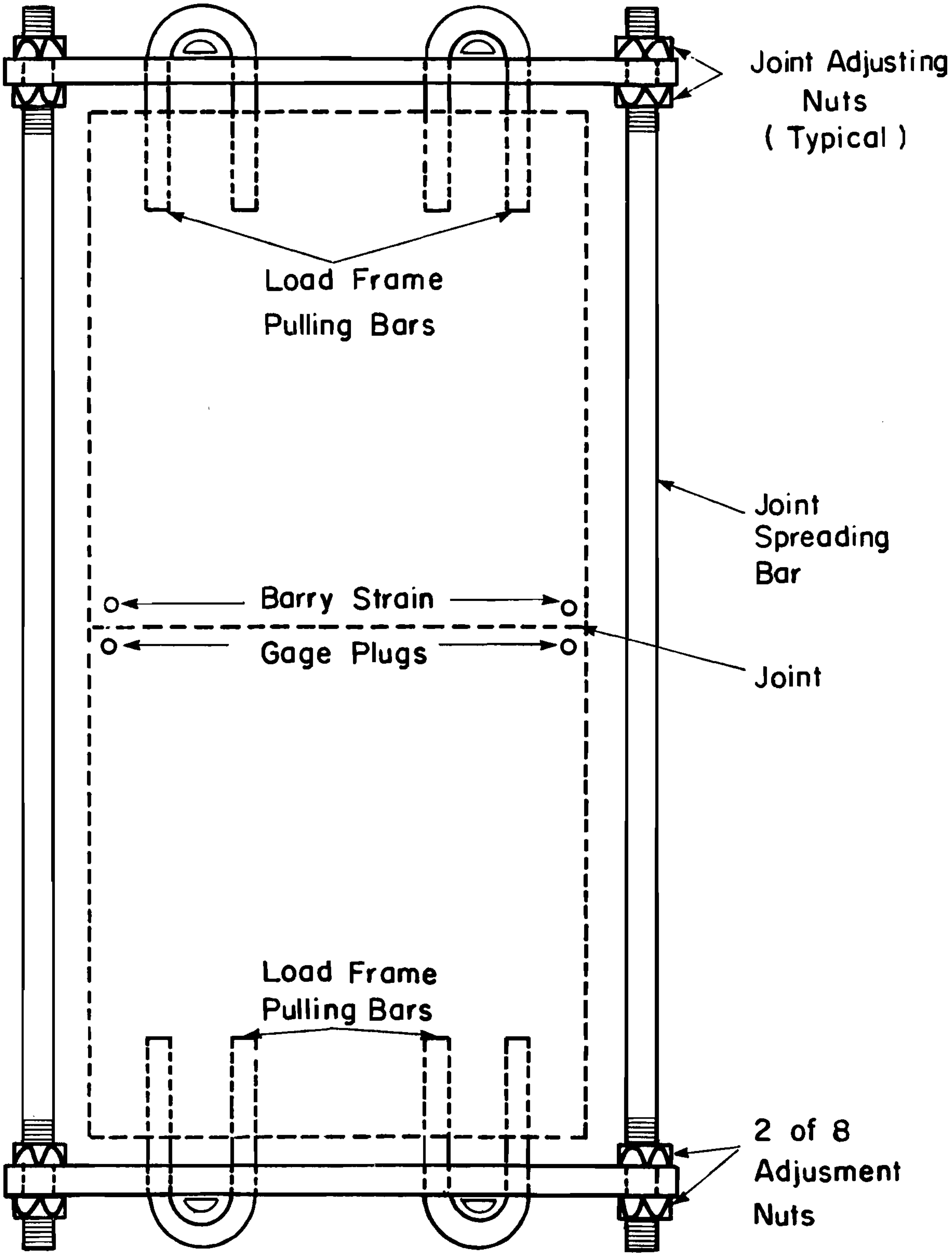


Fig 3.2. Pilot slab load frame.

VARIABLES CONSIDERED

The variables that were tested on the pilot slab include installation procedures of the dowel units, load transfer, installation of the DCDT holding unit, zeroing of the DCDT gage heads, and the joint gap measuring technique.

TEST PROCEDURE AND SET-UP

Once the slab was constructed and had cured for 28 days, a hydraulic ram (Fig 3.3) was positioned over the slab to provide the test load. The Direct Current Differential Transducers (DCDT) precision gage heads used to measure pavement deflection were not available at that time so three DCDT surface deflection gages were positioned as shown in Fig 3.4, to measure deflection and variable load transfer capabilities. Gage No. 2 was mounted next to the loading ram to measure maximum deflection. Gage No. 1 was mounted 8 inches away from gage No. 2 on the same side of the joint and gage No. 3 was mounted 8 inches from gage No. 2 on the opposite side of the joint. Each DCDT surface gage was calibrated prior to testing. The calibration results for each gage are shown in Table 3.1. The three DCDT surface gages were powered by a DC power supply. The load cell on the ram was powered by a signal conditioner that also amplified the strain gage output. The outputs from all four instruments (load cell and DCDT gages 1,2 and 3) were connected to a switch box which in turn was connected to a digital voltmeter which displayed the output (Fig 3.5). A manual hand pump and servo unit was used to load and unload the hydraulic ram on the pilot slab.

Testing of the pilot slab began by setting and measuring the joint gap at the desired gap width. Once the gap width was set, the DCDTs were

TABLE 3.1. CALIBRATION RESULTS OF DCDT SURFACE GAGES

Gage No.	Movement (in.)	Voltage Output	Movement (in.)	Voltage Output
1	--	--	--	--
	.1181	1.144	-.1181	1.153
	.2756	2.683	-.2756	2.683
	.3937	3.857	-.3937	3.845
	.5906	5.811	-.5906	5.781
	.6623	6.593	-.6623	6.553
	.7480	7.383	-.7480	7.322
	.7874	7.779	-.7874	7.708
2	--	--	--	--
	.1181	1.017	-.1181	1.028
	.2750	2.384	-.2756	2.394
	.3977	3.421	-.3937	3.430
	.5906	5.152	-.5906	5.170
	.6623	5.843	-.6623	5.859
	.7480	5.639	-.7480	6.554
	.7874	6.882	-.7874	6.902
3	--	--	--	--
	-.1181	-1.095	-.1181	1.130
	-.2756	-2.582	-.2756	2.611
	-.3937	-3.694	-.3937	3.718
	-.5906	-5.523	-.5906	5.542
	-.6623	-6.210	-.6623	6.268
	-.7980	-6.929	-.7480	6.956
	-.7879	-7.284	-.7874	7.315

r = .9999

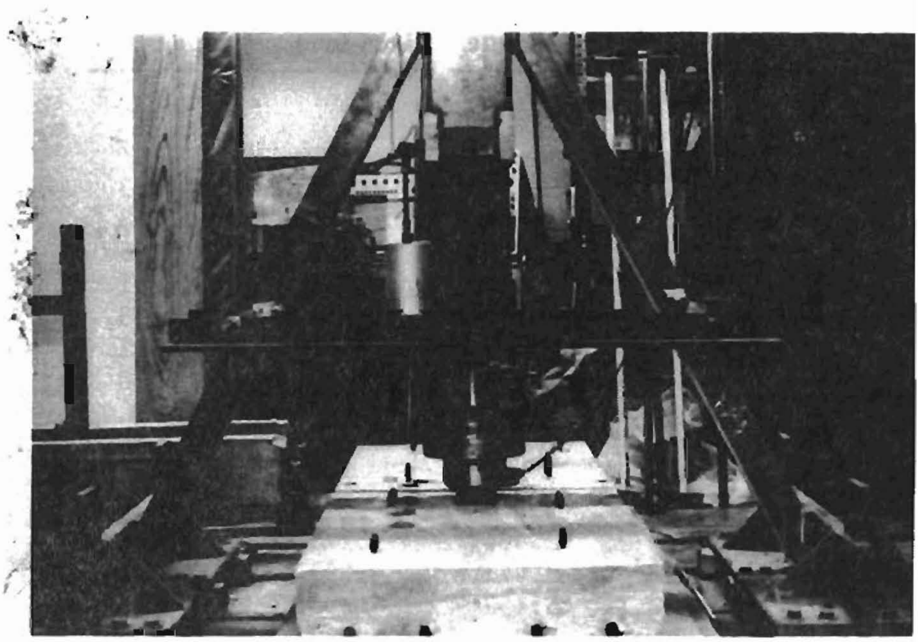


Fig 3.3(a). Pilot slab loading ram (front view).

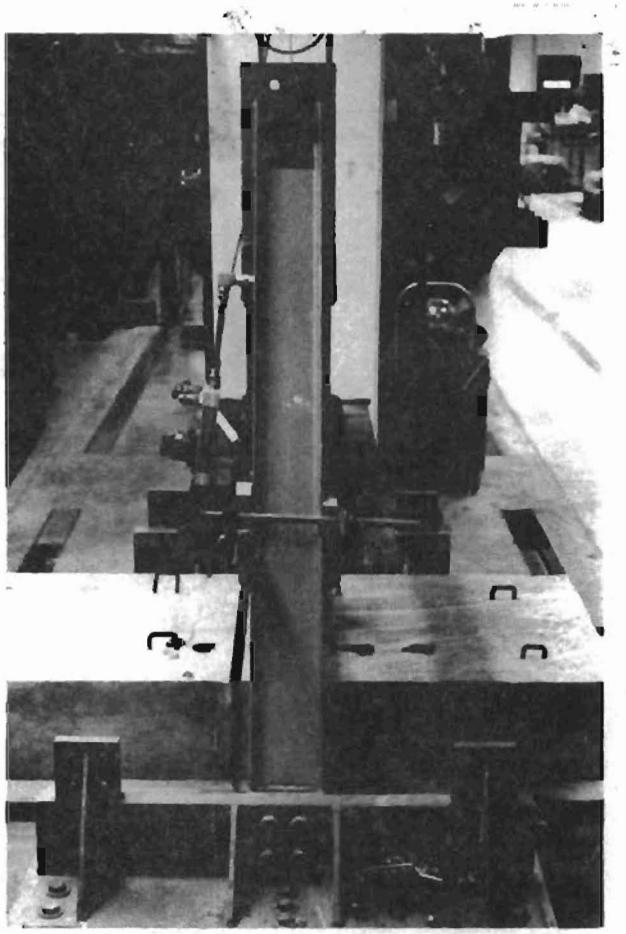
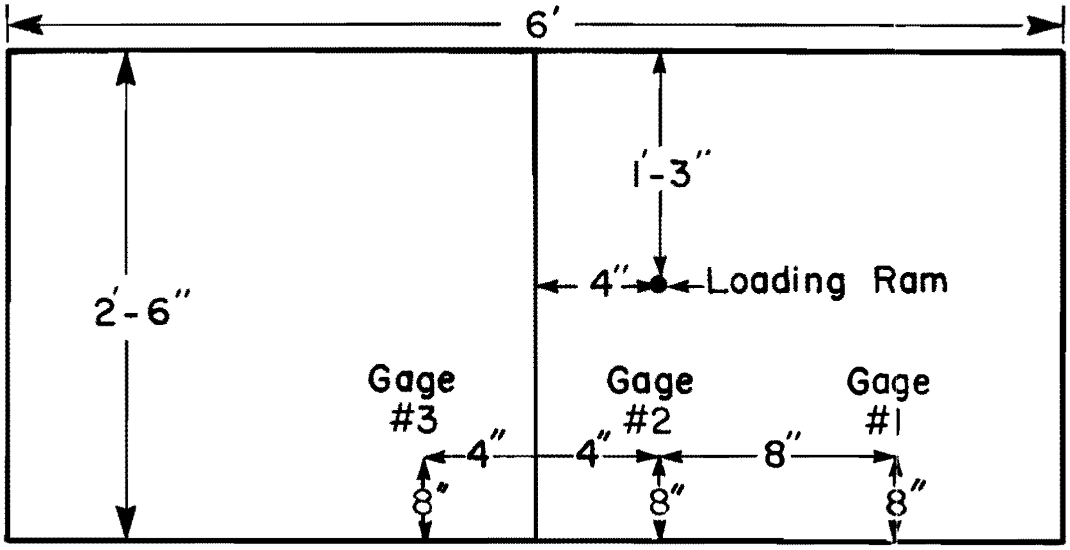
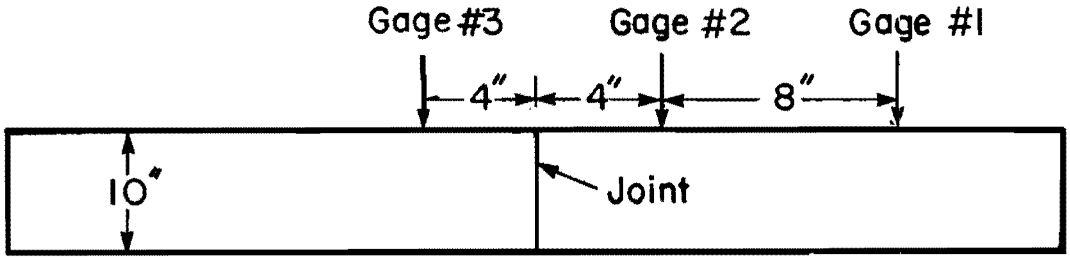


Fig 3.3(b). Pilot slab loading ram (side view).



(a) Plan view.



(b) Elevation.

Fig 3.4. Position of DCDT surface deflection gages on pilot slab.

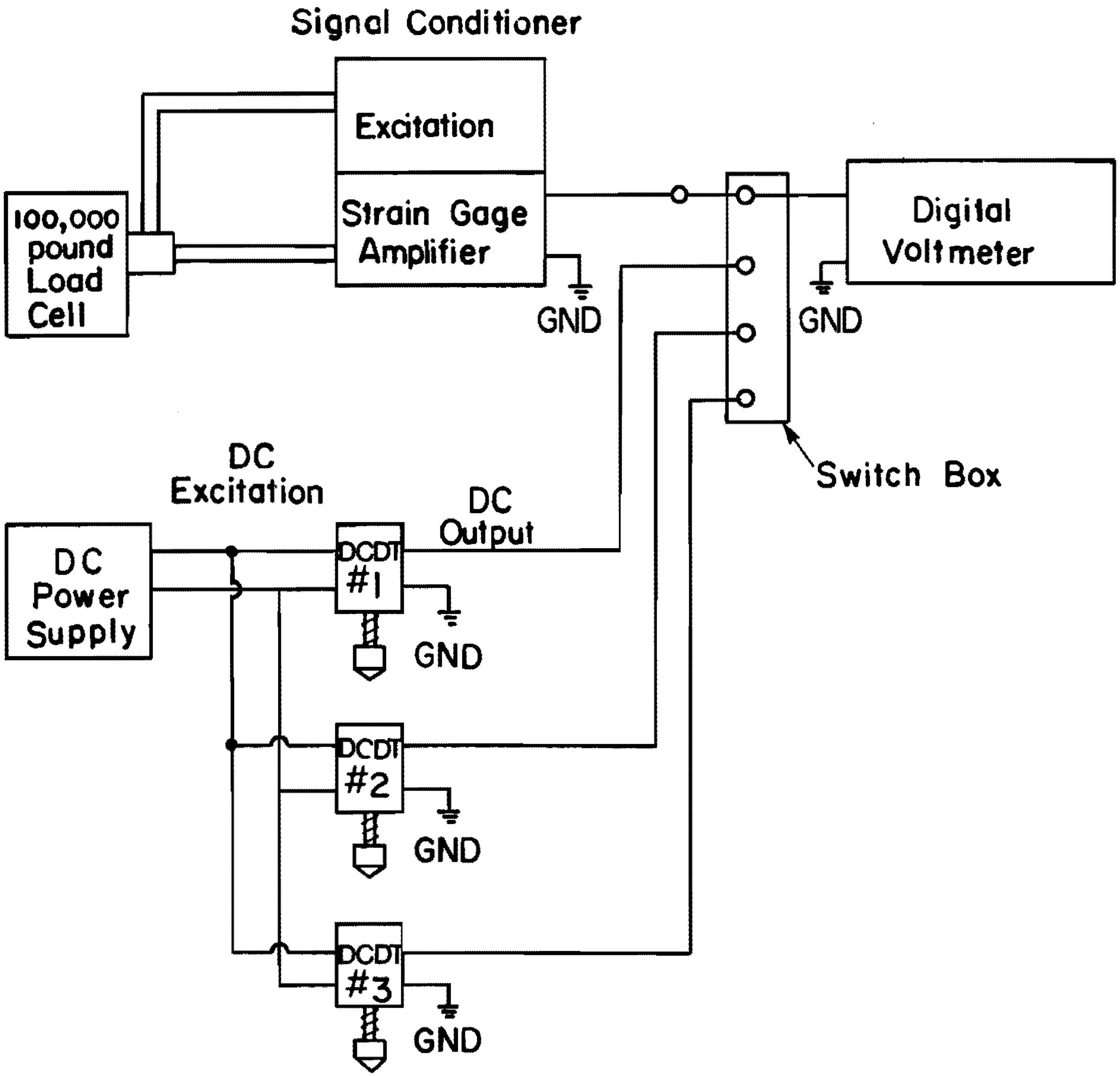


Fig 3.5. Electrical circuitry for pilot slab instrumentation.

adjusted so that the digital voltmeter read a zero output voltage for each unit. The slab was then preloaded to assure that the DCDTs were in a stable position on the pavement surface. After preloading, the slab was loaded in predetermined increments for each joint gap setting. During loading the voltmeter monitored the load cell circuit via the switch box until the desired load had been reached, then the DCDT surface gage data was recorded by switching the voltmeter to read each gage in turn while the load remained constant. The voltmeter was then switched back to read the load cell again and the load increment was raised. This procedure was followed for several joint gap widths, as shown in Table 3.2.

