INDIAN HIGHWAYS

SEPTEMBER 2026

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FEEDBACK

Suggestion/Observation on editorial and Technical Papers are welcome and may be sent to IRC Secretariat on Email-indhighways@gmail.com/dd.irc-morth@gov.in

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IMPORTANT ANNOUNCEMENT

85TH ANNUAL SESSION OF IRC TO BE HELD AT HITEX, HYDERABAD (TELANGANA) FROM 19TH TO 22ND NOVEMBER, 2026 (REVISED)*

On the invitation of Government of Telangana, the 85th Annual Session of the Indian Roads Congress will be held at HITEX, Hyderabad (Telangana) from 19th to 22nd November, 2026. The Invitation Booklet containing the Tentative Programme, Registration Form, Accommodation Form etc. will be available on our website https://irc.nic.in shortly. All members of IRC are invited to attend the 85th Annual Session.

This annual gathering serves as a unique platform for engineers, policymakers, researchers, industry professionals, and academicians for converge, exchange of knowledge, deliberation on critical issues, and foster collaborations that drive the progress of road infrastructure in our nation. The 85th Annual Session promises a comprehensive program featuring:

(i) Keynote Addresses by eminent national and international experts.
(ii) Technical Sessions covering a wide array of topics, including sustainable road construction, innovative materials, road safety, intelligent transportation systems, pavement design, tunnel and bridge engineering, and policy frameworks.
(iii) Interactive Panel Discussions offering insights into the challenges and opportunities in the highway sector.
(iv) Exhibition showcasing the latest technologies, equipment, and services from leading companies in the road industry.
(v) Networking Opportunities to connect with peers, industry leaders, and potential collaborators.

It is expected that more than 4000 Highway Engineers from all over the country and abroad will attend this Session. During the Annual Session of IRC, there has been a practice for various firms/organizations to make Technical Presentations on their products/technologies & case studies (with innovative construction methods or technologies or having special problems requiring out of the box thinking and special solutions). The presenters will get an opportunity to address a large gathering of highway professionals from Private Sector as well as decision makers in the Govt. Sector. These presentations evoke lively interaction among the participants.

A time slot of about 12-15 minutes is normally allocated for each Technical Presentation. Time is also given for floor intervention. During such Technical Presentation Session, no other meetings will be held parallel so as to ensure maximum attendance during the Technical Presentation Session. The stakeholders are, therefore, requested to participate in the event and book slots at the earliest.

Interested Organizations may write to IRC conveying their willingness for participation and send the topics of their Technical Presentation by **E-mail: dd.irc-morth@gov.in /tc.irc@gov.in or through Speed Post along with a Demand Draft for Rs.2,50,000/- (Rupees Two Lakh Fifty Thousand only) +18% GST** drawn in favour of the Indian Roads Congress, New Delhi latest by 30th September, 2026 so that necessary arrangements can be made by IRC.

For any enquiry about the 85th Annual Session like Registration, Advertisement in Souvenir, Membership etc. please address to Indian Roads Congress, Kama Koti Marg, Sector-6, R.K. Puram, New Delhi-110022. For assistance, the contact details are given as under:

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*** New revised date of IRC Annual Session: Postponed by one day.**

ROAD INFRASTRUCTURE: PREPAREDNESS FOR DISASTERS

Shri Rahul Gupta
Secretary General,
Indian Roads Congress &
(Addl. Director General, MoRTH)
Govt. of India

India, a country blessed with diverse physiographic, geological and climatological aspects, also has a history of multiple natural hazards such as earthquakes, landslides, floods, and glacial lake outbursts. In recent years, due to climate change, extreme weather events like cloudbursts followed by flash floods and landslides have become increasingly frequent, especially in the hilly states.

The latest disasters due to cloudbursts in Uttarakhand, Himachal Pradesh, and Jammu & Kashmir disrupted life, damaged infrastructure, and posed risks to livelihoods.

Roads and highways in mountainous regions serve as lifelines, connecting remote communities, tourists, pilgrims, and even armed forces along border areas. Yet, these are often blocked for extended periods due to landslides and floods triggered by sudden heavy rains. Such incidents and blockades cause severe social and economic distress -- people struggle to access healthcare, essential goods become prohibitively expensive, businesses suffer, and social obligations remain unfulfilled. These hardships repeat every monsoon, underlining the urgent need for a sustainable solution.

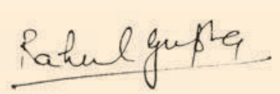
So, the preservation of water bodies, proper disposal of urban waste, a strict ban on encroachments, and revamping both surface and sub-surface drainage systems are crucial to reduce these risks. So far our disaster response has largely been reactive, focusing on post-disaster relief and rehabilitation, which strains budgets and often leaves affected areas vulnerable before the next monsoon arrives.

To manage landslide hazards, it is necessary to assess the causative factors of landslides, their intensities, areas of occurrence and their impact. With the data collection, storage and retrieval becoming highly technological and scientific, specialised tools such as Geographic Information Systems (GIS) and Artificial Intelligence (AI) are transforming how emergencies are visualised and managed. These tools help integrate diverse data sources, prioritise areas needing urgent attention, and enable faster, evidence-based decision-making—a vital asset in crisis situations. Some may require immediate attention while others can wait, some can be delegated and therefore allows faster decision making.

The Indian Roads Congress (IRC) has laid out guidelines to manage flood, earthquake, landslide disaster & its mitigation viz, IRC:SP:106-2015 ‘Engineering Guidelines on Landslide Mitigation Measures for Indian Roads’; IRC:SP:113-2018 ‘Guidelines on Flood Disaster Mitigation for Highway Engineers, IRC:138-2023 ‘Guidelines for Highway Engineers on Disaster Resilient Green Highways in Multi-Hazard Ecosystem’, etc. These documents explain source of various disaster hazard types, vulnerability and risk assessment, field studies, use of drone & other advance equipment in survey, forecasting and warning, technical specification for road and bridge works in disaster-prone and affected areas.

The failure to effectively tackle landslides and floods largely stems from the ever-increasing pace of development in the terrains prone to geological hazard and failure of the respective authorities to recognise such hazards and apply appropriate methods for their prevention/ mitigation. While natural disasters cannot be eliminated, we can mitigate their impact through timely warnings, strategic infrastructure planning, and sustained investment in resilient road networks.

We must shift from reactive disaster relief to proactive preparedness and resilient infrastructure development. What we can do is to issue pre-warning, better management of calamity, to take for mitigation in future occurrence and action for short- and long-term development in infrastructure.



(Rahul Gupta)
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STRUCTURAL EVALUATION OF AN IN-SERVICE THIN WHITE TOPPING PAVEMENT USING FWD TESTING




Sampath Kumar Pasupunuri[1] **Sachin Chaudhary[2]** **Akshansh Sharma[3]** **Amresh Kumar[4]**

ABSTRACT

Thin White Topping (TWT) has emerged as an effective rehabilitation strategy for distressed flexible pavements. However, comprehensive structural evaluation of in-service systems under field conditions remains limited. This study presents a detailed structural assessment of a service TWT pavement at Maharani Bagh Staff Quarters, New Delhi, integrating field testing, back-calculation techniques, and three-dimensional finite-element modelling. Falling Weight Deflectometer (FWD) testing was conducted to obtain surface deflection data, and layer elastic moduli were determined using KUAB PVD, BAKFAA, and ABAQUS, incorporating realistic interlayer frictional contact conditions. Model validation demonstrates strong agreement between simulated and measured deflection basins, confirming the reliability of the numerical framework. A comprehensive parametric study was performed to evaluate the influence of layer modulus, layer thickness, load application position (centre, edge and corner), and crack conditions (longitudinal and transverse) on pavement response. Results indicate that PCC modulus and thickness significantly influence surface deflection and stress distribution, while subgrade stiffness plays a critical role in overall structural performance. Corner loading produced the highest deflection and principal stresses, identifying it as the most critical loading condition. Crack simulation revealed increased deflection and reduced load transfer efficiency, particularly for the longitudinal crack. Despite these variations, computed stresses remained within permissible flexural strength limits, indicating adequate structural safety of the existing design.

1. INTRODUCTION

With increasing traffic volumes and premature pavement distress in conventional flexible pavements, highway agencies worldwide have sought more durable and cost-effective pavement rehabilitation techniques. One such promising method is Thin White Topping (TWT), which involves overlaying a thin layer of Portland Cement Concrete (PCC) over an existing asphalt surface. TWT serves not only as a structural enhancement but also significantly improves surface durability and reduces maintenance requirements. Several field projects have demonstrated the viability of TWT systems under varying loading and environmental conditions. However, the structural response of in-service TWT pavements, especially those subjected to real traffic over time, warrants a comprehensive evaluation to assess performance and predict long-term behaviour. Among the available tools for structural assessment, the Falling Weight Deflectometer (FWD) is widely used to determine surface deflections under a known dynamic load, which can be utilized to back-calculate the mechanical properties of different pavement layers. Despite the availability of empirical approaches, numerical simulation using Finite Element Modelling (FEM) provides more detailed insight into stress distributions, deflection profiles, and the impact of different pavement features. When validated with actual field data, FEM becomes a powerful tool for evaluating rehabilitation strategies such as TWT.

This study presents a case-based structural evaluation of an in-service TWT pavement located in Maharani Bagh Staff Quarters, New Delhi. It integrates Forward-Difference-Based field measurements, back-calculation techniques, and ABAQUS-based finite element modelling to assess and simulate pavement response. Furthermore,

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a detailed parametric study was conducted to investigate the influence of critical factors, including PCC, SDBC, GSB, subgrade modulus and thickness, load application positions (centre, edge, and corner of the slab), and the presence of transverse and longitudinal cracks. The overall objective is to better understand the performance of TWT overlays under realistic conditions and to identify zones of potential cracking risk based on deflection and stress responses, thereby aiding the design and maintenance strategies for these rehabilitation systems.

1.1 Research Gap

Although numerous studies have investigated TWT using laboratory or numerical approaches, limited research has validated finite element simulations using field-measured FWD data under real asphalt service conditions.

- Many models assume perfect bonding at the PCC asphalt interface.
- Limited parameter studies evaluate the combined effects of the modulus, thickness, load position, and cracking.
- Crack behavior under realistic interlayer friction is insufficiently explored.

The novel contribution of the present study lies in its integrated approach: it is among the first to combine field FWD testing on an in-service TWT pavement in India with multi-method backcalculation (KUAB-PVD, BAKFAA, and AREA), quantitative validation of a three-dimensional ABAQUS model, and a comprehensive parametric study that simultaneously varies modulus, thickness, load position, and crack conditions under realistic frictional interface assumptions. Unlike most prior FEM-based TWT studies that use idealised or laboratory-derived material properties, this study employs field-backcalculated moduli and models partial interlayer bonding with sensitivity analysis. The findings directly inform the practical design and rehabilitation guidance provided in IRC:SP:76-2015.

1.2 Objective

The objective of this study are:

- To evaluate in-service TWT pavement using FWD testing.
- To back-calculated elastic layer moduli using multiple approaches.
- To develop and validate a 3D ABAQUS model.
- To investigate structural response under varying modulus, thickness, load position, and crack conditions.

2. LITERATURE REVIEW

R.Y. Patil et al. (2022) found that the Design charts for Thin White Topping (TWT) were developed for rural roads, considering different Cement Treatment Base (CTB) thicknesses, subgrade CBR values, and concrete grades (M30, M35, and M40). The Study showed that increasing CTB thickness improves the composite modulus of subgrade reaction and optimizes TWT thickness, although the reduction in thickness is limited for low CBR subgrades, and joint spacing significantly affects the thickness requirement. Field performance after two years indicated no major distress, confirming that TWT with CTB using the CIPR technique is an economical and sustainable solution for low-volume rural roads[1]

S.R. Krishna et al. (2022) Studies on Ultra-Thin Whitetopping (UTW) showed that a 100 mm concrete overlay significantly improves fatigue life and reduces interface stresses and strains. Pavement performance increases with higher stiffness of the underlying bituminous and granular layers. Shorter joint spacing enhances durability by minimizing stress concentration[2].

T.R. Hebert et al. (2023) concluded that backcalculation of layer moduli for thin asphalt pavements is highly sensitive to assumptions regarding load contact pressure distribution and interlayer bonding conditions. While subgrade modulus estimates remain relatively stable, significant errors may occur in asphalt and base layer moduli. The results indicate that improving the FWD Deflection basin data, particularly through the inclusion of synthetic points, enhances the accuracy and reliability of back calculated moduli for thin pavement sections[3].

L. Eberhardsteiner et al. (2023) the study presents a performance based design approach for bonded concrete overlays on existing asphalt pavements, incorporating key factors such as residual HMA capacity, layer thickness, traffic loading, climate, and temperature dependent interface bonding. By integrating temperature-sensitive elastic properties into the model, the method enables more realistic prediction of overlay thickness and service life. A design catalogue was developed to determine the required concrete overlay thickness based on expected heavy goods vehicle traffic and existing pavement conditions[4].

S M Rashmi et al. (2020) evaluated the performance of Thin and Ultra-Thin White Topping as sustainable alternatives to conventional bituminous overlays for pavement rehabilitation. Different concrete combinations, including plain cement concrete, 50% GGBS replacement, admixture addition, and GGBS with admixture, were tested under repeated wheel loading conditions. The results indicate that a 100 mm thick concrete layer with 50% GGBS and admixture performs comparably to a 150 mm thick concrete slab with admixture, suggesting that slab thickness can be reduced without compromising performance[5].

V.J Bulusu et al. (2019) This Study investigated the effect of cement concrete and asphalt layer interface conditions on the structural response of thin white topping pavements using finite elements modelling. One-metre-square panels of varying thickness were analysed under different conditions, including the coefficients of friction at the interface. The results showed that changes in the concrete layer, with stress variations ranging from -9% to +15%, highlighted the importance of proper interface characterisation in TWT design[6].

D.R. Jundhare et al. (2012) developed a three-dimensional finite element model using ANSYS to evaluate the structural performance of a 100 mm thick Ultra-Thin Whitetopping (UTW) overlay placed over a 100 mm HMA layer on a compacted subgrade. Wheel loading was applied, and stresses and deflections at interior, edge, and corner locations were determined through linear static analysis. The numerical results were validated by comparison with Benkelmen Beam Deflection (BBD) test data and theoretical values based on modified Westergaard equations, showing good agreement [7].

The study by Roshan Katuwal et al. (2024) highlights the challenges of maintaining deteriorating bituminous pavements and the limitations of conventional asphalt overlays in terms of durability and life-cycle cost. It identifies Thin White Topping (TWT) as a sustainable and cost-effective rehabilitation alternative due to its improved structural performance and extended service life. The paper also outlines key design parameters, construction practices, and environmental benefits essential for the successful implementation of TWT[8].

In summary, the existing literature demonstrates that TWT and UTW overlays offer significant structural and economic advantages over conventional rehabilitation approaches. Finite element modelling, particularly using ANSYS and ABAQUS, has been established as a reliable tool for evaluating deflection and stress in layered pavement systems. Key findings from prior studies consistently highlight the importance of PCC thickness, interface bonding conditions, joint spacing, and subgrade support in governing TWT performance. However, most of these studies either rely on assumed or laboratory-derived material properties rather than field-backcalculated values, or they model a simplified two-layer system without evaluating the combined effects of modulus variation, thickness, load position, and cracking simultaneously. Furthermore, quantitative validation of three-dimensional FEM models against in-situ FWD deflection data from in-service TWT pavements in Indian conditions is largely absent. The present study addresses these gaps by integrating field FWD testing, multi-method backcalculation, and a validated ABAQUS model to conduct a comprehensive parametric investigation of an in-service TWT pavement, with direct relevance to IRC design practice.

3. STUDY LOCATION AND PAVEMENT CONFIGURATION

The study was carried out on a Thin White Topping (TWT) pavement section situated at the Maharani Bagh CRRI Staff Quarters in New Delhi. The pavement structure comprised several layers, beginning with a 150 mm thick Portland Cement Concrete (PCC) overlay placed above a 50 mm Semi-Dense Bituminous Concrete (SDBC) layer. Beneath this, a 150 mm layer of Granular Sub Base (GSB) provided additional support. In the finite element model, the subgrade was modelled as a 500 mm deep finite layer a practical truncation adopted to achieve computational efficiency. Although the natural subgrade extends much deeper, prior sensitivity checks confirmed that increasing the modelled subgrade depth beyond 500 mm produced less than 1% change in surface deflection, indicating that the truncation depth is sufficient and boundary reflection effects are negligible for the load magnitudes and frequencies involved in FWD testing.

4. METHODOLOGY

4.1 Falling Weight Deflectometer Testing

FWD testing was performed using a 38.6 kN impulse load applied through a 300 mm diameter plate. Surface deflections were recorded at radial offsets up to 1500 mm. These deflection were used for structural evaluation and model validation as per **Fig. 1.**

Fig.1 Field Testing Set for Falling Weight Deflectometer (FWD) Measurement

4.2 Backcalculation of Elastic Moduli

Elastic moduli of individual pavement layers were estimated using three independent approaches:

i. KUAB-PVD software

ii. BAKFAA

iii. AREA method

These methods ensured cross-verification of stiffness parameters used in modelling. **Table 1** shows elastic moduli calculated from various methods.

Table 1 Elastic Moduli from Different Methods

Pavement Layer	BAKFAA Modulus (MPa)	KUAB PVD Modulus (MPa)	AREA Theory Modulus (MPa)
PCC (TWT) Layer	27892	28322	28041.598
SDBC Layer	2700	3000	2800
GSB (Subbase)	75	85	80
Subgrade	35	37	30

The moduli obtained by the AREA method were chosen for finite element modelling for the following reasons. First, the AREA method yielded moduli that were consistently intermediate in value between the KUAB-PVD and BAKFAA estimates across all four layers, indicating robustness and reduced susceptibility to extreme outputs from either software platform. Second, a quantitative comparison shows that the three methods agree closely: the maximum inter-method deviation for the PCC layer is less than 1.5% (KUAB: 28,322 MPa; BAKFAA: 27,892 MPa; AREA: 28,042 MPa), and deviations for the SDBC, GSB, and subgrade layers are within 8–17%, which is within the acceptable range for pavement backcalculation (Hebert et al., 2023). Third, the AREA method is analytically transparent and directly linked to the deflection basin shape, making it straightforward to verify. Each method was initialised using seed moduli ranges based on material type: PCC (20,000–40,000 MPa), SDBC (1,500–5,000 MPa), GSB (50–150 MPa), and subgrade (15–60 MPa). These ranges are consistent with typical values reported in the literature for similar pavement types and ensured that the backcalculation converged to physically meaningful solutions. Cross-verification among all three methods enhanced overall confidence in the estimated stiffness parameters.

4.3 Finite Element Modelling

A 3D model was developed in ABAQUS, incorporating:

4.3.1 Geometry and layering

The model replicated the 3 m × 3 m layout of 1 m × 1 m PCC cells over a layered substructure, matching the actual slab panel dimensions at the study site. Each layer was modelled to the actual thickness reported on site. A single PCC cell at the centre was loaded during the simulation. The 3 m × 3 m lateral extent was selected based on a preliminary boundary sensitivity check: increasing the model footprint to 5 m × 5 m changed the centre deflection by less than 1.2%, confirming that the chosen domain is adequate to capture the structural response without significant boundary reflection effects. Lateral boundaries were constrained in the horizontal direction (roller conditions), and the bottom boundary was fixed in all directions, representing effectively rigid bedrock support beyond the 500 mm subgrade depth to mimic field testing. The overview of the pavement simulated in ABAQUS is shown in **Fig. 2.**

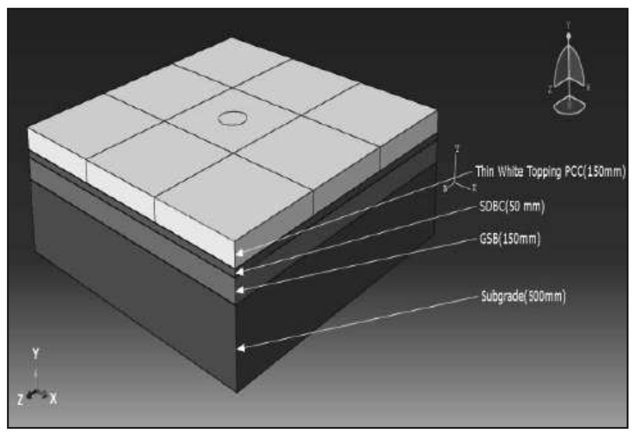

Fig.2 Overview of Pavement Model

4.3.2 Material properties

Each material layer was assigned linear elastic properties. The elastic modulus was back calculated, and the Poisson's ratio and density were based on literature and backcalculation results. **Table 2** shows material properties used in the Base Model.

