MITIGATION OF BLACKSPOTS WITH HELP OF STANDALONE FLYOVER ON STRETCHES OF NH 31 AND 31C IN STATE OF ASSAM

A Dissertation Submitted in Partial Fulfilment of the Requirement for the Award of the Degree of

MASTER OF ENGINEERING

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INFRASTRUCTURE ENGINEERING

Submitted by

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DECLARATION

I, Aditya Chatak, hereby declare that the work presented in this thesis entitled "Mitigation Of Blackspots With Help Of Standalone Flyover On Stretches Of NH 31 And 31c In State Of Assam" in fulfillment of the requirement for the award of degree of Master of Engineering submitted at Department of Civil Engineering, Thapar Institute of Engineering & Technology (Deemed to be University), Patiala is an authentic record of work carried out under the supervision of Dr. Tanuj Chopra (Assistant Professor) and Dr. Surya Kant Sahdeo (Assistant Professor), Department Of Civil Engineering, Thapar University from 2021 to 2023. The matter presented in this has not been submitted either in part or full to any other university or institute for the award of any other degree.

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TO WHOM IT MAY CONCERN

This is to certify that **Mr. Aditya Chatak, Roll No. 802123001** a student of **M.E Infrastructural Engineering** from "**Thapar Institute of Engineering & Technology**" has successfully completed his one year industrial training in our organization "**G-Eng Advisory Services Pvt. Ltd.**" from **18th Jul, 2022 to 10th Jul, 2023.**

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During the course of training, his code of conduct is appreciable. We wish him all the best for his future endeavors.

For G-Eng Advisory Services Private Limited

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ABSTRACT

This report examines the mitigation of black spots on NH 31 and NH 31C in the state of Assam through effective interventions such as geometric design, pavement design, signage planning, and junction development. Black spots, known for their high accident rates, pose significant challenges to road safety and traffic flow. This study evaluates the effectiveness of these specific measures in reducing accidents and improving overall highway safety. Geometric design plays a vital role in mitigating black spots. By utilizing advanced tools like Civil 3D, the report explores geometric improvements such as curve realignment, carriageway widening, and clear zone provisions. These design interventions aim to enhance driver visibility, maneuverability, and overall safety on the highway.

Pavement design is another critical factor in black spot mitigation. The report emphasizes the use of appropriate pavement thickness. Implementing these strategies minimizes accidents caused by poor road conditions and enhances overall safety. Signage planning is essential in black spot mitigation. The report highlights the importance of clear and strategically placed signage to provide timely information and warnings to drivers, aiding decision-making and reducing the likelihood of accidents. Moreover, the report addresses the significance of junction development. Effective design and engineering of junctions, including roundabouts and signalized intersections, significantly reduce accidents at critical points along the highway. Through comprehensive analysis and case studies, this report demonstrates the benefits and effectiveness of geometric design using Civil 3D, pavement design by IITPave, signage planning, and junction development in mitigating black spots on highways. Implementing these measures leads to a significant reduction in accidents and improves overall road safety. The recommendations provided in this report guide transportation agencies, engineers, and policymakers in implementing appropriate mitigation strategies for black spots. By integrating these interventions, highways can become safer, with reduced accidents, improved traffic flow, and enhanced transportation efficiency.

Table Of Contents

List of Tables

List Of Figures

Chapter 1 : Introduction

1.0 General

Every year, a heart breaking number of accidents occur on India's road network, and black spots continue to be a significant contributing element. Black spots are places where accidents happen alarmingly frequently on roads or highways, frequently resulting in serious injuries and fatalities.

Accident sites—often referred to as "black spots"—have no standard description and are open to interpretation. Areas having a high incidence of accidents are known as "black spots" in traditional use. Road-related, road-related, road-user-related, and environmental factors can all be characterized as causes of traffic accidents. Design restrictions, maintenance problems, and component failures, such as those in brakes, tires, and lighting, are all variables that are related to vehicles. Insufficient lane width, curves, and pavement problems are only a few examples of road-related concerns. The psychological state of the driver, their driving history, and external variables like poor weather and restricted visibility are all examples of elements that are associated to road users.[3]

The three E's strategy, which combines engineering, enforcement, and education, is frequently used to reduce accidents. A road's design elements, the state of the pavement, and the lighting on the road may all be evaluated and improved using engineering techniques. Performing before-and-after comparison studies to assess the success of modifications and performing preventive maintenance on vehicles are both essential. In especially among schoolchildren and college students, education activities concentrate on creating awareness and disseminating knowledge about road safety. The dissemination of messages about road safety involves numerous publicity efforts, seminars, and competitions. Traffic laws must be strictly enforced, traffic control devices must be put in place, and steps to reduce vehicle speed are all part of enforcement.

1.1 Defining Black spot

"Accident Prone Locations" or "Blackspots" are places that frequently experience or tend to accumulate traffic accidents. Nodes (intersections) and Links (mid-block locations between adjacent nodes) are examples of blackspots and accident-prone locations, as are any specific stretches of road with nearby land uses.

According to Geurts et al.'s definition from 2003, a black spot is a section of the road where the number of crashes has increased there by more than a specific amount in a given amount of time. For instance, a "black spot" is a place where at least four injury crashes have been reported over the course of the previous five years. Hazardous sites, hot spots, and black spots are terms used to describe high-risk areas where crashes tend to cluster over time. The global "black spots" for traffic accidents, however, are not defined in any particular or distinctive way. Traditionally, the definition of the "black spots" has been based on the quantity or frequency of incidents.

According to (MoRTH 2015), a road segment on NH with a length of roughly 500m where either five accidents or ten fatalities occurred during the previous three years constitutes a road accident black spot. Both death and injury accidents occur on the roads. Furthermore, the average severity index (ASI) is used to rank the observed black spots on NHs.

1.2 Causes of Blackspot on Roads and highway

Black spots on roads or highways, also known as “roadway blackspots,” refer to locations with a history of a higher frequency of accidents or incidents. Several factors can contribute to the development of these black spots, making them more prone to accidents. Here are some common causes or factors that contribute to the development of black spots:

A. **Geometry and Design**: Poor road geometry and design can create hazardous conditions, including sharp curves, improper lane markings, inadequate sight distance, or poorly designed intersections.
B. **Traffic Congestion**: Areas with high traffic congestion can increase the likelihood of accidents due to frequent stops and starts, lane changes, and overall congestion-related issues.
C. **Intersection Characteristics**: Intersections are often hotspots for accidents, especially when there are no traffic signals or stop signs, inadequate visibility, or confusing layouts.
D. **Road Surface Condition**: A worn-out or deteriorating road surface can reduce traction and increase the risk of accidents, especially during adverse weather conditions.
E. **Lack of Road Maintenance**: Roads that are not adequately maintained, including timely resurfacing, pothole repairs, and regular cleaning, can become hazardous to drivers.
F. **Weather Conditions**: Adverse weather conditions, such as rain, snow, ice, or fog, can significantly increase the risk of accidents on the road.
G. **Speeding**: Excessive speed reduces a driver’s reaction time and increases the severity of accidents. Black spots may be associated with higher speed limits or areas where drivers commonly exceed the speed limit.

H. **Poor Lighting**: Insufficient or inadequate street lighting can reduce visibility, especially during nighttime, making accidents more likely.
I. **Lack of Pedestrian Facilities**: Roads with inadequate or absent pedestrian facilities can lead to accidents involving pedestrians or cyclists.
J. **Driver Behavior**: Aggressive driving, tailgating, improper overtaking, and other reckless behaviors contribute to accidents at certain locations.

To identify and mitigate black spots, traffic authorities and transportation agencies analyze accident data, conduct safety audits, and implement measures such as improved signage, traffic signals, road repairs, and targeted enforcement. Additionally, educating drivers about road safety and responsible driving can help reduce the number of accidents in these areas

1.3 Traffic Analysis of Blackspots

Traffic data analysis serves as a crucial tool in identifying black spots, areas with a higher frequency of accidents, and gaining a comprehensive understanding of the underlying causes of these accidents. Advantages of Traffic Analysis :

A. **Identification of Accident Hotspots**: Through an in-depth examination of historical accident data, traffic analysts can pinpoint regions characterized by frequent accidents, commonly referred to as black spots. These findings empower authorities to focus their efforts and resources on improving safety in these specific locations.
B. **Recognition of Patterns**: By analysing traffic data, patterns associated with accidents, such as specific times of day, days of the week, or adverse weather conditions when accidents are more likely to occur, become apparent. Understanding these patterns allows for targeted implementation of safety measures during high-risk periods.
C. **Understanding Contributing Factors**: Traffic data analysis reveals common factors that contribute to accidents, such as speeding, distracted driving, drunk driving, or inadequate road conditions. This knowledge enables the development of suitable strategies to address these issues and reduce the number of accidents.
D. **Evaluation of Road Design**: By scrutinizing accident data in the context of road design, potential design flaws that may contribute to accidents can be identified. This information becomes instrumental in optimizing road layouts, signage, and traffic flow to enhance overall safety.
E. **Analysis of Traffic Flow**: Delving into traffic flow data, including congestion and bottleneck points, allows analysts to grasp how these conditions impact the likelihood

of accidents. Addressing traffic congestion can play a significant role in reducing accident risks in specific areas.

F. **Real-time Monitoring**: Utilizing real-time traffic data analysis enables swift identification of emerging black spots. This capability empowers authorities to respond promptly to potential issues, preventing accidents from escalating.

G. **Comparative Studies**: Traffic data analysis facilitates comparisons of accident rates across different locations or time periods. Such comparisons help identify areas or periods where accident rates are unexpectedly high, facilitating focused investigations and interventions.

H. **Predictive Analysis**: Advanced data analytics can be leveraged to create predictive models that forecast accident-prone areas based on various parameters. This proactive approach empowers authorities to implement preventive measures and allocate resources efficiently.

I. **Evaluation of Interventions**: After implementing safety measures, traffic data analysis plays a vital role in assessing the effectiveness of these interventions by tracking changes in accident rates. This feedback loop is essential for continuously refining safety strategies.

Traffic data analysis is an invaluable tool for comprehending accident patterns, identifying black spots, and addressing the root causes of accidents. By harnessing insights derived from data, authorities can strive towards creating safer road networks and reducing both the frequency and severity of accidents.

1.4 Methodology for Identification of Accidental Blackspots

- ***Data Collection***: The basic plan was to collect data from the police stations. And then search literature on black spot in state and click pictures of all intersections coming under the study area. The primary data includes the road inventory survey administered on the highway.[3,4]

  Following are the important factor considered:

  - ✓ Number of Lanes in each direction.
  - ✓ The presence of road markers and traffic signs.
  - ✓ Drainage conditions.
  - ✓ Presence of pedestrian crossings.
  - ✓ Effect of merging and converging traffic.

- ***Identification of Black spot***

  There are two ways to identify accident-prone or black spot locations:-

  1. Accident Severity Index method

2. Based on MoRTH Protocol

1.4.1 Accident Severity Index method

Accident Severity Index (ASI) is computed using accident data to determine the project corridor's risky spots. A technique of giving points based on the severity of the accident has been devised in order to quantify the criticality of an accident site. This rating is known as the Accident Severity Index (ASI).The Accident Severity Index is a dimensionless statistic that represents the danger level of a particular location on the road. The following formula has been employed:

ASI = (Nf x Wf) + (Ng x Wg) + (Nm x Wm)

Whereas, Nf = No. of fatal accidents at the spot in the last 3 years

Wf = Weight age assigned to fatal accident is 6

Ng = No. of grievous injury accidents at the spot in the last 3 years

Wg = Weightage assigned to grievous accident is 3

Nm = No. of minor injury accidents at the spot in the last 3 years

Wm = Weightage assigned to minor accidents is 1

Based on the Accident Severity Index (ASI) and Standard Deviation, the dangerous areas are prioritized. In statistics and probability theory, the standard deviation serves as a measure of variability. High standard deviation implies that the data points are dispersed throughout a wide range of values, whereas low standard deviation suggests that the data points tend to be extremely close to the mean. Locations are deemed to be "accident-prone" or "blackspot" hazards when the Accident Severity Index (ASI) exceeds the threshold value (average severity plus 1.5 times standard deviation).

Thus, Threshold value = Average of ASI +1.5 times standard deviation. [4]

Table 1.1: Identification of Blackspots based on ASI Value [4]

1 km stretch	Accident Location (km)	No. of fatal accidents in last 3 years	No. of Grievous injury Accidents in last 3 years	No. of Minor injury accidents in last 3 years	ASI Value
		Severity Weightages			
		6	3	1	
Average of ASI +1.5 times standard deviation					

1.4.2 Based on MoRTH Protocol

In their Circular No. RW/NH/15017/109/2015/P&M (RSCE) dated 28.10.2015, the Ministry of Road Transport & Highways (MoRTH) outlined the procedure for identifying road accident black spots on National Highways as follows.

Road Accident Blackspot is a stretch of National Highway of about 500m in length in which either 5 road accidents (in all three years put together involving fatalities/grievous injuries) took place during the last 3 calendar years or 10 fatalities (in all three years put together) took place during the last 3 calendar years.[3]

Table 1.2 – Identification of Blackspots based on MoRTH Protocol [4]

1 km stretch	Accident Location (km)	No. of fatal accidents in last 3 years	No. of Grievous injury Accidents in last 3 years	No. of Fatal and grievous injury accidents in last 3 years	Number of Fatalities/Deaths in the last three years	Blackspot as per protocol (Yes/No)

1.5 Prioritization of Black spot

The cluster of accidents in each kilometer from the Kilometer Analysis table should be checked for particular road features like (1) Curve, (2) Junction, (3) Median opening, or (4) mid-block section with land use close to road etc. in order to prioritize the locations of the blackspots or accident-prone locations. Prioritization must be done based on the quantity of accidents or the ASI value for the kilometer linked to the cluster of accidents along the length (let's say 300m or 750m, etc.). For the estimation of a "Priority Index" for pursuing mitigation or rectification measures, this might be used as the ratio of ASI and length in kilometers.[15]

1.6 Recommendations of Mitigation Measures

The type of implementation necessary may be determined based on a site inspection, preliminary survey, etc., and in response, the action for implementing corrective measures, i.e., short term measures and Long-term Measures, may be begun at the Authority's Level. Short-term remedies alone, or in some situations Long-Term remedies incorporating Cautionary Measures&/or Short-Term Measures, may be performed to rectify the problem depending on the site's (Black Spot location) requirements.

The following are suggested actions and recommendations to be taken in order to correct black spots:

1.6.1 Short-term actions - The following are some suggested things or actions:[11,12,13]

- Infrastructure for pedestrians, such as zebra crossings.
- Providing railings/ Crash barriers, Solar light.
- Improvement of Junction.
- Road signs include, for example, signs indicating speed limits, pavement or road markings, delineators, and studs or cats' eyes.
- Adding rumble strips to slow down traffic.
- Resurfacing or maintaining hazardous roads, including filling up the shoulder on national highways.
- Particularly in metropolitan areas, restrictions on the movement of several types of vehicles at once, one-way streets, reversible lanes, bus lanes, and restrictions on the use of certain vehicle types are all common.

1.6.2 Long – term measures

Table 1.3 long term Measures[11,12,13]

Black spot location	Remedial/ Corrective measures
In the clear zone, there are obstacles like trees, poles, structures, etc. Encroachments, too	These obstacles should always be moved or removed, and additional safety measures like crash barriers and other setback distances should always be implemented.
At grade junction	Underpasses, Overpasses, Flyover, Junction Improvement etc.
Mix traffic	Providing a service lane, a pedestrian walkway, a crash barrier, etc.
Narrow / Distressed Bridge /culvert	Reconstruction, rehabilitation / widening of the bridge
Pedestrian crossing, neighborhood school, hospital, educational institution, etc.	Foot over bridge etc.
Cattle/ Animal crossing	VUP/Cattle pass, fencing etc.

1.6.3 Mitigation by Building standalone flyovers

Building standalone Flyovers in strategic areas can reduce Blackspots on sections of NH 31 and NH31C in the state of Assam. Blackspots area areas of highways or roads where there have historically been many accidents or Fatalities.

The following are some ways that standalone Flyovers can lower collision rates and raise driving standards:

A. **Resolving Intersectional Disputes**: High traffic volume crossings or crossroads that frequently result in automobile collisions are known as “blackspots”. Independent flyovers enable smooth traffic movement without crossing, lowering the risk of collisions.

B. **Traffic Stream Separation**: Flyovers offer distinct lanes for vehicles traveling that frequently rectify. The probability of head-on collisions and other incidents brought on by cars merging into each other's lanes is decreased by this segmentation.

C. **Less Congestion**: Heavy traffic congestion, which frequently occurs in black areas, can cause unpredictable driving and accidents. By adding more room for traffic on the road and reducing congestion at congested areas, flyovers can enhance traffic flow.

D. **Better Visibility And Sig**ns: Standalone flyovers may be constructed with improved visibility and signs to direct motorists safely. Drivers can avoid taking the wrong turn or failing to see a crucial piece of roadside information by using clear and visible signboards.

E. **Speed Regulation**: The speed of vehicle can be more effectively regulated by creating Flyovers with suitable entry and exit ramps. Speed management can lessen the impact of collisions and increase general traffic safety.

F. **Appropriate Lighting and Maintenance**: Ensuring enough lighting and routine maintenance of the flyover and its surrounds can improve visibility during bad weather and at night, lowering the risk of accidents.

G. **Pedestrian Crossings**: If there are densely populated pedestrian areas next to the blackspots, building pedestrian crossings or underpasses alongside the flyover can increase pedestrian safety and lower the likelihood that they would be involved in accidents.

1.6.4 Mitigation Measures for improving Road safety in these Blackspots

1. Using Intelligent Transportation Systems (ITS): ITS technology, including as traffic signal Synchronisation, variable message signs, and traffic cameras, can be used to more effectively monitor and regulate traffic flow, lowering the risk of accidents.

2. Public Awareness and Education: Along with improvements to the physical infrastructure, raising public awareness of safe driving habits, the value of adhering to traffic laws, and the potential dangers of black spots can help lower the number of accidents.

3. Collaboration with local authorities: To successfully identify specific problem area carryout Safety audits, and implementing necessary measures, it is crucial to work closely with local authorities, traffic police, and other relevant stakeholders.

1.7 Basics of Geometric Design by Civil 3D

The process of designing a road in "Civil 3D" involves several steps within the software. Here is an overview of the geometric design process using "Civil 3D":

- Create and Import Base Data: Begin by importing or creating the base data for the road design. This includes existing ground contours, alignments, profiles, and any other relevant information.
- Establish the Design Criteria: Define the design criteria, including road classification, design speed, lane widths, superelevation, sight distances, and any other applicable standards or regulations.
- Create Alignment: Use the Alignment feature in "Civil 3D" to create the horizontal alignment of the road. This involves defining tangents, curves, spirals, and transition curves. One can specify curve radii, tangent lengths, and other parameters to achieve the desired alignment. Design the Vertical Profile: Utilize the Profile feature to design the vertical alignment of the road. This includes establishing the vertical curves, grades, and vertical transitions along the road. We can specify the desired grades, minimum sight distances, and vertical curve parameters to create a smooth and safe road profile.
- Establish the Cross-Section: Design the cross-section of the road by using the Assembly feature in "Civil 3D". This involves defining the road template, including lanes, shoulders, medians, and any additional features. You can specify the widths, slopes, and materials for each component of the road cross-section.
- Create Corridors: Generate the road corridor by using the Corridor feature in "Civil 3D". This combines the horizontal alignment, vertical profile, and cross-section information to create a 3D representation of the road design. The corridor can be adjusted and fine-tuned to meet the design criteria and standards.
- Analyse and Modify the Design: Analyse the road design for compliance with design criteria, sight distances, and other standards. Make any necessary modifications to the alignment, profile, cross-section, or corridor to achieve the desired results.

Generate Plan and Profile Sheets: Use the Plan and Profile Sheet tools in "Civil 3D" to create detailed plan views, cross-sections, and profile views of the road design. It's important to note that the specific steps and features used may vary depending on the project requirements, design standards, and the version of “Civil 3D” being used.[1,2]

The above steps provide a general overview of the road design process within “Civil 3D”geometric design capabilities.

1.8 Pavement Design

Creating a cost-effective and high-performing pavement structure is the goal of pavement design in highway construction initiatives. Environmental conditions, traffic volumes, and material properties are taken into account during the design process. To attain optimal pavement performance, a comprehensive design, construction, and maintenance strategy is necessary. As standards for flexible pavement design, guidelines and specifications such as IRC: 37-2018 and MORT&H Specifications for Road and Bridge Works are used.

The pavement model utilized for analysis accounts for the tensile strain at the base of the bituminous layer and the vertical subgrade strain at the top of the subgrade. The pavement performance is evaluated based on fatigue fracture and subgrade rutting criteria. There are equations for calculating fatigue life and rutting life based on strain, resilient modulus, and reliability levels.

Material characterization is essential, which includes determining the resilient modulus and Poisson's ratio for each stratum of the pavement structure. The designed pavement compositions are based on the analysis of stress and strain using the IITPAVE software, taking into account various design traffic loads and subgrade CBR values.

Pavement design requires consideration of multiple factors, application of guidelines and specifications, and examination of material properties. The objective is to design a pavement structure that satisfies performance standards for fatigue cracking and subgrade rutting. The design process includes the selection of appropriate layer thicknesses and compositions, taking into account traffic volumes and material properties, to guarantee a cost-effective and long-lasting pavement solution.

1.9 Signage and Junction Development Plan

A signage plan is a graphical representation that outlines the placement and design of signs in a specific location or along a road network. Signage is an integral part of traffic management and road safety, as it provides information, warnings, and direction to drivers, pedestrians, and other road users. In India, the sign plan adheres to the Indian Road Congress (IRC) and the Manual of Uniform Traffic Control Devices for India (MUTCDI) guidelines.

The IRC provides guidelines for numerous aspects of road signage, such as the varieties of signs, their dimensions, colors, symbols, and legends. It includes regulatory signs (like speed limits, parking restrictions, and lane usage), warning signs (for curves, intersections, and hazards), and informative signs (for destinations, distances, and services).[20]

The MUTCDI, which is published by the Ministry of Road Transport and Highways, is an exhaustive guide to traffic control devices in India. It includes guidelines for signage, road markings, traffic signals, and other measures of traffic control. Codes that are used are:

IRC: 67-2012: "Standard Specifications and Code of Practice for Road Signs": This code provides detailed specifications for the construction, materials, and retro reflectivity of road signs. It covers signboard dimensions, materials, lettering styles, colours, and symbols.

(IRC:SP:87-2019, IRC:99-2018).

A Junction Development Plan (JDP) is a comprehensive plan that describes the design, layout, and development of a road intersection or junction. It includes road alignments, lane configurations, traffic signal installations, pedestrian facilities, and geometric design characteristics. A JDP is intended to assure safe and efficient traffic flow, reduce congestion, and improve the overall functionality of the intersection.

JDPs are necessary because intersections or junctions are critical locations where multiple traffic streams converge and where collisions between vehicles, pedestrians, and cyclists are likely. By creating a well-designed JDP, transportation authorities are able to address these conflicts, improve traffic operations, and increase road user safety.

The Indian Road Congress (IRC) and the Ministry of Road Transport and Highways (MoRTH) establish the guidelines for junction development plans in India. While there is no IRC code dedicated solely to JDPs, IRC: 87-2019 is referred in this research.[19]

1.10 Objectives of Thesis

The objective of this thesis is to analyze and address the issue of black spots on India's road network, which are locations prone to frequent traffic accidents resulting in injuries and fatalities. The thesis aims to provide a comprehensive understanding of black spots, their causes, and the methodologies for identifying and prioritizing them. Furthermore, the thesis intends to propose recommendations for mitigating black spots and improving road safety.

Specific objectives include:

1. To investigate the site condition and analyze the conflict point.
2. To design Horizontal and Vertical Geometry of road, using “Civil 3D” software following IRC standards and Project Schedule. (IRC 38 -1988, IRC SP 23-1993, IRC: 87-2019)

3. To Design Pavement crust using IITPAVE software using IRC standards and Project Schedule.(IRC 37:2018)
4. To Develop Signage and Junction Plan using IRC standards and Project Schedules (IRC: 67-2017 ,IRC:99-2018, IRC: 87-2019)

By addressing these objectives, the thesis aims to contribute to the understanding of black spots and provide practical recommendations for enhancing road safety in India.

1.11 Organization of the Thesis

- Chapter 1 of this thesis gives a general introduction and outline about the work.
- Chapter 2 of this thesis presents the literature review on the works done.
- Chapter 3 of this thesis presents the methodology carried out in this work.
- Chapter 4 presents the analysis part of all the test results.
- Chapter 5 presents the conclusions made from the results.

Chapter 2 : Literature review

2.0 General

The purpose of this literature review is to critically analyze and synthesize the research paper titled. The chosen paper holds significance within the field of and its examination will provide insights into the current state of research, key findings, and potential areas for future investigation.

2.1 A review on the comparison of geometric design using Civil 3D software and manual method.*(Hemant Chakole , et al. 2022)*

This literature review discusses various factors affecting geometric design in highways. The review covers the following factors:

Design speed: Design speed is a critical factor that influences sight distance, horizontal curves, and vertical curves. It is different from legal speed limits and desired speed, and a suitable design speed is chosen to accommodate the majority of drivers.

Topography: The terrain plays a significant role in geometric design. Construction costs increase with steeper gradients, and different design standards are applied based on the terrain to manage costs and construction time.

Other factors: Factors such as vehicle characteristics, human factors (driver and pedestrian behavior), traffic volume, environmental considerations, economic feasibility, and aesthetic impacts are also important in geometric design decisions.

The review also mentions the use of AutoCAD "Civil 3D" software in civil engineering projects. It highlights the benefits of the software, such as creating 3D models, facilitating design changes, and improving project visualization, time efficiency, and accuracy.

The objectives of the project mentioned in the review are to study and design geometric features of roads using both "Civil 3D" software and manual methods. The aim is to compare and validate the designs and determine safe geometric features to minimize accidents.

The review further provides definitions and explanations of various geometric elements, such as alignment, profile, cross-section, sight distance, cross slope, crest curves, superelevation, horizontal curves, transition curves, and radius of horizontal curves. It discusses their significance and design considerations.

The conclusion emphasizes the importance of geometric design in meeting the goals of comfort, safety, efficient traffic operation, cost-effectiveness, environmental impact, and aesthetics. Geometric design ensures roads are designed to accommodate specific requirements and provide safe and suitable conditions for users. The role of AASHTO in guiding geometric design is also mentioned.[2]

2.2 A Review- Geometric Design of Highway with the help of Autocadd Civil 3D-(*Payal Gaikawad, et al. 2016*)

The summary of the workflows for basic road construction using AutoCAD Civil 3D are as follows:

- Creation of existing surface using a notepad file containing coordinates and elevation data.
- Model alignment using polylines to define the road's baseline.
- Application of design criteria such as speed and superelevation, with warning alerts for non-conforming alignments.
- Production of existing profile and design grades, displaying surface data and creating finished levels for the design alignment.
- Creation of assemblies, representing cross-section features of the roadway.
- Designing the horizontal and vertical geometry, as well as cross-sectional design features, in the corridor combination.
- Analysis of corridors for embankment, cutting and filling volumes, visual study, and information extraction.
- The design methodology includes survey data collection, technical criteria, horizontal and vertical alignment modeling, and the necessity for cutting and filling.
- The design procedure involves importing survey data, creating the existing surface, marking polylines for the road's centerline, designing according to the proposed alignment and design criteria, generating the existing profile, creating road top levels, assembling cross-section elements, generating the corridor, and generating a quantity report.

The conclusion states that AutoCAD “Civil 3D” is useful and user-friendly for three-dimensional roadway design, taking into consideration safety measures and guidelines from IRC and AASHTO. It allows for the establishment of horizontal alignment, drafting of vertical profiles, application of super elevation, and optimization of geometric design for cost efficiency, traffic flow, and safety. Careful planning of road widening and consideration of sight distance and vertical alignment can lead to reduced fuel consumption and improved efficiency.[3]

2.3 Black Spot analysis on National Highway – 04 (*Dr. C.B Bangal ,et al. 2016*)

The importance of road networks for the economic and social development of a country, with a focus on India, is discussed in the research paper titled "Black Spot Analysis on National Highway - 4." Specifically, the Pune-Bangalore National Highway is examined, which plays a crucial role in facilitating transportation and development in Maharashtra, a fast-growing state in India.

As the number of vehicles on the road increases, accidents are also on the rise, impeding economic and social progress. The need to study, identify, and rectify accident-prone zones on highways to reduce accidents is highlighted in the paper. The concept of "accidental black spots," locations where road traffic accidents have historically been concentrated, is introduced. The objective of the study is to identify accident-prone spots on the Pune-Bangalore National Highway between 820 km and 830 km. Data collected from the National Highway Authority of India (NHAI) is analyzed using a ranking method. The analysis considers parameters such as the nature, classification, and causes of accidents.An accident black spot is determined based on the presence of multiple accidents and the associated risk. The vulnerability of each spot is assessed by calculating the severity index, and a severity index benchmark is established. The study area is further examined through graphs representing the nature, classification, and causes of accidents, highlighting the spots that exceed the severity index benchmarks.

Based on the analysis, it is concluded that a total of 34 spots on the Pune-Bangalore National Highway fall within the category of accidental black spots. The parameters responsible for these accidents, such as skidding, grievous injuries, and overspeeding, are identified.In summary, the importance of identifying accident-prone areas on highways to improve road safety is emphasized in the research paper. By employing the ranking method and analyzing relevant data, black spots on the Pune-Bangalore National Highway are identified, providing insights for implementing remedial measures and reducing accidents.[4]

2.4 Identification of Accident Black spots on National highway (*Athira Mohan*)

The methodology used in the present study involved several steps for data collection and analysis. A summary of the methodology is provided below:

Data Collection: Primary data: Conducted road inventory study and traffic volume count at the identified accident black spots. A road inventory survey was carried out to measure roadway geometric parameters, such as width, footpath width, median, shoulders, surface type, surface condition, road markings, road signs, drainage facilities, and adjoining land use. Road attributes were coded using video graphic survey and data from Google Earth. Traffic volume count: Traffic volume count was conducted for six sections, with video footage available for two sections and data from the Comprehensive Mobility Plan Nagpur final report 2015 for another section.

Crash Data Collection: Accident data for three years (2014-2016 May) was collected from the Wadi police station. The data included information on fatalities, serious injuries, and minor injuries. The study focused on a 13.1 km stretch of Amravati Road due to insufficient data for other roads.

