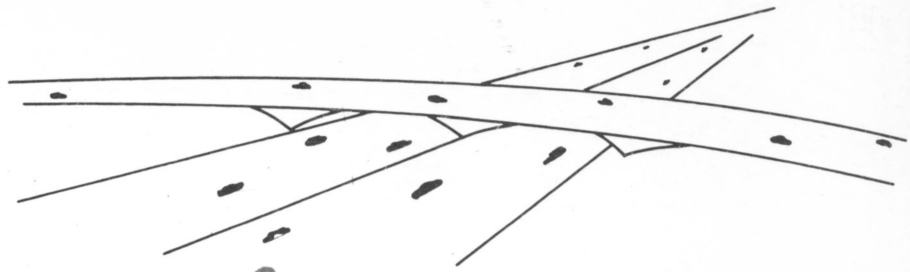

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DEPARTMENTAL RESEARCH

Report Number: **46 – 3**

EVALUATION OF SINGLE AXLE LOAD RESPONSE ON AN EXPERIMENTAL CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

Research Project 1 – 8 – 63 – 46

HIGHWAY DESIGN DIVISION

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Evaluation of Single Axle Load Response On An Experimental Continuously Reinforced Concrete Pavement

by

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Research Report Number 46-3

Performance Study of Continuously
Reinforced Concrete Pavement
Research Project 1-8-63-46

Conducted by

Highway Design Division, Research Section
The Texas Highway Department
In Cooperation with the
U. S. Department of Commerce, Bureau of Public Roads

April 1965

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A B S T R A C T

There is considerable lack of design and performance information on continuously reinforced concrete pavements. This study is an effort to learn more about pavement response due to load as measured by deflection, radius of curvature, and deflection basin. Data was gathered from pavements with steel percentages of 0.3, 0.4, 0.5, and 0.6, pavements with lightweight and conventional aggregate concrete, and preformed crack spacings of 5, 8, and 20 feet. The data was analyzed to evaluate the function of longitudinal steel, preformed crack spacing, and concrete modulus of elasticity in response to a single axle load. The study indicates that each parameter investigated is an important factor to consider in design of continuously reinforced concrete pavements. Data and graphs of the findings of this study are presented in this report.

Report On

EVALUATION OF SINGLE AXLE LOAD RESPONSE ON AN EXPERIMENTAL CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

I. INTRODUCTION

The many advantages of continuously reinforced concrete pavements (hereafter referred to as CRCP) have accelerated its construction throughout the state of Texas since its first use in 1951. This type of pavement is designed to eliminate all contraction and expansion joints. This is accomplished by placing enough longitudinal steel in the concrete to hold volume change cracks tightly together. Hair line cracks will develop which will permit contraction and expansion. The cracks should be so small as to prevent the entrance of foreign material and a minimum amount of moisture.

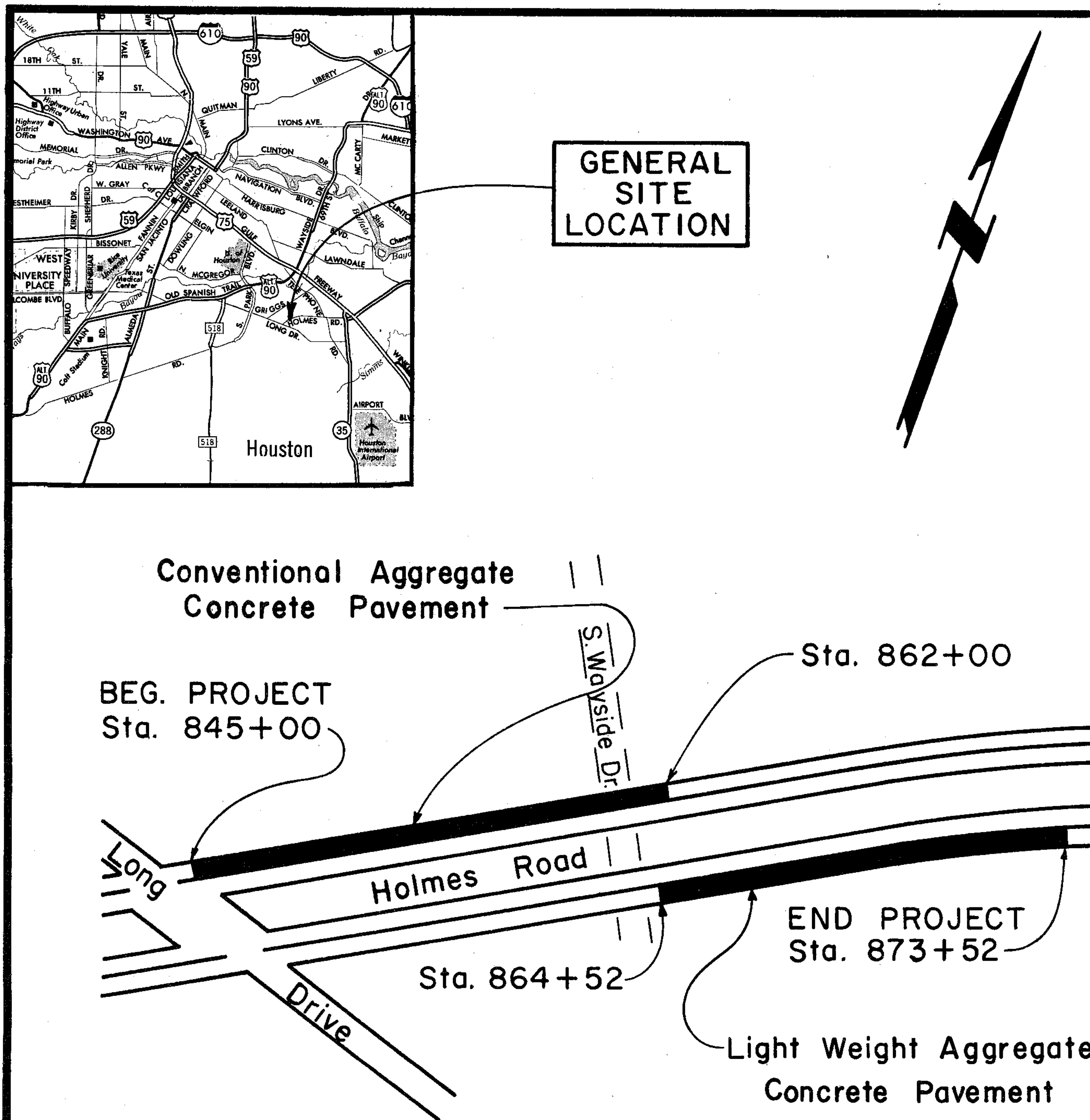
The need for more exact tools for optimum design of pavements for varying conditions is well known. The study of the single axle load response on an experimental CRCP is an effort to learn more about various variables and their relation to the radius of curvature, deflection, and deflection basin. The primary variables which are considered in this report are percent of longitudinal steel, preformed crack spacing, and modulus of elasticity of the concrete. Load is a secondary variable investigated in this study.

Objective

The objective of this study was to evaluate the single axle load response of CRCP in terms of deflection, deflection basin, and radius of curvature with varying percentages of steel, modulus of elasticity, and preformed crack spacing in the concrete. The studies presented herein on deflection and radius of curvature will be followed with a study of deflection of continuously reinforced pavements located throughout the state of Texas.

