

LONG-TERM PERFORMANCE STUDY OF RIGID PAVEMENTS

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This paper reports the performance of two types of concrete pavements throughout their complete life cycles. The pavements were constructed in Houston and have received a relatively large amount of traffic volume and loads. The two pavement types are a Jointed Reinforced Concrete Pavement (JRCP) and a Continuously Reinforced Concrete Pavement (CRCP). The jointed pavement was a part of the Gulf Freeway constructed in 1947 and rehabilitated in 1985, after 38 years of service. The continuously reinforced pavement was constructed on IH610 Loop frontage roads in 1964 and is still in service after 24 years.

Both pavements were considered to have experimental features at the time of construction. The jointed pavement was constructed with both the flexible subbase and the embankment soil being "wrapped" in an asphalt membrane. The continuously reinforced pavement contained several experimental sections in which the coarse aggregate type, the percent steel, and the preformed crack spacing was varied. The paper describes the study given to each experimental feature and suggests design and construction aspects which were developed from the analysis.

INTRODUCTION

Background

It is rare that performance observations are available for more than a 20-year period, as is the case of the pavements treated in this paper. Often the performance used for design or construction decisions is based on an observance period of about two to three years; therefore, this study is important since it has offered the opportunity for a study of a jointed reinforced concrete pavement and a continuously reinforced concrete pavement well along or at the completion of their life cycles.

The Gulf Freeway in downtown Houston, which is a section of IH45, was initially opened to traffic in December 1947 and was rehabilitated in September 1985. The facility was one of the first freeways in Texas and the paving was a jointed reinforced concrete. For the past 38 years, it has shown excellent performance.

Two small sections of the north and south frontage streets of Interstate Loop 610 around Houston were built in 1964 as experimental CRCP sections to study the effects of percent steel, preformed crack spacing, and type of coarse aggregate. Periodic information on the performance of these sections was collected after construction.

Objective

The objective of this study was to evaluate the long-term performance of two types of concrete pavement, JRCP and CRCP, and to find significant relationships between the long-term pavement performance and certain characteristics of pavement design and construction variables. This study does not compare the relative performance of the two pavement types, since the other variables such as frontage road vs. main lane, embankment preparation, etc. do not permit a one-to-one comparison.

DESCRIPTION OF PROJECTS

In the following sections the pertinent feature of the JRCP and the CRCP projects are described.

JRCP

The JRCP test section was in the northbound direction, between Scott and Cullen Streets in Houston, from station number 71+98.17 to 60+50.00, and was bounded by bridge embankments (see Fig 1). The distance between transverse joints was 20.5 feet and the longitudinal joints were installed at the lane lines. The subgrade preparation was specified to be at least 6 inches deep and compacted to 100 percent Proctor Density. The embankments were encapsulated in an asphalt membrane (OA-55). Monitoring studies for the first 20 years revealed a stable condition with no variation of the moisture content. The embankment soil was placed on this membrane, conforming to line and grade shown on the plans. On the top of this membrane, a 9-inch layer of flexible base material was laid in two equal courses. This subbase consisted of unbound seashell material dredged from the Texas Gulf Coast. A seal coat using a RC-2 and a pea gravel was constructed over the subbase. The seal coat was constructed to extra width so that the RC-2 lapped onto the OA-55 of the embankment to also encapsulate and seal the subbase. The seal coat prevented the contamination of the steel and concrete during the pavement construction. Eight inches of concrete pavement were laid on top of the seal coat layer.

Welded wire fabric, designated by W4 x W3 x 6 x 12, was used as steel reinforcement, and placed in the center of the 8-inch concrete depth. The longitudinal joints were formed by grooving the green concrete to a depth of approximately 2-1/2 inches. A debonding wax was then injected into the groove to form the joint. Tie bars 1/2 inch in diameter and 3 feet in length were centered about the longitudinal joints and tied on 24-inch

centers along the length of the slabs. The transverse expansion joints were formed using the CMI (cast malleable iron) cantilever type transmission unit. This unit was referred to as the "star lug" model D-13 and is shown in Fig 2. The spacing between load transfer units in transverse joints was approximately 20 inches. Although this load transfer device was used extensively in Texas during the 1940's and 50's, it has not been used in recent years.

Another unusual factor for this pavement is that the entire section is on an embankment thus above the natural ground level. All surface drainage flows away from the pavement, therefore with positive drainage and encapsulated soils. Infiltration downward is not experienced.

CRCP

The continuously reinforced concrete pavements (CRCP) discussed in this report are the frontage roads for IH610, an interstate loop in Houston. The frontage roads served as the main artery for a five year period prior to construction of the main lanes. These sections are on the south side of Houston and they were placed between Long Drive and Broad Street (see Fig 1).

The pavement in this area was originally conceived as a group of test sections, and these sections were designed, included in the plan set, and constructed under contract. The basic design called for a test section of 6-inch-thick CRCP with a width of 24 feet placed on 6 inches of cement stabilized subbase and constructed on a dark brown clay soil. The length was subdivided into (1) seven experimental sections on the north frontage road which used a siliceous river gravel as the coarse aggregate in the PC concrete (labeled conventional aggregate) and (2) four experimental sections on the south frontage road, in which a lightweight coarse aggregate was used in the PC concrete. The experimental features of the 11 test sections included a variety of preformed crack spacings and different longitudinal steel percentages as well as the coarse aggregate type, as shown in Fig 3. The cracks were preformed by attaching a length of corrugated metal sheet to the subbase in a position which was transverse to the roadway length. The corrugated metal sheet had been bent along a corrugation to form a "right" angle, with the bottom attached to the subbase and the remaining angle side placed vertically. The vertical side was slotted so as not to touch the longitudinal steel, which was placed at middepth. The variation in the longitudinal steel percentage was achieved by varying the spacing slightly and also by using different bar sizes.

The conventional aggregate sections were constructed with preformed crack spacings of 5 feet and 8 feet. Each of these preformed spacings had sections with 0.3, 0.4, and 0.5 percent longitudinal steel. The lightweight aggregate sections were constructed with preformed crack spacings of 8 feet and 20 feet and each preformed spacing had sections with 0.3 and 0.4 percent longitudinal steel. Section 7 (0.3 percent steel and 8-foot preformed crack spacing) is a replicate of Section 6 and occurs near the west end of the project.

Previous studies had indicated the bond area was as important as the percent steel. Therefore, these sections were all designed to have an equal amount of bond area/concrete volume even though percent steel was varied. This was accomplished by varying bar size as well as spacing (Fig 3).

The CRCP sections were constructed in 1963. The Texas State Department of Highways and Public Transportation (SDHPT) Research Report 46-2 explains the project and experimental sections in greater detail.

METHOD OF STUDY

Numerous field tests were performed on the pavement to characterize them for making a diagnostic evaluation. The JRCP is only characterized at the end of life cycle since previous data were not available. Measurements were taken on the CRCP during its life. The studies are designated in the following sections for each pavement type.