Analysis of Secondary Data by Weighted Severity Index Method (WSI): Accident black spots were identified using the Weighted Severity Index Method. Scores were assigned based on the number and severity of accidents at each location during the last three years. The Weighted Severity Index (WSI) was calculated using the formula:

WSI = (41 x K) + (4 x GI) + (1 x MI), where K represents the number of persons killed, GI represents the number of grievous injuries, and MI represents the number of minor injuries. Locations with a WSI above 40 were considered accident black spots.

By following this methodology, the study aimed to collect and analyze data related to road inventory, traffic volume, and crash data to identify and assess accident black spots on the National Highway.[5]

2.5 Road Accident Black Spot Analysis Using Weighted Severity Index Method at L B Nagar Zone Hyderabad (*D. Maheswara Reddy, et al. 2023*)

The Indian road network, spanning 5.8 million kilometers, is responsible for carrying a significant portion of commodities (64.5%) and passenger traffic (90%). However, the highest road accident mortality rate globally is attributed to India, with over 11% of all accident-related deaths worldwide being accounted for by the country. An increase in traffic accidents is being observed in Telangana, a state in India, despite its rapid development and urbanization. The focus of the study is on the L B Nagar Zone in Hyderabad, which falls under the Rachakonda area of Telangana. Various methods, including the Weighted Severity Index (WSI), Accident Density, Method of Ranking & Severity Index, and GIS software, were utilized in the study to identify accident black spots. The severity of accidents was analyzed based on factors such as fatalities, major injuries, and minor injuries. Data on traffic volume and spot speeds during peak and non-peak hours were also collected as part of the study. The locations with the highest number of accidents and their severity were revealed through the analysis. The need for effective black spot management techniques and the identification of primary causes of accidents were emphasized by the study to enable control and prevention. An increase in death rates in Patna city was observed based on data from previous years. The number of vehicles and accidents in Telangana state from 2015 to 2019, with specific areas like Cyberabad, Rachakonda, Warangal, Medak, and Sanga Reddy experiencing a significant number of accidents, is detailed in the provided table. The study area, L B Nagar Zone, was outlined, and the methodology for analyzing traffic volume, spot speeds, and accident data was explained.[6]

2.6 Black Spot On Highway And Remedial Measures: A *Review* (*Shailendra Singh et al. 2016*)

The problem of traffic accidents and the importance of studying and investigating their causes are discussed in the passage. The need for safe traffic movements and the reduction of accident rates through appropriate engineering and management are emphasized by traffic engineers. The impact of urbanization and increased traffic congestion on road networks, resulting in more accidents, is also highlighted. Several studies and methodologies for identifying accident-prone areas or black spots are mentioned, including statistical tests, GIS analysis, ranking methods, and performance measures. Various factors contributing to accidents, such as inadequate sight distance, poor road conditions, driver negligence, and speeding, are identified in the studies. Several remedial measures are suggested, including the construction of speed brakes or road humps, improved road markings, the installation of cautionary signs and markers, and the use of solar blinkers. Overall, the aim is to enhance road safety and reduce accidents at identified black spots.[7]

2.7 An Analytical Glimpse on Road Accidents in Assam *(A report on Traffic survey of Guwahati City)*

The report provides an analytical glimpse into road accidents in Assam, particularly focusing on the traffic survey of Guwahati City. Assam ranked first in road accidents in the North East region of India and 16th overall in the country in 2017. In 2018, Assam witnessed 8,248 road accidents, resulting in 2,966 fatalities and 7,375 injuries. The severity of crashes is indicated by the fact that 36 persons were killed and 89 injured per 100 road accidents in 2018. The occurrence of road accidents increased by 15% in 2018 compared to the previous year, with fatalities rising by 6.6% and overall injuries increasing by 19.6%. National Highways accounted for 48% of road accidents, while State Highways and Other Roads each accounted for 26%. Among the districts, Kamrup (Metro), Kamrup (R), Nagaon, Cachar, and Barpeta reported the highest number of accidents. The report also highlights the efforts made by the Guwahati Police to mitigate traffic problems, such as the deployment of additional traffic personnel, introduction of new traffic uniforms, and the functioning of Dial 100 for emergency responses. The Ambubachi Mela in Guwahati, with its large footfall of devotees, required elaborate traffic arrangements and demonstrated the efficiency of the police.[8]

2.8 Assessing the Black Spots Focused Policies for Indian National Highways ***(Laxman Singh Bisht et al**. 2019)*

Laxman Singh Bisht et al. provided an overview of the procedures and methods used for the identification of black spots. It examines various approaches, both model-based and non-model based, and discusses their advantages and disadvantages. The review also explores the identification of black spots on Indian highways and highlights best practices for black spot identification.

Methods of Identification: The identification process aims to select locations with a fair chance of needing remedial action and being cost-effective. Non-model based methods utilize crash numbers, crash frequency, and crash rate, while model-based methods employ category analysis, traditional approaches, and modern approaches. Model-based methods like Empirical Bayes (EB) method, Poisson or Negative Binomial (NB) distribution method, and category analysis method are considered effective but require high-quality crash, traffic, and road data. Non-model based methods are easier to use but may produce false positives and false negatives. Many countries, including European countries, the USA, Canada, and Australia, rely on non-model based methods for black spot identification.

Black Spot Identification on Indian Highways: In India, black spots on national highways (NHs) are identified based on fatality and accident data provided by state traffic police. Each black spot is assigned a unique identification number for monitoring and feedback purposes. Criteria for identification include the number of accidents (5 or more) and fatalities (10 or more) in a three-year period. However, data from some major states like Uttar Pradesh and Tamil Nadu are missing, despite their significant contribution to accidents and fatalities.

Best Practices for Black Spot Identification: The literature suggests the use of the Empirical Bayes (EB) method as the best approach for identifying black spots. However, caution is advised regarding blind faith in this methodology. The essential elements of a state-of-the-art approach to black spot identification include estimating the expected number of accidents, avoiding the use of sliding window methods, utilizing multivariate accident prediction models, validating critical values for identifying black spots, analyzing accident patterns at black spots, and conducting before-after studies to evaluate the effectiveness of black spot treatment programs.

Government Policies for Black Spots Management in India: The Government of India has implemented various policies and initiatives to enhance road safety and manage black spots. These include the establishment of the National Road Safety Council (NRSC), the National Road Safety and Traffic Management Board (NRSTMB), and the formulation of the National Road Safety Policy (NRSP). The policies focus on awareness, road infrastructure improvement, safer vehicles and drivers, enforcement of safety laws, and emergency medical services.[9]

2.9 Road Accidental Analysis and Identify the Black Spot ***(Jaffar Hussian et al. 2016)***

Accurate identification of black spots is crucial for improving road safety and reducing accidents. This Paper focuses on the methodology used to identify accidental black spots in a specific area. The data collection process involved cooperation with local police stations, and data was collected from four different stations. Main intersections and areas prone to accidents were observed and documented through photographs. Literature on black spots in the region was reviewed, and knowledge gained from friends, books, and internet sources was utilized.

The methodology for identifying black spots involved the use of the Rate-Quality-Control method (KGM). This statistical procedure consists of calculating three parameters for each road section: accident rate, accident frequency, and severity index. These values were compared with critical values to determine if a road section qualified as a black spot. The accident rate was calculated by dividing the total number of accidents by the road length. Accident frequency was categorized based on distance and the number of accidents within each range. The severity index represented the vulnerability of a particular accident spot and was calculated using a formula that considered accident causes and their respective weights.

Traffic volume data, in terms of average daily traffic (ADT) and passenger car units per hour (PCU/HR), were also collected for various years to assess the traffic conditions in the area.

To rank the black spot locations, weights were assigned to different factors affecting the occurrence of accidents. These factors included the relative severity index, the approximate number of vehicles per day, width of the road, frequent vehicle types, and drainage facilities provided. The assigned weights were based on the occurrence of accidents and ranged from 1 to 10. Total weights for each location were calculated by summing the individual weights and normalizing the value using the maximum weight.

Based on the final weights, the black spot locations were ranked. The locations with higher weights were considered less prone to accidents compared to those with lower weights. The ranking of sites was determined based on their Accident-Prone Level (APL), with the highest APL indicating a higher accident risk.

In conclusion, the methodology for identifying accidental black spots involved comprehensive data collection from police stations, observations of intersections and accident-prone areas, and a statistical analysis using the Rate-Quality-Control method. Factors such as accident rate, accident frequency, severity index, and traffic volume were considered in the analysis. The assignment of weights to different factors facilitated the ranking of black spot locations based on their accident-prone levels. This methodology provides valuable insights for identifying areas that require targeted interventions to improve road safety and reduce accidents.[10]

2.10 Road Accident Analysis and Identify the Black Spot location on State Highway-5 (*Halol- Godhra Section*) *2016*

This literature review focused on a study conducted on SH-5, a highway connecting Halol to Shamlaji in Gujarat state, with the objective of identifying engineering factors contributing to accidents and proposing improvements to prevent future incidents.

Study Scope and Data Collection The study stretch selected for analysis ranged from Chainage Km 335.170 to Km 380.00. Accident data from the past two years were collected from L&T, IDPL Toll Plaza with proper permission. The study stretch map was generated using Google Maps.

Accident Data Analysis Accident data from 2013 and 2014 were analyzed to understand the frequency and severity of accidents. A total of 443 accidents occurred in 2013, resulting in 51 fatalities and 274 injuries. In 2014, there were 471 accidents, with 30 fatalities and 392 injuries. The classification of road crashes based on severity (minor, major, fatal, non-injury) was also presented.

Nature and Causes of Road Crashes The nature and causes of road crashes were categorized and analyzed. It was found that 41% of road crashes were contributed by single-vehicle accidents. The causes of road crashes were categorized into over speeding/vehicle loss of control, defect in vehicle, fault of the driver, and others. Over speeding emerged as the leading cause, accounting for the majority of accidents.

Time and Location Analysis The time of road crashes was divided into eight 3-hour intervals. It was observed that approximately 20% of accidents occurred during the early afternoon hours, suggesting driver fatigue and drowsiness from overnight driving. The identification of black spots, which are high-risk locations with a significant collision potential, was also conducted based on one-year data.

Quantum of Road Crash Method The quantum of road crash method was used to identify crash-prone locations. The analysis revealed that the kilometer section between Km. 369 and Km. 370 had the highest vulnerability, with 33 crashes reported in 18 months, indicating a high crash rate.

Black Spot Identification Black spots were identified using various methods, including quantum of road crash and weightage. The top ten crash locations on Section-1 (Halol-Godhra) of SH-5 were determined based on the analysis.

In conclusion, this literature review highlights the significance of understanding the causes and patterns of road accidents to implement effective preventive measures. The study provides valuable insights into the engineering factors contributing to accidents and offers recommendations for improving road safety on SH-5 in Gujarat state.[11]

2.11 Mitigation of Black-Spot's on Highways by The Application of Safe System Approach *(Dinesh K Yadav et al. 2021)*

This study focuses on mitigating traffic volume and improving road safety parameters to reduce road fatalities. The research area is an 8 km stretch of National Highway (NH-66) in Alapphuza district, Kerala, India. Accident data was collected from the NHAI office and local police station and analyzed using the Accident Severity Index (ASI) method. Black spots were identified based on accident severity, and short-term measures were adopted to address these spots. The study identifies 10 black spot locations and proposes solutions. Keywords: Accident Severity Index, Black Spots, NHAI, Road Safety Parameters.

Methodology: Accident data was collected for the selected stretch on NH-66, and key parameters causing accidents were identified. The data was analyzed using the Accident Severity Index (ASI) method to rank and identify black spots. Statistical models were used to analyze the black spots, and countermeasures were proposed. Improvement initiatives related to geometric design were also suggested.

Data Collection and Analysis: Accident data from 2017 to 2020 was collected and categorized based on injury type, road condition, nature of accident, and more. The analysis revealed trends in different types of accidents and road conditions over the years.

Conclusion: The study analyzed accident data and identified black spots on a stretch of NH-66 in Alapphuza, Kerala. Based on the severity of accidents, short-term measures were proposed to address these spots. The findings provide insights into improving road safety and reducing fatalities. Further research and implementation of the proposed measures can contribute to enhancing traffic safety on the identified black spots.[12]

2.12 Identification and Improvements of Accident Black Spots on NH-75 (Nelamangala-Hassan section) *(K. B. Jayakumara et al. 2023)*

This literature review focused on road safety aspects related to national highways, with a specific emphasis on black spots. The study aims to review existing literature, gather accident and road geometry data, conduct investigations on selected black spots, propose long-term mitigation measures, and validate them using VISSIM simulation..

Black Spot Analysis Black spots, locations with a high concentration of accidents, have been the subject of extensive research. Factors contributing to black spots, including inadequate signage, poor road geometry, and driver behavior, have been identified through detailed investigations. Understanding the causes of accidents at black spots is crucial for developing targeted countermeasures.

Data Collection and Analysis Accident data and road geometry play a crucial role in analyzing road safety. Accurate and reliable data collection systems, along with the integration of road geometry data, have been proposed for comprehensive analysis. This approach assists in identifying critical areas prone to accidents and contributes to effective safety interventions.

Long-term Mitigation Measures Addressing road safety concerns on national highways requires the implementation of long-term measures. Studies have recommended a multifaceted approach, including improvements in road infrastructure, driver education and awareness campaigns, stricter traffic regulations enforcement, and the adoption of intelligent transportation systems. These measures aim to achieve sustainable improvements in road safety.

Simulation and Validation using VISSIM Simulation tools like VISSIM provide valuable platforms for evaluating the effectiveness of proposed road safety measures. Researchers have conducted simulation-based studies to assess the impact of different interventions on reducing accidents at black spots. These studies have demonstrated the effectiveness of targeted measures and emphasized the value of simulation tools for decision-making.

Analysis and Findings The study identified 13 black spots along National Highway 75, covering a study area of 84.09 km. Accident data from police stations and the National Highway Authority of India (NHAI) were collected and analyzed. Regression analysis was conducted to explore the relationship between accidents and black spots. Visual surveys and videography were carried out to assess the road conditions and key factors contributing to accidents.

Mitigation Measures and Validation Based on the analysis, long-term measures were suggested to mitigate accidents at the selected black spots. Recommendations included the construction of vehicular underpasses (VUPs) and associated road safety measures. The detailed estimate for VUP and service road construction was provided. The proposed measures were validated using VISSIM simulation, which involved modeling the suggested conditions and analyzing conflict areas at junctions.

The study gathered and analyzed accident and road geometry data, identified black spots, suggested long-term mitigation measures, and validated them using VISSIM simulation. The findings contribute to the understanding of road safety on national highways and provide insights for practical interventions to improve safety at black spots. Further research and implementation of these measures are crucial to ensure safer journeys on national highways.[13]

Fig 2.1 Aerial view of black spot[13]

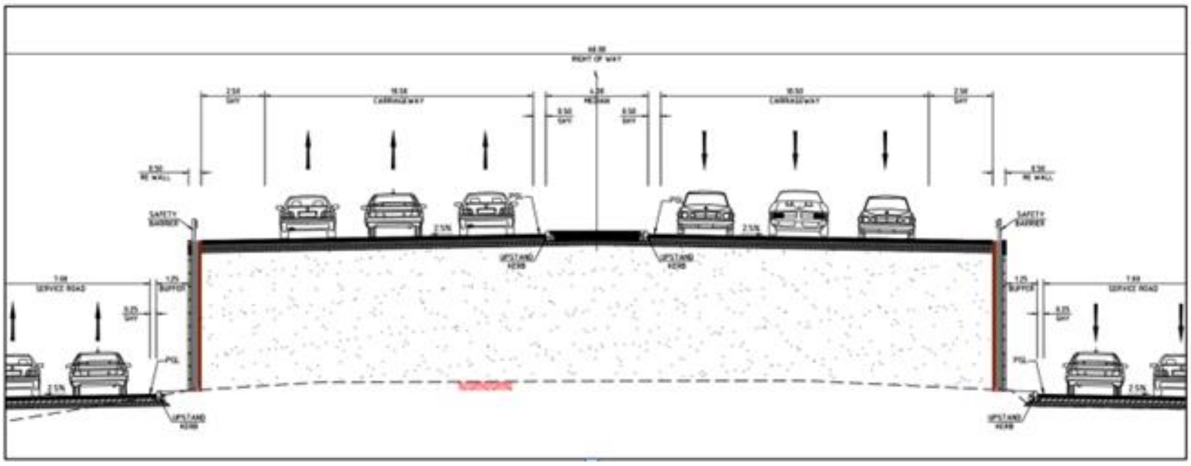


Fig 2.2 Typical Cross-Section VUP Approach[13]

2.13 Analysis and Providing Solutions for the Rectification of Black Spots On NH-27(OLD NH-28) *(Vishal Pandey et al. 2022)*

This literature review discusses a study conducted on black spots along National Highway NH-27 in Bihar, India. The research aims to identify and rectify hazardous locations to reduce road accidents. The selected study stretch is located from Kotwa to Muzzafarpur, covering approximately 81.2 km on NH-27 (old NH-28). Previous road accident data was collected from police stations, and black spots were chosen based on accident frequency.

Methodology: The study employed the Accident Severity Index (ASI) and Turning Movement Count (TMC) surveys to prioritize and analyze the selected black spots. ASI was calculated using the number of fatal, grievous, and injured accidents over a three-year period, assigning weights to each category. TMC surveys were conducted to assess traffic volume and vehicle types at the black spots.

Results: Based on the ASI values, the black spots with the highest severity were further analyzed: Kali Mandir Motipur, Narriyar area, and Chinmastika Mandir. Traffic flow diagrams and observations were provided for each black spot, highlighting congestion issues, disorientations, and other problems. Proposed solutions included the construction of underpasses, truck-lay bays, intermediate lanes, and service roads. Signage and lane markings were also recommended to improve traffic safety.[14]

Proposed solutions:

- Construct a Vertical Underpass (VUP) with a span of 12.0m and a vertical clearance of 5.5m to ensure unobstructed passage for vehicles.
- Provide a Truck-lay bay with a capacity to park 20 trucks, separate from the main carriageway, to alleviate congestion caused by parked trucks.
- Install intermediate lanes and service roads on both sides of the main carriageway to distribute traffic and offer alternative routes.
- Develop Entry/Exit points at the start and end of the service road for convenient access and improved connectivity.
- Install signage according to IRC:67-2012 guidelines to enhance driver guidance and awareness of road conditions.
- Implement lane markings as per IRC:35-2015 standards to delineate lanes, manage traffic flow, and reduce confusion among drivers.
- These proposed solutions aim to address the observed issues and improve traffic flow, safety, and driver experience at the identified location.

2.14 A Case Study Of Black Spots At Mangalore City And Proposal Of Mitigation Measures (*K P Deepdarshan et al. 2020*)

The objectives of studying accidents in Mangalore include identifying accident causes, evaluating existing designs, conducting before-and-after studies, estimating financial losses, and justifying improvement measures. The research methodology employed in this study involved collecting accident data from the police department, incorporating it into MS Excel, conducting visual surveys, prioritizing hazardous locations, performing pavement condition surveys, and analyzing black spots. The collected data provided insights into accident trends and severity.

Several black spots were identified in Mangalore, such as the K.P.T circle, Mukka junction, and Kulai junction. These locations experienced high traffic volumes and lacked proper traffic management measures. Visual surveys, traffic volume surveys, and physical data analysis were conducted to assess traffic patterns, vehicle movements, and accident-prone areas. The results highlighted the need for improved road infrastructure, including widened pavements, traffic signals, and road humps.

In conclusion, effective road safety measures are crucial to address the growing number of accidents in Mangalore. Short-term solutions such as road furniture, lane markings, and speed breakers, along with proper pavement maintenance, can help mitigate accidents. Long-term measures involve infrastructure improvements such as widened pavements, shoulders, and the provision of traffic signals, road humps, and underpasses. Implementing these measures and conducting future studies to assess their impact will contribute to enhanced road safety in the identified black spots. Continuous year-round road safety campaigns and strict enforcement of safety regulations are necessary to reduce accidents and prioritize public health and safety.[15]

2.15 Prioritization and mitigation measures of road accident black spots: A case study of Chandigarh city (*Har Amarit Singh Sandhu et al.*)

The study aimed to prioritize black spots, develop accident prediction models using Statistical Package for Social Science (SPSS) and Artificial Neural Network (ANN), and suggest remedial measures for road safety.

Methods: Data collection involved a road inventory survey and obtaining accident records from the traffic police department. The Accident Severity Index (ASI) was calculated based on fatal accidents, non-fatal accidents, minor injuries, and property damage. The ASI values were used to rank the black spots. Two methods were employed for accident prediction modeling: SPSS using multiple linear regression and ANN with three layers. The models were evaluated using R2 and Mean Absolute Percentage Error (MAPE).

The black spots were prioritized based on their ASI values, with the light point area (sector 46/47/48/49) identified as the most vulnerable. The study developed an accident prediction model using SPSS, revealing that the total number of accidents is influenced by the city's population and vehicle ownership. The ANN model with an architecture of 2/13/1 showed promising results with a high R2 value and low MAPE. Field visits helped identify additional factors contributing to road accidents, leading to the suggestion of remedial measures for improving road safety.

Conclusion: The study highlights the importance of addressing road accidents and implementing safety measures in Chandigarh. By prioritizing black spots and developing accident prediction models, valuable insights were gained into the factors influencing road accidents. The use of SPSS and ANN demonstrated the potential for accurate accident forecasting. The findings can guide policymakers and city planners in implementing targeted interventions to reduce road accidents and ensure safer mobility for all road users in Chandigarh.[16]

2.16 Traffic Accident Analysis and Mitigation Measures at Kariyad (NH -544), Ernakulam, Kerala *(Mridula G M et al. 2016)*

GM Mridula et al. conducted study at Kariyad, a location near Ankamaly, Ernakulum, to analyze the accident scenario in a 1-kilometer stretch on NH-544 and propose measures to mitigate the effects of accidents. The study involved collecting accident data from 2004 to 2014 and conducting surveys to determine factors such as traffic volume, spot speed, and speed and delay. The analysis revealed that Kariyad was a major black spot with a high number of accidents, particularly at a junction and sharp curve. The study also identified two curves, designated as curve 22 and curve 23, within the study area. The findings indicated that the design speed of the curves was lower than the actual speed of vehicles, highlighting the need for corrective measures. The proposed mitigation measures included implementing a speed limit of 75 kmph, increasing the curve radius, and providing adequate shoulder width. Design 1, which involved altering curve 23, was recommended as the most cost-effective option. Additional remedies suggested included improving pavement skid resistance, paving the shoulders, installing roadside markings, ensuring adequate horizontal clearance and sight distance, and promoting safe driving practices.[17]

2.17 A Study of a Flyover-Bridge - Improved Intersection *(Narabodee Salatoom et al. 2015)*

This literature review focused on the flyover-bridge intersection model used to increase traffic capacity and reduce congestion in suburban areas. The study selected five existing flyover intersections in Thailand and aimed to identify remaining traffic and road safety issues and propose improvements for these intersections.

The research framework consisted of six steps, including case study selection, data collection (physical data, traffic data, accident statistics), data assessment, data analysis using the SIDRA software (evaluating intersection designs), conclusion, and recommendations for improvement. Traffic data was collected under the bridge and on the bridge, categorizing vehicles into different groups. The traffic volume was converted to equivalent passenger car units (PCU) to analyze delay and queue length during peak times. The traffic signal programs used fixed-time control plans similar to the previous at-grade intersections.

Accident statistics from three agencies were collected to compute accident costs, considering the number and severity of accidents over a three-year period. The mean cost per accident was used to estimate the annual average accident cost.

The analysis revealed that although the flyover bridge improved intersection control, it had limitations in solving traffic problems on secondary roads. The fixed-time cycle plan for traffic signalization led to unnecessary vehicle time loss. The study identified both advantages (increased convenience for road users on the bridge, improved traffic flow on the main road) and disadvantages (obscured visual landscape, limited traffic capacity improvement on secondary roads) of the flyover intersection model.

Overall, the study highlighted the need for further improvements in the flyover-bridge intersection model to address remaining traffic and road safety issues.[18]

2.18 Study On Road Safety Improvement In India (*Vigneshkumar K et al. 2014*)

Vigneshkumar K *et al.* focused on road safety management and proposes measures to reduce accidents and minimize their impact. It emphasizes the importance of road traffic and human behaviour in causing accidents. The design of roads, including road junctions, road maintenance, and visibility, is discussed, highlighting the need for clear road design, speed control measures, and proper maintenance. Vehicle design factors such as ground clearance, braking systems, and safety features are also addressed. The role of drivers' behaviour, road safety training, experience, and physical fitness is emphasized. The study suggests safety education for the general public and emphasizes the importance of following rules and regulations. It concludes by providing recommendations for improving road safety, including standardized road signs, reduced speed near junctions, seat belt and helmet usage, and mandatory road safety training for drivers.[19]

Chapter 3 : Methodology

3.1 General

The National Highways Authority of India has been engaged in the development of National Highways. In this regard, it has decided to undertake "Construction of Six Lane standalone flyover at Chapaguri, Pathsala and Simlaguri Chowk junction on stretches of NH 31 and NH 31C (new NH 27) in the state of Assam under Bharatmala Pariyojna on EPC basis." NHAI awarded the project to M/s Shiv Build India Private Limited. M/s Shiv Build India Private Limited (Here after referred as Client) appointed G-Engineering Advisory Services Private Limited, Gurugram, as the "Design consultant" to carry out the Detailed Engineering Design Services for the project corridor.

Details of the project location are mentioned below:

1. Section of NH 31C from km 82+430 (Design Chainage 0+000) to km 83+840 (Design Chainage 1+410), Chapaguri in the State of Assam.
2. Section of NH 31 from km 1000+750 (Design Chainage 0+000) to km 1001+780 (Design Chainage 1+0230), Simlaguri, in the State of Assam.
3. Section of NH 31 from km 1029+530 (Design Chainage 0+000) to km 1030+470 (Design Chainage 0+940), Pathsala in the State of Assam.

3.2 Site visit

Initially a site visit to three blackspot locations was conducted accompanied by road contractor. The visit was aimed to verify and gather relevant information regarding the main carriageway and service road, structures (minor bridges and culverts), road side drainage and other roadside amenities as per the Contract Agreement Schedule. All the existing features was visually documented with the help of photographs.

Observations:

- The existing main carriageway at Pathshala and Simlaguri had an existing superelevation right at the junction with the connecting road. Therefore one of the outer edges of the main carriageway was raised creating a level difference with the connecting road of approximately 1.5m.

Fig 3.1 Existing Superelevation right at the junction with the connecting road

- In Chapaguri, Existing minor bridge was located near the junction upon which flyover would be designed. Additionally, no existing service road was observed near the MNB and junction.

Fig 3.2 Existing minor bridge upon which flyover to be designed

- Connecting road is at lower level thus there is lack of visible distance while entering into main carriageway potentially leading to one of reason behind black spot.

- Near Chapaguri storm water drain was observed on either side of main carriageway.

Fig 3.3 storm water drain in chapaguri

- In all the three locations there were few patches where the built up location was exceeding the existing right of way (ROW).
- Existing Road in all the three location is flexible pavement and with signs of distress, and visible irregularities.

Fig 3.4 Distress, and Visible irregularities in Pavement.

