Transportation Research Record 1022


Publication of this paper sponsored by Committee on Soils and Rock Instrumentation.

Abridgment

Pavement Failure Investigation: Case Study

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ABSTRACT

An investigation of pavement distress occurring along a major two-lane roadway 5 years after its construction is presented. The primary objective of the study was to determine the probable cause or causes of the pavement distress. The investigation involved a condition survey and an examination of the pavement structure and subgrade through soil borings. The condition survey showed that outer wheel path rutting and associated cracks were severe on both lanes and covered about 68 percent of the overall length of the roadway. The soils investigation revealed that the bank gravel subbase was saturated and the bituminous base course had deteriorated to a virtually cohesionless material that could be easily removed with the fingers. Distinct rapid seepage of water was observed at the interface of the base and subbase layers and within the subbase. On the basis of the findings of the investigation, it was concluded that the major factor causing distress was free water trapped within the pavement structure. This water, it was reasoned, infiltrated the pavement through cracks and a porous surface but because of the poor drainability of the subbase was unable to leave the pavement through the shoulders. This situation resulted in the pavement existing in a "bathtub" condition.

Most, if not all, flexible pavement structures undergo some form of distress during their design life. Investigation of the cause or causes of distress is required for successful pavement rehabilitation and to provide data for improving or modifying design methods, construction techniques, and job specifications.

An investigation undertaken to determine the probable cause or causes of continually occurring pavement distress along a major two-lane roadway is described.

BACKGROUND

The roadway investigated is located in Trinidad, West Indies, an island with a uniform average yearly temperature of 26° C (79° F) and annual rainfall of
1.5 to 3.0 m (5 to 10 ft). This roadway, situated in the Southern Basin, was constructed in 1975 as a connector road between a major four-lane divided highway and a secondary road at the southern extremity of the four-lane highway.

The cross section of the connector road consisted of two 3.66 m (12 ft) travel lanes with 1.22-m (4-ft) shoulders. The design pavement thickness was 267 mm (10.5 in.) under the travel lanes and consisted of 127 mm (5 in.) of asphaltic concrete pavement overlying 140 mm (5.5 in.) of down-graded bank gravel subbase with a maximum size of 38 mm (1.5 in.) and 25 percent passing the 0.074 mm (No, 200) mesh. The shoulder design consisted of 89 mm (3.5 in.) of chip-sealed asphaltic concrete overlying the bank gravel subbase.

Outer wheel path ruts, longitudinal cracks, and pavement distortions along both lanes of the roadway prompted an investigation to be undertaken in June 1980. The investigation included a pavement condition survey and a subsoil investigation. Before this investigation, isolated areas had been overlaid but the previous distress recurred.

**CONDITION SURVEY**

This survey, done by the guidelines outlined in the Manual for Condition Rating of Flexible Pavements (1), indicated that the major pavement distress manifestations were:

1. Outer wheel track rutting and associated fatigue cracks,
2. Pavement distortion, and
3. Longitudinal cracks and depressions along the shoulders.

These distress manifestations were predominant along the eastbound lane where only about 6 percent of the pavement surface was free from major defects.

**SUBSOIL INVESTIGATION**

**Test Holes**

Five boreholes, including two groundwater observation holes, and three test pits were sunk at locations shown in Figure 1. During the drilling, the following were observed:

1. Rapid seepage of water at the interface of the asphaltic base course and bank gravel layers and through the bank gravel itself. The quantity of flow was measured as roughly 76 cm³ (0.003 ft³) per second in Borehole 1.
2. Seepage or "bleeding" of water through cracks in the pavement surface.
3. Deterioration of the asphaltic concrete base course. This layer was found to be deficient in asphalt and extremely brittle. In Borehole 2, for example, the base course had deteriorated into an almost cohesionless material that could be easily removed with the fingers.

**Groundwater Conditions**

No groundwater was encountered in the test holes or in the two observation boreholes sunk off the edge of the shoulder. The observation holes were drilled to a depth of 5 m (15 ft) relative to the elevation of the carriageway at the test boring locations and observed over a period of 2 weeks following the site investigation.

**Soil Profile**

The profile deduced from the boreholes consisted of structural pavement layers overlying a silty clay subgrade soil. The thickness of the structural pavement varied between 300 and 584 mm (12 and 23 in.) and consisted of 120 to 406 mm (5 to 16 in.) of asphaltic concrete pavement. The subbase course consisted of bank gravel varying in thickness between 127 and 180 mm (5 and 7 in.).

