A Review on Development of OMPI of Bituminous Pavement using Bump Integrator and FWD

[1]Kishan. A. Patel, [2]Ms. Rena N. Shukla

[1]M.E. Student, Civil Engineering Department, L.D. College of Engineering, Ahmedabad, Gujarat, India,
[2]Associate Prof. Civil Engineering Department, L.D. College of Engineering, Ahmedabad, Gujarat, India.

Abstract: Pavement evaluation or pavement maintenance management is an important tool of assessing the current pavement condition. Highway pavement is such a component which leads to more deterioration after once started. In that situation pavement maintenance play important role. Therefore, there is an immediate requirement of strategy for pavement maintenance for highway network of transportation with economical consideration. Development of overall maintenance priority index set the order of maintenance with considering functional and structural distresses with its extent. Rutting, raveling, flushing, corrugation, cracking and patching are the point indicator of functional index. Functional indicator can be intact by developing pavement condition index (PCI) which is varying from 1 to 3, 1 for poor, 2 for fair and 3 for good. In this study the priority ranking for the maintenance program is given. It considers the distress, deflection factor and roughness factor. From these factors pavement condition index (PCI), international roughness index (IRI) using bump integrator (BI) and deflection index (DI) using falling weight deflectometer (FWD) developed. After which overall maintenance priority index (OMPI) is developed. OMPI represent the comparative maintenance priority for different section of the study highway stretch.

Index Terms **- Bump Integrator (BI), DI, Falling Weight Deflectometer (FWD), IRI, OMPI, Pavement Evaluation, PCI.**

I. INTRODUCTION

India is having the second largest road network in all over the world having approximate 33 lakhs as per the National Highway Authority of India (NHAI). India is having the second largest road network in all over the world and having more than 60% low volume roads. Low volume roads means where traffic is less, having problem of frequent maintenance due to less finance attainability. For proper management of these roads, scientific pavement management tools are necessary. Right maintenance treatment is to be given to the right place at the right time.

Roads play important role in the transportation network. Immense concern is taken in planning & developing the highways, may it be in planning the network of highways or planning parts of roads or in considering materials used in construction. Hence, it is concern to evaluate a flexible pavement for its reply for application of loads of means.

Highway pavement are deteriorating fast due to lack of timely maintenance, leading to higher vehicle operating costs and increasing number of accidents. Thus, timely maintenance of the highway pavement is essential. Once pavements start to deteriorate; they deteriorate rapidly beyond the point where maintenance is effective. There is an urgent need to develop a strategy for maintenance of pavement in a huge highway network.

The maintenance of highways, basically for flexible pavement is an immense requirement for the efficiency of road network. For better response of flexible pavements, require more care as compared to care required for rigid pavements. However, developing countries similar to India does not have sufficient finance or money to repay the needs.

The achievement of a maintenance administration system depends more on the competency of the maintenance scheduling that is produced. Useful maintenance scheduling is the schedule that measure what maintenance measure to be taken and which place and what time to appeal it so that the most money effective achievement are obtained. The procedure used to reply this problem is called the maintenance priority setting.

Quality and efficiency of the surface of the road affects the quality of the pavement life. Deterioration and default of pavements are mainly due to aging and improper using. Hence, maintenance and conservation of the pavements has a great important for country. PCI has emerged with discrete stages of composure and adopted whole world for prioritizing the road section for maintenance and repairing works. PCI is based on visual survey of different types of distress in surface of pavement. This method is very simple, easy and less costly one for finding the present condition of pavements and for evaluating the maintenance and rehabilitation needs. PCI is an identification process, which is determined according to the procedures, shown in IRC 82-2015 and is adopted in India for measuring the situation of the pavements by considering the functional parameters with the importance of its performance. Regular maintenance on the same pavements will shows variations in performance levels with time and it can also be used for prediction of current condition of pavements. In the present study distress data is collected on selected sections of pavement and PCI is evaluated after ascertaining measurements of distress, by assigning weightages and finding the estimated PCI values of study sections it is proposed to rank the pavements for prioritizing the maintenance program. There are several indices available for finding the pavement condition. Methods of pavement evaluation:

- Visual rating
- Present serviceability index concept
- Benkelman beam deflection method
- Roughness measurement

II. LITERATURE REVIEW

Soliman Abu-Samra et.al (2017)[12] conducted study to evaluate a comprehensive situation-rating model that involve a wide range of possible factors affecting flexible surface pavement performance. Data collected via questionnaires from experts and from various pavement evaluation in order to assess condition using multi attribute utility theory abbreviation as MAUT. The evaluated model prioritizes the identified factors, with transverse cracking value having the highest impact, 24.52%, in determining condition of

flexible- pavement. The model is validated via several stages showing 94% accuracy compared with real results. Allover, it is applied to a case study and the evaluations are compared with widely used pavement indicators for which the model showed a same pattern. The Evaluated model will serve as the selection of maintenance and repairing strategies for road networks.

Susan Rose et.al. (2017)[14] conducted study to compare the unified pavement condition indices developed using two ways i) using combination of distresses and deflection and the other one is ii) using a combination of roughness and deflection. For the purpose of prioritization of roads, pavement failure prediction models that can predict the situation of pavements at a future time are essential. Probabilistic way is considered while evaluating the pavement prediction models and critical percentile amounts were used for prioritization purpose. For deflection and roughness non-linear models were first calculated and the corresponding probabilistic models were derived. Unified pavement condition indices were evaluated with use of Analytic Hierarchy Process abbreviation as AHP and the priority of the sections were compared. AHP is a simple and effective way, which uses pair wise comparison and relies on the judgments of experts to derive priority scales. Comparative way in AHP is reasonable appealing and backbone by evidence. The result display that the indices evaluated from this study with use of both ways are comparable and hence prioritization of the less capacity roads can easily be done by use of the index evaluated by combining roughness and deflection values.

Stephen A. Arhin et.al. (2015)[13] conducted study that suggests that most of the pavement indices are related as a result of which several areas have developed models to predict one index from the other. This study used 2 years of IRI and PCI data sets to evaluate models that predict pavement condition index from international roughness index by functional classification and by surface type in the District of Columbia. The results of the detail statistics, based on the mean international roughness index and pavement condition index values, suggest that roads have a smoother ride than arterials, followed by collectors and other roads. Same way, when the data was analyzed by pavement surface type, the results show that Composite Pavement surface were smoother than Bituminous Pavements followed by Concrete Pavement. The regression models between the international roughness index and pavement condition index by functional classification and pavement surface type were determined to be statistically important within the margin of error (5% level of significance), with R^2 values from 0.56 to 0.82.

Bharath Boyapati et.al. (2015)[4] Tries to determine the Pavement Condition Index abbreviated as PCI via field data collection and analysis to prioritize the maintenance of surface of pavements. Distress data like cracks, ruts, potholes, patches, etc. collected along the identified stretches of pavements selected based on severity of distress. Corrected deduct values were obtained by giving weightages to different types of distress and Pavement Condition Index obtained. It was found from the evaluation of data that a thin overlay was required as a repairing measure for one of the study sections. The road authorities of this location also came out with the same solution thorough their own study, there by establishing one of the results of this study. Suitable remedial measures for repairing and rehabilitating the pavement to different study locations were concluded.

Minu P K et.al. (2014)[9] Conducted study to develop a Maintenance Priority Index abbreviated as MPI for the six stretches of the State Highway (SH-1) using certain factors affecting pavement surface maintenance. The factors considered in this case were pavement surface condition, traffic characteristics, riding quality, land use characteristics and characteristic deflection of the surface of road. An interrelation between distress parameters and pavement roughness like area of raveling, area of cracking etc. also developed. The pavement distress data was collected on state highway stretching from Vetturoad to Adoor. Roughness survey was carried using Benkelman beam and Bump integrator was used for the measurement of deflections on the surface of pavement. Pavement Condition Indexes (PCI) for every section was determined. The relation between pavement distress and pavement roughness was modelled with use of Multiple Linear Regression abbreviated as MLR analysis. The models were important as the forecasting errors were within the ranges.