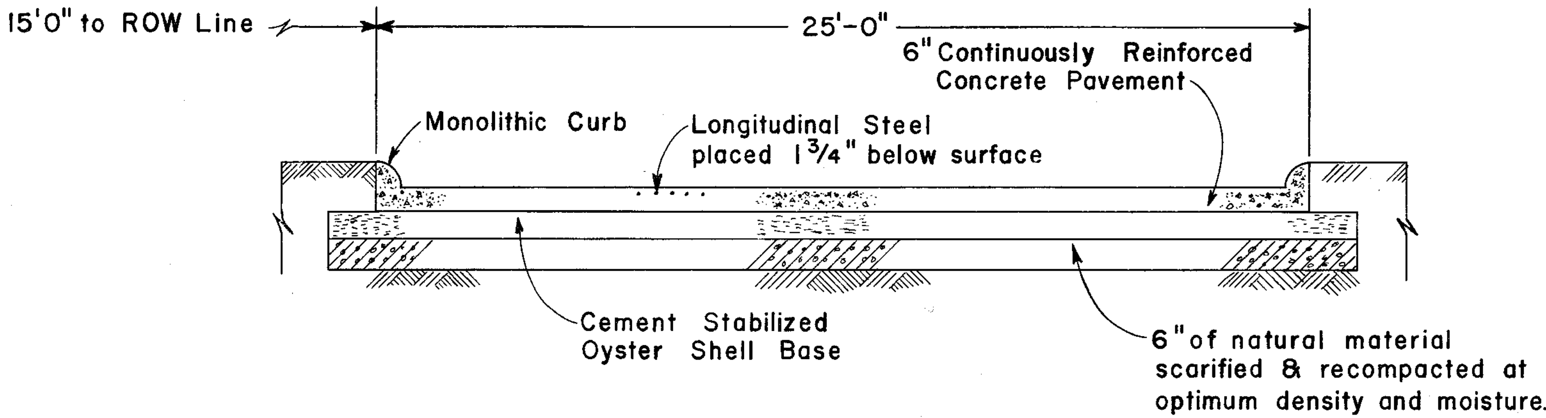
Background

The CRCP's undergoing tests are located in Harris and Walker Counties. The Harris County project is located in Houston, and is on the Frontage Road of IH 610, and was constructed in May 1964. One test slab is located on the North Frontage Road from Long Drive in an easterly direction for a distance of 1700 feet and consists of conventional aggregate CRCP. The second test slab is located on the South Frontage Road from Wayside Drive in an easterly direction for 900 feet and consists of lightweight aggregate CRCP. The construction job began at Station 841 on both the North and South Frontage Roads. Terminal anchorage anchor keys are located on each side of Long Drive on each Frontage Road. The new pavement of the North Frontage Road matched existing pavement at Station 866. The new pavement of South Frontage Road terminated at Station 876. The test sections as shown in Figure 1 are well within the project to avoid any end effects that the continuous pavement might experience. The terrain consists of a flat plain with black gumbo soil. Each test slab has two to three lanes and in each the traffic is in the same direction. A typical section for the project is shown in Figure 2. The top six inches of the subbase material is cement stabilized oyster shell. The test slabs are curbed. The curbs are six inches high and six inches wide. The test slabs are uniform, six-inch thick concrete placed in monolithic 22 to 24 feet widths. Where three lanes were required, an additional 11 foot wide monolithic slab was tied to the 22 foot slab with ½" tiebars at 24 inch center to center spacing. Some of the pertinent information on the concrete used in this pavement is tabulated below. All test results are at concrete age of 28 days.

