CASE STUDY ON FLEXIBLE PAVEMENT FAILURES ON DODA BHADERWAH ROAD (NH-1B) AND ITS REMEDIAL MEASURES

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ABSTRACT: This Study is a survey to evaluate the flexible pavement conditions to determine and specify the types of the failures in the pavement for the selected highway. It is very significant to evaluate and identify the causes of the flexible pavement failures and select the proper and best treatment and maintenance. The study has two major and critical goals which are covered by considering the following three tasks, the first was the visual evaluation and inspection of existing flexible pavement conditions including the failures, the second to determine and find out the actual treatments and maintenance types. As a case study, of Bhaderwah to Doda road (NH-1B) was selected for evaluation and inspection purpose. The field evaluation works were achieved on the existing flexible pavement conditions of the selected highway. The results were most of the damages and failures in the pavement are serious and extreme surface deformation, cracks disintegration, and surface defects. These damages and failures are caused by fatigue and other types of failures resulted from the movement of heavy vehicles and trucks, poor drainage design, unsuitable pavement layers thickness design, and improper pavement mix design and selected materials. Pavement is a multi-layer system that distributes the vehicular loads over the larger area. It helps to make them durable and able to withstand traffic and the environment.

Pavement consists of three basic layers, the first layer is Sub grade (Gravel) which is the foundation layer, the second layer is Sub-base (layer Assistant foundation) and the top layer is Base (a layer of pavement) which consists of Bituminous Carpet+Bituminous Macadam. Cracking of pavement is a defect that appears in the top layer of the road. Pavement can be under compression and tension at the same time, but in different directions. A crack may also form between the wheel tracks. The maintenance of roads means protecting,restoration and strengthening of all elements of the road to maintain sustainability of the road. A 20km length of the Doda-Bhaderwah road was selected for the study. Survey was carried out and the reasons for cracking and other failures in pavement were studied. Finally the required maintenance solution for each type of failures was identified and the best maintenance option was selected.

I. INTRODUCTION

Transportation infrastructure plays a lead role in economic growth and development of country. India has the second largest highway and road network system in the world. They carry almost 90 percent passenger traffic of our country and 65 percent of freight. Most highways in India are narrow and congested with poor surface quality. Though highways are well designed as well as properly constructed but still it may require maintenance, the extent which will depend on several factors including the pavement type. The functional deterioration is indicated by the changes in surface condition of the pavement in the form of deterioration in the riding quality, which can be measured by simple methods; it is also possible to restore the surface to original condition of the pavement by providing a profile correction course and a resurfacing layer. Scope of transportation system has developed very largely.

Ordinarily the term pavement only means the surface layer. But in the designing of the highways, it means the pavement total thickness including wearing course, base course and sub-base course. It is hard and tough crust constructed over the natural subgrade in order to provide stable and leveled or flat surface for vehicles. It is a structure consist from overlies layers of materials over the natural subgrade which its primary and major function is to transfer and distribute the vehicle axle loads to the subgrade. The structure of pavement should provide acceptable riding quality surface, sufficient skid resistance and minimum noise pollution. For designing purposes and depending on structural function and behavior, the road pavements types are generally divided or classified into two types:

- Flexible pavement
- Rigid pavement

Other pavement types include semi rigid or composite pavement and interlock cement concrete blocks pavement. These pavement types are less familiar than flexible and rigid pavement. Flexible pavement design is the process and method of selecting the most effective and economical composition of flexible pavement courses or layers to fit the subgrade foundation. And cumulative traffic axle load to be carried and handled during the pavements' design life. Flexible pavement structure design is different from building design and the bridges because of the fact that the design of pavement until today is based on semi-empirical or empirical method and there is no rationalistic design method. Flexible pavement design consists mainly from two steps:

1- Material mix design to be used in each layer of the pavement
2- Design the structure of the pavement.

The main and major factors to be taken in consideration in the flexible pavement design are:

1- Traffic volume
2- Climate and weather conditions along the year
3- The road geometric design

4- Position
5- Soil or subgrade
6- Drainage

TYPES OF FAILURES OF FLEXIBLE PAVEMENt

Different types of failure encountered in flexible pavements are as follow:

1. Alligator cracking or Map cracking
2. Consolidation of pavement layers
3. Shear failure cracking
4. Longitudinal cracking
5. Frost heaving
6. Lack of binding to the lower course
7. Reflection cracking
8. Formation of waves and corrugation
9. Bleeding
10. Pumping

Study Area

The condition of pavement between Doda to Bhaderwahis not good enough so that it requires some maintenance and rehabilitation. Road length of 20.0kms from Doda to Bhaderwah (NH-1B). it is the only road which connects Bhaderwah with Himachal Pradesh. The nearby area is mostly agricultural land and remains irrigated throughout the year. Many schools, marriage halls, colleges and residential areas are existing on the stretch, so the traffic volume will increase year by year. There are many college buses, loaded trucks, tractors, public transport travelling 24 hours on the length of road. So the pavement condition shall deteriorate under failing circumstances and unsafe for road users due to heavy traffic.

