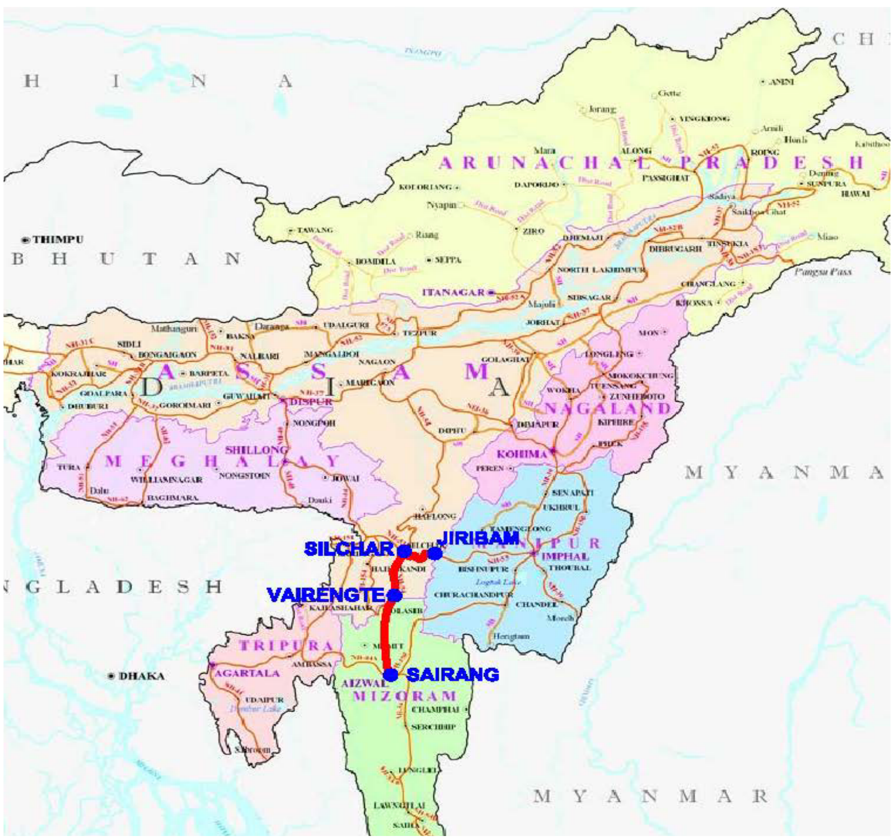
Ministry of Road Transport and Highways
(GOVERNMENT OF INDIA)

NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.

Head Office: 3rd floor, PTI building, 4- Parliament street, New Delhi-110001

Project office: Building of State Institute of Rural Development & Panchayati Raj Durlang Leitans, Mizoram Aizawl-796025

Consultancy Services for preparation of DPR for development of Economic Corridors, Inter Corridors and Feeder Routes to improve the efficiency of freight movement in India under Bharatmala Pariyojna (Lot-1) (Package-III) (Silchar-Vairengte (49.9 km), Vairengte-Sairang (111 km), Silchar-Jiribam (55 km)).



Draft Detailed Project Report-R1 (Silchar-Vairengte)

Package-1 (From Km 0+000 to Km 21+000)

Volume-II (DESIGN REPORT)

June 2022

Transsys Consulting Pvt. Ltd.

Head Office : 12th Floor, JMD Regent square, M.G. Roaad, Gurugram-122002, Haryana,
Email ID: sanjeev@transysconsulting.co.in
Regional office: 01-04, Ground Floor, Raheja Chambers, #12, Museum Road, Bangalore-560001
Phone +080-41461995/41261995 Email: transys_blr@transysconsulting.co.in

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DRAFT DETAILED PROJECT REPORT-R1

Section: Silchar to Vairengte (Package-1, Km 0+000 to Km 21+000)

VOLUME : I	MAIN REPORT	
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VOLUME : II	**DESIGN REPORT**	√
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Design Report (Highway)

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1.1 Introduction

Bharatmala Pariyojana is a mega plan of the government and the second-largest highways project after the NHDP. Many defined highway stretches totaling about 50,000 km are proposed to be developed as "**Economic Corridors, Inter Corridors & Feeder Routes" under "Bharatmala Pariyojna".**

Economic corridors are integrated networks of infrastructure within a geographical area designed to stimulate economic development. These corridors are generally developed to link cities or countries, manufacturing hubs, areas with high supply and demand, and manufacturers of value-added goods, whereas 44nos of corridors are identified. Inter Corridors & Inter-connection between different economic corridors, development of first mile & last mile connectivity. Under 'Logistic Efficiency Enhancement Programme', these are proposed to be developed by taking an end-to-end corridor view, rather than stretch-by-stretch road construction view to ensure consistent infrastructure along the corridor.

As a first step towards this task, preparation of DPR for development of Economic Corridors, Inter Corridors and Feeder Routes to improve the efficiency of freight movement in India under Bharatmala Pariyojana is being undertaken by National Highways Authority of India (NHAI). Numbers of consultants have been appointed by National Highway Authority of India (NHAI), to prepare the Detailed Project Report for identified economic corridors, inter corridors & feeder routes under Bharatmala Pariyojana.

The National Highways & Infrastructure Development Corporation Limited **(NHIDCL)** has been constituted through an Act of Parliament for faster, economical and quality Road Construction work throughout India.

National Highways and Infrastructure Development Corporation is a fully owned company of the Ministry of Road Transport & Highways, Government of India. The company promotes surveys, establishes, designs, builds, operates, maintains and upgrades National Highways and Strategic Roads including interconnecting roads in parts of the country which share international boundaries with neighbouring countries. . This would lead to the formation of a more integrated and economically consolidated South and South East Asia. The company would also endeavour to undertake infrastructure projects including but not restricted to urban infrastructure and urban or city transport and to act as an agency for development of all types of Infrastructure. The company envisages working towards cross sharing of technical know-how and enhancing opportunities for business development with other nations and their agencies including the multilateral organizations and institutions.

M/s. Transys Consulting Pvt. Ltd. has been appointed as consultants by National Highway Infrastructure Development Corporation Limited (NHIDCL), to prepare the Detailed Project Report for development of Economic Corridors, Inter Corridors, and Feeder Routes to improve the efficiency of freight movement in India (Lot-1) **Package-III** under Bharatmala Pariyojana.

NHIDCL will be the employer and executing agency for the consultancy services and the standards of output required from the appointed consultants are of international level both in terms of quality and adherence to the agreed time schedule. The consultancy firm will solely be responsible for submission of quality work in stipulated period.

1.2 Objective of Document

This Design Report presents the work approach & methodology proposed to be adopted by the Consultants while preparing the designs and drawings for the project. The report primarily covers the design philosophy, various standards & codes of practices, various bridge furniture details, design methodology, design & drawing standards, road safety features etc. which will be followed for development of economic corridors in terms of 4-lane access controlled.

This document aims at standardizing the procedure of designs to be performed in order to achieve techno-economic feasibility, financial viability of the project aspects of value engineering, requirement of quality & safety, safety of operation and efficient maintenance of the facility, durability and conformance to standards, optimization and ease of construction. The aim is also to highlight the basic philosophy of design and the work approach to the Client and Authority engineer at the start of project so that any input from client / IE can be taken care at the early stage of the project for incorporation in designs.

1.3 The Project Highway

As per Contract Agreement (CA)

As per CA the Project stretch Silchar to Vairengte is the section of NH-306 (old NH-54) start at the junction of NH-37 (old NH-53) at km 266+700 and Km 0+000 of NH-306 (Capital point) in Assam State and ends at Km 49+900 of NH-306 near Phainuam Junction of NH 306A at Vairengte town in Mizoram State for approximate length of 49.9 Km.

After Reconnaissance survey and further discussion with NHIDCL:

After reconnaissance survey, it has been learnt that from Km 0+000 to Km 8+800, the project road traverses through heavily built-up with narrow ROW up to km 8+000 (Sonabarighat village). Since, said stretch couldn't warrant for 4-lane development in line with geometrics, land acquisition, environment & social perspective hence, the start point has been shifted to Clock Tower (Junction of NH-37 and NH-27) at existing km 263+350 of NH-37 and continued traversing along NH-37 up to km 257+000 via Rongpur, Arkatipur and Kashipur.
However, at the same time it has also been found that Silchar bypass (partly constructed 2-Lane, on hold) exist on RHS of project road and intersects at km 7+950 of NH-306 hence, DPR consultant has proposed to utilize partial section of Silchar bypass for the length of 7.5 Km from the junction of NH 37 at Km 257+000 and terminates at Km 7+950 of NH 306 near Sonabarighat continuing towards Vairengte up to Km 43+000 of NH-306 (old NH-54) at Lailapur /vairengte border. Hence, considering above existing scenarios, project road starts at km 263+350 of NH-37 with junction of NH-27 (Guwahati-Silchar Road).

Further, as we all know that there is dispute over border between Assam and Mizoram states. Govt. of Mizoram has put massive effort to resolve the long pending state border dispute with Union minister of home affairs (HMA) to intervene and review the state boundary based on Bengal Eastern Frontier Regulation 1873 and the inner line of the Lushai Hills Notification, 1993. The matter is still pending.

However, information obtained from different sources like Local bodies, applicable maps, and Border check-post administrative, 3 locations on existing NH-306 road have been identified viz. at existing Km 40+150, Km 42+250 and km 43+900 respectively. So, considering the existing circumstances and facts, we have fixed end chainage of "Silchar-Vairengte Section" at existing Km 43+000 of NH-306. The same may be revised once the matter resolved.

Hence, DPR consultant has considered the start point as existing Km 263+350 of NH-37 (Old NH-53) with Design Ch. 0+000 and end point at Km 43+000 with Design Ch. 46+000 at Lailapur-Vairengte state border leading towards Aizawl.

Therefore, the total existing length of chosen route (along portion of NH-37 + portion of Siclar bypass + NH-306) is 48.900 kms.

The latitude and longitude of the start and end point of the project road are as given in below table.

Table 1.1 Latitude and Longitude of both ends of Project Road.

Location	Latitude	Longitude	Altitude
Rongpur (NH-37)	24°50'1.50"	92°51'40.91"	23.00
Silchar-Vairengte Border	24°30'58.93"	92°46'39.72"	119.00

Hence, for an obvious reason please accord these existing chainages for reference purpose "as tentative chainage" only.

The key plan diagram of project road is showing below;

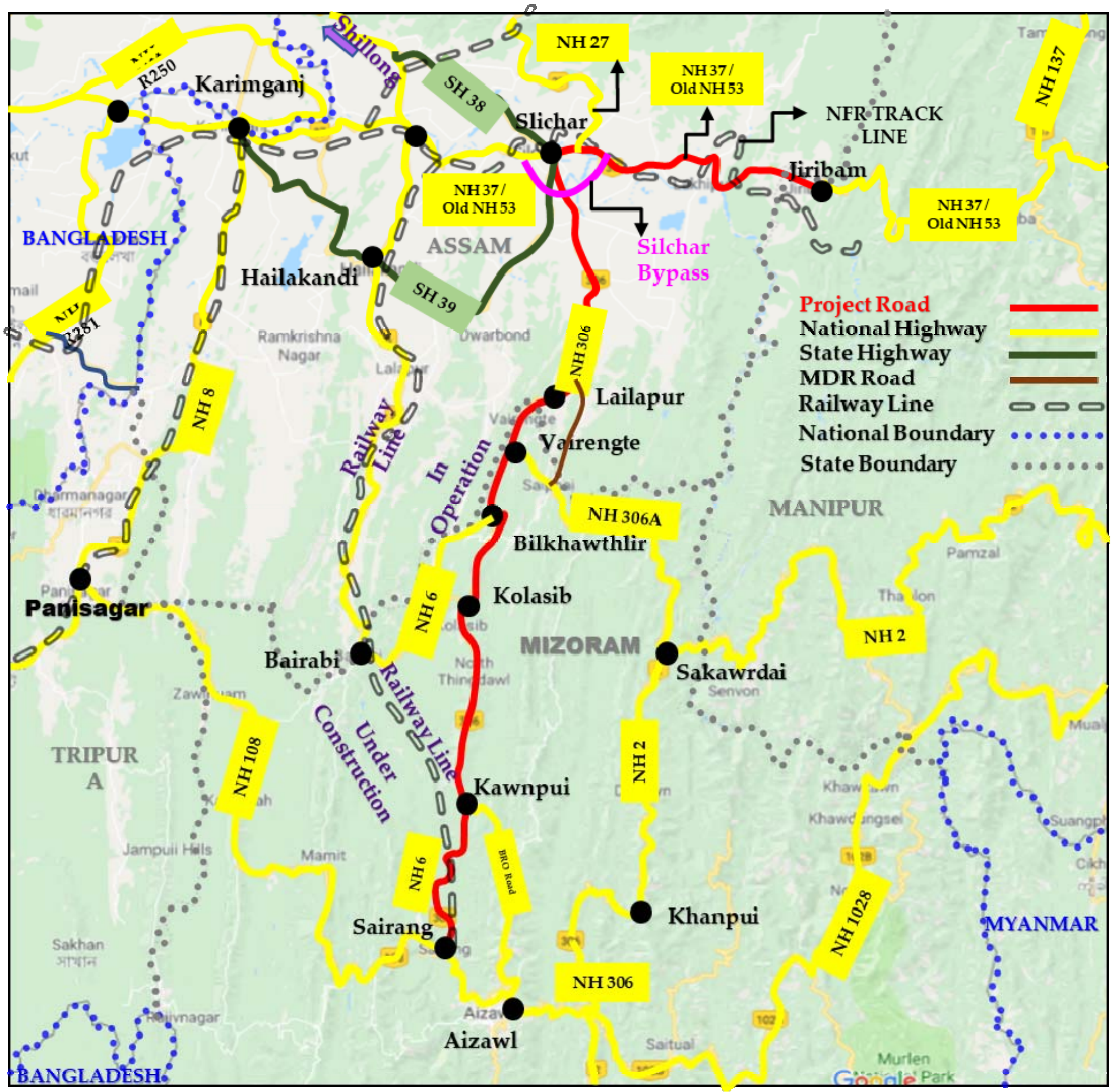


Fig 1.1 Key Plan of Project Road

In addition, this report mainly deals with Package-1 that starts at existing Km 263+350 of NH-37 (D. Chainage 0+000) and ends at Existing Km 13+200 of NH-306 (D. Chainage 21+000) however, for better comprehension DPR consultant has furnished the details from Sichar to Vairengte state border.

The key plan diagram of project road is showing below;

1.4 Project Site Appreciation

The project road from Silchar to Sairang is a part of Silchar-Aizawl corridor, which is considered as an important connecting road between Assam, Manipur, Meghalaya and Mizoram. The project road attracts the traffic from Shillong, Karimganj, Dawki, Manipur, Guwhathi, Silchar and other parts of Assam. The project road is the single source of trade for Mizoram and International trade like Mayanmar and Bangladesh. Hence the project road needs to be improved on priority under Bharatmala Pariyojana as an Economic corridor.

The project road from Silchar to Sairang is characterized by different level of traffic at individual sections falls within the State of Assam & Mizoram and taking into account of the traffic in terms of volume and character, it can be divided in five homogeneous section. Further addition to that in order to observe the traffic movement between Sairang and Aizwal, an additional homogeneous section from Sairang to Aizwal is also considered. The section details are indicated in below in table;

Table 1.2 Details of Homogenous road sections

Section	Homogenous Section	Chainage (Existing)		Length (Km)
		From (Km)	To (Km)	
Section – 1	**Silchar to Vairengte**	0+000	42+750	**42.75**

Note:

The stretch between Km 0+000 to Km 7+950 (at intersection point of Silchar bypass) is de-scoped from the project road as the proposed alignment follows partially constructed Silchar bypasss.

*The section between Sairang to Aizwal is not part of the project road. However, **since m**ajority of the traffic is originating/ destination from Aizwal and in order to observe the traffic movement between Sairang and Aizwal, this homogeneous section has been considered.

Further since, the project road from Silchar to Sairang lies in two different states ie. Assam and Mizoram, hence the Project Influence area (PIA) will be different for the Assam state and Mizoram state, hence the traffic analysis is represented for Silchar to Vairengte and Vairengte to Sairang separately.

The project road has 10.0m wide carriageway for 37.900 Km, 7.0 m carriageway for 3.5 Km, and 7.5 km is under construction flying along Silchar bypass.

- Throughout the project road, the type of pavement is of bituminous type consist of Bituminous Concrete (BC), Dense Bituminous Macadam (DBM) as binding course on base course of wet mix macadam (WMM)/ water bound macadam (WBM) and granular subbase as subbase course on varying type of sub grade all along the project road. Results of the test pit survey indicate appreciably varying thickness of pavement layers for the carriageway. Total thickness of the pavement is varying between 100 mm and 540 mm. The thickness of bituminous layer is varying between 80mm-120mm.

- The existing pavement surface condition varies from Poor to Fair for the project road length from Km 7+950 to Km 43+000 as per condition survey was conducted in the year 2018. However as per the latest site visit during February 2020, the road maintenance work was in progress by NH-PWD / NHIDCL department at some locations along the project road.

Table 1.3 Existing road configuration with Condition

Sl No	Existing Chainage		Length	Lane Configuration (as per site inventory)	Section	Remarks
	From	To				
1	263+350	257+000	6350	10m	Rongpur-Kashipur	Package-1 (263+350 to 13+200) (NH-37)
4	20+000	12+500	7500	-	Silchar Bypass	Package-1 (263+350 to 13+200) (Silchar Bypass)
5	7+950	12+100	4150	10.00 m	Uttar Krishnapur-Saidpur	Package-1 (263+350 to 13+200) (NH-306)
6	12+100	13+000	900	7.00 m	Saidpur-Sildubi Point	
7	13+000	13+200	200	10.00m	Sildubi point to Kabuganj	
8	13+200	22+000	8800	10.00m	Sildubi point to Kabuganj	Package-2 (13+200 to 43+000)

Sl No	Existing Chainage		Length	Lane Configuration (as per site inventory)	Section	Remarks
	From	To				
9	22+000	25+500	3500	10.00 m	Kabuganj to Jalenga	Package-2 (13+200 to 43+000)
10	25+500	40+400	14900	10.00 m	Jalenga to Lailapur	
11	40+400	43+000	2600	7.00 m	Lailapur-Vairengte	

- The project road passes through rolling and hilly terrain. The Existing Project road passes through hill cum thickly vegetated/forest **(Inner line reserve forest / Roadside reserve forest)** from Km 41+000 to Km 43+000 for an approximate 2.00 km. The land use along the project highway is 56.00% Built up Area, 12.00% Semi Built up Area, 29.00% Agricultural Land and 4.00% Hill cum Forest Area.

- The important habitations along the project road are Rongpur, Kashipur, Sonabharighat, Nutan Bazar, Kabuganj, Dolhai and Baga Bazar. The other important built-up areas are Saidpur Mukkam, Narsingpur, Katakal, Panibhora, Ramprasadpur, Saptagram, Islamabad and Lailapur. The Project road lies in Cachar district. Details of these built-up areas are given below:

Table 1.4 Land Use pattern and villages /Towns along Project Road

Sl. No.	Existing Chainage		Length (m)	Land Use	Side	Village Name	Remarks
	From	To					
1	263+350	259+500	3850	Built up	BHS	Rongpur	NH-37 Package-1 (263+350 to 13+200)
2	259+500	257+000	2500	Built up	BHS	Kashipur	
3	20+000	18+100	1900	Agricultural	BHS	Kashipur	Silchar Bypass Package-1 (263+350 to 13+200)
4	18+100	17+400	700	Built up	BHS	Badripar	
5	17+400	15+300	2100	Agricultural	BHS	Badripar	
6	15+300	14+500	800	Agricultural	BHS	Bagpur	
7	14+500	13+000	1500	Agricultural	BHS	Neairgram	
8	13+000	12+500	500	Built up	BHS	Sabashpur	
9	7+950	9+000	1050	Built up	BHS	Saidpur	NH-306 Package-1 (263+350 to 13+200)
10	9+000	10+700	1700	Built up	BHS	Sonabarighat	
11	10+700	11+500	800	Built up	BHS	Saidpur	
12	11+500	12+000	500	Built up	BHS	Dhanehari	
13	12+000	13+200	1200	Semi Built up	BHS	Dhanehari	

Sl. No.	Existing Chainage		Length (m)	Land Use	Side	Village Name	Remarks
	From	To					
14	13+200	14+000	800	Semi Built up	BHS	Dhanehari	NH-306 Package-2 (13+200 to 43+000)
15	14+000	16+300	2300	Agricultural	BHS	Kajidahar	
16	16+300	17+000	700	Built up	BHS	Nutan Bazar	
17	17+000	18+200	1200	Built up	BHS	Berabak	
18	18+200	19+700	1500	Semi Built up	BHS	Nagdirgram	
19	19+700	21+700	2000	Built up	BHS	Kabuganj	
20	21+700	24+000	2300	Agricultural	BHS	Narsingpur Pt I	
21	24+000	25+000	1000	Built up	BHS	Jalenga	
22	25+000	25+500	500	Agricultural	BHS	Jalenga	
23	25+500	26+000	500	Built up	BHS	Jalenga	
24	26+000	28+000	2000	Semi Built up	BHS	Jalenga	
25	28+000	29+000	1000	Built up	BHS	Ramprasadpur	
26	29+000	29+750	750	Built up	BHS	Ramprasadpur	
27	29+750	31+000	1250	Built up	BHS	Rajanikhal	
28	31+000	32+000	1000	Agricultural	BHS	Sadagram	
29	32+000	33+500	1500	Built up	BHS	Arjanpur	
30	33+500	34+500	1000	Built up	BHS	Saptagram	
31	34+500	35+000	500	Built up	BHS	Loknathpu	
32	35+000	36+000	1000	Built up	BHS	Islamabad	
33	36+000	36+500	500	Agricultural	BHS	Bhaga	
34	36+500	38+000	1500	Built up	BHS	Rajghat	
35	38+000	38+500	500	Built up	BHS	Rajghat	
36	38+500	39+500	1000	Agricultural	BHS	Howaitang	
37	39+500	41+000	1500	Built up	BHS	Joydhanpur	
38	41+000	43+000	2000	Hill cum Forest	BHS	Lailapur	

➢ As per the records available with PWD, NH division, the ROW in town/built-up areas varies from 9 to 15m and in rural areas, ROW vary from 20 to 25m along the entire stretch. The existing ROW along the stretch is given in following.

Table 1.5 Details of Proposed and Existing RoW

Sl. No.	Design Chainage (m)		Length (m)	Ex. ROW (m)	Proposed ROW (m)	Additional ROW (m)	Area of additional land to be acquired (Sqm)
	From	To					
1	0+000	0+850	850	30	55	25	21250
2	0+850	1+110	260	30	75	45	11700
3	1+110	1+160	50	30	65	35	1750
4	1+160	1+600	440	30	55	25	11000
5	1+600	1+700	100	30	45	15	1500
6	1+700	1+800	100	27.5	45	17.5	1750
7	1+800	2+000	200	26.5	45	18.5	3700
8	2+000	3+320	1320	20	45	25	33000
9	3+320	3+600	280	22	60	38	10640
10	3+600	3+800	200	20	60	40	8000
11	3+800	5+050	1250	Intersection			153127.4681
12	5+050	5+300	250	0	50	50	12500
13	5+300	5+600	300	19	50	31	9300
14	5+600	5+700	100	17	50	33	3300
15	5+700	5+800	100	19	50	31	3100
16	5+800	5+970	170	22	50	28	4760
17	5+970	6+070	100	22	60	38	3800
18	6+070	6+230	160	17	70	53	8480
19	6+230	6+330	100	20	60	40	4000
20	6+330	6+800	470	22	50	28	13160
21	6+800	6+980	180	0	60	60	10800
22	6+980	7+000	20	0	90	90	1800
23	7+000	7+050	50	22	90	68	3400
24	7+050	7+310	260	22	90	68	17680
25	7+310	7+530	220	50	80	30	6600
26	7+530	8+300	770	50	60	10	7700
27	8+300	8+700	400	50	65	15	6000
28	8+700	8+900	200	50	152	102	20400

Sl. No.	Design Chainage (m)		Length (m)	Ex. ROW (m)	Proposed ROW (m)	Additional ROW (m)	Area of additional land to be acquired (Sqm)
	From	To					
29	8+900	9+100	200	50	65	15	3000
30	9+100	12+340	3240	50	60	10	32400
31	12+340	12+590	250	50	80	30	7500
32	12+590	13+130	540	50	90	40	21600
33	13+130	13+290	160	50	80	30	4800
34	13+290	13+700	410	25	60	35	14350
35	13+700	14+390	690	50	60	10	6900
36	14+390	15+370	980	50	80	30	29400
37	15+370	15+700	330	50	90	40	13200
38	15+700	16+030	330	0	90	90	29700
39	16+030	16+410	380	0	80	80	30400
40	16+410	16+700	290	0	60	60	17400
41	16+700	16+900	200	0	65	65	13000
42	16+900	17+300	400	0	150	150	60000
43	17+300	18+800	1500	0	60	60	90000
44	18+800	19+400	600	0	80	80	48000
45	19+400	19+900	500	20	80	60	30000
46	19+900	20+010	110	20	50	30	3300
47	20+010	20+510	500	20	60	40	20000
48	20+510	21+000	490	20	50	30	14700
49	at Junction 820			0	3876.4823	3876.4823	3876.4823
50	at Junction 6580			0	845.4662	845.4662	845.4662
51	at Junction 12860			0	1927.6304	1927.6304	1927.6304
52	at Junction 19400			4285.3807	7479.1345	3193.7538	3193.7538
Total 893690.801 sqm							
220.836 Acres							
89.369 Ha							

- There are 54nos. of existing culverts, out of which 5nos are Slab on NH-306, 10nos are Box on NH-37 and 39 are Pipe culverts, out of which 15nos are on Silchar bypass and 24 nos. are on NH-306 along Silchar to Vairengte Section. However, as per Package-1 there are 01 nos of Slab culvert on NH-306, 10 nos. of Box on NH-37 and 16 nos. of pipe culvert, out of which 15 nos. are on Silchar bypass and 01 no is on NH-306.

- In Silchar to Vairengte Section, there is 1 no of existing major bridge over Barak River falling on Silchar Bypass, at km 13+830 (PWD km 13+000), which is constructed up to A1, P1 and P2 in 2-Lane standard, and abandoned and 09nos. of existing Minor bridges, out of which 01 no is on Silchar bypass at PWD Km 12+270 after crossing NH-306 near Saidpur, having a span arrangement of 3 x 10.5m having a deck width of 42.0m a total length of 63m and 08 nos are on NH-306 on Silchar to Vairengte Section. Out of 08 Nos. of Minor Bridges on NH-306, 5 Nos. are RCC Slab Type 2 No. is Box type, and 1 Nos. is Steel Truss type.

Table 1.6 Salient features of existing road

Sl. No.	Particulars	Existing Details Silchar to Vairengte to Sairang Section	Existing Details Package-1
1	**Start**	Km 23+350 on NH-37	Km 0+000 on NH-37
2	**End**	Km 43+000 on NH-306	Km 13+200 on NH-306
3	**Total Length**	48.900 Km	19.100 Km
4	**District**	1 No (Cachar)	1No (Cachar)
5	**Major Bridge**	01 nos (Constructed up to A1, P1 and P2 & Abandoned)	01 nos (Constructed up to A1, P1 and P2 & Abandoned)
6	**Minor Bridge**	09 Nos	04 Nos
7	**Culverts**	53 Nos	27 Nos = 16 no's HP, 01 no's Slab & 10 no's Box Culverts
8	**Level Crossing/ROB/ RUB**	Nil	Nil
9	**Major Junction**	08 Nos	03 Nos
10	**Minor Junction**	95 Nos	23 Nos
11	**Villages/Towns**	14 Nos	19 Nos
12	**Existing Pavement**	Flexible	Flexible
13	**Terrain**	Rolling & Hilly	Rolling
14	**Soil Type**	Silty and Clay	Silty and Clay
15	**ROW**	8 to 12m	8 to 12m

1.5 Highway Design Proposals

Design and Construction of project highway shall confirm to "The manual of specifications and standards for 4-laning of Highways through Public Private Partnership (IRC: SP: 84-2019).

As the project road is of 4-Lane configuration and accesses the existing alignment barring realignment stretches. The proposed scheme presents the 4-Lane in such a way that the project highway will be operated as a partially controlled access highway so as to improve the safety and operational efficiency of the highway. It passes through Rolling /Hilly terrain. The some portion of the road has Inner line-Forest land. Considering the physical constraints, it is considered desirable that the improvement proposals are conceived and developed under two sets of standards, namely:

- The desirable standards which could be adopted as a rule.
- The minimum standards, which could be accepted for difficult stretches where application of the desirable standards, would lead to additional land acquisition.

Accordingly design standards for geometric elements have been proposed under "desirable" and "minimum" categories. These proposed standards are consistent with and fall within the parameters recommended in the related standards of the Indian Roads Congress (IRC). The basic design philosophy is based on the consideration of providing suitable alignment, cross-sectional layout and geometrics to cater to the safe and uninterrupted movement of traffic.

1.5.1 Specifications and Standards

Design and construction of project highway shall conform to the “Manual of specifications & standards for Four laning of highways through public private partnership” (Second Revision) (IRC Publication No. IRC: SP: 84-2019) published by IRC. All circulars issued by NHAI/MoRTH amending/modifying specific clauses of IRC: SP: 84-2019 are applicable.

1.5.2 Design Speed

Design speed is the basic parameter, which determines geometric features of the road. As per table 2.1 of IRC: SP: 84-2019 and table 6.1 of IRC: SP: 48, for Mountainous /Steep terrain corresponding ruling and minimum speeds are 60 and 40 km/hr. respectively. In general, ruling design speed has been adopted for the various geometric design features of the road. Minimum design speed, however, be adopted in sections where, ROW is constraint and varying terrain conditions. Social and environmental impacts were also considered in the geometric design whereby where adverse impacts are present, exceptions to the standards were introduced.

The design speeds adopted at each section of the project highway are given below:

Table 1.7 Speed Zoning

From	To	Length (m)	Des Speed (Km/h)
0+000	4+040	4040	100
4+040	4+660	620	50
4+660	21+000	16340	100

Speed (Kmph) -->>	40	50	60	80	100
Length (m)	-	620	-	-	20380
% Length	-	2%	-	-	98%

1.5.3 Cross Sectional Elements

1.5.3.1 Cross-slopes

As per clause 2.8 of 4-lane manual IRC:SP:84-2019, the cross fall on straight sections of carriageway, paved shoulder, paved portion of median and Service Road shall be 2.5% for bituminous surface and 2.0% for cement concrete surface. The cross fall shall be unidirectional for either side carriageway sloping towards the shoulder in straight reaches and towards lower edge on horizontal curves. The camber on the existing road shall be modified to unidirectional cross fall.

Where the project road is passing through Rolling and Hilly terrain, coupled with continuous gradients and high intensity of rainfall calls for effective drainage of roads. Uncontrolled water is the primary cause of problems like erosion of valley side slopes, potholes, rutting, washed out shoulders, and even failure of complete sections of roadway structures. Hence the camber of road is proposed to be uni-directional, completely sloping towards hillside, so that water flows into longitudinal drains on hill side and then to culverts. However, on horizontal curves camber/ superelevation shall be provided as per the direction of curve.

The cross fall for earthen shoulder on straight portion shall be at least 0.5 steeper than the slope of the pavement and paved shoulder, subjected to a minimum of 3%. On super elevated sections, the earthen portion of the shoulder on the outer side of the curve would be provided with reverse cross fall of 0.5% so that the earth does not drain on the carriageway and the storm water drains out with minimum travel path.

Table 1.8 Cross fall

S.No	Description	Design Slope	Remarks
1	Paved Carriageway	2.5% / 2.0%	IRC:SP:84-2019
2	Service roads	2.5%	IRC:SP:84-2019
3	Earthen shoulder	Min. 3.0%	IRC:SP:84-2019

1.5.3.2 Width of carriageway, paved shoulder and earthen shoulder

The highway is proposed 4-Lane standard. The Consultants have studied various alternatives provided/proposed in similar projects, appropriate design standards satisfying the terrain and traffic scenario. Accordingly, the consultants are of the opinion that the minimum effective roadway width for the project road derived and recommended is as given below;

Table 1.9 Design Standards of Cross-sectional elements

Four-lane road (Built-up area)	
Paved Carriageway	2 x 7.0 m = 14.00m
Paved Shoulders	2 x 2.5m = 5.00m
Kerb shyness	4 x 0.50m = 2.00m
Median	1 x 2.50m = 2.50m
Separator	2 x 1.75 = 3.5m
Service Road	2 x 7.00 = 14.0m
Drain cum Footpath	2 x 1.50 = 3.0 m
Space for Service	2 x 2.00 = 4.0m
Total Roadway Width	48.00 m

Four-lane road (Rural area)		
Paved Carriageway		2 x 7.0 m = 14.0m
Shoulders	Paved	2 x 2.5m = 5.0m
	Unpaved	2 x 1.5m = 3.0m
Kerb shyness		2 x 0.50m = 1.00m
Median		4.00 m
Total Roadway Width		27.00 m

Table 1.10 Proposed Lane Configuration

Existing Chainage		Proposed Chainage			Lane Configuration
From	To	From	To	Length (km)	
263+350	13+200	0+000	21+000	21.000	4-Lane

1.5.4 Service Roads / Slip Roads

Service roads facility is provided at intersections to segregate the through traffic from diverted traffic and is provided as per manual. This facility will improve the free flow of project road traffic and provides partial access control. The details of service/Slip road provided along the project road are shown below. (According to proposed chainage).

Table 1.11 Location of Service / Slip Roads

LHS					RHS			
Sl No	Chainage (m)		Length (m)	Width (m)	Chainage (m)		Length (m)	Width (m)
	From	To			From	To		
1	0+225	3+800	3575	7.50	0+225	3+800	3575	7.50
2	5+260	7+530	2270	7.50	5+260	7+530	2270	7.50
3	12+340	13+290	950	7.50	12+340	13+290	950	7.50
4	14+400	16+410	2010	7.50	14+400	16+410	2010	7.50
5	18+800	21+000	2200	7.50	18+800	21+000	2200	7.50
Total Length=			**11005**				**11005**	

1.5.5 Typical Cross - Sections

In accordance with 4-lane and hill road manual, various cross-sectional elements discussed earlier and 10 types of typical cross sections have been proposed for the project road for various conditions expected to meet with during execution. These are shown in drawing **Volume-IX** of this report. Following table gives detailed description of each type of cross section.

The typical cross sections have been developed as per 4-lane manual. The different types of cross sections to be adopted for the project highway are specified also in schedule B and also below also for ready reference.

Table 1.12 List of Typical Cross Sections

Sl. No.	Type of Cross Section		Description	Length	Location/ Remarks
1	TCS-1	4 Lane with Paved Shoulder and RCC Drain on Both Side in Built-up Area along the Existing Road with 2.5 m Median	(2 x 7.00m) CW + (2x2.5m) PS+ + 2.5m Median (Include 2x0.5m Kerb shyness) + 2 x (1.5m) Footpath cum Drain	225	Built up
2	TCS-2	4 Lane Flyover Approaches with 7.5m wide Service Road and Paved Shoulder and RCC Drain on both side along Existing Road with 2.5 m Median	(2 x 7.00m) CW + (2x3.0m) PS+ + 2.5m Median (Include 2x0.5m Kerb shyness) +(2x0.55m) RCC CB + (2x1.5m) Footpath + (2x7.5m) SR+ (2x2.5m) PS + (2x1.5m) Footpath cum Drain	1135	Flyover Approaches
3	TCS-3	4 Lane with Paved Shoulder and 7.5m wide Service Road and RCC Drain on both side in Built-up Area along the Existing Road with 2.5m Median	(2 x 7.00m) CW + (2x2.5m) PS+ + 2.5m Median (Include 2x0.5m Kerb shyness) + (2x1.75m) Footpath with Railing + (2x7.5m) SR + (2x1.5m) Footpath cum Drain	2440	Built up
4	TCS-4	4 Lane with Paved Shoulder and Earthen Shoulder in Rural Area with 5.0m Median	(2 x 7.00m) CW + (2x2.5m) PS+ + 5m Median (Include 2x0.5m Kerb shyness) + (2x1.5m) ES	10230	Rural
5	TCS-5	4 Lane SVUP Approaches with 7.5m wide Service Road and RCC Drain on both side along Existing Road with 5.0 m Median	(2 x 7.00m) CW + (2x3.0m) PS+ + 5m Median (Include 2x0.5m Kerb shyness) +(2x0.55m) RCC CB + (2x1.5m) Footpath + (2x7.5m) SR+ (2x1.5) Footpath cum Drain	1170	Approaches of Flyover & SVUP
6	TCS-6	4 Lane with Paved Shoulder and Footpath with 7.5m wide Service Road and RCC Drain on both side in Built-up Area along the Existing Road with 5.0m Median	(2 x 7.00m) CW + (2x2.5m) PS+ + 5m Median (Include 2x0.5m Kerb shyness) + (2x1.75m) Footpath with Railing + (2x7.5m) SR + (2x1.5m) Footpath cum Drain	1710	Built up
7	TCS-7	4 Lane Grade Separated Approach with Toe wall (Flyover, VUP & SVPU)	(2 x 7.00m) CW + (2x2.5m) PS+ + 5m Median (Include 2x0.5m Kerb shyness) + (2x1.5m) ES	1970	Approach with Toe wall

Sl. No.	**Type of Cross Section**		**Description**	**Length**	**Location/ Remarks**
		with Both Service Road and Drain on inner side in Rural Area with 5.0m Median	+(2x1.5m) Footpath cum Drain + (2x7.5m) SR + (2x1.5m) ES		(Flyover, VUP & SVUP)
8	TCS-8	4 Lane Grade Separated Approach without Toe wall (Flyover, VUP & SVUP) with Both Service Road and Drain on inner side in Rural Area with 5.0m Median	(2 x 7.00m) CW + (2x2.5m) PS+ + 5m Median (Include 2x0.5m Kerb shyness) + (2x1.5m) ES +(2x1.5m) Footpath cum Drain + (2x7.5m) SR + (2x1.5m) ES	2580	Approach without Toe wall (Flyover, VUP & SVUP)
11	TCS-9	4-Lane- Buried Culvert (Pipe and Slab) at road level	(2 x 7.00m) CW + (2x2.5m) PS + 5m Median (Include 2x0.5m Kerb shyness) + (2x1.5m) ES		Buried Culvert
12	TCS-10	4-Lane Grade separated Structures & Box/Slab culvert at Deck Level	(2 x 10.50m) CW + (4x0.45m) RCC CB + Median + (4x0.1m)		GS/Box/Slab culvert
13	TCS-11	4-Lane Grade Separated Structure & Bridge at Deck Level without Footpath	(2 x 9.50m) CW + (4x0.45m) RCC CB + Median + (2x1.5m) ES + (4x0.1m)		GS/Bridge
13	TCS-12	4-Lane Separated Structure & Bridge at Deck Level with Footpath	(2 x 10.50m) CW + (4x0.45m) RCC CB + Median + (2x1.5m) Footpath + (2x0.4m) Double Beam Barrier + (4x0.1m)		GS/Bridge
14	TCS-13	6-Lane Separated Structure & Bridge at Deck Level with Footpath	(2 x 14m) CW + (4x0.45m) RCC CB + Median + (2x1.5m) Footpath + (2x0.4m) Double Beam Barrier + (4x0.1m)		GS/Bridge
Total Length				**21000**	

The above listed typical cross sections are depicted in TCS-1 and TCS-14 on subsequent pages.