3.3 Data From Site

Topological survey of all the location was obtained from the contractor in autocad file. This survey consisted of points having northing ,easting and elevation value of necessary road elements such as centerline, median bus bays, electric line, gas line, buildings etc

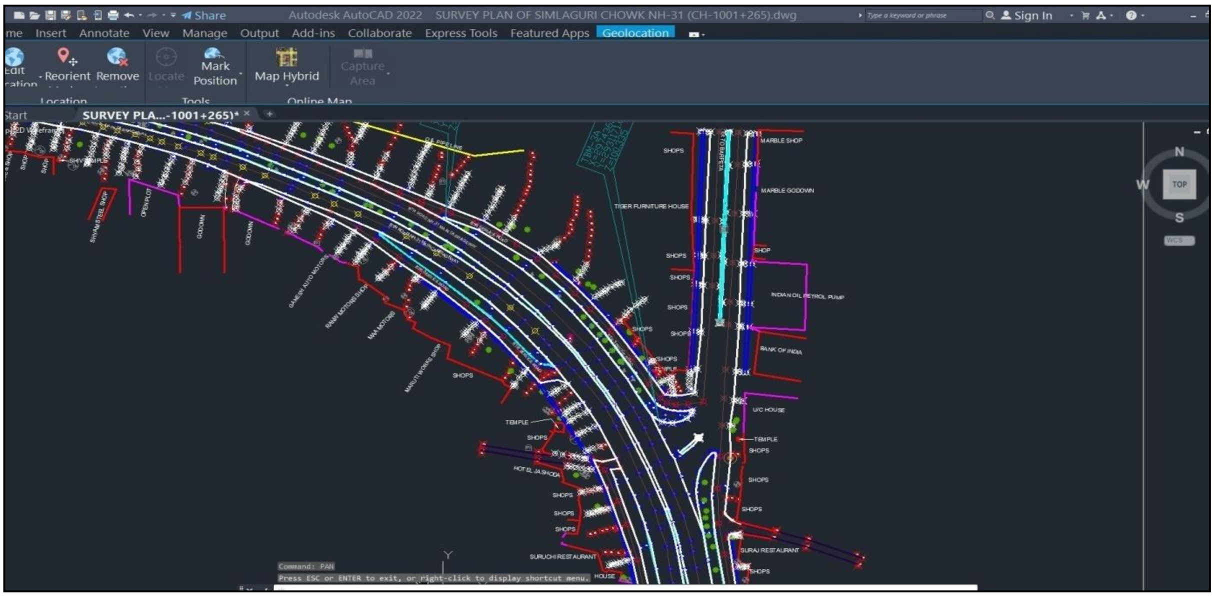


Fig 3.5 Shows topo survey of Simlaguri

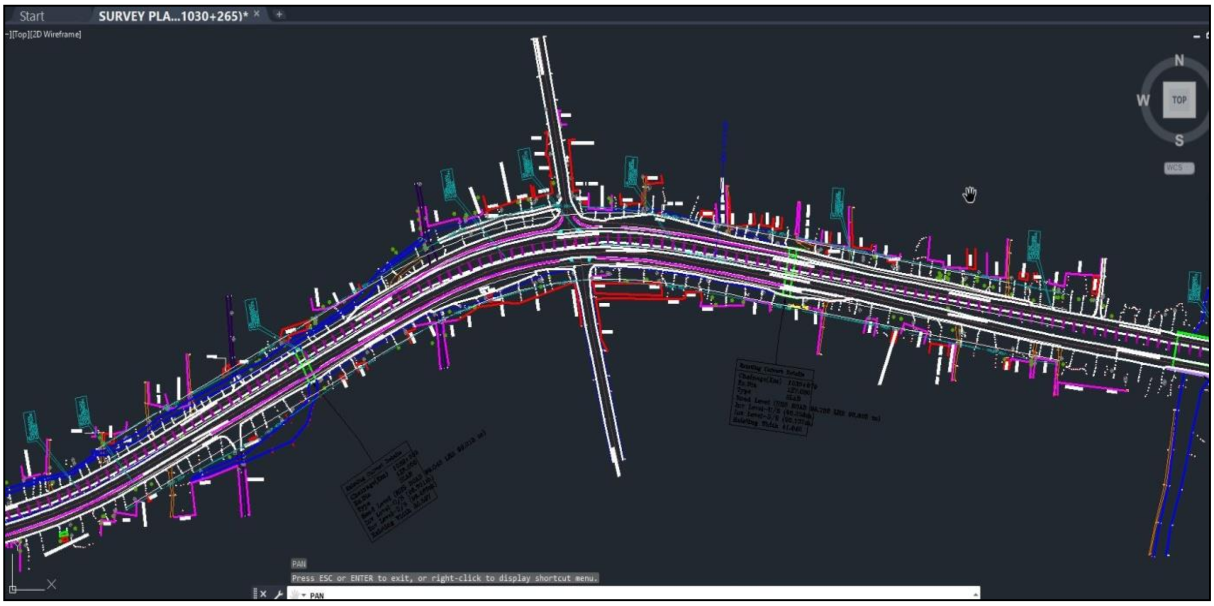


Fig 3.6 Shows topo survey of Pathshala

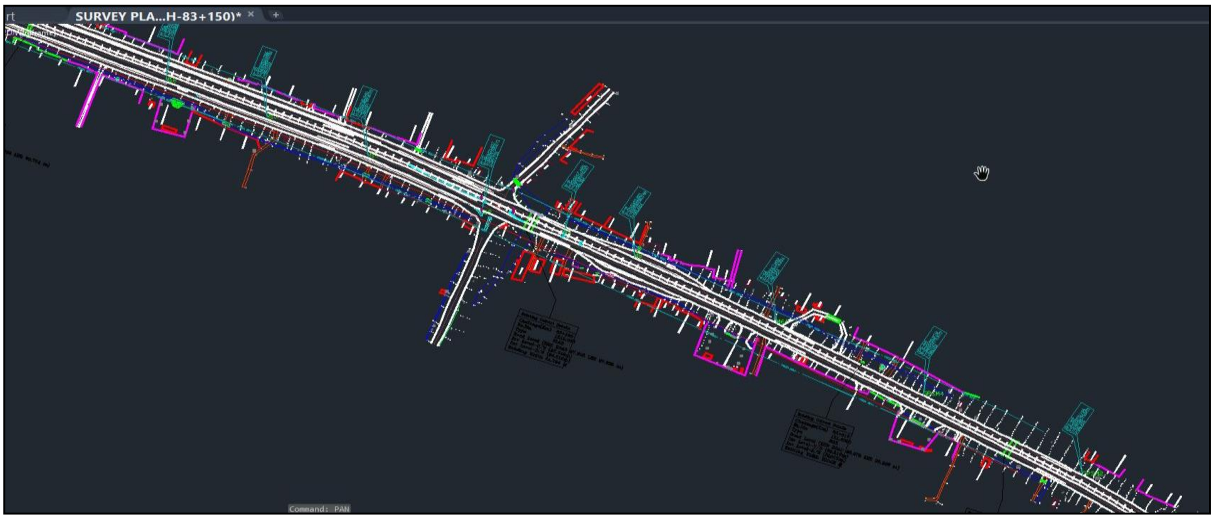


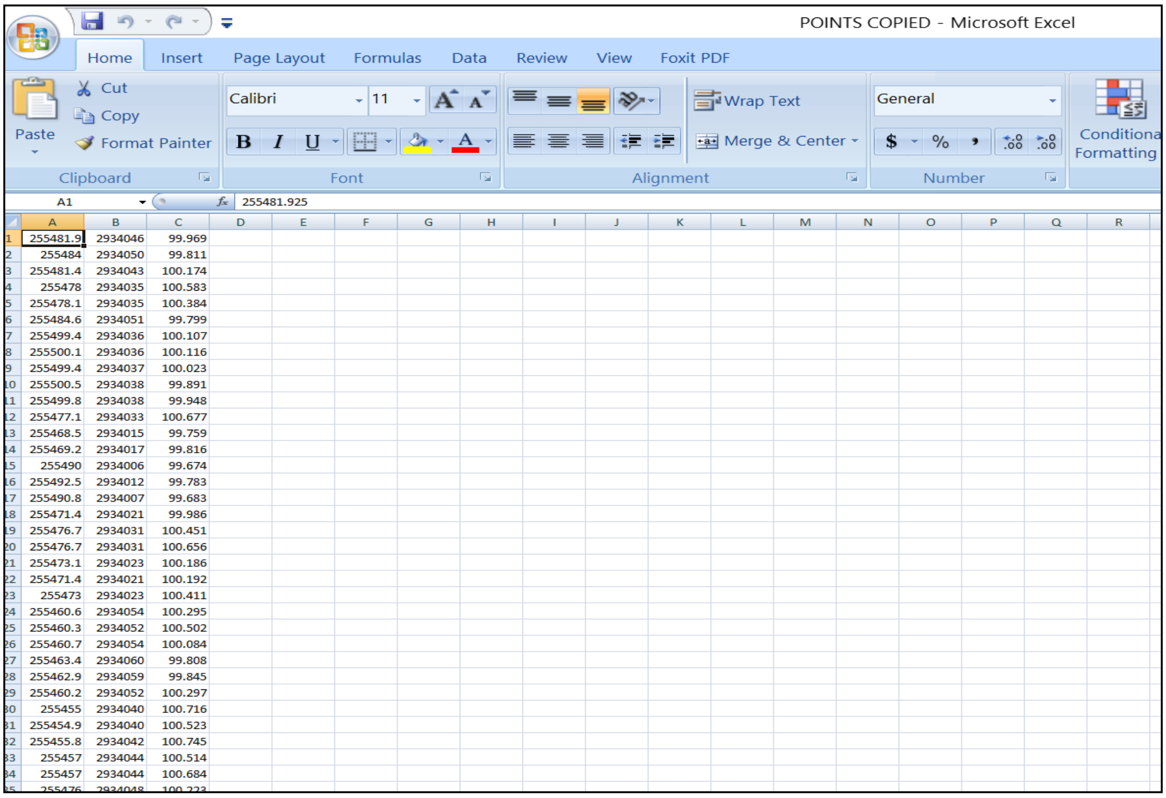
Fig 3.7 shows topo survey of Chapaguri

After survey was received the data points were thoroughly checked and verified.

3.4 Working in Civil3D

3.4.1 Data Extraction

The data points from the survey were copied and added to new drawing file. Using "Civil 3D" software, with the help of data extraction command, the coordinates of these data points were extracted and were converted into excel format having .csv extension. refer fig 3.4 and then data extraction was done.



	A	B	C
1	255481.9	2934046	99.969
2	255484	2934050	99.811
3	255481.4	2934043	100.174
4	255478	2934035	100.583
5	255478.1	2934035	100.384
6	255484.6	2934051	99.799
7	255499.4	2934036	100.107
8	255500.1	2934036	100.116
9	255499.4	2934037	100.023
10	255500.5	2934038	99.891
11	255499.8	2934038	99.948
12	255477.1	2934033	100.677
13	255468.5	2934015	99.759
14	255469.2	2934017	99.816
15	255490	2934006	99.674
16	255492.5	2934012	99.783
17	255490.8	2934007	99.683
18	255471.4	2934021	99.986
19	255476.7	2934031	100.451
20	255476.7	2934031	100.656
21	255473.1	2934023	100.186
22	255471.4	2934021	100.192
23	255473	2934023	100.411
24	255460.6	2934054	100.295
25	255460.3	2934052	100.502
26	255460.7	2934054	100.084
27	255463.4	2934060	99.808
28	255462.9	2934059	99.845
29	255460.2	2934052	100.297
30	255455	2934040	100.716
31	255454.9	2934040	100.523
32	255455.8	2934042	100.745
33	255457	2934044	100.514
34	255457	2934044	100.684
35	255476	2934048	100.223

Fig 3.8 Data points in .CSV format

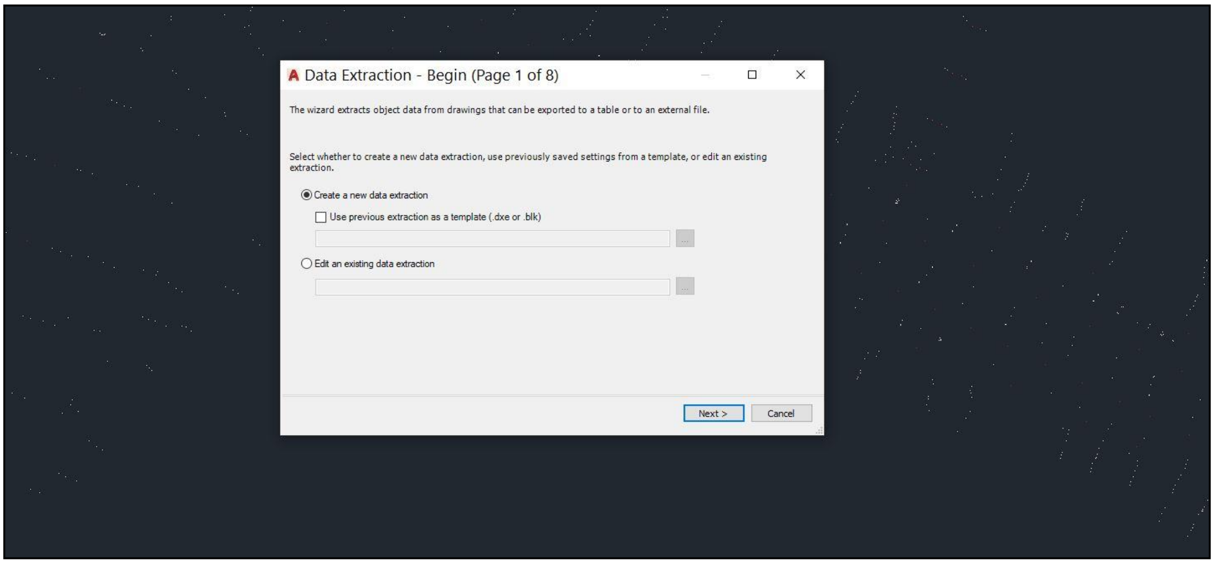


Fig 3.9 Data extraction dialog box and steps

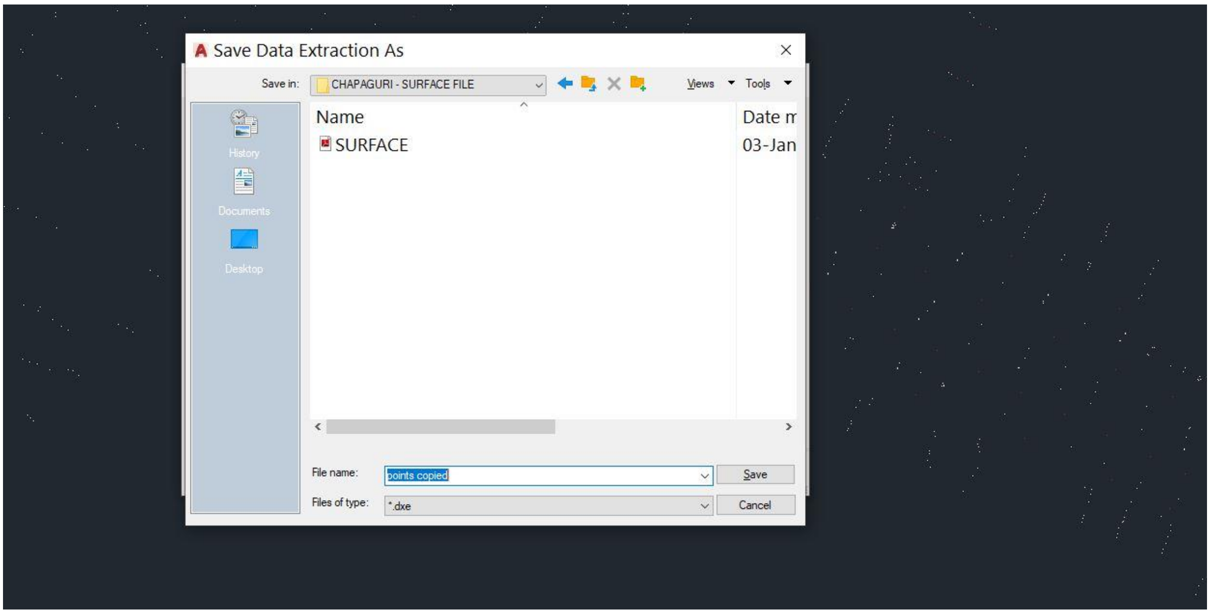


Fig 3.10 Data extraction file .dxe format

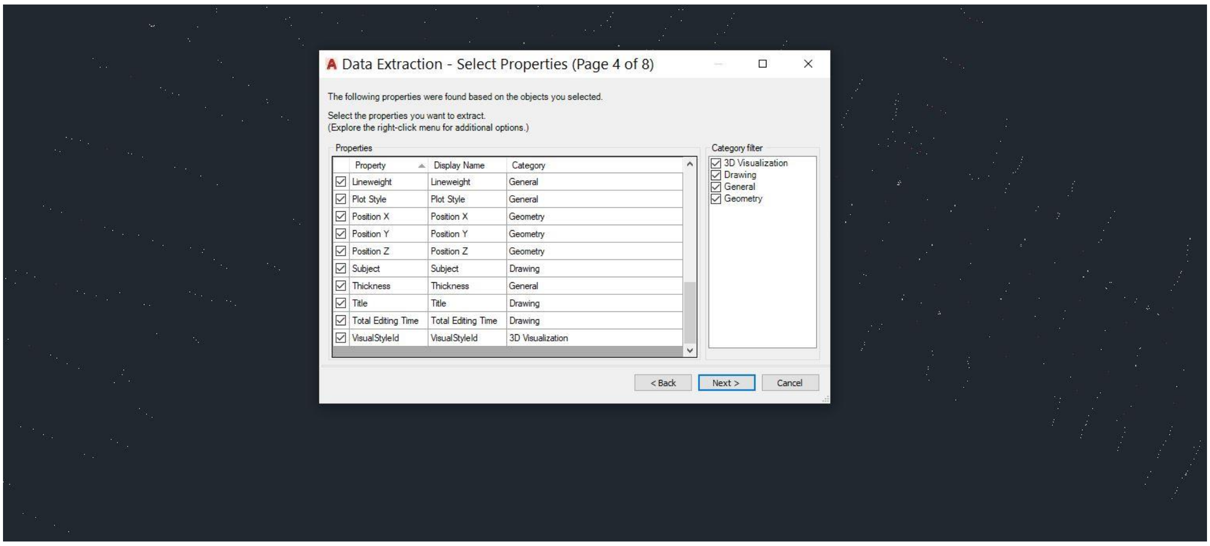


Fig 3.11 Data extraction- Select properties dialog box.

3.4.2 Surface Creation

The X,Y,Z coordinates in the CSV were therefore imported in C3D using Point Creation tools. The file format of ENZ was selected since the coordinates were in Easting, Northing and Elevation format. All the point were clubbed in a point group named Topo Points.

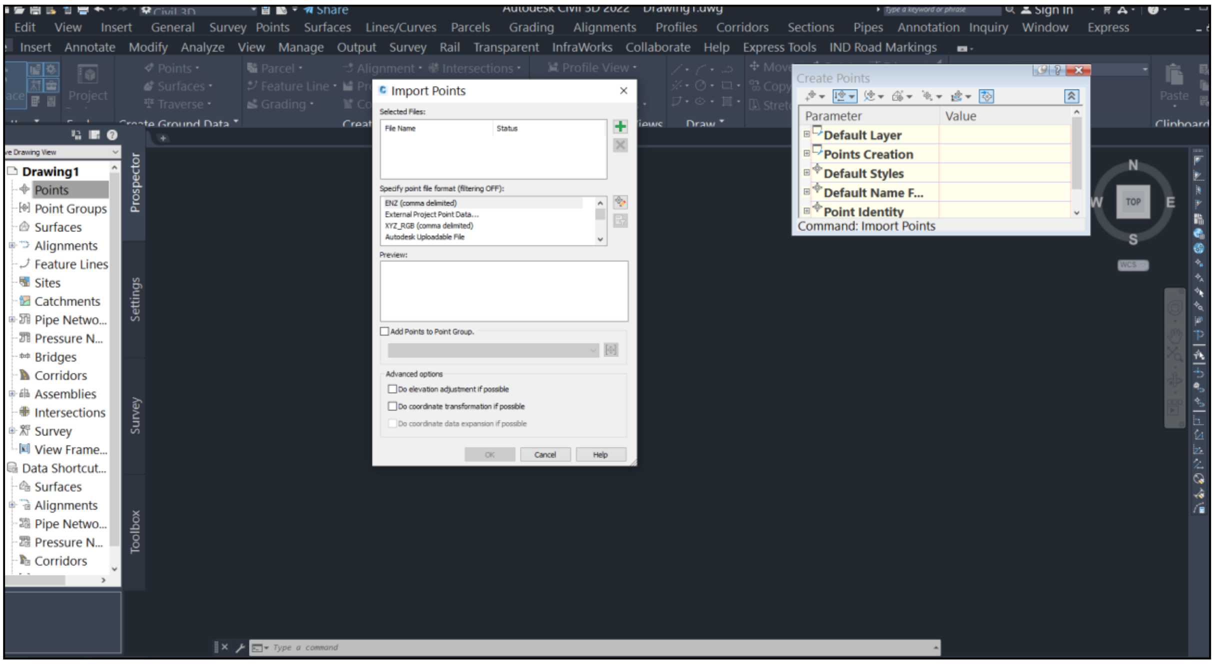


Fig 3.12 Point Creation tool and import point in ENZ format dialog box

In the toolspace, from the prospector tab new surface file was created from surfaces. The surface file was named and the "Topo Points" Point group was added to this. After the completion of this process the Surface was created.

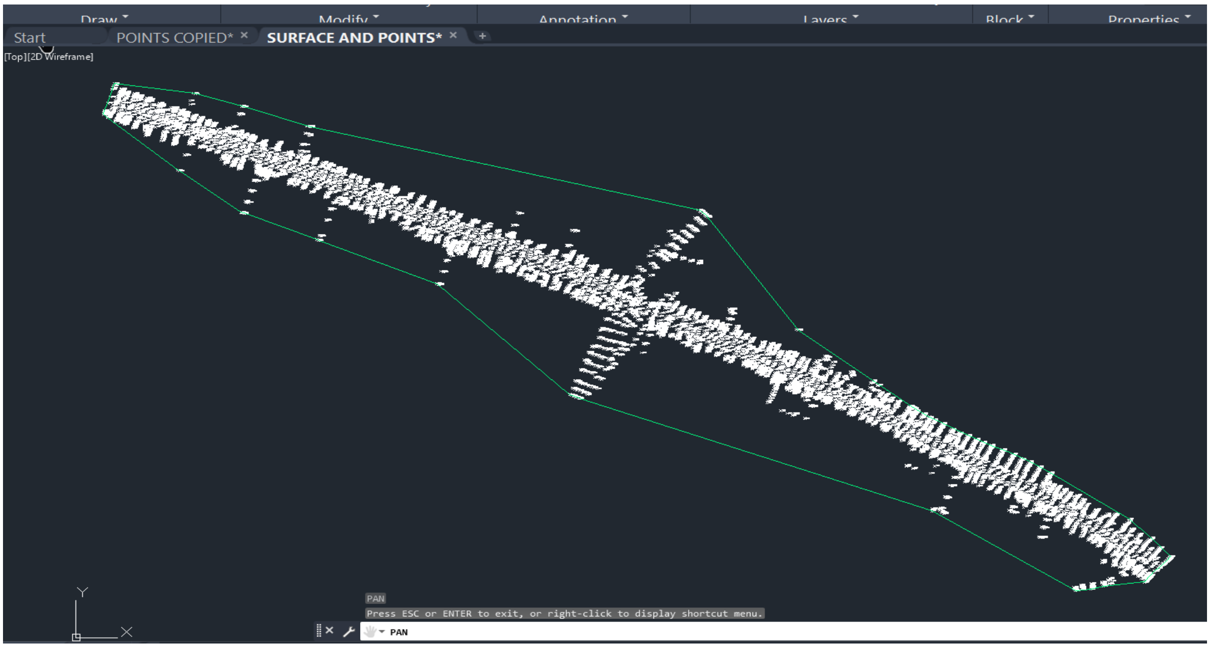


Fig 3.13 Surface and Point file

Surface file thus created were exported to Land XML format for making file lighter by removing the superimposed data points.

3.4.3 Horizontal Geometric Design

Initially, the Land XML file that was saved was imported showing only the surface along with boundary. On this Surface, the new proposed centreline is placed using Alignment Creation tools. In the alignment creation tool proposed centreline name was given alignment style was assigned once this process was completed geometric editor tool was opened. This editor tool was the basis for designing the centre line

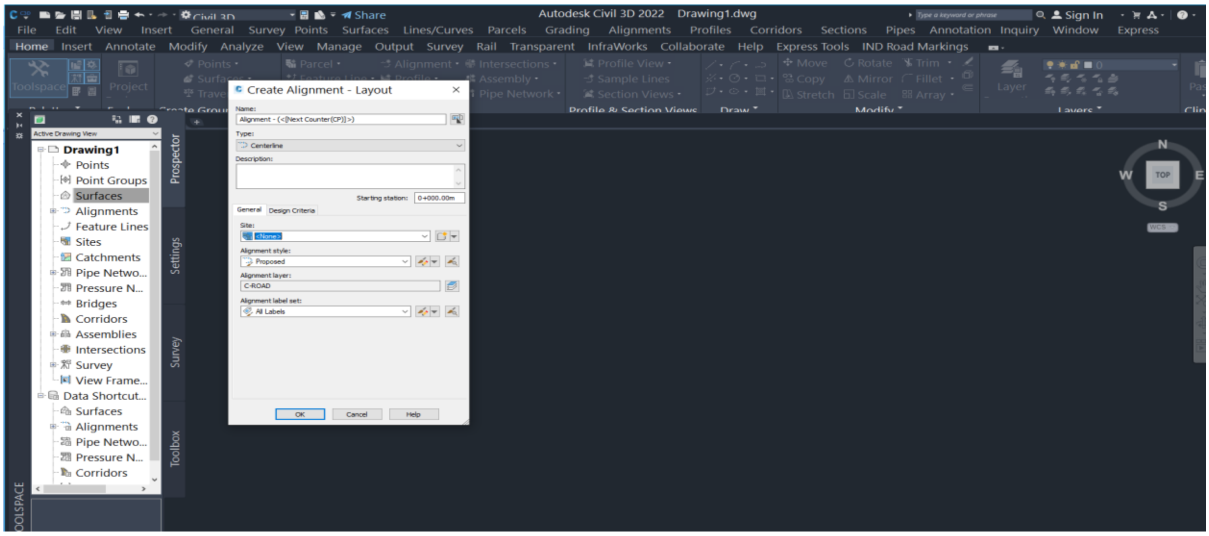


Fig 3.14 Alignment Creation Tool Dialog Box

3.4.3.1 Designing the Centreline

For designing the centreline, the topo survey was used as reference. Since in this project the existing centreline was to be followed therefore the median points and poly lines were copied from the survey and pasted in the design file as reference.The horizontal geometry of the centreline was tried to match with existing centreline. However the curve was improved wherever necessary as per design speed requirements mentioned in the schedule of contract agreement.

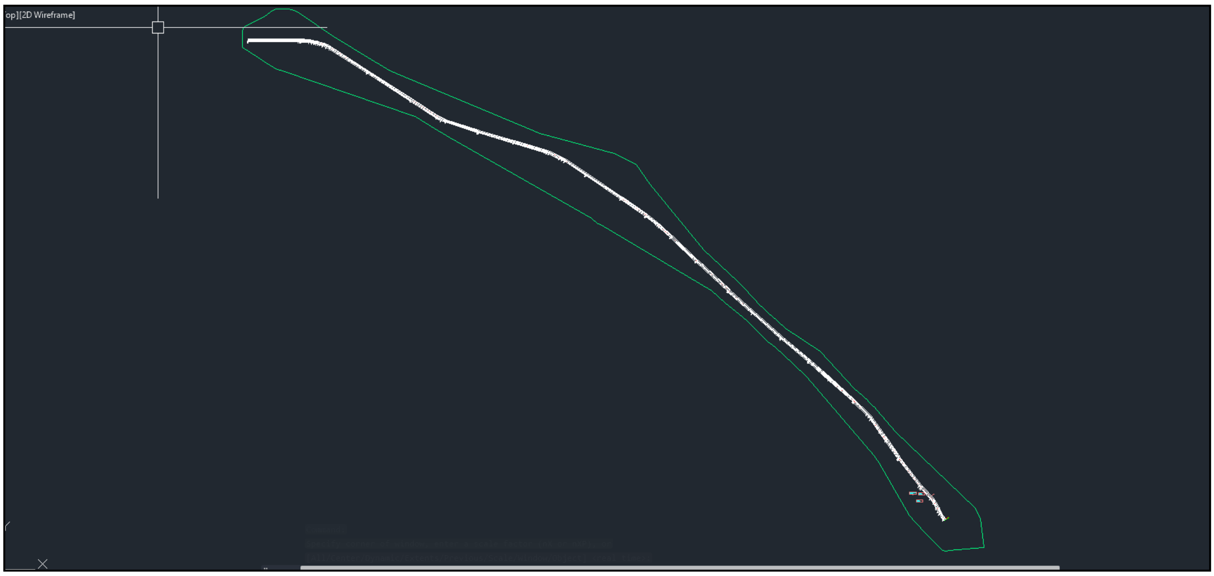


Fig 3.15 Existing centreline

3.4.3.2 Curve Design

The basic steps that were followed for curve design were

Opening geometric editor(Alignment tool) ⟹ Tangent drawn ⟹ PI inserted ⇓

Enter spiral or transition length or Enter curve radius ⟸ Spiral curve Spiral Selected

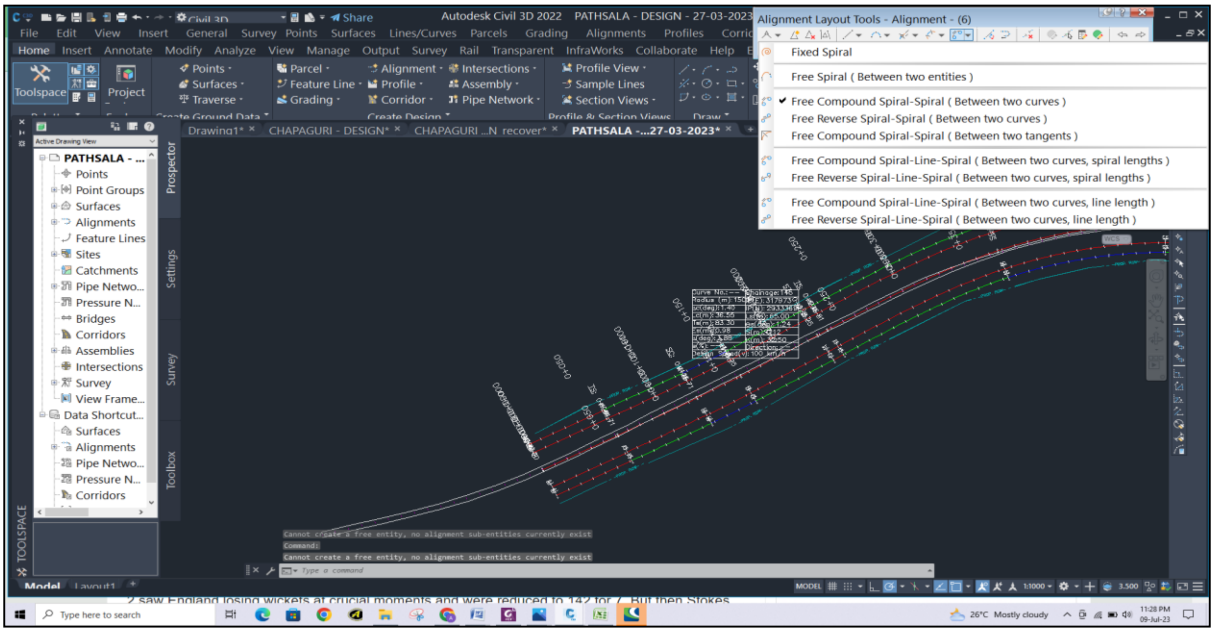


Fig 3.16 Alignment creation tool

Once the centreline was designed for the designated project length, Superelevation was added to the centreline The design centreline was selected and superelevation tab was selected present beside the geometric editor tab.

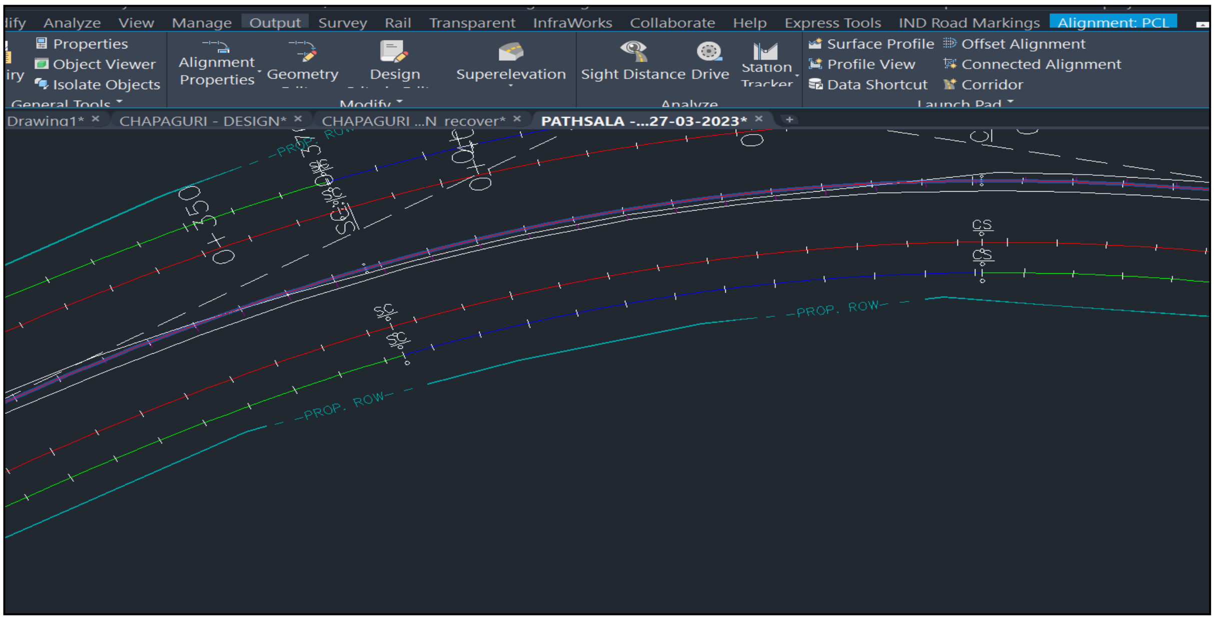


Fig 3.17 superelevation dialog box in C3D

The input values such as carriageway width,camber ,transtion design speed ,radius needed for calculating superelevation in C3D .

