A Review and Comparison of FWD and Benkelman Beam in Evaluation of Pavement Structure Capacity

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Abstract- A new asphalt layer is typically added to the original pavement structure as part of major rehabilitation projects for India's road network, which is largely degraded and in need of repair. Understanding and analyzing the structural capacity of the pavement is crucial to creating a rehabilitation design that is both durable and cost-effective. Measuring a flexible pavement's structural capacity in relation to the deflections it causes when a load is applied. In numerous nations, the Falling Weight Deflect to meter (FWD) and the Benkelman beam are the most often employed methods for determining pavement deflections; the former operates under dynamic loading conditions, while the latter operates under static loading. However, since these devices are still commonly used in many nations, including India, it is vital to compare the deflections measured by the Benkelman beam and the falling weight deflect meter, even though numerous design approaches, like AASHTO, do not support their usage under static stress. 30 deflection observation stations along a 1.5 km flexible urban roadway segment were chosen for this investigation, and deflections were measured using BBD and FWD methodologies. On a point-scoring basis, both exams are administered simultaneously. Also, the information gathered during booth testing complies with IRC 81-1997 and IRC 115-2014.

Keywords— AASHTO, BBD and FWD Methodologies, Deflections, Understanding, Analyzing the Structural Capacity of Pavement.

1. Introduction

One of the key methods for evaluating the structural and functional state of a pavement is pavement assessment. It is vital to assess the pavement from both a structural and functional standpoint because repetitive traffic loads and climate factors contribute significantly to pavement deterioration. By measuring the pavement's roughness, skid resistance, and current serviceability index, one may determine its functional performance, which includes its capacity to give riders a safe, comfortable, and cost-effective riding surface. In terms of the pavement's response to applied load, or deflection, the structural performance is related to the structural soundness or load carrying capacity of the pavement. There are two methods for evaluating the structural integrity of pavements: destructive testing and non-destructive testing. Because destructive testing requires cutting through pavement, it is costly and time-consuming. The pavement is loaded during non-destructive testing, and the response is expressed in terms of deflection. The Indian Road Congress (IRC) (IRC: 37, IRC: 115, and IRC: 81) suggests using non-destructive methods for road construction and assessment in order to apply analysis and design that is based on mechanistic-empirical principles. The first technique for measuring pavement deflections was the Benkelman beam deflect meter (BBD), which is affordable and widely accessible. Due to the fact that it does not replicate the loads of moving vehicles, it has a significant degree of uncertainty. For high traffic roads, IRC has advised using advanced technology like falling weight deflect meters (FWD).

FWD applies a dynamic load on the pavement, recording each layer's response. Due to its high cost, the procedure is not commonly utilized. Owing to the challenges involved in obtaining and being unfamiliar with FWD, several nations continue to evaluate road networks using BBD. Pavement layer thickness is measured using ground penetrating radar (GPR), as opposed to more conventional techniques like trial pit testing or coring. The lighter version of the falling weight deflect meter (FWD), known as the light falling weight deflect meter (LWD), applies a comparatively low impact load. A more accurate and multipoint probing version of the BBD is the rolling weight deflect meter (RWD). Using modulus data from the FWD test, the deflection bowl is predicted using the Finite Element Method (FEM) analysis. Using non-destructive methods, Vinod et al. assessed thin flexible pavement in low traffic roads. They then created a correlation between BBD and LWD deflection data, which produced a strong correlation with an R2 of 0.79. The back estimated modulus and structural capacity of pavements are influenced by various factors such as temperature variations, individual layer thickness, and the state of the pavement at now. In order to assess the capability of the pavement structure, Zhou et al. conducted comparison experiments between the Benkelman beam deflect meter (BBD) and the falling weight deflect meter (FWD), and they established a correlation between the deflection results.

2. Literature Review

Vinod et al. evaluated thin flexible pavement using non-destructive techniques in low volume roads and developed a correlation between BBD and LWD deflection data yielding good correlation with coefficient of correlation (R^2) of 0.79. Pavement structure including individual layer thickness, existing pavement condition and temperature variation affects the back calculated modulus and structural capacity of pavements.

