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An Innovative Strategy for Maintenance of Highway Pavement

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Abstract :

Highway pavement are deteriorating fast due to lack of timely maintenance, leading to higher vehicle operating costs, increasing number of accidents etc. Thus, timely maintenance of the highway pavement is essential. Because, once pavements start to deteriorate; they deteriorate rapidly beyond the point where maintenance is effective. Thus, there is an urgent need to develop a strategy for maintenance of pavement in a huge highway network. In this study, 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 priority of highway sections. In Stage II, priority of various maintenance activities to be carried out on various sections will be determined. Maintenance priority of the pavement is based on importance of the road sections, present road conditions, and future road conditions. The methodology proposed in this study is illustrated with the help of example of some hypothetical highway network consisting of 4 sections. Analysis results indicated that the proposed strategy is considered to be more rational, innovative & logical. Some strategies for maintenance of urban roads are also presented in this study. Therefore, it is expected that this study will be useful for maintenance of huge highway network in India and thus will be useful for preserving huge asset of pavement infrastructure.

Keywords - Highway Maintenance; Maintenance Strategy; Maintenance Priority; Maintenance of urban roads,

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.

Photograph 1 Different Types of Distress on Highway Pavement

In a road network it is so difficult to select the roads in a order of priority for their maintenance. Thus, there is an urgent need to develop a strategy for maintenance of pavement in a huge highway network. Prioritization of maintenance activity may be depends on several factors such as present condition of road i.e. quantity and quality of deterioration, increasing rate of deterioration, importance of the selected road, traffic load on the selected road etc. [Agarwal, 2006]. In this study, 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 priority of highway sections. In Stage II, priority of various maintenance activities to be carried out on various sections will be determined. Maintenance priority of the pavement is based on importance of the road sections, present road conditions, and future road conditions. The methodology proposed in this study is illustrated with the help of example of some hypothetical highway network consisting of 4 sections. Analysis results indicated that the proposed strategy is considered to be more rational, innovative & logical. Some strategies for maintenance of urban roads are also presented in this study.

The paper consists of five Section of which this is the first. The second section presents the proposed Strategy for pavement maintenance briefly.

To illustrate the strategy and to illustrate how the proposed strategy works, detailed analysis were carried out. Section 3 presents the analysis and results obtained. Section 4 presents some strategies for maintenance of urban roads. The last section presents the important conclusions drawn based on this study. It is expected that this study will be useful for maintenance of huge highway network in India and thus will be useful for preserving huge asset of pavement infrastructure.

II. STRATEGY FOR PAVEMENT MAINTENANCE

The main objective of this study is to develop the Maintenance Strategy for pavement in a Highway Network. It is proposed to select maintenance activities to be carried out on different pavement sections in two stages as follows:

Stage I: Pavement Section Priority based on the basis of the methodology proposed in this study
Stage II Priority of activity based on the overall importance of the section. Overall importance of the section is determined on the basis of highway class, political importance of the section and importance of the section to community etc.

Thus, the strategy proposes that first sections which are more critical for maintenance needs to be selected. The strategy identifies to select sections using minimal data. Further, strategy proposes that the sections identified in stage I needs to be evaluated n more details so that the various maintenance activities to be carried out on these sections can be prioritized. Thus, the proposed strategy will be more economical as details studies needs not to be carried out on all sections. The strategy to determine priority for stage I and stage II are briefly explained in sub Section 2.1 and sub section 2.2 as follows. However, for more details literature [Choudhary, 2011] can be refereed.

2.1 Strategy to determine maintenance priority of Pavement section (Stage-I)

The Strategy to determine maintenance priority of highway section suggests determining priority index of various sections (PI_s) as follows:

$$PIs = 0.35\ PHCI + 0.22\ FHCI + 0.43\ OHII$$

……Eq. 1.1 Where:-

PI_s = Priority Index of Section
PHCI = Present Highway Condition Index
FHCI = Future Highway Condition Index
OHII = Overall Highway Importance Index

Now, how to determine various terms required in equation 3.1 are explained as follows:

Present Highway Condition Index:-

$$PHCI = \frac{\text{Present Roughness at the section}}{\text{Maximum Present Roughness at any section}}.$$

Future Highway Condition Index:-

$$PHCI = \frac{\text{Future Roughness at the section}}{\text{Maximum Future Roughness at any section}}$$

Overall Highway Importance Index:-

$$OHII = 0.22HCI + 0.14\ ICI + 0.07\ IPI$$

….Eq. 1.2

Where:-

OHII = Overall Highway Importance Index
HCI = Highway Class Index
ICI = Importance of Community Index
IPI = Political Importance Index

Highway Class Index:-

$$HCI = \frac{\text{Traffic at the section}}{\text{Maximum Traffic at any section}}$$

Importance of Community Index:-

$$ICI = \frac{\text{Community Importance at that section}}{\text{Maximum Community Importance at any section}}$$

Political Importance Index:-

$$IPI = \frac{\text{Political Importance at the section}}{\text{Maximum Political Importance at any section}}$$

Objective of Stage-I is to develop the Maintenance Strategy for Highway Section.

