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Case Study

A STUDY OF PREMATURE FAILURE OF BITUMINOUS ROAD: JABALPUR- PATAN ROAD: A CASE STUDY

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Roads should last for the period for which they have been designed. But sometimes failure takes place on the roads well before their design life, commonly known as premature failure of highways and roads. Jabalpur-Patan road is a typical case of premature failure of a bitumen road in district Jabalpur, MP. A detailed study was conducted to find out various causes of premature failure of this road and to suggest remedial measures to prevent such failures in the future and to bring out solutions in practice from the point of view of Geotechnical and Highway engineering.

Keywords: Premature Failure, Pavement, Bituminous Roads, Geotechnical and Traffic Study, MORTH

INTRODUCTION

Roads are the lifelines of development of any area, state or country. The pace of progress is intimately connected with the network of roads, connectivity between various growth centers and hassle less movement of man and materials all the year round to various places of activity.

At one hand the speed of growth directly depends upon the effective network of roads and on the other hand an effective network of roads is the direct outcome of proper infrastructure development. Roads have become very important in our life because the economy of time and money is largely dependent on the availability of roads from point to point.

Sometimes failure takes place on the roads well before their design life, commonly known as premature failure of highways and roads.

There are multiple reasons for premature failure of bitumen roads and a variety of known and unknown factors responsible for such failures. More important factor is the error in following instructions given in the manuals for every stage of road construction, may it be raising of a new road or improvement of existing road in all the cases the guidelines given in the manuals in respect of materials to be used, quality control measures to be strictly adhered to and number of checks and rechecks by different agencies engaged in the task of constructing quality bitumen roads.

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It has been observed that frequent damage to the bitumen roads immediately after the construction of roads takes place.

STUDY ROAD DETAILS

Jabalpur- Patan road is a typical case of premature failure of a bitumen road, reconstructed by state PWD of M.P. in the year 2007. The distance between Jabalpur and Patan is approximately 30 km. This road connects Jabalpur to Damoh district via Patan and Tendukheda blocks. This road is a bituminous road and was constructed mainly to carry moderate traffic load of small buses, light commercial vehicles, tractors, bullock carts and light motor vehicles.

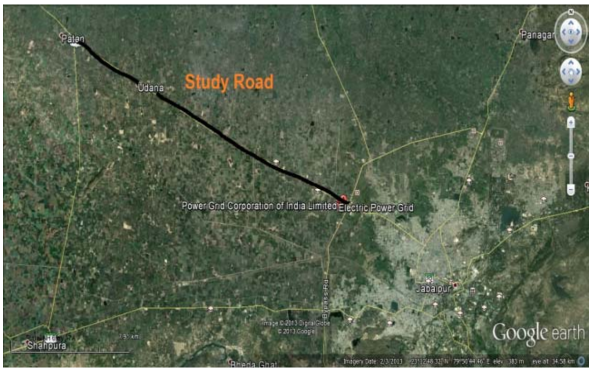
Out of the 30 km length of the road, for purpose of study a stretch of 20 km between the villages Sukha and Patan has been selected, as shown in the schematic sketch of the road outlay.

This existing road is a single lane road with

- Carriage width is 3.75 m
- Road way 7.5 m
- newly built shoulders
- Present road condition: Poor
- Having insufficient width to cross heavy vehicles safely.

Edge cracking, big pot holes and uneven settlement are some of the key features which are apparent when we travel on this road. At the same time the crossing of two vehicles is risky due to the edge cracking and narrow width of this road.

Figure 1: Map of the Study Road



OBJECTIVE OF THE STUDY

The objective of the study is to find out various causes of *premature failure* of such an important road and to suggest remedial measures to prevent such failures in the future and to bring out solutions in practice from the point of view of Geotechnical and Highway engineering.

LITERATURE REVIEW

An extensive literature review was undertaken to gather information pertaining to investigations of pavement failures as well as current materials requirements and design and construction practices utilized to minimize the risk of moisture-related damage in flexible pavements. This section provides a synthesis of the findings of the available literature. Research work has been done in this field on various roads in India and abroad. Brief description of some of the work is outlined here:

Mahesh Kumar *et al*. shown in their research work that Heavy vehicular loads cause damage to road crusts. Not adopting proper specifications in execution of work such as non sealing the surface of DBM, non preparation of berms with overlays, heavy axle loads and impervious bitumen layers resulted into the failure of highways.