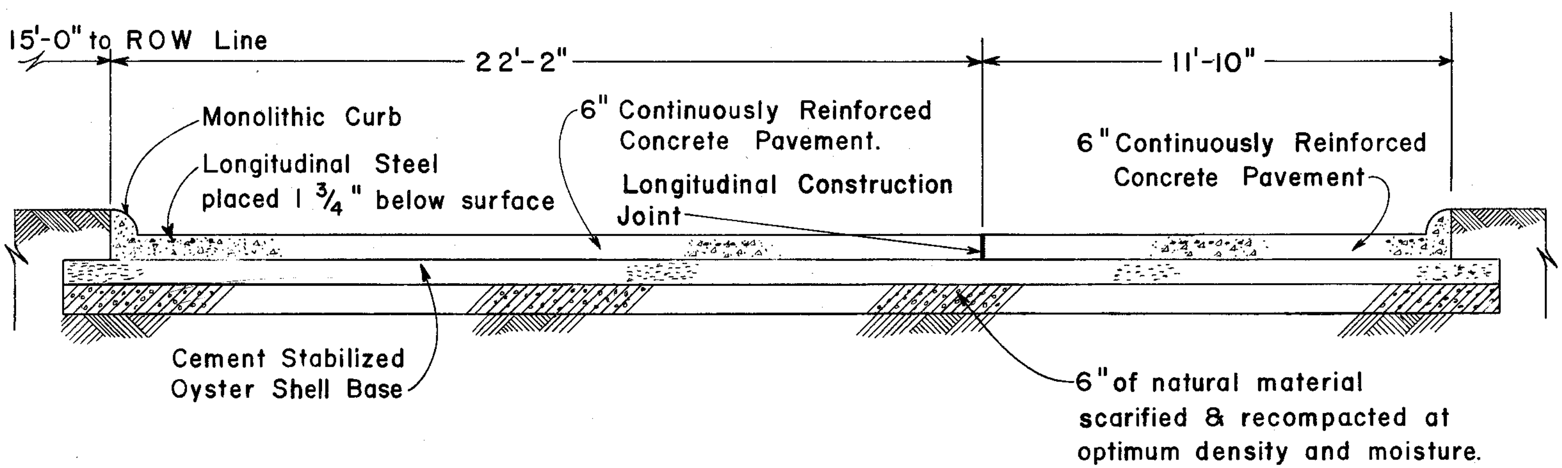


LOCATION AND LAYOUT OF HARRIS COUNTY PROJECT

Fig. 1



TWO LANE PAVEMENT



THREE LANE PAVEMENT

TYPICAL SECTIONS FOR HARRIS COUNTY PROJECT

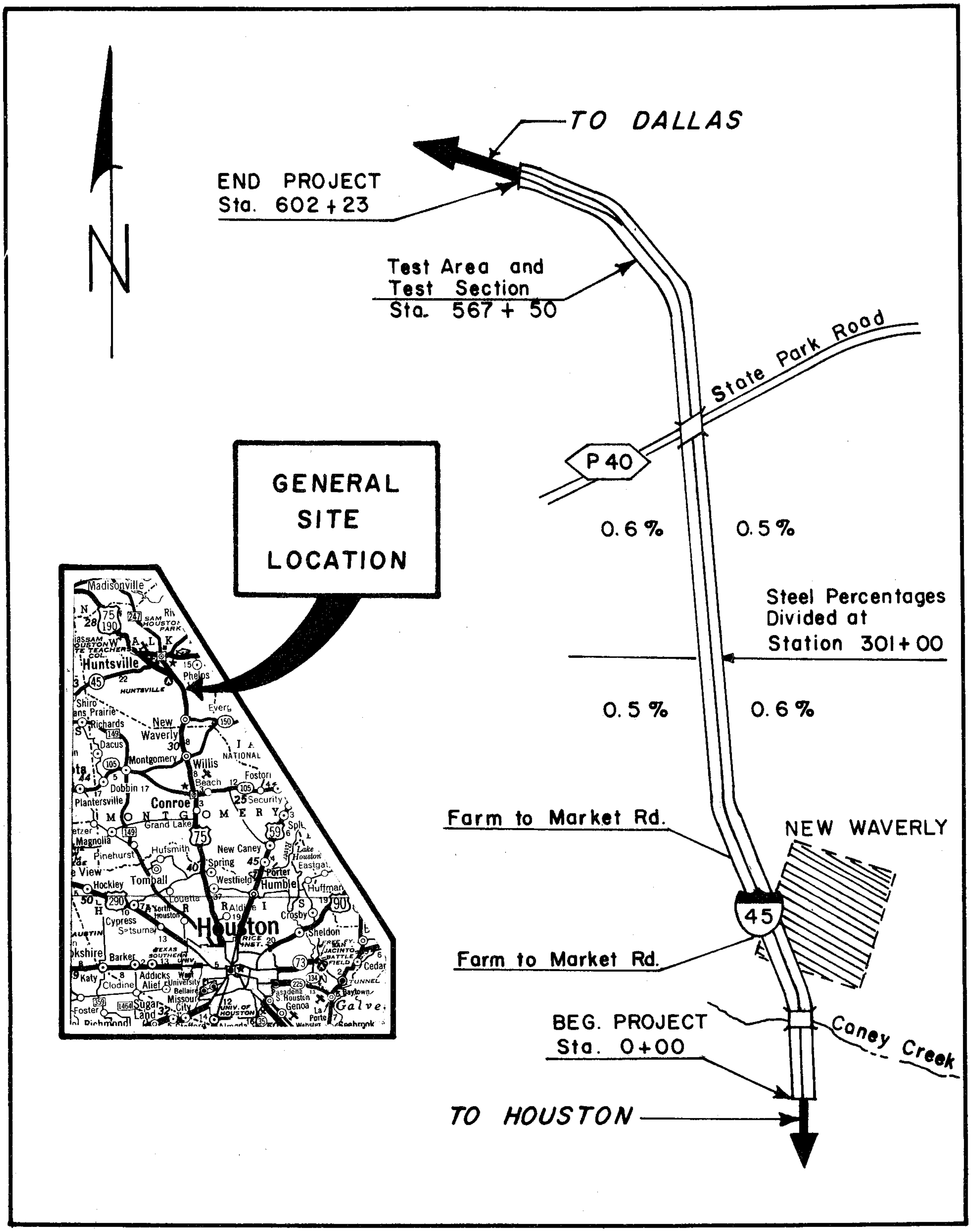
Figure 2

TABLE I

Concrete Properties

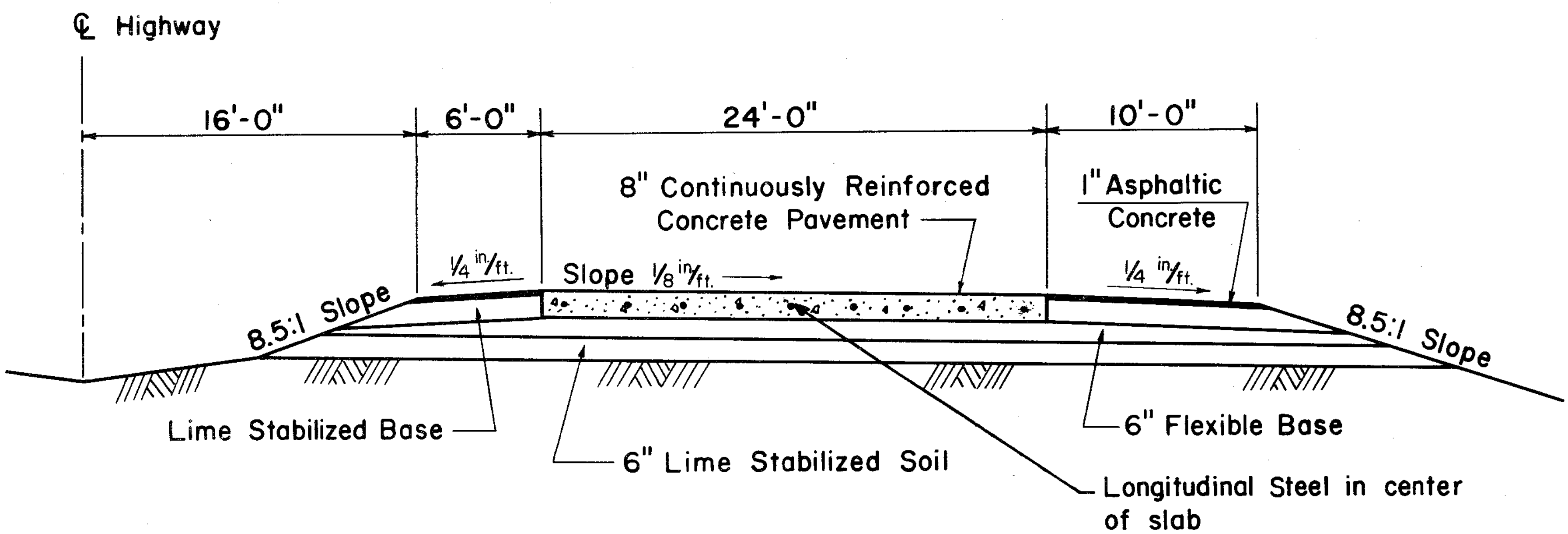
Concrete Coarse Aggregate Type	Compressive Strength (psi)	Tensile Strength (psi)	Modulus of Elasticity (psi)	Flexural Strength (psi)	Bond Strength (psi)
Conventional	4313	488	7.8×10^{6}	643	1206
Lightweight	3828	312	3.05×10^{6}	607	1011

The Walker County project was constructed in 1961 and is an experimental CRCP consisting of 11.3 miles of new location on Interstate Highway 45.[1] The location is in a rural area 2.0 miles south of Huntsville, Texas (See Figure 3). The highway is divided and consists of two lanes in each direction. A typical section of the pavement structure used on the project is shown in Figure 4. The pavement consists of a uniform eight inch thick slab, 24 feet wide, and placed monolithically. A crushed sandstone material was used as the subbase layer, while the top six inches of the natural sand-clay soil was treated with three percent lime (by weight) to form a stabilized layer and act as a moisture barrier to minimize the effects of moisture variations in the lower clay strata.



LOCATION AND LAYOUT OF WALKER COUNTY PROJECT

Figure 3



TYPICAL HALF SECTION FOR WALKER COUNTY PROJECT

Figure 4

Both the Harris and Walker County test slabs have a subgrade classification of poor, as classified by the Texas Triaxial Classification.[2,3] Additionally, the Harris County conventional aggregate concrete test slab and the Walker County test slabs consisted of siliceous river gravel.

II. DESCRIPTION AND LAYOUT OF EXPERIMENT

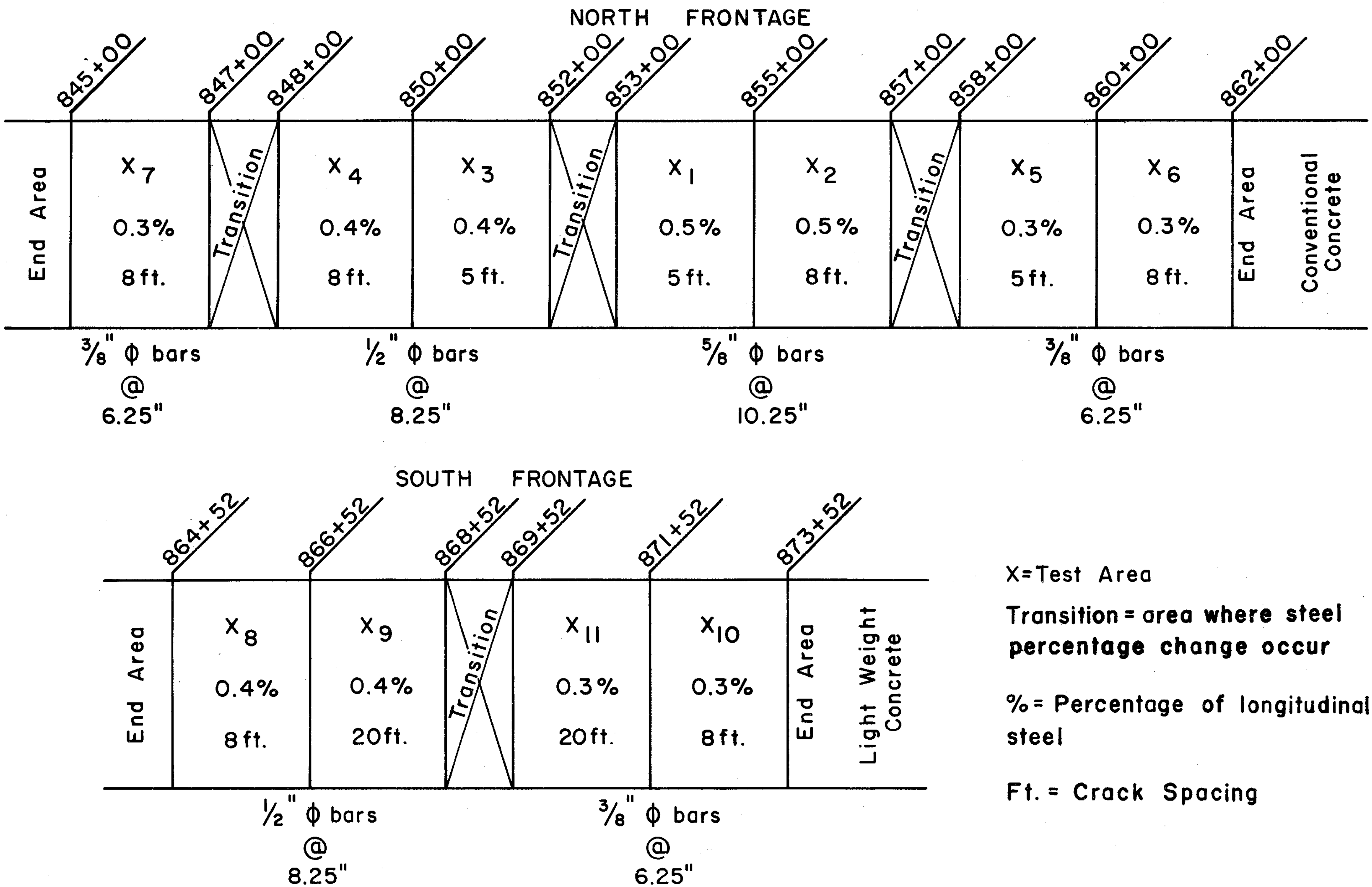
The controlling or primary variables in this test were percent longitudinal steel, preformed concrete crack spacing, and coarse aggregate type. Wheel load was a secondary variable. The experiment was conducted using two magnitudes of load, 18,000 pounds which is the maximum legal load and 24,000 pounds which was used to study trends due to excessive loads. Table 2 is a factorial presentation of the experiment. The numbers listed in the various spaces are the assigned test area numbers. There are 11 test areas in the Harris County Project, 10 of which are in the regular experiment and Test Area 7 is a replicate section. The measurements taken on Test Area 1, for this and previous experiments, have consistently varied from the expected pattern. A possible explanation for the results is that a large drainage ditch existed in the area previous to construction of the test area, and uniformity of subgrade construction was not achieved. The average measurements are not shown on Figures 6 and 8. Figure 5 indicates the entire test area layout, the test area number, the percentage of steel, the type of aggregate, and preformed crack spacing. Single axle loads of 18,000 and 24,000 pounds were used on the Harris County project.

Preformed Crack Spacing in ft. \ Aggregate Type / Percent Longitudinal Steel	Conventional 0.3	Conventional 0.4	Conventional 0.5	Conventional 0.6	Lightweight 0.3	Lightweight 0.4
5	5	3	1			
8	6&7	4	2		10	8
20					11	9
None			*W5	*W6		

* Note: Walker County Project

FACTORIAL OF COARSE AGGREGATE TYPE, PERCENTAGE OF LONGITUDINAL STEEL, AND PREFORMED CRACK SPACING

Table 2



TEST AREA LAYOUT FOR HARRIS COUNTY PROJECT

Figure 5

The Walker County project consisted of two percentages of longitudinal steel. One-half of the pavement had 0.5 percent longitudinal steel and the other one-half had 0.6 percent longitudinal steel. This design arrangement was made in order to compensate for the possibility of the unequal traffic flow on the two roadways, each directional roadway was divided equally between the two steel percentages. The north end of the northbound roadway contained 0.5 percent longitudinal steel, and the opposite ends of these roadways contained 0.6 percent longitudinal steel. Only a single axle load of 18,000 pounds was used on the Walker County project due to other extenuating circumstances (For complete details on this project, see Reference 1).