Table 2 Material Properties Selected for Final Modelling

Pavement Layer	Elastic Modulus (MPa)	Density (KN/mm³)	Poisson's Ratio
PCC (TWT) Layer	28,041.598	2.4×10^{-5}	0.18
SDBC Layer	2,800	2.3×10^{-9}	0.35
GSB Layer	80	2.1×10^{-9}	0.35
Subgrade	30	1.8×10^{-9}	0.35

4.3.3 Meshing

Hex-dominated mesh elements were used, with the sweep technique for improved accuracy. Mesh refinement was applied near the loading area. Bottom boundaries were fixed in all directions, while lateral boundaries were restricted in the horizontal direction. To ensure the accuracy and stability of finite element analysis in ABAQUS, a mesh sensitivity study was performed. In this study, mesh seed sizes of 50 mm, 75 mm, and 100 mm were applied to the TWT model, with all material properties, boundary conditions, and loading kept constant. The central deflection (U2) at the load centre was recorded for each case. The 100 mm mesh produced a centre deflection of −0.1938 mm, the 75 mm mesh gave −0.1930 mm (a 0.41% change), and the 50 mm mesh yielded −0.1922 mm (a further 0.41% change from the 75 mm case). Since the variation between the 50 mm and 75 mm mesh results was less than 0.5%, a commonly accepted convergence criterion in pavement FEM studies the 75 mm mesh was adopted for the parametric study as it provides an optimal balance between accuracy and computational efficiency. **Fig. 3** shows the meshing of the model.

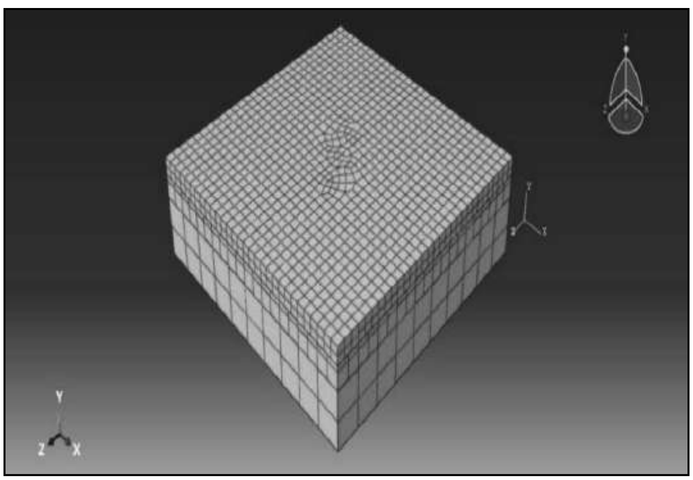

Fig. 3 Meshing of Model

4.3.4 Contact interaction between pavement layers

To simulate realistic interlayer behaviour, appropriate surface interactions were defined in ABAQUS using frictional contact with specified coefficients. At the time of construction, the PCC overlay was placed directly over the existing SDBC surface without any deliberate debonding treatment; the interface was left in a naturally weathered, milled condition. Based on site records and visual inspection, no bond-breaking membrane or separating layer was applied, implying partial to moderate bonding at the PCC–SDBC interface. Accordingly, a friction coefficient of 0.6 was assigned between the PCC overlay and the SDBC layer (PCC as master, SDBC as slave), consistent with values reported by Bulusu et al. (2019) for partially bonded concrete–asphalt interfaces, and within the range of 0.5–0.8 recommended for bonded TWT systems in the literature (Jundhare et al., 2012). For the SDBC–GSB interface, a coefficient of 0.4 was used (SDBC as master, GSB as slave), and at the GSB–subgrade interface, a lower coefficient of 0.2 was applied (GSB as master, subgrade as slave) to reflect the weaker contact characteristic of unbound granular–soil interfaces. Additionally, a friction coefficient of 0.4 was used between the opposing faces of cracked PCC cells to replicate partial load transfer across cracks. To assess sensitivity to the PCC–SDBC friction assumption, additional simulations were run with friction coefficients of 0.3 (representing nearly unbonded) and 1.0 (representing fully bonded). The results showed that changing the friction coefficient from 0.3 to 1.0 altered centre deflection by approximately 6–8%, confirming that while the interface condition influences the response, the base model with $\mu = 0.6$ represents a physically appropriate intermediate condition consistent with the site construction context. These definitions helped capture the true structural response of the layered system under loading.

4.3.5 Load application and boundary conditions

A surface pressure of 0.546 MPa was applied over a 300 mm diameter circular area, replicating the FWD load plate. The simulation was carried out using a static general step with nonlinear geometry enabled. Bottom boundaries were fixed in all directions, while lateral boundaries were restricted in the horizontal direction. **Fig. 4** shows load application and boundary condition applied on the model.

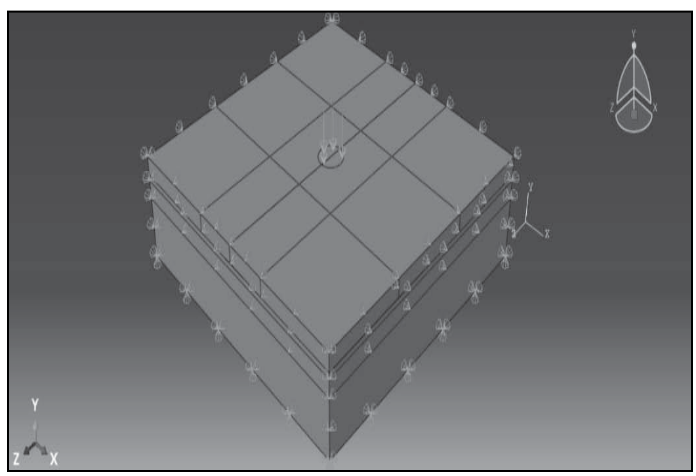

Fig. 4 Load Application and Boundary Condition

4.3.6 Model validation

ABAQUS-simulated surface deflections were extracted and compared against field-measured FWD values. The deflection profile was plotted radially from the load centre across geophone locations. A strong correlation was observed, indicating the model accurately replicated field behavior.

4.3.7 Parametric study design

To understand the influence of critical variables, the following parameters were varied individually:

- Modulus variation: PCC, SDBC, GSB, Subgrade
- Thickness variation: PCC (100 mm, 125 mm), SDBC (75 mm, 100 mm), GSB (200 mm, 250 mm)
- Load Location: Centre, Edge, Corner of slab
- Cracks: Load applied over simulated longitudinal and transverse cracks

Each scenario was analysed for its effect on surface deflection, bottom-layer stress, and potential for cracking risk. **Table 3** below presents the cases and variations that were analysed.

Table 3 Matrix of Parametric Study Cases

Case Type	Parameter Varied	Values Used	Other Conditions
Base Model		PCC: 150 mm, E = 28041 MPa SDBC:50 mm, E=2800 MPa GSB:150 mm, E=80MPa Subgrade:500 mm, E=30 MPa	Center Load, No Cracks
Modulus Variation	PCC Modulus	25,000 MPa, 28,041 MPa(base), 35,000 MPa	Center Load
	SDBC Modulus	2,200 MPa, 2,800 MPa(base), 4,000 MPa	Center Load
	GSB Modulus	60 MPa, 80 MPa(base), 120 MPa	Center Load
Thickness Variation	Subgrade Modulus	20 MPa, 30 MPa(base), 50 MPa	Center Load
	PCC Thickness	100 mm, 125 mm, 150 mm	Center Load
	SDBC Thickness	50mm(base)75 mm, 100 mm	Center Load
	GSB Thickness	150mm(base)200 mm, 250 mm	Center Load
Load Position Variation	Load Location	Center (base), Edge, Corner	PCC: 150 mm
Crack Modelling	Crack Type	Longitudinal, Transverse Crack	Load Applied on Crack Line

5. RESULT AND DISCUSSION

This section presents a comparative analysis between the ABAQUS simulation outputs and field observations from FWD testing, followed by a detailed parametric study evaluating the influence of layer modulus, thickness, load application location, and surface cracking on pavement response. The discussion focuses on both surface deflection and stress responses, with insights drawn to assess structural performance and cracking risk.

5.1 Validation of ABAQUS Model with FWD Deflection Data

To ensure the reliability of the finite element model, deflection values predicted by ABAQUS were compared with FWD-measured deflections under similar loading conditions. A comparison graph of deflection versus radial distance in **Fig. 5** shows strong agreement across all geophone offsets. To quantify this agreement, the Root Mean Square Error (RMSE) and percentage error were computed across the seven geophone locations (0, 300, 450, 600, 900, 1200, and 1500 mm). The RMSE was found to be 0.0082 mm, and the average percentage error was below 4.3%, with the largest deviations observed at the farthest offsets (1200–1500 mm) where absolute deflection magnitudes are small. The coefficient of determination (R^2) between simulated and measured deflections was 0.997, confirming an excellent fit across the entire deflection basin. This level of agreement confirms that the elastic layer assumptions, boundary conditions, and contact interactions closely replicate the behaviour of real pavements, validating the numerical model for subsequent parametric simulations.

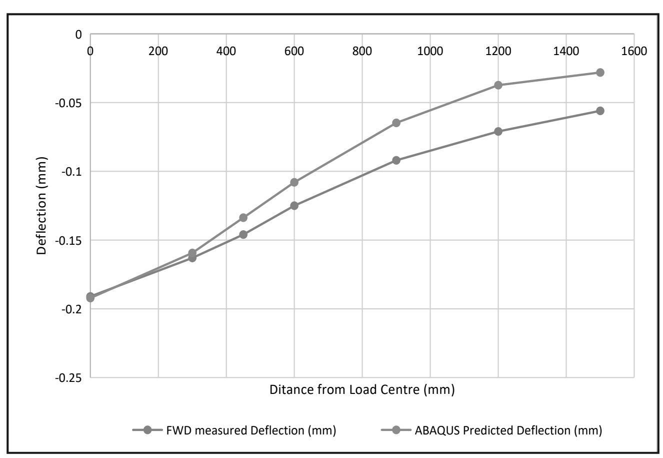

Fig. 5 Surface Deflection Basin Profile along Radial Distance (ABAQUS Model and FWD Test Results)

5.2 Layers Modulus Variation

5.2.1 Effect of variation in PCC modulus

A key parameter influencing the structural response of the composite pavement is the modulus of the Portland Cement Concrete (PCC) overlay. To assess this, simulations were conducted for three PCC elastic modulus values: 25,000 MPa, 28,041.6 MPa (base case), and 35,000 MPa. The vertical surface deflection across the geophone points was extracted (U2 direction), and the results showed a clear trend: higher PCC modulus consistently reduced surface deflections. The recorded deflection values at various distances are summarized in a graphical comparison presented in **Fig. 6.** These results confirm that the stiffer the PCC layer, the better the resistance against vertical deformation.

This happens because a higher modulus improves the load-spreading ability, thereby reducing stress transfer to lower layers.

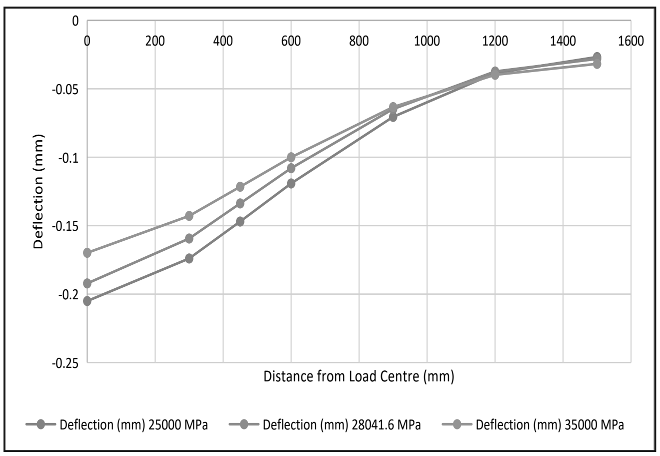

Fig. 6 Effect of PCC Elastic Modulus (25000 MPa and 35000 MPa) on Deflection Basin Profile

This inverse trend reduced deflection, but a slight increase in tensile stress is consistent with beam theory and field literature. As the modulus increases, load distribution improves, but the structure absorbs higher internal stress, which could accelerate fatigue if not kept within allowable limits.

5.2.2 Effect of variation in SDBC modulus

The Semi-Dense Bituminous Concrete (SDBC) layer plays a crucial role in distributing loads between the rigid PCC overlay and the granular layers beneath. Two modulus values were tested: 2200 MPa and 4000 MPa, alongside the base case of 2800 MPa. The surface deflection trends revealed that increasing the modulus of the SDBC layer had a marginal effect on reducing deflections. The recorded deflection values at various distances are summarized in **Table 4.**

Table 4 Influence of SDBC Elastic Modulus on Surface Deflection Response along Radial Distance

Distance from Load (mm)	Deflection (mm) – 2200 MPa	Deflection (mm) 2800 MPa [Base Model]	4000 MPa
0	-0.192219	-0.19218	-0.192129
300	-0.159402	-0.15937	-0.159325
450	-0.133749	-0.13372	-0.133685
600	-0.108020	-0.10799	-0.107968
900	-0.064779	-0.06476	-0.064748
1200	-0.037348	-0.03734	-0.037331
1500	-0.028125	-0.02812	-0.028114

The differences were almost negligible, suggesting that modulus changes in the SDBC layer have a less pronounced effect on surface deflection than changes in the PCC or subgrade layers. The system's structural insensitivity to changes in SDBC modulus may be due to its relatively thin placement and its location between two stiffer or more influential layers (PCC and GSB). Since SDBC primarily serves as a cushioning or intermediate transmission layer, minor changes in modulus don't significantly affect overall stress or deflection patterns.

5.2.3 Effect of variation in GSB modulus

The Granular Subbase (GSB) layer plays a vital role in stress dissipation and in supporting the upper pavement layers. Two values of GSB modulus were considered: 60 MPa and 120 MPa in comparison with the base case (80 MPa). The surface deflection values show that as GSB stiffness increases, deflection under loading decreases slightly, indicating improved load-bearing support. The recorded deflection values at different distances are summarized in **Table 5.**

Table 5 Influence of GSB Elastic Modulus on Surface Deflection Distribution along Radial Distance

Distance from Load (mm)	Deflection (mm) – 60 MPa	Deflection (mm) 80 MPa [Base Model]	Deflection (mm) – 120 MPa
0	-0.195267	-0.19218	-0.189001
300	-0.162297	-0.15937	-0.156357
450	-0.136471	-0.13372	-0.130900
600	-0.110527	-0.10799	-0.105409
900	-0.066816	-0.06476	-0.062686
1200	-0.039015	-0.03734	-0.035659
1500	-0.029653	-0.02812	-0.026588

Though the differences are not dramatic, the trend consistently shows areduction in surface deflection as the GSB modulus increases, highlighting its supporting influence. Although the GSB layer is not in direct contact with the load, its stiffness significantly contributes to load distribution across the subgrade. A stiffer GSB reduces vertical compressive strain in the underlying subgrade and slightly lowers deflection. The effect is modest due to the dominance of the upper PCC and SDBC layers, but still beneficial for long-term structural performance.

5.2.4 Effect of variation in subgrade modulus

The subgrade forms the foundational support of the pavement system. Its stiffness plays a key role in determining the extent of vertical deformation. For this study, subgrade moduli of 20 MPa and 50 MPa were analyzed, with 30 MPa serving as the base case. The recorded deflection values at various distances are summarized in **Table 6.**

Table 6 Influence of Subgrade Elastic Modulus on Surface Deflection Response along Radial Distance

Distance from Load (mm)	Deflection (mm) – 20 MPa	Deflection (mm) 30 MPa [Base Model]	Deflection (mm) - 50 MPa
0	-0.192105	-0.19218	-0.158567
300	-0.137411	-0.15937	-0.127522
450	-0.113781	-0.13372	-0.103879
600	-0.090151	-0.10799	-0.080618
900	-0.059548	-0.06476	-0.042755
1200	-0.049132	-0.03734	-0.019530
1500	-0.038717	-0.02812	-0.011881

The results clearly show that a stiffer subgrade (50 MPa) significantly reduces vertical deflections compared to the lower modulus (20 MPa). The 20 MPa case exhibits the highest deflection, reflecting the poor support and greater deformation capacity of weaker soils. Subgrade stiffness directly influences the load-carrying capacity of the pavement structure. A low-modulus subgrade is less able to resist vertical deformation, leading to higher surface deflections and increased tensile stress in the concrete overlay. In contrast, increasing the subgrade modulus improves the distribution of stresses and reduces structural deflection. This effect is especially important in maintaining long-term pavement integrity and minimizing fatigue cracking, particularly under repeated heavy loading.

5.3 Layers Thickness Variation

5.3.1 PCC layer thickness variation

Portland Cement Concrete (PCC) thicknesses of 100 mm and 125 mm were evaluated against the base case of 150 mm. To avoid redundancy, base model results already discussed are not repeated in graph or contour form. The recorded deflection values at various distances are summarized in **Table 7.**

Table 7 Influence of PCC Thickness on Surface Deflection Distribution along Radial Distance

Distance (mm)	Deflection (mm) 100 mm	Deflection (mm) 150 [Base Model]	Deflection (mm) 125 mm
0	-2.0040	-0.19218	-1.6028
300	-0.8006	-0.15937	-0.8722
450	-0.0875	-0.13372	-0.3230
600	0.4707	-0.10799	0.1140
900	1.1739	-0.06476	0.6579
1200	1.5427	-0.03734	0.9533
1500	1.6595	-0.02812	1.0568

As the thickness increases, the overall deflection reduces significantly. The 100 mm case shows extreme deflection, even changing from negative to positive, indicating excessive upward slab curling a sign of insufficient stiffness. The 150 mm slab performs best, resisting deformation more effectively. The change from negative to positive deflection in thinner PCC (100 mm) is likely due to curling or warping, as thinner slabs respond more sensitively to loading and boundary conditions. As a result, upward displacement is observed away from the loading point.

5.3.2 SDBC layer thickness variation

Two SDBC thicknesses, 75 mm and 100 mm, were compared to the base case of 50 mm. The recorded deflection values at various distances are summarized in **Table 8.**

Table 8 Influence of SDBC Thickness on Surface Deflection Distribution along Radial Distance

Distance (mm)	Deflection (mm) 75 mm	Deflection (mm) 50 mm [Base Model]	Deflection (mm) 100 mm
0	-0.1925	-0.19218	-0.1928
300	-0.1597	-0.15937	-0.1600
450	-0.1340	-0.13372	-0.1343
600	-0.1083	-0.10799	-0.1086
900	-0.0650	-0.06476	-0.0653
1200	-0.0376	-0.03734	-0.0378
1500	-0.0283	-0.02812	-0.0285

A consistent trend was observed, with deflection values lowest for the base case with a 50 mm SDBC thickness and increasing slightly as the SDBC thickness increased to 75 mm and 100 mm. This behaviour can be explained by the relative stiffness contributions of the SDBC layer. With an elastic modulus of 2,800 MPa roughly ten times lower than PCC the SDBC functions as a compliant interlayer. When SDBC thickness is minimised at 50 mm, the stiffer PCC slab dominates load distribution and the composite system behaves more rigidly. As SDBC thickness increases, the softer interlayer contributes additional compliance, reducing the overall composite bending stiffness of the pavement cross-section. This leads to marginally higher surface deflections despite the greater total pavement depth, because the additional SDBC material has a much lower load-resistance contribution per unit thickness relative to PCC. This result is consistent with beam-on-elastic-foundation theory: substituting effective (stiff) section depth with a softer material reduces overall composite stiffness. Thus, a thinner SDBC provides stiffer composite action and improved surface deflection performance.

