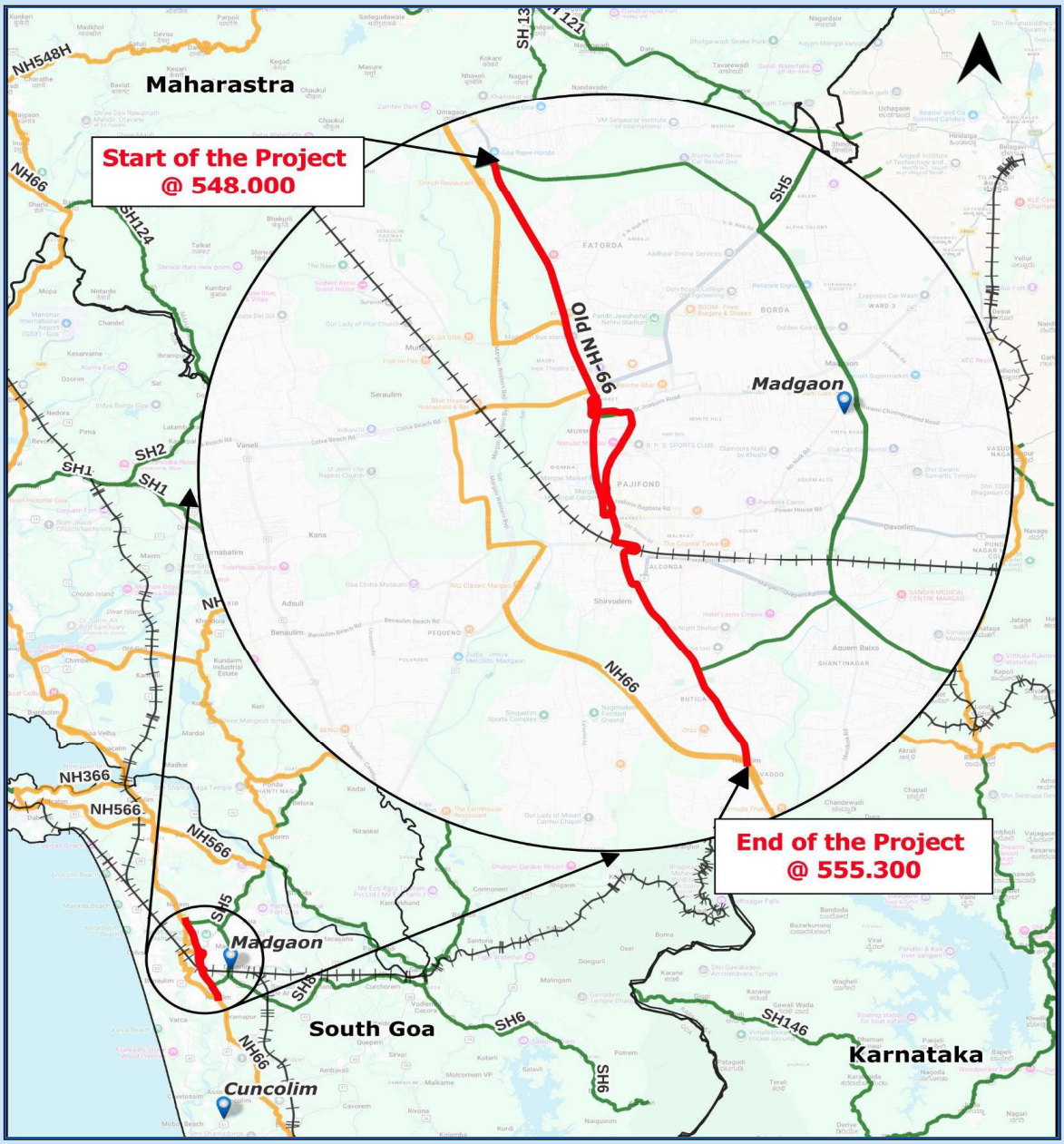
GOVERNMENT OF GOA

PUBLIC WORKS DEPARTMENT (NATIONAL HIGHWAYS)

One Time Improvement to bypassed NH-66 at Margao City from Km 548.000 to Km 555.300 in the state of Goa



MAIN REPORT

Consultant

aarvee engineering consultants limited

8-2-5, Ravula Residency, Srinagar Colony Main Road, Hyderabad-82, Telangana, India.

Tel: +91-40-4848 3456, 2373 7633; Fax: +91-40-23736277

e-mail: aarvee@aarvee.net; web: www.aarvee.com

Table of Contents

List of Tables

List of Figures		
S.No	**Item**	**Page.no**
1.1	Location Map of the Project	1-6
2.1	Index Map of the Project stretch	2-2
2.2	Map showing Traffic Survey Locations	2-4
2.3	Petrol Sales Variation	2-8
2.4	Diesel Sales Variation	2-8
2.5	AADT Modal Split near Fatorda (Km. 549.000)	2-10
2.6	Total traffic & Tollable traffic volume near Fatorda (Km. 549.000)	2-11

1. INTRODUCTION

1.1 General

The Government of India has envisaged to create a world-class infrastructure facility, to boost the economic development in the country and also to minimize the number of accidents/fatalities, for which Ministry of Road Transport and Highways (MoRTH) plays a key role. MoRTH has been entrusted to implement various developmental projects of National Highways in order to ensure safer and faster movement of the Vehicles. As part of this endeavor, MoRTH executes the works through the Public Works Department (PWD) in the state of Goa. Public Works Department (NH), Goa has taken up developement of road network in the state of Goa

Public Works Department (PWD) of Goa has appointed M/s Aarvee Engineering Consultants Ltd (Formerly M/s Aarvee Associates Architects Engineers & Consultants Pvt. Ltd., Hyderabad) to provide consultancy services for DPR for the infrastructure projects.

1.2 Project Background

1.2.1 NH Network of Goa

The length of National Highways in the state is around 280 Km. There are 6 National Highways running length and breadth of Goa state viz., NH-66, NH-748, NH-366, NH-566, NH-166S and NH-748AA.

Table 1.1: Details of Existing Alignment of the Road part in the State of Goa

S.No	NH	<2L	2L	2L+PS	4L	Total Length in Km
1	66	0	53.26	0	70.62	123.88
2	748	0	52.2	0	16.88	69.08
3	366	0	6	10	0	16
4	566	0	8	0	29.5	37.5
5	748AA	27	0	0	0	27
6	166S	0	0	0	6.58	6.58
Total Length in Km						**280.04**

National Highway No. 66 connects Mumbai to Kanyakumari, traversing the coastal regions of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. The entire corridor, passing through Navi Mumbai, Ratnagiri, Goa, Udupi, Mangalore, Kozhikode, Kochi, Thiruvananthapuram and Kanyakumari, has been sanctioned for development to 4-lane road configuration except for a small stretch of 8.71 Km in Goa.

In Goa, NH-66 starts from the Maharashtra/Goa border near Patradevi, passes through Mapusa, Panaji, Madgaon, Cuncolim, and ends at the Goa/Karnataka border near Polem, covering a total length of **124 km**. Out of this, **115.30 km has already been sanctioned**, remaining 8.71 Km is due for sanction.

NH-66 (erstwhile NH-17) passes through several urban centers along its alignment. In order to reduce congestion within cities and improve corridor capacity, bypasses have been constructed / are being constructed and the highway sections are being developed to 4-lane configuration. Margao city is one such important urban center along NH-66.

The stretch from Km 548.000 to Km 555.300 passes through the urban limits of Margao city and functions as a major arterial corridor carrying mixed local, inter-city, and commercial traffic.

As part of the improvement of the road network and to decongest through traffic on NH-66, a 4-lane bypass on the western side of Margao city was proposed and has since been completed and commissioned. The bypass has facilitated diversion of through traffic; however, the existing urban stretch continues to carry significant local, commuter, and commercial traffic and therefore requires improvement in terms of capacity, safety, and serviceability.

1.2.2 Margao City Overview and Need for Road Improvement

Margao city is one of the most important urban centers in the State of Goa. It functions as the commercial, cultural, and administrative hub of South Goa. The city accommodates important government offices, educational institutions, healthcare facilities, markets, and commercial establishments, serving the needs of both the local population and residents of surrounding

towns and villages. Margao is a major transit point for passenger and goods movement due to the presence of Margao Railway Station, one of the busiest railway stations in Goa, providing connectivity to major cities across India. The city also plays a significant role in tourism, acting as a gateway to popular beaches and heritage locations in South Goa. Owing to these factors, Margao attracts substantial daily commuter traffic, freight movement, and tourist inflow, making efficient transportation infrastructure essential for its sustained growth.

In addition, Margao accommodates several prominent educational institutions, including schools, colleges, and professional institutes. A large number of students and staff from surrounding towns and villages commute daily to the city to access these institutions, further contributing to regular traffic demand on the city road network.

Margao city is well connected through a network of National Highways, State Highways, Major District Roads, and urban roads, facilitating intra-city and inter-city movement. The road network caters to diverse traffic including local commuters, inter-district traffic, tourist vehicles, and heavy commercial vehicles. The existing road system provides connectivity between residential areas, commercial centers, industrial zones, bus terminals, railway station, and nearby villages. However, rapid urbanization, increase in vehicular ownership, and growing economic activities have resulted in congestion at key junctions and arterial roads, especially during peak hours. The existing urban road infrastructure is under increasing stress, highlighting the need for capacity augmentation and improved access management. The existing urban road infrastructure is under increasing stress, highlighting the need for capacity augmentation and improved access management. Considering the urban traffic characteristics, a bypass for NH-66 on the western side has been constructed and is now operational.

The urban stretch of NH-66 from Km 548.000 to Km 555.300 passing through Margao city requires improvement in terms of pavement condition, drainage facilities, pedestrian infrastructure, and organized parking areas. The existing road section exhibits deficiencies in riding quality, drainage performance, pedestrian safety, and access control, which adversely

affect traffic flow and safety. The proposed improvement is expected to yield the following outcomes:

- Reduction in travel time and improved traffic distribution within the city
- Enhancement of road safety by minimizing conflict points and improving access control
- Provision of pedestrian facilities to ensure safe movement of pedestrians
- Provision of continuous longitudinal drainage system
- Improvement of existing cross-drainage structures to ensure effective storm water disposal
- Facilitation of balanced urban and regional development in Margao and surrounding areas

1.2.3 Existing Land Use Pattern

The project corridor from Km 548.000 to Km 555.300 of NH-66 passes through the urban limits of Margao city, which is characterized by dense mixed land use. The adjoining areas along the corridor predominantly comprise residential, commercial, institutional, and public utility developments. Major commercial establishments, markets, retail shops, hotels, and offices are located along the corridor, particularly near junctions and central business areas.

Several important public and institutional facilities such as government offices, educational institutions, healthcare facilities, bus terminals, and railway station access roads are also located in the influence area of the corridor. The corridor serves as a major urban arterial road providing connectivity between residential neighborhoods, commercial centers, industrial areas, and inter-city transport nodes.

The high intensity of land use along the corridor generates significant pedestrian movement, on-street parking demand, and frequent access points, resulting in traffic conflicts and reduced

operational efficiency. The corridor also experiences high frontage activity, including commercial loading/unloading operations, which further affects traffic flow and safety.

Based on traffic assessment, the projected traffic on the existing road is 20,969 PCU/day.

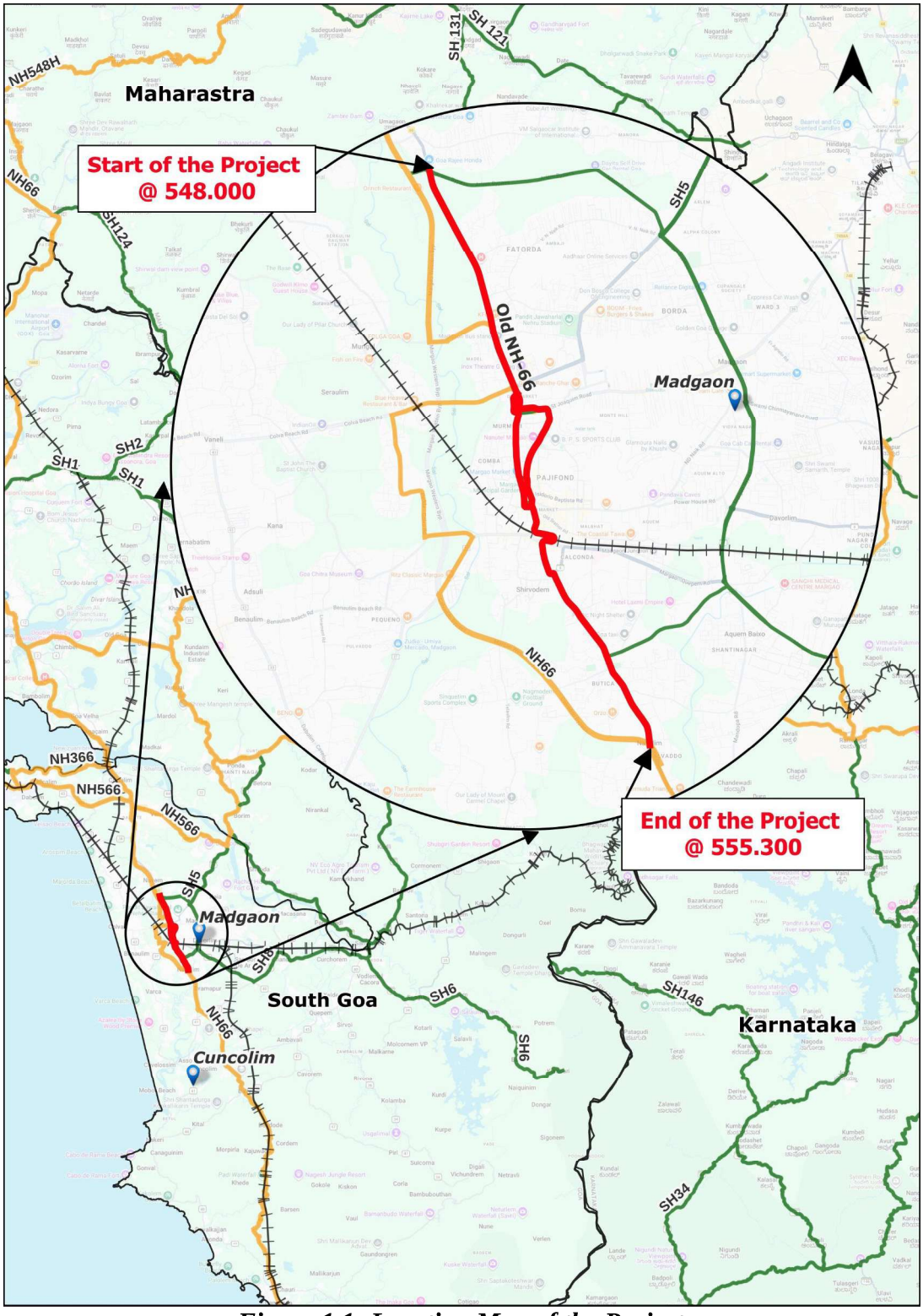


Figure 1.1: Location Map of the Project

1.3 Existing Road Condition

PWD (NH) entrusted M/s Aarvee Engineering Consultants Ltd. (formerly M/s Aarvee Associates Architects Engineers and Consultants) to study and propose improvement of the existing road stretch from Km 548.000 to Km 555.300 of NH-66.

The projected traffic on the stretch is 20,969 PCU/day. There has been a substantial increase in traffic volume in recent years due to population growth, expansion of urban limits, increased tourism activities, and rising commercial and institutional developments in Margao city.

The existing pavement is flexible in nature with carriageway width varying between 7.0 m to 14.0 m along the corridor. At most locations, the existing drainage condition is inadequate and requires improvement to prevent water stagnation and pavement deterioration. Pedestrians are currently forced to walk on the carriageway due to discontinuous and inadequate footpath facilities, leading to safety concerns and traffic conflicts.

1.4 Objectives

The main objective of the consultancy services is to undertake feasibility studies for the project highway for the purpose of firming up the Authority requirements in respect of development between Km 548.000 to Km 555.300.

