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PERFORMANCE EVALUATION OF FLEXIBLE PAVEMENT- A CASE STUDY


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ABSTRACT

Roads are an integral and mandatory asset to transport people and commodities from one place to another and play a vital role in the development of a country. Pavements are subjected to heavy loadings and harsh environmental conditions, causing deterioration with passage of time. Therefore, road performance has to be monitored regularly to evaluate the rate of deterioration and proper scheduling of maintenance and rehabilitation activities by using latest tools and techniques. This paper emphasizes the use of Falling Weight Deflectometer (FWD) for proper structural evaluation of flexible pavement and planning for subsequent maintenance and up gradation activities.

1. INTRODUCTION

The development of roads is taken up by the State as well as Union Govt in India but considering the vast area and requirement of huge network of roads, philosophy of maintenance of existing road infrastructure based on economy as well as durability concept is to be adopted in India. Overloading of commercial vehicles has been a regular malpractice in India, resulting in premature distress due to unexpected demands of growing traffic volume and heavier axle loads. As a result, the pavement gets distressed much before its design life and it needs to be upgraded regularly. True and exact evaluation of in-service pavement is necessary for rehabilitation of pavement and developing systematic maintenance system in highway sector.

2. PAVEMENT EVALUATION

Evaluation of road performance could be subjective, depending on visual inspection and evaluator's experience, or, objective, depending on standardized evaluation procedures and equipment. Visual inspection's success depends on the experience of the concerned person and varies from person to person. As a result, objective evaluation supersedes the visual inspection. The objective evaluation may be categorised as follows:

- Functional evaluation -pavement roughness is mainly concerned with the riding quality and may be judged visually or by Roughometer or IRIMETER. Pavement condition refers to the condition of the pavement surface in terms of its general appearance. In order to obtain a useful condition assessment of the pavement, unbiased and repeatable survey procedures must be used. The most common survey technique used worldwide is the Pavement Condition Index (PCI) procedure.
- Structural evaluation - Pavement structural evaluation is concerned with the structural capacity of the pavement as measured by deflection, layer thickness, and material properties. It is used to obtain information and to evaluate the need for maintenance, rehabilitation, and construction quality of the pavement.
- Safety evaluation - The condition of the pavement is determined by a field survey of the surface operational condition of all pavements using this procedure. The PCI - a measure of the pavement's surface operational condition and riding quality is a useful visual surveying tool.

2.1 Structural Evaluation of Pavements

Structural evaluation of pavement involves application of a standard load to the pavement and measuring its response in terms of stress, strain or deflection. Benkelman Beam

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has been among the earliest equipment used for measuring deflection and structural evaluation of pavements. In this technique, a static load is applied to the pavement surface and rebound deflections are measured at one or more locations. Measurement of deflection under a static load does not simulate the loading conditions produced in pavement by a moving vehicle. The evaluation of pavement by such method is labour intensive and in general, time consuming. The existing guidelines for strengthening of flexible pavements using Benkelman beam Technique are contained in IRC:81.

Significant developments have taken place internationally during the past few decades in terms of the equipment and the analytical tools adopted for structural evaluation of pavements. Impulse loading equipment commonly known as Falling Weight Deflectometer (FWD) has been developed, which closely simulates the duration and amplitude of the load pulses produced by moving wheel loads. In India, analytical tool in the form of a software KGPBACK to back calculate the elastic properties of the existing pavement has been developed by the Transportation Engineering Division of IIT Kharagpur.

2.2 Falling Weight Deflectometer (FWD)

Falling Weight Deflectometer (FWD) is extensively used worldwide because it simulates, to a large extent, the actual loading conditions of the pavement. When a moving wheel load passes over the pavement, it produces load pulses. Normal stresses (vertical as well as horizontal) at a location in the pavement will increase in magnitude from zero to a peak value as the moving wheel load approaches the location. The resulting load-deflection data can be interpreted through appropriate analytical techniques, such as back calculation technique, to estimate the elastic moduli of the pavement layers. The computed moduli may be used for:

(i) The strength evaluation of different layers of in-service pavement
(ii) The estimation of the remaining life of in-service pavement
(iii) Determination of strengthening requirement, if any
(iv) Evaluation of different rehabilitation alternatives such as overlay, recycling, partial reconstruction, etc.

