**CRACK FORMATION
IN
CONTINUOUSLY REINFORCED PAVEMENTS**

No. 7

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SYNOPSIS

A summary of the mechanics of crack formation in continuously reinforced pavement slabs, as understood from the literature on several field test pavements, is presented.

Results of a series of laboratory experiments on simulated continuously reinforced concrete slabs are given, with those results pertaining to the formation of cracks being emphasized. The findings of these laboratory experiments are correlated with the field observations reported in the literature and one criterion for the design of continuously reinforced pavements is suggested.

Some of the more important conclusions reached as a result of this research, subject to the limitations imposed by the range of variables studied, are:

1. The effects of concrete shrinkage, temperature changes, and wheel loads on the crack formation in continuously reinforced pavements can be adequately simulated in

the laboratory without producing actual temperature changes in an infinitely long pavement slab.

2. The formation of a complete crack pattern in a continuously reinforced pavement is the result of a superposition of the effects of concrete shrinkage, temperature changes, and live (wheel) loads. Perhaps the importance of live loads has been somewhat underestimated in past discussions of this problem.
3. Crack spacing in a continuously reinforced pavement with some age and use varies inversely with the percentage of longitudinal steel reinforcement, if the steel is placed at mid-depth, with a minimum average crack spacing of about 2 feet in a slab having 0.768 percent longitudinal steel.
4. It is generally agreed that a continuously reinforced pavement slab must be reinforced with longitudinal steel in sufficient amount to maintain all transverse cracks in a tightly closed condition. For mid-depth reinforcement this condition is met when increasing longitudinal forces caused by temperature drops, in combination with live loads, tend to cause additional cracks to form rather than to cause excessive opening of existing cracks. This standard is suggested as one

criterion (among others) for the design of continuously reinforced pavements.

5. The suggested design criterion is satisfied in these laboratory tests for an 8-inch pavement resting on a subgrade having a modulus of 160 pci, by 0.45 percent longitudinal reinforcement either in the form of deformed bars or welded wire fabric reinforcement placed at mid-depth in the slab.

INTRODUCTION

The mechanics of crack formation in continuously reinforced pavements is qualitatively understood as a result of long-term observation of the several test strips of such pavements now in existence (1, 2, 3, 4, 5). The formation of the cracks has, in fact, received more attention than any other phase of the experiments—correctly so, since the spacing and configuration of the cracks in continuously reinforced pavements form the common denominator of the other important design parameters such as crack widths, pavement deflections, and steel stresses. Cracks are generally considered to have been formed in these pavements by the combination of concrete shrinkage during curing and climatological temperature changes during and subsequent to the curing period.

Longitudinal reinforcement steel in a concrete slab offers restraint against shrinkage of the concrete. The tendency of concrete to shrink builds up longitudinal tension in the concrete and compression in the steel. If the tensile stress reaches the magnitude of the tensile strength of the concrete a crack forms, thus relieving the longitudinal stresses at and near the crack. This action presupposes the presence of adequate steel to resist the compressive force induced in the steel by the shrinking concrete. An infinitely long, adequately reinforced slab will crack at fairly regular intervals due to such concrete shrinkage.

Climatological temperature changes tend to cause volume changes of concrete and steel about alike; i.e., the coefficient of linear thermal expansion of the two materials is on the same order of magnitude, and an increase in temperature above casting temperature tends to make both materials expand about the same. However, a long continuously reinforced concrete slab is, in all regions at some distance from the slab ends, effectively restrained against longitudinal expansion, and the tendency of the materials to expand simply tends to close any transverse cracks and to build up longitudinal compressive stresses in the two materials. Since both materials are quite strong in compression, no damage normally comes from such expansion. On the other hand, a decrease in temperature tends to cause both materials to shorten. The effective restraint against this contraction tends to widen any existing transverse cracks, to build up tensile forces in the steel at cracks, to induce tensile forces in the concrete and steel between cracks, and to develop bond stresses between the steel and concrete near the cracks. The tensile stress in the concrete between cracks may reach the magnitude of the tensile strength of the concrete and thus form additional cracks.

