Simplified Approach for Pavement Evaluation of Flexible Pavements at the Network Level

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ABSTRACT: Pavement maintenance is one of the important aspects of highway engineering in a country like India as many pavements are nearing the end of their service life. India is seeing mixed vehicle traffic, making the pavement situation even worse. Rapid industrialization and urban growth in India have led to an increase in traffic and high consumption of roads, which catalyzes advertising in the same way. Therefore, pavement maintenance is a necessary measure of safety and cost efficiency, because pavement rehabilitation is very expensive. Pavement serves as a parameter for a nation's progress; Management therefore plays an important role in the growth of the economy, also raising traffic and living standards. The purpose of this project is to study the structural stability of the pavement using the Benkelman beam deflection and falling weight deflectmeter method and to determine the overlap to compensate for structural instability if continued. Corrective factors such as seasonal correction and temperature correction also occurred. Currently, there are few available simple procedures to identify structurally weak pavement sections utilizing Falling Weight Deflectometer (FWD) data & Pavement Condition survey data by NSV at the network level (e.g., city, state or province). A simple method is obligatory to regulate the structural condition of pavement sections that can be directly implemented and automated in current pavement databases. The objective of this research study is to improve a simple analysis method to determine the structural condition of pavement sections exploiting the currently available non-destructive testing (NDT) deflection measurement devices at the network level that can be unswervingly implemented and automated in the database of a typical transportation agency. In addition, the study had conducted an advanced mechanistic analysis to mimic the FWD deflection bowl obtained from the field. The developed structural condition parameters can be easily implemented in pavement management systems (PMS). This will aid Departments of NHAI and local highway agencies to make more well-versed decisions about the most appropriate maintenance and rehabilitation strategies. Those parameters were also utilized to forecast the remaining fatigue lives of the studied pavement sections.

Key Words: Distress, Highway Failures Maintenance and repairs.

1. INTRODUCTION

1.1 General

Government of India has decided to take up through National Highways Authority of India (NHAI) about 1000Kms of expressways under of the National Highways Development Project (NHDP).

India has national and state highways and urban and rural roads with a total road network of 5.5 million km. National highway represent 2% of the total road network and over 40% of the total traffic.

NHAI built 3,979 km of national highways during the 2019-2020 financial year. This is the highest road construction built during the exercise. The construction speed observed in Previous years achieved steady growth with the construction of 3,380 km in the 2018-19 financial year. The same trend Continues with the development of 3,979 km of national highways in the financial year 2019-2020.

India has a well-developed framework for Public-Private-Partnerships (PPP) in the highway sector. Asian

Development Bank ranked India at first spot in PPP operational maturity and also designated India as a developed market for PPPs.

The Government of India (GoI) plans to expand the National Highway Network to 200,000 km. The government has launched the Bharatmala project, which aims to build 66,100 km of economic corridors, border and coastal roads and expressways to augment the highway network. The program is expected to provide 4-lane connectivity to 550 districts, increase vehicle speeds by 20-25% and reduce supply chain costs by 5-6%. The first phase of the program will bring b 82 billion investment by 2022 to the development of 34,800 km of roads.

Fig. 1 Showing the Components of Road Maintenance

1.1 Objectives of Study

The main objective of the pavement evaluation system is to help the highway engineer to make timely and economic decisions regarding the maintenance and rehabilitation of sidewalks. In developing countries such as India, large road networks built at high costs are underused and overused. From an economic point of view, adequate maintenance measures must be taken before existing roads deteriorate further. The flooring evaluation system allows the timely planning and execution of adequate maintenance programs.

There are two main methods of conducting performance evaluation of flexible pavement viz,

a. Structural evaluation and
b. Functional evaluation.

1.2 Scope of the Study

The deflection of the pavement has been widely used as a destructive technique to evaluate the structural efficiency of the sidewalks at the project level. The current equipment in this study includes a descending weight deflectometer and the pavement condition of an NSV vehicle capable of recording the shape of the deflection cup. Based on the literature search, it can be observed that different models have been developed to form the parameters that describe the structural conditions of the pavement. However, many of the latest development indicators are:

Exclusively based on either central deflections or one deflection point along FWD deflection bowl. No comprehensive deflection or structural index is available that utilizes the entire FWD deflection bowl area.

a. Describe the remaining life of the pavement without calculating a predicted number of traffic load cycles to failure (e.g., fatigue).
b. To Calculate the Overlay Thickness of the Pavement.

