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# Assessment and Prioritization of Highway Stretch Deploying Functional and Structural Characteristics

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## ABSTRACT

Asphalt pavements deteriorate over time when subjected to fatigue; hence, it is critical to evaluate in-service pavements to keep them in good condition. The goal of pavement evaluation is to assess the functional and structural performance of a pavement section, with a view to improving both the pavement's serviceability and riding quality. Through field and laboratory experiments, the current study attempts to evaluate the performance of pavement stretches. The sections are ranked and prioritized based on the test results. Medchal-Dabilpur national highway was evaluated for pavement roughness, skid resistance and deflections. In addition, core samples with diameters of 100mm and 150mm were collected and tested in the laboratory for moisture susceptibility, tensile strength, stiffness and fracture characteristics. The current study also intends to establish a unique technique for prioritizing pavement maintenance sections based on functional and structural performance in the field and laboratory. The Artificial Neural Network (ANN) approach was used to develop the relationship between pavement functional and structural performance. Heat maps were created and ranked in Python Jupyter notebook to better visualize the performance of functional and structural characteristics of the pavement. The final evaluation results can be validated by supporting them with laboratory investigations based on the pavement-section field samples. The results demonstrate that there is a strong relationship between the structural and functional properties of the pavement. The developed Maintenance Priority Index (MPI) will be useful in rating the maintenance and rehabilitation actions depending on the level of necessity.

**KEYWORDS:** Functional and structural evaluation, Resilient modulus, Tensile strength ratio, Fracture properties, ANN technique, Maintenance priority index.

## INTRODUCTION

India has the world's second-largest road network, reaching 5.89 million kilometers (km) and the road network transports 64.5% of all commodities and 90% of all passenger traffic in the country (NHAI). Furthermore, it has been observed that road traffic has gradually increased over the years as connectivity between cities, towns and villages around the country has improved. Pavement structures are built to last for their design period, which is referred to as the service life. However, it is also noticed that some pavements may not last for their design period due to failures. Pavement failures may happen due to various reasons, like increased traffic, pavement materials, temperature, … etc. Failures can be reduced to an extent with proper timely maintenance by addressing the above issues. Routine maintenance can improve the in-service life with regular monitoring and proper measures for improved performance. Light-weight deflectometer (LWD) and Benkelman Beam Deflection (BBD)

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techniques were adopted to evaluate sub-grade moduli in low-volume roads. The results revealed that the light-weight deflectometer method of testing shall be used as a rapid tool for the strong determination of pavement sub-grade materials (Gazzarlapudi et al., 2016). Rusmanto et al. (2018) conducted a study to examine the functional and structural conditions of flexible pavements. The study results revealed that overlay thickness is required for the improvement of pavement serviceability. Sanjay et al. (2022) evaluated the structural conditions of pavement using light-weight deflectometer (LWD) and Benkelman Beam Deflection (BBD) processes, where correlations were developed for deflection measurements using both instruments exhibiting a strong relationship. Subramanyam et al. (2017) evaluated pavements using destructive and non-destructive methods. The results showed that the pavement is in fair condition and due to high characteristic deflection, an overlay is required. Gunde et al. (2022) evaluated the pavement surface modulus in the field using an Indigenous Light-weight Deflectometer (ILWD) and Dynamic Cone Penetrometer (DCP). The results of the field and laboratory tests showed that the calculated elastic modulus and stiffness characteristics are close to each other for the layer moduli of the pavement layers. Mooney et al. (2009) have investigated the stress-strain response within the soil using light-weight deflectometer (LWD) testing. Kuttah (2021) conducted field studies using light-weight deflectometer (LWD) and compared the measured field modulus values with the resilient modulus values measured by repeated-load tests (RLTs) carried out under similar testing conditions in the laboratory. The study concluded that the LWD test can be used to predict the resilient behavior of unbound pavement layers. Reddy et al. (2022) investigated fracture properties for modified mixes, where the fracture resistance and index were improved when compared to control mixes at intermediate temperatures. According to this study, fracture properties are necessary to evaluate the performance of mixtures. Ramesh et al. (2022) investigated the fracture characteristics of Dense Bituminous Macadam (DBM) and Bituminous Concrete (BC) mixes with modified binders and compared them with control mixes for pavement performance. Raunak et al. introduced an innovative approach for prioritizing pavement maintenance sections by developing a correlation between functional and structural performances using an Artificial Neural Network (ANN). The results showed that there is a strong relationship between the structural and functional characteristics of pavements. Majed et al. used a British pendulum skid tester to measure the skid resistance of nearly all highways in Jordan to develop the maintenance management system for roads in Jordan and the survey results revealed that 66% of the tested roads had skid resistance levels that were below the minimum acceptable levels. So, it is advised that serious actions and maintenance plans be taken to improve the roads. Issa et al. (2022) used Artificial Neural Networks (ANNs) to predict the pavement condition index (PCI) values of the various sections and model the relationships between distress type and severity and PCI. The results showed a low correlation between distress and PCI and that the ANN model is capable of predicting the PCI values with a high level of reliability. The majority of the studies have attempted to understand the structural capacity of pavements through field experiments. However, in this study, an attempt is made to examine the correlations between functional and structural performances and laboratory investigation for the development of sectional priority.

**Objectives of the Study**

The current study aims to forecast the field performance of pavement sections, in order to prioritize pavement maintenance. The objectives of the work include to investigate the functional and structural conditions of the pavement, estimate the mechanical-fracture properties of filed core samples in the laboratory and assess the functional and structural characteristics through Artificial Neural Network (ANN) techniques for maintenance priority and rank them accordingly.

**Methodology**

The methodology adopted for this study is summarized in the following flowchart (Fig. 1). It describes the field and laboratory investigations that are conducted as a part of this study.