The objective of the consultancy services also includes:

1. Enhanced safety and level of service for the road users;
2. Superior operation and maintenance enabling enhanced operational efficiency of the Project Highway;
3. Minimal adverse impact on the local population and road users due to road construction;
4. Minimal adverse impact on environment;
5. Minimal acquisition of land;

2.1 Traffic Analysis & Forecasting

2.1.1 General

The Government of India has envisaged to create a world-class infrastructure facility, to boost the economic development in the country and also to minimize the number of accidents/fatalities, for which Ministry of Road Transport and Highways (MoRTH) plays a key role. MoRTH has been entrusted to implement various developmental projects of National Highways in order to ensure safer and faster movement of the Vehicles. As part of this endeavor, MoRTH executes the works through the Public Works Department (PWD) in the state of Goa. Public Works Department (NH), Goa has taken up developement of road network in the state of Goa

Public Works Department (PWD) of Goa has appointed M/s Aarvee Engineering Consultants Ltd (Formerly M/s Aarvee Associates Architects Engineers & Consultants Pvt. Ltd., Hyderabad) to provide consultancy services for DPR for the infrastructure projects.

2.1.2 Project Location

The project corridor from Km 548.000 to Km 555.300 of NH-66 passes through the urban limits of Margao city, which is characterized by dense mixed land use. The adjoining areas along the corridor predominantly comprise residential, commercial, institutional, and public utility developments. Major commercial establishments, markets, retail shops, hotels, and offices are located along the corridor, particularly near junctions and central business areas.

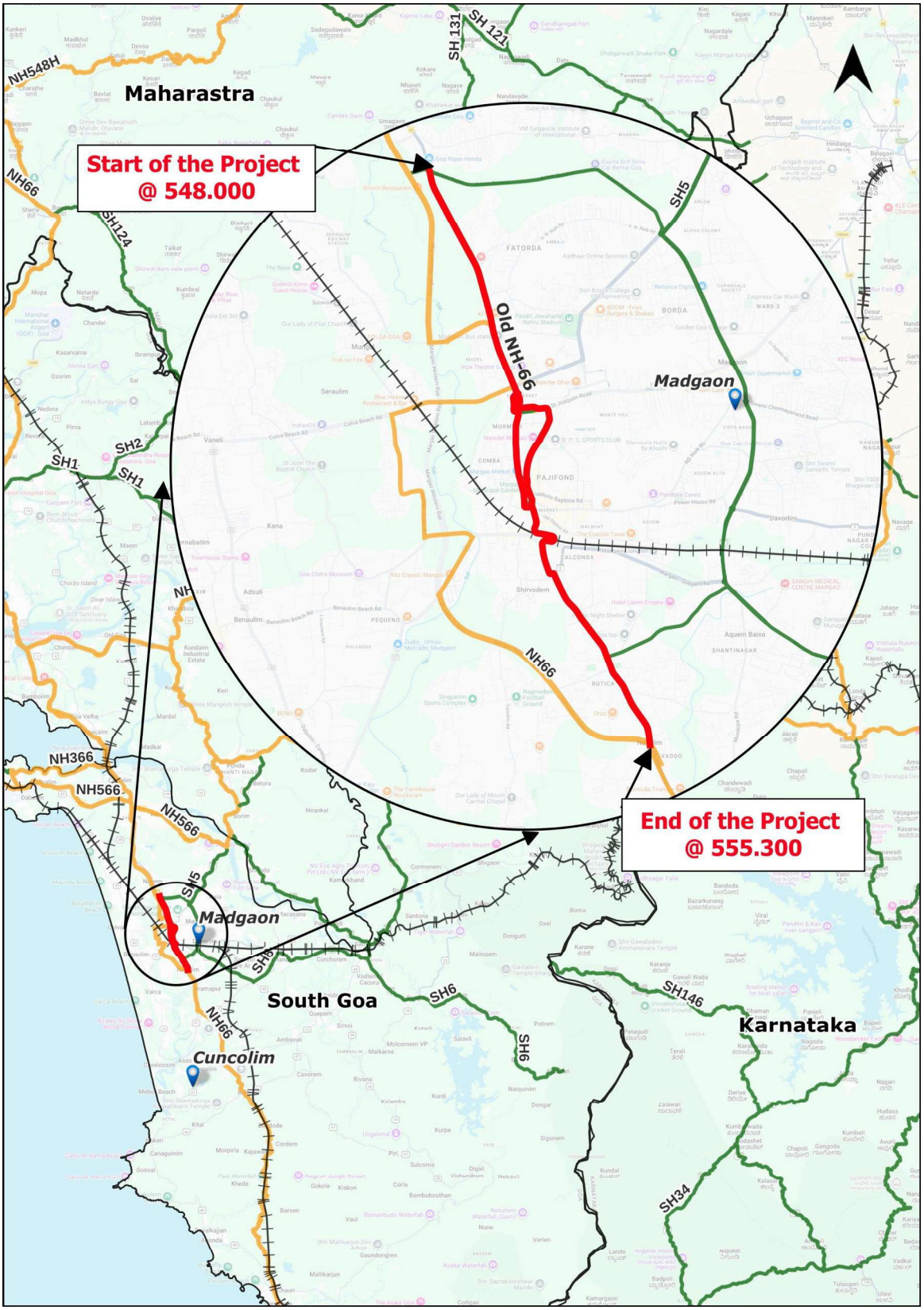


Fig. – 2.1: Index Map of Project Stretch

2.2 Traffic Surveys Planning & Schedule

2.2.1 Traffic Surveys and Collection of Data

The road network has been thoroughly studied during the reconnaissance stage. In order to assess the traffic pattern and volume, the Consultants have carried outClassified traffic volume count survey at Km 549.000 on Old NH-66. Further, to assess the traffic on internal roads the traffic data has been obtained from PWD.

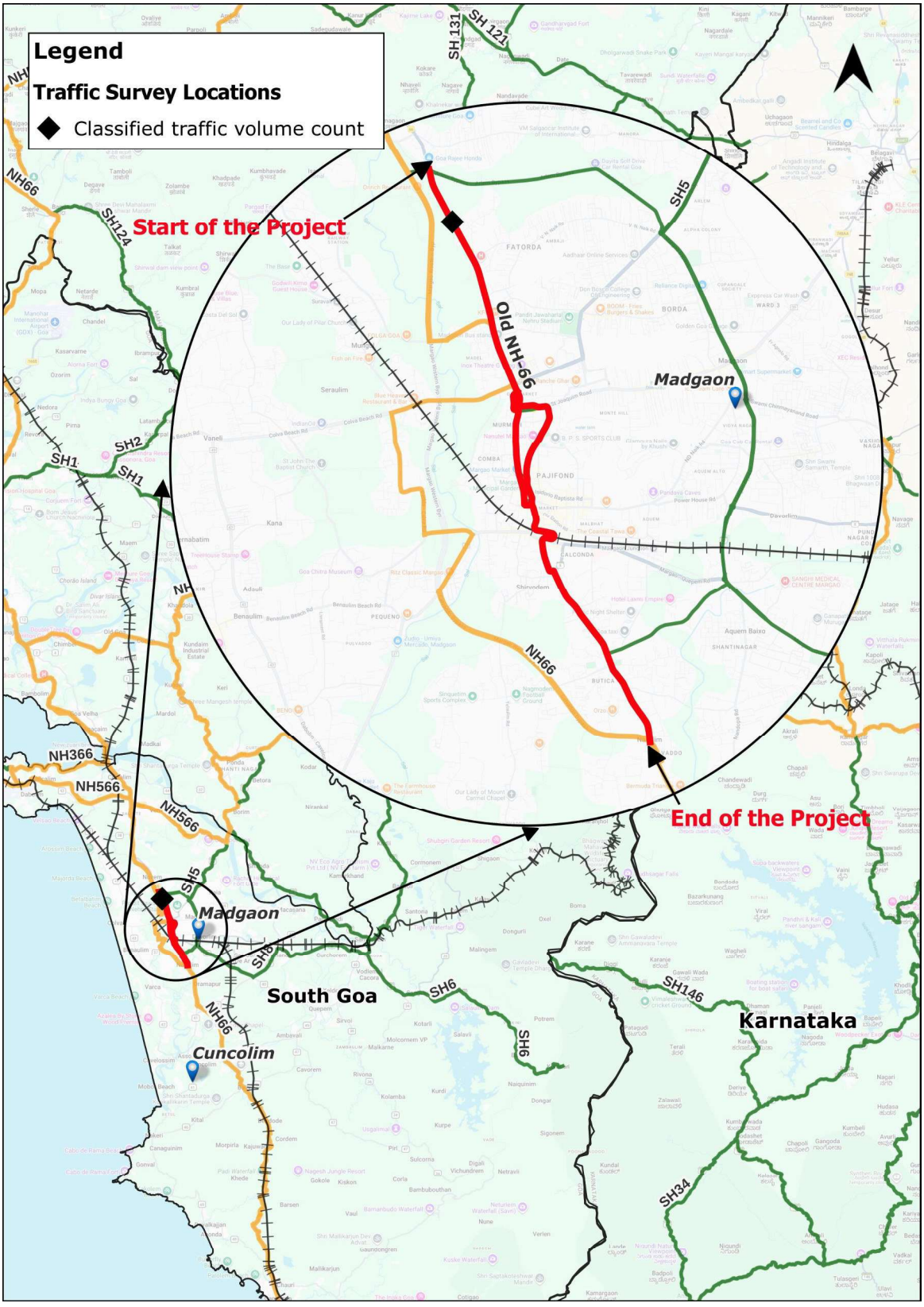


Fig.– 2.2: Map showing Traffic Survey Locations

2.2.2 Schedule of Traffic Surveys

A detailed schedule of all traffic surveys conducted along the project stretch are listed and presented below.

Table – 2.1: Traffic Surveys Schedule

S. No.	Type of Survey	Location	Date of Survey	Duration of Survey
1	Classified Traffic Volume Count	Near Fatorda (Km. 549.000)	03-04-2025	24 hours

2.2.3 Objectives of Traffic Surveys

The primary objective of these traffic studies is:

- To determine characteristics of traffic movement and to establish base year traffic demand
- To determine the travel pattern of goods and passenger vehicles
- For capacity assessment
- To determine the percentage of cross road traffic at road intersections as a guide to the intensity of vehicle – vehicle conflict
- To determine vehicle damage factor
- Input in toll revenue calculations.

2.2.4 Methodology of Traffic Surveys

- Cameras were installed at strategic locations at the location. The station is managed by a supervisor.
- Continuous 24-hour Turning Movement count survey was conducted. The survey was conducted in accordance with the guidelines provided by IRC: 9. The vehicles are broadly classified into motorized passenger vehicles, motorized goods vehicles and non-motorized vehicles. These groupings have further been sub-divided to reflect the present day traffic pattern more realistically.

2.3 Traffic Volume Surveys and Analysis

2.3.1 Data Collection

The data collected from primary and secondary sources are recorded in Excel sheets, compiled, checked and corrected before further proceeding for analysis. Traffic data analysis has been carried out, to understand traffic characteristics and travel pattern in the study area and to provide basic input for pavement design.

2.3.2 Traffic Volume Count

The analysis has been carried out to derive:

- Weekly Traffic Summary
- Average Daily Traffic (ADT) of fast and slow moving vehicles
- Average Daily Variation and Average Hourly Variation
- Annual Average Daily Traffic (AADT) after seasonal correction
- AADT Modal split

2.3.3 Average Daily Traffic

The classified traffic volume count data collected is analyzed to assess the traffic intensity along the project corridors. The Average Daily Traffic (ADT in number of vehicles) for the traffic surveys at the survey location with salient findings as shown in Table 2.2.

Table – 2.2: Average Daily Traffic

Mode	Km. 549.000
Two Wheelers	10745
Three Wheelers	20
Car / Jeep / Van	9482
Car Yellow board	79
Tata Magic	1
RTC Bus	281
Private Bus	464
School/College bus	0

Mode		Km. 549.000
Mini Bus		65
2 Axle		123
3 Axle		9
M Axle		106
HEM		7
LCV/LGV		514
Mini LCV		924
Three Wheeler goods		0
Tractor		0
Tractor with trailer/ others		1
Non-Motorized Vehicles		69
Govt. Exempted Vehicles		11
Tollable Traffic (vehicles)		12055
Tollable Traffic (PCU's)		14494
Total Vehicles	Motorized	22838
	Non-Motorized	69
	Total Traffic	22907
Total PCUs	Motorized	19914
	Non-Motorized	59
	Total Traffic	19973

2.3.4 Seasonal Variation factor (SVF)

The Average Daily Traffic (ADT) has to be adjusted for the seasonal variation along the project stretch. The seasonal variation factor is normally estimated using the past fuel sales data collected from the existing petrol bunks along the project stretch. The Diesel and Petrol sales data collected from petrol bunks along Old NH-66 for the past one year is analyzed for the monthly variation in the sales of fuel.

Table – 2.3: Seasonal variation for Petrol & Diesel vehicles on Old NH-66

Month	MS (kl)	HSD (kl)
Jan	317	437
Feb	282	463
Mar	280	439
Apr	260	444
May	270	469
Jun	252	471
Jul	244	433
Aug	262	430
Sep	255	419
Oct	293	439
Nov	302	442
Dec	362	526
Average	**1.08**	**1.02**

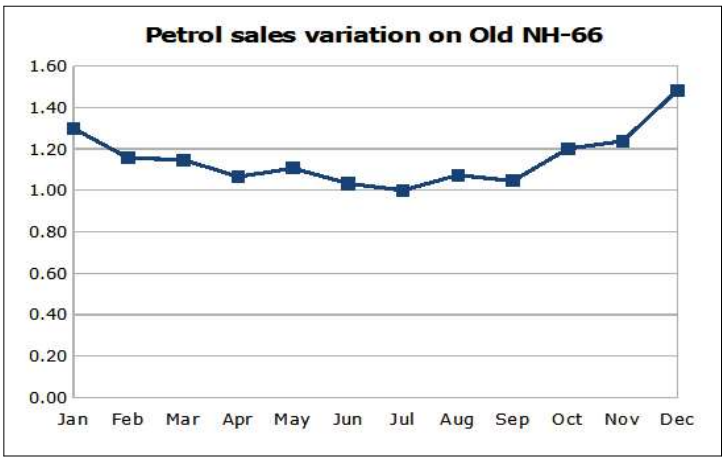


Figure – 2.3: Petrol Sales Variation

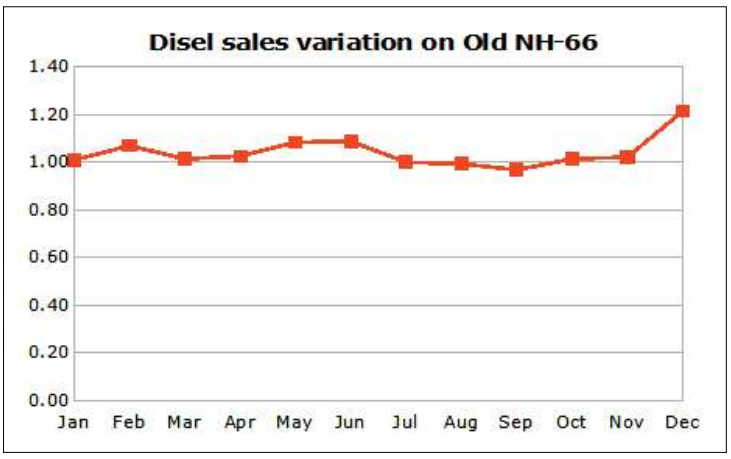


Figure – 2.4: Diesel Sales Variation

The traffic volume surveys are conducted in the month of April, 2025. From the analyzed fuel sales data, the seasonal variation factors have been considered as shown below Table-2.4 for AADT calculations.

Table – 2.4: Seasonal Variation Factors(SVF)

S. No.	Section	Petrol	Diesel
1	Margao city (NH-66)	1.08	1.02

2.3.5 Annual Average Daily Traffic (AADT)

The Annual Average Daily Traffic (AADT in no of vehicles) at the survey locations is obtained by multiplying the Average Daily Traffic (ADT) with the seasonal correction factor. The AADT of vehicles for the year 2025 at the survey location of traffic volume count survey along the Project corridor is presented below.