5.3.3 GSB layer thickness variation

The subbase thicknesses of 200 mm and 250 mm were tested against the 150 mm base case. The recorded deflection values at different distances are summarized in **Table 9.**

Table 9 Influence of GSB Thickness on Surface Deflection Distribution along Radial Distance

Distance (mm)	Deflection (mm) 200 mm	Deflection (mm) 150 mm [Base Model]	Deflection (mm) 250 mm
0	-0.1967	-0.19218	-0.1958
300	-0.1637	-0.15937	-0.1630
450	-0.1378	-0.13372	-0.1373
600	-0.1118	-0.10799	-0.1115
900	-0.0679	-0.06476	-0.0678
1200	-0.0400	-0.03734	-0.0400
1500	-0.0305	-0.02812	-0.0307

It was observed that the surface deflection was lowest when the Granular Subbase (GSB) thickness was 150 mm, compared to thicker alternatives of 200 mm and 250 mm. This trend can be attributed to the composite stiffness behavior of the pavement structure. In the 150 mm GSB case, the relatively thinner flexible subbase allows the stiffer upper layers namely the Portland Cement Concrete (PCC) and Semi-Dense Bituminous Concrete (SDBC) to dominate the structural response under loading, thereby reducing overall surface deflection. Conversely, increasing the GSB thickness to 200 mm and 250 mm leads to deeper load dispersion into the pavement system, engaging more of the softer subgrade layer. Because the GSB is less stiff, the increased thickness introduces greater flexibility, resulting in slightly higher vertical displacements. Thus, a thinner GSB, when paired with adequately stiff upper layers, can offer improved structural efficiency by minimizing surface deflections.

5.4 Effect of Load Application Location

The location of wheel load application significantly affects the pavement's structural response. Three critical positions were analysed: center, edge, and corner of the PCC slab. The base case represents the center loading discussed in the validation section, while this section compares it with the edge and corner cases. The recorded deflection values at different distances are summarized in the graphical comparison shown in **Fig. 7.**

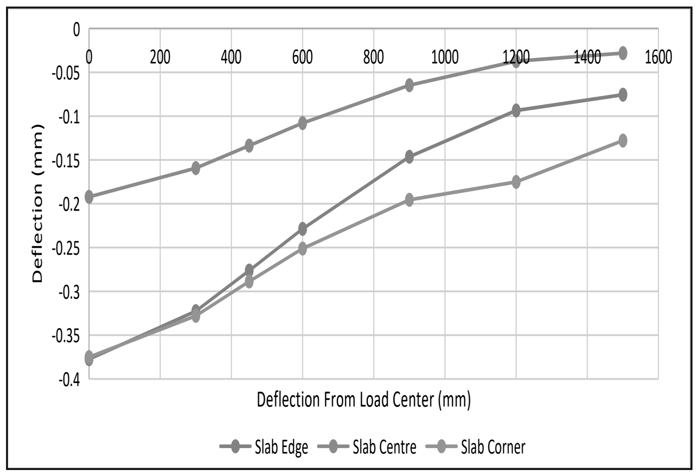

Fig. 7 Effect of Load Application Location on Surface Deflection along radial Distance

Edge and corner loading result insignificantly higher deflections, nearly double those of centre loading at 0 mm. The highest deflection occurred at the corner, consistent with real-world observations that corners are structurally most vulnerable due to a lack of lateral support. Edge and corner zones experience greater displacement because they lack support from all directions, unlike the central slab area. These regions are also more sensitive to load concentration, especially under repetitive loading.

5.5 Effect of Cracks

To simulate realistic field conditions, this section evaluates the structural behaviour of the white topping system in the presence of transverse and longitudinal cracks, with the load applied directly over the crack. Cracks were modelled using the partition technique in ABAQUS, wherein the PCC slab geometry was partitioned along the crack plane to create two abutting surfaces. A surface-to-surface frictional contact interaction with a friction coefficient of 0.4 was assigned between the opposing crack faces to represent partial aggregate interlock and partial load transfer, consistent with values reported for in-service cracked concrete pavements (Bulusu et al., 2019). Crack width in the model was effectively zero (the two faces are in initial contact), representing a hairline crack condition observed in the field. The crack extended through the full depth of the PCC overlay (150 mm) for both transverse and longitudinal orientations. For the transverse crack case, the crack ran perpendicular to the wheel path, while for the longitudinal case it ran parallel. These crack configurations interrupt structural continuity and reduce load transfer efficiency across the slab, which is directly relevant to rehabilitation planning under IRC:SP:76-2015 guidelines. The recorded deflection values at different distances are summarized in the graphical comparison for the Transverse crack and the longitudinal crack is shown in **Figs. 8** and **9**, respectively.

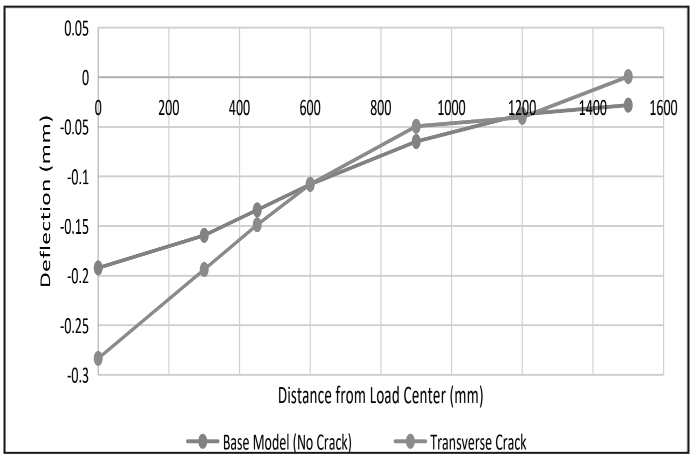

Fig. 8 Effect of Transverse Crack on Surface Deflection along Radial Distance

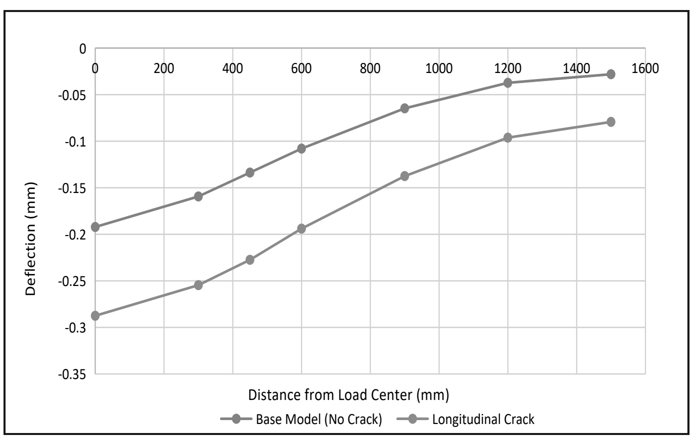

Fig. 9 Effect of Longitudinal Crack on Surface Deflection along Radial Distance

Both crack conditions resulted in increased deflection at the centre, exceeding those of the intact slab. The longitudinal crack resulted in the highest overall deflections, suggesting reduced load-transfer efficiency. Cracks introduce discontinuities, reducing the slab's structural stiffness and allowing greater deformation. The longitudinal crack especially interrupts continuity along the wheel path, explaining its greater impact on deflection. From a load transfer perspective, the increased deflection differential across cracked sections suggests reduced Load Transfer Efficiency (LTE), which, if left unaddressed, can lead to progressive joint faulting, increased corner stresses in adjacent panels, and accelerated fatigue damage. These findings are consistent with the distress mechanisms described in IRC:SP:76-2015 for TWT pavements, reinforcing the importance of monitoring crack propagation and providing timely maintenance interventions such as crack sealing or partial-depth repair to restore structural continuity.

6. CONCLUSION

This study successfully modelled the structural behaviour of Thin White Topping (TWT) pavement using a 3D finite element approach in ABAQUS and validated the model using Falling Weight Deflectometer (FWD) deflection data. The following key conclusions were drawn from the validation and subsequent parametric studies:

- **Model Validation**: The finite element model developed closely replicated the actual field deflection data, with the ABAQUS-simulated deflections aligning well with the measured FWD responses. This confirms the model's reliability for analysing TWT pavements.
- **Modulus Variation:** Increasing the elastic modulus of PCC, SDBC, GSB, and subgrade resulted in reduced surface deflection, indicating enhanced stiffness and load-carrying capacity. However, maximum principal stresses increased slightly with higher PCC modulus due to reduced slab flexibility. All stress values remained below the flexural strength (3.93 MPa), suggesting no cracking risk in any case.
- **Thickness Variation:** Increasing the thickness of layers especially PCC significantly reduced deflection and enhanced structural stability. Thinner slabs, particularly 100 mm PCC, showed deflection reversal from downward to upward beyond certain radial distances, highlighting the risk of slab uplift and warping under insufficient thickness.
- **Load Location Impact:** Deflections and stresses were highest when the load was applied at the corner of the slab, followed by the edge and centre, confirming known pavement failure patterns. Corner loading induced

the highest principal stress (1.87 MPa), although still within safe limits.

- **Crack Loading:** When the load was applied directly over transverse and longitudinal cracks, the deflection increased, and stress redistribution occurred. Notably, the longitudinal crack showed compressive stress under load due to partial contact, while the transverse crack exhibited more surface rotation and asymmetry in stress and displacement.

Overall, the study confirms that TWT pavements can perform satisfactorily under varying mechanical and geometric conditions if designed with adequate modulus, thickness, and load position considerations. Cracking risk was not observed in any scenario, validating the structural robustness of the current design.

Mechanistic Insights and Design Implications

The parametric findings of this study carry direct mechanistic and practical implications for the design and evaluation of TWT pavements in accordance with IRC:SP:76-2015. The following simplified design observations are drawn from the simulation results:

(i) *PCC Thickness Governs Structural Response*: The results confirm that PCC thickness is the single most influential design parameter. A reduction from 150 mm to 100 mm produces a tenfold increase in centre deflection and introduces slab warping. IRC:SP:76-2015 recommends a minimum PCC thickness of 100 mm for TWT; however, the simulations suggest that 150 mm should be treated as a practical lower bound in areas with subgrade modulus below 30 MPa or under heavy vehicle loading, as the 100 mm slab exhibited slab-edge uplift behaviour indicative of structural inadequacy.

(ii) *Subgrade Stiffness is Critical*: Increasing subgrade modulus from 20 MPa to 50 MPa reduces centre deflection by approximately 17%, which is comparable in magnitude to changes produced by significant PCC modulus increases. This underscores the importance of adequate subgrade preparation including stabilisation if necessary prior to TWT construction, a requirement that is acknowledged but not always quantified in IRC:SP:76-2015.

(iii) *Corner Loading is the Critical Design Case*: Corner deflections exceeded centre deflections by approximately 30–40%, and corner principal stresses (1.87 MPa) were the highest observed across all load positions. This confirms that corner loading, as also recognised in Westergaard-based design approaches, must govern the critical stress check in TWT design. Future iterations of IRC:SP:76-2015 may benefit from explicitly specifying corner loading as the primary evaluation scenario for slab thickness design.

(iv) *Interface Bonding Condition Influences Performance*: The sensitivity analysis showed that the PCC–SDBC friction coefficient affects centre deflection by 6–8%. Although all principal stresses in the parametric study remained below the flexural strength of 3.93 MPa, the interface condition becomes more critical in thinner or weaker slab designs. IRC:SP:76-2015 does not currently specify a minimum bond requirement or testing protocol; field-measured bond strength data should be incorporated into future design procedures.

(v) *Cracks Require Prompt Remediation*: The simulation of longitudinal and transverse cracks demonstrated increased deflection and reduced load transfer efficiency. Since all computed stresses remained within safe limits in the current study, the existing TWT pavement at Maharani Bagh is structurally adequate. However, these results show that crack propagation without remediation will progressively erode load transfer capacity, and periodic FWD-based evaluation combined with timely crack sealing is advisable, consistent with the maintenance strategy recommended in IRC:SP:76-2015.

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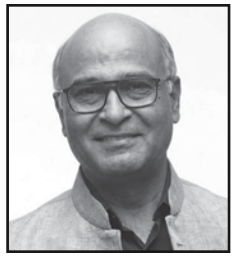
IRC Technical Committees Meeting Schedule for the month of September, 2026

Date	Day	Time	Name of Committee	Venue
03.09.2026	Thu	3:00 PM	Sub-Committee B-8.7 "Guidelines on Causes, Assessment and Repair of Cracks in Concrete Bridges"	Online
03.09.2026	Thu	2:30 PM	“Transport Planning & Traffic Engineering Committee” (H-1)	Online
05.09.2026	Sat	11:00 AM	“Bearings, Joints and Appurtenances Committee” (B-6)	Online
09.09.2026	Wed	3:00 PM	Sub-Committee B-1.5 "IRC-05-0102-Guidelines for the Design of Small Bridges, Culverts, Causeways and Submersible Bridges"	Online
23.09.2026	Wed	3:30 PM	“Reinforced, Prestressed and Composite Concrete Committee (B4)”	Online
30.09.2026	Wed	11:00 AM	“Steel and Composite Structures Committee” (B-5)	Online

AUNDH DP ROAD, STREET DESIGN PILOT PROJECT IN PUNE CITYEXECUTED UNDER SMART CITY MISSION : A BENCHMARK IN SUSTAINABLE URBAN STREET DESIGN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ABSTRACT

The Aundh DP Road pilot project in Pune city completed in 2017, is an outstanding example of the integration of sustainable urban street design and execution within the framework of the Smart Cities Mission of Govt of India. By employing Urban Street Design principles being endorsed by the Indian Roads Congress (IRC) in its latest revised codes for urban roads, the project has transformed a typical Indian city's collector street with haphazard traffic flow, unsafe pedestrian movement and major unutilized spaces into a vibrant, inclusive, and sustainable urban space focusing on the principles of equitable distribution of the street space, walkability with safety and universal accessibility amongst others. Even after 9 years into service since completion, the Aundh DP Road Street project offers excellent serviceability to all types of users showcasing the requirement for proper planning, design and durable urban road/street work execution. This paper outlines the urban street project's objectives, innovative planning, design and work execution strategies used, and its profound impact on urban mobility and quality of life, asserting the project's role as a model for future urban street infrastructure development initiatives in India.

The framework detailed in this paper sets the stage for a comprehensive examination of the Pune city's Aundh DP Road project within the context of India's Smart Cities Mission. The detailed elaboration of each section provides insights into the project's planning, execution, and impact, offering a valuable reference for urban designers, project management consultants, municipal engineers, policymakers, traffic police department and elected representatives engaged in the development of sustainable urban road and street infrastructure in a typical Indian city.

1. INTRODUCTION

The rapid urbanization of Indian cities necessitates a re-evaluation of urban road and street infrastructure to accommodate the growing needs for mobility, safety, and quality of urban life. The Smart Cities Mission, launched by the Government of India, aimed to address these challenges by promoting cities that offer core infrastructure, a clean and sustainable environment, and a high quality of life through smart solutions. The transition toward "Smart Cities" represents a fundamental paradigm shift in transport engineering, migrating from traditional asset-heavy highway construction to data-driven, adaptive asset management. Structurally, a Smart City integrates usability, convenience, Information and Communication Technology (ICT) with physical road networks to optimize the user safety. The Aundh DP Road project in Pune city is a pioneering initiative under this mission, designed to demonstrate how urban streets can be reimagined as inclusive public spaces that cater to the needs of all its users. The project was conceptualized in 2016 as the first Complete Street project using urban street design principles which are now part of the IRC Urban Road codes, was executed in a short span of 6 to 7 months with meticulous attention to the requirement of all users after a comprehensive stakeholder consultation process and subsequent refining of the street design.

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The project also focussed on solving the important issues faced by urban road engineers such as utility management and coordination with multiple stakeholders simultaneously addressing the issue of durability, longevity and aesthetics of urban roads. The project started with creating the network of nine streets and the execution of 1.5 km of DP road and ITI road as a pilot street, in the Aundh neighbourhood.

2. BACKGROUND INFORMATION OF AUNDH DP ROAD PUNE CITY

The Aundh area in Pune city is an upscale residential neighbourhood with a vast green cover and easy connectivity to the city centre and also to the Mumbai-Pune Expressway. Due to its proximity to the city's IT hub and availability of facilities such as schools, hospitals, markets, malls in the vicinity, Aundh is a preferred residential destination for the citizens. The Aundh DP Road is the main collector street in this neighbourhood connecting an arterial road at one end and a local street on another end. The existing road comprised of a four-lane divided carriageway with 2.0 m wide non-usable and discontinuous footpaths and significant unused spaces between the footpaths and main carriageway. The main carriageway consisted of 8 to 8.5 m wide bituminous pavement, which included 2 m parallel/ inclined parking on both sides of a 1.0 m wide central median. As the existing condition of the footpath was not walkable the pedestrians used the edge of the remaining 6 m carriageway which compromised the safety as well as reduced the throughput of vehicles. The wide and uncontrolled at-grade junctions caused hazardous crossing situations at the junctions.

Due to the mixed land use and commercial establishments such as shops, restaurants, banks, mall, the road has significant pedestrian traffic with 2100 pedestrians in both directions during peak hours. The road caters to mixed traffic of two wheelers, three wheelers, cars and some commercial and construction traffic. The traffic volume count in both directions for the said road in 2016 was 3000 PCU during peak hours. The project was proposed for retrofitting and redevelopment of existing road as a Smart Road by the Municipal Corporation under the Smart Cities mission.The funding for the project was provided under the Smart Cities mission as an Area Based Development (ADB) project. The **Photos 1** to **4** depict the condition of the project road prior to 2016 with unsafe walking conditions for pedestrians on a busy commercial street.

Photo 1 Unsafe Walking Conditions for Elderly and Children due to Narrow and Discontinuous Footpath

Photo 2 Unsafe Road Crossings and Junctions

Photo 3 Aundh DP Road in 2016 with Unsafe Pedestrian Movement

Photo 4 Narrow Footpaths with no Continuity and Trees with no Breathing Space –2016

The project was completed as part of the Smart Street development under the Smart Cities Mission of Govt. of India. The mission, aims to address these challenges by promoting cities that offer core infrastructure, a clean and sustainable environment, and a high quality of life through smart solutions. The Aundh DP Road, Pune Street project is a pioneering initiative under this mission, designed to demonstrate how urban streets can be reimagined as inclusive public spaces that cater to the needs of all users. The photos of the completed project street with the well designed and executed pedestrian facilities can be seen in **Photos 5** and **6**.

The footpath widths look much wider as the front setbacks of all the properties which have shops in front have been amalgamated along with the footpath, thus creating the continuous movement of shoppers/ customers from one shop to another. This was achieved with the help of local municipal corporator and cooperation of the merchant's association. Whereas the gates/entry and exit driveways to the residential and commercial buildings were maintained at the property line, established by the ROW, (Refer **Photos 22** to **29**)

Photo 5 Aundh DP Road Pilot Project Executed with 2 m. Parking Bay

Photo 6 Divided Carriageway with 6 m Width on each Side of Median (3 m Wide Lane)

3. OBJECTIVES OF THE PROJECT FOR STREET DEVELOPMENT OF AUNDH DP ROAD

- Create Healthy Hygienic and Humane neighbourhood by using 3 S concept of SAFETY, SHADE and SOCIETY.
- Providing SAFETY to all user groups
- Retaining the SHADE on the street
- Enhancing the street environment for the SOCIETY.

4. URBAN DESIGN PRINCIPLES AND PLANNING FOR THE PROJECT

Urban design and planning for the Aundh DP Road in Pune city was led by team of urban designers and architects, known for their innovative approach to urban space utilization and sustainability. The project was guided by principles of walkability, universal accessibility, and environmental sustainability, aiming to create a street that is not only a conduit for vehicles but a vibrant, multifunctional space for the community based on the 3 S concept of taking into care SAFETY of the people, SHADE provided by the tree canopy and creation of interactive spaces and pause points for the SOCIETY. The planning phase involved extensive stakeholder consultations to ensure that the design met the diverse needs of the city's residents. Key elements included wide and continuous footpaths, safe pedestrian crossings, demarcated cycle tracks, and green spaces that enhance the street's aesthetics and ecological value.

The urban street development of Aundh DP Road in Pune City, showcases a tangible application of modern urban design principles aimed at creating sustainable, efficient, and people-friendly urban environments. By incorporating these principles, Aundh DP Road serves as a model for urban street development that enhances the quality of life for residents while addressing urban challenges. The key planning and design aspects that were addressed in the project are explained briefly.