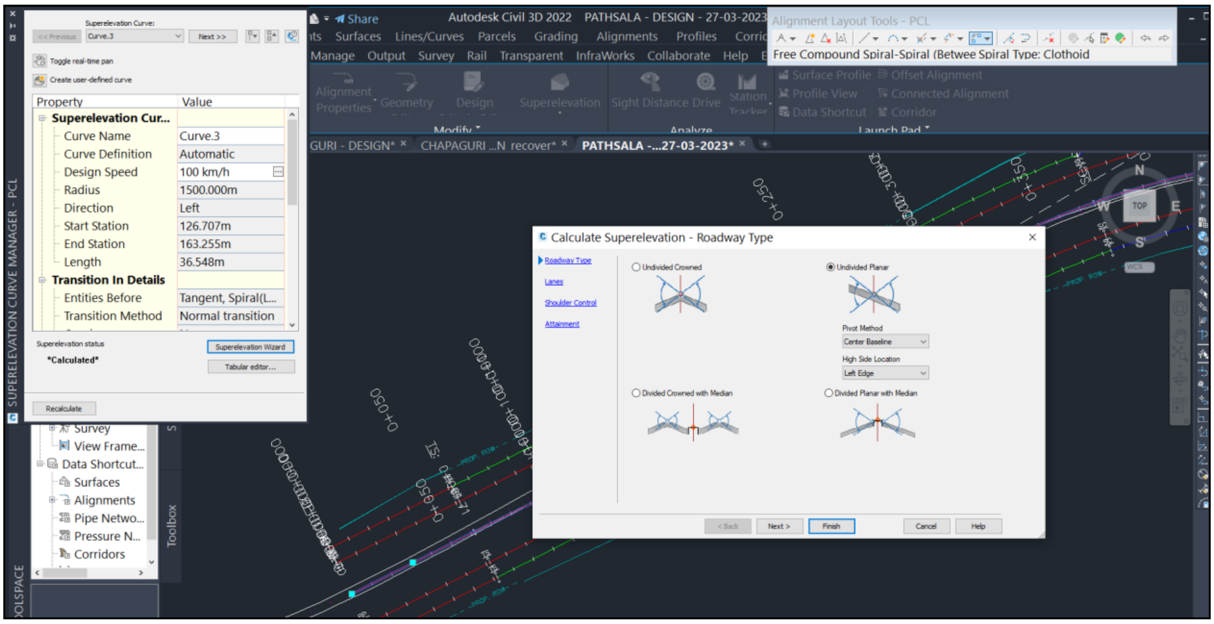


Fig 3.18 Superelevation input values

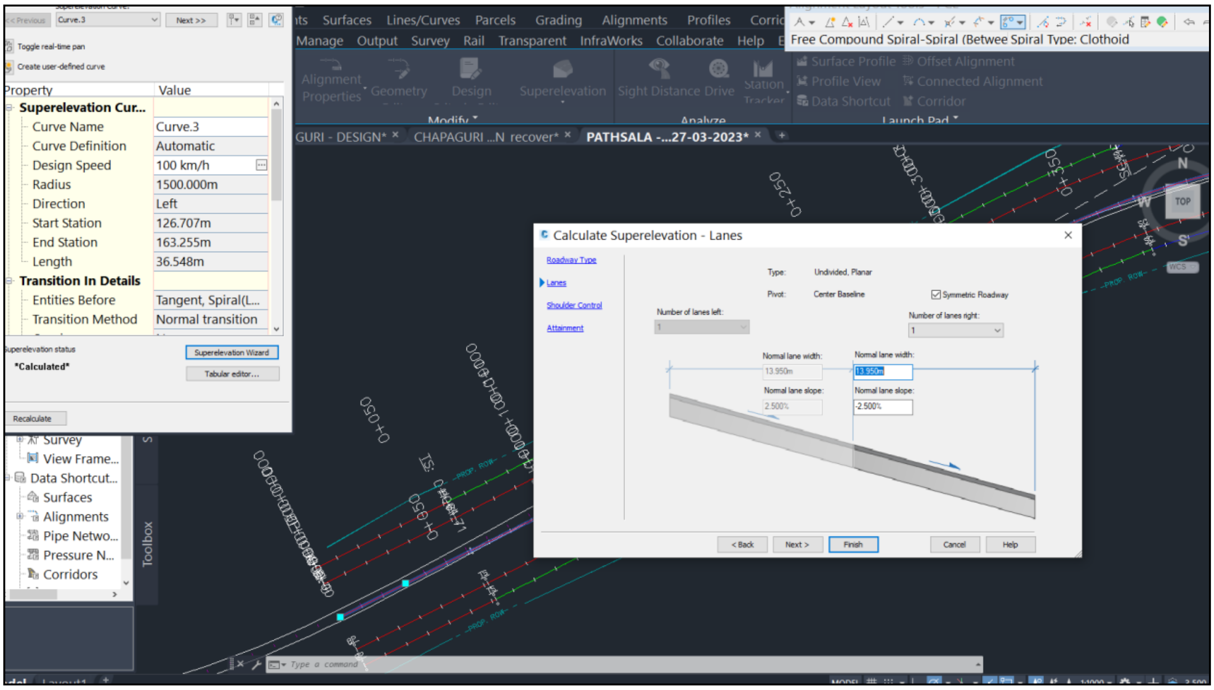


Fig 3.19 Superelevation input values

Once the horizontal geometry is done vertical geometry is created.

3.4.4 Vertical geometry design

Initially , the centreline was selected and surace profile is created using Surface Profile creation tool. A popup appears right after selecting the surface creation tool. In this tab the surface that was previously created is added and the complete process is finished.

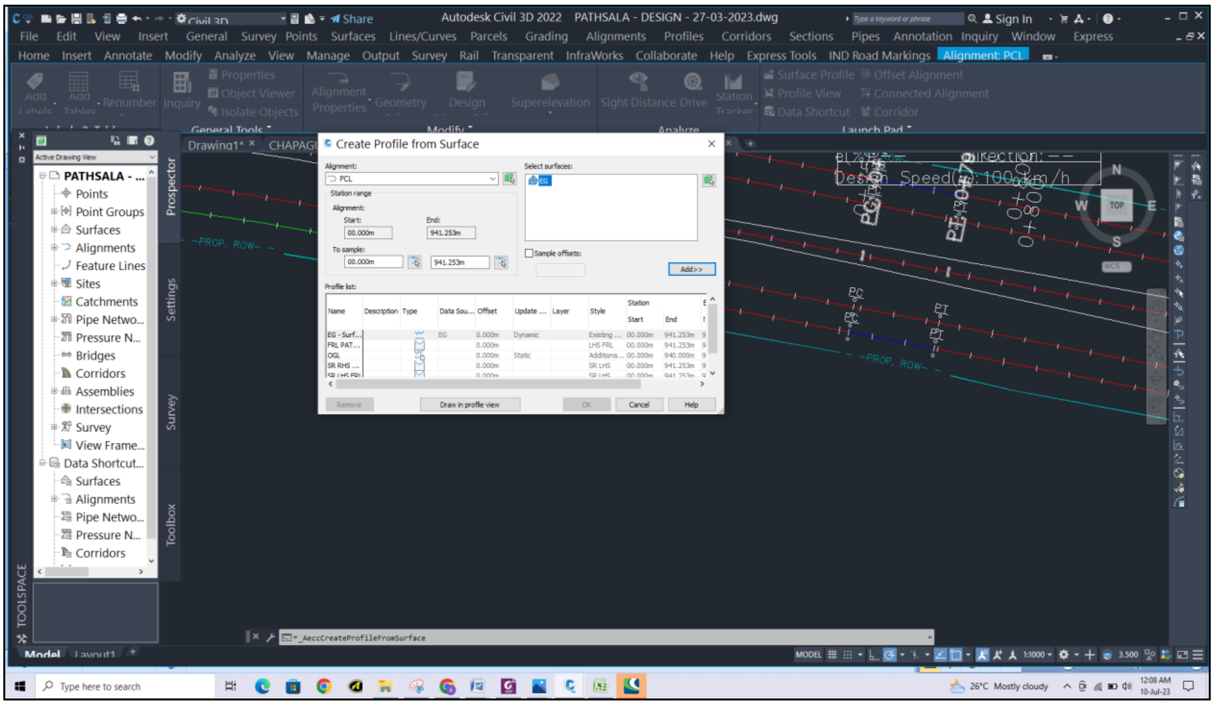


Fig 3.20 Surface Profile Creation Tool

After the process, the vertical profile was placed at the specified location. The vertical profile shows the existing ground points that is obtained from the surface data.

On this existing ground level the finished road level or frl are marked with help of proper vertical geometry.

This vertical road profile was created from profile creation tools which was in same line as alignment creation tool.Again we name the design profile and assign a design style.

Immediately after this step again a geometric editor popped up which was basis for design road profile

3.4.4.1 Elevation level

- ✓ Elevation level of the flyover structure was put based on the following criteria.
- ✓ Based on service road level
- ✓ Based on Minimum vertical clearance (5.5 m)
- ✓ Based on girder size.
- ✓ Based on deck slab size.
- ✓ Based on wearing coat thickness.
- ✓ Based on superelevation.

Since the structure is placed on the service road therefore it served as the basis for reference level based on which FRL of flyover was decided.

Similarly, the service road levels were also designed based on the existing service road data and the junction level.

The vertical curve of both main carriageway and service road was designed based on IRC standards and schedule design criteria.

3.5 Codes and Guidelines adopted for Roadway Design

IRC Codes

1) IRC: 38-1998: - Guidelines for Design of Horizontal curves for Highways and Design Tables (First Revision)
2) IRC: 73-1980: - Geometric Design Standards for Rural (Non-Urban) Highways

IRC-SP

3) IRC: SP: 87-2019: - Manual of Specifications and standards for Six Laning of Highway
4) IRC: SP: 23-1993: - Vertical Curves for Highways

3.6 Road Design Standards

3.6.1 Terrain Classification

Project road passes through Plain & Rolling terrain.

3.7 Design Speed

Table 3-1: Design Speed

Nature of Terrain	Design Speed (km/hr) as per IRC SP 87-2019	
	Ruling	Minimum
Plain and Rolling	100	80

3.8 ROW

The details of proposed ROW are given in Annex-II of the Schedule-B.

Table 3-2: Details of ROW

S. No.	Existing Chainage (km)		Length (km)	Proposed ROW (in m)
	From	To		
1	82+430	83+840	1.410	52-64
2	1000+750	1001+780	1.030	60
3	1029+530	1030+470	0.940	60

3.9 Width of Carriageway

The paved carriageway shall be 6 lane width divided carriageway [13.5m wide main carriageway on one side (10.5m carriageway + 0.5m wide Kerb Shyness + 2.0m wide Paved shoulder + 0.5m with Kerb Shyness) in accordance with the typical cross section given in the schedule B of Contract agreement.

3.10 Horizontal Alignment

Following principles followed for designing horizontal alignment: (As per IRC: 73 1980)

- Alignment is fluent and blend well with the surrounding topography.
- All horizontal curves requiring super elevation consist of circular portion flanked by spiral transitions at both ends.
- Reverse curves needed difficult in terrain. Sufficient length between two curves has been provided for introduction of requisite transition curves, and required super elevation.
- The curves in the same direction are separated by short tangents (known as broken back curves) were avoided.

3.10.1 Radius of Horizontal Curves:

The radius of horizontal curves for various terrain conditions are not less than ruling minimum values as per IRC:SP:87-2019 for the National Highways

Table 3-3: Radius of Horizontal Curve

Nature of Terrain	Desirable Minimum Radius	Absolute Minimum Radius
Plain and Rolling	400 m	250 m

3.10.2 Transition Curves:

All horizontal curves consists of circular curve flanked by transition at both the ends. Transition curve length is provided as per IRC Geometric Design Standards for Rural

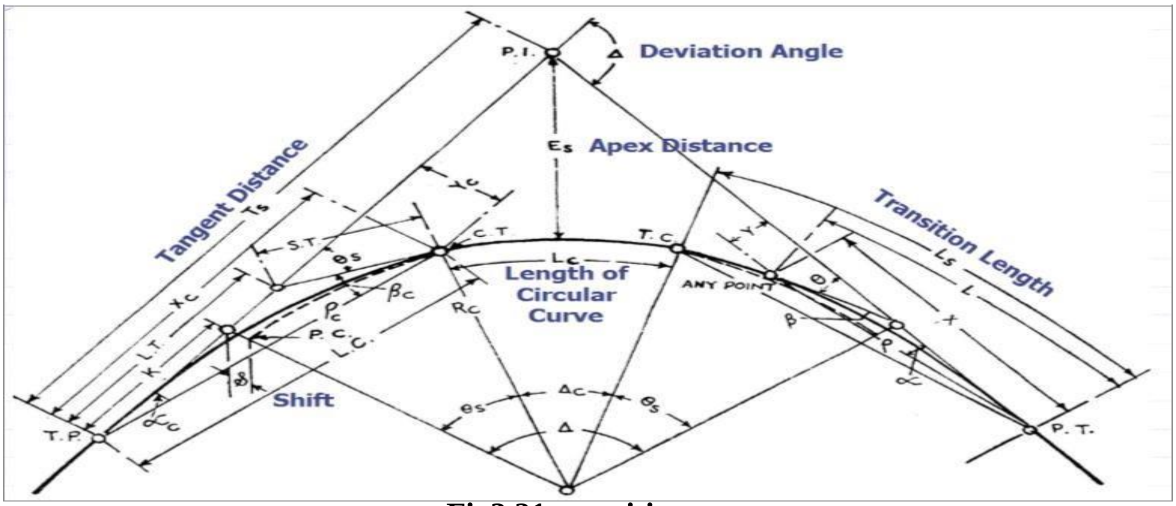


Fig3.21 transition curve

Highways, IRC: 73-1980. The required transition curve length for different speed has been adopted as per Schedules and as per IRC:SP:87-2019 for design shown in table below.

- Minimum length of transition curves is as given in Table 2-4 arrived as per IRC: 73-1980 for the specified design speed.

- The horizontal alignment of service roads and cart road is designed for minimum sight distance.
- The length of the horizontal curves with deflection angle between 5 degrees and 1 degree is according to IRC 73:1980 cl. 9.1.5.

Table 3-4: Minimum Transition Lengths for different speeds and Radius

Curve Radius	**Design Speed (km/h)**				
(m)	**100**	**80**	**65**	**50**	**40**
60				NA	75
90				75	50
100			NA	70	45
150			80	45	30
170			70	40	25
200		NA	60	35	25
250		90	50	30	20
300	NA	75	40	25	NR
360	130	60	35	20	
400	115	55	30	20	
500	95	45	25	NR	
600	80	35	20		
700	70	35	20		
800	60	30	NR		
900	55	30			
1000	50	30			
1200	40	NR			
1500	35				
1800	30				
2000	NR				

NOTATIONS:-

1 *NA= RADIUS NOT APPLICABLE*

2 *NR= TRANSITION NOT REQUIRED*

3.10.3 Camber

Camber/unidirectional cross-fall is provided for each carriageway including paved shoulders in accordance with IRC SP 87-2019. The cross fall on straight sections of the road main carriageway and Edge strip is 2.0% for bituminous surface & cement concrete surface. The cross fall for earthen shoulders on straight portion is 0.5% steeper than the slope of the pavement and paved shoulder subject to a minimum of 3.0%.For this project 2.5% is adopted

Table 3-5: Camber/ Cross fall for different surface types

Type of Surface	Camber
Bituminous (For Long life Perpetual Pavement)	2.0%
Bituminous (For Flexible Pavement-Service Road)	2.5%
Cement Concrete	2.0%
Earthen	3.0%

3.10.4 Super elevation

Superelevation has been provided on curves in accordance with IRC: 73-1980. The super elevation has been given up to a certain radius as presented in Table 7 based on IRC: 73 – 1980.

Table 3-6: Radii beyond which super elevation is not provided

Design Speed	Radius (m) for camber of			
	4%	3%	2.5%	2%
100	1100	1500	1800	2200
80	700	950	1100	1400
65	470	620	750	950
60	400	540	640	800
50	280	370	450	550
40	180	240	280	350

3.10.5 Sight Distance

As per Schedule D of the Contract agreement, stopping sight distance has been followed. Stopping Sight Distance is the clear distance ahead needed by a driver to bring his vehicle to a stop before meeting a stationary object in his path. These are based on the perception and brake reaction time. The design values for sight distances are given in the Table 8.

Table 3-7: Sight distances for design speed

Speed (kmph)	Desirable Minimum Sight Distance (m)
100	360
80	260
60	180
40	90

For Valley curves, the design is governed by night visibility which is considered in terms of Headlight sight distance. It is the distance ahead of the vehicle illuminated by the head light which is within the view of the driver. The headlight sight distance is equal to the safe stopping sight distance.

3.11 Vertical Profile

General principles followed for designing the vertical profile are:

- The vertical profile is designed as per IRC: SP: 23 – 1983.
- Gradients up to the value corresponding to ruling gradient is provided in accordance with IRC: 73 as specified in CA.
- Grade changes are not too frequent as to cause kinks and visual discontinuities in the profile. Desirably, there is no change in grade within a distance of 150m in case of new construction.
- The curves in the same direction separated by short tangents known as Broken back curves has been avoided.
- Curves has been provided at all grade change points with minimum length of Curve as given in Table 2-10.
- There is a coordination between horizontal alignment and vertical profile of the project highway and guidelines in accordance with IRC: 73-1980.
- The level of minor bridge/box culvert will work out with respect to High Flood level.

Table 3-8: Gradients

Type of Terrain	Ruling Gradient	Limiting Gradient
Plain and Rolling	2.5%	3.3%
Mountainous	5.0%	6.0%
Steep	6.0%	7.0%

Table 3-9: Adopted K value for vertical curve

Design Speed (km/h)	K Value for Summit Curve	K Value for Valley Curve
100	135	41.5
80	60	25.3
65	33.8	17.4
50	15	10
40	8.4	6.6
30	3.8	3.5

Table 3-10: Minimum length of vertical curves

Design Speed (km/hr)	Maximum grade change (%) not requiring a vertical curve	Minimum length of vertical curve (m)
40	1.2	20
60	0.8	40
80	0.6	50
100	0.5	60

3.12 Cross sectional elements

The cross-sectional elements has been provided in accordance to Schedule B of contract agreement. This is further based on the following:

- Ease of movement without conflict.
- Nature of Land use i.e. Rural and Semi-Urban
- Type of terrain i.e. Plain & Rolling.
- Requirement of an efficient drainage system, and operational safety such as segregation, separation etc.

The project highway is of Six-Lane. A Typical cross section along with different types of cross section is developed in different segments of the project highway as per Schedule-B of Contract Agreement.

The cross-section features of the main carriageway and paved shoulder are uniform across the length of the project highway. Service Roads/Slip Roads has been constructed at the locations and for the minimum width as per the Schedule-B of Contract Agreement.

Table 3-11: Cross section details of roadway width

Section of Road	Width (m)
For Main Carriageway:-	
Carriageway	2 x 10.5
Kerb Shyness	4 x 0.5
Paved Shoulder	2 x 2.0
For Service Road:-	
Carriageway	2 x 7.0

The elements like lane/Main carriageway width, Kerb Shyness and Paved shoulder are proposed as per the Typical Cross Sections given in Schedule B.

At Grade Intersections

Design standards for at-grade intersections are fixed in accordance with IRC Special Publication 41 'Guidelines for the Design of At-grade Intersections in Rural and Urban Areas and the MoRT&H "Type Designs for Intersections on National Highways". The intersections has been designed based upon the following parameters:

- Composition of traffic, Total traffic volume and Turning traffic volumes
- Number of approach roads and their category
- Width of approach roads
- Surface type

All Cross-Road and junctions falling within ROW below the grade are separated intersections referred in Clause 2.7 of Schedule B of Contract Agreement, has been improved as per the junction layout drawings or site/design requirements.

a. Grade separated structures

The type, location, length, number of openings and approach gradients for various grade separated structures like Vehicular Underpass, Overpass, Pedestrian Underpass and Flyover are provided as specified in Schedule B.

Table 3-12: Details of flyovers

Sr. No.	Existing Chainage (km)	Design Chainage (km)	Span arrangement (m)	NH no.
1	83+150	0+720	1x15m+1x35m+1x34.350m (Clear spans)	NH 31C
2	1001+265	0+487	1x26.8m+1x42.6m+1x26.8m (Clear spans)	NH 31
3	1030+000	0+477.5	1x26.8m+1x37.6m+1x26.8m (Clear spans)	NH 31

Table 3-13: Details of minor bridge

Sr. No.	Design Chainage (km)	Foundation	Structure type	Span arrangement (m)	Total Width(m)
1	83+190	Open	*Rcc Wall type(sub) and solid slab (super)*	1X10.5	10.2(lhs)
2	83+190	Open	*Rcc Wall type(sub) and solid slab (super)*	1X10.5	8.4(rhs)

3.13 Typical Cross-sections of the Project Highway

Table 3-14 : Applicable typical cross sections

Sl. NO.	CHAINAGE		LENGTH	TCS TYPE
	FROM	TO		
Proposed Flyover @ Chapaguri (Ch. 83+150 of NH-31C)				
1	0	150	150	-
2	150	1290	1140	1
3	1290	1414	150	-
Proposed Flyover @ Simlaguri (Ch. 1001+265 of NH-31)				
1	0	70	70	-
2	70	970	900	2
3	970	1030	60	-
Proposed Flyover @ Pathsala (Ch. 1030+000 of NH-31)				
1	0	50	50	-
2	50	900	850	2
3	900	940	40	-

3.13.1 Embankment

Height of the Embankment

- As per Cl 4.2.1 of IRC: SP-87-2019, the height of the embankment is based on the finished road levels. The following principles has been followed for fixing the road level.
- When the project alignment is sited within the flood plain or in the vicinity of water bodies where water cannot be efficiently drained, the bottom of the subgrade is 1.0m above the high flood level/ high water table/pond level.
- To fulfil the minimum free board requirement and provide smooth vertical profile for portions forming approaches to structures.

Structural features and design of embankment

Embankment has been designed in such a way to ensure the stability of the roadway and only those materials are incorporated, which are suitable for embankment construction.

- Fill Sections: Side slopes is 1.5H: 1V for height or as per slope stability.
- Cut Sections: Side slopes is as per IRC SP 87-2019 requirement.

High embankments (height 6m or above) in all soils has been designed from settlement & stability considerations. Design of high embankments has been carried out in accordance with IRC: 75-2015 and MORTH – Guidelines for Design of High Embankments.

The Slope protection by lawn or any other method using green technology is provided at locations, where embankment height is more than 1.00 m and in approaches of Viaducts/Flyover/Bridges as per manual and as directed by authority.

Suitable Slope Protection measures has been provided for embankment where either slope is steeper than 1V:1.5H or embankment height is more than 6 m.

3.13.2 RCC retaining wall

Retaining wall and toe walls has been constructed as per standard specifications mentioned at clause no. 13.10 in IRC SP-87-2019.

Retaining wall /RE Wall, if required to contain embankment slope within the available ROW, Shall be built

- At 7m distance from the outer edge of earthen shoulder leaving a clear space for 2 additional lanes for future widening.
- Wall and reinforcement shall be designed for full height and loads for future widening in consideration.

3.13.3 Utilities

Two metre wide strip of land at the extreme edge of ROW shall be kept for accommodating utilities, both over as well as underground & utility ducts in the form of 600 mm diameter NP-4 Pipe across the Project Highway at a spacing of 1 km shall be provided for crossing of underground utilities. (Refer Clause No. 2.16 of IRC: SP: 87-2019).

3.14 Pavement design for main carriageway and flexible pavement

The pavement design includes new pavement design and strengthening proposals formulated on the basis of the review of mandatory requirements of concession agreement, detailed investigations, studies, data collection, analysis and evaluation.

3.14.1 Selection of type of pavement

Table 3.15: Recommended Pavement Type

SI.No	Description of the Component	Recommended Pavement Type	Reasons
1	Flexible Pavement shall be constructed for Main Carriageway and Service Road	Flexible Pavement with layer combinations bituminous layers over WMM base GSB Subbase	As per schedule 'B'
2	Flexible Pavement shall be constructed for Main Carriageway and Service Road	Flexible Pavement with layer combinations bituminous layers over WMM base CTSub Subbase	As per schedule 'B'

3.14.2 Design Period

Design period has been considered as 20 years for flexible pavement.

3.14.3 Design subgrade CBR for main carriageway and service road

4-days soaked CBR@97%MDD of 500mm subgrade=**8.00%**

4-days soaked CBR@95% MDD of 500mm embankment = **8.0%**

Effective Subgrade CBR for Pavement Design = **8.0%**

3.14.4 Design Traffic (msa)

Table 3.16 : Design Traffic (in msa)

Sl. No.	Type of Structures	Design Chainage		Design Traffic (msa)
		From (km)	To (km)	
1	Proposed Flyover @ existing Km 83+150 of NH-31C	0+000	1+414	110
2	Proposed Flyover @ existing Km 1001+265 of NH-31	0+000	1+030	90
3	Proposed Flyover @ existing Km 1029+530 of NH-31	0+000	0+940	90

3.14.5 Recommended pavement composition of new flexible pavement applicable for main carriageway and service road

Table 3.17 : Designed layer thickness for new flexible pavement for main carriageway at km. 80+550 and km. 83+150 of NH-31C

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+WMM+GSB	110	8.0	50	140	250	200	140 mm DBM has to be laid in two layers. DBM lower layer to be laid with Va=3.5% and Vb= 11.50%
BC+DB+WMM+CTSB	110	8.0	50	95	150	200	95 mm DBM has to be laid in single layers with Va=3.5% and Vb= 11.50%

***Subject to availability of the material or Contractor's preference, any one of the two option may be used.**

Table 3.18 : Designed layer thickness for new flexible pavement for main carriageway at km. 1001+265 & km. 1029+530 of NH-31

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+WMM+GSB	90	8.0	50	130	250	200	130 mm DBM has to be laid in two layers. DBM lower layer to be laid with Va=3.5% and Vb= 11.50%
BC+DB+WMM+CTSB	90	8.0	40	95	150	200	95 mm DBM has to be laid in single layers with Va=3.5% and Vb= 11.50%

***Subject to availability of the material or Contractor's preference, any one of the two option may be used.**

3.14.6 Objective And Scope

The detailed scope for pavement design includes:

- Soil and Construction Material investigations
- Preparation of Detailed Pavement Design Report.

3.14.7 Pavement Design

Pavement design is an essential component of a highway project, as the cost of pavement construction makes up a significant portion of the overall project expenses. A well-designed and cost-effective pavement structure is as crucial as the design of any other engineering structure. The performance of the pavement under existing environmental conditions and expected traffic is of utmost importance, as it directly impacts the economic returns from the project. Insufficiently designed pavement will deteriorate prematurely, resulting in additional expenses for repairs. Conversely, an excessively extravagant design will needlessly deplete a limited budget. It is important to note that pavement design is just one aspect contributing to achieving optimal pavement performance. A comprehensive and integrated approach encompassing **DESIGN** (evaluation of materials and pavement composition), **CONSTRUCTION** (meeting design requirements, including tolerances and drainage), and

MAINTENANCE (ensuring pavement integrity) is necessary to achieve a high level of performance. The objective in road pavement design is to select appropriate pavement materials, layer thicknesses, and configurations that ensure satisfactory performance and minimal maintenance over the projected lifespan, considering the anticipated traffic loads. To accomplish this objective and accurately predict pavement performance, it is necessary to analyze material properties, traffic patterns, local environment and its effects, modes of failure of existing pavements, and available construction technologies. Furthermore, assumptions must be made regarding the desired level of performance and acceptable pavement condition. Given the numerous variables and their interactions influencing the outcome, it is advisable to follow a systematic approach when designing the pavement. Depending on the data collected and analysed or the number of assumptions made, the pavement design procedure can range from highly complex to relatively simple. This chapter presents the methodology adopted by the consultants for pavement design and also highlights the recommended final thickness of the pavement structure.

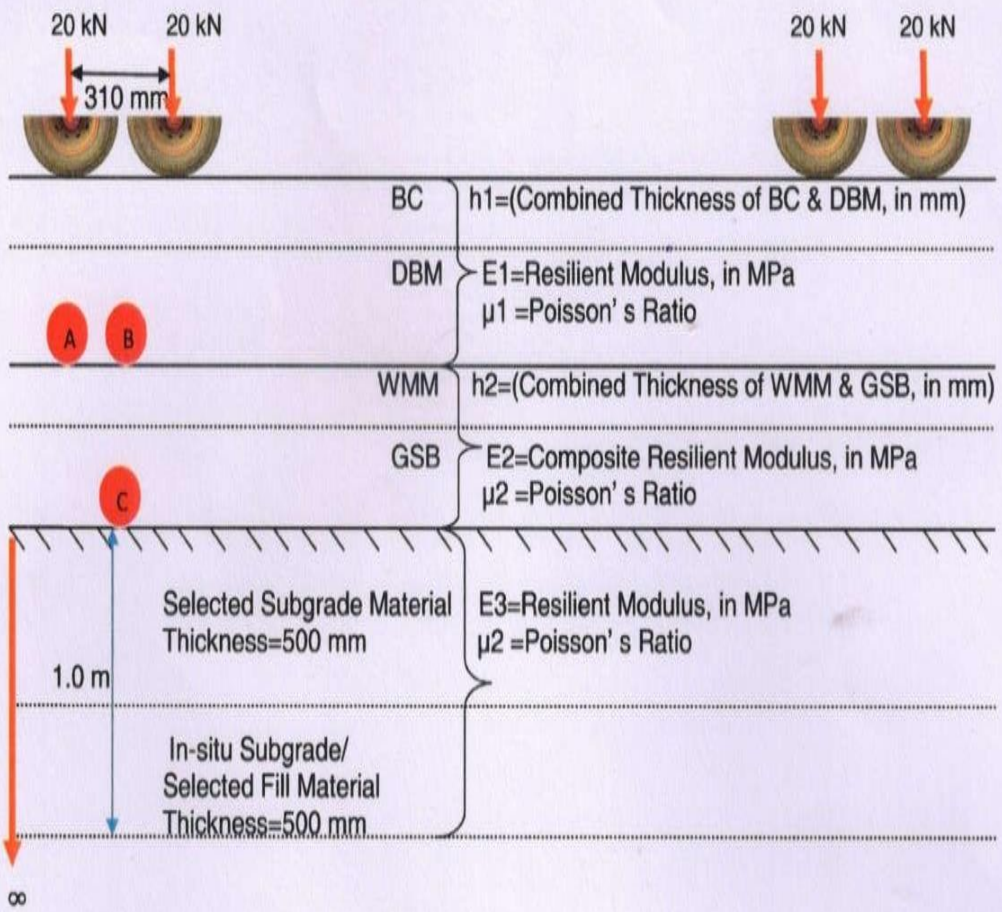
3.14.8 Application Manual, Pavement Design Standards And Construction Specifications

The adopted pavement design standard and construction specifications are presented next

- Guidelines for the Design of Flexible Pavements, IRC: 37-2018
- MORT&H Specifications for Road and Bridge Works (Fifth Revision), 2013

Pavement Model for Mechanistic Analysis

(Not in Scale)



Considerations:

Single Wheel-Load:20kN
Wheel configuration: Dual
Contact Pressure:0.56 MPa

Critical Locations:

A & B are the critical locations for horizontal tensile strains (ε_t) at the bottom of the bituminous layers. Maximum value of the strain is adopted for design. The location A is under the wheel, whereas the location B is centre of the dual-wheel.
C is the critical location for vertical compressive strain (ε_z) at top of the subgrade. The location C is centre of the dual-wheel.

