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Review On Indian Highway Rehabilitation Strategies for Urban Bituminous Surface Road

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ABSTRACT

In India, the road traffic volume has increased manifolds during the post-independence period. The traffic axle loading may also in many cases be much heavier than the specified limit. As a result of which, the existing road network has been subjected to severe deterioration leading to premature failure of the pavements. In such a scenario, development of the effective pavement management strategies would furnish useful information to ensure the compatible and cost-effective decisions so as to keep the existing road network intact. The pavement deterioration models can prove to be an effective tool which can assist highway agencies to forecast economic and technical outcome of possible investment decisions regarding maintenance management of pavements. The optimum maintenance and rehabilitation strategies developed in this study would be useful in planning pavement maintenance strategies in a scientific manner and ensuring rational utilization of limited maintenance funds. Once this strategy for urban road network is implemented and made operational; this would serve as window to the other urban road network of different regions.

Keywords: pavement, maintenance and rehabilitation, strategy, cost, benefits, deterioration.

I. INTRODUCTION

The main objective of this study is to develop a strategy to select the most appropriate activities to be carried out at different pavement sections of a highway network considering their priority for maintenance. By providing appropriate maintenance treatment at appropriate time, the rate of deterioration can be deferred to a great extent and this will reduce the maintenance cost of roads. If timely maintenance is not provided, the reconstruction will become unavoidable. Therefore, pavement maintenance is one of the most important components of the entire road system. There are different type of distresses can occur on the pavement like cracks, rutting, potholes, shallow depressions, hungry Surfaces etc. Photograph 1 shows some of the important distresses generally occur on highway pavement in India. Pavement deterioration causes for accidents on roads and which will increase the loss of life and properties. Once pavements starts to deteriorate; they deteriorate rapidly beyond the point where maintenance is effective. Thus, timely maintenance of the highway pavement is essential. The maintenance process involves the assessment of present conditions of road, judgment of the problem and adopting the most relevant maintenance.

PAVEMENT REHABILITATION

Pavement rehabilitation is defined as a structural or functional enhancement of a pavement which produces a substantial extension in service life, by substantially improving pavement condition and ride quality. Pavement maintenance activities, on the other hand, are those treatments that preserve pavement pavement condition, safety, and ride quality, and therefore aid a pavement in achieving its design life. Pavement maintenance activities are not addressed in this report. Individual rehabilitation treatments are often categorized as belonging to one of the "4 R's" – restoration, resurfacing, recycling, or reconstruction. There are some problems with trying to fit each rehabilitation treatment into one of these four major categories. For example, some treatments may be done as part of a restoration effort or as part of a resurfacing effort.

II. RESTORATION

Restoration is a set of one or more activities that repair existing distress and significantly increase the serviceability (and therefore, the remaining service life) of the pavement, without substantially increasing the structural capacity of the pavement. Resurfacing may be either of the following:

(a) A structural overlay, which significantly extends the remaining service life by increasing the structural capacity and serviceability of the pavement, usually in combination with preoverlay repair and/or recycling. A structural overlay also corrects any functional deficiencies present.

(b) A functional overlay, which significantly extends the service life by correcting functional deficiencies, but which does not significantly increase the structural capacity of the pavement.

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Recycling is the process of removing pavement materials for reuse in resurfacing or reconstructing a pavement (or constructing some other pavement). For asphalt pavements, this process may range from in-place recycling of the surface layer, to recycling material from all pavement layers through a hot mix plant.

For concrete pavements, recycling involves removal and crushing for reuse as aggregate, either in the reconstruction of the pavement or for surface, base, or subbase layers in other pavement construction. Recycling of asphalt-overlaid concrete pavement may be either surface recycling or removal and recycling of both asphalt and concrete.

In this case, the asphalt and concrete layers are removed and recycled separately. Reconstruction is the removal and replacement of all asphalt and concrete layers, and often the base and subbase layers, in combination with remediation of the subgrade and drainage, and possible geometric changes. Due to its high cost, reconstruction is rarely done solely on the basis of pavement condition. Other circumstances, such as obsolete geometrics, capacity improvement needs, and/or alignment changes, are often involved in the decision to reconstruct a pavement.