Table – 2.5: Annual Average Daily Traffic (AADT)

Mode	Km. 549.000
Two Wheelers	11637
Three Wheelers	20
Car / Jeep / Van	9950
Car Yellow board	83
Tata Magic	1
RTC Bus	285
Private Bus	471
School/College bus	0
Mini Bus	66
2 Axle	125
3 Axle	9
M Axle	108
HEM	7
LCV/LGV	522
Mini LCV	939
Three Wheeler goods	0
Tractor	0
Tractor with trailer/others	1

Mode		Km. 549.000
Non-Motorized Vehicles		22
Govt. Exempted Vehicles		33
Tollable Traffic (vehicles)		11795
Tollable Traffic (PCU's)		21697
Total Vehicles	Motorized	24242
	Non-Motorized	69
	Total Traffic	24311
Total PCUs	Motorized	20910
	Non-Motorized	59
	Total Traffic	20969

2.3.6 AADT Modal Split

- Car (White board) Traffic is about 40.93%, Goods contribute 7.06%. Two wheeler constitute 47.87% in the total traffic along the corridor as shown in Figure – 2.5.
- The share of non motorized vehicles is negligible.

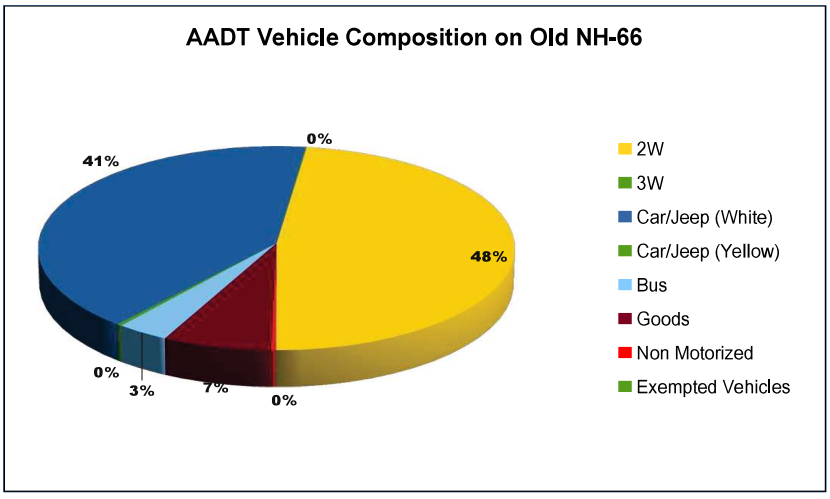


Figure – 2.5: AADT Modal Split Near Fatorda (Km. 549.000)

2.3.7 Total and Tollable Traffic

The share of Tollable traffic as a percentage of AADT, for the project section varies as shown below in Figure – 2.6.

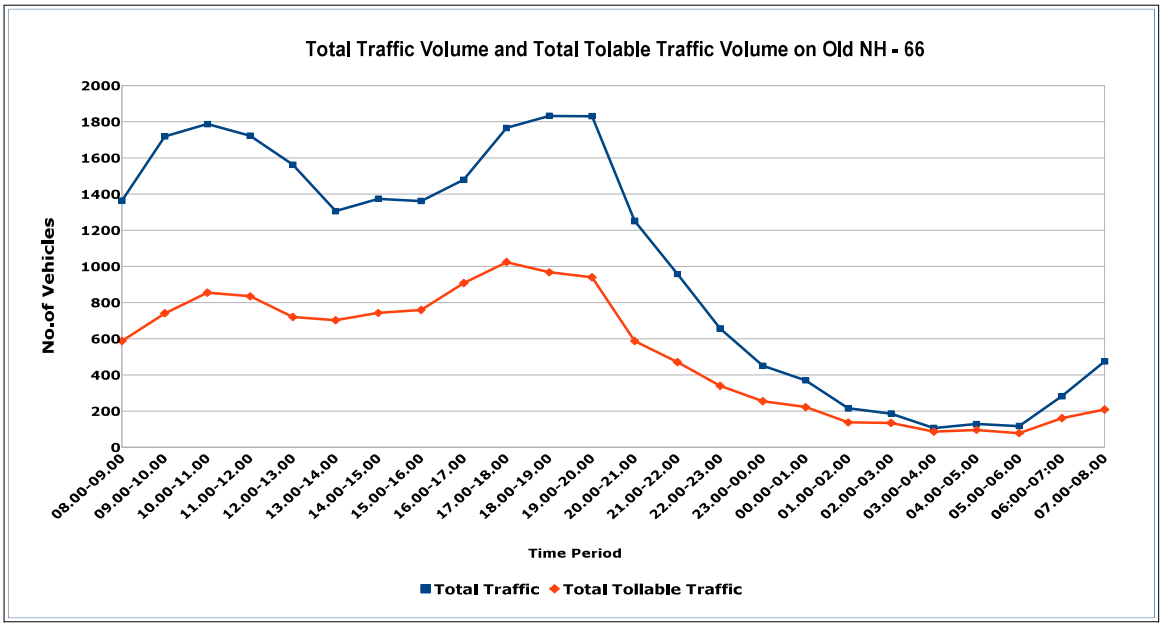


Figure – 2.6: Total traffic & Tollable traffic volume near Fatorda at Km. 549.000

2.3.8 Peak Hour Traffic

The peak hour factor is defined as the traffic volume during peak hour expressed as a percentage of AADT. The peak hour volume is taken as the highest hourly volume based on actual traffic counts. The maximum possible value for the peak hour factor is 1.00, which occurs when the volume in each interval is constant. The peak hour factor calculated for both the sections at the traffic count locations are given in Table – 2.6. The peak hour factors indicate fairly uniform distribution of the traffic volume during the day.

Table –2.6: Peak Hour Factor (PHF)

S. No.	Volume Count Location	Peak Hour	Peak Hour Volume	AADT	Peak Hour
1	Near Fatorda at Km.549.000	18:30 – 19:30	1877	20969	8.95%

3.0 Pavement Design Report

3.1 Introduction

The Government of India has envisaged to create a world-class infrastructure facility, to boost the economic development in the country and also to minimize the number of accidents/fatalities, for which Ministry of Road Transport and Highways (MoRTH) plays a key role. MoRTH has been entrusted to implement various developmental projects of National Highways in order to ensure safer and faster movement of the Vehicles. As part of this endeavor, MoRTH executes the works through the Public Works Department (PWD) in the state of Goa. Public Works Department (NH), Goa has taken up developement of road network in the state of Goa

Public Works Department (PWD) of Goa has appointed M/s Aarvee Engineering Consultants Ltd (Formerly M/s Aarvee Associates Architects Engineers & Consultants Pvt. Ltd., Hyderabad) to provide consultancy services for DPR for the above road section.

The consultants have carried out the traffic surveys to assess the traffic pattern and volume of traffic. Pavement design has been carried out based on the output of Traffic surveys conducted at the junction locations.

3.2 Pavement Design Objective

The Objective is to determine the total thickness of the pavement structure as well as thickness of individual structural layer components. Design strength of pavement must be adequate to support the projected traffic loading throughout the design period.

3.3 Design Guidelines

Design Life: "Flexible pavements are designed in accordance with IRC:37 and rigid pavement are designed in accordance with the method prescribed in IRC:58

- Clause 4.3.1 of IRC:38-2018, states: "A design period of 20 years may be adopted for the structural design of pavements for National Highways, State Highways and Urban Roads"
- Clause 5.4 of IRC:58-2015, states: Cement concrete pavements may be designed to have a life span of 30 years or more.
- Clause 5.7.4 of IRC: 58-2015, states: A subbase of Dry Lean Concrete (DLC) having a 7-day average compressive strength of 7 MPa determined as per IRC:SP:49 over GSB is recommended for highways. Minimum recommended thickness of DLC for major highways is **150 mm**. The DLC shall extend beyond the PQC by 0.5 m on either side.

- Clause 5.7.5 of IRC:58-2015, states: A de-bonding interlayer of polythene sheet white or transparent having a minimum thickness of 125 micron is recommended as per the current practice in India

3.4 Design CBR

The CBR of borrow material varies between 6% and 14%. Considering the fact that the contractor executing the works may opt for alternative sources than studied herein, an average value of 10% is adopted in the pavement design.

3.5 Traffic Volume Count Surveys

Since the proposed road is a brownfield corridor, traffic volume count surveys were conducted at the junction locations. The Consultant have carried out Classified Traffic Volume Count survey near Fatorda at Km. 549.000 on Old NH-66, round the clock for 24 hours at the location. Axle load survey conducted at the survey locations to assess the load characteristics of commercial vehicles. Accordingly the commercial traffic is estimated using the fraction of the vehicle movement between the influential zones applied to the Annual average daily traffic data. Only the commercial vehicles are to be converted into standard axles for the purpose of pavement design. Detailed analysis has been presented in Traffic Report.

Table-3.1: AADT for the survey location near Fatorda (Km. 549.000)

Mode	Fatorda (Km. 549.000)
Two Wheelers	11637
Three Wheelers	20
Car / Jeep / Van	9950
Car Yellow board	83
Tata Magic	1
RTC Bus	285
Private Bus	471
School/College bus	0
Mini Bus	66
2 Axle	125
3 Axle	9
M Axle	108
HEM	7
LCV/LGV	522
Mini LCV	939

Mode		Fatorda (Km. 549.000)
Three Wheeler goods		0
Tractor		0
Tractor with trailer/others		1
Non-Motorized Vehicles		22
Govt. Exempted Vehicles		33
Tollable Traffic (vehicles)		11795
Tollable Traffic (PCU's)		21697
Total Vehicles	Motorized	24242
	Non-Motorized	69
	Total Traffic	24311
Total PCUs	Motorized	20910
	Non-Motorized	59
	Total Traffic	20969

3.6 Traffic Growth Rates

Past trends in the growth rates along the proposed project corridor provide a valuable information to the likely future traffic. But in most cases, the past traffic data from statistical department is inconsistent and cannot be taken as a basis for future traffic growth rate. Alternatively the motor vehicle registration data at the state level during the recent past provides more consistent information regarding the trends in traffic growth and thus presents a better tool for estimating future growth rates of different categories of vehicles. A more rational method is to establish a relationship between the socio - economic variables such as population, Net State Domestic Product and Per-capita income on one hand and the past registration data of different categories of vehicles on the other to determine the Elasticity of Transport Demand with respect to different categories of vehicles. The detailed calculations of growth rates are given in traffic report. The computed traffic growth rates are given in the below Table-3.2.

Table-3.2: Actual growth rates in percentages

Traffic Growth Rates (%)	BUS	LCVs	2-Axle Trucks	3-Axle Trucks
Up to 2024	5.0 %	5.0 %	5.0 %	5.0 %
2024-2029	5.0 %	5.0 %	5.0 %	5.0 %
2029–2034	5.0 %	5.0 %	5.0 %	5.0 %
2034 – 2039	5.0 %	5.0 %	5.0 %	5.0 %
Beyond 2039	5.0 %	5.0 %	5.0 %	5.0 %

3.7 Axle Load Surveys

The Vehicle Damage Factor (VDF) is an index characterizing the traffic loading for a highway and is defined as a multiplier for converting the number of commercial vehicles of different axle loads to Standard Axle Loads (SAL). Equivalency factor (EF) is normally worked out by using the Fourth Power Rule derived by AASHTO. However, CRRI has suggested a factor of 4.5 for developing countries. In the present study, the Fourth Power Rule given by AASHTO has been adopted. With the help of equivalency factors and frequency distribution of axle loads, Equivalent Axle Loads (EAL) are computed. The standard axle loads and the legal axle loads considered while calculating the equivalency factors for various axles are furnished below.

Table-3.3: Standard & legal Axle loads

S.No	Type of Axle	Standard Axle Load (Tonnes)	Legal Axle Load (Tonnes)	Reference
1	Single Axle (1^{le} wheel)	6.60	6.60	IRC-3
2	Single Axle (2^{al} wheel)	8.16	10.20	IRC-37/IRC-3
3	Tandem Axle	15.09	19.00	IRC-37/IRC-3

VDF depends on the composition of commercial traffic, the load carried and the actual sample collected. The following table gives the VDF's adopted in design.

Table-3.4: Vehicle Damage Factor (VDF) adopted

Mode	Adopted VDF
LCV	0.74
2A	3.78
3A	4.53
MA	5.39

3.8 Million Standard Axles (MSA)

Design traffic in terms of Million Standard Axles (MSA) is determined at location, where both volume count and axle load surveys were conducted.

The traffic loading in terms of the cumulative number of standard axles for the design period is computed using the following relationship.

$N = 365 * [(1+r)^n - 1] * A * D * L * F / r$

Where,

N: The cumulative number of standard axles to be catered for in the design in terms of MSA.

A: Initial traffic in the year of completion of construction in terms of the number of commercial vehicles per day

L: Lane Distribution Factor

D: Directional Distribution Factor

n: Design Life in years

r: Annual Growth rate of commercial vehicles (5 %).

F: Vehicle Damage Factor

3.9 Pavement Investigations

The design consultants have undertaken the following pavement investigations to assess the condition of the existing pavement along with the quality of the materials that have been incorporated in construction. Pavement has been investigated subjectively as well as objectively at suitable interval where necessary, for its structural and functional performance. Following investigations were carried out for the project stretch.

- Condition survey by visual inspection
- Test Pit investigations
- Geotechnical investigation of subgrade
- Benkelman Beam Deflection Test

3.10 Preliminary Design of Flexible Pavement

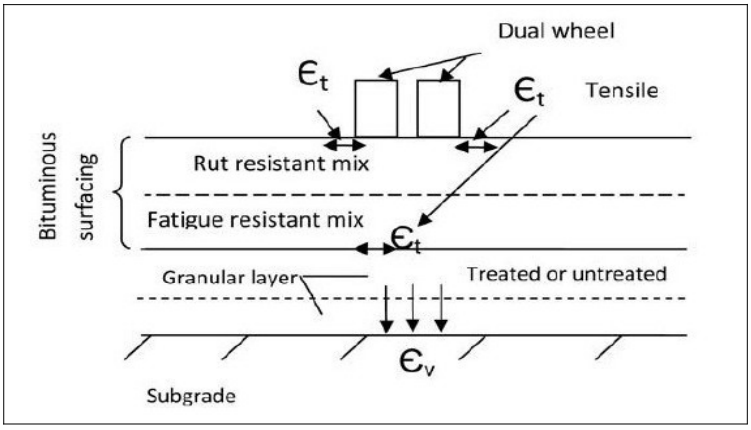
3.10.1 General

The flexible pavement is modeled as an elastic multi layer structure. Stresses and strains at critical locations are computed using linear layered elastic model. The stress – strain analysis software IIT-PAVE has been used for the computation of stress and strain in flexible pavements as mentioned below

- Horizontal Tensile Strain at bottom of bituminous layer, which can cause fatigue failure of bituminous layer.

- Vertical Compressive Strain at the top of subgrade, which can cause rutting failure of pavement layers.
- Horizontal Tensile Strain at bottom of Cement treated base, which can cause fatigue failure of cement treated layer.

The flexible pavement has low flexural strength and hence layers reflect the deformation of the lower layers/sub-grade on to the surface layer after the withdrawal of wheel load. To control the deflections in the sub-grade so that no permanent deflections results the pavement thickness is so designed that the stresses on the subgrade soil are kept within its bearing power. Loading of bituminous pavement requires the stiffest layers to be placed at the surface with successive weaker layers down to subgrade. For the purpose of structural design, only the number of commercial vehicles of laden weight of 3 tonnes or more and their axle loading will be considered.



3.10.2 Fatigue Model

Due to repetition of loads, tensile strain develops cracks at the bottom of bituminous layers which is a problem for long term serviceability. The phenomenon is called fatigue of the bituminous layer and the number of load repetitions in terms of standard axles that causes fatigue denotes the life of the pavement. Two fatigue equations are considered, one in which the computed strains corresponds to 80% reliability level and the other corresponding to 90% reliability level.