RESULTS

Results from the load transfer test are plotted in Figs 3.6 to 3.8 for joint gaps of 0, 0.5 and 1.0 inch, respectively. These graphs confirm that by varying the joint gap, we can indeed change the amount of load transfer across the joint. At a joint gap of 1.0 inches, the pilot slab joint developed load transfer at 2500 to 3000-pounds of load. These results cannot be used to predict how a pavement would deflect in the field because the pilot slab did not deflect as a rigid pavement would in the field. Rather than deflecting as a normal field slab would, with a curved deflection basin, the two slabs tilted like two individual blocks of concrete (Fig 3.9). Assumptions in most deflection prediction equations include the boundary condition that the concrete is continuous in the horizontal plane. The pilot slab was not continuous, and, consequently, the deflections were higher than are expected on the full-sized test pavement. The pilot slab was not used to predict deflections in the large pavement; instead, a computer analysis using a program called SLAB49 (Ref 7) was utilized to predict the maximum and

TABLE 3.2. DEFLECTION RESULTS FROM PILOT SLAB LOAD TRANSFER TEST

Joint Gap (in.)	Load (lb)	Gage			Joint Gap (in.)	Load (lb)	Gage		
		1 (mils)	2 (mils)	3 (mils)			1 (mils)	2 (mils)	3 (mils)
0	00	0	0	0	.75	00	0	0	0
	1000	?	16.2	10.8		1000	16.9	23.6	8.8
	1500	N/A	N/A	N/A		1500	N/A	N/A	N/A
	2000	14.5	18.7	12.4		2000	18.8	27.6	9.8
	2500	N/A	N/A	N/A		2500	N/A	N/A	N/A
	3000	15.3	20.0	13.3		3000	19.9	29.9	10.8
	4000	16.4	21.6	14.3		4000	20.9	32.3	11.7
	6000	17.8	24.1	15.9		6000	22.5	36.2	13.9
	7500	19.0	26.5	17.3		7500	23.2	38.1	14.9
.50	00	0	0	0	.25	00	0	0	0
	1000	16.3	21.6	8.7		1000	15.0	19.6	11.6
	1500	N/A	N/A	N/A		1500	N/A	N/A	N/A
	2000	18.4	25.7	10.8		2000	17.0	22.9	13.5
	2500	N/A	N/A	N/A		2500	N/A	N/A	N/A
	3000	19.4	27.8	12.1		3000	18.0	24.8	14.6
	4000	20.0	29.3	12.8		4000	18.9	26.4	15.6
	6000	21.5	32.6	14.8		6000	20.1	29.0	17.2
	7500	22.3	35.1	16.0		7500	21.1	31.1	18.2
1.0	00	0	0	0	0.1	00	0	0	0
	1000	17.9	25.5	8.4		1000	14.7	19.0	12.3
	1500	19.5	28.9	8.3		1500	N/A	N/A	N/A
	2000	20.4	31.0	8.2		2000	18.4	21.8	14.2
	2500	21.5	33.1	8.3		2500	N/A	N/A	N/A
	3000	22.9	34.6	8.9		3000	17.4	23.6	15.4
	4000	23.1	36.3	10.0		4000	18.5	25.5	16.6
	6000	24.6	40.7	12.3		6000	19.9	16.7	18.2
	7500	26.1	44.2	14.2		7500	21.0	30.3	19.5

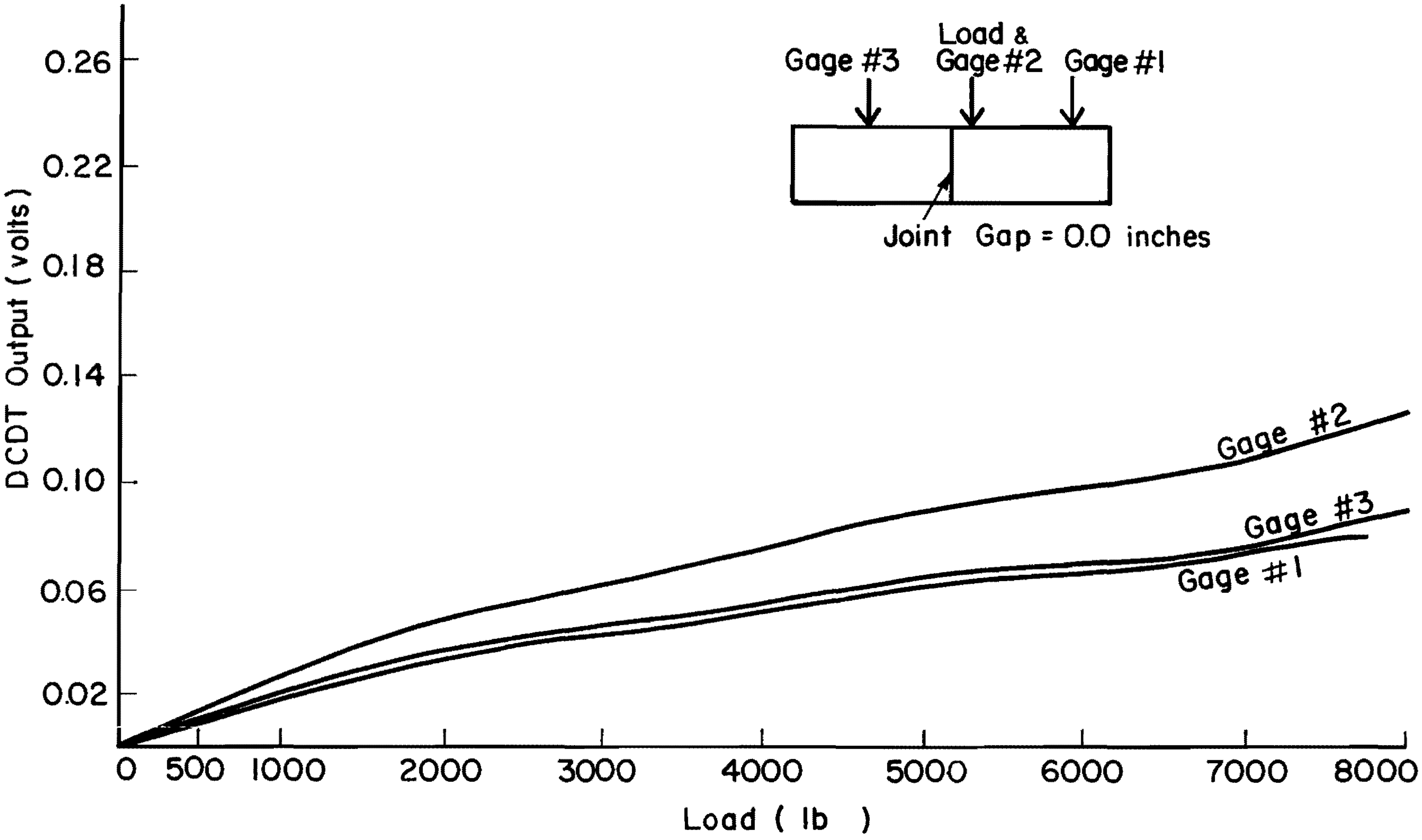


Fig 3.6. Load vs. DCDT output.

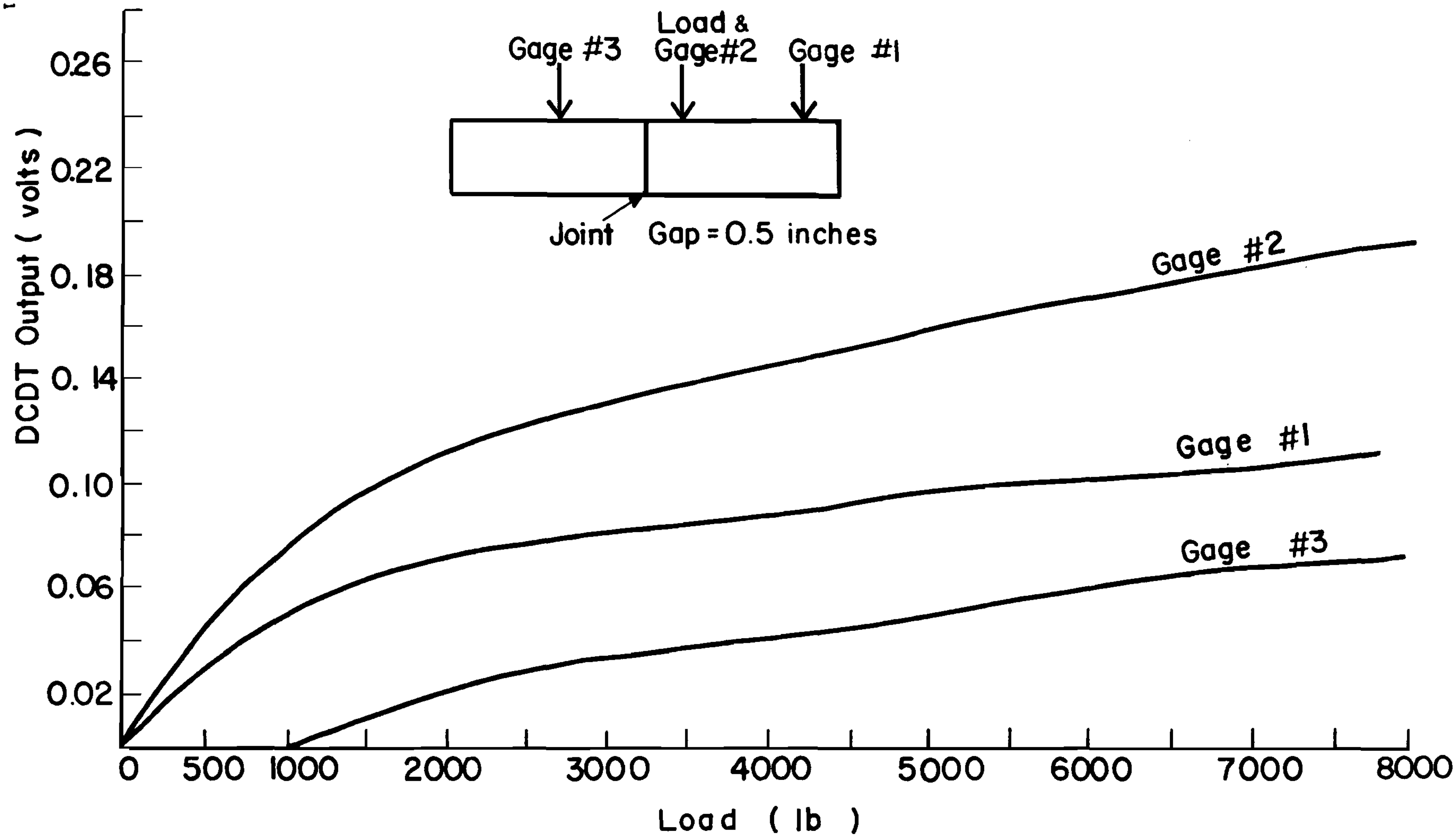


Fig 3.7. Load vs. DCDT output.

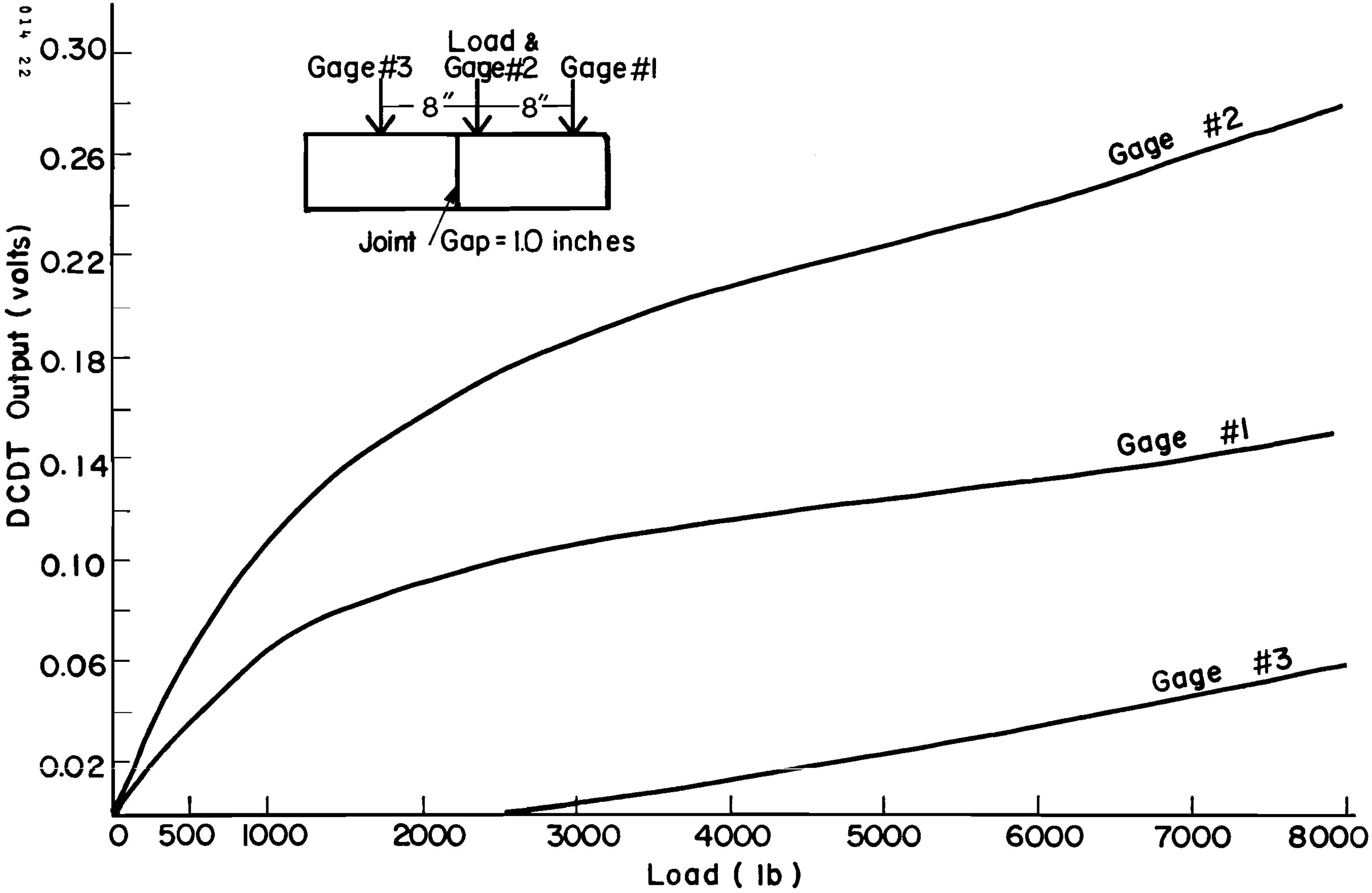
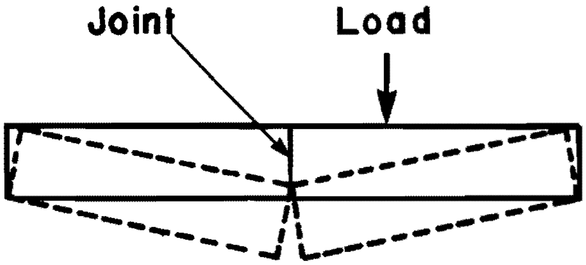
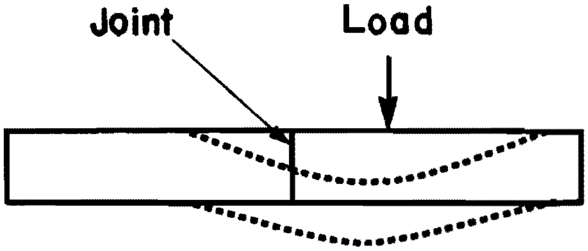


Fig 3.8. Load vs. DCDT output.



(a) True deflection basin.



(b) Assumed deflection basin.

Fig 3.9. Deflection basin examples.

minimum deflections expected in the test pavement. This analysis is described in an earlier chapter.

The DCDT holding units constructed with 1-1/4 inch ID PVC tubing (Fig 3.10) had to be redesigned as a result of tests with the pilot slab. The existing units were not stable during concrete placement and the holding units did not provide enough room for effectively adjusting the DCDT gage heads once they were in place. The new design provides a 2 inch diameter cup just below the surface of the pavement to facilitate the placement and adjustment of the gage heads. The new holding units will also be made of tubular steel welded together to provide support during concrete placement, as described in a later chapter.

A Berry Strain Gage was used to measure the joint gap. Unfortunately, the data was unreliable and user dependent. Readings varied, depending on who was taking the reading, and were not repeatable. Therefore, these gages will not be used to measure the joint gap on the large pavement. Instead, hardware that will hold two dial gages, one on each side of the joint, will be cast in place. These instruments should have less user related error and can be removed for night storage. The dial gages will provide a means for measuring joint gap and will also help to keep the joint in alignment. They are sensitive to 1/1000 of an inch.

The method of joint construction tested on the pilot slab held the dowels securely parallel to each other while the concrete was poured. It was very important that the dowel bars remain in perfect alignment and parallel in both vertical and horizontal planes, otherwise the dowels will bind when one slab is moved to vary load transfer.

The joint construction method used answered the need for perfect alignment. Not only did the dowel support hold the dowel bars rigid but this

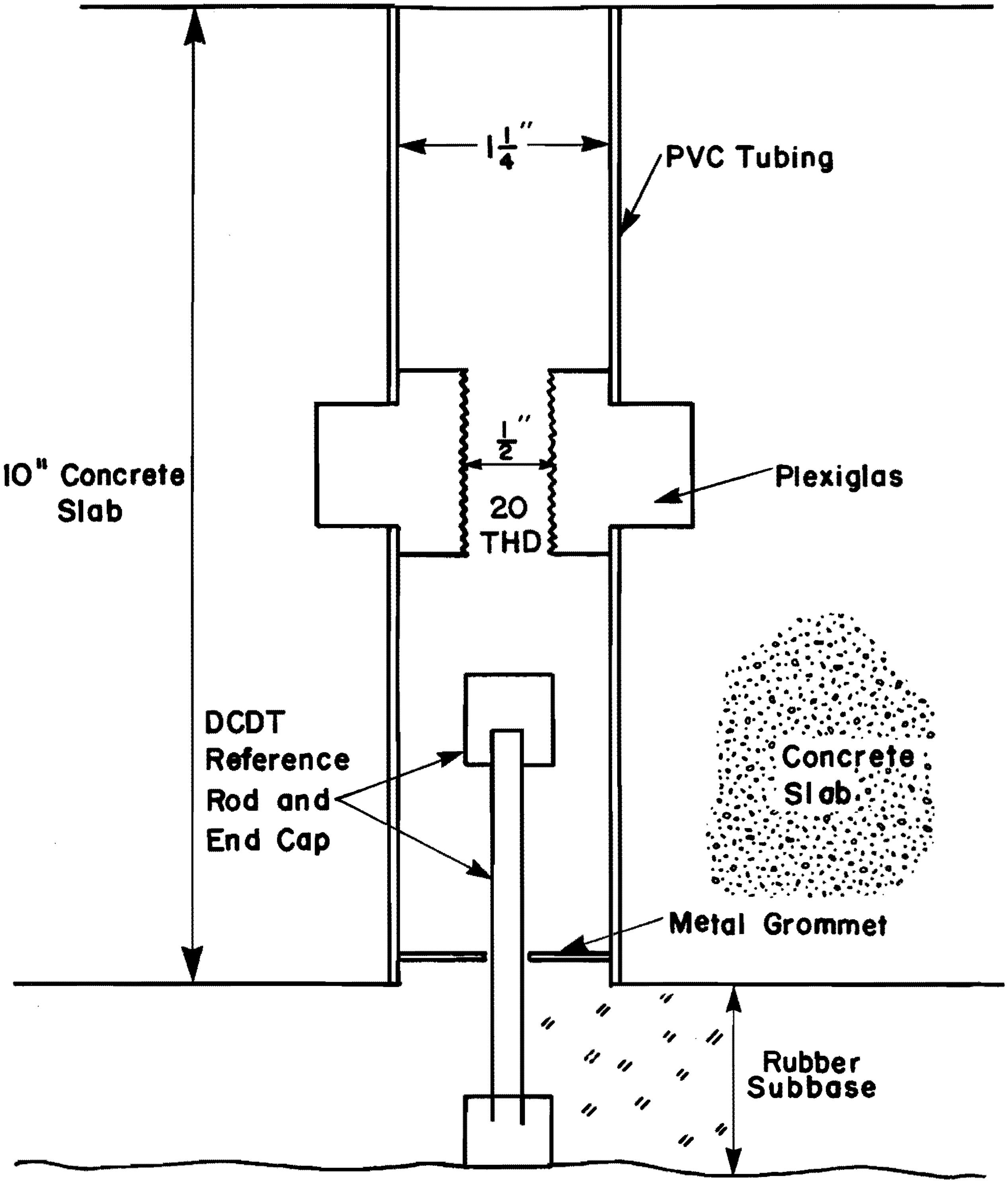


Fig 3.10. Pilot slab DCDT holding unit design.

construction method allowed for minute adjustments in the dowel bar to insure perfect alignment. A sheet metal spacer was used to separate the two 3 foot slabs. This spacer did not provide a straight transverse joint. The sheet metal was too flexible and, as a result, the joint was not smooth and even. The dowels, however, remained in perfect alignment on the pilot slab despite the warped sheet metal. In the planned test pavement, wooden formwork will be used at the joint. This will require two separate concrete pours but will result in a vertically and horizontally straight and smooth face at the transverse joint.

CHAPTER 4. INSTRUMENTATION

VARIABLES TO BE MONITORED

The objective of this project can be realized by constructing a test pavement and monitoring the variables that influence the output of nondestructive testing devices and other test equipment. Since these devices measure pavement deflection it follows that variables which influence deflection should be monitored. A long list of such variables was compiled and has been widely discussed between CTR and SDHPT personnel. The variables chosen for study are voids, slab temperature, gradient, moisture, load transfer, warping and curling. Independent deflection measurements will also be made during tests. This deflection basin data, measured with DCDT gage heads that are set inside the pavement, will be compared with deflection measurements made with the Dynaflect and the falling weight deflectometer.

SPECIFIC INSTRUMENTATION

Voids

Studies conducted in the past by the Center for Transportation Research (Ref 8) have shown a direct relationship between voids and deflection. For this reason, two voids will be cast in place beneath the pavement (Fig A.5). The voids will be placed on one side of the pavement while the other side will have full subgrade support for comparison tests. Both voids are 3 feet by 3 feet and will be constructed by placing a piece of one inch thick foamed styrene into depressions formed in the ACC base. After the slab is poured, solvent will be used to dissolve the styrene. The effect of voids will be examined at the joint and at an edge condition.

Measurement of Slab Temperature

On any day, the temperature of concrete through the depth of a slab varies as much as 3 degrees per inch of pavement (Ref 9). A pavement slab subjected to a temperature gradient will tend to warp. This warping action is counteracted by the weight of the slab. For example, if the upper surface of the slab is cooler than the bottom, the corners will tend to warp upward. Since the weight of the slab resists this movement, internal stresses develop. However, if the temperature gradient is large enough, the pavement will warp. When this happens, subgrade support is lost and subsequent edge deflections under load will increase. In a previous study by the Center for Transportation Research, temperature differential was found to affect edge deflection significantly (Ref 10). Therefore, it will be necessary to monitor the temperature gradient and see what influence it has on the output of NDT equipment.