JRCP

The study on JRCP sections consisted of (1) a field condition survey, (2) nondestructive tests using a Falling Weight Deflectometer and Dynaflect, (3) a number of laboratory tests on the cores taken from various locations at the test site, and (4) analysis and evaluation of the experimental data.

In a field condition survey, pavement distresses were visually surveyed. Load transfer at the joints and material characterization were accomplished through nondestructive tests. Various concrete properties were measured in a laboratory, using cores. Effort was made to correlate the findings from these investigations with long-term pavement performance.

CRCP

The method of studying the CRCP sections was to collect observation and nondestructive test information at periodic intervals. The information was collected almost constantly for the first 30 days since a research crew was "on site" during this period. Then frequent observations were made for the first year or until the parent research project ended. Finally, tests and observations were collected in 1974, 1984, and in 1988.

Traffic volume and traffic load information was obtained from the Texas SDHPT, Transportation Planning Division. This division used historical records to develop the information shown in Table 1. Linear extrapolation and interpolation were used to develop the traffic data for the test periods shown following. It should be noted that stage construction was used on IH610 south. The frontage road was constructed first and carried all the traffic until 1969, when the main lanes were completed. As the city developed, considerably more traffic has used the north frontage road than the south frontage road. The load information, expressed in 18-kip equivalent single axle loads (18-kip ESAL) shows the south frontage road has received about 2/3 the loads experienced by the north frontage road. Also note that the data are for one direction and that an additional lane (for a total of three lanes in each direction) has been added. An exit ramp was placed near the beginning of the north frontage road siliceous gravel sections.

Deflection measurements were obtained in 1964, 1974, and 1984. The 1964 measurements were obtained with a loaded truck (18-kip) and a Benkelman Beam. The 1974 and 1984 measurements were obtained with a Dynaflect.

Initial observations were of the development of the transverse cracks, especially the development of the preformed cracks in relation to the percent longitudinal steel. Later, full condition surveys included spalling, punchouts, and repairs as well as the transverse crack spacing.

PRESENTATION OF TEST RESULTS AND PAVEMENT PERFORMANCE

The pertinent results for each pavement type are discussed in the following sections.

JRCP

In this section, results from nondestructive and laboratory tests are presented, as well as pavement performance in terms of visual distresses. Joint efficiency at the transverse and longitudinal joints was evaluated using a Falling Weight Deflectometer (FWD). Table 2 presents joint efficiency values from the method proposed by Ricci et al (1). The transverse joints were construction joints, not contraction joints. There was no aggregate interlock, thus all the load transfer was by the dowels. High values of joint efficiency in the transverse joints indicate that dowels performed their intended functions in an excellent manner for 38 years. The mean value for joint efficiency of longitudinal construction joints was 0.46, which is much lower than the mean value of 0.81 occurring at the transverse joints. This finding indicates that load transfer devices used in transverse joints, so called "star lug," at 20 inches on centers have performed much better than tie bars used in the longitudinal joints at 24 inches on centers.

Material properties were back calculated from Dynaflect and FWD data using computer program RPEDD1 (2). Table 3 shows the mean moduli values in each lane obtained from back calculations, along with values obtained from laboratory testing (in compression). For the concrete layer, values obtained from FWD deflections were consistently higher than the laboratory values, whereas those from Dynaflect deflections underestimated the laboratory values. Ricci et al (1) made a comparison of estimated moduli using different nondestructive testing devices, and, as found in this study, values from the FWD were higher than those from the Dynaflect.

The mean tensile strength from 82 specimens was 531 psi and the standard deviation was 120 psi. The mean value of modulus of elasticity in compression was 4.16×10^6 psi, and standard deviation was 0.50×10^6 psi. Thermal coefficient measurements showed that variations between specimens were negligible, and the mean value was 6.09×10^{-6} inch/inch/°F.

The pavement experienced almost zero midspan cracking (less than one percent). In-place friction tests indicated the maximum frictional resistance was approximately one psi, a relatively low value in terms of subbases used at the present time. Since the slab was not restrained, i.e., low friction and expansion joints, low volume change stresses were experienced, hence basically zero cracking.

The pavement had experienced 31 million ESAL (18-kip) during its 37 year life and was still above the terminal level. Although the pavement was designed prior to ESAL concept, it was good for about 10 million ESAL with a 99 percent reliability. This demonstrates the traffic multiplying factor in the AASHTO Guide reliability. A multiplying factor of 3 was experienced and failure had not occurred when rehabilitated.

Some pavement roughness was experienced on the JRCP in the later stages of the life cycle. However, this roughness was attributed to load applications rather than expansive soil characteristics. The "membrane wrapped" subgrade fill seemed to reduce the soil expansion and provide a smoother pavement.

No major pavement distresses were observed. Joint sealant was missing at many joints, but of pumping was experienced during the pavement life.

CRCP

This portion of the paper presents the performance of the CRCP sections during the twenty-four years since their construction. The performance is analyzed in terms of transverse crack spacing, condition surveys, and deflection.

Transverse Cracks. The periodic observations and measurements of the transverse cracks indicate the first

transverse cracks truly *did* form along the planned preformed positions. Even though several cracks were late forming, generally, transverse cracks had formed at all the preformed locations within one year after construction. On the conventional aggregate sections, cracks continued to form between the preformed locations and began to stabilize at a spacing of 2 to 3 feet after 10 years or about three million 18-kip ESAL. The lightweight aggregate sections show the transverse crack spacing to stabilize at about an 8-foot preformed spacing.

Later observations of the conventional aggregate sections indicated the longitudinal steel had sheared in Sections 5 and 6 containing the 0.3 percent longitudinal steel. A faulted transverse crack was found within each section, with a wide crack occurring and the downstream (to traffic flow) slab lower in elevation than the upstream slab. These sections are directly in line with the off ramp to the main lanes and they receive high velocity traffic which is both cornering and decelerating.

Figure 4 shows a plot of the transverse crack spacing with time or age for the conventional aggregate sections. Note the crack spacings for Sections 5 and 6 are much larger than for the other sections. It is believed the longitudinal steel sheared at a relatively early age (approximately one year), and the stress relief resulted in longer average crack spacings, much like the unrestrained free end of CRCP.

Figure 5 is a similar plot of the lightweight aggregate sections. The crack spacing appears to become asymptotic at about 6 to 10 feet. Observations of the cracks in the lightweight aggregate sections reveal the cracks to be uniformly spaced, and straight, with little meandering longitudinally, and the crack widths to be relatively small, even though the crack spacing is relatively large.

Figure 6 shows the crack spacings for both the conventional and lightweight sections as the 18-kip ESAL increase. Note the lightweight sections have accumulated only about 2/3 the loads of the conventional sections, but show a much larger average crack spacing at equivalent cumulative loads as compared to the conventional sections.