The 80% reliability equation is used for the pavement where VG30 grade bitumen is used and 90% reliability equation is used for the pavement where VG40 grade bitumen is used. The two equations for the conventional bituminous mixes designed by Marshall method are given below.

$$N_f = 2.21 \times 10^{-4} \times (1/E_t)^{3.89} \times (1/M_R)^{0.854} \text{ ---------1 (80\% Reliability)}$$

$$N_f = 0.711 \times 10^{-4} \times (1/E_t)^{3.89} \times (1/M_R)^{0.854} \text{ --------2 (90\% Reliability)}$$

N_f = Fatigue life in number of standard axles

E_t = Maximum tensile strain at the bottom of Bituminous layer.

M_R = Resilient Modulus of the Bituminous layer

The ***equation 2*** is modified by considering 90% reliability with air voids around 3% and the volume of bitumen about 13%.

3.10.3 Rutting Model

Rutting is the permanent deformation in pavement usually occurring longitudinally along the wheel path. The rutting may partly be caused by deformation in the subgrade and other non-bituminous layers which would reflect to the overlying layers to take a deformed shape. The 80% reliability equation is used for the pavement where VG30 grade bitumen is used and 90% reliability equation is used for the pavement where VG40 grade bitumen is used. The rutting model considers the vertical strain in subgrade and the two equations are given below by considering 80% & 90% reliability.

$$N = 4.1656 \times 10^{-8} \times (1/E_v)^{4.5337} \text{ ------3 (80\% Reliability)}$$

$$N = 1.41 \times 10^{-8} \times (1/E_v)^{4.5337} \text{ ---------4 (90\% Reliability)}$$

N = Number of cumulative standard axles to produce 20 mm rutting.

E_v = Maximum Vertical subgrade strain (micro strain)

3.10.4 Pavement Layers

In accordance with IRC:37-2018 for the following base and sub-base options are available.

- Granular base and sub-base.
- Cementitious bases and sub-bases with a crack relief layer of aggregate inter-layer below bituminous surfacing.
- Cementitious bases and sub-bases with SAMI in between bituminous surfacing and the contentious base layer for retarding the reflection cracks into the bituminous layer.
- Cemented base and granular sub base with crack relief inter-layer of aggregate above Cemented base.
- Bituminous surfacing over treated RAP and cemented sub base.

Stage construction is not permitted when we are using cemented base and sub-bases according to the guidelines of the code as it may lead to cracking of the stabilized layer leading to failure of the pavement. Hence, the consultants adopting Granular Base & Granular Sub-base for main carriageway pavement with stage construction.

3.10.4.1 Sub-base layer:

The sub-base layer serves three functions like to protect the sub-grade from over stressing, to provide a platform for the construction traffic and to serve as drainage and filter layer. Material passing through 0.425 mm (425 micron), LL & PI shall not more than 25 and 6 %. Material shall have a minimum 10% fines when tested in compliance with BS:812. The wa-

ter absorption value (as per IS 2386) of the coarse aggregate shall be less than 2%, if not soundness test shall be carried out as per IS 383. 100% sample should pass through 75mm sieve and only 3-10% sample should pass through 0.075mm sieve for all the three grades. When coarse graded sub base is used as a drainage layer, Los Angeles abrasion value should be less than 40, so that there is no crushing during the rolling and the permeability is retained. The sub-base should be composed of two layers, the lower layer forms the separation/filter layer to prevent intrusion of subgrade soil into the pavement and upper layer forms the drainage layer to drain away any water that may enter through surface cracks.

Strength Parameter: Resilient Modulus (M_{Rgsb})

M_{Rgsb}= 0.2 X $h^{(0.45)}$ X $M_{R\ subgrade}$, where h is thickness of subbase layer in mm.

M_R value of subbase is dependent on M_R value of subgrade since weaker subgrade does not permit higher modulus of the upper layer because of deformation under loads.

$M_{R\ subgrade}$ = 10 X CBR if Subgrade CBR is <=5

$M_{R\ subgrade}$ = 17.6 X $(CBR)^{0.64}$ if Subgrade CBR is >5

3.10.4.2 Base layer:

Base layer consists of WMM, WBM, Crusher run macadam, reclaimed concrete etc. Relevant specifications of IRC/MORTH are to be adopted for the construction.

Strength Parameter: Resilient Modulus ($M_{R\ granular}$)

When both sub-base and base layers are made up of unbound granular layers, the composite resilient modulus of the granular subbase and base are as follows:

$M_{R\ granular}$= 0.2 X $h^{0.45}$ X $M_{R\ subgrade}$,

where h is combined thickness of subbase and base layers in mm.

3.10.4.3 Bituminous layers (Binder and Surface)

Binder layer consists of DBM and BM are to be adopted for construction. It acts like a load distribution and supporting layer.

Strength Parameter: Resilient Modulus ($M_{RBC/DBM}$)

The strength of bituminous mix based on extensive laboratory testing of Resilient Modulus Test. Based on the study data of India, IRC:37-2018 recommended resilient modulus for different mix types and temperatures are given below.

Table-3.5: Resilient Modulus of Bituminous Mixes, Mpa

Mix Type	Temperature °C				
	20	25	30	35	40
BC and DBM for VG10 bitumen	2300	2000	1450	1000	800
BC and DBM for VG30 bitumen	3500	3000	2500	2000	1250

Mix Type	Temperature °C				
	20	25	30	35	40
BC and DBM for VG40 bitumen	6000	5000	4000	3000	2000
BC with Modified bitumen (IRC:SP:13)	5700	3800	2400	1650	1300
BM with VG10 bitumen	-	-	-	500	-
BM with VG30 bitumen	-	-	-	700	-
RAP treated with 4% bitumen	-	-	-	800	-

3.10.5 Flexible pavement design

Design of flexible pavement is carried out in accordance with IRC:37-2018 for Granular base and sub-base. The standard designs given in plate-6, 14 and 22 of clause 12.1, 12.2 & 12.2 of IRC:37-2018 specify the minimum thickness and specifications of various component layers for different options for the given traffic in terms of cumulative standard axles and the 10% sub-grade CBR. Cumulative standard axles calculated for the 20 year design life for leg wise is given in the Table-3.6.

Table-3.6: Million standard axles for developmental traffic

Section	Cumulative MSA	Design MSA
Old NH_66	24	25

Anticipating heavy commercial traffic movement on the proposed highway due to the future developments flexible pavement is adopted for **25 MSA.** Along with the flexible pavement composition with conventional layers option, layer composition with alternate materials have been considered and given in the following tables:

Table-3.7: Conventional Pavement Composition (Option-1)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)				
				BC	DBM	WMM	GSB	Total
Old NH_66	10	25	VG-40	40	75	250	200	**565**

Table-3.8: Composition details Bituminous pavement with Cemented base and sub base with Crack Relief Interlayer of aggregate (Option-2)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)					
				BC	DBM	AIL	CTB	CTSB	Total
Old NH_66	10	25	VG-40	50	-	100	110	200	**460**

Table-3.9: Composition details Bituminous pavement with Cemented base and Granular Sub base with AIL (Option-3)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)					
				BC	DBM	AIL	CTB	GSB	Total
Old NH_66	10	25	VG-40	30	50	100	155	200	**535**

Table-3.10: Composition details Bituminous pavement with Cemented base and Cemented Sub base with SAMI Layer (Option-4)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)					
				BC	DBM	SAMI	CTB	CTSB	Total
Old NH_66	10	25	VG-40	30	50	SAMI	150	200	**430**

3.11 Recommended Pavement Option

Considering the use of the alternate materials in the composition of flexible pavement, due to the lack in the significant practical experience while adopting the mix design and performance after laying, flexible pavement option with the Granular sub base and Wet Mix Macadam is adopted for flexible pavement.

Recommended option: Flexible Pavement with Wet Mix Macadam (WMM) and Granular sub-base (GSB).

Table-3.11: Recommended Pavement Composition (BT, WMM & GSB)

Section	Eff. CBR (%)	MSA for 20 yrs design life	Bitumen Grade	Crust Composition (mm)				
				BC	DBM	WMM	GSB	Total
Old NH_66	10	25	VG-40	40	75	250	200	**565**

Table-3.12: Pavement Composition for Overlay

S.No	Pavement composition	Overlay (mm)
1	Bituminous Layer (BT)	40
2	Dense Bituminous Macadam (DBM)	60
Total (mm)		**105**

4. Proposals

4.1 General

The Government of India has envisaged to create a world-class infrastructure facility, to boost the economic development in the country and also to minimize the number of accidents/fatalities, for which Ministry of Road Transport and Highways (MoRTH) plays a key role. MoRTH has been entrusted to implement various developmental projects of National Highways in order to ensure safer and faster movement of the Vehicles. As part of this endeavor, MoRTH executes the works through the Public Works Department (PWD) in the state of Goa. Public Works Department (NH), Goa has taken up developement of road network in the state of Goa

Public Works Department (PWD) of Goa has appointed M/s Aarvee Engineering Consultants Ltd (Formerly M/s Aarvee Associates Architects Engineers & Consultants Pvt. Ltd., Hyderabad) to provide consultancy services for DPR for the infrastructure projects.

National Highway No. 66 connects Mumbai to Kanyakumari, traversing the coastal regions of Maharashtra, Goa, Karnataka, Kerala and Tamil Nadu. The entire corridor, passing through Navi Mumbai, Ratnagiri, Goa, Udupi, Mangalore, Kozhikode, Kochi, Thiruvananthapuram and Kanyakumari, has been sanctioned for development to 4-lane road configuration except for a small stretch of 8.71 Km in Goa.

In Goa, NH-66 starts from the Maharashtra/Goa border near Patradevi, passes through Mapusa, Panaji, Madgaon, Cuncolim, and ends at the Goa/Karnataka border near Polem, covering a total length of **124 km**. Out of this, **115.30 km has already been sanctioned**, remaining 8.71 Km is due for sanction.

NH-66 (erstwhile NH-17) passes through several urban centers along its alignment. In order to reduce congestion within cities and improve corridor capacity, bypasses have

been constructed / are being constructed and the highway sections are being developed to 4-lane configuration. Margao city is one such important urban center along NH-66.

The stretch from Km 548.000 to Km 555.300 passes through the urban limits of Margao city and functions as a major arterial corridor carrying mixed local, inter-city, and commercial traffic.

As part of the improvement of the road network and to decongest through traffic on NH-66, a 4-lane bypass on the western side of Margao city was proposed and has since been completed and commissioned. The bypass has facilitated diversion of through traffic; however, the existing urban stretch continues to carry significant local, commuter, and commercial traffic and therefore requires improvement in terms of capacity, safety, and serviceability.

The urban stretch of NH-66 from Km 548.000 to Km 555.300 passing through Margao city requires improvement in terms of pavement condition, drainage facilities, pedestrian infrastructure, and organized parking areas. The existing road section exhibits deficiencies in riding quality, drainage performance, pedestrian safety, and access control, which adversely affect traffic flow and safety. The proposed improvement is expected to yield the following outcomes:

- Reduction in travel time and improved traffic distribution within the city
- Enhancement of road safety by minimizing conflict points and improving access control
- Provision of pedestrian facilities to ensure safe movement of pedestrians
- Provision of continuous longitudinal drainage system
- Improvement of existing cross-drainage structures to ensure effective storm water disposal

- Facilitation of balanced urban and regional development in Margao and surrounding areas

Keeping in view of the above, following are the provisions considered in the estimate:

Sr. No	Stretch	Provisions
1.	Old NH-66 (From Km 548.000 to Km 555.300)	• Milling and Overlay on the existing road as below: a) Milling of 150mm and Overlay of 40mm BC and 60mm DBM for a length of 3.040 Km b) Milling and Overlay of 40mm BC for a length of 0.570 Km c) Overlay of 40mm BC for a length of 4.860 Km • Construction of Drain cum Footpath along with shot blasted paver blocks for a length of 3.61 km (including both sides) • Dismantling and construction of new drain along with cover slab of 0.9m width for a length of 3.4 km • Repair of drain and replacement of kerb and paver blocks for a length of 2.0 km (including both sides). • Provision of 0.3m saucer drain for a length of 5.98km(including both sides) • Provision of 0.6m saucer drain for a length of 2.50km(including both sides) • Improvement of Junctions • Beautification of Islands around Margao Municipal garden • Steel railing for footpath for a length of 2 Km. • Painting of Goan heritage style for Piers of ROB, Subways and walls within Margao city area.

		• Anti carbonation paint for existing ROB structure and protective coating for steel railing of ROB. • Dismantling of existing RCC structures including culverts, drain/footpath, compound walls etc. • Provision of Highway lighting along the stretch • Provision of 7 Nos of Bus shelters. • Provision of Bus Bay with cobble stone pavement at Hospocio Hospital at Km 549.150 • Pruning/Cleaning/removal of trees/vegetation/soil along existing road, drain and culverts. • Provision of Utility crossing duct at every 500m interval of size 600mm • Road furniture & Traffic calming measures including sign boards, RCC bollards, pavement markings, road studs(red/green), Table top crossings, Zebra Crossing, Solar Blinkers, Convex mirrors, Reflective Stickers, flexible median markers and Crash barrier indicators. • Plantation in the median at divided carraigeway. • Providing of additional 5,000 Sq.m of 100mm shot blasted Paver blocks with 30mm Sand bed at available spaces for parking area. • Providing of additional 5,000 Sq.m of 60mm shot blasted Paver blocks with 30mm Sand bed at available spaces for pedestrian walking. • Shifting of Utilities

- Provision of Cross Drainage Structures(Culverts):

S.No	Existing culvert type	Nos	Proposed culvert type
1	Pipe Culvert	01	Retained and Rehabilitation
2	Slab/arch Culvert	09	Dismantling and reconstruction to Precast Box culvert
3		01	Retained and Rehabilitation
4	Box Culvert	01	Retained and Rehabilitation
5	Box Culvert	05	New Culverts
Total		**17**	

4.2 Typical Cross Sections

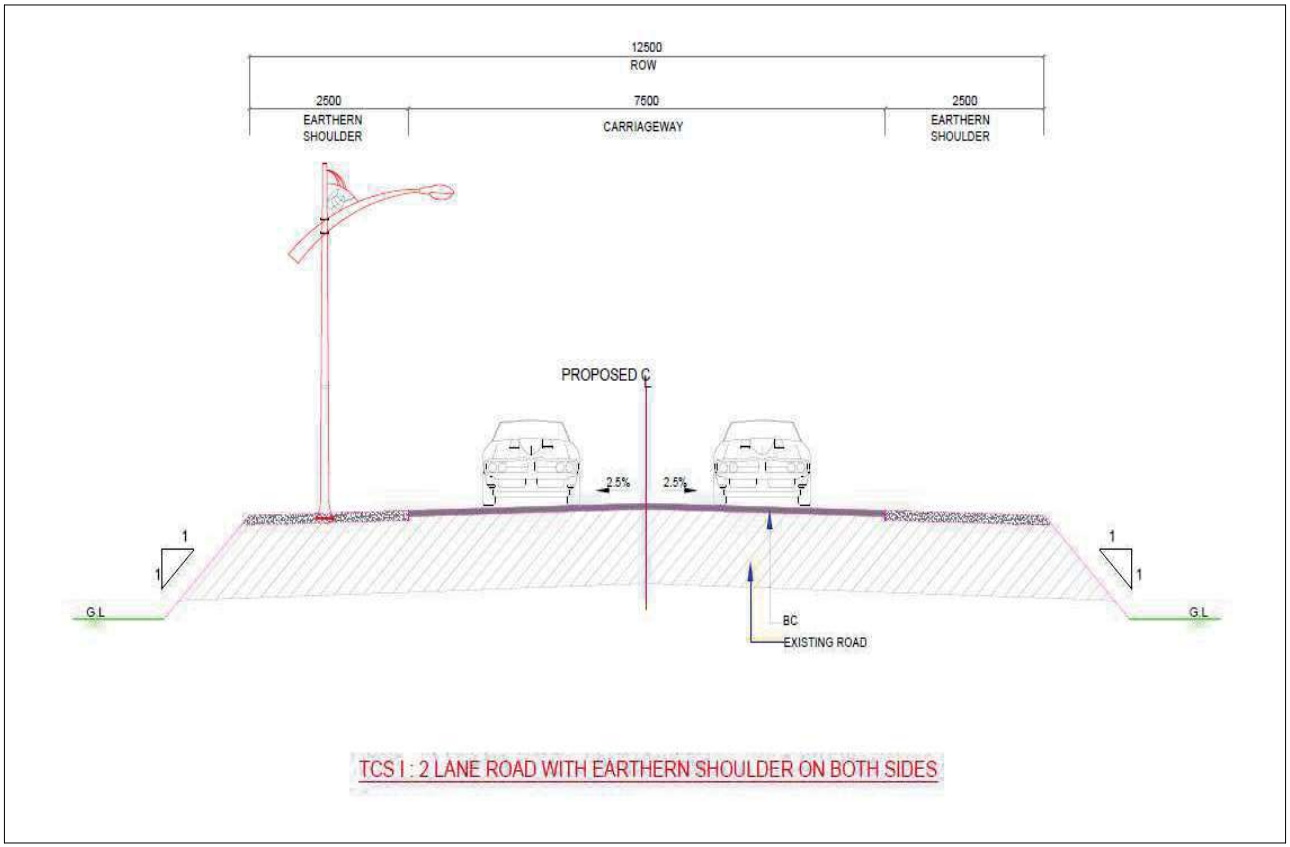
Following TCS schedule and drawings has been followed for the instant stretches:

Table 4.1: TCS Schedule

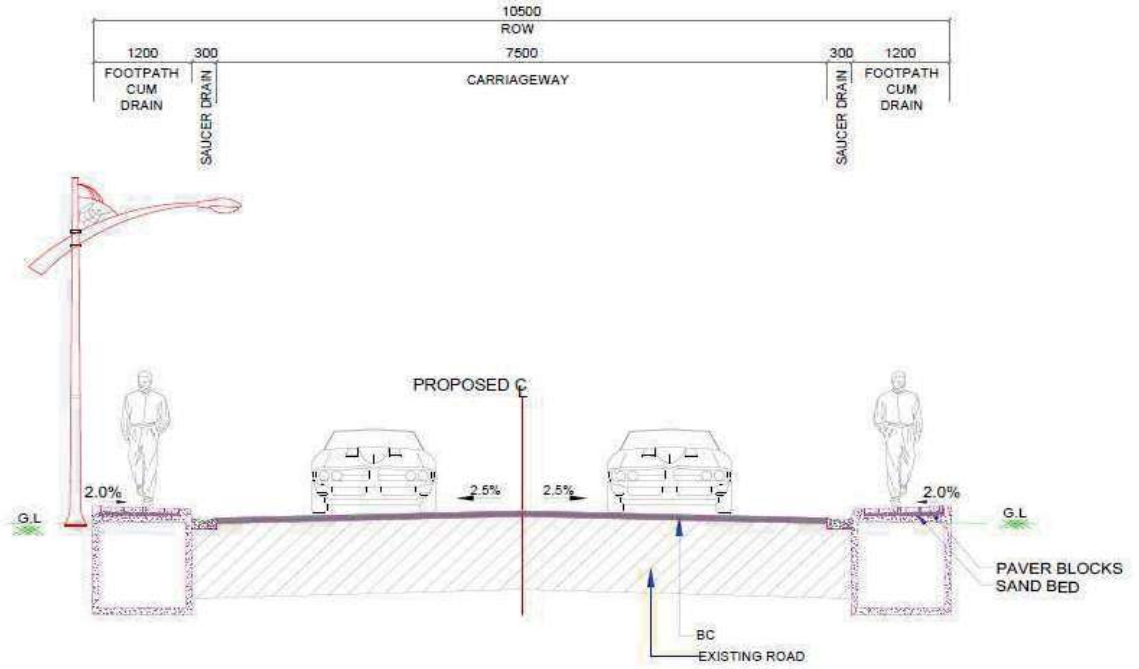
S.no	Chainage (Km)		Length (m)	TCS
	From	To		
1	548.000	548.665	665	I
2	548.665	549.535	870	II
3	549.535	550.560	1025	III
4	550.560	550.730	170	IV(A)
5	550.730	550.775	45	V
6	550.775	550.900	125	VI
7	550.900	551.030	130	VII
8	551.030	551.170	140	VIII
9	551.170	551.270	100	XVI
10	551.270	551.480	210	XVII
11	551.480	551.840	360	XVIII

S.no	Chainage (Km)		Length (m)	TCS
	From	To		
12	551.840	552.030	190	XIX
13	552.030	552.100	70	XX
14	552.100	552.430	330	XXI
15	552.430	553.000	570	IX
16	553.000	553.160	160	IV(B)
17	553.160	554.280	1120	X
18	554.280	554.550	270	XI
19	554.550	555.300	750	X
RHS Side				
20	550.630	551.500	870	XII
21	551.500	551.660	160	XIII
22	551.660	551.730	70	XIV
22	551.730	551.800	70	XV
Total			**8470**	