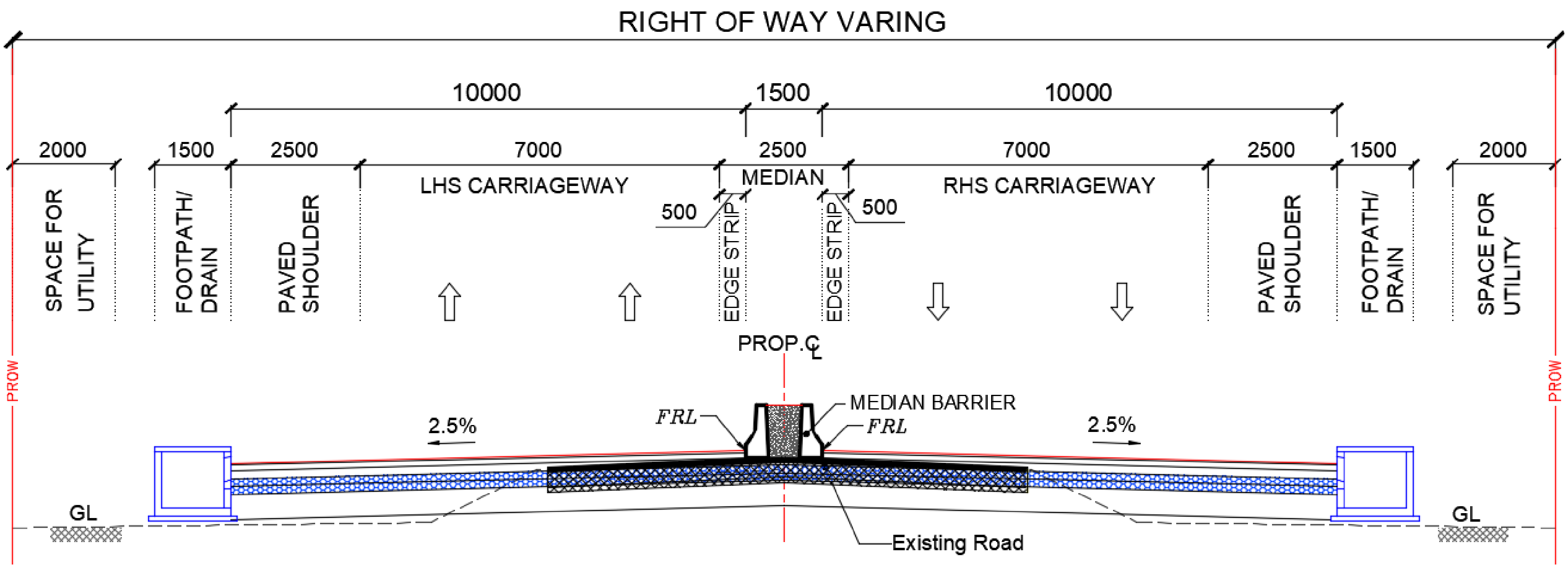


Fig 1.2 **4-lane** 4-Lane with Paved Shoulder and RCC Drain on Both Sides in Built-up Area along the Existing Road with 2.5 m Median (TCS-1)

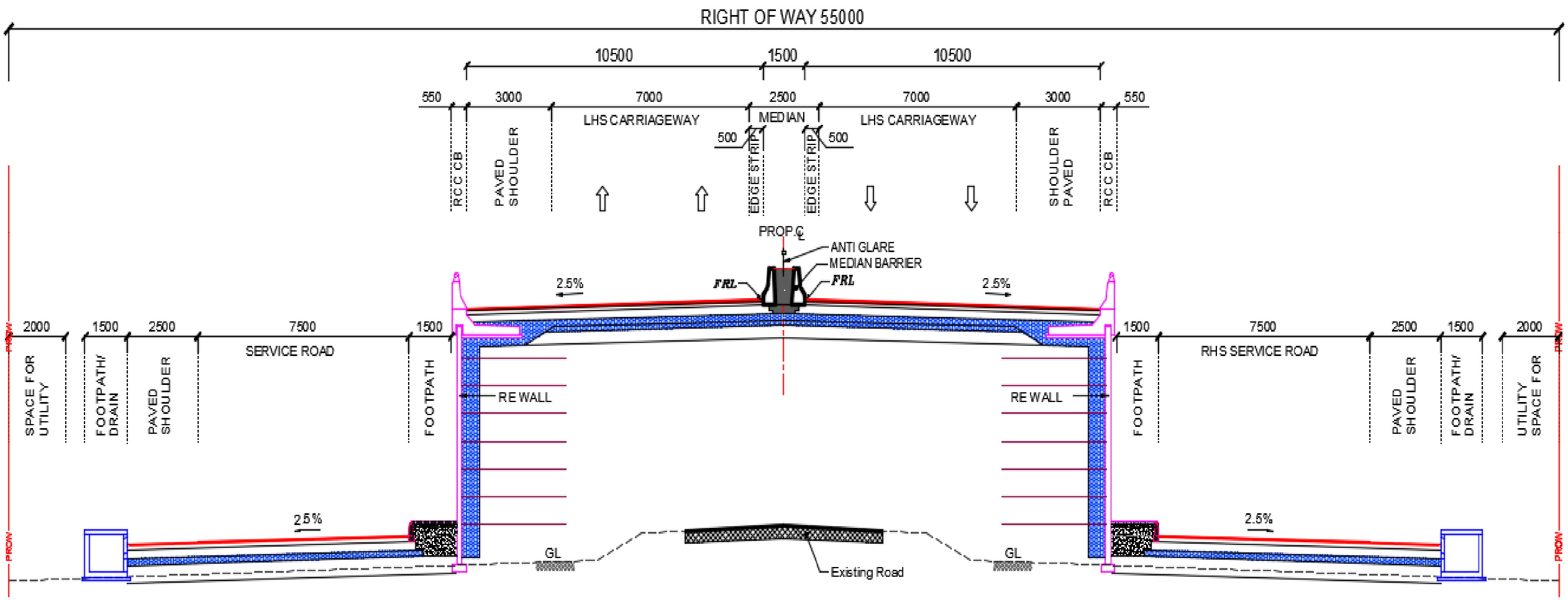


Fig 1.3 4-Lane Flyover Apporaches with 7.5m wide Service Road and Paved Shoulder and RCC Drain on both side along Existing Road with 2.5 m Median (TCS-2)

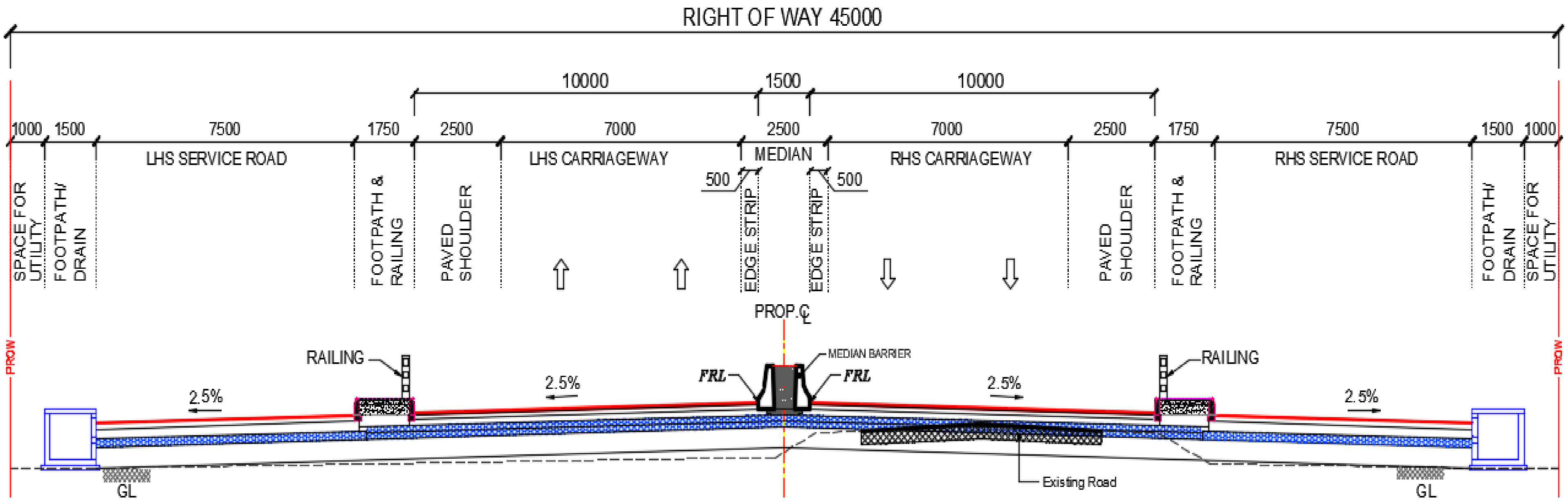


Fig 1.4 4-Lane with Paved Shoulder and 7.5m wide Service Road and RCC Drain on both side in Built-up Area along the Existing Road with 2.5m Median (TCS-3)

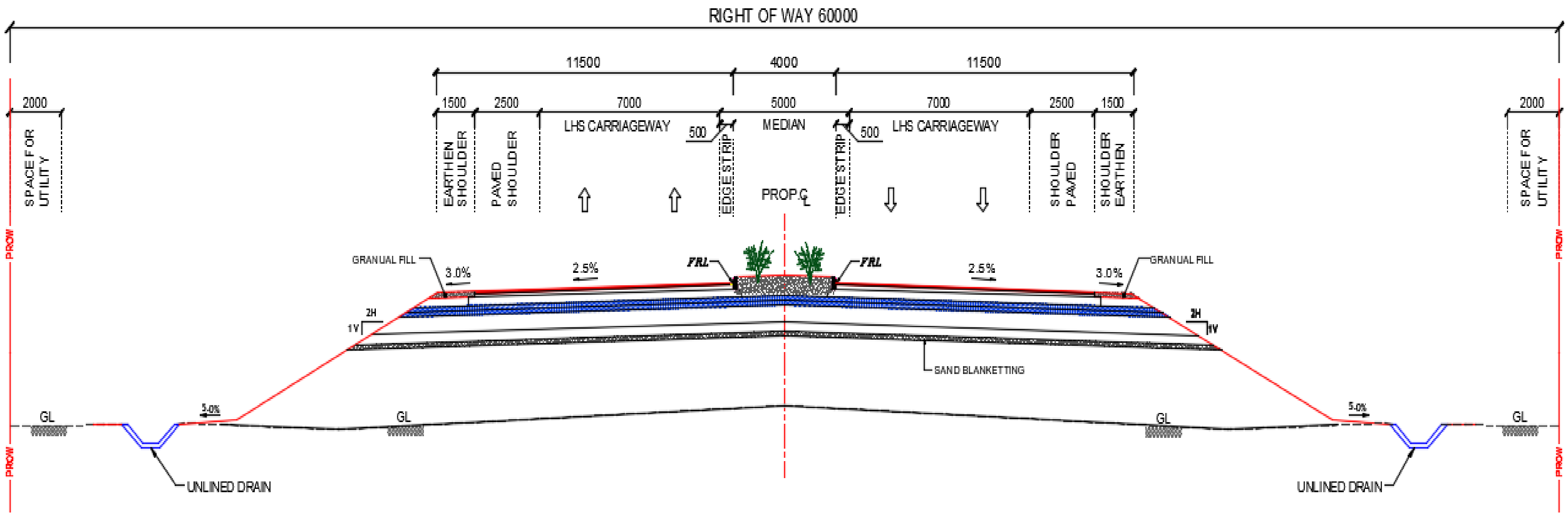


Fig 1.5 4-Lane with Paved Shoulder and Earthen Shoulder in Rural Area with 5.0m Median (TCS-4)

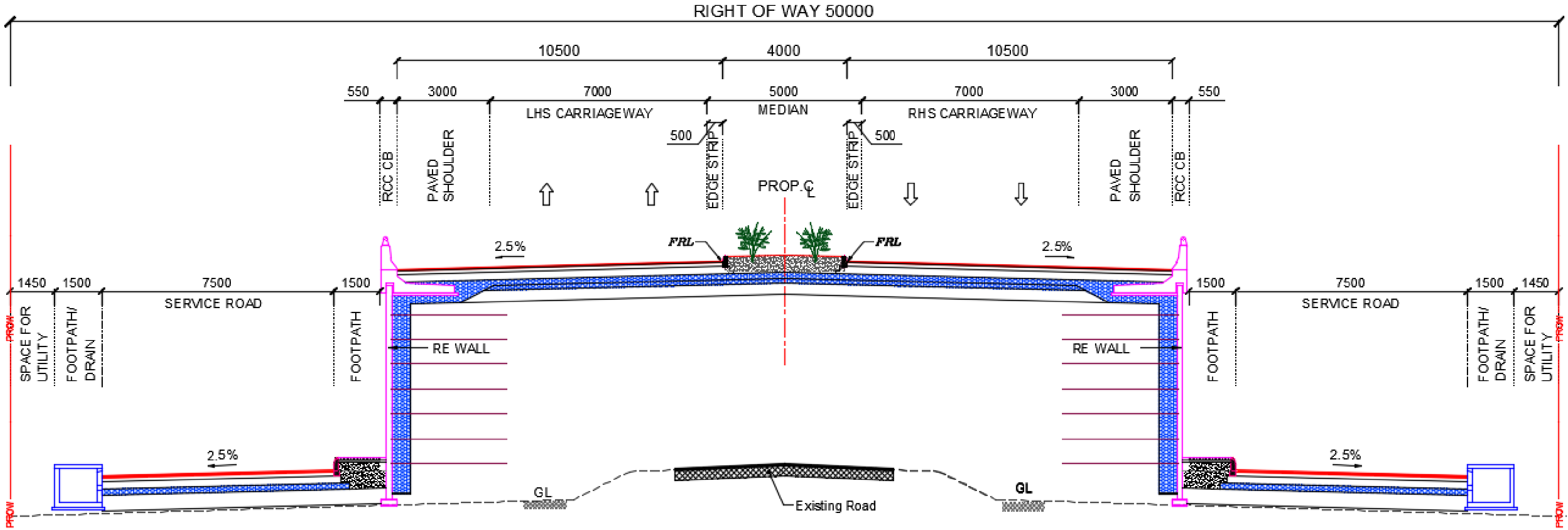


Fig 1.6 4-Lane SVUP Approaches with 7.5m wide Service Road and RCC Drain on both side along Existing Road with 5.0 m Median (TCS-5)

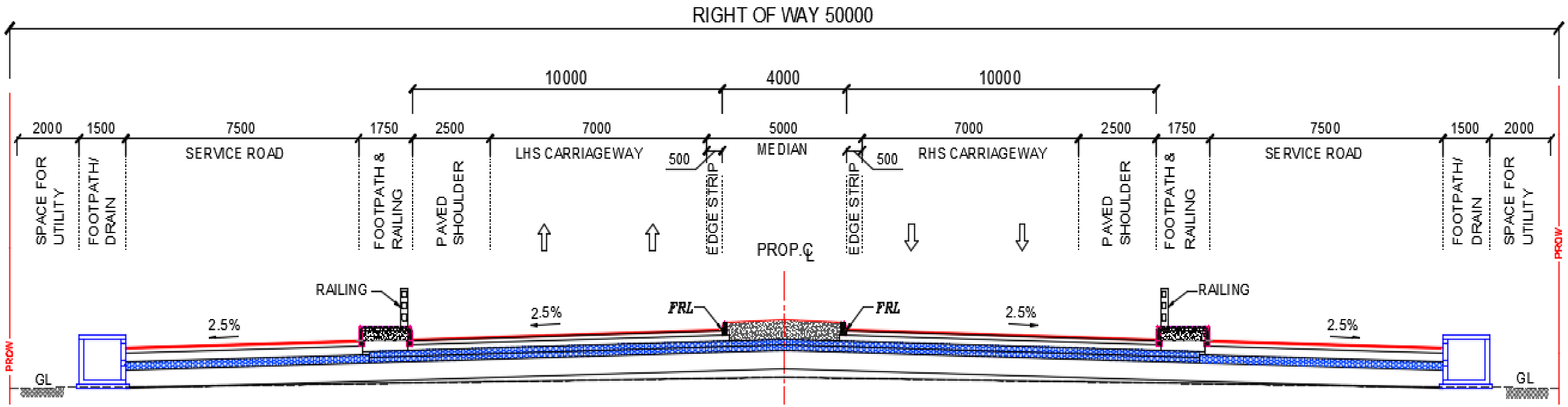


Fig 1.7 **4-Lane with Paved Shoulder and Footpath with 7.5m wide Service Road and RCC Drain on both side in Built-up Area along the Existing Road with 5.0m Median (TCS-6)**

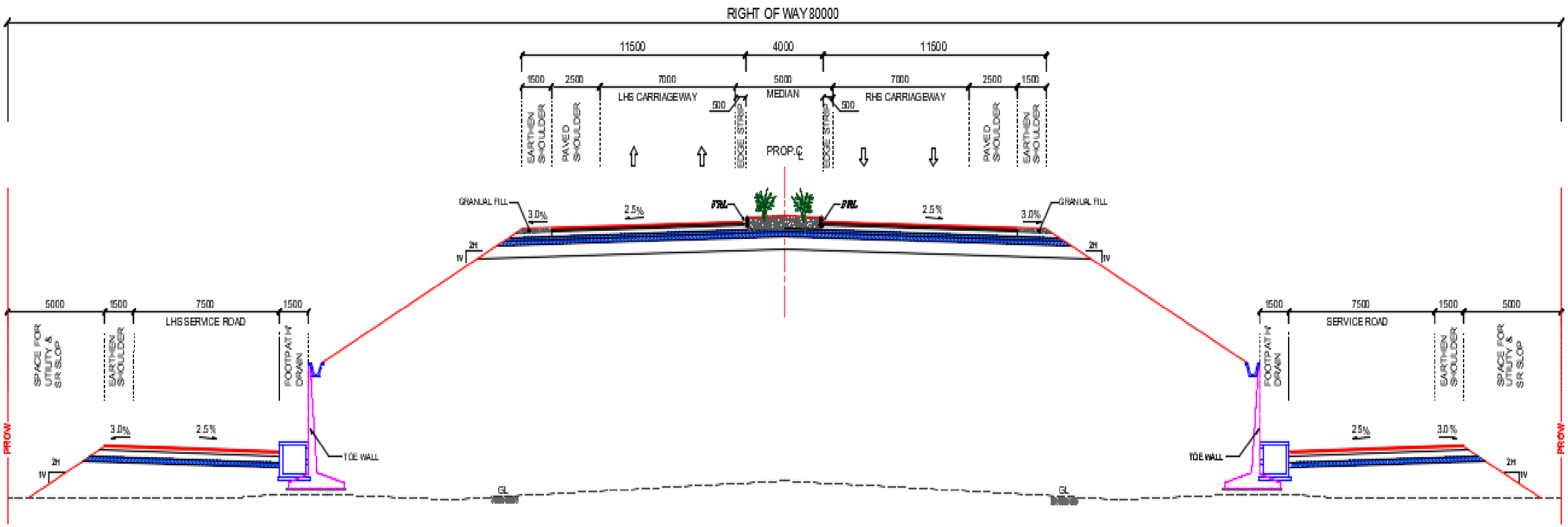


Fig 1.8 4-Lane Grade Separated Approach with Toe wall (Flyover, VUP & SVPU) with Both Service Road and Drain on inner side in Rural Area with 5.0m Median (TCS-7)

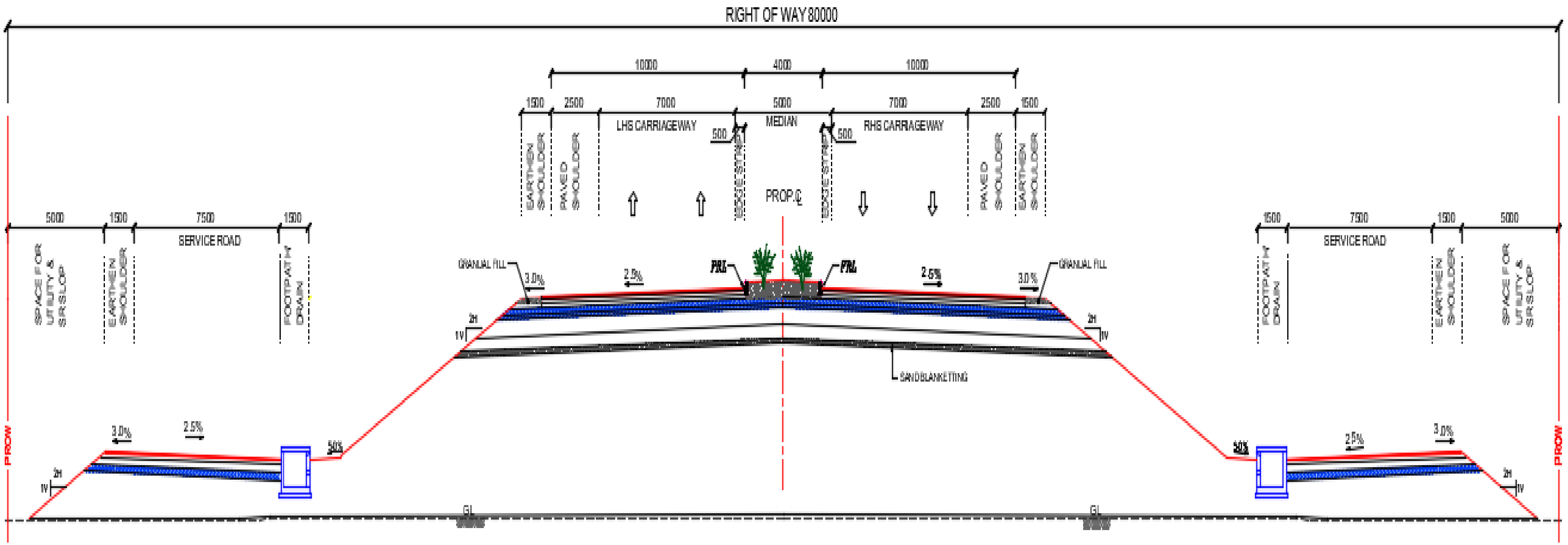


Fig 1.9 4-Lane Grade Separated Approach without Toe wall (Flyover, VUP & SVUP) with Both Service Road and Drain on inner side in Rural Area with 5.0m Median (TCS-8)

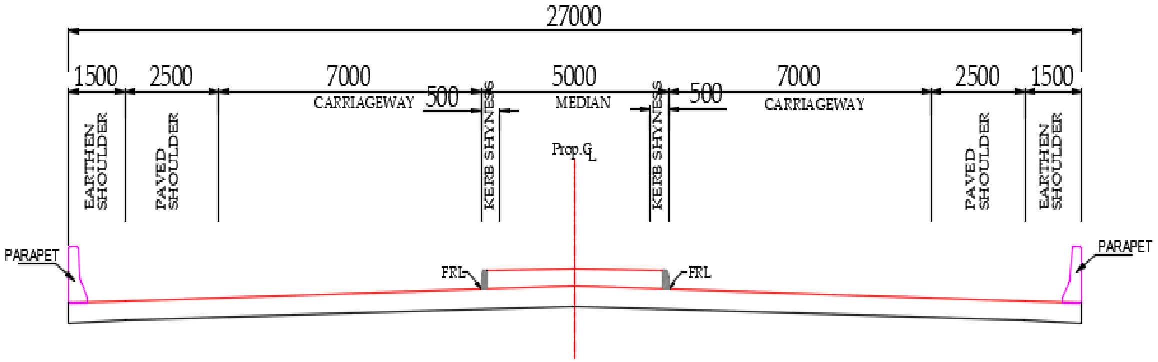


Fig 1.10 4-Lane- Buried Culvert (Pipe and Slab) at road level (TCS-9)

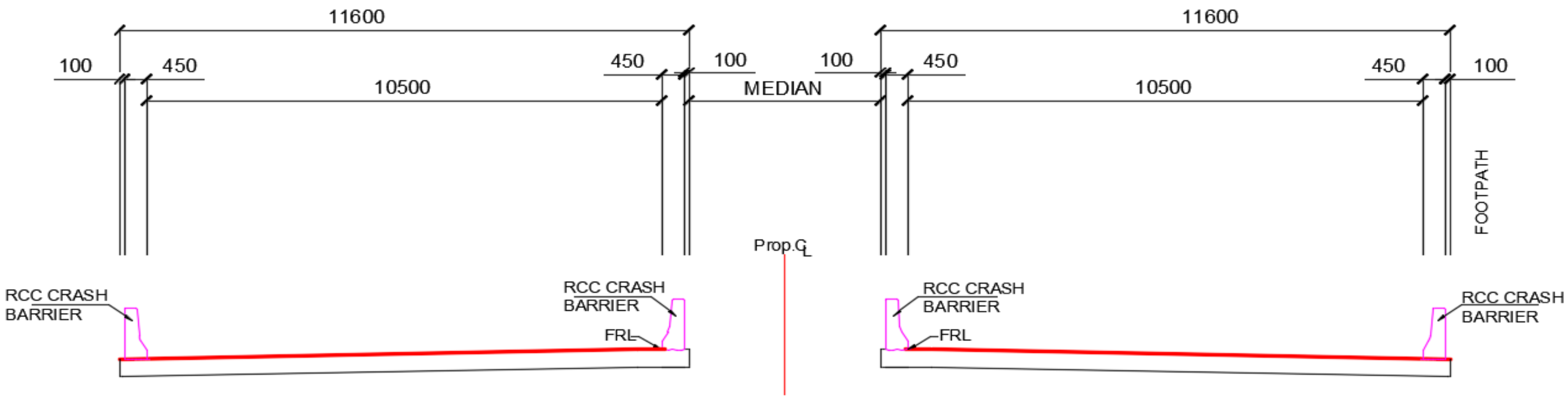


Fig 1.11 4-Lane Grade separated Structures & Box/Slab culvert at Deck level (TCS-10)

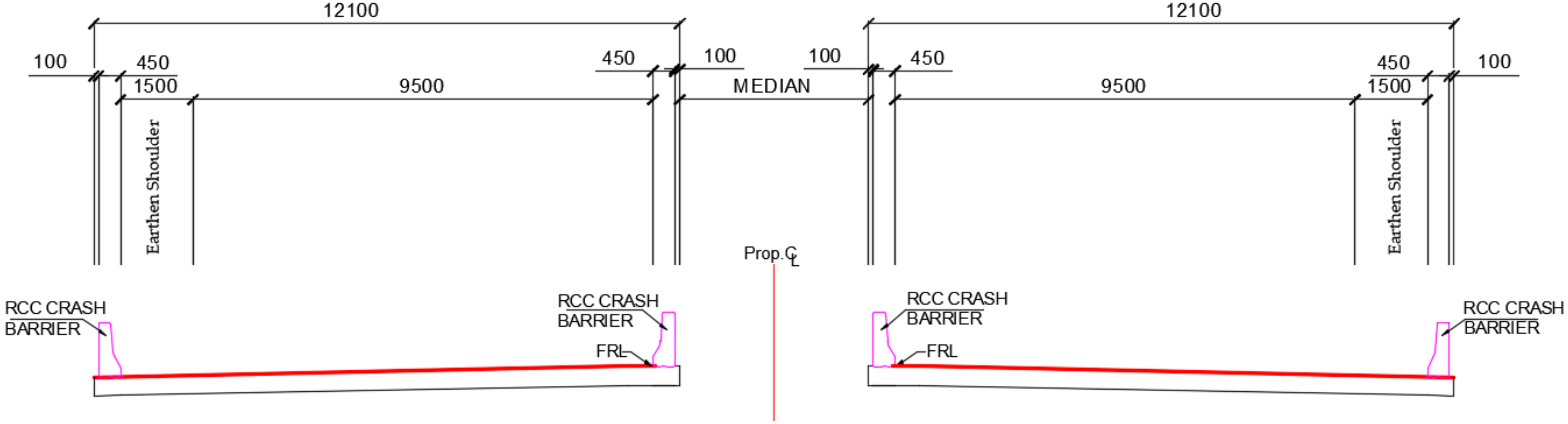


Fig 1.12 4-Lane Grade Separated Structure & Bridge at Deck Level without Footpath (TCS-11)

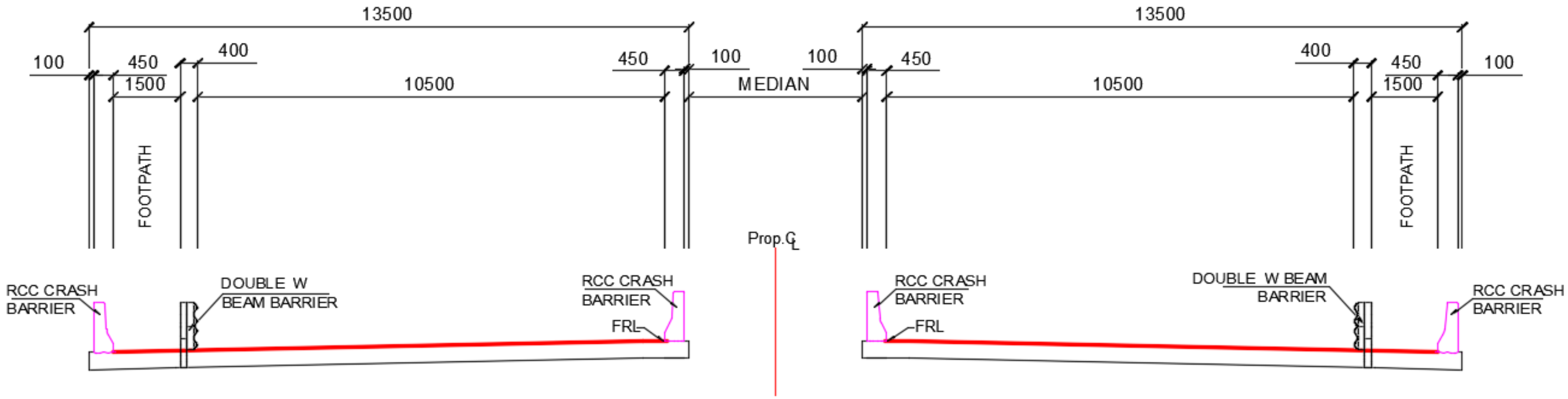


Fig 1.13 4-Lane Separated Structure & Bridge at Deck Level with Footpath (TCS-12)

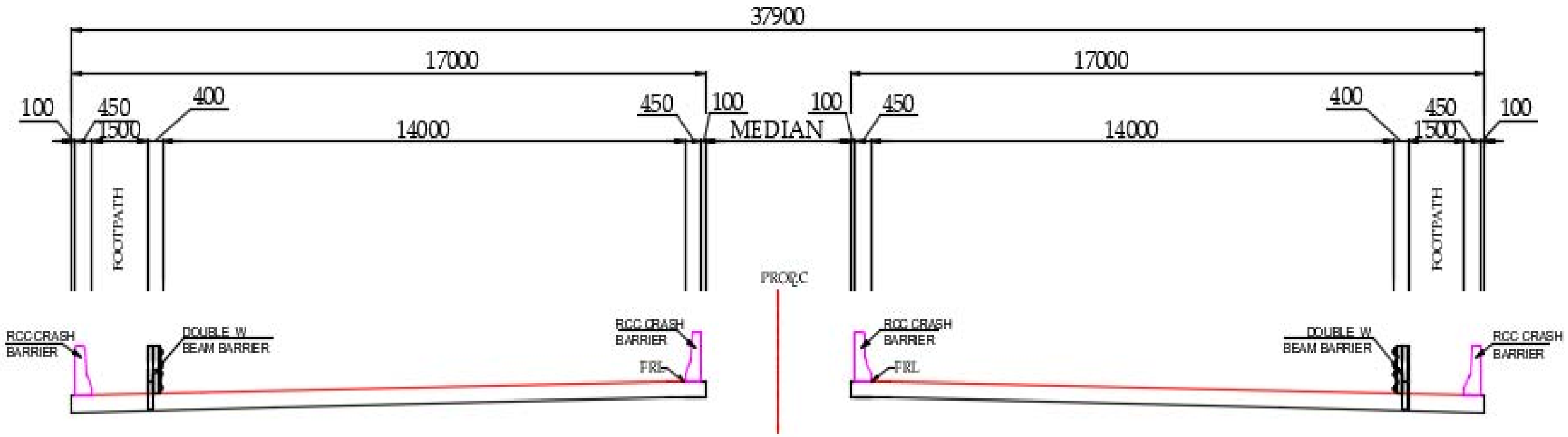


Fig 1.14 6-Lane Separated Structure & Bridge at Deck Level with Footpath (TCS-13)

Table 1.13 Schedule of Typical Cross Sections

Chainage (m)		Distance (m)	Existing CW	Const. Type	Area Type	TCS Type	Remarks
From	To						
0+000	0+225	225	7	Follow existing	Built up	TCS 1	
0+225	1+360	1135	7	Follow existing	Open Area	TCS 2	
1+360	3+800	2440	7	Follow existing	Built up	TCS 3	
3+800	5+260	1460	-	New Alignment	Open Area	TCS 4	
5+260	5+860	600	7	Follow existing	Open Area	TCS 5	
5+860	6+470	610	7	Follow existing	Built up	TCS 6	
6+470	7+040	570	7	Follow existing	Open Area	TCS 5	
7+040	7+280	240	-	New Alignment	Open Area	TCS 7	
7+280	7+530	250	-	New Alignment	Open Area	TCS 8	
7+530	12+340	4810	-	New Alignment	Open Area	TCS 4	
12+340	12+750	410	-	New Alignment	Open Area	TCS 8	
12+750	12+900	150	-	New Alignment	Open Area	TCS 7	
12+900	13+290	390	-	New Alignment	Open Area	TCS 8	
13+290	14+400	1110	-	New Alignment	Open Area	TCS 4	
14+400	14+610	210	-	New Alignment	Open Area	TCS 7	
14+610	15+400	790	-	New Alignment	Open Area	TCS 8	
15+400	16+100	700	-	New Alignment	Open Area	TCS 7	
16+100	16+410	310	-	New Alignment	Open Area	TCS 8	
16+410	18+800	2390	-	New Alignment	Open Area	TCS 4	

Chainage (m)		Distance (m)	Existing CW	Const. Type	Area Type	TCS Type	Remarks
From	To						
18+800	19+050	250	-	New Alignment	Open Area	TCS 8	
19+050	19+720	670	-	New Alignment	Open Area	TCS 7	
19+720	19+900	180	-	New Alignment	Open Area	TCS 8	
19+900	21+100	1200	-	New Alignment	Built up	TCS 6	

1.5.6 Horizontal Alignment Design

Horizontal alignment essentially comprises three major elements: tangent section, circular curve and transition curve. A balanced control on the above elements is required to provide safe and continuous flow of vehicles under general traffic conditions. The design parameters governing the curve elements are given in following sections.

1.5.6.1 Radius of Curves

Efforts have been made, during design of horizontal alignment, to take the proposed center line within or near to existing road, to make maximum use of existing roadway without making any compromise in standards. Desirable values have been adopted in conformity with the stated design standards.

The minimum radius of horizontal curves is calculated from the following formula:

$R = V^2 / 127 (e + f)$

Where,

V = vehicle speed in Kmph

e = Super elevation in metre per metre

f = coefficient of friction between vehicle tyre and pavement (taken as 0.15)

R = radius in metres

Based on this equation and the maximum permissible value of super-elevation, radii for horizontal curves corresponding to ruling and minimum design speeds will be given below:

Table 1.14 Minimum Radii of Horizontal Curves: IRC: SP: 84-2019

Nature of Terrain	Desirable Minimum Radius (m)	Absolute Minimum Radius (m)
Plain and Rolling	400	250
Mountainous & Steep	150	75

Table 1.15 Minimum Radii of Horizontal Curves: IRC: SP: 48-1998

Nature of Terrain	Desirable Minimum Radius (m)	Absolute Minimum Radius (m)
Mountainous	80	50
Steep	50	30

The summary of proposed horizontal curves are given below

Table 1.16 Summary of Proposed Horizontal Curves

Total No. of Curves	No. of Curves with Radius				No of curves with speed				
	R<75	R 76-150	R 151-300	R >300	40	50	60	80	100
33	-	1	1	21	-	1	-	-	23

Length (m)			% Length	
Total	In Straight	In Curve	In Straight	In Curve
21000	10037	10963	52%	48%

1.5.6.2 Super elevation

On a straight length of road, transverse drainage shall be accomplished by the use of cross fall at a standard rate of 2.5%. The surface of pavement shall fall towards hill side edge on mountainous terrain.

Super elevation is required to be provided at horizontal curves to counter the effects of centrifugal force and is calculated from the following equation.

$$e = V^2 / 225R$$

Where,

e = Super elevation in meter per meter width of road

V = design speed in km/h

R = radius of horizontal curve in m.

The above formula assumes that the centrifugal force corresponding to three-fourth of design speed is balanced by super elevation and one-fourth counteracted by the side friction between the tires of vehicle and the road surface.

Super elevation shall be limited to 7%, if radius of curve is less than the desirable minimum. It shall be limited to 5%, if the radius is more than desirable minimum and also at section where project highway passes through an urban section or falls on a major junction as per IRC: SP:84-2019, section 2.9.3. and as per IRC: SP:48-1998 clause 6.8.2.2., it is limiting to 10% in hilly areas not bound by snow.

Super elevation run-off:

Super elevation transition will be attained gradually over the length of transition so that the design super elevation is attained fully at the point of the circular portion. In cases where transition cannot be provided due to constraints, two third super elevation may be attained on the straight section before the start of the curve, the balance of which shall be inside the circular portion. In developing the required super elevation, the pavement edge is to be rotated such that, the longitudinal slope of the pavement edge compared to the centerline (i.e. the rate of change of super elevation) is not steeper than 1 in 150 for roads in plain and rolling terrain.

1.5.6.3 Transition Curves

Transition curves are necessary to have smooth entry from a straight section into a circular curve. The transition curves also improve aesthetic appearance of the road as well as provide a gradual application of the super elevation and extra widening of the carriageway needed at the horizontal curves. For this purpose, spiral curves shall be used.

As per IRC: 84, minimum length of the transition curve shall be determined from the following considerations and the larger of the values adopted for the design.

a) Ls = $0.0215V^3/CR$

b) Ls = $2.7\ V^2/R$ (for plain & rolling terrain) and

c) Ls = 150 x w x e

Where:

Ls = length of transition in meters
V = speed in Km/h
R = radius of circular curve in meters
C = 80/ (75+V) (subject to a maximum of 0.8 and minimum of 0.5)
e = Superelevation (%)
w = Width of Carriageway

The rate of change of super elevation should not be steeper than 1 in 150 for design in plain and rolling terrain, and 1 in 60 in mountainous and steep terrain.

