PERFORMANCE STUDIES OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

Progress Report No. 1

"Pavements Without Transverse Steel"

by

K. H. McGhee
Highway Research Engineer

Virginia Highway Research Council
(A Cooperative Organization Sponsored Jointly by the Virginia Department of Highways and the University of Virginia)

Charlottesville, Virginia

October 1972
VHRC 72-R8

SUMMARY

The status of studies of the three continuously reinforced pavement projects near Charlottesville is reported. Of particular interest in these studies are the effects of the elimination of transverse reinforcing steel, the changing characteristics of shrinkage cracking with age, and the end movements of anchor sections.

While the studies are somewhat inconclusive at this early age of the pavements, the following tentative conclusions are offered:

1. Cracks show a definite trend to become both more closely spaced and wider during the first 2 to 3 years of a continuously reinforced pavement's life. There is some inconclusive evidence that the widening process stabilizes after this time period.

2. While crack spacing can be influenced by weather conditions during pavement placement, there is no apparent relationship between crack width and either crack spacing or placement weather.

3. As expected, cracks are significantly wider at the surface during winter (pavement shrinking) than during summer (pavement expanding). (Note — Earlier studies have shown that cracks which are easily seen and measured at the surface are invisible in the immediate vicinity of the reinforcing steel.)

4. End anchor movement is very modest during the first year and seems to decrease slightly with age. There is a pronounced seasonal effect which produces joint movements in excess of the capabilities of poured joint sealants.

5. The elimination of full width transverse steel has had no effect on pavement performance for the first 2 to 3 years.

Acting upon a recommendation from these studies, the Department's pavement design engineer has instituted a requirement for the use of preformed compression seals in all expansion joints adjacent to the anchor slabs of continuously reinforced pavements.

PERFORMANCE STUDIES OF CONTINUOUSLY REINFORCED CONCRETE PAVEMENT

Progress Report No. 1

"Pavements Without Transverse Steel"

by

K. H. McGhee
Highway Research Engineer

INTRODUCTION

To supplement earlier studies of the behavior of continuously reinforced concrete pavements built in Virginia,[1,2] the three new (1970) projects on I-64 near Charlottesville are being studied in some detail. Much of the impetus for these studies arose from the fact that these projects are the first to be constructed in Virginia without full width transverse reinforcing steel. Several questions that have arisen since the earlier studies were made have brought the focus of the present studies to bear on the following questions:

1. Do the cracks tend to grow wider and more frequent with pavement age?
2. What are the end movements of anchored sections?
3. What are the effects of the elimination of full width transverse reinforcement?
4. What are the long-range effects of deicing chemicals on the reinforcing steel?
5. Has a cement stabilized subbase led to a substantially better pavement structure?

Studies are under way to answer the first three of the above questions, while the last two will be taken under consideration in the near future. It is the purpose of the present report to summarize the findings to date on the first three.

DESIGN FEATURES

All three of the Charlottesville projects have similar mainline features as outlined below:

Pavement Cross Section:

Subgrade: 6 inches cement stabilized in place soil (select material in undercut areas).

Subbase: 4 inches subbase material, size No. 21A cement stabilized, 4% by weight.

Surface: 8 inches continuously reinforced portland cement concrete.

Reinforcement:

Longitudinal: No. 5 deformed bars at 6 inches C-C (approximately 0.6% reinforcement).

Transverse: No. 4 deformed bars at 30 inches C-C used as tie bars between lanes.

Construction Feature:

Paving: Slipform paving in 24-foot lane widths (2 inch by 10 mil polyethelene strips used to create weakened plane between 12-foot traffic lanes).

Steel Placement: Longitudinal steel placed concurrent with concrete placement. Steel fed through guide tubes built into paver.

TEST SECTIONS

Mainline test sections have been established in each of the three projects. These sections were randomly located and are 200 feet long. They are intended primarily as typical sections to be studied periodically to determine the development of cracking characteristics. These locations are given in Table 1.

TABLE 1

LOCATION OF TEST SECTIONS

Site No.	General Locations	Stations From	Stations To	Placement Date
1	EBL, Between Routes 682 & 637, Albemarle County	2015	2017	5/20/70
2	" "	2110	2112	5/18/70
3	" "	2125	2127	5/18/70
4	" "	2170	2172	5/14/70
5	EBL, Between Route 250 East	2755	2157	7/25/70
6	and Route 22, Albemarle County	2765	2767	7/25/70
7	" "	2775	2777	/27/70
8	EBL, Between Routes 22 & 15, Albemarle County	238	240	——
9	WBL, "	2993	2995	12/12/69
10	" "	2983	2985	12/12/69
11	" "	—	—	12/9/69

CRACK SPACING AND WIDTH

Crack Spacing

The average crack spacings have been determined monthly for each of the test sections for the past 2½ years. A summary of these spacings grouped according to placement date is given in Table 2.