**SOIL CHARACTERISTICS**

Atterberg limits, shear strength, and standard Proctor compaction results for the subgrade soil are shown in Figures 2 and 3, and California bearing ratio (CBR) test results are summarized in Table 1. The subgrade soil was mainly of the CH type and exhibited very high potential expansiveness (Figure 4) as determined from Williams' chart (2).

Although swelling of the subgrade soil can contribute to pavement failure, there was no consistent evidence from the condition survey and the soils investigation that the distress along the carriageway was caused by subgrade volume change.

![FIGURE 1 Plan of connector road.](image-url)
SUBGRADE STRENGTH

For pavement design, the strength of the subgrade in tropical climates is normally assessed in terms of the California bearing ratio. Using shear strength parameters, $c = 36$ kPa (5.22 psi) and $\phi = 14$ degrees, and average of values within the top 0.6 m (2 ft) of subgrade in Boreholes 2 and 3, an estimated in situ CBR value of 6.3 percent was obtained (3). This value compares favorably with 6.6 percent obtained from laboratory tests on an in situ sample, (Table 1).

Although several criteria have been proposed for determining the soil strength to be used for design purposes (4-5), the 4-day soaking period is considered the most appropriate for soils exhibiting appreciable swell and for climates in which annual rainfall exceeds 245 mm (9.6 in.) (5). Therefore, the CBR of 2.9 percent rounded to 3 percent was considered appropriate for design.

TABLE 1 Summary of California Bearing Ratio Test Results

<table>
<thead>
<tr>
<th>Test Pit</th>
<th>Bulk Density in kg/m$^3$ (lb/ft$^3$)</th>
<th>Dry Density in kg/m$^3$ (lb/ft$^3$)</th>
<th>Moisture Content (%)</th>
<th>CBR (%)</th>
<th>Swell (%)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,902 (119)</td>
<td>1,514 (94)</td>
<td>25.6</td>
<td>6.8</td>
<td></td>
<td>Remolded</td>
</tr>
<tr>
<td>2</td>
<td>1,891 (118)</td>
<td>1,538 (96)</td>
<td>22</td>
<td></td>
<td></td>
<td>Standard Proctor optimum</td>
</tr>
<tr>
<td>3</td>
<td>1,869 (117)</td>
<td>1,506 (94)</td>
<td>24</td>
<td>7.1</td>
<td></td>
<td>4-day soak</td>
</tr>
<tr>
<td>4</td>
<td>1,810 (94)</td>
<td>1,510 (94)</td>
<td>23</td>
<td></td>
<td></td>
<td>Standard Proctor optimum</td>
</tr>
</tbody>
</table>

As a first step in pinpointing the cause of the pavement failures, the adequacy of the pavement design of the connector road was checked using the National Crushed Stone Association method of design (7). This method was chosen in the absence of actual traffic data.

Using a CBR of 3 percent, pavement thicknesses of 533 mm (21 in.), 610 mm (24 in.), 660 mm (26 in.), and 762 mm (30 in.) were obtained for four categories of traffic loadings—medium, medium heavy,
except for the design pavement thickness of 267
mm (10.5 in.) for the connector road, no information
could be found on the "thickness design" of this
roadway. However, for the adjoining main-line (four-
lane) highway the design pavement thickness was 394
mm (15.5 in.). This thickness was determined using
the Asphalt Institute's method of design (8), a de-
sign CBR of 2.5 percent, design traffic number of
82, and a 20-year design life (1970 to 1990). This
pavement was made up of 234 mm (9.2 in.) of asphaltic
concrete pavement overlying 140 mm (5.5 in.) of
downgraded bank gravel.

The pavement thickness of the connector road was
considerably less than that of the main line. How-
ever, when the in situ thickness of the connector
road at the time of investigation is considered, the
average pavement thickness as well as asphalt pave-
ment thickness far exceeded the design thickness of
the main line.

Because the connector road was only 5 years old
at the time of this investigation, the design thick-
ness of 267 mm (10.5 in.) should have been adequate
for a design traffic intensity similar to that of
the main line using planned stage construction for a
specified period (8).