The formation of additional cracks by temperature decrease completely relieves the concrete of tensile stress only at the cracks. The flexural action between cracks in slab segments caused by vertical loads (wheel loads) on the pavement superimposes longitudinal compressive and tensile stresses on the upper and lower

portions of the slab, respectively, directly under the load and vice versa, but of lesser magnitude, some distance away from the load. The superposition of these flexural stresses upon the temperature and shrinkage stresses may cause the tensile strength of the concrete to be surpassed and may thus form additional cracks.

From this discussion, it can be seen that the formation of the complete crack pattern in a given continuously reinforced pavement slab results from the superposition of concrete shrinkage, temperature changes, and wheel loadings. The first cracks develop as a result of shrinkage alone, more cracks are formed by the combination of shrinkage and temperature change, and the crack pattern finally becomes complete as the result of the combination of all three causes over a long period of time. In the literature, much emphasis has been given to the first two of these three primary causes of slab cracking; i.e., shrinkage and temperature changes.

PURPOSE AND SCOPE OF DISCUSSION

The objectives of this paper are:

1. To report the results of a series of laboratory experiments on simulated continuously reinforced concrete slabs, with emphasis on those results pertaining to the formation of cracks in the slabs.
2. To correlate the results of these laboratory experiments with reported field data on the cracking of continuously reinforced pavements.
3. To arrive at tentative criteria for the design of continuously reinforced pavements as suggested by this study of crack pattern formation.

In making use of the information included in this report, the limitations delineated by the range of the variables introduced in the laboratory experiments should be kept in mind. This range of variables, which is outlined in the following section, is being expanded through the continuation of this research program; future results may substantially add to or otherwise alter the findings reported here.

Important criteria for the design of continuously reinforced concrete pavements will result from the studies of stresses in the reinforcement and the deflections of the slabs. Results of such studies are reported elsewhere for laboratory experimental slabs continuously reinforced with deformed bars (7) and welded wire fabric (8).

LABORATORY EXPERIMENTS AND RESULTS

The specimens for these experiments were reinforced concrete slabs eight inches thick, three feet wide, and 28 feet long.¹ The controlled variables included in the experiments were type of reinforcement, percentage of longitudinal reinforcement, position of reinforcement, range of simulated temperature drop after casting of the concrete, and magnitude and position of simulated wheel loading. The partially controlled variables included primarily the strength and stiffness of the concrete. The slabs tested and the magnitude assigned to each variable for the various slabs are summarized in Table 1. The subgrade modulus was maintained constant at 160 pci for the experiments reported here, through the use of a rubber subgrade.

After each slab was cured, it was lowered onto the rubber subgrade and cracked through at each of the three weakened planes by slight non-uniform lifting of the slab. Thus the central test region of each slab had preformed cracks at 5-foot intervals. This was done to be certain that cracks would occur at the location of SR-4 strain gages on the reinforcement steel, although it was anticipated from the results of reported field tests that additional cracks would develop during the laboratory experiments.

Vertical loads were applied to each slab successively at eight load points on slabs 1 through 6 and 9 through 11 and at seven

¹ Details of slab fittings pertinent to the application of loads are described in other reports (9 and 10).

load points on slabs 7 and 8. The locations of these vertical load points are shown on Figures 1 through 11. The vertical loads were applied in magnitudes of 5,000, 10,000 and 15,000 pounds through bearing plates and rubber pads 12, 18, and 18 inches in diameter respectively.

In general, horizontal (longitudinal) loads were applied to each slab in increasing increments of 10,000 pounds, although increments of 5,000 pounds were used for slab 7 which had only 0.154 percent reinforcement. Horizontal loads were increased in each case until it became apparent that the longitudinal reinforcement steel had been stressed beyond its yield strength.

The usual sequence of applying combined vertical and longitudinal loads was as follows:

- a. No longitudinal load--vertical loads (5, 10, and 15 kips) at load points 1 through 8 successively.
- b. 10,000 pounds longitudinal load--vertical load sequence repeated
- c. 20,000 pounds longitudinal load--vertical load sequence repeated
- d. etc. to yielding of reinforcement.

