State of Illinois
DEPARTMENT OF TRANSPORTATION
Division of Highways
Bureau of Research and Development

INTERIM REPORT

ON THE PERFORMANCE OF THE

LAKE COUNTY INVERTED FLEXIBLE PAVEMENT

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by
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SUMMARY

The "inverted" pavement design was conceived as a possible method that would reduce or eliminate the transverse cracking in flexible pavement surfaces that develops as a reflection of transverse cracks in the underlying stabilized aggregate base. In the inverted design, an unbound layer of granular material, often used as a subbase beneath the stabilized base, is placed between the bituminous surfacing and the stabilized base material to serve as a "cushion course" separating the surfacing and the stabilized base. This reverses or "inverts" the normal positions of these layers, thus, the term "inverted pavement."

To test the feasibility and performance of this type of design, an experimental section, including control pavements of conventional design, was constructed. This paper reports the condition and performance of these pavements two years after construction. While time has not been sufficient to establish complete performance trends or to develop final study conclusions, four tentative conclusions are drawn from the performance to date:

1. The inverted design has been effective in reducing but not in eliminating transverse cracking.
2. Transverse cracks in the surfacing of both the inverted and conventional pavements are accompanied by underlying cracks existing in the stabilized base material.
3. Cracks that have developed in the inverted pavement have tended to lead to multiple cracking and signs of deterioration more rapidly than those in the conventional pavements.
4. The inverted pavement has been more susceptible to wheelpath rut development.

INTRODUCTION

During the early part of the century when highway construction became a major effort throughout the nation, abundant sources of high quality aggregates were available in most sections of the country. In recent years, the rapid depletion of many of these sources has produced a critical shortage in some areas and has caused reason for concern throughout the highway industry. This depletion has challenged the highway engineer to seek substitute materials and to develop means for more efficient utilization of remaining aggregate supplies.

In answer to this challenge, many agencies have increased their use of stabilized bases with their flexible pavements. This design reduces the quantity of material required and permits the use of lower quality aggregates. However, an inherent weakness in pavements of this design has been the development of cracks in the surfacing material as reflections of transverse cracks in the stabilized base. In an attempt to eliminate this weakness, the Department of Highways of Lake County, Illinois, proposed an "inverted" pavement design which includes a cushion of unbound granular material between the stabilized base and the bituminous surfacing. This design was termed "inverted" because it reversed the traditional positions of the stabilized and unbound layers.

To test the feasibility of this design and compare its performance with that of a conventional pavement design, the Illinois Division of Highways agreed to monitor and evaluate an experimental installation of the inverted pavement. This paper is an interim report on the condition of the test pavements two years after construction. No attempt is made to discuss or evaluate the materials used in the pavements.

STUDY DETAILS

The site selected for the installation is located on Midlothian Road at

Mundelein, Illinois (Figure 1). Since the test site included both rural and urban areas, the experiment was designed to have four test sections with an inverted and a conventional pavement design in both the rural and urban portions. Typical cross sections of these designs are shown in Figure 2.

Subgrade soils throughout the test site consist predominately of A-7-6 (12-19) brown clays. Design analyses, using the Illinois design procedure for flexible pavement, indicated that a conventional pavement design of three inches of bituminous concrete surfacing (Illinois Class I), six inches of lime fly ash stabilized aggregate base (minimum compressive strength of 750 psi after a seven day moist cure at 130° F.) and six inches of crushed gravel subbase should be adequate for a twenty-year design life. For the inverted pavement design, the positions of the base and subbase materials were reversed. This allowed a direct comparison of the performance of the two designs.

Since the inverted pavement was conceived primarily to reduce reflective cracking in the pavement surfacing, the principal parameter measured in the study has been crack development. This has been measured by periodic crack surveys. Other parameters measured in the test have been road roughness, wheel-path rutting, seasonal surface movements and pavement deflections under load. The comparison of the measured values of these parameters is expected to reveal the relative merit of the inverted design.

CRACK DEVELOPMENT

Crack surveys taken in March 1970 and April 1971 reveal that the inverted pavements have developed about half as many transverse cracks as have the conventional pavements. This is amply demonstrated by the April 1971 average crack intervals of 94 and 66 feet on the urban and rural inverted pavements and 40 and 32 feet on the corresponding conventional pavements. A more