A summary of the study of the transverse crack spacing is as follows:

1. The crack spacings have generally stabilized at equal values within a given aggregate type. Since all sections have equal bond area concrete volume, the importance of considering this factor in design is emphasized.
2. The difference in crack spacing for the aggregate type shows the influence of thermal coefficient and other concrete properties. A design procedure, therefore, must consider these factors also.
3. Because the longitudinal steel has sheared on Sections 5 and 6, 0.3 percent steel may not be sufficient for use with siliceous gravel.
4. The longer length preformed spacings tend to provide larger average crack spacings for longer time periods. The conventional aggregate sections show this trend for at least 10 years, or three million 18-kip ESAL and the lightweight sections still show the trend after 24 years and five million 18-kip ESAL. There may be an interaction between the preformed spacing and the amount of longitudinal steel.
5. CRCP composed of lightweight aggregate in the concrete provides larger average crack spacings compared to CRCP using siliceous gravel in the concrete.

Condition Surveys. Surveys which included spalling, punchouts, and pavement repairs were not reported prior to 1984 or prior to about seven million 18-kip ESAL on the conventional section. Periodic inspections revealed excessive

conditions did not exist prior to 1974, or about three million 18-kip ESAL. It can be assumed that failures began to occur between these two periods. Observations in 1988 show the conventional pavement condition is not extremely poor and the sections are carrying a large amount of traffic each day without problem. However, the SDHPT would probably want to provide rehabilitation to the conventional sections if money, time, and traffic permitted. The condition of the lightweight aggregate sections is different. These sections are in good shape, with no failures or repairs evident. Even considering the traffic differential, the lightweight aggregate sections reveal superior performance.

Spalls. Figure 7 is a bar chart showing the number of spalls found on each section. The spalls were approximately 3 inches deep and normally occurred along the transverse cracks. The following was developed from a study of this data:

1. No spalling was noted on the lightweight sections.
2. There is a general trend to have increased spalling with decreased steel percentages. There may be an interaction between percent steel and preformed crack spacing; however, it should be noted that the average crack spacing was much less than preformed spacing when spalling was first reported.

Punchouts. Figure 8 shows a bar chart with the number of severe punchouts occurring in each section. The following information was developed from a study of the data:

1. No severe punchouts were found in the lightweight sections.
2. The conventional aggregate sections having 0.3 percent steel and an 8-foot preformed crack spacing were found to have severe punchouts. Also, Section 3 having 0.4 percent steel and a 5-foot preformed crack spacing, was found to have severe punchouts.

Patches. Figure 9 is a bar chart showing the area of each section patched. The data are given in terms of the patched area (feet²) per station (100 feet) of 24-foot width. It should be noted that Section 2 is in an intersection with South Wayside Drive. As such, it receives traffic from both South Wayside and the frontage road. The traffic for South Wayside was not available; however, most of the patches in Section 2 are in the intersection area. The following was developed from a study of the data:

1. The lightweight sections have not required repairs.
2. Discounting Section 2 for the reasons given above, the area patched increases as the percent steel decreases. Of the conventional aggregate sections with the 0.3 percent steel, Section 5, with a 5-foot preformed spacing, has required less repair than Sections 6 and 7, with the 8-foot preformed spacing.

Deflection. Tables 4 through 6 show the average deflection values collected at each time period for measurements obtained near a transverse crack and midspan between transverse cracks. Figures 10 through 13 show plots of this information for 1974 and 1984.

A summary of the study of this data reveals the following:

The smaller preformed crack spacing sections of the conventional aggregate seem to produce lower deflection values as compared to the larger preformed spacings. However, for the lightweight sections the reverse is generally true with the larger preformed spacings having the lower deflection values. It could be postulated that the

closer spacings on the conventional aggregate sections provide better aggregate interlock at the cracks, therefore reduced deflection. For the lightweight sections, it may be postulated that due to the texture of the lightweight aggregate, excellent interlock is still provided with the wider crack. Hence, the variation may be due to other factors.

It also is apparent that aggregate interlock is lost with repetitive loads. Prior to 1974, the deflection data was logical, i.e., more deflection with wider cracks, but afterwards the deflection is random due to loss of interlock.

DISCUSSION

In this section, design implications deducted from the findings of this study are discussed for each pavement section.

JRCP

Concrete properties measured in this study were compared with the results of other projects (4 and 5). The values of all the variables except tensile strength were very similar to those obtained in other projects. Average tensile strength measured in this study was 531 psi, which was much higher than that found in other projects (4 and 5). In continuously reinforced concrete pavements using conventional aggregate, high concrete tensile strength is not necessarily desirable, because the crack spacings are generally large, which results in wide crack widths and excessive steel stress and possible steel failures. However, in jointed reinforced concrete pavements, high tensile strength of concrete reduces the possibility of cracking and increases pavement fatigue life.

The embankment soil was wrapped with an asphalt membrane. The moisture content for this material has been constant and the soil movement reduced. Therefore, the concrete stress due to differential volume changes of the embankment material resulting from moisture changes is believed to have been minimal. Relatively short joint spacing probably kept volume changes stress low.

In the AASHO Road Test, all failures in rigid pavements were preceded by pumping of material from beneath the concrete slabs. This indicates that prevention of pumping is essential for better performance of jointed concrete pavements. Pumping is a load-actuated erosion phenomenon by which material from the pavement foundation or shoulder is moved about by water. The prerequisites for the occurrence of pumping are load-induced pavement deflections, free water above or within a saturated subbase or subgrade, and loose or erodible particles (6). In the AASHO Road Test, severe pumping of the subbase material was experienced only in the sections with thinner slab thicknesses, and pumping increased as load increased and decreased as slab thickness increased. In this study, the elevation of subject pavements was relatively higher than the frontage road, and good drainage was accomplished. Since the subbase was also wrapped with asphaltic material, erodible particles were not available. At the same time, joint efficiency was very good considering the pavement was 38 years old, and pavement deflections at the joints are thought to have been reduced by effective load transfer at the transverse joints. The use of shoulders also is believed to have reduced the possibility of excessive edge deflections and edge pumping.

CRCP

The type of aggregate affects the performance of CRCP to a marked degree. The lightweight aggregate sections have performed remarkably well throughout the observation period, whereas, the conventional sections have experienced various degrees of cracking, spalling, punchouts, and repairs. This variation in performance suggests the aggregate or concrete materials properties merit additional study since they could affect the pavement design and construction costs.

The effect of a preformed crack spacing becomes confused in the later years of a pavement life cycle because the average crack spacing becomes smaller than the preformed crack spacing. However, preforming the crack offers several unique features which can potentially lengthen the pavement life. For example, the transverse cracks do occur relatively rapidly at the preformed locations; other transverse cracks form later, but tend to be midway between the preformed locations; "N" or "Y" cracking seems to be reduced; there is less longitudinal meandering of the transverse crack, which reduce early spalling or punchouts; and the stress in the steel as well as the concrete is probably distributed more uniformly.