Fig.3.22 Pavement model for mechanistic approach for GSB layer[G.eng report]

3.14.9 Principles Of Flexible Pavement Design

Pavement Model

The structural composition of a flexible pavement is represented as a multi-layered elastic structure. In the conventional approach to pavement design, the tensile strain (€t) at the bottom of the bituminous layer and the vertical subgrade strain (€z) at the top of the subgrade are regarded as crucial factors. These parameters aim to control the occurrence of cracking and rutting in the bituminous layers and non-bituminous layers, respectively.

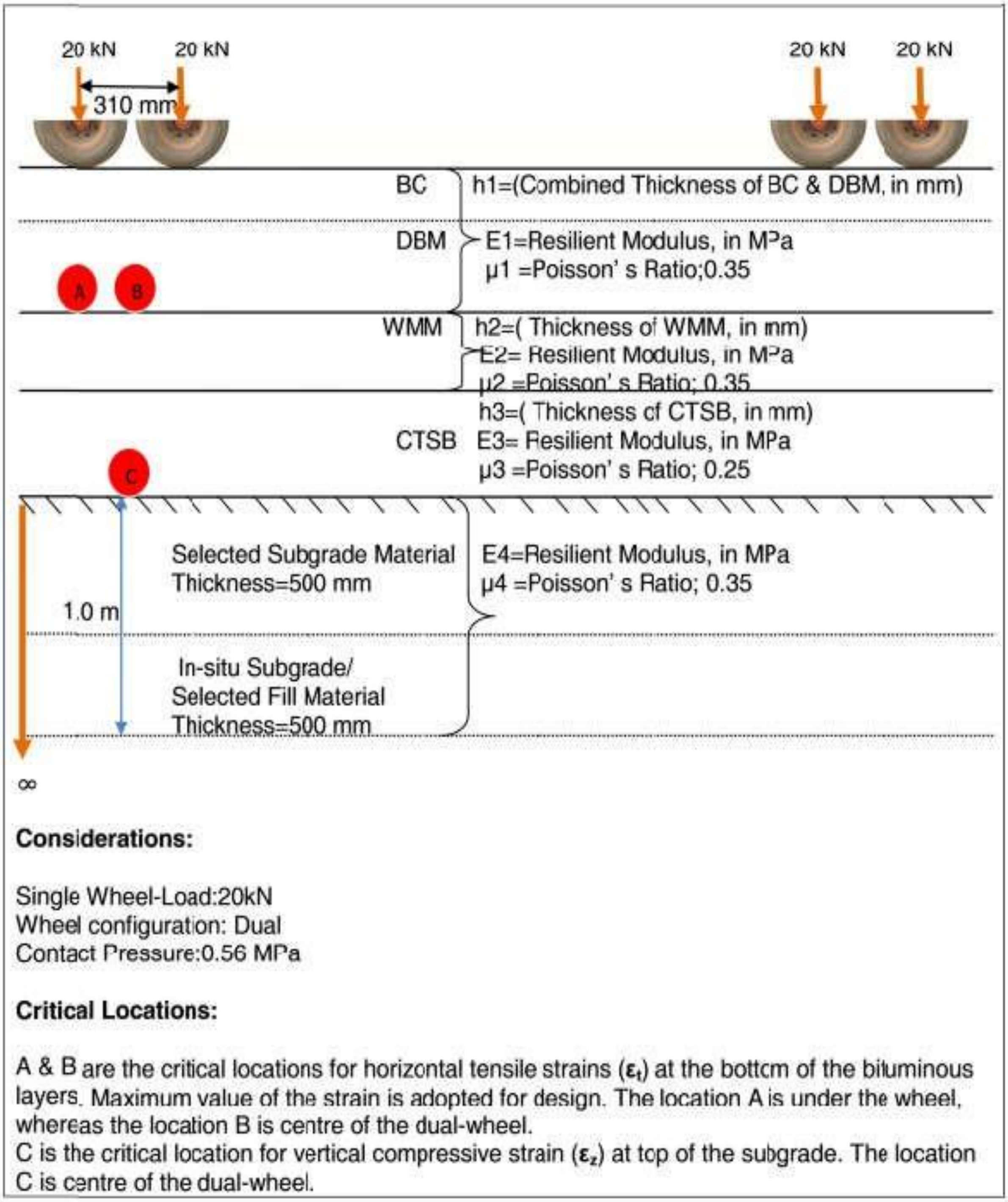


Fig.3.23 Pavement model for mechanistic approach for CTSB Layer[G.eng report]

3.14.10 Performance Criteria

The failure modes for the flexible pavement comprised of bituminous layers, unbound granular base and bound sub base considered are fatigue failure of bituminous layer & rutting failure of subgrade.

3.14.10.1 Fatigue cracking criteria for bituminous layer:

The critical or failure condition for the pavement is defined as the occurrence of fatigue cracking, wherein the total area of cracking in the road section being analyzed is equal to or exceeds 20% of the paved surface area. The equation 3.4 provides the equivalent number of standard axle (80 KN) load repetitions that the pavement can sustain before reaching the critical condition, considering 80% reliability level. Similarly, equation 3.4 accounts for a 90% reliability level. These equations represent the fatigue performance models for the conventional approach**.**

$Nf = 1.6064*C*10^{-4}[1/\varepsilon t]^{3.89}[1/MR]^{0.854}$ (80 percent reliability) …... (3.3)

$Nf = 0.5161*C*10^{-4}[1/\varepsilon t]^{3.89}[1/MR]^{0.854}$ (90 percent reliability) …… (3.4)

In the context of the following equations:

Nf represents the fatigue life measured in terms of cumulative axles, εt denotes the maximum horizontal tensile strain (in micro) at the bottom of the bituminous layer, and MR represents the resilient modulus of the bituminous layer in MPa.

It is commonly advised in literature to incorporate a factor denoted as 'C' into fatigue models to consider the influence of air voids (Va) and the volume of bitumen (Vb). This factor can be determined using the following relationships:

$C = 10^{M}$, M= 4.84 ((Vbe/(Va+Vbe))-0.69)

where 'M' is a variable factor that accounts for the specific characteristics of the air voids and volume of bitumen.

Corresponding to the values of Va and Vbe as stated above, introduction of 'C' in Equation **3.3 & 3.4 IRC 37: 2018**

Va = per cent volume of air void in the mix used in the bottom bituminous layer

Vbe = per cent volume of effective bitumen in the mix used in the bottom bituminous layer

3.14.10.2 Subgrade Rutting Criteria*:*

An average rut depth of 20 mm or more, measured along the wheel paths, is considered in these guidelines as critical or failure rutting condition. The equation number of Standard axle load (80 KN) repetitions that can be served by the pavement, before the critical average rut depth of 20 mm or more occurs, is given by equations 3.1 and 3.2 respectively for 80% and 90% reliability levels. These rutting equations are extracted below for ready reference.

N_R =4.1656*10^{-8}[1/εv]$^{4.5337}$ (80 per cent reliability)…….(3.1)

N_R =1.41*10^{-8}[1/εv]$^{4.5337}$ (90 per cent reliability)……… (3.2)

Where,

N_R = Subgrade rutting life (cumulative equivalent of 80KN standard axle loads that can be served by the pavement before the critical rut depth of 20 mm or more occurs)

εv = Vertical Compressive strain (in micro) at the top of subgrade calculated using linear elastic layered theory by applying standard axle load at the surface of the selected pavement system.

3.14.11 Material Characterization

Each layer is characterized by its Resilient Modulus (E) and Poisson's ratio The material characterization of each of the pavement layers is presented next:

3.14.11.1 Bituminous Layer

The design of pavement shall be carried out based on the actual values obtained with field designed DBM/BC/ mix subject to the values indicated in Table 9.2 of IRC:37-2018 for the selected mix (DBM/BC mix with selected unmodified binder) for an average annual pavement temperature of **35 °C.** For the climate conditions prevailing in the plains of India, the average Annual Pavement Temperature is Expected to be close to **35 °C.** If the resilient modulus value of the specimens prepared using the field bottom(base) bituminous mix is more than the Corresponding maximum value indicated in Table 9.2 of IRC:37-2018 for **35 °C,** the value given in the table shall be used for the analysis and design.The Poisson's ratio of bituminous layer values indicated in Table 11.1 of IRC:37-2018 a value of 0.35 is recommended.

3.14.11.2 Granular base and Sub Base Layer

The modulus of granular material is dependent not only on the intrinsic characteristics of these materials, but also on the stress level at which they operate and the stiffness of the underlying layers.Clause 7.2.3 of IRC: 37 -2018 stipulates that "When both the sub-base layer and base layers are made up of unbound granular layers, A weaker support does not permit higher modulus of the upper granular layer because of the larger deflections caused by loads result in de- compaction in the lower part of the granular layer. Equation 7.1 may be used for the estimation of the modulus of the granular from its thickness and the modulus value of the supporting layer.

MR-granular =0.2*(h)^$^{0.45}$ MR-Support……….(7.1)

Where,

h= thickness of granular sub-base and base, in mm M_{RGRAN} = resilient modulus of the granular layer (MPa) M_R support = resilient modulus of the supporting layer (MPa)

The Poisson's ratio of Unbound granular layer values indicated in Table 11.1 of IRC:37-2018 a value of 0.35 is recommended.

3.14.11.2 Material Characterisation of Cement Treated Sub-Base Layer (CTSB)

The resilient modulus and poison ratio of cement treated sub-base has been considered as 600 MPa and 0.25 respectively. The UCS strength (7-days) of CTSB has to be 1.5-3.0MPa. The grading of CTSB has to be grading-IV of MORT&H Table 400-1 so that neither strength nor drainage will get compromised.

3.14.12 Design Of Flexible Pavement For Main Carriageway & Service Road

Applicable Flexible Pavement Design Standard

Flexible pavement for new construction of main carriageway has been designed in accordance with IRC: 37-2018 in adherence to the applicable manuals. Mechanistic design of flexible pavement has been carried out using the project specific climate, material characteristics & design traffic loading. The details are elaborated in subsequent sections.

Selected Pavement Type

The selected Strengthening of existing flexible with Bituminous concrete & Dense Bituminous Concrete & Construction of new Flexible Pavement is bituminous layers over WMM base and GSB sub-base.

Sub-section presents the inputs parameters considered for the flexible pavement design.

Estimated Design Lane Traffic Loading (MSA)

The estimation of design period traffic loading involves analyzing traffic volume counts, making traffic projections for the design period, and determining vehicle damage factors based on axle load surveys. Since the Project Road has a divided carriageway, the design traffic is estimated separately for each direction. The traffic loading is quantified in million standard axles (MSA) as a unit of measurement. The calculation of design traffic loadings, in accordance with IRC: 37-2012, is based on cumulative standard axles, and the specific formulas for this calculation can be found in Volume-I of the traffic report:

$$N_{Des} = \frac{365 \times [(1+r)^n - 1]}{r} \times \mathrm{A} \times \mathrm{D} \times \mathrm{F}$$

Where,

N : The cumulative number of standard axles in the design period in terms of msa

r : Annual Growth Rate of commercial vehicles.

n : Design Life in years

A : Initial traffic in the year of completion of construction in terms of the number of commercial vehicles/days.

Design CBR of Subgrade

4days soaked CBR @ 97% MDD of 500 select Subgrade and 4 days soaked CBR@95% MDD of embankment just below select subgrade are selected as 8.0% and 8.0% respectively for the calculation of effective Subgrade CBR.

The procedure for determination of effective subgrade strength is detailed below:

The design depth of the subgrade has been considered as 1.0 m (500mm select subgrade and 500mm embankment fill just below it) for determination of the effective CBR of the subgrade.

Subgrade surface deflection under the action of a single wheel load computed using layered elastic theory has been used as the parameters to assess the equivalence. The loading arrangement considered is a single wheel load of magnitude 40 KN acting over a circular contact area at a pressure of 560 KPa. The two-layer and the equivalent subgrade systems with loading considerations are shown in Figure below

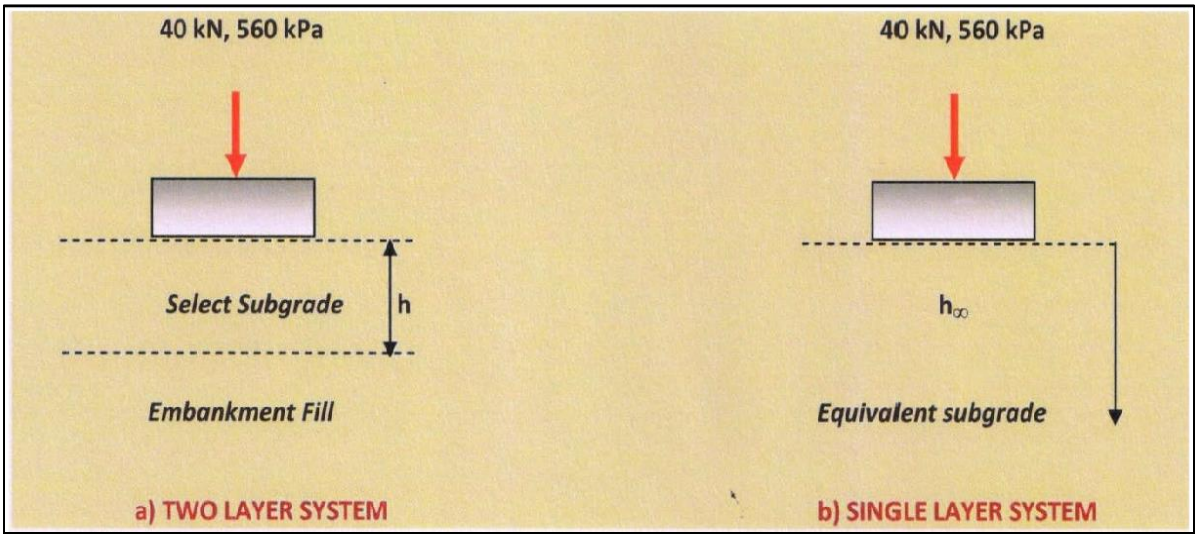


Figure 3.24: Two layer and Equivalent Subgrade System

Resilient modulus values of select subgrade and embankment fill are estimated from their CBR values using:

Resilient Modulus of Subgrade:

E (MPa) = 10 *CBR for CBR ≤ 5 % or

= $17.6*(CBR)^{0.64}$ for CBR >5%

From the computed surface deflection of the two-layer subgrade system using E-layer program, the corresponding modulus value of the equivalent single layer sub grade system is determined from the following equation

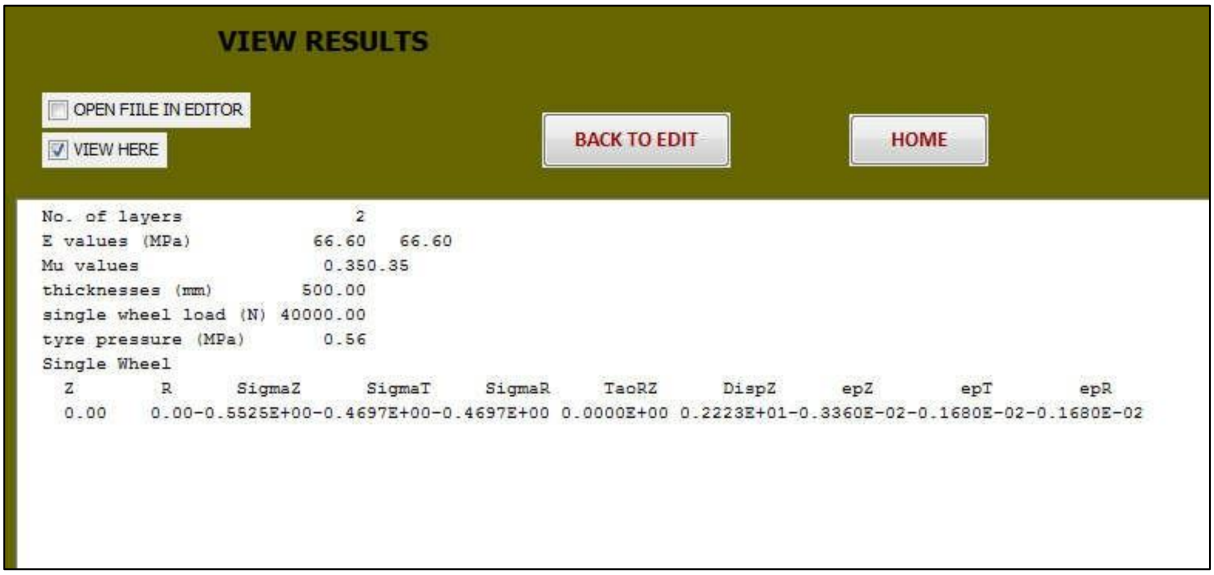


Fig 3.25 IITPAVE Result.

From the computed surface deflection 2.223mm of the two-layer subgrade system, the corresponding modulus value 66.67 MPa of the equivalent single layer subgrade system is determined from the following equation.

MRS = $[2(1-\mu^2)\ pa]/\ \delta$

MRS = Resilient modulus of subgrade μ = Poisson's ratio=0.35

p = Contact Pressure = 0.56 MPa

a = Radius of circular contact area, which can be calculated using the load applied (40,000N) and the contact pressure 'p' (0.56 MPa) = 150.8 mm

δ = Surface Deflection in mm

From the computed equivalent modulus of sub grade, effective subgrade CBR 8% has been calculated using above equation. **Hence, the effective CBR of subgrade for design of new rigid pavement has been considered as 8%.**

Material Characterisation of Granular Sub-Base Layer

Clause 7.2 of IRC: 37-2018 stipulates that "The sub-base layer serves three functions, viz., to protect the Subgrade from overstressing, to provide a platform for construction traffic, and to serve as drainage & filter layer. The design of sub-base, whether bound or unbound, should meet these functional requirements.

Consultant has selected unbound i.e., granular sub-base (GSB) layer. It will be crushed stone satisfying the requirements as specified in clause 401 of the MORT&H Specifications for Roads and Bridge Works.

Clause 7.2.2 of IRC: 37-2018 stipulates that Minimum thickness of granular sub-base layers

(i) The minimum thickness of drainage as well as filter layer shall be 100mm (i.e minimum thickness of each of these two layers is 100mm).

(ii) The minimum thickness of the single filter-cum-drainage layer shall be 150 mm from functional requirement.

(iii) The minimum thickness of any compacted granular layer should preferably be at least 2.5 times the nominal maximum size of aggregates subject to a minimum of 100mm.

Further, sub-clause 401.2.1 of MORT&H stipulates that "Grading V and VI shall be used as a sub-base -cum-drainage layer". In adherence to the same, Consultant has proposed Grading V of Table 400-1 of MORT&H Specification for GSB layer to account for both filter and drainage layer. The proposed design thickness of GSB has been worked-out as per structural strength requirement.

Material Characterisation of Granular Base Layer

Consultant has selected Wet Mix Macadam (WMM) for granular base layer. It will be crushed stone satisfying the requirements as specified in clause 406 of the MORT&H Specifications for Roads and Bridge Works.

WMM Grading as per **Clause 3.1.2 & Table -2 of IRC:109-2015**.

The resilient modulus and poison ratio of WMM have been considered as 0.35 respectively.

Material Characterisation of Selected Bituminous Layer

The resilient moduli of 2000 MPa (VG30 binder mix for BC as well as DBM) and 3000 MPa (VG40 binder mix for BC as well as DBM) where considered for less than 20 msa and 20 to 50 msa categories respectively. It may be noted that, for expressway and national highways, even if the design traffic is 20 msa or less, VG-40 bitumen shall be used for surface as well as DBM layers.As per **Table 11.1 of IRC:37-2018**, the Poisson's ratio of bituminous layer with VG40 Bitumen a value of 0.35 is recommended.

Designed Pavement Crust Thickness Main Carriageway

The computation of stresses and strains in flexible pavements has been carried out using the stress analysis software IITPAVE. This process involves an iterative approach where layer thickness and corresponding material characteristics (E&μ) are varied. Stresses and strains at critical locations are then calculated. To assess the adequacy of the design, the computed strains are compared with allowable strains predicted by the fatigue and rutting models at a 90%

reliability level. If the computed strains are lower than the allowable strains, the pavement composition is considered safe. Additionally, fatigue life and rutting life have been determined by utilizing the **fatigue model (equation 3.4) and rutting model (equation 3.2) specified in IRC: 37-2018**, corresponding to a 90% reliability level. The inputs & outputs of structural analysis are presented next for all three different layer combinations. **Result is shown chapter 4 of this thesis**

3.15 Junction development

Developing a junction according to the Indian Standard Code IRC:SP-87:2019 for a six-lane road involved a systematic methodology. The step-by-step approach for developing such junction was as follows:

1. Understanding the Design Parameters specified in IRC:SP-87:2019 for a six-lane road junction. These parameters included geometric design elements, traffic flow characteristics, sight distances, and safety considerations.
2. Collection of Data regarding turning movements at the proposed junction location. This data helped in determining the appropriate design elements and traffic control measures.
3. The collected data was analyzed to establish the design criteria for the junction. This included determining the required number of lanes, lane widths, median width, turning radii, sight distances, and other geometric elements based on the expected traffic flow and the design standards specified in IRC:SP-87:2019.
4. Conducted Traffic Analysis to assess the expected traffic volume, vehicular conflicts, and capacity requirements of the junction. This analysis will help in determining the appropriate traffic control devices, such as traffic signals or roundabouts, and the layout of entry and exit ramps.
5. Developed Junction Layout based on the design criteria and traffic analysis, create a preliminary layout of the junction. Considering the location and configuration of the entry and exit ramps, lane assignments, turning lanes, pedestrian crossings, and other traffic control measures.
6. Detailed Design for the junction, including cross-sections, longitudinal sections, pavement markings, signage, and drainage provisions. Ensure that the design is in accordance with the relevant sections of IRC:SP-87:2019 and other applicable codes and standards.[19]
7. Seek expert review and approval of the junction design from appropriate authorities, such as transportation departments or local authorities. Incorporate any suggested modifications or revisions to ensure compliance with all relevant regulations and standards.

3.16 Signage Plan

According to IRC SP 87 (2019), the placement of signage on highways should follow specific guidelines to ensure visibility, readability, and effectiveness. [19]

1. The locations of overhead traffic signs are determined and specified in Schedule 'C' of the Concession Agreement. Several conditions are considered when deciding on the placement of these signs. These conditions include current and future traffic volume, restricted sight distance, built-up areas, lack of space for ground-mounted signs, obstructions to ground-mounted signs due to road features or roadside activities, distances to important places and routes, and placement before major intersections, traffic bifurcations, and approaches to interchanges, flyovers, and VUPs (Vehicle Underpasses).
2. Road markings should be provided in conjunction with stop signs, give way signs, merging or diverging traffic signs, lane closed signs, road narrowing signs, slip roads/diversion signs, compulsory keep left/right signs, and any other signs as specified in IRC:67. These road markings serve to complement the signs and ensure proper guidance and safety for drivers on the road.
3. According to IRC:67, all road signs should be equipped with Prismatic Grade Sheeting corresponding to Class C Sheeting, as described in the guidelines. The sheeting material used should be Aluminum or Aluminum Composite Material, with options for Types VIII, IX, or XI as per ASTM D 4956-09. The selection of sheeting type depends on the specific situation and viewing requirements for road users. Sheeting with a high coefficient of retro-reflection is suitable for signs viewed from a long distance, while sheeting with a wide observation angle is preferred for better performance at short distances. Type XI micro prismatic sheeting is recommended for gantry-mounted overhead signs, while Type IV micro prismatic sheeting can be used for delineator posts. Gantry mounted signs should be installed on columns that are preferably positioned at least 7 meters or more away from the closest traffic lane, unless otherwise stated.[20]

5. Clear Line of Sight: Ensure that signage placement does not obstruct the driver's line of sight to the road or other critical elements. Avoid placing signage in areas where it may be blocked by vegetation, structures, or other visual obstructions.

6. Sign Height: Place signs at an appropriate height to maximize visibility and readability. The height should be based on factors such as the speed of traffic, the size of the sign, and the driver's field of vision.
7. Sign Size: Determine the appropriate size of the signage based on factors such as the speed of traffic, the distance from the road, and the desired legibility. Use larger signs for higher speeds or longer distances between the sign and the driver.
8. Sign Illumination: Ensure proper illumination for signs that are intended to be visible during nighttime or low visibility conditions. Install reflective materials or provide external lighting to enhance sign visibility.
9. Sign Clutter: Avoid cluttering signage in a single location. Place signs strategically, providing only the necessary information at each location to prevent driver confusion or overload of visual information. Road signs, traffic signals, and other devices used for traffic control, guidance, and information should not obstruct or obscure other traffic signs. It is prohibited to display advertisements on these signs and signals. There should be a minimum distance of 0.6 times the 85th percentile speed (V) in kmph between two signs. Generally, signs are installed on the shoulder side of the road, but for better visibility due to terrain or adjacent land use, signs can also be placed on the median side. In critical sections, an additional sign may be placed on the right side of the road to emphasize important information.
10. On project highways with curved alignments, it is important to install appropriate signs to alert drivers of sharp curves. Cautionary signs for sharp curves, depending on whether they are on the left or right, should be placed in advance of the curve. Chevron signs, rectangular in shape with a yellow background and black arrow, should be placed at the outer edge of the curve. In mountainous and steep terrain, the curve ahead sign should always be accompanied by chevron signs and appropriate delineation.

    The following guidelines should be followed for installing curve signs:

- ✓ Curves with radii up to 450 m should have advance curve warning signs and single chevrons placed uniformly along the outer edge of the curve.
- ✓ For curves with radii between 451 m and 750 m, single chevrons should be placed at 75 m spacing along the outer edge of the curve.
- ✓ Curves with radii between 751 m and 1200 m and a deflection angle greater than 20 degrees should have single chevron signs.
- ✓ Curves with radii between 751 m and 1200 m and a deflection angle less than 20 degrees, as well as curves with radii from 1201 m to 2000 m, should have forgiving type delineator posts placed at 40 m spacing along the outer edge of the curves

It is important to note that the specific placement of signage on highways may vary depending on the context, road geometry, traffic characteristics, and local regulations. Therefore, it is recommended to refer to the detailed guidelines and specifications provided in IRC SP 87 (2019) for precise instructions on signage placement on highways.

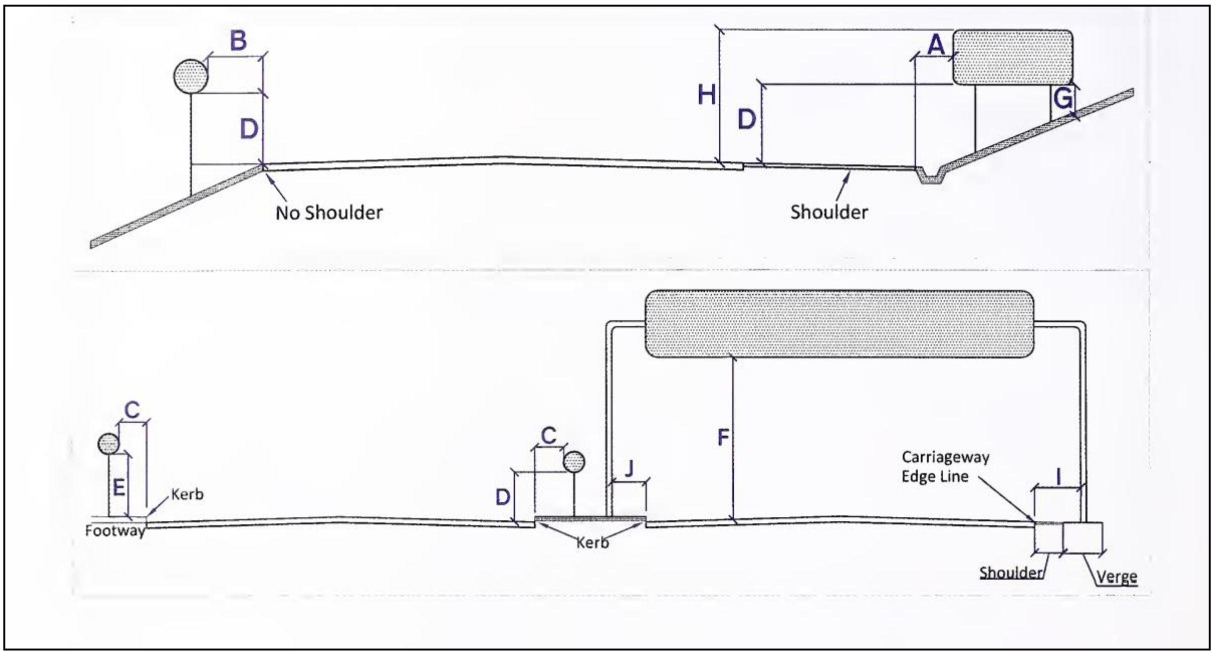


Fig 3.22 Siting of Signs with respect to Carriageway (Height and Clearance)[20]

3.17 Traffic Calming Measures

Traffic calming measures on main roads aim to reduce speeds, enhance safety, and create a calmer driving environment. Instead of vertical shifts, transverse bar marking is employed to alert drivers and encourage speed reduction.

Transverse Bar Marking: To address speed reduction without vertical shifts, transverse bar marking is employed on main roads. Fig. 3.23 and Fig. 3.24 illustrate alternatives with traverse bar markings of 5 mm and 15 mm, respectively, placed at the boundary of the speed zone. The 15 mm bar marking demands speed reduction and is accompanied by "SLOW" markings placed 20 m and 40 m before the bar marking to alert drivers.