Praveen Kumar *et al*. in their research paper on 'Case studies on failure of Bituminous Pavement' found that the pavement failure is 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 the pavement. The paper describes lessons learnt from pavement failures and problems experienced during the last few years on a number of projects in India. Based on the past experiences various pavement preservation techniques and measures are also discussed which will be helpful in increasing the serviceable life of pavement.

Dangar Rushikesh *et al*. conducted studies on Pavement Deterioration on National Highway 8b Section Rajkot-Bamanbore (Km 185/0-Km 216/8) and reached on very important findings on pavement deterioration.

According to them, 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. The paper analyze the condition survey of the NH 8-B (Section Rajkot-Bamnabore (km 185/0-km 216/8)). It gives an idea about problem of pavement deterioration and pavement condition at present.

Studies conducted by Horak *et al.* in their research found that premature failure in the form of cracking, stripping and brittleness of a hot mix asphalt surfacing on a major road in South Africa was investigated. Anecdotal evidence as well as pavement structural evaluation with the FWD confirmed that the distress was restricted to the surface layer alone. Testing on the recovered binder indicated that excessive filler material was present in the mix.

METHODOLOGY OF THE STUDY

After conducting the reconnaissance of the study road, it was decided to go for the detailed field work. Permission was taken from the authorities of MPPWD, Jabalpur.

Ten numbers of trial pits were dug to collect the sample from the study road at different locations. The location of the test pits were kept in staggered manner 2-3 km apart from each other.

The test pits measuring 1.2 m x 1.2 m were dug open upto the subgrade level to find out the thickness of the pavement layers to study the quality of the material as well as construction quality in order to check the causes of the causes of the premature failure of the study road. The average depth of the excavation of the test pits was 0.8 m.

The study road was investigated for the causes of distress and failure of the existing pavement. Traffic volume study was also conducted. Traffic volume data has been taken after carrying out the traffic survey at the site. The survey covered counting of different category of vehicles.

a. Traffic Volume Count Details of the Study Road

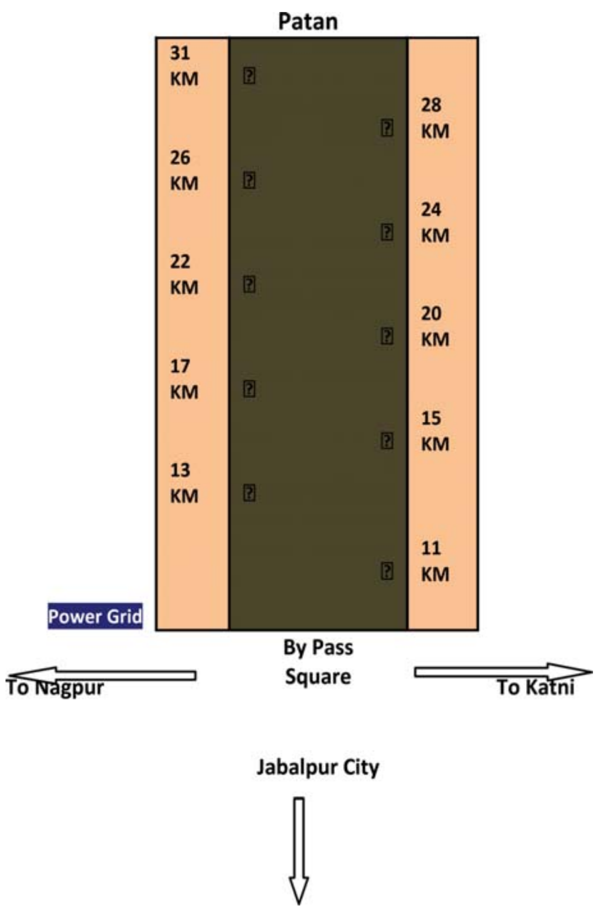
Traffic surveys were conducted on three different days for a period of 24 hours each day at the time of sample collection. The focus of traffic study was to count the total number of Commercial Vehicles Per Day (CVPD). The results of this study were used to calculate the design traffic in terms of Million Standard Axles (MSA)

b. Various Tests conducted on the Samples Collected from Test Pit:

For the detailed investigation of the causes of failure, various tests were performed on the sample collected from the crust of the study road are as follows:

1. Bitumen binder content
2. Gradation of particles

Figure 2: Schematic Diagram of the Study Road and Test Pits with Numbers



3. Atterberg's limits (LL, PI)
4. Water content
5. Field density
6. Compaction test
7. CBR test
8. Aggregate Impact Value test

The results of the above mentioned tests are represented in separate tables for different pavement layers.

Various tests were conducted on the samples collected from 10 different locations of the study road. Tests were performed as per the latest versions of IS and IRC standards in the laboratory and in the field as well. The results of various tests are represented in tabular form for different layers of the pavement of the study road.

RESULTS AND DISCUSSION

Figure 3: Photograph of the Existing Condition of the Study Road

1. Wearing Course (25 m SDBC + 50 mm BM) as per design)

Table 1: Bitumen Binder Content

Sample No.	Binder Content %	Surplus/ Deficit (As per design)	Thickness of layer (mm)	Surplus/ Deficit (As per design)
1	3.23	Deficit (0.1%)	65	Deficit (10 mm)
2	3.29	Deficit (0.01%)	70	Deficit (5 mm)
3	2.9	Deficit (0.4 %)	72	Deficit (3 mm)
4	3.25	Deficit (0.05%)	78	Surplus (3 mm)
5	3.11	Deficit (0.19%)	65	Deficit (10 mm)
6	4.16	Surplus (0.86%)	78	Surplus(3mm)
7	4.08	Surplus (0.58%)	64	Deficit (11 mm)
8	3.5	Sufficient	59	Deficit (16 mm)
9	3.61	Surplus (0.11%)	65	Deficit (10 mm)
10	2.89	Deficit (0.41%)	79	Surplus (4 mm)

Binder Content should be between 3.3- 3.5 % for BM as per MORT&H Specification.

Table 2: Grading of the aggregates in BM Layer

Percentage Passing by Weight Through IS Sieve

Sieve Size (mm)	Samples										Permissible Limits*
	1	2	3	4	5	6	7	8	9	10	
26.5	100	100	100	100	100	100	100	100	100	100	100
19	92.68	95.68	94.38	91.77	93.67	95.98	92.68	90.4	94.36	92.32	90-100
13.2	78.13	68.32	67.81	85.11	78.76	69.59	78.32	65.36	68.21	71.26	56-88
4.75	29.58	17.38	21.56	26.82	32.33	25.91	11.38	15.85	18.36	20.87	16-36
2.36	11.34	12.76	7.56	9.91	15.56	18.82	12.76	10.98	12.56	14.21	4-19
0.3	7.55	8.33	11.62	12.26	6.68	5.88	7.33	8.02	8.67	9.56	2-10
0.075	3.56	2.36	2.45	4.48	5.24	6.17	2.36	4.36	4.56	5.21	0-8

2. Base Course (Water Bound Macadam) Grade I, II and III layer

Table 3: Aggregate Gradation, Liquid Limit, Plasticity Index of WBM G I Layer (Layer Thickness=100 mm)

Percentage Passing by Weight Through IS Sieve

Sieve Size (mm)	Samples										Permissible Limits*
	1	2	3	4	5	6	7	8	9	10	
Gradation for Coarse Aggregates											
125.0	100	100	100	100	100	100	100	100	100	100	**100**

Table 3 (Cont.)