Zhou et al. carried out comparative studies between falling weight deflect meter (FWD) and Benkelman beam deflect meter (BBD) for the evaluation of pavement structure capacity and developed a correlation between deflection values with R^2 value of 0.957. It is better to supplement temperature measurements by monitoring layer moisture and groundwater level.

Feo and Urrego developed linear as well as exponential relationships with R^2 value 0.8251 and 0.8089 respectively by correlating the deflection measurements obtained from FWD and BBD.

Guzzarlapudi et al. carried out comparative analysis on sub grade moduli by both static and dynamic methods and the proposed correlation equations for different type of soils yielded a good correlation with R^2 varying from 0.75 to 0.91.

Garg et al. conducted a comparative study for strengthening of existing flexible pavement using FWD and BBD techniques by performing both FWD and BBD on the same test location and the results were analyzed with suitable back calculation technique. The overlay thickness obtained from BBD is relatively more than that obtained from FWD.

Murillo Feo C.A. and Bejarano Urrego L.E, Research on Correlation between deflections measurements on flexible pavements obtained under static and dynamic load techniques. Aim of this paper is Correlation between deflections measurements on flexible pavements obtained under static and dynamic load techniques. The techniques most used in Colombia to measure pavement deflections are the Falling Weight Deflect meter (FWD) and the Benkelman beam, the first one works under dynamic loading and the second device under static loading. different associations like the AASHTO do not recommend the use of deflect meters under static load, but in several countries, including Colombia which presents damage in the most of the road network, these devices are still in use especially the Benkelman beam, not only for structural evaluation but also for design of pavement structures; this is due especially to difficult acquisition, unfamiliarity and cost of falling weight deflect meter. Therefore, it is important to determine the degree of correlation between these two devices to be able to obtain FWD deflections as a function of Benkelman beam deflections. In this paper representative results of deflection basins acquired in the study. The tendency of the deflection curves is deep and of short length, which means that the sub grade corresponds to a poor-quality soil and deficient pavement performance. It was observed that the deflection basins obtained from the Benkelman beam are much deeper (12 to 232 mm^2) than those obtained using FWD (31, 29 to 164, 14 mm^2) giving more critical quality of the structure. The effective structural number (SNeff) was obtained using the methodology of the Hogg Model for BBD and FWD measurements.

3. Data Assembling

(i) Deflection Observation Points are marked- Because the road is divided into four lanes and has lane widths more than 3.75 meters, the deflection observation locations are marked at a transverse distance of 1.5 meters from the pavement's edge. Only the outer wheel path on the left side of the lane has markers at those locations.

(ii) Designating the Observation Points for Deflection- The thickness of the current pavement layers above the sub grade layer is 330 mm for the base, 210 mm for the sub-base layer in the base layer of WBM (Water Bound Macadam), 120 mm for the sub-base layer (GSB, or Granular Sub Base), and 100 mm for the BT (Bituminous Thickness) layer, as shown in figure (b).

Fig 1 (a): View of Test Pits

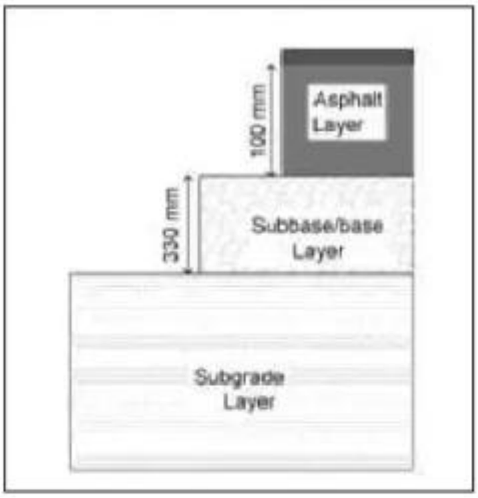

Fig 1 (b): Layers of existing pavement

(iii) Deflection of Benkelman Beams (BBD) Test- Benkelman beam deflection measuring equipment is less expensive, and the study methodology is straightforward and uncomplicated. Using the Benkelman beam, the amount of rebound deflection of a flexible pavement is measured when a truck's standard wheel load is shifted forward. This survey is conducted on thirty deflection observation locations along a predetermined stretch. The following describes the tools, steps, and field data gathering used in BBD investigations. There is a Benkelman Beam survey conducted every 50 meters.