Transition curves shall not be required if the radius of horizontal curves is greater than the values indicated in below table:

Table 1.17 Curve Radius (m) Not Requiring Transition

Design Speed (Kmph)	100	80	65	50	40
Radius (m)	2000	1200	800	500	300

Details of proposed geometrics with all curve points like, Beginning of Spiral (BS), Beginning of Curve (BC), End of Curve (EC), End of Spiral (ES), Side of curve, Radius of Horizontal Curve, Length of Transition curve and Design speed achieved, and location are given in below table;

Table 1.18 Summary of Proposed Horizontal Curves From Km 0+000 to Flyover Ramp towards Jiribam Km 4+960

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Super elevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
						Start	0	482439.93	2746853.655	30.886	482464.049	2746872.946	30.886					
						Transition	30.886	482464.05	2746872.946	90.886	482511.317	2746909.896	60.000					
1	482630.26	2747005.87	22	57	41.3	Arc	90.886	482511.32	2746909.896	391.564	482777.572	2747046.564	300.678		Right	100	900	4.94%
						Transition	391.564	482777.57	2747046.564	451.564	482835.150	2747063.430	60.000					
						Straight	451.564	482835.15	2747063.43	989.496	483353.037	2747208.909	537.932	74 18 34.1				
						Transition	989.496	483353.04	2747208.909	1069.496	483430.879	2747227.087	80.000					
2	483485	2747245.98	35	46	5.9	Arc	1069.496	483430.88	2747227.087	1176.779	483537.513	2747223.003	107.283		Right	100	300	7.00%
						Transition	1176.779	483537.51	2747223.003	1256.779	483613.737	2747198.923	80.000					
						Straight	1256.779	483613.74	2747198.923	1430.496	483776.897	2747139.287	173.717	110 4 40.1				
3	483926.06	2747084.77	351	44	32	Arc	1430.496	483776.9	2747139.287	1747.572	484081.504	2747052.236	317.076		Left	100	-2200	-2.50%
						Straight	1747.572	484081.5	2747052.236	2745.958	485058.719	2746847.729	998.386	101 49 12				
4	485190.16	2746820.22	6	59	10.3	Arc	2745.958	485058.72	2746847.729	3014.208	485317.285	2746776.929	268.250		Right	100	2200	-2.50%
						Straight	3014.208	485317.29	2746776.929	3749.368	486013.199	2746539.937	735.160	108 48 22.3				
						Transition	3749.368	486013.2	2746539.937	3849.368	486108.839	2746510.886	100.000					

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Super elevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
5	486338.71	2746429.08	299	11	27.9	Arc	3849.368	486108.84	2746510.886	4280.026	486517.784	2746594.817	430.658		Left	100	-500	5.00%
						Transition	4280.026	486517.78	2746594.817	4380.026	486594.250	2746659.191	100.000					
						Straight	4380.026	486594.25	2746659.191	4527.574	486703.895	2746757.925	147.548	47 59 50.2				
6	486858.04	2746896.74	7	54	39.4	Arc	4527.574	486703.9	2746757.925	4941.790	487029.832	2747013.009	414.216		Right	100	3000	-2.50%
						Straight	4941.79	487029.83	2747013.009	4960.328	487045.184	2747023.399	18.538	55 54 29.6				

Table 1.19 Summary of Proposed Horizontal Curves of RAMP A

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Superelevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
						Start	0	486508.89	2746572.195	83.141	486439.735	2746526.039	83.141					
						Transition	83.141	486439.74	2746526.039	163.141	486377.295	2746476.383	80.000					
1	486310.63	2746439.87	289	0	12.7	Arc	163.141	486377.3	2746476.383	281.400	486336.287	2746368.316	118.259		Left	65	-160	7.00%
						Transition	281.4	486336.29	2746368.316	361.400	486350.066	2746289.737	80.000					
						Straight	361.4	486350.07	2746289.737	370.671	486352.421	2746280.771	9.271	165 16 55.1				

Table 1.20 Summary of Proposed Horizontal Curves of RAMP B

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Superelevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
						Start	0	486325.69	2746272.441	82.052	486290.662	2746346.640	82.052					
						Transition	82.052	486290.66	2746346.64	142.052	486262.396	2746399.496	60.000					
1	486242.16	2746449.37	314	46	17.6	Arc	142.052	486262.4	2746399.496	239.929	486190.511	2746464.480	97.877		Left	65	-200	7.00%
						Transition	239.929	486190.51	2746464.48	299.929	486135.079	2746487.286	60.000					
						Straight	299.929	486135.08	2746487.286	333.718	486103.229	2746498.564	33.789	289 29 57.1				

Table 1.21 Summary of Proposed Horizontal Curves of RAMP C

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Superelevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
						Start	0	486698.56	2746762.582	26.900	486677.348	2746746.040	26.900					
						Transition	26.9	486677.35	2746746.04	111.900	486606.931	2746698.737	85.000					
1	486553.78	2746649.68	59	6	46.3	Arc	111.9	486606.93	2746698.737	233.243	486488.720	2746681.299	121.343		Right	65	200	7.00%
						Transition	233.243	486488.72	2746681.299	318.243	486407.644	2746706.253	85.000					
							318.243	486407.64	2746706.253	403.243	486325.506	2746725.307	85.000					

Table 1.22 Summary of Proposed Horizontal Curves From Flyover Km 4+040 to the end of package Km 31+000

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Superelevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
						Start	4040	486296.8	2746510.821	4049.346	486305.913	2746512.902	9.346					
						Transition	4049.346	486305.91	2746512.902	4149.346	486397.347	2746550.583	100.000					
1	486259.24	2746502.24	83	8	59.6	Arc	4149.346	486397.35	2746550.583	4507.541	486239.188	2746664.941	358.195		Left	50	-100	7.00%
						Transition	4507.541	486239.19	2746664.941	4657.541	486253.115	2746519.322	150.000					
						Straight	4657.541	486253.12	2746519.322	4840.845	486314.960	2746346.766	183.304	160 16 55.4				
						Transition	4840.845	486314.96	2746346.766	4940.845	486346.441	2746251.874	100.000					
2	486396.85	2746118.29	30	45	39.6	Arc	4940.845	486346.44	2746251.874	5216.661	486367.166	2745978.623	275.816		Right	100	700	5.00%
						Transition	5216.661	486367.17	2745978.623	5316.661	486350.358	2745880.069	100.000					
						Straight	5316.661	486350.36	2745880.069	5692.084	486278.447	2745511.598	375.423	191 2 35				
						Transition	5692.084	486278.45	2745511.598	5792.084	486257.255	2745413.886	100.000					
3	486245.9	2745344.82	17	2	25	Arc	5792.084	486257.26	2745413.886	5930.011	486211.128	2745284.082	137.927		Right	100	800	5.00%
						Transition	5930.011	486211.13	2745284.082	6030.011	486165.908	2745194.910	100.000					
						Straight	6030.011	486165.91	2745194.91	6107.323	486129.513	2745126.700	77.312	208 5 0				
						Transition	6107.323	486129.51	2745126.7	6192.323	486090.569	2745051.155	85.000					
4	486025.19	2744931.19	339	41	49.9	Arc	6192.323	486090.57	2745051.155	6461.674	486007.890	2744795.662	269.351		Left	100	-1000	4.44%
						Transition	6461.674	486007.89	2744795.662	6546.674	485995.191	2744711.623	85.000					
						Straight	6546.674	485995.19	2744711.623	6591.434	485989.132	2744667.275	44.760	187 46 49.9				
						Transition	6591.434	485989.13	2744667.275	6691.434	485978.908	2744567.843	100.000					
5	485959.27	2744448.74	322	22	57.6	Arc	6691.434	485978.91	2744567.843	6919.707	486022.196	2744345.727	228.273		Left	100	-500	5.00%
						Transition	6919.707	486022.2	2744345.727	7019.707	486069.010	2744257.411	100.000					

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Superelevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
						Straight	7019.707	486069.01	2744257.411	7043.605	486080.900	2744236.681	23.898	150 9 47.5				
						Transition	7043.605	486080.9	2744236.681	7143.605	486127.714	2744148.366	100.000					
6	486191.12	2744044.51	37	48	58.2	Arc	7143.605	486127.71	2744148.366	7373.614	486170.937	2743924.515	230.009		Right	100	500	5.00%
						Transition	7373.614	486170.94	2743924.515	7473.614	486160.368	2743825.120	100.000					
						Straight	7473.614	486160.37	2743825.12	7675.298	486132.371	2743625.389	201.684	187 58 45.7				
						Transition	7675.298	486132.37	2743625.389	7760.298	486121.766	2743541.060	85.000					
7	486111.91	2743479.42	348	1	36.5	Arc	7760.298	486121.77	2743541.06	7884.269	486117.458	2743417.242	123.971		Left	100	-1000	4.44%
						Transition	7884.269	486117.46	2743417.242	7969.269	486122.176	2743332.380	85.000					
						Straight	7969.269	486122.18	2743332.38	7980.087	486122.929	2743321.589	10.818	176 0 22.2				
						Transition	7980.087	486122.93	2743321.589	8080.087	486127.120	2743221.707	100.000					
8	486135.29	2743144.52	23	58	6.9	Arc	8080.087	486127.12	2743221.707	8231.086	486106.185	2743072.569	150.999		Right	100	600	5.00%
						Transition	8231.086	486106.19	2743072.569	8331.086	486074.658	2742977.702	100.000					
						Straight	8331.086	486074.66	2742977.702	8808.062	485911.720	2742529.419	476.976	199 58 29.1				
9	485876.57	2742432.71	357	38	31	Arc	8808.062	485911.72	2742529.419	9013.841	485845.423	2742334.627	205.779		Left	100	-5000	-2.50%
						Straight	9013.841	485845.42	2742334.627	9599.735	485668.104	2741776.210	585.894	197 37 0.1				
10	485635.12	2741672.35	355	0	29.8	Arc	9599.735	485668.1	2741776.21	9817.540	485611.306	2741566.012	217.805		Left	100	-2500	-2.50%
						Straight	9817.54	485611.31	2741566.012	10234.628	485520.144	2741159.009	417.088	192 37 29.9				
11	485492.87	2741037.23	4	45	51.1	Arc	10234.628	485520.14	2741159.009	10484.080	485455.570	2740918.134	249.452		Right	100	3000	-2.50%
						Straight	10484.08	485455.57	2740918.134	11072.008	485279.862	2740357.076	587.928	197 23 20.9				
12	485229.06	2740194.84	7	46	49.2	Arc	11072.008	485279.86	2740357.076	11411.489	485156.754	2740040.983	339.481		Right	100	2500	-2.50%
						Straight	11411.489	485156.75	2740040.983	11964.674	484921.486	2739540.321	553.185	205 10 10.1				
						Transition	11964.674	484921.49	2739540.321	12064.674	484876.823	2739450.874	100.000					

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Superelevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
13	484720.19	2739111.94	62	17	2.1	Arc	12064.674	484876.82	2739450.874	12725.616	484347.080	2739097.731	660.942		Right	100	700	5.00%
						Transition	12725.616	484347.08	2739097.731	12825.616	484247.335	2739090.912	100.000					
						Straight	12825.616	484247.34	2739090.912	13142.435	483930.828	2739076.835	316.819	267 27 12.2				
						Transition	13142.435	483930.83	2739076.835	13227.435	483845.981	2739071.857	85.000					
14	483688.85	2739066.07	337	25	2.1	Arc	13227.435	483845.98	2739071.857	13536.578	483547.004	2738998.211	309.143		Left	100	-1000	4.44%
						Transition	13536.578	483547	2738998.211	13621.578	483469.552	2738963.211	85.000					
						Straight	13621.578	483469.55	2738963.211	14137.120	483002.806	2738744.279	515.542	244 52 14.3				
						Transition	14137.12	483002.81	2738744.279	14197.120	482948.657	2738718.438	60.000					
15	482825.97	2738661.33	347	25	18.9	Arc	14197.12	482948.66	2738718.438	14466.414	482719.155	2738578.248	269.294		Left	100	-1500	2.96%
						Transition	14466.414	482719.16	2738578.248	14526.414	482671.443	2738541.868	60.000					
						Straight	14526.414	482671.44	2738541.868	14551.846	482651.323	2738526.313	25.432	232 17 33.2				
						Transition	14551.846	482651.32	2738526.313	14651.846	482570.250	2738467.847	100.000					
16	482499.92	2738409.26	31	31	47.9	Arc	14651.846	482570.25	2738467.847	14826.997	482408.616	2738402.731	175.151		Right	100	500	5.00%
						Transition	14826.997	482408.62	2738402.731	14926.997	482309.655	2738388.670	100.000					
						Straight	14926.997	482309.66	2738388.67	15504.960	481735.048	2738326.476	577.963	263 49 21.2				
						Transition	15504.96	481735.05	2738326.476	15604.960	481636.037	2738312.713	100.000					
17	481177	2738266.08	274	15	11.1	Arc	15604.96	481636.04	2738312.713	16328.071	481195.521	2737805.048	723.111		Left	100	-550	5.00%
						Transition	16328.071	481195.52	2737805.048	16428.071	481195.850	2737705.085	100.000					
						Straight	16428.071	481195.85	2737705.085	17267.901	481224.051	2736865.729	839.830	178 4 32.3				
						Transition	17267.901	481224.05	2736865.729	17337.901	481227.082	2736795.798	70.000					
18	481247.16	2736177.87	302	52	52.2	Arc	17337.901	481227.08	2736795.798	18464.195	481777.702	2735860.425	1126.294		Left	100	-1200	3.70%
						Transition	18464.195	481777.7	2735860.425	18534.195	481837.376	2735823.837	70.000					

HIP / Curve No.	HIP		Deflection Angle			Element	Start			End			Length (m)	Bearing (dd mm ss)	Hand of Arc	Design Speed (KM/H)	Radius (m)	Superelevation (%)
	Easting	Northing	Deg	Min	Sec		Chainage (m)	Easting	Northing	Chainage (m)	Easting	Northing						
						Straight	18534.195	481837.38	2735823.837	18944.011	482188.816	2735613.030	409.816	120 57 24.5				
						Transition	18944.011	482188.82	2735613.03	19044.011	482273.467	2735559.825	100.000					
19	482570.36	2735384.17	52	31	1.2	Arc	19044.011	482273.47	2735559.825	19677.287	482607.492	2735041.215	633.276		Right	100	800	5.00%
						Transition	19677.287	482607.49	2735041.215	19777.287	482620.923	2734942.139	100.000					
						Straight	19777.287	482620.92	2734942.139	20140.117	482662.161	2734581.660	362.830	173 28 25.7				
20	482672.75	2734489.14	355	43	59.7	Arc	20140.117	482662.16	2734581.66	20326.288	482690.185	2734397.654	186.171		Left	100	-2500	-2.50%
						Straight	20326.288	482690.19	2734397.654	21124.064	482839.577	2733613.990	797.776	169 12 25.4				

1.5.7 Geometric Improvements/ Bypasses or Re-Alignments

Bypasses or Re-Alignments

There are some major settlement areas with ribbon developments along the project road. These settlements require bypasses because of continuous and thick ribbon developments, poor geometry and non-availability of ROW. The entire Package-2 is falling under Green field alignment.

Details of these improvements are given for Silchar to Vairengte and summary of subsequent package is presented below:

There are three options provided as below,

Option A: Utilise by upgrading the under-construction bypass and proposal of new bypass,

Option B: Improvement of existing road with bypass options at Major built up

Option C: Green filed alignment.

The detail of the same is given below. The most economical with minimum disturbance has been considered, which details of these improvements are given in subsequent sections and summary is presented below.

Table 1.23 List of Bypass Proposals.

Sl. No	Location	Exist. Chainage (Km)		Exist. Length (m)	Prop. Chainage (Km)		Prop Length (m)
		Start	End		Start	End	
	Falls under Package-1						
A.	**Upgrading the under constructed 2-lane Silchar Bypass to 4-lane road**						
1.	Silchar Bypass	20+000	11+170	8830	7+040	14+400	7360
		Total Length (m)		**8830**			**7360**
B.	***Improvement of existing road with bypass options at Major Built up**						
1	Sonabarighat Bypass	7+950	12+500	**4550**	14+400	19+750	**5350**
		Total Length (m)		**13380**			**12710**
	Note: As per recent development the proposed alignment is to be follow as per option-B shown below; Falls under Package-2						
2	Nutan Bazar Bypass	15+240	22+180	6940	These individual bypasses		

Sl. No	Location	Exist. Chainage (Km)		Exist. Length (m)	Prop. Chainage (Km)		Prop Length (m)
		Start	End		Start	End	
3	Katakhal Bypass	23+000	26+800	3800	have been studied and considered under modified / re-route alignment.		
4	Dholai Bypass	28+950	31+000	2050			
5	Baga Bazar Bypass	31+500	39+250	7750			
		Total Length (m)		**20540**			
C	**Option of Partial Green Field Alignment, Falls under package-2 (now proposed to be modified)**						
1	Green Field Alignment	13+200	43+000	29800	21+000	46+000	25000
		Total Length (m)		**29800**			**25000**
	Total Approval Length (m) along bypasses / Green Field Alignment			**41850**			**37710**

1.5.8 Vertical Alignment Design

Vertical alignment essentially comprises two major elements: longitudinal gradient and vertical curve. A balanced control on the above elements is required to provide safe and continuous flow of vehicles under general traffic conditions. The profile of the project alignment was designed primarily on the basis of DTM data collected during the topographic survey. The following considerations are made to design the vertical profiles.

1.5.8.1 Gradient

The selection of suitable maximum gradient is dependent on vehicle characteristics, particularly those of trucks. Recommended gradients for different classes of terrain as per IRC: SP: 84-2019 are given below

Table 1.24 Recommended Gradients for different terrain conditions

Sl. No.	Terrain	Ruling Gradient	Limiting Gradient
1	Plain or Rolling	2.5 %	3.3 %
2	Mountainous	5.0 %	6.0 %
3	Steep	6.0 %	7.0 %

The "Limiting Gradient" is adopted only where the adoption of gentle gradient would result in excessive cost or other limiting factor like underpasses and intersections necessitating a change in gradient.

The cumulative rise/fall in elevation over 2 Km length shall not exceed l00 in mountainous terrain and 120 m in steep terrain.

Vertical alignment should provide a smooth longitudinal profile. Desirably there should be no change in grade within a distance of 150 m. Vertical profile should be coordinated suitably with horizontal alignment.

However, for the VUP and Fly-over approaches, a maximum gradient of 2.5% is considered.

Summary of proposed alignment length as per gradient is given below;

Table 1.25 Distribution of proposed vertical grades

Gradient -->>	<=4	>4 & <=5	>5 & <=6	>6 & <=7	>7
Length (m)	21000	-	-	-	-
% of Length	100%	-	-	-	-

1.5.8.2 Sight Distance

Visibility is an important requirement for safety on roads. For this, it is necessary that sight distance of sufficient length is available to permit drivers enough time and distance to control their vehicles so that chances of accidents are minimized.

As per 2.9.6 clause of IRC: SP: 84-2019, design shall provide for values of at least stopping sight distance (SSD) corresponding to the design speed. The desirable values of sight distance shall be adopted unless there are site constraints. A minimum of safe stopping sight distance shall be available throughout.

Table 1.26 - Safe Sight Distance

Design Speed (Kmph)	Intermediate Sight Distance (m)	Stopping Sight Distance (m)
100	360	180
80	260	130
60	180	90
50	120	60
40	90	45

Criteria for design of geometric elements:

Desirable – Intermediate Sight Distance
Minimum – Stopping Sight Distance

Where horizontal and summit vertical curves overlap, the design should provide for the required sight distance both in vertical direction, along the pavement and in horizontal direction on the inside of the curve.

1.5.8.3 Vertical Curves

Parabolic vertical curves shall be provided at all changes in grade except where the change is 0.5% or less. The minimum length of vertical curve for the ruling design speed of 100 Kmph shall be 60m.

A. Summit

Summit curves are designed for choice of sight distance.

(i) For safe stopping sight distance the length of summit curve shall be calculated from the following formula:

When the length of curve (L) exceeds the required sight distance (S) i.e. L > S,

$L = NS^2 / 4.4$

Where,

N = Deviation angle

L = Length of parabolic vertical curve

S = Sight distance in metres.

When the length of curve (L) is less than the required sight distance (S) i.e. L < S,

$L = 2S – 4.4 / N$

(ii) For intermediate or overtaking sight distance the length of summit curve shall be calculated from the following formula:

When the length of curve (L) exceeds the required sight distance (S) i.e. L > S,

$L = NS^2 / 9.6$

Where,

N = Deviation angle

L = Length of parabolic vertical curve

S = Sight distance in metres.

When the length of curve (L) is less than the required sight distance (S) i.e. L < S, L = 2S – 9.6 / N

B. Valley Curves

Valley curves are designed for head light sight distance. The length of valley curves shall be calculated by the following two criteria:

(i) When the length of curve (L) exceeds the required sight distance (S), i.e. L > S,

$$L = NS^2 / (1.50 + 0.035S)$$

(ii) When the length of curve (L) is less than the required sight distance (S), i.e. L < S ,

$$L = 2S - [(1.50 + 0.035S)/N]$$

Where,

N = Deviation angle

L = Length of parabolic vertical curve

S = Sight distance in meters.

C. "K" Value

Vertical curves will be designed to provide for visibility at least corresponding to the desirable sight distance. More liberal values will be adopted wherever this is economically feasible. Valley curves will be designed for headlight sight distance. The 'K' values for design control and the minimum length of vertical curves will be as follows.

Table 1.27 "K" Value of Summit and Valley Curve

Terrain	'K' value for summit curves		'K' value for valley curves		Minimum length of curve (m)
	Desirable	Minimum	Desirable	Minimum	
Rolling	38	18	28	18	60
Mountainous/ Steep	9	5	10	7	30

Minimum length of vertical curve as per IRC: 73-1980 Clause 10.3.3 is 60m for 100 km/hr & 50m for 80 km/hr. Based on the same clause the vertical curve is not required if % of grade difference is less than 0 5% for 100 km/hr and 0.6% for 80 km/hr

The summary of proposed vertical curves are shown in below table,

Table 1.28 Summary of Vertical Curve from Km 0+000 to Flyover Ramp towards Jiribam Km 4+960

Sl. No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
1				Grade	0.000	22.352	227.366	23.034	0.300				227.366
2	277.366	23.184	2.200	Sag Curve	227.366	23.034	327.366	24.434		4545	2.200	45.455	100.000
3				Grade	327.366	24.434	478.000	28.200	2.500				150.634
4	818.000	36.700	-5.000	Hog Curve	478.000	28.200	1158.000	28.200		-13600	-0.735	136.001	680.000
5				Grade	1158.000	28.200	1228.082	26.448	-2.500				70.082
6	1293.082	24.823	2.300	Sag Curve	1228.082	26.448	1358.082	24.693		5652	1.769	56.522	130.000
7				Grade	1358.082	24.693	1884.959	23.639	-0.200				526.877
8	1934.959	23.539	0.400	Sag Curve	1884.959	23.639	1984.959	23.639		25000	0.400	250.000	100.000
9				Grade	1984.959	23.639	2320.912	24.311	0.200				335.953
10	2370.912	24.411	-0.400	Hog Curve	2320.912	24.311	2420.912	24.311		-25000	-0.400	250.000	100.000
11				Grade	2420.912	24.311	2895.007	23.363	-0.200				474.095
12	2945.007	23.263	0.400	Sag Curve	2895.007	23.363	2995.007	23.363		25000	0.400	250.000	100.000
13				Grade	2995.007	23.363	3492.576	24.358	0.200				497.569
14	3542.576	24.458	-0.400	Hog Curve	3492.576	24.358	3592.576	24.358		-25000	-0.400	250.000	100.000
15				Grade	3592.576	24.358	4375.002	22.793	-0.200				782.426
16	4425.002	22.693	0.400	Sag Curve	4375.002	22.793	4475.002	22.793		25000	0.400	250.000	100.000
17				Grade	4475.002	22.793	4960.328	23.763	0.200				485.326

Table 1.29 Summary of Vertical Curve of RAMP A

S.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
1				Grade	0.000	23.593	51.908	23.749	0.300				51.908

S.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
2	76.908	23.824	2.200	Sag Curve	51.908	23.749	101.908	24.449		2273	4.400	22.729	50.000
3				Grade	101.908	24.449	312.817	29.721	2.500				210.909
4	337.817	30.346	-2.198	Hog Curve	312.817	29.721	362.817	30.421		-2274	-4.397	22.743	50.000
5				Grade	362.817	30.421	370.671	30.445	0.301				7.854

Table 1.30 Summary of Vertical Curve of RAMP B

S.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
1				Grade	0.000	29.555	20.818	29.493	-0.300				20.818
2	50.818	29.403	-2.200	Hog Curve	20.818	29.493	80.818	28.653		-2727	-3.667	27.273	60.000
3				Grade	80.818	28.653	259.638	24.182	-2.500				178.820
4	289.638	23.432	2.200	Sag Curve	259.638	24.182	319.638	23.342		2727	3.667	27.273	60.000
5				Grade	319.638	23.342	333.718	23.300	-0.300				14.080

Table 1.31 Summary of Proposed Vertical Curves of RAMP C

S.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
1				Grade	0.000	22.298	131.460	22.693	0.300				131.460
2	161.460	22.783	2.200	Sag Curve	131.460	22.693	191.460	23.533		2727	3.667	27.273	60.000
3				Grade	191.460	23.533	446.636	29.912	2.500				255.176

Table 1.32 Summary of Proposed Vertical Curves from Flyover Km 4+040 to the end of package Km 21+000

Sl.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
1				Grade	4040.000	22.938	4073.426	22.871	-0.200				33.426

Sl.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
2	4138.426	22.741	2.700	Sag Curve	4073.426	22.871	4203.426	24.366		4815	2.077	48.149	130.000
3				Grade	4203.426	24.366	4337.500	27.718	2.500				134.074
4	4680.000	36.280	-5.000	Hog Curve	4337.500	27.718	5022.500	27.718		-13700	-0.730	136.999	685.000
5				Grade	5022.500	27.718	5083.086	26.203	-2.500				60.586
6	5188.086	23.578	4.500	Sag Curve	5083.086	26.203	5293.086	25.678		4667	2.143	46.666	210.000
7				Grade	5293.086	25.678	5305.000	25.916	2.000				11.914
8	5575.000	31.316	-3.800	Hog Curve	5305.000	25.916	5845.000	26.456		-14210	-0.704	142.104	540.000
9				Grade	5845.000	26.456	5867.004	26.060	-1.800				22.004
10	5902.004	25.430	1.500	Sag Curve	5867.004	26.060	5937.004	25.325		4667	2.143	46.667	70.000
11				Grade	5937.004	25.325	6504.524	23.623	-0.300				567.520
12	6569.524	23.428	2.800	Sag Curve	6504.524	23.623	6634.524	25.053		4643	2.154	46.429	130.000
13				Grade	6634.524	25.053	6722.500	27.252	2.500				87.976
14	7042.500	35.252	-4.700	Hog Curve	6722.500	27.252	7362.500	28.212		-13617	-0.734	136.171	640.000
15				Grade	7362.500	28.212	7400.411	27.378	-2.200				37.911
16	7450.411	26.278	2.200	Sag Curve	7400.411	27.378	7500.411	26.278		4545	2.200	45.455	100.000
17				Grade	7500.411	26.278	7998.924	26.278	0.000				498.513
18	8048.924	26.278	-0.300	Hog Curve	7998.924	26.278	8098.924	26.128		-33333	-0.300	333.333	100.000
19				Grade	8098.924	26.128	8406.080	25.207	-0.300				307.156
20	8456.080	25.056	0.500	Sag Curve	8406.080	25.207	8506.080	25.157		20000	0.500	200.000	100.000
21				Grade	8506.080	25.157	9492.364	27.129	0.200				986.284
22	9542.364	27.229	-0.400	Hog Curve	9492.364	27.129	9592.364	27.129		-25000	-0.400	250.000	100.000
23				Grade	9592.364	27.129	11419.363	23.475	-0.200				1826.999

Sl.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
24	11469.363	23.375	0.400	Sag Curve	11419.363	23.475	11519.363	23.475		25000	0.400	250.000	100.000
25				Grade	11519.363	23.475	11958.218	24.353	0.200				438.855
26	12008.218	24.453	-0.436	Hog Curve	11958.218	24.353	12058.218	24.335		-22945	-0.436	229.453	100.000
27				Grade	12058.218	24.335	12392.995	23.545	-0.236				334.777
28	12447.995	23.416	2.236	Sag Curve	12392.995	23.545	12502.995	24.516		4920	2.033	49.200	110.000
29				Grade	12502.995	24.516	12590.225	26.260	2.000				87.230
30	12840.225	31.260	-3.700	Hog Curve	12590.225	26.260	13090.225	27.010		-13514	-0.740	135.141	500.000
31				Grade	13090.225	27.010	13131.066	26.316	-1.700				40.841
32	13206.067	25.041	3.200	Sag Curve	13131.066	26.316	13281.066	26.166		4688	2.133	46.876	150.000
33				Grade	13281.066	26.166	13450.000	28.700	1.500				168.934
34	13510.000	29.600	-1.500	Hog Curve	13450.000	28.700	13570.000	29.600		-8000	-1.250	80.000	120.000
35				Grade	13570.000	29.600	14090.607	29.600	0.000				520.607
36	14130.607	29.600	1.000	Sag Curve	14090.607	29.600	14170.607	30.000		8000	1.250	80.000	80.000
37				Grade	14170.607	30.000	14229.183	30.586	1.000				58.576
38	14454.183	32.836	-3.300	Hog Curve	14229.183	30.586	14679.183	27.661		-13636	-0.733	136.364	450.000
39				Grade	14679.183	27.661	14755.421	25.907	-2.300				76.238
40	14805.421	24.757	2.000	Sag Curve	14755.421	25.907	14855.421	24.607		5000	2.000	50.000	100.000
41				Grade	14855.421	24.607	15176.746	23.643	-0.300				321.325
42	15241.746	23.448	2.800	Sag Curve	15176.746	23.643	15306.746	25.073		4643	2.154	46.428	130.000
43				Grade	15306.746	25.073	15390.000	27.155	2.500				83.254
44	15730.000	35.655	-5.000	Hog Curve	15390.000	27.155	16070.000	27.155		-13600	-0.735	136.001	680.000
45				Grade	16070.000	27.155	16211.944	23.606	-2.500				141.944

Sl.No.	Vertical Intersection Points			Element	Vertical Tangent Points					Radius	M Value	K Value	Length of Element
	Chainage	Level	%Grade Diff.		Start Chainage	Level	End Chainage	Level	Grade (%)				
46	16276.944	21.981	2.700	Sag Curve	16211.944	23.606	16341.944	22.111		4815	2.077	48.148	130.000
47				Grade	16341.944	22.111	17113.721	23.655	0.200				771.777
48	17163.721	23.755	-0.400	Hog Curve	17113.721	23.655	17213.721	23.655		-25000	-0.400	250.000	100.000
49				Grade	17213.721	23.655	17465.827	23.150	-0.200				252.106
50	17515.827	23.050	1.700	Sag Curve	17465.827	23.150	17565.827	23.800		5882	1.700	58.824	100.000
51				Grade	17565.827	23.800	17633.500	24.815	1.500				67.673
52	17873.500	28.415	-3.500	Hog Curve	17633.500	24.815	18113.500	23.615		-13714	-0.729	137.142	480.000
53				Grade	18113.500	23.615	18168.508	22.515	-2.000				55.008
54	18228.508	21.315	2.300	Sag Curve	18168.508	22.515	18288.508	21.495		5217	1.917	52.174	120.000
55				Grade	18288.508	21.495	18833.773	23.131	0.300				545.265
56	18898.773	23.326	2.200	Sag Curve	18833.773	23.131	18963.773	24.951		5909	1.692	59.091	130.000
57				Grade	18963.773	24.951	19060.000	27.357	2.500				96.227
58	19400.000	35.857	-5.000	Hog Curve	19060.000	27.357	19740.000	27.357		-13600	-0.735	136.001	680.000
59				Grade	19740.000	27.357	19829.651	25.116	-2.500				89.651
60	19894.651	23.491	2.674	Sag Curve	19829.651	25.116	19959.651	23.604		4861	2.057	48.612	130.000
61				Grade	19959.651	23.604	21047.605	25.499	0.174				1087.954

1.6 Pavement Design

The basic design philosophy for the pavement is based on the consideration of providing pavement design for project specific, strong, sustainable with adverse environmental and traffic conditions Pavement structure is the most vital component of a Road and therefore its design must be assured to support the projected traffic loading throughout the design period. The purpose of pavement design and option study is to make analysis of different pavement alternatives to provide a basis for selection of the most advantageous solution, considering all costs occurring during the life of the pavement viz. construction cost, road user cost and maintenance cost.

The pavement design for flexible pavement will be done based on the IRC 37-2012 and the pavement design for rigid pavement will be done based on the IRC 58-2015.

1.6.1 Pavement Options

Option-01: Design of Flexible pavement as IRC-37 2018.

Option-02: Design of Flexible pavement with cement treated base (CTB) and cement treated sub-base (CTSB) as per IRC-37 2018.

Option-03: Design of Geo-grid Reinforced pavement section as per IRC: SP: 59-2019.

Option-04: Design of Rigid pavement as per IRC 58-2015.

1.6.2 Option-01 Flexible Pavement Design for Main Carriage way

Depending upon the available CBR and Cumulative Million Standard axles on the road, new flexible pavement may comprise of Bituminous Concrete (BC) wearing course is laid over Dense Bituminous Macadam (DBM). Underneath the DBM, Wet Mix Macadam (WMM) shall be provided to act as a base course. To ensure internal drainage of the pavement, the Granular Sub-Base (GSB) layer shall be provided under WMM course and shall be extended to full width across the shoulder on the embankment to the side drain.

1.6.2.1 Design Life

As per IRC: 37-2018 clause 4.3.1, for National Highways flexible pavement shall be designed for minimum 20 years and as per IRC: SP-84-2019 clause 5.4.2, the rigid pavement shall be designed for a minimum design period of 30 years.

1.6.2.2 Design CBR

4-days soaked CBR tests have been carried out on the subgrade soil to determine their suitability as subgrade and embankment material. Soaked CBR value of existing subgrade and barrow area varies from 6.2% to 7.1% for subgrade layer. Hence CBR of embankment soil is considered as 6%, CBR of Subgrade is considered as 8% and effective CBR of Subgrade is taken as 7.57%.

1.6.2.3 Homogeneous section for Pavement design

For the design purpose based on the traffic along the project road, the proposed alignment from Silchar to Sairang is divided into 4-homogenious sections and the details of the homogeneous section are given in below table.

Table 1.33 Details of Homogenous Section

Section	Homogenous Section	Chainage		Design Length (Km)
		Existing	Design	
Section – 1	Start point of P-1 to Vairengte	From Km 263+000 (NH-37) to 42+750 (NH-306)	From Km 0+000 to Km 46+000	46.000

1.6.2.4 Axle load survey

The axle load survey provides data to enable the assessment of the damaging effect of the loaded vehicles. The survey was carried out 48 hours using the electronic axle-weighing pad. Due to the requirement of stopping the vehicle for weighing, it was not possible to weigh all the commercial vehicles passing through the site. So commercial vehicles were weighed on a random sampling basis. About 30% to 50% of commercial vehicles in both directions were stopped for weighing in the 48-hour duration (two days) on a random sampling basis to get the vehicle Damage Factor (VDF). The time of measurement, the axle load, and the axle load group have been recorded.

Axle load pads have been calibrated on a weigh bridge before commencement of surveys. Necessary police help and other arrangements for lighting and shade have been made before the commencement of survey. Enumerators for the surveys were trained properly for the identification of axle type and vehicle type. The traffic volume survey has also been carried out in conjunction with axle load surveys.

Based on the Axle load survey data, Vehicle Damage Factor (VDF) for estimation of cumulative Million Standard Axles (MSA) for thickness design of Flexible Pavements and Spectrum of axles loads for rigid pavement design where cumulative damage principle is used for determining fatigue life of cementitious bases for heavy traffic are calculated.

The Vehicle Damage Factor (VDF) is a multiplier to convert the number of commercial vehicles of different axle loads and axle configuration into the number of repetitions of standard axle load of magnitude 80 KN. It is defined as equivalent number of standard axles per commercial vehicles. The VDF varies with the vehicle axle configuration and axle loading.

The equations for computing equivalency factors for single, tandem and tridem axles as given below has been used for converting different axle load repetitions into equivalent standard axle load repetitions.

Single axle with single wheel on either side	=	$\left(\frac{\text{axle load in KN}}{65}\right)^4$
Single axle with dual wheels on either side	=	$\left(\frac{\text{axle load in KN}}{80}\right)^4$
Tandem axle with dual wheels on either side	=	$\left(\frac{\text{axle load in KN}}{148}\right)^4$
Tridem axle with dual wheels on either side	=	$\left(\frac{\text{axle load in KN}}{224}\right)^4$

Analysis of axle load data for finding the value of VDF for individual category of commercial vehicles has been given at Chapter: 04 "Traffic Studies and Demand Forecast. Based on analysis, the VDF values of each category of commercial vehicles for the different homogeneous sections of the project road are given below;

Table 1.34 Vehicle Damage Factor (VDF)

Sl No	Section	Section (Design Chainage)	Direction	LCV	Bus	2-Axle Trucks	3-Axle Trucks	Multi Axle Trucks
1	Section 1	From Km 0+000 to Km 46+000	Silchar to Vairengte	0.63	0.79	6.44	5.49	7.88
			Vairengte to Silchar	0.03	0.78	0.54	3.06	1.52
			Adopted VDF	**0.63**	**0.79**	**6.44**	**5.49**	**7.88**

Axle load survey was carried at Km 29+200 (Ext. Chainage) and for section from 0+000 to 46+000 (Design Chainage) the VDF values/ axle load spectrum at Km 29+200 is considered.

1.6.2.5 Design commercial traffic:

The design traffic in terms of the cumulative number of standard axles to be carried during the design life of the road has been computed based on the

- Annual Average Daily Traffic of Commercial vehicles
- Annual growth rate of commercial vehicles at different horizon years.

Base year commercial traffic: The base-year (2020) average daily classified commercial traffic volumes based on the classified traffic volume count surveys carried out for the project road are given in Chapter 4: under "Traffic Studies and Demand Forecast". Since, the section from Silchar to Vairengte, the proposed alignment follows mostly green filed and partially Silchar bypass, the commercial traffic along the existing road has been considered at km 29+200 for the design of flexible pavement whereas, section from Vairengte to Sairang, traffic at location Km 98+000 being considered. The summary of the same is given in table below.

Table 1.35 Summary of commercial traffic volumes

Section (Design Chainage)	Bus	LCV	Truck		
			2 Axle	3 Axle	Multi Axle
From Km 0+000 to Km 46+000	31	235	739	283	12

Traffic Volume Growth Factor: The mode-wise percentage growth factors derived on the basis of traffic demand estimates are given in **Chapter 4 of Vol-I Main report** submitted and the summary is given in table below:

Table 1.36 Summary of Growth Factors adopted for the project road from Silchar to Vairengte

Vehicle Type	Upto 2025	2026-30	2031-35	2036-40	Beyond 2040
Bus/Minibus	5.00%	5.00%	5.00%	5.00%	5.00%
LCV	5.00%	12.40%	10.85%	5.00%	5.00%
2A Trucks	5.00%	5.00%	5.00%	5.00%	5.00%
3A Trucks	5.00%	7.00%	6.50%	6.00%	5.00%
MAV	5.00%	7.00%	6.50%	6.00%	5.00%

The details of the traffic growth rates are given in the chapter 4 Traffic report

Design Traffic Loading : As suggested in IRC: 37 – 2018, the design traffic loading is considered in terms of the cumulative number of standard axles in the lane carrying maximum traffic, to be carried during the design life of the road. Design Traffic loads were computed using the following equation:

$$N = 365 \times \left\{ (1+r)^{n-1} \right\} \times A \times D \times \frac{F}{r}$$

Where,

N	=	the cumulative number of standard axles to be catered for in the design in terms of CSA (Cumulative Standard Axles)
A	=	Initial traffic in the years of completion of construction in terms of the number of commercial vehicles per day
D	=	lane distribution factor as per IRC: 37 – 2018 (cl: 4.5.1)
F	=	Vehicle Damage Factors
n	=	Design life in years (20 years)
r	=	Annual growth rate of commercial vehicles

The traffic in the year of completion is estimated using the following formula:
$A=P\ (1+r/100)^{x}$

Where,

P	=	Number of commercial vehicles
x	=	Number of years between the count and the year of completion of construction i.e. 5 years
A	=	Traffic in the year after completion of construction
r	=	Annual growth rate of commercial vehicles

The detail calculation sheets for cumulative number of standard axles at different design period for different volume count locations have been presented in **Annexure** attached here. The design traffic volume for different design period in terms of Million Standard Axles for different section based on volume count stations of the project road is given below;

Table 1.37 Design Traffic in Million Standard Axles (MSA)

Sl. No	Section (Design Chainage)	Million Standard Axles (For both side Carriageway)				Remark
		5 Year	10 Year	15 Year	20 Year	
1	Km 0+000 to Km 46+000	9.16	16.57	26.29	38.86	Annex.6.1A

***The copy of the Annexure is attached in** Chapter 6 of Vol-I Main report.*

1.6.2.6 Design of Flexible Pavement for Main Carriageway)

The pavement design for flexible pavements for main carriageways is carried out in accordance with IRC: 37-2018 "Guidelines for the Design of Flexible Pavements and with the recommendations as per IRC: SP: 84-2019 "Manual of Specifications & Standards for Four laning of Highways with paved shoulder". IITPAVE software has been used to compute the strain of the pavement layers. To give proper consideration to the aspects of performance, the following types of pavement distress resulting from repeated (cyclic) application of traffic loads are considered.

- Vertical compressive strain at the top of the sub-grade which can cause sub-grade deformation resulting in permanent deformation at the pavement surface.
- Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the bituminous layer.
- Horizontal tensile strain or stress at the bottom of the bituminous layer which can cause fracture of the Cement Treated Base.

A flexible pavement is modelled as an elastic multilayer structure. Stress and strains at critical locations are computed using linear layered elastic model. The Stress analysis software IIT-PAVE has been used for the computation of stresses and strains in flexible pavements. Tensile strain (εt) at the bottom of the bituminous layer and the vertical subgrade strain (εv) on the top of the subgrade are conventionally considered as critical parameters for pavement design to limit cracking and rutting in the bituminous layers and non-bituminous layers respectively. Below figure shows the critical locations for stress and strain at pavement layers.