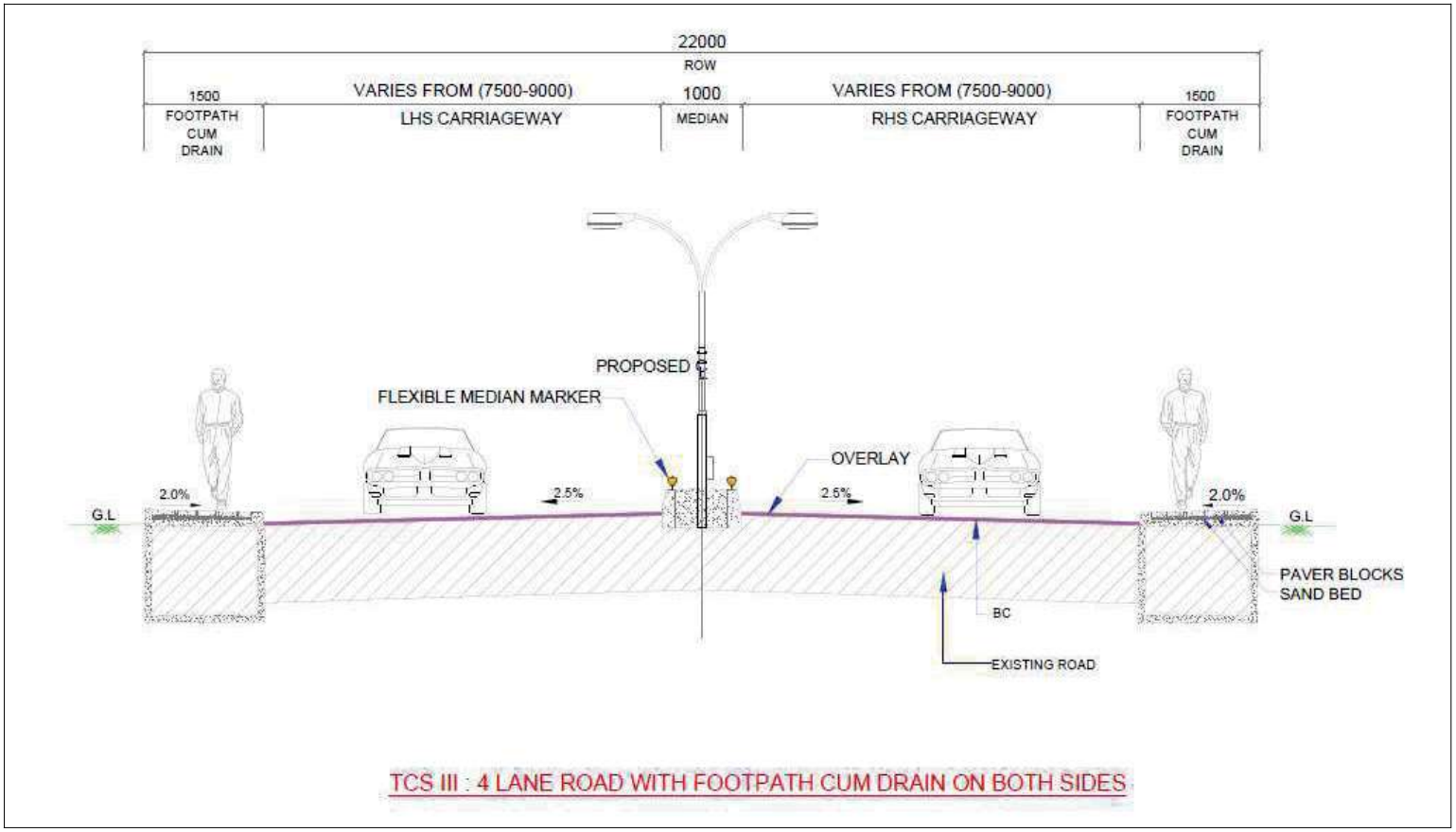
Typical Cross Sections



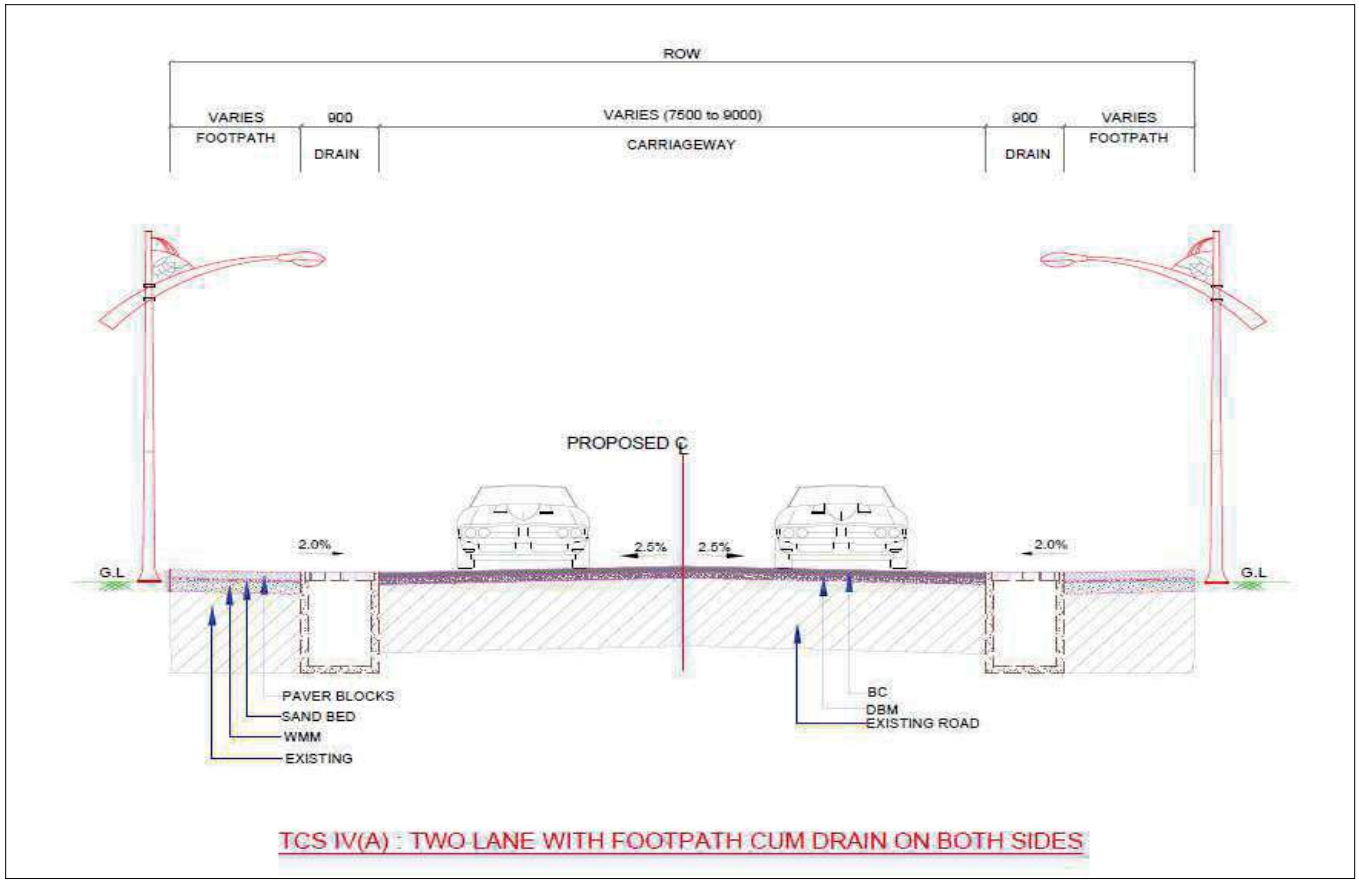
TCS I : 2 LANE ROAD WITH EARTHERN SHOULDER ON BOTH SIDES



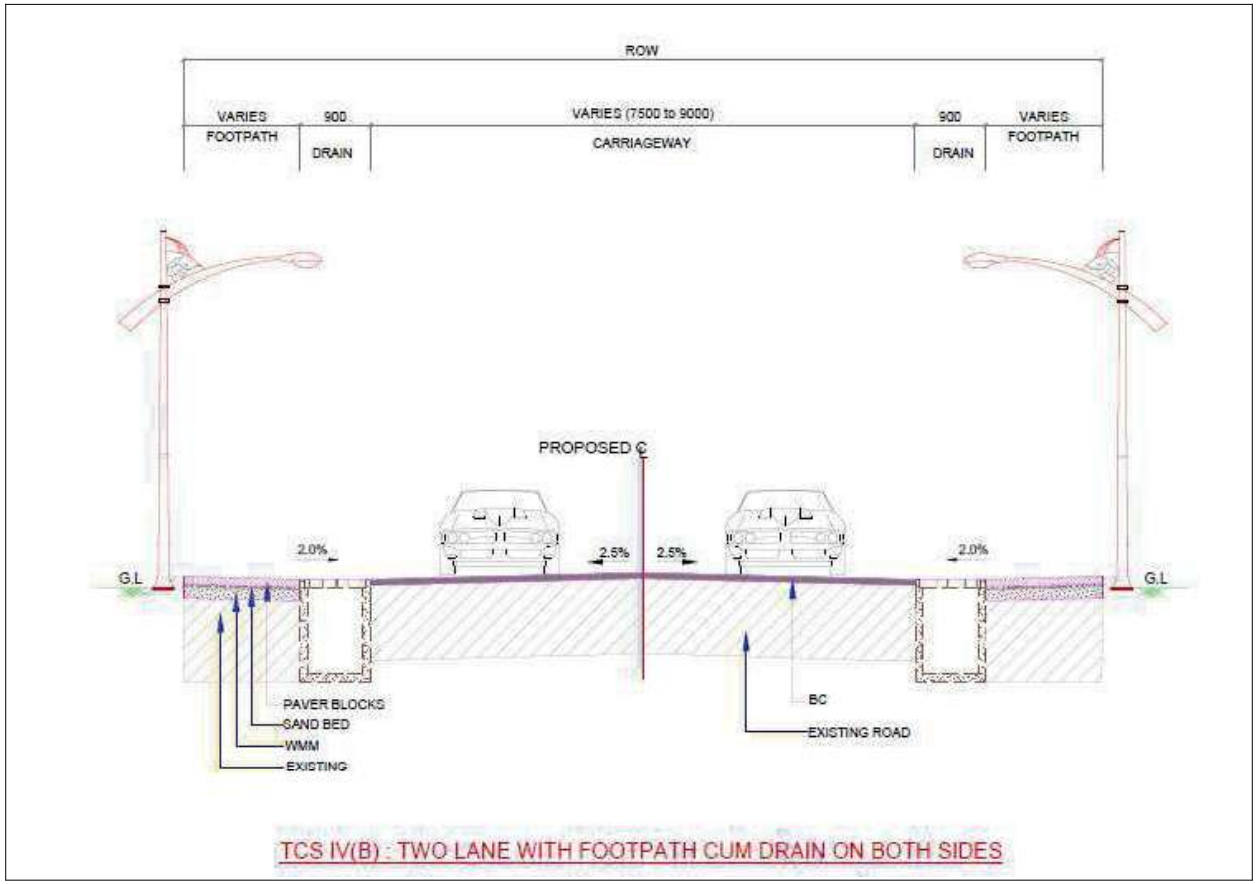
TCS II : 2 LANE ROAD WITH FOOTPATH CUM DRAIN ON BOTH SIDES



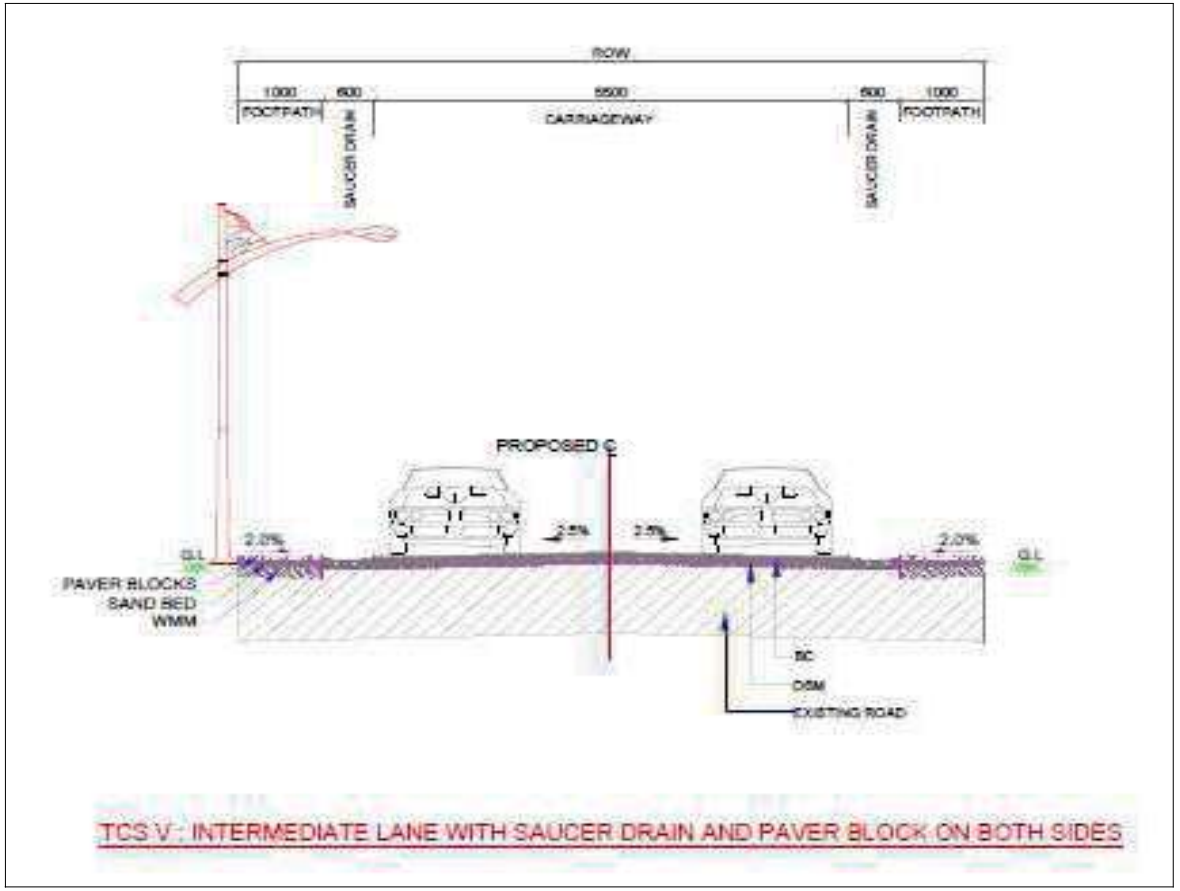
TCS III : 4 LANE ROAD WITH FOOTPATH CUM DRAIN ON BOTH SIDES



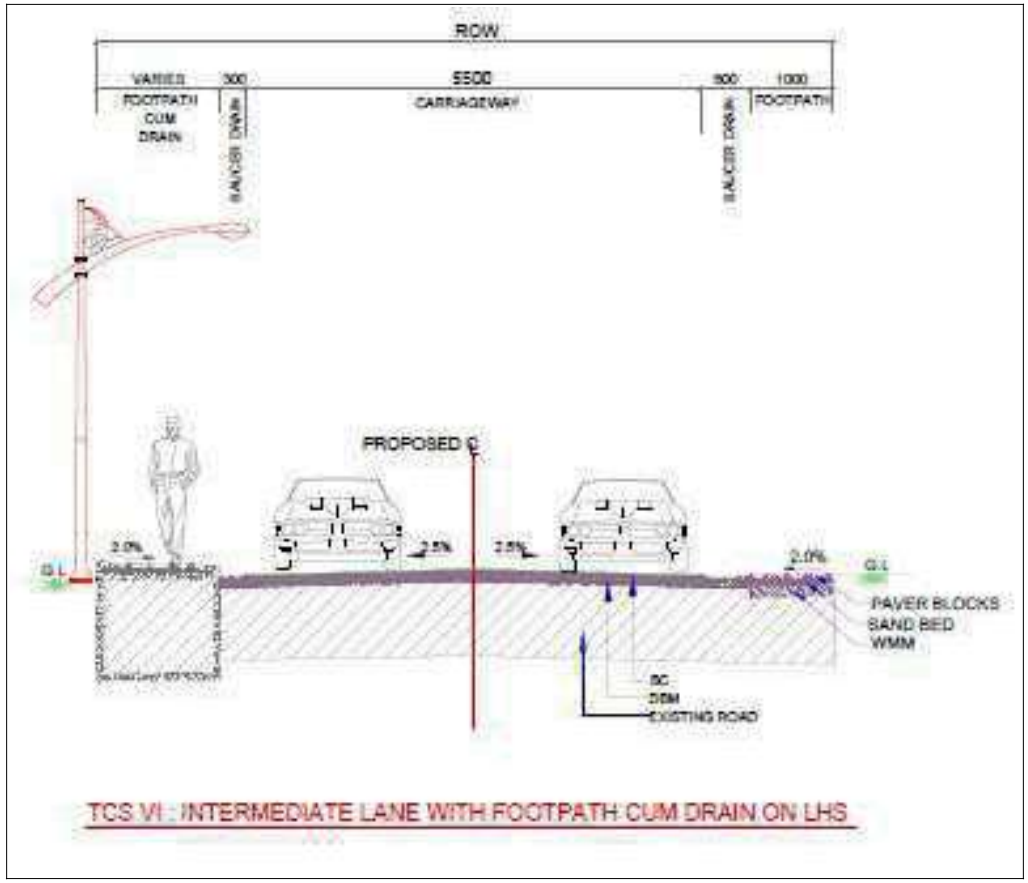
TCS IV(A) : TWO LANE WITH FOOTPATH CUM DRAIN ON BOTH SIDES



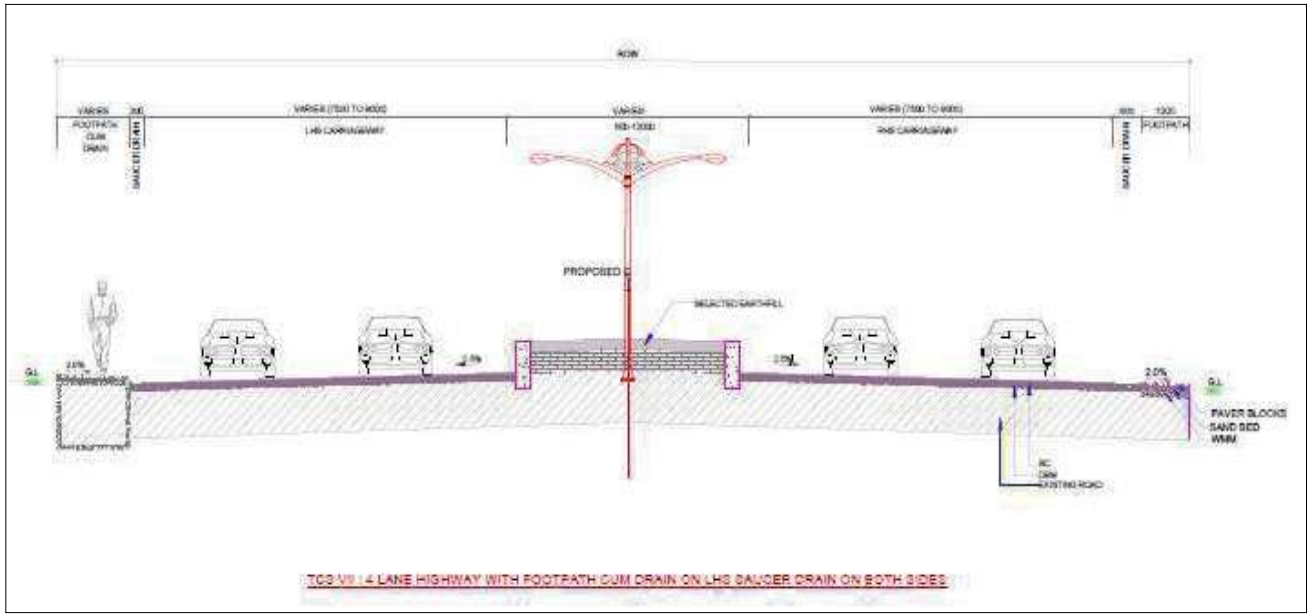
TCS IV(B) : TWO LANE WITH FOOTPATH CUM DRAIN ON BOTH SIDES

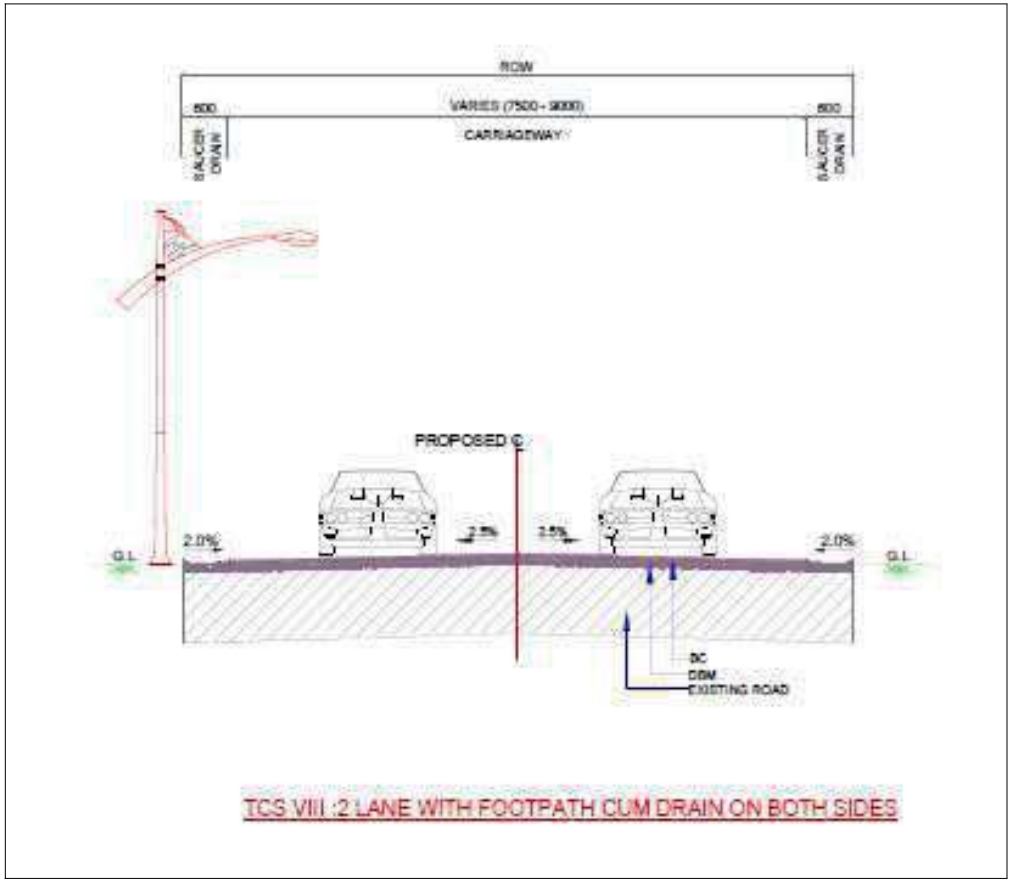


TCS V : INTERMEDIATE LANE WITH SAUCER DRAIN AND PAVER BLOCK ON BOTH SIDES

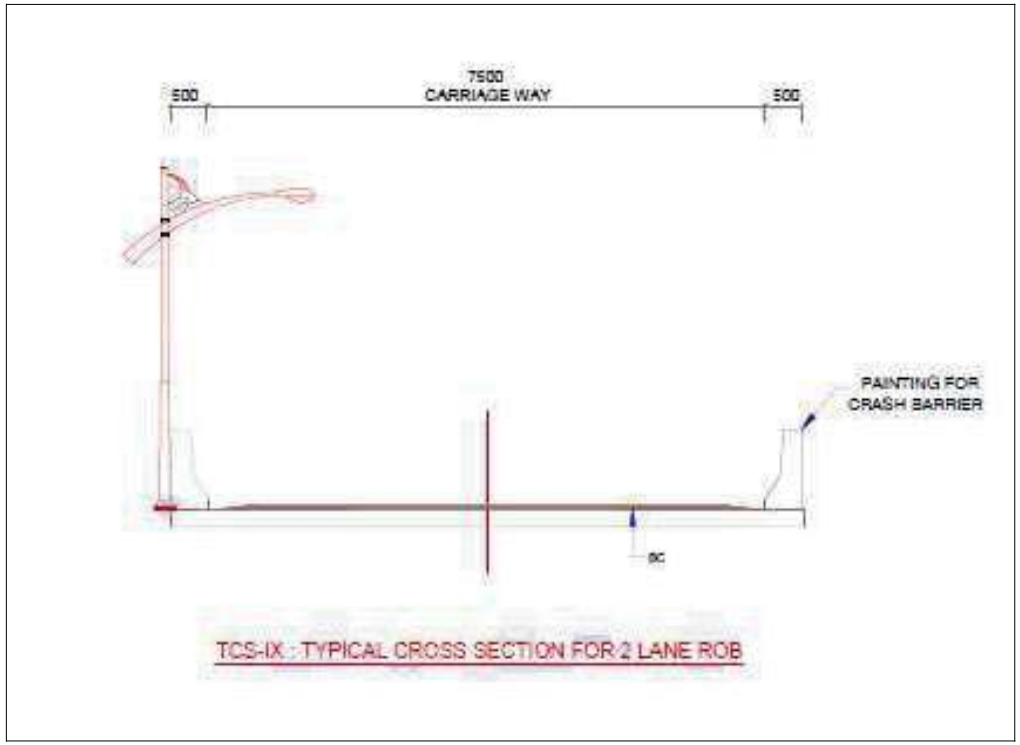


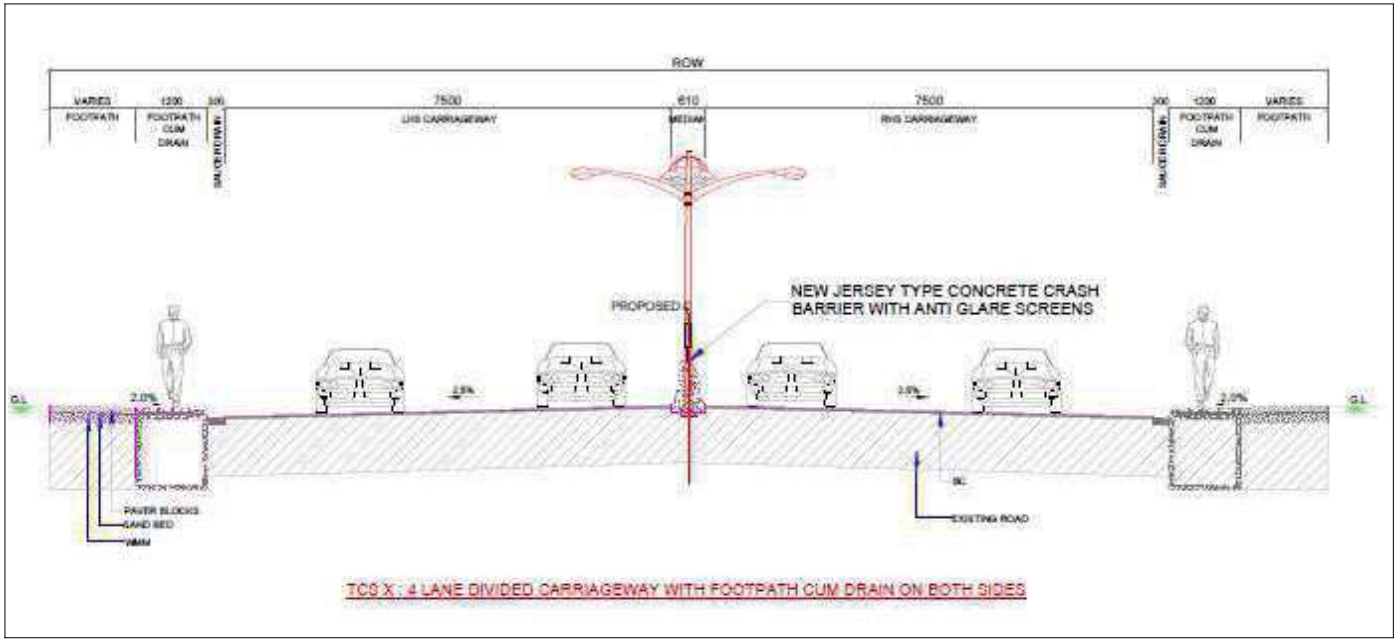