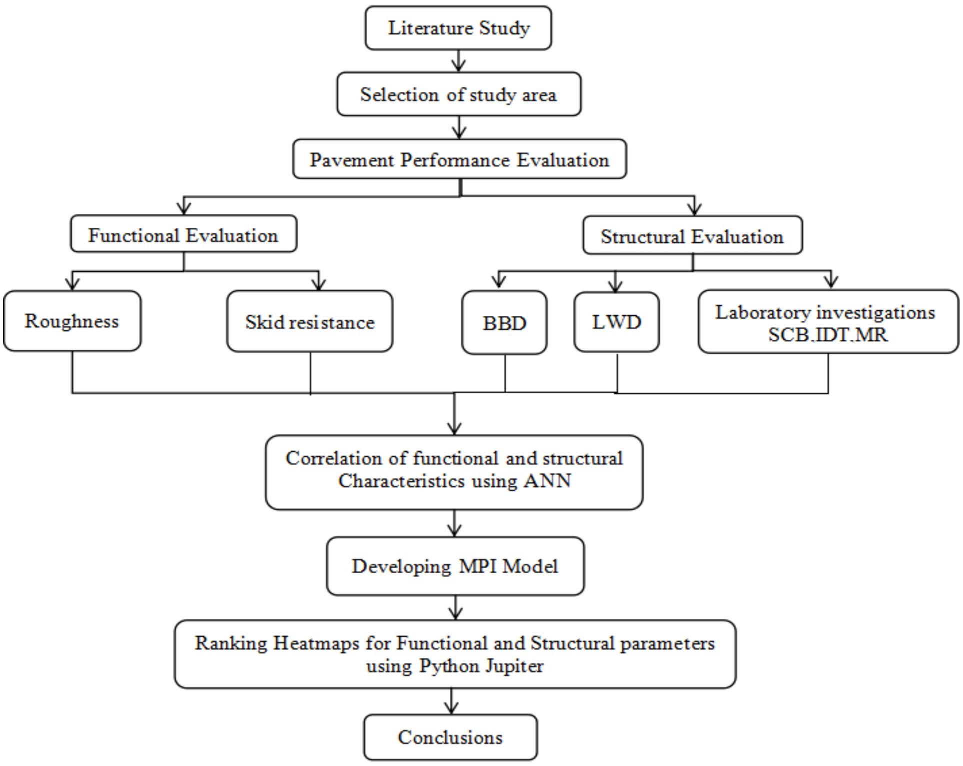



**Figure (1): Schematic flowchart of the methodology adopted for this study**

**Experimental Program**

**Selection of Study Area**

This study was carried out on NH – 44 (National Highway) Medchal to Dabilpur stretch, as shown in Fig. 2. The study road chainage begins at 463+000km in Dabilpur and ends at 471+000km in Medchal. During the pavement evaluation process, the entire study stretch of pavement was divided into eight (8) equal portions with a 1km interval. The existing flexible pavement has four lanes, each 3.5m wide and a paved shoulder. The median width is 1.5m, while the width of the paved and earthen shoulders ranges from 2.5m to 3.0m.

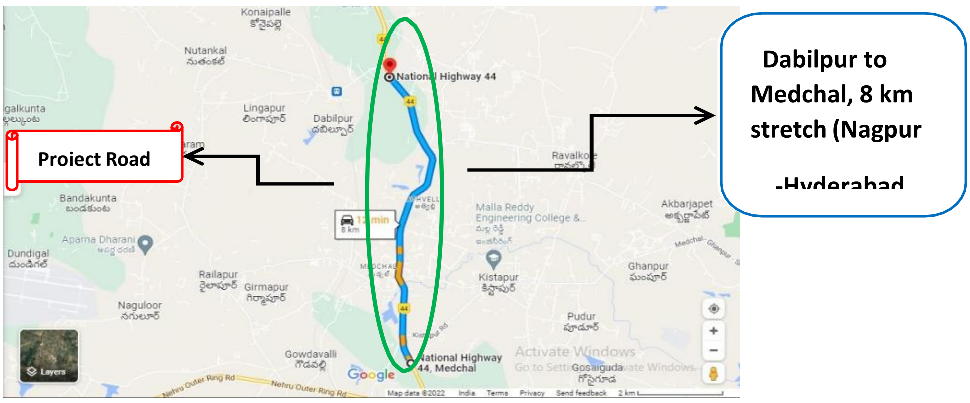



**Figure (2): Study stretch from Dabilpur to Medchal (463+000 km to 471+000km)**

**Functional Evaluation**

A functional evaluation consists of an assessment of pavement features that directly influence the safety and comfort of road users. Skid resistance and road roughness are the primary functional evaluation characteristics assessed during the investigation.

***Skid Resistance Study***

Road users and engineers are primarily concerned with the safe passage of vehicles, as slippery pavements have been responsible for road crashes. British Pendulum Tester was used to conduct the skid resistance test on the selected stretch from Dabilpur to Medchal (463+000km to 471+000km) in both the left-hand side (LHS) section and the right-hand side (RHS) section. The test was carried out in accordance with Indian Road Congress (IRC):82-2015.

***Roughness Measurements***

Pavement roughness is commonly described as an indication of irregularities on the pavement surface that degrade the road's ride quality. The longitudinal unevenness of the road surface is defined as roughness. The roughness data was obtained using the machine for evaluating roughness using low-cost instrumentation (MERLIN) equipment, developed by Transport and Road Research Laboratory (TRRL) and commonly used for the measurement of road roughness (IRC: SP 16, 2019).

**Structural Evaluation**

Pavement structural evaluation is a measure of the structural adequacy of the pavement. Non-destructive testing is commonly used for the assessment of structural capacity. LWD, BBD and falling-weight deflectometer are used as commonly used for pavement investigation.

***Benkelman Beam Deflection Test***

This instrument is used to calculate the pavement's rebound deflection induced by the wheel load as outlined in IRC: 81-1997. The characteristic deflection values are used to design the overlay thickness. The structural number (SN) is an index that indicates both the thickness of the pavement layers and the overall structure of the pavement. The deflections were measured in the field with BBD equipment and data shall be also used to determine the SN of the pavement sections. The formulae for computing SN using characteristic deflection (DEF) measurements are presented in Equations (1) and (2).

$$SN = 2.2\ DEF^{-0.63}\ \text{(Base is cemented)} \qquad (1)$$

$$SN = 3.2\ DEF^{-0.6}\ \text{(Base is not cemented)} \qquad (2)$$

***Indigenous Light-weight Deflectometer (ILWD)***

The ILWD is a portable device used to measure the deflection of unpaved surfaces and thin asphalt layers. The apparatus was developed in the laboratory (Gunde et al., 2022) and was used in the study for pavement evaluation. The ILWD equipment has unique characteristics, such as a trigger assembly for the release mechanism (20 to 25 kg of mass drop) and a base cylinder with a load-cell arrangement on top and a fixture arrangement for fitting the central geophone on the bottom. Above the load cell, a rubber buffer is fabricated and fitted to give an impulse load with a load pulse rate time range of 15- 40ms. The base plate's diameter spans from 150 to 350 mm. The dynamic deformation modulus of unbound and thin asphalt pavement layers must be calculated using the observed deflection at the center of the plate and radial. The instrument was designed and developed in accordance with ASTM E2583-07 (2015). Structural number (SN) is a well-known pavement index that is calculated as the product of structural layer coefficients and layer thicknesses. The AASHTO 1993 formula is used to compute the Effective Structural Number (SNeff) as follows:

$$SN_{eff} = 0.0045\ D\sqrt[3]{E_p} \qquad (3)$$

where D is the overall thickness of the pavement system above the sub-grade level in inches and Ep represents the effective modulus of the pavement layers above the sub-grade in pounds per square inch.

**Collection of Pavement core samples**

Pavement core samples were collected at various points throughout the study stretch. The core locations were distributed at random along the section's length and breadth. For each core, the in-place layer thicknesses, the ASTM D 6931 indirect tensile (IDT) test, ASTM D4123, ASTM D 7369-20 resilient modulus and fracture properties as described in ASTM 8044-16 were all examined in the laboratory.

**Laboratory Investigations**

Soon after the surface-deflection measurements, test trenches were dug to gather soil samples.

Soil samples were collected at every 1-kilometer interval in both directions. Laboratory tests were conducted in accordance with Indian Standards to evaluate conventional index and volumetric characteristics, such as liquid limit, plastic limit, average dry density and average moisture content. CBR testing was also performed on soil samples collected from all test locations.

***Indirect Tensile Strength Test (IDT)***

The crack resistance of bituminous pavement material shall be determined using indirect tensile strength test. Equation (4) is used to determine the tensile strength of pavement core samples. The tensile strength ratio (TSR) compares the tensile strength of a conditioned specimen to that of a controlled dry specimen. The experiment was conducted in line with ASTM D 6931-07.

$$IDT=2P/\pi dt \qquad (4)$$

where P= max. load, d=diameter of the sample and t=thickness of the sample.