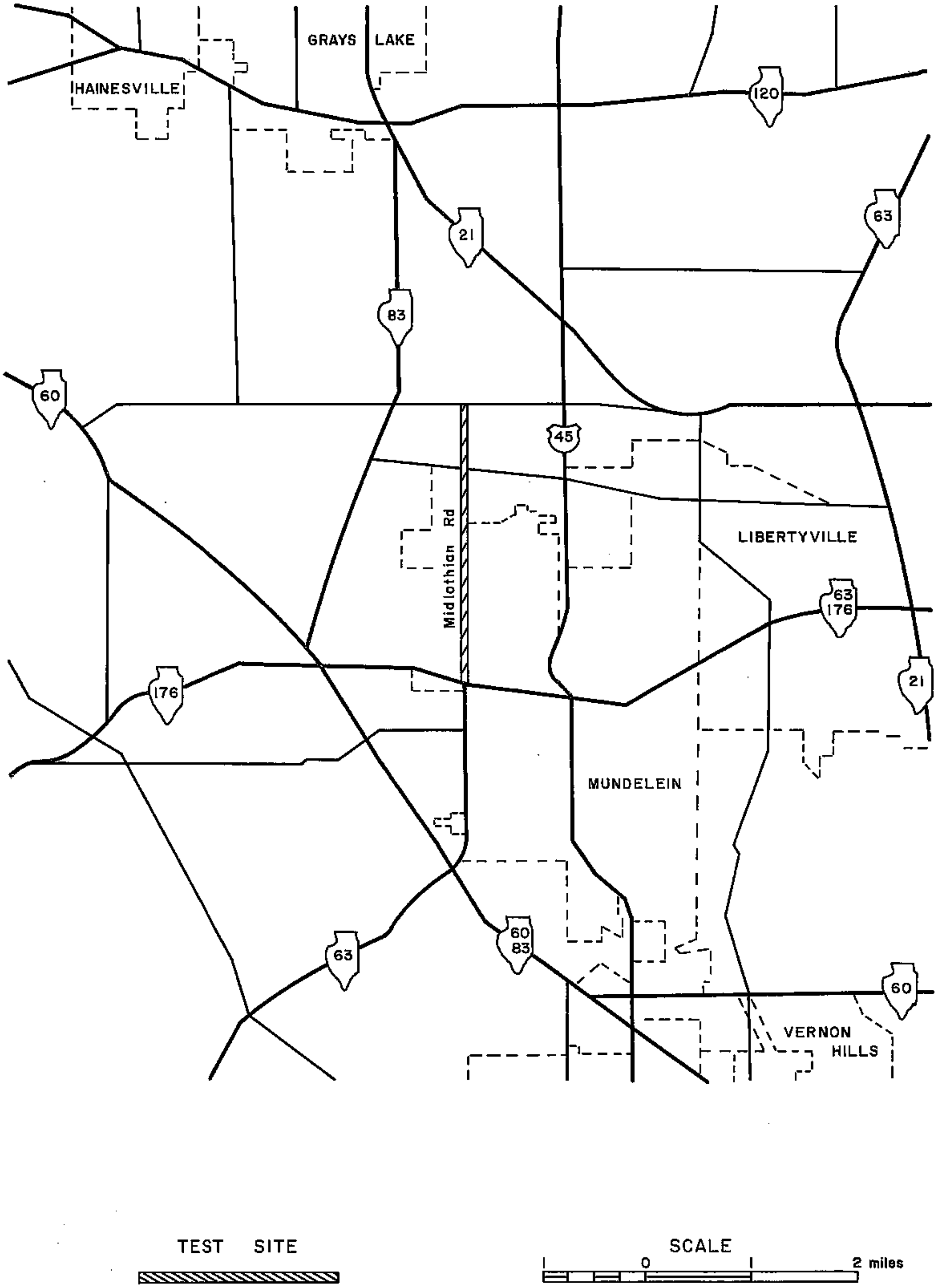
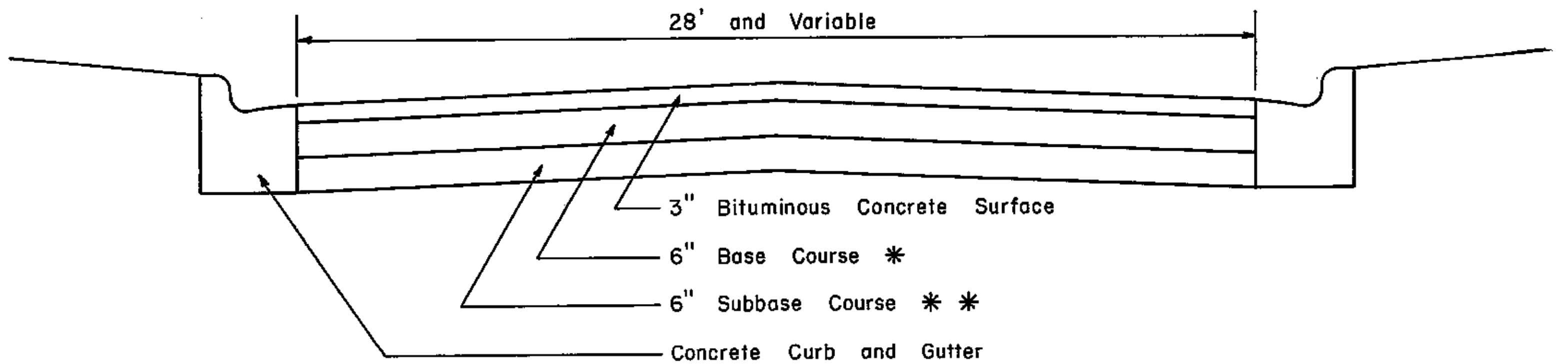
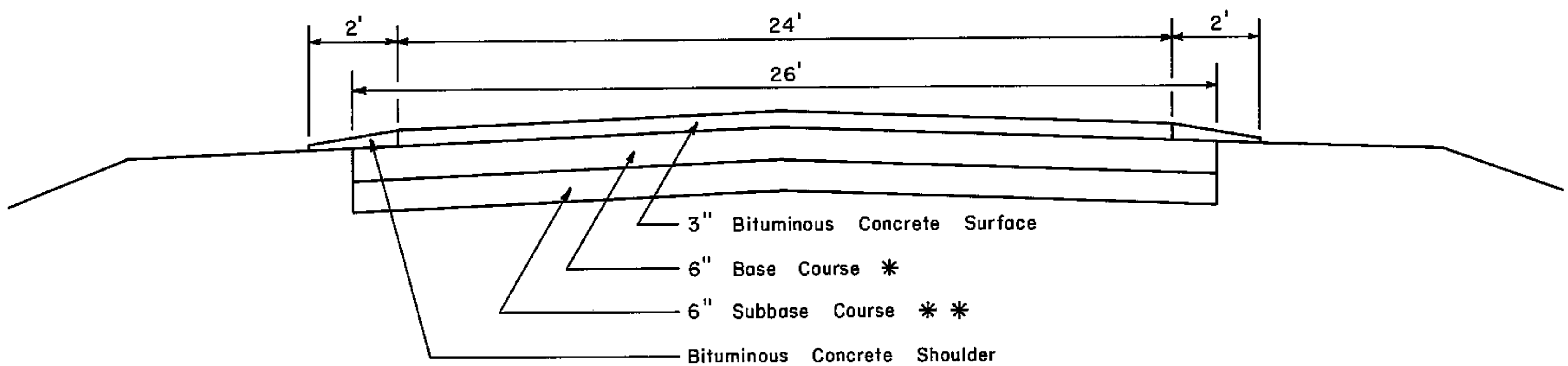


