Functional Evaluation and Overlay Design of Existing Flexible Pavement: A Case Study of Karni & Khara Industrial Area Road in Bikaner

Harshita Mehta[#]
[#]*Under Graduation Student, Civil Engineering Department, Rajasthan Technical University College of Engineering and Technology, Karni Industrial Area, Bikaner-334001, Rajasthan, India.*

Abstract

Road transportation constitutes a major portion in the overall transportation system. With the increase in traffic volume, there is observatory increase in the distress of pavement structure, which in turn causes excessive deterioration. With time, the failure goes on increasing gradually due to overloading of axles and significant variations in daily and seasonal temperature of pavement which is responsible for early development of distress symptoms like potholes, rutting, cracks, and undulations in bituminous surfacing. Thus the evaluation of the condition of pavement becomes quite necessary to choose appropriate improvement technique that can be implemented to improve the quality and strength of the pavement structure. This paper presents a case study on structural and functional evaluation of flexible pavement and analyzes the condition of the pavement which includes relevant data like soil sub grade data, existing pavement structure, traffic data, laboratory investigations, rebound deflection by using BBD technique and finally the design of the overall thickness of the pavement and overlay, required to strengthen the pavement. The paper also includes comparison between the existing and the newly designed pavement thickness. Conclusions are also drawn from the overall study conducted on the road stretches followed by some useful recommendations.

Keywords – *Functional evaluation, Structural evaluation, BBD technique, Overlay design, Strengthen the pavement, Rebound deflection.*

I. INTRODUCTION

Road transport plays a chief role in the overall transportation system, because of various advantages like, door to door service, flexibility, easy availability, and many more. Hence, it becomes necessary to provide a good road network for the development of any country. Pavements once constructed needs periodic inspection for maintenance purpose. Since reconstruction of the damaged pavements is very expensive and can highly affect the economy of the country, strengthening method is highly adopted worldwide as a pavement maintenance measure. The maintenance cost can be reduced through following ways such as proper planning, designing, construction and quality control. If the causes of possible distress are removed, or judiciously taken care of, during design stage, the expenditure due to maintenance measures on in-service roads gets reduced to a great extent. The paper analyzes the method of pavement strengthening by Benkelman Beam Deflection technique and then the useful conclusions from the study are deduced and applied in the field for the strengthening of in-service pavements.

II. OBJECTIVE OF THE STUDY

The main objectives of the study are –

1. Evaluation of the pavement condition to choose appropriate improvement technique and equipment to improve the quality and strength of the pavement structure.
2. Collection of relevant data like soil sub grade data, existing pavement structure, traffic data and rebound deflection by using BBD technique.
3. To compute the overall thickness of the pavement and to design the overlay.
4.

III. STUDY AREA

The scope of study is limited to two stretches of road each of 1 km long. The stretch 01 is from Karni Industrial area and stretch 02 is from Khara Industrial Area. Study area stretches were selected based on the category of the road, terrain, traffic conditions and geographical location. These stretches can be named as Site 01 and Site 02.

A. Site 01

In the year 1991, when land stock of both the phases of Industrial Area Bichchwal was leading to exhaust, a loud demand for another phase was immerging up among the entrepreneurs of Bikaner city. Existing Industrial Area Bichchwal was surrounded by NH-15 / RAC Line in the East, Central Arid Zone Research Centre (CAZRI) in the West,

Central Sheep and Wool Research Institute (CSWRI) in the North and Indira Gandhi Nahar Pariyojna (IGNP) colony in South. There was no way out other than to go on Pugal road in region already marked as industrial land in Master Plan of Bikaner city.

Karni Industrial Area is situated on SH-3 leading to Chhatargarh. The distance from Bikaner city is only 5 kilometers.

B. Site 02

The Ministry of Industry, Department of Industrial Development and Government of India approved five Growth Centers in Rajasthan. I.G.C. Khara, Bikaner is one of those five growth centers. This area was established in the year 1992 and was also approved by Government of India in the same year. This area has been established for the development of minerals, wool, ceramics, food products & agro-based industries.