To illustrate the methodology and to illustrate how methodology works, six Different Types of cases were analyzed and details of analysis and results obtained are presented in [Choudhary, 2011]

A Strategy to determine priority of Maintenance Activities to be carried out on Different highway sections (Stage-II)

The Strategy to determine maintenance priority of various activities to be carried out on highway section (PI_{as}) is presented as follows:

$$Plas = Wac * Wscd * Clsd * Wd * Pls$$

…Eq. 1.3

Where:-

PI_{as} = Priority Index of activity at that Section

W_{ac} = Weightage of activity in improving Distress condition
$W^s cd$ = Weightage of Component C in Improving Distress Condition D
EX: (Weightage of Distorted surface in improving Structural Condition)

$CI^s d$ = Condition Index of Distress D at a section S
Wd =Weightage of the Distress Condition
PI_s = Priority Index of Section

Now, how to determine various terms required in equation 1.3 are explained as follows:

PDCI consists of three indices are Present Fractured Surface Index (PFSI), Present Distorted Surface Index (PDTSI), Present Disintegrated Surface Index (PDISI).

Now the previous equation will be:-

$$PI_{as} = [W_{ac}\ W^s fs\ (PFSI)\ Wd\ PI_s] + [W_{ac}\ W^s fs\ (FFSI)\ Wd\ PI_s] + [W_{ac}\ W^s dts\ (PDTSI)\ Wd\ PI_s] + [W_{ac}\ W^s dts\ (FDTSI)\ Wd\ PI_s] + [W_{ac}\ W^s dis\ (PDISI)\ Wd\ PI_s] + [W_{ac}\ W^s dis\ (FDISI)\ Wd\ PI_s] + [W_{ac}\ W^s cd\ (PSCI)\ Wd\ PI_s] + [W_{ac}\ W^s cd\ (FSCI)\ Wd\ PI_s]$$

Where:-
PFSI = Present Fractured Surface Index
FFSI = Future Fractured Surface Index
PDTSI = Present Distorted Surface index
FDTSI = Future Distorted Surface index
PDISI = Present Disintegration Surface index
FDISI = Future Disintegration Surface index
PSCI = Present structural condition index
FSCI = Future structural condition index

2.3 Methodology for Prediction of future highway condition:-

Prediction of future highway condition based on the pavement performance data collected from existing pavement section. Model has been developed to predict initiation and progression of cracks, rutting, pothole, raveling and structural condition. Empirical model have developed to predict the growth of unevenness.

Empirical modal for prediction of future highway condition are:-

FFSI: - Cracking Progression Modal
FDSI: - Roughness Progression Modal
FDISI: - Pot holes Progression Modal
FSCI: - Deflection Progression Modal

(1).FFSI: Cracking progression modal: -

$$\frac{\Delta CRt}{t_i} = \frac{4.26\,[CSALYR]^{0.56} * SCRi^{0.32}}{MSn}$$

Where:-
CSALYR = Cumulative standard axle per year (millions) MSN = Modified structural number
MSN = 3.28 (DEF) -0.23
ΔCRt = Percentage change in crack area over time (t) in year (%)
SCRi = Initial cracking area (%)
T = Time interval (year)

(2).FDSI: Roughness progression modal: -

$$UI_t = iUI\,[1 + 0.3012\,(N_t * DEF_0)^{0.08\,Age}$$

Where:-
UIt = Roughness Progression
iUI = Initial Roughness
Nt = Cumulative standard axle per year (millions)
DEF0 = Initial Deflection, in mm
Age = Age of the pavement

(3). FDISI: -RAVELLING PROGRESSION MODAL:-

$$\frac{RV_t = 3.94\ AXLEYR^{0.32} * SRV_i^{0.46}}{t_i}$$

Where:-
RV_t = Raveling at time t (%)
AXLEYR = No. of Vehicle axle per year (million)
SRV_i = Initial Raveling (%