The scope of this study is to overcome the limitations associated with present structural models. As an initiative, new area ratio parameter will be introduced that utilize entire FWD deflection bowl (i.e., 1524 mm from the load plate). The developed area ratio parameter will be related to the measured fatigue cracking of the respective pavement sections and the remaining service life will be predicted.

2. LITERATURE REVIEW

FWD tests have been part of assessing the condition of flexible flooring for over a decade. Various approaches and approaches for the analysis of the deflection of FWD have been developed in several studies (Xu et al., 2002a, Xu et al., 2002b). These FWD deflection policies and guidelines do not take into account the dynamic loading effect either

Nonlinear material behavior. Although some of these approaches are considered, their implementation is very demanding due to their complexity and large number of variables (Xu et al., 2002a, Xu et al., 2002b).

Sebali et al. (1986) analyzed dynamic analysis data from weight loss using multi-level elastic freedom analysis, which was based on the synthesis of the Fourier solution for the periodic loading of layered layers of elastic or viscoelastic modules. The results indicated that the effects of inertia were significant in estimating the pavement response.

Xu et al., 2002 developed a mechanical relationship between the deflection of the FWD and the conditions of the asphalt pavement layers. From the results, the parameters of the deflection basin (DBP), the effective layer modulus and the stresses and the deformation pavement layers were identified as condition indicators.

Xay et al., 2002 also presented a new condition assessment standard for flexible pavement layers using FWD from field data. The evaluation criteria of the demonstration conditions for the application were developed in conjunction with the conditional evaluation indicators using the deflection of the deflectometer with decreasing weight.

Oliver Lynn et al. (2014) Conduct a study on "The study of the modelling of pavement conditions - A Wick Roads using the surface conditions data" on the optimization algorithm developed in this research. The network functions in the cost-benefit analysis to optimize the processing, traffic volume and limited budget available.

Vinay HN et al. (2014)) conducted a study on "Rehabilitation of low-volume flexible flooring by white topping" and concluded that "pavement rehabilitation measures are considered to be based on PCI, IRC and deflection values".

3. DATA COLLECTION

The project road, owned by the PWD division of Vijayawada, was built by Vishwa Samudra Engineering Pvt. Ltd. with their technical partners Avani Eco Projects Pvt. Ltd., Hyderabad. The length of the project road is 2.2 km. The 6 km track to the project road is up to 0.6 km and the remaining length is single lane with a width of 3.75 m. The design stretch arrangement shown in Figure.

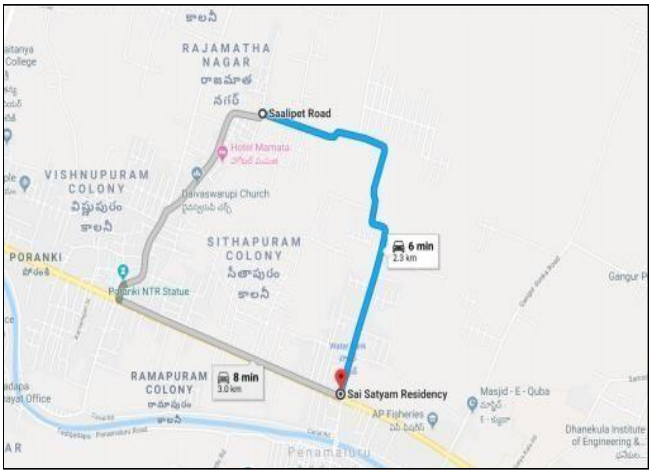

Figure 1: Project Location Map

After signing the contract, the KDM FWD Machine & Survey Crew was brought together on Salipet Road near Vijayawada to collect the data. As a result, the traffic volume counting survey was conducted and the load survey was conducted for 24 hours. The FWD test was also conducted using Geotron FWD on March 18-20 at a distance of 2.2 km. The following table provides a schedule of all the surveys conducted on the project road.

