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Flexible Pavement Structural Evaluation And Pavement Maintenance And Rehabilitation

Vankar Vijay R.[1], Dr. L. B. Zala[2], Dr.P. N. Patel[3],Prof. A. A. Amin[4]
[11]M.Tech. (Civil) Transportation Engineering, BVM Engineering College, Vallabh Vidyanagar, Gujarat
[2]Head of Department, Civil Engineering Department, BVM Engineering College, Vallabh Vidyanagar, Gujarat
[3]Assistant Professor, PG Coordinator Transportation Engineering, Civil Engineering Department, BVM Engineering College, Vallabh Vidyanagar, Gujarat
[4]Assistant Professor, Transportation Engineering, Civil Engineering Department, BVM Engineering College, Vallabh Vidyanagar, Gujarat

Abstract:*Identifying the properties is the first step in developing effective pavement maintenance and management strategies. the structural strength of the pavement material This can be accomplished by investigating the response of the pavement to the applied load. In this study, the Falling Weight Deflectometer (FWD) and KGPBACK were used to evaluate the performance of a road section. investigate the deflection in response to load applied at selected union territory points Dadara-nagar, Heveli, Silvassa, India FWD was used to apply a dynamic load to existing pavement, and the pavement's response to the load was measured. The obtained deflection values were then used in the KGPBACK software to calculate the elastic moduli of the pavement's modelled layers. The obtained in-situ elastic moduli were then used in the IITPAVE software for pavement overlay design. Following the application of an overlay, one section of road developed extensive cracking, prompting the decision to reconstruct the entire pavement. A cost comparison is then performed to determine the cost effectiveness of the maintenance and rehabilitation strategy. It will be useful for pavement engineers and administration in determining when the pavement needs to be rehabilitated or maintained.*
Keywords:*Pavement, Maintenance,Rehabilitation,Deflection, FWD, KGPBACK, IITPAVE.*

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I. INTRODUCTION

As the nation's vast highway system ages, highway and transportation agencies throughout India must assume increased responsibility for maintaining, rehabilitating, and managing existing highway networks. Pavement structural evaluation is becoming more important as highway engineers use the results to determine maintenance and rehabilitation needs, set project priorities, allocate spending, and schedule and design maintenance and rehabilitation activities. The static deflection technique is the most widely used technique for evaluating the pavement performance of Indian roads. However, this empirical approach does not simulate the loads applied by fast-moving traffic and does not measure the entire deflection profile.To overcome the limitations of this method, pavement engineers have used nondestructive testing (NDT) methods such as the Falling Weight Deflectometer (FWD) for years to assess the structural integrity of pavements. FWD is an impulse loading device that applies a transient impulse load to the pavement surface and measures the deflection shape of the pavement using a series of geophones spaced at different radial distances. This method provides a more accurate characterization of the structure condition of the pavement layers. Using an appropriate analysis technique or software, the surface deflections obtained from FWD testing were used to backcalculate in situ material properties.KGPBACK is one such software that is based on the key features of the genetic algorithm that is used for back calculation of layer moduli of each pavement layer from measured deflection basins. In KGPBACK, an iterative technique is used in which the calculated deflection values for various assumed elastic moduli values are compared to the observed deflection values. The estimated deflection values are then adjusted by varying the elastic moduli, and the iteration process is repeated until the calculated and observed deflection values are nearly identical. The precise elastic moduli are determined in this manner.Using the IITPAVE software, the elastic moduli of a pavement serve as an important parameter for predicting the right overlay design. Furthermore, in India, the current practise for determining the timing of rehabilitation activities is primarily based on experience and subjective judgement. With the growing interest in structural design procedures, pavement performance studies are required to establish critical conditions at which strengthening/resurfacing measures will be more appropriate and cost-effective to extend the service life of a pavement beyond the original life.