1. Signal Control: Signal control techniques can also contribute to traffic calming on main roads. Holding back traffic on a radial to avoid saturating downstream junctions helps reduce queuing and encourages smoother traffic flow. However, physical speed-reducing measures are necessary to prevent drivers from speeding up once the congestion eases.
2. Linking Junctions: In cases where signaled junctions are closely spaced, linking them to provide a "green wave" for main traffic movements can promote a calmer driving speed of 40 km/h. This technique encourages drivers to maintain an appropriate speed

to catch the successive green lights, improving traffic flow and reducing the need for sudden accelerations and decelerations.[23]

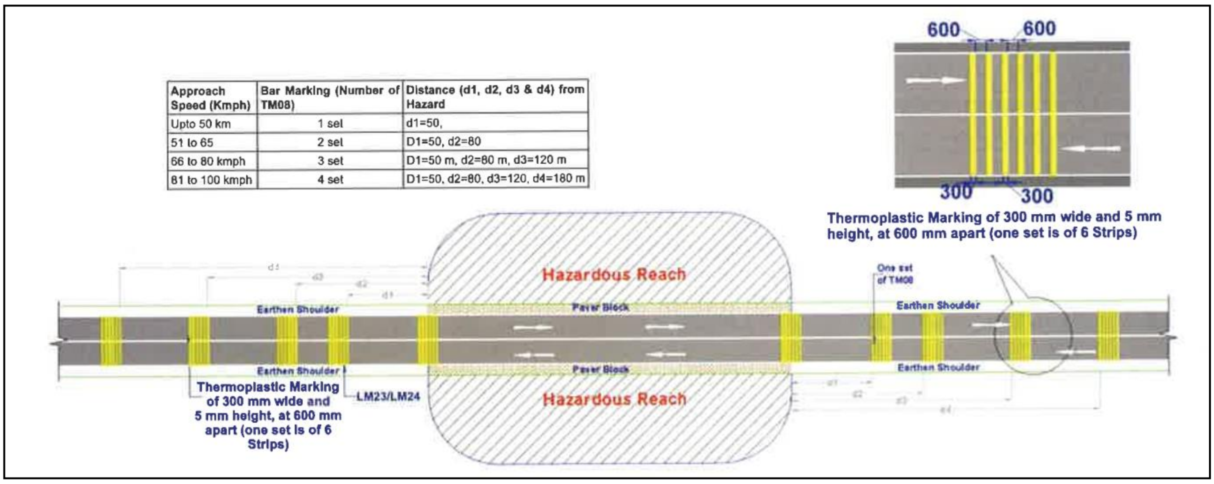


Fig 3.23 Transverse Bar Marking as alerting measure.[23]

232

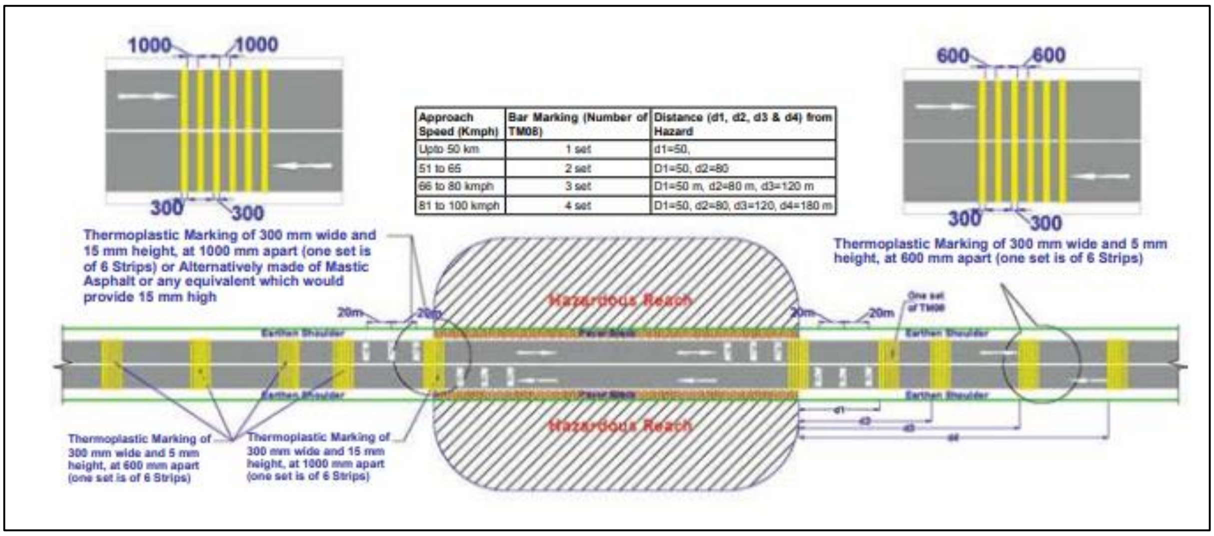


Fig. 3.24 Transverse Bar Marking with Stricter Compliance[23]

Chapter 4 : Results and Discussion

4.0 General

This chapter provides comprehensive details on various aspects of road design, including geometric design encompassing horizontal and vertical design elements, pavement design for enhancing road durability, and an exaggerated junction development plan.and Signage plan for visual assistance.

4.1 Results of Chapaguri site

This section include Plan and profile drawing of blackspots mitigated site along with curve radius , design speed ,HIP and VIP report.

1. Design speed was 80 kmph in schedule but we have improved it to 100 kmph.
2. Elevation level was attained with a grade in of 1.81% and grade out of 2.5%.
3. Curve radius is 5000 which is greater than 2000 hence no transition curve is required.
4. K value maintained 135 for 100 kmph as per IRC specifications.
5. PVI (point of vertical intersection is 106.321 as as at this curve grade in 0+564 and grade out in 0+933 is 0 this is point where flyover is to be constructed.
6. The service road is designed at speed of 40 kmph.
7. The HIP(Horizontal Intersection Point) and VIP(Vertical Intersection Point) report of highway is shown below along with Plan and Profile.
8. Pavement is designed for (BC+DBM+WMM+GSB) for 110 msa at km. 80+550 and km. 83+150 of NH-31C. Design fatigue life is determined to be 114.68 msa and the rutting life is 317.15 msa, using “IITPAVE”.
9. Pavement is designed for (BC+DBM+WMM+CTSUB) for 110 msa at km. 80+550 and km km. 83+150 of NH-31C using IITPAVE resulting design fatigue life is determined to be 125.160 msa and the rutting life is 118.117 msa. These values exceed the required minimum of 110 msa for both fatigue life and rutting life.
10. TCS is attached to the report
11. Signage plan is planned as per IRC 67: 2012 and IRC 87: 2019, IRC 99 :2018 attached in report
12. Junction plan is made according to IRC 87: 2019 attached in report

CURVE No.	HIP			RADIUS	HAND OF ARC	TRANSITION			CIRCULAR			DESIGN SPEED	Δ	Δ_c	θ_s	Ts	Es	S	K	e
	CHAINAGE	EASTING	NORTHING			START CHAINAGE	LENGTH (Ls)	END CHAINAGE	START CHAINAGE	LENGTH (Lc)	END CHAINAGE									
				m			m			m		Km/hr	Deg.	Deg.	Deg.	m	m	m	m	%
1	0+510	256014	2933813	3000	RIGHT	-	-	-	0+406	209.430	0+615	100	4.000	4.000	-	104.760	1.830	-	-	NC
2	0+998	256451	2933597	5000	RIGHT	-	-	-	0+829	211.770	1+104	100	2.430	2.430	-	105.900	1.120	-	-	NC
3	1+303	256719	2933451	3000	RIGHT	-	-	-		42.870		100	0.820	0.820	-	21.430	0.080	-	-	NC

MAIN CARRIAGEWAY											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	100.403	-	-0.52%	-	100
2	0+047	Sag	60.000	202.252	0+017	0+077	100.156	-0.52%	-0.23%	0.30%	100
3	0+203	Sag	84.462	41.5	0+161	0+246	99.801	-0.23%	1.81%	2.04%	100
4	0+564	Crest	244.106	135	0+442	0+686	106.321	1.81%	0.00%	1.81%	100
5	0+933	Crest	337.500	135	0+765	1+102	106.321	0.00%	-2.50%	2.50%	100
6	1+247	Sag	100.299	41.5	1+196	1+297	98.488	-2.50%	-0.08%	2.42%	100
7	1+410	-	-	-	-	-	98.352	-0.08%	-	-	100

SERVICE ROAD LHS											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	100.003	-	-0.46%	-	40
2	0+103	Sag	30	256.435	0+088	0+118	99.526	-0.46%	-0.35%	0.12%	40
3	0+589	Sag	30	76.318	0+574	0+604	97.843	-0.35%	0.05%	0.39%	40
4	1+290	Crest	30	289.979	1+275	1+305	98.172	0.05%	-0.06%	0.10%	40
5	1+410	-	-	-	-	-	98.104	-0.06%	-	-	40

SERVICE ROAD RHS											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	100.003	-	-0.46%	-	40
2	0+103	Sag	30	255.724	0+088	0+118	99.526	-0.46%	-0.35%	0.12%	40
3	0+589	Sag	30	76.344	0+574	0+604	97.843	-0.35%	0.05%	0.39%	40
4	1+290	Crest	30	291.451	1+275	1+305	98.172	0.05%	-0.06%	0.10%	40
5	1+410	-	-	-	-	-	98.105	-0.06%	-	-	40

Fig. 4.1 HIP and VIP report for Chapaguri

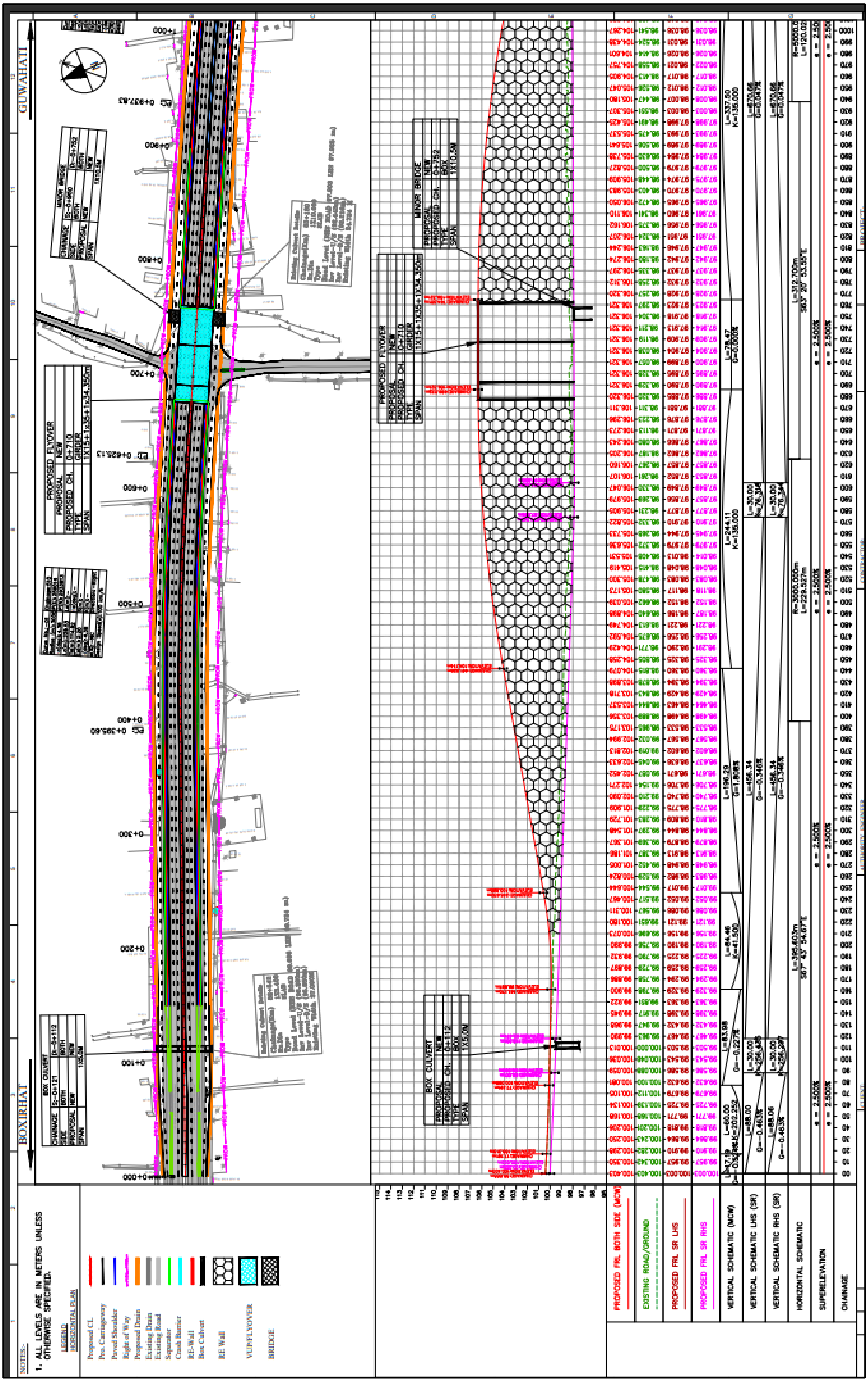


Fig. 4.2 Plan and Profile of Chapaguri

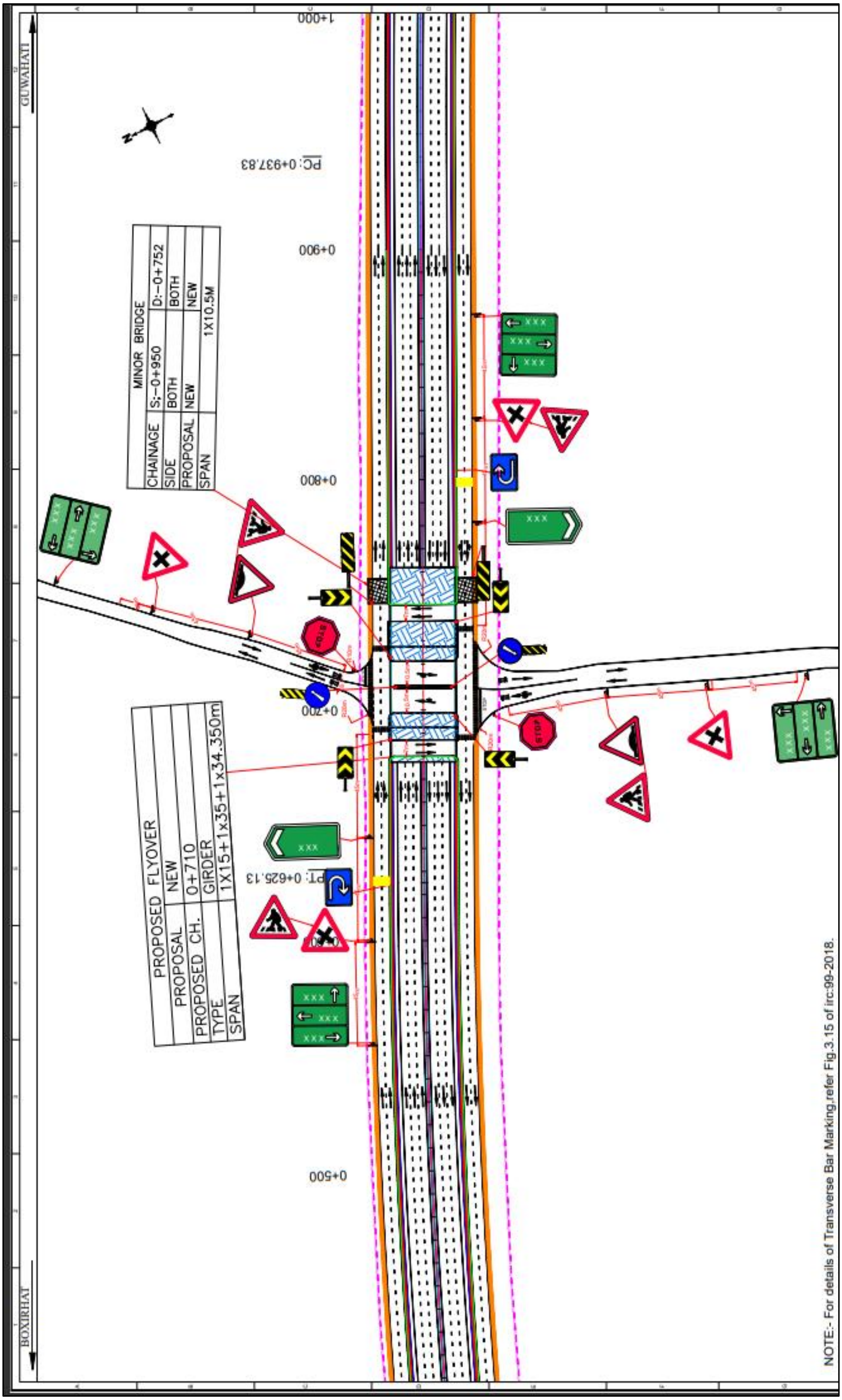


Fig. 4.3 Junction Plan of Chapaguri

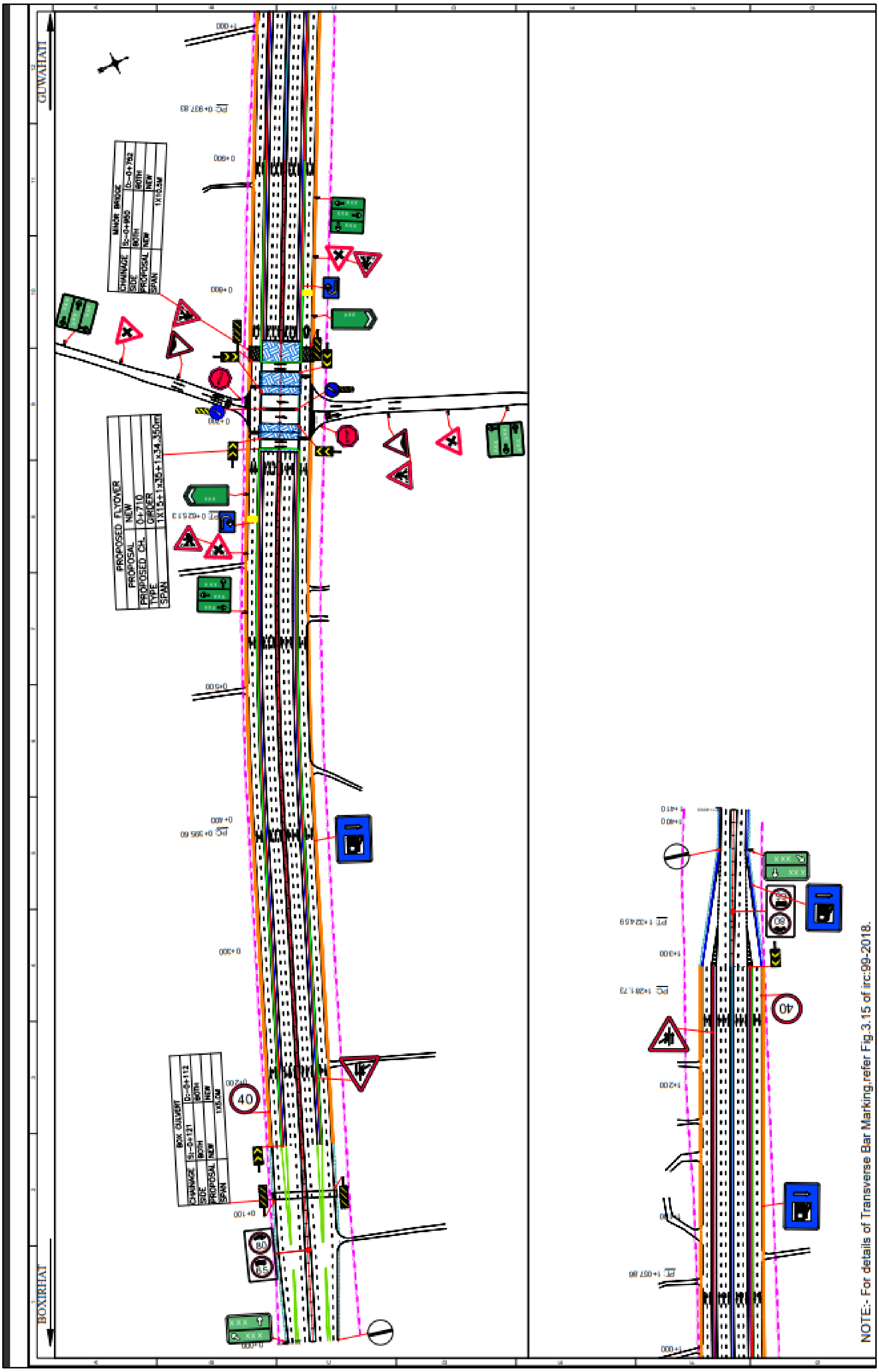
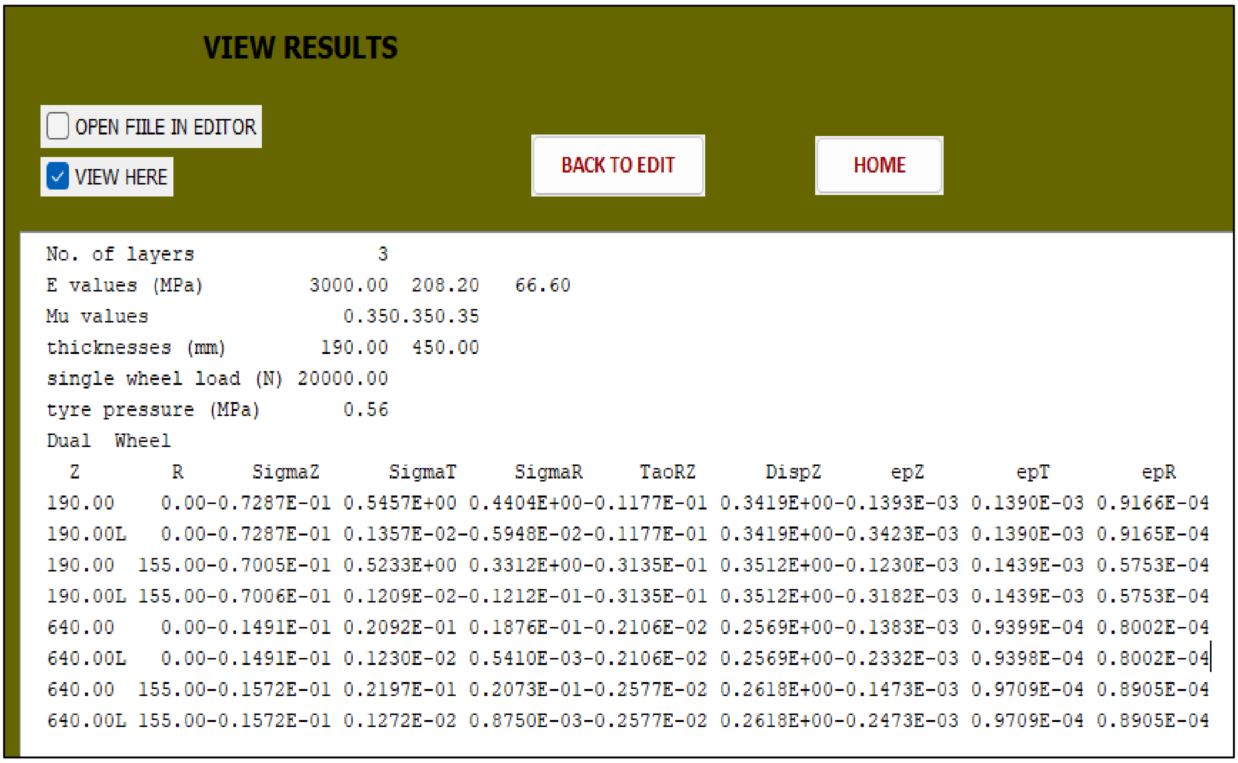