(4).FSCI: DEFLECTION PROGRESSION MODAL:-

iDEF Range(mm)	Model Form
0.44<iDEF<0.61	Dt=iDEF+0.07884[(Nt*Age)iDEF]
0.66<iDEF<0.80	Dt=iDEF+0.002exp[(iDEF*Nt)iDEF]+0.859(Age)
0.84<iDEF<1.05	Dt=IDEF +0.04513(expNt)0.45 +0.0924(expAge)log iDEF
1.01<iDEF<1.25	Dt=iDEF+0.03658[exp(iDEF*Nt]0.5 +0.19864(Age)0.26

Where:-
iDEF = Initial Deflection(mm)
Dt = Corrected Characteristic rebound deflection (mm) at any time t
Nt = Cumulative standard axle per year (millions)
Age = Age of the pavement

To illustrate the methodology and to illustrate how methodology works, five different types of cases were analyzed and details of analysis and results obtained are presented in [Choudhary, 2011]

III. Analysis and Results

To illustrate the methodology and to illustrate how the proposed methodology works, detailed analysis were carried out. As explained earlier, the strategy consists of the following two stages:

Stage –I: Strategy to determine maintenance priority of highway section

Stage II: Strategy to determine priority of Maintenance Activities to be carried out on Different highway sections

This section presents the analysis and results for these two stages. Section 3.1 presents the analysis and results for stage-I and section 3.2 presents the analysis and results for stage-II

3.1 Analysis & Results for Stage-I- Strategy to Determine Maintenance Priority of Highway Sections

As discussed in Section 2, stage–I determines the maintenance priority of highway section. To illustrate the methodology and to illustrate how the proposed methodology for stage –I works, detailed analysis were carried out. Six different cases were analyzed. A hypothetical network consists of 4 highway sections were assumed. Details of different cases considered, input data and analysis results for each case is presented elsewhere [Choudhary, 2011]. However, analysis & results of a typical case is presented as follows. Table 1.1 presents the input data used for the analysis.

Table1.1: Input data: Details of Road Section

		Overall Condition	Highway	Overall Importance	Highway	
S.No.	Highway Designation	Present Highway Condition (Roughness) mm/km	Future Highway Condition (Roughness) mm/km	Highway Class Traffic (CVPD)	Important places connected	Political Importance
1	S_1	658	1019.37	2338	0.4	0.5
2	S_2	1350	2125.87	4125	0.9	0.7
3	S_3	938	1469.37	3445	0.6	0.8
4	S_4	368	567.21	1952	0.3	0.2

The above data were analyzed to determine the various indices. These indices are determined as per the methodology explained. The analysis results and the values obtained are given in Table 1.2.

Table 1.2: Analysis Results for determination of condition indices, PI_S & Rank

Highway Designation	Highway Class Index	Importance community Of	Political Importance index	Present Highway Condition Index	Future Highway Condition Index	Overall Highway Importance Index	Priority Index of Section	Rank
	HCI	ICI	ICI	PHCI	FHCI	OHI I	PI_S	
S_1	1	1	1	0.488	0.488	0.43	0.463	3
S_2	1	1	1	0.249	0.249	0.43	0.327	4
S_3	1	1	1	0.695	0.695	0.43	0.581	2
S_4	1	1	1	1.000	1.000	0.43	0.755	1

These indices were used to determine maintenance priority of different section i.e. PIs. After determining PIAS various sections were ranked in the order of their PIs. PIs values and Rank of various sections are also given in Table 1.2. Further, the PIs obtained for different sections are also plotted with respect to Highway Condition & Overall Highway Importance. Fig 1.1 presents the maintenance priority of section with their respective Highway Condition & Highway Importance. Ranks obtained for different section are also shown in the Fig 1.1. It is clear from the Fig 1.1 that Section S2 gets highest Priority for maintenance. S2 section is having Highest Present Roughness and highest Future Roughness and Section 2 also having highest highway Class (Traffic).