Sieve Size (mm)	Samples										Permissible Limits*
	1	2	3	4	5	6	7	8	9	10	
Percentage Passing by Weight Through IS Sieve											
90.0	91.22	92.37	91.88	97.82	95.32	96.67	89.36	93.56	91.65	87.45	**90-100**
63.0	67.88	59.45	61.29	70.17	72.28	29.57	72.85	72.77	78.23	69.31	**25-60**
45.0	7.13	6.79	2.76	3.88	11.45	16.67	14.85	11.78	7.03	12.24	**0-15**
22.4	3.33	3.24	8.33	4.65	3.25	4.23	5.36	3.12	6.64	7.66	**0-5**
Gradation for Screenings											
13.2	100	100	100	100	100	100	100	100	100	100	**100**
11.2	96.63	94.54	90.44	92.58	89.56	88.65	94.23	96.24	95.32	92.3	**95-100**
5.6	22.24	25.38	26.23	27.52	29.77	28.12	28.65	25.69	22.13	28.66	**15-35**
0.18	5.28	5.56	4.67	3.57	2.87	6.67	5.05	4.95	6.87	5.66	**0-10**
Field Density (gm/cc)	2.12	2.11	2.06	2.21	2.12	1.98	1.95	2.13	2.18	2.10	**2.168**
Degree of Compaction	Good	Good	Sufficient	Good	Good	Sufficient	Sufficient	Good	Good	Sufficient	**>98**
Field Moisture Content (%)	7.5	6.25	6.68	7.25	5.39	7.45	8.03	7.12	6.42	7.21	
Impact Value %	22.03	23.6	18.6	19.54	20.12	21.36	19.24	18.23	20.63	22.58	
Liquid Limit%(LL)	21.26	25.21	22.56	24.36	20.32	20.95	20.03	21.03	25.87	21.18	
Plasticity Index(PI)**	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	**< 6**

Note: * As per MORT&H Specifications, 4TH Revision, ** For Materials Finer than 425 Micron Sieve.

Table 4: Aggregate Gradation, Liquid Limit, Plasticity Index of WBM G II Layer

Sieve Size (mm)	Samples										Permissible Limits*
	1	2	3	4	5	6	7	8	9	10	
Percentage Passing by Weight Through IS Sieve											
Gradation for Coarse Aggregates											
90	100	100	100	100	100	100	100	100	100	100	**100**
63	96.24	92.37	93.88	94.82	91.32	96.67	89.36	90.54	91.65	87.45	**90-100**

Table 4 (Cont.)

Sieve Size (mm)	Percentage Passing by Weight Through IS Sieve										Permissible Limits*
	Samples										
	1	2	3	4	5	6	7	8	9	10	
53	66.88	46.45	61.29	40.17	52.28	29.57	62.85	72.77	78.23	69.31	**25-75**
45	10.53	15.79	12.76	13.85	14.45	11.67	14.85	13.78	7.03	12.24	**0-15**
22.4	4.63	6.24	8.33	4.65	3.25	4.23	5.36	3.12	6.64	7.66	**0-5**
Gradation for Screenings											
13.2	100	100	100	100	100	100	100	100	100	100	**100**
11.2	98.73	96.54	91.44	95.58	89.56	88.65	90.23	96.24	91.32	92.3	**95-100**
5.6	24.74	26.38	26.23	24.52	29.87	23.12	30.65	25.69	32.13	28.66	**15-35**
0.18	5.28	5.56	4.67	3.57	2.87	6.67	5.05	4.95	6.87	5.66	**0-10**
Field Density (gm/cc)	2.03	2.11	2.06	2.20	1.86	1.98	1.95	2.13	2.08	2.10	**2.168**
Degree of Compaction	Sufficient	Good	Sufficient	Good	Sufficient	Sufficient	Sufficient	Good	Sufficient	Sufficient	**>98**
Field Moisture Content%	7.8	6.22	5.68	6.24	6.39	8.45	7.03	6.12	5.45	6.21	
Impact Value%	18.50	20.6	19.6	19.54	24.12	22.36	19.24	18.23	21.64	21.52	
Liquid Limit% (LL)	24.36	26.21	21.56	25.36	21.32	22.95	20.03	24.03	24.87	20.18	
Plasticity Index(PI)**	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	**< 6**

Note: * As per MORT&H Specifications, 4TH Revision; Materials Finer than 425 Micron Sieve

Table 5: Aggregate Gradation, Liquid Limit, Plasticity Index of WBM G III Layer

Sieve Size (mm)	Percentage Passing by Weight Through IS Sieve										Permissible Limits*
	Samples										
	1	2	3	4	5	6	7	8	9	10	
Gradation for Coarse Aggregates											
63	100	100	100	100	100	100	100	100	100	100	**100**
53	92.3	91.38	89.57	88.76	98.78	91.26	88.36	90.56	91.65	87.45	**95-100**

Table 5 (Cont.)