The salient features of the Road Section are:

Length of the road under study is 20.0 kms .Type of pavement is Bituminous.Width of carriageway is 7.5m. Type of traffic running is mixed. Side shoulders of the section of road are unpaved.

Need for study

In this study the most frequently occurring types of cracks and the defects on the DodaBhaderwah Road will be considered, by visual inspection and through examination will be analysed.After which, the reasons which cause defects in the pavement are studied and the best maintenance option for each type of cracks and defects will be selected.

II. LITERATURE REVIEW

Pavement failure is defined in terms of decreasing serviceability caused by the development of surface distresses such as cracks, potholes and ruts. They reported that before going into the maintenance strategies, highway engineers must look into the causes of failures of bituminous pavements. They found that failures of bituminous pavements are caused due to many reasons or combination of reasons. It has been seen that only three parameters i.e. unevenness index, pavement cracking and rutting are considered while other distresses are ignored.

Following are the literature reviews used for evaluation of flexible pavement failures:

Hofstra and Klomp (1972) [1]found that the deformation in flexible pavements was greater in loading enforcement surface and gradually reduced depending on the depth. This is because the wheel tracking is a permanent deformation and thus increasing the depth increases the resistance and shear stresses are reduced. Asphalt with low shear strength, essential for resistance to repetitive loads of traffic, have intense display wheel tracking problem. The problem is more acute especially during the summer season, as high temperatures are observed on the roadway.

Lytton (1987) [2] said that there are a number of variables that affects the deteriotation of pavements. These major factors affecting pavement performance are considered in pavement design procedures. For accurate prediction, the same factors should be considered in condition prediction models. These factors include treatment type, materials traffic loading, pavement structure, climates and pavement condition prior to the treatment.

Sousa et al. (1991) [3] in their research told that wheel tracking gradually grows under the influence of repeated loadings and typically depicted in the form of deformations along the wheel tracks, accompanied by small rearrangements at the ends. Two causes that contribute to wheel tracking is the compression and shear deformation. Its appearance may occur at various times during the life of a pavement.

S. Jain, P. Kumar (1998) [4] analyzed that the cracking consists of visible discontinuities in surface and can be an indication of the pavement's structural condition and serious. The main problem with cracks is that they allow moisture into pavement, giving accelerated deterioration of pavement. Cracks can occur in a wide variety of patterns (see Plate 1). They may result from a large number of causes, but generally are the result of either ageing and embrittlement of surfacing, environmental conditions, structural or fatigue failure of the pavement, or any other causes.

Sikdar et al (1999) [5] reported that if the potholes are numerous or frequent, it may indicate underlying problem such as inadequate pavement or aged surfacing requiring rehabilitation or replacement. Water entering pavement is often the cause, and could be caused by a cracked surface, high shoulders or pavement depressions ponding water on pavement, porous or open surface, or clogged side ditches.

Caltrans (2001) [6] categorized the main types of pavement failures as either deformation failures or surface texture failures. Deformation failures include corrugations, depressions, potholes, rutting and shoving. These failures may be due to either traffic or environmental influences. It may also reflect serious underlying structural or material problems that may lead to cracking. Surface texture failures include bleeding, cracking, polishing, stripping and raveling. These failures indicate that while the road pavement may still be structurally sound, the surface no longer performs the function it is designed to do, which is normally to provide skid resistance, a smooth running surface and water tightness. Other miscellaneous types of pavement failures include edge defects, patching and roughness.

Woods and Adcox (2004) [7] said pavement failure may be considered as structural, functional, or materials failure, or a combination of these factors. Structural failure is the loss of load carrying capability, where the pavement is no longer able to absorb and transmit the wheel loading through the structure of the road without causing further deterioration. Functional failure is a broader term, which may indicate the loss of any function of the pavement such as skid resistance, structural capacity, and serviceability or passenger comfort. Materials failure occurs due to the disintegration or loss of material characteristics of any of the component materials.

A Ahmed (2008) [8] 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.

