Improving the Pavement Conditions : Pavement Condition Assessment methods, Methods for optimizing the reparation and maintenance cost for roads

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ABSTRACT

In a developing country highway infrastructure is the backbone for economic development. Pavements are the assets of any country. A good pavement is the heart of a highway or an airport. With increase in traffic and loading, pavement deterioration occurs which needs to be monitored and captured continuously for preparing efficient maintenance proposals. Hence there is a need to preserve these assets in good condition, by providing maintenance derived from optimum rational strategies. Pavement evaluation is a key step in selecting deteriorated roads for maintenance. Pavement condition rating through various distress identification and measurement is the need of an hour.The purpose of maintenance is to ensure that the pavements remain serviceable throughout its design life.Maintenance prolongs their life by reducing the rate of deterioration, thereby safeguarding investments in repair and rehabilitation, which will lower the cost of operating vehicles by providing a smooth-running surface, keeps the road open for traffic with least delay,contributes to better transport services,sustains socialand economic benefits due to improved road.

This paper covers the need of a good pavement, causes of failures of pavement, methods of pavement condition assessment, measurement of various surface distresses, rating of condition of pavement by IRC, ASTM and AASHTO. Various defects in Bituminous surfacing and different types of road maintenance and their relevance to roads maintained by BRO have been discussed. Important aspect for cost-effective maintenance is the **Selection and Timing** of maintenance activities. Preventive Maintenance relatively inexpensive. It preserves the system, retards future deterioration and improves functional condition. It is most effective when the pavement is structurally sound and exhibits little or no distress.**Highway Development and Management Tool (HDM-4)**- developed by WB is a powerful management software tool for the analysis, planning, management and appraisal of road maintenance, improvements and investment decisions. Optimization of cost of maintenance of road has been discussed and worked out by proposing a 10 mm thick micro surfacing layer on good conditioned road in J&K by delaying the renewal coat of AC 30 mm for two years.

1. INTRODUCTION

Pavement is the structure consisting of superimposed layers of selected and processed materials placed on a subgrade to support the applied loads and distribute themtosoilfoundation.

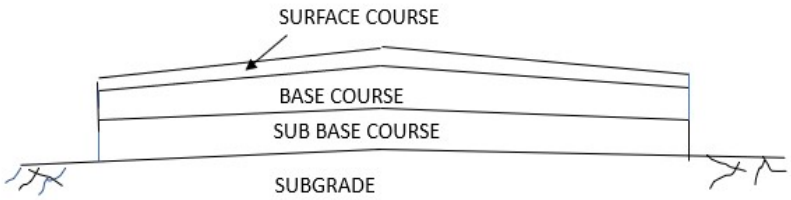

Fig 1.1. Typical cross section of a Flexible Pavement.

It provides adequate, smooth, durable and serviceable support for the loads imposed by trafficat all times in all weather conditions. A good pavement contributes to a large extent to the quality of **a highway or airport.**

2. REQUIREMENT OF A GOOD PAVEMENT

Fig 2.1. Damaged Pavement

Pavement in good condition ensures

(i) Increase in riding quality and saving in **Vehicle Operation Cost**.
(ii) Saving in travel time.
(iii) **Reduction in accident rate**.
(iv) Less fatigue and discomfort during travel.
(v) Increased mobility of **Essential services and Defence forces**.
(vi) Reduced suffering and pain of those involved in highway accidents.
(vii) Savings in maintenance cost.

3. CAUSES OF PAVEMENT FAILURES

Pavements deteriorate over the period of time due to heavy traffic movement and variation in climatic conditions.

(i) Defects in the quality of materials used.

(ii) Defects in construction method and quality control during construction.

(iii) Inadequate surface and subsurface drainage.

(iv) Increase in traffic volume and magnitude of wheel loads.

(v) Inadequate pavement crust thickness.

(vi) Settlement of foundation of embankment of the fill material.

(vii) **Natural and Environmental factors - heavy rainfall, land slides, soil erosion, high water table, snow fall, frost action.**

4. PAVEMENT PERFORMANCE AND ITS EVALUATION

Pavement Performance - It is the ability to serve traffic safely and comfortably over a period of time.

Pavement evaluation - is a technique of assessing the condition of a pavement, both structurally and from the point of view of surface characteristics.It is also known as pavement condition survey and rating of pavement.

Objectives of Evaluation

(i) To assess as to whether and to what extent the pavement fulfils the requirement.

(ii) To plan maintenance and strengthening jobs in time.