A series of thermocouples will be used to measure slab temperature. The thermocouples will be placed at four separate locations in the 40 foot slab (Fig A.3). At each location, the temperature at the top, mid-depth and bottom of the slab will be monitored, thus, a total of 12 thermocouples will be cast in the slab. They were fabricated and calibrated in the laboratory. Type T (copper-constantane) thermocouple wire was used to minimize corrosion over a long period of time. Each thermocouple was made by taking 50 foot lengths of thermocouple wire and connecting the two dissimilar wires at one end with Leeds and Northrup Quicktip thermocouple pressure connectors and casting each temperature sensing end in a block of concrete mortar (Fig 4.1). These blocks have attachments to secure each thermocouple to the

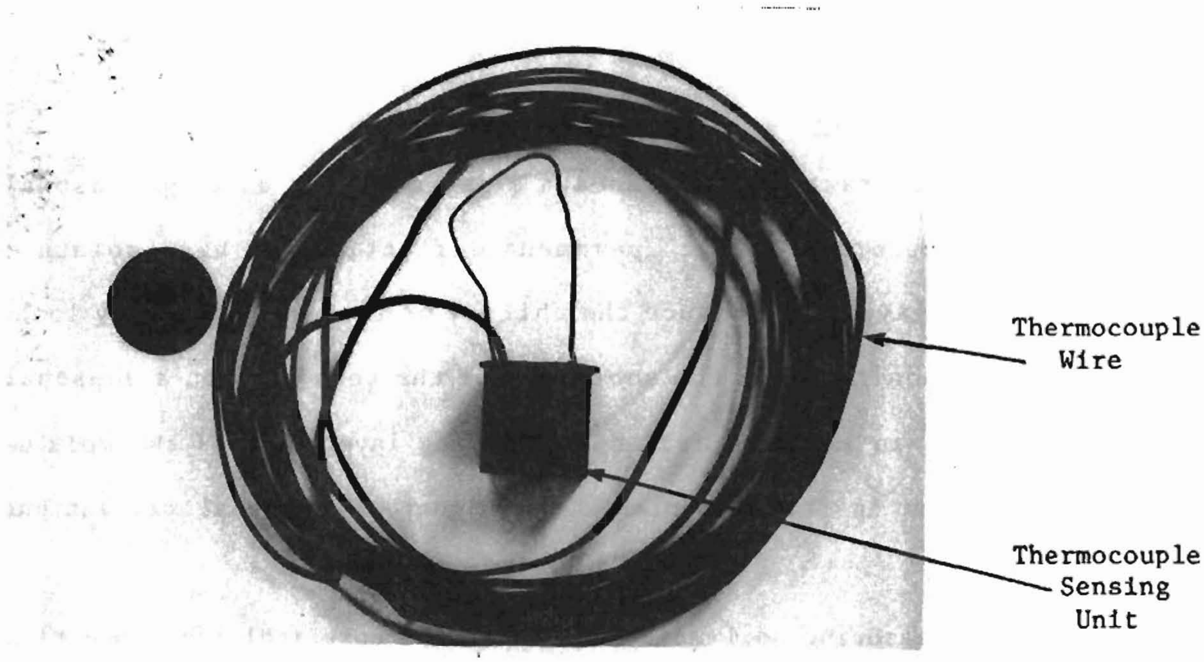


Fig 4.1. Concrete thermocouple block.

reinforcement at the proper location in the slab. The lead wires to the thermocouples will be run along the reinforcement and out of the west side of the test slab.

Moisture Measurements

The moisture content of soil beneath a pavement can undergo seasonal changes and can therefore change pavement deflection. A high moisture content in the sublayers can reduce the ability of that soil to carry load. Moisture will be monitored in the sublayers of the test slab on a seasonal basis. An increase in moisture for any supporting layer reduces the modulus of subgrade reaction in that material, and higher than normal deflections should be detected.

Methods for measuring soil moisture tend to be unreliable for long term measurement. Also, results can be erroneous as the calibration of some moisture blocks change with time. For these reasons, three separate systems will be set up to measure the moisture content in the sublayers. Having two redundant systems allows for one or two failures in the equipment. Also, a comparison can be made between the systems to check for accuracy. The systems that will be used for the test soil moisture condition are fiberglass blocks, psychromers, and a nuclear gage. The fiberglass blocks use the electrical resistance method of determining soil moisture. The blocks have a pair of electrodes embedded in a fiberglass material. The resistance between the electrodes varies with the moisture content in the fiberglass which is dependent on the moisture content of the soil it contacts (Fig 4.2).

Nuclear gages operate by emitting radioactive waves into the soil. The number of gamma rays deflected by the soil particles is recorded by the instrument detectors to indicate wet density. The level of soil moisture is

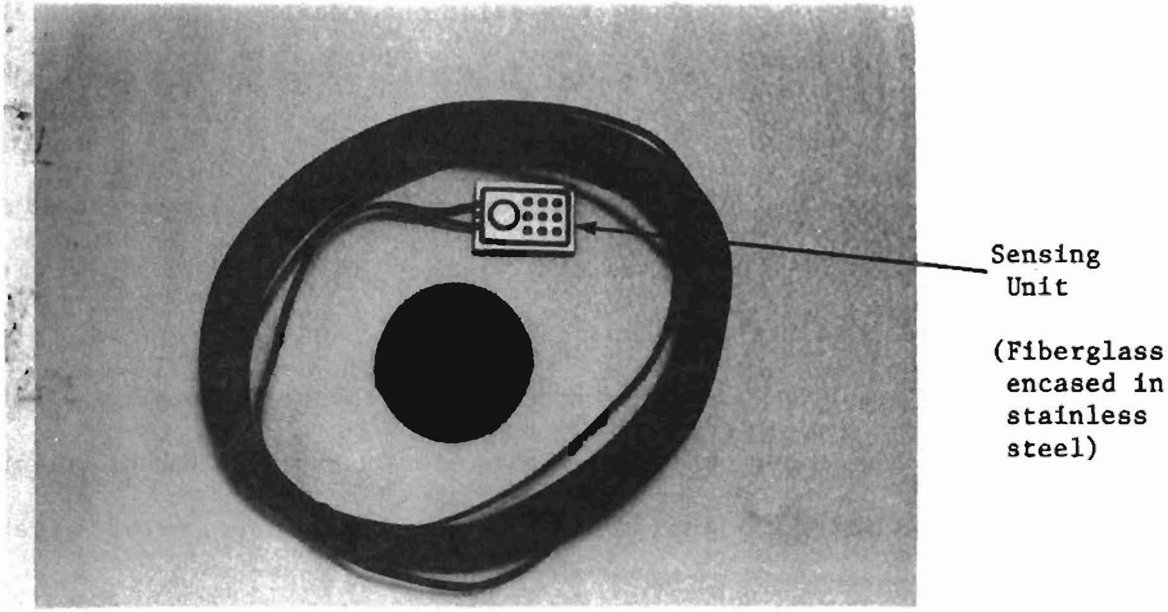


Fig 4.2. Fiberglass moisture block.

determined by the number of neutrons deflected, which is recorded by detectors to indicate moisture content.

The psychrometer is an instrument that can measure the energy per unit volume required to remove pure water from solutions, soil, or any material that contains water (Fig 4.3). This energy is called the water potential and the unit of measure is the bar, which is equivalent to 10^6 dynes per cm^2. The instrument uses a small chromal-constantan thermocouple mounted in a hollow porous bulb. Water is conducted to the inner surface where it evaporates until the humidity approaches 100 percent. Then the thermocouple is cooled below the dew point and water condenses on the thermocouple. After cooling is discontinued, the thermocouple is used to measure the dewpoint depression, or the wet bulb depression, which is a function of water potential.

Measurement of Joint Movement

To achieve variable load transfer, it is necessary to move the small slab to change the gap at the joint. By increasing the gap, the tapered dowels lose contact and, thus, load transfer across the joint is reduced.

To measure the amount of movement in the small slab, dial gauges will be mounted on the slab, one on each end of the joint. They will be held in place by holding units cast into the concrete slab (Fig A.2). Berry strain gages were going to be used; however, data from the pilot slab study shows readings from the gage were user dependent and not as repeatable as those from the dial gage. The dial gage holding units are designed so that the gages can be easily removed for storage between testing periods.

Curling of the pavement surface caused by environmental forces can influence the output of NDT equipment. Several components contribute to this

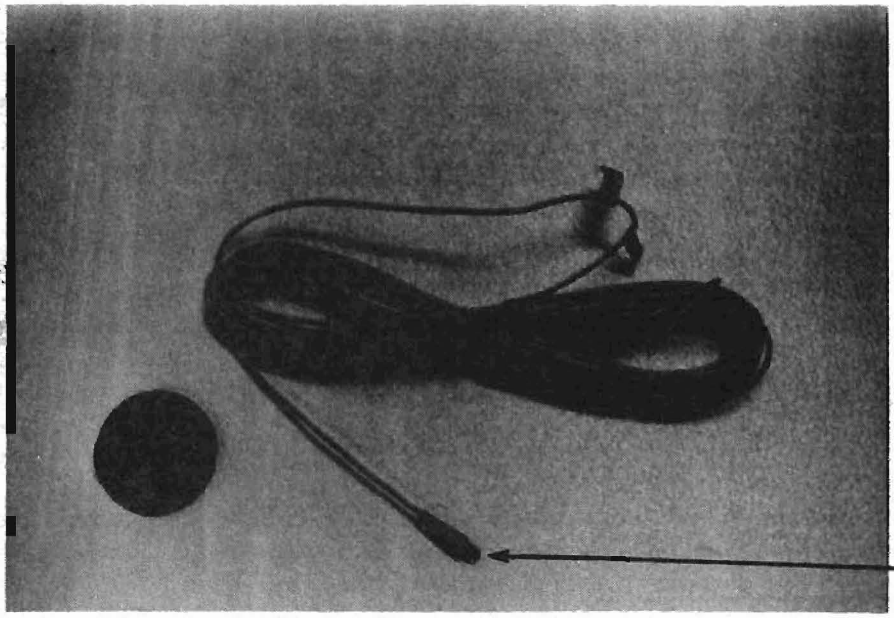


Fig 4.3. Psychrometer type moisture sensing block.

deformation. Temperature and moisture gradients through the depth of the slab are the major contributors to this problem.

Surface curling will be measured using a precision level device and a series of dial gages attached to a rigid frame. Any excessive curling can cause the dowels at the joint to bind. Therefore, the slab should be tested when curling is at a minimum.

Weather

Weather conditions just prior to and during slab testing will have some effect on test results. Naturally, we cannot control this variable. However, by monitoring environmental conditions such as air temperature, humidity, rainfall, wind speed and solar radiation, a better understanding of how the environment affects pavement deflection can be gained.

Independent Deflection Measurement

A method was needed to measure pavement deflection independent of the means provided by NDT equipment so that comparisons could be made between the output of NDT equipment and an independent measure of deflection. In addition, a means of measuring pavement deflections under static loading conditions was needed.

The instrument chosen to measure deflection is the DCDT (direct current differential transformer) (Fig 4.4). A special holding unit designed by project personnel (Fig 4.4), will hold the DCDT's rigid and vertically aligned within the pavement during testing. These holding units are constructed of steel, welded together and cast in place in the pavement. When the pavement deflects, the entire holding unit also deflects. The core of the DCDT rests on a reference rod that is buried to a 12 foot 6 inch depth, down to the bedrock. The motion of the pavement relative to the Fig

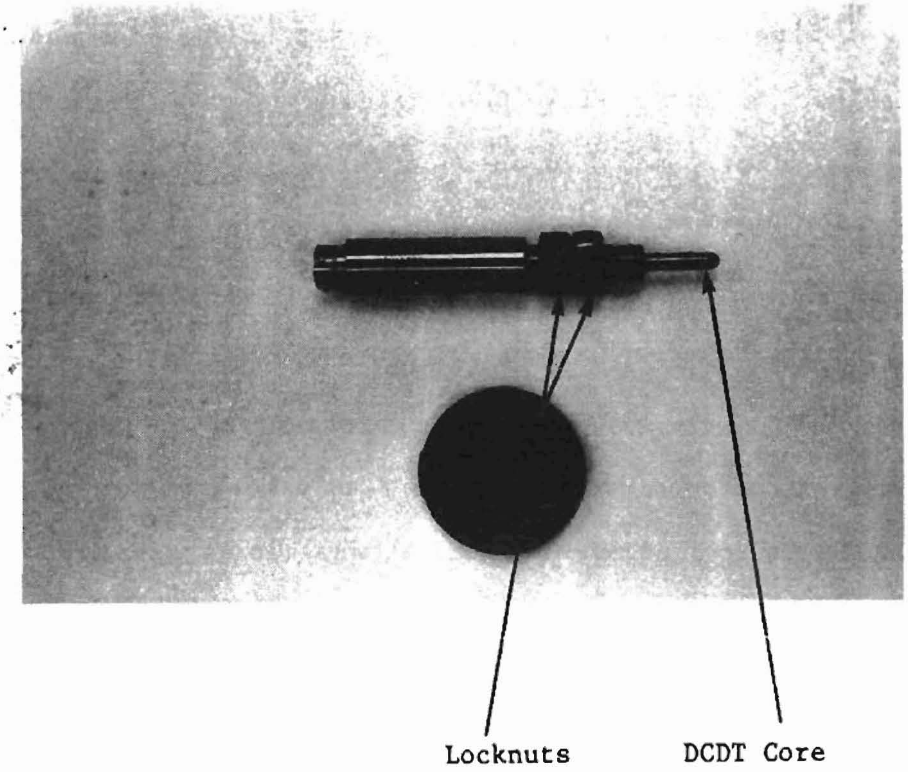


Fig 4.4. DCDT gage head.

reference rod will be measured by the DCDT. The DCDT's will be mounted inside the pavement to allow room for loading equipment on to the pavement surface. Deflection measurements will be monitored at 30 locations on the pavement (Fig A.5). On the no void side of the pavement, there are two sets of six DCDT holding units at the joint (one set at the edge and one set in the wheel path), one set of five DCDT holding units at the pavement edge (away from the joint), and two sets of three DCDT holding units at the pavements wheel paths (away from the joint). On the void side of the pavement, there is one set of four DCDT holding units at the joint and one set of three DCDT holding units at the edge to measure the effects of the two voids. The DCDT gage heads are waterproofed and encased in stainless steel for extended outdoor use. They are also removable for safe storage at night. Since the gages are removable, it was not necessary to purchase a DCDT for each holding unit. Rather, only the section of pavement being tested will be instrumented with these units.

Load Transfer

In addition to measuring deflection, the DCDT gages will be used to measure load transfer. Three DCDT holding units will be cast in place in the small slab, two on the no-void side, at the edge and in the wheel path, and one on the void side at the edge. As the large slab is being loaded at the joint, the DCDT in the small slab will register a deflection only when the large slab has been deflected enough to overcome the vertical distance between the tapered dowels. Measuring the load that causes the dowels to contact will give an indication of load transfer across the joint at a given joint gap.

The loss of load transfer at a transverse joint can be measured by taking deflection measurements across the joint. Actual field data on load transfer are scarce; therefore it was felt important to study how various amounts of load transfer affect the output of NDT equipment. Lateral movement of the 20 foot slab is restricted to 3/4 inch. It is the DCDT holding units cast in the small slab that limit The amount of horizontal movement in the 20 foot slab to 3/4 of an inch. As shown in Fig 4.5, the critical gap (A) is between the DCDT reference rod cap and the walls of the DCDT holding unit. When the 20 foot slab has been moved 3/4 of an inch, tne cap and wall come into contact. This contact could influence the output of the DCDT's, which is undesirable. The reference rod cap was modified as shown in Fig 4.6 and the entire holding unit left-justified to permit the 3/4 inch movement.

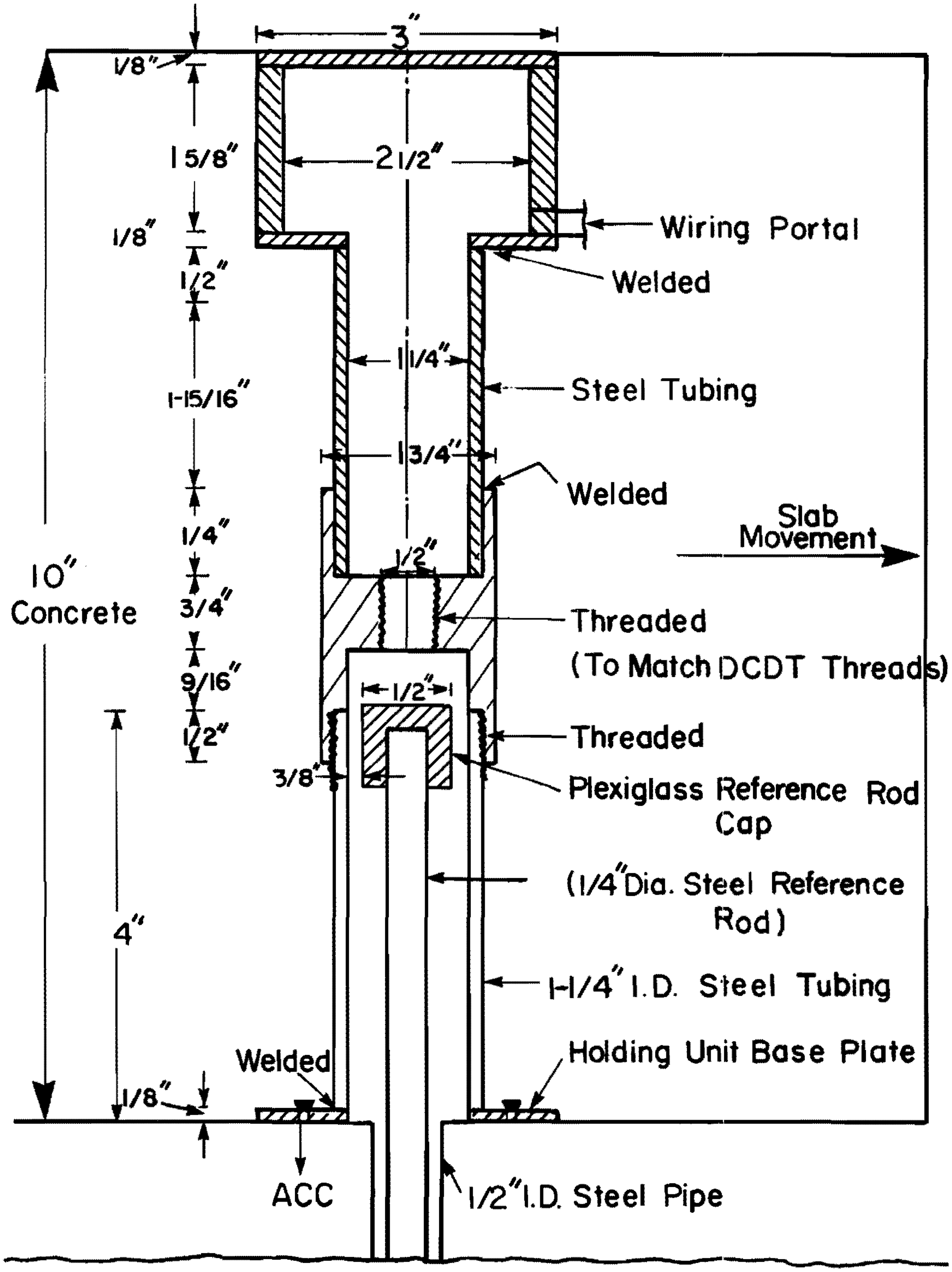


Fig 4.5. Typical cross section of DCDT holding unit (long slab).