During the entire loading sequence, measurements of concrete strain and crack widths were made at the upper surface of each slab. Steel plugs had been embedded in the surface of each slab in the test area at ten-inch intervals, longitudinally. Gage holes were

drilled in these plugs and a ten-inch Whittemore strain gage was used to make surface strain and crack width measurements. For an uncracked gage length the average unit strain was taken as the change in the gage length divided by ten. When a transverse crack occurred between two plugs, it was assumed that the total change in that gage length was due to a change in the crack width. This continuous set of gage lengths thus made it possible to determine the over-all change in length of the 130-inch test region due to the various combinations of horizontal and vertical loads. Throughout the testing of each slab specimen, the formation of new cracks (in addition to the preformed cracks) was observed and recorded.

The longitudinal tensile loads simulated the effects of temperature drops. Correlation of the magnitude of longitudinal load to temperature drop was made by calculations. The over-all increase in length of the central test region of a slab due to longitudinal load was equated to the decrease in length of the same span of reinforced concrete due to a temperature drop, Δt . Thus the condition of effective full restraint against longitudinal movement in a continuously reinforced slab away from the end regions was assumed.

In equation form

$$e = \alpha L \Delta t$$

or

$$\Delta t = \frac{e}{\alpha L}$$

where

e = elongation (inches) of central test region

L = length (inches) of central test region

α = coefficient of linear contraction — assumed to be
0.000006 in./in./degree F. for both steel and concrete.

Δt = temperature drop (degrees F.)

Concrete curing shrinkage does not affect appreciably the foregoing computation. Shrinkage of the concrete in a continuously reinforced pavement slab tends to cause the length of concrete between adjacent cracks to shorten and the cracks to widen. In the measurement of the over-all length of a central region of slab the shortening of concrete and the widening of cracks compensate for each other. Shrinkage is accompanied by stress changes in the concrete and steel; however, these stress changes are non-uniform throughout the length, with tendencies toward tensile stresses in the steel at cracks, compressive stresses in the steel between cracks, tensile stresses in the concrete between cracks, and compatible bond stresses between the concrete and the steel. These alternating type stresses have no appreciable influence on the over-all change in length of a central test region and thus can be neglected in the temperature correlation calculations.

During the experiments, as the loading sequence was followed, each slab specimen was scrutinized carefully for the development of new cracks. New cracks would usually begin in the vicinity of

the vertical load position and advance under increasing loads from the bottom to the top of the slab. The progress of crack formation was observed and marked with chalk on the side of the slab.

Figures 1 through 11 summarize the cracking history of slabs 1 through 11 respectively. In each of these figures, the upper plan view shows the vertical (wheel) loading positions; the lower plan view shows the number of the cracks in the order of their occurrence, the horizontal load and the position of the vertical load causing each crack, and the temperature drop (degrees F.) simulated by the horizontal load.

Figs. 1 through 4 show clearly the effect of percentage of deformed bar reinforcement (placed at mid-depth) on the crack pattern. In the lightly reinforced slab (0.278 percent steel), one additional crack formed—at a 47 degree temperature drop with the vertical load at load point 6. Simulated temperature drops of 86 degrees combined with vertical loads caused no more cracking. No cracks in addition to the three preformed ones formed in slab 2 which had 0.430 percent steel. Longitudinal loads simulating 103 degrees of temperature drop, along with the vertical loads, only altered the widths of the preformed cracks in this slab. Slab 3 with 0.533 percent steel showed additional cracks at 39 degrees drop and vertical load at point 6, 70 degrees drop and no vertical load, 70 degrees drop and vertical load at point 3, 70 degrees drop and vertical load at point 7 (2 cracks), and

96 degrees drop and no vertical load. Thus slab 3 showed a total of nine cracks in a length of about 21 feet (average crack spacing 2.3 feet) after a simulated temperature drop of about 100 degrees. In slab 4, which had 0.768 percent steel at mid-depth, two additional cracks developed during loading of point 6 with no simulated temperature drop, one developed at 54 degrees temperature drop with vertical load at point 3, one at 54 degrees drop with vertical load at point 6, one at 87 degrees drop without vertical load and five at 115 degrees drop with no vertical load. Slab 4 contained a total of 13 cracks in a length of about 24 feet (average crack spacing about 2 feet) after a simulated temperature drop of 115 degrees.