II. NEED OF STUDY:

The development of road infrastructure is now a top priority for the government of India in order to (I) satisfy the needs of expanding travel demand and (ii) aid in the quicker expansion of economic activity. The national highway development programme (NHDP), which is currently underway, aims to connect (a) four metropolitan cities, namely Delhi, Kolkata, Chainai, and Mumbai, forming the golden quadrilateral; and (b) Srinagar to Kanyakumari and Silchar to Porbandar, constituting the north-south and west-east corridors.The recently announced Pradhan Mantri Gram Sadak Yojana (PMGSY) planned to deliver all-weather connection to India's communities by 2007. It is apparent that the costly highway infrastructure must be examined on a regular basis to determine the necessity for restoration measures.

The NHAI has now made the use of FWD for structural evaluation of flexible pavement on national and expressways mandatory. As a result, the purpose of this research is to measure the structural strength of flexible pavement using a falling weight deflectometer. In Dadra-Nagar haveli, India, a case study of (1) khadoli-khanvel (Ch. 13+800 to Ch. 19+400)(2) Khanvel-Dudhani(19+500 to35+000) determines overlay thickness if necessary and new pavement design.

In terms of structural evaluation of in-service pavements, the Benkelman beam has become a standard instrument used by numerous organisations for non-destructive testing of pavements since its inception in 1953 (Zube and Forsyth, 1996). The Indian Road Congress (IRC) suggests utilising the Benkelman beam to evaluate in-service pavements for the design of flexible overlays. The measured pavement deflections, adjusted for standard temperature and moisture, are utilised to establish the essential overlay thickness in the IRC design approach (IRC:81-1997). Because this technology only measures one surface deflection, appropriate information regarding the structural state of several layers of pavement cannot be obtained. As a result, this strategy does not allow for consistent forecast of performance of pavements.Some efforts were undertaken in India (Reddy and Pandey, 1994; road research project R-56, 1996) to include mechanistic concepts into overlay design process with changes made to the mechanistic approach.

The qualities of the existing pavement layers can be assessed in the research laboratory for the mechanistic design of an overlay by obtaining field cores. A mechanistic method may be used to calculate the residual life of the pavement as well as the need for overlay and new pavement design. A more sensible approach would be to conduct structural examination of in-service pavements by non-destructive testing of pavements, which is quick and causes the least disruption to traffic.

Over the last three decades, a variety of NDT equipment for analysing in-service pavements has been developed. Among them, FWD is thought to be the most appropriate since it represents the short-term loading of a moving wheel. Because the FWD measures six or more deflections, it is able to better understand the structural behaviour of pavements. The FWD deflections may be utilised to back compute the pavement layer moduli, which can then be used for analysis and calculation of the residual life of the pavement, as well as defining the precondition for overlay and new pavement design.

III. LITERATURE REVIEW

[1]The current research shows that Pavement deflection data is frequently used to examine the structural characteristics of a pavement in a non-destructive manner. The elastic moduli of pavement layers are determined from surface deflections by backcalculation. It has been established that by automating the processing of NDT data using knowledge-based systems, it is feasible to minimise the time necessary to analyse a large NDT data set while increasing the accuracy of the results. Instead of spending a significant amount of time conducting painstaking basin-by-basin analysis, pavement engineers may depend on computers to do the majority of the job while only being called upon on occasion to make critical judgments. Using a knowledge-based method in NDT data analysis allows a less-experienced analyst to achieve the same solutions as an expert analyst while also comprehending the rationale behind the answers. The created PASELS knowledge-based system is a prototype that may be upgraded to encompass a wide range of expert viewpoints. Before a final manufacturing system suited for local application is developed, it must be reviewed by several pavement specialists utilising field data and augmented with local expertise. This is a common phase in the creation of knowledge-based systems, and it is one of the reasons that effective knowledge-based system deployment has been rare. Currently, the PASELS system lacks the capacity to learn from its experience, as does a human expert. Rather, when experience accumulates or new information emerges, human experts must update the rule foundation. The ability to learn is a critical characteristic for an intelligent system. The advancement of automated learning in the field of artificial intelligence has demonstrated that the capacity to learn may be obtained, but the work required to build such a system with present technology can be significant. Given the relevance of NDT in pavement analysis, design, and management, it is proposed that PASELS be developed in the future.