The Walker County project was made a part of this experiment in order that the relative effectiveness of the longitudinal steel in amounts of 0.5 and 0.6 percent could be evaluated. This is a valid addition in that the Walker County results are not compared directly with the Harris County results. This data is used only to determine the shape of curves in the 0.5 to 0.6 percent range; therefore any direct comparisons of magnitude should take into account subbase type, edge conditions, pavement thickness, etc.

III. EXPERIMENTAL PROCEDURE

Equipment

The single axle load response of the CRCP in this experiment was measured with two different measuring devices, the Benkelman Beam and Basin Beam. A detailed discussion of the equipment, together with its method of operation, and the related mathematics are presented in another report.[4] The Benkelman Beam was used to measure the total magnitude of pavement deflection. The Basin Beam measurements were used for determining the radius of curvature of the slab as the pavement deflects under the wheel load. The radius of curvature measure gives an indication of the relative stresses in the pavement, i.e. the larger the radius of curvature, the less the stress.

Additionally, the Basin Beam was used to determine the deflection basin characteristics. The deflection basin as used here refers to the area of influence of the load as indicated on the top surface of the pavement measured in a vertical direction. As the load was moved from the center of the deflection area, measurements were taken every two feet until the load was out of the area of influence. The load was then returned, taking measurements each position previously measured.

Procedure

Houston Experimental CRCP. On the Houston project, four inch corrugated metal spacers were placed vertically on the subgrade material at predetermined distances to induce cracking of the concrete on a predetermined basis.

The data was taken on August 20, 1964 and November 25, 1964. A single axle load of 18,000 pounds was used on Run I, and 24,000 pounds for Run II. Deflection and radius of curvature measurements were taken approximately every 25 feet on each test area. On each test area measurements for deflection and radius of curvature were taken at the crack and midspan positions. The midspan position, being a point midway between two cracks. A total of approximately 300 measurements were made on each of the two runs. The final measurements for each run were determined by averaging the measurements of each test area. Deflection measurements were corrected to zero degree temperature differential, using the results of the AASHO Road Test as a guide.[5] The purpose in reducing each measurement to zero degree temperature differential was to eliminate this factor as a variable and establish a common basis for analysis and comparison. The results of a previous study indicate that radius of curvature is not a function of temperature differential; therefore, corrections for temperature were not made. Only one set of readings for deflection basin characteristics was obtained for each test area studied. Deflection basin readings were taken during Run II.

Walker County CRCP. No provision for preformed crack spacing was made on the Walker County CRCP. Data runs were made on November 6, 1963, February 6, 1964, and June 30, 1964. In analyzing the data, the three data runs were averaged, thus the graphs related to the Walker County CRCP contained herein are based on the average of the three data runs. The same procedure was used here as in the Houston Experimental CRCP with the exception that readings were taken approximately every 200 feet. A total of approximately 300 measurements were made. The single axle load on each of the three runs was 18,000 pounds.

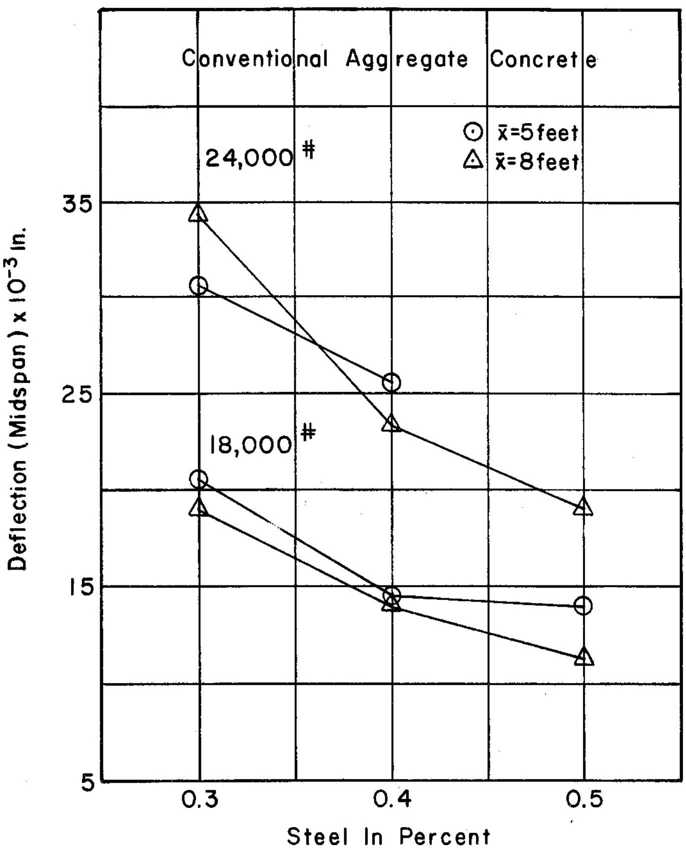
IV. PRESENTATION OF RESULTS

The results of the response of CRCPs due to single axle loads in terms of deflection, radius of curvature, and deflection basin measurements are presented in this chapter. The results of each type of measurement are used in evaluating the characteristics of the CRCPs in relation to the percentage of steel, preformed crack spacing, and modulus of elasticity of the concrete.

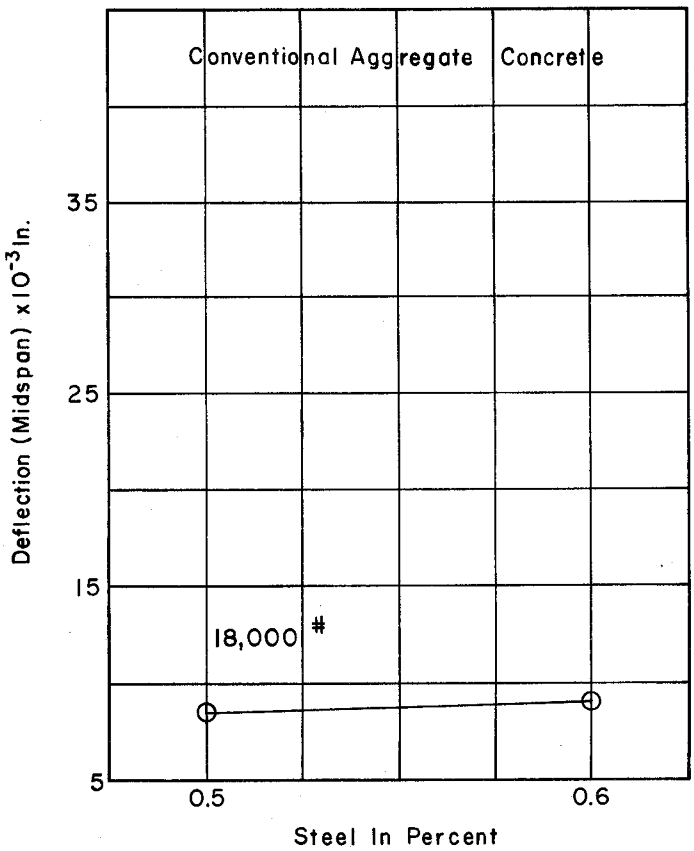
Deflection

Percent Steel. The conventional aggregate concrete data gathered shows that at both the crack and midspan positions, the deflection measurements vary inversely with the percentage of longitudinal steel from 0.3 percent through 0.5 as indicated in Figures 6 and 8. The five foot crack spacing does not conform to this at 0.5 percent steel. Further, as the steel percentage increases, the effectiveness of the steel in reducing deflection becomes less. The Walker County results presented in Figures 7 and 9 indicate that the difference in deflection between continuous pavements with 0.5 and 0.6 percent longitudinal steel is very small, and for practical purposes, steel percentages greater than 0.5 have no significant effect on deflection alone.

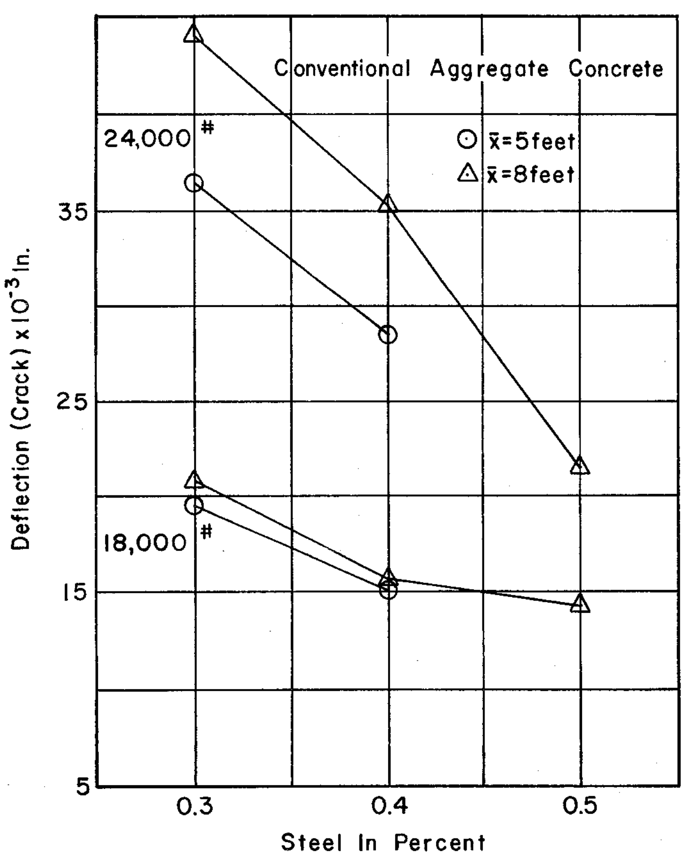
The overall average deflection measurements on the Houston project were greater at the crack position than



