Characterization of Pavement Distress from Test Pit Observation

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ABSTRACT: The characteristics of the roadbed material are critical to the overall performance of the pavement. The paper presents examples with discussion of the form of distress experienced within the pavement layers, based on observations made during the profiling exercise of an investigation into the causes of the premature failure of a pavement. The field investigation entailed a detailed inspection and recording of the profile exposed in test pits, with particular attention being paid to areas with cracks, noting their positions and extent within the pavement layers. The focus of the paper is on the observed orientation of crack propagation within the pavement layers. It is shown that the crack propagation is not always in the vertical plane. This has implications in dealing with crack sealing procedures. The causes of the observed distress were attributed to the behavior of the roadbed as it experienced fluctuating moisture conditions.

INTRODUCTION AND BACKGROUND

A road project consisted of the widening and improvement of an old distressed pavement. However the rehabilitated road experienced longitudinal cracking in the single sealed shoulders and in the outer portions of the asphalt carriageway within a year or so after completion of construction. Several investigations were instituted to determine the causes of the observed failure. The work presented in this paper is based on one of the investigations. The purpose of the investigation was to determine the cause of the observed distress in the pavement with quantitative field and laboratory data and therefore confirm the findings of an earlier study which were primarily based on visual inspection and project document studies.

The project involved strengthening of the existing pavement by either adding a 100 mm or 175 mm granular base on a granular subbase with varying thickness of selected fill on existing pavement and on other sections, crushed stone subbase mixed with milled material from the existing surfacing was used. A 50 to 75 mm asphaltic concrete was used for surfacing. Widening was required to increase the pavement width and the shoulders. The aim of the paper is to quantify the extent of distress observed within the pavement layers during the test pit profiling exercise of the investigation into the causes of the premature failure of the pavement.

SUBSURFACE INVESTIGATION

A walk-over inspection was made over the section that had been identified for investigation, noting the extent of the problem in an effort to select positions that would give as much information as possible regarding the pavement distress problem but also take into account safety for those involved with excavation and inspection of the trenches. Selected test pit locations had to have clear and long distant sighting for traffic with no blind rises or sharp curves.

The field investigation work involved excavation of a series of test pits along the road. This entailed a detailed inspection and recording of the profile exposed in each of the test pits, with particular attention being paid to areas with cracks, noting their positions and extent within the pavement layers. In situ densities of the base and subbase were also determined during the investigation.

A laboratory testing program on collected samples was undertaken to document and characterize the subsurface materials and conditions beneath and within the pavement. The samples were taken at various depths and positions across the test pits from the road side embankment toe to area under the carriageway up to centre line. Moisture content determination assisted in fully defining the moisture regime within and around the pavement structure at the sections where test pits were made.

In-situ Pavement Materials

Crushed unweathered basalt was used as base aggregate. The in-situ maximum dry density values ranged between 2.01 Mg/m^3 and 2.38 Mg/m^3 with a degree of compaction of between 96 % and 99 % and CBR values ranging between 77 and 94%. Red cinder gravel was used as subbase and the in-situ maximum dry density ranged between 1.60 Mg/m^3 and 1.80 Mg/m^3, with a degree of compaction of between 98 % and 101 %, and CBR values ranging between 35 and 60%.

Volcanic ash and a tuffaceous material were used as fill for widening the road shoulders and to raise the road. The laboratory permeability of the borrow pit material from which these materials were sourced ranged between 1.4 x 10^{-7} and 1.6 x 10^{-5} cm/sec at varying degrees of compaction, with maximum in-situ dry densities ranging between 1.58 Mg/m^3 and 1.66 Mg/m^3.

Backfill in sections where the partial replacement of the in situ black cotton soil was done comprised of red silty clay, which was sourced from two different borrow pits. The liquid limit and plasticity index values for the replacement red silty clay were 50% and 13% for the first borrow pit material and 63% and 25% for the second borrow material. The clay content was 16% and 68% with 86% and 93% finer than 0.075 mm for the material from the first and second borrow pit respectively.

Subgrade Characterization

The average clay content, based on percentage passing the 0.002 mm sieve, was greater than 47% giving liquid limit values that varied between 43% and 103% while the plasticity index values varied between 9 and 54%.