P.Kumar and A.Gupta (2010) [9] defined flexible pavement deterioration and failure as a decreasing in the serviceability resulted from the development of surface failure and deterioration such as rutting, cracking and pothole.

Mubarak (2011) [10] investigated recently buildings and streets in old Omdurman City were noted to deteriorate. These deteriorations were attributed to the presence of penetrated water at foundation level, accumulated on impermeable strata of mudstone at shallow depths. She also noted this type of failure in the main road of Alazhari.

Queensland Transport (2012) [11] reported the effect of moisture content changes on the strength and stiffness of pavement materials. They found that excess moisture reduces the strength and stiffness of pavement materials, being worse for the subgrade material, than for the sub base or base. Excess moisture and particularly high degrees of saturation result in significant pore pressures within the material. Depending on the degree of saturation, failure may occur as any of rapid shear or bearing failure, premature rutting, lifting of wearing course due to positive pore pressures, or embedment of cover aggregate due to weak base.

N.G Sorum, T. Guite and N.Matina (2014) [12]defined flexible pavement failure and deterioration by consistence of ruts, cracks, potholes, settlements, localized depression, etc. normally the localized depression is followed with rising in the proximity .The sequence creates waves in the surface of the pavement. The failure or deterioration of any one or more of flexible pavement structure components creates the corrugation and waves on the surface of the pavement or rutting and shoving. Unleveled flexible pavement may itself consider as a failure and deterioration when it is excrescent. The flexible pavement failure and deterioration subject is considered to be complicated as several factors participate to its failure and deterioration. The oxidation and aging of asphalt films cause the failure and deterioration of flexible pavement.Destructive actions in flexible pavement are quickly increased when surplus water is retained in the flexible pavement void spaces.

Omer et al., (2014) [13] studied the pavement failures in the ring road in Khartoum. They observed from the site visit to the road severe trenched on the west lane that might have been caused by the movements of heavily loaded truck-trailers, tippers, as well as loaded fuel tankers. The damage could also be attributed to insufficient implementation process, inadequate design or improper pavement materials used.

III. METHODOLOGY

The objective of this study is to establish guidelines describing systematic method for inspection and evaluation of pavement failures and to find out the possible causes of these failures. The proposed method has some basic steps as follows:

i. Inspection and Evaluation Plan
ii. Pavement Condition Survey
iii. Experimental work
iv. Determine Probable causes of Failure
v. Select the best Maintenance Option
vi. Report on Outcomes

Structural failure may arise due to certain factor .Some of them are as follows.

1. Ageing of flexible pavement
2. Increase in traffic volume from that of the predicted one
3. Random changes in climate
4. Overloading

These structural failures may results in certain stresses in the existing pavements which lead to the total failure of the pavements.

Inspection and Evaluation Plan

Planning is important to ensure that inspection and evaluation of pavement failures were carried out their intended tasks within a reasonable time frame and at the lowest cost.

When planning the evaluation program, a general review of the problem should first be conducted, along with the possible scope of inspection and maintenance work that may need to be carried out. This plan should be drafted, addressing goals, budgeting constraints, operations planning and the investigative synthesis. The technical team should be decided upon.

Pavement Condition Survey

The pavement condition survey may include visual examination of pavement failures, the effectiveness of drainage structures and other details such as topography and alignment should be recorded, and the soil and geology of the surrounding areas may also be of importance in determining the causes of the pavement failure. An effective visual survey of pavement failures is essential, to ensure that the cause of the failure can be diagnosed efficiently and it is a guide to what testing should be carried out and where. Distress surveying should be carried out on failed pavement sections to find out the amount, type, and condition or severity level of distress, as well as the condition or effectiveness of any previously applied distress treatments.

This phase of operation, which shall precede the actual deflection measurement, consists primarily of visual observations supplemented by simple measurements for rut-depth using a 3 meter straight edge. Based on these the road length shall be classified into sections of equal performance in accordance with the criteria given in Table 3.1

Table 3.1 Criteria for Classification of Pavement Sections

Classification	Pavement Condition
Good	No cracking, rutting less than 10 mm.
Fair	No cracking or cracking confined to single crack in the wheel track with rutting between 10 mm and 20 mm.
Poor	Extensive cracking and/or rutting greater than 20 mm. Sections with cracking exceeding 20 percent shall be treated as failed.