4.1 Pedestrian Prioritization

Aundh DP Road's redesign places a strong emphasis on pedestrian safety and comfort, featuring well-paved and uninterrupted walkable sidewalks, seating zones, and safe crosswalks. The aim is to encourage walking as a primary mode of transport for shorter distances, thus reducing vehicle reliance and enhancing the street ambiance, making the area accessible and enjoyable for residents and visitors.

4.2 Cycle Demarcation

A 1.8-meter-wide painted non-segregated cycle lane was marked along the edge of the 6-meter-wide street, prioritizing safe and uninterrupted movement for cyclists. Similar to the right-of-way granted at a zebra crossing for a pedestrian, cyclists have priority for movement in this designated painted lane for safety. Additionally, a diagonal painting acts as a buffer, guiding the cyclist to drive away from the car parking edge to prevent possible accidents caused by the sudden opening of car doors **(Photo 8).**

4.3 Neighbourhood Shuttle

A hop-on, hop-off shuttle service was introduced across the nine streets of the neighbourhood, initiated and introduced by the urban designer and local elected representative. This service was intended to provide a reliable, accessible, and eco-friendly transportation option for short-distance travel within the area. It helped citizens to move from one point to another for their daily needs/purchases, which usually are heavy to carry and hence result in taking out a two-wheeler or a car, for such trips. The intention of this shuttle was also that it would benefit children and senior citizens in particular to move within the neighbourhood for various activities and reduce the dependence on family members to escort them in a vehicle, thus reducing the number of trips within the neighbourhood and contribute it in reduction of traffic congestion. The shuttle also helps to enhance the last mile connectivity to the metro stations, bus depots, bus stops, and other centres like education institutes, malls and shopping streets.

4.4 Green Infrastructure

All the existing trees in the neighbourhood were retained, thus contributing to environmental sustainability, helping in temperature regulation, air purification, rain absorption, and shaded footpaths for the users. Every tree was provided with breathing space around it, with stone work which acted as a seating **(Photo 17)**. These stone seatings contributed as a social space, sensitively designed by providing an inclined edge, which acts as a non-seating zone, along the pedestrian movement line, thus ensuring safety and seamless walkability. Additionally, small trees were provided with concrete gratings instead of cast iron ones to prevent corrosion and pilferage. Concrete bollards were used in the streetscape for their durability and resistance to vandalism and theft, making them a more sustainable alternative to stainless steel or other materials.

4.5 Smart Technology Integration

Embracing smart technology, Aundh DP Road features advanced traffic management systems, and smart lighting solutions enhance energy-efficient lighting. Excellent quality lighting was used to ensure the safety of the citizens **(Photo 9).** This integration of technology into the street design underlines the Smart Cities Mission’s goal to improve urban living through enhanced efficiency, safety, service quality, and improved urban mobility. A proposal for a parking policy was initiated, where in through smart technology, parking spaces and its availability was to be integrated along with the financial model, incorporating parking charges for vehicles in a telescopic manner.

4.6 Inclusive Design

Aundh DP Road’s urban design prioritizes accessibility for all, ensuring that sidewalks, crossings, and public transportation are user-friendly for the elderly, children, and people with disabilities. This approach fosters an inclusive urban environment where every individual can navigate and enjoy the public spaces comfortably. The design ensures equitable distribution of road space, accommodating all the street users. The MV lane of 6 m assures safety for the cyclists with speed calming measures. The signages are placed at appropriate locations, which makes the street informative and user-friendly.

4.7 Cultural and Contextual Sensitivity

The redesign of Aundh DP Road respects the people’s behaviour and creates an environment which is comfortable, convenient, connected, and climate-friendly, helping enhance the commercial viability of the street. An identity is created by the use of local stone in the creation of seating, a kids’ play area, and gym equipment. Public art installations created from junk, crafted and curated by the Pune Biennale foundation, were incorporated to add to the aesthetic quality of the urban space **(Photo 10).**

4.8 Economic Vitality

Recognizing streets as vital spaces for economic activity, the area encourages demarcated and controlled street markets, outdoor cafes, and local businesses. By creating pedestrian-friendly zones, Aundh DP Road stimulates economic growth and fosters vibrant, dynamic urban spaces that attract residents and tourists alike. The involvement of key stakeholders, such as shopkeepers, in incorporating the front setbacks in the pedestrian realm was possible only due to the active role played by local elected representatives, who helped in acquiring the front setbacks **(Photos 23, 25, 27 & 29)**. This facilitated in creation of a pedestrian realm that extended right up to the shops, enhancing accessibility and seamless movement from one shop to another, increasing the footfall of customers, and enhancing sales. The dedicated two-wheelers and four-wheelers parallel parking bays were provided, which would generate revenue for the corporation through on-street paid parking **(Photo 12).** Over the last 8 years, a substantial resale has resulted in shops being transformed into showrooms of major brands, which is an indicator that economic transformation can happen through sensitive revitalization of the public realm.

4.9 Innovative design Elements

The standard 900 mm high concrete median commonly used was replaced with a welded mesh railing flanked by bougainvillea plantation on both sides. This soft-edge treatment enhances safety, particularly for motorcyclists who may fall onto the median during an accident. Additionally, the use of a mesh railing reduces the “shy-away” space typically maintained by car drivers near rigid concrete dividers, thereby improving lane efficiency and increasing vehicle throughput.

Conventional speed-calming measures such as rumble strips and speed humps were replaced with a 10-meter stretch of stone cobble paving. This design effectively reduces vehicle speed before approaching the raised pedestrian crossing, enhancing safety and comfort for all road users **(Photo 13).**

Parking has been provided parallel to the street rather than at an angle, thereby reducing the risk of conflict while reversing from parking bays. Additionally, turning buffers have been incorporated on both sides of property entrances to prevent vehicles from being parked in front of gates. These buffers contribute to better-organized parking, facilitate the integration of access ramps aligned with the footpath level, and provide designated spaces for installing signage and dustbins. As a result, an uninterrupted pedestrian walkway is maintained. Moreover, the turning buffers offer space for shrub plantation, enhancing the visual character and landscape of the street **(Photo 14).**

4.10 Ease of Construction, Maintenance, and Safety

High-quality Street illumination is essential to ensure pedestrian safety on urban streets. To support this, two parallel black bands of 100x100 mm pavers are provided one along the outer edge of the footpath and the other on the inner side spaced 3 meters apart and repeated every 10 meters. These bands mark the location of underground electrical lines, allowing for easy identification and maintenance without disrupting the footpath. Around bollards, electrical poles, and FRP chambers, exposed aggregate chips are used instead of cutting pavers, preserving the continuity and durability of the pavement. Existing feeder pillars were relocated to soft landscape areas and enclosed within a welded mesh cuboid structure with a door for safe and easy access during maintenance. This enclosure particularly enhances child safety. To further enhance the street’s visual appeal, the feeder pillars were artistically painted by the Pune Biennale Foundation, adding cultural character to the public realm **(Photo 11).**

The project followed the Urban Street Design Guidelines (USDG) for Pune Municipal Corporation., prepared by ITDP (Institute for Transportation and Development Policy). The other documents referred were the Global Street Design Guidelines, prepared by GDCI (Global Designing Cities Initiative), in partnership with the National Association of City Transportation Officials (NACTO). The guidance was also taken from organisations like Parisar, Pedestrian First and SPTM (Save Pune Traffic Movement) from Pune.

Photo 7 Street Ambience after Work Completion

Photo 8 Painted Bicycle Lane

Photo 9 Excellent Lighting Ensuring Safety of all Users

Photo 10 Sculptures from Waste Material

Photo 11 Covered and Painted Electrical Feeder Pillar Boxes

Photo 12 Parallel Parking Bays

Photo13 Traffic Calming Cobble Surface and Soft Median with Boungevilla Plants

Photo 14 Signage and Dustbins in Turning Buffer

Photo 15 Safe and Raised Pedestrian Crossing

Photo 16 Tree Grating Around Small Trees

Photo 17 Stone Seating around Large Trees

Photo 18 Use of Levelled Footpath Surface for Prams

Photo 19 Wheelchair Access Ensured through Universal Accessibility Provisions

4.11 Before and after Construction Transformation

Through the application of these principles, Aundh DP Road project illustrates how thoughtful urban street design can significantly enhance urban living, making it a benchmark for future projects under India's Smart Cities Mission. The design principles and unique features of the project are illustrated in **Photos 20** to **27** which depict the before and after situation of the road at the same locations.

Photo 20 Before Image

Photo 21 Completed Footpath

Photo 22 Haphazard Parking along the Footpath

Photo 23 Provision of organized Parallel Parking Bay

Photo 24 Existing Footpath Condition

Photo 25 Completed Footpath with Street Elements

Photo 26 Discontinuous Footpath

Photo 27 Organised Street with Footpath and Street Furniture

5. PARADIGM SHIFT IN LANE WIDTH NORMS – 3 M WIDE SINGLE LANE

The length of the DP road is 980 m and included three major junctions. Another section of the road parallel to DP Road is having length of 520 m. The project ROW as per the Municipal Development Plan (DP) is 30 m. The existing ROW on site ranged between 24 to 25 m and it required the acquisition of additional ROW on both sides of the street for full width development. The existing four lane street (2 lane each way) comprised of 8 to 9 m varying width of main carriageway.

The existing footpaths were almost dysfunctional due to 2.0 m narrow width blocked by the existing trees with wide girths, utility boxes, street poles thus, forcing the pedestrians to walk on thecarriageway creating highly unsafe walking conditions. Almost 2.0 to 2.50 m to 3.0 m widespace of the 8 m carriageway was unused and fully occupied by parked vehicles in haphazard manner throughout the day.

During the consultation process, the existing 4 lane carriageway (2 lanes each way) was unanimously voted to be retained after extensive debates and public meetings. However, the width of the carriageway was restricted to 6 m (2 lanes of 3 m each) on both sides of the central median having 1.5 m width. This was a bold decision taken by the authorities after testing the traffic movement for a week using temporary measures along the carriageway edge.

Encouraging results and no major bottlenecks even with the 6.0 m wide carriageway marked a significant turning point in the project design and all future projects taken up in Pune and other cities. The 3.0 m wide single lane used in the Aundh DP Road project was also endorsed by the IRC 86 code for Geometric Design standards for Urban roads which was revised in 2018. The Aundh DP road project showed that a 3.0 m wide lane is feasible without major disturbances in an Indian urban road scenario having mixed traffic conditions. **Photos 28** and **29** show the 6.0 m wide main carriageway with central median and 1.80 m painted cycle lane within the 6 m carriageway.

6 TECHNICAL ASSESSMENT OF ROAD BEFORE CONSTRUCTION AND PROJECT COST ESTIMATION

6.1 Technical Assessment of Road before Construction

The existing flexible pavement was assessed by taking trial pits at 4 locations for assessment of the crust thickness and overlay design. As the existing flexible pavement consisted of more than 150 mm bituminous layers and the cost effective and sustainable White topping treatment was used for this project. Before the design of the white topping overlay, the benkelman beam deflection test for determination of K value on top of existing pavement and traffic volume counts were conducted as per requirement of IRC:SP:76 for overlay thickness design. The existing flexible pavement crust consisted of 160 mm bituminous layer and 350 mm granular base and subbase layers. The K value of 12 kg/cm^2/cm was derived based on characteristic deflection from Benkelman Beam deflection test value of 0.71 mm. The white topping overlay of 175 mm was designed by using M 40 grade concrete.

Photos 28 and 29 - 4 Lane Carriageways with Provision of 6.0 m Wide Concrete White Topping Overlay as Carriageway on Both Sizes and 1.8 m Paint Marked Cycle Lane

Photo 30 Benkelman Beam Deflection Test for K value Determination before Overlay

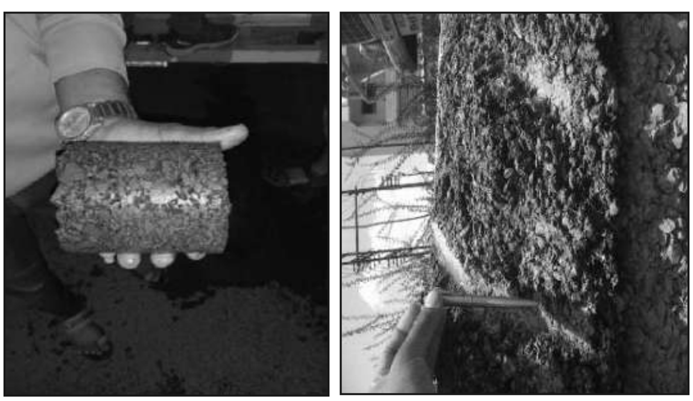

Photo 31 Trial Pit & Bituminous Core in Existing Pavement before White Topping Overlay Design

6.2 Project Report Preparation and Project Cost Estimation

The project technical report included the design principles of the urban road design based on various codes and guidelines along with the other technical inputs such as field surveys and investigation data, design for under road utilities, storm water drainage, road geometry, pavement overlay design apart from the project cost estimate and material specifications. The total length of the project road was 1.50 km and the width for development was 24 to 25 m. The 30 m ROW for development was available for almost 75% of the road length. Eventually, during the construction stage, balance land and road ROW was made available by the Municipal Corporation after discussion and dialogue with the shop owners and local residents.

The integrated/combined cost estimate for the item including civil work, water, sewer, electrical and OFC utilities, crossings, gardening work was prepared based on the SOR of Pune Municipal Corporation for year 2016. The estimate and BOQ included all the relevant work items in a single integrated contract. The total cost of the project was Rs. 22.90 Crore (2016 SoR rates) including all taxes, duties and royalties. The per sqm rate for the project work worked out to Rs. 5088 per sqm of the road area. The integrated tender with all the items for civil work, utility relocation work, arboriculture was invited through competitive bidding on percentage rate format and successfully executed in 7 months period through a local contractor.

7. GEOMETRIC DESIGN AND PROVISIONS FOR THE URBAN STREET PROJECT

The Urban Street Design Guidelines (USDG) prepared and accepted by Pune Municipal Corporation in its General Body in 2016 based on the available literature and guidelines from DDA, ITDP India were used for preparation of the designs for the street project.

The detailed design was undertaken by urban designers appointed by the Pune Smart City Development Corporation. The final configuration for the road included 4 lane divided carriageway with 6.0 m width on both sides of the 1.5 m wide central median, 2.0 m wide parallel parking on both sides at selected location and combined 6.50 m wide footpath, cum Multiuser Zone (MUZ) on both sides of the road. The presence of large number of wide girth trees required the footpath and MUZ space to be widened in order to enable the availability of walkable and universally accessible footpaths throughout the road stretch. The walkable width of the footpath included minimum 3.5 m uninterrupted space at all locations even with the presence of trees, utility boxes, street poles and other street elements and street furniture etc.

Although the corridor functions as a collector street, a context-sensitive operating-speed of approximately 35–40 km/h was intentionally adopted considering the high pedestrian intensity, mixed commercial frontage, frequent property accesses and short intersection spacing. Accordingly, raised pedestrian crossings, compact junction geometry and rough-textured traffic-calming surfaces were incorporated to moderate operating speeds rather than optimize the corridor solely for vehicular speed.

3 Nos compact designed at grade intersections are a key feature of the project. The intersections prioritize pedestrian safety, reduce vehicle turning speeds, and improve overall traffic calming. By minimizing the corner turning radii and shortening pedestrian crossing distances, compact junctions in the project enhance safety, walkability and accessibility. The compact design also improved visual connectivity between road users and reduced conflict zones, making intersections safer for all users. In the pilot project, the implementation of compact junctions has demonstrated effective integration of multimodal transport while maintaining urban character and optimizing land use at intersections. **Fig. 1** shows the sample of detailed layout prepared for the project that includes all the street elements with minute detailing and dimensions. **Fig. 2** shows the typical section and widths of the street elements along with the details of the underground utilities in the project.

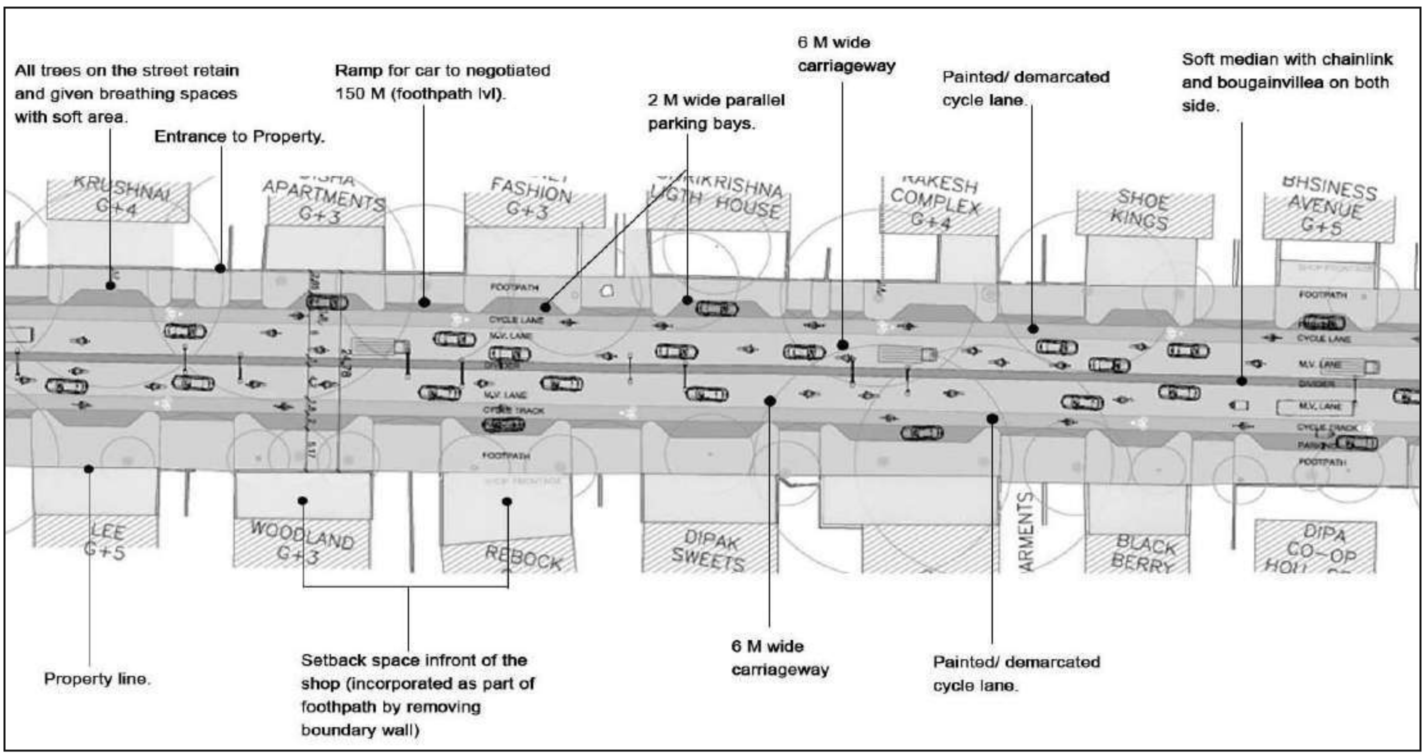

Fig. 1 Sample of Detailed Layout Drawing Showing Various Elements for the Urban Street Project with 30 m Wide ROW

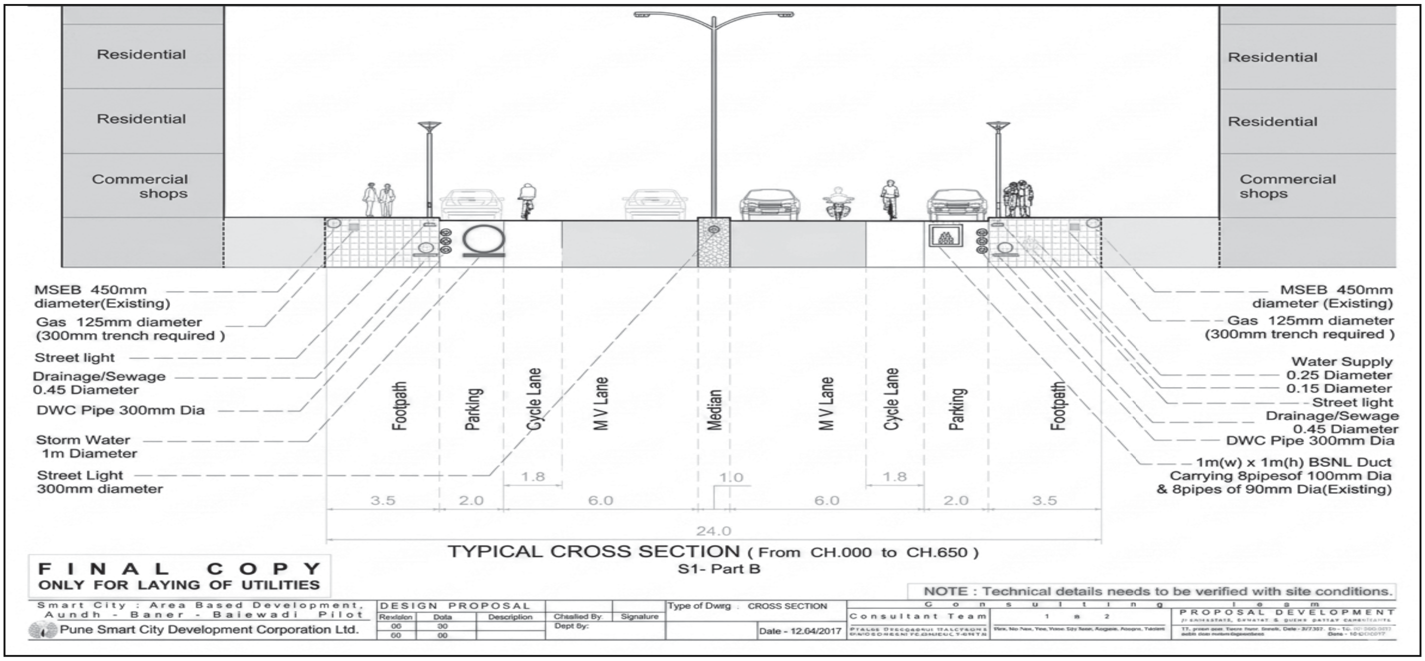

Fig. 2 Typical Cross Section for the Urban Street Project with 30 m Wide ROW

8. NEW AND INNOVATIVE MATERIALS FOR THE STREET PROJECT

The street retrofitting and redevelopment project using urban street design guidelines required the incorporation of state-of-the-art and innovative materials from design, aesthetic, usability, durability and safety considerations. Some of the new materials were specifically designed and manufactured for the first time in the city for this project. These items included factory finished kerbs of various shapes such as semicircular, rectangular and varied sizes. High grade M 40 concrete was used for the factory finished and prestressed kerbs which are extensively used in the street project work. The concrete bollards were also designed and cast for the purpose of restricting two wheelers from accessing the wide footpaths and still allow the passing of wheelchairs by providing the appropriate space of 1.0 m between the bollards.