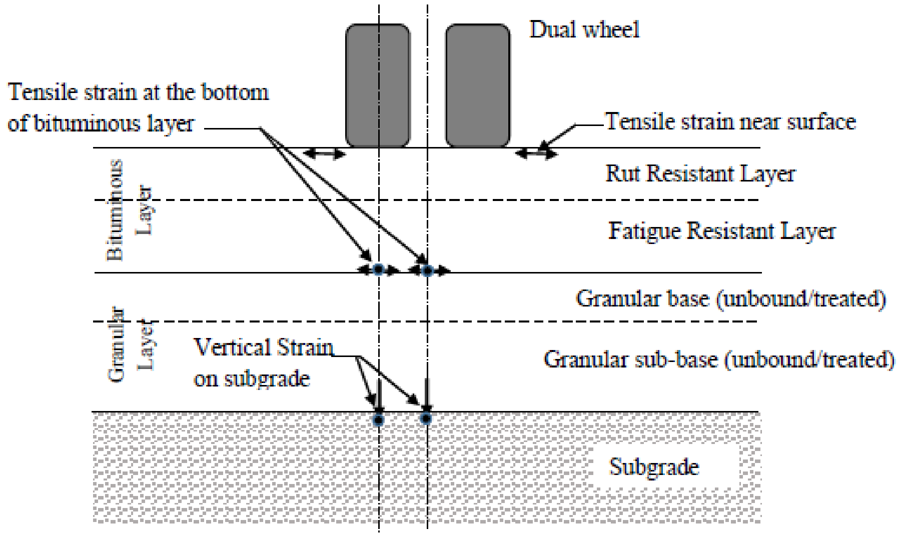


Fig 1.15 Critical locations of Stress and Strain in Flexible Pavement

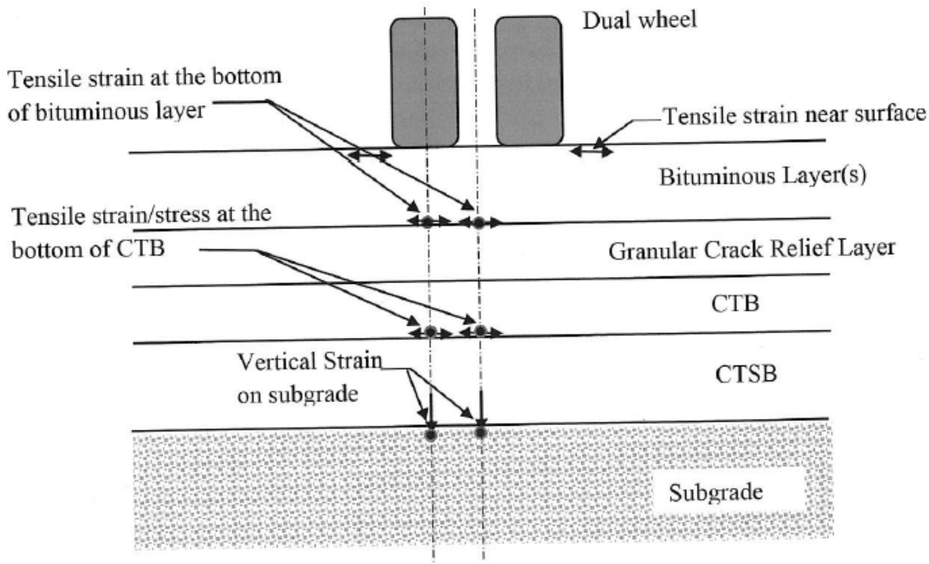


Fig 1.16 Critical locations of Stress and Strain in CTB and CTSB

1.6.2.7 Design Traffic (Million Standard Axles - MSA):

The design traffic is defined in terms of the cumulative number of standard axles in MSA that can be carried before a major strengthening, rehabilitation or capacity augmentation of the pavement is necessary. The design MSA calculation for different traffic count locations of the road has been presented at clause 6.2.7 of **Chapter 6 of Vol-I Main report**. The recommended design MSA considered for flexible pavement design is given below.

Table 1.38 Adopted MSA for different sections of the road.

Sl. No	Section (Design Chainage)	Million Standard Axles (For both side Carriageway)	Remark
		20 Year*	
1	From Km 0+000 to Km 46+000	40	

*Note: * Since, proposed road from Km 0+000 to Km 16+000 is the part of Silchar bypass and acts as common connecting road for all traffic that are coming from Meghalaya via NH-37, from Guwahati via NH-27, from Mizoram via NH-306 (oldNH-54), from Manipur via NH-37 including Silchar local traffic hence, on the safer side and sudden commercial traffic growth after COD, the DPR consultant has considered the design traffic as 40MSA for above said section.*

***Design period is considered after 4 years from base year 2020 i.e. from 2020 to 2024 due to LA process which has not been started and spill-over time period for COD.*

1.6.2.8 Pavement Material Properties

a) Properties of Subgrade

The subgrade is the top 500 mm of the embankment immediately below the bottom sub-base layer of the pavement, and is made up of in-situ material, selected soil, or stabilized soil that forms the foundation of a pavement. It should be well compacted to limit the scope of rutting in pavement due to additional densification during the service life of pavement. The selected soil forming the subgrade should have a minimum CBR of 8 per cent. Based on the test results of the existing subgrade materials, borrow area soil samples and the existing OGL soil, the recommended Effective CBR value of the proposed subgrade soils for different sections of the road is given at below table.

The behavior of the subgrade is essentially elastic under the transient traffic loading with negligible permanent deformation in a single pass. Resilient modulus is the measure of its elastic behavior determined from recoverable deformation in the laboratory tests. The Resilient Modulus is an important parameter for design and the performance of a pavement. This can be determined in the laboratory by conducting tests as per procedure specified in AASHTO T 307-99 (2003). Since the repetitive triaxle testing facility is not widely available and is expensive, the default resilient modulus can be estimated from generally acceptable correlations which are as follows.

The relations between resilient modulus and the effective CBR is given as:

M_R (MPa) = 10 x CBR for CBR < 5

M_R (MPa) = 17.6 x $(CBR)^{0.64}$ for CBR ≥5

M_R = Resilient modulus of subgrade soil.

The proposed effective CBR value adopted for different sections of the road is given below;

Table 1.39 Properties of proposed Subgrade Material

Sl No	Section (Design Chainage)	Effective CBR value in %	M_R (MPa) Resilient Modulus	μ Poisson's Ratio
1	From Km 0+000 to Km 136+400	7.57	64.29	0.35

Limiting Strain in Subgrade (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 bituminous mixes also may undergo rutting due to secondary compaction and shear deformation under heavy traffic load and higher temperature. Excessive rutting greatly reduces the serviceability of the pavement and therefore, it has to be limited to a certain reasonable value.

Subgrade strain criterion is used to limit the compressive strain in the top of subgrade to a tolerable level throughout the life of the pavement. The pavement is designed for limiting rutting as per the equations given below;

Table 1.40 Rutting Model equations

Design MSA	Reliability Factor	Equation
Less than equal to 30 MSA	80 %	$N = 4.1656 \times 10^{-08} \times [1/\varepsilon_v]^{4.5337}$
Greater than 30 MSA	90 %	$N = 1.41 \times 10^{-08} \times [1/\varepsilon_v]^{4.5337}$

Where,
N = Number of cumulative standard axles, and
ε_v = Vertical strain in the subgrade

b) Properties for Granular Sub- Base layer:

Unbound granular subbase is proposed for pavement design. The material to be used for Granular Subbase is **Crusher broken aggregate** conforming to MoRT&H Specifications. Granular subbase material is obtained from crushed natural aggregates. The Physical property of subbase is tabulated below;

Table 1.41 Physical Properties of GSB

Properties	Requirement as per MoRT&H
Water absorption value (%)	Less than 2%, if more than 2% Wet AIV should be performed.
Aggregate Impact	40 % Maximum
Liquid Limit	Maximum 25
Plasticity Index	Maximum 6
CBR at 98% dry density	Minimum 30

c) Properties for Granular Base Layer:

Unbound granular base (Wet Mix Macadam) is proposed for pavement design. The material to be used for WMM shall conform to MoRT&H specification. Granular base material is obtained from crushed natural aggregates. The physical property of WMM is tabulated in the table below.

Table 1.42 Physical properties of WMM

Properties	Requirement as per MoRT&H
Water absorption value (%)	Less than 2 %, if more than 2% soundness test should be carried out
Aggregate Impact Value	30% Maximum
Combined Flakiness and Elongation index (Total)	Maximum 35%

When both Sub-Base and Base layers are made up of granular layers, the composite resilient modulus of the granular sub-base and the base is given as:

$M_{R\_Granular} = 0.2 * h^{0.45} \times M_{R\_Subgrade}$

Where h= thickness of granular sub-base and base, mm

Poisson’s ratio of granular bases and sub-base is recommended as 0.35.

d) Properties of Bituminous Layer:

Pavement Temperature: for the purpose of design Average annual pavement temperature is considered as 35oC. For a National highway with design traffic in terms of MSA ranging from 20 to 50 MSA and less than 20 MSA, richer bituminous mixes with stiffer VG-40 binder should be used.

The Resilient Modulus of Bituminous mixes with different temperature conditions and with different grade of binders as adopted is given below;

Table 1.43 Properties of Bituminous Mixes:

Design traffic	Mix Type	Adopted weather Temperature	Resilient Modulus of Mix, (MPa)
20 MSA to 50 MSA	BC(CRMB) & DBM with VG-40 Bitumen	35°C	3000

Fatigue Criteria for Bituminous layer:

Table 1.44 Fatigue Model equations

Reliability Factor	Equation
90 %	$N = 0.516 \times C \times 10^{-04} \times [1/\varepsilon_t]^{3.89} \times [1/M_R]^{0.854}$

$C = 10^M$

M = (V_{be}/ (V_a+V_{be}))
V_a = 3.5 % (Per cent volume of air voids in the mix used in the bottom bituminous layer)
V_{be} = 11.5 % (Per cent volume of air voids in the mix used in the bottom bituminous layer)

Fatigue cracking in cement treated base layers - As per equation 3.5, IRC: 37-2018 fatigue life of cement treated layers in terms of standard axles is given below:

$N = RF\,[(113000/E^{0.804} + 191) / \varepsilon t]^{12}$

N : Fatigue life of cemented layer in number of standard axles
RF : Reliability factor (1)
E : Elastic modulus of cemented layer
εt : Allowable tensile strain at the bottom cement treated base layer

1.6.2.9 Flexible pavement design – Option 1

Pavement crust in this option has been designed by considering the following materials in different layers-

- Surface Layer - BC with (CRMB/PMB)
- Bituminous Base layer - DBM with VG40
- Granular Base layer – Wet mix macadam (WMM)
- Sub-base layer – Granular sub-base (GSB)

The Proposed pavement layer thickness is computed based on IRC: 37-2018 for a CBR of 7.57% and for the traffic as shown in below table. The pavement has been modelled as a three-layer system and strain at critical locations have been computed using the linear viscoelastic model IITPAVE analytical design of flexible pavements. The proposed crust thickness, corresponding allowable strains from fatigue/rutting models and computed strains from IITPAVE software are given below.

Table 1.45 – Proposed Pavement Crust (Option-1)

Design Period	20 Years
Design Traffic (MSA) - BT	40.0
Effective CBR of Subgrade	7.57
Grade of Bitumen for DBM	VG40
Grade of Bitumen for BC	PMB/CRMB
Bitumen Content (%)	4.50
Volume of air voids (%)	3.50

Pavement Crust (mm)	
Granular Sub-base (GSB)	200
Wet Mix Macadam (WMM)	250
Dense Bituminous Macadam (DBM)	110
Bituminous Concrete (BC)	40

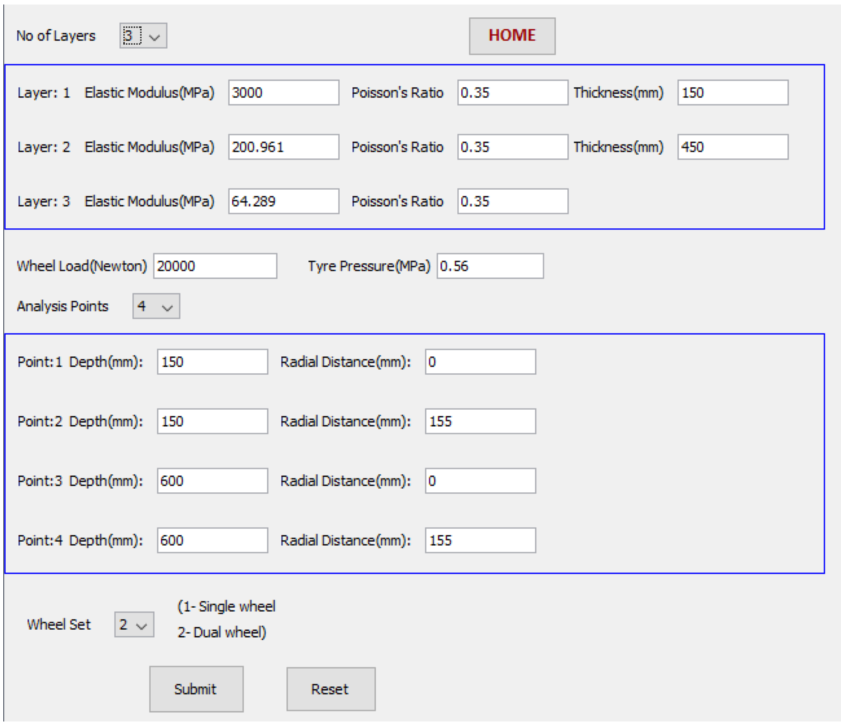
Resilient Modulus in Mpa of	
Subgrade	64.29
Granular layer (GSB+WMM)	200.96
Bituminous Layers (DBM & BC)	3000.00

Poissons Ratio (μ) of	
Subgrade	0.35
Granular layer (GSB+WMM)	0.35
Bituminous Layers (DBM & BC)	0.35

Allowable Strains	
Volume of air voids (Va)	3.50
Volume of Bitumen (Vb)	11.50
"C" Value	2.35
Horizontal tensile strain at the bottom of DBM layer (εt)	188.647E-06
Vertical strain at top of subgrade (ε_v)	390.45E-06

Computed strains	
Horizontal tensile strain at the bottom of DBM layer (εt)	185.500E-06
Vertical strain at top of subgrade (ε_v)	311.90E-06

Input Screen



Output screen

```
No. of layers                 3
E values (MPa)          3000.00   200.96   64.29
Mu values                  0.350.350.35
thicknesses (mm)         150.00   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
150.00     0.00-0.1009E+00 0.7179E+00 0.5754E+00-0.1451E-01 0.4028E+00-0.1845E-03 0.1839E-03 0.1198E-03
150.00L    0.00-0.1009E+00-0.2577E-02-0.1212E-01-0.1451E-01 0.4028E+00-0.4763E-03 0.1839E-03 0.1198E-03
150.00   155.00-0.9166E-01 0.6404E+00 0.3313E+00-0.4418E-01 0.4140E+00-0.1439E-03 0.1855E-03 0.4640E-04
150.00L  155.00-0.9167E-01-0.3156E-02-0.2386E-01-0.4419E-01 0.4140E+00-0.4091E-03 0.1855E-03 0.4640E-04
600.00     0.00-0.1789E-01 0.2562E-01 0.2264E-01-0.2750E-02 0.2910E+00-0.1731E-03 0.1192E-03 0.9919E-04
600.00L    0.00-0.1805E-01 0.1574E-02 0.6668E-03-0.2750E-02 0.2911E+00-0.2930E-03 0.1191E-03 0.1001E-03
600.00   155.00-0.1909E-01 0.2705E-01 0.2524E-01-0.3468E-02 0.2975E+00-0.1861E-03 0.1239E-03 0.1118E-03
600.00L  155.00-0.1909E-01 0.1661E-02 0.1084E-02-0.3469E-02 0.2975E+00-0.3119E-03 0.1239E-03 0.1118E-03
```

1.6.2.10 Flexible pavement design – Option 2

Pavement crust in this option has been designed by considering the following materials in different layers-

- Surface Layer - BC with (CRMB/PMB)
- Bituminous Base layer - DBM with VG40
- Aggregate inter layer - Wet mix macadam (WMM)
- Bound Base layer – Cement treated Wet mix macadam (CT-WMM)
- Sub-base layer – Cement Treated Granular sub-base (CT-GSB)

The Proposed pavement layer thickness is computed based on IRC: 37-2018 for a CBR of 7.57% and for the traffic as shown in below table. The proposed crust thickness, corresponding allowable strains from fatigue/rutting models and computed strains from IITPAVE software are given below.

Table 1.46 – Proposed Pavement Crust (Option-2)

Design Period	20 Years
Design Traffic (MSA)	40.0
Grade of Bitumen for DBM	VG40
Grade of Bitumen for BC	PMB/CRMB
Volume of Bitumen (%) Vbe	11.50
Volume of Air Voids (%) Va	3.50
CBR of embankment soil (Upper 500mm)	6.00
CBR of Subgrade (%)	8.00
Effective CBR of Subgrade (%)	7.57

Pavement Crust (mm)	
Cement Treated Sub-base (CTGSB)	200 mm
Cement Treated Base (CTWMM)	165 mm
Crack Relief Layer (WMM)	100 mm
Dense Bituminous Macadam (DBM)	80 mm
Bituminous Concrete (BC)	40 mm

Resilient Modulus in Mpa of	
Subgrade	64.27
Cement Treated Sub-base (CTGSB)	600.00

Cement Treated Base (CTWMM)	5000.00
Crack Relief Layer (WMM)	450.00
Bituminous Layers (DBM & BC)	3000.00

Poissons Ratio (μ) of	
Subgrade	0.35
Cement Treated Sub-base (CTGSB)	0.25
Cement Treated Base (CTWMM)	0.25
Crack Relief Layer (WMM)	0.35
Bituminous Layers (DBM & BC)	0.35

Allowable Strains	
Volume of Air Voids (%) Va	3.50
Volume of Bitumen (%) Vbe	11.50
"C" Value	2.35
Tensile strain at the bottom of DBM layer (εt)	188.65E-06
Compressive strain at top of subgrade (ε_v)	390.45E-06
Tensile strain at the bottom of CTB layer (εt)	072.31E-06

Computed strains	
Horizontal tensile strain at the bottom of DBM layer (εt)	113.2 E-06
Vertical strain at top of subgrade (εv)	182.8 E-06
Tensile strain at the bottom of CTB layer (εt) with 0.80 Mpa tyre contact pressure	045..4 E-06

Input Screen

No of Layers: 5 | HOME

Layer	Elastic Modulus(MPa)	Poisson's Ratio	Thickness(mm)
Layer: 1	3000	0.35	120
Layer: 2	450	0.35	100
Layer: 3	5000	0.25	165
Layer: 4	600	0.25	200
Layer: 5	64.289	0.35	

Wheel Load(Newton): 20000 Tyre Pressure(MPa): 0.56

Analysis Points: 6

Point	Depth(mm)	Radial Distance(mm)
Point:1	120	0
Point:2	120	155
Point:3	385	0
Point:4	385	155
Point:5	585	0
Point:6	585	155

Wheel Set: 2 (1- Single wheel 2- Dual wheel)

Output Screen

```
No. of layers                5
E values (MPa)         3000.00  450.00 5000.00  600.00   64.29
Mu values                 0.350.350.250.250.35
thicknesses (mm)        120.00  100.00  165.00  200.00
single wheel load (N) 20000.00
tyre pressure (MPa)       0.56
Dual  Wheel
  Z        R      SigmaZ      SigmaT      SigmaR     TaoRZ      DispZ      epZ        epT         epR
120.00    0.00-0.2222E+00 0.3575E+00 0.2732E+00-0.1511E-01 0.2662E+00-0.1477E-03 0.1132E-03 0.7528E-04
120.00L   0.00-0.2222E+00-0.4810E-01-0.6075E-01-0.1511E-01 0.2662E+00-0.4092E-03 0.1132E-03 0.7528E-04
120.00  155.00-0.1708E+00 0.2015E+00-0.1278E+00-0.6968E-01 0.2641E+00-0.6555E-04 0.1020E-03-0.4617E-04
120.00L 155.00-0.1708E+00-0.4797E-01-0.9736E-01-0.6968E-01 0.2641E+00-0.2666E-03 0.1020E-03-0.4617E-04
385.00    0.00-0.3281E-01 0.2532E+00 0.2070E+00-0.1215E-01 0.2327E+00-0.2957E-04 0.4193E-04 0.3038E-04
385.00L   0.00-0.3281E-01 0.2076E-01 0.1521E-01-0.1215E-01 0.2327E+00-0.6967E-04 0.4193E-04 0.3038E-04
385.00  155.00-0.3641E-01 0.2728E+00 0.2324E+00-0.2070E-01 0.2372E+00-0.3254E-04 0.4476E-04 0.3465E-04
385.00L 155.00-0.3641E-01 0.2205E-01 0.1720E-01-0.2070E-01 0.2372E+00-0.7704E-04 0.4476E-04 0.3465E-04
585.00    0.00-0.1087E-01 0.4856E-01 0.4270E-01-0.1535E-02 0.2214E+00-0.5614E-04 0.6767E-04 0.5547E-04
585.00L   0.00-0.1088E-01 0.5223E-03-0.5725E-04-0.1535E-02 0.2214E+00-0.1718E-03 0.6767E-04 0.5550E-04
585.00  155.00-0.1148E-01 0.5123E-01 0.4748E-01-0.2013E-02 0.2249E+00-0.6026E-04 0.7038E-04 0.6257E-04
585.00L 155.00-0.1148E-01 0.5808E-03 0.2087E-03-0.2013E-02 0.2249E+00-0.1828E-03 0.7038E-04 0.6257E-04
```

Check for fatigue cracking in cementations layers using cumulative damage analysis:

The thickness of cement treated base layer is first evaluated from fatigue considerations in terms of cumulative standard axles and corresponding tensile stresses at the bottom of cement treated base layer due to individual wheel load was computed using IITPAVE software.

Since there are plenty of single, tandem and Tridem axle loads which are far higher than standard axle load used for pavement design, thickness of cemented layer is checked for sudden fracture of cemented base due to higher axle loads using cumulative damage principle. Axle weights of tandem and Tridem axle are taken as equivalent to two and three single axles respectively. The fatigue life has been calculated using the following equation.

Where,

$$\text{Log } N_{fi} = \frac{0.972 - (\sigma_t / M_{Rup})}{0.0825}$$

Nfi : Fatigue life in terms of cumulative number of axle load of class i
σt : tensile stress under cement treated base layer
Mrup : 28 day flexural strength of cement treated base layer

Computed Tensile stress below cement treated base layer – 0.354 (From IITPAVE); Flexural strength of cement treated base layer – 1.4 Mpa

Cumulative fatigue damage analysis has been carried out for all axle configurations and is given below:

Table 1.47 Commercial vehicles (nos.)

Year	in both directions					Total Veh. in one direction per year	Cumulative Comm Veh.
	Bus	LCV	2A Truck	3A Truck	M Axle Truck		
2020	34	238	862	166	62	497261	
2021	36	250	905	174	65	522125	
2022	37	262	950	183	69	548231	
2023	39	276	998	192	72	575642	
2024	41	289	1048	202	76	604424	
2025	43	304	1100	212	79	634646	634646
2026	46	319	1155	223	83	666378	1301024
2027	48	355	1213	238	89	709092	2010116
2028	50	394	1273	255	95	754897	2765013
2029	53	438	1337	273	102	804048	3569061

Year	in both directions					Total Veh. in one direction per year	Cumulative Comm Veh.
	Bus	LCV	2A Truck	3A Truck	M Axle Truck		
2030	55	487	1404	292	109	856821	4425882
2031	58	541	1474	312	117	913521	5339403
2032	61	594	1548	333	124	970931	6310334
2033	64	652	1625	354	133	1032279	7342613
2034	67	715	1707	377	141	1097861	8440474
2035	71	785	1792	402	150	1167998	9608472
2036	74	862	1881	428	160	1243035	10851507
2037	78	905	1976	454	170	1307333	12158840
2038	82	950	2074	481	180	1374975	13533814
2039	86	998	2178	510	191	1446135	14979950
2040	90	1048	2287	540	202	1520998	16500948
2041	95	1100	2401	573	214	1599758	18100706
2042	99	1155	2521	601	225	1679746	19780452
2043	104	1213	2647	631	236	1763733	21544185
2044	110	1273	2780	663	248	1851920	23396105

Total Number cumulative commercial vehicles in the design year (2044) – 23396105

Table 1.48 Cumulative Fatigue Damage Analysis – Option 2

Axle load in KN	Expected single axle repetitions (ni)	Tensile Stress at the bottom of CTB σt, in Mpa	Stress Ratio (σt/Mrup)	Fatigue life (Nf)	Fatigue life consumed (ni/Nf)
Single Axles					
190	188787	0.63	0.45	2.35E+06	0.080
180	283181	0.59	0.42	4.52E+06	0.063
170	283181	0.56	0.40	8.71E+06	0.033
160	943935	0.53	0.38	1.68E+07	0.056
150	1038329	0.49	0.35	3.23E+07	0.032
140	1415903	0.46	0.33	6.23E+07	0.023
130	1793477	0.43	0.31	1.20E+08	0.015
120	1510296	0.39	0.28	2.31E+08	0.007
110	1415903	0.36	0.26	4.46E+08	0.003

Axle load in KN	Expected single axle repetitions (ni)	Tensile Stress at the bottom of CTB σt, in Mpa	Stress Ratio (σt/Mrup)	Fatigue life (Nf)	Fatigue life consumed (ni/Nf)
100	1038329	0.33	0.23	8.59E+08	0.001
90	1887870	0.30	0.21	1.65E+09	0.001
85	19917030	0.28	0.20	2.30E+09	0.009
Cumulative Fatigue Damage in CTB due to Single Axles					**0.322**
Tandem Axles					
400	0	0.66	0.47	1.22E+06	0.000
380	0	0.63	0.45	2.35E+06	0.000
360	0	0.59	0.42	4.52E+06	0.000
340	579726	0.56	0.40	8.71E+06	0.067
320	0	0.53	0.38	1.68E+07	0.000
300	1159453	0.49	0.35	3.23E+07	0.036
280	2318906	0.46	0.33	6.23E+07	0.037
260	3478359	0.43	0.31	1.20E+08	0.029
240	7536444	0.39	0.28	2.31E+08	0.033
220	3478359	0.36	0.26	4.46E+08	0.008
200	9275624	0.33	0.23	8.59E+08	0.011
180	11594530	0.30	0.21	1.65E+09	0.007
170	26087692	0.28	0.20	2.30E+09	0.011
Cumulative Fatigue Damage in CTB due to Tandom Axles					**0.238**
Tridem Axles					
600	0	0.66	0.47	1.22E+06	0.000
570	0	0.63	0.45	2.35E+06	0.000
540	0	0.59	0.42	4.52E+06	0.000
510	0	0.56	0.40	8.71E+06	0.000
480	0	0.53	0.38	1.68E+07	0.000
450	0	0.49	0.35	3.23E+07	0.000
420	0	0.46	0.33	6.23E+07	0.000
390	0	0.43	0.31	1.20E+08	0.000
360	0	0.39	0.28	2.31E+08	0.000
330	0	0.36	0.26	4.46E+08	0.000
300	0	0.33	0.23	8.59E+08	0.000

Axle load in KN	Expected single axle repetitions (ni)	Tensile Stress at the bottom of CTB σt, in Mpa	Stress Ratio (σt/Mrup)	Fatigue life (Nf)	Fatigue life consumed (ni/Nf)
270	14037663	0.30	0.21	1.65E+09	0.008
255	84225978	0.28	0.20	2.30E+09	0.037
Cumulative Fatigue Damage in CTB due to Tridem Axles					**0.045**

Cumulative Fatigue Damage			
Due to Single Axles	Due to Tandem Axles	Due to Tridem Axles	Total CFD
0.322	0.238	0.045	0.606

The cumulative fatigue life consumed is less than 1, the design is safe from fatigue considerations. Similar analysis has been carried out for other option also and summary is given below:

1.6.2.11 Option 03: Flexible Pavement Design with Geo grid provision in hill / mountainous region

Pavement crust in this option has been designed by considering the following materials in different layers-

- Surface Layer - BC with (CRMB/PMB)
- Bituminous Base layer - DBM with VG40
- Biaxial Geo-grid
- Granular Base layer – Wet mix macadam (WMM)
- Sub-base layer – Granular sub-base (GSB)

Table 1.49 Proposed Pavement Crust (Option-3)

Design Period	20 Years
Design Traffic (MSA) - BT	40.0
Effective CBR of Subgrade	7.57
Grade of Bitumen for DBM	VG40
Grade of Bitumen for BC	PMB/CRMB
Bitumen Content (%)	4.50
Volume of air voids (%)	3.50

Pavement Crust (mm)	
Granular Sub-base (GSB)	300
Wet Mix Macadam (WMM)	150
Geo-Grid	Biaxial
Dense Bituminous Macadam (DBM)	60
Bituminous Concrete (BC)	40

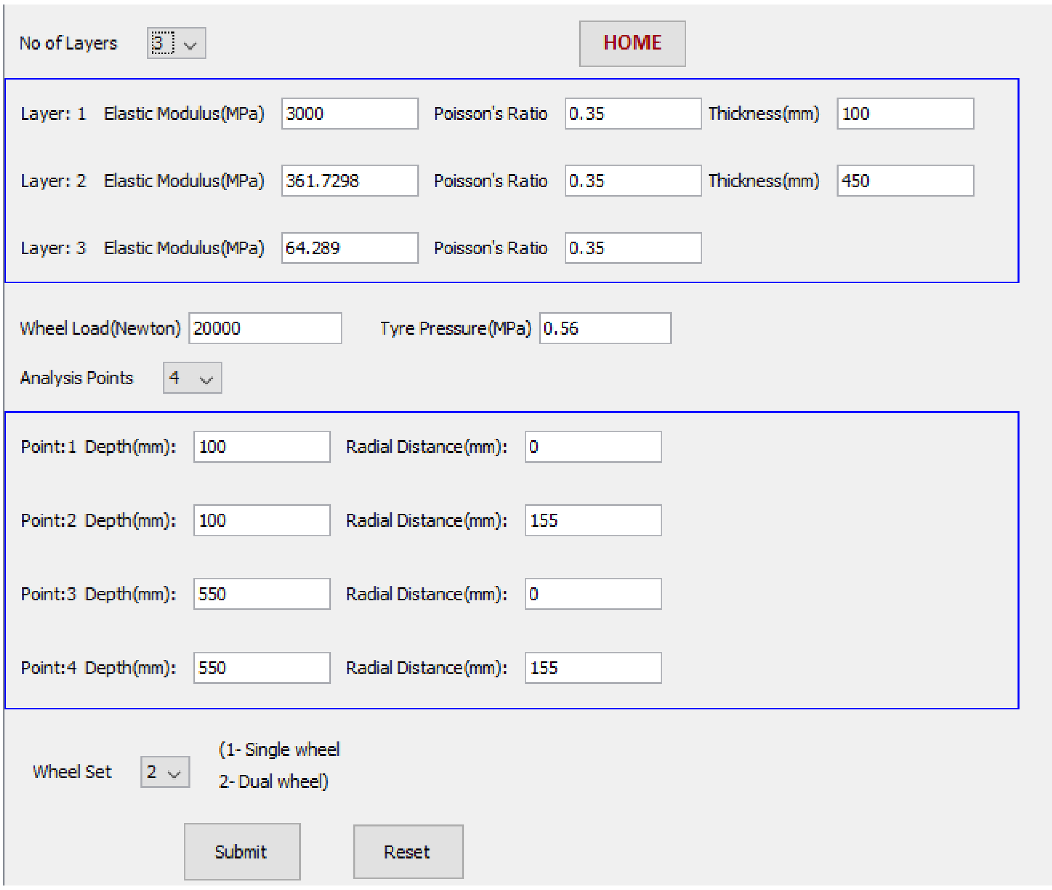
Resilient Modulus in Mpa of	
Subgrade	64.29
Granular layer (GSB+WMM)	361.73
Bituminous Layers (DBM & BC)	3000.00

Poissons Ratio (μ) of	
Subgrade	0.35
Granular layer (GSB+WMM)	0.35
Bituminous Layers (DBM & BC)	0.35

Allowable Strains	
Volume of air voids (Va)	3.50
Volume of Bitumen (Vb)	11.50
"C" Value	2.35
Horizontal tensile strain at the bottom of DBM layer (εt)	188.647E-06
Vertical strain at top of subgrade (ε_v)	390.45E-06

Computed strains	
Horizontal tensile strain at the bottom of DBM layer (εt)	186.900E-06
Vertical strain at top of subgrade (ε_v)	327.40E-06

Input Screen



Output screen

```
No. of layers                 3
E values (MPa)          3000.00   361.73   64.29
Mu values                  0.350.350.35
thicknesses (mm)         100.00   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
100.00    0.00-0.2119E+00 0.6754E+00 0.5392E+00-0.2063E-01 0.3943E+00-0.2123E-03 0.1869E-03 0.1257E-03
100.00L   0.00-0.2119E+00-0.1891E-01-0.3533E-01-0.2063E-01 0.3943E+00-0.5333E-03 0.1869E-03 0.1257E-03
100.00  155.00-0.1489E+00 0.4523E+00-0.3536E-01-0.1000E+00 0.3969E+00-0.9829E-04 0.1723E-03-0.4718E-04
100.00L 155.00-0.1489E+00-0.1598E-01-0.7479E-01-0.1000E+00 0.3969E+00-0.3239E-03 0.1723E-03-0.4719E-04
550.00    0.00-0.1848E-01 0.5690E-01 0.4970E-01-0.3083E-02 0.2891E+00-0.1542E-03 0.1271E-03 0.1002E-03
550.00L   0.00-0.1860E-01 0.1856E-02 0.5722E-03-0.3091E-02 0.2891E+00-0.3025E-03 0.1270E-03 0.1001E-03
550.00  155.00-0.1995E-01 0.6099E-01 0.5601E-01-0.4223E-02 0.2963E+00-0.1684E-03 0.1337E-03 0.1151E-03
550.00L 155.00-0.1995E-01 0.2005E-02 0.1119E-02-0.4302E-02 0.2963E+00-0.3274E-03 0.1337E-03 0.1151E-03
```

As shown in above table it is observed that by introducing geo-grid over GSB layer will reduce the thickness of WBM by 45mm and WMM by 100mm. The cost difference per Km between conventional flexible pavement and Flexible pavement with geo-grid provision is App. 50 lack per km i.e. Flexible pavement is costlier that reinforced geo-grid pavement. Flexible pavement works out to be cheaper by 10 lack per km compared to Flexible pavement with cement treated base and sub base.

Moreover, the CBR of existing soil is less and the availability of aggregate material along the project road is less due to lack of availability of Stone aggregate.

Hence, DPR consultant has recommended Reinforced geogrid flexible pavement.

1.6.3 Option 04: Rigid Pavement Design for Main Carriageway

Cement concrete pavements are subjected to stresses due to a variety of factors acting simultaneously. The severest combination of different factors that induce the maximum stress in the pavement will give the critical stress condition

The factors commonly considered for the design of pavement thickness are flexural Stresses due to traffic loads and temperature differentials between the top and bottom fibers of the concrete slab, as the two are assumed to be additive under critical condition. The maximum combined tensile stress in three regions of the slab will thus be caused when effects of temperature differential are such as to be additive to the load effects. This would occur during the day in case of interior and edge regions at the time of maximum temperature differential in the slab. In the corner region temperature stress is negligible but the load stress is maximum at night when the slab corners have a tendency to lift up due to warping and loose partly the foundation support. Considering the total combined stress for the three regions i.e. corner, edge and interior, for which the load stresses decreases in that order while the temperature stress increases. The critical stress condition is reached in the edge region. The effective modulus of Subgrade reaction (k) is obtained based on the Subgrade CBR. The axle loads are divided into axle load spectrum and pavement is checked for the cumulative fatigue damage for night and day traffic.

1.6.3.1 Wheel load

The legal axle load limits in India are 10.2, 19 and 24 tonnes for single axle, tandem axle and Tridem axles respectively. However, the design axle loads for the project road has been arrived through the axle load surveys conducted along the project road 2020. The details of axle load surveys are given in Traffic Report.

1.6.3.2 Tyre Pressure

Tyre pressures and shape of contact areas of the commercial vehicles (CV) also govern load stresses. For most of the commercial vehicles, it ranges from 0.7 to 1 MPA, but it is found that stresses in concrete pavements having thickness of 20cm or more are not affected significantly by the variation of tyre pressure. A tyre pressure of 0.8 MPa has been adopted for design as per section 5.2 of IRC: 58-2015.

1.6.3.3 Design Traffic

As per clause 5.5.2.2 and 5.5.2.3 of IRC:58-2015, Design traffic for bottom-up cracking and top-down cracking shall be 25% and 12.5% of total traffic in the direction of predominant traffic. The cumulative number of axles during the design period have been computed using the below equation.

$$C = \frac{365 \times [(1+r)^n - 1]}{r} \times A$$

C= Cumulative number of axles during the design period
A= Initial number of axles per day in the year when the road is operations.
r = Annual rate of growth of commercial vehicles traffic.
n = Design period in years.

Expected number of applications of different axle load groups during the design period is estimated from the axle load spectrum.

1.6.3.4 Temperature Differential

Temperature differential between the top and bottom of concrete pavements causes the concrete slab to warp, giving rise to stresses. For the slab proposed thickness of 300 mm for main carriageway, the temperature differential adopted is 16 0C /14.3 0C as given in table 1 of IRC: 58-2015.

Table 1.50 Temperature Differential

Zone	State / Region	Max. temperature differential °C in Slab thickness			
		150 mm	200 mm	250 mm	300 to 400 mm
III	Assam	15.6	16.4	16.6	16.8
I	Hilly Region	12.5	13.1	14.3	15.8

1.6.3.5 Characteristics of Sub grade and Sub base

The strength of Subgrade is expressed in terms of modulus of Subgrade reaction (k). It is obtained from Table 2 of IRC: 58-2015 for the design CBR. A Dry Lean Concrete (DLC) subbase is generally recommended for modern concrete pavements particularly those with high intensity of traffic. The effective modulus of sub grade reaction over DLC is obtained from Table 4 of IRC: 58-2015.

Design CBR of subgrade is 8 is considered for Silchar to Vairengte section and 8 is considered for Vairengte to Sairang section, k value corresponding 8% CBR is 50.3 MPa/m and effective k over 150mm DLC is 285 MPa/m.

1.6.3.6 Characteristics of Sub grade and Sub base

- The strength of Subgrade is expressed in terms of modulus of Subgrade reaction (k). It is obtained from Table 2 of IRC: 58-2015 for the design CBR. A Dry Lean Concrete (DLC) sub base is generally recommended for modern concrete pavements particularly those with high intensity of traffic. The effective modulus of sub grade reaction over DLC is obtained from Table 4 of IRC: 58-2015.

- Design CBR of subgrade is 8 is considered for Silchar to Vairengte section and 8 is considered for Vairengte to Sairang section, k value corresponding 8% CBR is 50.3 MPa/m and effective k over 150mm DLC is 285 MPa/m.

1.6.3.7 Characteristics of Concrete

- Dry Lean Concrete (DLC) conforming to MORTH specifications shall be provided as base course. The DLC shall have average 7 day strength of 7 MPa as per IRC: SP: 49. DLC shall have thickness of 150mm and shall extend beyond the PQC by 0.75 m or as required for facilitating the paver movement

- The Pavement Quality Concrete (PQC) shall conform to MORTH specifications and shall have 28 day flexural strength of 4.5 MPa. The design parameters of PQC have been considered in accordance with IRC: 58-2015 and the same have been shown in Table below.

Table 1.51 Characteristics of Concrete

Elastic Modulus of PQC, MPa	30000
Poisson's Ratio (μ)	0.15
Unit weight of PQC, kN/m3	24
28 days flexural strength, MPa	4.5
Grade of Concrete	M40

1.6.3.8 Fatigue behaviour of Cement Concrete

Due to repeated application of Flexural stresses by the traffic loads, progressive fatigue damage takes place in the cement concrete slab in the form of gradual development of micro cracks especially when the applied stress in terms of Flexural strength of concrete is high. The ratio between the Flexural stress due to the load and Flexural strength of the concrete is termed as Stress Ratio (SR). If the SR is less than 0.45 the concrete is expected to sustain infinite number of repetitions. As the SR increases the number of load repetitions (N) required to cause cracking decreases.

N = Infinite for SR <0.45

$$N = \left[\frac{4.2577}{SR-0.4325}\right]^{3.268}$$ When 0.45 <= SR <= 0.55

$$\log_{10} N = \frac{0.9718 - SR}{0.0828} \quad for\ SR > 0.55$$

1.6.3.9 Stress Calculation:

For bottom-up cracking, Stresses are calculated using regression equations V.1 given in Appendix - V of IRC: 58-2015.

For top-down cracking, Stresses are calculated by using regression equations V.2 shown in Appendix - V of IRC: 58-2015.

1.6.3.10Dowel bars at Transverse Joints

Load transfer to relieve part of the load stresses in edge and corner regions of pavement slab at transverse joints is provided by means of mild steel round dowel bars at transverse joints.

The bearing stress in concrete is responsible for the performance of dowel bars at the joints. High concrete bearing stress can fracture the concrete surrounding the dowel bars, leading to the looseness of the dowel bar and the deterioration of the load transfer system with eventual faulting of the slab. Larger diameter dowel bars are found to provide better performance.