Khara is situated at 18 kilometers from Bikaner city on NH-15 leading to Shri Ganganagar.

IV. CLIMATIC CONDITION

The study region experiences low rainfall, extreme diurnal during summers and extreme cold during winters. Annual temperature is high, low humidity and high-velocity winds.

Summer-March, April, May
Monsoon-June, July, August
Post monsoon-September, October, and November
Winter-December, January, February
The table below shows the details of study stretches.

TABLE I - DETAILS OF STUDY STRETCHES

S.No.	Name of the road	Category	Terrain
1.	Karni Industrial Area	SH	Plain
2.	Khara Industrial Area	NH	Plain

V. EVALUATION OF PAVEMENT

A. Functional Evaluation

Pavement Condition Survey and/or Roughness Survey are carried out to evaluate functional properties of pavement. Pavement roughness is defined as an expression of irregularities in the pavement surface that adversely affect the ride quality of a vehicle.

B. Structural Evaluation

Structural evaluation of pavement deflection is the structural property of the pavement. Benkelman Beam is used to evaluate the structural properties of the pavement (as per IRC: 81 – 1997 and IRC: 37 – 2001). This method has been most widely adopted in India.

VI. FUNCTIONAL EVALUATION

A. Pavement Condition Survey(PCS)

In accordance with IRC: 81-1997 (Clause 4.2), this phase of operation, which precedes 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 the table.

TABLE II 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 to 20 mm
Poor	Extensive cracking and/or rutting greater than 20 mm. Sections with cracking exceeding 20% shall be treated as failed.

- **Site 01:** In this site, there are negligible ruts, cracking or any other road distresses, this part is good from PCS point of view.
- **Site 02:** In this site, there are some visible ruts and cracking, this part is fair from PCS point of view.

B. Pavement Structure Survey (PSS)

- **Site 01:** The existing crust of pavement layers is 220 mm GSB, 250 mm WBM.
- **Site 02:** The existing crust of pavement layers is 160 mm GSB, 250 mm WBM.

The existing road is highly in distress condition due to increase in traffic. As the industrial area is saturated and most of the industries are in production, hence the heavy traffic is increasing day by day. Thus road needs strengthening by providing overlay thickness.

C. Laboratory Investigation

The sub-grade soil samples were collected from three different locations of the road and following tests were carried out:

TABLE III - LABORATORY TEST RESULTS FOR SITE 01

Tests Performed	Sample 1	Sample 2	Sample 3
Moisture Content	1.23%	1.21%	1.24%
Plasticity Index	NP	NP	NP
CBR Value	7.3%	7.3%	7.3%

But considering the code, CBR value is taken as 7 % for the ease of calculations and design.

TABLE IV - LABORATORY TEST RESULTS FOR SITE 02

Tests Performed	Sample 1	Sample 2	Sample 3
Moisture Content	1.13%	1.12%	1.13%
Plasticity Index	NP	NP	NP
CBR Value	8.03%	8.03%	8.03%

But considering the code, CBR value is taken as 8 % for the ease of calculations and design.

VII. TRAFFIC SURVEY

The design traffic is considered in terms of the cumulative number of standard axles to be carried out during the design life of the road. It's computation involves estimation of the initial volume of commercial vehicles per day, lateral distribution of traffic, growth rate, design life (in years) and the vehicle damage factor (number of standard axle per commercial vehicle) to convert commercial vehicles to standard axles.

TABLE V - THREE DAY TRAFFIC COUNT OF SITE 01

Day	Vehicles Class									Total
	Car, Jeeps, Vans, Three-Wheelers	Motorized Two Wheelers	Light Commercial Vehicles	Trucks	Agricultural Tractors/ Trailers	Buses	Cycles	Cycle Rickshaws	Animal Drawn Vehicles	
Day 1 (25.07.17)	935	1,864	326	227	172	9	295	--	44	3,872
Day 2 (26.07.17)	784	1,485	327	117	120	5	306	--	16	3,160
Day 3 (27.07.17)	887	1,287	368	167	113	12	276	--	22	3,132
Total	2,606	4,636	1,021	511	405	26	877	--	82	10,164
Average Daily Traffic	869	1,545	340	170	135	9	292	--	27	3,388
PCU Factor	1.0	0.5	1.5	3.0	3.0	3.0	0.5	2.0	4.0 for Horse Drawn 8.0 for Bullock Drawn	
Average Daily Traffic PCU's	869	773	510	510	405	27	146	0	216	3,456
Total CVPD			340	170	135	9				654