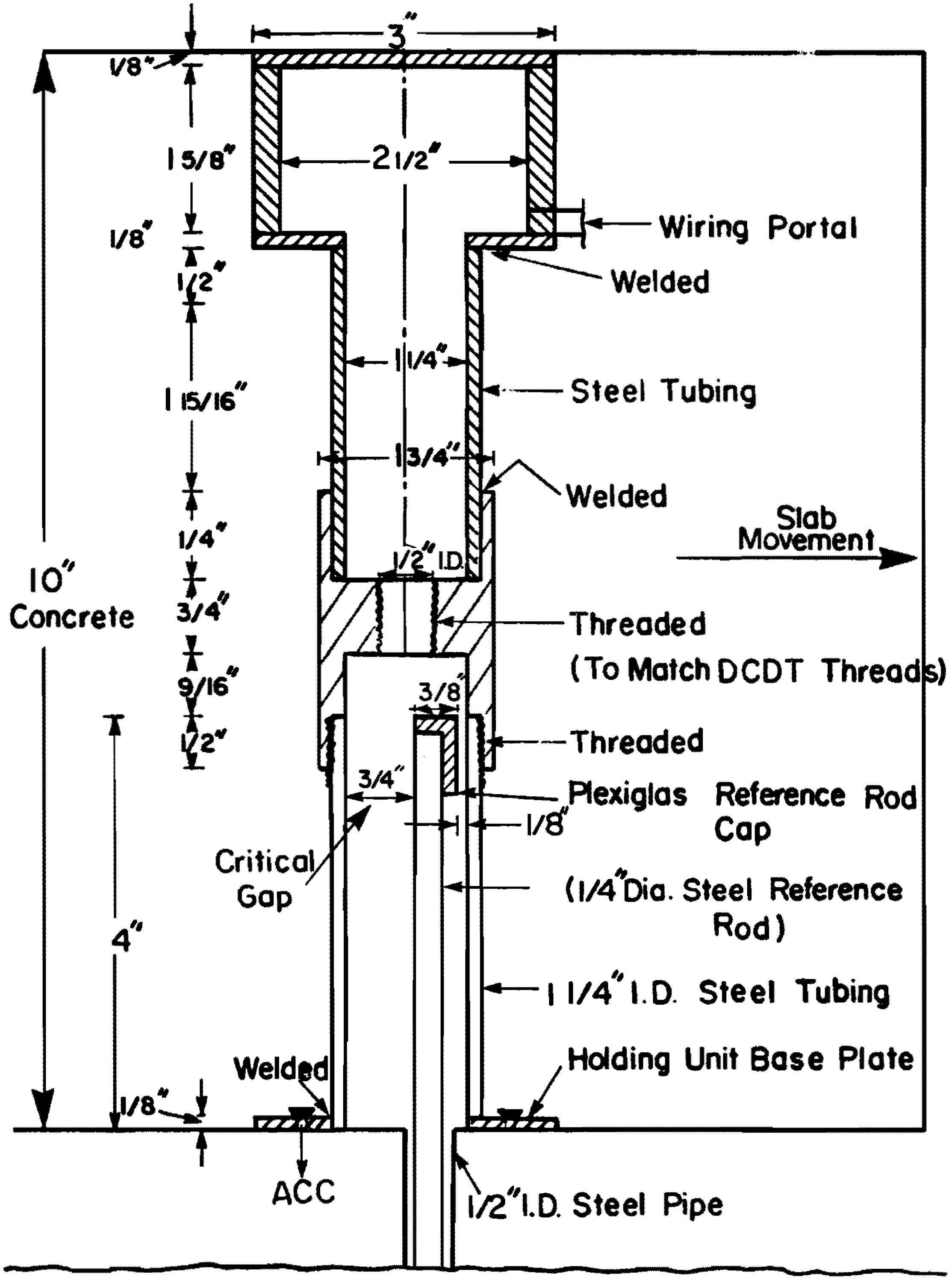


Fig 4.6. Typical cross section of DCDT holding unit (short slab).

CHAPTER 5. CONSTRUCTION OF TEST PAVEMENT

BACKGROUND

In an effort to keep construction methods and techniques as practical as possible at the test facility, Texas State Department of Highways and Public Transportation 1982 Standard Specifications (Ref 5) were used for the design and construction of this project. The SDHPT staff of District 14 drew the plans for contractor bids (Appendix A). These plans were finalized from a draft set of plans compiled by the project staff based on design and instrumentation requirements. The specifications were taken directly from the SDHPT 1982 Standard Specifications (Ref 5) where possible. When construction deviated from typical Texas highway construction practices, special provisions were written to clarify the required work. Special provisions included bore holes for the DCDT reference rods and moisture probes, load frame and flange anchor bolts, instrumentation installation, placement of polyethylene friction reducing sheets, slab anchor bolts and the construction sequence.

A special sequence of construction will be followed to minimize the chance of delay to the contractor. A flow diagram was developed to illustrate the proper sequence of tasks (Fig 5.1). The pavement will be completed in two separate concrete pours. This is necessary because the short slab and the sleeper slab portion of the load frame overlap. Also, completing the job in two pours allows use of wooden forms at the joint. This insures the construction of a straight and smooth joint.

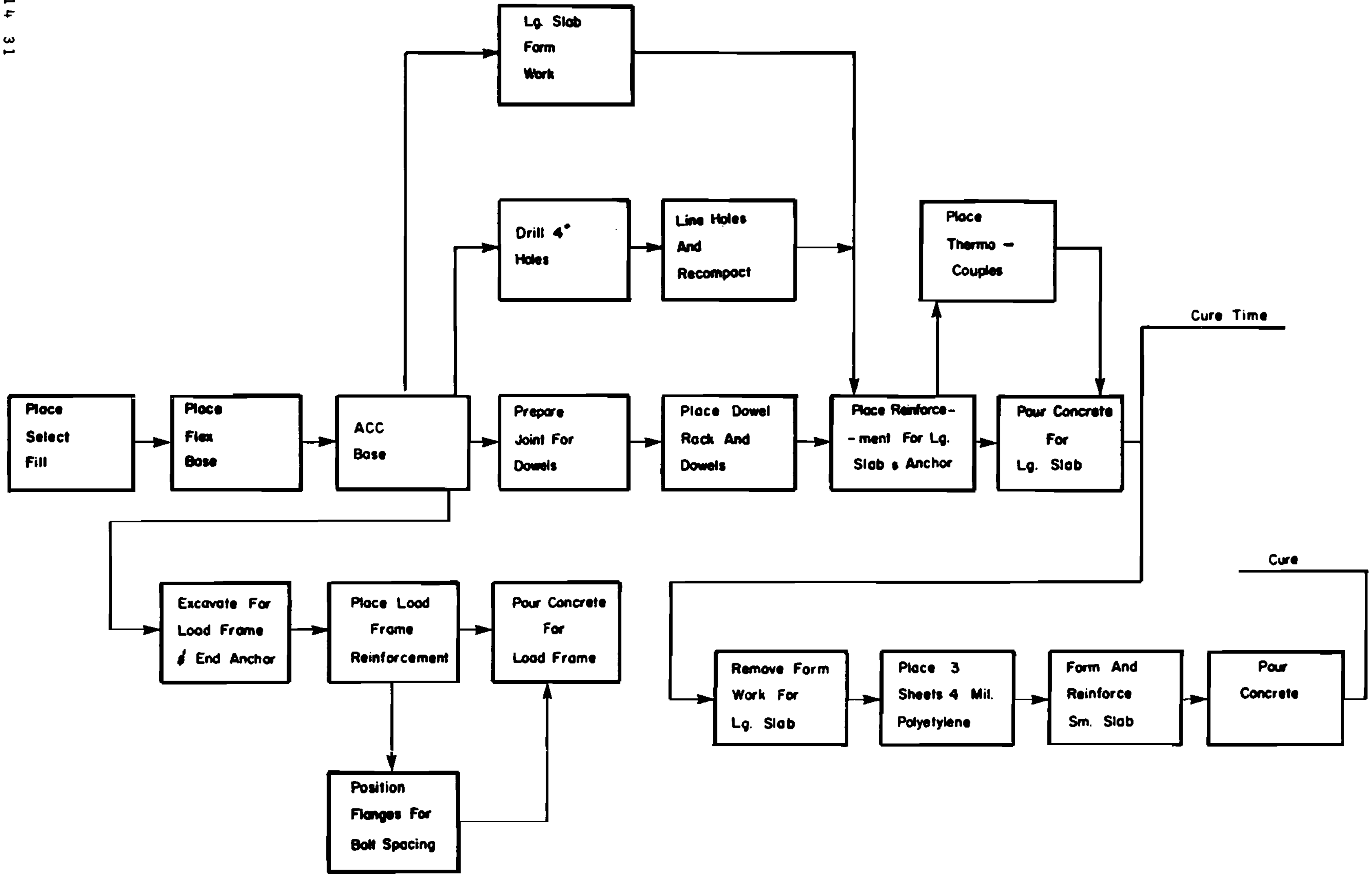


Fig 5.1. Flow diagram.

CONSTRUCTION SEQUENCE

Once the plans and specifications are approved, they will be sent out for bids and a contract will be awarded to the lowest bidder.

The first task performed by the contractor will be placing select fill on the existing embankment. Ordinary compaction methods are specified for the select fill layer. This method of compaction requires that compaction be carried to the extent directed by the Engineer and it is fully described in Ref 5. Six inches of crushed stone flexible base will be placed on top of the select material and "density control" compaction procedures will be used to control compaction of this layer. This method requires that a specified density be met and that density measurement be made to insure compliance. This procedure is fully described in Ref 5.

After the flexible base is placed, three inches of type C asphaltic cement concrete will be placed in two 1-1/2 inch lifts to provide a good working platform and a smooth surface on which to pour the slab. This layer will also add some structural support to the concrete pavement. On top of the embankment a 20 foot width of crushed stone (Fig A.1) will not be covered with asphalt to allow possible future testing of prestressed-precast concrete slabs on a crushed stone base. Once the ACC base layer is placed, the engineers will immediately place the joint formwork and align the dowels. The holding units for the dial gages will also be placed into position.

Next, the contractor will begin the formwork and excavation necessary to construct the large slab, end anchor, and load frame. The bore holes for the DCDT reference rod casings and moisture probes will be drilled by the contractor at this time at the locations specified on the plans (Figs A.3 to A.5). As the bore holes are finished, project personnel will case the holes, place a reference rod, and back fill around the casing with a special tamp (Fig 5.2).

The DCDT gage head holding units will be placed in proper alignment and fixed into position with special braces (Fig 5.3) to stabilize the holding units during concrete placement. DCDT holding unit and reference rod placement procedures are described in more detail later in this chapter.

Moisture blocks will be installed at the same time the DCDT holding units are placed. Then preformed voids will be placed at the locations shown on the plans. Once all the DCDT holding units, moisture blocks, and void generating equipment have been placed, the contractor will place the reinforcement for the large slab, end anchor, and load frame. Thermocouples will be placed next by project personnel, at the location specified on the plans (Fig A.3). The placement procedure that will be used is detailed later in this chapter. With the thermocouples in place, the contractor will proceed to pour the concrete for the large slab and end anchor, while project personnel place three sheets of 4 mil polyethylene at the location specified on the plans (Fig A.1). Formwork and reinforcement will be placed on the small slab while the large slab cures. After three days, the formwork at the joint will be removed and the face of the concrete at the joint will be coated with a bond breaker to prevent adhesion of the small slab to the large slab. The seams where the male dowel is inserted into the female dowel socket will be caulked to hold the dowels together during concrete placement and prevent concrete from contaminating the dowel taper. After the reinforcement and slab anchor bolts are placed, the concrete for the small slab will be poured and cured and the formwork removed. All the wiring to the instrumentation will be layed in conduits leading to the instrumentation shed (Fig 5.4). Then the contractor will place a 10 inch thick, 6 foot wide

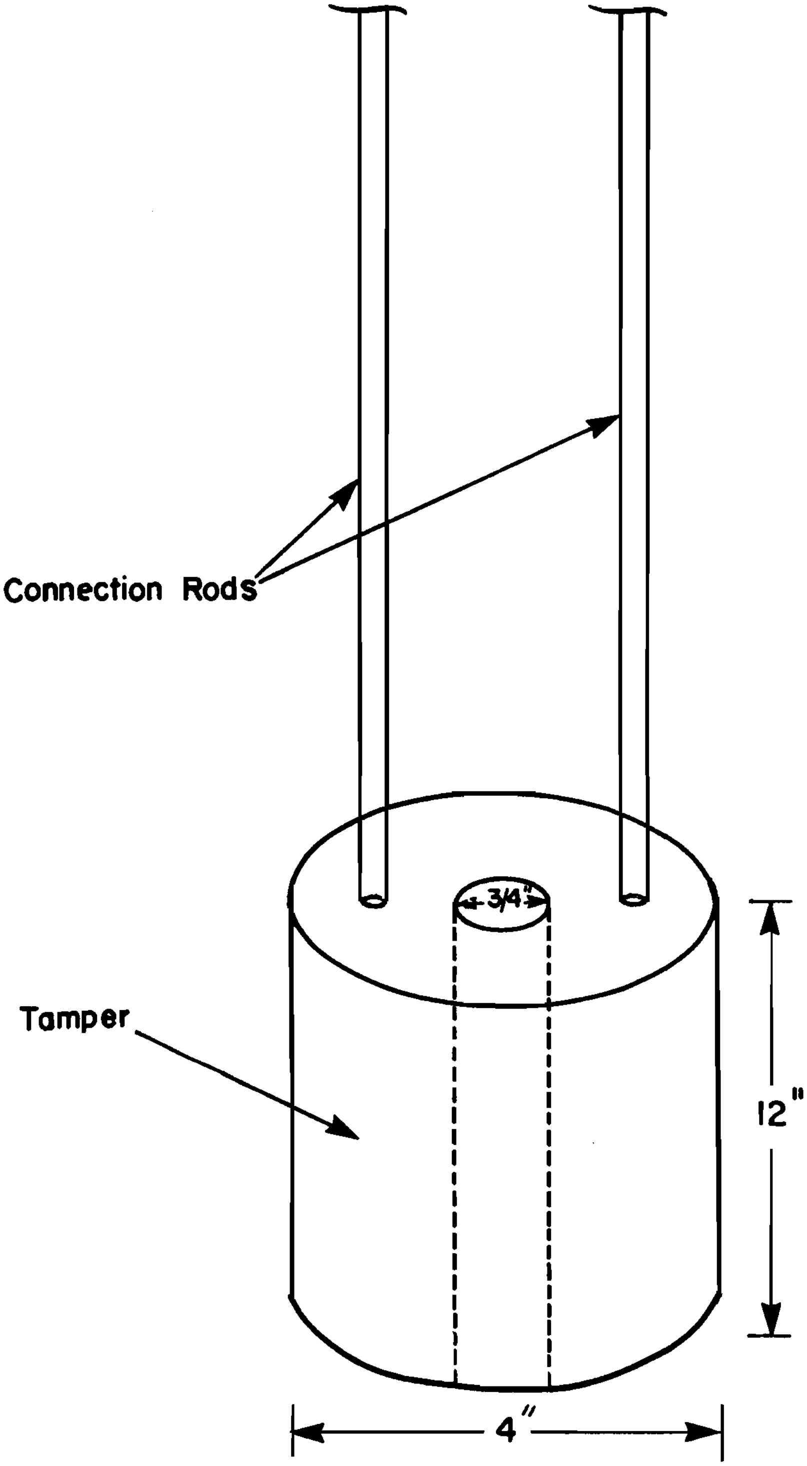


Fig 5.2. Tamper for backfilling DCDT boreholes.

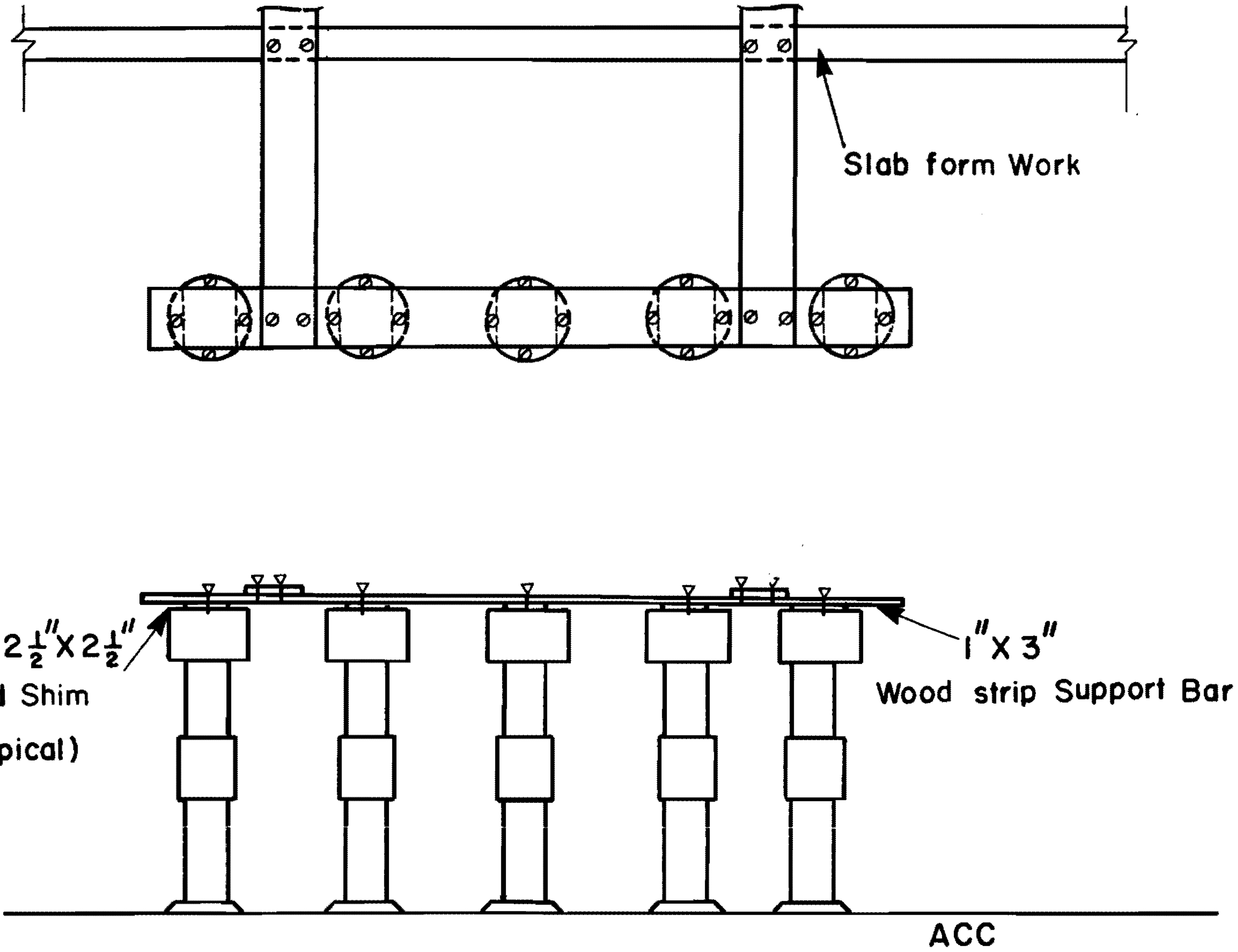


Fig 5.3. DCDT holding units brace.

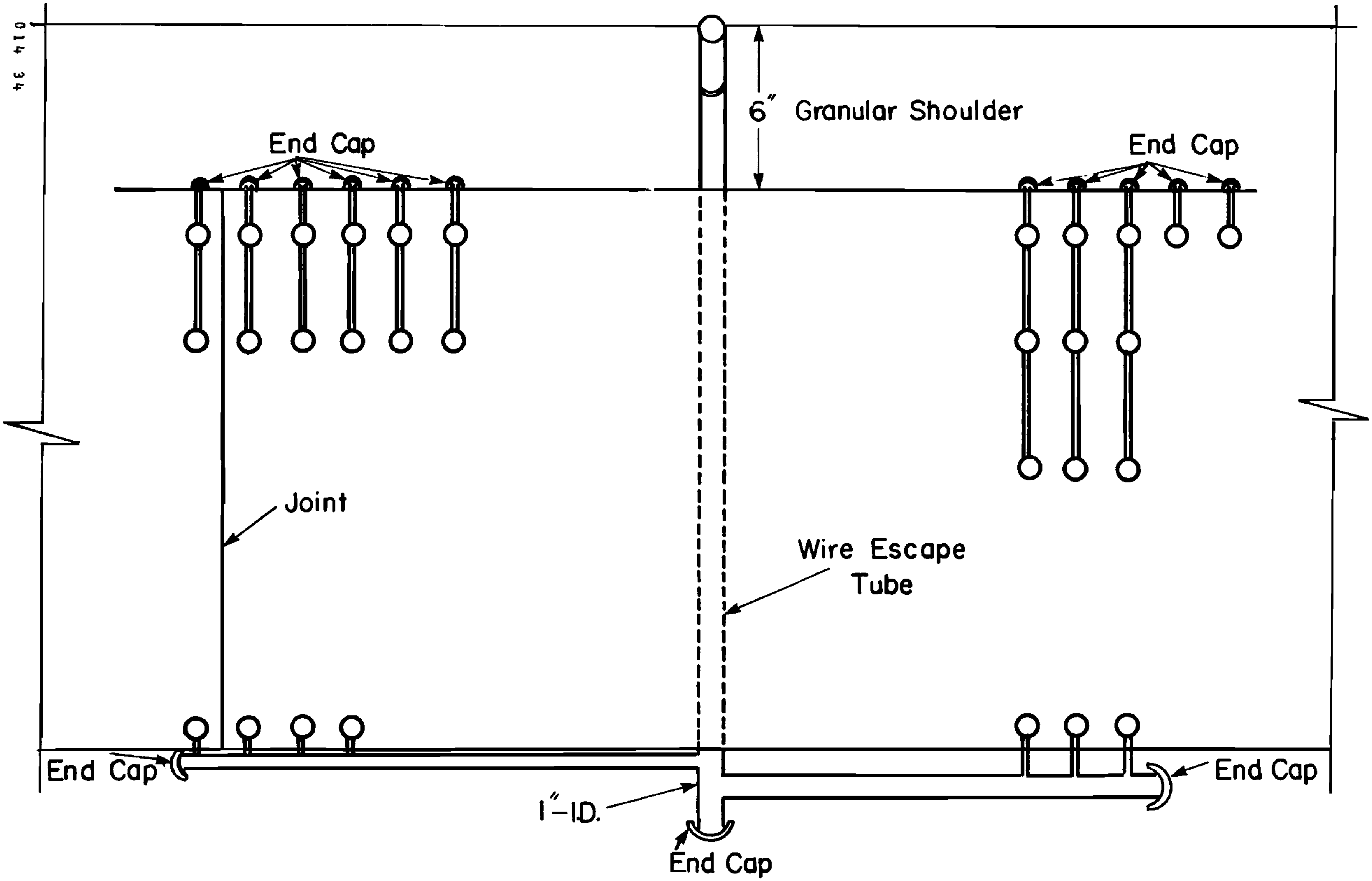


Fig 5.4. Instrumentation wiring conduits.

shoulder on the west side of the slab, as shown in the plans (Fig A.1). The shoulder will be constructed with crushed stone.