5. PAVEMENT CONDITION ASSESSMENT METHODS

A. VISUAL EVALUATION

Visual evaluation is a simple method Distresses (Alligator cracking, Longitudinal and transverse cracking, Bleeding, Pothole, Patching, Ravelling, Rutting) are visually noted and recorded.

B. FUNCTIONAL EVALUATION

based on Riding quality (road roughness), Pavement distresses and Skid resistance.

Surface distresses are actually measured in smaller representative stretches.

1. Pavement Condition Rating (PCR)

The IRC: 82-2015 gives guidelines for Practice of Maintenance of Bituminous Road. For a Highway, the IRC guidelines asks to collect measurement of following pavement distresses through observations; cracking, ravelling, potholes, shoving, patching, settlement and rut depth. based on the measured distresses the standard condition is as below table 5.1

(i) It provides a measure the present condition of pavement.
(ii) Provides an objective and rational basis for determining maintenance and repair needs.

(iii)Used to establish the rate of pavement deterioration for early identification of rehabilitation needs.

Table 5.1: Pavement Distress Rating

Defect(type)	**Range of Distress**		
Cracking (%)	>10	5 to 10	<5
Ravelling (%)	>10	1 to 10	<1
Pothole (%)	>1	0.1 to 1	<0.1
Shoving (%)	>1	0.1 to 1	<0.1
Patching (%)	>10	1 to 10	<1
Settlement & Depression (%)	>5	1 to 5	<1
Rut depth in mm	>10	5 to 10	<5
Rating	**1**	**1.1 – 2.0**	**2.1 – 3.0**
Condition	**Poor**	**Fair**	**Good**

After assigning rating to each parameter, an appropriate weightage is given to rating value of each parameter for calculation of Weighted Rating Value for each parameter.

Table 5.2:**Pavement Distress Weightage**

S.No	Defect(Type)	Weightage(fixed) Multiplier factor
1	Cracking (%)	1.0
2	Ravelling (%)	0.75
3	Pothole (%)	0.50
4	Shoving (%)	1.0
5	Patching (%)	0.75
6	Settlement & Depression (%)	0.75
7	Rut depth in mm	1.0

The **Final Rating Value** is calculated by taking the average of the **Weighted Rating Values** of all parameters viz. cracking, ravelling, potholes, shoving, patching, settlement and rut depth.

2. Pavement Condition Index (PCI)

The PCI is a numerical indicator that rates the surface condition of the pavement in the scale of 0 to 100. This has been developed by **ASTM**. The PCI provides a measure of the present condition of the pavement based on the distress observed on the surface of the pavement, which also indicates the structural integrity and surface operational condition (localized roughness and safety).

Standard PCI Rating Scale	
100	Good
85	Satisfactory
70	Fair
55	Poor
40	Very Poor
25	Serious
10-0	Failed

The ASTM method is a deduct value approach method which considers and the types of possible distress and its severity parameter. The severity of the distress typeis the most important index in pavement performance evaluation. The ASTM method is time consuming and requires accurate measurements and severity identification. The ASTM recommends 19 types of pavement distresses.

3. Present Serviceability Index (PSI)

This has been developed by **AASHTO** involving the measurement of permanent deformation, riding quality and the extent of cracking and patching. PSI is probably the most widely used pavement rating measure in existence today.

rating 1 represents very poor pavement

rating 5 represents excellent pavement

Flexible Pavements

$PSI = 5.03-1.91 \log(1+SV)-1.38(RD)^2 - 0.01\sqrt{(C+P)}$

Rigid Pavements

$PSI = 5.41-1.80 \log(1+SV) - 0.09\sqrt{(C+P)}$

SV = Slope variance giving an index of the longitudinal profile.

RD = Rut depth under a 4 ft. strait edge.

C = Amount of cracking(lineal feet of cracks/1000 sq ft. area).

P = Patched area(sq ft/1000 sq ft area).

C.STRUCTURAL EVALUATION

Measurement of transient deflection of pavement under design wheel loads serve as an index of the pavement to carry traffic loads under the prevailing conditions. The following tests are used for assessing theload carrying capacity of the pavement.

i) Static Plate Bearing Test.
ii) Benkelman Beam method.
iii) Falling Weight Deflectometer.
iv) Lacroix Deflectograph.
v) Dynaflect.

6. PAVEMENT CONDITION SURVEY

Condition surveys are carried out before monsoon and after monsoon in case of NHs and after every monsoon for other roads.Surface condition is assessed in terms of **roughness, pavement surface distresses, skid resistance and texture depth.**Based on condition survey and condition rating, type of maintenance activity will be decided. A plan has to be drawn for preventive maintenance or periodic renewals based on pavement condition rating.