It is of interest to note, however, that in a
recent 20-year design (1980 to 2000) of the south
extension of the main line, a pavement thickness of
851 mm (33.5 in.) was recommended. This design was
based on a design traffic of 2 to 6 million standard
axles and a subgrade CBR of 2 percent. The design
pavement was to be made up of 76 mm (3 in.) of as-
phaltic concrete surface and leveling courses, 150
mm (6 in.) of asphaltic concrete base course, 200 mm
(8 in.) of crushed rock base course, and 425 mm (17
in.) of stone and sand-free clay surface coatings.

Compared to the 1970 and 1975 main-line and con-
ector road designs, this recent design suggests a
large escalation in axle loads that could probably
not have been anticipated during the previous de-
signs. This increase in traffic was due to the in-
creased off-shore exploration along the south coast
of Trinidad and the increasing sales of commercial
and passenger vehicles caused by a booming econo-
my—the spin-off of increased world market oil prices
in the mid 1970s. In 1979, for example, the waiting
period for a new vehicle was about 3 years.

On the basis of the foregoing, it can be readily
concluded that both the connector and the main line
were seriously underdesigned. On the other hand, be-
cause the connector road with an in situ asphaltic
concrete pavement of 406 mm (16 in.) and an overall
pavement thickness of 583 mm (23 in.) still suffered
failures, it is questionable whether inadequate
pavement thickness was the principal cause of dis-
tress.

Corroboration that inadequate pavement thickness
was not the principal factor was provided by an in-
vestigation of the northbound carriageway of the
main line in areas where seepage through the pave-
mint surface was noted. In such areas the only ex-
ternal evidence of pavement distress was short dis-
continuous longitudinal cracks concentrated along
the inner and outer wheel paths. Investigation of
these areas showed pavement seepage and deteriora-
tion of the asphaltic base course similar to that
found during the investigation of the connector
roadway.

On the basis of these observations, it was con-
cluded that the major factor influencing distress
among lanes of the connector road was water trapped within the pavement section. Inadequate
pavement thickness, although identified, was not
considered a significant factor.

DISCUSSION

It is surmised, in the absence of detailed informa-
tion on the history of construction or postconstruc-
tion performance of this roadway, that this water
entered the pavement from surface infiltration
through cracks and a porous asphalt surface. This
conclusion was reached because there was no evidence
of groundwater seepage in any of the test holes or
groundwater observation holes.
That the roadway sec-

The loss of serviceability of the base course as
a result of the presence of water is readily appreci-
ated on examination of the base course. As men-
tioned previously, this layer has been reduced to an
almost cohesionless material. It is the author's
opinion that the drainage of the entrapped water oc-
curs only by "bleeding" through the pavement surface
as noted during the investigation.

Bleeding occurs through cracks in the pavement
surface and is encouraged by repeated traffic load-
ings and thermal changes. Bleeding was noted to oc-
cur principally during the warmer portion of the
day. The effect of increased temperature is to heat
the air entrapped in the pavement and thereby give
the water a "lift."

Good lateral drainage of the pavement structure,
a factor considered essential to pavement longevity,
could only have occurred through the bank gravel
subbase course. However, the bank gravel used was
moderately plastic (liquid limit 29 percent, plastic
limit 18 percent). In addition, properly compacted
bank gravel has a low permeability due to the high
percentage of minus 0.074 mm (No. 200) fraction. Low

Drainability of the subbase was substantiated by the
following observations:

- The amount of water observed to be contained
within the carriageway on removal of the asphaltic
layers and

- Water standing for a day or two on the sur-
face of the subbase material after a period of rain-
fall.
The combination of the poor drainability of the sub-base and the presence of water caused the pavement section to exist in a "bathtub" condition (9).

CONCLUSION

An investigation of the cause of pavement distress along a major two-lane roadway has been described. The results of this study have shown that the major factor affecting pavement performance was free water trapped within the pavement section. Overall, this study demonstrates the influence of water on pavement performance and the necessity for providing good drainage within the pavement structure in climates with moderate to heavy rainfall.

ACKNOWLEDGMENTS

The work described was undertaken by the author during employment as Civil Engineer, Soils, in charge of the Soils and Materials Branch of Ministry of Transportation and Communications, Trinidad. The use of the information presented is gratefully acknowledged. The author also acknowledges the assistance of Joanne Donnelly in typing this manuscript.

REFERENCES


Publication of this paper sponsored by Committee on Subsurface Drainage.