VOID PLACEMENT

As previously mentioned, the preformed voids will be 3 feet by 3 feet by 1 inch deep and filled with foamed styrene. A depression one inch deep and approximately 3 feet wide and 3 feet long will be formed where the styrene material is to be placed. Sand will be used to level up the bottom of each hole so that the void units will line up flush with the ACC surface. Sand will be filled in around the edges to smooth out the surface around the void. After the slab is cast in place, solvent will be sprayed into the void to dissolve the styrene.

PLACEMENT OF MOISTURE BLOCKS

Moisture in the soil beneath the pavement will be measured by three different instruments: the psychrometer from Wescor, electric resistivity type from Soil Test, and the nuclear gage. Two redundant systems are being used because moisture measuring devices tend to become unreliable over a long period of time.

The nuclear gage requires 2 inch outside diameter aluminum irrigation tubing to provide access to the soil by the nuclear probe. The inside of the tube must be free of water. This requires that both the top and the bottom of the irrigation tube be sealed at all times. The top of the tube (at the pavement surface) will be sealed with a rubber stopper (except when testing occurs). The opening at the bottom of the tube must be sealed with a special device that will be open while the tube is being inserted into the 2 inch bore hole and then be closed once the tube is in place. A device that will perform this function has already been used successfully in the field by University staff (Fig 5.5). This device is essentially a stopper with a built in valve. When the tube is being inserted, the valve will be open to allow air that is trapped below the tube to escape. When the tube is in place, a special wrench will be used to shut the valve, thus preventing moisture from entering the tube (Fig 5.6). Two of these nuclear probe access tubes will be placed at the locations specified in the plans (Fig A.3). The top 15 inches of each tube must be painted with epoxy to prevent the aluminum from reacting adversely with the concrete. After the concrete is poured, the tubing will be cut off flush with the pavement surface and sealed with a rubber stopper.

The psychrometer and the electrical resistance moisture blocks will be placed into two 4 inch bore holes at the location and depth shown in Fig 5.7. When placing the moisture blocks, the holes must first be back filled with natural soil to the desired elevation of the first set of thermocouples. Then 2 inches of sand will be placed and tamped down with a special tamp that is scaled to indicate bore hole depth. After the 2 inches of sand are in place, a moisture block will be tied to a long straight piece of steel rod with a slip knot. The rod will help guide the moisture block to the bottom of the hole. When the detector is in place, the slop knot will be released and the steel rod removed, leaving the moisture block in place at the bottom of the hole. Then, project staff will place the other moisture block, being careful not to damage the moisture block already in place. After the two detectors are placed in the bottom of the hole, another 2 inches of sand will be placed and compacted lightly with the tamp. Care must be taken not to damage the moisture blocks at the bottom of the hole or the lead wires that

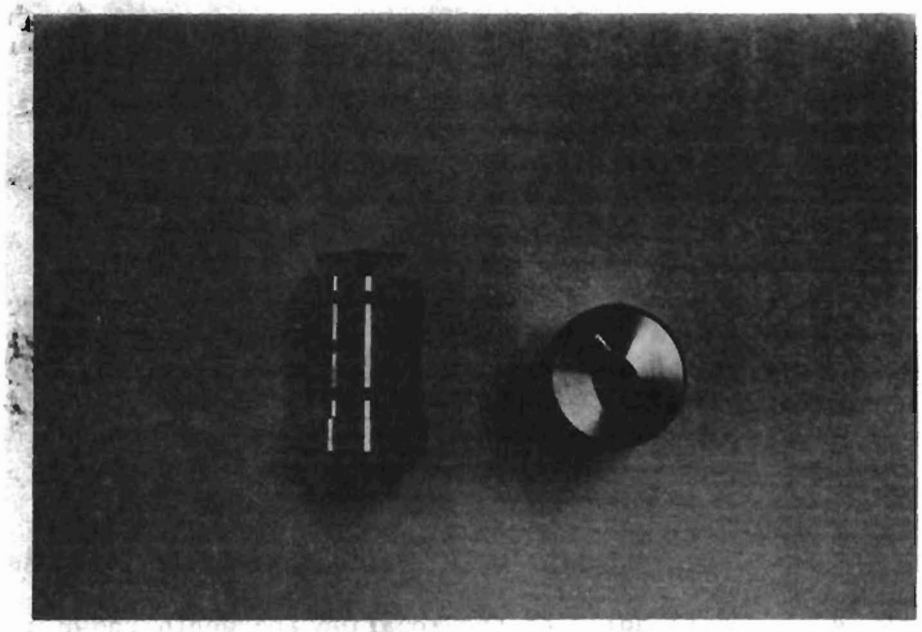


Fig 5.5. Nuclear gage access tubing air valve.

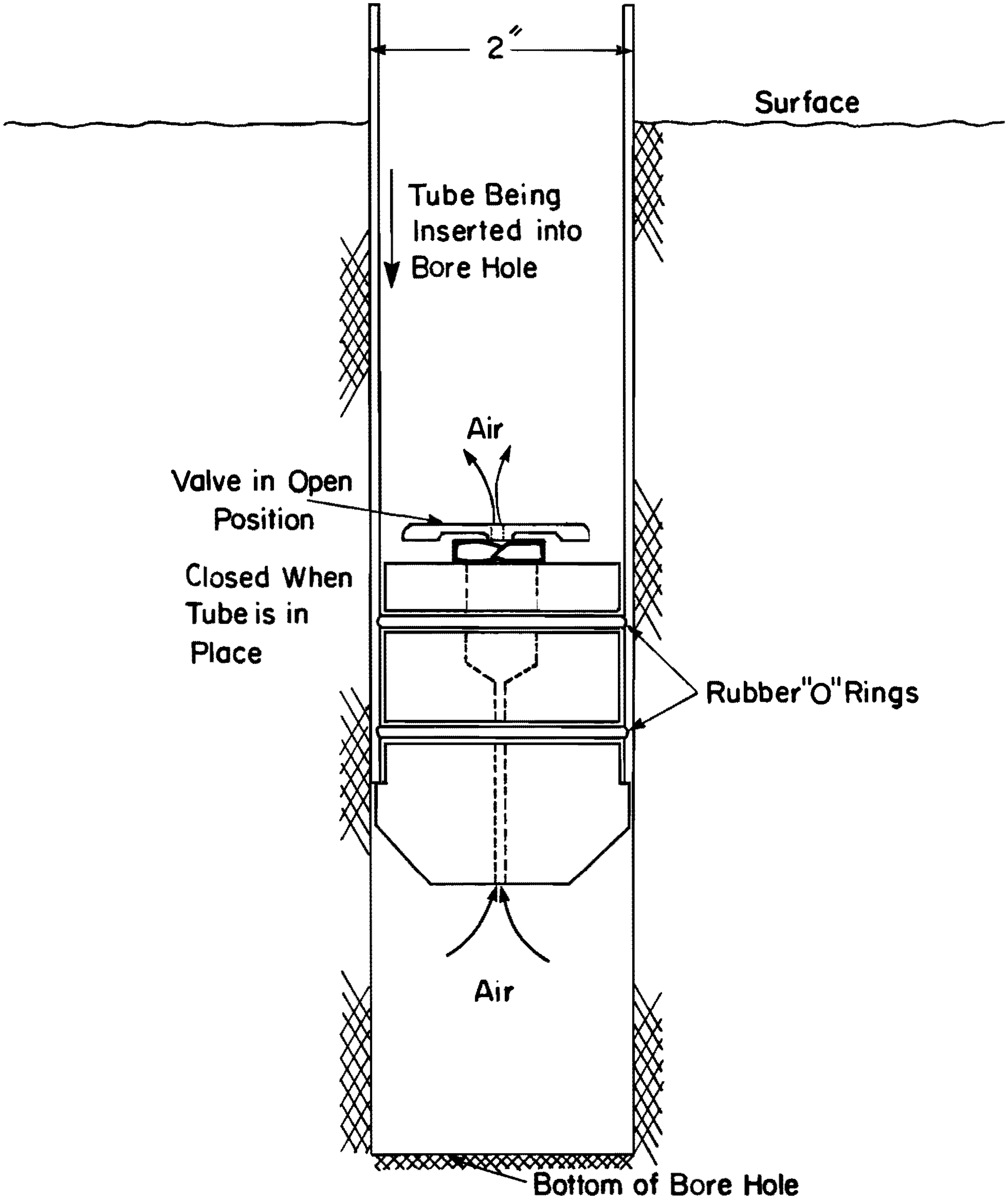


Fig 5.6. Placement of aluminum irrigation tubing.

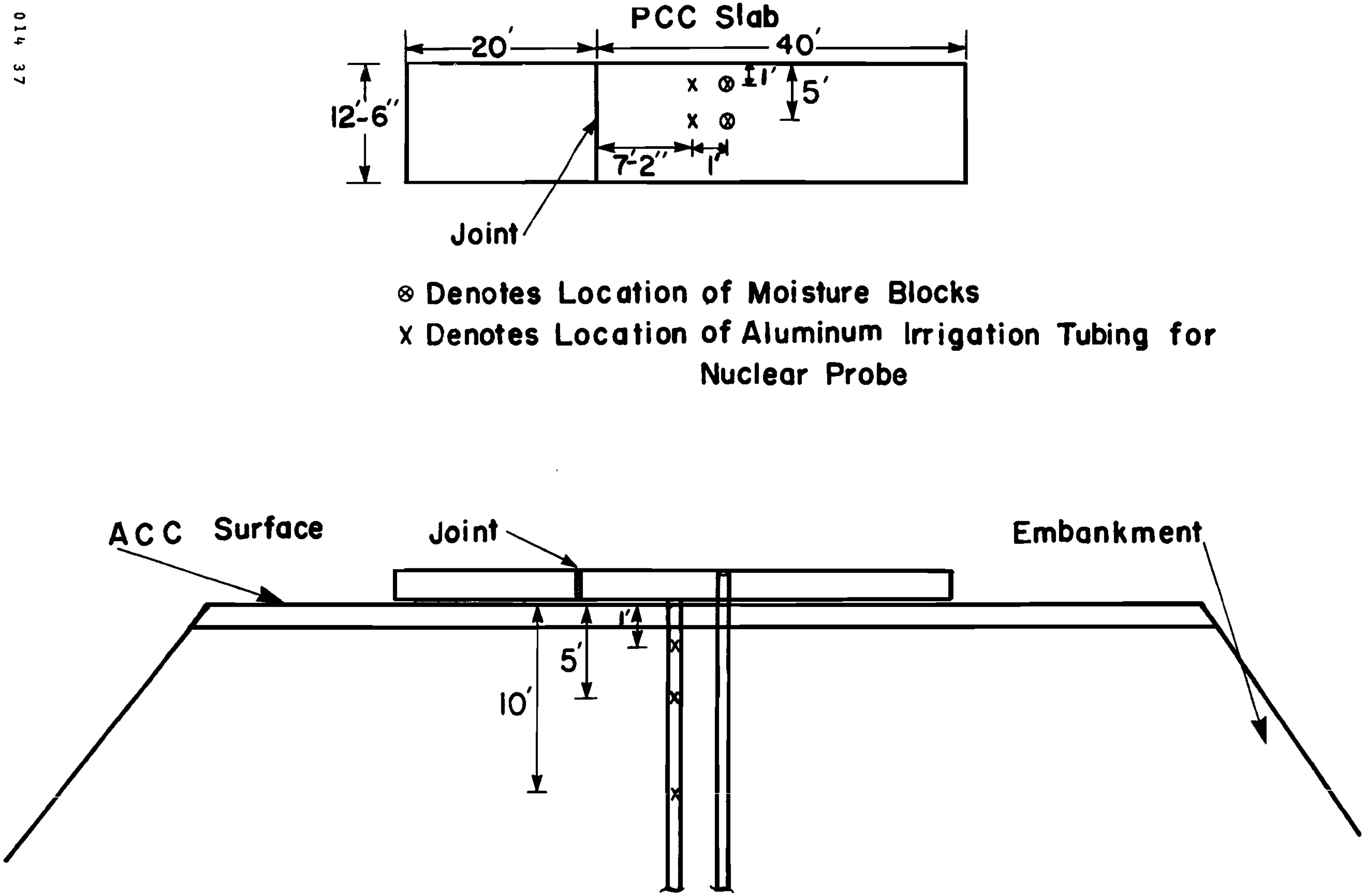


Fig 5.7. Location of moisture detection devices under the pavement.

will extend up the hole. When the 2 inches of sand are in place, the two moisture blocks will be checked with portable equipment to see if they are still functioning, and the hole will be back filled with clay in one foot lifts to the desired elevation of the next set of moisture blocks and the procedure repeated. When all six moisture blocks are in place and the hole is being backfilled to the surface in one foot lifts, extreme care must be taken not to damage the lead wires that will be in the hole. One person will have to hold the wires taut while another backfills to help prevent damage during this operation. Once again, the units should be monitored at all times during backfilling to check for damage to the units during this procedure. Before the last foot or so of a bore hole is backfilled, the moisture block wires will be sheathed in flexible tubing from this point to a point outside of the slab. This will protect the wires from wear, thus prolonging the life of the units. The sheathing with the four moisture block wires running through it can be laid on the ACC surface, or a shallow trench can be dug to bury the sheathing as it leaves the slab.

Calibration of Moisture Blocks

The equipment necessary to calibrate the psychrometer is available at The University of Texas at Austin. The basic procedure for calibrating the psychrometer as well as the electrical resistivity type of moisture block begins by placing each unit in a sample of soil in a closed environment with a known water content. When this system has reached equilibrium, the output of these units will be recorded. Then, a small, known quantity of water will be introduced into the soil and conditions will be allowed to reach equilibrium before the output is recorded again. The same amount of water should be added each time a reading is taken. When enough data have been gathered, the soil in the closed system will be tested for water content once again. The relationship between initial water content and final water content should be a straight line, provided the system was closed and the same amount of water was added at each increment. Thus, the water content after each quantity of water was added can be calculated. With this information, a plot that relates soil water content to moisture block output for each moisture block can be developed. Reference 11 contains more detail on the operation of psychrometers. The nuclear gage is already calibrated for standard soil types. These calibration curves should be adequate for estimating water content with these instruments.

Placement of Thermocouples

The thermocouples are placed at four locations throughout the pavement to measure temperature gradient. At each location there will be a thermocouple one inch from the top, at mid-depth and one inch from the bottom of the slab. These instruments are made of thermocouple wire with the temperature sensing end cast into a small block of cement mortar. A piece of baling wire was cast into each block to secure the bottom and middle thermocouples to the reinforcement. The thermocouples placed one inch from the surface will be installed in the freshly placed concrete. The baling wires connected to these thermocouples are marked so the instruments can be set at the desired depth in the concrete pavement.

Placement of the Joint

The joint assembly will be constructed on the ACC surface. Two by twelve inch wooden forms will be used to provide a smooth and even joint. The form work will also give support to the dowels prior to placement of the concrete. Each dowel bar unit (Fig A.5) is 2 feet long. A 1/4 inch hole will be drilled at precisely the same location on both ends of every dowel unit. These holes are for a 1/4 inch diameter, 14 foot long threaded rod to pass through. Nuts will be screwed onto the rod to hold the dowel bars parallel to one another in the horizontal plane. Height adjustable stands will be used to hold the dowel bar parallel in the vertical plane (Fig 5.8). This method of joint construction will allow small adjustments to be made in the alignment of individual dowel bars and will also hold the dowel bars rigidly in place, during concrete and reinforcement placement. The seams around each dowel bar at the formwork will be caulked to prevent concrete from contaminating the tapered area of the dowel. The hardware that holds the dial gauges will also be fixed into the wooden joint, as shown in Fig A.2.

DCDT Placement Procedure

Placing the 30 DCDT holding units will require close coordination with the contractor. The holding units will be placed in groups of 3, 4, 5 and 6 units. The units within a group will be placed at one foot centers to measure deflection basins (Fig A.5). The contractor will drill 4 inch diameter bore holes 12 feet 6 inches deep from the ACC surface to the rock strata. When a contractor finishes one bore hole, project personnel will put approximately 6-1/2 pounds of concrete into the hole to form a layer of concrete one foot thick at the bottom. A 1/2 inch ID PVC pipe and a 1/4 inch diameter steel rod with a 2 inch diameter base plate (Fig 5.9) will be inserted into each hole and embedded in the concrete; the reference rods will extend 4 to 7 inches above the surface of the ACC and the casing units will be cut off flush with the ACC surface.

When a group of 3, 4, 5 or 6 holes has been lined, a piece of flat stock steel with 1/4 inch holes drilled at one foot centers will be placed over a

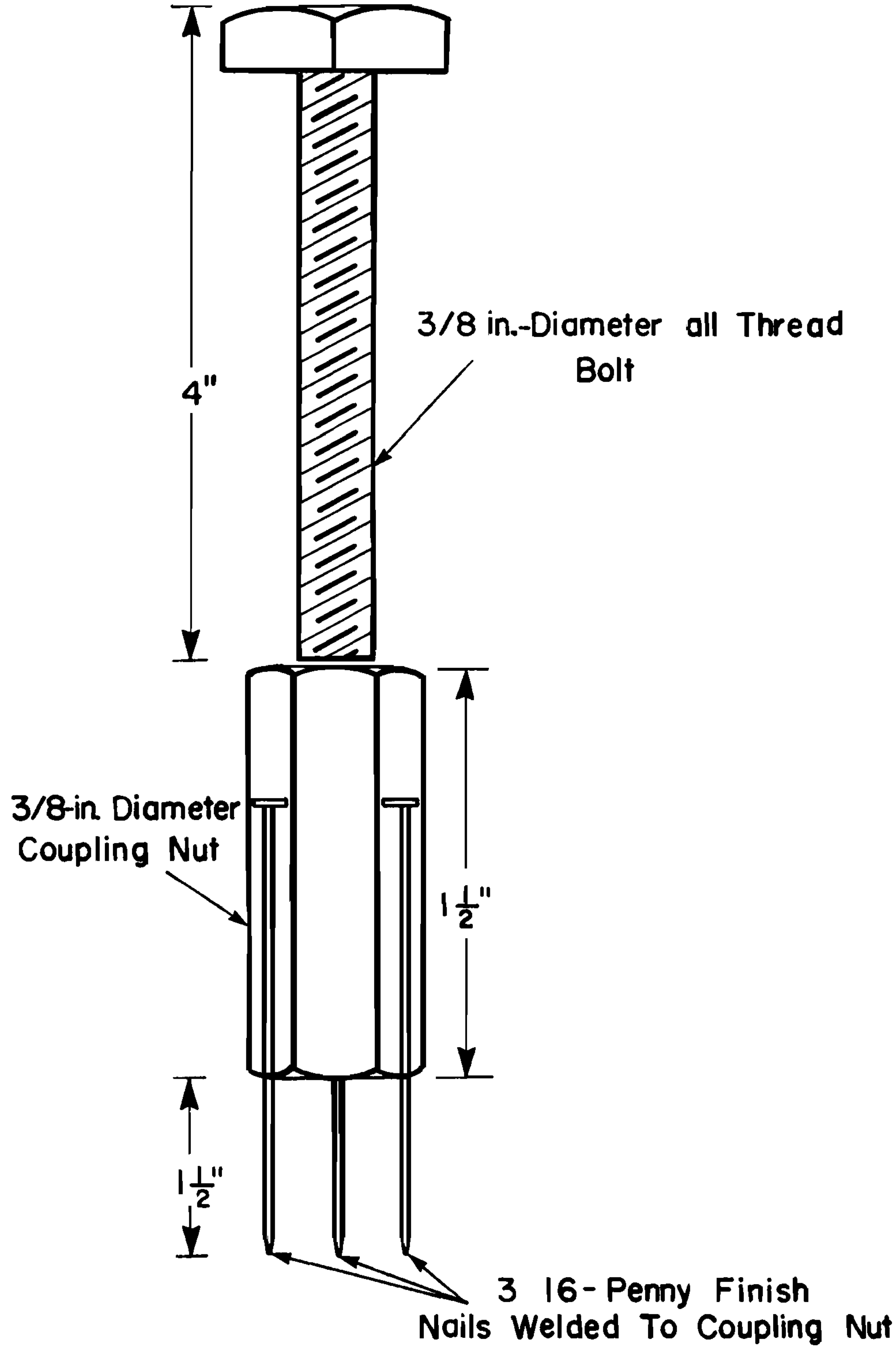


Fig 5.8. Height adjustable stands for joint placement.