2.3 Structural Evaluation of Pavement by FWD

The FWD is driven to site/location and measurements are taken at pre-set distances along the surface. Sensors are placed at pre-set distance from the load plate axis which measures the deflection. Deflection sensors are adjustable to variable distance from load plate according to user requirements and generally paced at 300 mm spacing. The split load plate is lowered to pavement surface and a weight is raised above the load plate and at pre-set height the load is dropped on to the load plate which causes a controlled load pulse into the pavement. The studies were carried out as per IRC:115-2014

2.4 Case Study

State Highway-84A, Mainpuri - Kurawali Road connecting NH-2(Kanpur-Agra section) to NH-91(Kanpur-Delhi section), is an important highway in the State of Uttar Pradesh. The Highway was upgraded to four lane dual carriageway in 2016. The stretch was selected for performance evaluation by FWD.

1. Following data was collected regarding the project:
   CVPD-1753(2014)
   CBR-5%
   Design Traffic- 24.50 MSA
   Crust composition on the basis of IRC:37-2012 Guidelines is as follows:
   *Granular layer-550 mm comprising of GSB and WMM 275 mm each *Bituminous layer-150 mm comprising of 110 mm DBM and 40mmBC
2. Deflection measurements were carried out on 30th Dec 2020 at 3 different locations on the stretch at chainage 0.550, 1.500 and 2.150 respectively. Sensors were placed at offset of 0, 300, 600, 900, 1200, 1500 and 1800 mm respectively. It was observed that maximum deflection was recorded at chainage 1.500 while minimum deflection was recorded at chainage 2.150.

Fig.1 SH-84A Mainpuri-Kurawali Road

Fig.2 Evaluation by FWD at site

3. The inputs were selected as follows:

i. Since the road was designed as per IRC:37-2012, the DBM and BC was done with VG-30 bitumen whose resilient modulus as per 2012 Guidelines was 1700

MPa, while as per IRC:37-2018, it's 2000 Mpa. IRC:115-2014 provides guideline to input the range of moduli as 750-3000 Mpa, so a range of 1000-2000 MPa was considered appropriate for input.

ii. For granular layer (Combined) the moduli range suggested for input, as per IRC:115-2014, is 100-500 MPa, but the range for input is kept as 100-450 MPa (Since as per IRC:37-2018, the modulus value for WMM layer is given as 450 MPa).

iii. The modulus input for subgrade was chosen on slightly conservative side in comparison to the values given in IRC:115.

iv. The minimum design modulus for in-service pavement was considered in place of 15th percentile value.

v. The Poisson's ratio values recommended by IRC:115 are 0.50,0.40,0.40 for bituminous, granular and sub-grade respectively but in the analysis, values 0.35,0.35,0.35 as given in IRC:37-2018 are adopted.