As with the preformed crack spacing, there is a relationship between the steel percentage and the type of aggregate used in the concrete. Because the steel has sheared or parted on two of the three sections having conventional aggregate with 0.3 percent steel, it is believed that 0.3 percent steel is insufficient for CRCP which uses this aggregate type. However, the lightweight aggregate sections having 0.3 percent steel are still performing well. The majority of the crack spacing and condition survey data shows performance of the conventional aggregate sections increases as the steel percentage increases. The large difference in the performance of pavements containing the different coarse aggregates suggests that the thermal and shrinkage properties of the concrete should be considered along with the strength.

A comparison was made of actual mean crack spacing and predictions from computer program CRCP (Version 3). Figure 14 compares crack spacings measured in 1973 with predicted values in conventional sections. Generally, computer predictions agree with actual crack spacings except in sections 6 and 7. In Section 6, steel failure caused fewer cracks to develop by reducing concrete stress, and the reason for a discrepancy in section 7 is, for now, unexplainable. In lightweight aggregate sections, there is a large difference between predictions and actual values (Fig 15). Low thermal expansion and thermal conductivity of lightweight concrete reduces the tendency towards warping or thermal movements. Low modulus values and unit weight of lightweight concrete could also reduce warping stress. Higher values in long-term creep of the lightweight concrete could reduce concrete volume change stress. The above factors are believed to contribute to the large mean crack spacings in lightweight concrete sections and to explain the large discrepancy between actual mean crack spacing and predicted values. The computer program does not consider the effect of creep. More detailed study seems necessary to take advantage of desirable properties of lightweight concrete in rigid type pavements.

It should be noted that even though different steel percentages were used for various sections, the ratio of bond area to concrete volume was held relatively constant by changing bar sizes for various steel percentages. The bond area is probably more important in controlling the transverse cracking than the steel percentage. It has been found in this study that the crack spacing at the conventional aggregate sections was reduced from the preformed spacings to a length of about 3 feet. The ratio of bond area to concrete volume for each of the conventional aggregate sections was about 0.0318 inch²/inch³ whereas the steel percentage was varied from 0.3 to 0.5 percent. Similarly the average crack spacings for the

lightweight aggregate sections are all about 8 feet. The ratio of bond area to concrete volume was the same as the conventional sections and the steel percentage varied from 0.3 to 0.4 percent. The fact that the average crack spacings after 24 years of service are all about the same for CRCP with a given aggregate type could be the result of the use of a constant bond ratio. Again, additional study including bond area as a variable is suggested.

CONCLUSIONS

The following are conclusions from this study:

1. Embankment soil wrapped in an asphalt membrane deters the movement of expansive soil, possibly by maintaining a relatively constant moisture content in the soil. Concrete stressed by soil movement or excessive pavement roughness was not found in the observations of the subject paving.
2. Good drainage and prevention of pumping were essential in the good performance of JRCP, and can be inferred to be applicable to CRCP. Subbase composed of flexible material wrapped with asphalt seems to improve performance of JRCP.
3. Concrete composed of lightweight coarse aggregate is a viable paving material.
4. A preforming technique to initiate transverse cracks in CRCP was found to be a useable technique in prolonging pavement life. It is recommended that preforming the cracks be considered in CRCP design, with a preformed spacing established considering factors at the site, such as thermal coefficient, environmental conditions, etc. for conventional aggregate and 16 feet for lightweight aggregate. Those dimensions are approximately twice the crack spacing expected to be developed. It is expected that additional cracks would form between the preformed locations.
5. A strong relationship between concrete material properties, steel bond area/concrete volume and percent steel exists. This research emphasizes the need for designing the steel for a given site and material, rather than applying one design detail to all aggregate types.
6. CRCP-3 does a reasonable job of predicting the mean crack spacing for siliceous gravel aggregate. However, additional work is needed to improve the concrete material property input for a better prediction from the computer program.

RECOMMENDATIONS

The following recommendations result from this study.

1. This study considered CRCP sections with one depth, 6 inches. Information similar to that developed in this study is needed for pavements with different and larger depths.
2. This work has shown that additional study is needed on concrete materials properties as related to the CRCP performance. The thermal coefficient of expansion, drying shrinkage, and strength during the early life of a CRCP, as well as the thermal and strength properties that resist seasonal environmental changes and traffic loads, are very important. These studies should concern the coarse aggregate and proportioning of materials in the

mix. Benefits could be derived from revision or even reduction in steel quantities.

- Even though the percent steel statistic is needed in design, this study indicates continued work is needed to develop the correct bond area or surface area of the steel expressed as a function of the concrete volume.

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DISCLAIMER

The contents of this paper reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views of the Federal Highway Administration. This paper does not constitute a standard, specification, or regulation.

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TABLE 1. TWENTY-FOUR YEAR TRAFFIC INFORMATION FOR CRCP SECTIONS

Year	Conventional Aggregate		Lightweight Aggregate	
	ADT	Cumulative 18 KSAL	ADT	Cumulative 18 KSAL
1964	2,500	460,000	2,500	460,000
1974	6,119	3,268,000	1,530	3,096,000
1984	11,100	6,098,000	3,030	4,488,000
1988	13,500	6,811,000	3,600	4,923,000

TABLE 2. JRCP JOINT EFFICIENCY MEASURED WITH FWD

Lanes	Average Value	
	Transverse Joint	Longitudinal Joint
1	0.92	- -
2	0.76	- -
3	0.76	- -
2 & 3	- -	0.46

TABLE 3. MODULUS VALUES FOR JRCP BACK CALCULATED WITH DEFLECTION DATA AND LABORATORY VALUES

Lane	FWD	Dynaflect	Laboratory Values
1	5.61 ^a (1.16) ^b	3.70 (0.51)	4.31 (0.46)
2	5.37 (0.98)	3.34 (0.39)	4.25 (0.50)
3	5.51 (1.35)	3.51 (0.51)	3.74 (0.46)

Mean values ($\times 10^6$ psi)
Standard deviation ($\times 10^6$ psi)

TABLE 4. DEFLECTION (MILS) AT CRACK AND AT MIDSPAN FOR 18,000 POUND LOAD IN 1964 FOR CRCP

		Aggregate Type				
		Conventional Percent Steel			Lightweight Percent Steel	
Preformed Cracks		0.3	0.4	0.5	0.3	0.4
5	Midspan Crack Average	21 19 20	15 15 15	14 - 14		
8	Midspan Crack Average	18 21 19.5	14 16 15	12 14 13	6 7 6.5	9 9 9
20	Midspan Crack Average				8 8 8	8 7 7.5