PIs V/s Section

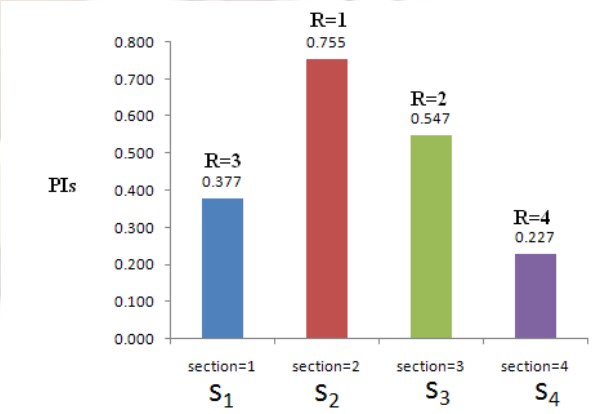

Fig 1.1: Variation of PIs for different highway sections

3.2 Analysis & Results for Stage-II: Strategy to Determine Priority of Maintenance Activities to be carried out on Different highway sections

As discussed in section 2, stage–II determines the maintenance priority of maintenance activity. To

illustrate the methodology and to illustrate how the proposed methodology for stage –II works, detailed analysis were carried out. Five different cases were analyzed. A hypothetical network consists of 4 highway sections were assumed. Details of different cases considered, input data and analysis results for each case is presented elsewhere [Choudhary, 2011]. Table 1.3 presents the input data used for the analysis.

Table 1.3: Input data Details of Road Section

Activities	PFS (m)	PDTS (m)	PDIS (m)	PSC (mm)	FFS (m)	FDTS (m)	FDIS (m)	FSC (mm)
	m^2	m^2	m^2		m^2	m^2	m^2	mm
S_1	352	658.7	504	1.84	509.06	876.34	821.55	2.06
S_2	280	335.6	430	0.78	417.97	437.64	720.83	0.88
S_3	473	1350	931	1.43	630.51	1792.79	1146.93	1.65
S_4	560	953	735	1.75	744.75	1275.04	1086.52	2.12

The above data were analyzed to determine the various indices. These indices are determined as per the methodology explained. The analysis results and the values obtained are given in table 1.4

These indices were used to determine maintenance priority of Activities. PI_{As}. PI_{AS} values and Rank of various sections are also given in Table 1.4. Further, the PI_{AS} obtained for different sections are also plotted with respect to Structural Condition. Fig 1.2 presents the maintenance priority of Activity with their respective Structural Conduction. . Ranks obtained for different activity are also shown in the Fig 1.2. It is clear form the Fig 1.2 that activity of Higher Weightage on section with highest Poor Condition gets highest priority for maintenance

TABLE 1.4: ANALYSIS RESULTS FOR CASE II-E DETERMINATION OF CONDITION INDICES, PIAS & RANK

Sections	Activities	Wac	W^c_{cd}	Wd	Traffic	Calculated PI_{AS}		Rank
S_1	A_{11}	0.2	0.0228	0.0114	2338	PI_{11}	0.0010	**14**
	A_{12}	0.25	0.0513	0.0285	2338	PI_{12}	0.0029	**12**
	A_{13}	0.25	0.0912	0.057	2338	PI_{13}	0.0061	**9**
	A_{14}	0.3	0.1881	0.1197	2338	PI_{14}	0.0221	**3**
S_2	A_{21}	0.2	0.0228	0.0114	1952	PI_{21}	0.0005	**16**
	A_{22}	0.25	0.0513	0.0285	1952	PI_{22}	0.0009	**15**
	A_{23}	0.25	0.0912	0.057	1952	PI_{23}	0.0034	**11**
	A_{24}	0.3	0.1881	0.1197	1952	I_{24}	0.0061	**8**
S_3	A_{31}	0.2	0.0228	0.0114	2745	PI_{31}	0.0026	**13**
	A_{32}	0.25	0.0513	0.0285	2745	PI_3	0.0011	**7**
	A_{33}	0.25	0.0912	0.057	2745	PI_{33}	0.0193	**5**
	A_{34}	0.3	0.1881	0.1197	2745	PI_{34}	0.0328	**2**
S_4	A_{41}	0.2	0.0228	0.0114	3256	PI_{41}	0.0052	**10**
	A_{42}	0.25	0.0513	0.0285	3256	PI_{42}	0.0133	**6**
	A_{43}	0.25	0.0912	0.057	3256	PI_{43}	0.0277	**4**
A_{44}	**0.3**	**0.1881**	**0.1197**	**3256**	**PI_{44}**	**0.0398**		**1**