Sieve Size (mm)	Percentage Passing by Weight Through IS Sieve — Samples 1	2	3	4	5	6	7	8	9	10	Permissible Limits*
45	67.71	72.01	73.37	80.05	86.03	76.56	77.85	76.77	77.23	79.31	**65-90**
22.4	11.08	12.71	9.89	7.76	8.56	12.26	12.85	11.78	7.96	12.86	**0-10**
11.2	2.33	5.72	6.79	8.16	3.22	4.23	5.36	6.12	8.64	7.66	**0-5**
Gradation for Screenings											
11.2	100	100	100	100	100	100	100	100	100	100	**100**
5.6	96.3	98.5	90.26	97.52	89.77	88.12	88.65	85.69	82.13	88.66	**90-100**
0.18	29.92	25.56	24.67	23.57	20.87	16.67	15.05	14.95	16.87	15.66	**15-35**
Field Density (gm/cc)	2.10	2.13	2.05	2.11	2.02	2.03	1.95	2.17	2.18	2.10	**2.168**
Degree of Compaction	Good	Good	Sufficient	Good	Sufficient	Sufficient	Sufficient	Good	Good	Sufficient	**>98**
Field Moisture Content	7.8	6.22	5.68	6.24	6.39	8.45	7.03	6.12	5.45	6.21	
Impact Value %	23.8	24.6	22.6	19.24	21.42	23.44	18.24	20.63	24.64	21.48	
Liquid Limit % (LL)	22.76	24.21	21.56	23.24	21.7	20.4	20.03	21.03	25.87	22.20	
Plasticity Index (PI)**	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	**<6**

Note: * As per MORT&H Specifications, 4TH Revision; Materials Finer than 425 Micron Sieve

3. Sub-Base Course (Granular Sub Base Layer)

Table 6: Aggregate Gradation, Liquid Limit, Plasticity Index of GSB Layer(Layer Thickness=180 mm)

Sieve Size (mm)	Percentage Passing by Weight Through IS Sieve — Samples 1	2	3	4	5	6	7	8	9	10	Permissible Limits*
75.0	100	100	100	100	100	100	100	100	100	100	**100**
53.0	85.3	88.2	90.2	92.1	95.2	80.2	82.6	81.6	82.1	82.2	**80-100**
26.5	56.6	74.5	72.4	69.5	69.5	68.6	64.2	66.2	75.3	72.3	**55-90**

Table 6 (Cont.)											
Percentage Passing by Weight Through IS Sieve											
Sieve Size (mm)	**Samples**										**Permissible Limits***
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
9.5	45.02	36.23	52.01	56.36	65.24	70.21	36.22	49.21	45.5	56.26	**35-65**
4.75	32.2	35.3	26.2	27.5	28.7	27.1	28.6	29.6	25.1	28.6	**25-55**
2.36	25.56	24.21	28.32	30.28	34.25	39.04	38.54	36.25	37.25	29.32	**20-40**
0.425	11.20	15.03	14.85	14.85	13.01	9.54	12.32	15.44	17.9	19.6	**10-25**
0.075	5.28	5.56	7.67	9.57	12.8	6.67	5.05	11.9	6.87	9.66	**0-5**
Field Density (gm/cc)	1.96	2.02	2.06	2.16	2.02	1.94	1.98	2.12	2.16	2.00	**2.212**
Degree of Com-paction	Sufficient	Sufficient	Sufficient	Good	Sufficient	Sufficient	Sufficient	Good	Good	Sufficient	
Field Moisture Content	6.8	6.22	5.28	6.24	6.1 9	7.45	7.03	6.12	5.45	5.21	
Impact Value %	28.05	27.36	30.4	27.74	30.12	19.36	29.24	28.45	26.64	25.98	
Liquid Limit % (LL)	19.2	18.21	17.56	18.25	16.32	20.95	17.03	19.03	24.87	20.18	
Plasticity Index (PI)	NP	NP	NP	NP	NP	NP	NP	NP	NP	NP	**<6**
CBR Value (%)	35	38	36	37	31	35	32	33	35	31	**>30**

Note: * As Per Mort&H Specification, 4th Revision.