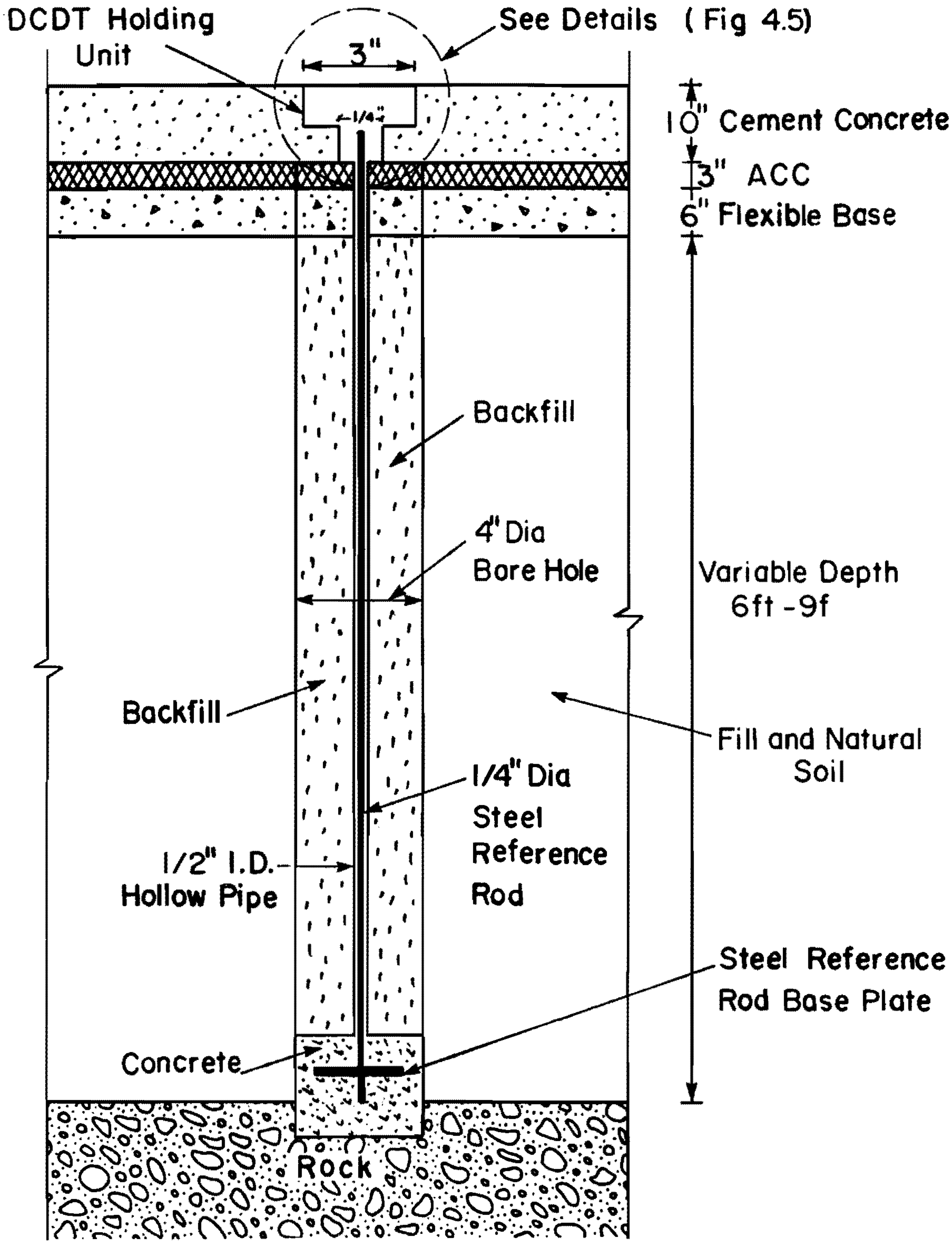


Fig 5.9. Bore hole casing unit and reference rod for DCDT.

group of reference rod to maintain the one foot spacing while the concrete cures. Once the concrete is stiff, the reference rod spacer will be removed and the holes back filled with a special tamper fabricated in a machine shop (Fig 5.2). A PVC end-cap with a 1/4 inch hole drilled into it will be placed at the top of each casing unit to stabilize the reference rods at the surface. Each reference rod will then be capped with plexiglass to provide a bearing area for the core of the DCDT gage unit. The top of each reference rod cap will be set at exactly 4 inches above the ground surface.

When this job is complete, a set of DCDT holding units will be placed over the reference rods and braced to the formwork to prevent any movement during concrete placement as shown in Fig 5.3. Once the concrete is poured and vibrated, the DCDT holding unit braces will be removed to allow the contractor to finish the concrete surface.

CHAPTER 6. RECOMMENDED TESTING AND FUTURE USES OF TESTING FACILITY

INTRODUCTION

The rigid pavement test facility being constructed at Balcones Research Center can be a first class research tool for investigating new pavement technologies. This chapter outlines some basic testing and data gathering necessary to help solve the questions raised in the original proposal. A short section deals with possible future testing and uses of the facility.

The first research study to be conducted at this facility will test and compare the Dynaflect, the Falling Weight Deflectometer, the spectral-analysis-of-surface-waves (SASW) method, and other non-destructive testing (NDT) equipment under various structural and environmental conditions. The variables to be studied include slab temperature gradient, slab warping, variable load transfer, sub-surface soil moisture content, and voids. The data from both the Dynaflect and the Falling Weight Deflectometer will be compared to determine which, if either, gives more reliable, accurate, and useful results. This comparison can be achieved by analyzing deflection basins measured by the devices during a period of one year. The layer moduli, estimated from these deflection basins will also be compared with the modulus derived from laboratory soil tests and SASW tests.

Environmental factors and loading position have a substantial effect on the magnitude and shape of deflection basins measured by NDT equipment. At least one theoretical analysis of pavement deflections has been completed. This analysis used a computer program called SLAB49 (Ref 7). Field data from the research facility can be compared with other field studies as well as to theoretical studies. Information from these comparisons will be used to improve pavement evaluation, rehabilitation, and design procedures. An operating manual such as that developed in Ref 12 can be developed for other NDT devices, such as the Falling Weight Deflectometer. The Texas SDHPT is purchasing a FWD to compare with the Dynaflect and also to evaluate other potential uses such as void detection. The results of the information that is gathered will be summarized in a report that details the performance capabilities of a FWD. In addition, a recommended operating procedure for rigid pavement evaluation will be developed for this device.

TESTING PHASE

The testing phase of this project will begin immediately after the slab is constructed. As soon as possible after the concrete is poured, precise elevations at the pavement surface will be measured at various points on the pavement so that slab warping can be detected. Excessive slab warping can affect soil support and load transfer across the joint, thus influencing the output of NDT equipment. For this reason, it is important to monitor and record any vertical movement in the pavement.

Soil Testing

A meeting was held by project staff to discuss soil and flexible base testing that would be necessary to characterize the materials at the site where the pavement is to be built. The results from these tests will be presented in the next report. There should be no problem associated with running these tests after the pavement at BRC is built.

The tests are as follows:

(1) Modulus of Resilience Test (M_R) - run on embankment material and flexible base. The test is complicated and requires an outside lab to do the work. If the cost is not too high, perhaps more than one sample per layer can be tested. The SDHPT can run this test out of D-9.

(2) Resonant Column Test (ε) - gives an indication of the strain sensitivity of a soil. Young's Modulus (E) is plotted against strain (ε) to give an indication of the strain sensitivity. This test will be run on samples from the existing subgrade and embankment. This test can be done at the CTR by a soils student. This test may also be done on the flexible base material.

(3) Sand-Cone Density Test - has been performed on some of the embankment already in place (Fig 6.1). A value of 120 pcf was measured. Once the rest of the embankment is compacted, densities will be determined again by project staff. Each successive layer will be tested for density.

(4) SASW Tests - already run once (Fig 6.1) on part of the embankment and should be run at the surface of each successive layer, starting with the top of the embankment. Figure 6.2 shows how the SASW test was set up at the construction site. Successive SASW tests should be performed as close to the original test as possible. The variation of Young's modulus with depth is predicted by this test. The results of the first test with 2 feet of embankment in place is shown in Fig 6.3.

(5) Plasticity Index and Unified Soil Classification - will be performed on each layer except the asphaltic cement layer.

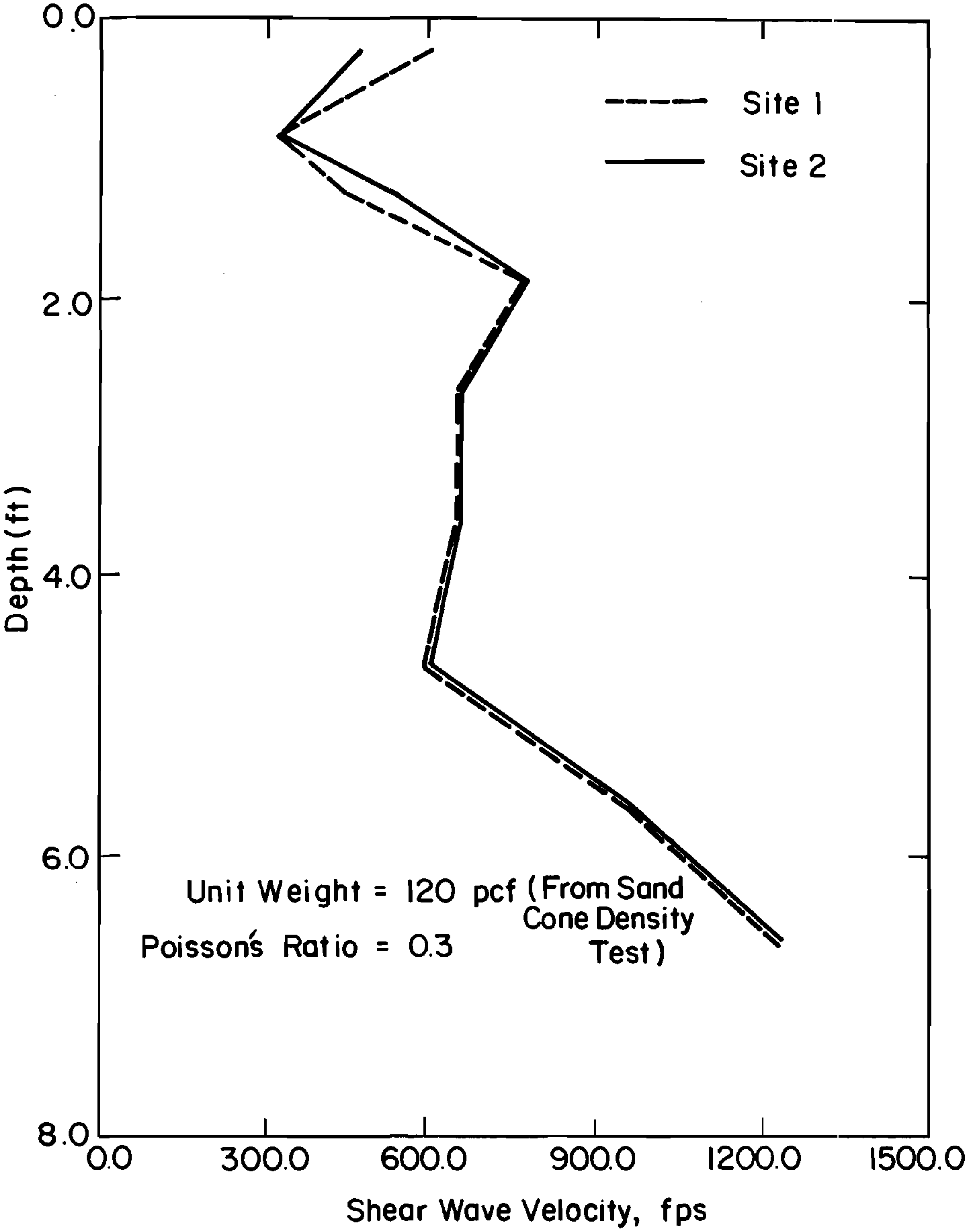


Fig 6.1. Shear wave velocity of embankment at Balcones versus depth.

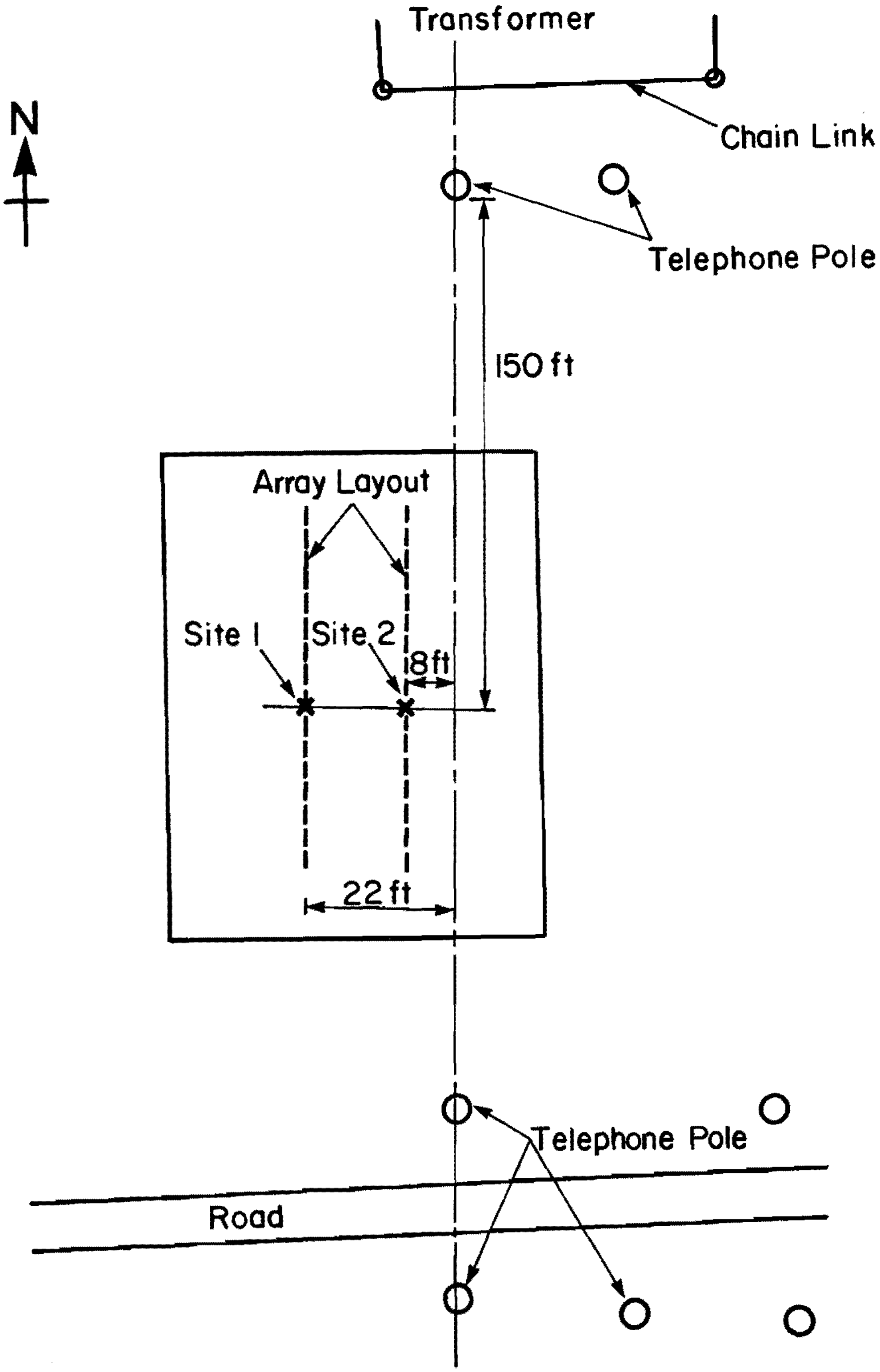


Fig 6.2. Layout of Balcones test sites (not to scale).

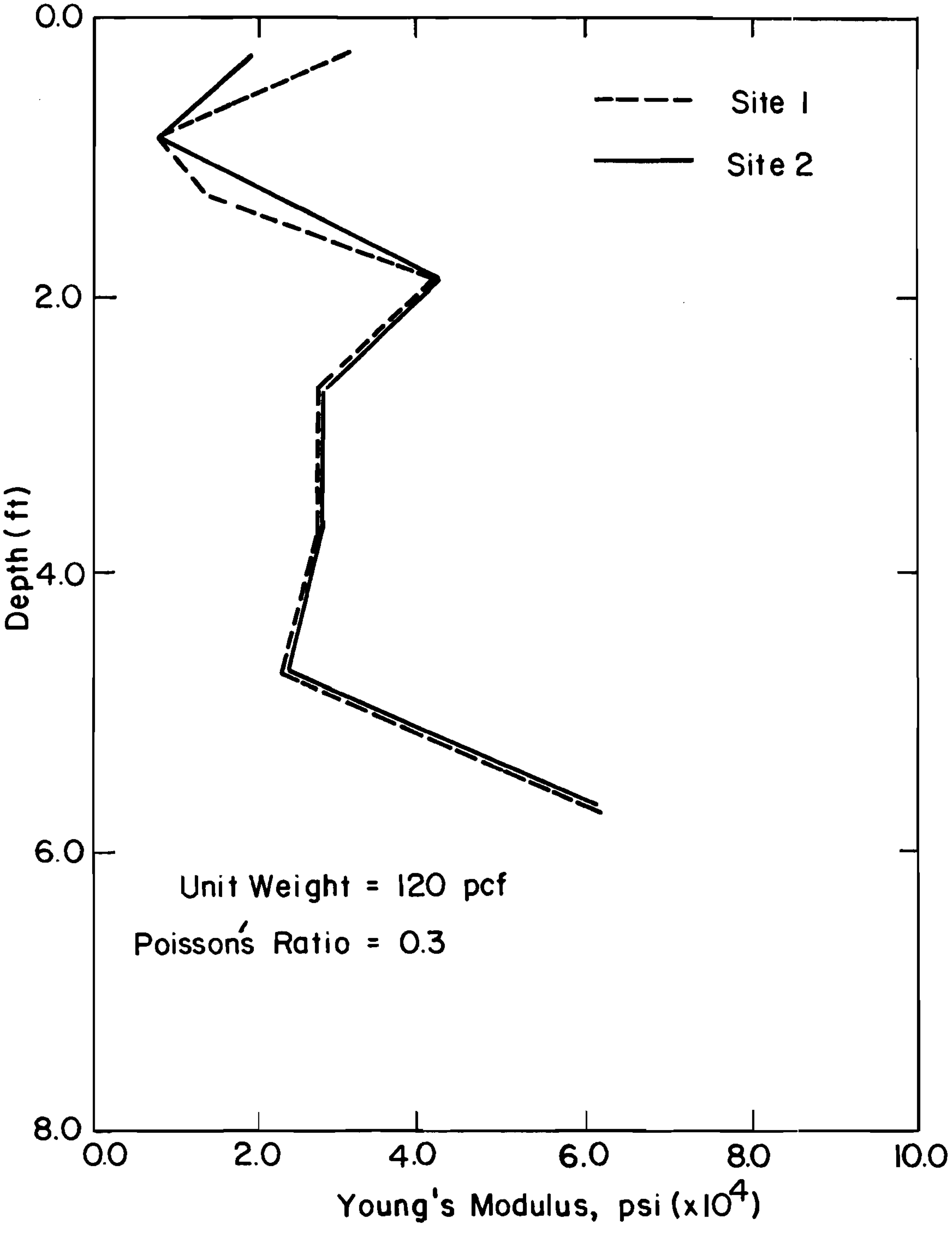


Fig 6.3. Modulus of embankment at Balcones versus depth.