***Repeated-load Cyclic Test***

The resilient modulus is a ratio of applied vertical stress to that of recoverable axial strain and the test process is shown in Fig.3(a). A cylindrical specimen is subjected to a repetitive axial load with a half-sinusoidal waveform for seconds at 35ºC. The applied load is the average of the cycle's sinusoidal wave peaks. The horizontal and vertical deflections are measured using a Linear Variable Differential Transformer (LVDT) on either side of the specimen. The total resilient modulus is computed using recoverable deformation, which is the sum of instantaneous and time-dependent continuous recoverable deformation throughout the unload or test phase of one cycle. The test was carried out in accordance with ASTM D 7369-20. The resilient modulus is calculated using Equation 5.

$$M_R=P(0.27+\mu)/t*\Delta h \qquad (5)$$

where MR= resilient modulus, P= maximum load in N, $\mu$=Poisson's ratio, T=thickness of sample in mm and Δh= deflection in mm.

*(a) Resilient modulus test setup* *(b) Semi-circular bending test setup*

**Figure (3): Laboratory investigations of pavement core samples collected from the study location**

Asphalt mixes cracking resistance is determined using the semi-circular bending test as presented in Fig.3(b). The fracture-mechanics technique is used to characterize the initiation and progression of fractures in asphalt mixtures. The specimen is loaded with 0.5mm/min load-point displacement, with 5mm and 10mm notch lengths being examined. This test evaluates the asphalt-mixture fracture resistance in terms of (i) fracture toughness (K), (ii) fracture energy (G), (iii) flexibility index, (iv) cracking resistance index (CRI) and (v) critical-strain energy release. The test was performed in accordance with ASTM D 8044-16. The equations provided below in Table 1 were used to compute fracture characteristics.

**Table 1. Fracture parameters**

| | |
|---|---|
| **Fracture energy (Gf)** | **Gf = W0+mgδ0/Alig** (6)<br>*where W0 = fracture work area under the load-displacement curve, m = mass (negligible because small samples are used), g=gravitational acceleration, δ = deformation, Alig =ligament area = t(r-c), t = thickness, r = radius and c = notch length of SCB specimen.* |
| **Flexibility index (FI)** | **FI=0.01(Fracture energy/Post peak slope at inflection point)** (7) |
| **Fracture toughness (K)** | $K=\sigma * Y_1 (sqrt (\pi * a)$ (8)<br>*σ=stress at failure N/mm =Pmax/2rt*<br>*Pmax − maximum load at failure in (N)*<br>*Y1 - geometric factor equal to 4.782 – 1.219 c/r + c/r * 0.063* $e^{7.045}$<br>*where r – specimen radius (mm), c – notch length (mm), t = thickness of sample (mm).* |
| **Stress intensity factor** | YI(t/d) = YI (100/150) = YI (0.66)<br>$\mathbf{Y_I (0.66) = 4.782+1.219(c/r) +0.063e^{\wedge}(7.045*c/r)}$ (9)<br>*where c-notch length and r-radius of specimen.* |
| **Crack resistance index (CRI)** | **CRI=Gf/Pmax** (10)<br>Gf - fracture energy in J/$m^2$ and *Pmax − maximum load at failure in (N).* |
| **Critical strain energy release rate (J integral)** | For two notch lengths:<br>$\mathbf{J_c = (A_1/t_1-A_2/t_2) *1/a_2-a_1}$ (11)<br>*A1, A2 = area under curve up to maximum load Pmax, a1, a2 = initial notch lengths and*<br>*t1, t2 = thicknesses of samples.* |

**Model of Maintenance Management**

The project's primary goal is to develop a maintenance management plan based on the structural and functional attributes. ANN technique was adopted along with pavement functional and structural characteristics; the SN of the pavement was determined. Equations 12 and 13 were used to calculate the deflection index and roughness index.

*Deflection Index= (Predicted Deflection/Maximum Permissible Deflection) X 5* (12)

*Roughness Index = (Present Roughness/Maximum Allowable Roughness) X 5* (13)

The MERLIN International Roughness Index values are used to measure roughness, while the deflection values of the ANN approach are used to predict deflection. The maximum allowed deflection value was determined using IRC 81-(1997) and the maximum traffic value was 100 million standard axles (MSA). IRC: SP 16-2019 stipulates that the maximum permitted roughness value is 2.55 m/km. The maintenance priority index (MPI) and road-condition index (RCI) are calculated using Equations 14 and 15.

*RCI = Roughness index + Deflection index* (14)

*Maintenance Priority Index = RCI*Traffic Factor* (15)

According to IRC SP: 72 (2015), Equivalent Standard Axle Load (ESAL) was computed for the design life of the roads using current traffic data. The traffic factor was estimated using the total number of ESAL applications. The total number of ESAL applications from Dabilpur to Medchal is 998196. For all ESAL applications combined, the traffic factor is 7(seven). The ESAL applications value from Medchal to Dabilpur is 1076777 with a traffic factor of 8(eight). Prioritizing road sections for maintenance and repairs was done using the MPI parameter. A high MPI number denotes that a particular stretch of road needs additional maintenance.

### *Artificial Neural Network (ANN) Approach*

The Artificial Neural Network (ANN) technique was employed in this study owing to its beneficial properties, including its capacity to learn and model complex, non-linear connections as well as its ease of use. The Multilayer Feed Forward Neural Network (MFNN) is the most prevalent variety of ANN. The approach takes into account the input, hidden and output kinds of linked neuron layers. Levenberg-Marquardt method is the most used training method and the error is assessed in terms of the Mean Square Error (MSE).

## RESULTS AND DISCUSSION

### Traffic Volume Count

During 16th to 18th February, 2022, a comprehensive three-day traffic volume count from Medchal to Dabilpur was conducted and the video data was recorded. The traffic volume from Medchal to Dabilpur direction is approximately 34659 vehicles per day (Vpd) and from Dablipur to Medchal direction is 33595 Vpd. The peak hours were observed from 9 AM to 10 AM (5874Vpd) in the morning and from 5 PM to 6 PM in the evening.

### Functional Characteristics Results

Functional evaluation is carried out in two ways *viz.* skid resistance and roughness. The calculations are performed in accordance with the Indian Road Congress (IRC) standards and the results are presented in Fig. 4.