Based on a number of methods presented in Carter and Bentley (1991), Chen (1988), Holtz and Gibb (1956), Nelson and Miller (1992), Seed et al. (1960), and Van der Merwe (1964) that establish relationships between expansion potential and plasticity index and clay contents, the analysis showed that, irrespective of the method used, the subgrade had a high to very high swell potential. The categorization of the roadbed based on the analysis confirmed that the material is highly expansive. It should therefore be expected that the roadbed will be susceptible to volume change with variations in the moisture condition. It is also worth noting that the selected fill material from both borrow pits, can be categorized as not being sufficiently inert for replacement fill. The fill materials themselves would possibly require measures to be taken to minimize potential expansiveness under fluctuating moisture content conditions. The problem of volume change in subgrade material and its effects on pavement behaviour has been well documented in the literature for example in Nelson and Miller (1992) and Aubeny and Lytton (2002).

The observed moisture content distribution in the subgrade around and under the pavement indicated that there was vertical moisture migration through the surface of the embankment where granular fill was used. This was an indication that the material used as fill for the widening of the road was letting water infiltrate down to the roadbed. The in-situ moisture content values for the subgrade samples varied between 24 and 53% with the lowest values being under the central area of the pavement and the high values being under the shoulder, where there were cracks. The fluctuating moisture contents varied between about 22 and 60 per cent outside the equilibrium zone. It should be appreciated that the investigation was carried out at the end of the wet season.

Pavement Distress Characterization

This section presents the observed form of distress within the pavement along the road as determined from the test pits. While pavement surface deformations were also observed, the most prevalent distress observed was longitudinal cracking near the edge of the pavement and along the shoulders Fig. 1 shows the typical conditions with respect to longitudinal cracking observed on the road. Fig. 1b shows a sealed crack.

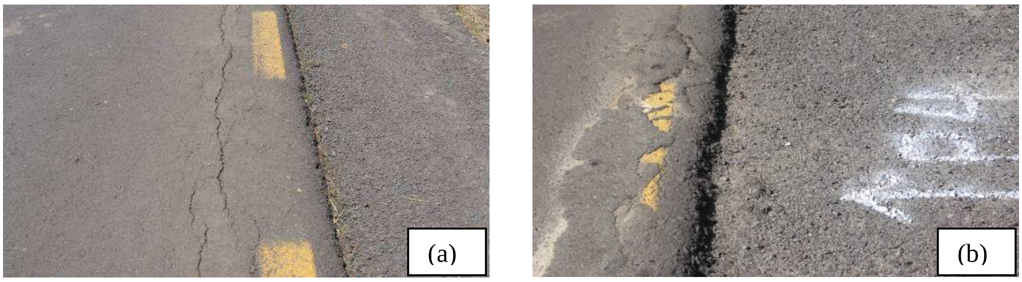

FIG. 1. Typical unsealed and sealed longitudinal crack. Fig. 1a from Mgangira & Paige-Green (2008)

Cracks were also observed on the shoulders with very little or no differential elevations. Fig. 2 shows the crack propagation on the shoulders from two different test pits.

Fig. 3 shows the propagation of a crack in the in-situ material under the embankment. The reddish soil is the selected fill. The crack in this case is not vertical

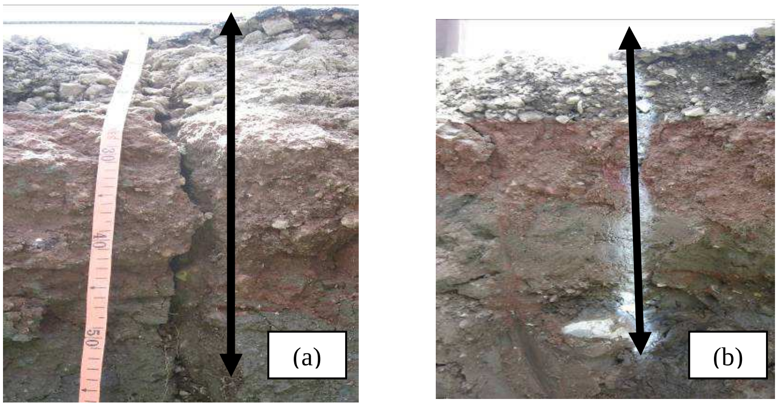

FIG. 2. Observed crack propagation on shoulders. Fig. 2a Modified from Mgangira and Paige-Green (2008)