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S. No.	Type of Survey	Location	Survey Dates
1	Traffic Volume Count	Km 0+200	16-03-2020 to 19-03-2020
		Near Harijanawada (Km 1+900)	17-03-2020 to 18-03-2020
2	Axle Load Survey	Km 0+200	18-03-2020 to 19-03-2020
3	Falling Weight Deflectomer Test	Entire Stretch	18-03-2020

4.1 METHODOLOGY FOR TRAFFIC VOLUME COUNT SURVEY

Motorized Traffic	Non-Motorized Traffic
2 Wheeler	Bi-cycle
3 Wheeler	Cycle Rickshaw
Passenger Car	Animal Drawn Vehicles (ADV)
Utility Vehicles (Jeep, Van etc.)	Hand Cart
Mini Bus / Matador	Other non-Motorized Vehicles
Standard Bus	
LCV Passenger	
Freight	
MCV 2-Axle Rigid Chassis Truck	
3-Axle Rigid Chassis Truck	
Multi-Axle Truck Semi articulated	
Articulated	

The classified traffic volume count is done for 3 days for 24 hours in both directions at one location and at other location volume count is done for 24 hours. The vehicle classification system adopted for the study is as follows. The traffic count is done manually by the trained enumerators in three 8 hour shifts on each day. The traffic count data is recorded at 15 minute intervals. The format for field data is mentioned below.

Figure 3: Few snaps taken during Traffic Volume Count Survey

1. Safety of surveyor should be kept in mind and safe location should be selected. This becomes more important in rural area where carriageway is not well-defined.
2. Equipment's used while automatic count should be placed such that they do not draw attention of driver.

4.2 Equipment

A portable electronic weighing system is used for detection. The system consists of 2 pad weights and a remote indicator. The weight bearing is positioned close to the upper level of the bearing on the shoulder so that when measuring the wheel load, the vehicle axle is horizontal. The equipment is pre-calibrated before the start of the survey.

When there are no IRC / IS standards on this matter, this work is done following the consultants internal approach based on the manufacturer's recommendation.

Figure 4: Few snaps taken during Axle Load Survey

Applicable Standard

4.3 Work Procedure:-

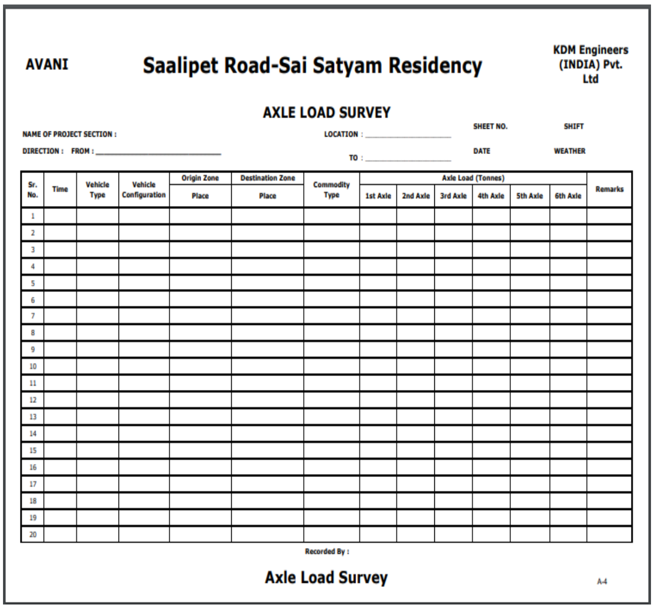
The work consists of several activities, and process control checks are exercised on these. These include:

- Choice of location of weigh stations
- Correct positioning of weigh pads
- Making arrangement for jerk-free mounting of vehicle tires onto the pads
- Recording load data on the data sheets and taking the axle load to be twice that of the weighed wheel load.
- Ensuring that the sample covers all types of commercial vehicles, viz. LGVs, 2-axle trucks, 3-axle trucks and MAV‟s of different axle configurations.
- A few representative buses will also be weighed.
- Vehicles whether they are empty or full would be weighed.

The commodity carried by the vehicle would also be noted.

4.4 Safety Considerations

The axle load detection station is located where the road is steep and more or less level and where adequate shoulder space is available. This place is far enough away from narrow weak bridges or congested stretches. Preferably, the location is in a bright place. Otherwise, temporary lights are used to conduct detection during the night. In addition, the flags with red flags and red lights guide public vehicles and drive heavy vehicles to weigh the bridge / pad. Safety cones are also positioned to illuminate the path of heavy vehicles. The format for the field data is shown below.