TABLE VI-THREE DAY TRAFFIC COUNT OF SITE 02

Day	Vehicles Class									Total
	Car, Jeeps, Vans, Three-Wheelers	Motorized Two Wheelers	Light Commercial Vehicles	Trucks	Agricultural Tractors/ Trailers	Buses	Cycles	Cycle Rickshaws	Animal Drawn Vehicles	
Day 1 (25.07.17)	530	1,012	193	163	340	1	41	--	1	2,281
Day 2 (26.07.17)	470	970	167	186	343	--	43	--	2	2,181
Day 3 (27.07.17)	426	843	170	239	249	--	45	--	1	1,973
Total	1,426	2,825	530	588	932	1	129	--	4	6,435
Average Daily Traffic	475	942	177	196	311	0	43	--	1	2,145
PCU Factor	1.0	0.5	1.5	3.0	3.0	3.0	0.5	2.0	4.0 for Horse Drawn 8.0 for Bullock Drawn	
Average Daily Traffic PCU's	475	471	267	588	933	0	22	--	8	2,764
Total CVPD			177	196	311	0				684

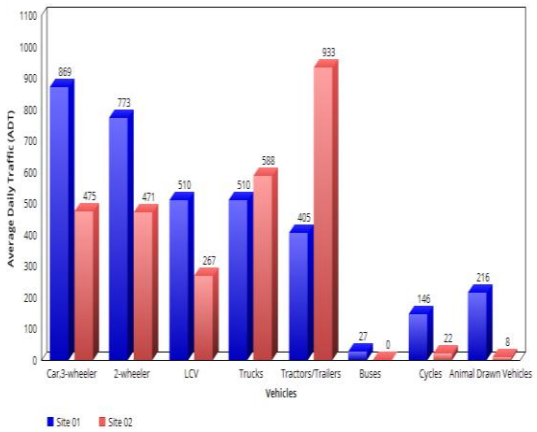

Fig 1: Average Daily Traffic (ADT) of both the sites

From the 3-day 24 hour traffic survey for each site, the total commercial vehicle per day for Site 01 is 654 vehicles/day (≥3 tons) and that for the Site 02 its value is 684 vehicles/day (≥ 3tons). For design traffic, CVPD values are used in the formula and the final traffic result is computed in terms of Million Standard axles (msa).

The values of design traffic come out to be:

- Site 01 – 8.7 msa
- Site 02 – 6.3 msa

VIII. STRUCTURAL EVALUATION

Fig2: Benkelman Beam Deflection Equipment

The values of CBR and traffic data obtained are then used in the recommended graphs of IRC: 37-2001 (Fig 1) to deduce the value of overall thickness of the pavement.

The overall thickness of the pavement comes up to be:

- Site 01 – 560 mm
- Site 02 – 490 mm

A. Experimental Setup of Benkelman Beam Deflection Equipment

The Benkelman beam measures the deflections under standard wheel load condition. The beam is a handy instrument which is most widely used for measuring deflection of pavements. It consists of a lever 3.66 m long, pivoted 2.44 m from the end carrying the contact point which rests on the surface of the pavement. The deflection of the pavement surface produced by the test load is transmitted to the

other end of the beam where it is measured by a digital recorder. The load on the dual wheel can be in the range of 2.7 to 4.1 Tones.

B. Equipment used in survey

1. Thermometer
2. Truck
3. Auger
4. Benkelman Beam
5. Mandrel
6. Dial Gauge
7. Glycerol
8. Tape

1) Temperature data: The standard temperature for doing the experiment is 35°C. The procedure followed for determining the temperature is given below –

a) A hole is drilled into the pavement with the help of a mandrel. The depth of the hole is 45 mm and the diameter of the hole at the top is 1.25 cm and at the bottom is 1 cm.

b) The hole is then filled with glycerol and the temperature is recorded after 5 minutes with the thermometer (range of temperature between 0° - 100°) with 1° division.

c) The temperature readings are measured for every hour during the survey.

