Assessment of Performance and Maintenance of Flexible Pavement Using KENLAYER and HDM-4

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ABSTRACT: This paper describes the performance of flexible pavement using the KENLAYER and Highway Development and Management (HDM-4) software for urban roads. This study includes the study area of four-lane and two-lane roads at Hyderabad city, such as Gandi Maissama to Bachupally (GB), Bachupally to Nizampet (BN), Miyapur to Bachuapally (MB), JNTU to Pragathi Nagar (JP). The distress data like rutting, fatigue, pothole, patches, and edge drop data of each roads section were taken by adopting the manual methods. The pavement deterioration model was selected and developed based on the available distress using both the software KENLAYER and HDM-4. The current study aims to forecast the performance of specific roads in order to calculate the damage ratio. It also provides the design life of the roads as per the current and future traffic based on the distress model. Further, the maintenance of the particular roads is carried out using the HDM-4 models. It is also noticed that major damage was found in Gandi Maissama to Bachupally than the other road section. This study concluded that the comparative study of different roads section and governing factors for distress along with the allowable limits of distress in each section of the flexible pavement were found. Finally, the output of KENLAYER and HDM-4 has been compared.

Key words: Rutting, Fatigue, Pothole, Patches, KENLAYER and HDM-4.

1. Introduction

Pavement structure is one of most important civil infra-structure for growth of the any country. The pavement quality and service life gain attention toward optimum performance maintenance strategies. Many pavement distress are evaluated and analysed under the dynamic response of the road surface. The present study focus on the utilisation of KENLAYER and HDM-4. The design analysis of particular stretch in the form of vertical and horizontal stress using the KENLAYER. HDM-4 were used for develop the deterioration flexible pavement.

From the literature study, it was noticed that the many of the distress like rutting, fatigue, pothole, patches, and edge drop etc are cause poor riding quality for flexible pavement structure. To arrest these distresses, there is need of proper maintenance approaches. It is required to improve the performance of the pavement for long time period within given cost. Furthermore, the mechanistic procedure of flexible pavements is a new design technology that includes several distress models, including fatigue cracking and rutting. These models are used to calculate the design life of pavements. The flooring is built in accordance with industry standards and design specifications [1]. Daba (2006) for predicting the performance, the project level models and network level models divide into two parts. The work involved assessing, selecting and calibrating performance prediction models for models for pavement worsening. The cracking model was found to govern out of the eight deterioration models. Studies have shown that the pavement life of HDM-4 is lower than the life of KENLAYER software. However, because of early degradation, paving facilities are not efficient, safe, convenient, or cost-effective during the design period. Deterioration of paving is generally based on original layouts, material types, building quality, volume of traffic, Characteristics of axle load, road geometry, conditions of the environment and paving age as well as maintenance policies [2].

To determine the maintenance and rehabilitation needs of pavements, a scientific approach must be developed. Efforts must also be made to develop road management and planning tools in order to
improve the existing road network. These tools are critical for determining financial requirements, alternative maintenance strategies, and work priorities. In this case, an effective Pavement Management System (PMS) development and practices will provide objective data and useful make sure continuous and efficient decision-making on road network maintenance. The functional evaluation of flexible pavement the inventory data like Cracking, Patching, Rutting, fatigue and Potholes along with the traffic volume data of each stretches. Further, to analyse the performance of the urban KENLAYAR AND HDM-4 software are considered to predict the pavement's performance. During the data collection, road surveys will be carried out and noticed the structure and functionality of the pavement. Data are then collected and uploaded to the software KENLAYER & HDM-4 which is used this study. Morosick et al., (2000) it was reported that HDM-4 relationships for cracking, rutting, and roughness were calibrated against observed rates of deterioration of inter-urban pavements in West Java. The detailed designs were found to be very useful for estimating the extent of defects on poorly designed or constructed pavements. In the detailed model, the calibration factor was close to unity, with a value of 1.3 for heavy traffic roads and 1.0 for light to medium traffic roads. To compensate for the lack of distress terms, the aggregate model's value of K had to be increased roughly fivefold, i.e., 5.3 for roads with heavy traffic and 5.5 for roads with light traffic. When issues with records and information, engineering, and systems are resolved and major reinvention is implemented, the paper emphasises that they can be transformed into chances that significantly enhance the pavement [3].

The HDM-4 analyses demonstrated that the maintenance process with SDBC of 25 mm was optimal on urban roads and the average periodical interval required for the renewal of road surface was 2 years among the numerous alternatives indicated in government of India requirements [5, 6]. Jain et al. (2005) HDM-4 pavement deterioration models were calibrated using national highway portions in India's Uttarakhand and Uttar Pradesh states. Data on cracking, ravelling, potholes, and roughness were gathered and utilised to calibrate HDM-4 pavement deterioration models. To ensure the correctness of the calibrated models, these models were verified using percent variability and coefficient of determination (R2). They discovered 10.8 to 28.2 percent variability between observed and projected values for cracking, 15.4 to 39.4 percent variability for ravelling, 0 to 66 percent variability for potholes, and 2.1 to 15.1 percent variability for roughness [7].