TABLE 2

CRACK SPACING

Date Paved	Average Crack Spacing (ft.) After 2 mo.	After 1 winter	After 2 winters
May 1970	9.09	5.37	5.10
July 1970	8.57	5.97	4.92
December 1969	20.51	13.33	12.90

Note that the spacing for the spring and summer concrete is approaching that expected for the type of pavement under study. Similar pavements (0.6% reinforcement) have been reported earlier to have crack spacings of from 3 to 5 feet at ages 2 to 3 years.[1, 2]

The winter concrete, on the other hand, shows signs that the spacing may never be as close as expected. This is no doubt due to the extremely cold weather during which the concrete was placed. Overnight temperatures typically fell into the 20's (^{o}F) during this December 1969 paving period. The nearly 13 foot average crack spacing contrasts sharply with that for some of the July 1970 pavement, which had an average spacing of about 15 feet within 48 hours after placement at temperatures ranging to 90^{o}F. Clearly hydrothermal stresses have had a more pronounced effect on the summer than on the winter concrete. It is apparent that the winter concrete, placed at very low temperatures, has seldom been exposed to significant tensile stresses and, that unless the pavement experiences an extremely cold and dry winter, the number of cracks will never increase significantly.

Crack Width

Changes in crack width have been determined by gage plugs spanning randomly located cracks within the previously described test sections. The gage plugs are $\frac{1}{2}$ inch diameter by 1 inch long brass cylinders tightly bound in predrilled holes with a paste made of expansive cement. Gage points were drilled in the plugs after allowing several days for the cement paste to harden. A gage length of 10 inches is used for monthly measurements with a dial gage. Initial measurements were made with a Whittemore gage which was later replaced by a larger dial gage (Figure 1) built in the Research Council shop. The latter gage was necessary because end anchorage movement (discussed later) exceeded the capacity of the Whittemore gage.

Measurements are recorded to the nearest 0.0001 inch and are corrected for concrete volume changes within the gage length. This correction is computed from measurements made on uncracked pavement immediately adjacent to the cracks. Average crack widths for the three study groups at critical times (maximum and minimum spacing) are shown in Table 3, where each entry represents an average of twelve measurements. Cracks were originally instrumented at an early date and at a width assumed to be nearly zero.

TABLE 3

CHANGES IN CRACK WIDTH WITH TIME

Paving Date	Summer 1970	Winter 1970-71	Summer 1971	Winter 1971-72	Summer 1972
May 1970	0	0.0138	0.0034	0.0139	0.0073
July 1970	0	0.0170	0.0139	0.0305	0.0248
December 1969	0	0.0185	0.0068	0.0239	0.0160

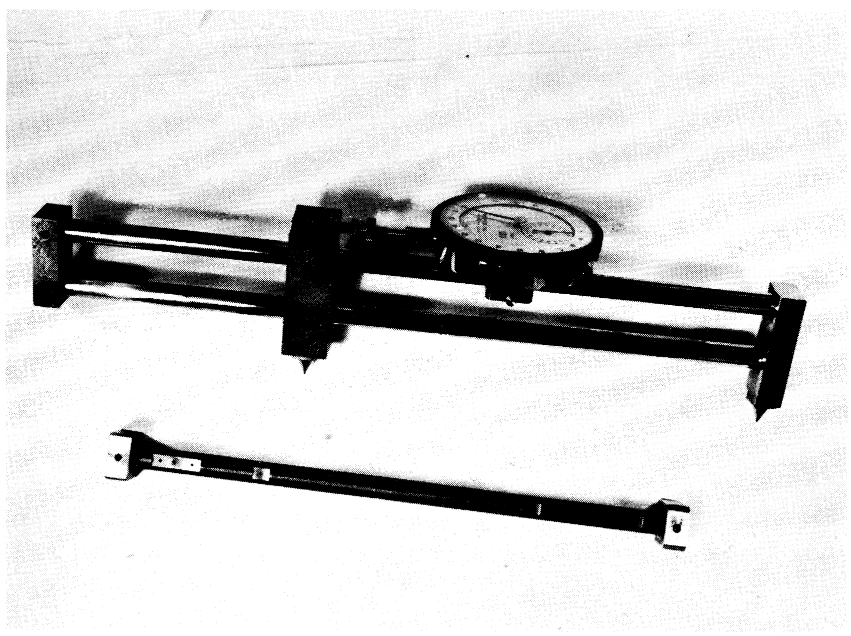

Figure 1. Extensometer and standard, used for crack and joint movement measurements.