Experimental work

The experimental work includes filed and laboratory testing. Field testing program can assess the strength of the pavement materials. The conventional field tests may be carried out include Benkelman Beams, Dynamic Cone Penetration (DCP) test, roughness and surface evenness measurement, skid resistance testing. Coring on pavement structure may be used to provide material samples for laboratory testing, and also allows visual examination of pavement layers.

Laboratory testing should be conducted on representative samples taken from pavement layers to determine physical characteristics of the materials. The tests on soils and aggregates may aim to measure the index properties by particle size and shape, the plasticity and specific gravity and to assess the strength by the compaction and California Bearing Ratio (CBR) tests. Geotechnical tests may include measurement of the shear strength, consolidation and determine the water table level during site investigation.

Asphalt tests may be used to measure the consistency by penetration, viscosity and ductility. Marshall Tests for stability and flow measurements of asphalt concrete sample and extraction test is also necessary to perform.

Field and Laboratory

Tests Following tests were conducted during the course of this study:

a). Sieve Analysis
b). Lose Angeles Abrasion Test
c). Modified Procter Compaction Test
d). In situ Density Test (Sand replacement method)
e). DCP Test (In situ and soaked condition)
f). Laboratory CBR Test (Soaked condition at in situ density)

IV. DATA COLLECTION AND ANALYSIS

Soil Profile

Soil is the basic material for road construction. Soil is the accumulation or deposition of ground materials, naturally derived from rock breakage or vegetation decay that can be easily drilled with field power equipment. Before constructing the road, physical properties of the soil must be determined. The supporting soil beneath the pavement is called sub grade. Compacted sub grade is the soil compacted by controlled movement of heavy compactors. There are many types of soils that are used in road construction; the best ones are derived from rock breakage but this type are expensive. In municipal projects they used inexpensive soil such as alluvial soil because it's available in J&K.

Common Types of Distresses

Type of Distress

S. No.	Type of Distress	Description
1	Map cracking	Series of interconnected cracks caused by fatigue failure under repeated traffic loading
2	Block cracking	Interconnected cracks that divide the pavement up into rectangular blocks (approx. 0.1 m2 to 9 m2)
3	Longitudinal cracking	Cracks parallel to the pavement's centerline direction
4	Patching	An area of pavement that has been replaced with new material to repair the existing pavement
5	Potholes	A hole in a road surfaces that result from gradual damage caused by traffic or weather.
6	Raveling	Asphalt raveling is the progressive disintegration of a hot mix asphalt layer from the surface downward as a result of the dislodgement of aggregate particles

Distress Measurements

Measurements of the distress in Doda to BhaderwahRoad

Section	Type of Distress	Length (mm)	Width (mm)	Depth (mm)
PulDoda to Pranoo	Longitudinal cracking	2101	4.8	-
	Edge failure	1862	-	-
	Patching	375	1760	-
	Pothole	396	-	10.9
	Edge failure	1134	-	-
	Raveling	1220	5465	-

Measurements of the distress in Doda to BhaderwahRoad

Section	Type of Distress	Length (mm)	Width (mm)	Depth (mm)
Pranoo to Bhalla	Pothole	696	-	45
	Raveling	790	2465	-
	Edge failure	1096	-	-
	Pothole	315	-	36
	Longitudinal cracking	1890	11.4	- -

Measurements of the distress in Doda to BhaderwahRoad

Section	Type of Distress	Length (mm)	Width (mm)	Depth (mm)
Bhalla to Khellani	Longitudinal cracking	1420	6	-
	Patching	490	180	-
	Edge failure	580	-	-
	Pothole	125	-	25.5
	Patching	863	4180	-
	Block cracking	656	3.8	-

Measurements of the distress in Doda to Bhaderwah Road

Section	Type of Distress	Length (mm)	Width (mm)	Depth (mm)
Khellani to Seri	Pothole	385	-	36.5
	Longitudinal cracking	762	3.2	-
	Raveling	2120	4580	-
	Edge Failure	1125	-	-
	Block cracking	1580	6.26	-

Suitable Causes and Remedies

Alligator cracking

S. No.	Possible Causes	Suggested Treatment
1	Inadequate pavement thickness	Strength the pavement or reconstruction
2	Low module base	Strengthen the base or reconstruction
3	Poor base drainage	Improve the drainage and reconstruction
4	Brittle base	Base recycling or reconstruction

Edge Cracking

S. No.	Possible Causes	Suggested Treatment
1	Inadequate pavement width	Widen the pavement
2	Seepage and heavy rainfall	Proper and efficient drainage
3	No shoulder	Construct shoulders