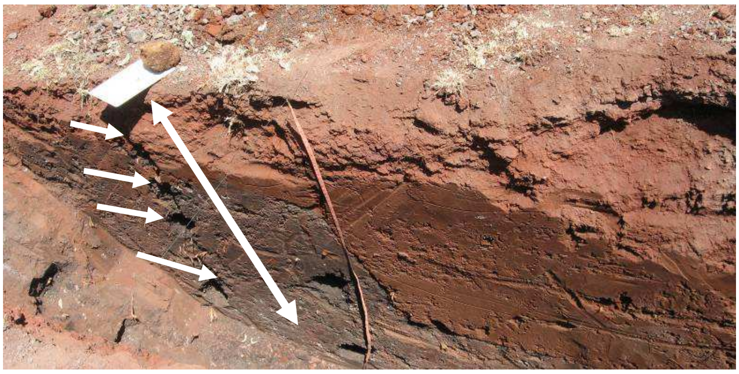

FIG. 3. Crack propagation within the embankment

Fig. 4 shows the typical pavement structure. It also shows the general orientation of the crack at this test pit, which is again not vertical.

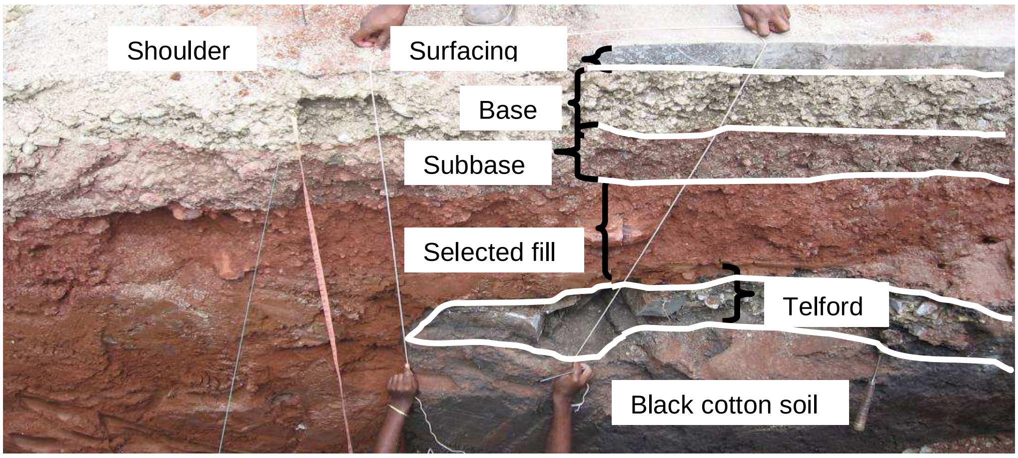

FIG. 4. Typical pavement structure

that the orientation of the crack is again not vertical and that it can also change direction within the pavement, Fig. 5b. Note the binder flowing out of the Telford which came from the crack sealing. What it means is that only the upper portion of the crack was actually sealed. Fig. 6 shows the crushing experienced by the subbase under the area with surface depression within the outer wheel path.