[2]The use of a Falling Weight Deflectometer (FWD) for pavement evaluation is gaining popularity in many countries because this can simulate the magnitude and duration of load applied by a fast-moving vehicle

on highways. However, due to the high cost of the equipment and the difficulties encountered in maintaining it, the use of FWD in India has been very limited so far. This paper describes the details of a FWD system designed and developed for structural evaluation of pavements by the Transportation Engineering Section of the Civil Engineering Department of Indian Institute of Technology, Kharagpur, India. The key characteristics of the backcalculation algorithm used in the evaluation system are presented.The paper also includes details of structural evaluations of some highways conducted as part of a research programme sponsored by the Ministry of Road Transport and Highways (MORT & H), Government of India. This paper highlights the key features of FWD models developed by the Indian Institute of Technology, Kharagpur, India for structural evaluation of Indian highways. The creation of an indigenous FWD was needed for the advancement of pavement technology in India as well as the adoption of rational design approaches. The two FWD models were considered to be reliable and satisfactory.The FWD-based pavement evaluation system developed by IIT Kharagpur is anticipated to help in the rising popularity of the use of rational tools in the design and evaluation of pavements.

[3]The study's goal is to calibrate the HDM-4 pavement deterioration model in terms of rutting and roughness for the Patiala urban road network (Punjab, India). In our study, we chose 15 road segments and classified them based on traffic volume and pavement age. The pavement condition data, which was collected between 2012 and the end of 2014, is fed into the HDM-4 distress models. The calibration process is carried out using statistical analysis between the observed and predicted values of the distress while aiming for the lowest Root Mean Square Error (RMSE) and highest R-square value (R2).After calibration, the HDM-4 distress model obtained a good correlation between observed and predicted distress values, indicating that a calibrated HDM-4 model can also serve as a good predictive model for pavement distress in urban road networks.

- The percentage of variability for the rutting distress model ranges from 8 to 24 percent, and for the roughness distress model ranges from 1 to 7 percent, which is quite reasonable given the different climatic conditions, pavement age, and traffic.
- The calibration factor for the rutting distress model ranges from 2.63 to 2.84, and the roughness distress model ranges from 2.01 to 2.75, both of which are quite reasonable for flexible pavement in Patiala, Punjab, India's urban city road network.
- The obtained calibration factors can be applied to the urban road network of a city with similar traffic and environmental conditions, such as Patiala, Punjab, India.

[2]This paper describes the details of a FWD system designed and developed for structural evaluation of pavements by the Transportation Engineering Section of the Civil Engineering Department of Indian Institute of Technology, Kharagpur, India. The key characteristics of the backcalculation algorithm used in the evaluation system are presented. The paper also includes details of structural evaluations of some highways conducted as part of a research programme sponsored by the Ministry of Road Transport and Highways (MORT & H), Government of India. This paper highlights the key features of FWD models developed by the Indian Institute of Technology, Kharagpur, India for structural evaluation of Indian highways. The creation of an indigenous FWD was needed for the advancement of pavement technology in India as well as the adoption of rational design approaches. The two FWD models were considered to be reliable and satisfactory. The FWD-based pavement evaluation system developed by IIT Kharagpur is anticipated to help in the rising popularity of the use of rational tools in the design and evaluation of pavements.

[4]The Falling Weight Deflectometer is used to assess the structural condition of the pavement. Backcalculation is analysed to know the modulus of elasticity of existing in-service pavement. Backcalculation required in-depth field experience for the input of the range of modulus of elasticity of bituminous, granular, and subgrade layers, but also the number of trials required to find such matching moduli with the observed FWD deflection on the field.The study was carried out on the Barnala-Mansa State Highway in Punjab state, which is 20 kilometres long, using FWD before and after overlay; the deflections were obtained at 0 on the load cell, 300, 600, 900-, 1200-, 1500-, and 1800-mm intervals from the load cell. Deflection bowl parameters such as Surface Curvature Index (SCI), Middle Layer Index (MLI), and Lower Layer Index (LLI) are calculated using the seven deflection results (LLI). The SCI, MLI, and LLI indices are useful for predicting the structural performance of in-service pavement layers and identifying homogeneous sections for condition assessment.