TABLE 5. DYNAFLECT DEFLECTION (MILS) AT CRACK AND AT MIDSPAN IN 1974 FPR CRCP

		Aggregate Type				
		Conventional Percent Steel			Lightweight Percent Steel	
Preformed Cracks		0.3	0.4	0.5	0.3	0.4
5	Midspan	0.75	0.65			
	Crack	0.84	0.73			
	Average	0.80	0.69			
8	Midspan	0.81/0.89	0.90	0.74	0.84	0.63
	Crack	0.93/0.93	0.87	0.78	0.70	0.95
	Average	0.88/0.91	0.88	0.76	0.77	0.79
20	Midspan				0.73	0.77
	Crack				0.68	0.76
	Average				0.70	0.77

TABLE 6. DEFLECTION (MILS) AT CRACK AND AT MIDSPAN FOR 1984

		Aggregate Type				
		Conventional Percent Steel			Lightweight Percent Steel	
Preformed Cracks		0.3	0.4	0.5	0.3	0.4
5	Midspan	0.72	0.72			
	Crack	0.75	0.91			
	Average	0.78	0.81			
8	Midspan	0.82/0.81	1.08	Not Measured	0.92	1.16
	Crack	0.92/0.82	1.00		1.04	0.78
	Average	0.80/0.81	1.04		0.98	0.97
20	Midspan				0.66	0.63
	Crack				0.66	0.71
	Average				0.66	0.67

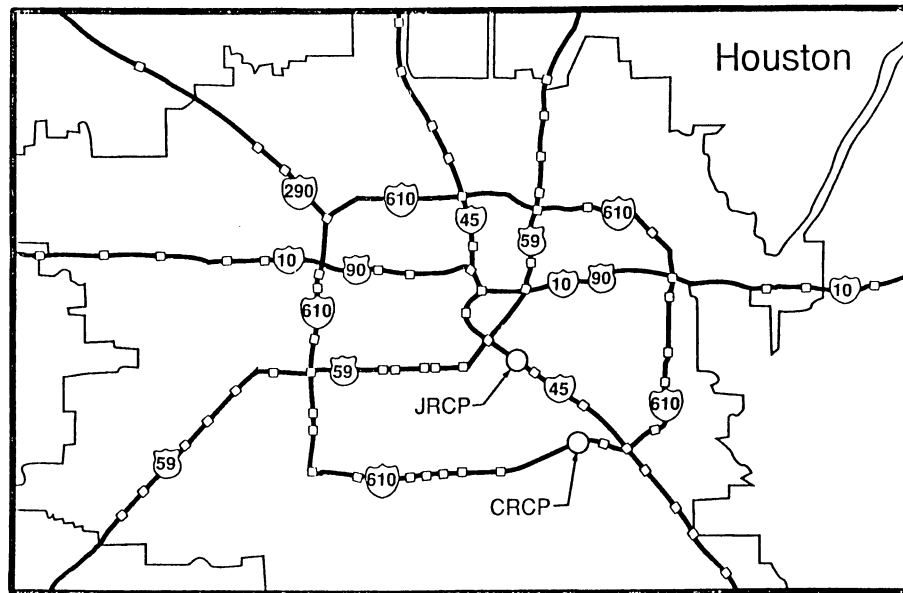


Fig 1. General site locations.

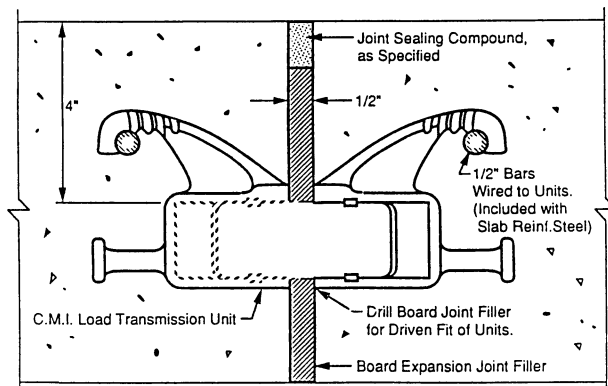


Fig 2. Plan view of load transfer unit.

North Frontage											
	* 196	100	191	200	100	201	244	75	187	202	
End Area	(7)	Transition	(4)	(3)	Transition	(1)	(2)	Transition	(5)	(6)	End Area
	0.3%		0.4%	0.4%		0.5%	0.5%		0.3%	0.3%	Conventional
	8ft		8ft	5ft		5ft	8ft		5ft	8ft	Concrete
	3/8" ϕ bars		1/2" ϕ bars			5/8" ϕ bars			3/8" ϕ bars		
	@ 6.25"		@ 8.25			@ 10.25"			@ 6.25"		

South Frontage					
	199	204	100	200	202
End Area	(8)	(9)	(11)	(10)	
	0.4%	0.4%	0.3%	0.3%	
	8ft	20ft	20ft	8ft	End Area
	1/2" ϕ bars	3/8" ϕ bars			Light Weight
	@ 8.25"	@ 6.25"			Concrete

○ = Test Area Number

Transition = Area where steel percentage change occurs

% = Percentage of longitudinal steel

ft = Crack Spacing

* Actual Length as constructed

Fig 3. Test area layout for CRCP.

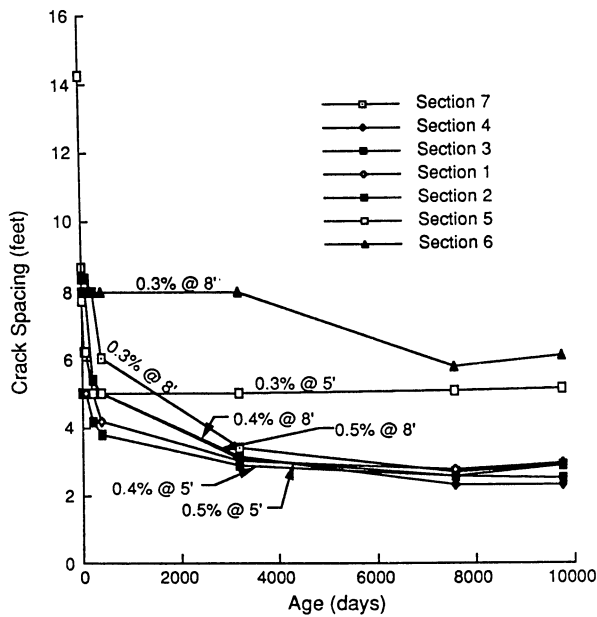


Fig. 4. Average crack spacing for the conventional aggregate sections by age.

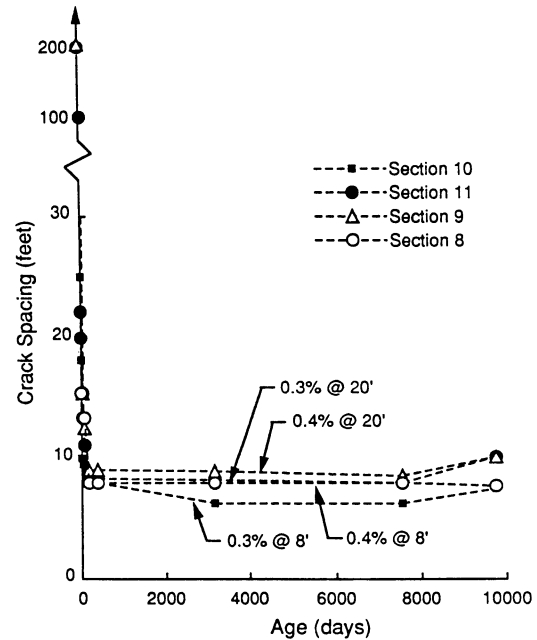


Fig. 5. Average crack spacing for the lightweight aggregate sections by age.