PAVEMENT TYPES ADDRESSED

This report addresses rehabilitation of highway pavements; it does not address rehabilitation of unpaved or surface-treated low-volume roads, nor rehabilitation of urban streets, although many of the concepts and techniques are applicable to these types of facilities.

The pavement types addressed in this report are briefly described below. Asphalt concrete pavement is also sometimes referred to as asphalt pavement or flexible pavement. Asphalt pavement on untreated or treated base has a hot-mixed asphalt concrete surface, usually over a base layer which may be either untreated or treated granular material, and possibly a subbase layer (usually untreated). Full-depth asphalt concrete pavements are those in which all layers contain an asphaltic binder. The asphalt concrete layers (which may be of different gradations and asphalt cement contents) are constructed directly on the prepared subgrade. Portland cement concrete pavement is also sometimes referred to as concrete pavement or rigid pavement. Jointed plain concrete pavement (JPCP) has transverse joints typically spaced less than about 20 ft apart, and no reinforcing steel is provided in the slabs. It may have steel dowel bars across transverse joints, and steel tiebars across longitudinal joints.

Jointed reinforced concrete pavement (JRCP) has transverse joints typically spaced more than 20 ft apart. The reinforcement (welded wire fabric or deformed steel bars) comprises about 0.15 to 0.25 percent of the cross-sectional area of the slab. Due to its longer joint spacing, jointed reinforced concrete pavement is expected to develop midslab cracks. The purpose of the steel reinforcement is to keep these cracks tight. Transverse joints are typically doweled in jointed reinforced concrete pavement. Continuously reinforced concrete pavement (CRCP) does not have transverse joints, other than the transverse construction joints placed at the end of each day's paving and at abutting pavement ends and bridges. Continuously reinforced concrete pavements have a considerably higher steel content than jointed reinforced concrete pavements – typically 0.6 to 0.8 percent of the cross-sectional area.

The purposes of the longitudinal steel are to control the spacing of cracks resulting from drying shrinkage and temperature changes and to keep these cracks tight. Transverse reinforcing steel is often used to support the longitudinal steel during construction and to control any random longitudinal cracks which may develop. All three types of concrete pavements are usually constructed on a layer of untreated or treated granular material, commonly referred to as the base layer. In some cases, a lower-quality gravel is used to separate the base from the subgrade. This layer is commonly referred to as the subbase.

III. LITERATURE REVIEW

[1] Bhavesh Jain et al. Rapid urbanization and exponential increase in the number of vehicles on city roads have triggered issues like air pollution and accidents, endangering the health of millions of people in Indian cities. Vehicular emission is a major contributor to air pollution in Indian cities. This study primarily analyses the relative effects of riding quality and pavement surface type on vehicular fuel consumption (FC) in an urban environment. This study utilizes the Road Asset Management System (RAMS) applications to predict FC in different scenarios of pavement maintenance. Highway Development and Management (HDM-4) software was integrated into RAMS for network & economic analysis and FC prediction of the road network. The study was conducted on the Pune city road network in India, and the results revealed a 2.32 % reduction in fuel use if timely maintenance is provided. Over 0.128 million liters of fuel per 1000 vehicle-km can be saved over the study network of only 36.5 km over the next 15 years, equivalent to US$ 155,206.18 in 2021. The analysis of covariance test results showed the significant effect of pavement surface type on fuel consumption, with 4.86 % less fuel

consumed on cement concrete surfaces than bituminous surfaces. About 99.431 liters per 1000 vehicle-km of fuel were utilized by the vehicle fleet on concrete pavements, while 104.513 liters per 1000 vehicle-km of fuel were consumed on bituminous pavements after adjusting for roughness characteristics of both the surface types.