AVANI

Saalipet Road-Sai Satyam Residency

KDM Engineers (INDIA) Pvt. Ltd

AXLE LOAD SURVEY

NAME OF PROJECT SECTION : LOCATION : ____________ SHEET NO. SHIFT

DIRECTION : FROM : ____________ TO : ____________ DATE WEATHER

Sr. No.	Time	Vehicle Type	Vehicle Configuration	Origin Zone	Destination Zone	Commodity Type	Axle Load (Tonnes)						Remarks
				Place	Place		1st Axle	2nd Axle	3rd Axle	4th Axle	5th Axle	6th Axle	
1													
2													
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20													

Recorded By :

Axle Load Survey A-4

Figure 4: Field format for Axle Load Survey

4.5 METHODOLOGY FALLINGWEIGHT DEFLECTOMETER (FWD) TEST

KD Muses GEOTRAN Falling Weight Deflectometer. This unit is an on-destructive pavement testing device which provides accurate data on the response of the pavement (specifically the surface deflection bowl) to dynamic loads by simulating actual wheel loads in both response and duration. This allows more accurate and rapid measurement of pavement deflection under load than traditional methods.

Figure 5: Few snaps taken during FWD Survey

The dynamic load is produced by releasing the mass on a plate with a diameter of 300 mm from a predetermined height. The extent of the load and the response of the pavement are measured by a load cell and seven geophones. One geophone is immediately under load, the others are offset variable from the center of the load.

The test load varies between 7 and 70 KN to meet specific job requirements and the flooring response can be measured up to four different magnitudes during any test sequence. The geophone offsets can be set at a distance of 1800 mm from the center of the load and complete a simple sequence in about a minute. Therefore very precise measurements of the deflection bowl are possible and FWD is very useful for conducting surveys on large-scale flooring.

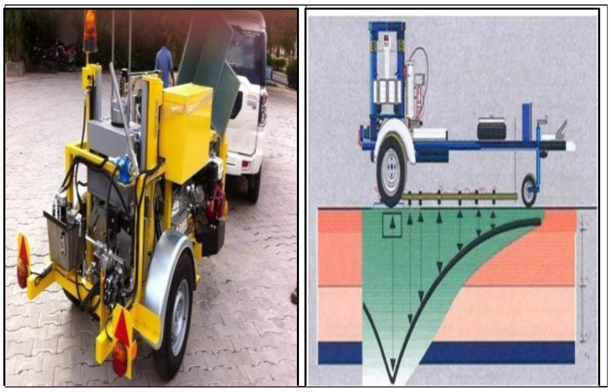


Figure 6: Location of Geo-Phones

This data helps in applications such as the design of pavement overlaps, surveys on pavement conditions and the development and operation of pavement management systems (PMS). It is also used as an input for counting down the pavement module packages.

The FWD is integrated into the trailer, towed by a special vehicle. All tests are controlled by a personal computer in the vehicle, similar to FWD. As a result, in most cases only one operator is required to conduct an investigation, which involves less manpower / equipment than traditional methods.

Working Principle

- A set of weights is dropped on to a platform with springs (rubber buffers) and the impact load is transferred to the pavement through a loading plate.
- The load simulates the dynamic load from a truck
- Normally, the load applied on road pavements is 40kN
- When subjected to a load, the pavement will bend and a deflection bowl is created. The deflections at various distances from the loading centre are recorded by the sensors (geophones) and stored in a data file.

5. SITE OBSERVATIONS AT THE TIME OF SURVEY

During the Site visit we have identified the Pavement Inventory and its condition details

5.1 ROAD INVENTORY

Carriageway:-The total length of the project road is 2.2 km. The project road has a track of 6 m up to 0.6 km and the rest of the length is a single lane configuration of 3.75 m wide for the road. Carriageway is built with BT and WMM with a three-layer dressing stabilizing agent.

Terrain:-Project road passing through plain terrain. It can cater to the design speed of about 30-50 km/hr except in some of the built-up area and at sharp curve locations. **Land use**:-Project road generally traverse through built up area and few sections it is traverse through Agricultural and Barren land. Dilip Build con Concrete mixing plant also observed along the project road.