A. Measurement of Unevenness or Roughness

Unevenness or Roughness can be defined as "deviations of a travelled surface from a true planar surface with characteristic dimensions that affect riding quality, vehicle dynamics, dynamic pavement loads and pavement damage"

The methods of measuring roughness can be broadly grouped under two categories:

1. Direct measurement of the longitudinal profile.
2. Response type instrument methods.
   It is assessed in terms of Roughness Index in mm/km.

(i) Fifth wheel Bump Integrator.
(ii) Car axle Mounted Integrator.
(iii) Laser Profilometer.

B. Measurement of Pavement Surface Distress

Distress is developed in the pavement in the form of cracking, ravelling,potholes, edge break, rut depth, patch work, texture with passage of timedue to traffic volume, loads and climatic conditions.

(i) Manual method.
(ii) Pavement surface imaging technique.

C. Measurement of Skid Resistance

The following devices are used for measurement of skid resistance.

i) Stopping of test vehicles.

ii) Braking of vehicles with a test wheel.

iii) Portable Skid resistance Tester.

iv) Mu-Meter.

D. Measurement of Texture Depth

i) Sand patch method(for macro texture depth)

ii) Laser based system(for micro texture depth)

7. SERVICEABILITY INDICATORS FOR HIGHWAYS

S.No	Serviceability Indicator	Level 1(good)	Level 2(Fair)	Level 3(poor)
1	Roughness(max permissible)	1800 mm/km	2400 mm/km	3200 mm/km
2	Skid Resistance(Skid Number) Min desirable	60 SN	50 SN	40 SN

Level 1- match with new pavement condition.
Level 2- in service minimum desirable level.
Level 3- warrant for intervention to restore the pavement to level 1.

8. MAINTENANCE OF ROADS

Road Maintenance - Preserving and keeping each type of roadway, roadsides, structures as nearly as possible in its original condition as constructed or as subsequently improved to provide satisfactory and safe transportation.

Road maintenance includes

Maintenance of pavement, structures, drains and cross-drainage works, shoulders and slopes, bridges, road furniture.

The timely upkeep and maintenance of bituminous surfacing offers numerous benefits for preservation of road asset.

i) Improvement of Riding quality.
ii) Reduction in rate of **deterioration and improvement in life of road**.
iii) Reduction in Vehicle Operation Costs (VOC).
iv) Reduction in rate of accidents.
v) Keeping roads **traffic worthy in all weathers**.
vi) Reduction in pollution due to reduced fuel consumption.
vii) Savings in budgetary expenditure of restoration/ reconstruction.

Timely and regular maintenance of roads have been known to provide economic return as high as 15 to 20% depending upon the category of road and traffic volume.

9. TYPES OF MAINTENANCE

1. **ROUTINE MAINTENANCE**

This covers items such as filling of potholesrepairing of cracks and patch work, maintenance of shoulders and cross slope, up-keep of road side drains,pavement markings which are undertaken by the maintenance staff almost round the year.

2. **PREVENTIVE MAINTENANCE**

A planned maintenance activity, which decreases the rate of surface deterioration and **extend service life** of bituminous pavement. This provides following longterm solutions.

(i) Improved level of service resulting from improved pavement performance.
(ii) Delayed need for rehabilitation and reconstruction.
(iii) Life cycle cost saving.

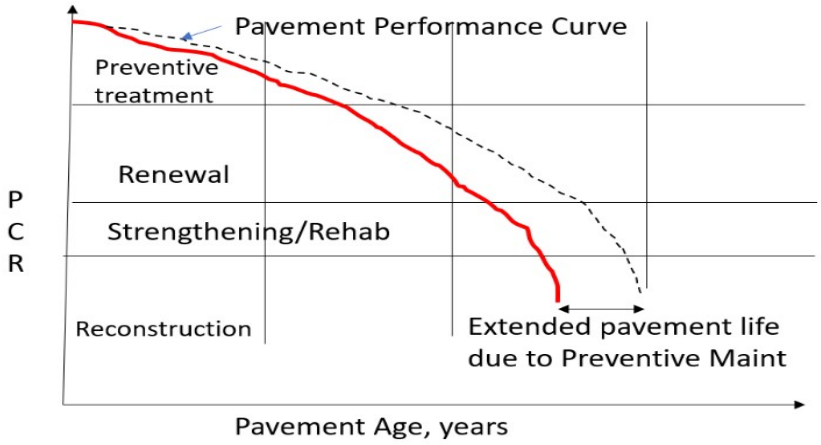

Fig 9.1. Timing of Preventive Maintenance.