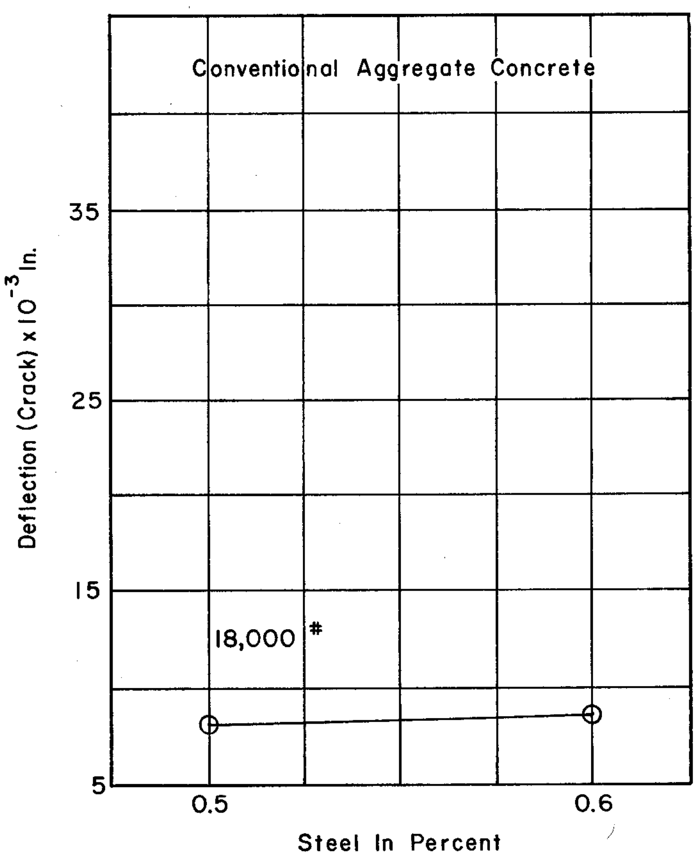
DEFLECTION VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 6



DEFLECTION VS STEEL
WALKER COUNTY PROJECT
Figure 7



DEFLECTION VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 8

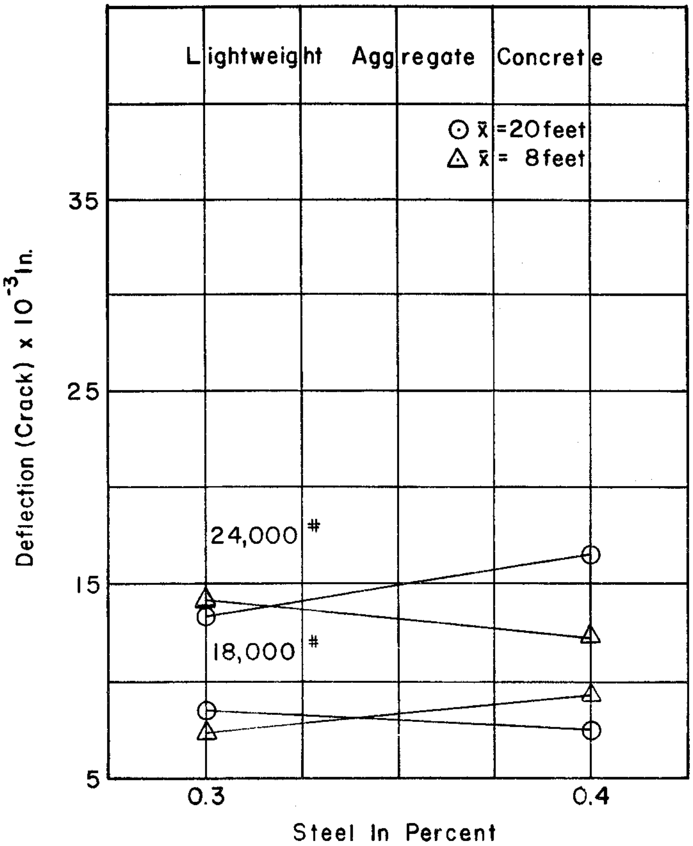


DEFLECTION VS STEEL
WALKER COUNTY PROJECT
Figure 9

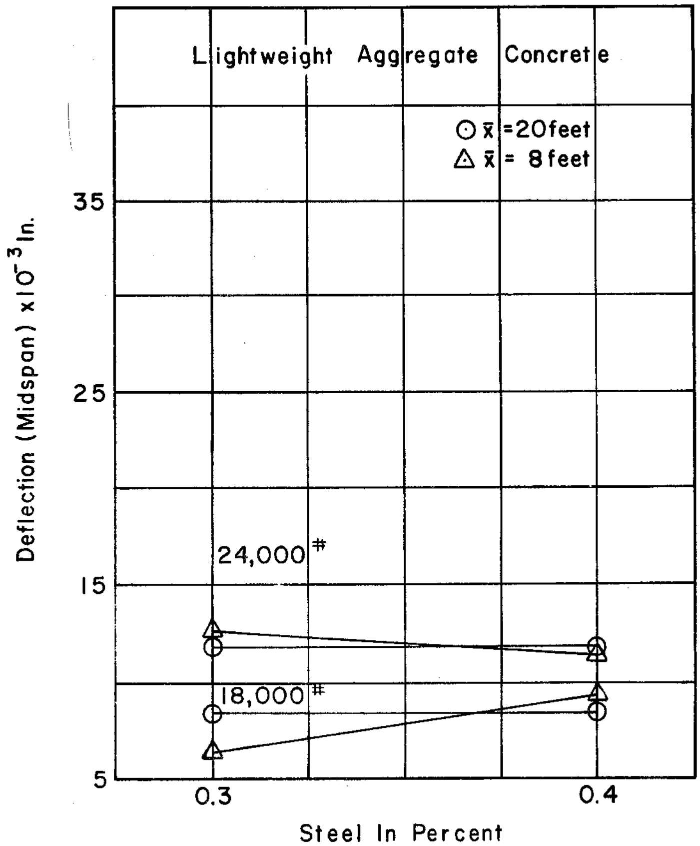
the midspan position especially with the lower steel percentages. This is as expected in that it appears logical that a concrete slab would be less effective in resisting a bending load at a crack position than would be the case if the concrete were continuous. There are exceptions to this as is indicated on Figures 6 and 8. The Walker County data as shown in Figures 7 and 9 indicates that the average deflections were about the same at the crack and midspan positions. This observation is logical in that the steel percentage is large enough to approach the optimum condition of keeping the cracks tightly closed. However, where exceptions do exist, they are relatively small.

Study of the deflection results for the lightweight aggregate concrete indicated that the difference in effectiveness between the 0.3 and 0.4 percent steel is small and inconclusive (Figures 10 and 11). The average deflection at the crack is greater than midspan measurements as one would expect.

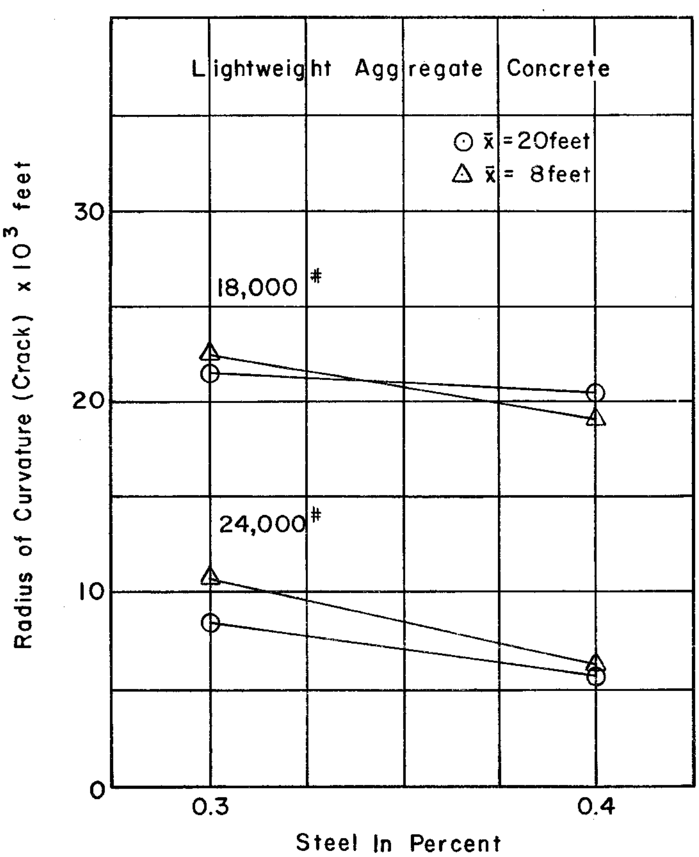
<u>Preformed Crack Spacing</u>. A part of the Houston Experimental CRCP conventional aggregate concrete data indicates that deflection is a function of preformed crack spacing. For 18,000 and 24,000 pound single axle loads, the average