Longitudinal cracking

S. No.	Possible Causes	Suggested Treatment
1	Reflection of shrinkage cracks	Cut and patch
2	Displacement of joints at pavement widening	Reconstruction of joints

Table 4.9 Potholes

S. No.	Possible Causes	Suggested Treatment
1	Loss of surface course due to heavy rainfall	Patching
2	Moisture entry to base course through a cracked pavement surface	Cut and patching

Table 4.10 Raveling

S. No.	Possible Causes	Suggested Treatment
1	Insufficient bitumen content	Thin bitumen overlay
2	Deterioration of aggregate	Thin bitumen overlay
3	Construction during wet weather	Thin bitumen overlay

Table 4.11 Patching

S. No.	Possible Causes	Suggested Treatment
1	Insufficient bitumen content	Thin bitumen overlay
2	Deterioration of aggregate	Thin bitumen overlay

The Common Types of Defects and Cracks Found

Block Cracking

Block cracking is overlapping cracks that divide the pavement into rectangular or square pieces. The area of the blocks range from 0.1 m2 to 9 m2. Large blocks are classified as transverse or longitudinal cracking. The difference between the Block cracking and Alligator/Fatigue Cracking is that the Alligator Cracking is small pieces and located in the wheel path but the Block cracking is located everywhere on the pavement.

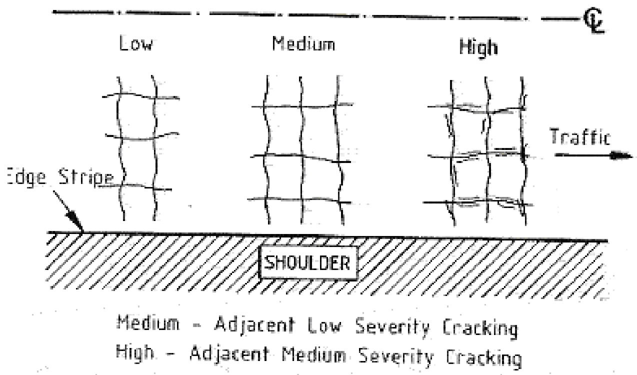


Fig. 4.5.1 Block Cracking Severity Levels

Severity Levels

- Low: Cracks with a mean width ≤ 6 mm.
- Moderate: Cracks with a mean width > 6 mm and ≤ 19 mm.
- High: Cracks with a mean width > 19 mm

Table 4.12 Severity levels in block cracking

Section	Type of Distress	Length (mm)	Width (mm)	Severity Levels
Bhalla to Khellani	Block	654	3.2	Low

Khellani to Seri	Cracking	1520	6.2	Moderate

Suggested Maintenance Methods

The block crack in section Bhalla to Khellani has low severity level and section Khellani to Seri has moderate so they need to be treated with Crack seal to prevent moisture entering into subgrade through the cracks.

4.5.2 Longitudinal Cracks

The longitudinal cracks are parallel slits to the pavement's centerline; these cracks are structural defects and Functional defects. The loads and moisture accelerate the deterioration of these cracks.

Fig. 4.5.2 Longitudinal Cracking

Severity Levels

- Low: Cracks with a mean width ≤ 6 mm.
- Moderate: Cracks with a mean width > 6 mm and ≤19 mm.
- High: Cracks with a mean width > 19 mm.

Table 4.13 Severity levels in longitudinal cracking

Section	Type of Distress	Length (mm)	Width (mm)	Severity Levels
PulDoda to Pranoo	Longitudinal cracking	1750	4.8	Low
Pranoo to Bhalla		1820	11.9	Moderate and Low
		1360	2.4	
Bhalla to Khellani		1710	4	Low
Khellani to Seri		950	3.9	Low

Suggested Maintenance Methods

The longitudinal cracking in section PulDoda to Pranoo, Pranoo to Bhalla, Bhalla to Khellani and Khellani to Seri are of low severity levels. So, the suggested maintenance is Crack seal to prevent moisture entering into subgrade through the cracks. Provide side drainage ditches to reduce cracking.

4.5.3 Edge Cracking

Edges cracking generally are parallel to the edge of the pavement. The shape of cracks is crescent or fairly continuous cracks. Edge cracks are increased due to excess traffic loads.

Fig. 4.5.3 Edge Cracking

Severity Levels

- Low: Cracks with no breakup or loss of material.
- Moderate: Cracks with some breakup and loss of material for up to 10% of the length of the affected portion of the pavement.
- High: Cracks with considerable breakup and loss of material for more than 10% of the length of the affected portion of the pavement.