FIGURE I. TEST SITE LOCATION



TYPICAL URBAN SECTION



TYPICAL RURAL SECTION

	INVERTED DESIGN	CONVENTIONAL DESIGN
* BASE	Crushed Gravel	Lime Flyash Stabilized Aggregate
* * SUBBASE	Lime Flyash Stabilized Aggregate	Crushed Gravel

FIGURE 2. TYPICAL CROSS SECTIONS

comprehensive picture of the transverse cracking is displayed in Figure 3 which shows the quantity of cracking for each 200-foot segment of the test pavements.

However, while fewer in number, the transverse cracks in the inverted pavement appear to be potentially more troublesome. Multiple cracking adjacent to transverse cracks has developed in most of the rural (67 percent of the cracks) and some of the urban (9 percent of the cracks) inverted pavement. A typical example is shown in Photo 1. Similar developments have not been viewed in the conventional pavements. A typical transverse crack in the conventional pavement is shown in Photo 2.

No significant difference between designs has been observed in the quantity of longitudinal cracking (Figure 4). However, here again the inverted pavement seems to offer the more potentially troublesome cracking. Multiple cracking is again in evidence, a minor amount of which has developed into alligator cracking. The longitudinal cracks in the conventional pavement have remained sharp and distinct. Typical examples of longitudinal cracks in the two designs are shown in Photos 3 and 4.

In May 1970, an investigation of the transverse cracks was undertaken. Pavement cores were taken at four crack locations in the conventional designs. At each location, the surface crack was found to be the reflection of a crack existing in the stabilized base material. At the same time, four crack locations in the inverted pavement were examined by removing a three-foot square section of surfacing and excavating the granular base material. At each location, a crack was found in the stabilized material directly below the surface crack (Photo 5) suggesting that the surface crakks in the inverted pavements may also be reflective cracks.

