Towards sustainable local urban road pavements

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Abstract

Preservation of pavements reduces the waste from reconstruction and the associated costs, delays and environmental effects. Controlling the deterioration of road pavement through timely maintenance can extend its life and reduces the likelihood of failure and/or further damage and subsequent traffic and environmental problems. The type of maintenance program and the accuracy of its timing depends largely on the reliability of the available performance models, which is dependent on the quality of condition data. Local government agencies in Australia have a limited budget to manage their road assets and limited condition data is collected every 5-10 years. This paper describes a simple methodology for developing cracking models of asphalt-surfaced pavements from the available limited condition data. The models developed in this study were validated using other data sets and compared with some of the published cracking models. The new methodology proved to be effective and reliable.

Keywords: cracking, flexible pavements, local roads, deterioration model.

1 Introduction

Local Government Authorities (LGAs) across Australia have adopted a variety of Pavement Management Systems (PMS) to guide the development of their maintenance and rehabilitation strategies at the lowest life-cycle costs. Many managers are reporting that forecasts of pavement performance from their PMS packages do not always predict actual conditions. This is due primarily to the pavement prediction models used in existing PMS’s being based more on the performance of overseas pavements, and not necessarily reflecting Australian conditions, Martin [1]. Further many of these models were developed for pavements with heavy loadings and require input data that is not normally
collected by LGAs. The mechanisms of distress of such pavements differ from the ones observed in lightly loaded local pavements. The deterioration of the latter pavements is not traffic related. The damage caused to these pavements is mainly environment and material related. They are usually built with thin asphalt seal on granular base and subbase, which makes them more susceptible to thermal cracking and hardening than pavements with thick surfacing, Boutin and Lupien [2]. Therefore it is not surprising that the forecasts obtained using these PMSs proved unsatisfactory. Cracking is a very important performance parameter of these pavements as it influences potholing and patching and they in turn influence rut-depth progression.

Pavement deterioration models are a critical component in any PMS and accurate models are essential in order to better manage road pavements and ensure their structural, functional and economical sustainability (optimize the limited available budget). Controlling the deterioration of road pavement through timely maintenance can extend its life, improves its serviceability and reduces the likelihood of failure and/or further damage and subsequent traffic and environmental problems. This paper describes the development of a simple methodology for developing cracking progression models of asphalt-surfaced flexible pavements from the limited condition data collected by five Victorian LGAs.

2 Description of the database

Pavement condition data of local roads is collected through visual assessment surveys. The most important distress observed in the databases of the participating LGAs with reliable data was cracking. The databases contain information from one or two condition surveys performed in the last 10 years. The data represent different pavement sections with different ages i.e. a snapshot of pavement condition at a point in time. The information available for each section of road was: Unique identification code, year of construction, dates and types of major treatments, date of surveys and results of the survey in percentage of area affected, type of original surface, type of base and subbase, traffic volume and percentage of heavy vehicles.

3 Method of analysis

The first step in the analysis was to categorise pavement sections into similar groups according to type and thickness of the structure (surface and base), type of last treatment and traffic volumes. All the analysed sections were based on granular bases and two different treatment groups were identified namely, asphalt overlays and reseals. The age of the road section at the time of the survey was calculated from the date of most recent rehabilitation treatment. The calculated age of the sections analysed in this study varied from 0 to 90 years. This large age span was probably caused by unreported maintenance. As a result, the primary analysis of this study was performed on the data with the age band 0
to 15 years. Figure 1 shows a typical data set for one of the participating LGAs for sections with 25mm original asphalt surfacing.

Figure 1: Data distribution of one LGA.

The analysis of the homogeneous data sets indicated that for any age, a wide range of pavement conditions (percentage of cracking) could be observed. This range usually varies from zero to a maximum value that increases as the pavement age increases. Graphically a typical data set can be visualised as columns that increase in height with age as presented in figure 2. Cracking progression of the sections with high extent of cracking can be represented by the trends of the values at the top of these columns.

Figure 2: Typical model of data distribution in a snapshot survey.
Figure 2 also shows that the rate of cracking progression is low (1st Stage) during the first 4 to 6 years after cracking initiation. After that, cracking progression rate increases with time. This was observed in every LGA database. It can be also noticed from the figure that cracking data is arranged in parallel trends over different age ranges. These parallel trends could be explained by the fact that a homogeneous section of road will not develop cracking in its entire surface at the same time. However, when cracking starts, the deterioration curve always follows the same trend of progression, Paterson [3]. Therefore, parallel deterioration trends will be developed, indicating the start of cracking progression at different ages.

Figure 3 shows the database for one of the participating LGAs. Although this database is small compared to the rest but it has enough information to outline a clear trend. The observations at the top of the columns represent the sections that start to crack first. They form the envelope that provides the worst-case performance model of the asset under conditions of no rehabilitation (top curves in figures 2 and 3). The envelope trends represent the performance (cracking progression) of pavement sections with different cracking initiation times.

![Graph showing cracking progression over age](image)

Figure 3: Data set with a clear space between the main and the secondary trend.