The SCI, LLI, and MLI results show a relationship between old and new pavement. The SCI represents the condition of the bituminous layer; based on observation, the limiting value of SCI may be considered up to and greater than 240 microns as poor, and less than 100 microns as good. The old pavement before overlay has most SCI values greater than 240 microns in the entire study stretch, and visual observation of pavement condition is also poor. The SCI index is helpful in determining whether the condition is good or poor when assessing the condition of the bituminous layer. The MLI-Middle layer index represents the state of the base and subbase layers.The observation demonstrates that there is no statistically significant difference in the index. The old layer index was 140, while the new layer index was 100. It demonstrates that the condition of the middle layer is also good in old pavement. The LLI- Lower layer index, which represents the subgrade condition. The index observations for old and new pavements are 15 and 10, respectively. The index value is the same as MLI; there is no significant difference because the condition of the subgrade layer is the same before and after overlay. as shown in Table 9. The Moduli value observed before overlay for the upper bituminous layer was in the 600 to 2000 Mpa range. This higher value was observed in some areas as a result of a consolidated thin bituminous layer.The middle layer moduli for both old and new pavement are in the range of 100 to 450 MPa, indicating that both are in good condition. The lower layer moduli range from 80 to 300 Mpa.

[5]This paper presented preliminary findings from a recently completed study on the NH-8 section between Kamrej and Chalthan for structural evaluation of flexible pavement using a falling weight deflectometer. A total of 16.350 km of section has been chosen for investigation. These road segments were subjected to FWD tests to determine the structural condition of the existing pavement. As a result, evaluate the structural conditions of existing pavements and recommend required thickness values based on FWD-based critical pavement responses computed and compared to computed values for pre-established fatigue and rutting damage models. Through FWD, the M-E overlay design method successfully identified structural flaws in the original pavement configurations, resulting in reliable overlay solutions. Tensile strain and vertical strain are both less than the allowable strain after a functional overlay of 50 mm is applied. As a result, for all of these sections, a functional overlay of 50 mm is sufficient, with the exception of the section beginning at 0.100 km and ending at 0.600 km, which requires a 75 mm overlay thickness [4].

[6]The paper study shows that The study route in this paper is NH-218 (Bajpur to Hubballi). The FWD test was performed at the selected locations, and the test results were analysed using KGP Back software in conjunction with IRC 115-2014, and the design was affirmed using IIT-Pave software. IRC 37-2012 Equations 6.3 and 6.5 are used to calculate the allowable strains, which are then compared to the calculated strains from IIT-Pave. Based on the KGP back and IIT-Pave results, a new thickness has been proposed. This paper explains the significance of KGP Back software in establishing revised pavement thicknesses

Deflection measurements were taken on the pavement utilising the established FWD system on three selected sections classed as H-1, H-2, and H-3 depending on pavement condition in this study. KGPBACK software was used to calculate the elastic moduli of each layer based on the deflection data. FWD was utilised to apply a dynamic load to existing pavement, and the pavement's response to the load was measured. The resulting deflection values were then utilised in the KGPBACK programme to calculate the elastic moduli of the pavement's modelled layers. The acquired in-situ elastic moduli were then employed in the IITPAVE programme for pavement overlay design. The study's data was also utilised as an input parameter in the HDM-4 model to estimate pavement deterioration over time owing to the extended application of traffic loads. The HDM-4 model was also utilised to examine the influence of bituminous overlay maintenance on the distress models, and it was discovered that all four distress (cracking, ravelling, rutting, and roughness) decreased. As a result, the analysis presented in this article provides a guideline approach that administrators might use to determine when and how much financing would be needed to protect and maintain the Indian Highway Road network.[5].

[7] This paper study shows that ANN have recently gotten a lot of attention and have contributed to a wide range of applications in civil engineering and other fields. ANN-based pavement overlay design tool was developed in this study using neurosolutions software, version 5.06. Several network architectures were trained using training data sets created by the WINFLEX M-E overlay design programme. The predicted overlay thickness of the trained network was determined using different testing data sets, whereas the calculated ones were determined by the WINFLEX programme. The calculated and predicted overlay thicknesses were compared to determine the accuracy rate. The results indicate that the ANN technology can be used to determine the pavement overlay thickness with high accuracy based on M-E procedure. This study is considered an important attempt to simulate the M-E overlay design procedure using ANN technology.Comparing with other papers related to the application of ANN in pavement design, the ANN models have proved to be a powerful tool in providing pavement engineers and designers with sophisticated solutions, without the need for a high degree of expertise in the input and output of the problem, to rapidly analyze and design flexible pavements.