Stamped concrete finishes with coloured and varied textures having service life of above 20 years was used for the footpath areas along with M 50 grade concrete paver blocks to provide aesthetic appeal as well as usability to enable local removal of blocks in case of emergency or unforeseen utility work at a later date. The Fibre Reinforced Polymer (FRP) utility and manhole chambers with the city logo embossed were also used in the project. Concrete white topping with M 40 grade concrete overlay having thickness of 175 mm and 1 m X 1m small panel was used in order to reclaim the existing bituminous pavement and avoid excavation and wastage of available bituminous pavement crust.

Innovative rectangular boxes with perforated steel sheets were casted to cover the electrical and utility boxes and strategically placed in the soft / plantation areas to avoid the blockage of the pedestrian walkways. The perforated steel boxes were painted by college students as part of the beautification drive and competition. Unique sculptures typical to the nature of the existing commercial business establishments along the road were also designed from waste material and metal from scrap yard. **Photos 32 to 37** show the various new materials, and finishes items used in the project.

Photo 32 Various Shape and Sizes of Semi-Circular Prestressed Concrete Kerbs Designed and Factory Casted for Project

Photo 33 Fixing of Specially Cased Heavy-duty Kerbs for Footpath and Soft Areas

Photo 34 Special Stamped Concrete Coloured Finish for Children's Play Area

Photo 35 Special Type of Chip Finishing for Fixing of Concrete Bollards in Rectangular and Uneven Areas

Photo 36 Cobble Stone Finishing used as a Traffic Calming Measure near Pedestrian Crossings

Photo 37 FRP Chamber Cover and Frames with Client Name Embossing for Utility Manhole Chambers

9. PROJECT MANAGEMENT AND EXECUTION STRATEGY

Project Management Consulting (PMC) was instrumental in guiding the execution of the work within the scope of Smart Cities Mission, particularly with projects like the transformation of Aundh DP Road project.

The Client appointed experienced project management consultant, facilitating the collaboration between urban designers, Municipal Corporation engineers, and contractors. Their expertise in the project estimation, procurement process and supervision with overall project management ensured the project's execution within the set timelines and budgets while maintaining high standards of quality and workmanship. The execution strategy emphasized on rigorous quality control, strict supervision and rejection of poor work, efficient resource allocation, and stakeholder engagement, ensuring seamless integration of the project's components and adherence to the Smart Cities Mission's objectives.

The focus on proper material selection in consultation with the urban designers and municipal authorities, selection of improved specifications, innovation in the design elements, strict supervision, local contractor capacity building with continuous handholding, and training underscores the multifaceted approach required to ensure these projects not only meet but exceed their intended goals. This section delves into these aspects, emphasizing their importance in the project's success through 10 key pointers.

9.1 Strategic Material Selection

i. The choice of materials for Aundh DP Road is pivotal to its sustainability, durability, and aesthetic appeal. The urban designer and project management consultants were involved in conducting rigorous research to select materials that are locally available, environmentally friendly, and capable of withstanding the local climate and traffic conditions. This includes high-quality paving materials, innovative water-permeable surfaces, and pollution-absorbing greenery, ensuring the project's longevity and sustainability.

ii. Specially designed concrete kerbs with semi-circular shape, concrete bollards, stamped concrete finishes and stone masonry sit outs around the large trees provided the required aesthetic and pleasing appeal to the street project.

iii. Sand-blasted pavers of 200 x 200 x 80 mm were used on the pedestrian movement area, and heavy-duty 200 x 200 x 100 mm pavers were used in parking and driveways to the property entrances.

iv. 100 x 100 x 80 mm sand-blasted black pavers were used to demarcate the electrical lines in a 400 mm band, which makes provision for electrical poles every 10 m in the pedestrian zone.

v. For balance spaces, niches, odd spaces, around bollards, below electrical light poles, and around manhole covers, exposed aggregate chipping with the ratio of 3 units – yellow chips, 2 units – red chips, and 2 units – white chips. The size no. 3 was considered for the execution.

vi. Locally available basalt stone was used for seating around the trees.

9.2 Detailed Technical Specifications

Drafting precise specifications for every aspect of the project is crucial. For the project, this meant creating detailed documents that outline the standards for construction materials, design parameters, and execution methodologies. These specifications ensured that all contractors and stakeholders had a clear understanding of the project requirements, leading to consistency and high-quality outcomes across the board. The detailed technical specifications for the newly designed items such as semicircular kerbings, stamped concrete finished, concrete bollards, masonry sit outs, cobble finishes etc were prepared and the item rates were approved by the concerned authorities for preparation of the project estimates. Details of the material used for the road work are detailed in the table.

Material Specification of Work	Relevant IRC/ IS Specification	Remarks
M 40 grade concrete for white topping of main carriageway	IRC:SP:76-2015	No deviation from IRC code
Interlocking concrete paver blocks (60/80/100 mm)	IRC:SP:63-2018	No deviation from IRC code
Stamped concrete finishes	--	International best practice adopted
RCC tree gratings	--	M 30 grade concrete used
RCC pipes for utility and road crossings	IS 783 -1985	No deviation from IRC code
DWC pipes for OFC utilities	IS 16098 -2013	No deviation from IRC code
Cyle lane marking paint for demarcated cycle lane	IRC 35-2015	No deviation from IRC code
UCR masonry for sit outs	IS 1597-1992	No deviation IS code
Concrete Bollards	IRC 103-2012	M 30 grade concrete used
Cobble finish for traffic calming	IS 1129:1972	International best practice adopted
Precast RCC kerbing (M 30 Grade)	IS 5758:2020	M 40 grade concrete used
Stone chipping finishes	--	M 25 concrete and broken marble / granite chips used

10. PUBLIC ENGAGEMENT& PROJECT TRIAL

Extensive public engagement was conducted over a period of three to four months prior to finalizing the design and issuing the tender. Multiple rounds of consultations were held with various stakeholders, including the MLA, local corporators, residents' associations such as Aundh Vikas Mandal, and the shopkeepers' association. Discussions also involved NGOs, traffic police, MSEB, and relevant departments of the Pune Municipal Corporation such as water supply and sewerage to ensure a comprehensive and integrated planning approach.

Photo 38 Extensive Public Consultation Process before Finalization of the Street Design

10.1 Mock Trial run for the Pilot Project

Before actual commencement of the project the authorities implemented a full-scale mock trial run of the project using temporary elements such as loose kerbs, plastic bollards, temporary paint markings for cycle tracks and temporary signages and boards. The mock trial run was enforced for a full week to give the residents and shop owners confidence about the project outcomes and understand the difficulties that may arise from the project implementation. The Traffic police department was taken into confidence and their suggestions were implemented during the trial runs. The mock trials were welcomed by the residents and number of citizens from other parts of the city visited the project site during the week-long mock which also hosted a number of painting competitions, open art exhibition for budding artists and suggestion boxes. A number of improvement and fine-tuning suggestions were compiled based on the experience and discussions during the mock trial with users which resulted in further reshaping the final designs for the street project. The **Photos 39** and **40** show the implementation of mock trial run before project commencement.

Photo 39 Mock Trial Run of Urban Street Project using Temporary Elements like Plastic Bollards

Photo 40 Pedestrian Walkway and Cycle Lane Marked with Temporary Paint for Mock trial

11. UTILITY MAPPING AND UTILITY SHIFTING/ REORGANIZATION

Being a brownfield road project,it posed a significant challenge in relocation of the existing utilities. The primary objective of this exercise was to avoid the shifting/excavation of the existing utilities for repair/ maintenance or new connections for a period of at least 15 to 20 years after construction.

With this intention, the detailed mapping of existing utilities along and across the road was completed using GPR equipment and taking trial cuts across the roads in footpath portions between the junctions. A detailed layout map and cross sections of existing utilities were prepared to plan for the relocation of critical utilities only and provision of essential new utility pipes considering future development.

The plans were discussed and deliberated with various municipal internal utility departments such as water supply, sewer, electrical, garden, solid waste etc and external utility service providers such as BSNL, MSEDCL, OFC service vendors, piped gas vendors, CCTV camera agencies etc. The final provisions for relocation of some existing old utilities and provision of only vital new utilities were included into a single integrated contract (same contracting agency for all the civil and utility works) were prepared by taking inputs from the respective utility service providers with clear intention to avoid the impending road cutting.

The utility works were executed consequently with additional provisions of service and dummy chambers at regular intervals to avoid future road excavation to tap the underground utilities. Systematic, coordinated planning and execution has resulted in zero road cutting in the past 8 years for the completed street project. **Fig. 3** shows the detailed layout of various existing and proposed utility on the project plan. **Photos 41** to **44** show the provisions for various underground utilities in the project.

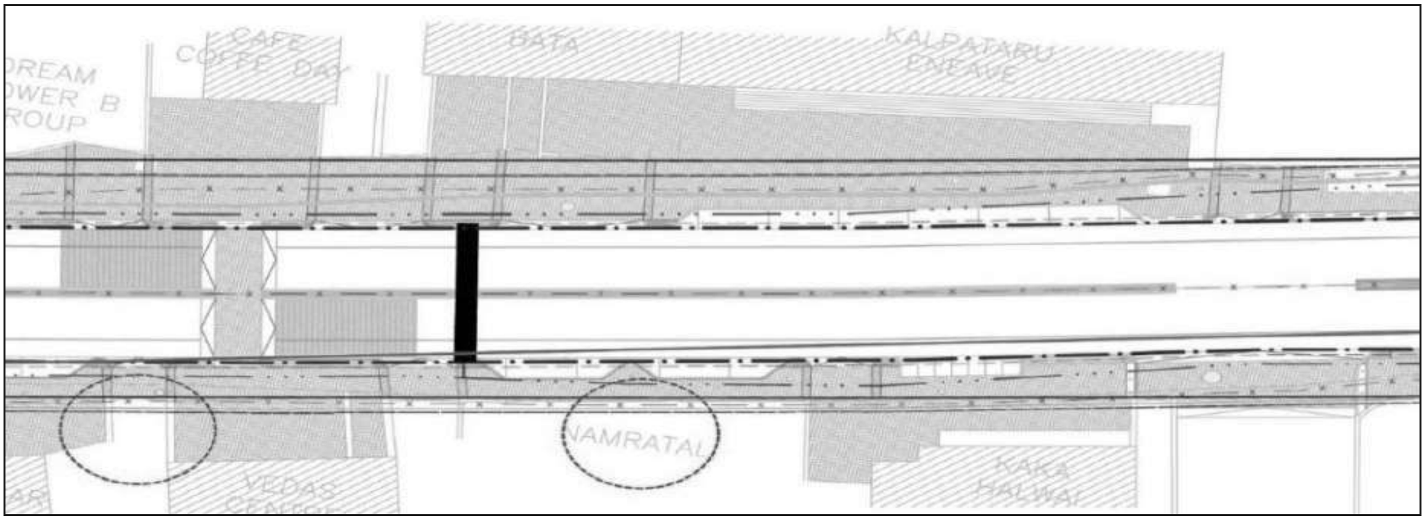

Fig. 3 Detailed Layout Map Showing Existing and Planned Utilities for Easy Understanding during Execution Process

Photo 41 Laying of Double Wall Corrugated (DWC) Pipes 3 Rows for OFC Utilities

Photo 42 Chambers at Regular Intervals of 25 to 30 m for DWC Pipes and Individual Property Connections from Chamber

Photo 43 Individual Property Connections from Main Water Line

Photo 44 Individual Property Connections from Main Sewer Line

11.1 Storm Water Management for the Street Project

Raised wide footpaths and other street elements resulted in the blocking of the water channels from property towards the road. Hence in order to avoid water stagnation and flooding during monsoon season, the storm water mapping was undertaken for individual properties and the collection chambers inside the properties were connected to the main storm water line and chambers along the carriageway edge resulting in zero water logging incidents reported in the past 8 years. **Photos 45** and **46** show the main storm lines and individual property connectivity to the main lines through service chambers.

Photo 45 Laying of Storm Water Line with RCC Chambers along Edge of Main Carriageway

Photo 46 Individual Property Connections to Main SWD Line Chamber

12. RIGOROUS CONSTRUCTION SUPERVISION

Effective supervision ensures that the project adheres to its planned specifications and timelines. For Aundh DP Road, PMC entailed the continuous on-site supervision, regular quality checks, and coordination meetings.

This hands-on approach guaranteed that construction activities were executed accurately, efficiently, and in compliance with the project's standards. The project management team along with the Municipal engineers and urban designers ensured timely decisions to the contractor team to avoid delays and reworking. However, poor or unacceptable workmanship was strictly rejected by the Consultants with necessity of multiple instances of reworking for items such as masonry, kerb laying, stamped concrete finishes etc. **Photos 47** and **48** depict the minute aspects of work quality and following proper construction methodology.

Photo 47 Meticulous attention to Work Quality and Construction Process Like Curing of Joints between Kerbs

Photo 48 Use of Steel Frames for Raised Pedestrian Crossings to Avoid Paver Block Movement under Traffic

12.1 Contractor Capacity Building and Handholding

Developing the capacity of local contractors was vital for the project's success. For the project, it included organizing multiple workshops and training sessions on the required construction methodology, quality, workmanship and finishing aspects, sustainability practices, and safety protocols for the contractor site staff along with the urban designer and project management team. This handholding approach not only enhanced the contractors' abilities but also ensured a high level of workmanship and finesse in executing the high-quality project.

12.2 Continuous Quality Assurance and Control

Throughout the project lifecycle, maintaining strict quality control was paramount. For the project, this involved implementing a robust quality assurance plan that included regular inspections, material testing, and performance evaluations. Ensuring that all construction phases met the predefined standards of quality guarantees the project's integrity and effectiveness. During the construction process for white topping overlay the routine testing was conducted for the PQC material by casting the cubes and beams as per requirement of IRC:15 and MoRTH Section 600. The test results were found to be above 45 MPa for the compressive strength and 4.7 MPa for the flexural strength of the concrete used for overlay construction. Regular slump testing was conducted for the overlay concrete and slump was maintained below 50 mm as paving was done manually using screed type finisher.

Post construction of the white topping overlay, the cores were taken to assess the overlay thickness as well as the in-situ strength of the concrete. It was observed that the core thickness was well above the design thickness of 175 mm and the average core test values were reported above 44 MPa. The roughness of the completed white topping overlay was checked after construction and 3 years post construction. The roughness values were found to be below the requirement of 2200 mm/ km after 7 years (2024) on the white topping overlay surface.

The role of the Project management consultant and Municipal Engineers in rejection of poor-quality work and substandard workmanship was very important to achieve the desired results from durability and aesthetics angle for the project.

Photo 49 Cube and Flexural Beam Casting for White Topping Concrete Overlay work

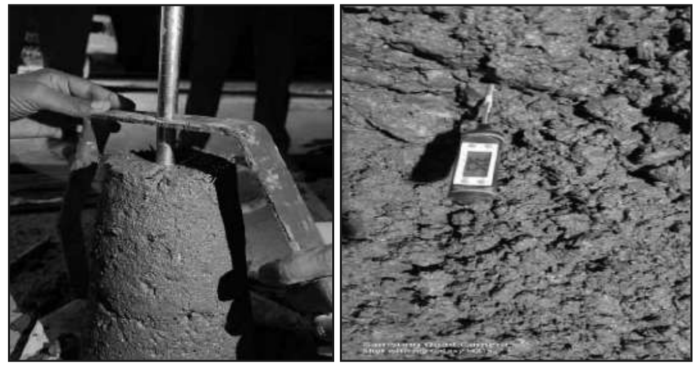

Photo 50 PQC Slump and Temperature Checks during White Topping Overlay

Photo 51 Compaction Density Checking for Utility Backfill and Footpath Portions

Photo 52 Ride Quality Assessment of Main Carriageway using Vehicle Mounted Bump Integrator Device

13. RESULTS AND IMPACT OF THE STREET PROJECT

Since its completion, the Aundh DP Road pilot project has significantly improved pedestrian safety, traffic flow, environmental quality and aesthetics along with improved business footfall for local shop owners. The project is used as an open mall with multiple activities such as pedestrian movement, shopping, recreational activities, sports activity, leisure walking, informal meetings and community engagements being practised in the reclaimed urban road space. The street has become a model for sustainable urban living, encouraging active lifestyles and enhancing public transport usage. The project's success is evidenced by its positive reception among residents and its recognition through several awards. Its impact extends beyond immediate functional and aesthetic improvements, contributing to broader goals of urban resilience and sustainability.

Photos 53 and 54 Visits to the Completed Aundh DP Road Street Projects by Various City Delegations

The Aundh DP project was visited by delegations from more than 35 cities and towns across India to understand the planning and implementation process for this project. Multiple cities across India implemented the learnings from this project and have constructed similar projects in their respective cities and towns under the smart cities mission and municipal funds. The Pune municipal corporation based on the learnings from the pilot project scaled the project to multiple arterial, sub arterial and collector as well as local streets across the city and has implemented more than 100 km streets using USDG principles and guidelines providing safe and pedestrian friendly roads. The **Photos 53** and **54** show the visit of delegations from other cities to study the learnings from Aundh DP Road project.

The said street is transformed in terms of pedestrian safety, traffic flow, and environmental quality. The project is seen as a model of sustainable urbanized way of living and encouragement towards constant lifestyle changes, besides reaping the increased use of public transport. Evidence of the success is in the form of residents taking the project in a very positive light, and awards conferred in plenty. But wider impacts are supposed to reach beyond these two aspects, instigating function and aesthetics in the immediate context and advancing further to contribute to the general goals of resilience and sustainability in urban communities.