There is no apparent relationship between paving date, crack spacing, and crack width. There is a pronounced seasonal effect as evidenced by the differences between the summer (narrow) and the winter (wide) openings. Note that the summer 1972 measurements are wider than those for the summer of 1971. This may indicate a gradual increase width. On the other hand, it may partially result from different seasonal conditions between the two summers. Further studies over the next several years should determine whether or not there is a progressive increase in crack width. The 1971-72 winter openings of from 0.01 to 0.03 inch is in line with the results of earlier studies both in Virginia and in other states for similar pavements.[1, 2]

END ANCHOR MOVEMENT

Continuously reinforced concrete pavements typically employ massive end anchorage systems to provide protection to adjoining conventional pavement or structures. Virginia's first comprehensive studies of these systems were reported by Mitchell in 1963.[3] These studies were of a theoretical nature and were applied to models only. Since no continuously reinforced full size pavements had been built in Virginia at that time, no realistic end movement data were available. While others now have provided end movement data for various types of anchorage systems used in other states,[4, 5] it was considered desirable to collect data on anchorages built in Virginia since the 1963 studies.

The Virginia anchor systems consist primarily of the type seen in Figure 2.[6] While these anchor systems appear to have been very effective they are costly and time consuming to construct. Thus, any simplification of their future design based on documented small end movements of the present systems would be of economic benefit.

The Charlottesville projects, unlike the design standard (Figure 2), were constructed with six 20 ft. long plain pavement slabs between the anchor slabs and the structural approach slabs. Thus, a total of seven 1-inch expansion joints were provided between the anchor slabs and structures.

The two anchor slabs selected for instrumentation are located in the westbound lane of I-64 at the eastern ends of bridges over Routes 637 and 682. Instrumentation was similar to that described earlier for the crack opening studies. In this case, the expansion joint immediately adjacent to the anchor slab and the third expansion joint from the anchor slab were spanned by sets of gage plugs.

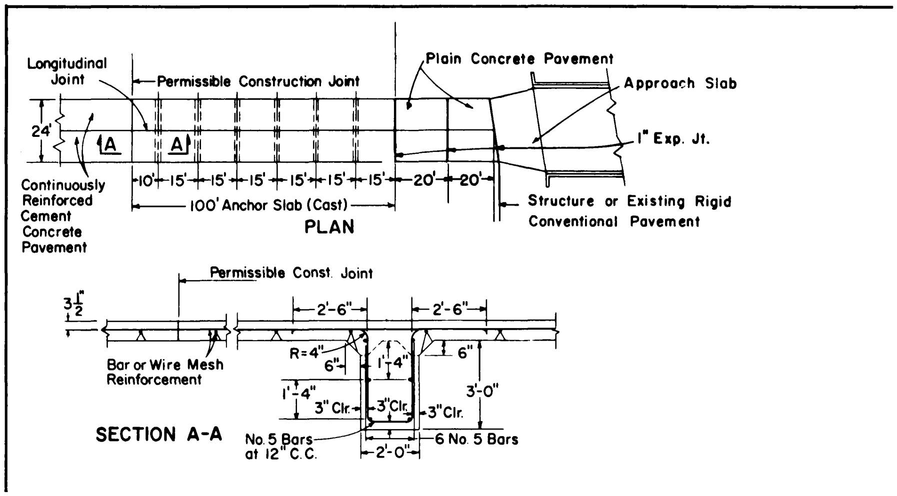

Figure 2. Anchor slab. (Adapted from reference 6.)

The results of gage plug measurements for 22 months early in the pavement's life are shown in Figure 3. Each data point represents the average width change for the two end joints or the two intermediate joints. While only averages are shown in the figure, the results of measurements on the two installations are remarkably similar even though the lengths of pavement anchored are approximately 3 miles and 1 mile for the Route 637 and the Route 682 sites, respectively. This similarity in movements seems to validate the findings of others that, because of subbase friction, only about 500 feet on either end of a continuously reinforced pavement contributes to end movements.[5] End movements have been found to be related to pavement length for continuous sections less than 1,000 ft. long.[5]

Note in Figure 3 that the seasonal effect is dramatic, with the joints closing in summer and opening in winter as expected. Note also that the end joints move approximately three times as much as the intermediate joints (maximum annual movement, from the widest winter position to the narrowest summer position). The intermediate joint movement is almost exactly what would be predicted for any conventional pavement undergoing a similar temperature range and having the same slab length.[7] Differences in movements between the end joints and the intermediate joints were presumed to be attributable to anchor slab movement. A triangulation scheme utilizing shoulder reference points is being used to verify the true end movements as opposed to joint movement.