S.K. Suman et.al (2013)[10] carried out study that focuses on method involved in the suggesting of pavement condition using probabilistic ways. Since traffic loading, construction methods, pavement materials and environmental condition are not deterministic, so that, probabilistic techniques are used. Markov chains have the characteristic that probabilities having the process will evolve in the future, depending purely on the current state of the process and so are not dependent of the events in the past. The transition matrix state will be defined depend on the overall pavement quality indices abbreviated as OPQI, and element of the transition matrix will be determined by using various methods. Roughness indices and Deflection may be obtained by using following Equations, respectively:

1. Deflection Index = Percent deflection (Predicted) / Maximum deflection (permissible)

2. Roughness Index = Percent roughness (Predicted) / Maximum roughness (permissible).

Asma Th. Ibraheem et.al. (2013)[3] Describes the Evaluation of development of Pavement Condition Model software abbreviated as EPCM, which having of three main elements. The first component deals with a road network definition to evaluate a database for each section in the network to prepare future predictions of pavement surface condition. The second component evaluates the present status of bituminous pavement depending on the severity, type and extent of distress after that calculates the amount of a pavement condition index. For each value there is particular pavement condition requiring one type of repairing activity. The third component deals with suggestion of the pavement condition in hereafter. The written software was applied to this study of other road in local city in Baghdad having length of 1450 m and a width of 8 m. The evaluation of this application was that road required an bituminous overlay. According to the local municipality, the required repairing activity for this road was resurfacing, which is the gemeral maintenance method in Iraq. This is vary because of the independency on a fixed range to select a maintenance method.

Yogesh U.Shah et.al (2013)[15] conducted study on the location consists of 10 road stretches in urban area constituting 29,920 m of Noida city. The methodology includes recognition of urban road sections, data collection of pavement distress, development of individual distress index and after that developing a combined OPCI for the network. The four performance indices viz. PCI for Distress-Pavement Condition Distress Index, PCI for Roughness-Pavement Condition Roughness Index, PCI for Structure- Pavement Condition Structural Capacity Index and PCI for Skid-Pavement Condition Skid Resistance Index are developed individually. Then all these indices are joined together to form an OPCI giving importance of each indicator. The given index is expected to be a good suggestive of pavement condition and performance. The evaluated OPCI was used to select the repairing strategy for the pavement section.

Sandeep Choudhary et.al. (2013)[11] Proposed a base on newly strategy for maintenance of roadway pavement is proposed. A two stage repairing strategy is proposed. In stage I, it suggested to determine priority of roadway sections. In Stage II, priority of various

repairing activities to be carried out on various sections will be determined. Maintenance priority of the surface is based on significance of the road sections, future road conditions and present road conditions. The methodology proposed in this study is described with the help of example of some psychological highway network consisting of four sections. Analysis results indicated that the suggestive strategy is considered to be highly rational, logical & innovative. Some strategies for repairing of urban roads are also presented in this case study.

Jain, K. et.al. (2012)[8] described to analyze the data of recognized on flexible pavement sections to compare the schedule and condition responsive repairing strategies. The scheduled maintenance and repairing strategy has been selected as per the maintenance norms provided by the MORTH in year 2001. Whereas the condition responsive maintenance and repairing strategy has been selected as per the serviceability ranges up to which the respective pavement section is to be maintained. The study is to describe the optimum utilization of maintenance finance based on comparison. The effect of International Roughness Index abbreviated as IRI was taken for this comparative study. For this case a NH stretch from Ghaziabad to Hapur (NH-24) was taken.

III. NEED OF STUDY

Overall maintenance priority index (OMPI) can be used for prioritizing the road section, which have urgent maintenance required. Pavement condition index (PCI) provides information regarding the pavement distresses and International roughness index (IRI) gives the data regarding the roughness. Deflection index (DI) is based on Pavement deflection measurements using FWD on selected stretch. There are many reasons such as rainy condition can deteriorate the pavement if pavement is not structurally sound. In such situation, OMPI gives the priority of road section for maintenance.

IV. METHODOLOGY

The scope of work is divided into the following steps:

- Study area characteristics and identification of study sections.
- Distress measurement
- Assigning acceptability levels and weightages.
- Roughness measurement
- Deflection measurement
- Determination of OMPI.
- Determination of priorities for maintenance

An innovative strategy for maintenance of highway pavement is proposed. A two stage maintenance strategy is proposed. In stage I, it is proposed to determine various indices of highway sections. In Stage II, priority of various maintenance activities to be carried out on various sections will be determined. For this, the section in a network is to be prioritized based on its importance with regard to the extent of deterioration.