Qualitative user acceptance was assessed through stakeholder consultations, interviews and feedback from residents, shopkeepers, pedestrians and local authorities; a statistically structured post-project perception survey was not undertaken and is acknowledged as a limitation of the present case study.

14. LEARNINGS FOR CONSTRUCTION OF DURABLE ROAD AND STREET INFRASTRUCTURE

The Aundh DP Road pilot project was completed in a short span of 7 months in 2017. After 8-9 years into operation the street project had required maintenance only in the form of repainting of road markings and arboriculture maintenance for trimming of shrubs in soft area, median etc. Apart from these minor activities, there has been no maintenance expenditure on civil or utility work or any other activity completed under the project. The project has showed zero or negligible damages or utility cuts in the past 8 years which were a result of meticulous planning, use of better material specifications and strict quality control and workmanship supervision from the authorities and consultants. The **Photos 55** and **56** show the present condition of the Aundh DP road project after 8 years into service since completion. Some key learnings that came out of the pilot project for construction of durable street infrastructure are enlisted below:

- Use of better specifications for civil works such as high-grade concrete, mortar, higher grade paver blocks, FRP material etc.
- Maximum use of factory finished products which have a longer service life.
- Capacity building of local contractors and agencies with handholding and training, knowledge upgradation sessions for the site and field staff.

- Strict supervision and vigilance during construction process and rejection of poor quality and workmanship
- Encouragement to contractors with good performance with bonus/incentives
- Proper coordination between utility service providers and road building agency and integrated contract with single responsible agency for all work items.




Photos 56, 57, 58 and 59 Aundh DP Road Street in 2026 - 9 years into Service Without Excavation or Road Maintenance

15. CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE PROJECTS

The Aundh DP Road project offers valuable lessons in urban street design and project execution and project management. Key takeaways include the importance of community engagement in the planning process, the benefits of interdisciplinary collaboration, and the need for flexible, adaptive project management strategies and tackling of the existing utilities with appropriate provisions. For future projects, the paper recommends a continued focus on sustainability, inclusivity, and innovation, proper assessment of existing utilities and future requirements suggesting that the principles and practices demonstrated by the Aundh DP Road can serve as a blueprint for the development of brownfield urban street infrastructure across India and beyond. A performance indicator table that captures various parameters addressed and improved under this project is presented.

The typical problems faced during execution of a brownfield urban road project which included the reorganization utilities were tackled by appropriate decisions regarding the laying of new utilities or retaining of the existing utilities with safe cover and future maintenance provisions. The problems related to the raising of the road and footpath level above the adjacent properties was addressed by ensuring the connection of the low-lying areas inside the property to the main storm lines through extra catchpit chambers. During the past 8 years of service, the removal of paver blocks for sewer line maintenance has occurred on single occasion. Apart from this incidence, no major cutting or disturbance to the road infrastructure was required due to appropriate treatment of the existing utilities.

Some of the innovative design features successfully implemented on this project and some recommendations for future projects are tabulated.

Performance Indicator	Before Construction 2016	After redevelopment / present (2026)	Change/Outcome	Evidence
Effective walkable footpath width	Severely constrained/ discontinuous	≥3.5 m uninterrupted and continuous	Major improvement in safe walkability for all users with universal accessibility for specially abled persons	Site measurements and observations
Traffic Volume	3,000 PCU/h	3,500 PCU/h	Observed peak-hour traffic throughput increased by approximately 16–17%, while traffic remained satisfactorily accommodated after channelization and lane-width rationalisation	Site Traffic survey
Lane width	3.5 to 3.7 m	3.0 m	Lane and carriageway width is rationalised and traffic is streamlined	As-built drawing/ site measurement
Raised Pedestrian crossing	Not available	Provided at every 250 m	Improved accessibility and safe crossing for all users	As-built and observations
Utility road cuts	frequent/risk due to absence of crossing and utility ducts along the road	Zero major road cutting in past 8 years	Major improvement in avoiding utility cuts for city road	PMC records/ site inspection
Waterlogging observations	3 to 4 locations of waterlogging	Zero reported in 8 years	Improvement in the storm water management and dispersal	PMC/site records
Pavement roughness	Bump integrator (BI) roughness values above 2900 mm/km	BI value less than 2000 mm /km	Satisfactory and improved ride quality	Bump Integrator testing as per IRC
Concrete core strength	—	>44 MPa	Satisfactory	Core testing repots as per IS
Road maintenance	conventional recurring overlay requirement after 3 to 4 years	negligible over 8 years. No maintenance overlay required	Improved durability and serviceability	PMC/project records
Road Level	Frequent changes due to overlay and patching	Fixed and unchanged over past 8 years	Road level fixed and unchanged	Site inspections and observation
Trees retained	140 Trees	100 % retained with addition of 25 new trees	Environmental benefit and retention of complete green cover	Project records
User perception	Poor walkability, un-safe crossings and haphazard road use, wastage of road space	Channelization of traffic, availability of walkable, shaded and safe footpaths with universal accessibility, safe crossings and adequate lighting	Acceptance by public & elected representatives with replication of this designand learning concepts on additional 80 km of other roads in the city	User interviews /survey

Innovative feature	Purpose	Aundh DP Road experience/ performance	Recommendation for future projects
3.0 m lane width	Rationalised carriageway	Functioning successfully	Suitable after traffic trial/ context assessment
Full-scale mock trial	Test design before execution	User feedback incorporated and refinement in design	Strongly recommended
Utility marker paver bands	Locate electrical utilities, OFC etc	Easy maintenance	Replicable for other projects
Integrated utility contract	Avoid repeated trenching & responsibility shifting	Zero major road cutting & ease of execution of project	Highly recommended for future road projects
White topping Overlay	Long-term maintenance free pavement	Good 8-year performance	Suitable subject to pavement evaluation
Turning buffers	Access/parking management	Clear property access	Replicable for other roads
Tree breathing/seating zones	Preserve canopy/social space, tree soil cover	Existing trees retained	Recommended
Cobble traffic-calming zone	Reduce pedestrian crossing approach speed	Functioning successfully ensuring safe road crossing	Use after skid/comfort assessment

There were an inordinate number of learning experiences and lessons that can be gleaned from the Aundh DP Road project, in the context of urban street design and project management in general. This is likely to involve lessons about the engagement of communities in the planning process, the payoffs from interdisciplinary collaboration, and flexible and adaptive strategies of managing a project. A continuing cry is such, therefore, on the other projects, for sustainability, inclusion, and innovation in planning. Of the Aundh DP Road, and probably every part of India, it can be referred to as a prototype of its kind in the development of urban road infrastructure in a developing country.

As cities continue to redevelop existing urban corridors, the principles demonstrated by the Aundh DP Road project reinforces the importance of designing streets as Complete Streets, from property edge to property edge (between the existing Right of way). Complete streets accommodate equitable distribution of road space which includes vehicular movement, parking, safe and seamless walking and cycling, trees, street lighting, signages, dustbins, landscape, organised hawkers –as per need availability of space.

An effort of creating designed streets will help in achieving walkability and encourage cycling by people up to 1 - 1.5 km (popularly called last mile) as a part of once daily routine.This will help in reducing the use of motor vehicles for shorter trips in particular, leading to reduction of pollution and congestion on streets. Research has also proved that walking and cycling when made part of the daily activities reduce blood-pressure, diabetes, hyper tension thus helping in, creation of Healthy, Hygienic and Humane neighbourhoods. To achieve this, it is very important to have the political and administrative will of all government agencies such as municipal corporations, traffic police etc. along with support of stakeholders such as commercial establishments, educational institutes, residential welfare associations, NGO's etc.

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IMPROVEMENT OF FWD ANALYSIS WITH COMBINATION OF KGP BACK AND IIT PAVE



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ABSTRACT

The Indian Roads Congress (IRC) published IRC:115-2014 for conducting deflection testing using the Falling Weight Deflectometer (FWD) and for analysing deflection data through the KGP Back Analysis software. The maximum allowable resilient modulus of the subgrade is limited to 100 MPa as per IRC: 37-2018 whereas Austroads 2024 and AASHTO 1993 allow values up to 150 MPa.

This paper proposes an improvement to the KGP Back Analysis by introducing a deflection bowl matching approach using IIT Pave to achieve improved results. Although a similar concept is embedded within the KGP Back analysis, the proposed method be responsible for a more refined execution. The deflection bowl obtained from field FWD tests is compared with analytically computed surface deflections at sensor locations using IIT Pave software. Initially, the E-values of pavement layers are determined using KGP Back software through a trial-and-error process, and the best-fit values are identified using the Least Squares Error method, Root Mean Square Error (RMSE) method and Normalised Root Mean Square Error (NRMSE) method.

A case study was adopted and analysed using KGP Back. The E-values achieved from KGP Back were then used in IIT Pave software to generate the corresponding deflection bowl. The subgrade modulus is subsequently determined using the same deflection bowl matching approach. This combined methodology using KGP Back and IIT Pave software provides a practical and effective solution.

The resilient modulus of the subgrade was found to exceed 100 MPa. Based on this finding, an upper limit of 150 MPa for the subgrade resilient modulus may be considered, in line with Austroads 2017; however, further investigation through laboratory and in-situ testing is required. The deflection bowl matching method is shown to be a more accurate and practical approach for determining reliable resilient moduli of existing pavement layers and for enhancing overlay thickness.

The modulus ranges are identified through multiple iterations by evaluating the corresponding NRMSE values, with the lowest NRMSE indicating the best-fit modulus range. This best-fit range is then selected for FWD-based analyses such as remaining life assessment and overlay design. To streamline and expedite this iterative modulus range selection an Excel tool has been developed.

1. INTRODUCTION

The Indian Roads Congress (IRC) developed IRC:115-2014 for field test and the analysis of Falling Weight Deflectometer (FWD) test results for flexible pavements. However, this code has several limitations which are not clearly defined in this code and outlined here in:

- The deterioration of resilient modulus (E-value) of asphalt mixtures over time is not clearly defined;
- Selection of the initial resilient modulus for analysis;
- The relationship between the initial E-value and pavement temperature along with age of pavement;
- The code mandates the use of a 15th percentile modulus, which can lead to conservative estimates;
- The E-value, after temperature correction, tends to be more conservative than the actual in-situ value;
- The analysis approach for newly constructed pavements

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differs significantly from that for pavements aged 5, 7, 10, or 15 years;

- Poisson ratio variation. Literature review suggests that pavement may be considered as similar to new pavement up to 6 years of service pavement.
- Determination E-value from grading, penetration of bitumen and other rheological properties of bitumen etc.

1.1 Percentile Explanation

The 15th percentile is a statistical portion representing thE-value below which a specified percentage of observations in a dataset fall. Specifically, the 15th percentile specifies thE-value below which 15 per cent of the observations lie, meaning that the remaining 85 per cent of values are higher than this point. It describes the lower-end distribution of data and is commonly used to identify conservative or characteristic values in fields such as engineering, quality control and performance assessment. By ranking the data from smallest to largest and locating the position corresponding to 0.15 of the total number of observations, analysts can determine this percentile and better understand variability and relative standing within the dataset.

1.2 Limitations of Current FWD Analysis Practice in India

FWD analysis is based on both forward and back-calculation procedures. However, it has been observed that the FWD deflection bowl obtained from field tests often does not align well with the deflection bowl simulated using IITPave software when E-values derived from the KGP Back Analysis output are used. Similar observation is noticed from the analysis of Rubicon and Elmold Software. This mismatch leads to inaccurate or potentially misleading results, which is a common issue in FWD analysis, including with KGP Back. Additional trials are required to obtain more reliable and accurate outcomes. The issue can be addressed by plotting the deflection bowl curve using field FWD data alongside predicted data generated in IITPave using the E-values obtained from KGP Back, particularly since KGP Back does not currently provide a deflection bowl graph as output. Accordingly, KGP Back may be modified to generate deflection bowl plots and error calculation. Furthermore, multilayer analysis, including four- and five-layer systems, should be incorporated into KGP Back.

Finally, KGP Back requires modification to prepare deflection bowel graph, determination value of NRMSE and FWD analysis of pavements with more than three layer pavement system.

1.3 Subgrade Resilient Modulus Calculations and Limitations

IRC:37-2018 recommended limiting the maximum California Bearing Ratio (CBR) to 15% for pavement design purposes. The following equations are used to estimate the Resilient Modulus (E) of the subgrade based on CBR:

For CBR ≤ 5):E=10×CBR (MPa) (1)

For CBR > 5):E=17.6×CBR$^{0.64}$(MPa) (2)

According to this, if CBR = 15, the subgrade modulus is calculated as: $E=17.6\times15^{0.64}\approx99.6$ MPa≈100 MPa. As per IRC Sub-section 6.4.2**,** the maximum resilient modulus is therefore limited to 100 MPa**.**

1.4 International Comparisons

Other international standards recommend different approaches:

- AASHTO (1993):E=1500×CBR (in psi)
- Austroads (2017):E=10×CBR (in MPa)

Austroads further limits the maximum CBR to 15, corresponding to a maximum resilient modulus of 150 MPa. The recommended maximum subgrade CBR, as specified in IRC:37-2018 and Austroads 2017/2024, is 15 per cent. The PMGSY Manual recommended determining the CBR of subgrade based on the material gradation, while AASHTO 1993 provides correlation graphs between CBR and E-values, R-values, and other relevant parameters. The PMGSY figure is shown in **Fig. 1**. From this **Fig. 1**, it is noticed that CBR more than 15 % is possible and relooking of E-value of subgrade may be reviewed. However, Triaxial test results/field E-value using light weight falling deflectometer will be finally reviewed but this results are not available for presently.

1.5 Field Observations and Implications

Presently, FWD tests are being conducted on numerous road projects across India. It has been observed that in many borrow areas, the CBR values exceed 15 percent, and in some cases are significantly higher. Despite this, current IRC codes do not permit the use of higher CBR values when determining E-values, which may lead to an underestimation of the true strength of the subgrade.

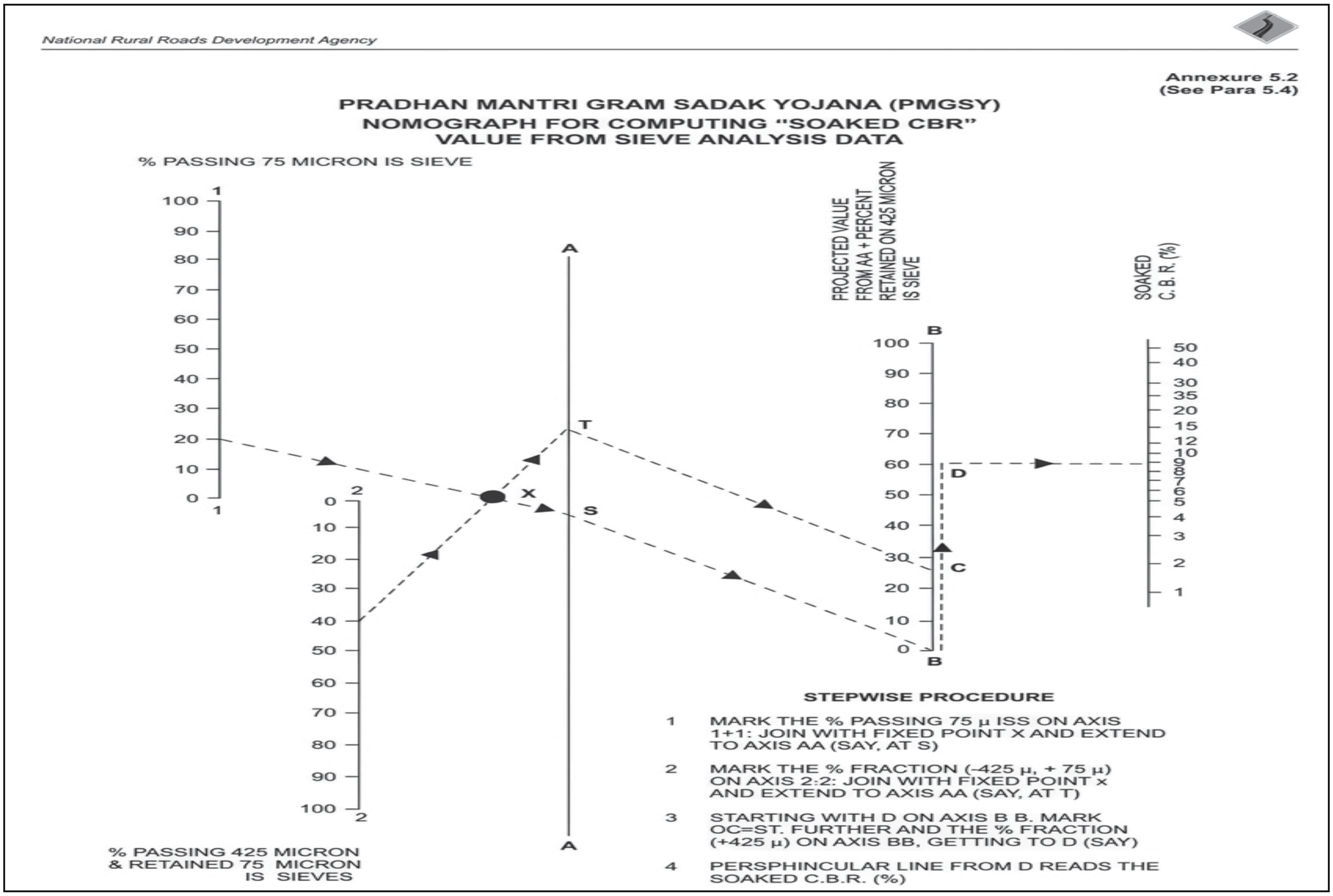

Fig. 1 Determination of CBR Based on Soil Gradation (Source: PMGSY Manual)

Analysis of FWD field results from various projects indicates that the resilient modulus of the subgrade often exceeds 100 MPa. This highlights the need to revise codal limits and consider adopting higher permissiblE-values for the resilient modulus, in line with international practices such as Austroads 2017/2024.

This study may be carried out based on FWD results with a separate study taking FWD results from different parts of India along with light weight falling deflectometer/plate load test results correlation/field CBR using truck loading.

2. OBJECTIVES AND SCOPE OF THE PRESENT STUDY

As discussed earlier, practicing engineers often encounter two key challenges during the analysis of FWD data. These are:

- The upper limit of subgrade resilient modulus (E-value) prescribed by current standards may not accurately reflect actual field conditions.
- The theoretical deflection bowl calculated using software, such as IITPave, often does not correspond with the actual field deflection bowl obtained from FWD tests, particularly when using E-values derived from KGP Back Analysis.

This present study addresses both of these issues:

- The need to re-evaluate and potentially increase the upper limit of the subgrade resilient modulus to 150 MPa, in line with international standards such as Austroads 2017/AASHTO 1993 based on very limited FWD Field Results.
- The development of a reliable method for deflection bowl matching, ensuring that the field-measured FWD deflections make even more closely with theoretical predictions.