Road Geometries:-There are sharp curves originate along the alignment. The vertical alignment is usually having smooth geometry. There are some sites observed, where adequate sight distances are not available which need improvement to the standards.

Pavement Condition:-Entire stretch of the project road is in good state. At few places it is found that half of the carriageway is covered by house hold trash which has thrown by local people.

6. ANALYSIS METHODOLOGY AND RESULTS

6.1 TRAFFIC VOLUME COUNT:-

6.1.1 Average Daily Traffic (ADT)

Traffic volume count data by direction at each location for 3 days duration is averaged to obtain the Average Daily Traffic (ADT). Summary showing the daily directional totals, daily traffic and the average daily traffic is presented in **Appendix1**. The directional daily traffic by each hour of the day for the two locations over the survey period is presented in **Appendix 2**. Summary of ADT for each section is given in Table below.

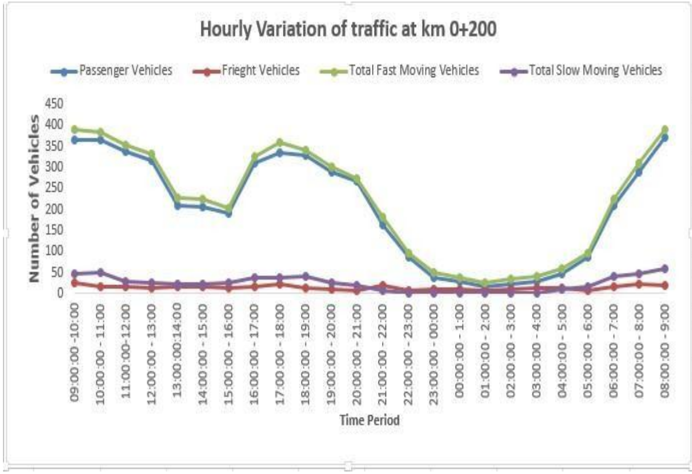
Table 2: Summary of Average Daily Traffic

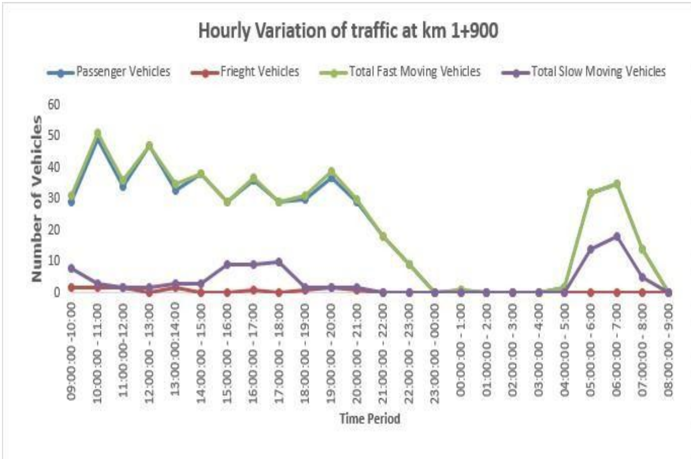
Vehicle Type/ Location	Location 1 (KM 0+200 of Saalipet Road)	Location 2 (KM1+900 of Saalipet Road)
Total Passenger Vehicles	4903	531
Total Freight Vehicles	362	13
Total Fast Moving Vehicles	5257	544
Total Slow Moving Vehicles	581	93
Total Vehicles	5846	637

6.1.2 Distribution of Traffic:

Hourly variation of traffic at the count stations in terms of passenger vehicles, freight vehicles and total vehicles is presented in figure below. Details of peak hour and directional distribution of traffic at the survey.

Figure 7: Hourly Variation of Traffic at KM 1/900 on Saalipet Road Table 3: Peak Hour and Directional Distribution





6.1.3. Traffic Composition:

Composition of traffic observed at the count stations is presented in Figure below. It is observed across all the stations that share of non-motorized traffic are arranging from 9% to 12%. Composition of Cars varies from 4 to 8%. Composition of freight vehicles is in the range of 1% to 6%. Buses constitute around 1%. The two wheelers which constitute maximum share at all locations is ranging from 71% to 76%.