Fig. 4.4 Signage Plan of Chapaguri

(BC+DBM+WMM+GSB) for 110 msa at km. 80+550 and km. 83+150 of NH-31C

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No. of layers                3
E values (MPa)         3000.00   208.20    66.60
Mu values                 0.350.350.35
thicknesses (mm)        190.00   450.00
single wheel load (N) 20000.00
tyre pressure (MPa)       0.56
Dual  Wheel
  Z        R       SigmaZ      SigmaT     SigmaR     TaoRZ      DispZ      epZ        epT        epR
190.00    0.00-0.7287E-01 0.5457E+00 0.4404E+00-0.1177E-01 0.3419E+00-0.1393E-03 0.1390E-03 0.9166E-04
190.00L   0.00-0.7287E-01 0.1357E-02-0.5948E-02-0.1177E-01 0.3419E+00-0.3423E-03 0.1390E-03 0.9165E-04
190.00  155.00-0.7005E-01 0.5233E+00 0.3312E+00-0.3135E-01 0.3512E+00-0.1230E-03 0.1439E-03 0.5753E-04
190.00L 155.00-0.7006E-01 0.1209E-02-0.1212E-01-0.3135E-01 0.3512E+00-0.3182E-03 0.1439E-03 0.5753E-04
640.00    0.00-0.1491E-01 0.2092E-01 0.1876E-01-0.2106E-02 0.2569E+00-0.1383E-03 0.9399E-04 0.8002E-04
640.00L   0.00-0.1491E-01 0.1230E-02 0.5410E-03-0.2106E-02 0.2569E+00-0.2332E-03 0.9398E-04 0.8002E-04
640.00  155.00-0.1572E-01 0.2197E-01 0.2073E-01-0.2577E-02 0.2618E+00-0.1473E-03 0.9709E-04 0.8905E-04
640.00L 155.00-0.1572E-01 0.1272E-02 0.8750E-03-0.2577E-02 0.2618E+00-0.2473E-03 0.9709E-04 0.8905E-04
```

Fig. 4.5 IITPAVE result for 110 msa

Based on the calculated values of the maximum horizontal tensile strain at the bottom of the bituminous layer (143.90 microstrain) and the maximum vertical compressive strain at the top of the subgrade (247.30 microstrain), the resulting design fatigue life is determined to be 114.68 msa and the rutting life is 317.15 msa. These values exceed the required minimum of 110 msa for both fatigue life and rutting life.

Designed Pavement Composition

The designed pavement composition for 8.0% effective Sub grade CBR for the new construction section is given in Table below:

Table 4.1: Design of flexible pavement for main carriageway at km. 80+550 and km. 83+150 Of NH-31c

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+ WMM+GS B	110	8.0	50	140	250	200	140 mm DBM has to be laid in two layers. DBM lower layer to be laid with Va=3.5% and Vb= 11.50%

(BC+DBM+WMM+CTSUB) for 110 msa at km. 80+550 and km. 83+150 of NH-31C

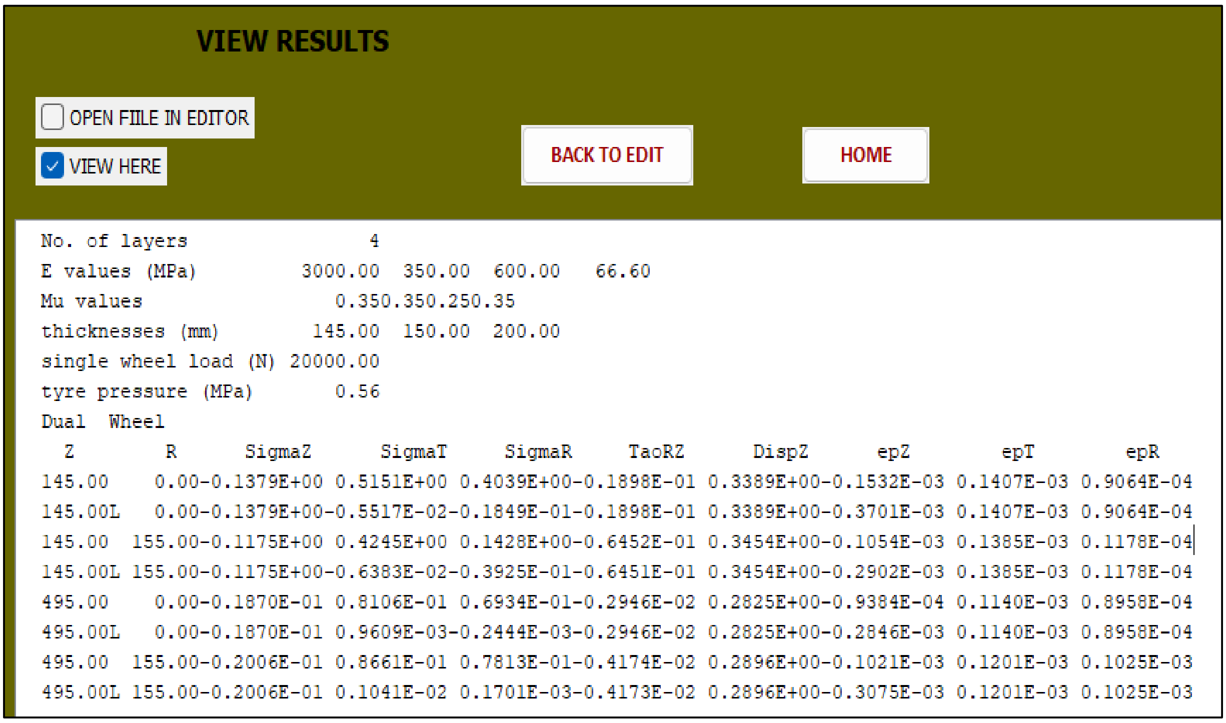


Fig. 4.6 IITPAVE result for 110 msa

Based on the calculated values of the maximum horizontal tensile strain at the bottom of the bituminous layer (140.70 micro strain) and the maximum vertical compressive strain at the top of the subgrade (307.50 micro strain), the resulting design fatigue life is determined to be 125.160 msa and the rutting life is 118.117 msa. These values exceed the required minimum of 110 msa for both fatigue life and rutting life.

Designed Pavement Composition

The designed pavement composition for 8.0% effective Sub grade CBR for the New construction section is given in Table below

Table 4.2 : Design of flexible pavement for main carriageway at km. 80+550 and km. 83+150 of NH-31c

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+ WMM+C TSB	110	8.0	50	95	150	200	95 mm DBM has to be laid in single layers. DBM to be laid with Va=3.5% and Vb= 11.50%

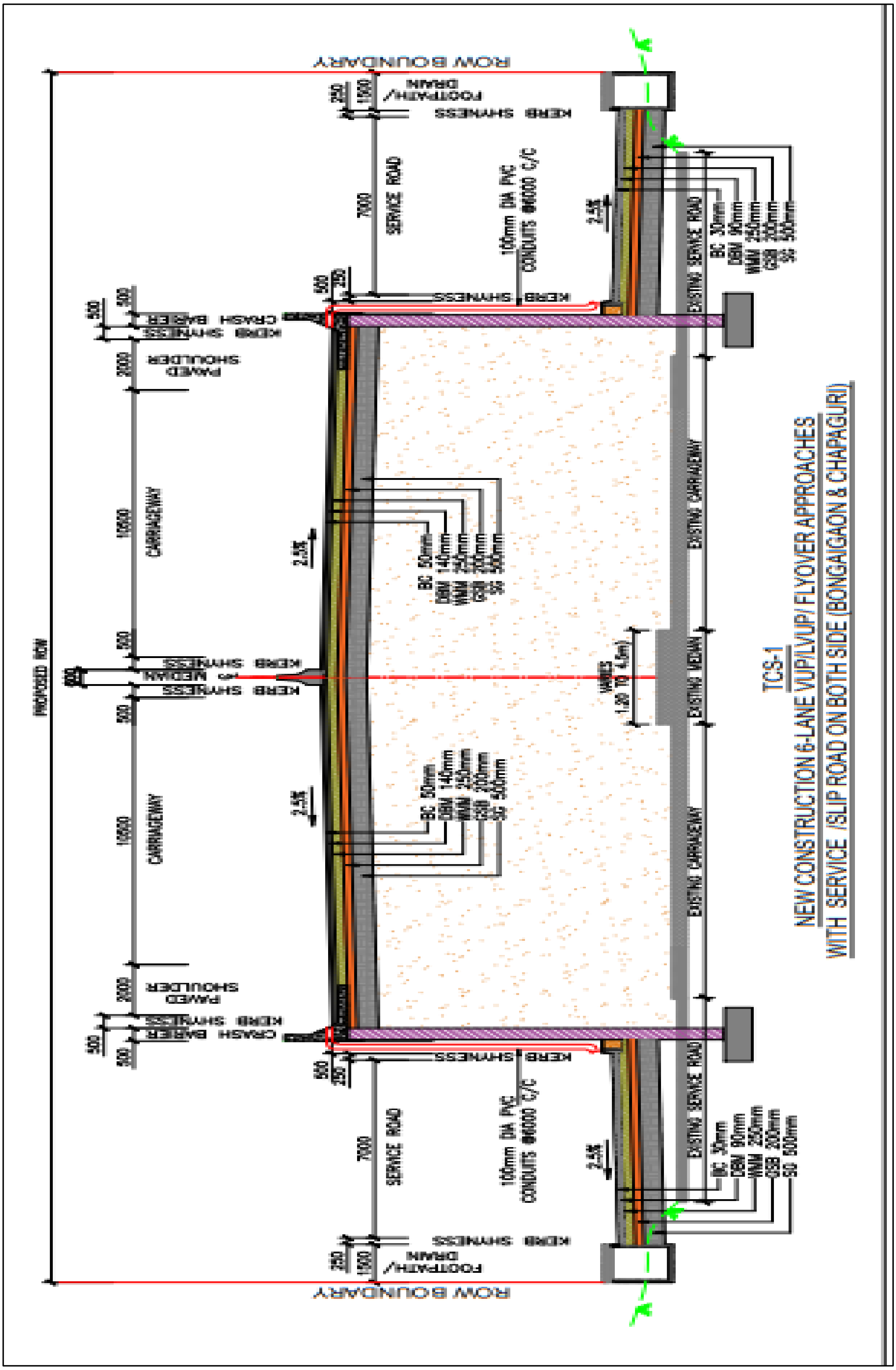


Fig. 4.7 TCS of Chapaguri site

4.2 Results of Simlaguri site

This section include Plan and profile drawing of blackspots mitigated site along with curve radius , design speed ,HIP and VIP report.

1. Design speed adopted 65 kmph.
2. Elevation level was attained with a grade in of 2.5% and grade out of 2.5%.
3. Curve radius is 320 which is less than 2000 hence transition curve is required. The transition curve starts from chainage 0+117, ends at 0+708. The length of the transition curve is 150 m. Design speed is 80 kmph.
4. K value adopted 33.8 for 65 kmph as per IRC 23 specifications.
5. PVI (point of vertical intersection is 108.016 as at this curve grade in 0+396 and grade out in 0+577, this is point where flyover is to be constructed.
6. The service road is designed at speed of 40 kmph.
7. The HIP(Horizontal Intersection Point) and VIP(Vertical Intersection Point) report of highway is shown below along with Plan and Profile.
8. Pavement is designed for (BC+DBM+WMM+GSB) FOR 110 MSA at km. 80+550 and km. 83+150 of NH-31C. Design fatigue life is determined to be 114.68 msa and the rutting life is 317.15 msa, using IITPAVE.
9. Pavement is designed for (BC+DBM+WMM+CTSUB) FOR 110 msa at km. 80+550 and km. 83+150 of NH-31C using IITPAVE resulting design fatigue life is determined to be 125.160 msa and the rutting life is 118.117 msa. These values exceed the required minimum of 110 msa for both fatigue life and rutting life.
10. TCS is attached in report
11. Signage plan is planned as per IRC 67: 2012 and IRC 87: 2019, IRC 99 :2018 attached in report
12. Junction plan is made according to IRC 87: 2019 attached in report

CURVE No.	HIP			RADIUS	HAND OF ARC	TRANSITION			CIRCULAR			DESIGN SPEED	Δ	Δc	θs	Ts	Es	S	K	e
	CHAINAGE	EASTING	NORTHING			START CHAINAGE	LENGTH (Ls)	END CHAINAGE	START CHAINAGE	LENGTH (Lc)	END CHAINAGE									
				m			m			m		Km/hr	Deg.	Deg.	Deg.	m	m	m	m	%
1	0+412	297471	2931262	320	LEFT	0+117	150	0+708	0+267	291.380	0+558	80	79.030	52.170	13.430	341.200	98.590	2.920	74.860	7.000

MAIN CARRIAGEWAY											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	100	-	-0.52%	-	65
2	0+062	Sag	52.585	17.4	0+036	0+089	99.675	-0.52%	2.50%	3.02%	65
3	0+396	Crest	84.500	33.8	0+354	0+438	108.016	2.50%	0.00%	2.50%	65
4	0+577	Crest	84.500	33.8	0+534	0+619	108.016	0.00%	-2.50%	2.50%	65
5	0+973	Sag	40.403	17.4	0+953	0+994	98.095	-2.50%	-0.18%	2.32%	65
6	1+034	-	-	-	-	-	97.988	-0.18%	-	-	65

SERVICE ROAD LHS											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	99.670	-	-0.37%	-	40
2	0+240	Sag	30	74.995	0+225	0+255	98.774	-0.37%	0.03%	0.40%	40
3	0+487	Crest	80	261.918	0+447	0+527	98.840	0.03%	-0.28%	0.31%	40
4	0+710	Sag	30	1009.74	0+695	0+725	98.219	-0.28%	-0.25%	0.03%	40
5	0+890	Sag	30	178.839	0+875	0+905	97.771	-0.25%	-0.08%	0.17%	40
6	1+034	-	-	-	-	-	97.654	-0.08%	-	-	40

SERVICE ROAD RHS											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	99.670	-	-0.37%	-	40
2	0+240	Sag	30	74.995	0+225	0+255	98.774	-0.37%	0.03%	0.40%	40
3	0+487	Crest	80	261.918	0+447	0+527	98.840	0.03%	-0.28%	0.31%	40
4	0+710	Sag	30	1009.74	0+695	0+725	98.219	-0.28%	-0.25%	0.03%	40
5	0+890	Sag	30	178.839	0+875	0+905	97.771	-0.25%	-0.08%	0.17%	40
6	1+034	-	-	-	-	-	97.654	-0.08%	-	-	40

Fig. 4.8- HIP and VIP report of Simlaguri

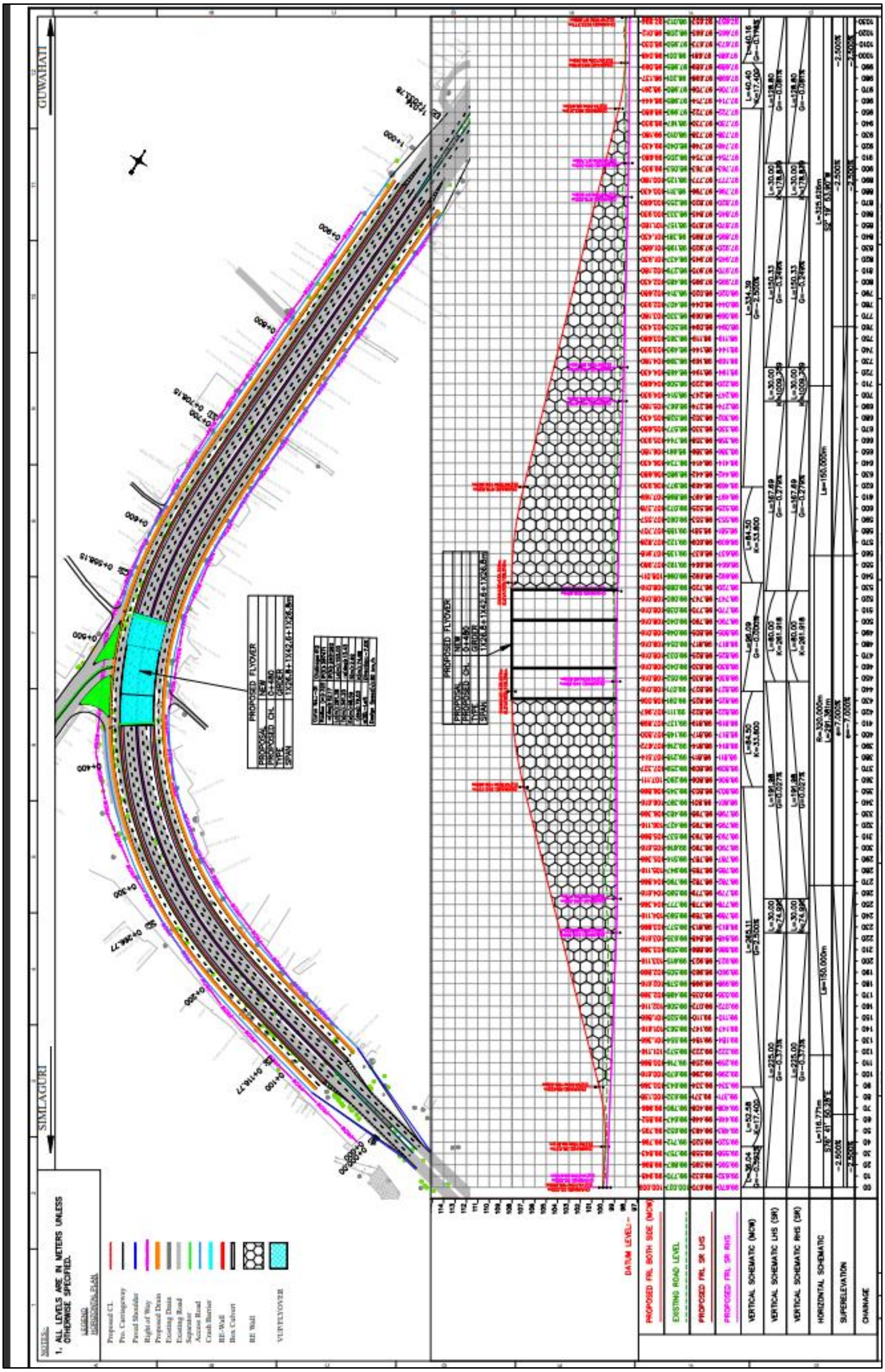


Fig. 4.9 Plan and Profile of Simlaguri

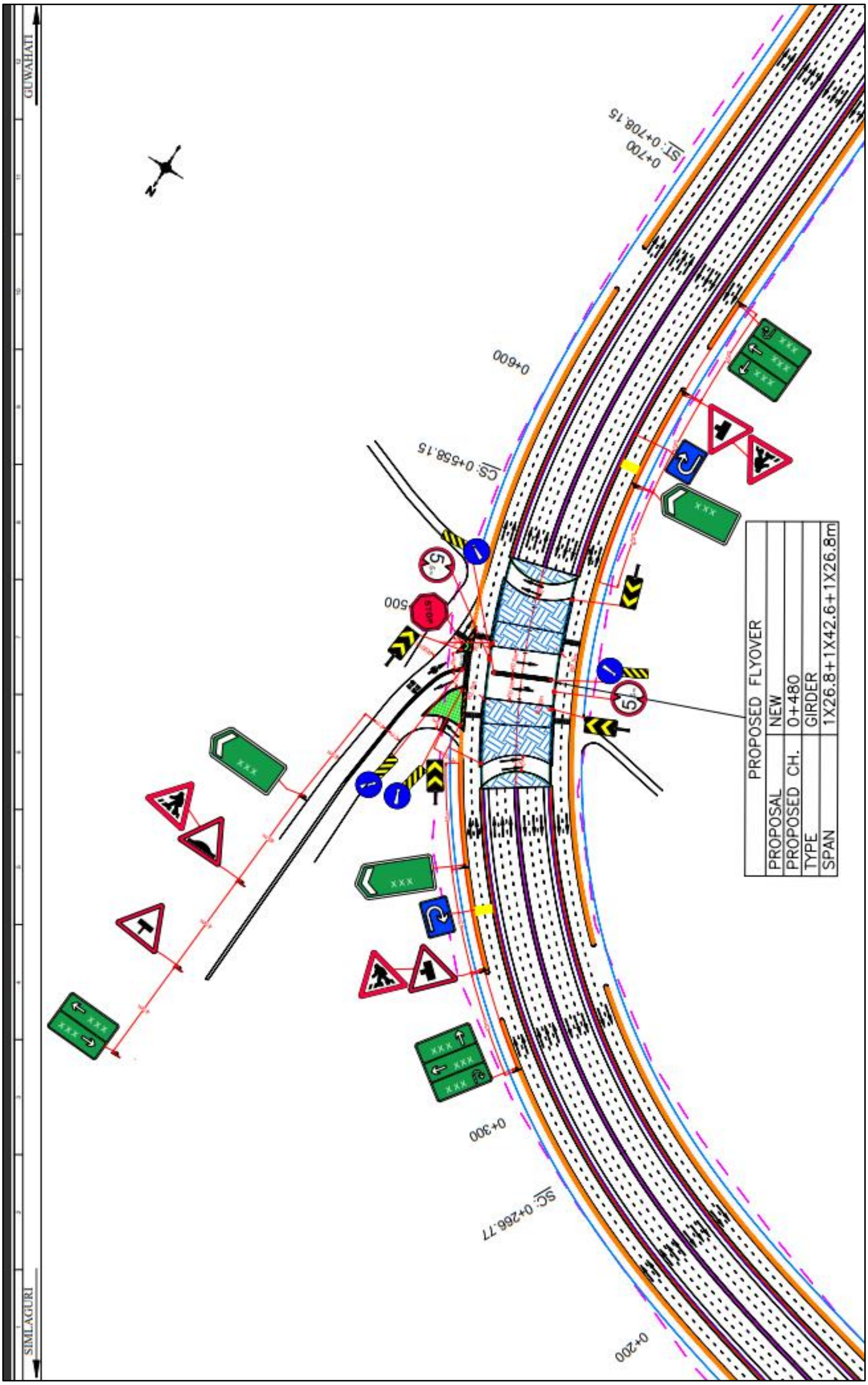


Fig. 4.10- Junction development plan of Simlaguri

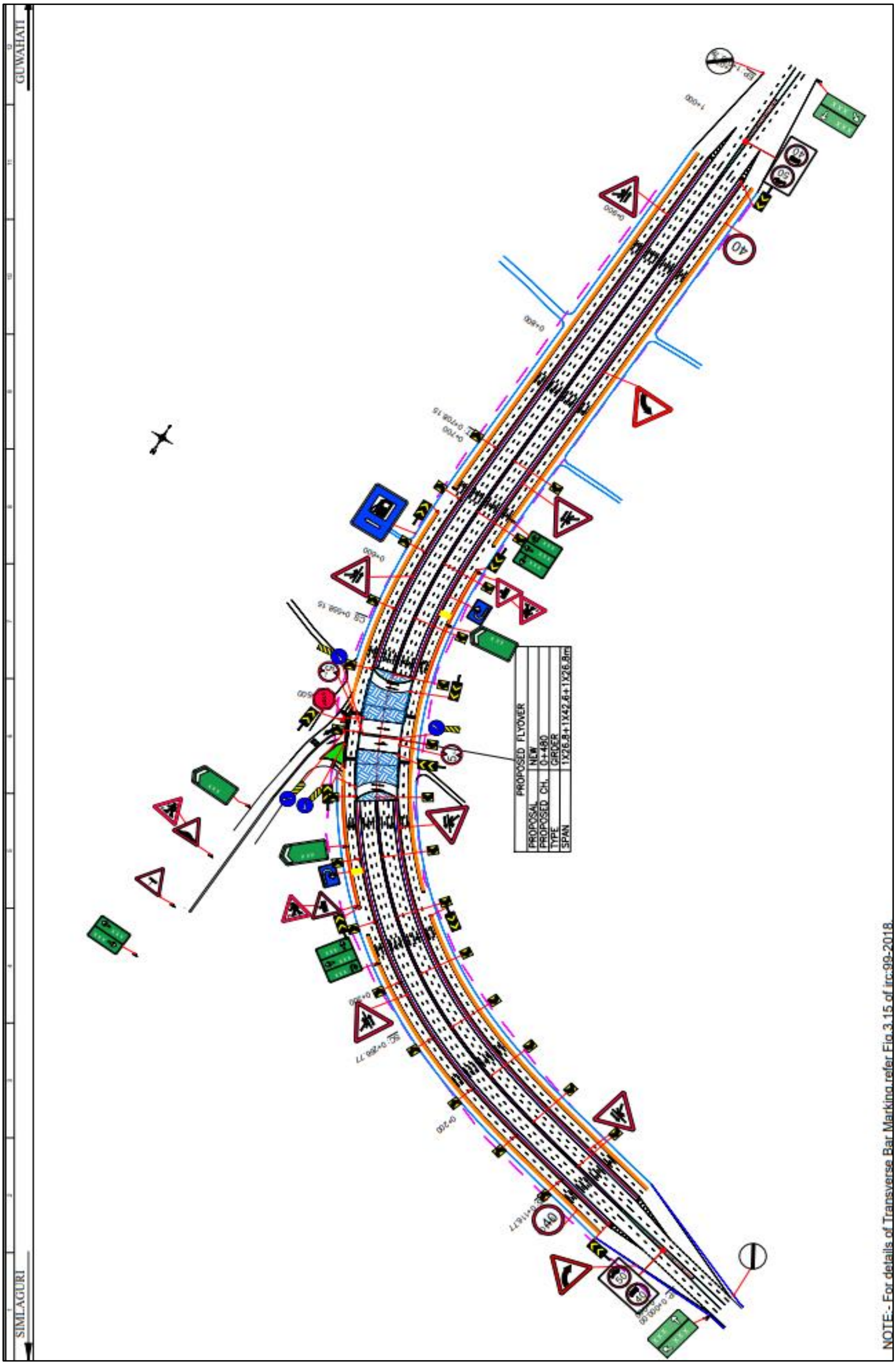


Fig. 4.11- Signage Plan of Simlaguri

(BC+DBM+WMM+GSB) for 90 msa at km. 1001+265 & km. 1029+530 of NH-31

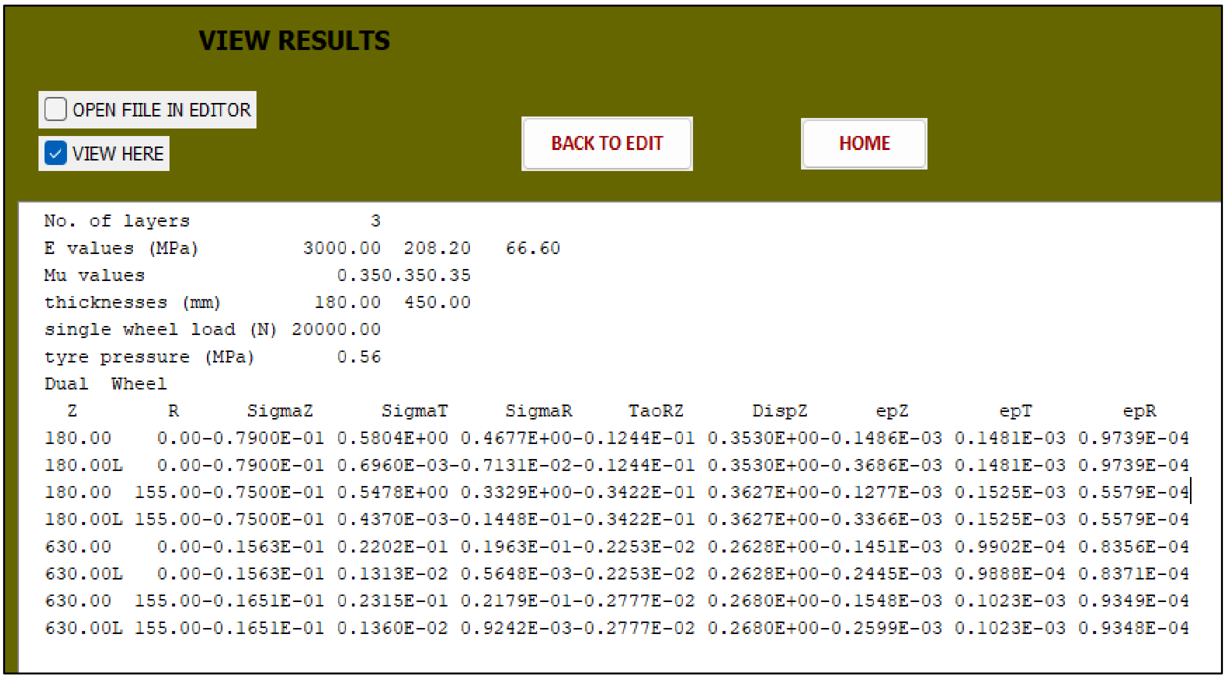


Fig. 4.12 IITPAVE result for 90 msa

Based on the calculated values of the maximum horizontal tensile strain at the bottom of the bituminous layer (152.50 microstrains) and the maximum vertical compressive strain at the top of the subgrade (259.90 microstrains), the resulting design fatigue life is determined to be 91.50 msa and the rutting life is 253.17 msa. These values exceed the required minimum of 90 msa for both fatigue life and rutting life.

Designed Pavement Composition

The designed pavement composition for 8.0% effective Subgrade CBR for the New construction section is given in Table below:

Table 4.3 : Design of flexible pavement for main carriageway at km. 1001+265 & km. 1029+530 Of NH-31

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+ WMM+GS B	90	8.0	50	130	250	200	90 mm DBM has to be laid in single layers. DBM to be laid with Va=3.5% and Vb= 11.50%

(BC+DBM+WMM+CTSUB) for 90 msa at Km. 1001+265 & Km. 1029+530 of NH-31

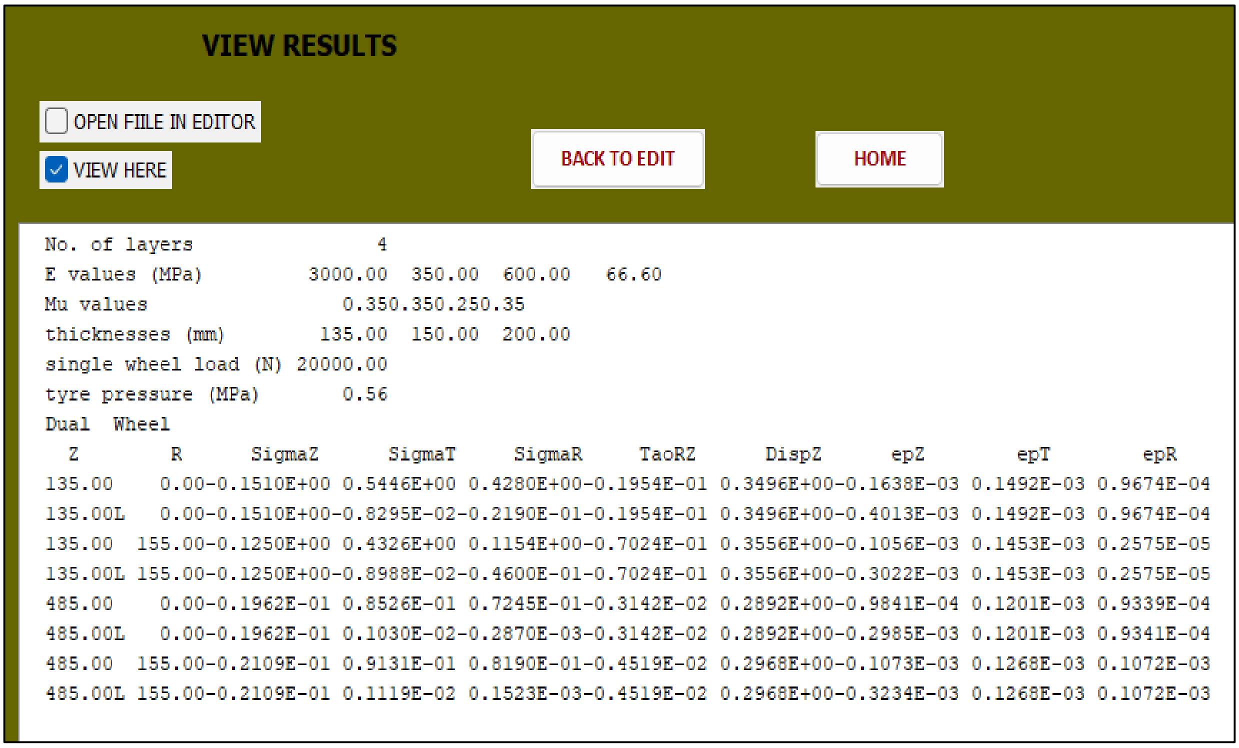


Fig. 4.13 IITPAVE result for 90 msa CTSB

Based on the calculated values of the maximum horizontal tensile strain at the bottom of the bituminous layer (149.20 micro strain) and the maximum vertical compressive strain at the top of the subgrade (323.40 micro strain), the resulting design fatigue life is determined to be 99. 63 msa and the rutting life is 99.97 msa. These values exceed the required minimum of 90 msa for both fatigue life and rutting life.

Designed Pavement Composition

The designed pavement composition for 8.0% effective Sub grade CBR for the New construction section is given in Table below

Table 4.4 : Design of flexible pavement for main carriageway at km. 1001+265 & km. 1029+530 Of NH-31

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+ WMM+CT SB	90	8.0	40	95	150	200	95 mm DBM has to be laid in single layers. DBM to be laid with Va=3.5% and Vb= 11.50%

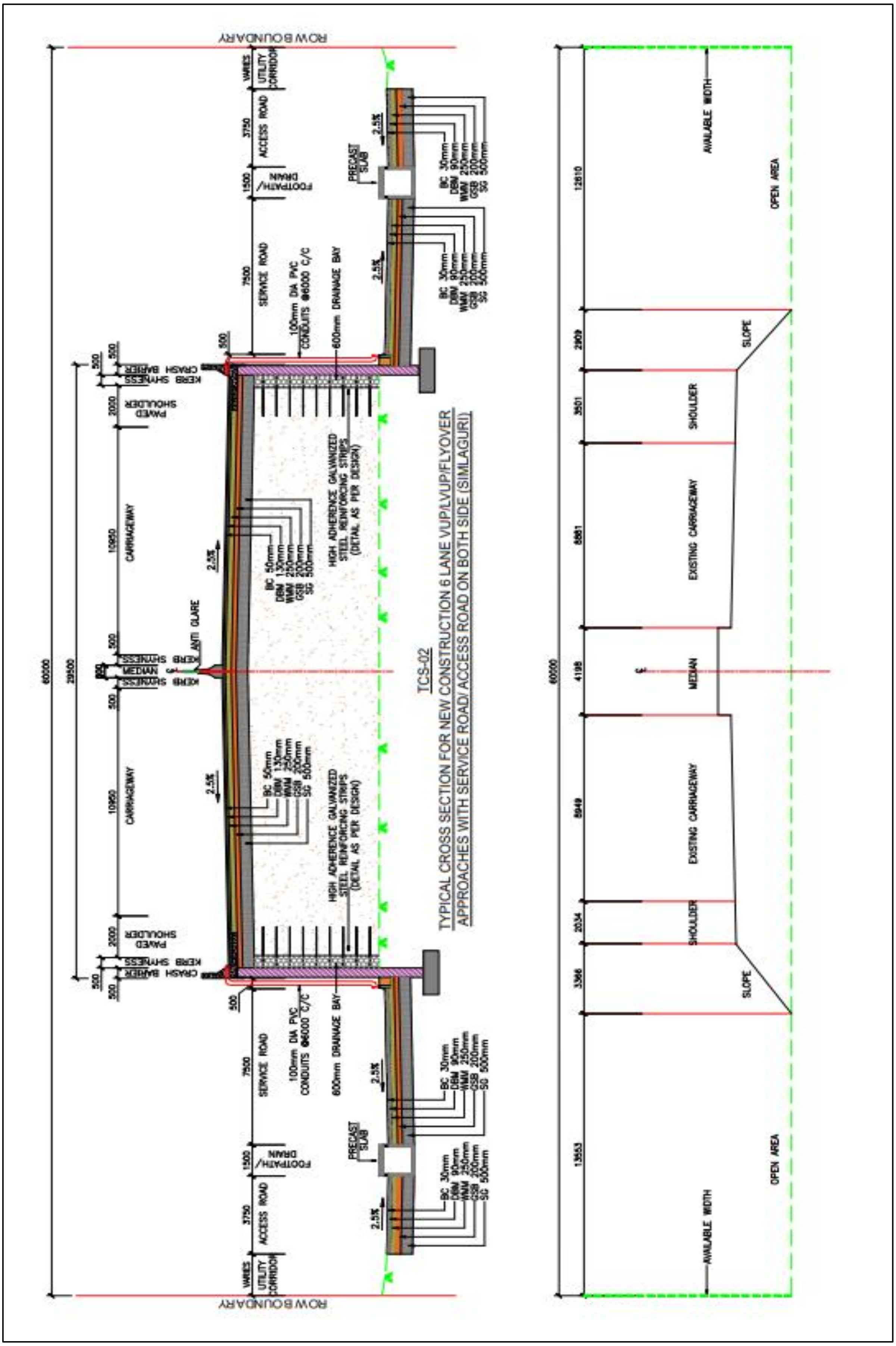


Fig 4.14 TCS of Simlaguri

4.3 Results of Pathshala site

This section include Plan and profile drawing of blackspots mitigated site along with curve radius , design speed ,HIP and VIP report.