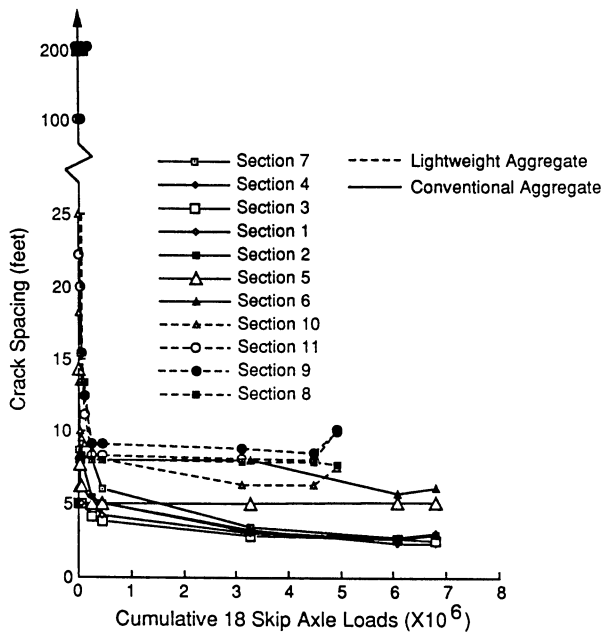


Fig. 6. Average crack spacing by traffic loads.

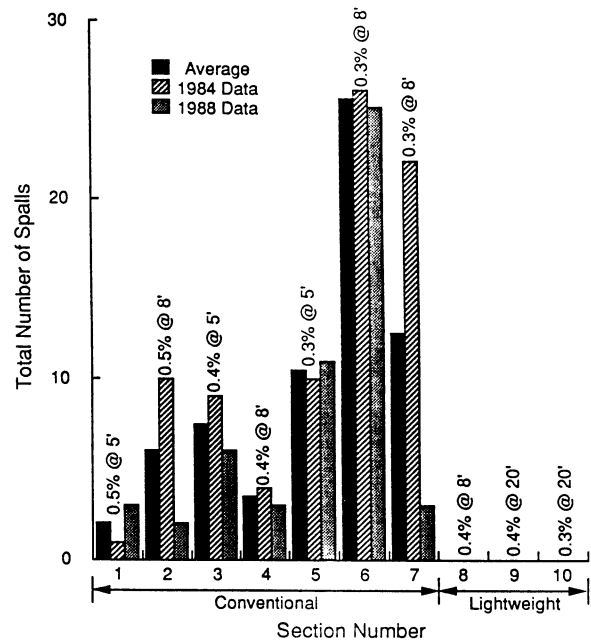


Fig. 7. Number of spalls for each test section.

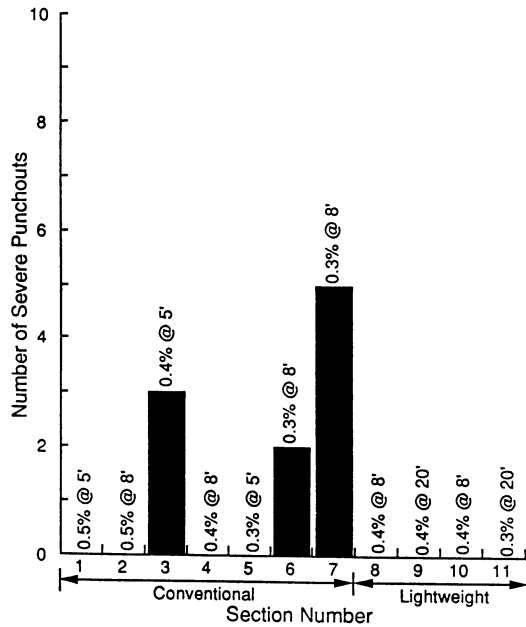


Fig 8. Number of severe punchouts for each test section.

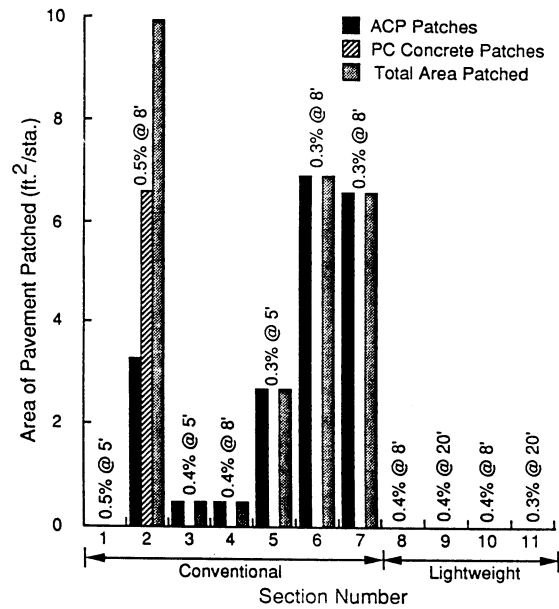


Fig 9. Area patched for each test section.

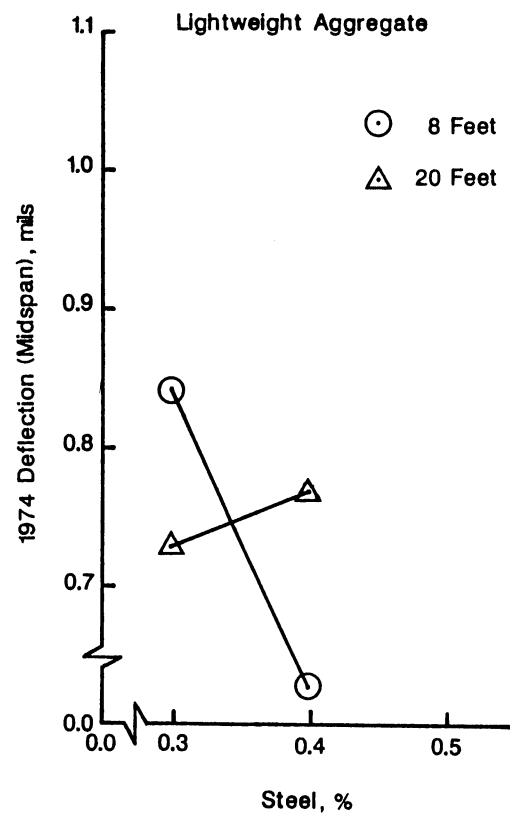
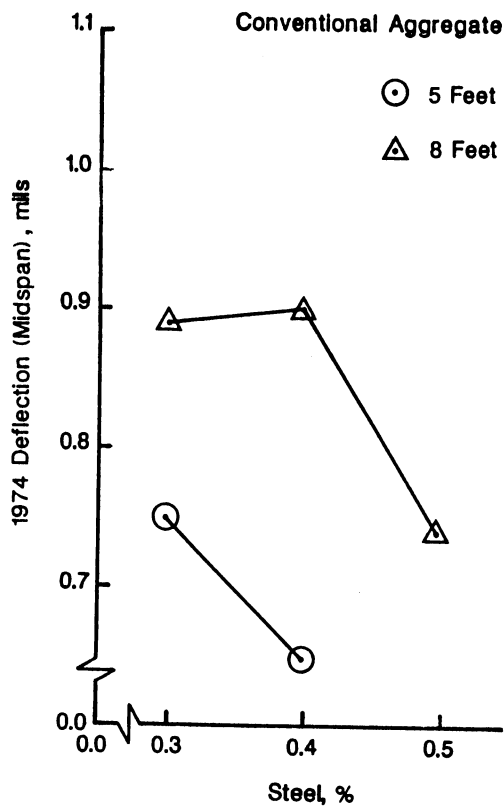