RUTTING

Based on the serviceability and performance criteria developed for the

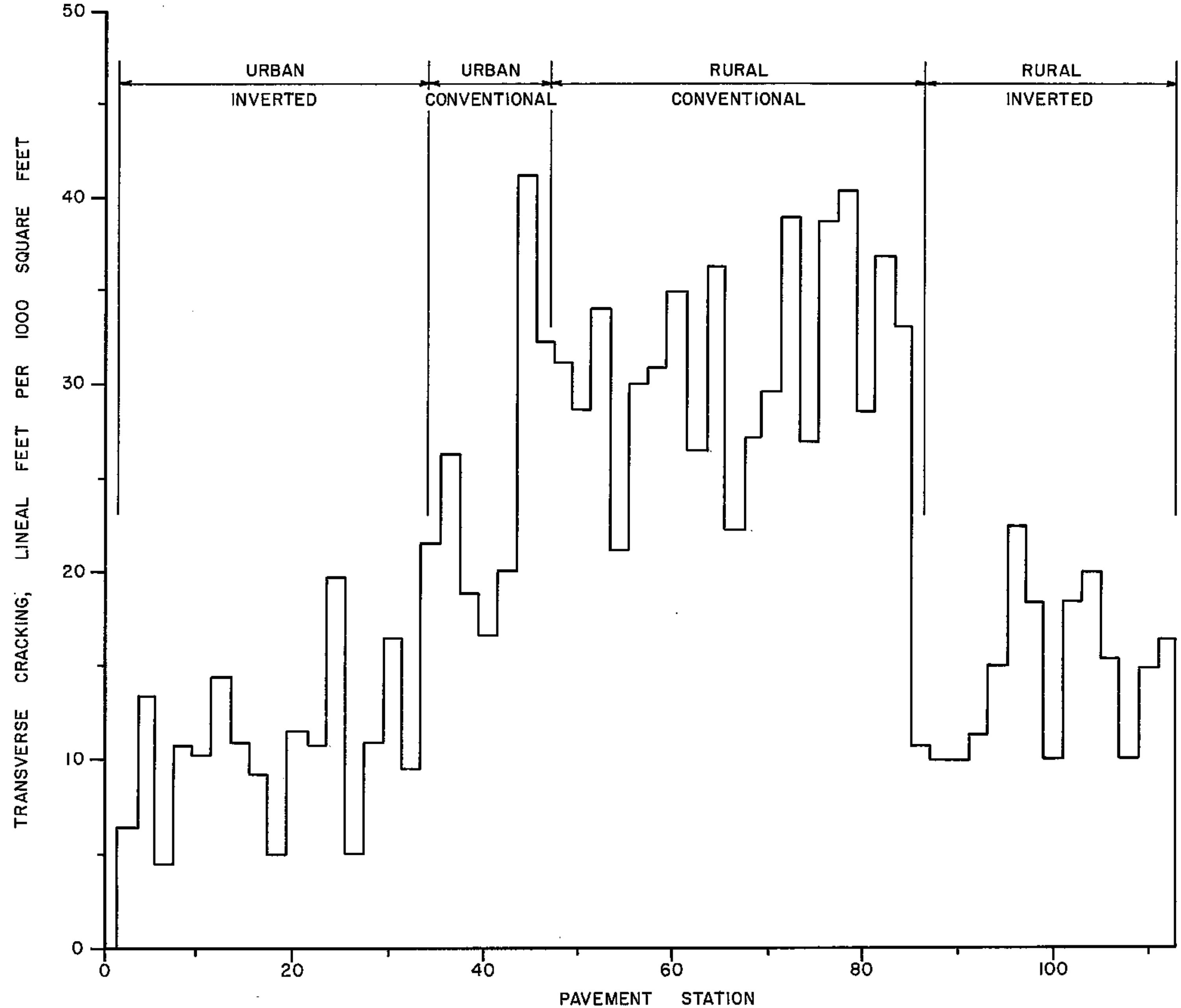


FIGURE 3. RATE OF TRANSVERSE CRACKING IN THE TEST PAVEMENTS, APRIL 1971

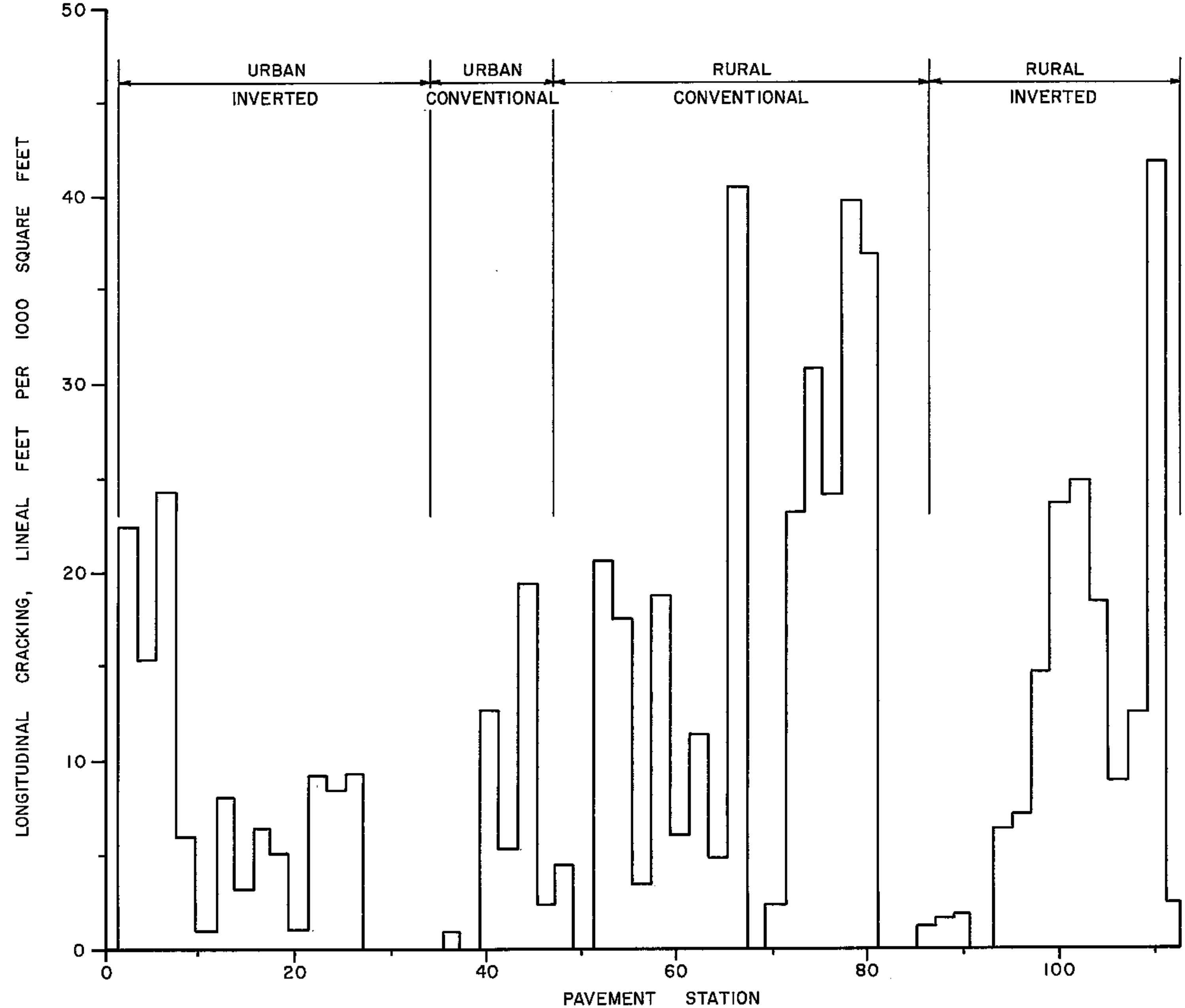


FIGURE 4. RATE OF LONGITUDINAL CRACKING IN THE TEST PAVEMENTS, APRIL 1971

AASHO Road Test, wheelpath ruts less than 0.3 inches deep are not considered detrimental to the pavement. From this point of view, significant rutting has not developed on any of the test pavements except at one location in the inverted design where a 0.3 inch rut depth was measured. However, from the measurements taken to date, the inverted design appears to be much less resistant to rut development than the conventional design. Of twenty-eight inverted pavement wheelpath ruth depth measurements taken on March 30, 1971, one was 0.3 inch, six were 0.2 inch, ten were 0.1 inch, and the remaining eleven showed no measurable depth of rut. By comparison, no ruts greater than 0.1 inch were found on the conventional pavements. Eighteen of twenty-four measurements on the conventional pavements had a rut depth of 0.1 inch and the remaining six showed no rutting.

PAVEMENT DEFLECTIONS

Pavement deflections caused by an 18-kip single axle load have been measured periodically with a Benkelman beam at seven locations on the inverted pavements and six locations on the conventional pavements. At each location, four readings were taken, one in each wheelpath of both lanes. The same locations have been used each time.

The average measured deflection on each design is shown plotted against the time of measurement on Figure 5. While, from a statistical standpoint, the differences between designs are not significant, it does appear that the inverted pavements deflect slightly more than the conventional pavements. In the future, measurements will be taken at more locations to get a better estimate of any difference that might exist.