[2] Aditya Singh et al. The foremost requirement for developing efficient pavement maintenance and management strategies is to ascertain the properties of the pavement material and its structural capacity. This can be done by studying the response of the pavement to the applied load. In this study, the Falling Weight Deflectometer (FWD) and KGPBACK were used to evaluate the performance of a road section of the National Highway in the state of Haryana in India by studying the deflection in response to the load applied at selected points on the highway. FWD was used to put a dynamic load on existing pavement and the response of the pavement to the load was measured. The deflection values thus obtained were used in the KGPBACK software to determine the elastic moduli of the modelled layers of the pavement. The in-situ elastic moduli obtained were further used in IITPAVE software for overlay design of the pavement. Data obtained from the study was also used as the input parameter in the HDM-4 model to predict the deterioration of the pavement with time due to the prolonged application of traffic loads. The HDM-4 model was also used to check the effect of bituminous overlay maintenance on the distress models and all four distress (cracking, ravelling, rutting and roughness) were found to decrease. Therefore, the study provided in this paper presents a guideline methodology that could be used by administrators in order to estimate when and how much of funding would require to preserve and maintain the Indian Highway Road network.

[3] Kanchi Anantharaman Vinodhini et al. Road surfaces are highly affected by climatic changes which caused potholes and cracks. Maintenance of the road is a need-of-the-hour process for preventing the physical damage caused for vehicles. The important process in road maintenance is the detection of potholes and cracks. Automatic detection of potholes in bituminous roads is a tedious task. This paper proposed the detection of potholes using transfer learning and convolution neural networks. The results are promising, and The suggested method can provide valuable information that can be used for various ITS services. One such service is alerting drivers about potholes, allowing them to be more cautious while driving. Additionally, this information can be utilized to assess the initial maintenance needs of a road

management system and promptly address any repairs or maintenance required. The achieved results through the proposed method are compared with the state-of-the-art detection algorithms like Transfer Learning + Recurrent neural network, Transfer Learning + Generated adversarial network. In that, the result obtained through the proposed method (Transfer Learning + Convolutional neural networks achieves 96 % of accuracy.

[4] N H Riyaz Khan et al. The periodic assessment of pavement condition is one of the important requirements in ensuring not only the service life of the pavement but also for the safety of motorists as pavement distresses like potholes led to many fatal accidents in recent years in India. The traditional approach of manual evaluation is a cumbersome and time-consuming process which can be replaced by latest technologies like LiDAR. Literature on use of Terrestrial LiDAR for distress detection are very limited and even the reported studies have used mostly the raw point cloud data from LiDAR for detecting only selected distresses. However, there are many outputs which can be derived from Terrestrial LiDAR data like Digital Elevation Model (DEM), Hillshade, etc. which are not explored much. Hence in the present study, an attempt has been made to utilize all the possible outputs of Terrestrial LiDAR data, i.e., raw 3D model from point cloud data and LiDAR derived DEM and Hillshade to detect 15 pavement distresses in both bituminous and concrete pavement for a case study area of Vellore in Tamilnadu, India. Their suitability also was compared in order to find which output would be more suitable in identifying a particular distress on the road. The results revealed that Hillshade maps can detect all the pavement distresses except cracks when compared to 3D model and DEM. For the detection of pavement cracks, an image processing-based solution using LiDAR data was tried out and was found to perform well in detecting the alligator cracks. The distress parameters such as length, width, depth, etc. were also calculated using LiDAR data and compared with the field observations. The error was found to be only few cms and thus indicate that the Terrestrial LiDAR can be employed to detect the pavement distresses accurately than the conventional manual methods.

[5] Yash Aryan et al. In recent years, there has been a sharp rise in the number of life cycle assessment (LCA) studies related to road pavements and road infrastructures. The main aim of this study is to perform a critical analysis of various studies undertaken so far to examine goals, scopes, impact categories, life cycle phases, methods and approaches, and limitations. A total of 67 LCA studies reported in literature were analysed and categorized into four categories viz.