6.1.4 Daily Traffic

Seasonality factors for different vehicle types are necessary in order to arrive at the average traffic representing the whole year. The factors are generally established from past PWD traffic data or from the petrol/ diesel sales data at existing petrol pumps along the project roads.

In the absence of above said data, seasonal correction factor of „1.0" has been adopted for all type of vehicles in this study. Mode-wise factors are applied to Average Daily Traffic volumes to obtain the Average Annual Daily Traffic (AADT) for individual survey stations.

6.2 AXLE LOAD SURVEY

The axle load detection was conducted at a point along the project road to find out the load model along the project road. Dilip build with concrete mixing plant was discovered along the section of the project. Therefore, during the axle load investigation, it can be observed that 2 and 3 axle trucks mainly transport concrete and other building materials. The load sensing positions on the axes and on the planning are listed below.

The spectrum of pivot loads for the different categories of commercial vehicles and the equivalent standard pivot numbers 8.16T were determined based on the detection of the pivot load.

The gross vehicle weight was determined according to the 1996 central government notification. The following table provides details of 6 different types of vehicles and their details.

The dispositions of the pivoting wheels and the GAVE implications reported above in the notification are shown below in schematic form for assistance during the investigations on the axle load and the subsequent data analysis.

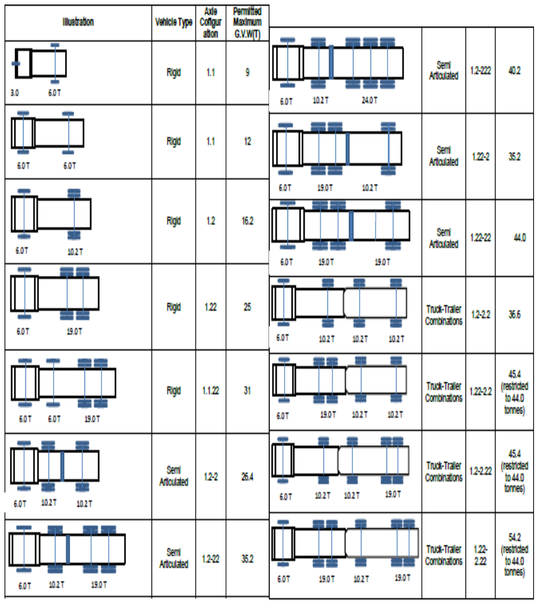


Figure 8: Axle Configurations

Maximum Deflection: GEOTRAN Falling Weight Deflectometer (FWD) was used to collect pavement strength and stiffness in formation and these values are reported in mm. The results of the normalized maximum deflection testing are presented below.

Normalized Deflection Values: In accordance with international best practice and with Section 4.4 of IRC 115, the recorded deflection values have been normalized to the equivalent applied pressure of 40KN. This Load is representative of a standard ESAL. The following figure presents the Peak Deflection.

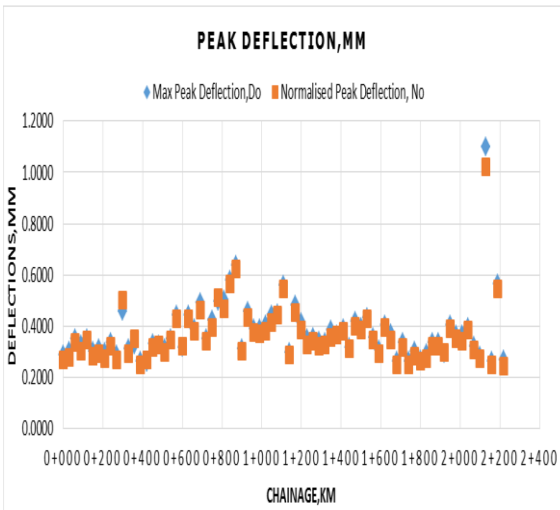


Figure 9: Peak Deflection Values

Modulus Values: In accordance with IRC 115 and IRC 37:2012, the recorded deflection values have been analyzed to determine back-calculated modulus value. The processed results are attached in Appendix.