(iv) Falling Weight Deflect meter (FWD)- With the Falling Weight Deflect meter (FWD), an impulse-loading instrument, the deflected shape of the pavement surface is measured after a transient load is given to the pavement. Surface deflections observed at various radial distances and the operating principle of a typical FWD are depicted in Figure DO, D1, etc. A falling mass that is permitted to descend vertically onto a set of springs positioned above a circular loading plate applies the impulse load. Displacement sensors, positioned at various radial distances starting from the load plate center, are used to measure the deflected shape of the pavement surface. Figure 2 and 3 below depicts the FWD test results for the research region location. Deflection measured at the same BBD observation sites.

(a) **Data from Subgrade Evaluation**- At the pavement composition survey locations, a soil sample is taken at a distance of 0.900 kilometers. On the collected sample, tests such as MDD, CBR, liquid and plastic limits, and grain size analysis are performed.
(b) **Benkelman beam deflection test analysis**- Every 50 meters, the Benkelman Beam survey is conducted. Three 500 m sub stretchor sections make up the entire 1.5 km stretch.

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Fig 2: Benkelman beam survey at the research site

Fig 3: Weight deflect meter tests that fail at the study site

4. Methodology

(i) Locating the study area- Gujarat, India's administrative center is located in Ahmedabad City. The city is the hub for Ahmedabad district's social, educational, commercial, residential, cultural, political, and economic activity. It is situated at latitude 23.0300° North and longitude 72.5800° East. Details of the study part and survey. Divine Road, located at 230 33' 53.16" N 720 25' 30.55" E, is an urban highway in Gujarat State's Ahmedabad city. It is close to Ahmedabad's Science City Road in Sola. The 1.5 kilometer urban highway that connects Sola Gam Road is used as the study area.

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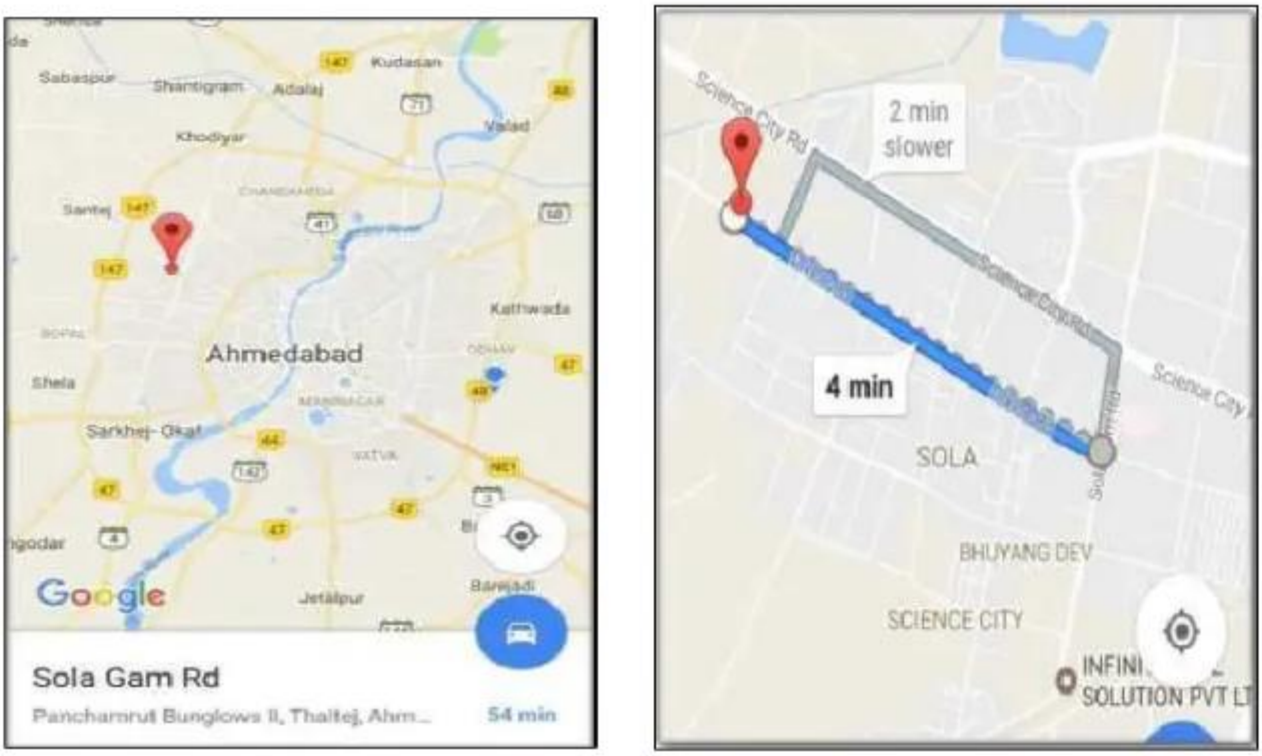