Thube and Thube (2013) calibrated the HDM-4 software's pavement deterioration progression models for low volume roads (LVR) in India Calibration of cracking, ravelling, edge break, and pothole progression models for unbound base kinds of pavement composition was done. The best calibration factors were found by changing the calibration factor from 0.1 to 20 at 0.1 increments. The best calibration factor for each model was chosen based on its average absolute error (AAE), root mean square error (RMSE), and coefficient of determination (R2) [4, 8].

1.1. Objectives of Present study

i. To identify and analyze the various types distress in flexible pavement

ii. To predict the distress models using KENLAYER and HDM-4 for different stretches.

iii. To develop the systematic approaches to reduction of distress for current and future traffic.

2. Asphalt Pavement Distress

For periodic floor assessments, distress surveys are required. The surveys are designed to assess the daily management required to avoid accelerated distress and to identify the type of rehabilitation measures required. The surveys provide the information required to define distress, severity, and density. Furthermore, the surveys contain the information required to calculate the deduction values for each level of distress and severity. This section describes some of the pavement stress parameters, such as cracking, patching, ravelling, rutting, and potholes, as well as their likely causes. There are four types of major common bitumen surface distress: Default on the surface: rutting, fatigue, pothole, Surface deflection: Rutting, distortion, settling, frozen heave, Cracks: Cracks transverse, reflective, slip, longitudinal, Potholes and patches.
3. METHODOLOGY

The current study analysed the KENLAYER pavement overall performance programme and the HDM-4 using a test section in Hyderabad City. KENLAYER takes under consideration distress models: fatigue and rutting at the lowest of the asphalt layer and on top of the subgrade, respectively. The programme predicts how well the new pavement will perform. The HDM-4 software program is used to decide the once a year situation of the pavement after it's been constructed, in addition to flexible pavement signs that may be used to suggest the every year scenario of pavement structure. Two distress models in the maximum current model of the KENLAYER computer programme, in addition to deterioration models in the HDM-4 software program, have been used to forecast pavement overall performance. The outputs have been as compared on the way to decide the models that govern distress and deterioration. Finally, HDM-4 has been placed to apply for maintenance.

4. Data collection

In this study, From Gandi Maissama to Bachupally (GB), Bachupally to Nizampet (BN), Miyapur to Bachuapally (MB), JNTU to Pragathi Nagar (JP) these stretches are collected the data. Data has been collected for the following distress are to be collected. Potholes, Fatigue, Rutting, Edge Drops, Patches and traffic volume etc. the below figure 1 and 2 shown the manual data collection of patches at Pragathi nagar. The table 1 depicts the percentage of distress data.

![Figure. 1 Patches at Pragathi Nagar in transfer direction.](image1)

![Figure. 2 Patches at Pragathi Nagar longitudinal direction](image2)

These data was collected in manual and it will be takes for different stretches in above mentioned routes there will be added dataset in respectively.

**Table 1. Percentage of distress data**

| Parameter   | GB  | JP  | BN  | MB  |
|-------------|-----|-----|-----|-----|
| Pothole     | 1.29| 1.39| 0.62| 1.02|
| Rutting     | 0.56| 0.43| 0.63| 0.41|
| Fatigue     | 0.12| 0.32| 0.31| 0.32|
| Patches     | 0.50| 0.28| 0.63| 0.71|
| Edge Drop   | 0.16| 0.22| 0.05| 0.11|
5. Traffic Volume Counts

Traffic counts were carried out manually by a sufficient number of enumerators. Vehicles are listed as representative cars, such as two wheeled vehicles (TW), a passenger car (PC), a bus (BUS), a Light Commercial Vehicle (LCV) (HCV). On the left and right wheel path, traffic data were collected. The collected data is a classified volume count of 10 hours observed (motorised and non-motor vehicles). Both the summit in the morning and the summit in the evening were taken together with the peak time opened to traffic. In HDM-4, there are deterioration models, primarily structured empirical models. The study area of the present study was shown in below figure 3.

![Figure 3. Different road Sections](image)

6. ANALYSIS OF DATA AND DISCUSSION

The traffic data of different stretches are shown in figure 4. The annual average data of each route were noticed during peak hours. It is indicate higher traffic volume at MB stretch then the others stretches such as 24000 AADT to 53000 AADT for 2021 to 2035 respectively.