Fig 10. Deflection at a midspan (1974) versus percent steel reinforcement.

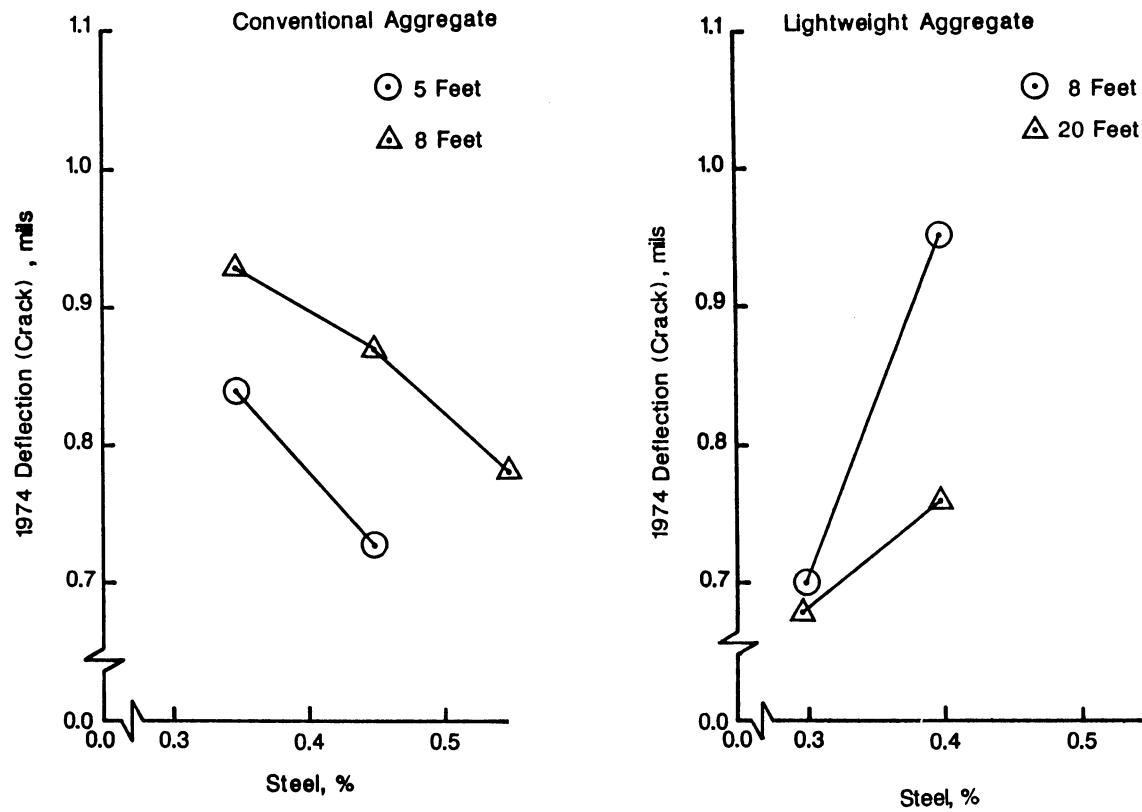


Fig 11. Deflection at a crack (1974) versus percent steel reinforcement.

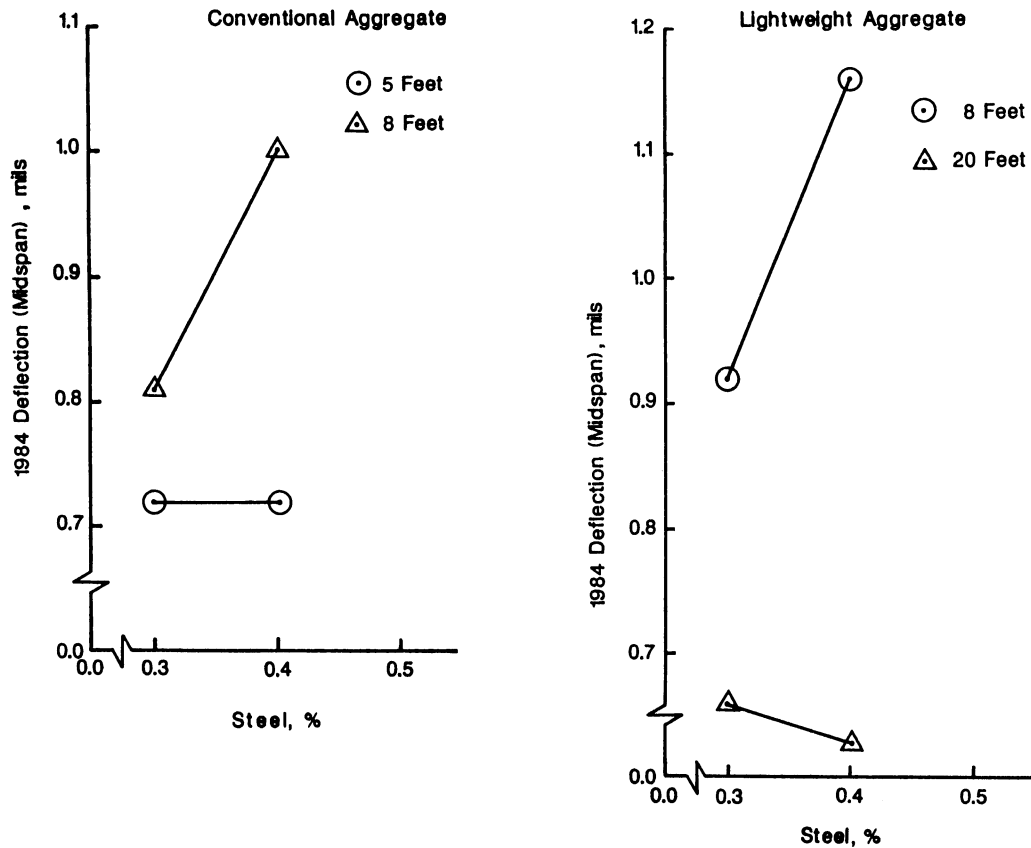


Fig 12. Deflection at a midspan (1984) versus percent steel reinforcement.