SEASONAL MOVEMENTS

To measure the movement of the pavement surfaces for the various seasons of

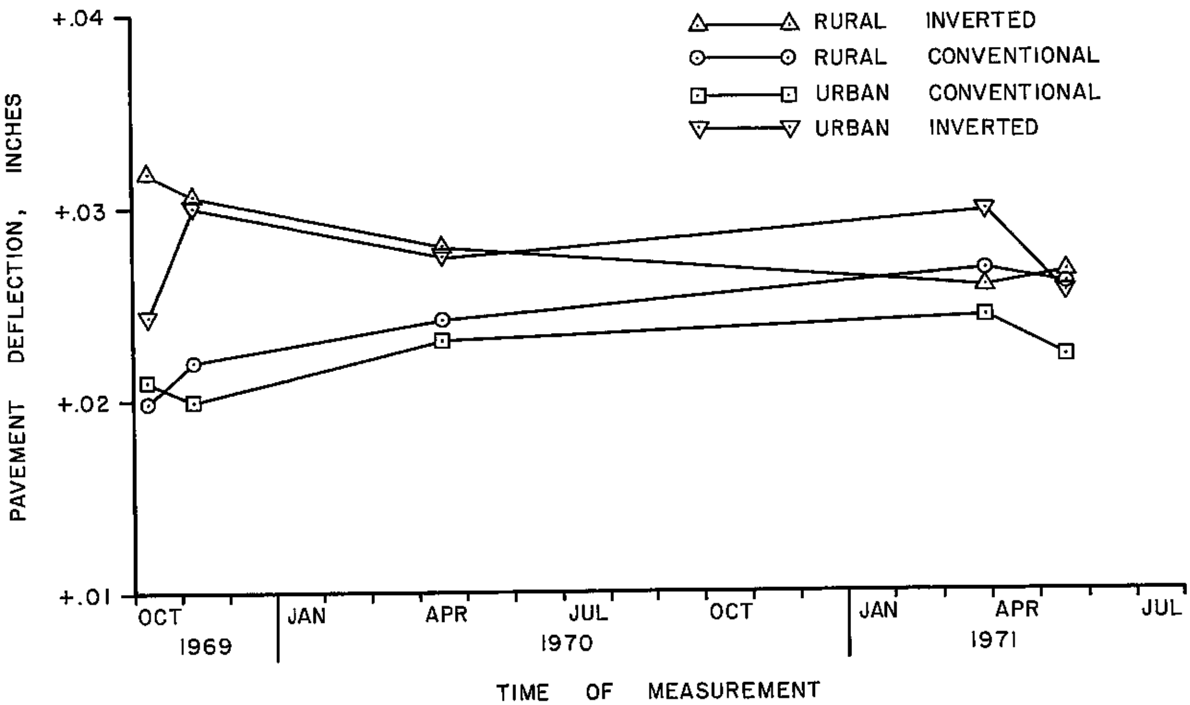


FIGURE 5. MEASURED DEFLECTIONS OF TEST PAVEMENTS

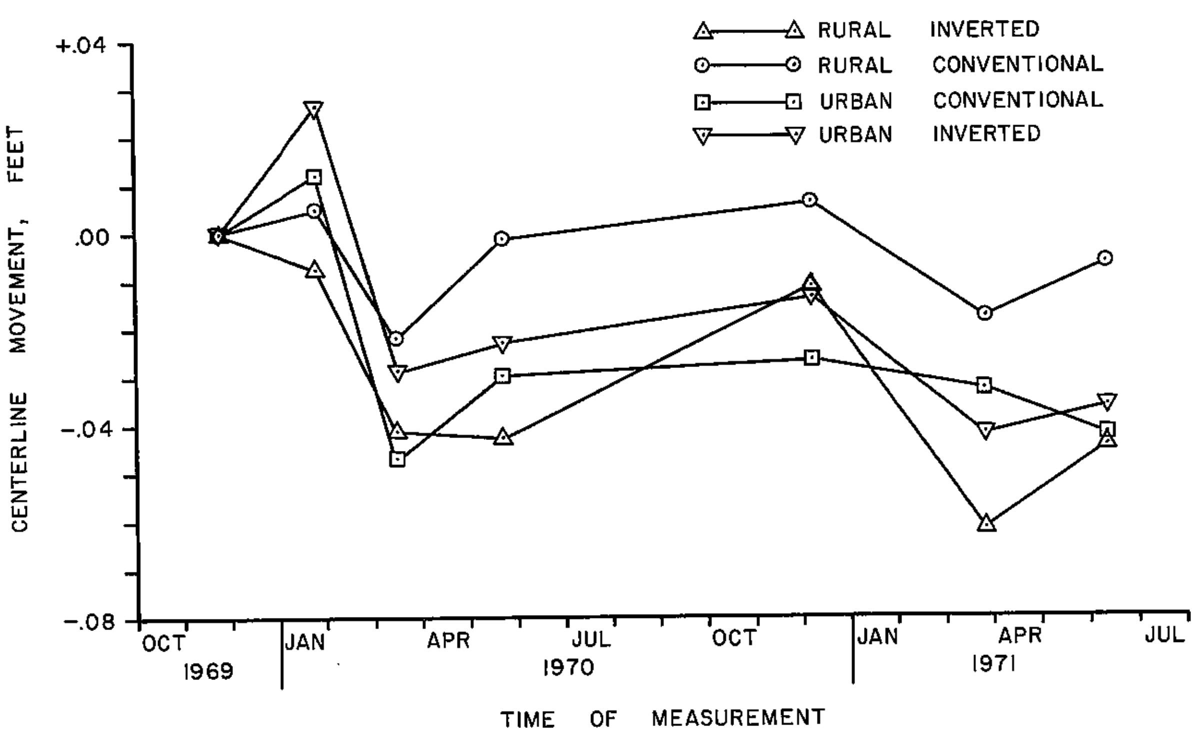


FIGURE 6. AVERAGE VERTICAL MOVEMENTS OF CENTERLINES OF TEST PAVEMENTS

the year, cross sections have been taken periodically at the locations used for the deflection measurements. Figure 6 displays the average vertical movements of the pavement centerline in each design. From the data, the inverted designs appear to have experienced the greater amount of seasonal movements. This suggests that frost heave and the subsequent reduction in pavement strength in the spring may be greater for the inverted pavement. This might explain the multiple cracking and signs of surface deterioration developing at transverse and longitudinal cracks in the inverted pavement.

PAVEMENT ROUGHNESS AND PERFORMANCE

Possibly the most important property of any pavement is its ability to maintain a smooth riding surface. This is demonstrated by the serviceability concept developed in connection with the AASHO Road Test in which an index, based on physical measures of pavement surface properties and called the Present Serviceability Index, is used to approximate the highway user's opinion of a pavement's ability to serve traffic at any specific point in time. Road roughness is by far the most influential of the physical properties included in the index.