Maximum bearing stress between the concrete and dowel bar is obtained from the equation:

$$\sigma_{max} = \frac{KP_t}{4\beta^3 EI}(2 + \beta z) \qquad \beta = \sqrt[4]{\frac{kb}{4EI}}$$

β = Relative stiffness of the bar embedded in concrete.
K = Modulus of dowel/concrete interaction (dowel support, MPa/m)
b = Diameter of the dowel, m
z = Joint width (5 mm for contraction joint and 20mm for expansion joint)
E = Modulus of the elasticity of the dowel, MPa
I = Moment of inertia of the dowel, mm4
Pt= Load transferred by a dowel bar, KN.

Modulus of dowel support is 415,000 MPa/M. Each dowel bar should transfer load that is less than design load for the maximum bearing pressure. The allowable bearing stress is calculated by using the equation presented below.

$$F_b = \frac{(10.16 - b)f_{ck}}{9.525}$$

Where;
Fb = Allowable bearing stress, MPa
B = Dowel diameter, mm
fck = Ultimate compressive strength of concrete, MPa (For M40 concrete, fck = 40 MPa (28 days) and 48 MPa (90 days)

1.6.3.11 Tie bars at Longitudinal Joints

Tie bars are used across the joints of concrete pavements wherever it is necessary or desirable to ensure firm contact between slab faces or to abutting slabs from separating. The area of steel required per meter length is computed by using the following formula:

$$A_s = \frac{bfW}{S}$$

Where;
A = Area if steel in mm2 required for per meter length of joint
b = Distance between the joint in question and nearest free joint or edge in m
f = Co-efficient of friction between pavement and Sub grade (usually taken at 1.5)
W = Weight of pavement slab per sq meter in kg, i.e., 24 KN/sqm per cm thickness and
S = Allowable working stress of steel in kg/sqm

Length of any tie bar should be at least twice that required to develop bond strength equal to the working stress of the steel. It is calculated by using the equation shown below.

$$L = \frac{2SA}{BP}$$

Where;
L = Length of tie bar, cm
S = Allowable working stress in steel, MPa
A = Cross-sectional area of one tie bar mm2
B = Maximum permissible bond stress, MPa

1.6.3.12 Design of Slab Thickness for Section from Km 0+000 to Km 46+000 (Design Chainage)

The pavement composition is calculated for the traffic survey carried out at Km 29+200 (Existing chainage). The loading pattern between Silchar to Vairengte is more critical as compared to the loading pattern between Vairengte to Silchar.

The input data considered and detailed design calculations are given below:

Pavement Structure Details

Design Period	=	30	Years
Thickness of Subgrade	=	0.500	m
Thickness of Granular Sub base (GSB)	=	0.150	m
Thickness of Dry Lean Concrete (DLC)	=	0.150	m
Thickness of Pavement Quality Concrete (PQC), h	=	0.270	m
Effective CBR of compacted subgrade	=	8	
Modulus of subgrade reaction of subgrade	=	50.3	Mpa/m
Modulus of subgrade reaction of foundation (Subgrade, GSB, DLC)	=	284.67	Mpa/m
Unit weight of concrete	=	24	KN/m3
Grade of Concrete	=	40	
28 day Flexural strength of cement concrete	=	4.5	Mpa
Modulus of elasticity of concrete, E	=	30000	Mpa
Poisson's ratio, μ	=	0.15	
Radius of relative stiffness, l	=	0.684	
Coefficient of thermal expansion of concrete, ∝	=	10×10^{-6}	per ^{0}C
Maximum day-time temperature differential in slab (for bottom-up cracking)	=	16.6	^{0}C
Night-time temperature differential in slab (for top-down cracking)	=	13.3	^{0}C

If two texturing is considered in a design life of 30 years, a thickness of 0.28 m will be appropriate.

Spacing of Transverse Joints (L)	=	3.50	m
Maximum Spacing of Longitudinal Joints (W)	=	4.50	m
Diameter of dowel bars	=	36	mm
Spacing between dowels	=	300	mm
Length of dowel bar	=	450	mm
Diameter of tie bar (Deformed)	=	12	mm
Spacing of tie bar	=	460	mm
Length of tie bar	=	640	mm

1.6.3.13 Projected commercial traffic:

The base year traffic has been projected for the period of 30 years with the above growth rates and given in the following table along with year-wise cumulative number of commercial vehicles.

Table 1.52 Cumulative number of commercial vehicles at Ch 7+100

Year	@ Km 29+200 (Existing Chainage)					Total Vehicle in both directions per year	Cumulative Vehicle in both directions
	Bus	LCV	2A Truck	3A Truck	Multi Axle Truck		
2020	31	235	739	283	12	474420	Design, Land acquisition and Construction period
2021	32	247	776	297	13	498141	
2022	34	259	815	312	13	523048	
2023	36	272	856	327	14	549200	
2024	38	286	898	344	15	576660	
2025	39	300	943	361	15	605493	605493
2026	41	315	990	379	16	635768	1241261
2027	43	354	1040	406	17	678948	1920209
2028	46	398	1092	434	18	725545	2645754
2029	48	447	1146	464	20	775873	3421627
2030	50	503	1204	497	21	830282	4251909
2031	53	565	1264	532	22	889156	5141065
2032	55	626	1327	566	24	948714	6089779
2033	58	694	1394	603	25	1012757	7102536
2034	61	770	1463	642	27	1081663	8184199
2035	64	853	1536	684	29	1155847	9340045
2036	67	946	1613	728	31	1235761	10575807
2037	71	993	1694	772	33	1300320	11876127
2038	74	1043	1779	818	35	1368274	13244401
2039	78	1095	1867	868	37	1439801	14684202
2040	82	1150	1961	920	39	1515091	16199293

Year	@ Km 29+200 (Existing Chainage)					Total Vehicle in both directions per year	Cumulative Vehicle in both directions
	Bus	LCV	2A Truck	3A Truck	Multi Axle Truck		
2041	86	1207	2059	975	41	1594344	17793638
2042	90	1268	2162	1024	43	1674062	19467699
2043	95	1331	2270	1075	45	1757765	21225464
2044	100	1397	2383	1128	48	1845653	23071117
2045	105	1467	2503	1185	50	1937936	25009052
2046	110	1541	2628	1244	53	2034832	27043885
2047	115	1618	2759	1306	55	2136574	29180459
2048	121	1699	2897	1372	58	2243403	31423861
2049	127	1784	3042	1440	61	2355573	33779434
2050	133	1873	3194	1512	64	2473351	36252786
2051	140	1966	3354	1588	67	2597019	38849805
2052	147	2065	3521	1667	70	2726870	41576675
2053	147	2066	3523	1668	70	2728233	44304908
2054	147	2067	3525	1669	71	2729598	47034506

1.6.3.14 Design Traffic Estimation

a) at Km 29+200 (Ext. Chainage)

Design Period (years)	30
Cumulative No of Commercial vehicles during design period (two-way), **A**	43290066
% of Day Traffic (8 AM to 8 PM)	46%
% of Night Traffic (8 PM to 8 AM)	54%
Average No of axles per commercial vehicle, **B**	2.00
Cumulative No of Commercial Axles during design period (two-way), **C = A*B**	86580132
Proportion of traffic in predominant direction, **D**	49%
Lateral Placement factor, **E = 0.25*D**	10606066
Factor for selection of traffic for BUC analysis (for six-hour period	0.23

during day), **F**	
Factor for selection of traffic for TDC analysis (for six-hour period during day), **G**	0.27
Design axle repetitions for BUC analysis (for 6 hour day time traffic), **H = C*E*F**	2437580
Proportion of vehicles with spacing between front and the first rear axle less than the spacing of transverse joints, **I**	19.15%
Design axle repetitions for TDC analysis (for 6-hour night time traffic), **J = C*E*G*I**	548803
Proportion of Front single (steering) Axles, **K1** (As per Axle load surveys)	0.502
Proportion of Rear single Axles,**K2** (As per Axle load surveys)	0.180
Proportion of Tandem Axles, **K3** (As per Axle load surveys)	0.316
Proportion of Tridem Axles, **K4 = (1-K1-K2-K3)**	0.002
Design Axle Load Repetitions for Fatigue Analysis	
For Bottom-up Cracking Analysis	
Front single (steering) Axles = H * K1	1223665
Rear single Axles = H * K2	438764
Tandem Axles = H * K3	770275
Tridem Axles = H * K4	4875
For Top-Down Cracking Analysis	
Front single (steering) Axles = J * K1	275499
Rear single Axles = J * K2	98785
Tandem Axles = J * K3	173422
Tridem Axles = J * K4	1098

1.6.3.15 Axle load spectrum

Expected number of applications of different axle load groups has been estimated using the details of commercial traffic volume, expected rate of growth of commercial traffic. As per the axle load surveys conducted, the loading pattern in the stretch between Silchar to Vairengte is more critical than between Vairengte to Silchar. The axle load spectrum corresponding to Km 29+200 (existing Chainage) is considered and is given below:

Table 1.53 Axle load spectrum

Load (KN)	% of Vehicles at Ch 29+200 Km (Existing Chainage)					
	Silchar To Vairengte			Vairengte To Silchar		
	Single Axle	Tandem Axle	Tridem Axle	Single Axle	Tandem Axle	Tridem Axle
0-85	52.98	9.65	0.00	97.67	69.79	50.00
85-95	14.39	11.40	0.00	0.78	13.54	0.00
95-105	5.61	0.00	0.00	0.39	3.13	0.00
105-115	3.51	0.00	0.00	0.39	5.21	50.00
115-125	4.56	0.88	0.00	0.39	1.04	0.00
125-135	5.96	8.77	0.00	0.00	0.00	0.00
135-145	3.16	0.88	0.00	0.00	1.04	0.00
145-155	3.86	4.39	0.00	0.00	0.00	0.00
155-165	1.40	0.88	0.00	0.00	1.04	0.00
165-175	1.40	7.89	0.00	0.00	0.00	0.00
175-185	1.05	3.51	0.00	0.00	0.00	0.00
185-195	1.40	0.88	0.00	0.39	2.08	0.00
195-205	0.70	7.02	0.00	0.00	0.00	0.00
205-215	0.00	7.02	0.00	0.00	0.00	0.00
215-225	0.00	1.75	0.00	0.00	1.04	0.00
225-235	0.00	0.88	0.00	0.00	0.00	0.00
235-245	0.00	10.53	0.00	0.00	0.00	0.00
245-255	0.00	10.53	0.00	0.00	0.00	0.00
255-265	0.00	0.88	0.00	0.00	0.00	0.00
265-275	0.00	6.14	0.00	0.00	0.00	0.00
275-285	0.00	3.51	0.00	0.00	0.00	0.00
285-295	0.00	0.88	0.00	0.00	0.00	0.00
295-305	0.00	0.88	0.00	0.00	0.00	0.00
305-315	0.00	0.88	0.00	0.00	0.00	0.00
315-325	0.00	0.00	0.00	0.00	0.00	0.00
325-335	0.00	0.00	0.00	0.00	0.00	0.00
335-345	0.00	0.00	0.00	0.00	0.00	0.00

Load (KN)	% of Vehicles at Ch 29+200 Km (Existing Chainage)					
	Silchar To Vairengte			Vairengte To Silchar		
	Single Axle	Tandem Axle	Tridem Axle	Single Axle	Tandem Axle	Tridem Axle
345-355	0.00	0.00	0.00	0.00	0.00	0.00
355-365	0.00	0.00	0.00	0.00	0.00	0.00
365-375	0.00	0.00	0.00	0.00	0.00	0.00
375-385	0.00	0.00	0.00	0.00	0.00	0.00
385-395	0.00	0.00	0.00	0.00	0.00	0.00
395-405	0.00	0.00	0.00	0.00	0.00	0.00
405-415	0.00	0.00	0.00	0.00	0.00	0.00
415-425	0.00	0.00	0.00	0.00	0.00	0.00
	100.00	100.00	100.00	100.00	100.00	100.00

1.6.3.16Fatigue Damage Analysis

Due to the simultaneous application of traffic loads and temperature differentials between the top and bottom of a concrete slab, concrete pavements are subjected to Bottom-Up Cracking (BUC) during day hours and Top-Down Cracking (TDC) during night hours. Hence, the pavement design is checked for cumulative bottom-up and top-down cracking damages.

Analysis has been done for the following cases:

Bottom-up Cracking – For single rare axle and tandem rare axle
Top-down Cracking – For single, tandem and Tridem rare axle

Location: - At Km 29+200 Km (Existing Chainage)

Table 1.54 Cumulative Fatigue Damage Analysis at Ch: 7+100 Km

Axle load (AL), KN		Flexural Stress, MPa	Stress Ratio	% of Axles	Expected Repetitions (ni)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
i) Cumulative Fatigue Damage Analysis for Bottom-up Cracking (BUC)							
Rear Single Axles							
<=85	190	2.61	0.527	52.98	232468	256613.486	0.906
85-95	90	1.74	0.351	14.39	63120	Infinite	0.000
95-105	100	1.83	0.369	5.61	24632	Infinite	0.000
105-115	110	1.91	0.386	3.51	15395	Infinite	0.000

Axle load (AL), KN		Flexural Stress, MPa	Stress Ratio	% of Axles	Expected Repetitions (ni)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
115-125	120	2.00	0.404	4.56	20014	Infinite	0.000
125-135	130	2.09	0.421	5.96	26172	Infinite	0.000
135-145	140	2.17	0.439	3.16	13856	Infinite	0.000
145-155	150	2.26	0.456	3.86	16935	22475442.1	0.001
155-165	160	2.35	0.474	1.40	6158	3730355.49	0.002
165-175	170	2.43	0.492	1.40	6158	1178385.19	0.005
175-185	180	2.52	0.509	1.05	4619	503535.205	0.009
185-195	190	2.61	0.527	1.40	6158	256613.486	0.024
195-205	200	2.69	0.544	0.70	3079	146794.714	0.021
205-215	210	2.78	0.562	0.00	0	89511.3979	0.000
215-225	220	2.87	0.579	0.00	0	54939.1368	0.000
225-235	230	2.95	0.597	0.00	0	33719.8259	0.000
235-245	240	3.04	0.614	0.00	0	20696.1143	0.000
245-255	250	3.13	0.632	0.00	0	12702.5908	0.000
255-265	260	3.22	0.650	0.00	0	7796.43026	0.000
265-275	270	3.30	0.667	0.00	0	4785.19114	0.000
275-285	280	3.39	0.685	0.00	0	2936.99212	0.000
285-295	290	3.48	0.702	0.00	0	1802.62867	0.000
295-305	300	3.56	0.720	0.00	0	1106.39388	0.000
Fatigue Damage from Rear Single Axles							**0.968**

Rear Tandem Axles							
<=205	200	1.47	0.297	56.14	432435	Infinite	0.000
205-215	210	1.51	0.305	7.02	54054	Infinite	0.000
215-225	220	1.55	0.313	1.75	13514	Infinite	0.000
225-235	230	1.59	0.321	0.88	6757	Infinite	0.000
235-245	240	1.63	0.329	10.53	81082	Infinite	0.000
245-255	250	1.67	0.336	10.53	81082	Infinite	0.000
255-265	260	1.70	0.344	0.88	6757	Infinite	0.000
265-275	270	1.74	0.352	6.14	47298	Infinite	0.000
275-285	280	1.78	0.360	3.51	27027	Infinite	0.000
285-295	290	1.82	0.368	0.88	6757	Infinite	0.000

Axle load (AL), KN		Flexural Stress, MPa	Stress Ratio	% of Axles	Expected Repetitions (ni)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
295-305	300	1.86	0.376	0.88	6757	Infinite	0.000
305-315	310	1.90	0.384	0.88	6757	Infinite	0.000
315-325	320	1.94	0.392	0.00	0	Infinite	0.000
325-335	330	1.98	0.400	0.00	0	Infinite	0.000
335-345	340	2.02	0.408	0.00	0	Infinite	0.000
345-355	350	2.06	0.416	0.00	0	Infinite	0.000
355-365	360	2.10	0.423	0.00	0	Infinite	0.000
365-375	370	2.14	0.431	0.00	0	Infinite	0.000
375-385	380	2.17	0.439	0.00	0	Infinite	0.000
385-395	390	2.21	0.447	0.00	0	Infinite	0.000
395-405	400	2.25	0.455	0.00	0	27167467.8	0.000
405-415	410	2.29	0.463	0.00	0	10194165	0.000
415-425	420	2.33	0.471	0.00	0	4800788.39	0.000
425-435	430	2.37	0.479	0.00	0	2604344.28	0.000
435-445	440	2.41	0.487	0.00	0	1556122.19	0.000
445-455	450	2.45	0.495	0.00	0	997430.201	0.000
455-465	460	2.49	0.503	0.00	0	674355.171	0.000
465-475	470	2.53	0.510	0.00	0	475439.607	0.000
475-485	480	2.57	0.518	0.00	0	346720.4	0.000
Fatigue Damage from Rear Tandem Axles							**0.000**
ii) Cumulative Fatigue Damage Analysis for Top-down Cracking (TDC)							
Single Axle							
<=85	80	1.81	0.366	52.98	52338	Infinite	0.000
85-95	90	1.87	0.378	14.39	14211	Infinite	0.000
95-105	100	1.93	0.390	5.61	5546	Infinite	0.000
105-115	110	1.99	0.402	3.51	3466	Infinite	0.000
115-125	120	2.05	0.414	4.56	4506	Infinite	0.000
125-135	130	2.11	0.426	5.96	5892	Infinite	0.000
135-145	140	2.17	0.438	3.16	3120	Infinite	0.000
145-155	150	2.23	0.450	3.86	3813	Infinite	0.000
155-165	160	2.29	0.462	1.40	1386	11396631.2	0.000

Axle load (AL), KN		Flexural Stress, MPa	Stress Ratio	% of Axles	Expected Repetitions (ni)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
165-175	170	2.35	0.474	1.40	1386	3718917.68	0.000
175-185	180	2.41	0.486	1.05	1040	1617556.99	0.001
185-195	190	2.47	0.498	1.40	1386	833605.56	0.002
195-205	200	2.53	0.510	0.70	693	480538.511	0.001
205-215	210	2.59	0.522	0.00	0	299960.367	0.000
215-225	220	2.64	0.534	0.00	0	198713.541	0.000
225-235	230	2.70	0.546	0.00	0	137855.662	0.000
235-245	240	2.76	0.558	0.00	0	98189.0736	0.000
245-255	250	2.82	0.571	0.00	0	70217.4601	0.000
255-265	260	2.88	0.583	0.00	0	50214.2604	0.000
265-275	270	2.94	0.595	0.00	0	35909.4724	0.000
275-285	280	3.00	0.607	0.00	0	25679.7611	0.000
285-295	290	3.06	0.619	0.00	0	18364.2388	0.000
295-305	300	3.12	0.631	0.00	0	13132.7261	0.000
305-315	310	3.18	0.643	0.00	0	9391.5406	0.000
Fatigue Damage from Single Axles							**0.004**
Rear Tandem Axles							
<=205	200	1.93	0.390	56.14	97360	Infinite	0.000
205-215	210	1.96	0.396	7.02	12170	Infinite	0.000
215-225	220	1.99	0.402	1.75	3042	Infinite	0.000
225-235	230	2.02	0.408	0.88	1521	Infinite	0.000
235-245	240	2.05	0.414	10.53	18255	Infinite	0.000
245-255	250	2.08	0.420	10.53	18255	Infinite	0.000
255-265	260	2.11	0.426	0.88	1521	Infinite	0.000
265-275	270	2.14	0.432	6.14	10649	Infinite	0.000
275-285	280	2.17	0.438	3.51	6085	Infinite	0.000
285-295	290	2.20	0.444	0.88	1521	Infinite	0.000
295-305	300	2.23	0.450	0.88	1521	Infinite	0.000
305-315	310	2.26	0.456	0.88	1521	24056663.3	0.000
315-325	320	2.29	0.462	0.00	0	11396631.2	0.000
325-335	330	2.32	0.468	0.00	0	6206750.96	0.000

Axle load (AL), KN		Flexural Stress, MPa	Stress Ratio	% of Axles	Expected Repetitions (ni)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
335-345	340	2.35	0.474	0.00	0	3718917.68	0.000
345-355	350	2.38	0.480	0.00	0	2388668.31	0.000
355-365	360	2.41	0.486	0.00	0	1617556.99	0.000
365-375	370	2.44	0.492	0.00	0	1141885.51	0.000
375-385	380	2.47	0.498	0.00	0	833605.56	0.000
385-395	390	2.50	0.504	0.00	0	625618.727	0.000
395-405	400	2.53	0.510	0.00	0	480538.511	0.000
405-415	410	2.56	0.516	0.00	0	376452.396	0.000
415-425	420	2.59	0.522	0.00	0	299960.367	0.000
425-435	430	2.62	0.528	0.00	0	242566.451	0.000
435-445	440	2.64	0.534	0.00	0	198713.541	0.000
445-455	450	2.67	0.540	0.00	0	164666.833	0.000
455-465	460	2.70	0.546	0.00	0	137855.662	0.000
465-475	470	2.73	0.552	0.00	0	116110.685	0.000
475-485	480	2.76	0.558	0.00	0	98189.0736	0.000
Fatigue Damage from Tandem Axles							**0.000**
Rear Tridem Axles							
<=205	200	1.73	0.349	0.00	0	Infinite	0.000
205-215	210	1.75	0.353	0.00	0	Infinite	0.000
215-225	220	1.77	0.358	0.00	0	Infinite	0.000
225-235	230	1.79	0.362	0.00	0	Infinite	0.000
235-245	240	1.81	0.366	0.00	0	Infinite	0.000
245-255	250	1.83	0.370	0.00	0	Infinite	0.000
255-265	260	1.85	0.374	0.00	0	Infinite	0.000
265-275	270	1.87	0.378	0.00	0	Infinite	0.000
275-285	280	1.89	0.382	0.00	0	Infinite	0.000
285-295	290	1.91	0.386	0.00	0	Infinite	0.000
295-305	300	1.93	0.390	0.00	0	Infinite	0.000
305-315	310	1.95	0.394	0.00	0	Infinite	0.000

Axle load (AL), KN		Flexural Stress, MPa	Stress Ratio	% of Axles	Expected Repetitions (ni)	Allowable Repetitions (Ni)	Fatigue Damage (ni/Ni)
315-325	320	1.97	0.398	0.00	0	Infinite	0.000
325-335	330	1.99	0.402	0.00	0	Infinite	0.000
335-345	340	2.01	0.406	0.00	0	Infinite	0.000
345-355	350	2.03	0.410	0.00	0	Infinite	0.000
355-365	360	2.05	0.414	0.00	0	Infinite	0.000
365-375	370	2.07	0.418	0.00	0	Infinite	0.000
375-385	380	2.09	0.422	0.00	0	Infinite	0.000
385-395	390	2.11	0.426	0.00	0	Infinite	0.000
395-405	400	2.13	0.430	0.00	0	Infinite	0.000
405-415	410	2.15	0.434	0.00	0	Infinite	0.000
415-425	420	2.17	0.438	0.00	0	Infinite	0.000
425-435	430	2.19	0.442	0.00	0	Infinite	0.000
435-445	440	2.21	0.446	0.00	0	Infinite	0.000
445-455	450	2.23	0.450	0.00	0	Infinite	0.000
455-465	460	2.25	0.454	0.00	0	Infinite	0.000
465-475	470	2.27	0.458	0.00	0	Infinite	0.000
475-485	480	2.29	0.462	0.00	0	Infinite	0.000
Fatigue Damage from Rear Tridem Axles							**0.000**

CFD for BUC Case		CFD for TDC Case			Total CFD
Due to Single Axles	Due to Tandem Axles	Due to Single Axles	Due to Tandem Axles	Due to Tridem Axles	
0.968	0.000	0.004	0.000	0.000	0.972

The sum of cumulative fatigue damage for both cases of Bottom-up cracking and Top-down cracking is less than 1. Hence, the thickness of 270 mm is safe for the expected traffic.

Considering two retexturing in 30 years, a thickness of 280 mm is recommended. The load for the design of Dowel bar is considered based on maximum axle load irrespective of direction at each location. The traffic estimation, Dowel bar & Tie bar design is done for the data.

1.6.3.17Design of Dowel Bars

i. At Km 29+200 (Existing Chainage)

Input Data

Dia of dowel bar, b_d	=	36	mm
Spacing between the dowel bars	=	300	mm
Length of the dowel bar	=	450	mm
Slab Thickness, h	=	300	mm
Joint width at contraction joints, z	=	5	mm
Joint width at expansion joints, z	=	20	mm
Modulus of subgrade reaction, k	=	50.33	MPa/m
Modulus of the elasticity of the dowel, E	=	200000	Mpa
Modulus of dowel support, k_{mds}	=	415000	MPa/m
Grade of concrete	=	40	
Characteristic compressive strength of concrete cube(15cm) after 28 days curing concrete, fck	=	40	Mpa
Permissible bearing stress in concrete, F_b	=	28	Mpa

Check for Bearing Stress

Maximum single axle load	=	160.000	KN
Maximum single wheel load	=	80.000	KN
Wheel load for dowel bar design	=	56.000	KN
Percentage of load transfer through dowel bar	=	50.000	
Load to be transferred by dowel bar	=	28.000	KN
Moment of Inertia of the dowel, I	=	82406	mm^4
Radius of relative stiffness, l	=	1027.686	mm
Relative stiffness of bar embedded in concrete	=	0.022	mm^{-1}
Number of dowel bars participating in load transfer	=	4.0	
The total load transferred by dowel bar system	=	2.337	Pt
Load carried by the outer dowel bar, Pt	=	12	KN
Bearing stress in dowel bar at contraction joints	=	15	< 29
Bearing stress in dowel bar at expansion joints	=	18	< 29

Hence assumed spacing and dia of dowel bar are safe

Adopted Design

Diameter of dowel bar	=	36	mm
Spacing between dowels	=	300	mm
Length of dowel bar	=	450	mm

1.6.3.18 Design of Tie Bars

i. at Km 29+200 (Existing Chainage)

Design Parameters

Slab thickness, h	=	0.30	m
Lane width, b	=	4.50	m
Co-efficient of friction, f	=	1.5	
Density of concrete	=	24	KN/m^3
Allowable tensile stress in deformed bars, S	=	200	Mpa
Allowable bond stress in deformed tie bars, B	=	2.46	Mpa
Diameter of tie bar, d	=	12	mm

Spacing and length of the deformed tie bar

Area of steel bar per metre width of joint to resist the frictional force at slab bottom , As	=	243	mm^2/m
Cross sectional area of tie bar , A	=	113.10	mm^2
Perimeter of tie bar , P	=	37.70	mm
Spacing of tie bars , A/As	=	465.0	mm
Length of tie bar , L	=	487.80	mm

Increase length by 10 cm for loss of bond due to painting and another 5 cm for tolerance in placement.

Therefore, Length of tie bar , L	=	637.80	cm
	Say	640.0	cm

Adopted Design

Diameter of tie bar (Deformed)	=	12	mm
Spacing of tie bar	=	460	mm
Length of tie bar	=	640	mm

1.6.4 Recommendation

The current policy directives from MoRT&H stipulate that consultant shall consider rigid pavement for the Bypasses and wherever there is eccentric widening for more than 3 km length. However, consultant has considered the following while deciding on pavement type.

a. IRC: SP:48 -1998 (Hill Road Manual) Page 111 Clause 10.2.1 and page 139 Clause 10.23.1 which clearly state that rigid pavement is generally not recommended for hill roads.

b. Achieving a high level of smoothness in concrete pavements without sacrificing long-term performance for the curvilinear alignment require special adjustment at time of construction.

c. It is more difficult to construct a smooth surface for PCC pavements along horizontal curves than those on tangents because of the transitions for super elevation. Generally, roughness is more prevalent in transitions and super elevated portions of a horizontal curve than on tangents. In the transition sections, the profile pan must adjust to meet the varied cross slope requirements of the curve. As with an uneven track line, the constant adjustments of the paving machine can adversely affect the smoothness of the pavement.

d. As the horizontal curvature increases, the potential for roughness within the curve increases. When the degree of curvature exceeds 6 degrees (or the radius of curvature falls below 300 m) increased attention to the machine operation and the string line-staking interval is required and it is virtually impossible to construct the surface to the same specified tolerance desirable for a tangent section because of the significant corrective adjustments necessary by the equipment.

e. In majority of curves along the project section which occur in quick succession with very little straight tangents in between and the radii are much less than 300m. Thus, it will be very difficult and time consuming to achieve the surface finish to the desired levels.

f. As far as option-2 using CTB/CTSB is concern, we have shown in above table that by introducing geo-grid over GSB layer will reduce the thickness of WBM by 45mm and WMM by 100mm. The cost difference per Km between conventional flexible pavement and Flexible pavement with geo-grid provision is App. 50 lack per km i.e., Flexible pavement is costlier than reinforced geo-grid pavement. **Further, flexible pavement with geo-grid provision also works out to be cheaper by 10 lack per km compared to Flexible pavement with cement treated base and subbase.** Moreover, the CBR of existing soil is less and the availability of aggregate material along the project road is extremely limited so, introducing geogrid would be most suitable option in Mountainous / Hilly terrain condition.

g. **Hence, considering all the above facts the consultant has recommended flexible pavement with geogrid for project road.**

The summary of proposed pavement type is shown below.

Table 1.55 Summary of Pavement Type

Sl No	Sections	Length (Km)	Type of Pavement	Thickness
1	From Km 0+000 to Km 46+000	46.000	Flexible with Geogrid	BC = 40 mm DBM = 60 mm WMM = 150 mm Geogrid = Biaxial GSB = 300 mm Subgrade = 500 mm

Based on above recommendation the BOQ and cost estimate has been estimated.

As the proposed alignment is passing through high embankment and falls under submerged area were the CBR value varies from 4.5 % to 4.8 % hence, an additional geogrid layer has been introduced between natural ground (after clearing and grubbing) and selected earth (Embankment). The typical figure of the pavement cross section is given below.

A sand blanket has been considered between subgrade and selected earth (embankment) wherever applicable/as per site condition.

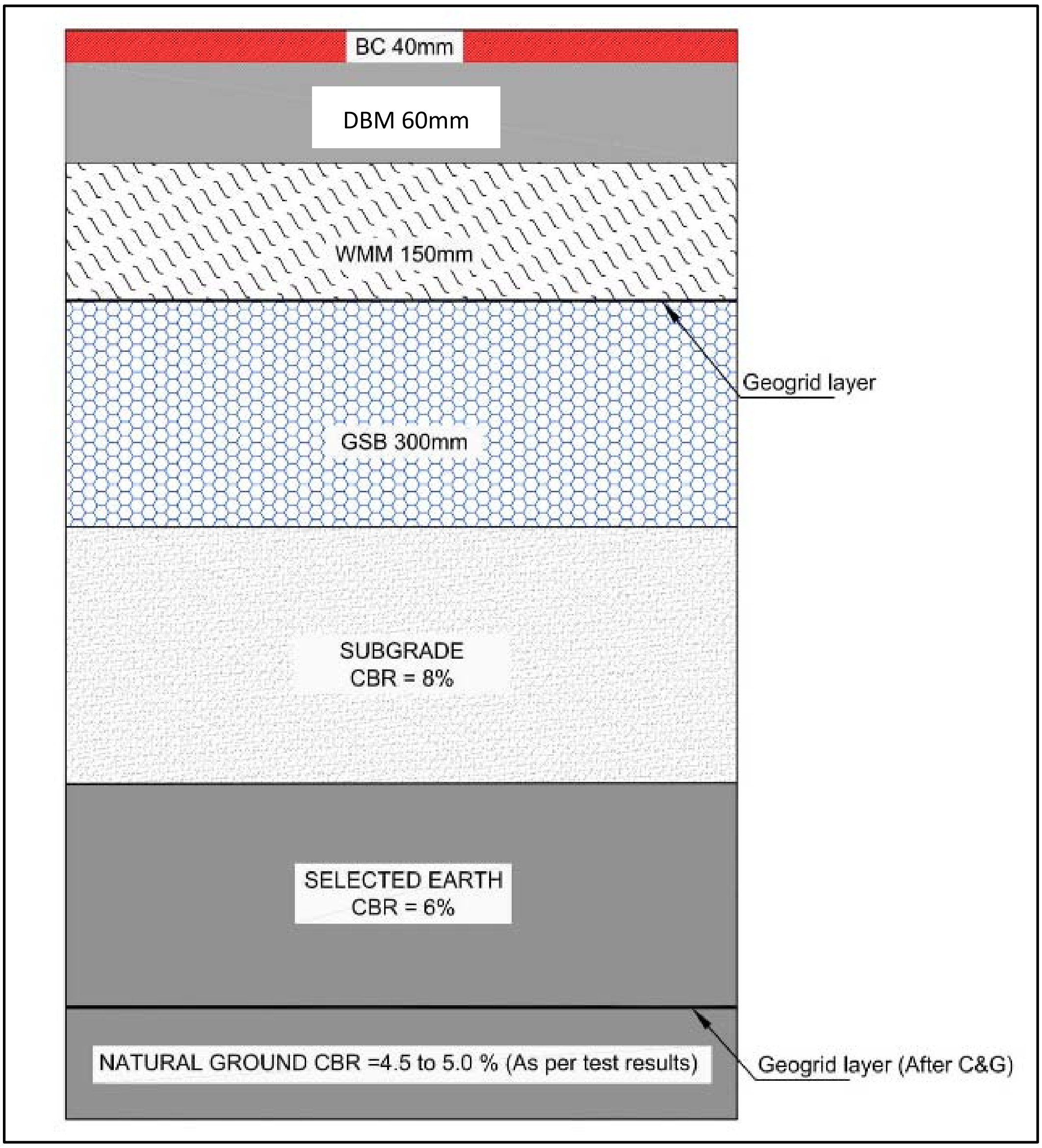


Fig 1.17 Flexible Pavement cross section with Geo grid provision

1.6.5 Design thickness for service road

As per the Clause 5.5.4 of IRC SP: 84-2019 service roads shall be designed for 10 MSA. The pavement layer thickness for design traffic of 10 MSA and 8% CBR is given in below table.

Table 1.56 Summary of Pavement thickness for Service road

Sl. No	Section (Design Chainage)	Layers	CBR (%)	Thickness in mm	Resilient Modulus	Poison's Ratio	MSA
1	Km 0+000 to Km 136+400	BC (VG-30)	8	30	2000	0.35	Adopted 10 MSA
		DBM (VG-30)		60		0.35	
		WMM		250	208.19	0.35	
		GSB		200		0.35	
		Sub-Grade		500	CBR 8%	0.35	

The details of service/Slip road provided along the project road are shown below (according to proposed chainage).

Table 1.57 Location of Service / Slip Roads

LHS					RHS			
Sl No	Chainage (m) From	Chainage (m) To	Length (m)	Width (m)	Chainage (m) From	Chainage (m) To	Length (m)	Width (m)
1	0+225	3+800	3575	7.50	0+225	3+800	3575	7.50
2	5+260	7+530	2270	7.50	5+260	7+530	2270	7.50
3	12+340	13+290	950	7.50	12+340	13+290	950	7.50
4	14+400	16+410	2010	7.50	14+400	16+410	2010	7.50
5	18+800	21+000	2200	7.50	18+800	21+000	2200	7.50
Total Length=			**11005**				**11005**	

1.6.6 Design thickness for Bus Bay:

If the Bus shelter comes adjacent to the main carriage way then the thickness for bus shelter will be same as the thickness of main carriageway, if the bus shelter will come adjacent to the service road then the thickness service road will be taken as the thickness of Bus shelter.

Table 1.58 Details of Bus bays

Sl. No.	Design Chainage	Side	Name Of Village	Remarks
1	1+030	LHS	Silchar	On Main Lane
2	0+980	RHS	Silchar	On Main Lane
3	6+100	LHS	Badripur	On Main Lane
4	6+200	RHS	Badripur	On Main Lane
5	6+920	LHS	Badripur	On Service Road
6	7+170	RHS	Badripur	On Service Road
7	12+750	RHS	Bagpur	On Service Road
8	13+000	LHS	Bagpur	On Service Road
9	15+500	RHS	Rahimore	On Service Road
10	15+900	LHS	Rahimore	On Service Road
11	20+140	RHS	Kajidahar	On Main Lane
12	20+380	LHS	Kajidahar	On Main Lane

1.6.7 Design thickness for Truck Lay by:

If the Truck layby comes adjacent to the main carriage way then the thickness for Truck layby will be same as the thickness of main carriageway, if the Truck layby will come adjacent to the service road then the thickness service road will be taken as the thickness of Truck layby.

Truck lay-byes have been proposed at 2 no's location. Locations of truck lay-bye are given below in table.

Table 1.59 Details of Truck Lay Bye

Sl. No.	Design Chainage	Side	Name Of Village
1	8+500	LHS	Silchar Bypass
2	8+900	RHS	Silchar Bypass

1.6.8 Rest Areas

Location of Rest Area given below in table;

Table 1.60 Details of Rest Area

Sl. No.	Design Chainage	Side	Name of Village
1	8+800	LHS	Silchar Bypass

1.6.9 Toll Plaza

Location of Toll Plaza is given below in table;

Table 1.61 Details of Rest Area

Sl. No.	Design Chainage	Name of Village
1	17+100	Sonabarighat Bypass

1.7 At Grade Intersections

Road junction/intersection is a key element of highway design. The efficiency, safety, speed and capacity of road system very much depend on the intersection design. The main objective of intersection design is to reduce the severity of potential conflicts between motor vehicles, buses, trucks, bicycles, pedestrians and facilities while facilitating the convenience, ease and comfort of people traversing the intersections. The standards proposed in IRC SP: 41 "Guidelines for the Design of At-Grade Intersection in Rural and Urban Areas" will generally be followed.

All the junctions are developed as per manual with parallel entry/exit at built-up areas and tapered entry/exits at rural areas. Schematic arrangement of junctions is given below:

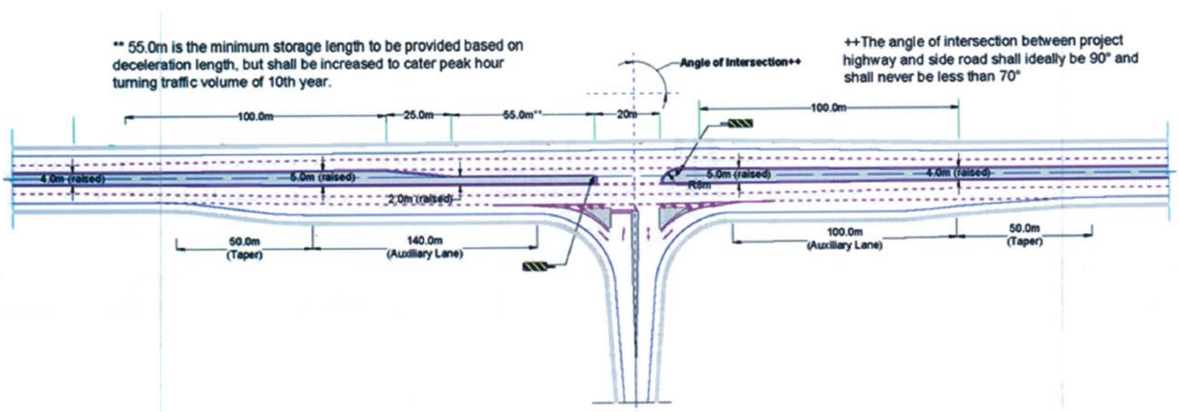


Fig 1.18 Schematic Plan of T-Intersection

1.7.1 Major Intersections

All junctions are designed as at-grade junctions with proper acceleration and deceleration arrangements.

These junctions have been developed as per IRC SP: 41 "Guidelines for the Design of At-Grade Intersection in Rural and Urban Areas" and "Type designs for intersections on National Highways" published by MoRT&H. Details of Major Intersections are mentioned below;

Table 1.62 List of Major Road Junctions

Sl. No.	Location			At Grade	Side	Type of Road (SH/ MDR/ ODR/ VR)	Types of C/W	Remarks
	Design Chainage	Ex. Chainage	Name of junction					
1	0+818	262+520 (NH-37)	Haflong, Guwahati	T	LHS	NH-27	1-Lane BT	
2	5+055	-	Banskandi	Interch ange	LHS	NH-37	IL-BT	
3	7+043	257+022	Jiribam	T	LHS	City Road	2-Lane BT	
4	12+860	Silchar Bypass	Kasipur, -Niarigram	Y	BHS	New Dayapur Bagan Road	1-Lane BT	
5	14+405	8+800	Aizawl-Silchar	T	LHS	NH-37	2-Lane BT	
6	15+730	Sonabarighat Bypass	Karimganj	+	RHS	Niarigram-Kasipur Road	2-Lane BT	
7	19+400	-	Silchar Bypass	+	LHS	NH-306	1-lane BT	

1.7.2 Minor Intersections

Details of Minor Intersections are mentioned below;

Table 1.63 List of Minor Road Junctions

Sl. No.	Design Chainage	Existing Chainage	Type of Road (BT, CC, Gr.)	Type of Junctions (T, Y, +)	Side	Remarks
1	1+535	261+804	1-Lane BT	T	LHS	
2	2+805	260+534	1-Lane BT	T	LHS	
3	3+750	259+580	1-Lane BT	T	LHS	
4	6+580	-	1-Lane BT	T	RHS	
5	20+210	13+280	1-Lane BT	T	LHS	
6	20+270	13+340	1-Lane BT	T	RHS	

1.7.3 Speed Changing Lanes at major junctions

1.7.3.1 Acceleration lanes

Acceleration lanes are provided so that slow moving traffic on service road can join the nearside lane of the main CW at approximately the same speed as that of nearside lane of road. Recommended lengths of the acceleration lane can be referred to table 4.8 of IRC: SP: 41 – 1994, Guidelines for the design of at – grade intersection in rural and urban areas. Below table shows the length of acceleration lanes depending on the speed of service lane and Inner side lane of main highway.