flexible pavement; rigid pavement; flexible and rigid pavement; and road infrastructure. The analysis revealed that 80% of the studies were carried out in developed countries while just 20% of studies were from developing countries. Most of the road pavement LCA studies (~76%) considered material and construction phase and assessed the impacts in terms of only two impact categories viz. global warming potential and energy demand. Only 10–15% of studies considered a wide range of impact categories and used commercial software such as GaBi and SimaPro for impact assessment. 19 studies were on flexible pavements, 4 on rigid pavements, 30 on both flexible and rigid pavements and 14 on infrastructure. Bridges, tunnels, drainage, lighting, and road marking were the major components of road infrastructure studied while other road infrastructures such as culverts, toll plazas, and vehicle underpasses were not included. Majority of the studies depended on secondary or background data for the development of life cycle inventory. Out of 67 studies, only 18 studies performed the sensitivity analysis while only 6 studies carried out uncertainty analysis. There is a need for inclusion of all supporting infrastructures along with road pavement, and also for paying greater attention to sensitivity and uncertainty analysis in studies pertaining to the transportation sector. During construction phase, no LCA study considered the important impacts due deforestation, defragmentation, restriction of free wildlife movement etc. Hence, future LCA road studies must evaluate the negative consequences of these as well as integrate social and economic impacts via Multi-Criteria Decision Making to make LCA a robust decision-making tool for sustainability.

[6] Zhuangzhuang Liu et al. Recent trends in road engineering have explored the potential of incorporating recycled solid wastes into infrastructures that including pavements, bridges, tunnels, and accessory structures. The utilization of solid wastes is expected to offer sustainable solutions to waste recycling while enhancing the performance of roads. This review provides an extensive analysis of the recycling of three main types of solid wastes for road engineering purposes: industrial solid waste, infrastructure solid waste, and municipal life solid waste. Industrial solid wastes suitable for road engineering generally include coal gangue, fly ash, blast furnace slag, silica fume, and steel slag, etc. Infrastructure solid wastes recycled in road engineering primarily consist of construction & demolition waste, reclaimed asphalt pavements, and recycled cement concrete. Furthermore, recent exploration has extended to the utilization of municipal life solid wastes, such as incinerated bottom ash, glass waste,

electronics waste, plastic waste, and rubber waste in road engineering applications. These recycled solid wastes are categorized into solid waste aggregates, solid waste cements, and solid waste fillers, each playing distinct roles in road infrastructure. Roles of solid waste acting aggregates, cements, and fillers in road infrastructures were fully investigated, including their pozzolanic properties, integration effects to virgin materials, modification or enhancement solutions, engineering performances. Utilization of these materials not only addresses the challenge of waste management but also offers environmental benefits aiming carbon neutral and contributes to sustainable infrastructure development. However, challenges such as variability in material properties, environmental impact mitigation, secondary pollution to environment by leaching, and concerns regarding long-term performance need to be further addressed. Despite these challenges, the recycled solid wastes hold immense potential in revolutionizing road construction practices and fostering environmental stewardship. This review delves into a bird's-eye view of the utilization of recycled solid wastes in road engineering, highlighting advances, benefits, challenges, and future prospects.

[7] Joao Santos et al. The increasing fuel consumption demand, the accelerated pressure imposed by the depletion of scarce raw materials and the urgent environmental protection requirements are forcing the change of pavement industry and academia community's research endeavours towards the development of low emissions road paving technologies able to significantly reduce mixing and compaction temperature as well as the consumption of virgin raw materials. One of the relatively recent technologies in the field of pavement materials that aims at addressing those concerns is the incorporation of reclaimed asphalt pavement (RAP) in the production of warm mix asphalt (WMA).

It is within this context that this study presents a full process-based comparative life cycle assessment (LCA) looking at understanding the environmental impact of reducing mixing temperature, through the use of warm mix technologies, namely chemical additives-based and foamed-based, and different rate of recycling (0% and 50% RAP). Furthermore, the investigation explores the effect of combining these technologies in the construction, maintenance and rehabilitation (M&R) of wearing courses for flexible road pavements. The results of this study showed that, for the conditions considered and assumptions performed, a pavement construction and M&R scenario in which a foamed-based WMA mixture with a RAP content of 50% is employed in the wearing course throughout the pavement life cycle is the most environmentally friendly alternative among all the competing solutions.