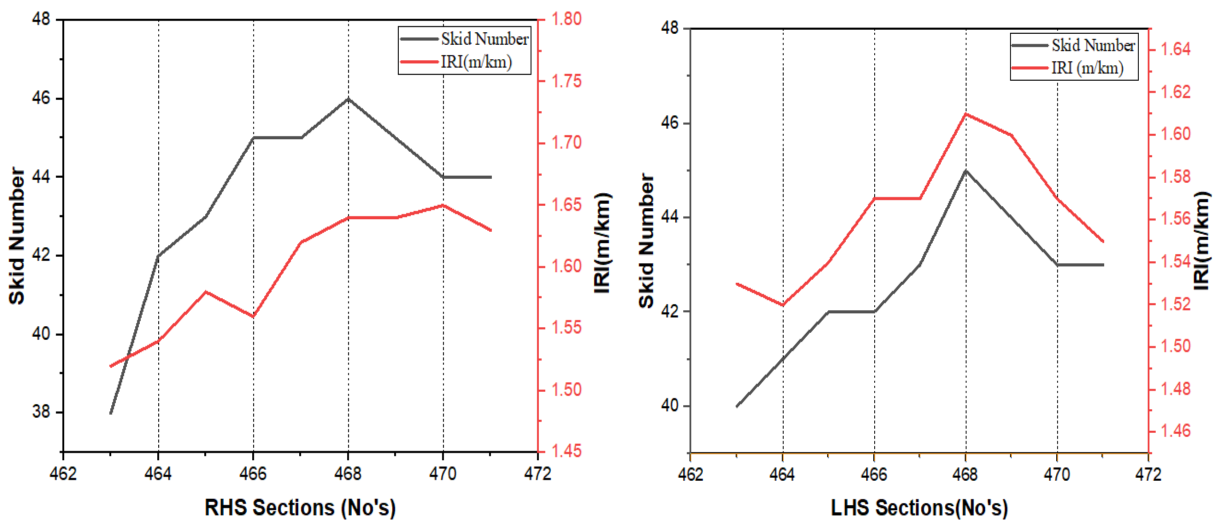



**Figure (4): Comparison graphs of skid-resistance data and IRI data in both directions**

According to the skid-resistance statistics, the majority of the sections studied for the research are suitable for high occupancy vehicle travel against frictional characteristics on dry and wet pavements, while frequent monitoring is required in oil conditions. The average International Roughness Index (IRI) values for the selected stretch in both directions is 1.55 m/km and 1.57 m/km, which are less than 1.8 mm/km according to IRC SP:16-2019 and IRC 82-2015, indicating that the pavement is in good condition. From Fig. 4, it is observed that the skid resistance of asphalt pavement increases due to marginally changes in pavement-surface roughness. This is caused by the vehicle polishing the attached asphalt binder and aggregates at the surface and the polished aggregates' surface. The evolution of skid resistance is often characterized by an initial increase in friction coefficient, which happens after the laying of the road surface and due to vehicular traffic actions. Each aggregate is more exposed to tyre contact, resulting in increased skid resistance. This is referred to as the "early-life skid resistance" phase.

**Structural Characteristics Results**

Non-destructive testing methods, such as deflection studies, were employed in the field to evaluate structural properties. Soil properties were also required and samples were gathered in both directions. In the laboratory, moisture content, density and California Bearing Ratio (CBR) values were also measured. This data was utilized to compute characteristic deflection (CD) and the results are depicted in Figure 5(a) & Figure 5(b).

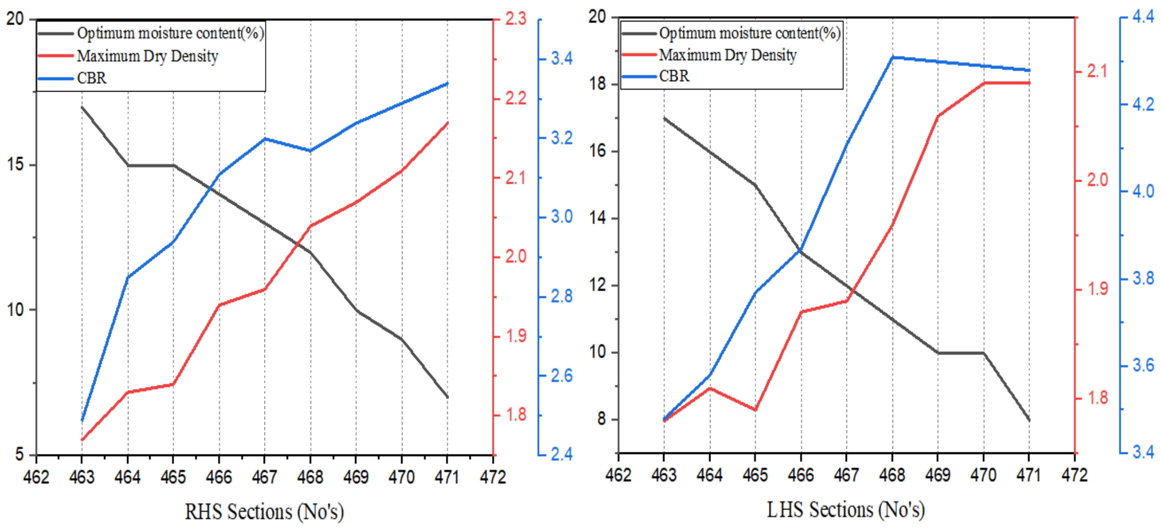



**Figure (5): (a) Soil properties on study stretches**

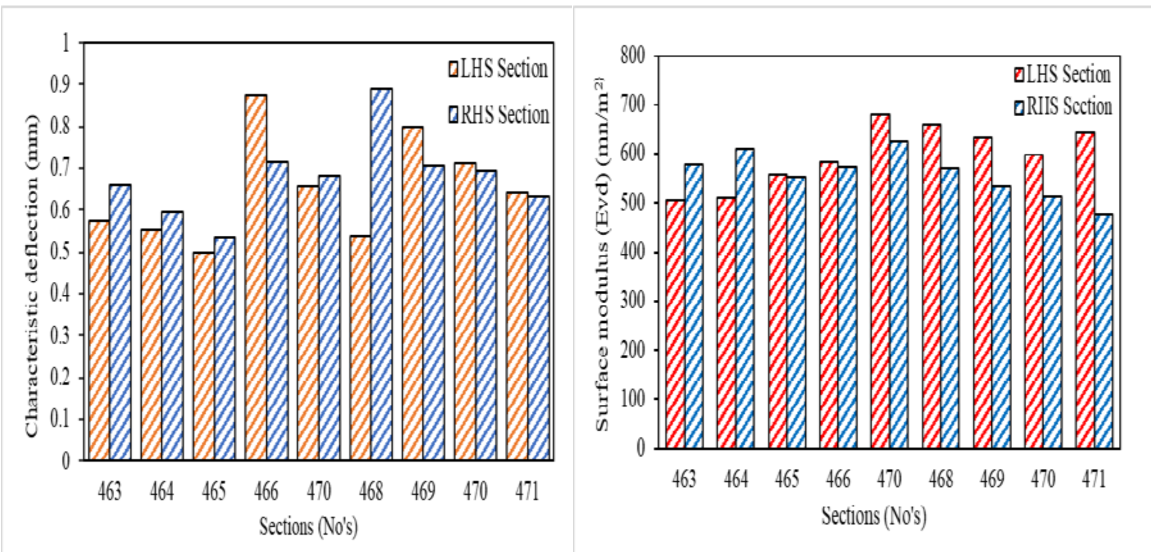



**Figure (5): (b) Characteristic deflection and dynamic deformation modulus derived by LWD test**

**Pavement Core Samples' Evaluation from Laboratory Investigations**

In the present study, to characterize the mixes, core samples were collected from the field and were analyzed in the laboratory. Moisture sensitivity, resilient modulus, indirect tensile strength (IDT) and tensile strength ratio (TSR) were determined for various study sections as presented in Figure 6.