The failure of the pavement can be both structural and functional. The integration of distress data over the pavement life is a tedious process; however the collection of roughness data, which is a result of the distresses occurring on surface, is much easier. Repairing priority of the pavement is based on the importance of the road sections, future road conditions, and present road conditions.

Pavement condition indices are numerical indicators of the structural and material integrity of a pavement. Because these indexes appear to be similar essentially a 1– 3 scale, with 1 for poor, 2 for fair and 3 for good. It can be tempting to use different indexes for comparing the performance of pavement networks in different states or jurisdictions within a state. Due to repeated application of loads, the performance of the pavement deteriorates and hence, damage assessment procedures are carried out to rectify the defects produced in flexible pavement to provide PCI by conducting distress survey. The main objective of this study is to determine the Pavement Condition Index (PCI) through field data collection and analysis to prioritize the maintenance of pavements. Distress data such as cracks, patches, potholes, ruts etc. are to be collected along the identified sections of pavements selected based on severity of distress. By percentage of different types of distress with considering, ranges of PCI are obtained.

The present study develops Overall Maintenance Priority Index (OMPI) for the any number of sections of the State Highway using certain factors affecting pavement maintenance. The factors consider in this study are pavement condition, deflection characteristics and riding quality of the pavement. Overall Maintenance Priority Index (OMPI) is a rating used to prioritize the maintenance schedule of pavement based on the certain factors affecting maintenance. The present study develops an Overall Maintenance Priority Index by using PCI, DI and IRI. In last conclusion given that which section has to be prioritized for maintenance?

4.1 Visual Inspection

It is the starting investigation and it can be done along the deteriorated places of the pavement. From the visual inspection, it can be seen that the pavements majorly had Cracks, Patches and Potholes and Ruts.

4.2 Distress Measurement

Data should be collect continuously starting from section 1 to all sections of study highway stretch. Data should be collected for if third part of pavement section along length by capturing photographs and keeping steady camera using scale effect distresses are measure. They are measure in terms of area (m^2). However, Rutting measures using straight edge in terms of depth (mm).

Area of pavement= width of the section * length of stretch/3

Percentage of distress=total area of cracking/area of pavement

Rating to each distress from 1 to 3 is to be given as per IRC 82:2015.

Table 1 Distress Ranges

Defect Type	Range of Distress		
Cracking (%)	>10	5 to 10	<5
Patching (%)	>10	1 to 10	<1
Potholes (%)	>1	0.1 to 1	<0.1
Flushing (%)	>1	0.1 to 1	<0.1
Depression (%)	>5	1 to 5	<1
Reveling (%)	>10	1 to 10	<1
Rutting (%)	>10	5 to 10	<5

Source: IRC: 82:2015

4.3 Roughness Measurement

Data should be collect continuously starting from section 1 to all sections of study highway stretch. Bump Integrator, Measurement tape and towing Vehicle (Jeep) are requiring for data collection. It gives very fast a quantitative integrated development of surface irregularities on a digital counter. It includes of a trailer of single wheel with a pressure tyre fixed on a chassis over which an integrating device is fitted. The machine has a panel board fitted with liquid crystal display or digital counters for counting the length in Meter and Bumps in centimeter. (Per Set length) for measuring the unevenness index value at a pre-set length from 50 m to 9999 m. or Direct reading at a reference point say kilometer stone or some other reference point by pressing reference point push Button. The machine has operating speed of 30+1/2 km/hr. usually a jeep is the machine which tow the equipment.