(6) Other tests that will be done by the Center for Transportation Research include gradation and water content tests for each layer.

The only test that is not performed by project staff is the modulus of resiliance test which is involved and requires a good deal of experience.

Slab Testing

Primary pavement testing at the research facility will be conducted in four phases, one for each season of the year. Depending upon the results, multiple tests may be necessary during each phase to achieve statistically significant results. Each testing phase will begin by recording meteorological data one to two weeks before any deflection measurements are made. The weather data will continue to be recorded until all pavement testing in a phase is completed. The meteorological variables that will be recorded include precipitation, ambient temperature, solar radiation, and humidity.

When measuring pavement deflection, the Dynaflect and the FWD will be positioned on the pavement to measure the same deflection basins as the DCDT's. The joint will be in the full load transfer position (no joint gap) for the first set of measurements. When deflection measurements are complete for this condition of load transfer, the joint will be opened slightly with hydraulic rams in order to reduce load transfer across the joint. The dial gages that measure joint gap will be manually recorded each time the joint spacing is adjusted.

For all levels of load transfer, the deflection measuring equipment will measure deflections at the same locations on the pavement. Since there are a limited number of DCDT gage heads (six), these units will have to be moved to each location where deflection measurements are to be made. Both void and no-void conditions will be measured before the joint is adjusted again.

The maximum horizontal joint opening is 3/4 inch because of the restricted space between the DCDT reference rods and the DCDT holding units in the 20 foot slab (Fig 4.6). If the 20 foot slab is moved beyond the 3/4 inch limit, these reference rods may bend and become inoperable. The joint gap can be adjusted on the pavement by pulling the slab in pre-determined increments from zero joint gap (full load transfer) or pushing the slab from the 3/4 inch maximum gap (zero load transfer). Stresses will be induced in the 20 foot slab by the loading rams during slab movement. Deflection measurements should not be made under these conditions. However, releasing the hydraulic pressure in the rams will return, these stresses to zero. Joint gap measurements should be made after the ram pressure is released since rebound effects may change the dial gage readings.

During the deflection measuring process, slab temperature gradients and soil moisture content will be recorded for later correlation with the deflection measurements. The slab temperature should be measured continuously during the day. However, changes in soil moisture occur much slower and can therefore be measured less frequently. In addition, the elevation of the pavement should be measured often to check for slab warping.

The previous section does not attempt to describe a comprehensive experimental design or the test facility. Rather, it describes in basic terms some testing procedures that should be followed to develop a set of baseline data.

FUTURE USES OF THE RESEARCH FACILITY

The experiment outlined above will yield some basic data that will satisfy the objectives of the present research project. The facility can continue to serve the Center for Transportation Research and the Texas State Department of Highways and Public Transportation as a valuable research tool on many other projects.

The Texas SDHPT has expressed an interest in using the facility to calibrate state owned Dynaflects. This can be done once a set of baseline data are gathered. The facility will be ideally suited for calibrating the Dynaflect and Falling Weight Deflectometer since many variables that influence pavement deflection will be monitored.

The influence that shoulder type has on pavement deflection is another topic that could be studied at this facility. A temporary crushed stone shoulder, 6 feet wide, will be provided on the west side of the pavement so that testing equipment will have access to the pavement surface. However, this could easily be removed and replaced with a concrete or asphaltic type shoulder for future research.

Another potential use of the research facility is the study of thin bonded overlays (Ref 13). One objective of this study is to develop construction specifications for thin bonded overlays over an existing portland cement concrete pavement and to implement the procedure in the field. This type of construction could be added to the test pavement with additional instrumentation placed as necessary to monitor the behavior and performance of the overlaid layer.

Comparisons of deflections in the field with deflections predicted by programs based on layer and slab theories can be made at this facility to determine how well theory matches actual pavement deflection. Since the properties of all the sublayers will be known, these values can be used as input to duplicate field conditions in a computer program. Similarly, programs for structural evaluation of pavement can be calibrated by using deflection data generated in the research slab facility.

Another possible use of the test facility, is the testing of prestressed-precast concrete slabs on the flexible base adjacent to the pavement. Both dynamic and static deflection measurements should be measured on prestressed slabs of various thicknesses, lengths, widths, and prestress magnitudes. The resulting empirical data would be helpful in developing design criteria for prestressed pavements. As well as deflection measurements, other data, such as strain variation through the horizontal plane of the slab, should be gathered to determine how effective the prestressing strands transfer compression to each slab.

The above list is a short summary of possible uses of the pavement research facility at Balcones Research Center that should be considered for study both during and after the completion of Project 355. There are a number of feasible topics that can be studied at this facility by adapting the existing pavement to the needs of a new project or by construction a new slab adjacent to this one. The embankment placed at Balcones, designed to buffer the effects of reduced pavement deflection caused by the underlying rock strata, is sufficiently large to allow for the construction of another slab next to the one that is currently being built.

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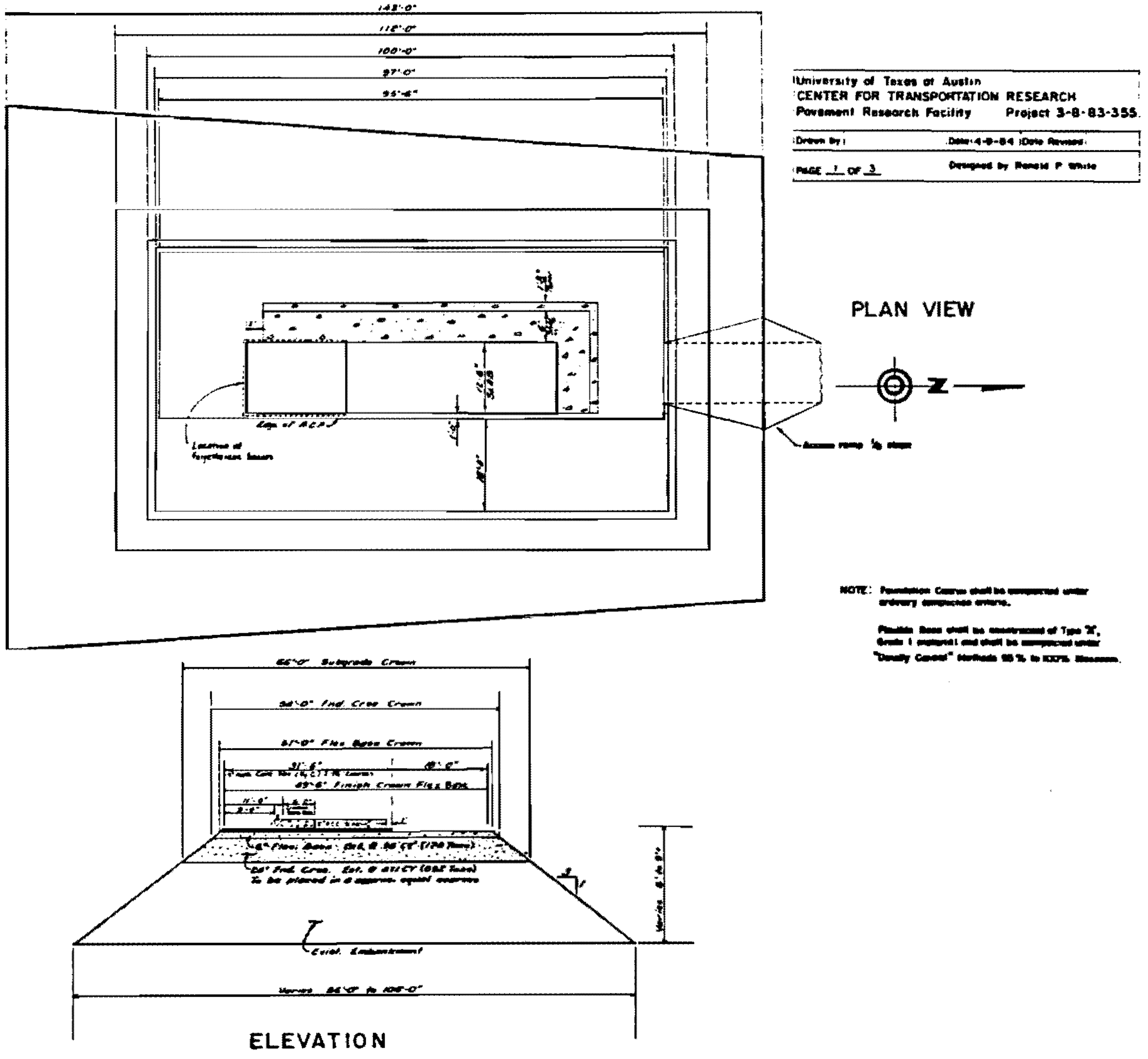
APPENDIX A

CONSTRUCTION PLANS



148'-0"
118'-0"
100'-0"
97'-0"
95'-6"
University of Texas at Austin
CENTER FOR TRANSPORTATION RESEARCH
Pavement Research Facility Project 3-8-83-355
Drawn By:
Date: 4-8-84
Date Revised:
PAGE 1 OF 3
Designed by Ronald P White
PLAN VIEW
N
Access ramp
Edge of A.C.P.
Location of
NOTE: Foundation Course shall be compacted under ordinary compaction criteria.
Flexible Base shall be constructed of Type 'A', Grade 1 material and shall be compacted under "Density Control" Methods 95% to 100% Maximum.
66'-0" Subgrade Crown
54'-0" Fnd. Crse Crown
51'-0" Flex Base Crown
31'-6"
18'-0"
49'-6" Finish Crown Flex Base
11'-0"
8'-6"
6" Flex. Base
24" Fnd. Crse.
To be placed in 4 approx. equal courses
Exist. Embankment
Varies 84'-0" to 108'-0"
ELEVATION

Fig A.1

University of Texas at Austin
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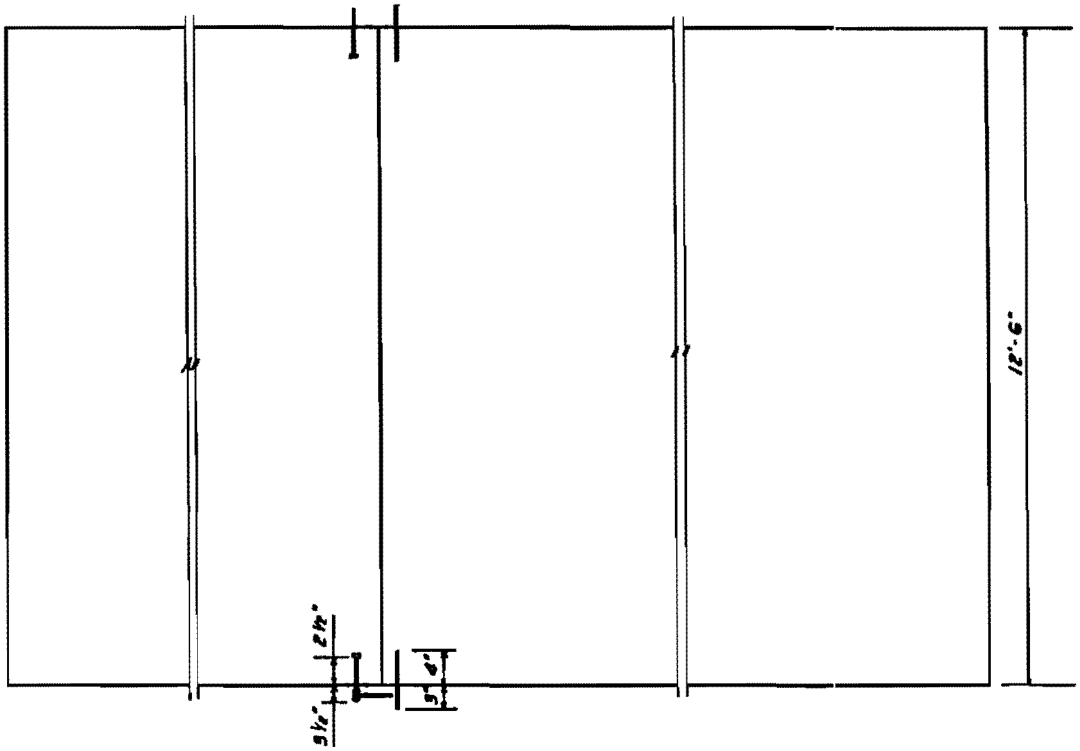
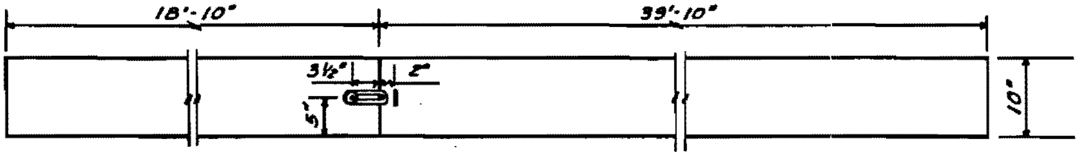
Pavement Research Facility Project 3-8-83-355

Drawn by		Date	4-9-84	Date Revised	

PAGE 2 OF 3 Designed by Ronald P. White



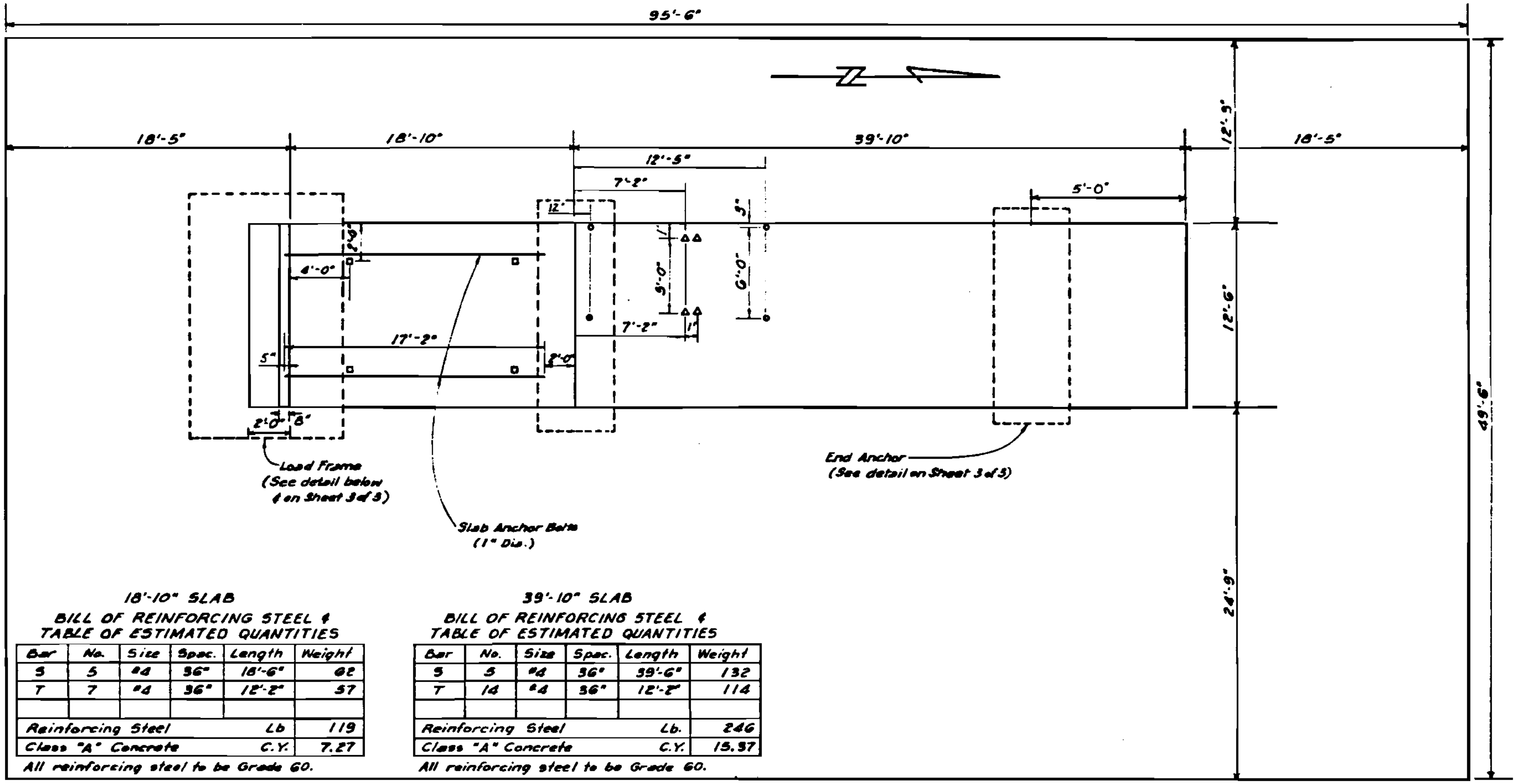
PLAN



ELEVATION

NOTE: The necessary components will be fabricated and placed by the Engineer as part of the joint assembly.

Fig A.2.



18'-10" SLAB

BILL OF REINFORCING STEEL &
TABLE OF ESTIMATED QUANTITIES

Bar	No.	Size	Spac.	Length	Weight
S	5	#4	36"	18'-6"	62
T	7	#4	36"	12'-2"	57
Reinforcing Steel				Lb	119
Class "A" Concrete				C.Y.	7.27

All reinforcing steel to be Grade 60.

39'-10" SLAB

BILL OF REINFORCING STEEL &
TABLE OF ESTIMATED QUANTITIES

Bar	No.	Size	Spac.	Length	Weight
S	5	#4	36"	39'-6"	132
T	14	#4	36"	12'-2"	114
Reinforcing Steel				Lb.	246
Class "A" Concrete				C.Y.	15.37

All reinforcing steel to be Grade 60.

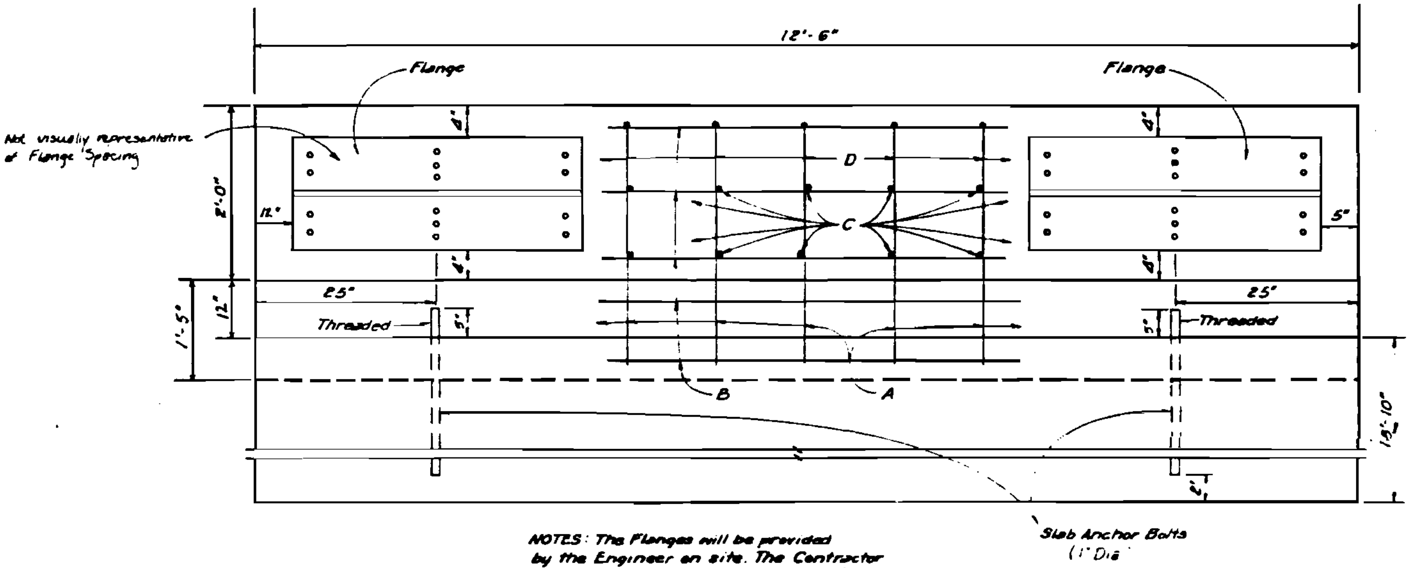
LEGEND

- △ 2" diameter bore holes locations for moisture probes
- ▫ location of threaded inserts
- ○ location of thermo couples
- *See Sheet 3 of 3 for locations of 4" diameter bore holes.