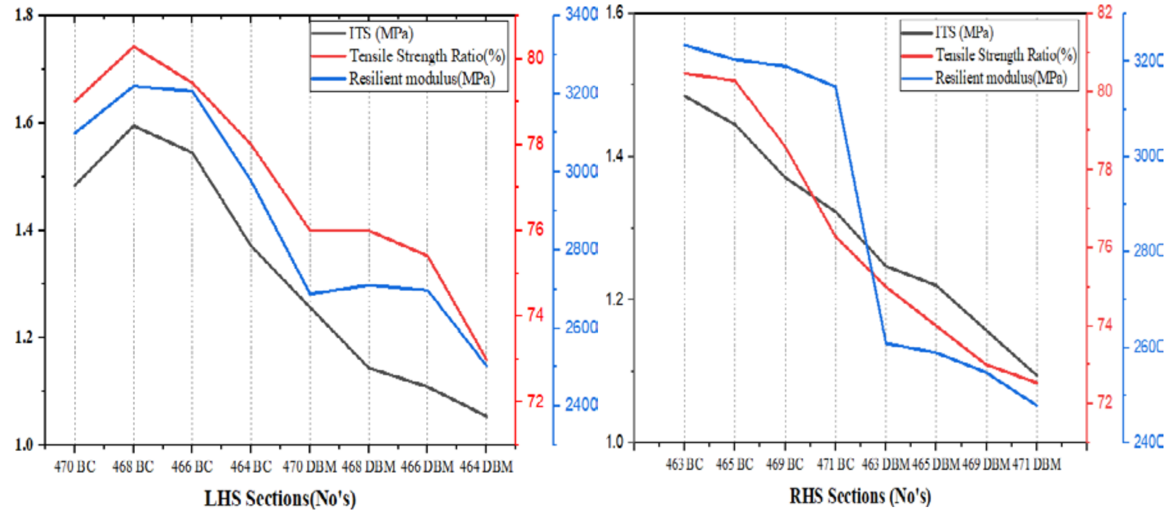
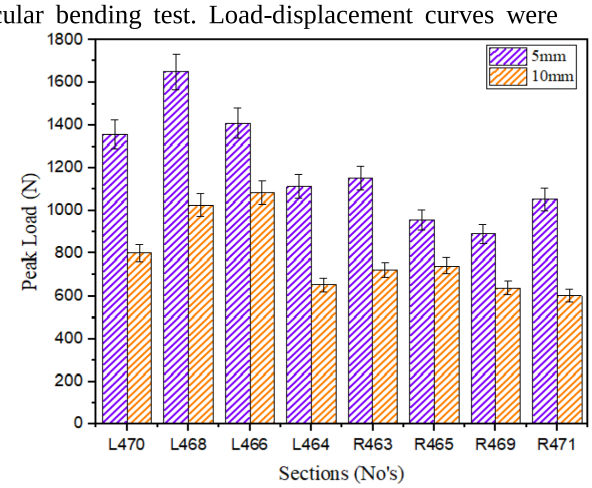
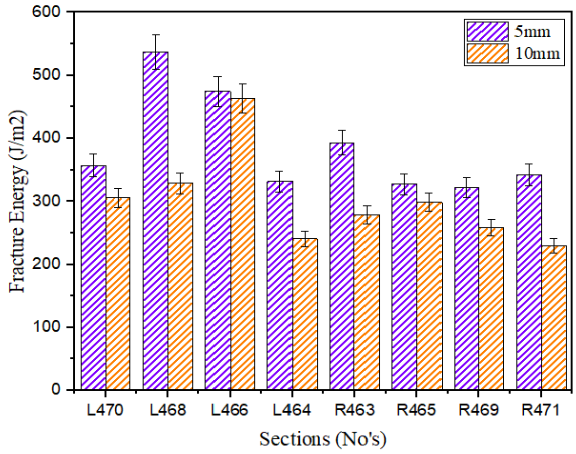



**Figure (6): Comparison of ITS, TSR and resilient modulus in both directions**

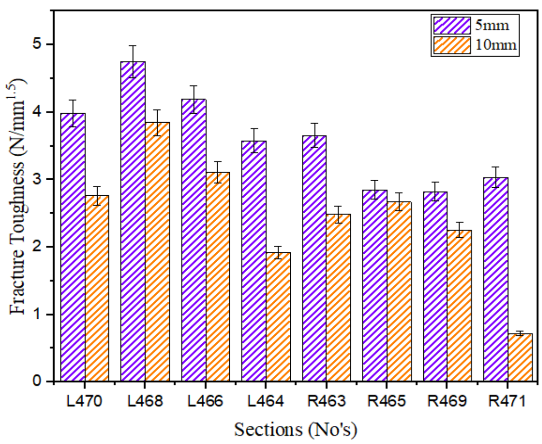
Similarly, field samples of 150 diameters were cut in half and used to assess fracture properties using a semi-circular bending test. Load-displacement curves were obtained at four chain ages for 5-mm and 10-mm notch depths, as presented in Fig.7.



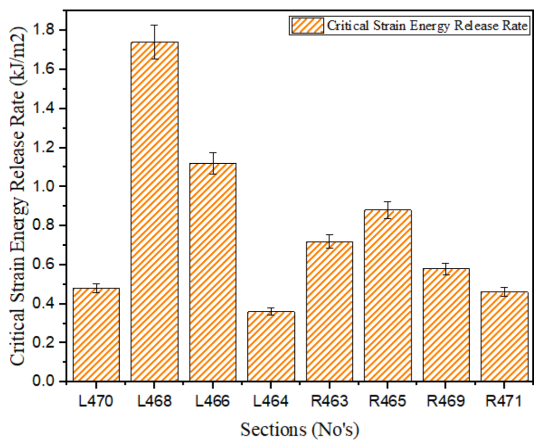

*(a) Peak load*




*( b) Fracture energy*




*(c)Fracture toughness*




*(d) Critical strain energy release rate*

**Figure (7): Fracture properties for different samples in both directions**

**Correlation between Functional and Structural Characteristics Using ANN**

A novel method for evaluating the relationship between functional and structural performances of asphalt pavements was developed. Skid number (SN), CBR value (CBR), pavement temperature (Temp) in degrees, maximum dry density of the soil sub-grade (MDD) in g/cc and International Roughness Index (IRI) from MERLIN were the independent variables in this study. The structural number calculated from the BBD and LWD deflections was the dependent variable.

**Table 2. Consolidated data used for correlation (Medchal to Dabilpur direction)**

| Road Sections | IRI (m/km) | Dry SKD | Water SKD | Oil SKD | Pavement Temp(°C) | MDD (g/cc) | BBD SN | LWD SN |
|---|---|---|---|---|---|---|---|---|
| 471 | 1.55 | 49 | 43 | 37 | 40.90 | 1.96 | 4.37 | 4.29 |
| 470 | 1.57 | 44 | 42 | 39 | 40.95 | 1.88 | 4.09 | 4.07 |
| 469 | 1.6 | 47 | 45 | 42 | 40.26 | 2.04 | 4.64 | 4.57 |
| 468 | 1.61 | 45 | 42 | 39 | 37.70 | 2.00 | 4.89 | 4.75 |
| 467 | 1.57 | 45 | 43 | 31 | 37.50 | 2.06 | 4.22 | 4.18 |
| 466 | 1.52 | 46 | 44 | 42 | 37.65 | 1.98 | 4.77 | 4.67 |
| 465 | 1.51 | 43 | 44 | 42 | 37.70 | 1.79 | 4.15 | 4.05 |
| 464 | 1.49 | 43 | 37 | 30 | 38.30 | 1.88 | 4.04 | 4.02 |
| 463 | 1.53 | 47 | 43 | 41 | 36.59 | 1.98 | 4.29 | 4.45 |

**Table 3. Consolidated data used for correlation (Dabilpur to Medchal direction**

| Road Sections | IRI (m/km) | Dry SKD | Water SKD | Oil SKD | Pavement Temp(°C) | MDD (g/cc) | BBD SN | LWD SN |
|---|---|---|---|---|---|---|---|---|
| 463 | 1.57 | 43 | 37 | 30 | 38.57 | 1.98 | 5.13 | 4.93 |
| 464 | 1.54 | 39 | 36 | 33 | 38.98 | 1.88 | 4.66 | 4.56 |
| 465 | 1.5 | 47 | 44 | 40 | 39.48 | 1.79 | 4.71 | 4.64 |
| 466 | 1.57 | 46 | 44 | 42 | 38.43 | 1.98 | 4.09 | 3.68 |
| 467 | 1.55 | 36 | 34 | 32 | 29.50 | 2.06 | 4.31 | 4.17 |
| 468 | 1.74 | 44 | 41 | 37 | 30.00 | 2.00 | 4.85 | 4.74 |
| 469 | 1.53 | 47 | 45 | 42 | 30.20 | 2.04 | 3.94 | 3.48 |
| 470 | 1.51 | 44 | 40 | 39 | 30.28 | 1.88 | 4.48 | 4.24 |
| 471 | 1.63 | 45 | 42 | 40 | 36.59 | 1.96 | 4.24 | 4.09 |

where SKD = skid number, SN= structural number and MDD=maximum dry density.