Preventive Maintenance Treatments are:

(i) Crack sealing/crack filling.

(ii) Fog seal.

(iii) Slurry seal.

(iv) Micro surfacing.

(v) Surface dressing.

(vi) Thin surfacings.

(vii) Ultra thin friction courses.

3. **PERIODIC MAINTENANCE**

Periodic maintenance consist of the provision of a surfacing layer at regular intervals of time or at a specified condition so as to preserve the required serviceability level of **the pavement surface and offset the wear and tear caused by traffic and weathering**. Periodic renewals represent the maintenance , which is needed to prevent deterioration of the pavement and to ensure that initial qualities are kept up for the future requirements of the pavement.
It is carried out:

(i) To extend the service life of an existing pavement.
(ii) To improve the load carrying capacity.
(iii) To preserve the required serviceability level of the pavement.
(iv) To offset the wear and tear caused by traffic and weathering.

This includes

Surface dressing (one or two coats),Thin premix carpet, Mixed seal, Stone matrix asphalt,Dense bituminous concrete,Micro surfacing (one or two layers).

4. **SPECIAL REPAIRS**

Special Repairs and strengthening of pavement with overlays are needed to prevent pavement failures. It includes

(i) Strengthening of pavement structure.
(ii) Reconstruction of pavement.
(iii) Widening of roads.
(iv) Improvement of geometrics.
(v) Repair of damages caused by monsoon/floods.
(vi) Repair of subsurface drainage and cross drainage structures

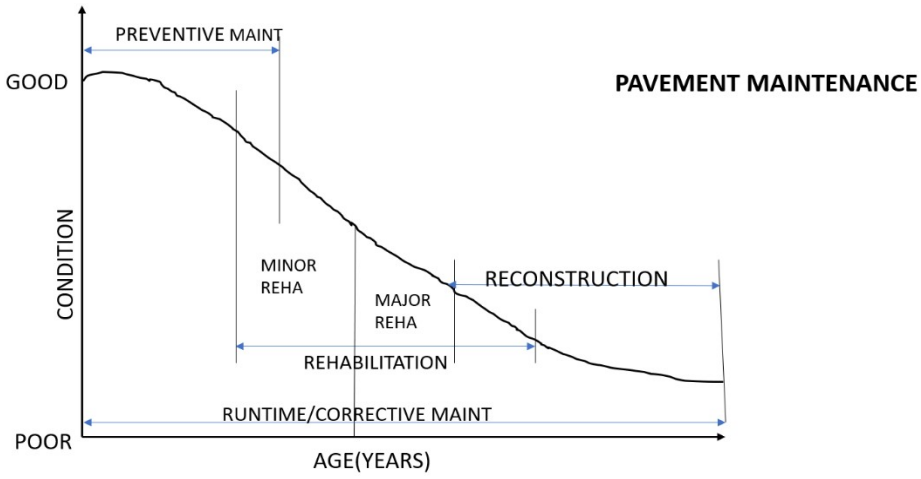

Fig. 9.1. Pavement Maintenance.

10. DEFECTS IN BITUMINOUS SURFACING

The types of defects in bituminous surfacing are grouped under four categories as under:

1. **SURFACE DEFECTS** **Bleeding or Fatty surface** - Applying heated coarse sand, open graded premix, milling out the affected portion.
   Smooth surface - Resurfacing with premix carpet, surface dressing or micro surfacing.
   Streaking - Application of new surface.
   Hungry Surface - Slurry seal or fog seal

2. **CRACKS** **Hair-line cracks** - Fog seal, slurry seal, micro surfacing
   Alligator cracks - Crack sealing, milling and resurfacing
   Longitudinal cracks- Crack sealing, remove and replace with fresh overlay
   Edge cracks - Good drainage along edge of the road, permeable material on shoulders
   Shrinkage cracks - Fog seal, slurry seal, micro surf
   Reflection cracks -Fog seal, slurry sealing, application of liquid rejuvenating agents, use of SAM or SAMI

3. **DEFORMATION** **Slippage** -Removal of affected area and replacement with fresh material
   Rutting- Filling the depressions with premix material
   Corrugations -Scarification and relaying of surfacing, cutting high spots and filling low spots
   Shoving-Removing the material to firm base and relaying a stable mix.
   Shallow depression-Fillingwith premix materials
   Settlements and upheaval -Excavate defective fill and redone, strengthening.