1. Design speed adopted 65 kmph.
2. Elevation level was attained with a grade in of 2.5% and grade out of 2.5%.
3. The curve radius is 370 m which is less than 2000 m hence transition curve is required. Transition curve starts from chainage 0+237, and ends at 0+642. Length of Transition curve is 140 m. Design speed is 100 kmph.
4. The curve radius is 1500 m which is less than 2000 m hence transition curve is required. Transition curve starts from chainage 0+261, and ends at 0+228. The length of the Transition curve is 65m. The design speed is 100 kmph.
5. K value adopted 33.8 for 65 kmph as per IRC 23 specifications.
6. PVI (point of vertical intersection is 107.935 as as at this curve grade in 0+432 and grade out in 0+604, this is point where flyover is to be constructed.
7. The service road is designed at speed of 40 kmph.
8. The HIP(Horizontal Intersection Point) and VIP(Vertical Intersection Point) report of highway is shown below along with Plan and Profile.
9. Pavement is designed for (BC+DBM+WMM+GSB) FOR 110 msa at km. 80+550 and km. 83+150 of NH-31C. Design fatigue life is determined to be 114.68 msa and the rutting life is 317.15 msa, using IITPAVE.
10. Pavement is designed for (BC+DBM+WMM+CTSUB) FOR 110 msa at km. 80+550 and km. 83+150 of NH-31C using IITPAVE resulting design fatigue life is determined to be 125.160 msa and the rutting life is 118.117 msa. These values exceed the required minimum of 110 msa for both fatigue life and rutting life.
11. TCS is attached in report
12. Signage plan is planned as per IRC 67: 2012 and IRC 87: 2019, IRC 99 :2018 attached in report
13. Junction plan is made according to IRC 87: 2019 attached in report

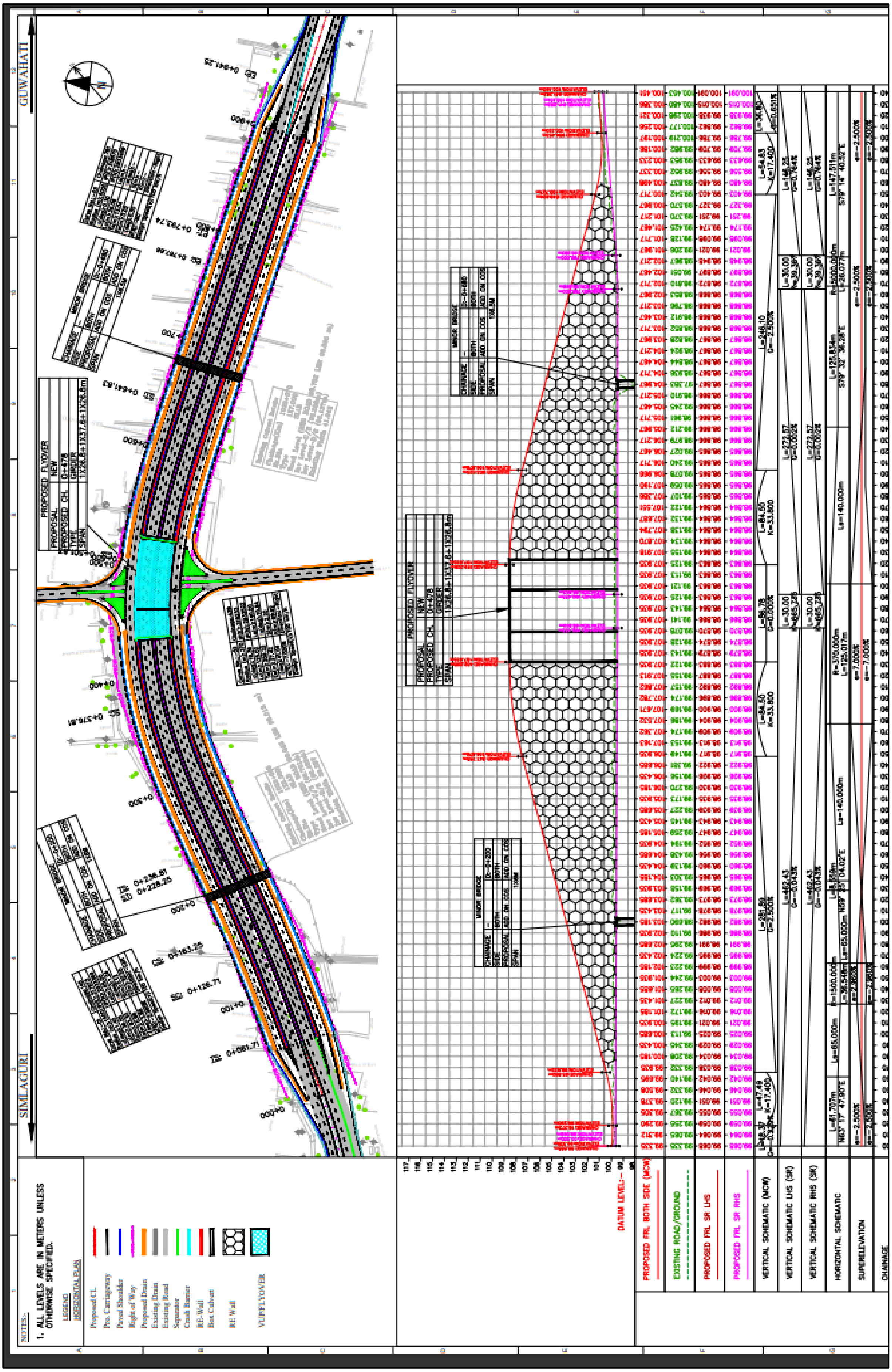


Fig 4.15 Plan and profile of Pathshala

CURVE No.	HIP			RADIUS	HAND OF ARC	TRANSITION			CIRCULAR			DESIGN SPEED	Δ	Δc	θs	Ts	Es	S	K	e
	CHAINAGE	EASTING	NORTHING			START CHAINAGE	LENGTH (Ls)	END CHAINAGE	START CHAINAGE	LENGTH (Lc)	END CHAINAGE									
				m			m			m		Km/hr	Deg.	Deg.	Deg.	m	m	m	m	%
1	0+145	317973	2933369	1500	LEFT	0+061	65	0+228	0+127	36.550	0+163	100	3.880	1.400	1.240	83.300	0.980	0.120	32.500	2.960
2	0+439	318233	2933522	370	RIGHT	0+237	140	0+642	0+377	125.020	0+502	100	41.040	19.360	10.840	209.220	27.420	2.200	69.920	7.000
3	0+781	318575	2933459	5000	RIGHT	-	-	-	0+768	26.080	0+794	100	0.300	0.300	-	13.040	0.020	-	-	NC

MAIN CARRIAGEWAY											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	99.335	-	-0.23%	-	65
2	0+042	Sag	47.489	17.4	0+018	0+066	99.238	-0.23%	2.50%	2.73%	65
3	0+390	Crest	84.500	33.8	0+348	0+432	107.935	2.50%	0.00%	2.50%	65
4	0+561	Crest	84.500	33.8	0+519	0+604	107.935	0.00%	-2.50%	2.50%	65
5	0+877	Sag	54.830	17.4	0+850	0+904	100.041	-2.50%	0.65%	3.15%	65
6	0+941	-	-	-	-	-	100.460	0.65%	-	-	65

SERVICE ROAD LHS											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	99.068	-	-0.04%	-	40
2	0+477	Sag	30	665.735	0+462	0+492	98.862	-0.04%	0.00%	0.05%	40
3	0+780	Sag	30	39.367	0+765	0+795	98.869	0.00%	0.76%	0.76%	40
4	0+941	-	-	-	-	-	100.101	0.76%	-	-	40

SERVICE ROAD RHS											
Sl. No.	IP CHAINAGE	CURVE TYPE	CURVE LENGTH	K VALUE	CURVE START CHAINAGE	CURVE END CHAINAGE	PVI ELEVATION	CURVE IN GRADIENT	CURVE OUT GRADIENT	GRADE DIFFERENCE	SPEED
1	0+000	-	-	-	-	-	99.068	-	-0.04%	-	40
2	0+103	Sag	30	665.735	0+462	0+492	98.862	-0.04%	0.00%	0.05%	40
3	0+589	Sag	30	39.367	0+765	0+795	98.869	0.00%	0.76%	0.76%	40
4	1+290	Crest	-	-	-	-	100.101	0.76%	-	-	40

Fig 4.16 HIP and VIP report of Pathshala

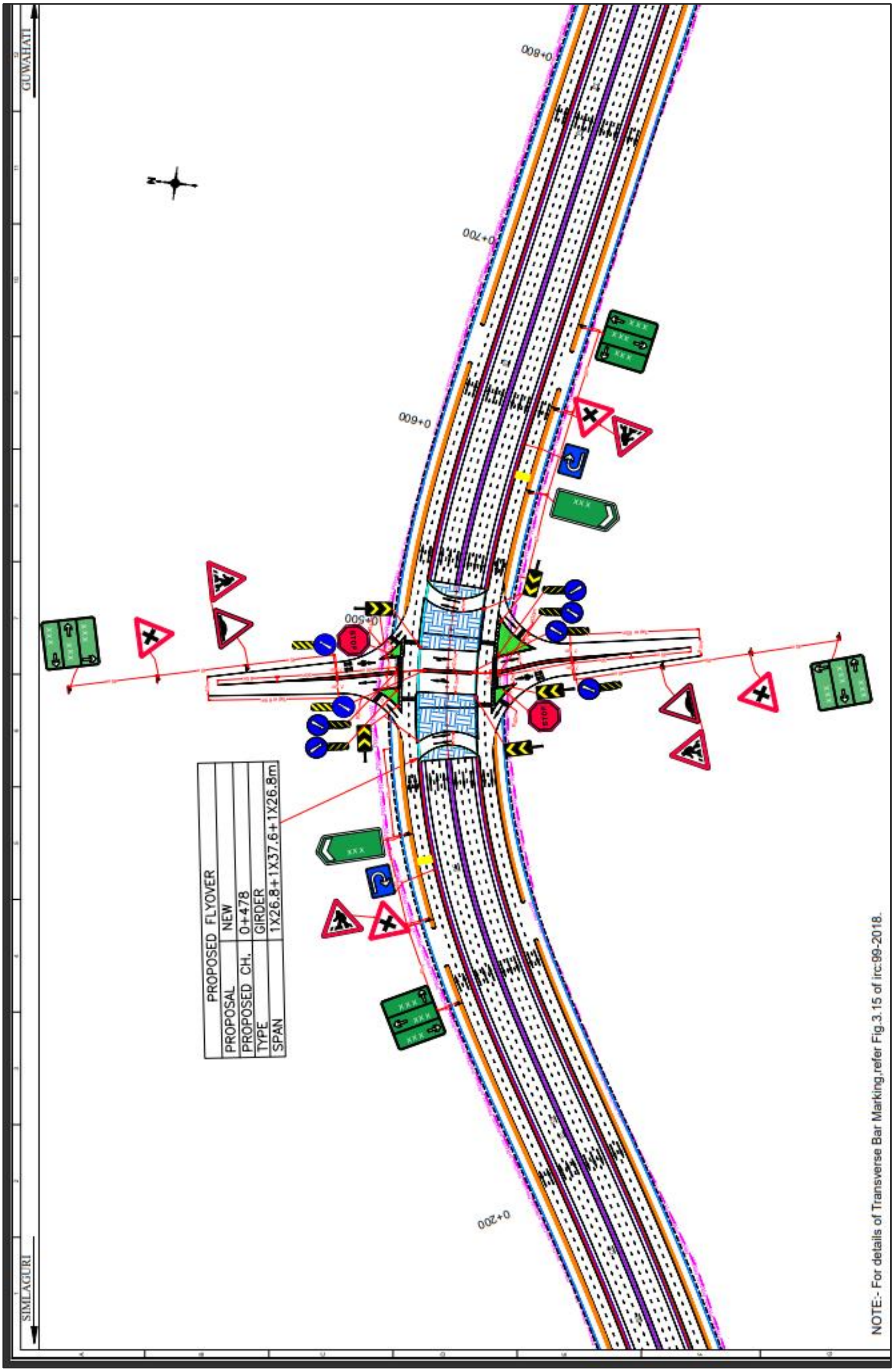


Fig 4.17 Junction Plan Pathshala

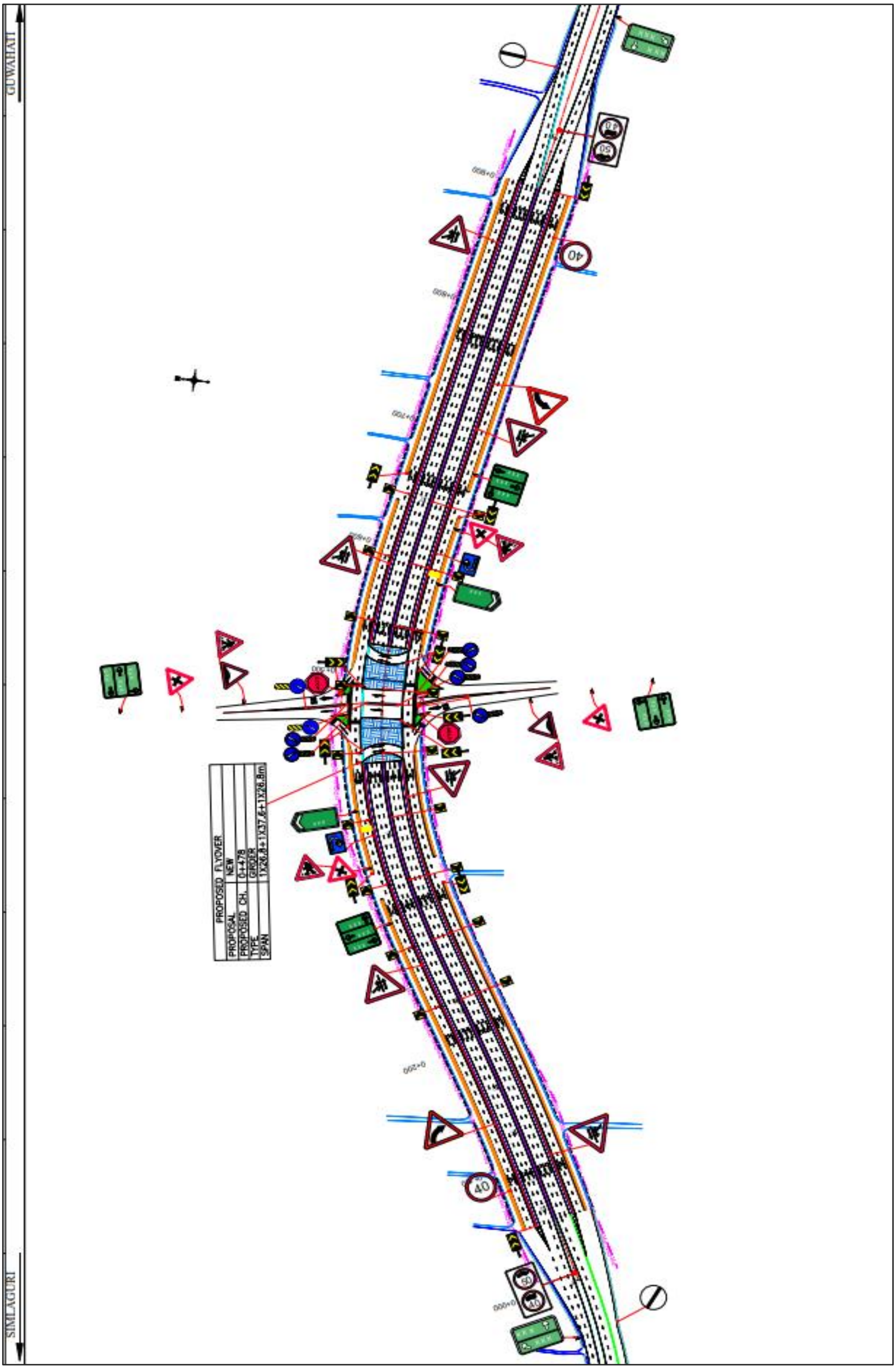
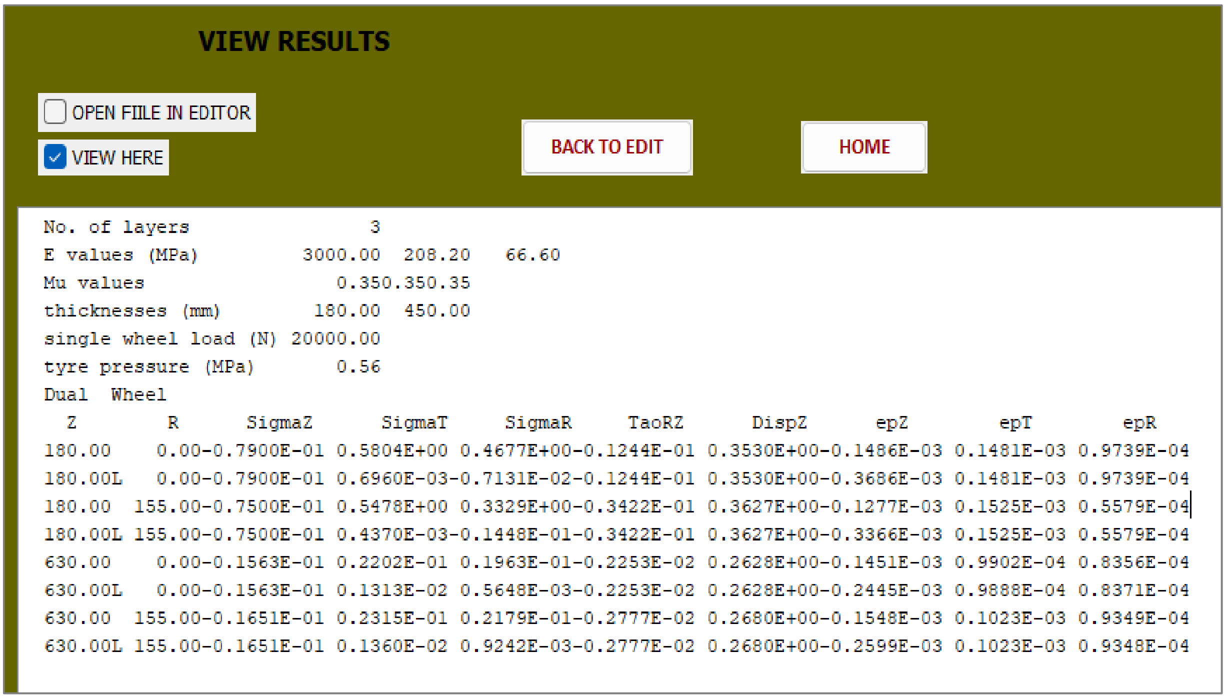


Fig 4.18 Signage plan Pathshala

(BC+DBM+WMM+GSB) for 90 msa at km. 1001+265 & km. 1029+530 of NH-31

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No. of layers               3
E values (MPa)         3000.00  208.20   66.60
Mu values                 0.350.350.35
thicknesses (mm)        180.00  450.00
single wheel load (N) 20000.00
tyre pressure (MPa)       0.56
Dual  Wheel
  Z        R      SigmaZ      SigmaT     SigmaR     TaoRZ      DispZ      epZ        epT        epR
180.00    0.00-0.7900E-01 0.5804E+00 0.4677E+00-0.1244E-01 0.3530E+00-0.1486E-03 0.1481E-03 0.9739E-04
180.00L   0.00-0.7900E-01 0.6960E-03-0.7131E-02-0.1244E-01 0.3530E+00-0.3686E-03 0.1481E-03 0.9739E-04
180.00  155.00-0.7500E-01 0.5478E+00 0.3329E+00-0.3422E-01 0.3627E+00-0.1277E-03 0.1525E-03 0.5579E-04
180.00L 155.00-0.7500E-01 0.4370E-03-0.1448E-01-0.3422E-01 0.3627E+00-0.3366E-03 0.1525E-03 0.5579E-04
630.00    0.00-0.1563E-01 0.2202E-01 0.1963E-01-0.2253E-02 0.2628E+00-0.1451E-03 0.9902E-04 0.8356E-04
630.00L   0.00-0.1563E-01 0.1313E-02 0.5648E-03-0.2253E-02 0.2628E+00-0.2445E-03 0.9888E-04 0.8371E-04
630.00  155.00-0.1651E-01 0.2315E-01 0.2179E-01-0.2777E-02 0.2680E+00-0.1548E-03 0.1023E-03 0.9349E-04
630.00L 155.00-0.1651E-01 0.1360E-02 0.9242E-03-0.2777E-02 0.2680E+00-0.2599E-03 0.1023E-03 0.9348E-04
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Fig. 4.19 IITPAVE result for 90 msa

Based on the calculated values of the maximum horizontal tensile strain at the bottom of the bituminous layer (152.50 microstrain) and the maximum vertical compressive strain at the top of the subgrade (259.90 microstrain), the resulting design fatigue life is determined to be 91.50 msa and the rutting life is 253.17 msa. These values exceed the required minimum of 90 msa for both fatigue life and rutting life.

Designed Pavement Composition

The designed pavement composition for 8.0% effective Sub grade CBR for the New construction section is given in Table below:

Table 4.3 : Design of flexible pavement for main carriageway at km. 1001+265 & km. 1029+530 of NH-31

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+WMM+GSB	90	8.0	50	130	250	200	90 mm DBM has to be laid in single layers. DBM to be laid with Va=3.5% and Vb= 11.50%

(BC+DBM+WMM+CTSUB) for 90 msa at km. 1001+265 & km. 1029+530 of NH-31

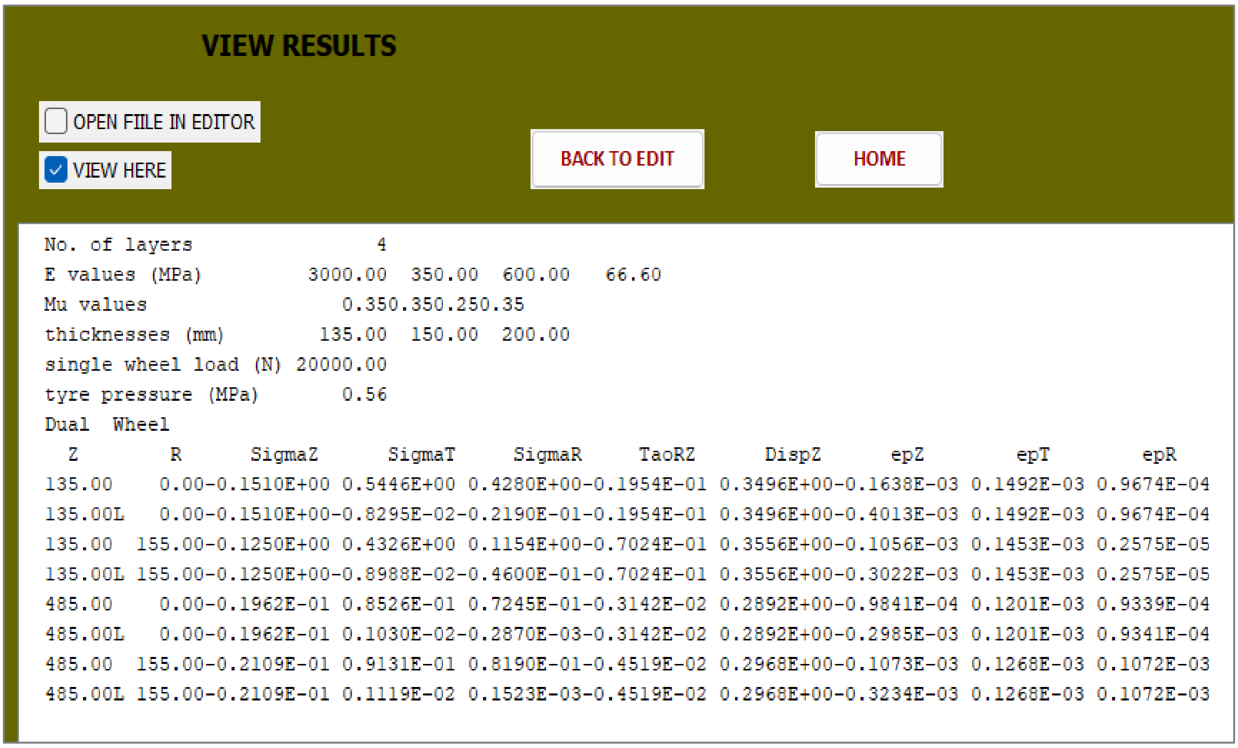

Fig. 4.20 IITPAVE result for 90 msa CTSB

Based on the calculated values of the maximum horizontal tensile strain at the bottom of the bituminous layer (149.20 micro strain) and the maximum vertical compressive strain at the top of the subgrade (323.40 micro strain), the resulting design fatigue life is determined to be 99. 63 msa and the rutting life is 99.97 msa. These values exceed the required minimum of 90 msa for both fatigue life and rutting life.

Designed Pavement Composition

The designed pavement composition for 8.0% effective Sub grade CBR for the New construction section is given in Table below

Table 4.4 : Design Of Flexible Pavement For Main Carriageway At Km. 1001+265 & Km. 1029+530 Of Nh-31

Pavement Design	Design msa	Effective Subgrade CBR (%)	Thickness (mm) as per IRC:37-2018				Remarks
			Designation of the Pavement Layer				
			BC with VG-40	DBM with VG-40	WMM	GSB Grading V Morth Table 400-1	
BC+DB+ WMM+CT SB	90	8.0	40	95	150	200	95 mm DBM has to be laid in single layers. DBM to be laid with Va=3.5% and Vb= 11.50%

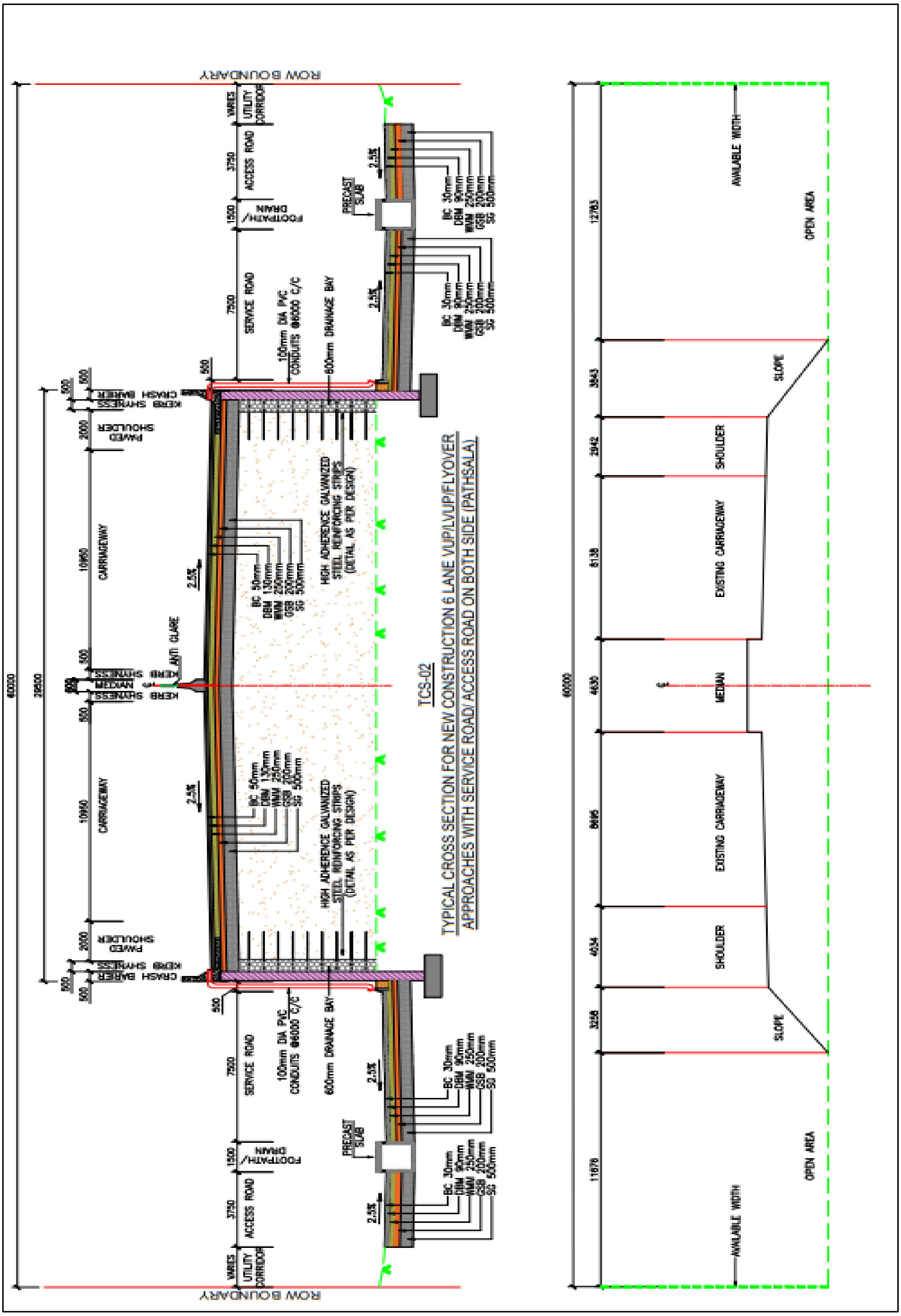

Fig. 4.21 TCS of Patshala

Chapter 5: Conclusion

5.0 General

An attempt has been made in this project to Mitigate Blackspots of some stretches of NH31 and 31C. This chapter is about the work carried out and the conclusion drawn from an application point of view. On the whole, this study provides various aspects such as geometric design by "Civil3d", Pavement design by iitpave, junction development, and road signage. This study is an attempt to mitigate the blackspots in the state of Assam.

5.1 Concluding Remarks

1. During the site visit, it was discovered that there were three blackspots that needed immediate attention and mitigation. These blackspots, known for their high accident rates or hazardous conditions, posed a significant risk to safety. Therefore, it was crucial to address these areas promptly.
2. All three blackspots have been mitigated by providing flyover structures and implementing proper geometric design.Chapaguri was designed for 100 kmph Simlaguri was designed for 65 kmph. Patshala was designed for 65 kmph.
3. The pavement is designed to address irregularities in the road and meet the required Million Standard Axle (msa) based on traffic survey data. Chapaguri was designed for 110 msa whereas Simlaguri and Patshala were designed for 90 msa.
4. Even though a grade-separated flyover structure was designed with proper vertical and horizontal geometry, it was essential to ensure that the junction layout was also properly designed to prevent any further accidents.
5. A well-designed signage plan incorporating all necessary signs such as speed limits, lane guidance, upcoming exits, hazards, and directions to various destinations was implemented to enhance driver awareness, reduce confusion, and promote safe driving behaviours.

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