The statistics presented in Table 2 and Table 3 demonstrate that the structural assessment performed with the Benkelman beam method is more critical than the one performed with the LWD, because the deflections achieved with the Benkelman beam method are marginally higher and the SN computed for the BBD is slightly higher than the SN calculated by the LWD test.

The AASHTO 1993 formula is used to determine the LWD Effective Structural Number (SNeff). The equation is based on the modulus of the pavement layer and is computed using the central deflection values obtained from the LWD test. The structural number is attributed to the strength of the pavement and because the pavement is good, the SN values obtained by both instruments are marginally close.

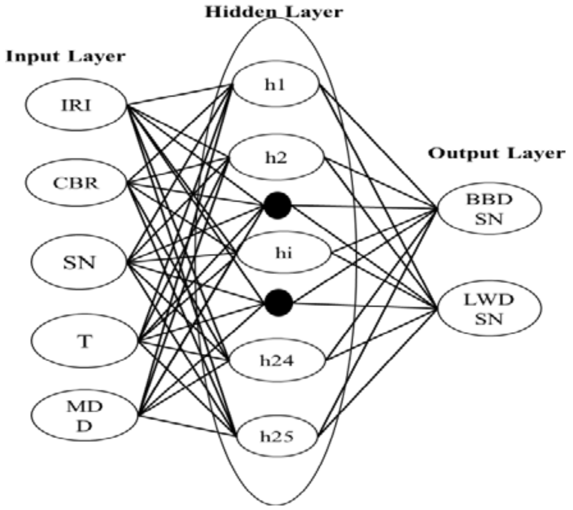



**Figure (8): MLP - ANN architecture used in this Study**

The ANN model uses the above consolidated data as input. Fig. 8 depicts the structure of the multi-layer perceptron (MLP) ANN architecture employed in this work. The characters $h_1$, $h_2$, hi... $h_{25}$ represent the 25 hidden neurons. Based on the output obtained by the ANN, Figure 9(a) and Figure 9(b) depict the regression charts for the training, validation, test and total sample phases based on the ANN output.

The network was simulated using a new set of values for each independent variable. As output, the structural numbers of this set were determined. The relationship between the measured deflection value from the field and the expected deflection value from the ANN model is depicted in Figure 9(b). For all directions, the $R^2$-values were 0.90 and 0.88 for observed deflection values and projected deflection values from the ANN model. As a result of the numerical application, it is concluded that the ANN may be efficiently used as a powerful tool for forecasting deflection performance using various pavement properties. Regression charts show that there is a strong correlation between functional and structural characteristics of the pavement.