![Figure 4. HDM-4 Vehicles data](image)

6.1. Pothole

Potholes are hollows in the road's surface that resemble bowls. Potholes are the most severe type of pavement distress, caused by spalling of wide cracks and disintegration of the surfacing and, eventually,
the base material. The progression of potholes was modelled as a function of modified structural number, pavement age since last renewal, initial pothole area, initial ravelling area, and construction quality.

Potholes are surface distresses that occur due to cracking, ravelling, or both. The presence of water in cracking and ravelling hurries up the pothole formation through weakening the pavement shape and decreasing the resistance of the floor and base substances to disintegration. For modelling the potholes, creation defects indicator (CDB) is used as a variable and the usual pothole unit is taken into consideration as 0.1 m². The determined numbers of preferred pothole gadgets on the give up of the year 2035 for the identical six pavement sections are in comparison with the ones anticipated through HDM-four pothole development model. The determined and anticipated values of pothole on the give up of the year 2035 and their variations. The figures 5 and 6 proven the pothole facts in step with stretches and HDM-four evaluation respectively.

6.2. Rutting

Rutting is described because the everlasting or unrecoverable traffic-related deformation inside pavement layers which, if channelized into wheel paths, accumulates through the years and manifests as a rut. Rut intensity modelling is completed after the values of all of the floor distresses (that is, cracking, ravelling, potholing and edge-break) on the give up of the year had been calculated. The underneath figures 7 and 8 proven the rutting facts with respective numerous stretches and HDM-four evaluation respectively.
6.3. Edge Drop

Edge Drop can be defined as the loss of surface and base material at the pavement edge, caused by the shear failure, and attrition. This defect commonly on narrow roads with unsealed shoulders, where vehicles wheels pass on or close to the pavement edge. No edge break is predicted for roads with a carriageway width greater than 7.5 meters. The measure for edge break that is provided as input into the model, and the corresponding output data, is in square meters per km. The edge drop data were collected and analysed were shown in figure 9 and 10 respectively.

In above figure the edge drop is highest values are occurred in JNTU To Pragathi nagar (JP) -1.520 & Gandi Maissama to Bachupally (GB) – 1.239 .To compare these particular junctions to the pavement condition is better than Bachupally to Nizampet (BN).

6.4. Patches

Patches in the road profile is a major concern for road users because it affects the dynamics of moving vehicles and vehicle wear and tear. The rate of distortion is accelerated when the pavement weakens due to surface defects such as cracking, ravelling, potholing, and so on. The progression of roughness is modelled as a function of Modified Structural Number, Initial Roughness, Initial Ravelling, Initial...
Pothole, Pavement age since last renewal, and Construction. The below figures 11 shows the patches data according to stretches using the HDM-4 analysis.

Figure 11. Section wise patches data

6.5. Fatigue cracks

Cracking is the one of the maximum distress in bituminous pavements. Fatigue is getting old had been identified because the most important factors, which make contributions to cracking of bituminous pavement layer. The propagation of cracking is accelerated on account of the getting old and the ingress of water, which could drastically weaken the underlying pavement layer. There are cracking taken into consideration in HDM-4. Structural cracking, transverse thermal cracking.

Figure 12. Section wise fatigue data

Fatigue data of each stretches were evaluated and shown in figure 12. It is noticed that the maximum fatigue at JP route as 2.012 m². The minimum fatigue were found as 0.75 at GB route. The fatigue analysis were carried out using HDM-4 it was shows in figure 13.

Figure 13. Analysis of fatigue data using HDM-4
From the study, it was noticed that the various distress at different level. The figure 14 shows the each stretch distress data like pothole, rutting, fatigue, patches and edge drop. It is observed that the pothole are more and lower distress were found as edge drop in each stretches respectively.

7. Analysis Using KENLAYER:

For the design period, all axle loads in the ESAL method have been translated into comparable standard axle loads. Because it involves strengthening an existing route, the design term has been set at 15 years. ESAL at end of the 15 year period, using annual growth 6%. 51.45 (msa), and the identical has been used for predicting pavement performance. Horizontal tensile pressure at the lowest of the asphalt concrete layer and vertical compressive pressure at the top of subgrade are dealt with the use of layout techniques Asphalt Institute (AI) and Shell layout techniques. The sum of harm ratio is 0.00635, and layout lifestyles is 20 years. Respectively. The distress models using KENLAYER are depicted in Table 2.

Further design of flexible pavement the present traffic load is considered. All the load were converted and taken in Equivalent Standard Axial load (ESAL) and the design life of pavement were extended as 15 years. The distress like rutting and fatigue were studied and analysed using the KENLAYEAR and also the stress and strain in existing pavement were determine. This is use full in development of pavement deterioration models.