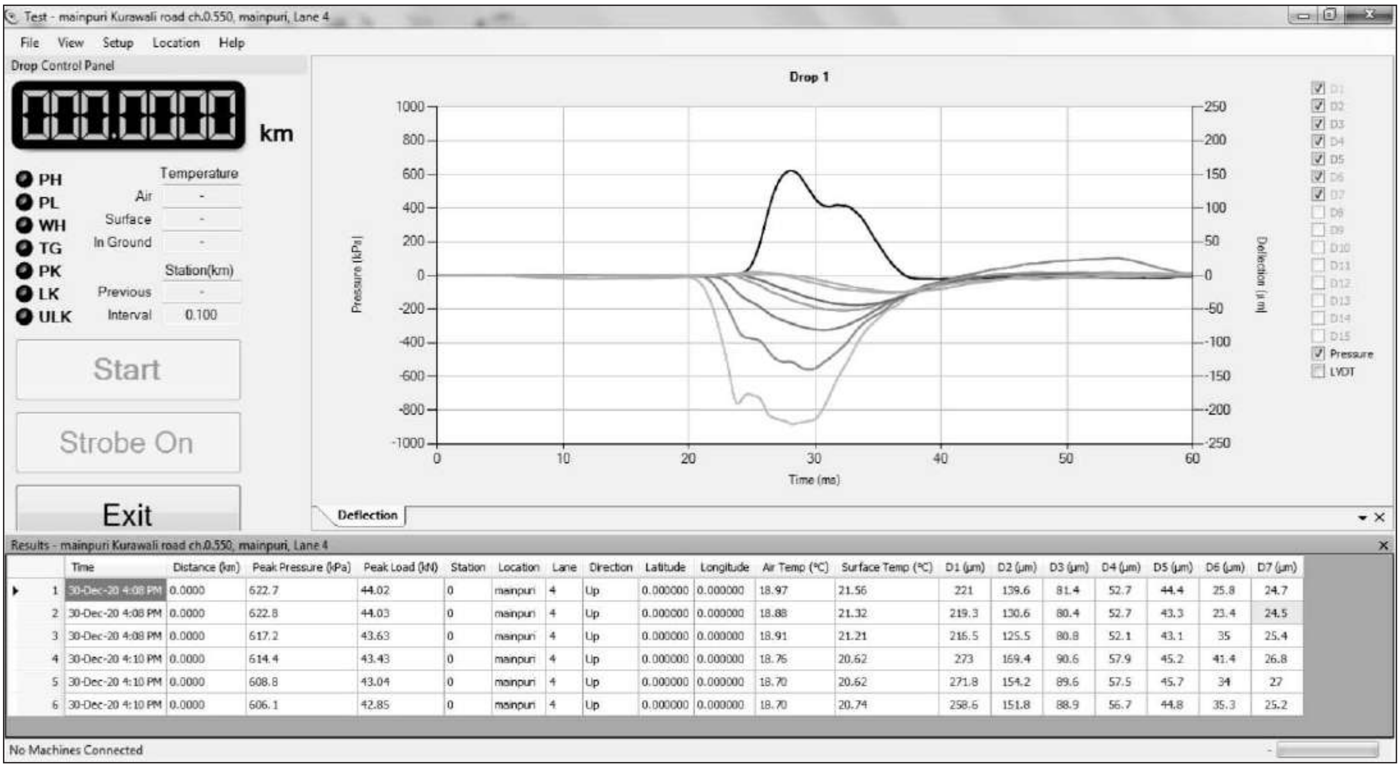

Fig. 3 Screen Shot of FWD Output Showing Pavement Deflection at Various Offsets on Chainage 0.550

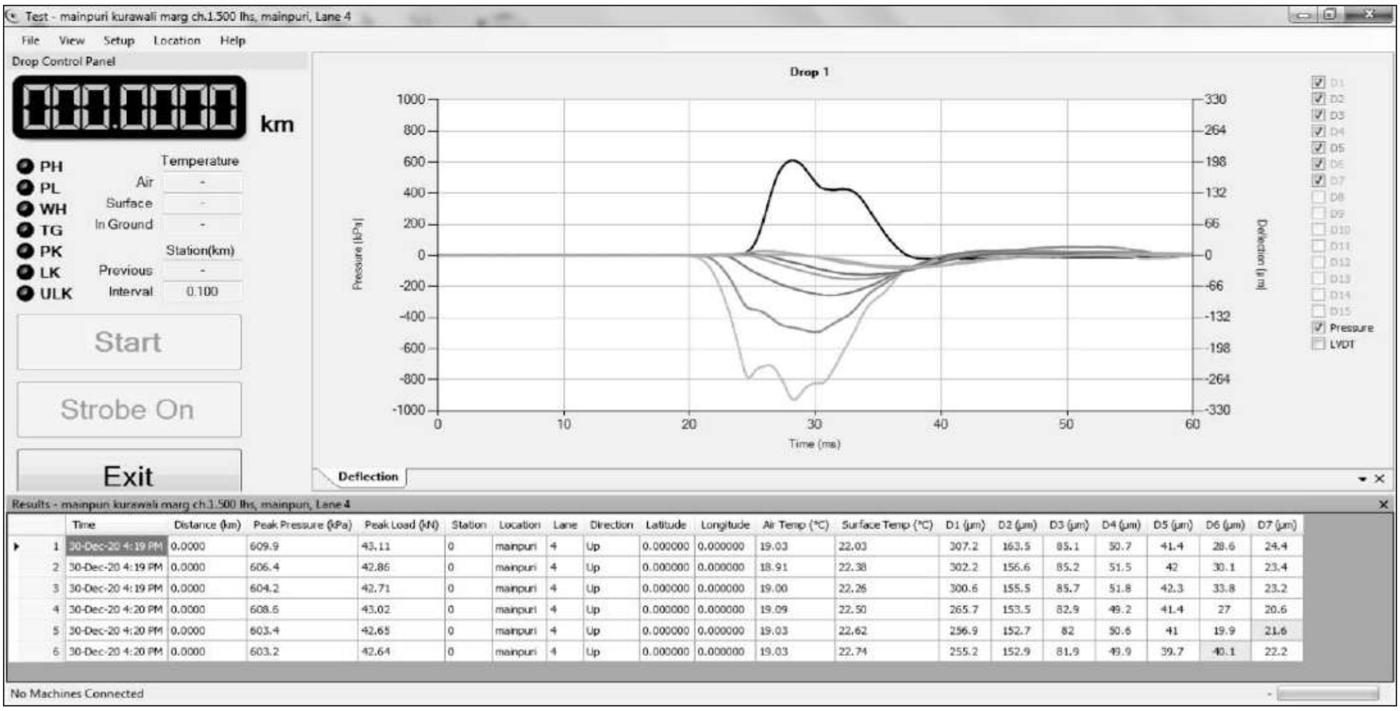

Fig.4 Screen Shot of FWD Output Showing Pavement Deflection at Various Fffsets on Chainage 1.500