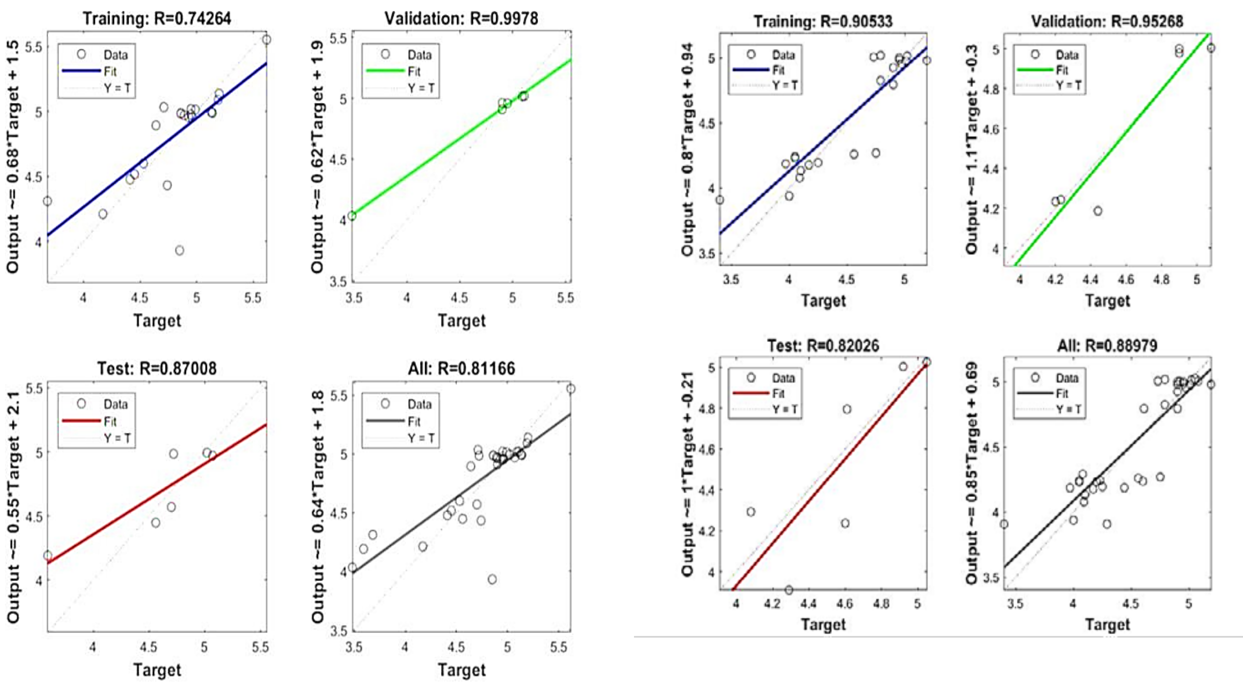



**Figure (9): (a) Regression charts for Medchal to Dabilpur sections**

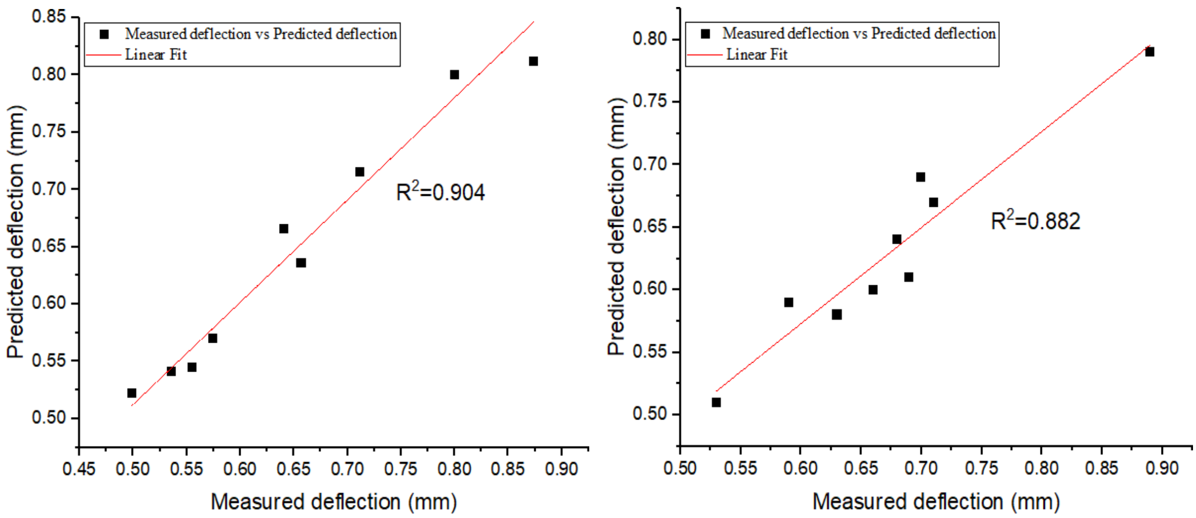



**Figure (9): (b) Observed deflection in field and ANN predicted deflection (both directions)**

**Table 4. Maintenance priority index for Medchal to Dabilpur (471+000 km to 463+000km)**

| Road Sections | Deflection Index (DI) | Roughness Index (RI) | Road Condition Index (RCI) | Maintenance Priority Index (MPI) | Priority for Road Sections |
|---|---|---|---|---|---|
| 471 | 3.069 | 3.039 | 6.108 | 48.863 | 6 |
| 470 | 3.447 | 3.078 | 6.525 | 52.201 | 3 |
| 469 | 3.468 | 3.137 | 6.606 | 52.844 | 2 |
| 468 | 2.982 | 2.922 | 5.903 | 47.226 | 8 |
| 467 | 3.303 | 3.078 | 6.382 | 51.055 | 5 |
| 466 | 3.488 | 2.980 | 6.468 | 51.746 | 4 |
| 465 | 2.841 | 2.961 | 5.802 | 46.418 | 9 |
| 464 | 4.088 | 3.157 | 7.245 | 57.962 | 1 |
| 463 | 3.072 | 3.000 | 6.072 | 48.576 | 7 |

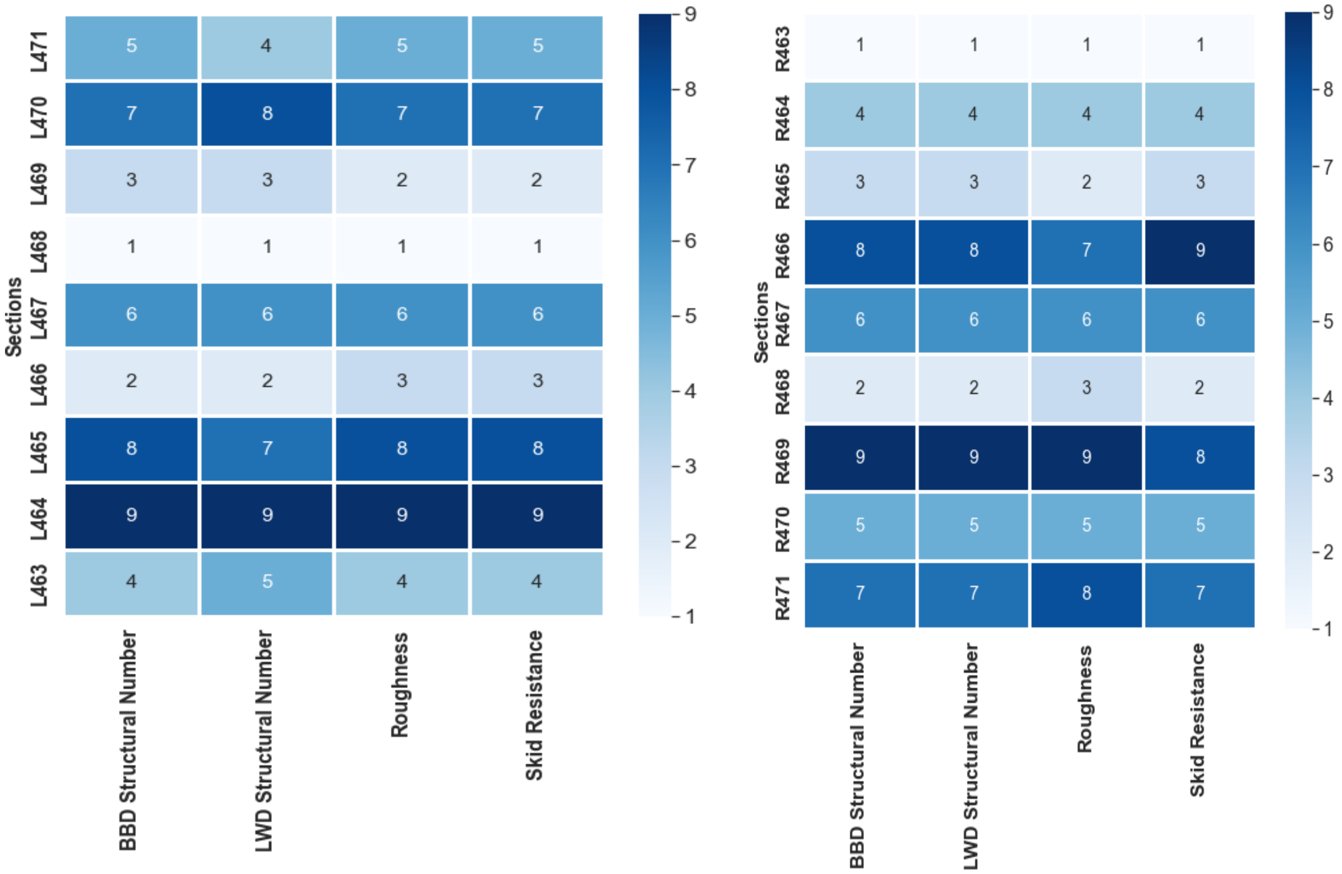
**Table 5. Maintenance priority index for Dabilpur to Medchal (463+000 km to 471+000km)**

| Road Sections | Deflection Index (DI) | Roughness Index (RI) | Road Condition Index (RCI) | Maintenance Priority Index (MPI) | Priority for Road Sections |
|---|---|---|---|---|---|
| 463 | 2.603 | 2.941 | 5.544 | 44.355 | 9 |
| 464 | 2.836 | 3.020 | 5.856 | 46.846 | 8 |
| 465 | 2.927 | 3.048 | 6.005 | 48.043 | 6 |
| 466 | 4.665 | 3.078 | 7.743 | 61.947 | 1 |
| 467 | 3.368 | 3.039 | 6.407 | 51.256 | 5 |
| 468 | 3.106 | 3.412 | 6.517 | 52.139 | 4 |
| 469 | 4.227 | 3.000 | 7.227 | 57.813 | 2 |
| 470 | 2.988 | 2.961 | 5.949 | 47.591 | 7 |
| 471 | 3.591 | 3.196 | 6.787 | 54.296 | 3 |

Pavement-maintenance managers can prioritize road sections for repair work based on MPI.A high MPI rating implies that a certain section of the road needs extra care. However, regardless of MPI, remedial measures should be undertaken as quickly as feasible if a route has a DI or RI value greater than 4. Tables 4 and 5 summarize MPI values for the study sections.