Table 4.14 Severity levels in edge cracking

Section	Type of Distress	Length (mm)	Severity Levels
PulDoda to Pranoo	Edge Cracking	1120	Moderate
		1210	Low
Pranoo to Bhalla		1580	High
Bhalla to Khellani		570	High
Khellani to Seri		1235	Moderate

Suggested Maintenance Methods

- Improve drainage. Remove vegetation close to edge.
- Reconstruct of the edge and support the edge with paving stones.

4.5.4 Raveling

Raveling is loss of material that covered asphalt surface or is the progressive disintegration of HMA layer as a result of the dislodgement of aggregate particles. These defects indicate that asphalt materials may be hardness or the asphalt mixture that was used is poor.

Severity Levels

Not applicable. The presence of raveling indicates potential mixture related performance problems. Extent is sufficient to monitor any progression

Severity levels in raveling

Section	Type of Distress	Length (mm)	Width (mm)	Severity Levels
PulDoda to Pranoo	Raveling	670	590	Not Applicable
Pranoo to Bhalla		840	309	
Bhalla to Khellani		2230	618	

Suggested Maintenance Methods

For small raveled areas which centered areas of raveling, Remove the raveled pavement and patch. For large raveled areas indicative of general HMA failure, Remove the damaged pavement and overlay.

4.5.5 Pothole

Pothole is a hole in a road surfaces that penetrate the road through the HMA layer down to the base course. Potholes generally have sharp edges and vertical sides near the top of the hole. Normally the potholes occur on road that has the thickness less than 70mm.

Severity Levels

- Low: the depth < 25 mm.
- Moderate: the depth between 25 mm to 50 mm.
- High: the depth > 50 mm.

Table 4.16 Severity levels in potholes

Section	Type of Distress	Length (mm)	Depth (mm)	Severity Levels
PulDoda to Pranoo	Pothole	410	9,2	Low
Pranoo to Bhalla		780	45	High
		280	35	Moderate
Bhalla to Khellani		130	19.20	Low
Khellani to Seri		440	35.5	Moderate

Severity Levels

- Low: Patch has; at most, low severity distress and Low impact on driving quality.
- Moderate: Patch has moderate severity distress and moderate impact on driving quality.
- High: Patch has high severity distress of any type including rutting and high impact on driving quality.

Table 4.17 Severity levels in patching

Section	Type of Distress	Length (mm)	Width (mm)	Severity Levels
PulDoda to Pranoo	Patching	410	618	High
Pranoo to Bhalla		520	130	Low
		890	611	Moderate

Abrasion value is determined by taking the grading of aggregates used into account

Table 4.18Determination of Los Angeles Abrasion Value

Sieve size Passing (mm)	Retained on (mm)	Weight of test sample in gm						
		A	B	C	D	E	F	G
80	63					2500		
63	50					2500		
50	40					5000	5000	
40	25	1250					5000	5000
25	20	1250						5000
20	12.5	1250	2500					
12.5	10	1250	2500					
10	6.3			2500				
6.3	4.75			2500				
4.75	2.36				5000			

Table 4.19 Selection of Abrasive Charge

Grading	No of Steel balls	Weight of charge in gm.
A	12	5000 ± 25
B	11	4584 ±25
C	8	3330 ± 20
D	6	2500 ± 15
E	12	5000 ± 25
F	12	5000 ± 25
G	12	5000 ± 25