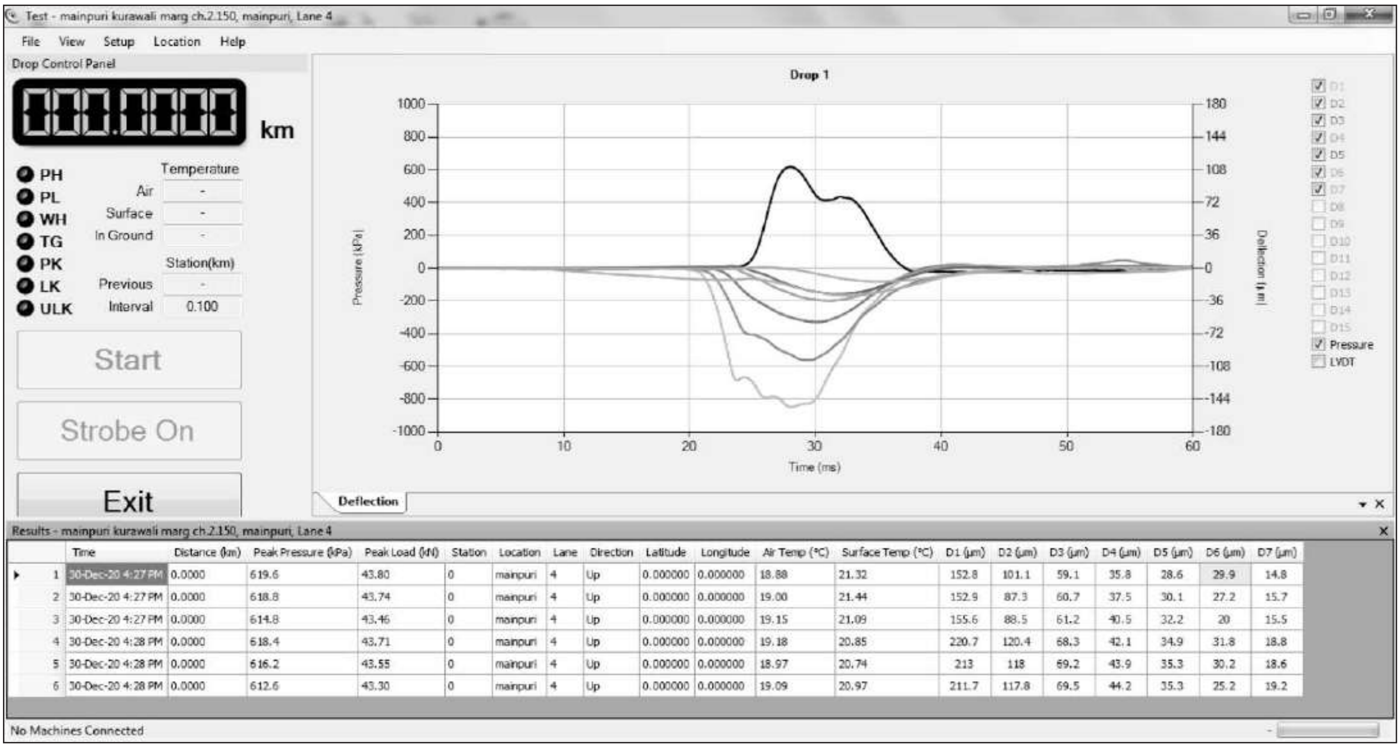

Fig.5 Screen Shot of FWD Output Showing Pavement Deflection at Various Offsets on Chainage 2.150

2.5 Analysis

1. The back calculated Bituminous layer modulus is corrected for a standard pavement temperature of 35 degree Celsius and granular & subgrade layer moduli are corrected for monsoon season as per equations provided in IRC:115-2014. The moduli values back calculated using KGPBACK software for all the test points of the homogeneous section and the corrected moduli are given in the **Table 1** below:

Table 1

chainage	Deflection reading	Resilient Moduli before correction			Resilient Moduli after correction		
		bituminous	granular	subgrade	bituminous	granular	subgrade
0.550	Highest	1998	448.3	69.9	1100	362.5	**58.8**
	Lowest	1987.3	448.6	69.9	1120.9	362.6	58.8
1.500	Highest	2000	442.8	70	1166.6	358.8	58.9
	Lowest	1983.4	439.7	70	1179.4	**356.8**	58.9
2.150	Highest	1979.5	449.3	70	**1095.0**	363.2	58.9
	Lowest	1967.7	443.8	70	1120.4	359.0	58.9

2. The in-service three-layer pavement system is analysed by IITPAVE software using bituminous layer modulus as 1095MPa, granular layer modulus as 356.8 (Round off to 350MPa) and subgrade layer modulus as 58.8 (Round off to 50MPa) and following strain values were obtained:

Tensile strain at the bottom of bituminous layer- 0.1989E-03
Vertical strain at top of subgrade- (-)0.2678E-03

3. The remaining life of pavement using IRC:37-2018 is calculated as 31.17 MSA and the calculated strains were found safe for 16 years design life, leading to observation that in case of no major change in traffic pattern and other factors thereon, the pavement may not require any overlay for the next 16 years.
4. If any superficial cracks appear subsequently, then the pavement may be given a treatment of micro surfacing.
5. FWD analysis is recommended to be repeated after every five years to re- evaluate the pavement.
6. Pavement condition is excellent even after around 6 years of construction and it may be attributed to excellent quality control during the execution of work besides other factors.

3. CONCLUSIONS

1. The quality control during the construction was

excellent. As per records of the project, it can be ascertained that testing was performed at the frequency as prescribed in the MORTH standards.

2. This road has a granular crust of 550mm and bituminous crust of 150 mm, but since VG-30 bitumen was used in bituminous layers as per the prevailing standards, lower resilient modulus (1095 MPa) is obtained. Recycling of the existing BC layer by using VG-40 bitumen may be adopted, which would give us a resilient modulus of 3000 MPa and that would further enhance the life of the pavement by many years. As a last resort, an overlay may be provided whenever needed.

3. Many changes have been incorporated in IRC:37-2018 as compared to the Guidelines issued vide IRC:37-2012. It appears that the roads designed as per IRC:37-2012 should be re-evaluated again as per IRC:37-2018 to have an idea of how the design differs and if there is any scope of taking advantage of those changes in the planning for future course of action.

Two significant differences between the IRC:37-2012 Guidelines and IRC:37-2018 Code are-

I. Change in philosophy of granular layers thickness
ii. Change in philosophy of moduli of granular layers

Authors have felt that a road designed as per IRC Guidelines IRC:37-2012 originally, when analysed as per Code IRC:37-2018, should be evaluated keeping in mind that some hidden margins may be there which may benefit the designer in achieving economy in planning for future.

4. FWD is a perfect tool to plan the future course to be followed while evaluating a flexible pavement. For important roads, its wiser to do the condition survey as per need, instead of having a fix renewal/overlay period as adopted in NH projects vide MoRTH circular dated 21.08.2018 (Ref-6). It gives a fair chance to extend the normal resurfacing interval. Also, in case of stage construction, intermittent testing of pavement is needed to evaluate the performance of pavement and plan the future course of action as suggested by authors in "Stage construction of flexible pavements" (Ref Indian Highways- October, 2020). Authors recommend to treat a BC layer as an overlay and propose to take advantage of the potential of the existing pavement by recycling the bituminous layer with richer bitumen and an overlay should be chosen as a last resort.

5. By using FWD, we may bring dynamism in our approach of designing of pavements. By its application we may rationalize the treatment to be provided in time and also prolong the anticipated treatment to have an economical and fair system instead of a common to all basis.

4. ACKNOWLEDGMENT:

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IRC's Technical Committees Meeting Schedule for the month of February, 2023

Date	Day	Time	Name of the Committee	Venue
02-02-2023	Thurs	03.00 PM	Road Maintenance and Asset Management (H-6)	Online Platform
		04:00 PM	Sub-group IRC:SP:114 (B-2.4)	Online Platform
04-02-2023	Sat	11.00 AM	Project Preparation, Contract Management, Quality Assurance & Public Private Partnership (G-1)	Hybrid Mode
11-02-2023	Sat	11.00 AM	Loads and Load Combination (B-2)	Physical
16-02-2023	Thurs	03.00 PM	Management, Maintenance and Rehabilitation (B-8)	Hybrid Mode
17-02-2023	Fri	03.00 PM	Foundation, Sub-Structure Protective Works and Masonry Structures (B-3)	Online Platform
25-02-2023	Sat	03.00 PM	Foundation, Sub-Structure Protective Works and Masonry Structures (B-3)	Online Platform