TCS VI : INTERMEDIATE LANE WITH FOOTPATH CUM DRAIN ON LHS


PROPOSED
PAVER BLOCKS
SAND BED
WMM
TC3 VII / 4 LANE HIGHWAY WITH FOOTPATH CUM DRAIN ON LHS SAUCER DRAIN ON BOTH SIDES

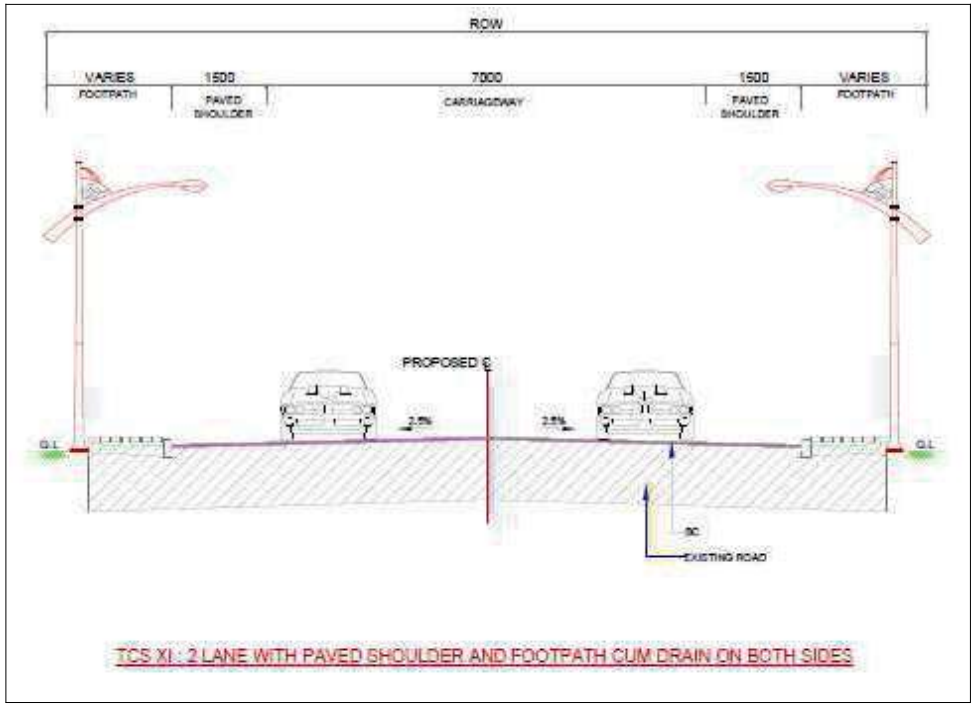


TCS VIII :2 LANE WITH FOOTPATH CUM DRAIN ON BOTH SIDES

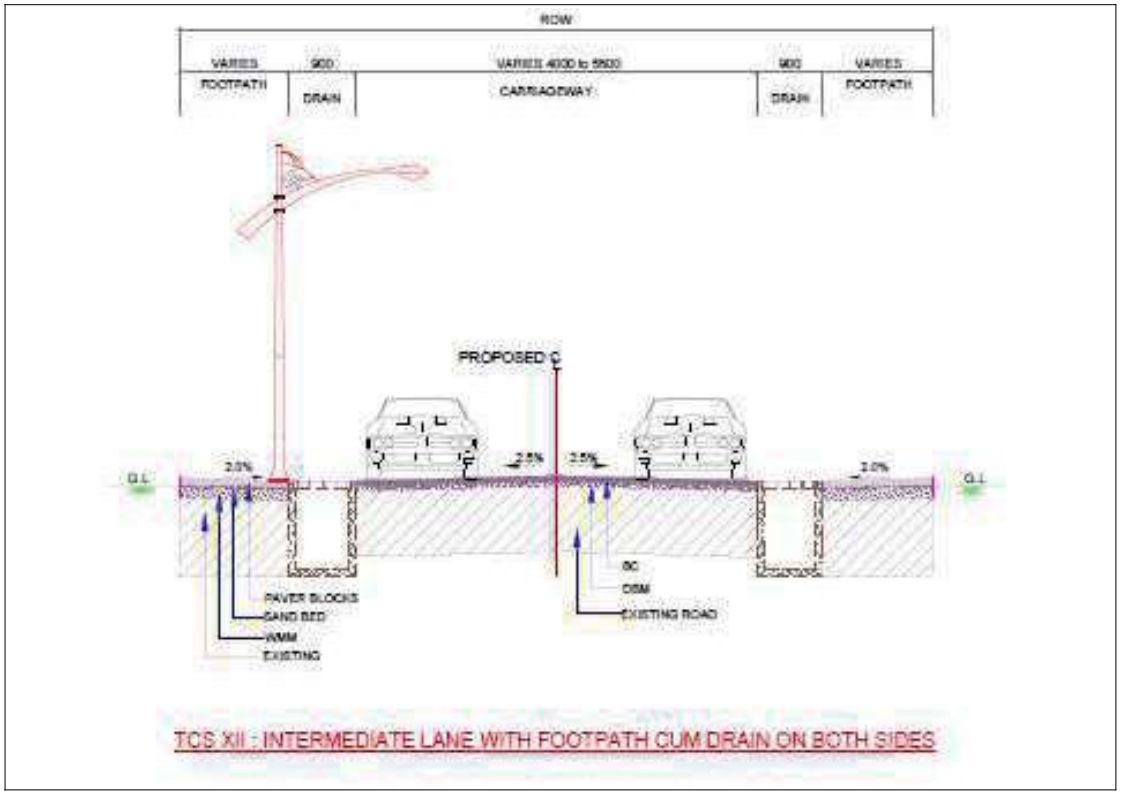

7500
CARRIAGE WAY
500
500
PAINTING FOR
CRASH BARRIER
TCS-IX : TYPICAL CROSS SECTION FOR 2 LANE ROB



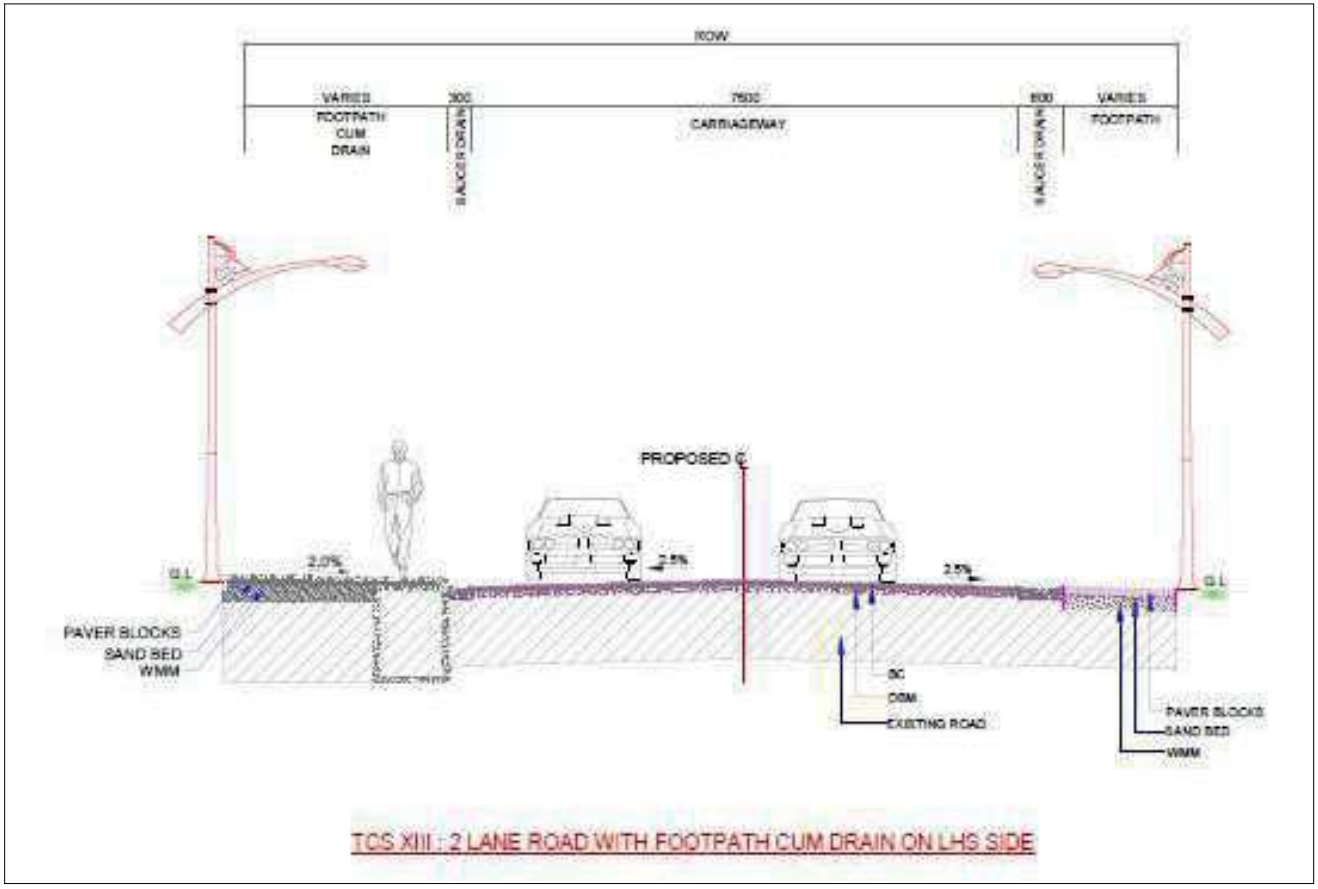
TCS X : 4 LANE DIVIDED CARRIAGEWAY WITH FOOTPATH CUM DRAIN ON BOTH SIDES



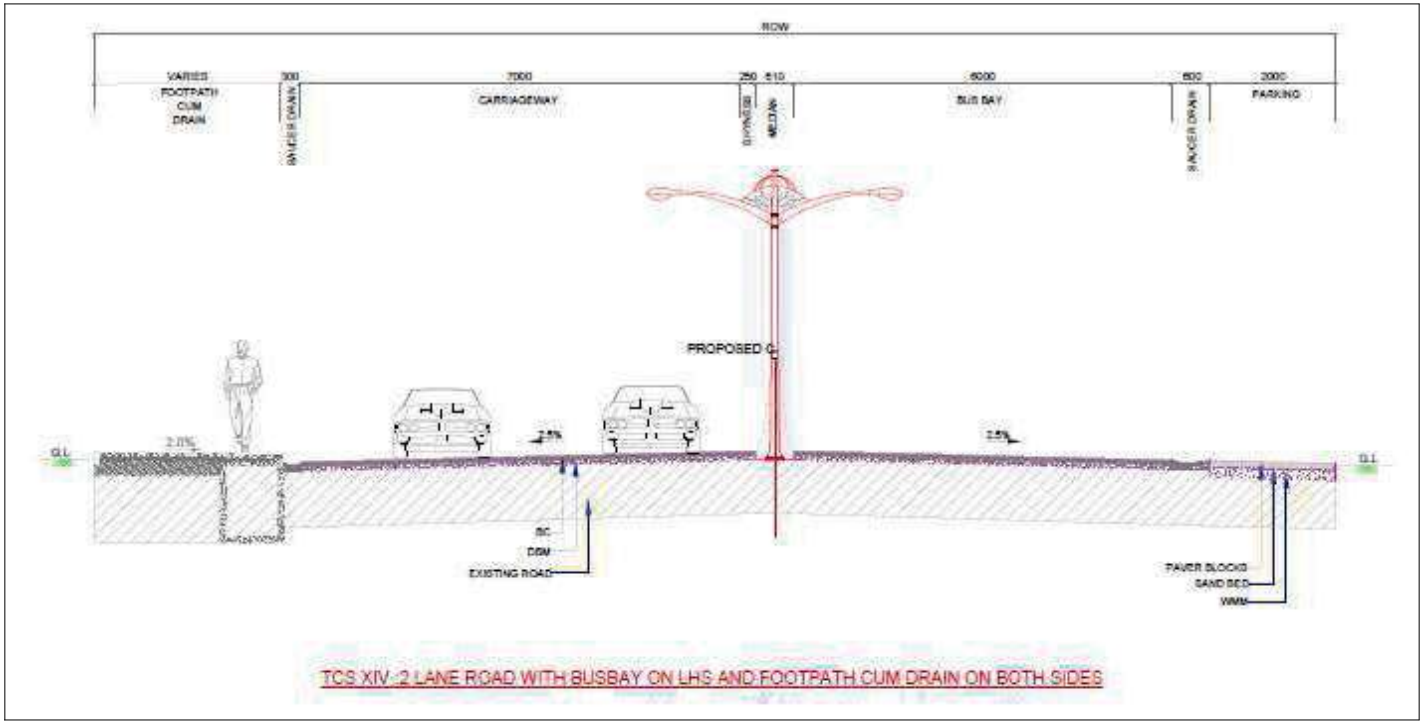
TCS XI : 2 LANE WITH PAVED SHOULDER AND FOOTPATH CUM DRAIN ON BOTH SIDES



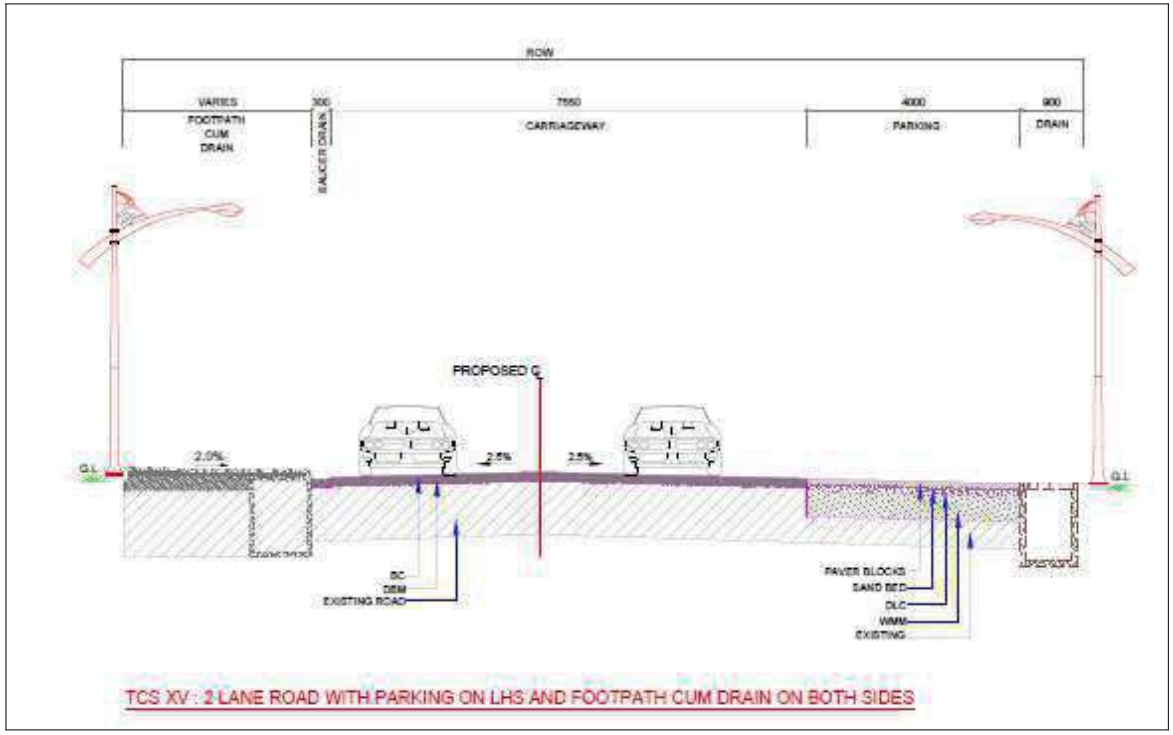
TCS XII : INTERMEDIATE LANE WITH FOOTPATH CUM DRAIN ON BOTH SIDES