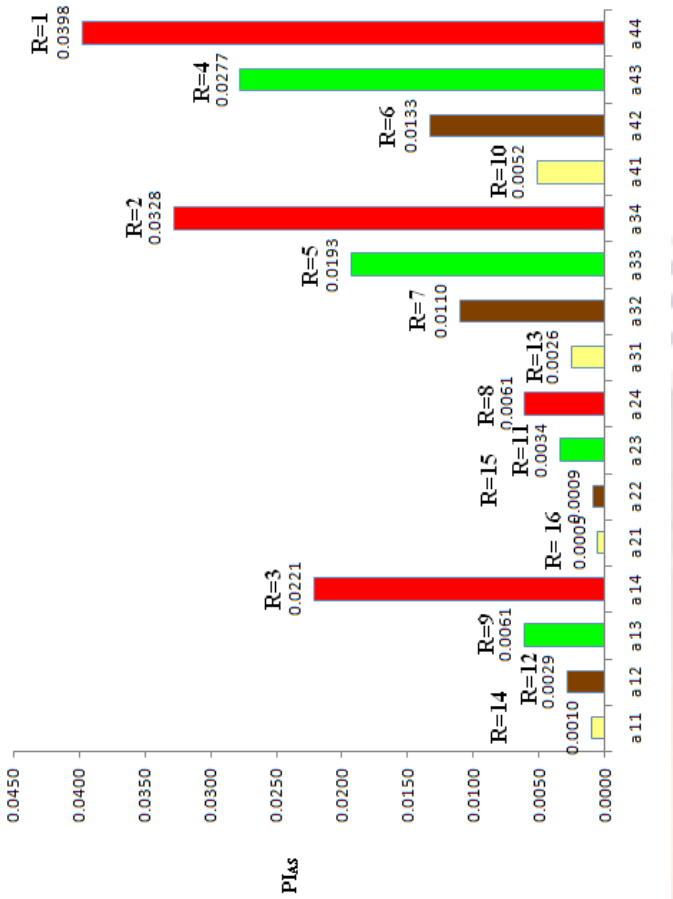

Fig 1.2: Variation of PI_{AS} of Activity for different highway sections

IV. Strategy for Maintenance of Urban Roads

The maintenance of urban roads has more specific problems. Some of the specific problems are identified as follows [Nagabhushana, 2010]**:**

- Temperature of mix goes down due to transportation of mix from long leads, which is turn result in poor compaction.
- Quality control at plant at a distance form laying site is difficult.
- Tendency of overheating causes sharp decrease in durability of mix.
- Repeated overlaying by thicker layer of hot mixes causes severe drainage problems.
- Cooking of mastic asphalt for 3-4 hours in cookers is another serious cause of environmental pollution in habitat areas.
- Bituminous produced and available is deficient with respect to its chemical composition
- Wide variation in daily and seasonal temperature in urban roads
- Inadequate drainage condition in many of the roads
- Poor adhesion of bitumen with aggregate due to higher stripping value of the aggregates available for use
- Fast ageing of the bituminous mix during processing , laying as well as in service cause early cracking bitumen surfacing

Thus, there is an urgent need to evolve innovative strategy for maintenance of pavement of urban roads. The strategy should be to technically feasible and economical. In view of the above problems, the following types of cement concrete overlays may be adopted:

- Dry lean concrete
- Roller compacted cement concrete
- Cement concrete for PQC
- Ultrathin overlay

The use of cement concrete technologies in place of bituminous technologies for urban roads has the following advantages:

- Higher durability
- Cost effectiveness.
- Frequent intervention for maintenance not required
- Poor drainage Conditions in urban roads causing frequent damage of bituminous road
- Suitable for heavy and slow moving traffic in urban area

Thus, there is an urgent need to develop an appropriate pavement management system for rigid pavement for urban roads in India [Choudhary, 2011]

V. Conclusions

The following important conclusions may be made based on this study:

[1] The strategy proposes that first pavement sections which are more critical for maintenance needs to be selected. The strategy identifies to select such pavement sections using minimal data. Further, strategy proposes that the sections identified in stage I needs to be evaluated in more details so that the various maintenance activities to be carried out on these sections can be prioritized. Thus, the proposed strategy will be more economical as detailed studies needs not to be carried out on all sections.

[2] It can be concluded from the above study that proposed strategy priorities the pavement section on more important section as well as more important distress i.e. section will get higher priority if it is to be carried out on more important section as well as for more important distress. Therefore the proposed methodology is considered to be more rational and logical

[3] It can be concluded from proposed methodology for priorities the Activity on more important section as well as more important distress i.e. Activity will get higher priority and if it is to be carried out on more important pavement section as well as for more important distress. Therefore the proposed methodology is considered to be more rational and logical.

[4] The maintenance of urban roads has more specific problems. The use of cement concrete technologies in place of bituminous technologies has the several advantages such as higher durability and cost effectiveness.

This study presents a simple (easy to use) strategy for maintenance of pavement in a huge highway network. This proposed methodology is less time consuming simple and cost effective and can be executed with minimal data and those can be obtained easily and economically from each section of a highway network

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