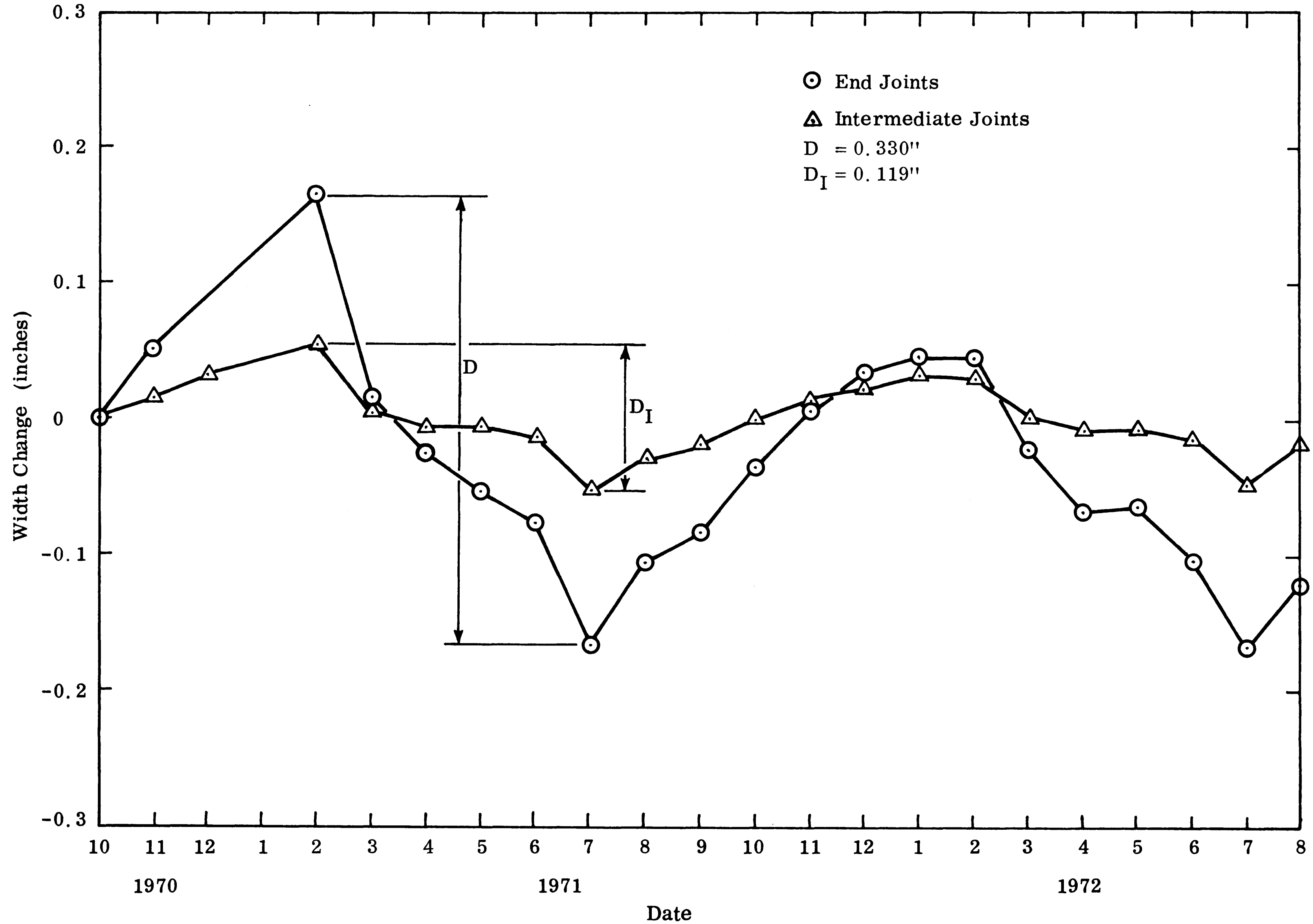

Figure 3. Expansion joint movements with time.