- General Specification of BI:
  - Total Length: 2.400m.
  - Total Width: 0.700m.
  - Height: 1100mm.
  - Weight: 350 Kg. (approx.)
  - Size of tyre: 6.00*16.6 ply
  - Inflation Pressure: 2.1 Kg/cm2 (30 lb/ sq.in.)
  - Operating speed (standard): 30+- ½ KM/hr

Table 2 Roughness limits

Maximum permissible values of roughness(mm/km) for road surface				
Sr. No.	Type of Surface	Condition of Road Surface		
		Good	Average	Poor
1	Surface Dressing	<3500	3500- 4500	>4500
2	Open Graded Premix Carpet	<3000	3000- 4000	>4000
3	Mix Seal Surfacing	<3000	3000- 4000	>4000
4	Semi-Dense Bituminous Concrete	<2500	2500- 3500	>3500
5	Bituminous Concrete	<2000	2000- 3000	>3000
6	Cement Concrete	<2200	2200- 3000	>3000

Source: IRC:SP:16-2004

Data should be collect for if third part of whole pavement section by running bump integrator. Roughness can be given by unevenness index (UI) as below.

UI (mm/km) =Bump Integrator (BI) counter reading (cm)*10*Distance counter reading per km/ Distance counter reading in test length

In India generally IRI is given as IRI=UI/720

4.4 Deflection Measurement

Data should be collect continuously starting from section 1 to all sections of study highway stretch. Data should be collected as per IRC specification for falling weight deflectometer. Among the equipment available for structural evaluation of pavements, the Falling Weight Deflectometer abbreviated as falling weight deflectometer is very much used world-wide because it extent, simulates, the real loading conditions of the pavement surface. When a moving wheel load passes over pavement it produces load pulses. Highest load and the corresponding pavement responses are of region interest for pavement evaluation.

The working principle of a typical FWD is surface deflections measured at various radial distances. Impulse load applied by means of a falling mass, which is allowed to drop in vertical direction on a system of springs placed on a circular loading plate. The deflected shape of the surface of pavement is measured using displacement sensors which are placed at various radial distances starting with the center of the load plate. Falling weight deflectometer, which is Trailer mounted used for data collection. A mass of weights is fallen from a pre- fixed height onto a series of springs placed on top of a loading plate. The corresponding highest load and peak vertical surface deflections at various radial locations measured and noted down. The target peak load to be applied on bituminous pavements is 40 kN (+/- 4 kN). The load can be increased to produce deflection of at least 10 micrometer at a radial distance of 1.2. If the applied highest load differs from 40 kN, the measured deflections have to be corrected to correspond to the standard target load of 40 kN.

Deflection Index DI = Average deflection/Maximum deflection which is Permissible

As per IRC 115:2014 max spacing for two lane two way carriageway of pavement for good condition is 0.500 km per km length and for fair condition is 0.130 km per km length of road.

4.5 Data Analysis

The PCI and its rating are based on the weightage given to them. According to IRC 82-2015 the calculation are based on following weightages and final rating is average of these values. Distress weightage given as 1.00, 0.75, 0.50, 1.00, 0.75, 0.75 and 1.00 in order of parameter cracking, ravelling, potholes, shoving, patching, settlement and rut depth as mentions in IRC: 82:2015. Analysis for pavement condition index (PCI) various variables such as cracking, patching, potholes, flushing/bleeding, depression/ settlement, raveling and rutting consider and measures in relevant unit. Systematically as Cumulative Area of Pavement, percentage of distress, Range of distress, Condition Rating, Weightage, Weighted Rating Value, Final Rating Value and Overall condition are put one by one.

Analysis for International Roughness index (IRI) systematically Sr. no, Section Distance (m), Distance in BI(m), Bumps (cm), Observed UI (mm/km), Calibrated UI (mm/km), Average UI (mm/km), Condition of road Surface, Maximum UI (mm/km) and IRI (m/km) are put one by one. Do Analysis for all the sections of study highway stretch.

Analysis for deflection index (DI) systematically as Section, average deflection, average deflection for section, maximum permissible deflection and DI are put one by one. Do Analysis for all sections of study highway stretch.

V. RESULTS

For OMPI the indices incorporated are PCI, DI and IRI factor that play important role. It is given by ratio of multiplication of deflection index (DI) and International Roughness index (IRI) to the pavement condition index (PCI). The distress profile demonstrates by percentage parameter value with parameter comparison for sections of study highway stretch. Values of these parameters provide some supplement guidance for maintenance priority. Roughness profile demonstrates by unevenness with length of section. From above that overall interaction chart is prepare.