Table: 2 Distress models using KENLAYER

| Methods of traffic volume | Method of Design     | Design Life in year |
|--------------------------|----------------------|---------------------|
| ESAL                     | Asphalt Institute (AI)| 20                  |
|                          | Shell                | 19                  |
8. HDM-4 Deterioration Models

The HDM-4 Road Deterioration and Work Effects models attempt to estimate pavement deterioration and maintenance over time based on a variety of environmental, road, pavement, and traffic parameters. These models include provisions for adapting relationships to local conditions via ‘deterioration (calibration) factors.’ These variables are linear multipliers of predictions for the onset and rate of progression of various modes of distress, such as cracking, ravelling, pot-holes, and roughness. Users can specify the calibration factors, and if no user specifications are provided, the model uses a default value (usually one) for each.

Figure 15. Surface damage sections in HDM-4

These are the measured with different distress data will be collected in different stretches like (GB, JP, BN, MB) the collecting data will be adopted on Rutting, Fatigue, Pothole, Patches, Edge drop, etc. The surface damage of section in HDM-4 is depicted in Figure 15.

9. Maintenance of Pavement using HDM-4

The maintenance intervention, but with limits based on HMD-4, for which no standards exist in India. HDM-4 was used to perform condition-responsive maintenance on pavements over a 15-year period. Only rutting and roughness were found to be critical and in need of maintenance. The effects of maintenance on both are discussed further below.

10. Maintenance of Effective

Condition-responsive maintenance for roughness and rutting was completed after 15 years. The roughness and rutting of the pavement have returned to their original levels as a result of the maintenance intervention.

Figure 16. Average Roughness overall sections in HDM-4
The average roughness of the particular route were found as HDM-4 analysis, its shown in figure 16. It is indicated that at the end of the 15 years the pothole can reach upto the 13 m/km.

![Progression of Damaged Surface Area over time](image1)

**Figure 17.** Overall Damaged surface data in HDM-4

From the analysis of pavement, the progress damage were noticed and shows in figure 17. The progression of damage were shows as more after 8 years (2029). It was found the total damage will take place with all distress are 30 percent. The below figure 18 shows the progress of rutting in each stretches with respective duration (Years) is shown.

![Progression of the Rutting over time](image2)

**Figure 18.** Rut depth different road sections data

11. CONCLUSION

From the study, the following are the conclusion are drawn such as:

- The analysis of stress with respective obtained AADT were made using the KENLAYER for 15 years, how the distress were obtained form the data. We can analysing road management system and evaluated the assist the pavement design.
- These distress model were developed to compare in HDM-4 from each route and discussed. It is noticed that pothole are affected road surface then the other distress. The study indicated the maximum patches in BN and MB route. The progression of damage with respective duration were also estimated.
- This study indicate the maximum and minimum distress for various route such rutting, Fatigue, pothole etc. Among the route are the maximum obtained Miyapur and Bachupally Pothole 4.064 Rutting 2.899 fatigue 1.560 and respectively.
The study concluded that the major distress like pothole (4.064 m$^2$) and patches were accrues in higher traffic roads, were rutting as found as in permissible limits. So that the study recommends the particular stretches (GB and JB) is needed an overlay.

REFERENCES

[1] Gedafa, D. S. (2007, August). Performance prediction and maintenance of flexible pavement. In Proceedings of the 2007 Mid-Continent Transportation Research Symposium, Ames, Iowa (pp. 16-17).

[2] Gedafa, D. S. (2006). Present Pavement Maintenance Practice: A Case Study for Indian Conditions Using HDM-4. In 2006 Transportation Scholars Conference Iowa State University, Ames.

[3] Morosiuk, G., Toole, T., Mahmud, S., & Dachlan, T. (1999). Modelling the deterioration of bituminous pavements in Indonesia within a hdm-4 framework. In The 21st World Road Congress, PIARC, Kuala Lumpur, Malaysia.

[4] Thube, D. T. (2013). Highway Development and Management Model (HDM-4): calibration and adoption for low-volume roads in local conditions. International Journal of Pavement Engineering, 14(1), 50-59.

[5] Jorge, D., & Ferreira, A. (2012). Road network pavement maintenance optimisation using the HDM-4 pavement performance prediction models. International Journal of Pavement Engineering, 13(1), 39-51.

[6] Veeraragavan, A., & Reddy, K. R. (2003). Application of highway development and management tool for low-volume roads. Transportation research record, 1819(1), 24-29.

[7] Jain, S. S., Aggarwal, S., & Parida, M. (2005). HDM-4 pavement deterioration models for Indian national highway network. Journal of Transportation Engineering, 131(8), 623-631.

[8] Sood, V. K., & Sharma, B. M. (1996, November). Development of pavement deterioration models for Indian conditions. In Journal of the Indian Roads Congress (Vol. 57, No. 3)