Table 1.64 Minimum Acceleration Lane Lengths

Highway		Acceleration Length (m) for entrance curve design speed (kmph)								
		Stop condition	25	30	40	50	60	65	75	80
Design Speed (kmph)	Speed Reahed (kmph)	And initial speed (kmph)								
		0	20	30	35	40	50	60	65	70
80	60	230	210	190	180	150	100	50	-	-
100	75	360	340	330	300	280	240	160	120	50

As the target design speed of road is expected to reach 100 Kmph after the provision of partially access controlled 2 laning and design speed of service road is expected to be 60 Kmph, so the acceleration lane length of 150m followed by 1:15 taper and 60m nose length is recommended for safe operation of acceleration lane. Width of Acceleration lane is 5.5m minimum.

1.7.3.2 Deceleration lane

Deceleration lanes are provided are provided for the fast moving vehicles to take diversion from main road to service road. The deceleration lane is also provided where fast moving traffic intends to enter into U turn configuration. Recommended lengths of the deceleration lane can be referred to table 4.9 of IRC: SP: 41 – 1994, Guidelines for the design of at – grade intersection in rural and urban areas. Below table shows the length of deceleration lanes.

Table 1.65 Minimum Deceleration Lane Lengths

Highway		Deceleration Length (m) for design speed of exit (kmph)								
		Stop condition	25	30	40	50	60	65	75	80
Design Speed (kmph)	Speed Reachd (kmph))	For Average Running Speed of Exit Curve (kmph)								
		0	20	30	35	40	50	60	65	70
80	70	130	120	120	110	100	90	70	50	-
100	85	160	150	150	140	130	125	100	90	70

The length of deceleration lane should be sufficient for vehicles to slow down from the average speed of traffic in the near side lane to the speed necessary for negotiating the curve at the end of it. The curve radius must permit a speed of at least 40-60 Kmph but not less than 40m.

1.7.4 Entry/Exit arrangement

Entry/exit has been provided at the start and end of slip roads as per Fig 2.1A of manual. Schematic arrangement of Entry/Exit Ramp is given below:

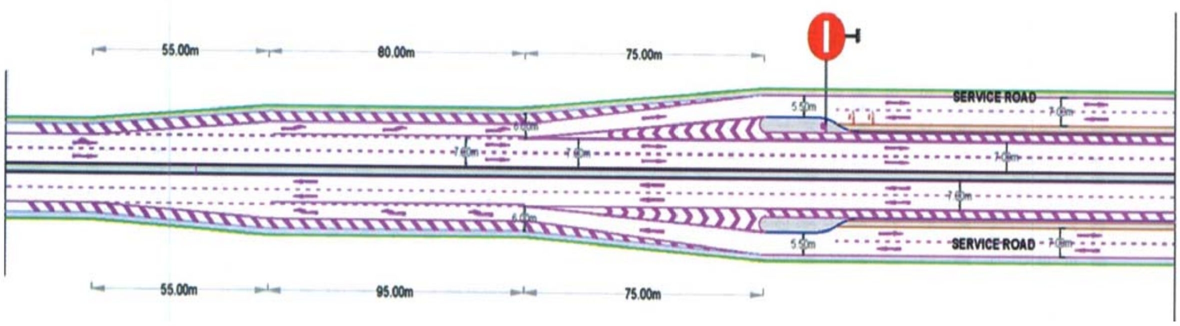


Fig 1.19 Schematic Plan of entry/exits

1.8 Drain Design

Keeping in view the good health of the road, a proper drainage design is one of the important aspects. Open side drains are normally provided on both or one side of the roadway in order to intercept surface water runoff from the carriageway, shoulders and verges. Drains in rural area will be designed as per the guidelines fixed in IRC: SP-42 and in urban area are to be designed as per IRC: SP-50.

1.8.1 Design parameter and assumption

The proposed cross fall on the road pavement is 2.5% to ensure proper drainage of the road surface. For road segments traverses through plain terrain, in areas of super elevation transition a minimum longitudinal grade of 0.3% is to be adopted to ensure that the pavement surface drains properly.

Longitudinal side drains shall be provided, on both side of road, for entire length of the project road. The type of section and size of side drain shall depend on the locations as mentioned below:

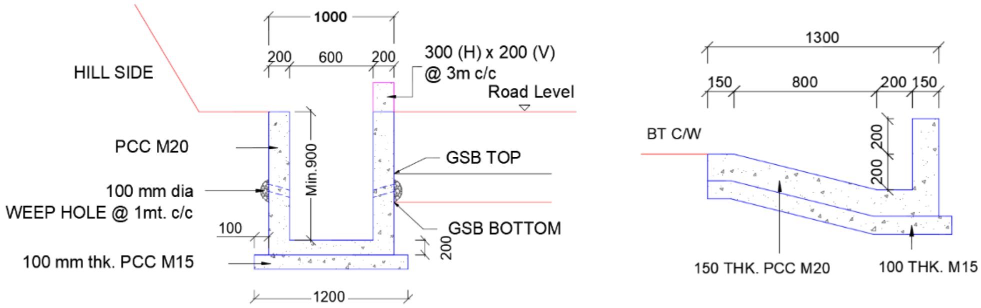
In Rural Areas: Unlined open trapezoidal drains have been proposed along the project road. Side drains shall be designed to a depth of minimum 300mm below sub-base which will allow drainage of the upper pavement layers as well as carry water from the road surface.

In urban areas: Lined covered drains have been proposed along the road passing through built-up areas. RCC covered drain, which shall serve as footpath also has been provided. And at the locations where the cross section is in cutting, trapezoidal type lined drains have been proposed.

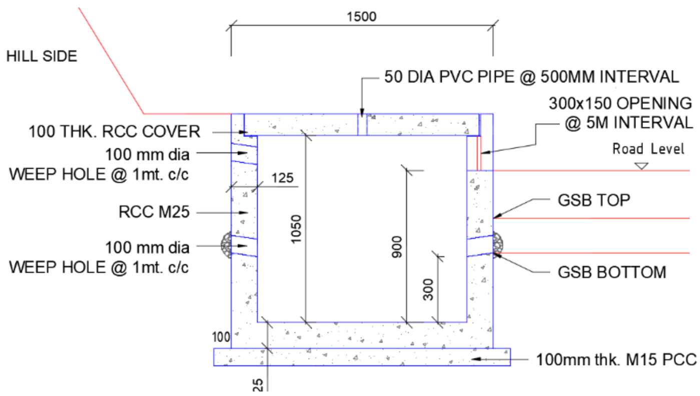
In rural area, open unlined trapezoidal drain will be provided. As per guidelines for four lane manual IRC: SP: 84-2019, side slope of unlined drain shall not be steeper than 2H: 1V. These slopes can be made steeper in case of lined drains.

- Permissible non erodible flow velocity should be kept in view in accordance with IRC: SP: 42. If it gets increased beyond this limit, flow channels need to be lined. This is as per IRC: SP: 42.
- Open unlined drains if provided at ground level, should be kept sufficiently away from the toe of the embankment.
- Top of unlined toe drain will be kept below subgrade bottom or at ground level, whichever is lower.
- In case of depressed median, longitudinal drain (lined or unlined) shall be provided to drain off rain water. The drain should have adequate longitudinal slope to the nearest culvert to drain off transversely. In super elevated sections the longitudinal drains should be designed to take the discharge from one side carriageway also. In super elevated sections combination of covered longitudinal and cross drains shall be provided.
- To avoid erosion of slopes in high embankment and approaches to structures, provision of chute drain is to be given. The chutes may be lined with cement concrete on stable base and will be located at 10 to 15m interval depending upon the rainfall, width, cross slope and longitudinal slope of the carriageway. Energy dissipation device i.e. stilling basin would be provided at the end of the chute drain to avoid the erosion of toe of the embankment.

- For important roads like National Highways and State Highways, the frequency of the storm shall be taken as 25 year and for depressed roads and underpasses, it may be increased to 50 years.
- The drain shall be designed for a flash flood of 1 hour. Drain design would be based on 25 years return period with one hour flash flood.



a. **PCC Open Drain Hill Side** b. **PCC Open Drain Valley Side**



c. **RCC Covered Drain**

Note: Ref. separate TCS drawings for more details.

Fig 1.20 Types of Drain

1.8.2 Hydrological Design of Drain

To estimate the amount of runoff from the carriageway, rational method is a universally adopted empirical formula.

Once the quantity of runoff is estimated, next stage is to do the hydraulic design of the drain. Capacity of the drain is to be determined by Uniform flow equation i.e. Manning's equation;

Q = $1/n * A * R^{2/3} * S^{1/2}$

Where

Q = Discharge in (cum/sec)

V = Mean velocity (m/sec)

n = Manning's roughness coefficient, is to be adopted as per IRC: SP-42

R = Hydraulic radius in m

S = Energy slope of the channel, which is roughly taken as slope of drain bed

A = Area of the flow cross-section in sq.m

1.8.3 Longitudinal Drainage

Details of drain schedules are mentioned below;

Table 1.66 RCC Cover Drain

Sl No	LHS			RHS		
	Chainage (m)		Length (m)	Chainage (m)		Length (m)
	From	To		From	To	
1	0+000	0+225	225	0+000	0+225	225
2	1+360	3+800	2440	1+360	3+800	2440
3	5+860	6+470	610	5+860	6+470	610
4	19+900	21+000	1100	19+900	21+000	1100
Total Length=			**4375**			**4375**

Table 1.67 RCC Cover Drain at Grade Separator

Sl No	LHS			RHS		
	Chainage (m)		Length (m)	Chainage (m)		Length (m)
	From	To		From	To	
1	0+225	1+360	1135	0+225	1+360	1135
2	5+260	5+860	600	5+260	5+860	600
3	6+470	7+040	570	6+470	7+040	570
4	7+040	7+280	240	7+040	7+280	240
5	7+280	7+530	250	7+280	7+530	250

Sl No	LHS			RHS		
	Chainage (m)		Length (m)	Chainage (m)		Length (m)
	From	To		From	To	
6	12+340	12+750	410	12+340	12+750	410
7	12+750	12+900	150	12+750	12+900	150
8	12+900	13+290	390	12+900	13+290	390
9	14+400	14+610	210	14+400	14+610	210
10	14+610	15+400	790	14+610	15+400	790
11	15+400	16+100	700	15+400	16+100	700
12	16+100	16+410	310	16+100	16+410	310
13	18+800	19+050	250	18+800	19+050	250
14	19+050	19+720	670	19+050	19+720	670
15	19+720	19+900	180	19+720	19+900	180
	Total Length		6855			6855

Table 1.68 Open Un-line Drain

Sl No	LHS			RHS		
	Chainage (m)		Length (m)	Chainage (m)		Length (m)
	From	To		From	To	
NIL						

1.9 Highway facilities

The following items, necessary for traffic safety, shall be provided as per Schedule C.

- **Traffic Signs and Pavement Markings** - as per IRC: 67 and IRC: 35 respectively.
- **Blinker Signals and Object Markers** to be provided at major intersections and all traffic diversion during construction for night time visibility.
- **Metal Beam Crash Barriers**: As per cl.9.7.1.1 of IRC: SP-84-2019 Roadside safety barriers is warranted at locations with embankment height more than 3.0m when embankment slope is 2H:1V.
- **Pedestrian Guard Rails** - on bridges on outer side of footpath and between main carriageway and service road. However, it is also required at other locations such as Junctions/Intersections, in the vicinity of Schools and bus-stops.

- **Chevron Signboards** - on either side of carriageway at horizontal curvature. Minimum 2No.s of boards shall be visible at all sections of curvature
- **Road Studs** - on all curves on both carriageways, at median openings and at intersections as per clause IRC: SP-84-2019.
- **Kilometer and hectometer stones** - based on IRC:8 and MORTH circular
- **Road Boundary Stones** - at every 200m interval
- **Overhead Gantries** - Start and end of Project Highway
- **Hazard Markers** – at every structure like culverts, bridges and flyovers

Vol-II

Design Report (Structure)

Consultancy Services for preparation of DPR for development of Economic Corridors, Inter Corridors and Feeder Routes to improve the efficiency of freight movement in India under Bharatmala Pariyojna (Lot-1) (Package-III) (Silchar-Vairengte(49.9 km), Vairengte-Sairang (111 km), Silchar-Jiribam (55 km))

Section: Silchar to Vairengte (Package-1, Km 0+000 to Km 21+000)

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1 Volume-II Design Report (Structure)

1.1 Introduction

Bharatmala Pariyojana is a mega plan of the government and the second-largest highways project after the NHDP. Many defined highway stretches totalling about 50,000 km are proposed to be developed as "**Economic Corridors, Inter Corridors & Feeder Routes" under "Bharatmala Pariyojna".**

Economic corridors are integrated networks of infrastructure within a geographical area designed to stimulate economic development. These corridors are generally developed to link cities or countries, manufacturing hubs, areas with high supply and demand, and manufacturers of value-added goods, whereas 44nos of corridors are identified. Inter Corridors & Inter-connection between different economic corridors, development of first mile & last mile connectivity. Under 'Logistic Efficiency Enhancement Programme', these are proposed to be developed by taking an end-to-end corridor view, rather than stretch-by-stretch road construction view to ensure consistent infrastructure along the corridor.

As a first step towards this task, preparation of DPR for development of Economic Corridors, Inter Corridors and Feeder Routes to improve the efficiency of freight movement in India under Bharatmala Pariyojana is being undertaken by National Highways Authority of India (NHAI). Numbers of consultants have been appointed by National Highway Authority of India (NHAI), to prepare the Detailed Project Report for identified economic corridors, inter corridors & feeder routes under Bharatmala Pariyojana.

The National Highways & Infrastructure Development Corporation Limited **(NHIDCL)** has been constituted through an Act of Parliament for faster, economical and quality Road Construction work throughout India.

National Highways and Infrastructure Development Corporation is a fully owned company of the Ministry of Road Transport & Highways, Government of India. The company promotes surveys, establishes, designs, builds, operates, maintains and upgrades National Highways and Strategic Roads including interconnecting roads in parts of the country which share international boundaries with neighbouring countries. . This would lead to the formation of a more integrated and economically consolidated South and South East Asia. The company would also endeavour to undertake infrastructure projects including but not restricted to urban infrastructure and urban or city transport and to act as an agency for development of all types of Infrastructure. The company envisages working towards cross sharing of technical know-how and enhancing opportunities for business development with other nations and their agencies including the multilateral organizations and institutions.

M/s. Transys Consulting Pvt. Ltd. has been appointed as consultants by National Highway Infrastructure Development Corporation Limited (NHIDCL), to prepare the Detailed Project Report for development of Economic Corridors, Inter Corridors, and Feeder Routes to improve the efficiency of freight movement in India (Lot-1) **Package-III** under Bharatmala Pariyojana.

NHIDCL will be the employer and executing agency for the consultancy services and the standards of output required from the appointed consultants are of international level both in terms of quality and adherence to the agreed time schedule. The consultancy firm will solely be responsible for submission of quality work in stipulated period.

1.2 Objective of Document

This Design Report presents the work approach & methodology proposed to be adopted by the Consultants while preparing the designs and drawings for the project. The report primarily covers the design philosophy, various standards & codes of practices, various bridge furniture details, design methodology, design & drawing standards, road safety features etc. which will be followed for development of economic corridors in terms of 4-lane access controlled.

This document aims at standardizing the procedure of designs to be performed in order to achieve techno-economic feasibility, financial viability of the project aspects of value engineering, requirement of quality & safety, safety of operation and efficient maintenance of the facility, durability and conformance to standards, optimization and ease of construction. The aim is also to highlight the basic philosophy of design and the work approach to the Client and Authority engineer at the start of project so that any input from client / IE can be taken care at the early stage of the project for incorporation in designs.

1.3 The Project Highway

As per Contract Agreement (CA)

As per CA the Project stretch Silchar to Vairengte is the section of NH-306 (old NH-54) start at the junction of NH-37 (old NH-53) at km 266+700 and Km 0+000 of NH-306 (Capital point) in Assam State and ends at Km 49+900 of NH-306 near Phainuam Junction of NH 306A at Vairengte town in Mizoram State for approximate length of 49.9 Km.

After Reconnaissance survey and further discussion with NHIDCL:

After reconnaissance survey, it has been learnt that from Km 0+000 to Km 8+800, the project road traverses through heavily built-up with narrow ROW up to km 8+000 (Sonabarighat village). Since, said stretch couldn't warrant for 4-lane development in line with geometrics, land acquisition, environment & social perspective hence, the start point has been shifted to Clock Tower (Junction of NH-37 and NH-27) at existing km 263+350 of NH-37 and continued traversing along NH-37 up to km 257+000 via Rongpur, Arkatipur and Kashipur.

However, at the same time it has also been found that Silchar bypass (partly constructed 2-Lane, on hold) exist on RHS of project road and intersects at km 7+950 of NH-306 hence, DPR consultant has proposed to utilize partial section of Silchar bypass for the length of 7.5 Km from the junction of NH 37 at Km 257+000 and terminates at Km 7+950 of NH 306 near Sonabarighat continuing towards Vairengte up to Km 43+000 of NH-306 (old NH-54) at Lailapur /vairengte border. Hence, considering above existing scenarios, project road starts at km 263+350 of NH-37 with junction of NH-27 (Guwahati-Silchar Road).

Further, as we all know that there is dispute over border between Assam and Mizoram states. Govt. of Mizoram has put massive effort to resolve the long pending state border dispute with Union minister of home affairs (HMA) to intervene and review the state boundary based on Bengal Eastern Frontier Regulation 1873 and the inner line of the Lushai Hills Notification, 1993. The matter is still pending.

However, information obtained from different sources like Local bodies, applicable maps, and Border check-post administrative, 3 locations on existing NH-306 road have been identified viz. at existing Km 40+150, Km 42+250 and km 43+900 respectively. So, considering the existing circumstances and facts, we have fixed end chainage of "Silchar-Vairengte Section" at existing Km 43+000 of NH-306. The same may be revised once the matter resolved.

Hence, DPR consultant has considered the start point as existing Km 263+350 of NH-37 (Old NH-53) with Design Ch. 0+000 and end point at Km 43+000 with Design Ch. 46+000 at Lailapur-Vairengte state border leading towards Aizawl.

Therefore, the total existing length of chosen route (along portion of NH-37 + portion of Siclar bypass + NH-306) is 48.900 kms.

The latitude and longitude of the start and end point of the project road are as given in below table.

Table 1.1 Latitude and Longitude of both ends of Project Road

Location	Latitude	Longitude	Altitude
Rongpur (NH-37)	24°50'1.50"	92°51'40.91"	23.00
Silchar-Vairente Border	24°30'58.93"	92°46'39.72"	119.00

Hence, for an obvious reason please accord these existing chainages for reference purpose "as tentative chainage" only.

The key plan diagram of project road is showing below;

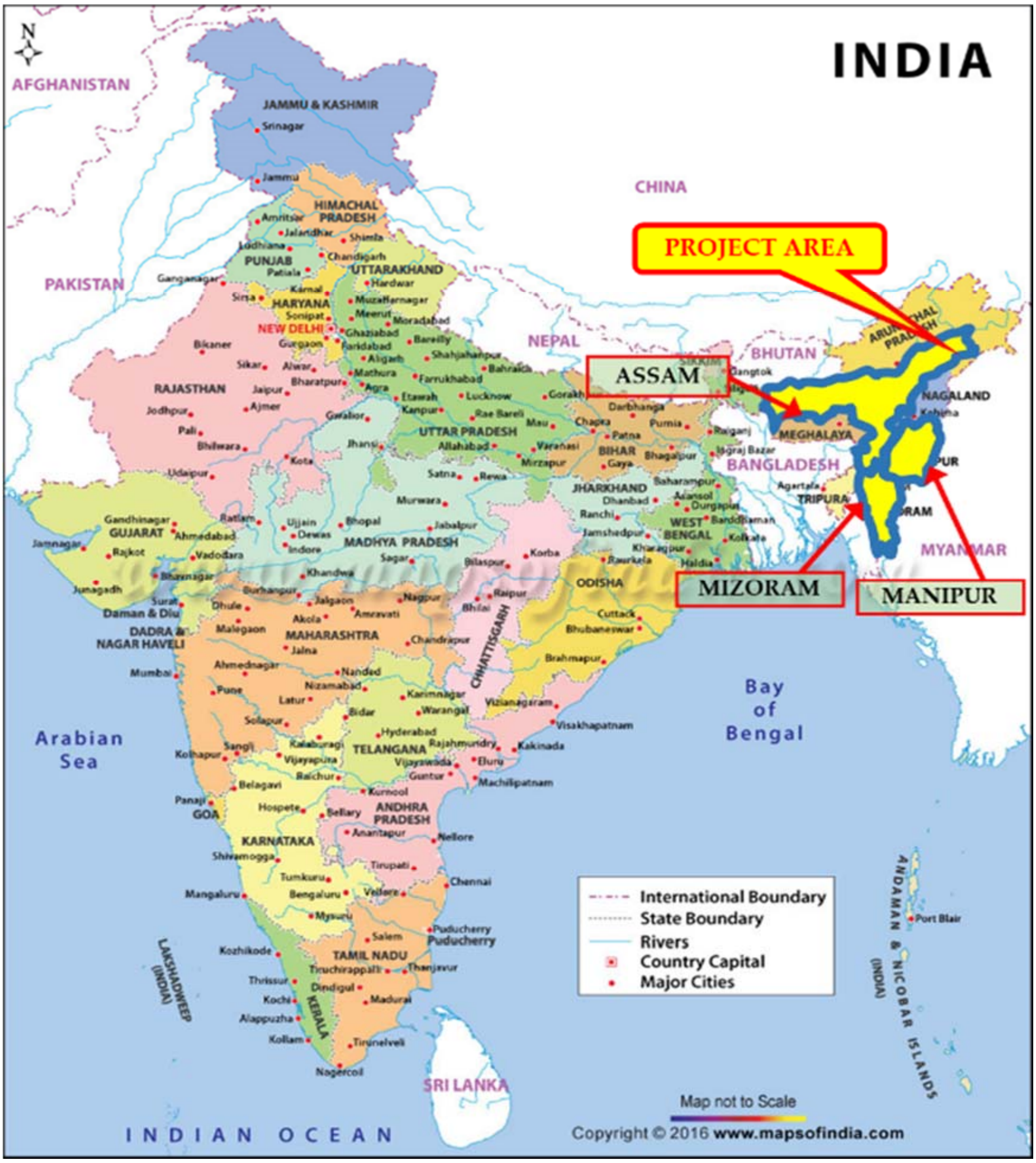


Fig 1.1 Key Plan of Project Road

In addition, this report mainly deals with Package-1 that starts at existing Km 263+350 (D. Chainage 0+000) and ends at Existing Km 13+200 and (D. Chainage 21+000) however, for better comprehension DPR consultant has furnished the details from Silchar to Vairengte state border.

1.4 Structures

The structures are classified based on their functional use. The structures for the project road are classified as given below:

i) Drainage Structures

- Culverts
- Major Bridges
- Minor Bridges

iii) Grade Separators

ii) Viaducts

The Bridges having an overall length varying above 6 m to 60 m are termed as minor bridges and those having an overall length more than 60 m are termed as major bridges.

The structures carrying the project road over land and spanning across the valleys are termed as viaducts. The structures carrying the cross roads above the project road are termed as overpasses and the structures carrying the cross roads below the project road are called underpasses.

1.4.1 Culverts

Topography of hill generates numerous water courses. This coupled with continuous gradient of roads in hill and high intensity of rain fall calls for effective drainage of roads. Uncontrolled water is the primary cause of problems like soft surfaces, pot holes and even failure of complete sections of road. Adequate drainage is a primary requirement for maintaining the structural soundness and functional efficiency of a road.

The existing drainage infrastructure consists mainly of small diameter pipe culverts and slab culverts. Culverts which are found in good condition are proposed to be widened in case of proposed alignment follows existing road and the culverts which are in bad condition are proposed to be reconstructed. There are 54nos. of existing culverts, out of which 5nos are Slab on NH-306, 10nos are Box on NH-37 and 39 are Pipe culverts, Out of which 15nos are on Silchar bypass and 24 nos are on NH-306 on Silchar to Vairengte Section. However, as per Package-1 there are 01 no of Slab & 01 no of Pipe culvert on NH-306, 10 nos of Box on NH-37 and 15 no's of pipe culvert on Silchar bypass.

Treatment of culverts on the project road was determined after carrying out detailed inventory and condition surveys to note all details including structural condition and hydraulic adequacy.

Existing road is a 2-Lane road, which has to be 4-Lane road with improved vertical and horizontal geometric. Following categories of existing culverts have been proposed for reconstruction:

- Culverts whose pipe / box/ slab or its abutment are damaged.
- Culverts where the proposed centerline of the project road falls outside of the existing carriageway, because of improvement of geometric.
- Culvert requires reconstruction on account of the vertical profile of proposed road not matching with existing road or deck level of the culvert due to geometric improvements.
- Culverts where bedding underneath the pipe has been washed away due to storm water action. Now water flows underneath the pipe until water level increases above inlet level.
- Pipe culvert-having dia. of less than 0.9m, considered for reconstruction with 1.2m dia. pipe.

It has been found that there is not even single culvert, which does meet any one or many of above-mentioned conditions. Hence all new culverts will be constructed on new alignment of 4-lane road.

New culverts along the proposed alignment have been proposed which are as per locations of streams. Extra culverts have been added along existing alignment also where present number of culverts has been found to be less as compared to requirements based on topography. Locations of culverts are designed in such a way that side drains and culverts are integrated with each other.

RCC Box culverts/ Pipe culverts are provided as per the prevailing site condition to ease out the pressure of the cross flow of water. Generally, at perennial nallahs, Box culverts of different sizes are proposed. To drain of the road surface drainage and local hill side storm water, 1x1.2m dia. pipe culverts are proposed.

The overall width of culverts between innermost faces of parapets shall be equal to the roadway width of approaches (Paved carriageway + Shoulders), and in service road stretches will extend to the shoulder of service road. In case of high banks, the width of culvert shall be increased to avoid high face walls. The minimum width of the culverts is 2 x 11m.

Summary of Existing and Proposed culverts, proposed culvert according to sizes and Improvement Proposal of culvert are presented in below table;

Table 1.2 Summary of Culverts

Existing			Proposed						Total
Pipe	Slab	Box	New Box	Reconstruction	Widening	Retained	Abandoned (not falling under proposed alignment)	Dismantle	
16	01	10	27	36	*19	-	-	02	55

**Note: Existing 06 numbers of culverts have been proposed to change in bridges. Out of which 05 nos are proposed for Minor Bridge and 1 no is proposed for Major Bridge.*

Table 1.3 Summary of proposed culvert according to sizes

Type	Size	Nos.	Total no.
BOX	1 x 2	30	55
BOX	1 x 3	25	

Table 1.4 Culverts Improvement Proposal

Sl. No.	Existing Details				Design Chainage (Km)			Proposal	Remarks
	Existing Design Chainage (Km)	Type	Size	Deck Width (m)	Chainage (Km)	Type	Size		
1	-	-	-	-	670	BOX	1 x 2 x 2	New Construction	NH-37
2	262+300	Box	1 x 2	12.60	1035	BOX	1 x 2 x 2	Reconstruction	
3	261+960	Box	1 x 2	12.60	1372	BOX	1 x 2 x 2	Reconstruction	
4	-	-	-	-	1850	BOX	1 x 2 x 2	New Construction	
5	260+900	Box	1 x 2	12.60	2479	BOX	1 x 2 x 2	Reconstruction	
6	260+320	Box	1 x 2	12.6	3006	BOX	1 x 2 x 2	Reconstruction	
7	-	-	-	-	3430	BOX	1 x 2 x 2	New Construction	
8	-	-	-	-	3930	BOX	1 x 3 X 3	New Construction	
9	-	-	-	-	4230	BOX	1 x 3 X 3	New Construction	
10	-	-	-	-	4220	BOX	1 x 3 X 3	New Construction	
11	-	-	-	-	4500	BOX	1 x 3 X 3	New Construction	

Sl. No.	Existing Details				Design Chainage (Km)			Proposal	Remarks
	Existing Design Chainage (Km)	Type	Size	Deck Width (m)	Chainage (Km)	Type	Size		
12	-	-	-	-	4750	BOX	1 x 3 X 3	New Construction	
13	-	-	-	-	5010	BOX	1 x 3 X 3	New Construction	NH-37
14	258+750	Box	1 x 2	12.60	5385	BOX	1 x 2 X 2	Reconstruction	
15	258+240	Box	1 x 2	12.60	5925	BOX	1 x 2 X 2	Reconstruction	
16	257+890	Box	1 x 2	12.60	6245	BOX	1 x 2 X 2	Reconstruction	
17	-	-	-	-	6560	BOX	1 x 2 X 2	New Construction	
18	257+305	Box	1 x 2	12.60	6880	BOX	1 x 2 X 2	Reconstruction	
19	-	-	-	-	7110	BOX	1 x 2 X 2	New Construction	Silchar Bypass
20	-	-	-	-	7395	BOX	1 x 2 X 2	New Construction	
21	-	-	-	-	7985	BOX	1 x 3 X 3	New Construction	
22	18+685	Pipe	2 x 0.9	-	8355	BOX	1 x 3 X 3	Reconstruction	
23	-	-	-	-	8750	BOX	1 x 3 X 3	New Construction	
24	-	-	-	-	9010	BOX	1 x 3 X 3	New Construction	
25	17+765	Pipe	2 x 1.2	-	9275	BOX	1 x 3 X 3	Reconstruction	
26	17+531	Pipe	2 x 1.0	-	9509	BOX	1 x 3 X 3	Reconstruction	
27	16+198	Pipe	2 x 1.0	-	10842	BOX	1 x 3 X 3	Reconstruction	
28	15+135	Pipe	2 x 1.2	-	11905	BOX	1 x 3 X 3	Reconstruction	
29	14+871	Pipe	2 x 1.2	-	12169	BOX	1 x 3 X 3	Reconstruction	
30	14+513	Pipe	2 x 1.2	-	12527	BOX	1 x 2 X 2	Reconstruction	
31	13+988	Pipe	1 x 1.2	-	13052	BOX	1 x 2 X 2	Reconstruction	
32	-	-	-	-	13450	BOX	1 x 3 X 3	New Construction	
33	-	-	-	-	14175	BOX	1 x 3 X 3	New Construction	
34	-	-	-	-	14370	BOX	1 x 3 X 3	New Construction	

Sl. No.	Existing Details				Design Chainage (Km)			Proposal	Remarks
	Existing Design Chainage (Km)	Type	Size	Deck Width (m)	Chainage (Km)	Type	Size		
35	12+230	Pipe	1 x 1.2	-	14810	BOX	1 x 2 X 2	Reconstruction	
36	12+119	Pipe	1 x 0.9	-	14921	BOX	1 x 2 X 2	Reconstruction	Silchar Bypass
37	-	-	-	-	15090	BOX	1 x 2 X 2	New Construction	
38	-	-	-	-	15320	BOX	1 x 2 X 2	New Construction	
39	-	-	-	-	15600	BOX	1 x 2 X 2	New Construction	
40	-	-	-	-	15780	BOX	1 x 2 X 2	New Construction	Sonabarigh at Bypass
41	-	-	-	-	15990	BOX	1 x 2 X 2	New Construction	
42	-	-	-	-	16610	BOX	1 x 3 X 3	New Construction	
43	-	-	-	-	17030	BOX	1 x 3 X 3	New Construction	
44	-	-	-	-	17360	BOX	1 x 3 X 3	New Construction	
45	-	-	-	-	17770	BOX	1 x 3 X 3	New Construction	
46	-	-	-	-	18020	BOX	1 x 3 X 3	New Construction	
47	-	-	-	-	18390	BOX	1 x 3 X 3	New Construction	
48	-	-	-	-	18690	BOX	1 x 3 X 3	New Construction	
49	-	-	-	-	18970	BOX	1 x 2 X 2	New Construction	
50	-	-	-	-	19320	BOX	1 x 2 X 2	New Construction	
51	-	-	-	-	19580	BOX	1 x 2 X 2	New Construction	(Dhanehari village, NH - 306)
52	-	-	-	-	19880	BOX	1 x 2 X 2	New Construction	
53	-	-	-	-	20160	BOX	1 x 2 X 2	New Construction	
54	12+400	Pipe	2x0.9	17.00	20485	BOX	1 x 2 X 2	Reconstruction	
55	-	-	-	-	20800	BOX	1 x 2 X 2	New Construction	

In addition to the above 11 No. of 1x2x2m Box culverts of 7.5 m length are proposed for crossroads.

Table 1.5 Culverts for Cross Road

Sl. No.	Design Chainage	Type	Span (m)	Minimum Vent Height (m)
1	1+500 (at Cross Road)	Box Culvert	1x2	2.0
2	3+800 (at Cross Road)	Box Culvert	1x2	2.0
3	5+300 (at Cross Road)	Box Culvert	1x2	2.0
4	5+600 (at Cross Road)	Box Culvert	1x2	2.0
5	6+600 (at Cross Road)	Box Culvert	1x2	2.0
6	7+040 (at Cross Road)	Box Culvert	1x2	2.0
7	12+800 (at Cross Road)	Box Culvert	1x2	2.0
8	14+400 (at Cross Road)	Box Culvert	1x2	2.0
9	15+700 (at Cross Road)	Box Culvert	1x2	2.0
10	19+400 (at Cross Road)	Box Culvert	1x2	2.0
11	20+300 (at Cross Road)	Box Culvert	1x2	2.0

1.4.2 Grade Separated Structures

The structures through which the traffic flows at different levels are called grade separated structures. The project road cuts across Major Roads at number of locations are proposed grade separation facilities of different configuration for different classes of crossings along the route. In addition, there are many crossings of other district and village roads and also it passes through no. of places of habitation. Junctions with NH, SH and Major District Road and other important junctions are to be upgraded so as to comfort the manoeuvre of the traffic diverting from the main carriageway by providing deceleration lane and acceleration lane for the traffic exiting from and entering into the main carriageway. As all the other roads are joining the project highway at habitations, at grade junction improvement is proposed. However, consultants proposed grade separation facilities of different configuration for different classes of crossings along the route.

Such under/over passes shall also be provided across other categories of roads as per site requirements for crossing of traffic. The structure may be either an underpass or an overpass depending upon the nature of terrain, vertical profile of road and availability of adequate right of way etc. Decision whether the cross road or the Project Highway will be carried at the existing level will be taken at the time of preparing the feasibility report and would be based on considerations of drainage, land acquisition, provision of ramps for the grade separated facility, height of embankment and project economy etc.

There is 1 no of existing VUP structure on Silchar Bypass to NH-306 at exist. Km 7+950 of NH-306 along the project road which is under construction and it is proposed for reconstruction at design Km 14+405 since geometric improvement of alignment.

These grade separation facilities are classified and tabulated in following Table.

Table 7.1 Details of Grade Separated Structures

Sl. No.	Type / Location of Structure	Name	Concept	Leaading to	Category of Road	Span arrangement and Vertical clearance	Total Width of Structure (m)
1	0+818	Flyover	4-Lane BT	LHS - Haflong, Guwahati	NH-27	Span = 1 x 30 + 1 x 40 + 1 x 30m	2 x 11.6
2	4+679	Flyover	4-Lane BT	LHS - Jiribam	NH-37 (New Alignment)	Span = 2 x 35m Vertical Clearance = 5.5 m	2 x 12.1
3	5+055	SVUP	1 Lane BT	LHS- Kasipur Grant	City Road	Span = 1 x 7.0m Vertical Clearance = 4.0m	2 x 17.0
4	5+575	LVUP	Intermediate Lane BT	LHS - Banskandi	New Dayapur Bagan Road	Span = 1 x 12m Vertical Clearance = 4.0 m	2 x 11.6
5	7+043	VUP	2 Lane BT	LHS - Jiribam	NH-37	Span = 1 x 20m Vertical Clearance = 5.5m	2 x 12.1
6	12+860	LVUP	1 Lane BT	LHS - Kasipur, RHS - Niarigram	Niarigram -Kasipur Road	Span = 1 x 12m Vertical Clearance = 4.0 m	2 x 11.6
7	14+405	VUP	2 Lane BT	LHS - Aizawl, RHS - Silchar	NH-306 (Existing)	Span = 1 x 20m Vertical Clearance = 5.5 m	2 x 12.1
8	15+730	Flyover	2 Lane BT	RHS - Karimganj	Silchar Bypass	Span = 1 x 30m Vertical Clearance = 5.5m	2 x 12.1

Sl. No.	Type / Location of Structure	Name	Concept	Leaading to	Category of Road	Span arrangement and Vertical clearance	Total Width of Structure (m)
9	17+874	SVUP	1-Lane BT	LHS – NH 306, RHS – SH 39	PWD Road	Span = 1 x 7.0m Vertical Clearance = 4.0m	2 x 11.6
10	19+400	Flyover	2-Lane BT	LHS - Silchar	NH-306 (Existing)	Span = 1 x 30m Vertical Clearance = 5.5m	2 x 12.1

1.4.2.1 Vehicular Underpass (VUP)

A grade separated structure which is provided for crossing of vehicles under the Project Highway is called as Vehicular Underpass (VUP).

1.4.2.2 Vehicular Overpass (VOP)

A grade separated structure which is provided for crossing of vehicles over the Project Highway is called as Vehicular Overpass (VOP).

1.4.2.3 Light Vehicular Underpass (LVUP)

A grade separated structure which is provided for crossing of light vehicles under the Project Highway is called as Light Vehicular Underpass (LVUP).

These structures are provided for bridging over a 2-Lane roadway and the span of these LVUP's shall be 1 x 12m. The typical arrangement is shown in the following diagram. Vertical Clearance at these locations is 4.0m.

1.4.2.4 Small Vehicular Underpass (SVUP)

A grade separated structure which is provided for crossing of small vehicles under the Project Highway is called as Small Vehicular Underpass (SVUP).

1.4.2.5 Flyover

Flyover is synonymous to VUP/OP/LVUP/SVUP.

1.4.2.6 Road Over Bridge (ROB)

A structure provided over the railway lines to carry the Project Highway is called Road over Bridge (ROB).

a) In case a 2-lane bridge exists over the railway tracks, another two-lane bridge shall be constructed for one side traffic. The treatment to existing structure shall be considering as per clause no 7.3 (IV) of IRC: SP: 84-2019.

b) In case the bridge is to be provided over an existing level crossing, twin 2-lane bridges shall be constructed with overall width as given in Clause no 7.3 (ii) of IRC: SP: 84-2019. If the alignment of road at the existing railway crossing has skew angle more than 45 degrees, the alignment of road or of pier/abutment shall be suitably designed to reduce skew angle up to 45 degrees.

c) The horizontal and vertical clearances to be provided shall be as per requirement of the Railway authorities.

d) The Concessionaire shall be required to obtain approvals of all designs and drawings from the concerned Railway authorities.

e) The construction of ROB within the railway boundary shall be under the supervision of Railway authorities.

f) The approach gradient shall not be steeper than 1 in 40.

g) In cases of ROB, the service road on both the sides shall be joined through one of the viaducts of ROB. This arrangement shall be on either side of the railway crossing.

1.4.2.7 Road under Bridge (RUB)

A structure provided below the railway lines to carry the Project Highway is called Road under Bridge (RUB).

a) Full roadway width as in the approaches shall pass below the bridge structure allowing for widening of Project Highway to 6-lane at a later date. The service roads where provided shall be continued in the bridge portion also.

b) The vertical and lateral clearances shall be as per Guidelines of IRC: SP: 84-2019.

c) These structures shall be designed to carry railway loads. The Concessionaire shall be required to obtain approvals of all designs and drawings from the concerned Railway Authorities. The design of structure shall be in accordance with relevant Railway codes.

d) The construction of RUB and its approaches shall be carried out in conformity with the terms specified in the approval granted by the Railway Authorities.