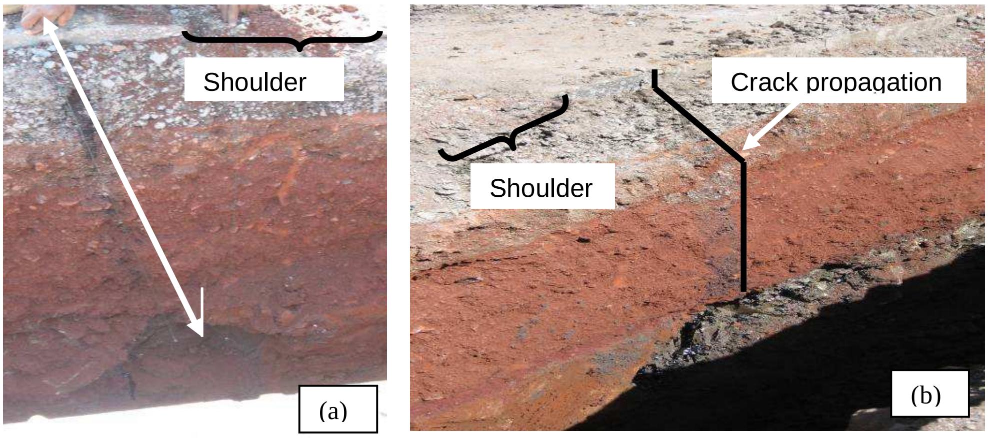

FIG. 5. Observed different crack propagation

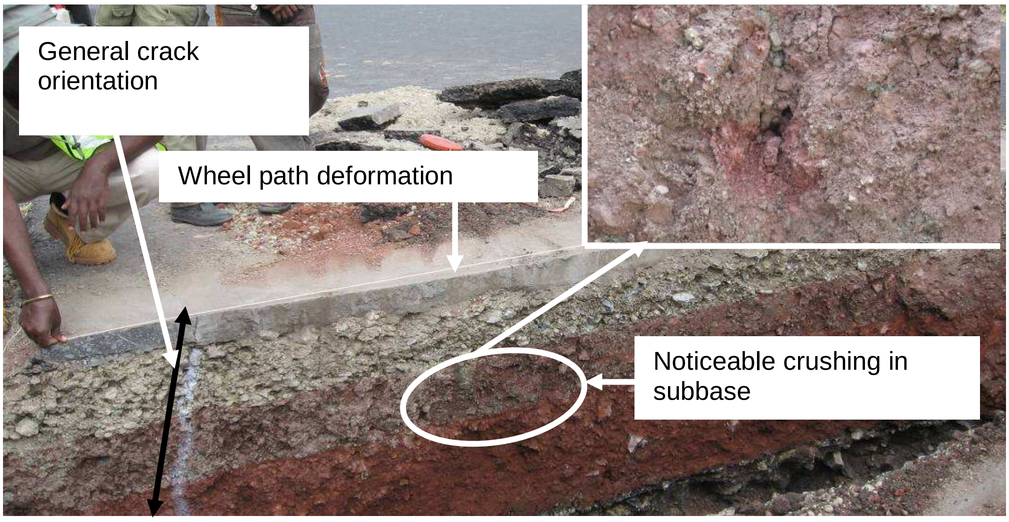

FIG. 6. Observed form of distress

The above figures have shown that the crack propagation underneath the carriageway is near the outer wheel path. The cracks pass through all of the pavement layers and that they are not always vertical. The orientation of crack propagation may be a function of the zone on the side of the road that is subjected to variation in moisture content during the dry and wet seasons. While in most cases the cracks could not easily be discerned in the roadbed itself, the extensive existence of fractures and highly slickensided structure was indicative of the seasonal movement taking place within the clay. Fig. 7 shows one of the rare situations where it was possible to discern the crack propagation within the black cotton soil subgrade. It shows for all practical reasons a vertical crack.

FIG. 7. Crack propagation within the black cotton soil subgrade

CONCLUSIONS

Based on test pit observations it has been possible to elucidate the nature of distress within a pavement that failed prematurely as a result of the highly expansive roadbed on which it was built with inadequate measures taken into account during the design for minimizing the effects of moisture changes and the associated volumetric changes. In addition test pit observations have shown that the longitudinal cracks are not always in a vertical plane with depth, they may vary in orientation within the pavement. This observation has practical implication when performing crack sealing maintenance work. When deciding on a crack sealing exercise determination of crack orientation is essential otherwise crack sealing is only effective within a limited depth.

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REFERENCES

Aubeny, C. and Lytton, R. (2002). "Properties of high-plasticity clays." *Report 0-2100,* Texas transportation Institute, College Station, Texas.

Chen, F.H. (1988). “Foundations on expansive soils.” *Developments in Geotechnical Engineering, Vol. 54*. New York: American Elsevier Science Publications

Holtz, W.G and Gibbs, H.J (1956). “Engineering properties of expansive clays.” *Transactions, American Society of Civil Engineers*, 121:641-677

Nelson, J.D and Miller, D.J. 1992. “Identification and classification of expansive soils" *Expansive soils: Problems and practice in foundation and pavement engineering*. Wiley, New York, 40-57

Mgangira, M.B and Paige-Green, P. (2008). "Evaluation of damage to a road and sports complex on expansive clays." *Proc., 6th Int. Conf. on Case Histories in Geotechnical Engineering,* Missouri University of Science and Technology, Arlington, Va., Paper 8.08b.

Seed, H.B., Woodward, R.J and Lundgren, R (1962). "Prediction for swelling potential for compacted clays." *Journal of the Soil Mechanics & Foundation Engineering Division, American Society of Civil Engineers*. Part 1, 88 (SM3):53-87

Van der Merwe, D H (1964). "The prediction of heave from the plasticity index and the percentage clay fraction of soils." *Trans. S Afr. Instn Civ. Engnrs*, 6(6): 103-107.