C. Pavement Deflection Measurement

Three types of data are required for knowing the deflection:

The temperature of the test region came up to be 35°C. Hence no correction has to be applied.

2) Soil data: Deflection measurements were done during the monsoons when the pavement is in its weakest condition. Hence a correction for seasonal variation has to be applied for the deflection which is a function of the soil sub-grade. But since the region has low rainfall, the correction is not applied.

3) Truck specifications for conducting the test:
Rear axle weight of the truck: 8170 kg
Tyre pressure: 5.6 kg / cm^2
The spacing between the tyre walls: 30-40 mm.

TABLE VII SUMMARY OF FIELD DEFLECTIONS OF SITE 01

NAME OF ROAD – KARNI INDUSTRIAL AREA ROAD **DATE AND TIME OF OBSERVATION – 28/07/2017 AT 14:00 HRS.**
NO. OF LANES – 2 **CLIMATIC CONDITION – SUNNY**
AIR TEMPERATURE – 35°C **PAVEMENT TEMPERATURE – 35°C**

S.No.	Location of Test Points and Identification of Lanes	Pavement Temperature (°C)	Type of Soil and PI	Moisture Content %	Dial Gauge Reading (mm)			True Pavement Deflection (X_T) (mm)
					Initial	Intermediate	Final	
1.	00/00-03/00	35°C	SANDY/ GRAVELLY NP	1.23%	24.41	24.34	24.20	1.23
2.	03/00-12/00				16.40	16.29	16.14	1.39
3.	12/00-22/00				46.50	46.37	46.24	1.27
4.	22/00-32/00				21.50	21.38	21.23	1.41
5.	32/00-42/00				29.40	29.32	29.17	1.35
6.	42/00-52/00				22.48	22.37	22.24	1.27
7.	52/00-62/00				21.90	21.85	21.71	1.22
8.	62/00-72/00				15.08	14.96	14.81	1.41
9.	72/00-82/00				31.77	31.66	31.52	1.34
10.	82/00-92/00				14.27	14.23	14.07	1.36
11.	92/00-102/00				18.72	18.66	18.51	1.31
12.	102/00-112/00				25.23	25.17	25.01	1.40
13.	112/00-122/00				27.77	27.69	27.55	1.30

TABLE VIII - SUMMARY OF FIELD DEFLECTIONS OF SITE 02

Name of road – Khara IndustrialArearoad No. of lanes–2 Air temperature–35°C					Date and time of observation – 28/07/2017 at 16:00 hrs Climatic condition –Sunny Pavement temperature –35°C			
S.No.	Location of test points and identification of lanes	Pavement temperature (°C)	Type of soil and PI	Moisture content %	Dial Gauge Reading (mm)			True pavement Deflection (X_T) (mm)
					Initial	Intermediate	Final	
1.	00/00-03/00	35°C	Sandy/ gravelly NP	1.12%	28.59	28.55	28.42	1.10
2.	03/00-12/00				15.48	15.37	15.23	1.31
3.	12/00-22/00				25.30	25.17	25.04	1.27
4.	22/00-32/00				18.72	18.62	18.46	1.45
5.	32/00-42/00				18.25	18.15	18.02	1.20
6.	42/00-52/00				27.77	27.65	27.54	1.13
7.	52/00-62/00				31.23	31.19	31.03	1.37
8.	62/00-72/00				14.25	14.17	14.01	1.40
9.	72/00-82/00				29.46	29.32	29.21	1.15
10.	82/00-92/00				22.48	22.28	22.18	1.21
11.	92/00-102/00				16.31	16.29	16.14	1.23
12.	102/00-112/00				21.29	21.26	21.10	1.30
13.	112/00-122/00				15.08	14.94	14.81	1.32

