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Case Study on Pavement Composition by Using Benkelman Beam Deflection

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Abstract: Pavement deterioration is a serious problem for road and traffic sector in almost every country. Failures of bituminous pavements are caused due to many reasons or combination of reasons. Failures of bituminous pavements are caused due to many reasons or combination of reasons. Pavement failure occurs when an asphalt surface no longer holds its original shape and develops material stress which causes issues. Pavement failure issues include cracking, potholes, depressions, rutting, shoving, upheavals, and ravelling. This study is discusses the possible causes of pavement failures, and recommends better ways to minimize and hopefully eliminate the causes of failures in bituminous pavements. Pavements are complex structures involving many variables, such as materials, construction methods, loads, environment, maintenance, and economics. Thus, various technical and economic factors must be well understood to design, build pavements, and to maintain better pavements. Moreover, the problems relating to pavement maintenance are still complex due to the dynamic nature of road pavements where elements of the pavement are constantly changing, being added or removed. These elements deteriorate with time and therefore to be maintained in good condition requires substantial expenditure. In this study new construction of road overlay of section or any other preventative measure is suitable relevance with technical & financial viability may be incorporated.

Key Words: Pavements, potholes, rutting, shoving, upheavals and ravelling.

1. Introduction

1.1 General

The National Highways network of India is a network of trunk roads that is owned by the Ministry of Road Transport and Highways. It is constructed and managed by the National Highway Authority of India (NHAI), the National Highways and Infrastructure Development Corporation (NHIDCL), and the public works departments (PWDs) of state governments. NHAI was established by the National Highways Authority of India Act, 1988. Section 16(1) of the Act states that the function of NHAI is to develop, maintain, and manage the National Highways and any other highways vested in, or entrusted to, it by the Government of India.

1.2 Objectives

1. Detection of distress of pavement surface.
2. Significance of Benkelman beam deflection method.
3. Approaches to carry out Pavement Investigation.
4. Economical analysis of pavement composition.

2. Literature Review

For the purpose of my study I have undergone various research papers, various codes and other prominent documents. Prominent of them are discussed below.

[Dangar P.R. et al. (2011])] It is thus concluded that the damage is mostly due to heavy traffic and subsurface exploration revealing that the subgrade have clayey sand and that the main deficiency is the aggregate base, which in some cases are much less than the original pavement recommendations. The pavement deterioration probably starts when moisture migrates into the clay subgrade. Once the clay subgrade becomes wet, its shear strength is reduced and because of the thin aggregate base, the pavement section cannot sustain the traffic loads, causing the deterioration. It has been also observed that water flows through the base material. The base consisted of a granular material placed on stop of a clay subgrade.

[S.Adlinge Sharad et al. (2009)] Sudden increase in traffic loading especially on new roads where the design is based on lesser traffic is a major cause of cracking. After construction of good road, traffic of other roads also shifts to that road. This accelerates the fatigue failure. Temperature variation ranging from 50º C to below zero conditions in the plain areas of North and Central India

leads to bleeding and cracking. Poor drainage conditions especially during rainy seasons, force the water to enter the pavement from the sides as well as from the top surface. In case of open graded bituminous layer, this phenomenon becomes more dangerous and the top layer gets detached from the lower layers. If the temperature of bitumen/bituminous mixes is not maintained properly, then it also leads to pavement failure. Overheating of bitumen reduces the binding property of bitumen. If the temperature of bituminous mix has been lowered down then the compaction will not be proper leading to longitudinal corrugations.

[Michael Tiza et al. (2016)] Pavement thickness was so small, thus, the reason for the devastating rate of deterioration. Very poor drainage is responsible for the rate of failure since flexible pavements have high vulnerability to failure when in contact with water. At most points on the stretch selected for study, it was observed that the distresses could hardly be identified since there was a combination of many types of distresses. Due to poor road condition, too much dust is produced during the dry season, while too much water is found on the pavement in wet seasons. Poor maintenance culture of Highways contributed tremendously to the damages.

[Bin Rashid Zulufqar et al. (2017)] The pavement failure was defined in terms of decreasing serviceability caused by the development of cracks and ruts. The purpose of this study was to evaluate the possible causes of pavement distresses and to recommend remedies to minimize distress of a pavement. In this study various pavement preservation techniques and measures are discussed from the past experience which would be helpful in increasing the serviceable life of pavement.