Observation of Los Angeles Test

Original weight of aggregate sample =5000 g

Weight of aggregate sample retained =3300 g

Weight passing 1.7mm IS sieve= (5000-3300) g

Abrasion value = (5000-3300)/5000×100

Results

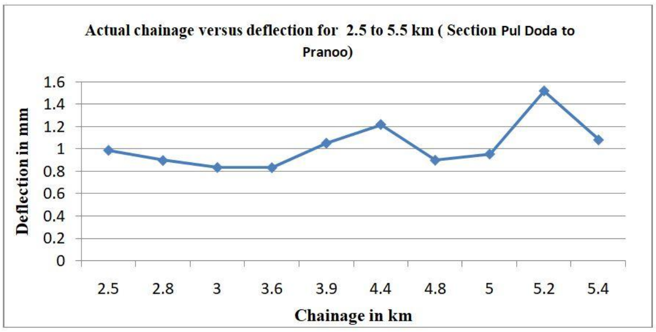
Los Angeles Abrasion value =34

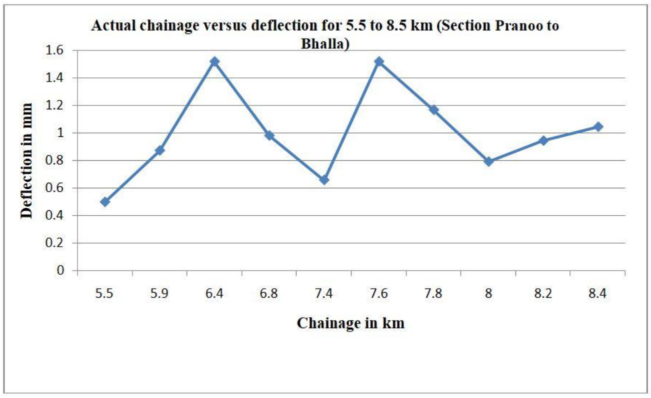
Depending upon the value, the suitability of aggregates for different road constructions can be judged as per IRC specification as given

S. No.	Type of Pavement	Max. permissible abrasion value in %
1	Water bound macadam sub base course	60
2	WBM base course with bituminous surfacing	50
3	Bituminous bound macadam	50
4	WBM surfacing course	40
5	Bituminous penetration macadam	40
6	Bituminous surface dressing, cement concrete surface course	35
7	Bituminous concrete surface course	30

Table 4.20 Calculation for rebound deflection and characteristic deflection

			Bankleman Beam dial gauge reading(mm)				
Sr.no	**Location of test point and identification of lane**	**Pavement temperature °C**	**Initial**	**Intermediate**	**Final**	**Rebound deflection (mm)**	**Corrected deflection (mm)**
PulDoda to Pranoo							
1	0L	34	5.3	5.55	5.6	0.891	0.9911
2	50R	34	6.3	6.6	6.63	0.835	0.9295
3	100L	34	3.2	3.37	3.43	0.8092	0.90112
4	150R	34	4.5	4.71	4.77	0.89	0.99
5	200L	34	3.6	3.82	3.86	0.7528	0.83908
6	250R	34	6.5	6.68	6.73	0.751	0.8371
7	300L	34	4.6	4.7	5.0	0.751	0.8371
8	350R	34	2.3	2.24	2.51	0.9438	1.04918
9	400L	34	1.6	1.84	1.9	0.9492	1.05512
10	450R	34	5.7	5.89	6.0	1.2402	1.37522
11	500L	34	6.0	6.12	6.23	1.1002	1.22122
12	550R	34	6.3	6.54	6.57	0.715	0.7975
13	600L	34	6.1	6.31	6.36	0.811	0.9031
14	650R	35	1.8	2.03	2.06	0.695	0.7645
15	700L	35	4.1	4..34	4.39	0.871	0.9581
16	750R	35	6.3	4.9	6.67	0.973	1.5202
17	800L	35	4.6	6.63	5.0	1.382	1.0702
18	850R	35	3.0	3.31	3.36	1.011	1.1121
19	900L	35	6.5	6.68	6.67	0.9856	1.08416
20	950R	35	5.3	5.47	5.56	1.0438	1.14818
Pranoo to Bhalla							
1	0L	36	2.6	2.71	2.76	0.455	0.5005
2	50R	36	3.6	3.81	3.86	0.811	0.8151
3	100L	36	4.5	4.78	4.81	0.795	0.8745
4	150R	36	4.6	4.88	4.88	0.56	0.539
5	200L	36	2.9	3.2	3.3	1.382	1.5202
6	250R	36	6.3	6.6	6.64	0.913	0.9273
7	300L	36	4.3	4.59	4.63	0.893	0.9823
8	350R	36	1.3	1.65	1.68	0.935	0.9515
9	400L	35	5.6	5.7	5.9	0.60	0.66
10	450R	35	6.3	6.56	6.6	0.833	0.8393
11	500L	35	5.6	5.9	6.0	1.382	1.5202
12	550R	35	7.3	7.49	7.53	0.693	0.6853
13	600L	36	6.3	6.4	6.4	0.20	0.209
14	650R	37	6.4	6.81	6.85	1.133	1.1693
15	700L	37	1.3	1.62	1.65	0.875	0.9515
16	750R	37	4.6	4.8	4.85	0.791	0.7931
17	800L	37	1.3	1.49	1.57	1.0056	1.09516
18	850R	36	5.6	5.83	5.89	0.9292	0.94512
19	900L	35	1.6	1.83	1.87	0.7728	0.83908
20	950R	35	4.0	4.31	4.36	1.011	1.0461
Bhalla to Khellani							
1	0L	36	2.3	2.51	2.59	1.0456	1.128804
2	50R	36	3.4	3.59	3.63	0.693	0.68997
3	100L	37	3.0	3.24	3.3	0.9492	1.023728
4	150R	37	2.6	2.76	2.86	0.633	0.62457
5	200L	37	4.6	4.81	4.89	1.0456	1.128804
6	250R	37	2.4	2.61	2.66	0.811	0.81859
7	300L	38	5.6	5.96	5.99	0.955	1.03005
8	350R	38	1.60	1.83	1.89	0.9292	0.94742
9	400L	37	2.4	2.59	2.63	0.693	0.74447
10	450R	37	4.8	5.09	5.15	1.0492	1.078228
11	500L	39	4.9	5.14	5.21	1.0274	1.10896
12	550R	39	7.6	7.81	7.86	0.811	0.81859
13	600L	39	6.3	6.48	6.55	0.9074	0.967266
14	650R	39	4.1	4.42	4.46	0.9528	0.973152
15	700L	39	4.0	4.24	4.29	0.871	0.92759
16	750R	39	5.1	5.37	5.41	0.853	0.86437
17	800L	38	5.6	5.81	5.86	0.811	0.86219
18	850R	38	3.0	3.23	3.29	0.9292	0.958328
19	900L	38	3.2	3.46	3.53	1.0674	1.141666
20	950R	38	5.6	5.81	5.88	0.9674	0.99996