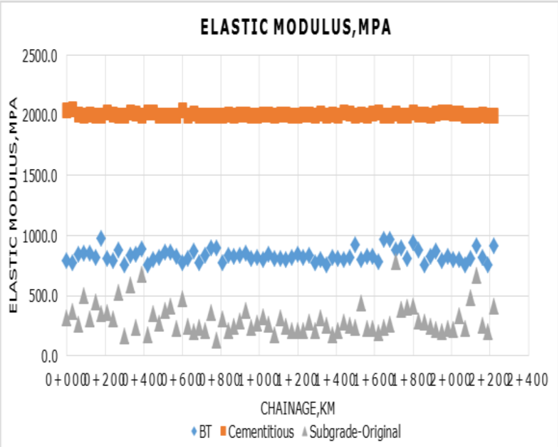


Figure 10: Back calculated

7. CONCLUSION

The project consists of a small road sections near Saalipet road near Poranki in Vijayawada, Andhra Pradesh. The total length of the existing project corridor is 2.2 km approx.

Traffic Volume Count (TVC) and Axle Load Survey has been conducted on Saalipet road near Poranki, Vijayawada TVC Survey has been conducted for continuous 3 days from16-03- 2020 to 19-03-2020 and Axle load survey has been conducted for 24 hours on18-03-2020.

The analysis results and observations of TVC and Axle load survey are mentioned below.

- From TVC survey, it is observed that share of non-motorized traffic are ranging from 9% to 12%. Composition of Cars varies from 4 to 8%. Composition of freight vehicles is in the range of 1% to 6%. Buses constitute around 1%. The two wheelers which constitute maximum share at all locations is ranging from 71% to76%.
- Composition of Commercial vehicles which affects pavement are mentioned below

Buses s	LCV	2Axle Truck	3 Axle Truck	MAV
45	94	92	56	2

- During axle load survey it is observed that trucks moving towards Dilip Build con concrete mixing plant are 83% overloaded and having maximum Gross vehicle weight more than 45 tones.
- Vehicle Damage Factor (VDF) for each type of commercial vehicles has been calculated and mentioned below.

Vehicle Type	VDF
LCV	1.58
Bus	0.1
2Axle	1.8
3Axle	9.64
MAV	16.74

- Design traffic has been estimated for 15 years by assuming the growth of 5% at each year and reported as 8msa (million standard axles)

KDM‟s GEOTRAN Falling Weight Deflectometer was engaged for data collection and the survey was done on 18-Nov-2018. The testing was undertaken in all sections that reflected the road conditions and pavement composition. Subsequently the analysis was undertaken with appropriate pavement compositions as per IRC guidelines - IRC 115: 2014 and IRC 37: 2012.

The results from the entire stretch are presented in Section 7. The results indicate:

Saalipet road section has a uniform Pavement composition.

During initial Testing, it is observed the deflection readings recorded in these sub sections indicates a very stiff under lying layers ensuring the privilege so the high performance heavy volume pavements.

1. For Back calculation process, the limits for Subgrade and Bituminous layer has been considered based on the IRC 115: 2014 and for cementations layer the limits have been considered based on IRC 37: 2012. The same has been discussed7.1.
2. The predicted design traffic for 15 years (i.e., 2019-2034) estimated as 8 msa. Whereas through the performance check, remaining life of pavement obtained as 320 msa from KGP BACK and IIT PAVE analysis. Considering the above, at the end of 15^{th} year (2034) the service life of the pavement will remain80%.
3. Overall the existing pavement has approximately 75 years of remaining life, which means that the existing pavement will acceptable functionally and structurally with only routine maintenance for 75years.

Variability in the calculated results may be a reflection on variability of the pavement composition along the alignment. For each section, the available information only supports the consideration of provided pavement composition in that section.

8. REFERENCES

1. IRC:37-2012 :- Guidelines for The Design of Flexible Pavements (3^{rd} Revision)
2. IRC: 115-2014:- Guidelines for Structural Evaluation and Strengthening of Flexible Roads Pavements using Falling Weight Deflectometer (FWD) Technique.
3. IRC:37-2018:- Guidelines for The Design of Flexible Pavements (4^{th} Revision)
4. IRC: SP: 84-2014:- Manual of Specifications & Standards for Four Laning of Highways Through Public Private Partnership
5. IRC: 58-2011:- Guidelines for The Design of Plain Jointed Rigid Pavements for Highways.