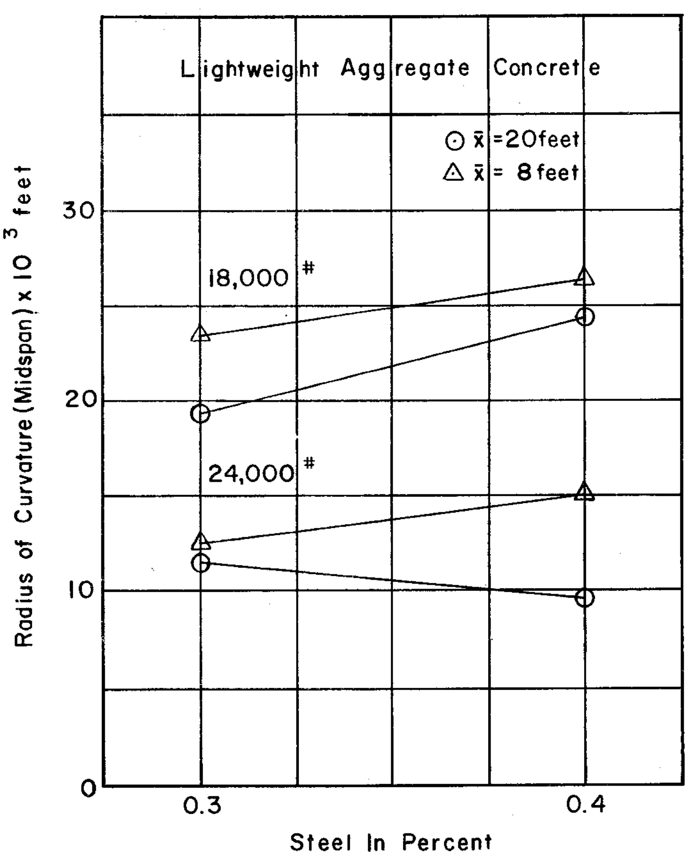
DEFLECTION VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 10



DEFLECTION VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 11



RADIUS OF CURVATURE VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 12



RADIUS OF CURVATURE VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 13

deflection of the pavement at the crack position was approximately four and 23 percent greater for the preformed crack spacing of eight feet than for five feet, respectively (Figure 8).

A study of the midspan deflection measurements, using an 18,000 pound load, indicates that the CRCPs with the five foot preformed crack spacing have a 10 percent greater average deflection than did the eight foot crack spacing (Figure 6). This is converse to the findings at the crack position. For the 24,000 pound load, the average deflection at the midspan position was five percent greater for the eight foot than for five foot preformed crack spacing (Figure 6).

From an overall point of view, the data appears to indicate that deflection is a direct function of crack spacing. Other research has also indicated a lack of conclusiveness on the subject, and therefore it is believed that more research should be done before a final conclusion is made.

The preformed crack spacing for the lightweight aggregate concrete of 20 feet had changed to an average crack spacing of eight feet through natural cracking before the measurements of this experiment were made. Thus, crack spacing was no longer a variable. The results correlate with this fact, in that the effect of crack spacing is indicated to be inconclusive (Figures 10 & 11).

Concrete Modulus of Elasticity. The study of the Houston Experimental CRCP data shows that the lightweight aggregate concrete deflected considerably less than did the conventional aggregate concrete. This observation is converse to what would be expected from theory[6], but numerous cross checks in relation to procedure were made to verify this observation. Furthermore, data collected in a statewide study that will be presented in another report also reveals this same trend. Test Areas 4 and 8 have equal variables except for the modulus of elasticity. In evaluating the results for equal conditions, it was found that the high modulus of elasticity concrete average deflection at the crack and midspan positions for 18,000 and 24,000 pound loads is 54 and 148 percent greater than the low modulus of elasticity concrete, respectively (Figures 6, 8, 10 & 11). Further, considering the average crack and midspan deflection for all conditions, the conventional aggregate concrete deflection is approximately 115 percent greater than the lightweight aggregate concrete deflection (Figures 6 through 11).

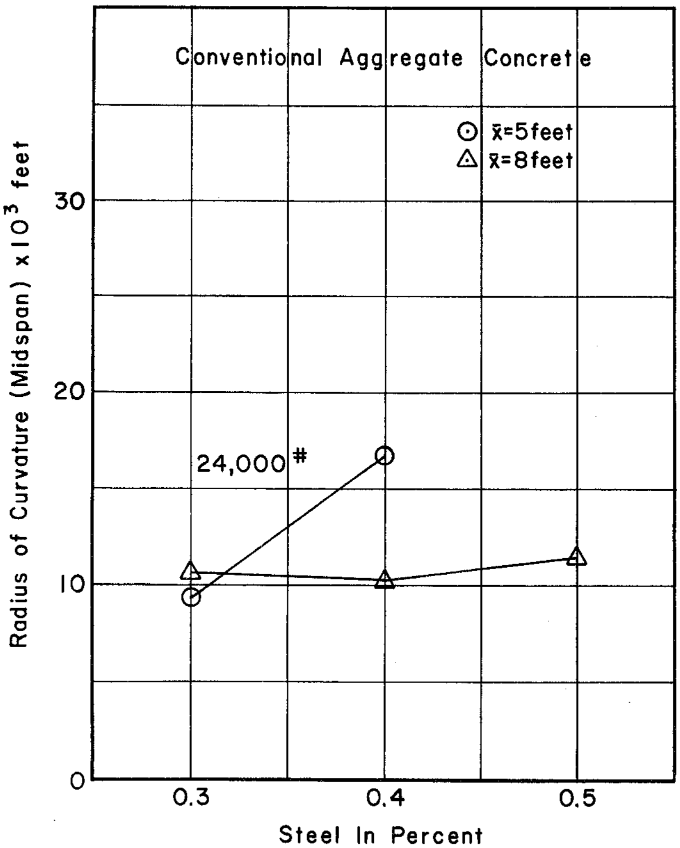
Radius of Curvature

The radius of curvature is an indication of the stress in the pavement. This is in accordance with the fundamental strength of materials relationship.

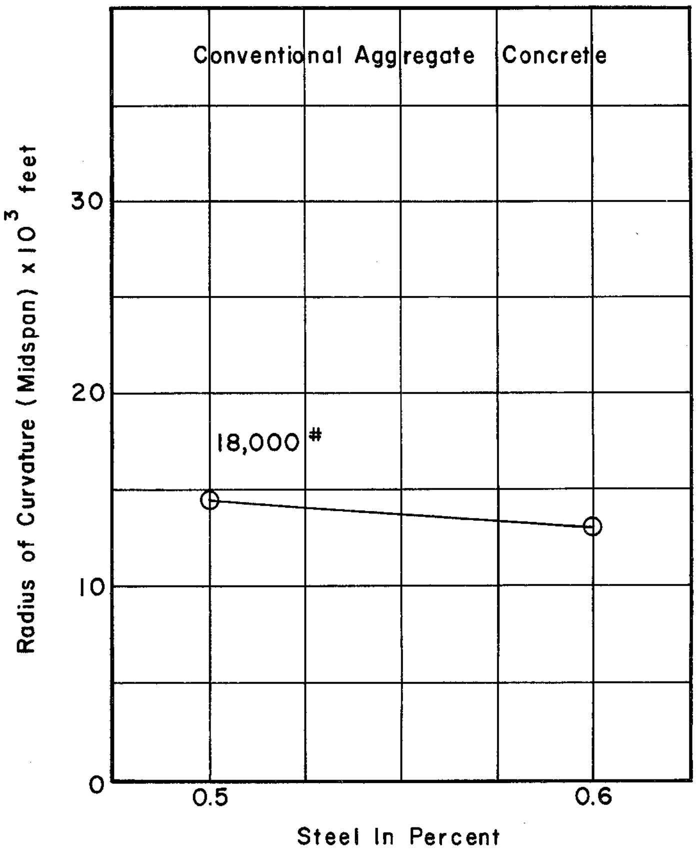
Percent Steel. The Houston Project conventional aggregate concrete data indicates, at both the crack and midspan positions, that the radius of curvature increases as the longitudinal steel in the concrete increases from 0.3 to 0.5 percent (Figures 14 and 16). The greatest relative increase was from 0.3 to 0.4 percent steel. The Walker County Project shows that the difference in the radius of curvature for 0.5 and 0.6 percent longitudinal steel pavements is very small, and for practical consideration is the same (Figures 15 & 17).

In that crack spacing is not considered a variable for the lightweight aggregate concrete test areas as discussed previously, all four test areas are considered in this discussion. The average radius of curvature for the 18,000 and 24,000 pound single axle loads, at the crack position was 12 and 49 percent greater for the 0.3 percent than for the 0.4 percent longitudinal steel, respectively (Figure 12). The midspan results for the same condition as above indicate that at the midspan position the radius of curvature is 18 and four percent greater for the 0.4 percent steel, respectively (Figure 13). Thus, the difference in radius of curvature is small for lightweight aggregate concrete, and for practical consideration can be considered the same.