VI. CONCLUSION:

Maintenance priority ranking means priorities the pavement based on the significance and emergency of repair. The Overall maintenance priority index is use to establish pavement maintenance priority ranking procedure in which all factors consider which affecting to it. For OMPI, the indices incorporate are PCI, DI (using FWD) and IRI (using BI) factor which play important role. Average rating value of PCI describes in percentagewise in order of its parameter and section. Average rating value of IRI and DI describes in index value in order of its parameter and section. Highest index value gives first priority and lowest index value gives last priority. Deflection index and International Roughness index higher values give more priority of section to be repair which is useful in OMPI. Analysis for overall maintenance priority index(OMPI) systematically as location, PCI, IRI(using BI), DI (using FWD) OMPI and Priority Level are demonstrated row wise, Which shows priority level in decreasing level for sections of study stretch.

REFERENCES

[1] Amit Patted, Vinodkumar, Shivaputra and Poornima (2016), "Pavement Performance and Functional Evaluation for Selected Stretches", IJSRD, Vol. 4, Issue 03, 1719-1721.

[2] Ankit Gupta, Praveen Kumar and Rajat Rastogi(2011), "Pavement Deterioration and Maintenance Model for Low Volume Roads", ISSN 1997-1400 Int. J. Pavement Res. Technol. 4(4):195-202.

[3] Asma Th. Ibraheem and Aff.M.(2013), "Modelling the Methods of Flexible Pavements Maintenance" ASCE Journal of Transportation Engineering, ISSN 0733-947X/04013014(5), 04013014, 1-5.

[4] Bharath Boyapati and R. Prasanna Kumar (2015), "Prioritisation of Pavement Maintenance based on Pavement Condition Index" Indian Journal of Science and Technology, Vol 8(14), 1-5.

[5] IRC 115-2014, "Guidelines for Structural Evaluation and Strengthening Of Flexible Road Pavements Using Falling Weight Deflectometer (FWD) Technique"

[6] IRC 82-2015, Code of Practice for Maintenance of Bituminous Road Surfaces (First Revision).

[7] IRC: SP: 16-2004 "Guidelines or The Surface Evenness Of Highway Pavements"

[8] Jain, K., Jain, S.S. and Chauhan, M.P.S. (2012), "Schedule and Condition Responsive Maintenance Strategies for Optimum Utilization of Maintenance Budget", International Journal of Engineering Research and Development, ISSN: 2278-067X, Volume 1, Issue 8 (June 2012), 47-53.

[9] Minu P K, Sreedevi B G and Roshina Babu (2014), "Development of Pavement Roughness Model and Maintenance Priority Index for Kerala State Highway I, IJERT, Vol. 3 Issue 11.

[10] S.K. Suman and S. Sinha(2013), "Pavement Performance Modelling Using Markov Chain", Springer ISEUSAM, DOI 10.1007/978-81-322-0757-3_39.

[11] Sandeep Choudhary and P. K. Agarwal (2013), "An Innovative Strategy for Maintenance of Highway Pavement", International Journal of Engineering Research and Applications (IJERA) Vol. 3, Issue 3, 054-060.

[12] Soliman Abu-Samra, Tarek Zayed, F. and Wael (2017), "Pavement Condition Rating Using Multiattribute Utility Theory", ASCE J. Transp. Eng., Part B: Pavements, 2017, 143(3): 04017011(1-15)

[13] Stephen A. Arhin, Lakeasha N. Williams, Asteway Ribbiso and Melissa F. Anderson (2015), "Predicting Pavement Condition Index Using International Roughness Index in a Dense Urban Area", Journal of Civil Engineering Research, Vol.5(1), 10-17

[14] Susan Rose, Binu Sara Mathew and Kuncheria Palampoikayil Isaac (2017) "Development of Probabilistic Deterioration Models and Prioritisation of Low Volume Roads for Maintenance" International Journal for Traffic and Transport Engineering, 7(2): 216 – 231.

[15] Yogesh U.Shaha, S.S. Jainb, Devesh Tiwaric and M.K. Jaind (2013), "Development of Overall Pavement Condition Index for Urban Road Network", Procedia - Social and Behavioural Sciences 104, 332 – 341.