Thus it is seen that within the range of variables studied, an increase in percentage of deformed bar steel reinforcement at mid-depth tends to result in a more closely spaced crack pattern in the slab, with individual crack widths of less magnitude. The two slabs having the lower percentages of steel (0.278 and 0.430) remained essentially with the preformed crack pattern. This indicates that one could expect crack spacings on the order of magnitude of five feet or more in slabs having these amounts of reinforcement if the experiments were conducted without preforming cracks in the slabs. The slabs with the higher percentages of steel showed a definite decrease in crack spacing (to about 2 to 2-1/2 feet) with very little difference between the slab

reinforced with 0.533 percent steel and that having 0.768 percent steel. It is doubtful that the crack spacing would average significantly less than two feet for any practicable amount of reinforcement.

The nature of the formation of individual cracks in the slabs reinforced at mid-depth is of interest. When one of the more significant horizontal loads (temperature drops) was applied to either slab 3 or 4, a crack would usually begin at the bottom of the slab under a 5,000-pound vertical load and would break completely through under the 10,000-pound or 15,000-pound vertical load. During the late stages of testing each of these slabs, several cracks appeared to be caused directly by the large horizontal loads being applied. The influence of vertical loads can be seen, however, since most of the cracks formed in the region of influence of vertical loads until the simulated temperature drop was extremely large.

Comparison of the cracking of slabs 3, 5, and 6 having 0.533 percent deformed bar reinforcement at mid-depth, two inches below mid-depth, and one inch below mid-depth, respectively, shows the influence of position of steel on the crack pattern. Slab 5 differed markedly from slab 3 in that the simulated temperature drops and the vertical loads both caused many cracks to start in the lower portion of slab 5, but caused only few to break completely through. In fact, up to 132 degrees equivalent temperature drop,

no complete cracks in addition to the three preformed cracks at 5-foot spacing had formed. At 132 degrees equivalent temperature drop, one complete crack developed at each end of the slab, each at four feet from the nearest preformed crack. These cracks each formed completely as a result of the negative bending moment produced during the application of vertical load at the adjacent preformed crack, superimposed upon the simulated temperature change. Slab 6 with its 0.533 percent reinforcement at one inch below mid-depth contained six complete cracks after a temperature drop of 125 degrees. These six cracks were spaced nearly uniformly at 2-1/2 feet. This slab also contained some of the partial cracks that characterized slab 5, but not as many as appeared in slab 5.

The eccentricity of the longitudinal forces which simulated the temperature drops in slabs 5 and 6 produced positive bending moments in slab segments between complete cracks which tended to cause compression in the top surface of the slab and tension in the bottom surface. This effect, when superimposed upon the influence of the direct tensile force of temperature drop and the effects of vertical loading, accounts for the partial cracks produced by the eccentrically placed steel reinforcement. The partial cracking was most pronounced in slab 5 which had its steel placed with greatest eccentricity.

The influence of percentage of welded wire fabric reinforcement placed at mid-depth is shown on Figures 7, 8, and 9 for slabs

designated by the same numbers. In studying these figures, one must keep in mind that the reinforcement in each 28-foot specimen consisted of three separate lengths of fabric, lap spliced as shown on each figure. Slab 7 with 0.154 percent longitudinal steel in its fabric reinforcement developed no cracks in addition to the three preformed cracks, even though it was subjected to horizontal (longitudinal) tensile forces equivalent to temperature drops greater than any practical value. Slab 8 which had 0.300 percent longitudinal steel sustained one additional crack at a temperature drop of about 60 degrees, approximately under a vertical load at position 5. No other cracks developed until the slab was in a condition of general yielding to longitudinal tension force. Slab 9 with 0.450 percent longitudinal steel in its welded wire fabric received an additional crack under a vertical load at point 2 accompanying a temperature drop of 16 degrees and another at the same temperature drop under a vertical load at point 6. In addition, this slab cracked five feet from one of the outermost preformed cracks and four feet from the preformed crack nearest the other end. These two cracks occurred, however, at a horizontal load equivalent to more than 150 degrees temperature drop—beyond any practical range of temperature change. Cracks would probably have occurred somewhere in the same vicinity at less temperature drop if the slab had been subjected to vertical loads throughout its length. Thus slab 9 indicated that a crack spacing of about 2-1/2 feet could be

expected in a slab eight inches thick, reinforced at mid-depth with fabric providing 0.45 percent longitudinal steel, and resting on a fairly flexible subgrade ($k = 160$ pci).