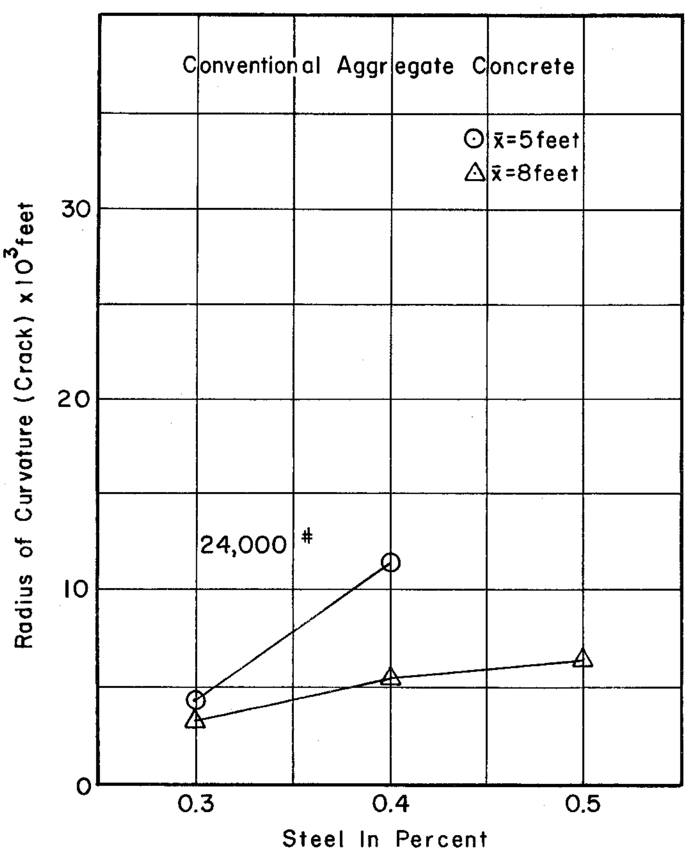
Preformed Crack Spacing. Investigation of the data for conventional aggregate concrete for both loads at the



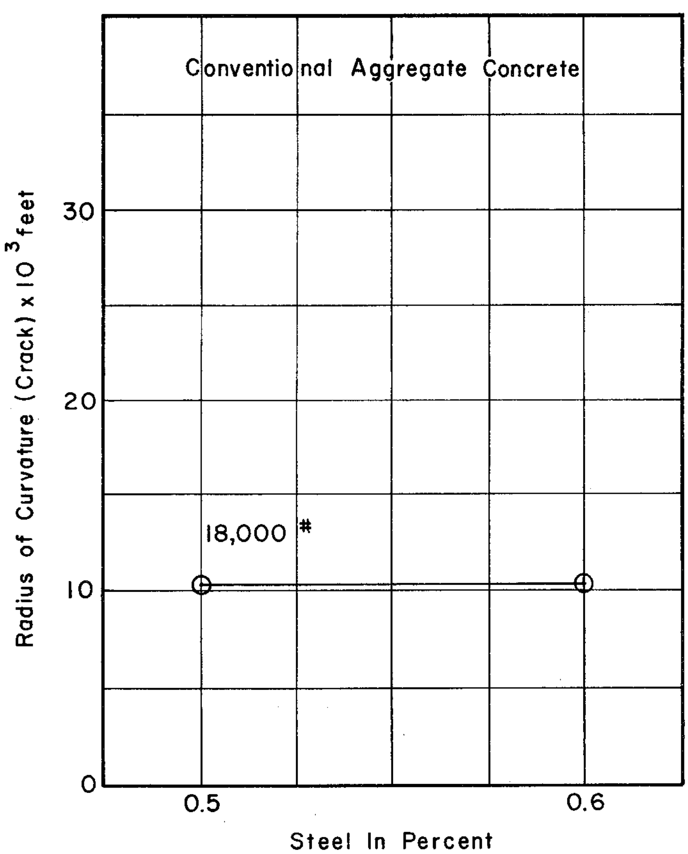
RADIUS OF CURVATURE VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 14



RADIUS OF CURVATURE VS STEEL
WALKER COUNTY CRCP
Figure 15



RADIUS OF CURVATURE VS STEEL
HOUSTON EXPERIMENTAL CRCP
Figure 16



RADIUS OF CURVATURE VS STEEL
WALKER COUNTY CRCP
Figure 17

crack and midspan position showed that in three out of a total of four comparable conditions, the radius of curvature is greater for the smaller value of preformed crack spacing, which indicates relatively less stress in concrete pavement with the smaller preformed crack spacing. The results indicate that stress is a direct function of preformed crack spacing (Figures 14 and 16).

Modulus of Elasticity. The Houston experimental CRCP has two test areas, four and eight, where all variables are the same except the modulus of elasticity. Comparing the radius of curvature as measured at the crack and midspan positions on the lightweight and conventional concrete, the radius of curvature on the lightweight or low modulus of elasticity concrete was 20 percent greater than that at the crack position of the high modulus concrete and 41 percent greater at the midspan position. This is portrayed graphically in Figures 13 and 14 and 12 and 16 respectively.

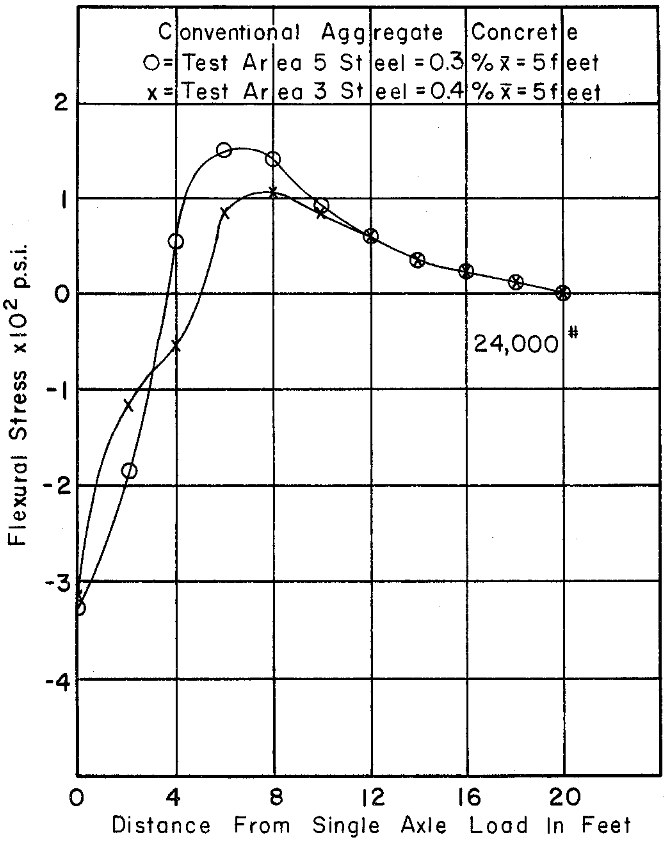
Comparing the average of all conditions for the 24,000 pound load, the radius of curvature as measured at the crack and midspan positions are 22 and two percent greater for the low modulus of elasticity concrete, respectively (Figures 12, 13, 14, and 16).

Deflection Basin

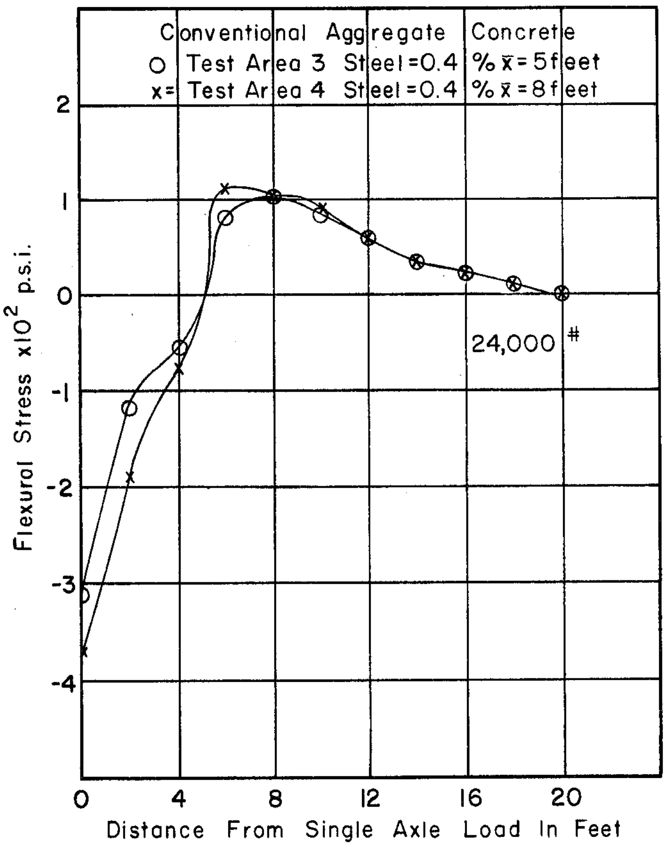
The deflection basin results were evaluated by comparing the relative stresses as calculated at the surfaces of the pavement. The stresses were calculated by use of the basin beam readings and theory, for relative comparisons; hence, they do not represent actual stresses. The method of calculation is covered in another report.[4]

Steel Percent. Test Areas 5 and 3 have 0.3 and 0.4 percent longitudinal steel, and each has a preformed crack spacing of five feet. The maximum positive and negative stresses for the 0.3 percent longitudinal steel are 43 and four percent greater than for 0.4 percent longitudinal steel, respectively. The stress curves for the two test areas are similar in shape through 12 feet of the basin, and from 12 feet through 22 feet they are practically identical (Figure 18). The limited results available indicate that longitudinal steel percentage has no effect on the length of the deflection basin. However, the use of 0.4 percent longitudinal steel reduces the maximum positive and negative stresses, as indicated in Figure 18.