2.1 Proposed Methodology

The study proposes a methodology based on:

i. The concept of FWD deflection bowl matching through trial-and-error adjustment of pavement layer E-values using IITPave Software.

ii. An evaluation of the upper bound of subgrade resilient modulus, with consideration for increasing it from

100 MPa (as per IRC) to 150 MPa based on FWD analysis using deflection bowel matching method/ concept.

This approach is designed to enhance the accuracy of back-calculation and improve the reliability of pavement performance evaluation. The detailed methodology adopted in this study is illustrated in **Fig. 2.**

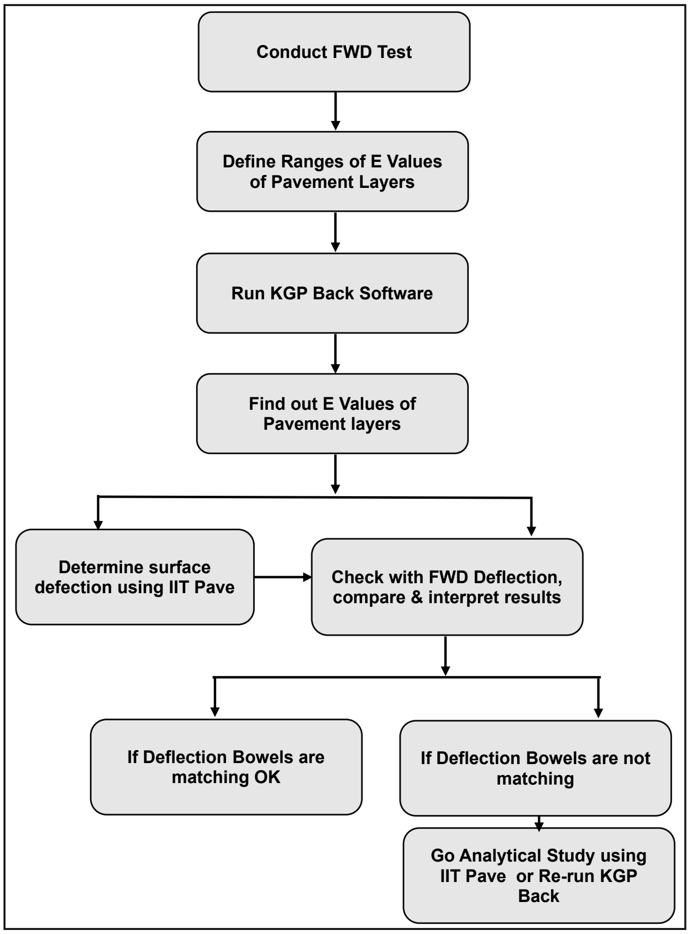

Fig. 2 Flow Chart for Proposed Methodology

According to IRC:115-2014, the initial range of the resilient modulus (E-value) for the asphalt mix is typically selected between 2600 and 3000 MPa, based on field pavement temperatures of 35°C to 37°C during FWD testing and VG 40 bitumen was used in the mix design. The pavement was constructed two years ago. Past literature suggested that behaviour of pavement with service life up to 6 years may be considered as new pavement. Poisson Ratio and Fatigue life equation as mentioned in IRC:37-2018 may be used FWD analysis. Generally, asphalt layer is constructed around 6% air void during construction and after 2 years' service air void reduces to around 3% and climatic effect is less. Hence, there will not be very much variation of asphalt mix properties.

An alternative approach involves matching the field deflection bowl obtained from FWD testing with the theoretical deflection bowl calculated using IITPave Software taking output of FWD analysis. This will minimise the error to determine the most accurate set of layer moduli. This concept is illustrated through a practical example and presented here in.

In the FWD setup, seven sensors are positioned at distances of 0, 200, 300, 450, 600, 900, and 1200 mm from the load center to record surface deflections. The spacing may be varied as per requirement of purchasing agency. After obtaining the E-values of pavement layers using KGP Back Analysis, the corresponding theoretical surface deflections are calculated at the same sensor positions using IITPave Software.

Both the measured and theoretically predicted deflection bowls are plotted. The sum of the absolute differences (errors) between the two or more sets of deflections is calculated, and the dataset yielding the minimum error is identified as representing the best-fit E-values for the pavement layers.

The average normalised deflection readings collected over a 5 km stretch of the project road at the specified sensor locations are presented in **Table 1**. The FWD tests were conducted under pavement surface temperatures ranging from 35°C to 37°C.

Table 1 FWD Reading

Sensor	D0	D1	D2	D3	D4	D5	D6
Distance (mm)	0	200	300	450	600	900	1200

It is generally assumed that the resilient modulus (E-value) of asphalt mix decreases over time. However, field observations suggest that the E-value often remains constant or even increases after construction but crack may be devloped. E-value will be reduced due to crack formation and reduction E-values as mentioned in IRC:115/Austroads and AASHTO 1993 may be followed for reliable analysis. This can be attributed to high-quality construction practices, the use of VG 40 bitumen, and age hardening effects due to oxidation and stiffening of the bitumen over time.

In this study, VG 40 bitumen was used in the bituminous mix. The E-value was taken as 3000 MPa at 35°C and 2600 MPa at 37°C, based on temperature-dependent behavior of E-value as shown in Table 9.2 of IRC:37-2018 and same is shown in **Fig. 3**. E-value at 37^{0}C is calculated, E=-37*200+10000=2600 MPa

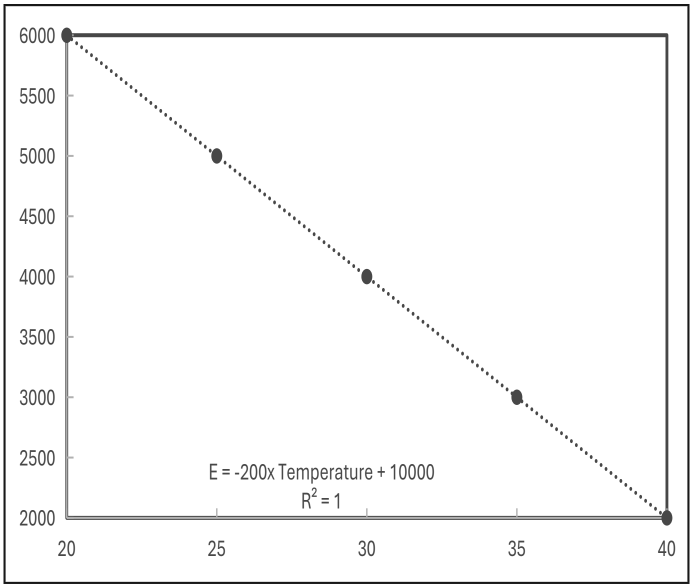

Fig. 3 Relationship between E-value Vs Temperature for VG 40 Asphalt Mix

For the subgrade, an E-value of approximately 99.6 MPa corresponds to a CBR of 15%, which is rounded to 100 MPa as per IRC guidelines. However, due to high DCP-CBR values, a broader range of 100 to 200 MPa was considered for the subgrade E-value. IRC:115 also recommended that E-value varied from 5 to 20 times of CBR of subgrade.

The resilient modulus of the granular layer was estimated using the empirical formula:

$E=0.2\times100\times(200)^{0.45}\approx217\ \text{MPa}$

For the analysis, the following ranges were adopted initially and revised later:

- Subgrade: 100–150 MPa
- Granular layer: 200–300 MPa
- Bituminous layer: 2600–3000 MPa

Using these ranges, and revised range later, the KGP Back Analysis Software provided the following E-values:

- Bituminous layer: 2606.5 MPa
- Granular layer: 285.1 MPa
- Subgrade: 100 MPa

ThesE-values were then used in IITPave software to calculate theoretical/predicted surface deflections at sensor locations of 0, 200 mm, 300 mm, 450 mm, 600 mm, 900 mm, and 1200 mm, respectively. The results are shown in **Fig. 4.**

To address the mismatch between theoretical and field deflection bowls, the FWD deflection bowl matching approach was applied. The least squares regression method was adopted to identify the best-fit E-values by minimising the sum of squared errors between the measured and theoretical deflections. The ER^2 was also calculated to assess the goodness of fit.

This method requires multiple trial iterations to refine the E-values and achieve optimal results.

2.2 Least Square Method, RMSE & NRMSE Methods

The least squares method is a widely used statistical technique for finding the best fit between observed data and a predictive data. Its general applications include:

- Determining the best-fit line or curve by minimising the sum of squared differences (residuals) between observed values and model-predicted values.
- Predicting dependent variables based on independent variables in regression models.
- Justifying the placement of a trendline or curve among scattered data points.
- Supporting both linear regression (Ordinary Least Squares) and non-linear regression models.
- Minimising vertical distances between data points and the regression line or curve, thus reducing variance and increasing model accuracy.

For instance, an analyst may use this method to define the relationship between input and output variables in experimental or field data. When a linear relationship is suggested, the resulting regression line minimises the total squared deviation between actual and predicted values hence the term “least squares.”

The accuracy of predicted pavement responses was evaluated using the Normalized Root Mean Square Error (NRMSE), which quantifies the average deviation between measured and computed values relative to the data magnitude. Following widely accepted guidelines in statistical modeling and pavement back-calculation practice (Hyndman and Athanasopoulos 2018; Willmott 1982; FHWA 1997; AASHTO 2008; TRB 2000), the RMSE-values were classified into a five-point rating system to assess model performance. **Table 2** summarises the rating scale proposed in this study. Rating scale revised to achieve better results.

The standard Equations will be used to determine RMSE and NRMSE determined using the following Equation.

$$RMSE = [(\frac{1}{N}) \times \sum_{i=1}^{i=N} (Dmeasured - Dpredicted)^2]^{0.5}$$

where,

$D_{measuredi}$= Measure deflection from FWD

$D_{predictedi}$= Deflection obtained from IITPave

N= Number of sensors are used during test.

$$NRMSE=\frac{RMSE}{Dmax-D\ min}$$

where,

D max= Maximum Measured Deflection

Dmin= Minimum Measured Deflection

Table 2 NRMSE (%) Value Rating System

NRMSE-value (%)	Analysis Rating	Remarks
0-2.5	Excellent	Acceptable
1.5-5.0	Good	Acceptable with minor improvement of E-values
5.0-10.0	Fair	Acceptable with major improvement of E-values
10-15	Poor	Not acceptable. Need more trial
>15	Very Poor	Not acceptable. Need more trial

2.2.1 Application in pavement deflection analysis

In this study, the least squares method is used to match the field-measured FWD deflection bowl with the theoretical deflection bowl computed using IITPave software by minimising the sum of squared errors between the corresponding deflection values. The step-by-step procedures are as follows:

i. Field Deflection Data: Let the deflections measured at sensor locations (0, 200, 300, 450, 600, 900, and 1200 mm) be denoted as d1f,d2f,dnf.

ii. Assumed Moduli ranges: For a trial set, assume:

iii. Subgrade modulus: Esub

iv. Granular layer modulus: Egran

v. Asphalt mix modulus: EmixE

vi. Computed Theoretical Deflections: Using IITPave, calculate deflections at the same points: d10, d20, dn0d, dn0

vii. Residual Error Calculation: $ER^2 = \sum i = 1n\ (dif-di0)^2 = \sum n\ (dif-di0)^2$ where ER^2 is the sum of squared differences between field and theoretical deflections for a given trial. Lowest RE^2 in the analysis set will be considered possible best results. Ideal case, value of RE^2 will be zero.

viii. Alternatively RMSE or NMRSE method will be followed as mentioned above and rating value is shown in **Table 2.** Lower range may be adopted to achieve better E-values of pavement layers.

ix. Optimisation: Repeat the process for multiple trial sets. The trial that results in the minimum ER^2 or lowest RMSE or NMRSE is considered the best-fit and provides the most realistic E-values for the pavement layers.

3. RESULTS AND CASE STUDY

The method was applied to FWD test data collected from a project constructed two years ago. As per IRC:115-2014, the followings were considered:

- Single wheel load: 40 kN
- Tyre pressure: 0.56 MPa
- Normalized surface deflections were recorded at sensor locations.

These data were input into the KGP Back Analysis Software, which uses an internal trial-and-error process to generate the best-fit E-values for pavement layers. The resulting output from KGP Back was:

- Asphalt mix: 2606.3 MPa
- Granular layer: 275 MPa
- Subgrade: 100 MPa

Using thesE-values, theoretical surface deflections were calculated at sensor points and plotted in **Fig. 4**. The corresponding error value, ER^2, was found to be 20764, as shown in **Table 3**.

To improve the accuracy, the Deflection Bowl Matching method was applied using the trial-and-error method in IITPave. A series of E-value combinations were tested, and the theoretical deflections were compared against field deflections. The error ER^2 for each trial was computed.

The best-fit trial yielded ER^2 value of 456.5 as shown in **Table 3** and best fit matching deflection bowel is shown in **Fig. 5**, significantly lower than that of the KGP Back output, indicating a much better matching of deflection bowels.

4. REVISED SUBGRADE MODULUS

During the trials, the subgrade modulus was varied between 100 MPa and 170 MPa. The best match between field and theoretical deflections was obtained at a subgrade modulus of 165 MPa. This value is well above the currently accepted upper limit of 100 MPa as per IRC:37-2018.

It is found from field observations from multiple FWD studies, the results strongly suggest that the upper limit for subgrade resilient modulus should be re-evaluated.

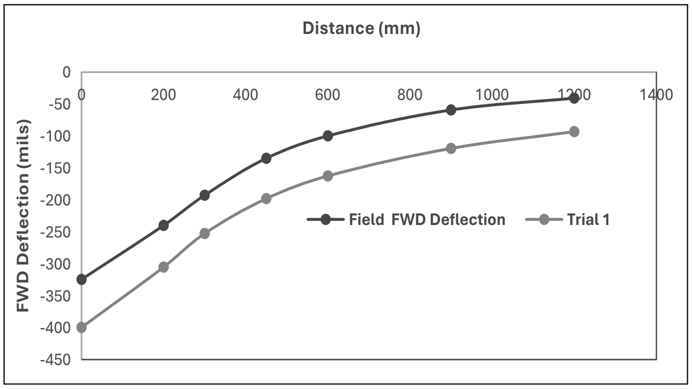

Fig. 4 Deflection Bowel after Initial Trial and Actual Filed FWD Deflection

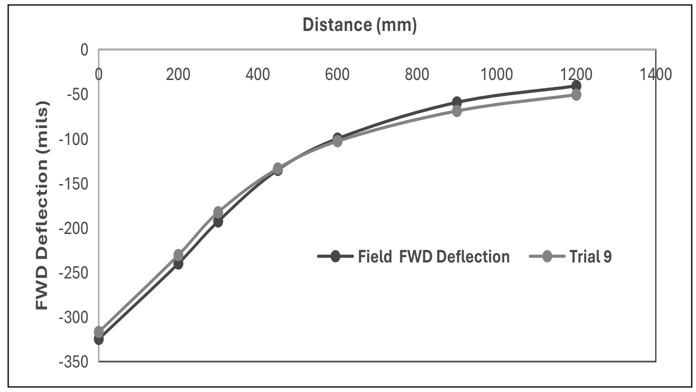

Fig. 5 Deflection Bowel at 9th Trial and Actual Filed FWD Deflection

The final analysis is carried using IITPave Software and presented in **Fig. 6**. Selected ER^2 and RMSE-value is shown in **Table 3.**

```
E values (MPa)        2900.00  285.00  165.00
Mu values                0.350.350.56
thicknesses (mm)       120.00  450.00
single wheel load (N) 40000.00
tyre pressure (MPa)       0.56
Single Wheel
  Z        R      SigmaZ      SigmaT     SigmaR     TaoRZ      DispZ      epZ        epT        epR
  0.00    0.00-0.5525E+00-0.1268E+01-0.1268E+01 0.0000E+00 0.3168E+00 0.1155E-03-0.2174E-03-0.2174E-03
  0.00  200.00-0.2187E-02-0.4456E+00-0.1425E+00-0.4001E-08 0.2305E+00 0.7022E-04-0.1362E-03 0.4899E-05
  0.00  300.00 0.3002E-03-0.2168E+00 0.5228E-01 0.1854E-08 0.1825E+00 0.1996E-04-0.8111E-04 0.4416E-04
  0.00  450.00 0.4694E-03-0.8112E-01 0.9057E-01 0.1690E-07 0.1334E+00-0.9785E-06-0.3896E-04 0.4097E-04
  0.00  600.00 0.1268E-03-0.3819E-01 0.6352E-01-0.5783E-08 0.1028E+00-0.3013E-05-0.2085E-04 0.2650E-04
  0.00  900.00-0.8508E-04-0.1385E-01 0.2761E-01-0.6363E-08 0.6889E-01-0.1689E-05-0.8099E-05 0.1120E-04
  0.00 1200.00 0.3002E-04-0.5797E-02 0.1639E-01-0.7715E-09 0.5061E-01-0.1268E-05-0.3980E-05 0.6346E-05
```

Fig. 6 IITPave Output

Table 3 Sample Calculation of ER^2 Values and RMSE-values

Distance (mm)	Field FWD Deflection	Trial 9	ER^2	Trial 1	ER^2
0	-324.6	-316.8	60.84	-387.2	3918.76
200	-240	-230.5	90.25	-296	3136
300	-192.8	-182.5	106.09	-245	2724.84
450	-135	-133.4	2.56	-191	3136
600	-99.9	-102.8	8.41	-156	3147.21
900	-59.3	-68.9	92.16	-111.8	2756.25
1200	-40.8	-50.61	96.2361	-84.9	1944.81
		Sum	456.5461		20763.87
		NRMSE	2.85 %		19.1 %

NRMSE-value of trial 9 is found to be 2.85 % which lesser than 19.1 % as found from trial 1.

Deflection bowels have also been prepared using other Software (Rubicon & Elmold) and presented in **Fig. 7** and deflection results are presented in **Table 4.**

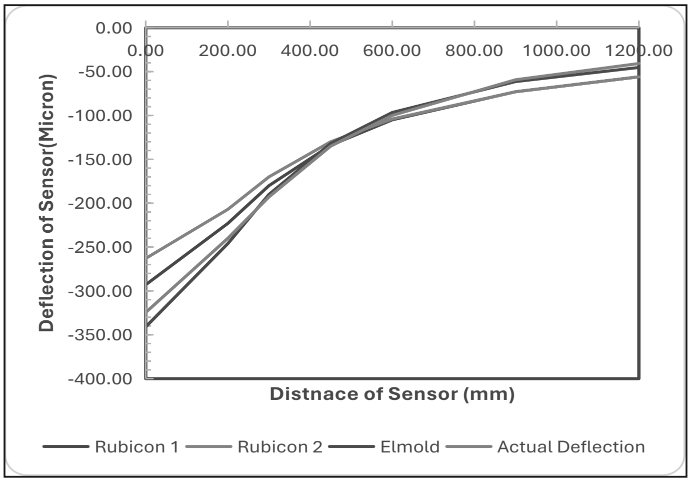

Fig. 7 Deflection Bowels using Different Software

Table 4 Deflection Analysis Using Different Software

Sensor Distance (m)	Rubicon 1	Rubicon 2	Elmold	Actual FWD Deflection
0.00	-293.00	-263	-341	-324.60
200.00	-223.00	-207	-246	-240.00
300.00	-180.00	-170.00	-190	-192.80
450.00	-134.00	-130.00	-132	-135.00
600.00	-105.00	-104.00	-96.6	-99.90
900.00	-73.00	-73.00	-61.4	-59.30
1200.00	-56.00	-56.00	-45.3	-40.80
NRMSE (%)	5.80	10.20	2.52	0
E-value in MPa				
E-value of Asphalt	2000	2900	2912	2900*
E-value of Granular	265	285	208	285*
E-value of Subgrade	165	165	201	165*

*Note * Best value*

From **Fig. 7**, it is found that there are also wide variation of deflection bowels as obtained from Rubicon Software for varying E-values of the pavement layers. Hence, the analysis is found to be satisfactory RMSE and NRMSE-values as shown in **Table 4**.

Variation of E-value of subgrade has been carried out using different ranges of subgrade E-values and other layers as shown in **Table 5**. Coefficient of variation for E-value of subgrade is found to be 9.2% which is less than maximum upper limit of 25%. Hence, analysis is satisfactory.

Table 5 Analysis of Subgrade E-value Variation

Layer	E-value Range (MPa)				
	Trial 1	Trial 2	Trial 3	Trial 4	Best Trial
Asphalt	2850-2950	2875-2925	2890-3500	2600-3300	
Granular	290-300	285-295	280-350	250-400	
Sungrade	160-170	162-172	100-250	75-240	
E-values obtained from KGP BACK					
Asphalt	2852	2893	2926	2623	2900
Granular	290.2	285.1	280.1	250.4	285
Sungrade	170.2	172	197	201.1	165
Mean subgrade	181.06				
Standard Deviation	16.69				
Coefficient of Variation	9.2%	< 25 %			

4.1 Range of Subgrade

Many FWD analyses in India have carried out based on FWD Field results from different parts of India. IRC limited maximum E-value is 100 MPa. From FWD analysis as shown in **Table 5**, it exceeds 100 MPa. E-value is limited to 150 by Austroads and AASHTO 1993. IRC:115 recommended that range of subgrade varying from 5 to 20 times of CBR (Refer Section III.8.4 Page 30 of IRC:115). Considering CBR 15 and upper range is found to be 300 MPa. Hence, E-value of subgrade may be exceeded 100 MPa but this needs further investigation to determine field CBR using Light Weight Falling Deflectometer (LWFD) and Field CBR using truck loading. This LWFD analysis is not carried out presently and this is not reported. However, subgrade E-value determination using deflection bowel concept may be useful based on FWD Results and same may be revalidated using light weight falling dfelectometer or field CBR using plate load test / truck mounted vehicle.