Slab 10 was also reinforced with 4 x 12 00000/0 fabric but had its reinforcement placed 1-1/2 inches below mid-depth. The crack pattern which developed in this slab did not differ greatly from the pattern of slab 9; however, slightly greater temperature drops were required, in combination with the vertical loads, to cause the first cracks to appear. Crack No. 7 appeared at the end of the 2-foot lap over preformed crack 2 during a horizontal force of 40 kips which was equivalent to a temperature drop of 94 degrees. Stress concentration in the concrete caused by the lap ending was probably the cause of this crack at only one foot away from the preformed crack.

Slab 11 with its 0.450 percent reinforcement placed 1-1/2 inches above mid-depth developed a crack pattern having little significant difference from that of slab 10 in the central test portion, however, it showed more top surface cracks near its ends at practical temperature drops than did slab 10. The greater number of top surface cracks was obviously due to the eccentricity of the reinforcement. It could not be ascertained if these cracks extended clear through to the bottom of the slab.

CORRELATION OF RESULTS OF LABORATORY EXPERIMENTS WITH REPORTED FIELD TESTS

The crack patterns developed in the seven laboratory slabs with the reinforcement at mid-depth agree in general with the patterns reported for the field experiments in Indiana, Illinois, New Jersey, California, and Texas which contained somewhat comparable reinforcement (11). The minimum crack spacing reported for each of those field test pavements was in the same order of magnitude as the crack spacing finally obtained in these laboratory experiments; i.e., 2-2.5 feet for slabs having 0.45 percent or more longitudinal reinforcement and up to 5 feet or more for less reinforcement. While these laboratory experiments did not include the effects of the great numbers of repeated loads obtained in the field tests, the maximum combined effects of shrinkage, maximum wheel loads, and equivalent temperature drops were obtained in a relatively short time in the laboratory with slabs resting on a relatively flexible subgrade.

The laboratory slabs in which the reinforcement was placed below mid-depth have no counterparts among the continuously reinforced test pavements in existence. It is anticipated that the results reported here for these eccentrically reinforced test specimens will be comparatively verified in the laboratory where additional slabs having eccentric reinforcement are to be tested on a stiffer subgrade. Results of these laboratory experiments may suggest the need for additional field tests.

It is to be noted that the data presented show, in general, the effects of equivalent temperature drops as great as 100 degrees with some crack formation described for temperature drops of 125 degrees. The horizontal forces applied to the slabs in the laboratory were in most cases carried to magnitudes corresponding to considerably greater temperature drops. Those data which extended far beyond limits of practicality have been omitted in this presentation.

Depending upon the construction locale and the temperature at the time of pouring the concrete, data presented for temperature drops greater than 90 to 100 degrees may be unreliable in predicting the behavior of continuously reinforced pavement. A temperature decrease to below freezing would freeze and stiffen the concrete and would thus temporarily provide a greater subgrade modulus.

DESIGN CRITERION

It is the common theme of all engineers involved with design or research on continuously reinforced pavements that the slab must be reinforced with continuous longitudinal steel in sufficient amount to maintain all transverse cracks in a tightly closed condition without adverse effect on the concrete. The laboratory experimental results obtained for slabs having reinforcement at mid-depth indicate that this condition is met when increasing longitudinal forces (temperature decrease), in combination with live (wheel) loads tend to cause additional cracks to form rather than to cause excessive opening of existing cracks. If this criterion were to be applied to

choose slabs adequately reinforced at mid-depth from among those tested in the laboratory, 0.430 percent deformed bar reinforcement would be inadequate while 0.533 percent deformed bar reinforcement would be judged adequate. Likewise, 0.30 percent welded wire fabric longitudinal reinforcement would be inadequate while 0.45 percent welded wire longitudinal reinforcement would be judged adequate. Within the limitations of the properties of the materials used in these experiments one could conclude from the research data that 0.450 percent longitudinal reinforcement, either in the form of deformed bars or welded wire fabric, would satisfy this one criterion for an 8-inch continuously reinforced concrete pavement slab resting on a subgrade having a modulus of 160 pci.