Analysis of the data with ages >15 years indicated the presence of progression trends that are parallel to the one observed in the main age band (0 to 15 years) as can be seen in figure 4. This confirms the fact that cracks starting at any age will propagate at the same rate. Therefore, the secondary age bands were used to validate the trends obtained with the main age band. To test the parallelism of the trends between the different age bands, the ages of the secondary band observations were adjusted by a certain number of years (trial and error) to move them along the age axis without modifying their original slope until the trends of the different bands overlap.
The most important step in developing cracking models using the data in the top envelope is selecting the data forming the envelope. It was not possible to determine a unique selection criterion due to the differences among all the considered databases. Databases with relatively small number of observations, like the one shown in figure 3, a space between the trends could be observed therefore the data above such space was selected. In some LGAs’ databases, the number of observations is sparse and the scatter plot of the data is displayed in columns, usually formed by clusters of data such as those shown in figure 1. The
clusters in the top of each column were selected to determine the envelope because they represent the cracking progression of the worst case observed for those datasets.

In databases where the columns are formed by continuous data as the one presented in figure 5, the criterion is to include as many observations as possible at the top of the columns that result in a trend located as close as possible to the top of the dataset. In figure 4 the top trend was obtained using the data in the top 5% of each column while the second trend was obtained using the top 10% and it can be noticed clearly that the difference is not significant, both have the same slope.

A similar approach was utilised in the databases with large number of observations. The data was not arranged in columns and it was necessary to draw a line parallel to the trendline observed for the whole data set. All the data above that line was selected to determine the envelope. As in the previous method, the displacement of the line, including more or less data, did not disturb the slope of the best-fit line. It was observed that normally this line intercepted the x-axis between ages 4 and 6 year. In every case the envelope was considered satisfactory if it closely follows the progression trend for the whole data set.

4 Results

The procedures mentioned above were used to determine the trends of cracking progression using the data from the top envelope (worst-case scenario) of the first age band (0 to 15 years). The general form selected for these models is exponential as it best characterises cracking progression.

Eleven (11) models were developed from the databases of five Victorian LGA’s. Three different rates of cracking progression were identified as can be seen in figure 6. Road sections (group 1) constructed with thick asphalt wearing surfaces (50 –100mm) resulted in the lowest rate of cracking progression. Road sections (group 2) constructed with thin asphalt surfacing (25 mm) and sprayed seals resulted in a higher rate of cracking progression. The highest rate of progression was obtained from sections (group 3) constructed with thin asphalt surfaces (10 mm or conventional sprayed seals). These models were developed from using high number of observations from the most reliable part of each data set. Therefore, it is safe to assume that the trends in the first and second groups provide good representations of cracking progression rates for Victorian LGAs.

Cracking data from 73 main roads in Victoria with relatively low traffic volumes and located within similar climatic regions to the participating LGAs, were analysed using this methodology. Three different trends of cracking progression were observed for these road sections. A comparison with the trends obtained for LGA’s databases indicated that the rate of cracking progression for main roads is significantly higher. However, it is very similar to the rate observed for the LGAs’ third group.

The models developed for the main roads (VicRoads low, Mid, high) are presented in figure 7 with typical models developed for LGAs in this study and others proposed in other studies. The models for main road sections are very
similar to the trends proposed by Paterson [3] for heavily loaded pavements. The LCRM model developed by Norrison et al. [4] for Victorian LGAs with 50 mm asphalt wearing course is very similar to the one obtained in this study for pavements with similar characteristics.

![Typical LGA cracking progression models.](image)

**Figure 6:** Typical LGA cracking progression models.

## 5 General model

Two exponential models were developed for cracking progression in Victorian LGA networks. The parameters included in the models include, age of the surfacing, thickness of the original surfacing (Thk) and an environmental factor, the Thornthwaite Moisture Index (TMI). TMI is a number that indicates the relative wetness or dryness of a particular soil-climate system, Nelson and Miller [5].

The model developed for pavements constructed with original asphalt surfacing and treated with asphalt overlays has the form shown in equation (1).

$$ CRK = e^{\left(0.764 \times Age^{0.615} + 0.007 \times TMI - 0.018 \times Thk\right)} - 1 $$  \hspace{1cm} (1)

Equation 2 presents the model form developed for pavements constructed with original asphalt surfacing and treated with conventional sprayed seals.
These models can be applied to local roads constructed with original asphalt surfaces with thickness between 25 and 100 mm and located in areas with TMI between −5 and 8. The prediction capability of the models seems to be good ($r^2 = 0.68$ and 0.84 respectively) however additional analysis is required to extend the applicability of the model to a broader range of conditions and to determine the influence of many factors that were omitted in this study due to the lack of information.

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CRK = e^{\left(1.707 \times Age^{0.458} - 0.168 \times TMI - 0.024 \times Thk\right)} - 1 \tag{2}
\]

Figure 7: Comparison of the LGA trends of cracking progression with published models.

6 Conclusion

A new and simple method of analysis is developed and tested for use in developing deterioration models from snapshot pavement condition data collected by visual assessment. The models developed (described herein) using this methodology compared well with other published models for lightly loaded pavements. Two general models for local urban pavements with different surfacing and treatment types are proposed.

This methodology proved to be a promising tool for developing deterioration models from visual assessment surveys. However it is important to note here
that this method is effective only with proper categorisation of the surveyed road sections into homogenous groups. Further good understanding of the mechanism of distress development and interaction with the factors that affect its development is essential. Local government agencies can use these deterioration models in their PMSs to prioritise and optimise their maintenance and rehabilitation programs and secure their assets’ sustainability.

References