[Abubakar Wada Surajo et al. (2016)] Road deterioration is a critical situation for road sector because of the high cost for construction of new roads and maintenance of existing roads and routes. Better funding and management should be provided in order to keep the pavements in good condition and from getting damaged due to the aforementioned distresses. Global warming on the other hand has also taken deep impact in many countries nowadays, and this phenomenon also influences the performance of the pavement in different ways.

[Gupta Rakesh et al. (2017)] Proper design, regular inspection and maintenance of drainage system is of utmost importance in preserving the investment made on highway system and in providing comfort and safety to the road user. The defects in existing highway system and in maintenance practices must be clearly understood and eradicated. The small distress (cracking, potholes, shoving, rutting, etc.) must be repaired before any major maintenance (overlay, renewal coat) is done. Even reduced thickness of overlay will show better results if minor defects are repaired before overlays are done.

[Razak Deepu et al. (2018)] Flexible pavement overlay design was carried out as per IRC: 81- 1997 - Guidelines for Flexible Road Pavement Strengthening using Benkelman beam deflection (BBD) technique. The design thickness as per evaluated of Benkelman beam deflection is 85 mm bituminous layer. They have done overlay design as per IRC 37 2012 base on fatigue and rutting failure criteria. The various inputs required for the design is computed through deflection & existing pavement layer thickness as per IRC guidelines. The computed fatigue & rutting strain is 0.0837 micron and 169 micron due to material which is lower than strain due to traffic so the overlay design found safe in both criteria.

[Umersalam et al. (2015)] On the basis of PCS, it was found that the periodic maintenance procedures on the two roads were lacking despite the fact that both roads are of great importance to the nation, which led to the fast deterioration of the road surface characteristics. Water affects the entire serviceability of a road. Too much water in the base materials weakens the road. Water allowed remaining on top of gravel or blacktopped road weakens the surface, and when combined with traffic causes potholes, cracking, and rutting. If improperly channeled, water causes soil erosion and breakdown of pavement edges. No proper drainage system was present to remove the water from the road surface during the rains even the water from the areas around the road comes on the road surface.

[Kumar Shelendra et al. (2015)] Valuable information has also been obtained regarding the performance of new technology thick bituminous layers. The steps to be followed for design of bituminous overlays using the FWD evaluation based approach proposed in the present study have been presented. The development of an indigenous FWD system and performance criteria were necessary for the advancement of pavement technology in India and for the adoption of rational overlay design approaches. Easy availability of the low-cost FWD in India is expected to popularize the use of rational tools in the overlay design and evaluation of pavements in India.

[Khan Shemyla et al. (2017)] On evaluation it was found that the total existing pavement thickness of the road is less than the Designed overall pavement. After excavation and installation of utilities the infill was not compacted properly due to which with due course of time the soil compacted under the wheel load has affected the entire pavement. Water affects the entire road as too much of water in the base materials weakens the road water allowed remaining on top of gravel or blacktopped road weakens when combined with traffic causes potholes, cracking and rutting, if improperly channelled water causes soil erosion etc and breakdown too. Pavement maintenance should be carried out before its deterioration is apparent.

[Gadiya Akshay et al. (2015)]The use of BBD technique may not be only limited to evaluate flexible pavements. Evaluation of newly constructed rigid pavements on the basis of Load Transfer Efficiency of dowel bars gives an idea of the overall performance. The dowel bar systems are designed such that a group of dowel

bars can transfer 40% of the design axle load, across the joint to the adjoining slab. Therefore it can be concluded that BBD test can be a useful for evaluating the performance of rigid pavements, reliable and alternative tool to Falling Weight Deflectometer (FWD) for the study and performance evaluation of rigid pavements.

[Vaidya O. V. et al. (2018)] The Benkelman Beam is used to measure the deflection for various purpose mentioned above. Road projects are costly and a slight error in mm can causes financial losses. This paper gives you detailed information about how the Benkelman beam deflect-meter is used and its specification. Many papers related to this topic will give you information about the evolution of their project. This paper will help you to know the features of Benkelman Beam deflect-meter. The detailed description of working, specification and factors considered while using this instrument are mentioned in this paper.

[Sharma Umesh et al. (2014)] It has been concluded that there is heavy traffic on the study road more than the capacity of the two lane road. The buses of CTU, vehicles from Truck Union, commercial vehicles from District Mohali and nearby villages passing through this road; Therefore this creates lot of heavy traffic loading on the road and causing heavy stresses in the pavement This has caused the degradation of the road due to structural inadequacy of the pavement. Keeping in View the present condition of the road and circumstances prevailing, it is recommended to provide the overlay on the existing road.