The smoothness of the test pavements has been measured periodically with the Illinois roadometer. This device provides a measure, called the Roughness Index, of surface deviations expressed in inches per mile. The change in this value with time provides an indication of a pavement's ability to maintain a smooth riding surface. Figure 7 displays the history of the Roughness Indices of the test pavements. To the present time, the differences in Roughness Index values are not significant.

Performance, based on the AASHO Road Test concepts, is defined as the change in the Present Serviceability Index of a pavement with traffic applications.

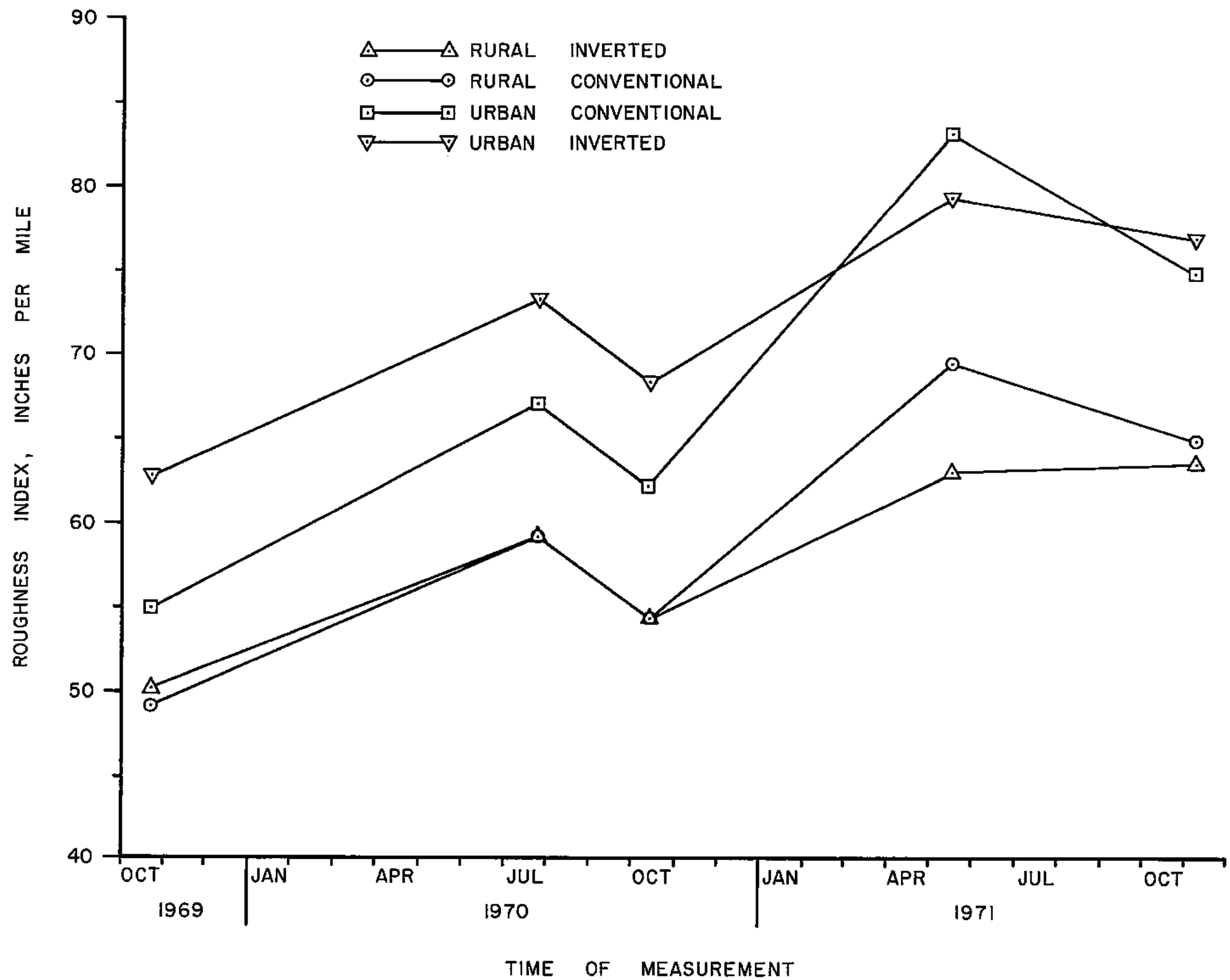


FIGURE 7. ROUGHNESS INDEX HISTORY OF THE TEST PAVEMENTS

The performance of the test pavements is compared in Figure 8. To date, the performances have been very similar.