5. CONCLUSIONS

Based on the findings of the present study, the following conclusions may be drawn:

- The use of KGP Back Software may be modified, as it presents limitations in accuracy and flexibility compared to the proposed methodology. This needs more trial to get reliable E-values of pavement layers so that deflection bowel obtained from IITPave and actual FWD Field are comparable. Normalised Root Mean Square Error (NRMSE)) value will be within 5 to 7.5% error. Error more than 7.5% needs more KGP Back trial.

- IRC:115-2014 provides guidelines for FWD testing and analysis of flexible pavements, but several restrictions exist i.e., undecided deterioration of asphalt E-values over time, selection of initial E-values /seed modulus, temperature-age effects of E-value, mandatory use of the 15th percentile, conservative temperature-corrected E-values, and variations in analysis for pavements of different ages.
- FWD analysis often shows a mismatch between field-measured deflection bowls and predicted E-value from IITPave Software when using KGP Back-derived E-values, leading to potentially inaccurate results. This is also same for Rubicon Software.
- KGP Back currently cannot generate deflection bowl plots and is limited to analysing up to three layers; and multilayer (four- and five-layer) analysis are recommended for upgradation of KGP Back in future.
- IRC:37-2018 limits subgrade CBR to 15%, corresponding to a maximum E-value of 100 MPa, whereas international standards (Austroads 2017/2024, AASHTO 1993) allow higher values up to 150 MPa. Field FWD data in India based on FWD results indicate subgrade E-values often exceed 100 MPa, suggesting a need to revise codal limits.
- FWD deflection bowl matching using IITPave and least squares, RMSE, and NRMSE methods provides a more accurate determination of pavement layer E-values. Multiple trial iterations refine the best-fit values.
- Case study results show significant improvement in matching deflection bowls: KGP Back output ER^2 = 20,764, while trial-and-error deflection bowl matching reduces ER^2 to 456.5, with the subgrade E-value optimised at 165 MPa.
- Analysis of E-value variation subgrade along with other layers shows a coefficient of variation of 9.2% for subgrade, within acceptable limits (<25% as recommended Austroads 2017), confirming satisfactory analysis /results.
- Subgrade E-values in India may exceed the IRC limit of 100 MPa, potentially up to 150–300 MPa based on CBR correlations; further validation using Light Weight Falling Deflectometer or field CBR is recommended.
- The methodology ensures improved accuracy in pavement performance evaluation, reliable back-calculation of layer moduli, and practical implementation for overlay design and remaining life assessment.

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PROFORMA FOR GENERAL REPORT ON ROAD RESEARCH

IRC HIGHWAY RESEARCH BOARD
PROFORMA - A

PROJECTS REPORTED FOR THE FIRST TIME & ON GOING PROJECTS

REPORTING ORGANISATION:

Section Code

SUB-Section Code

1 Project Title
   1.1 Date of Start
   1.2 Date of Completion (Targeted/Actual)
2 Organisation(s)*
3 Scope and Objectives
4 Methodology
5 Interim Conclusions/Conclusions/Supporting Data
   5.1 Significance/Utilisation Potential
   5.2 Limitations of Conclusions/Recommendations for further work/further proposed work
6 Reports/Publications
7 Further information/Copy of report can be obtained from:
   7.1 Address ____
   7.2 Mobile ____________________ Phone ____________________
   7.3 e-mail ID: ____

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* Please indicate the appropriate organization code – (R), (S), (C), (I), (R,S), (R,C), etc. after each organization.

IRC HIGHWAY RESEARCH BOARD
PROFORMA - B

COMPLETED PROJECTS

REPORTING ORGANISATION:

Section Code

SUB-Section Code

1 Project Title
   1.1 Date of Start
   1.2 Date of Completion (Targeted/Actual)
2 Present Status and Progress
   2.1 Status: Ongoing/Completed
   2.2 Year of Last Report
   2.3 Progress
3 Further Findings/Conclusions/Supporting Data
4 Limitations of Conclusions or Interim Conclusions
5 Recommendations for further Work (if completed)
6 Reports / Publications
7 Recommendations for Dissemination/Revision of Codes/Specifications (if completed)
8 Field Applications
9 Further information/Copy of report can be obtained from:
   9.1 Address ____
   9.2 Mobile ____________________ Phone ____________________
   9.3 e-mail ID: ____

(Presentation Material may be e-mailed to ircjrr2026@gmail.com / secygen.irc@gov.in)

PROFORMA FOR GENERAL REPORT ON ROAD RESEARCH

IRC HIGHWAY RESEARCH BOARD

PROFORMA - C

RESEARCH PROJECTS RELATED TO THESIS FOR POST-GRADUATION/PH.D.

REPORTING ORGANISATION:

Section Code

SUB-Section Code

1 Project Title
   1.1 Date of Start and Duration
   1.2 Date of Completion
2 Institution*
3 Scope and Objectives
4 Proposed Methodology (Type of Study, Laboratory/Field)
5 Salient-Findings and Conclusion(s)
6 Recommendations for Dissemination/Revision of Codes/Specifications (if completed)
7 Further information/Copy of report can be obtained from:
   7.1 Address ____________________
   7.2 Mobile ____________________ Phone ____________________
   7.3 e-mail ID: ____________________

(Presentation Material may be e-mailed to ircjrr2026@gmail.com / secygen.irc@gov.in)

* Please indicate the appropriate organization code – (R), (S), (C), (I), (R,S), (R,C), etc. after each organization.

IRC HIGHWAY RESEARCH BOARD

PROFORMA - D

R&D ACTIVITY REPORT BY CONSULTANCY FIRMS/CONTRACTORS/CONCESSIONAIRES

REPORTING ORGANISATION:

Section Code

SUB-Section Code

1 Project/Activity Title
   1.1 Date of Start and Duration
   1.2 Date of Completion (Actual/ Targeted)
2 Organisation(s)*
3 Special Situations/ Problems faced During Investigations/ Constructions:
4 Methodology / Procedure adopted for solving the Problems:
5 Any New Materials/ New Technologies if Adopted:
6 Performance of such New Materials/ Technology:
7 Additional R&D / Work required in this area:
8 Further information/Copy of report can be obtained from:
   8.1 Address ____________________
   8.2 Mobile ____________________ Phone ____________________
   8.3 e-mail ID: ____________________

* Please indicate the appropriate organization code – (R), (S), (C), (I), (R,S), (R,C), etc. after each organization.

No. NH-24028/03/2026-H
GOVERNMENT OF INDIA
MINISTRY OF ROAD TRANSPORT & HIGHWAYS
(Highways Section)
Transport Bhawan, 1, Parliament Street, New Delhi- 110001.

Dated: 29.07.2026

Subject: Cost Escalation Compensation Mechanism for National Highway projects on EPC / HAM / PBMC due to significant increase in bitumen prices - reg.

Ref:- (i) Ministry's letter no. NH-24028/03/2026-H dated 01.04.2026 on monthly payment and
(ii) Ministry's letter no. NH-24028/03/2026-H dated 17.04.2026 on Bitumen escalation mechanism in contracts with no price escalation clause
(iii) Ministry's letter no. NH-24028/03/2026-H dated 25.04.2026 on Bitumen escalation mechanism in / HAM Projects
(iv) Ministry's letter no. NH-24028/03/2026-H dated 18.05.2026 clarification regarding applicability on all category of bitumen

Sir,

Ministry has issued the Cost Escalation Compensation Mechanism for National Highway projects on EPC / HAM / PBMC for significant increase in bitumen prices vide above referred circulars in order to mitigate the impact of the abnormal increase in prices of bitumen which was affecting highways construction projects.

2. The increased rate of bitumen has been re-examined and observed that rates are still in a higher range

3. Considering the prices of bitumen being in higher range, validity of the above circulars is being extended till 30.09.2026

4. This circular shall have effect for works done in the period from 1st April to 30th September 2026.

5. This issue with the concurrence of IFD and approval of Competent Authority.

Digitally signed by SHOBA BASIL
Date: 29-07-2026 12:10:30

Yours faithfully,

(Shoba Basil)
Under Secretary
Telephone 011- 2371 4001
Email: morth.planning@gmail.com

Copy of the circular available on MoRTH website www.morth.nic.in

IMPORTANT ANNOUNCEMENT

IRC PT. JAWAHARLAL NEHRU BIRTH CENTENARY AWARD FOR THE YEAR 2025

Nominations are invited in prescribed proforma for the IRC Pt. Jawaharlal Nehru Birth Centenary Award for the year **2025**. The last date for receipt of nominations is **15th September, 2026**.

For the year **2025** the nominee's age should not be more than 45 years. The particulars about the award are given below:

1. PREAMBLE

This award has been instituted by the IRC during Pt. Jawaharlal Nehru Birth Centenary Year and will be made each year for outstanding contribution in the field of Highway Engineering.

2 NATURE OF AWARD

Award will be in the form of medal/Citation certificate and will be made annually for notable and outstanding contribution, applied or fundamental, in the field of Highway Engineering (including Bridges).

3. PURPOSE

For recognizing outstanding work in engineering technology, utilization, etc. in the highway sector and encouraging young and upcoming engineers/scientists in the profession.

4. ELIGIBILITY AND SELECTION OF THE AWARDEE

a. Any Engineer/Scientist or any individual of India who is member/individual associate memberof IRC and is engaged in the field of highway engineering will be eligible for the award.

b. The award will be bestowed on a person who, in the opinion of the Selection Committee constituted by the Executive Committee, has made conspicuously important and outstanding contribution to Road Development of the country in the preceding 5 years of the nomination for the award.

5. The age of nominee shall be less than 45 years on the 31st May of the year in which the nomination is received.

6. The award will be made on the basis of contributions made primarily by work done in India. The criteria for selection of the contribution for the award will be the following:

i) Important addition, modification or improvement to the available design criteria.

ii) Important contribution to present day knowledge of physicial phenomenon or behaviour of relevance to engineering practice.

iii) New approach or methodology for utilization of development of new technology or new techniques for solving problems in applied engineering technology.

iv) Specific contribution made in the following fields:

(a) Investigation Methods	(g) Repairs and Rehabilitation
(b) R&D Management	(h) Environment
(c) Standardisation	(i) Highway Safety
(d) Software Development	(j) Construction and Management
(e) Planning	(k) Protective Works
(f) Maintenance	(l) Traffic Engineering

7. Nominations

a) Names of candidates may be proposed by or through any member of the IRC Council. Each such nomination shall be on the basis of proforma, accompanied by detailed statement of work and contribution of the nominee by the sponsor, and a critical assessment report bringing out the importance of the significant contributions of the nominee made during the preceding five years. The nominations alongwith copies of work assessment reports is to be sent to the Secretary General, IRC on or before **15th September, 2026**.

b) A candidate once nominated should be considered for a total period of 3 years, if otherwise eligible, unless revised nomination is received. Once such nomination has been received, the Secretary General, IRC may correspond directly with the candidate for supplementary information, if necessary.

IMPORTANT ANNOUNCEMENT

PROFORMA

IRC-PT. JAWAHARLAL NEHRU BIRTH CENTENARY AWARD
(NOMINATION FOR THE YEAR 2025)

1. Name of the Nominee.
2. Roll. No.____________as member of IRC and the year since he is member of IRC.
3. Discipline under which to be considered.
4. Date of Birth.
5. Academic qualifications beginning with Bachelor's Degree.
6. Present employment and post held.
7. (a) Outstanding achievements of the nominee (in about 500 words) during the last 5 years (Attach separate sheet)

   (b) Benefit derived/anticipated or measurable impact of the work/contribution/achievement.

   (c) Assessment by the sponsor of the importance of the contribution (not more than 100 words)
8. Whether these achievements/contributions have already been recognized for awards by any other body. If so, the name of the body, the name of award and the year of award may be given.
9. Other awards/honours already received including fellowships of professional bodies.
10. Papers published, if any (reprints to be enclosed)
11. Names & address of three experts in the area (preferably in India) as possible reference.

    (a)

    (b)

    (c)

Place : ____________________ Signature ______________________

Name & Designation of the Sponsor

(IRC Council Member)

NOTE :Ten copies of the Proforma along with ten copies of the detailed statement of achievement/contribution neatly typed should be supplied along with reprints of relevant Papers.

IMPORTANT ANNOUNCEMENT

IRC – U.P. Medal for Innovative Technology in Roads

Item	Description
Purpose of the Award	Promote the adoption of cutting-edge, innovative technologies in road development projects. Encourage Government Organizations/State PWDs to move beyond conventional methods and embrace sustainable, cost-effective, and efficient solutions. Showcase and disseminate best practices in innovative road construction technologies across the country. Improve the quality, durability, and longevity of road infrastructure in India. Recognize projects that demonstrate a significant positive impact.
Eligibility	This Medal is awarded to the Organisition (Central/State Govt., Central/State PSU, Urban Bodies) for implementation of cost effective, environmentally sustainable and durable innovative technology in construction of Public Roads.
Nominations	(Central/State Govt., Central/State PSU, Urban Bodies) through open advertisement in IRC website and also published in the Indian Highways magazine. Council Members and other stakeholders may also submit their recommendations on the nominations for consideration of IRC.
Selection Criteria	1. The technology has been implemented in a scale of reasonable size (cost of particular item of works incorporating the innovative technology not less than Rs. 10 crore) and is capable of adoption on a larger scale. 2. Easiness for users to adopt and utilise the proposed technology effectively. 3. Environmentally sustainability of the technology. 4. Technology should not pose any risks to users, the environment or the community. 5. Potentiality to develop National/ International collaborations. 6. Sufficient laboratory and field performance data for 2-3 years in support of technology indicating the effectiveness and value of technology. 7. The degree of novelty and originality of the technology compared to conventional solutions shall be given prime importance. 8. Technology should have a positive impact on society, industry and on the environment.
Number of Awards	**Upto maximum two Awards** may be given accompanied by a citation, a Plaque and Shawl etc. However, IRC reserve the right not to recommend an award in a year.
Value of Award	The **"IRC UP Medal for Innovative Technology in Roads"** will consist of a medal. A citation certificate. The winning organization will be invited to present their project case study during the Annual Session also.
Presentation of the Awards	The **"IRC UP Medal for Innovative Technology in Roads"** will be presented during the Annual Session of IRC. The award ceremony will be attended by HOD/Senior Officer from the Department nominated by the government.
Last Date of receipt of Nomination	**15th September, 2026**

IRC- U.P. MEDAL FOR INNOVATIVE TECHNOLOGY IN ROADS
(NOMINATION FOR THE YEAR 2025)

1. Name of the Nominee/Govt. Organization: ______________________________
2. Name of Project: ____
3. Project Cost: ____
4. Date of start the project: ____
5. Date of completion of the project: ___________________________________
6. Achievement

Signature with Seal___________________

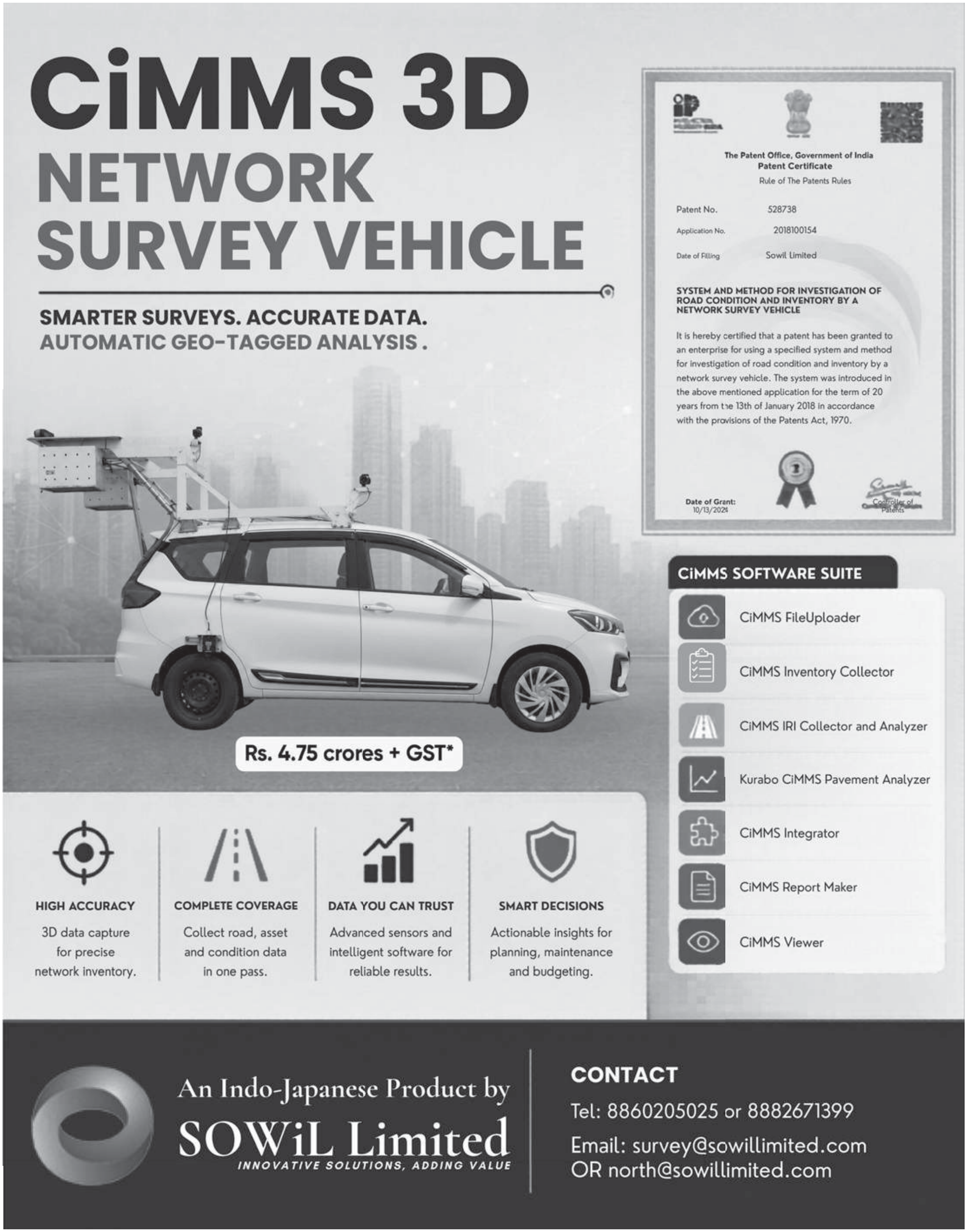
Place : _________

Name & Designation __________________

Date:____________

Department:__________________________

State: _______________________________


CiMMS 3D
NETWORK
SURVEY VEHICLE
SMARTER SURVEYS. ACCURATE DATA.
AUTOMATIC GEO-TAGGED ANALYSIS .
The Patent Office, Government of India
Patent Certificate
Rule of The Patents Rules
Patent No. 528738
Application No. 2018100154
Date of Filling Sowil Limited
SYSTEM AND METHOD FOR INVESTIGATION OF ROAD CONDITION AND INVENTORY BY A NETWORK SURVEY VEHICLE
It is hereby certified that a patent has been granted to an enterprise for using a specified system and method for investigation of road condition and inventory by a network survey vehicle. The system was introduced in the above mentioned application for the term of 20 years from the 13th of January 2018 in accordance with the provisions of the Patents Act, 1970.
Date of Grant: 10/13/2024
Controller of Patents
Rs. 4.75 crores + GST*
CiMMS SOFTWARE SUITE
CiMMS FileUploader
CiMMS Inventory Collector
CiMMS IRI Collector and Analyzer
Kurabo CiMMS Pavement Analyzer
CiMMS Integrator
CiMMS Report Maker
CiMMS Viewer
HIGH ACCURACY
3D data capture for precise network inventory.
COMPLETE COVERAGE
Collect road, asset and condition data in one pass.
DATA YOU CAN TRUST
Advanced sensors and intelligent software for reliable results.
SMART DECISIONS
Actionable insights for planning, maintenance and budgeting.
An Indo-Japanese Product by
SOWiL Limited
INNOVATIVE SOLUTIONS, ADDING VALUE
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