Fig 4: Study Area: 1.5 km to CH from Divine Road CH: 0.00

(ii) Methodology-

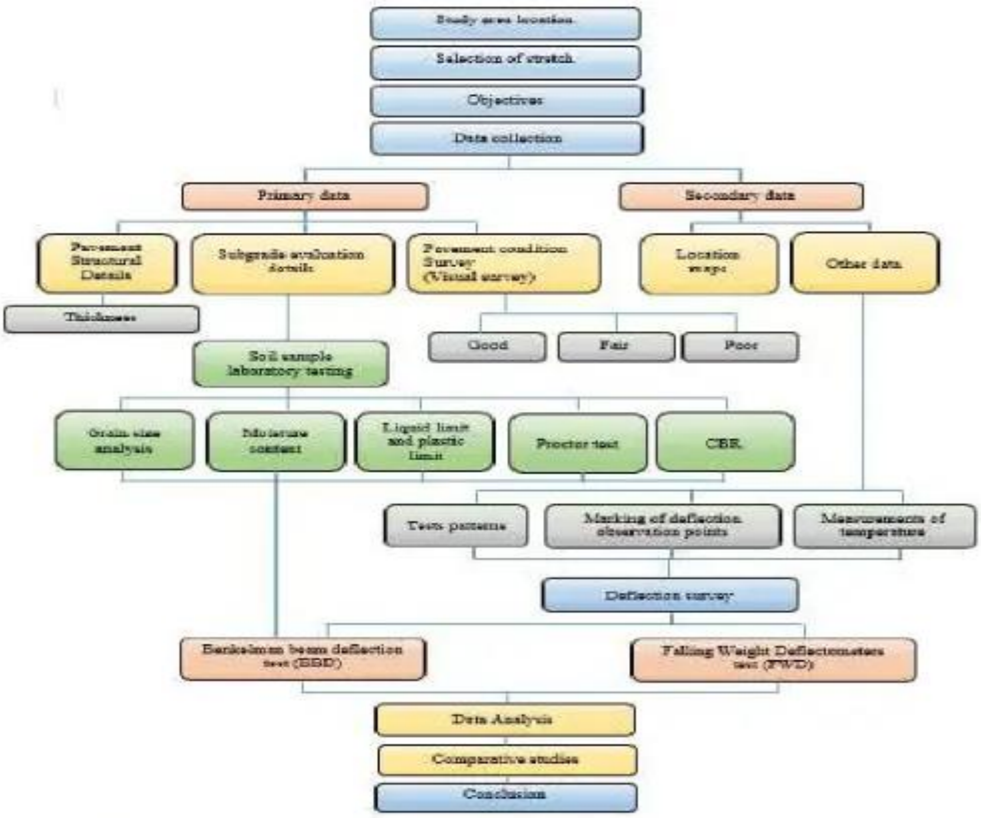

Fig 5: Methodology Flow Chart

5. Conclusion

I have gathered data for this study from the study area, which is located on Divine Road in Sola, Ahmedabad. Major data from the Benkelman beam deflection test, data from falling weight deflect meters, and further laboratory test data from soil samples are all included in the data collection process. A thorough study and structural analysis were conducted on the chosen section of the National Highway. The conclusions that follow are derived from the findings. While BBD uses static loading, which does not replicate moving traffic, FWD uses dynamic loading, which replicates moving traffic load and is hence more deterministic. The deflection caused in the pavement as well as the elastic compression of different pavement layers are indicated by the peak deflection that is acquired from FWD.

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