While the design criterion discussed above appears to be fundamental, one should expect that other criteria will come out of the study of stresses and deflections in continuously reinforced concrete pavements. Such other criteria may be more severe than this one, thus making this one automatically satisfied. Too little data now exist to determine what alterations to this design criterion should be made in order to judge the adequacy of eccentrically placed reinforcement. This question will receive attention in the laboratory experiments which are continuing.

CONCLUSIONS DRAWN FROM LABORATORY RESEARCH

As a result of this study of the formation of cracks in continuously reinforced pavements, and within the limitations imposed by the range of variables studied, the following conclusions are drawn:

1. The effects of concrete shrinkage, temperature changes, and wheel loads on the crack formation in continuously reinforced pavements can be adequately simulated in the laboratory without producing actual temperature changes in an infinitely long pavement slab.
2. The formation of a complete crack pattern in a continuously reinforced pavement is the result of a superposition of the effects of concrete shrinkage, temperature changes, and live (wheel) loads. Perhaps the importance of live loads has been somewhat underestimated in past discussions of this problem.
3. Crack spacing in a continuously reinforced pavement with some age and use varies inversely with the percentage of longitudinal steel reinforcement if the steel is placed at mid-depth. A minimum average crack spacing of about 2 feet may be expected in a slab having 0.768 percent longitudinal steel in the form of deformed bars.
4. The position of 0.533 percent deformed bar reinforcement in an 8-inch slab has a marked difference on the crack

pattern. With the steel 2 inches below mid-depth, temperature decreases and vertical loads cause many cracks to start in the lower part of the slab but only a few to break completely through. Five feet seems to be about the minimum spacing between complete cracks in a slab thus reinforced. With the same amount of steel 1 inch below mid-depth, the spacing of complete cracks decreases to about 2-1/2 to 3 feet, and less partial cracks appear.

5. Welded wire fabric reinforcement of 0.450 percent longitudinal steel placed 1-1/2 inches below mid-depth in the slab produces a crack pattern only slightly different from that produced by the same steel placed at mid-depth. However, slightly greater temperature drops are required to cause the first cracks to appear at the surface of the slab having the lowered reinforcement.
6. It is generally agreed that a continuously reinforced pavement slab must be reinforced with longitudinal steel in sufficient amount to maintain all transverse cracks in a tightly closed condition without adverse effect on the concrete. For mid-depth reinforcement this condition is met when increasing longitudinal forces caused by temperature drops, in combination with live loads, tend to cause additional cracks to form rather than to cause excessive opening of existing cracks. This standard is suggested

as one criterion (among others) for the design of continuously reinforced pavements.

7. The single design criterion stated in conclusion number 6 is satisfied in these laboratory tests for an 8-inch pavement slab resting on a subgrade having a modulus of 160 pci, by 0.45 percent longitudinal reinforcement either in the form of deformed bars or welded wire fabric reinforcement placed at mid-depth in the slab.

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TABLE 1

DESCRIPTION OF SLAB SPECIMENS

Slab No.	Reinforcement ²	Percent Reinforcement	Position of Reinforcement below top	Reinforcement ³ Yield Point Stress, psi	Reinforcement Ultimate Strength, psi	Concrete Compressive Strength, psi
1	D.B. #4 at 9" O.C.	0.278	4 inches	57,300	94,600	4800
2	D.B. #5 at 9" O.C.	0.430	4 inches	56,300	97,500	5200
3	D.B. #5 at 7" O.C.	0.533	4 inches	56,300	97,500	4270
4	D.B. #6 at 7" O.C.	0.768	4 inches	55,800	97,600	4730
5	D.B. #5 at 7" O.C.	0.533	6 inches	69,500	104,400	5690
6	D.B. #5 at 7" O.C.	0.533	5 inches	69,500	104,400	3500
7	WWF 6 x 12 0/3	0.154	4 inches	—	93,400	5360
8	WWF 6 x 12 00000/0	0.303	4 inches	—	80,400	4721
9	WWF 4 x 12 00000/0	0.450	4 inches	—	80,400	4620
10	WWF 4 x 12 00000/0	0.450	5-1/2 inches	—	80,400	4230
11	WWF 4 x 12 00000/0	0.450	2-1/2 inches	—	80,400	4450

² D.B. is abbreviation for deformed bars; WWF stands for welded wire fabric.