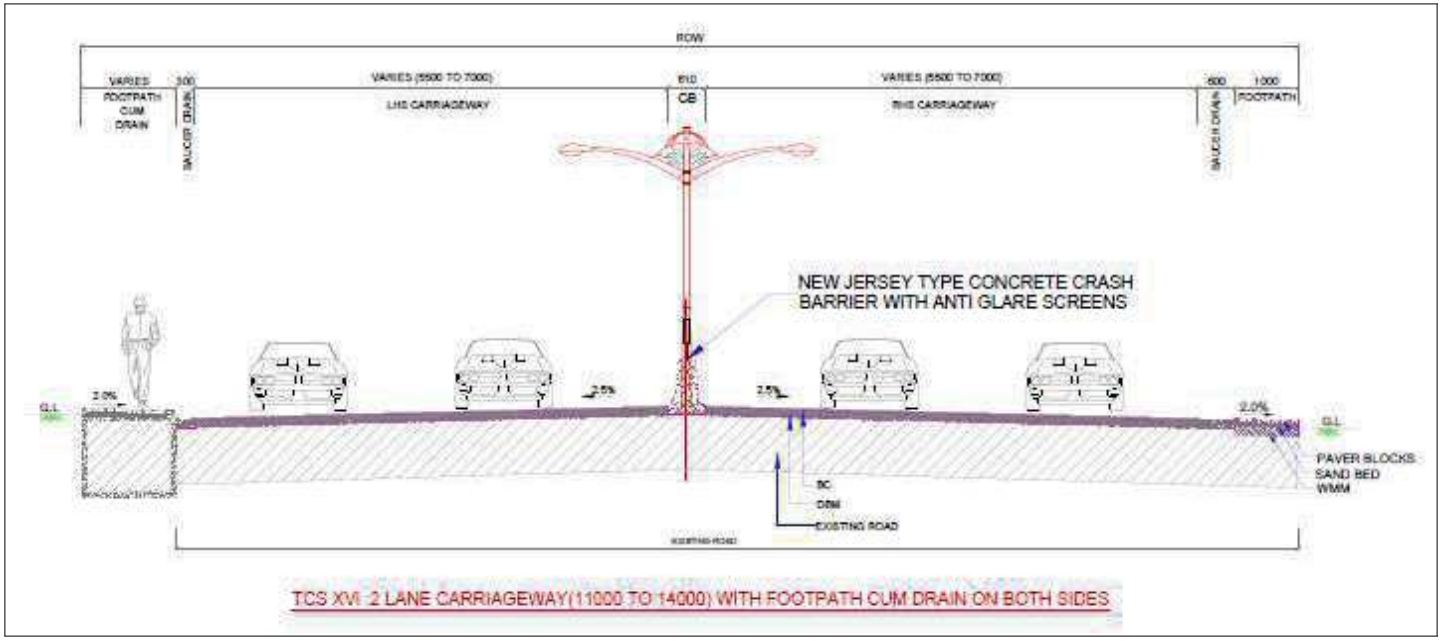
TCS XIII : 2 LANE ROAD WITH FOOTPATH CUM DRAIN ON LHS SIDE



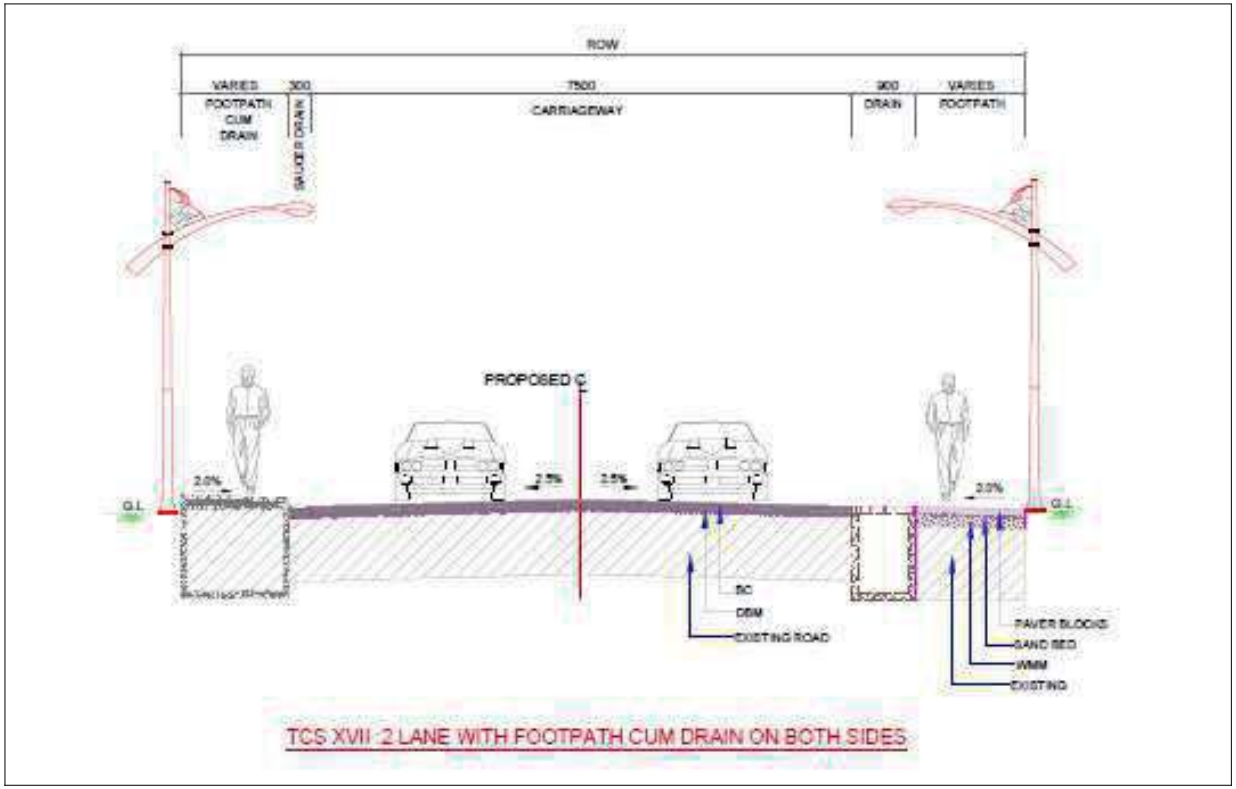
TCS XIV -2 LANE ROAD WITH BUSBAY ON LHS AND FOOTPATH CUM DRAIN ON BOTH SIDES



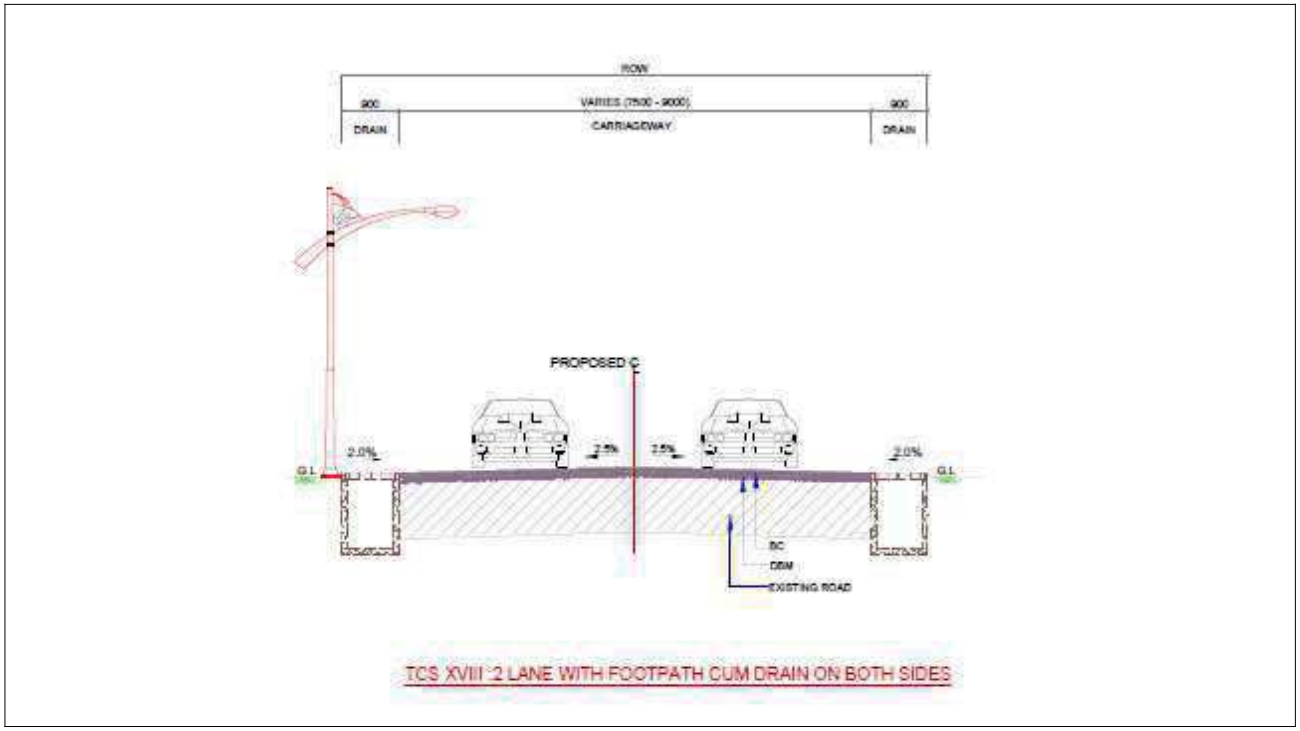
TCS XV : 2 LANE ROAD WITH PARKING ON LHS AND FOOTPATH CUM DRAIN ON BOTH SIDES



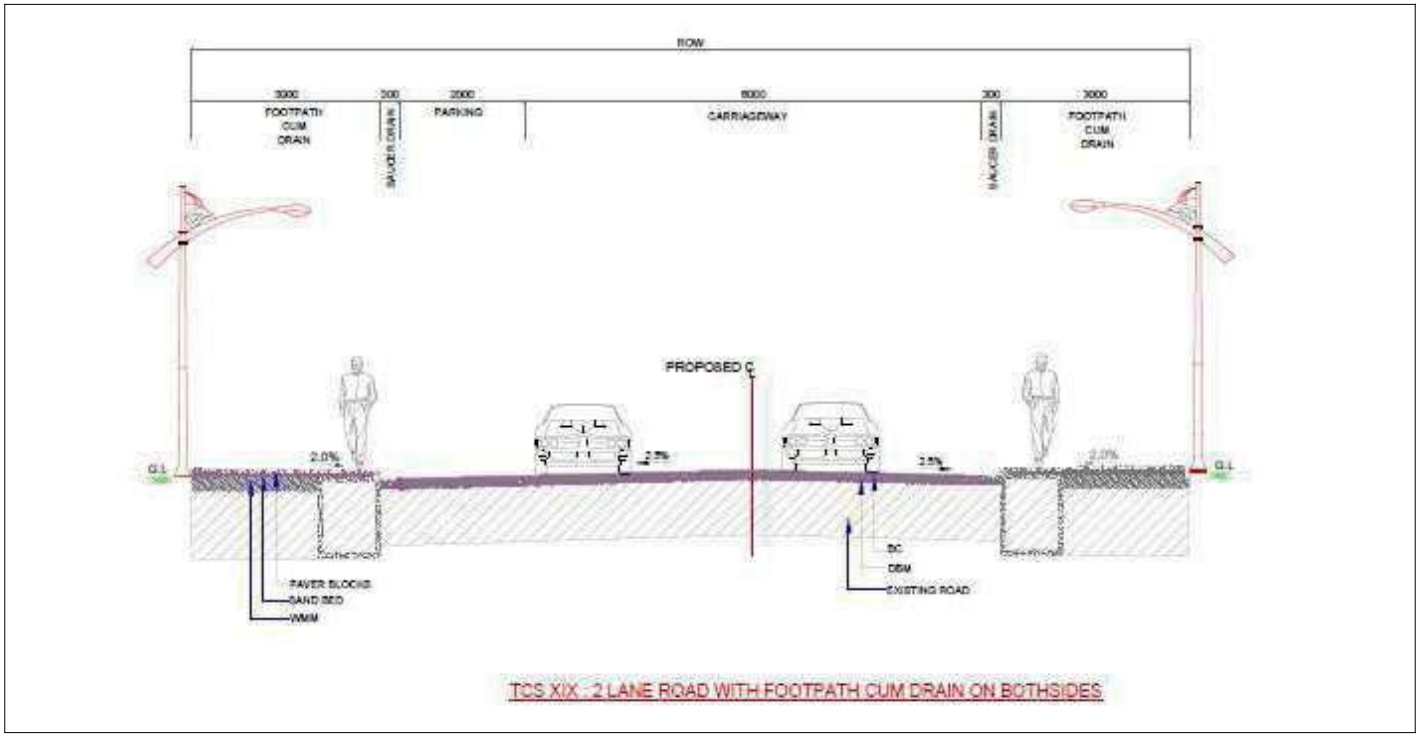
TCS XVI -2 LANE CARRIAGEWAY(11000 TO 14000) WITH FOOTPATH CUM DRAIN ON BOTH SIDES



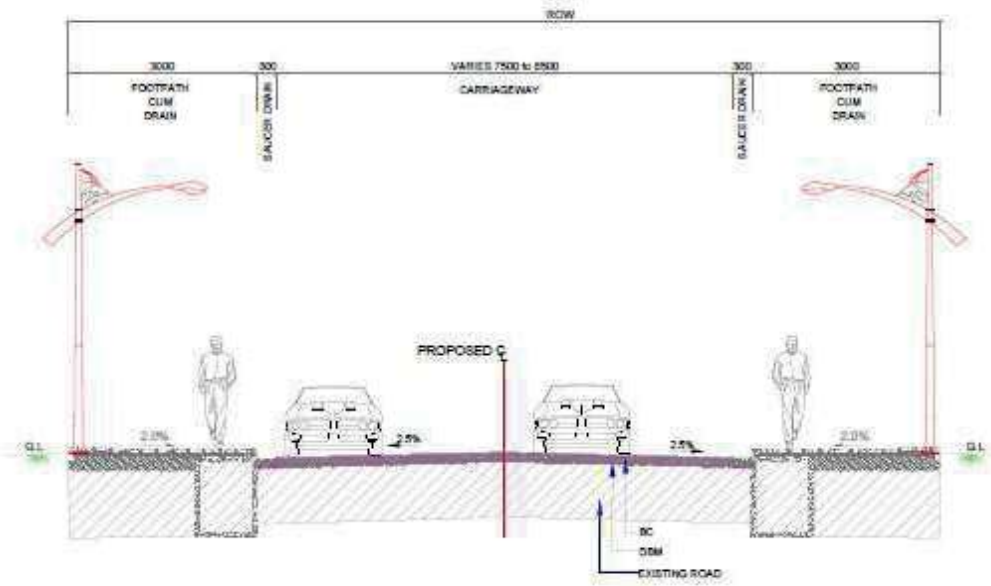
TCS XVII 2 LANE WITH FOOTPATH CUM DRAIN ON BOTH SIDES



TCS XVIII :2 LANE WITH FOOTPATH CUM DRAIN ON BOTH SIDES



TCS XIX : 2 LANE ROAD WITH FOOTPATH CUM DRAIN ON BOTHSIDES



TCS XX : 2 LANE ROAD WITH FOOTPATH CUM DRAIN ON BOTHSIDES