[8]The elastic response of the whole deflection bowl may be properly measured with modern non-destructive survey equipment such as the FWD. This facilitates the use of the entire deflection bowl in empirical or theoretically based (mechanistic) pavement structure study processes. Correlations between a number of deflection bowl characteristics and mechanistically calculated structural assessments of a variety of pavement types provide the opportunity to utilise these parameters to analyse pavements in a semi-empirical-mechanist approach. These metrics can be used in conjunction with visual surveys and other evaluation approaches to classify pavement structural layers as sound, warning, or severe in terms of structural capability. This methodology may be utilised in a "sieving" activity to discover structural failure and pin it down to specific layers for additional extensive examinations using other evaluation techniques. The example on a high-traffic

road proved the approach and value of this expanded usage of the deflection bowl and associated parameters in structural evaluation and assessment of pavements in rehabilitation calculations. In summary, this "sieving" method to deflection bowl data helps to precisely identify uniform portions, locate the reason of structural distress, which is frequently perceived as various types of surface distress, and explain the mechanism of degradation. It allows us to focus on such troubled regions with further research such as field and laboratory testing.

[9]Falling weight Deflectometer (FWD) testing is becoming a popular instrument for assessing the structural integrity of a pavement. The study's goal was to determine the structural capability of flexible pavement by analysing the FWD surface deflection test data for the Nairobi Eastern Bypass. The study discovered that when deflection values increase throughout the pavement length, the pavement shows varied characteristics ranging from strong to moderate, with majority of the pavement stretch being defined as quite strong. Three spots around chainages14.4km, 24.2kms, and 25.8kms revealed indicators of a moderate pavement that required a thin overlay despite the pavement structure exhibiting stability features. For pavement surface treatment, 10/14 class 1 chippings and 80/100 penetration grade bituminous binder were advised for the whole length of the study section. As the deflection values change throughout the pavement length, the pavement shows varied characteristics ranging from strong pavement to mild pavement. Much of the pavement section was classified as reasonably solid, however it may require overlay depending on traffic demand. The pavement surface curvature index indicated strong top layers in the pavement structure, and it was discovered that the upper layers of the pavement had a considerable curvature impact on the structural state of the pavement A firm subgrade might also be used to support the pavement construction.[9].

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[10]This report describes Indiana's experience with FWD and GPR pavement assessment at the network level. As part of a research to overcome conventional limitations to the use of FWD and GPR in pavement evaluation at that level, such as data gathering costs, limited resources, and a lack of simplified analytical techniques, a network level FWD and GPR testing programme was established. This testing programme comprised Interstate Highways 64, 65, 69, 70, and 74, as well as a variety of US roadways and state routes. The following are the key results and conclusions:

- Network level testing with FWD and GPR is a critical, technically sound initiative that will give a baseline of structural capacity for Indiana's in-service pavements. The compilation of essential data on a regular basis will be important in establishing how to effectively measure the loss in structural capacity and estimate the annual construction budget.
- The abundance of information gleaned from network level testing may be applied to pavement design, maintenance, rehabilitation, and management.
- GPR is not expected to eliminate the requirement for coring entirely. GPR can be used to determine coring needs, aid in the interpretation of GPR data, fill gaps in thickness estimation, and check thickness results.
- INDOT interstate highways have a pooled standard deviation of performance of 0.497, a dependability level of 90 percent, and a safety factor ranging from 3.8 to 5.2.[10].