[Kumar Mahendrakar et al. (2015)] The growth of traffic on this stretch from last two decades are tremendously increased, increased traffic and heavy axle load vehicles are causing repeated deterioration of this road, hence the road stretch is redesigned for contemporary traffic condition, tonnage suitably. The drainage system both longitudinal and transverse on the selected stretch are inefficient and is not working properly especially at check post, leading to failures pertaining to improper drainage system, namely Pot holes, Stripping etc. Observing the nearest sites it is found that the ground water table at this site is very closer to ground surface, which leading to different types of pavement distress.

[Admute A. M et al. (2017)] This paper describes about the permeable pavements, its types, needs and its present applications. This paper also looked at various literature and studies conducted on permeable pavement systems. The water quality and life span aspects were outlined for permeable pavement systems. Types of contaminant present in the water and which are removed in this system are explained here. Future research and scope of this system is discussed in this paper briefly.

[Raina Sachin et al. (2018)] Studied highway surface drainage system and problems of water logging and concluded that adverse roadway elements contributing to highway accidents were substandard roadway alignment or geometry, lack of shoulders and shoulder defects, absent or inappropriate pedestrian facilities, narrow and defective lanes and bridges/bridge approaches, roadside hazards, undefined pavement centre and edge lines, poor sight distances and visibility, unmarked and inappropriate design of intersections, serious allocation deficiencies along the route, haphazard bus stops, and others are causes of water logging problem in highway.

[Naik Ashpaq et al. (2018)] Concluded the formation of cracks in the pavement surface causes numerous problems such as discomfort to the users, reduction of safety, etc. In addition to the above, intrusion of water causing reduction of the strength in lower layers as well as lowering of bearing capacity of subgrade soil by pumping of soil particles through the cracks is also a major problem associated with the pavements.

[Mohod Milind V. et al. (2016)] In flexible pavement load is transferred from grain to grain and because of that many failures occurs such as fatigue cracking, rutting and thermal cracking. But in rigid pavement no such phenomenon of grain to grain load transfer exists, hence there is fewer amounts of failure. Life span of rigid pavement is more than the flexible pavement with low maintenance cost. Life cycle cost of flexible pavement will be about 19 % higher than the rigid pavement after 20 years. Initial cost of rigid pavement is higher but when comparing total cost of pavement through life span rigid pavement is more economical than flexible pavement.

[Kotak Bhrugu et al. (2015)] The problems relating to pavement maintenance are still complex due to the dynamic nature of road pavements where elements of the pavement are constantly changing, being added or removed. Pavements are complex structures involving many variables, such as materials, construction methods, loads, environment, maintenance, and economics.

[Choudhary Devendra Kumar et al. (2014)] The thickness of crust varies with the change in the value of C.B.R. With higher value of C.B.R. the crust thickness is less and vice versa. From this laboratory test it has been observed that the soil Kopra is suitable for the construction purpose for soil sub grade in comparision with the Yellow soil (Clayey silt) on the basis of higher values of C.B.R. Due to the saving in crust less quantity of material will be applicable so that, huge amount of money can be saved. Due to the higher values of C.B.R the kopra soil will be more durable in comparison to Yellow soil (Clayey silt).

[Sachdeva S.N et al. (2014)] Design of Flexible Pavement using non-conventional layer requires less thickness of pavement and less quantity of bitumen (which is one of costlier material of pavements, saving of bitumen layer up to 47 %) which leads to less usage of material specially the aggregate which is good for environmental point of view. Saving of bitumen and more usage of cement is a better practice as cement is abundantly available which bitumen depends on the imports. The traffic and sub-grade soil characteristics are necessary in order to design a pavement. The IRC method of design can be used to find the total pavement thickness due to its simple approach. A decline in the yearly variation of

commercial vehicles like bus, truck and HCM/EME was observed from the data analysis of traffic volume data.

3. Methodology

Any structure that is built will deteriorate with time when it is subjected to loads and various climatic factors so all structures including pavements will deteriorate with time. So, it is necessary that these structures for example in our case pavements have to be evaluated occasionally, periodically to assess their structural condition and also to assess the remaining life of the pavement and how much more time the pavement can serve the users satisfactorily. So for that one should have appropriate tools to evaluate existing pavements collect some data, collect some information and one should be able to interpret the data that is obtained and make right decisions in terms of the condition of the existence pavement and what is to be done with the existing pavement if its life has to be extended by a given number of years.