1.4.2.8 Trumpet

A Trumpet interchange is a grade separator structure provided at major T-junction facilitating uninterrupted flow of traffic in each direction.

1.4.2.9 Cloverleaf

A Cloverleaf is a grade separator structure provided at a major crossroad junction facilitating uninterrupted flow of traffic in each direction.

1.4.2.10Median

The width is the distance between inside edges of carriageway is depending upon the availability of Right of Way. Minimum width of median, subject to availability of Right of Way is mentioned below;

Table 1.6 Width of Median

Type of Section	Minimum Width of Median (m)		
	Plain and Rolling Terrain		Mountainous and Steep Terrain
	Raised	Depressed Median	Raised
Approach to Grade Separated Structures	5.0	NA	2.5

* Including kerb shyness of 0.50m on either side.

In case width of median is different from the approach section due to constraints, transition of 1 in 50 shall be provided approaches for guiding vehicular traffic. The median shall be open to sky with 0.5m safety barrier from the edge of carriageway. A suitable designed catch pit shall be provided to collect and carry discharge from median drain.

1.4.2.11Shoulders

The minimum shoulder width on the outer side is given below

Table 1.7 Width of Shoulders in different terrain

Type of Section	Terrain		Width of Shoulder (m)		
			Paved	Earthen	Total
Approach to Grade Separated Structures	Plain and Rolling		2.5	-	2.5
	Mountainous and Steep (Hilly Area	Hill Side	0.25 m+ 1.5 m (Raised)	-	1.75
		Valley Side	0.25 m+ 1.5 m (Raised)	-	1.75

Width of Paved Shoulder in approaches to grade separated structures shall extend on either side of the structure in the entire length of retaining walls. The retaining walls on either side shall be abutting the paved shoulders and shall have crash barriers on the top.

1.4.2.12Lateral and Vertical Clearance

In case of any type of underpass, the proposed structure base shall be kept 150mm above the ground level to prevent water accumulation. Guard rail/Crash barriers shall be provided for protection of vehicles from colliding with the abutments and piers and the deck of the structures.

The minimum horizontal and vertical clearances are given below;

Table 1.8 Clearances for Underpasses

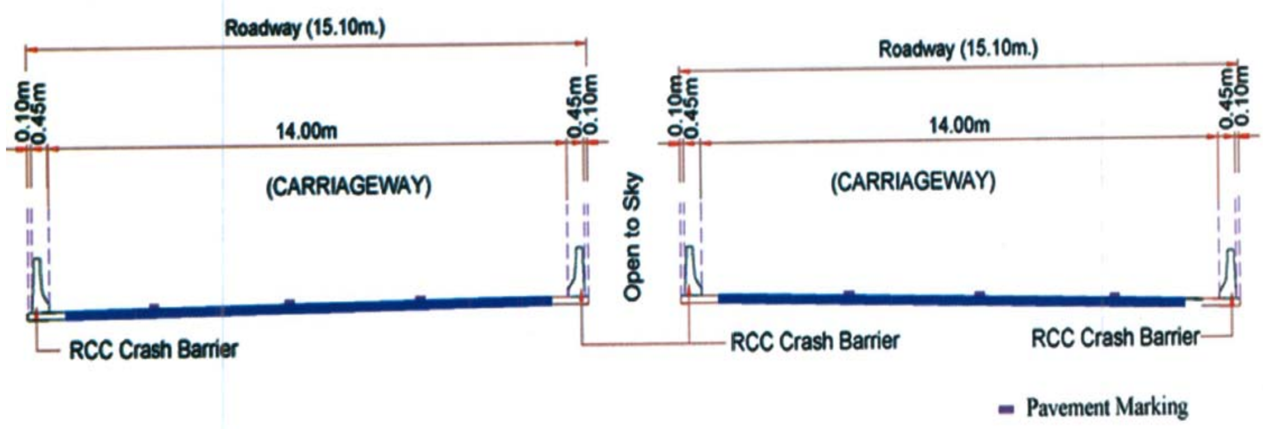
Type of Underpass	Vertical Clearance (m)	Horizontal Clearance (m)
Vehicular Underpass (VUP)	5.5	20.0
Light Vehicular Underpass (LVUP)	4.0	12.0
Smaller Vehicular Underpass (SVUP)	4.0	7.0

Whenever any structure is provided over the Project Highway, the minimum clearance of 5.5m shall be provided at all points of carriageway.

1.4.2.13 Width of Structure

The width of new structure shall be as per 6-Lane standards. It shall be designed for the condition when footpath is used as carriageway. The footpath portion may be provided at the same level as the structure carriageway and separated by crash barrier in non-built up area. In built up areas, raised footpaths shall be provided.

The design for service life of structure shall be of 100years.



1.4.3 Bridges

1.4.3.1 General

As we discussed in previous chapter i.e. we are starting the Package-1 from Km 0+000 from NH-37 by connecting Silchar bypass from Km 7+040 to Km 15+730 and from there after the proposed road diverted to left side on Sonabarighat to towards Dhanehari till Km 21+000.

There is 1 no of existing major bridge over Barak River falling on Silchar Bypass, at km 13+830 (existing km 13+000), which is constructed up to A1, P1 and P2 in 2-Lane standard, cannot be exploit for 4-Lane design standard. Hence is proposed for new construction of Major Bridge. There is also 1 nos. of Hume pipe culvert (partially constructed) along Silchar bypass at design chainage 7+660 (existing km 19+380) is proposed for reconstruction to major bridge.

Hence there are new proposal of bridges as per the site requirement with standard design. The new bridges are proposed in standard of per IRC: SP: 84- 2019.

The following improvement proposals have been considered for new bridges.

Table 1.9 Summary of Proposal of Major Bridges

Existing		Proposed			Retained	Total
Type	No.	New	Reconstruction	Widening		
Major Bridge	1	0	02	-	-	02

Table 1.10 Improvement Proposal of Major Bridges

New additional Major bridges:

Sl. No.	Ex. Des Ch. (Km)	Des.Ch (Km)	Span Arrangement Proposed		Type of Structure	Proposed Deck Width (m)	Remarks
			No. of Span	Span Length (m)			
NIL							

Major bridges to be reconstructed:

Sl. No.	Ex. Des Ch. (Km)	Des.Ch (Km)	Span Arrangement Proposed		Proposed Type of Structure	Proposed Deck Width (m)	Remarks
			No. of Span	Span Length (m)			
1	19+380	7+660	2	40	Girder, with Footpath	2 x17.0	Silchar Bypass
2	13+000	13+830	16	30	Girder, with Footpath	2 x13.5	Silchar Bypass (Barak River)

Minor Bridges:

There is total 4 nos. of minor bridges falling under this package, out of which 1 no is lying on Silchar Bypass which is proposed for reconstruction and 3nos. are abandoned due to proposal of new Sonabarighat Bypass.

Also, there is 5 nos. of culverts along Silchar bypass that proposed to be converted in to minor bridges due to design demand hence, the said culverts need to be dismantled and reconstructed with new bridges.

The following improvement proposals have been considered for the minor bridges.

Table 1.11 Summary of Minor Bridges

Existing		Proposed				Total
Type	Existing No	New	Reconstruction	Widening	Abandoned	
Minor Bridge	04	01	06	-	03	07

Table 1.12 Improvement Proposal of Minor Bridges

Reconstruction of Minor Bridges

Sl. No.	Ex. Des Ch. (Km)	Des.Ch. (Km)	Span Arrangement		Type of Structure Proposed	Total Deck Width (m)	Proposal	Remarks
			No. of Span	Span Length (m)				
1	263+100 NH-37	0+210	1	10	RCC Deck Slab, with Footpath	1 x 48.1	Reconstruction	
2	17+200 Silchar Bypass	9+839	1	10	RCC Deck Slab, with Footpath	2 x 13.5	Reconstruction	
3	16+715 Silchar Bypass	10+325	1	10	RCC Deck Slab, with Footpath	2 x 13.5	Reconstruction	
4	15+910 Silchar Bypass	11+130	1	10	RCC Deck Slab, with Footpath	2 x 13.5	Reconstruction	
5	15+440 Silchar Bypass	11+600	1	10	RCC Deck Slab, with Footpath	2 x 13.5	Reconstruction	
6	12+270 Silchar Bypass	14+630	2	20	RC Deck Slab, with Footpath	2 x 11.6	Reconstruction	

New Construction of Minor Bridges

Sl. No.	Ex. Des Ch. (Km)	Des.Ch. (Km)	Span Arrangement		Type of Structure Proposed	Total Deck Width (m)	Proposal	Remarks
			No. of Span	Span Length (m)				
1	-	16+277	3	12	RCC Deck Slab, with Footpath	2 x 12.1 + 2 x 11.0	New Construction	

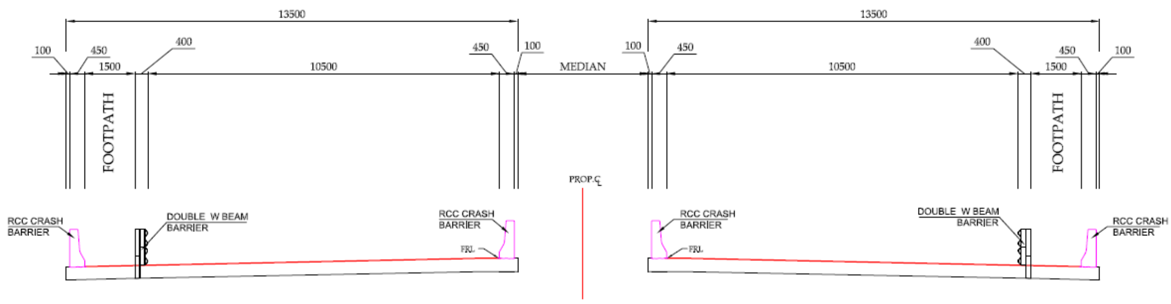
1.5 Design & engineering methodology

1.5.1 Salient Features

1.5.1.1 Width of Structures

New Minor and Major Bridge structures are proposed to be designed as 4-lane carriageway facilities with footpath.

The overall width of the new bridges is proposed as under:



Typical Cross Section (TCS TYPE) - 6
Typical cross section of Bridge at Dect Level with Footpath 4-Lane divided Highway

It is proposed to provide an overall deck width of 2x13.50 m for bridges consisting of 10.5 m for carriageway, 1.50 m for footpath 0.550 m for the concrete crash barrier on either side of deck and 0.40 m for double w-beam crash barrier between footpath & carriageway.

1.5.1.2 Deck Levels of Structures

The deck levels of the structures carrying the project road would be worked out based on the following parameters:

- Vertical clearance required above the crossroads;
- Vertical profile of the proposed project road and
- Vertical clearance required above the high flood level.

To achieve salient features of the design, competitive and analysis for the loading is given below:

1.5.1.3 Design Loading

The loading conditions are generally based on the requirements of IRC: 6- 2017 and the design criteria given in the tender document. The salient dead loads are listed below for ready reference.

a) Dead Loads

Plain Cement Concrete	2300 Kg / m^3
Reinforced Cement Concrete	2400 kg / m^3
Pre-stressed concrete	2500 kg / m^3
Earth fill / sand fill	1800 kg / m^3
Wearing Coat (Bitumastic concrete)	2200 / m^3

b) Carriageway Live Load

Vehicular Loading is as per IRC 6-2017 and Vehicular Combinations are considered depending on the lane width (carriageway width) of the Bridge has been provided.

c) Tractive and Braking Force

The tractive and braking forces have been considered as per the provisions of clause no. 211 of IRC: 6-2017.

d) Footpath Live Load

The footpath live load has been considered as per the provisions of clause no. 206 of the IRC: 6-2017. The intensity of the footpath loading has been considered as 500 Kg/sq. m as per clause no. 206.1 of IRC: 6-2017.

e) Wind Loads

More severe effect of the wind at right angles to the viaduct or with 65% of right angle to the viaduct and 35% along the traffic has been considered. Procedures are given in IRC: 6:2017 clause no. 209.

f) Temperature Loads

Effect of temperature differences within the superstructure for positive temperature difference and reverse temperature differences are considered for design purpose according to IRC: 6.2016.

g) Seismic Loads

Since the Project road falls in the seismic Zone V, as per IRC:6-2017 all the structures have been designed by considering seismic coefficient as applicable for Zone V.

Seismic forces have been calculated in accordance with IRC SP114-2018. Longitudinal and transverse seismic restrainers have also been proposed as per IRC: 6-2017.

h) Erection Loads

Normally these considered as 60% over loading. The launching will be generally by pneumatic tyres mounted cranes.

i) Earth Pressure

The following soil parameters for fill materials behind abutment shall be adopted as per MORTH standards.

Dry density Saturated density

Angle of internal friction

Cohesion

j) Water current

The force due to water current on pier will be considered as per clause 210 of IRC: 6. under seismic condition, the MSL shall be considered as 0.9 times the scour depth as per clause 703.3.1.2 of IRC: 78.

k) Buoyancy Effects

The following buoyancy effects have been considered wherever applicable for the design of various components of the structures:

For Foundations	100 %
For Substructure below water level	15 %

1.5.2 Material

1.5.2.1 Cement

For construction of structures 43 grade ordinary Portland cement conforming to IS: 8112 and 53 grade ordinary Portland cement conforming to IS: 12269 will be used.

1.5.2.2 Concrete

The grade of concrete will be as per design requirement and will be mentioned in the drawings for each component of the structure. Cement and water content will be as per mix design requirement; however minimum grade of concrete, minimum cement content and maximum water cement ratio will be conforming to table 14.2 of IRC: 112 for moderate condition. The maximum cement content will be restricted to 450 kg/m3 of concrete as per clause 14.3.2.5 of IRC: 112-2011.

1.5.2.3 Water

Water used for mixing and curing will be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel. The pH value of water will not be less than 6. Other permissible limits for solids in water are given in table – 18.6 of IRC: 112.

1.5.2.4 Admixtures

To improve workability of concrete, admixtures conforming to IS: 9103 will be used

1.5.2.5 Aggregates

Aggregates will consist of clean, hard, strong, dense, non-porous and durable crushed stone for coarse aggregates and natural particles for sand. The aggregates will conform to IS: 383 and will be tested to conform to IS: 2386 parts I to VIII. Size of coarse aggregate will be selected as per mix design requirement. Details of size of aggregate are as follows:

a. For Foundation: 40 mm down

b. For Substructure & Superstructure: 20 mm down

1.5.2.6 Reinforcement

Deformed or TMT reinforcement bar conforming to IS: 1786 will be used for components of the structures. The reinforcement grade will be Fe500D.

1.5.2.7 Prestressing Steel

Prestressing tendons normally take the form of separate wires, wires spun together helically to form strands or bars. For pre-tensioned steel, wires, strands and occasionally bars are used, simply to permit the concrete to bond directly to them; when post-tensioning is used, it is common practice to group the separate tendons together, so as to reduce the number of anchorages and ducts required to accommodate them. When grouped in this way, the tendons in each duct are usually termed a cable.

Uncoated stress relieved low relaxation steel conforming to IS: 14268 will only be used for pre-stressing steel so as to reduce losses due to relaxation. Data in respect of modulus of elasticity, relaxation loss at 1000 hours, minimum ultimate tensile strength, stress-strain curve etc. will necessarily be obtained from manufacturers. Pre-stressing steel will be subjected to acceptance tests prior to actual use on the works (guidance may be taken from BS: 4447). The modulus of elasticity value, as per acceptance tests, will conform to the design value which will be within a range not more than 5 percent between the maximum and minimum.

Many cables with different arrangements of wires and strands and different methods of anchorage are available as pre-stressing steel. So, type and size of cable and methods of anchorage will be decided on the basis of design requirement.

1.5.2.8 Sheathing

The duct or sheath for cables to be used of Corrugated HDPE having coefficient of friction as 0.17 and wobble coefficient per meter length of steel 0.002. The thickness of sheathing will be as specified in clause 13.4.3 of IRC: 112. The sheathing will conform to the requirement specified in clause 13.4 of IRC: 112 and test certificate will be furnished by the manufacturer. The joints of all sheathing will be water tight and conform to the provision contained in clause 13.4.1 of IRC: 112.

1.5.3 Preliminary Design and Methodology

This aims at providing the basic criteria for design of foundation, substructure, superstructure etc. for the various parameters of loads, stresses, materials, grades of concrete for various structural elements, exposure criteria, foundation designs, functional elements, finishing item etc. The flyover structures have been modelled by Finite element Technique using CSI bridge software Advanced Version 17 / STAAD Pro V8i. Analysis has been performed to get various output such as bending moment, shear forces and torsion values at various locations along the span of flyover/Minor Bridges. The detail design of super structure is performed as per IRC standards using in-house developed spread sheet programs.

The substructure components such as abutment, piers, pile foundation and other miscellaneous structural elements have been designed by using in-house developed programs (spread sheets) based on various formulas, expressions & empirical equations to satisfy IRC codal stipulations. A modular standardized span design has been followed to reduce variation & ease in construction & maximum use of post-tensioned pre-cast members.

Based on the input parameters, design approach is formulated to take into account the various parameters such as minimum land acquisition etc., which primarily consists of the following.

1.5.3.1 Superstructure

This consists of standard span configuration of 25m, 38m, & 40m, as PSC I Girder and 15m Pre-cast RCC I Girder, and with a cast-in-situ deck slab for major bridges minor bridges and flyover.

a. Design of RCC I Girder

a) For span up to 20 mts. span RCC girders will be considered for design

b) The structure behaves as composite section for all loads since the staging is released only after the deck slab gains strength.

c) The deck structure will be analyzed for dead loads, SIDL and live loads using grillage analogy method. The superstructure will be idealized into a criss cross set of discrete members which are able to resist the loads applied in a plane perpendicular to the plane of assemblage, through bending, shear and torsional rigidities of the members.

d) The minimum dimension of various elements will be provided conforming to the latest IRC codes and standards. The minimum deck slab thickness will be kept as not less than 200mm. Thickness of cross girders will not be less than the thickness of longitudinal girder.

e) For obtaining maximum shear stress, the section at a distance equal to effective depth from the face of the support will be checked and the shear reinforcement calculated at the section will be continued up to the support.

f) The design of deck slab supported transversely on the precast girder will be carried out assuming un-yielding support at the girder points and using effective width method.

b. Design of PSC I Girder

g) For span up to equal to 20 mts. or more PSC girders will be considered for design

h) The design of such type of structure is very much dependent on the construction sequence. The structure is in iso-static condition up to the stages of casting of deck slab {Deck Slab is to be casted in two parts: (a) Precast Planks, (b) Cast-In Situ} and diaphragm. After developing proper bond with girder, the structure behaves as composite section.

i) The design therefore will be done with only the girder section being effective up to the stage of casting of deck slab and diaphragm and composite section will be considered for all subsequent loads (i.e. for SIDL and live loads).

j) The deck structure will be analyzed using grillage analogy method for SIDL and Live Loads. Self-weight of girder and Dead Load of slab will be applicable on girder section alone and hence the design forces for DL will be calculated separately and results superimposed. The superstructure will be idealized into a criss cross set of discrete members which are able to resist the loads applied in a plane perpendicular to the plane of assemblage, through bending, shear and torsional rigidities of the members.

k) The minimum dimension of various elements will be provided conforming to the latest IRC codes and standards. The minimum deck slab thickness will be kept as not less than 200mm. Thickness of cross girders will not be less than the thickness of longitudinal girder.

l) For obtaining maximum shear stress, the section at a distance equal to effective depth from the face of the support will be checked and the shear reinforcement calculated at the section will be continued up to the support.

m) The design of deck slab supported transversely on the precast girder will be carried out assuming un-yielding support at the girder points.

n) Effect of differential shrinkage and creep between precast girder and in-situ slab will be considered.

c. Design of PSC segmental box girder

o) For 50m span or greater, PSC segmental Box Girder can be adopted.

p) The longitudinal analysis of superstructure will be done using stick model. Self-weight of girder, super imposed dead load, live load and other loads shall be applied to obtain BM & SF at salient points. Stress check will be applied under SLS condition with appropriate partial safety factors. For ultimate stage check of flexural capacity of section and for shear (and torsion) reinforcement calculations, appropriate ULS partial safety factors as specified in IRC:6 will be considered.

q) For transverse analysis and reinforcement design, a segmental slice of box girder will be idealized in STAAD.PRO and all other loads are applied on this model. The support under the frame will be provided at center of webs. The forces (bending moment & shear force) are obtained. Ultimate bending moment and shear force is calculated by applying load factors as per IRC:6 and sections are checked for ultimate bending and shear as per section 10 of IRC:112.

1.5.3.2 Sub Structure

Based on the available data, Piers are of RCC cast-in-situ wall type piers, Circular type piers with cantilever pier cap to house the bearings. The abutment also consist end wall type abutments with flared capital to accommodate the dirt wall and bearings. . Pre-cast retaining earth panels with a soil reinforcement strips assembled to constitute the return walls in the approach ramp area for flyover and end return wall is provided for the major bridge.

a. Foundation

Based on the available soil data input, the foundation are designed as open foundations the required depths of foundations are finalized by considering the scour depth and by SBC of soil as per IRC recommendations.

Open Foundation

The design of open foundation will confirm to provisions of IRC: 78-2014. The various specific assumptions to be made for the design of pile and pile cap will be as follows:

a) Open foundations may be provided where the foundations can be laid in a stratum which is in-erodible or where the extent of scour of the bed is reliably known. The foundations are to be reliably protected by means of suitably designed aprons, cut-off walls or/and launching aprons as may be necessary.

b) The thickness of the footings shall not be less than 300 mm.

c) For solid wall type substructure with one-way reinforced footing, the bending moments can be determined as one-way slab for the unit width subjected to worst combination of loads and forces.

d) For two-way footing, bending moment at any section of the footing shall be determined by passing a vertical plane through the footing and computing the moment of the forces acting over the entire area of footings one side of the vertical plane.

e) The shear strength of the footing may be checked at the critical section which is the vertical section at a distance 'd' from the face of the wall for one-way action where 'd' is the effective depth of the section at the face of the wall.

f) To ensure proper load transfer, a limiting value of ratio of depth to length/ width of footing equal to 1:3 is specified. Based on this, for sloped footings the depth effective at the critical section shall be the minimum depth at the end plus 1/3rd of the distance between the extreme edges of the footing to the critical section for design of the footing for all purposes.

Well Foundation

In general, the design of well and well cap will conform to provisions of IRC: 78-2014. The various specific assumptions to be made for the design of Well and Well cap will be as follows:

a. Well foundations shall be taken down to the depth which will provide a minimum grip of 1/3rd the maximum depth of scour below the design scour level specified in Clause 703.3 of IRC: 78-2014. The minimum dimension of dredge-hole shall not be less than 3 m.

b. The thickness of the staining should be such that it is possible to sink the well without excessive Kent ledge and without getting damaged during sinking or during rectifying the excessive tilts and shift. The staining should also be able to resist differential earth pressure developed during sand blow or other conditions, like, sudden drop.

c. The minimum thickness of staining shall be not less than 500 mm and also satisfy the following relationship:

H = Kd √l

h = minimum thickness of staining in m

d = external diameter of circular well of dumb dell shaped well or in case of twin D wells smaller dimensions in plan area in meters

l = depth of well in meters below the toe of well cap or LWL whichever is more (for floating cassion 'l" may be taken as depth of well in meters below bed level)

K = a constant

Values of constant shall be as follows:

Well in cement concreteK = 0.03
Well in brick masonryK = 0.05
Twin D wellsK = 0.039

Bottom Plug

The bottom plug shall be provided in all wells and the top shall be not kept lower than 300 mm in the centre above the top of the curb as shown in Appendix – 3 (Fig. 2) of IRC 078: 2014.

Well Cap

The bottom of well cap shall be laid as low as possible but above the LWL in the active channel. Where the bed level is higher than LWL the bottom of well cap may be suitably raised

The design of well cap shall be based on any acceptance rational method, considering the worst combination of loads and forces as per Clause 706 if IRC 078: 2014.

Pile Foundation

In general, the design of pile and pile cap will conform to provisions of IRC:78. The various specific assumptions to be made for the design of pile and pile cap will be as follows:

a. The vertical load carrying capacity of the pile will be determined based on static formula given in Appendix-5 of IRC:78 which shall be given by Geo-tech

b. The vertical load carrying capacity as calculated by static formula will be verified by conducting initial load tests and routine load tests on piles conforming to IS:2911 (Part 4).

c. The lateral load carrying capacity of the pile will be determined by using empirical formula given in IS:2911 (Part-1/Sec-2) by limiting the lateral deflection to 1% of pile diameter at its tip considering it as fixed headed pile under normal conditions. The capacity so evaluated will be used purely for the purpose of arriving at the upper bound of lateral load capacity. Routine load test shall be conducted to verify lateral load carrying capacity of pile. This deflection limitation will not be applicable in load combination with seismic/wind conditions for which the resulting stresses and the structural capacity of the section would be the governing criteria.

d. Soil stiffness for lateral loads will be taken from IS:2911 (Part-1/Sec-2), Appendix C. Unconfined compressive strength will be calculated from the results of Geotechnical Investigation Reports. Cohesion, as calculated using unconsolidated undrained test with required modification of angle of internal friction will be used for working out unconfined compressive strength. For cohesionless soil (sand), standard penetration resistance (N), as calculated from Standard penetration test will be used.

e. For calculating the bending moment in a pile shaft corresponding to unit lateral force, a single pile is idealized in STAAD.PRO. The pile is restrained by spring supports along the length of pile representing soil stiffness with appropriate value as per IS:2911 (Part 1/Sec 2). Then, reinforcement in pile shaft will be curtailed as per the bending moment of the pile shaft.

Pile cap

a. The minimum thickness of pile cap will be kept as 1.5 times the pile diameter.
b. Top of the pile will project 50mm into the pile cap.
c. Pile cap will be designed either by truss analogy or by bending theory, depending upon the spacing and number of piles in a pile group.
d. Pile cap will be provided with an offset of at least 150mm beyond the outer face of the outer piles.

Pier and Pier cap

a. The piers are to be designed for combined axial load and biaxial bending as per the provisions of IRC: 112. Piers shall also be checked for Slenderness as per clause 11.2 of IRC: 112.
b. Pier cap is checked as either as a flexural member or as a bracket, depending upon the span/depth ratio.
c. In case it is a flexural member, the bending moments are checked at the face of pier support. Shear force will be checked at a distance deff away from the face of support.
d. In case the pier cap acts as a bracket, the design will conform to clause 16.7 of IRC:112 for bracket design.
e. Analysis, design and detailing will in general conform to the stipulations of relevant clauses of IRC:112 and good engineering practices.
f. In case of PSC pier cap: stress check will be applied under SLS condition under different stages of loading with appropriate load factors. The ultimate stage check of flexure capacity and shear reinforcement calculation, appropriate load factors shall be considered.

1.5.3.3 Seismic Design & Detailing

Elastic Seismic Acceleration Method (Seismic Coefficient Method):

The project falls under seismic zone-V as per seismic map given in IRC SP:114, Seismic analysis of the bridge structure is proposed to be carried out in 3 steps.

Step-1: To carry out modal analysis to obtain the fundamental vibration period (T) of the bridge in two orthogonal directions (i.e. longitudinal & transverse direction).

Step-2: To calculate Sa/g as 1/T or 1.36/T this depends on soil condition.

Step-3: To estimate seismic forces as defined in IRC SP: 114.

Vertical seismic coefficient will be taken as per the provisions of the code.

The calculation for fundamental period shall be done by modelling the structure in analysis software and carrying out dynamic analysis.

Seismic Detailing

Superstructure

Since the bridges are located in Seismic Zone V, seismic thrust blocks (reaction blocks) shall be provided as additional safety measure to prevent dislodgement of superstructure in the event of failure of bearings (If applicable). In case of Integral structures, no such arrangement is required.

Bearings (If applicable)

POT PTFE/Spherical, Pin & Guided bearings will be used to resist the vertical loads and horizontal loads arising out of braking/tractive, wind/seismic etc. for the service life of 50 years as per clause 6.7.3 of IRC SP: 99.

Bearings & connections shall be designed to resist the lesser of the following forces, i.e.

(a) Design seismic forces obtained by using the response reduction factors.

(b) Forces developed due to over strength moment when hinge is formed in the substructure.

(c) When bearings & stoppers are designed as additional safety measures in the event of failure of bearings, R value as specified above which are confirming to Table 4.1 of IRC SP: 114 for appropriate substructure shall be adopted.

Substructure & Foundation

In loose sands or poorly graded sands with little or no fines, vibrations due to earthquake may cause liquefaction or excessive total and differential settlements. Liquefaction potential will be assessed. If found necessary, remedial measures will be undertaken to mitigate liquefaction potential. For liquefaction analysis specialist literature may be referred. Liquefied soil will not offer any resistance to the foundation system and it has to be ignored in design of foundation.

Plastic hinges should develop in columns rather than in capping beams or superstructure under seismic conditions. And the force demands on foundations should be based on capacity design principle that is, plastic capacity of bases of columns/piers multiplied with an appropriate over strength factor. Pile Foundations may experience limited inelastic deformations; in such cases these should be designed and detailed for ductile behaviour.

Ductile detailing specification

Since the project lies in seismic zone-III, ductile detailing will be done as per clause 17.2 of IRC: 112 & clause 9.1 of IRC SP: 114 for all piers and columns and as per clause 17.3 of IRC: 112 for foundations. In general, clauses given in IRC SP: 114 shall be followed. The ductile detailing will be done only in substructure if plastic hinge will be formed in substructure first. If first formation of plastic hinge is not ensured in substructure, then ductile detailing will be done in foundation too.

Minimum grade of concrete will be M25 for RCC Works (fck = 25 MPa) and M15 for PCC works.

Steel reinforcement of grade Fe 500D (see IS 1786: 1985) will be used.

1.5.3.4 Bearings

Bridge bearing must be designed to transmit all the loads and appropriate horizontal forces. From the material point of view, these bearings can be made from metal, rubber, metal and elastomer and even concrete.

Elastomeric Bearings

Elastomeric bearing can accommodate translation movements in any direction and rotational movements in any axis by elastic deformation. They should not be used in tension or when rotation is high and vertical load small. The basis of design is that the elastomer is an elastic material, the deflection of which under a compressive load is influenced by its shape (shape factor). Reinforcing plates should be bonded to the elastomer to prevent any relative movement at the steel/elastomer interface. The dimension and the number of internal layers of elastomer chosen will satisfy the following clauses of IRC: 83(Part-II).

IRC: 83 (Part-II) recommends that chloroprene (CR) only will be used in the manufacture of bearing. The elastomer will conform to all the properties specified in table 1 of IRC: 83 (Part-II), and tolerances in dimensions specified in table2 of IRC: 83 (Part-II).

Pot/PTFE Bearings, Metallic Pin / Guided Bearings

Due to easy availability, maintenance free and easy replacement, for simply supported structures elastomeric bearing will be used. Wherever it is unavoidable POT/ PTFE bearings will be used. However, for continuous structure POT/ PTFE bearing will be used.

The design of the POT/ PTFE bearing will be done by the manufacturer conforming the provisions of material as well as design parameters IRC: 83(part-III). However, the forces, movements and rotation etc will be provided by the designer of the project on the format given in appendix –1 of IRC: 83 (part-III). In support of quality assurance, acceptance specification given in clause 928 of IRC: 83(part-III) will be followed.

1.5.3.5 Loading

a) Superimposed dead load

Loads corresponding to the dimensions given for bridge furniture details in item 5.0 will be considered as SIDL for design of structure. For the purpose of loading, the load is taken as 200 kg/m2 (Surfacing) & 800 kg/m (Crash Barrier).

b) Differential Settlement

In case of structure sensitive to differential settlement such as continuous/Integral structures the value of differential settlement will be taken as recommended by soil consultant. Long term values of Modulus of Elasticity of concrete will be considered to account for creep effects in this case.

c) Global Temperature Variation

Global Temperature Variation is considered as per clause 215.3 IRC: 6-2017 for the purpose of analysis. The coefficient of thermal expansion (alpha) is considered as 12.0 x 10-6 per degree Celsius. For design purpose, maximum variation in temperature is considered as below:

Maximum temperature = 35.5C (As per Notification 2 of IRC: 6-2017)

Minimum temperature = 6.1 C (As per Notification 2 of IRC: 6-2017)

While deriving the effect of global temperature variation, long term modulus of concrete of superstructure (half the instantaneous modulus of concrete) shall be taken.

d) Differential Temperature Gradient

The Superstructure is designed for the positive & reverse temperature gradient along the depth of superstructure as per clause 215.3 of IRC: 6-2017.

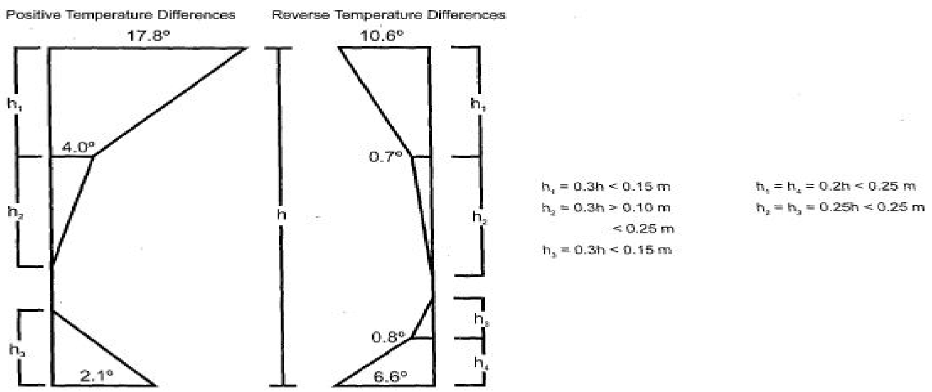


Fig. 10 (a) Design Temperature Differences for Concrete Bridge Decks

While deriving the effect of temperature gradient variation, short term/instantaneous modulus of concrete shall be taken.

e) Wind Force

Maximum wind speed will be taken as 50m/sec estimated from figure 10 of IRC:6-2017. Wind pressure will be estimated for plain terrain from table 12 of IRC:6-2017.

f) Seismic Force

The seismic forces will be calculated for seismic zone V, with zone factor Z=0.36 and Importance factor I= 1.2. Response reduction factor for various structural components will be taken from Table 4.1 of IRC SP: 114-2018.

g) Condition of exposure

Moderate Exposure conditions shall be adopted as per table14.1 of IRC: 112-2011.

h) Other Loads

The loads which are not mentioned in this Clause, will be as per IRC: 6-2017.

i) Load Combinations and Stress Levels

Various load combinations for the purpose of design of various structural elements are as per Annexure B (Clause 202.3) of IRC: 6-2017. Every element of bridge is designed for ultimate limit state (ULS) and checked for limiting stresses under serviceability limit state (SLS).

As per IRC: 112-2011, under SLS condition, maximum compressive stress in concrete at any fibre shall be restricted to 0.48 fcj. Maximum tensile stress in steel is restricted to 0.8 fyk in rare combinations.

The section is checked for flexure, shear & torsion under ULS condition.

1.5.3.6 Deflection Limitations

For RCC/PSC structures, deflection criteria shall be checked as per clause 12.4 of IRC: 112.

a. For vehicular live load: Span/800

b. For vehicular LL on cantilever: cantilever span/300

1.5.3.7 Cover

Minimum clear cover to any reinforcement bar closest to concrete surface for different component will be as follows. Provisions of IRC: 112-2011 will be followed in any case.

Component	Minimum Cover in mm
Superstructure	40
Substructure	40/50
Foundation	75
Pre-stressing cable duct	75 (Post Tensioning)
	65 (Pre-Tensioning)
Pre-cast elements	35

1.5.3.8 Minimum Diameter of Bar

Diameter of any reinforcing bar including transverse ties, stirrups etc., will not be less than 8 mm. Diameter of any longitudinal reinforcement bars in columns/vertical member will not be less than 12 mm. However, diameter of the reinforcing bars will not exceed 25 mm in deck slab, and 32mm in all other components. Bundling of bars wherever required shall be adopted as per clause 15.2.7 of IRC: 112.

1.5.3.9 Expansion Joints

Provisions of IRC: SP:69-2011 will be followed. These will also conform to Section 2600 Specifications for Roads & Bridge Works issued by MoRT&H.

Types of Expansion joints based upon the length of the span and movements are given below:

Sr. No.	Span	Expansion Joints
(i).	For RCC slabs up to 11 m span only	Buried type expansion joints
(ii).	For all other bridges having span longer than 11 m and where movements are up to total 80mm	Elastomeric Single Strip Seal type expansion joints
(iii).	For all other bridges having span longer than 11 m and where movements are more than 80mm	Elastomeric Modular Strip Seal type expansion joints

1.5.3.10 Approach slab & Bracket to support Approach Slab

Reinforced concrete approach slabs, 3.5 m long and 300 mm thick, in M30 grade concrete at either end of the bridge, will be provided. One end will be supported on the reinforced concrete bracket projecting from the wall over abutment and the other end resting over the soil, in accordance with the guidelines issued by MoRT&H.

A levelling course, 15 cm thick, in M-15 grade concrete will be laid under the approach slabs.

1.5.3.11 Drainage Spouts

Drainage spouts will be provided in accordance with MOST standard plans. The minimum spacing will be kept preferably as 5.0m c/c which may be adjusted to suit span length.

1.5.3.12 Miscellaneous elements

This comprises of Drainage planning & design of the deck structure. Provisions of the bearing for smooth transfer of super structure loads to the sub structure are made. Expansion joints to take care of the movements of superstructure, crash barrier for safety to the traffic movements, wearing courses are provided.

Drainage – To ensure effective drainage of the deck superstructure, it is proposed to provide transverse chamber and to trap the drainage water at intervals through MS gratings and guide through a common header to be tapped at intervals at pylons.

Further, this will be connected & guided to the chambers at grade level before connecting to the at- grade box drain.

Crash Barrier – These are designed & detailed to take up the accidental loads as per codes and as a safety barrier for the movement of the traffic. They are detailed as New Jersey RCC cast-in-situ crash barrier with MS tube railing at the top.

RCC hand rail - These are designed & detailed to take up the loads as per codes and as a safety barrier for the movement of the pedestrian traffic.

Wearing Coat – It is being planned to provide as an insulation layer to the deck from traffic movement and also serve as a waterproofing layer (mastic asphalt layer) and laid with bituminous concrete.

1.6 Protection Works

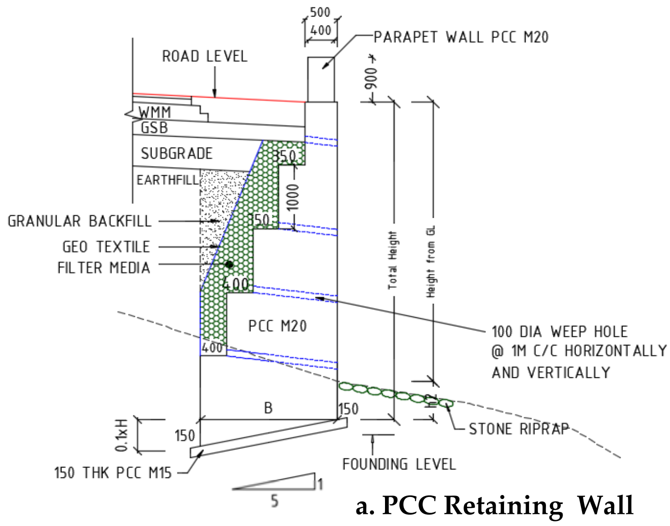
The proposed road alignment passes through hilly terrain, major stretch of the road passes through reaches with either full cutting or part cutting and filling. Due to high cut & fill natural stability of the hill slopes disturbs. Watercourses along the slopes cause erosion affecting road stability. Soil movement along slopes tend to disturb the road formation. All these must be effectively countered to obtain a stable road, to avoid instability of the slopes and landslides in future by provision of structures/slope stability arrangements to act as retaining, restraining and protective structures.

The alignment is so designed to minimize the height of cut & fill and least disturbance to natural hill slopes. Various types of retaining structures/Slope stability arrangements are proposed considering the following factors.