**Ranking of Functional and Structural Characteristics**

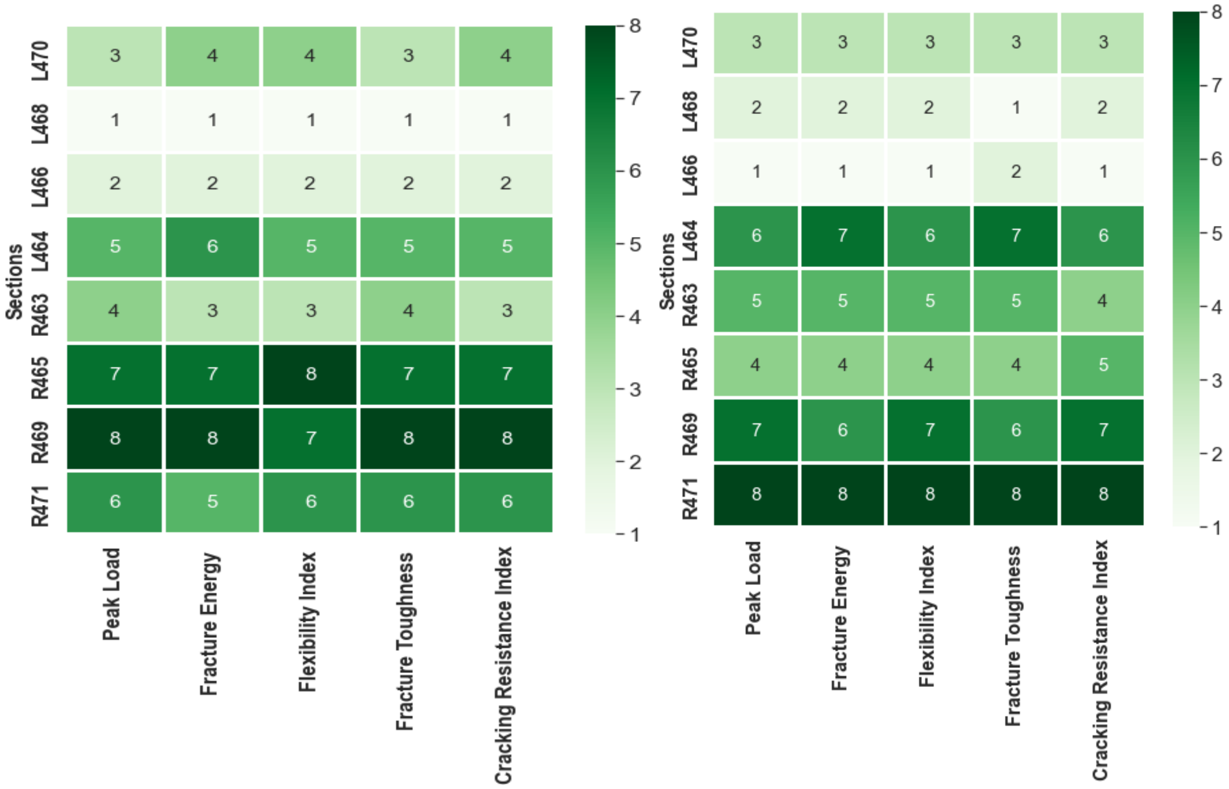
Heatmaps were developed to represent the performance ranking of the pavement using Python Jupyter Notebook. The ranking of structural and functional parameters is presented in Figure 10.




*a) LHS section* *b) RHS section*

**Figure (10): Heat maps for functional and structural parameters on LHS and RHS sections**

Tensile strength, TSR, resilient modulus and fracture characteristics of the pavement core samples were ranked based on the performance levels for various sections as presented in Figures 11 and 12, where a relative ranking for these metrics is presented.




*a) 5mm notch* *b) 10mm notch*

**Figure (11): Ranking heat maps for fracture properties**

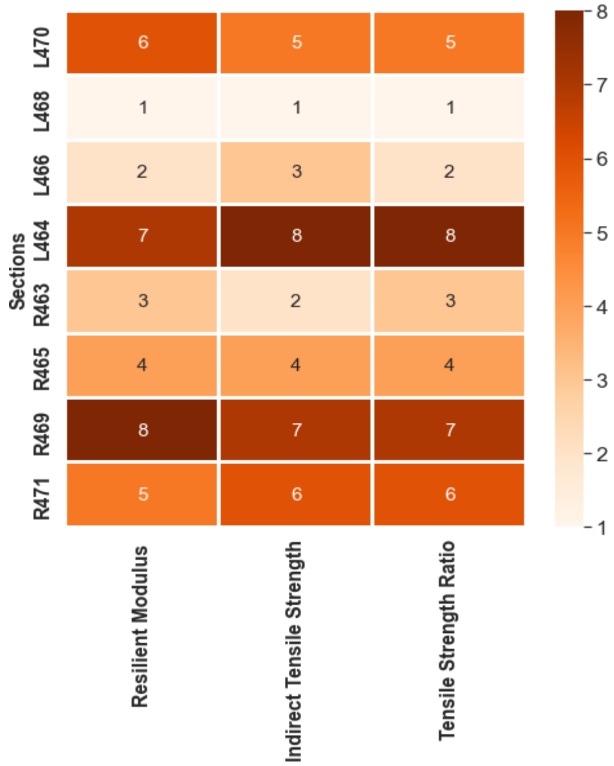



**Figure (12): Heat map showing the relative ranking for TSR, MR and IDT**

From heatmap ranking, it was observed that:

- In the ranking between functional and structural parameters case, as shown in Fig.12, Section L468 has a good performance and Section L464 has a poor performance when compared to other sections on the LHS side and Section R463 has a good performance while Section R469 has a poor performance when compared to other sections on the RHS side.
- In terms of fracture-analysis ranking, Section L468 on the LHS side performed well, whereas Section L464 performed relatively poorly for a 5-mm notch opening. Section R463 performed well; however, Section R469 performed poorly when compared to other sections with a 5-mm notch opening.
- In comparison to other road sections, Sections L468 and R463 had higher resilient modulus, tensile strength and TSR, whereas sections L464 and R469 had lower resilient modulus, tensile strength and TSR.

## CONCLUSIONS

After a thorough functional and structural examination of the selected pavement, the following conclusions are drawn.

- By visual inspection as well as from the requirements of roughness index, it was observed that the pavement is in a good condition. However, from deflection measurements, LHS and RHS recorded characteristic deflections *viz*. 1.05 and 0.9 mm, respectively, and as per IRC 81:1997 guidelines, an overlay thickness of 145 and 135mm is required for LHS and RHS, respectively.
- Higher peak load, stiffness and strength values were recorded for Sections L468 and R463. Section L468 recorded a higher peak load by 5.24% when compared to Section R463.
- The flexibility index was used to evaluate the failure behavior of BC and DBM samples. As the flexibility index rises, the likelihood of cracking decreases. The fracture resilience index increases the toughness of pavement fractures. The fracture toughness was found to be nearly identical in both areas.
- It was observed that the fracture energy and toughness for Section L468 recorded higher by 4.27% than Section L466 and Section L464 exhibited a lower resistance to cracking and toughness compared to other sections by about 5% less than Section L468. Similarly, on the RHS, Section R463 exhibited a higher resistance to cracking and section R469 exhibited a lower resistance to cracking, by 3.47% and 3%, respectively. L466 and R469 have a lower CRI value, by 3.12% and 6.00% less than Sections L468 and R463, respectively.
- In the ranking between functional and structural parameters, Section L468 has a good performance and Section L464 has a poor performance when compared to other sections on the LHS side, Section R463 has a good performance, while Section R469 has a poor performance when compared to other sections on the RHS side. Sections L468 and R463 had higher resilient modulus, tensile strength and TSR, whereas samples from Sections L464 and L469 had lower resilient modulus.
- The ANN model has revealed that the functional and structural characteristics of the pavement are strongly correlated with a correlation coefficient of 0.81.
- The highest maintenance priority index was observed at chainage 468km in the direction from Medchal to Dabilpur and at chainage 466km in the direction from Dabilpur to Medchal. As a result, it is recommended that these sections of the road should be prioritized first for maintenance and rehabilitation works.

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