On performing the pavement deflection measurements using BBD technique, the characteristic deflection comes up to be:

- Site 01 – 1.35 mm
- Site 02 – 1.30 mm

IX. OVERLAY DESIGN FOR FLEXIBLE PAVEMENT

Using the values of characteristic deflection to design the overlay for strengthening of the two selected sites the thicknesses as per the recommended graph of IRC: 81-1997 (Fig 9) comes out to be:

- Site 01 – 90 mm
- Site 02 – 80 mm

As per IRC: 37-2001 (plate 1)Recommended Pavement Design for Traffic Range 1 – 10 msa, the pavement composition for two selected sites is given as –

TABLE IX
PAVEMENT COMPOSITION OFSITE 01

Pavement composition	Allowable thickness
GSB	220 mm
GB (WBM)	250 mm
Bituminous Surfacing	
Wearing Course (BC)	40 mm
Binding Course (DBM)	50 mm

TABLE X - PAVEMENT COMPOSITION OFSITE 02

Pavement Composition	Allowable thickness
GSB	160 mm
GB (WBM)	250 mm
Bituminous Surfacing	
Wearing Course (BC)	30 mm
Binding Course (DBM)	50 mm

X. ANALYSIS AND RESULT

In table XI and table XII, the existing and the proposed crust for both the sites have been compared and thus the overlay thickness is deduced.

TABLE XI - COMPARISON OF EXISTING AND PROPOSED CRUST OFSITE 01

Existing Crust	Proposed Crust
GSB – 220 mm WBM – 250 mm Total– 470 mm	GSB – 220 mm WBM – 250 mm DBM – 50 mm BC – 40 mm Total – 560 mm

TABLE XII - COMPARISON OF EXISTING AND PROPOSED CRUST OF SITE 02

Existing Crust	Proposed Crust
GSB – 160 mm WBM – 250 mm Total– 410 mm	GSB – 160 mm WBM – 250 mm DBM – 50 mm BC – 30 mm Total –490 mm

In the figure given below, the new pavement thickness is designed for both the sites.

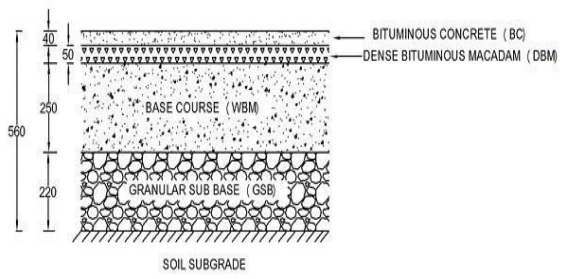

Fig 3:Newly designed pavement thickness for site 01

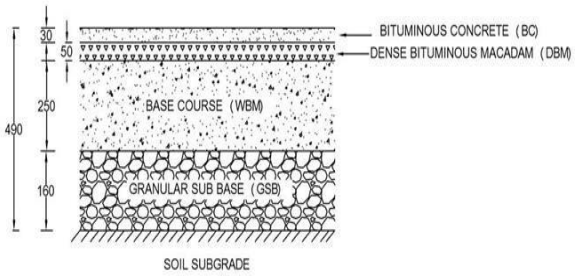

Fig 4:Newly designed pavement thickness for site 02

XI. CONCLUSION

- It is advisable to implement the necessary maintenance measures at an early stage when the distresses have just started showing up. It is seen that proper pavement measures at an early onset of distresses, can obviate major maintenance expenditure in future.
- Out of all the deflection measuring methods, the BBD method is the most simple and reliable method.
- This method is used to measure the rebound deflection of pavement only under static load.
- The correction of temperature is needed when bituminous layer is appreciably thick and temperature is standardized to 35°C.

XII. RECOMMENDATION

- Periodic maintenance procedures should be implemented so as to maintain the design serviceability and increase the life span of the pavement.
- While designing the new pavements, proper investigation and IRC guidelines should be followed.
- The infill used must be of desired characteristics which can be fully compacted with ease to attain the required strength.
- Proper camber and shoulders should be present.
- There should be coordination between the various agencies responsible for lying of utilities and the construction of roads.

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