[8] Ufuk Kırbaş et al. The correct budget allocation for road maintenance, which represents a significant infrastructure investment in urban roads, requires the accurate prediction of the deterioration of bituminous hot mix asphalt (HMA). In this study, three different deterioration models have been developed that can predict the future performance of pavements in urban HMA paved roads. First, the current condition of the pavements was measured by using the pavement condition index (PCI), which is approved by the PAVER system. Then, three different models were developed to predict deterioration in the PCI as a function of pavement age, and applied to urban road networks in Samsun (Turkey). The models used were deterministic regression analysis, multivariate adaptive regression splines (MARS) and artificial neural networks (ANN). Variations of each model were explored and the one with the highest computational efficiency was employed for ranking pavement sections with respect to rehabilitation needs. Results indicated that the three approaches had comparable prediction accuracies and R-squared values, although predictions provided by the ANN model were more accurate compared with the other models. The article provides a detailed comparison of the performance of the three models.

[9] U. Shah Yogesh et al. The Urban roads constitute about 9.0% (4.11 lakh kms) of the total road length in India. The urban roads especially in metropolitan cities carry a huge traffic volume which affects the road condition adversely. The other factors responsible for poor roads in urban areas are the problem of overloading, encroachment on the road land and ribbon development along road side, lack of attention to drainage which may lead to failure of pavement, and various utility services which necessitate frequent digging thereby disturbing homogeneity of pavement. Therefore, there is a need of an efficient Urban Pavement Maintenance Management System (UPMMS) which would be useful to the highway agencies in planning pavement maintenance strategies in a scientific manner for urban cities, to ensure rational utilization of limited maintenance funds.

[10] Tiziana Campisi et al. The objective of this work is to evaluate the walkability of urban environments from the perspective of visually impaired people, developing a qualitative analysis based on Commented Paths Method (CPM) to derive subjective evaluations from the practical experience of specific paths. Multiple-choice questions, in applying Likert scale were

used to assess physical characteristics (e.g. slope surface, sidewalk width) related to infrastructural elements of the analyzed path and their influence in the difficulty of movement, as well as interferences (e.g. need to stop, help from other people) and feelings (e.g. anxiety, tiredness) experimented along it. The elaboration of single judgments allowed the calculation of disaggregated and global Walkability Indices and the elaboration of associated thematic maps, as an innovative integration of the method, to highlight the critical aspects related to each stretch in which the path was divided.

IV. CONCLUSIONS

A life-cycle cost analysis of pavement rehabilitation strategy alternatives, when done correctly, permits the identification of the strategy which yields the best value, by providing the desired performance at the lowest cost over the analysis period. Ideally, a comprehensive life-cycle cost analysis would consider quantitatively all of the costs incurred by both the agency and the users over the analysis period. However, some of these costs are difficult to quantify, necessitating some simplifications to the life-cycle cost analysis. Furthermore, differences of opinion exist about how to quantify some inputs to life-cycle cost analysis, and about how to define the inputs to the analysis. Each agency must make its own decisions about which costs (a) the agency expects to differ significantly among rehabilitation strategy alternatives, and (b) the agency is capable of estimating reasonably well.

The conduct of this project has demonstrated clearly that, despite the enormous amount of funding dedicated to pavement rehabilitation in the United States every year, the pavement field's ability to predict the performance of different rehabilitation techniques – primarily as a function of their time of application, preoverlay repair, and thickness design – remains very limited. A great deal has been written about how rehabilitation techniques should be constructed and what materials should be used, but relatively little useful research has been done into how long and how well these different rehabilitation techniques perform. This Guide provides the designer with a step-by-step process for project-level evaluation of pavements in need of rehabilitation, selection of rehabilitation techniques believed to be appropriate, and formation of rehabilitation strategies expected to be feasible and cost-effective. As the pavement field's ability to predict rehabilitation performance improves, the process outlined in this Guide may be further refined and customized to the needs of individual State agencies.

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