[11]The main purpose of the research presented in this paper is to investigate data-mining strategies and to develop a prediction method of the structural condition trends for network-level applications, which do not require FWD testing. The research team first evaluated the existing and historical pavement condition, distress, ride, traffic, and other data attributes in the Texas Department of Transportation (TxDOT) Pavement Maintenance Information System (PMIS); applied data-mining strategies to the data; discovered useful patterns and knowledge for SCI value prediction; and finally provided a reasonable measure of pavement structural condition which is correlated to the SCI. To evaluate the performance of the developed prediction approach, a case study was conducted using the SCI data calculated from the FWD data collected on flexible pavements over a 5-year period (2005–2009) from 354 PMIS sections representing 37 pavement sections on the Texas highway system. The preliminary study results showed that the proposed approach can be used as a supportive pavement structural index in the event when FWD deflection data is not available and help pavement managers identify the timing and appropriate treatment level of preventive maintenance activities[11].

[12]The study shows that Using a backcalculated procedure, falling weight deflectometer (FWD) testing has been utilised to evaluate the structural state of pavements and estimate the layer moduli. However, even if the computed and measured deflection basin meets the norm and is within certain permissible limitations, the anticipated pavement layer moduli are not always accurate. The projected pavement structural capacity and back computed layer modulus are affected by pavement structure features such as pavement layer thickness condition and temperature change. The primary goal of this research is to analyse the FWD test results of flexible pavement in Western Australia in order to forecast the structural capability of the pavement. In

addition to FWD measurements, collected data contains core data and pavement distress surveys.The results shown that the dynamic analysis of the falling weight deflectometer test and prediction for the strength of character of flexible pavement layer moduli were accomplished, and methods for deflection basin interpretation were enhanced. For the majority of projects, the changes in moduli of all layers over the length of sections are accurate and compatible with observed and computed projections

[13]Pavement modelling has long been a complex and tough topic for transportation engineers. There are complicated and accurate computer programmes available today that allow engineers to compute theoretical behaviour. In contrast, full-scale field testing has lagged, and new testing instruments are just now becoming widely available. For many years, the Benkelman beam was the accepted approach, and subsequent innovations were often compared to it. However, it became clear that improved approaches were needed to accurately simulate pavement behaviour under moving wheel loads. This document presents an overview of comparative tests undertaken throughout Scandinavia. The comparison includes two falling weight deflectometer (FWD) designs, Dynaflect, plate bearing, travelling Deflectograph, vibrators, and Benkelman beam. As a result, there is no necessity to try to win acceptability by linkages. As a result, pavement modelling that use methodologies such as elastic layer theory needs feedback from field experiments that as nearly as possible mimic the actual behaviour. Recent research in Europe and the United States has shown that load response using the FWD is very near to real-world situations, and as a result, the FWD is being advocated as the optimum testing method. The research presented here has allowed us to assess the relative benefits of two FWD systems and compare them to other ways. According on the findings of the study, the following conclusions appear to be justified:

- FWDs have a force pulse form that simulates moving wheel loads better than the other devices tested in this study.
- In a comparison of the two FWDs, the two-mass system appeared to have higher accuracy and repeatability.
- In terms of precision and repeatability, the Dynaflect outperformed other instruments. However, it performs a poor job of replicating full-scale moving wheel loads. Pavement vibrators performed well in comparison to other devices, except in pavements with soft subgrades, such as peat.

IV. CONCLUSION

Many countries are adopting the use of a Falling Weight Deflectometer (FWD) for pavement evaluation because it can simulate the magnitude and duration of load applied by a fast-moving vehicle on highways. Because the FWD is so close to real-world situations, it is being promoted as the best testing method. This study demonstrates the importance of deflection measurement by FWD, which provides a force pulse shape that tends to simulate moving wheel loads better than the other device. Based on this research, it is also possible to conclude that FWD can be used as a BT, granular layer, and subgrade strength evaluating tool for pavement construction and maintenance.All of the studies show that factors such as traffic loading, environment, pavement age, pavement composition, construction quality, and drainage have the greatest impact on the design life of the pavement and reduce it. The study concluded that temperature variation for bound layers and seasonal variation for un-bound layers must be corrected because it affects deflection data, so this correction must be applied to deflection data based on the geography and climate condition of the pavement to obtain accurate deflection values. It is suggested that a timely functional and structural evaluation of Indian road pavement would provide existing pavement condition, which would be useful for highway engineers in proper planning, management, and allocating funds for pavement maintenance and rehabilitation.

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