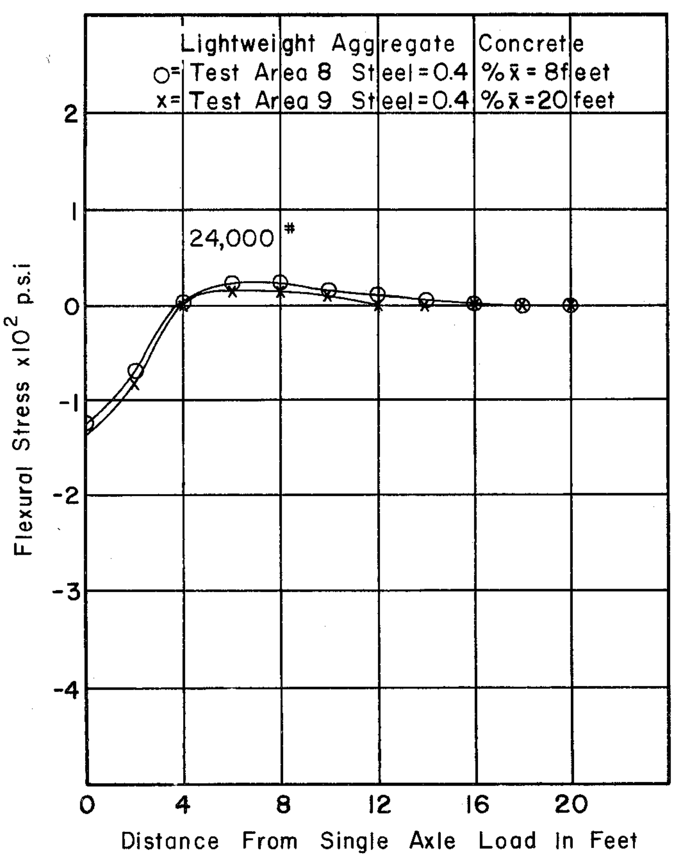
Crack Spacing. Test Areas 3 and 4 have 0.4 percent steel and a preformed crack spacing of five and eight feet, respectively. The shape of the two stress curves as shown in Figure 19 are very similar and for practical consideration identical from 12 through 22 feet. The maximum positive and negative stresses for five foot preformed crack spacing are 19 and 11 percent greater than for eight foot preformed crack spacing, respectively. The results indicate that



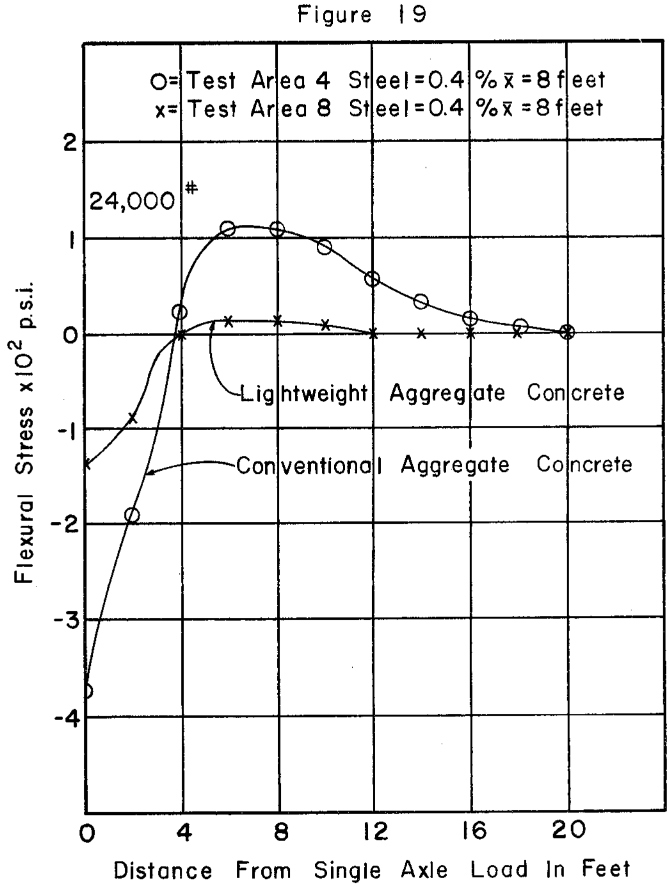
FLEXURAL STRESS VS LOAD
HOUSTON EXPERIMENTAL CRCP
Figure 18



FLEXURAL STRESS VS LOAD
HOUSTON EXPERIMENTAL CRCP
Figure 19



FLEXURAL STRESS VS LOAD
HOUSTON EXPERIMENTAL CRCP
Figure 20



FLEXURAL STRESS VS LOAD
HOUSTON EXPERIMENTAL CRCP
Figure 21

the length of the basin is not a function of crack spacing. However, the maximum positive and negative stresses are greater for the longer preformed crack spacing. Test Areas 8 and 9 consist of lightweight aggregate concrete, 0.4 percent steel, and 8 and 20 feet preformed crack spacing, respectively. As mentioned previously, the crack spacing in the 20 feet preformed crack spacing test areas have reduced to 8 feet through natural processes, and therefore, crack spacing was not a variable at the time the measurements were made. The stress curves for Test Areas 8 and 9 shown in Figure 20 are almost identical, as would be expected.

Modulus of Elasticity. Test Areas 4 and 8 each have a preformed crack spacing of eight feet and 0.4 percent steel. Test Areas 4 and 8 consist of conventional and lightweight aggregate concrete, respectively. The stress curve for high modulus of elasticity concrete is considerably different from the low modulus of elasticity concrete in that the high modulus is more accentuated in all respects, including the length of the basin. The maximum positive and negative stresses in the high modulus of elasticity concrete are 413 and 193 percent greater than are the stresses in low modulus of elasticity concrete, respectively (Figure 21). The results indicate that modulus of elasticity of the concrete is a factor affecting basin length and that low modulus of elasticity is superior to high modulus of elasticity concrete in that the deflection basin is modified and thereby reduces the stresses appreciably. Further, the results indicate that stress is a direct function of the modulus of elasticity of the concrete (Figure 21).

V. DISCUSSION OF RESULTS

The response of CRCPs to a single axle load of either 18,000 or 24,000 pounds as measured by either deflection, radius of curvature, or deflection basin indicate comparable results considering the percentage of steel, preformed crack spacing, or modulus of elasticity of the concrete. The total results indicate that the primary variables studied are important factors of design within specific limits. The results show that steel percentages, 0.3 through 0.5 are progressively more effective, and pavements with 0.5 through 0.6 percent steel show only slight variation in effectiveness. It is also indicated that low modulus of elasticity concrete responds to load more effectively than does high modulus of elasticity concrete. Further, for conventional aggregate concrete, the load reaction is a direct function of the preformed crack spacing; that is, the preformed crack spacing of five feet proved the most effective of the spacings considered.

The results indicate that deflection basin length is a function of the concrete modulus of elasticity. However, the higher steel percentage, the lower modulus of elasticity concrete, and the smaller crack spacing considered produced an optimum basin shape. Modulus of elasticity of the concrete is indicated to be the most powerful variable considered in this regard.

VI. CONCLUSIONS

Based on the results of this study the response of CRCPs to a single axle load as measured by deflection, radius of curvature and deflection basin the following is concluded:

1. Deflection varies inversely with percent longitudinal steel.

2. That for conventional aggregate concrete, 0.5 percent longitudinal steel is an optimum.

3. That for lightweight aggregate concrete 0.3 percent longitudinal steel is an optimum.

4. That low modulus of elasticity concrete is superior to high modulus of elasticity concrete in its capability to respond to a single axle load.

5. That for conventional aggregate concrete, an optimum preformed crack spacing is five feet.

6. Radius of curvature varies directly with percent longitudinal steel.

7. That the deflection basin length is a function of the concrete modulus of elasticity.

8. That an optimum shape for deflection basin is attained on the test areas consisting of low modulus of elasticity concrete.

9. That axle loads of 18,000 and 24,000 pounds indicate the same trends.

BIBLIOGRAPHY

1. Shelby, M. D. and McCullough, B. F., "Determining and Evaluating the Stresses of an In-Service Continuously Reinforced Concrete Pavement," Highway Research Record, No. 5, Washington, D. C.; National Academy of Sciences, January 1963.

2. Design Manual for Controlled Access Highways, Texas Highway Department.

3. Texas Highway Department Laboratory Manual.

4. McCullough, B. F., "Development of Equipment and Techniques for a State-wide Rigid Pavement Deflection Study," Report Number 46-1, Texas Highway Department, January 1965.

5. Highway Research Board, The AASHO Road Test, (Report No. 5, Pavement Research). Washington, D. C.; National Academy of Sciences, 1962.

6. Westergaard, H. M., "Stresses in Concrete Pavements Computed by Theoretical Analysis," Public Roads, Volume 7, No. 2, April 1926.