4.Subgrade Layer

Table 7: Properties of Subgrade Soil											
Sieve Size (mm)	**Samples**										**Permissible Limits***
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	
Field Moisture Content (%)	8.25	9.35	9.45	10.21	10.65	11.38	12.33	10.8	8.44	8.65	
Field Dry Density (gm/cc)	1.54	1.66	1.32	1.78	1.45	1.94	1.77	1.65	1.80	1.69	

Table 7 (Cont.)

Sieve Size (mm)	Samples										Permissible Limits*
	1	2	3	4	5	6	7	8	9	10	
Maximum Dry Density (gm/cc)	1.87	1.69	1.99	2.01	2.08	1.99	1.79	1.93	1.97	1.85	
Optimum Moisture Content (%)	10.23	10.66	11.5	12.32	11.02	11.36	12.20	16.25	15.03	12.45	
Relative Compaction (%)	82	98	66	88	69	97	98	84	91	91	
CBR Value (%)	5.65	6.57	5.4	5.6	6.2	7.14	6.10	5.36	6.6	5.29	
Liquid Limit (%)	24.3	25.6	22.4	28.5	24.9	25.6	23.8	24.2	25.6	26.8	
Plasticity Index	6.8	7.2	8.1	11.1	8.6	9.1	5.2	4.8	8.3	7.3	

DISCUSSIONS

The analysis of the above results and comparing them with the MORTH specifications, the results of the WBM (G I, GII and GIII) and GSB layers were found as per the design and are satisfactory. The thicknesses of different layers of the WBM were also found OK along with their different parameters like gradation, Atterberg's limits, Aggregate Impact Value, water content and field density were as per within the range the MORTH specifications.

Whereas, the outcomes of the bituminous course were not as per the specifications both in terms of thickness and binder content. Gradation of this layer was within range.

The results of the subgrade were of major concern especially the strength of the subgrade in terms of the CBR value and degree of compaction. Large variations were found in the analysis of the tests results of the subgrade layer.

The results of the traffic survey were also surprising in terms of the increase of Commercial Vehicles Per Day (CVPD).

CONCLUSION

After conducting different tests on various layers of the existing pavement crust and subgrade of the study road and analyzing them the following conclusions were drawn:

1. The chief cause of the premature failure of the study road was that the designed traffic in terms of CVPD got increased by around 100% in a period of about 8 years which was not anticipated.
2. As per the traffic volume count of the study road, the traffic increased to 541 CVPD from 270 CVPD at the time of the design of road pavement.
3. The pavement of the study road was not

able to withstand the increased traffic load in such a short duration of around 8 years.

4. The traffic increase on the study road was mainly due to the construction of the Jabalpur – Damoh road via Katangi during that period. This caused the HCVs and vehicles to take the Jabalpur Patan road.

5. The existing width of the carriageway is 3.75 m only which is not adequate for the crossing of two heavy vehicles.

6. The second major cause was of premature failure was the inadequate strength of the subgrade level in terms of CBR value.

7. The design CBR was minimum 7% but after finding the CBR value of the samples collected from the subgrade the CBR value was below 7 % in most of the test pits.

8. The inadequate CBR value was also one of the major factors for the premature failure of the study road.

9. The thicknesses of the wearing course were not found proper as per the crust design of the study road. As per the design the thickness of the bituminous course was 75 mm (25 mm SDBC + 50 mm BM), which was not found adequate in most of the test pits.

10. The top of the road was not properly sealed in most of the places on the entire road and on test locations.

11. Water has entered in the non bituminous layers i.e., the base course (WBM) and the sub- base course (GSB) from the top and side of the crust. This moisture reduced the strength of different layers of the pavement.

12. Edge cracking was also evident in most of the places throughout the length of the study road. This cracking took pace due to improper construction and compaction of the shoulders and the berms.

Note: This paper is only for academic interest and cannot be used by anyone for any personal interest.

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