³ Section 4(a) of ASTM Specification A82-34 for Cold Drawn Steel Wire for Concrete Reinforcement specifies yield stress to be 0.8 ultimate tensile strength. Section 4(d) states that "the yield point shall be determined by the drop of the beam or halt in the gage of the testing machine. In case no definite drop of the beam or halt in the gage is observed until final rupture occurs, the test shall be construed as meeting the requirement for yield point in Paragraph (a)." Thus, while the wire reinforcement had no definite yield point, it satisfied the specification. Specification A82-34 has been in effect during the entire time of this project.

SLAB DETAILS

CONCRETE - 8" THICK

REINFORCEMENT

MID-DEPTH

NO. 4 DEF. BARS

0.278 % STEEL

SUBGRADE MODULUS

155 PSI PER INCH

① ② ③ ④ ⑤ ⑥ ⑦ ⑧

POSITIONS OF VERTICAL LOADS

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 ← FEET FROM END

CRACK NUMBER IN
ORDER OF OCCURRENCE

1
0^K
0

2
0^K
0

4
30^K-6
47

3
0^K
0

HORIZONTAL LOAD AND
POSITION OF VERTICAL
LOAD CAUSING CRACK

CRACK FORMATION - SLAB I

TEMPERATURE DROP
(DEGREES FAHRENHEIT)
SIMULATED BY
HORIZONTAL LOAD

FIG. I

FIG. 3

SLAB DETAILS

CONCRETE - 8" THICK

REINFORCEMENT
2" BELOW MID-DEPTH
NO. 5 DEF. BARS
0.533 % STEEL

SUBGRADE MODULUS
160 PSI PER INCH

5'-0" 5'-0"
POSITIONS OF VERTICAL LOADS

CL OF 4' LAP
OF WIRE FABRIC

CL OF 2' LAP
OF WIRE FABRIC

SLAB DETAILS

CONCRETE - 8" THICK

REINFORCEMENT
1 1/2" BELOW MID-DEPTH
WELDED WIRE FABRIC
(4 x 12, 00000/0)
0.450% STEEL

SUBGRADE MODULUS
160 PSI PER INCH

POSITIONS OF VERTICAL LOADS

FEET FROM END

CRACK NUMBER IN
ORDER OF OCCURRENCE

HORIZONTAL LOAD AND
POSITION OF VERTICAL
LOAD CAUSING CRACK

TEMPERATURE DROP
(DEGREES FAHRENHEIT)
SIMULATED BY
HORIZONTAL LOAD

14	13	12	8	3	17	4	11	1	5	16	2	18	7	10	9	6	15
60-3	60-3	40-1	0	0	20-3	0	0	30-5	60-6	60-6	50	0	40	50	40	60-3	
116	60-3		94	0	60-6	60-2	26	0	45	116	0	116	94	101	94	116	

CRACK FORMATION - SLAB 10

FIG. 10

CL OF 4' LAP
OF WIRE FABRIC

CL OF 2' LAP
OF WIRE FABRIC

SLAB DETAILS

CONCRETE - 8" THICK

REINFORCEMENT

1 1/2" ABOVE MID-DEPTH

WELDED WIRE FABRIC

(4 x 12, 00000/0)

0.450% STEEL

SUBGRADE MODULUS

160 PSI PER INCH

POSITIONS OF VERTICAL LOADS

FEET FROM END

CRACK NUMBER IN
ORDER OF OCCURRENCE

HORIZONTAL LOAD AND
POSITION OF VERTICAL
LOAD CAUSING CRACK

TEMPERATURE DROP
(DEGREES FAHRENHEIT)
SIMULATED BY
HORIZONTAL LOAD

CRACK FORMATION - SLAB II

FIG. II