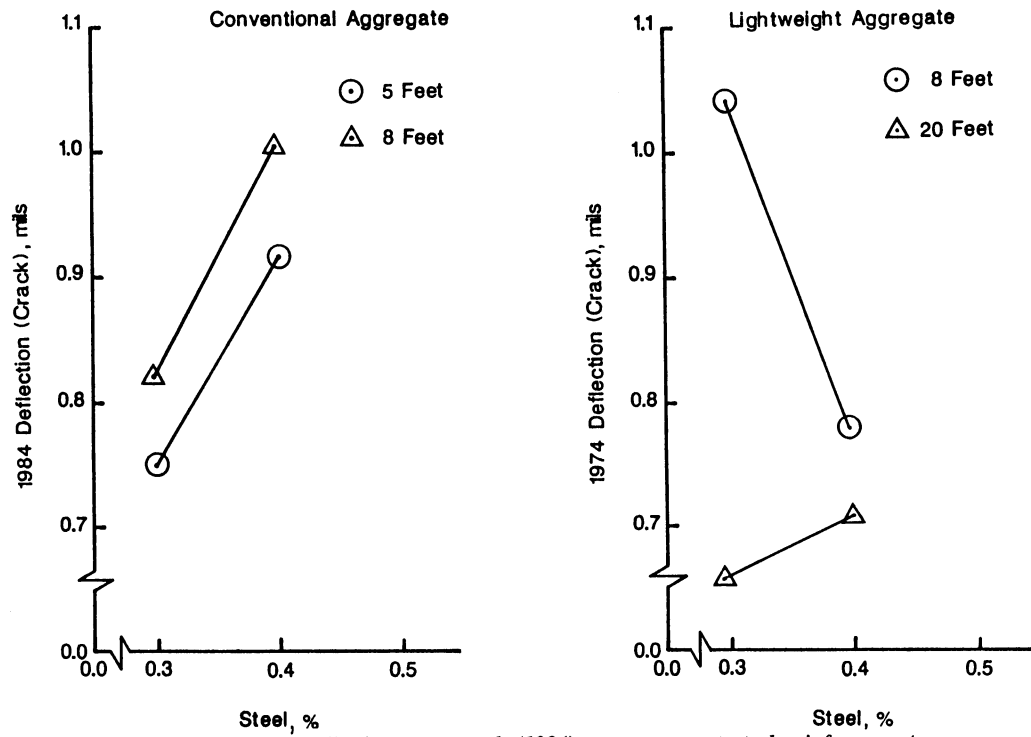


Fig 13. Deflection at a crack (1984) versus percent steel reinforcement.

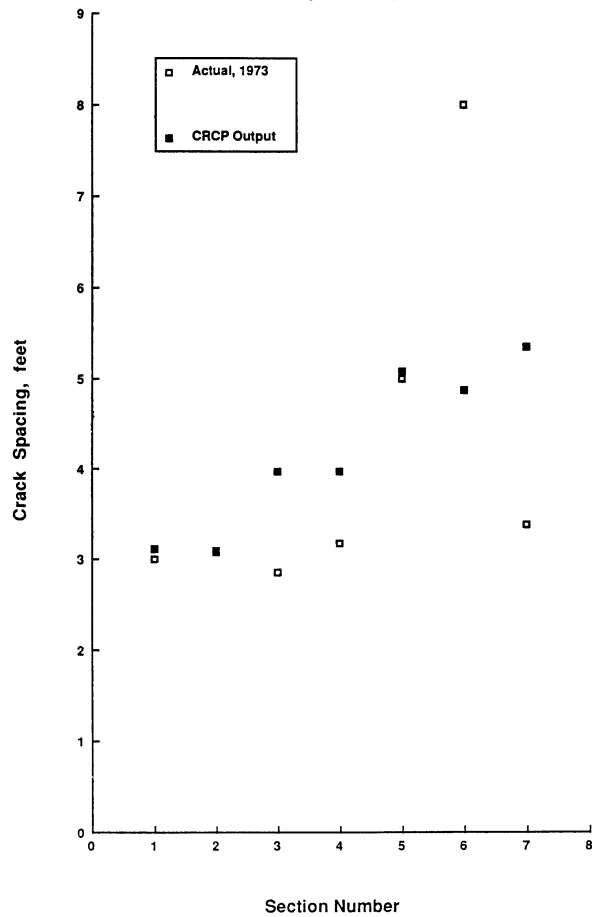


Fig 14. Comparison of actual crack spacing (1974) and predicted values for conventional aggregate sections.

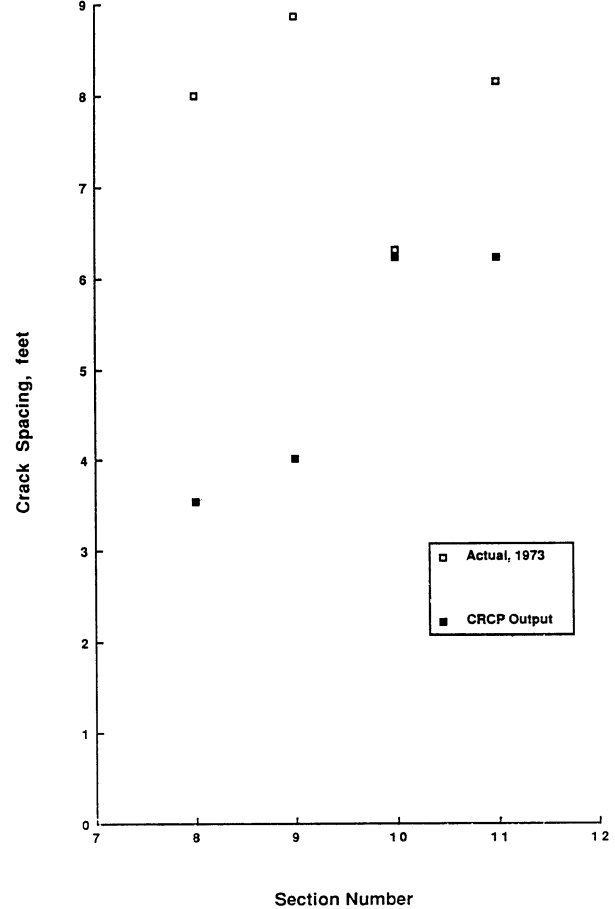


Fig 15. Comparison of actual crack spacing (1974) and predicted values for lightweight aggregate sections.