The highway pavement evaluation methodologies by various approach, in our study the following methods will be adopted.

Pavements are evaluated typically for two types of performance-

i. Functional Performance
ii. Structural Performance

1. Functional Performance –

Functional performance is the ability of the pavement to provide comfortable, safe, economical riding surface to the users. That basically is a function of the pavement as far as the user is concerned, user requires safe and comfortable ride. As long as the pavement is in a position to give satisfactory service to the road user in terms of safe comfortable ride the pavement continues to be in a functionally acceptable condition.

Methods for measures roughness, cracking, and longitudinal slope variance-

(i) Present serviceability index (PSI)
(ii) Roughness 5th wheel bump indicator
(iii) MERLIN roughness index {Old method}

2. Structural Performance-

Structural evaluation of pavements which is required to assess the structural soundness of the pavement at a given point of time, which is also required for estimating the remaining life of the pavement and to determine the requirement of rehabilitation that is to calculate overlay thickness if it is required.

Methods for measures destructive or non-destructive evaluation

(i) Destructive method {cut core in situ condition}
(ii) Non Destructive test (NDT)
(a) Benkelman Beam Deflection Method (BBD)
(b) Falling Weight Deflection (FWD)

3.3.1. Visual Condition Survey

Condition of existing pavement is the most important data that leads to the maintenance strategy. The basic pavement condition was evaluated by visually observed existing distresses and with the measurements wherever required. Visual pavement condition survey has been carried out.

The observed and recorded data for Pavement Condition Survey are given in Appendix-1.

During field surveys following observations were made:

- Project road consists of flexible pavement. Most of the project road is 7m carriageway width in two lane section.
- The pavement condition of the project road from ex. km 0+000 Barmer to km 27+000 is fair to good.
- Majority of project road is above existing ground level where project road embankment height varies from 0.5m to 1.25m above ground level. The condition of embankment is found fair to good.
- Visual condition survey is carried out and found shoulders condition of entire road projected is fair to good.

The photographs showing pavement condition are presented below

Fig.3.1 Pavement Condition at km 10+100

Fig.3.2 Pavement Condition at 26+500

The visual observation has been classified into three categories i.e. good (very good and good), fair and Poor (poor & very poor). The criteria for pavement distress as per IRC 82:2015 as follows-

Table 5.1 Pavement Distress Based Rating for Highways

Defects (type)	Range of Distress		
Cracking (%)	>10	5 to 10	<5
Ravelling (%)	>10	1 to 10	<1
Potholes (%)	>1	0.1 to 1	<0.1
Shoving (%)	>1	0.1 to 1	<0.1
Patching (%)	>10	1 to 10	<1
Settlement and Depression (%)	>5	1 to 5	<1
Rut depth (mm) using 3 m straight edge	>10	5 to 10	<5
Rating	1	1.1 - 2	2.1 - 3
Condition	Poor	Fair	Good

Pavement condition is presented in pie chart presented in Fig

Condition	Km	%
Good	22	81%
Fair	4	15%
Poor	1	4%
Total	**27**	100.0%

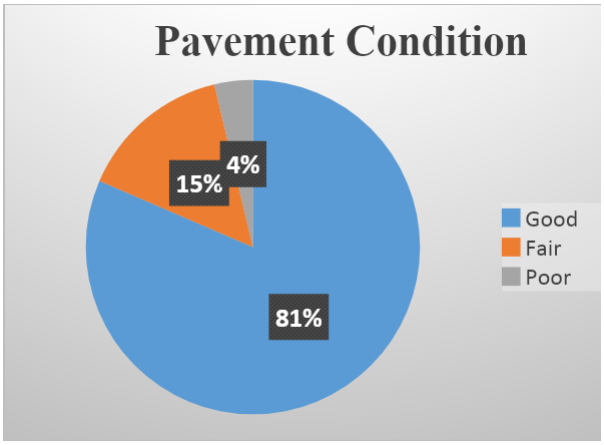

Fig. 3.3 Pavement Condition

3.3.2 Crust Composition

The detailed layer composition of the existing pavement is recorded from each open pit and its observations are presented. Generally the existing pavement structure comprise of three layers namely wearing coarse, base course and sub-base course. The wearing course consists of bituminous material that may be termed as Bituminous Top (BT). The base and sub base layers are consist of Water Bound Macadam (WBM), Murram and soil or combination of any two or all materials. The total thickness of pavement crust varies in Barmer to Chava from 370 mm to 475 mm.