NOTE: The slab anchor bolts will be provided by the Engineer and placed by the Contractor at mid depth.

& Bore holes shall be drilled by the Contractor to a depth of 12'-6" below compacted ACC surface

Fig A.3.



NOTES: The Flanges will be provided by the Engineer on site. The Contractor shall use the Flanges as templates for spacing the Flange Anchor Bolts or the Contractor may drill holes into the cured concrete and set the bolts with epoxy The two Flanges combined must withstand a force of at least 30 tons without pulling out of the concrete.

Fig A.4.

University of Texas at Austin CENTER FOR TRANSPORTATION RESEARCH Pavement Research Facility		Project 3-8-83-355
Drawn by	Date 4-9-84	Date Revised
PAGE 3 OF 3	Designed by Ronald P. White	

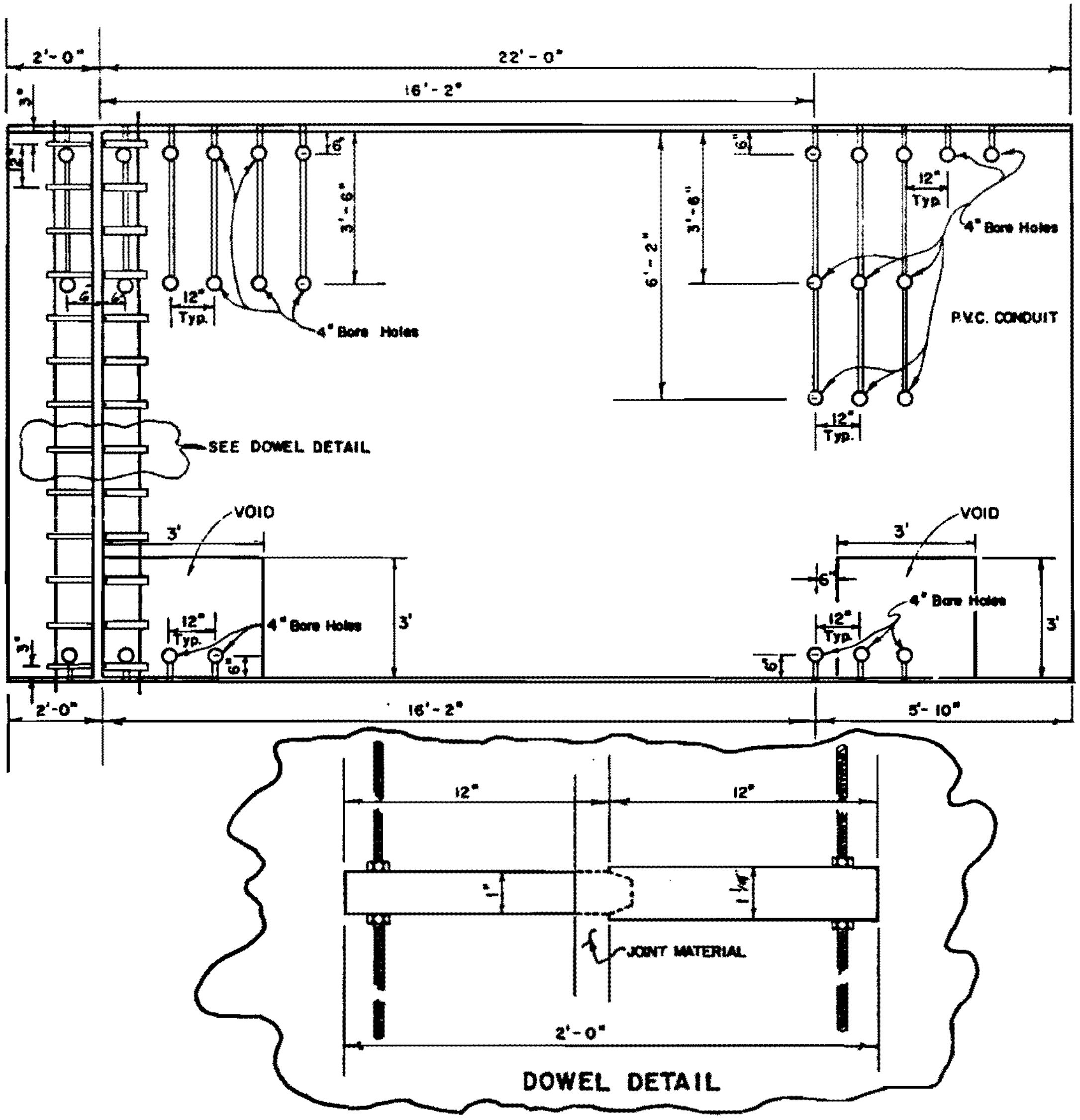


Fig A.5.

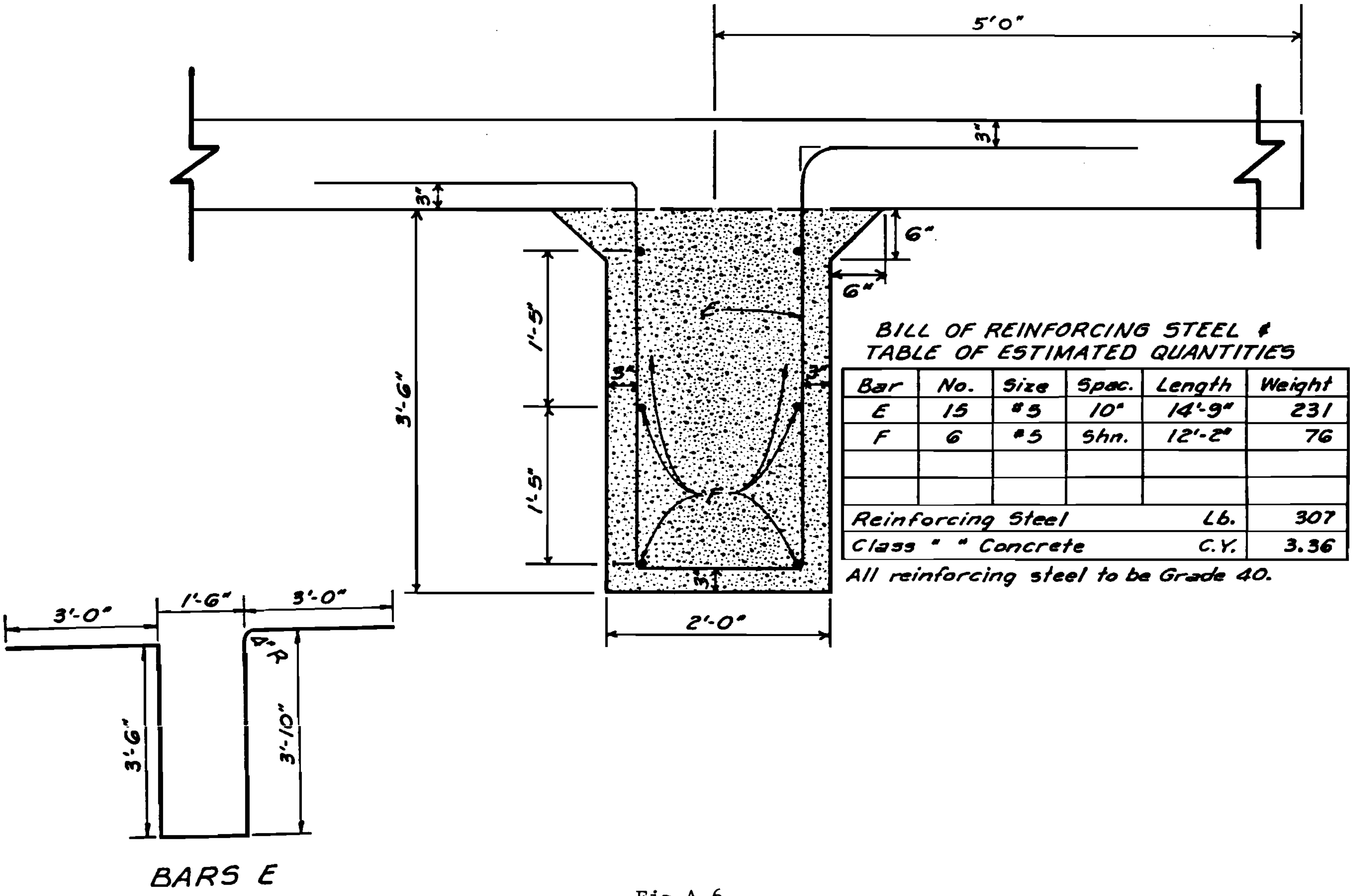
NOTES: The Joint Detail is for the Contractors information. The entire joint assembly will be constructed in place by the Engineer.

The dowels will be placed at mid depth in the pavement cross section, all slab reinforcement shall be positioned on top of the dowels. The reinforcement shall not move the dowels in anyway.

The reinforcement shall be placed so that the dowels can be adjusted by the Engineer.

Bore Holes shall be drilled by the Contractor to a depth of 12'-6" below compacted A.C.C. Surface.

Two 3' x 3' x 1" voids will be placed as shown as directed by the Engineer.

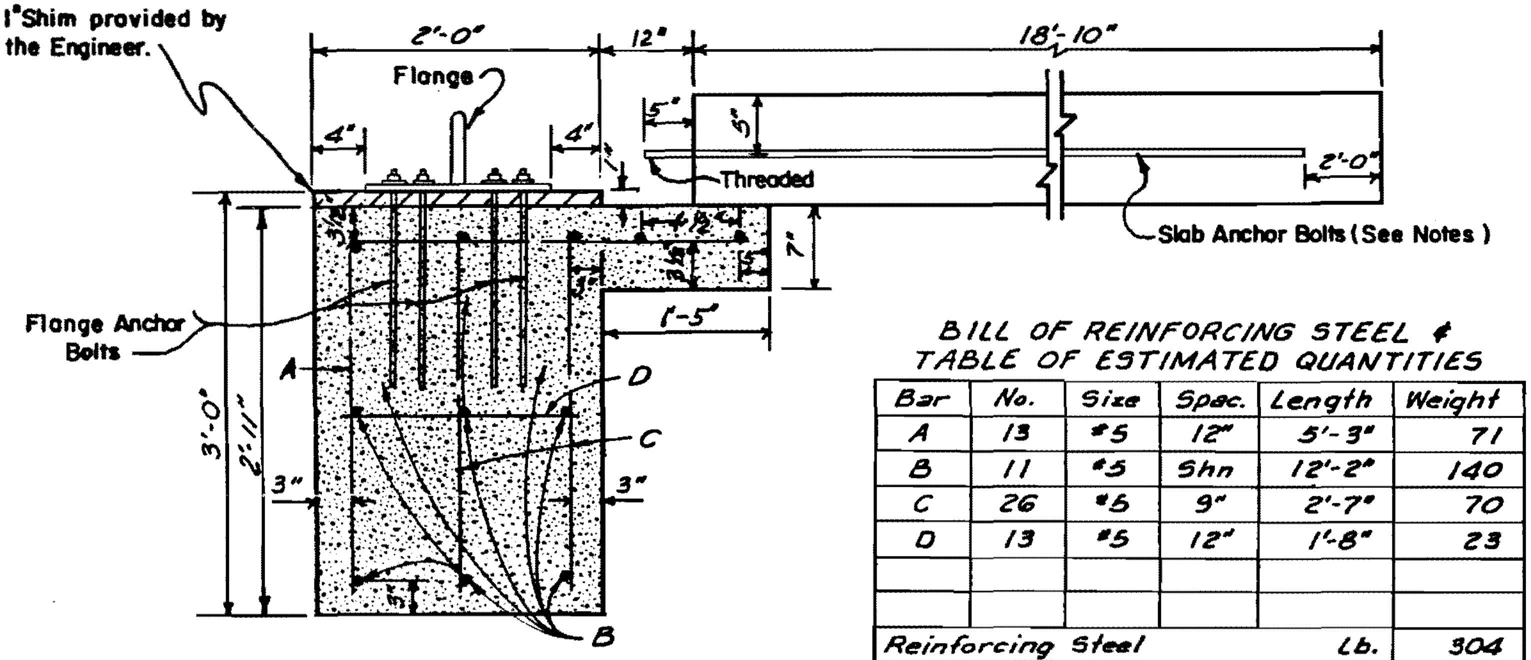


BILL OF REINFORCING STEEL &
TABLE OF ESTIMATED QUANTITIES

Bar	No.	Size	Spac.	Length	Weight
E	15	#5	10"	14'-9"	231
F	6	#5	Shn.	12'-2"	76
Reinforcing Steel				Lb.	307
Class " " Concrete				C.Y.	3.36

All reinforcing steel to be Grade 40.

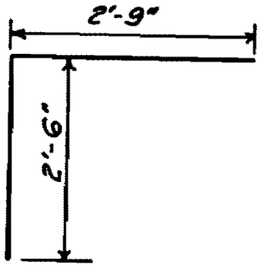
Fig A.6.



BILL OF REINFORCING STEEL & TABLE OF ESTIMATED QUANTITIES

Bar	No.	Size	Spac.	Length	Weight
A	13	#5	12"	5'-3"	71
B	11	#5	Shn	12'-2"	140
C	26	#5	9"	2'-7"	70
D	13	#5	12"	1'-8"	23
Reinforcing Steel				Lb.	304
Class "A" Concrete				C.Y.	3.09

All reinforcing steel to be Grade 40.



BARS A

NOTE: Slab Anchor Bolts must extrude through the south face of the form Work.

The 1/2" dia. Flange Anchor Bolts shall be either cast in place or placed by drilling holes in the concrete after curing. The Flange Anchor Bolts shall be supplied and placed by the Contractor.

Fig A.7.

APPENDIX B

PROJECT SPECIFICATIONS

APPENDIX B. PROJECT SPECIFICATIONS

ITEM 246 - FOUNDATION COURSE

Placement of foundation course shall conform to Item 246 of the State Department of Highways and Public Transportation 1982 Standard Specifications. "Ordinary compaction" methods shall be used. There may be a slight delay after this layer is in place while the engineer tests the surface of the foundation course for structural properties. Careful coordination between the engineer and the contractor will be necessary to minimize this delay.

ITEM 249 - FLEXIBLE BASE
(Delivered)

Material shall be Type A, Grade 1 flexible base material. Placement shall adhere to provisions in Item 249 of the Texas State Department of Highways and Public Transportation 1982 Standard Specifications. The material shall be placed under the provision of "density control" compaction and placed as shown in the plans.

ITEM 340 - HOT MIX ASPHALT CONCRETE PAVEMENT

Item 340 of the Texas State Department of Highways and Public Transportation 1982 Standard Specifications shall govern the placement of the asphaltic concrete base course. Two levels of Type C (coarse graded surface course) shall be specified. A prime coat shall be applied on the flexible base according to Item 310 of SDHPT 1982 Standard Specifications. A tack coat shall be applied on the first ACC course according to Item 340-6-(3) as desired by the engineer. Mix design shall be the contractor's responsibility and shall be approved by the engineer.

ITEM 364 - CONCRETE PAVEMENT

This item shall consist of a pavement slab of Portland cement concrete with reinforcement as shown on the plans, and constructed in accordance with the Texas State Department of Highways and Public Transportation 1982 Standard Specifications, Item 364, Concrete Pavement, on the prepared ACC surface in conformity with the thickness and typical cross-section shown on the plans.

Type I Portland cement and crushed limestone coarse aggregate shall be used by the contractor. Except where specified on the plans, the contractor shall place all forms in accordance with the SDHPT 1982 Standard Specification Item 369. Internal vibrators will be used to consolidate the pavement and remove air pockets. Vibrators shall not be used to level or spread the concrete.

ITEM 440 - REINFORCING STEEL

Steel reinforcing bars as required, including ties bars shall conform to the State Department of Highways and Public Transportation 1982 Standard Specifications, Item 440, Reinforcing Steel.

SPECIAL PROVISIONS

Two void areas will be formed during ACC placement as directed by the engineer in cooperation with the contractor. They will consist of two depressions in the the ACC surface at the locations and dimensions specified on the plans. Each void will be one inch deep and will be filled with styrofoam to keep concrete from filling the hole.

Thirty-four holes shall be drilled to the diameter shown in the plans to a depth of 12 feet 6 inches below the surface of the compacted asphalt layer at the locations specified on the plans. The contractor shall perform the excavation required for the shafts through whatever materials encountered. Shaft alignment shall not deviate from vertical by more than one inch over the length of the shaft. All casing and back filling will be performed as necessary by the engineer. Form work and excavation necessary for the placement of the loading frame, Terminal Anchorage and the 39'10" by 12'6" slab section shall commence. However, no reinforcement shall be placed in the 39' 10" by 12' 6" slab until the engineer has completed the casing operations of the drilled shafts. Once installed, the casing will extend a minimum of 10 inches above the compacted surface of the asphaltic mixture. Care must be taken by the contractor not to disturb the casings as reinforcement is placed. Should any casing be broken or otherwise disturbed, the engineer shall be notified immediately. The slab shall be laid in two separate sections. The 39' 10" by 12' 6" slab (large slab), end anchorage, joint, and load frame shall be constructed first in accordance with the dimensions specified on the plans.

After the reinforcement has been placed in the large slab and prior to pouring the concrete, the engineer shall be allotted time as necessary to install thermocouples at the locations indicated on the plans. These devices will be attached to the reinforcement to secure their position. Care shall be taken by the contractor during concrete laying not to step on or otherwise move or damage the thermocouples. If such damage occurs, the engineer shall be notified immediately.

The joint and associated dowel bars will be placed and secured by the engineer. Care shall be taken by the contractor to ensure that the dowel bars are not moved during reinforcement or concrete placement. Should any permanent movement of the dowel bar or dowel bar assembly occur, the engineer shall be notified immediately.

When reinforcement and dowels, shaft casing or other apparatus conflict with one another, the reinforcement shall be bent and/or moved slightly to accommodate the instruments. All such movement or bending must be approved by the engineer. The reinforcement shall be placed so that minor adjustments in dowel bar alignment can be made by the engineer.

After the boreholes are complete and prior to placing any reinforcement for the small slab, three sheets of 4 mil polyethylene film shall be placed as specified on the plans and secured such that no wind damage can occur. The polyethylene may be temporarily folded to keep it free from construction. Once the reinforcement is placed in the small slab by the contractor, 4 threaded inserts will be placed at locations specified on the plans by the engineer. Two anchor bolts will be provided by the engineer and placed by the contractor at the locations in the small slab as specified on the plans. These anchor bolts will extend 5 inches from the south face of the test pavement. One inch diameter round holes will be necessary in the formwork to accommodate this requirement. The equipment to be cast in place that will hold the dial gauges will be provided and installed by the engineer. An access ramp shall be constructed as shown on the plans. Any material used must support heavy vehicles and shall be stabilized to prevent erosion.

ITEM 368 - TERMINAL ANCHORAGE AND LOAD FRAME

The terminal anchorage and load frame shall be installed in accordance with Item 368 of the Texas State Department of Highways and Public Transportation Standard Specification (1982). The anchor bolts necessary to secure the metal flange to the load frame shall be spaced by using the flanges blocked up in an appropriate position on the site. The flanges will be provided on site by the engineer. Any special equipment necessary to move, or otherwise adjust the flanges shall be the contractors responsibility. The anchor bolt shall be cast in place with the flanges acting as templates to space the bolts or by drilling the cured concrete and fixing the anchor bolt with epoxy. The position and spacing of the flanges shall be in accordance with the plans. The flange anchor bolts shall extend 5 inches above the surface of the load frame.

The project shall be constructed in accordance with the sequence of work Items shown on the attached flow chart provided in the specifications. Any deviation from this sequence must be checked with the engineer.