The apparent end movement to date of approximately $\frac{1}{4}$ inch is somewhat less than had been expected intuitively. It is, however, in line with that predicted by an equation developed by Texas researchers for a similar anchor system.(5) These researchers found that grade, temperature change, subbase friction, pavement length, and the number of lugs were important parameters. When applied to the I-64 anchor systems with an assumed friction coefficient of 1.9 for the cement stabilized subbase, the predicted end movement is approximately 0.28 inch. The Texas report also cites evidence, based on 7 to 15 years of observations, that with certain subbase and grade combinations the anchor lugs can be eliminated.

Clearly end anchor movement for the first two years has been very modest. Also, there is evidence from the data that movement has stabilized somewhat by the end of the second year. Still, it would be premature to suggest drastic changes in anchor design without the benefit of sufficient time for indicated trends to become fully developed.

One fact that was clearly established early in the life of the pavement was the inadequacy of poured joint sealants in the expansion joints adjoining the anchor slabs. Here even the modest movement measured was in excess of the rated capabilities of hot or cold poured joint sealing materials.(7) For this reason, the two-component polysulfide seal provided in the end joints failed in a very short time. The failure was cohesive and resulted in a torn seal through which water and incompressible materials could easily enter. The seals were repoured while the pavement was still under construction. Again, failure took only a short time. As a result of this finding, it was recommended to the pavement design engineer that only preformed compression seals be permitted in expansion joints adjacent to continuously reinforced pavements. This recommendation has been adopted as a design standard.

EFFECTS OF THE ELIMINATION OF TRANSVERSE STEEL

Periodic examinations of the Charlottesville projects along with a study of the relevant literature has revealed no detrimental effects of the elimination of transverse steel from continuously reinforced pavements. While there was at one time some concern that occasional random longitudinal cracking was related to the elimination of the steel, studies showed that the cracking seldom went beyond the limits of the transverse tie bars provided between the 12-ft. lanes. It was also determined that several older projects having full width transverse steel had even more of the longitudinal cracking than the Charlottesville projects.

The conclusion that elimination of the steel has not influenced the behavior of the Charlottesville pavements is further substantiated by the similarity of transverse cracking characteristics, discussed earlier, to those on the Richmond projects studied earlier.

CONCLUSIONS

The following conclusions appear to be warranted from the findings presented in this report. It should be emphasized that the pavements studied are relatively young and that some of the behavior patterns do not appear to have fully developed.

1. Cracks show a definite trend to become both more closely spaced and wider during the first 2 to 3 years of a continuously reinforced pavement's life. There is some inconclusive evidence that the widening process stabilizes after this time period.

2. While crack spacing can be influenced by weather conditions during pavement placement, there is no apparent relationship between crack width and either crack spacing or placement weather.

3. As expected, cracks are significantly wider at the surface during winter (pavement shrinking) than during summer (pavement expanding). (Note — Earlier studies have shown that cracks which are easily seen and measured at the surface are invisible in the immediate vicinity of the reinforcing steel.)

4. End anchor movement is very modest during the first year and seems to decrease slightly with age. There is a pronounced seasonal effect which produces joint movements in excess of the capabilities of poured joint sealants.

5. The elimination of full width transverse steel has had no effect on pavement performance for the first 2 to 3 year.

RECOMMENDATION

As a result of these studies, a recommendation to the Department's pavement design engineer has resulted in the adoption of preformed compression seals in all expansion joints adjacent to the anchor slabs of continuously reinforced pavements.

ACKNOWLEDGMENTS

The author gratefully acknowledges the cooperation and interest displayed by R. W. Gunn, highway construction inspector, in his data collection and analysis duties on the project.

The project is under the general direction of Jack H. Dillard, state highway research engineer, and is being financed from state research funds.

REFERENCES

1. Newlon, Howard H., and K. H. McGhee, Survey of Crack Characteristics on Virginia's First Continuously Reinforced Concrete Pavement, Virginia Highway Research Council, October 1967.

2. McGhee, K. H., Review of Crack Characteristics on Virginia's First Continuously Reinforced Concrete Pavement, Virginia Highway Research Council, April 1969.

3. Mitchell, R. A., "End Anchors for Continuously Reinforced Concrete Pavements," Highway Research Board, Record No. 5, 1963.

4. Henry, Robert L., Final Report on a Study of Control of Pavement Movements Adjacent to Structures, University of Mississippi, Engineering Experiment Station, February 1968.

5. McCullough, B. F., An Evaluation of Terminal Anchorage Installations on Rigid Pavements, University of Texas, January 1971.

6. Virginia Department of Highways, Road Designs and Standards, 1972.

7. McGhee, K. H., and B. R. McElroy, Study of Sealing Practices for Rigid Pavement Joints, Virginia Highway Research Council, June 1971.