The overall crust details summary is presented in followings Table. In which base and sub base considered as a single layer. The Figure 1.2 show the graphical representation of crust details. Kilometer wise summary sheets shown in Appendix-2

Table 3.1: Summary of Crust Details at Barmer to Chava Stretch

Type of Layer	**Barmer to Chava Strecth**	
	Min(mm)	**Max(mm)**
Bituminous layer	**60**	**90**
Base/Sub base layer	**280**	**415**
Crust thickness	**370**	**475**

3.3.3 Soil Classification

The soil is classified based on the IS soil classification system. This classification is carried out based on the particle size distribution and results of Atterberg's limit. The results of Atterberg's limit shows that liquid limit of existing sub grade soil varies from 21% to 26% at Barmer –Bishangarh section; Plasticity Index of soil is non Plastic. Sub grade soil on the project road comes into soil group SM (Silty Sand).

3.3.4 Modified Proctor Test

The collected soil samples from test pits were compacted with different moisture content in the laboratory in order to obtain dry density v/s moisture content relationship. The method of heavy compaction in accordance with IS: 2720 (Part- 8) was used to determine maximum dry density. The maximum dry density at two stretches respectively (i) Barmer to Chava Stretch 1.760 to 1.87 gm/cc.

3.3.5 Laboratory California Bearing Ratio (CBR)

Laboratory CBR tests are carried out on pit samples as per IS: 2720 (Part- 16). CBR mould are prepared by compacting the soil in five layers giving compaction of 97% of MDD and quantity of water taken during remolding of CBR specimen is equal to Optimum Moisture Content. Four days soaked CBR value with swelling factor if any is worked out. Soaked CBR of Sub grade soil is found varied in (i) Barmer to Chava Stretch 13.10% to 18.07 %.

The Summary of existing subgrade soil at Barmer to Chava Stretch presented in following table 3.2

Table 3.2 Summary of Ex. Subgrade Soil at Barmer to Chava Stetch

Type of Test	Minimum	Maximum
Liquid Limit %	21	25.20
Plastic Limit %	NP	NP
Plasticity Index%	NP	NP
MDD gm/cc	1.76	1.87
OMC %	11.85	14.35
Soaked CBR %	13.10	18.07

3.3.6 Laboratory Test Results of Existing Base / Sub-base

There are various tests were performed to identify the engineering property of soil in the laboratory. They are Grain Size Analysis, Atterberg's limit, Modified Proctor Test and CBR test in accordance with the relevant IS codes. Results obtained from the test pits are presented in Appendix and summary of result is given in Tables 3.3.

Table 3.3 Summary of Results of Existing Base / Subbase (GSB) Barmer to Chava Stretch

Type of Test	Minimum	Maximum
Plasticity Index%	**2.81**	**5.09**
MDD gm/cc	**1.95**	**2.03**
OMC %	**8.80**	**10.85**
Soaked CBR %	**30.07**	**32.38**

Fig. 3.4(a) Caried out BBD Test

Fig. 3.4(b) Caried out BBD Test

The characteristic deflection for each kilometer(where applicable) is calculated by applying seasonal and temperature correction factor in accordance with clause 4.4 and 4.5 and along with satisfying clause 4.3.2 & 4.4.1 of IRC: 81- 1997. The characteristic deflection is determined by taking the average deflection plus 2 times the standard deviation.

3.3.7 Benkelman Beam Deflection Test

Entire project road section in Barmer to Chava, Benkelman beam deflection test has been carried out. Benkelman Beam Deflection (BBD) tests are carried out on the project road in accordance with the guidelines given in IRC: 81, 1997. The deflection data was analyzed to determine the characteristic deflection used for structural evaluation of the pavement.

4. Conclusion

After considering literature review around the research area we taken about idea for implementing the research. According to methodology and codal provision various test has been carried out. From the various test results we find out criteria for both type of construction i.e for overlay and new construction. The ex. layers of road have enough structural strength to sustain the traffic. We could propose and recommend overlay construction for that kind of road, it is technically and finically viable for this type of project and its increases life span of road.

Here given below following Conclusion obtained from research-

- From visual condition survey it has been observed that no such serious distress has been found and 81% of pavement condition is good.
- Deflection test Benkelman beam is carried out and max. Characteristic Deflection is 1.40 mm.
- The difference of cost amount between new construction and overlay construction is around 16 Crore.
- Overlay construction is beneficial from new construction financially & technically.

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