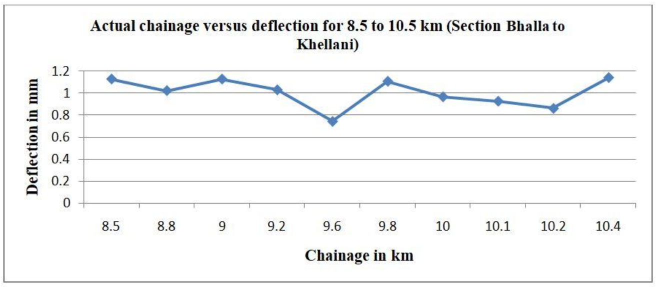


Fig.4.6 Variation of deflection with chainage

Calculation of characteristic deflection from the analysis of test data for section 2.5 to 5.5 km

Mean deflection mm, X $=\frac{\sum x}{n}$ = 1.0192 mm

Standard deviation mm, σ = $\frac{\sqrt{\sum(x-X)^2}}{n-1}$ = 0.0442 mm

Characteristic deflection mm, Dc = X + 2σ = 1.10767 mm

Calculation of characteristic deflection from the analysis of test data for section 5.5 to 8.5 km

Mean deflection mm, X $=\frac{\sum x}{n}$ = 0.9127 mm

Standard deviation mm, σ = $\frac{\sqrt{\sum(x-X)^2}}{n-1}$ = 0.0628 mm

Characteristic deflection mm, Dc = X + 2σ = 1.0383 mm

Calculation of characteristic deflection from the analysis of test data for section 8.5 to 10.5 km

Mean deflection mm, X $=\frac{\sum x}{n}$ = 0.9418 mm

Standard deviation mm, σ = $\frac{\sqrt{\sum(x-X)^2}}{n-1}$= 0.0342mm

Characteristic deflection mm, Dc = X + 2σ = 1.01022mm

V. CONCLUSION AND FUTURE SCOPE

Conclusion

Some causes of road cracks and deterioration and defects are due to poor construction quality, structural failure of base, poor highway facilities, poor maintenance policy, poor supervision.

Pavement deterioration process starts very slowly so that it may not be noticeable, and over the time it accelerates at faster rates, there must be implementation of the proper maintenance and repair work in suitable time; which will maintain the pavement in a safe and acceptable operational condition and helps to save cost of maintenance.

Road maintenance is one of the important components of the entire road system. Even if the roads are well designed and constructed, they may require maintenance. Repair and maintenance procedures cannot overcome bad design problems but can help prevent these problems resulting from degradation.

The possible causes of deterioration on the study of road are firstly during construction of road,failure in the layers of the pavement, the asphalt mixture arrival at the site is not at required temperature, the wrong way in the casting and compaction of asphalt and secondly after construction, expansion and contraction of asphalt materials, high stress, lack of water drainage system and many more. Early detection and repair of road defects are important to maintain the permanence of road. The suggested maintenance for the cracks and defects in the selected road are crack seal (fill the crack) to prevent moisture entering into subgrade through the cracks, improve (construct) drainage system, reconstruction of the pavement edging and its support with paving stones and patching.

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