4. **DISINTEGRATION** **Stripping** -Replacement with fresh bituminous mix added with anti-stripping agent, slurry seal, micro surfacing.
   Ravelling-Slurry seal, micro surfacing,resurfacing**.**
   Pot holes-Filling with cold/hot mixes, ready mixes, penetration patching.
   Edge breaking-Cutting the affected area and rebuilding

11. MAINTENANCE COST OF ROADS

The cost of maintenance of roads depends on

(i) Volume and intensity of traffic.
(ii) Cost of materials.
(iii) Labour and machinery.
(iv) Type of terrain.
(v) Type of wearing surface.
(vi) Minimum level of serviceability considered for that category of road.
(vii) Climatic conditions.

12. OPTIMIZATION OF MAINTENANCE COSTS

Important aspect for cost-effective maintenance is the **Selection and Timing of maintenance activities.**

Preventive Maintenance relatively inexpensive - Preserves the system, retards future deterioration and improves functional condition. Most effective when the pavement is structurally sound and exhibits little or no distress.

Preventive maintenance shall be undertaken before **PCR** drops to 2.

If the Pavement distress already present- corrective maintenance (pothole repair and patching, joint replacement or slab replacement) is more appropriate.

Routine maintenance like crack filling may be considered for small distress.

Periodic renewals may be undertaken at a **PCR** of 2.

Strengthening requirement be assessed if **PCR** is 1.

13. PAVEMENT MANAGEMENT SYSTEM (PMS)

A tool or method that assists inoptimizing strategies for providing and maintaining pavements in a serviceable condition over a given period of time.

PMS constitutes the following aspects

(i) Pavement Condition Data.
(ii) Maintenance Standards.
(iii) Economic Analysis.
(iv) Programming.
(v) Control of Works and Feedback.
(vi) Budgetary Analysis.

It helps users select cost-effective alternatives for pavement maintenance and rehabilitation.

Highway Development and Management Tool (HDM-4)

A powerful management software tool developed by WB for the analysis, planning, management and appraisal of road maintenance, improvements and investment decisions. It is used to

(i) to make comparative cost estimates and economic evaluations of different construction and maintenance options.

(ii) perform a comprehensive life-cycle analysis of agency costs, user costs, and benefits using condition deterioration models for roughness, cracking, ravelling, rutting and edge breaking.

14. COST SAVING IN MAINTENANCE

DATA

Project Area	-	Jammu & Kashmir (UT)
Name of Road	-	BG – POONCH (NHDL)
Pavement	-	in good condition
Length	-	40 km
Type of renewal coat	-	30 mm AC
Re surf cycle Period	-	3 years
Maint& Re Surf rates	-	2017-18
Preventive maint to be adopted	-	Micro surfacing 10 mm thick.

CALCULATIONS

Cost of RoutineMaint as per Scale = 40x4.63 = 185.2 lakhs.

Cost of Resurf 30 mm AC with correction work 50 mm BM - 1604 lakhs.

Cost of Micro surf 10 mm th with 2% cement = 40x7x1000x1.05x200 =588 lakhs (rate of micro surf Rs 200/sqm).

Assuming the recycle period is differed by 2 years by adopting preventive maintenance of micro surfacing.

Total Cost of Maint = Routine Maint Cost for 5 y + Preventive Maint cost (Micro surf) = 185.2x5+588x1 = 1514 lakhs.

Total Cost of Maint without Preventive Maint = Routine Maint Cost for 5 Y + Cost of Renewal coat = 185.2x5+1604 = 2530 lakhs.

Saving in cost of maint in 5 year period = 2530-1514 = 1016 lakhs (40.16% of total maint cost**)**

15. CONCLUSION

1. There is a need to introduce the system of assessing the condition of each road before planning the maintenance works to be carried out in BRO.
2. In BRO, maintenance of roads is being carried out as **Routine Maintenance** (drain clearance, berm filling, patch repair etc),**Periodicrenewals**(resurfacing) and **Special/Emergent repairs**(IRMD, SRMD, Improvement/Rehabilitation of roads).
3. There is no concept of costeffective**Preventive Maintenance** (fog seal, slurry seal, micro surfacing, thin asphalt layers with NMAS of 9.5 mm) in BRO which **extend the life of pavement and reduces the costs of renewal coats and rehabilitation**.
4. A certain percentage (about **20%**) of **Periodic renewal** funds may be utilized for **Preventive maintenance** with better materials.
5. **Condition survey** of important roads in each Project should be carried out through Consultancy Agencies for working out the time and type of preventive treatment to be applied on each road and to conclude a consolidated **Performance Based Maintenance Contract**.

Resurf works carried out by self in 2017

Resurf works carried out by Self in 2017