CONCLUSIONS

To the present time, the test pavements have not been in service sufficiently long to establish any definite conclusions as to the relative merits of the inverted and conventional pavements. However, based on the limited data collected to date, the following tentative conclusions are in order:

1. The inverted design has been effective in reducing but not in eliminating transverse cracking. The inverted pavements presently have approximately half as many transverse cracks as the conventional pavements. Neither design has shown an amount of transverse cracking that is cause for immediate concern.
2. The transverse cracks in the surfacing of both the inverted and conventional pavements are accompanied by underlying cracks existing in the stabilized base. The pavement was examined at eight transverse crack locations - four in the inverted design and four in the conventional design. At each location, a crack was found in the stabilized base immediately below the surface crack.
3. The cracks that have developed in the inverted pavements appear to be potentially more troublesome than those in the conventional pavements. This is evidenced by the development of multiple cracking and early signs of distress adjacent to most of the transverse and longitudinal cracks in the inverted pavements.
4. Wheelpath rutting, while not yet significant in either design, has developed to a greater extent in the inverted pavements and may eventually prove to be detrimental to their performance.

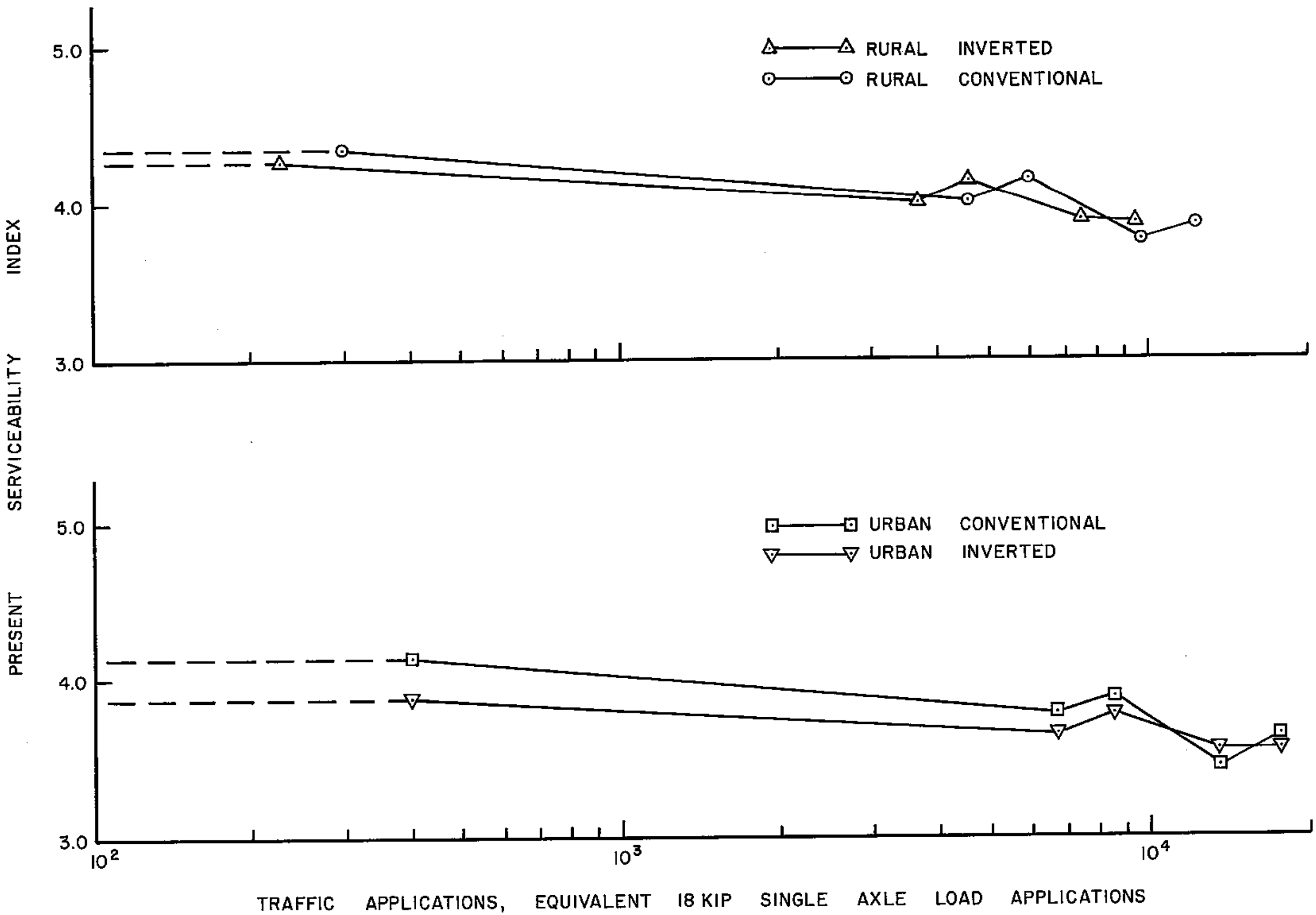


FIGURE 8. PERFORMANCE OF TEST PAVEMENTS

In view of these tentative conclusions, the future performance of the inverted pavements relative to that of the conventional pavements cannot be viewed with optimism. However, it should be noted that many factors which could affect the relative performance of the two designs have not been included in the test and are not discussed in this paper.

For the present time, observation and evaluation of the test pavements will continue until more definite trends are established and final conclusions can be made.