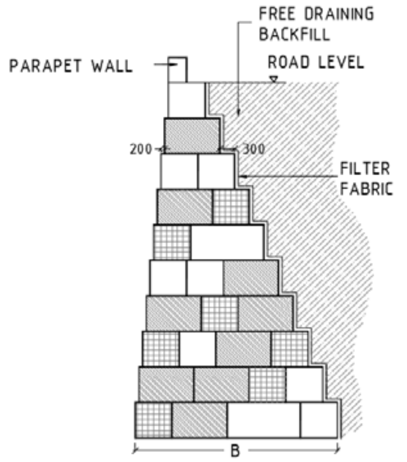
- Height of Cut/Fill
- Cross slope the existing ground/hill
- Soil properties
- Height of hill above the finished road level

1.6.1 Retaining Walls

Retaining walls are permanent structures usually built at the toe of the slope or at shoulder edge to resist lateral pressure due to existing soil, earth filling, back fill, water pressure etc. Retaining walls have been proposed, a) where the existing ground is steep, and embankment is not feasible b) to restrict the formation width at ROW constraint locations.



a. PCC Retaining Wall



a. Gabion Retaining Wall

Note: Ref. separate Standard drawings for more details.

Fig 1.2 Retaining Wall Types

Detail locations of Retaining walls are given below;

Table 1.13 Schedule of Retaining Wall

Sl No	LHS Chainage (m) From	LHS Chainage (m) To	Length (m)	Height (m)	Remarks	RHS Chainage (m) From	RHS Chainage (m) To	Length (m)	Height (m)	Remarks
1	4+770	4+910	140	8	RCC	4+770	4+910	140	8	RCC
2	7+060	7+330	270	3	PCC	7+050	7+280	230	3	PCC
3	12+660	12+840	180	3	PCC	12+770	12+850	80	3	PCC
4	14+420	14+680	260	4	PCC	14+420	14+600	180	4	PCC
5	15+400	16+070	670	5	PCC	15+400	16+120	720	5	PCC
6	19+040	19+730	690	3	PCC	19+070	19+710	640	3	PCC
Total Length=			**2210**					**1990**		

1.6.2 Crash Barrier

Steel Crash barrier (W-Beam) is proposed where the embankment height is 3m or more, on curves having radii less than 150m for upgrades and 300m for downgrades and at locations where, ground slope is steeper than 2 horizontal 1 vertical (2:1) on valley side, on the approaches of bridges for a length of at least 30m on both sides. With these criteria, detail length of W-beam crash barrier is given below;

Table 1.14 Schedule of Crash Barrier

	LHS			RHS		
Sl No	**Chainage (m)**		**Length (m)**	**Chainage (m)**		**Length (m)**
	From	**To**		**From**	**To**	
1	0+100	0+300	200	0+100	0+300	200
2	0+180	0+240	60	0+180	0+240	60
3	4+050	4+660	610	4+050	4+660	610
4	4+150	4+450	300	4+150	4+450	300
5	0+000	0+250	250	0+000	0+250	250
6	4+910	5+260	350	4+910	5+140	230
7	7+060	12+430	5370	7+530	7+730	200
8	12+600	13+000	400	7+860	10+060	2200
9	13+330	14+700	1370	10+280	11+270	990
10	15+350	16+200	850	11+460	12+340	880
11	16+600	17+100	500	12+600	13+000	400
12	17+600	18+150	550	13+370	14+700	1330
13	19+000	19+750	750	15+350	16+200	850
14				16+600	16+700	100
15				17+600	18+150	550
16				19+000	19+750	750
Total Length=			**11560**			**9900**

1.7 Codes

- IRC: 5-2015 : Standard Specifications and Code of Practice for Road Bridges, Section I – General Features of Design (Eighth Revision)
- IRC: 6-2017 : Standard Specifications and Code of Practice for Road Bridges, Section-II Loads and Stresses (Revised Edition)
- IRC: 22-2015 : Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design) (Third Revision)

- IRC: 24-2010 : Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method) (Third Revision)
- IRC: 78-2014 : Standard Specifications and Code of Practice for Road Bridges, Section VII- Foundations and Substructures (Revised Edition)
- IRC: 83-2015 (Part I) : Metallic Bearings
- IRC: 83-2018 (Part II) : Elastomeric Bearings
- IRC:83-2018 (Part III) : Standard Specifications and Code of Practice for Road Bridges Section – IX Bearings (Part III: Pot, Pot-cum PTFE, Pin and Metallic Guided Bearings)
- IRC:22-2015 : Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit States Design) (Third Revision)
- IRC: SP:114-2018 : Guidelines for Seismic Design of Road Bridges
- IRC: 112-2011 : Code of Practice for Concrete Road Bridges
- IRC: SP:13-2004 : Guidelines for the Design of Small Bridges and Culverts (First Revision)
- IRC: SP:69-2011 : Guidelines and Specifications for Expansion Joints
- IRC: SP:71-2006 : Guidelines for Design & Construction of Precast Pre-tensioned Girders for Bridges
- MoRT&H : Specifications for Road and Bridge Works, 2013 (Fifth Revision)
- IRC: 87-2011 : Guidelines for the Design and Erection of Falsework for Road Bridges
- IS-2911-2002 : Code of practice for design and construction of pile foundations Part I Section II

Other relevant codes.

Annexure – 1 Hydrology Report

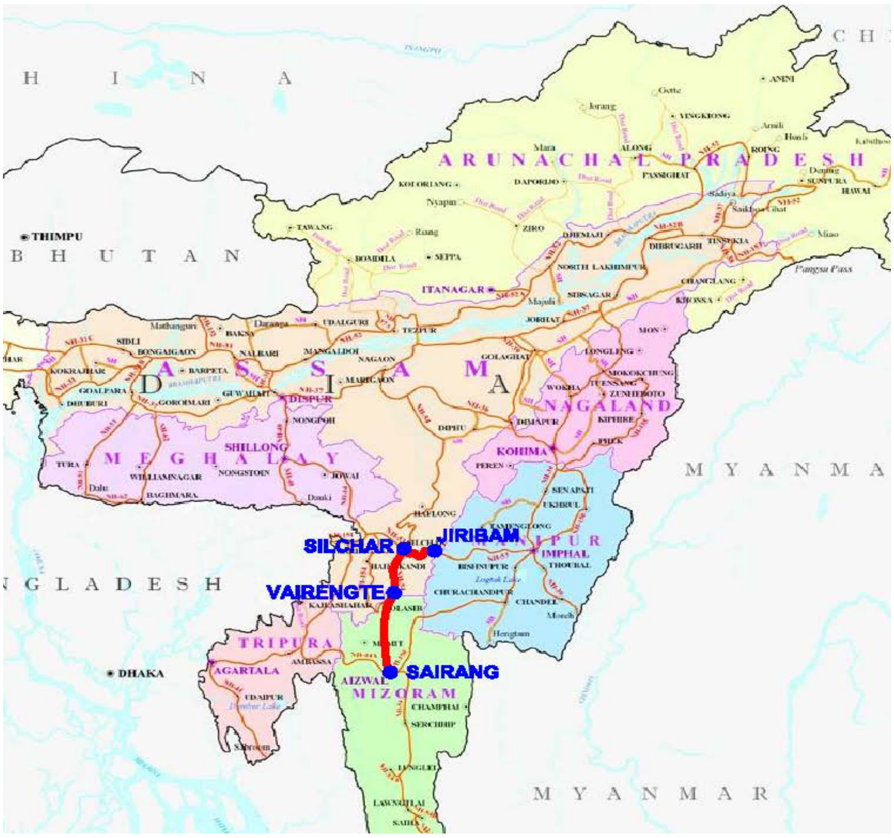
Ministry of Road Transport and Highways
(GOVERNMENT OF INDIA)

NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LTD.

Head Office: 3rd floor, PTI building, 4- Parliament street, New Delhi-110001

Project office: Building of State Institute of Rural Development & Panchayati Raj Durlang Leitans, Mizoram Aizawl-796025

Consultancy Services for preparation of DPR for development of Economic Corridors, Inter Corridors and Feeder Routes to improve the efficiency of freight movement in India under Bharatmala Pariyojna (Lot-1) (Package-III) (Silchar-Vairengte (49.9 km), Vairengte-Sairang (111 km), Silchar-Jiribam (55 km)).



Hydrology Report (Silchar-Vairengte)
Package-1 (From Km 0+000 to Km 21+000)

June 2022

Transys Consulting Pvt. Ltd.

Head Office : 12th Floor, JMD Regent square, M.G. Roaad, Gurugram-122002, Haryana,
Email ID: sanjeev@transysconsulting.co.in
Regional office: 01-04, Ground Floor, Raheja Chambers, #12, Museum Road, Bangalore-560001
Phone +080-41461995/41261995 Email: transys blr@transysconsulting.co.in

Hydrology Report

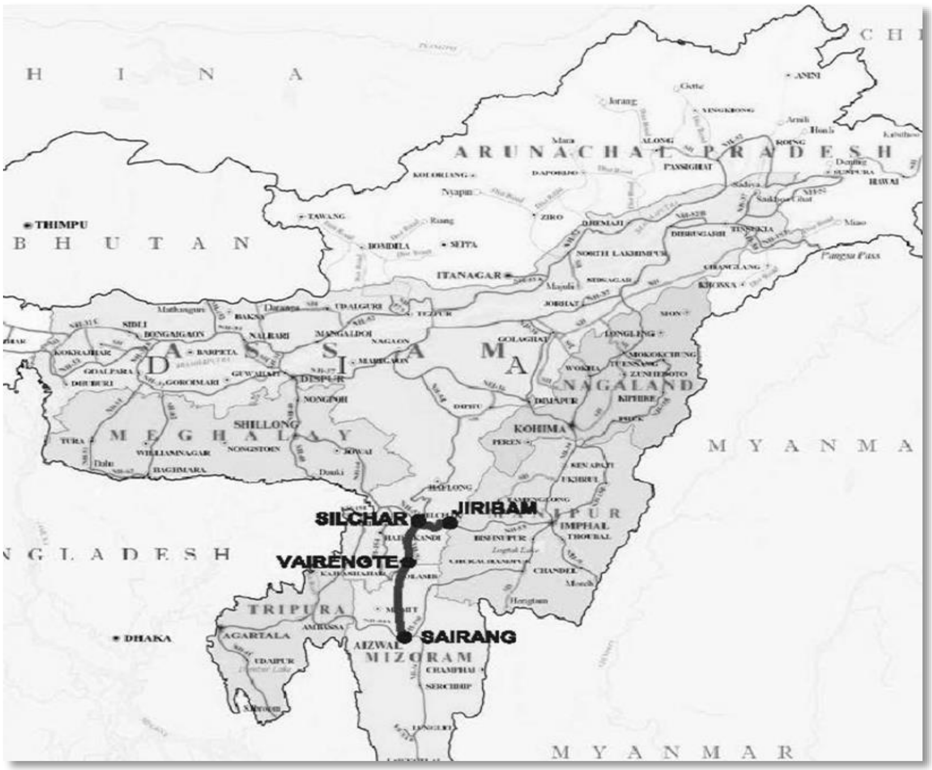
AUTHORITY:	
	NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION Ltd.

PROJECT: **Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)**

Consultancy Services for preparation of DPR for development of Economic Corridors, Inter Corridors, and Feeder Routes to improve the efficiency of frieght movement in India under Bharatmala Pariyojana (Lot-1) (Package-III)

TITLE OF DOCUMENT:	Hydrology Design Calculation - DDPR-R1

Doc. Number:	HYDROLOGY-DDPR-R1	Prepared By:	Varun/Venu
Rev. No:	R0	Checked By:	Amith
Date:	15/06/2022	Approved By:	Chetan



Date:	Rev No.	Revision	By
15/06/2022	R0	For Review and Approval	Varun/Venu

DESIGN CONSULTANT:

Transys Consulting Pvt. Ltd.

12th Floor, JMD Regent Square, M.G Road, Gurugram – 122002, Haryana.

Tel: 124-4195950; e-mail: info@transysconsulting.co.in; Website: www.transys.in

Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation - DDPR-R1		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

INDEX

1. Introduction

The Ministry of Road Transport & Highways (MoRT&H), Gov. of India, has announced a comprehensive programme to improve road connectivity across the nation under pro- posed Bharatmala Pariyojana. Many defined highway stretches totalling about 50,000 km are proposed to be developed as "Economic Corridors, Inter Corridors & Feeder Routes" under "Bharatmala Pariyojana".
Consultancy Services for preparation of DPR for development of Economic Corridors, Inter Corridors and Feeder Routes to improve the efficiency of freight movement in India under Bharatmala Pariyojna (Lot-1) (Package-III) (Silchar-Vairengte(49.9 km), Vairengte-Sairang (111 km), Silchar-Jiribam (55 km)) .

2. Project Road Description

project road lies in Cachar district of Assam and it traverse through major area like. Rongpur, kashipur, Sonabharighat, Nutan Bazar, Kabuganj, Dolhai and Baga Bazar. The other important built-up areas are Saidpur Mukkam, Narsingpur, Katakal, Panibhora, Ramprasadpur, Saptagram, Islamabad and Lailapur.

3. Terrain & Land Use

Project existing road passes through mainly plain and hilly terrain at certain location. The alignment mostly passes through agricultural area, semi built-up, built-up areas and few stretches lying on hill cum forest area.The Existing Project road passes through hill cum forest area from Km 41+000 to Km 42+750 for an approximate 1.75 km. The Project Highway is lying with moderate number of trees on both sides after Lailpur town from Km 41+000 to Km 42+750

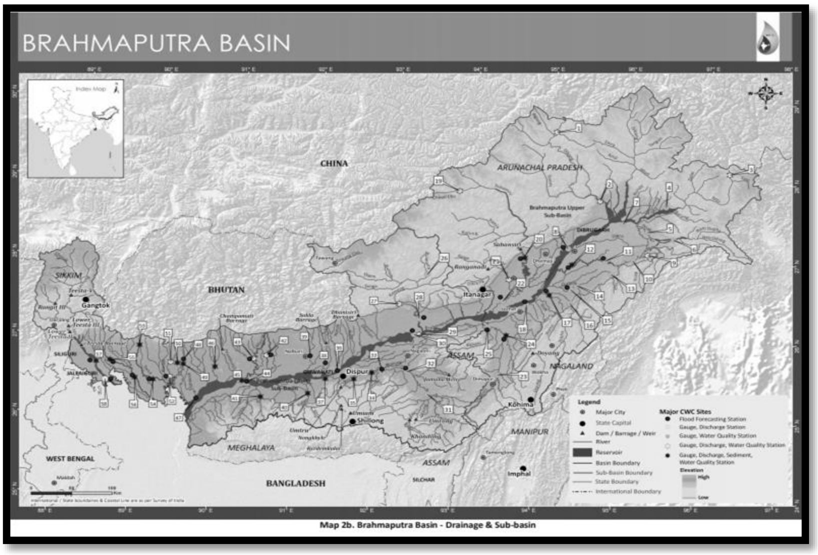


Figure 1: South Brahmaputra Subzone Basin

4. Hydrology and Hydraulic Study

4.1 Objective and Scope

The main objective of the hydrological and hydraulic study is to determine the required size of drainage structures to allow the estimated design flow of the streams to cross the road safely, and to check whether waterways of existing structures are sufficient to transmit the flow without risk so that appropriate decisions could be taken concerning their rehabilitation.

The hydrological and hydraulic study for the project has been based on:
• Topographic survey data of cross drainage structures
• Topographic Data and Maps of Streams, Up-Stream and Down-Stream.
• HFL from the local enquiries and telltale marks and hydraulic condition at the existing drainage structure.

The scope of work is to prepare the Detailed Hydrological Report for all the Major Bridges and Major Bridges of the project.

4.2 Collection of Data

4.2.1 Field Survey

Data collected from the visit to site were collated and studied along with the Google Earth Imageries. The Design Approach has been formulated through careful examination of the following data collected:

• Local inquiries, Data collected from, Road/ culvert Inventory, HFL, History of flooding/ overtopping, mean annual rainfall, regional runoff coef- ficient, canal crossings

• Survey of India Topo Sheets – Land use, soil type, cover condition, slope, and catchment area

• Visual inspection – Bed level, clearance, HFL, Overtopping, vegetation cover, flood plain, blockage/sedimentation, flow direction, terrain, presence of tanks in catchment area and presence of scour holes.

4.3 Methodology

4.3.1 Assessment of Design Discharge

The design discharge has been calculated by the following methods:
• Empirical Method
• Rational Method
• Slope Area
• SUG Method

4.3.1.1 Empirical Formula

During the past decade, numbers of inventers / scientists have evolved many empirical formulas, to be utilized in different zones across the world. IRC: SP13-2004 has recommended using empirical formulae like Dicken's, Ryves and Inglis. Wherever hydrological records are inadequate, empirical formulae developed for the region is used. The common type of formula makes the flow function of catchment area i.e. C * (M) ^ n. The important formulae used in India are Dicken's and Ryve's. But in general, only one empirical formula i.e. Dicken's method considered. The exponent 'n' has been assigned the value of 3/4, 2/3 respectively in Dicken's and Ryve's formulae. But in general, we take only one empirical formula i.e. Dicken's method.

Dicken's Formula

Q = CM^ (3/4)

Where,
Q = Peak runoff in cumecs
M = Catchment area in Sq.km.
C = 11-14 where the annual rainfall is 600 mm to 1200 mm
= 14 -19 where the annual rainfall is more than 1200 mm
=22 in Western Ghats

4.3.1.2 Rational Formula

The rational formula for assessment of peak discharge from catchment considers rainfall, runoff under various circumstances, time of concentration and criti- cal intensity of rainfall. For small size catchment (less than 25 Sq. Km), design discharge is estimated using the techniques described in "IRC Approach"

IRC Approach

Rational Formula for Peak Run-off is given as

Q = 0.028*P*f*Ic*A

Where,
Q = Maximum discharge (cumecs)
P = Coefficient of Runoff for the Catchment characteristics
f = Fraction of maximum point intensity at center of storm, depends on area
A = Catchment Area in Hectares
Ic = Critical intensity of Rainfall in cm/hours

4.3.1.3 Slope Area Method

The slope area method for the calculation of design discharge considers the bed slope along the river, cross-sectional area of the river at the bridge location, up-stream and down-stream. It also takes into account the type of bed material present the river bed.

Slope-area method is a most commonly used indirect method of measurement. In this method discharge is computed on the basis of a uniform flow equation involving channel characteristics, water surface profile and a roughness coefficient. The drop-in water surface profile for a uniform reach of channel represents losses caused by bed roughness. The well-known Manning's equation is used in this method. The discharge is given by equation.

$$Q = 1/n\ A.R^{2/3}\ S^{1/2}$$

Where,
Q is discharge in cumec
A is cross-sectional area in m^2
R is hydraulic mean radius
S is friction slope, and
n is roughness coefficient

4.3.1.4 Synthetic Unit Hydrograph (SUG)

The approach consists of working out regional Synthetic Unit hydrograph (SUG) parameters with pertinent physiographic characteristics from the recommended formulae in the particular Sub Zone flood estimation report drawing and adjusting SUG computation of design storm duration and point rainfall & areal rainfall, distribution of areal rainfall during design storm duration to obtain rainfall increments for unit duration intervals, assessment of effective rainfall units after subtraction of prescribed loss rate from rainfall increments estimation of hourly rainfall excess, estimation of base flow and computation of 100 year peak flood and 100 year design flood hydrograph. This method is applicable for catchment area ranging from 25 Sq. Km to 2500 Sq. Km as per Introduction of Zone 2(b) of CWC flood estimation report.

Determination of physiographic parameters

Step 1:

a) Preparation of Catchment area plan (A): The point of study i.e. structure location is located on toposheet published by Survey of India and catchment plan is marked on it considering contours and tributaries of main stream.

b) Length of longest stream (L): Length of the longest main stream in Km from the farthest point of catchment /water shed boundary to the point of study of structure site is marked and measured on catchment area plan.

c) Length of the longest main stream (Lc): From a point opposite/near to center of gravity of catchment to point of study.

d) Centre of gravity of catchment area: Determination of center of gravity of the catchment.

e) Stream slope: Equivalent stream slope (Seq): Equivalent slope can be computed by the formula: Longitudinal section is broadly divided into 3 or more segments and the following formula is used to calculate the Equiva- lent slope of main stream.

$$Seq \sum (Li * (Di+Di-1))/ L^2$$

Where,

Li = Length of the ith segment in Km.

Di , Di-1 = Heights of successive bed location at the contour points and in- tersections (Elevations of the river/nallah bed at ith intersec- tions points of contours are reckoned from the bed elevation at the point of study point/structure site considered as datum).

L = Length of the longest main stream, Km.

Step 2: Determination of Synthetic Unit graph parameters:

The following SUG relationships are used to compute 1-hour SUG parameters for each structure site as per clause 3.4.3 (Recommended SUG Relation) of 2b.

Sl. No.	Relationship	Equation No.
1	$Q_p = 0.905\ (A)^{0.758}$	3.4.3.2
2	$t_p = 2.87\ (q_p)^{-0.839}$	3.4.3.3
3	$W_{50} = 2.304\ (q_p)^{-1.035}$	3.4.3.4
4	$W_{75} = 1.339\ (q_p)^{-0.978}$	3.4.3.5
5	$W_{R50} = 0.814\ (q_p)^{-1.018}$	3.4.3.6
6	$W_{R75} = 0.494\ (q_p)^{-0.966}$	3.4.3.7
7	$T_B = 2.447\ (t_p)^{1.157}$	3.4.3.8
8	$T_m = t_p + t_r/2$	3.4.3.9
9	$Q_p = q_p \times A$	3.4.3.10

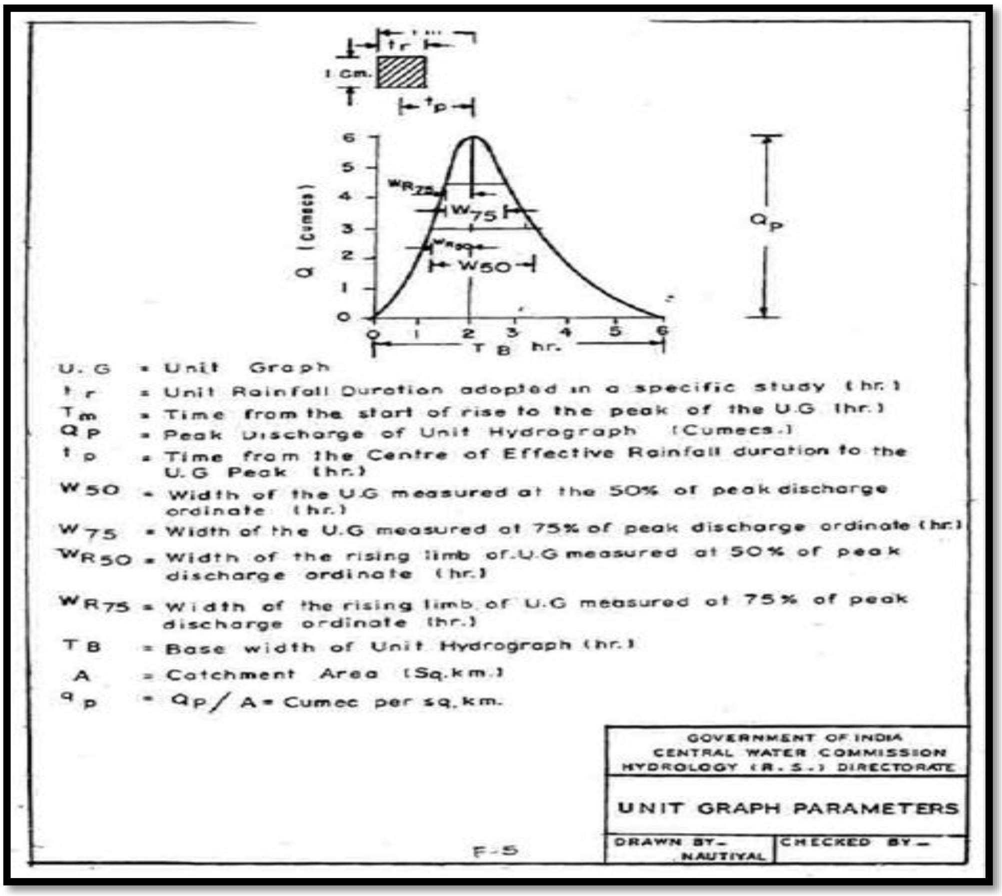


Figure 2: SUG as per CWC South Brahmaputra Sub-Zone 2(b)

Obtain unit graph parameters by substituting appropriate basin/unit graph parameters given in the above equation. The above estimated parameters of unit graph are plotted on a natural graph paper and the plotted points are joined to draw synthetic unit graph. Suitable adjustment is made to ensure that volume of unit graph is 1 cm depth of effective rainfall over the catchment. The discharge ordinates (Qi) of the unit graph at ti = tr=1 hr interval is summed up i.e. ∑ (Qi * ti) (cumecs/hr) and compared with the volume of 1.0 cm direct runoff depth over the catchment with the formula.

$$\sum(Qi * ti) = 2.78 * A/tr$$

Where,
A = Catchment Area in sq. km.
tr= 1 (Unit Duration) in Hours.

Step 3: Determination of design loss rate and design base flow:

a) Loss Rate: Direct surface runoff is the product of storm rainfall after infiltration into surface soils, sub surface and ground besides abstractions like evaporation. According to CWC flood estimation report for Zone 2(b), loss rate of 81 flood events analyzed were plotted against the storm duration and average design loss rate 0.35 Cm/hr Recommnded As per Clause 3.6 of zone 2(b)

LOSS RATE RANGES - NUMBER OF FLOOD EVENTS
(In cm. per hour)

Sl.No.	Br. No.	C.A. (km²)	Upto 0.2	0.2 to 0.4	0.4 to 0.7	0.7 to 1.00	1.00 to 2.00	above 2.00	Total
1	4(MOT)	1270	9	3	3	-	-	-	15
2	463	875	6	3	3	1	-	-	13
3	414	554	5	2	1	-	-	-	9
4	6(MOT)	476		5	4	-	1	-	15
5	160	470	2	-	2	-	-	-	4
6	8	264	-	-	6	-	-	-	6
7	146	210	-	1	1	-	1	-	3
8	184	171	1	-	1	1	-	-	3
9	215	136	-	2	2	1	-	-	5
10	446	54	-	2	-	1	-	-	3
11	130	46	3	2	1	-	-	-	6
12	440	46	1	2	1	1	-	-	5
13	70	31	-	3	1	2	-	-	6
14	3(MOT)	29	1	1	2	1	2	-	7
	Total		33	26	28	9	4	-	100

Figure 3: Design Loss Rate as per CWC South Brahmaputra Sub-Zone 2(b)

b) Design Base Flow: According to CWC flood estimation report for Zone 2(b), the average base flow rate of 0.05cumes/ sq km has been considered in report.

Step 4: Determination of design storm rainfall:

The areal distribution and time distribution of rainfall of a given duration are two main meteorological factors deciding the design flood peak and the shape of the hydrograph. This input has to be converted into effective rainfall and applied to the transfer function (Synthetic unit hydrograph) to obtain the response (flood hydrograph).

a) Isopluvial maps: The isopluvial maps of 100- Year, 24- hour rainfall are available, which can be used to derive 24- hour rainfall estimates for 100-year return period at any desired location in the zone. Procedure: Locate project site / structure site, with the help of their Latitude and Longitude, under study on 100-Year, 24-hour isopluvial map and obtain the 100-Year, 24-hour point rainfall value in cm. For a catchment covering more than one isopluvial, compute the average point rainfall.

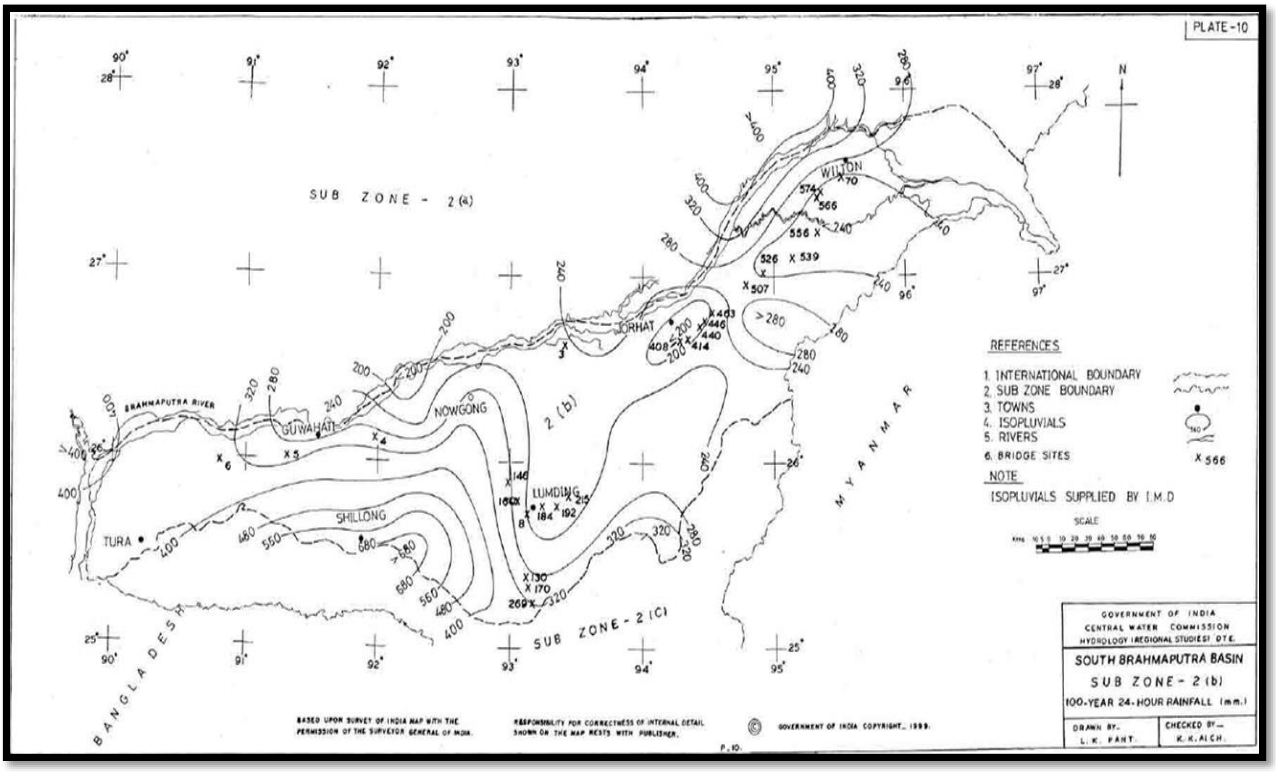


Figure 4: 100 Years 24 hr. Isopluvial Map of South Brahmaputra Sub-Zone 2(b)

b) Short duration ratio: Procedure- Read the conversion ratio for particular storm duration TD from the available Table/Figure and multiply the 100-Year 24-hour point rainfall values to obtain 100-Year TD hour point rainfall.

c) Areal reduction factor: Procedure- Read the areal reduction factor corresponding to storm duration TD and the given catchment area of Project site in the available Table / Figure and multiply the 100- Year, TD-hour rainfall by this factor to obtain the 100-Year, TD hour areal rainfall over the catchment.

d) Time distribution factor: Procedure- Read the time distribution co-efficient for 1, 2…, (TD-1) hours corresponding to storm duration TD from the relevant Graph/Table and multiply the 100- Year TD-hour areal rainfall by this coefficient to obtain cumulative depths of 1, 2…, (TD-1) hour catchment rainfall.

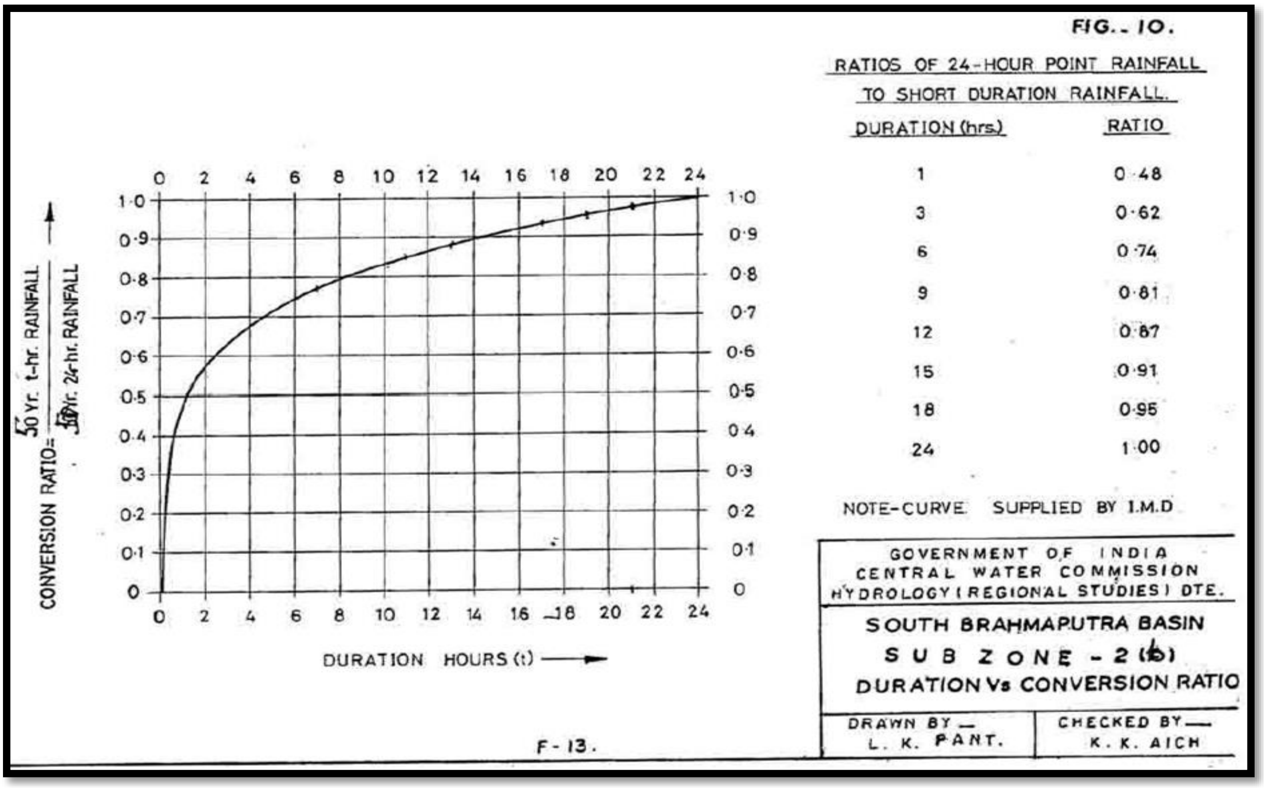


Figure 5: Graph Showing ratio for 24-hours Point Rainfall to Short Duration Rainfall

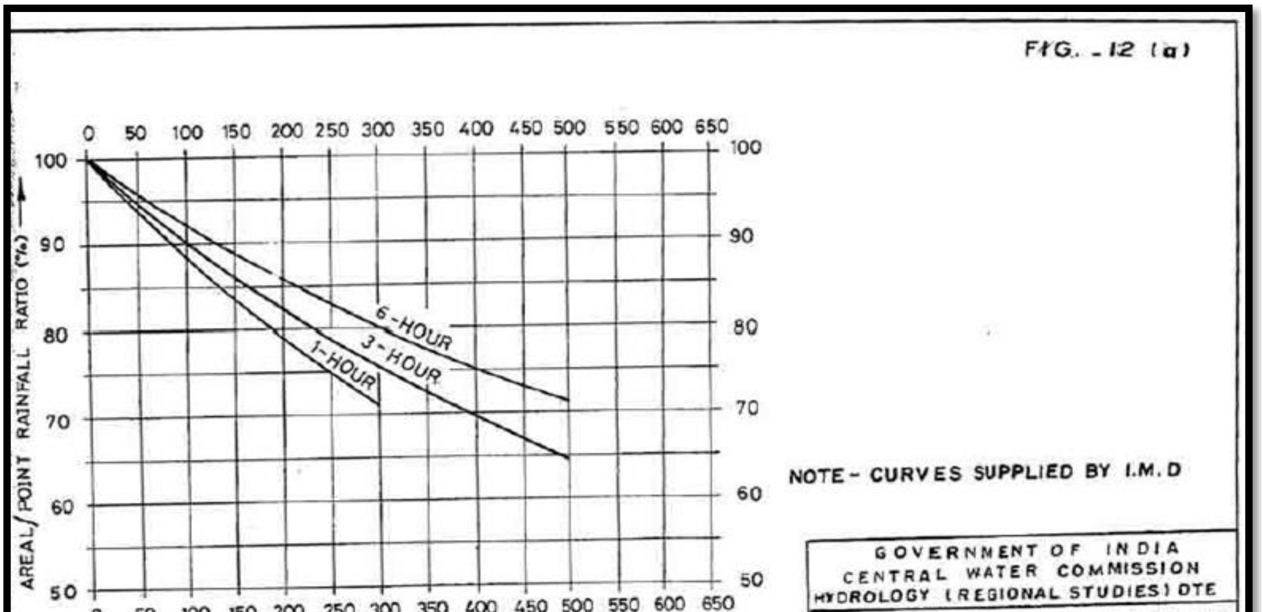


Figure 6: Graph showing Arial to Point Rainfall ratio depending on Catchment Area

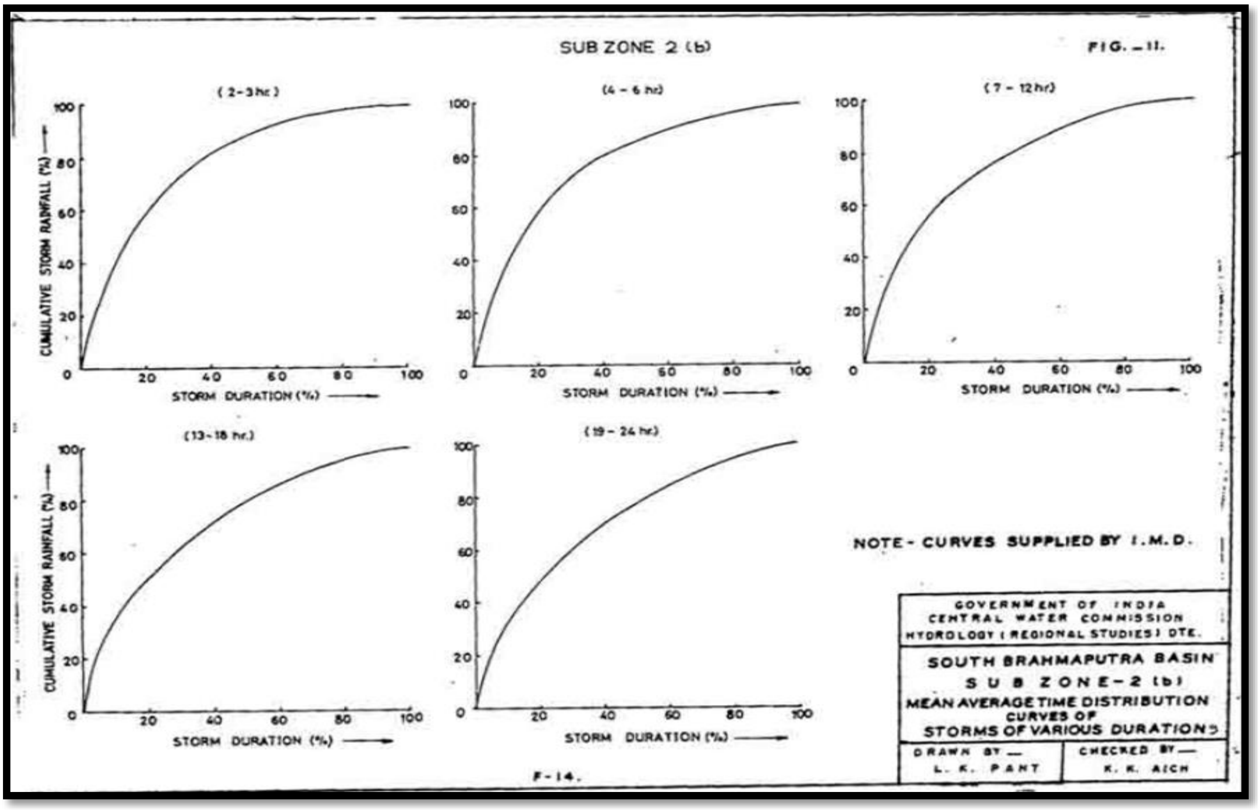


Figure 7: Storm Map of various Duration for South Brahmaputra Sub-Zone 2(b)

Step 5: Determination of Design flood (Peak Only):

For the estimation of the peak discharge, the effective rainfall units were rearranged against the unit graph ordinates such that the maximum effective rainfall was placed against the maximum U. G. Ordinates, the next lower value of effective rainfall against the next lower value of U. G. Ordinate and so on. Summation of the product of U. G. Ordinate and the effective rainfall gives the total direct runoff.

5. Fixing of Design Discharge

Design discharge has been taken the maximum of the peak flood discharge by different methods provided it does not exceed the next highest discharge more than 50%. If it exceeds, it is restricted to that limit (As per Article 6.2.1 of IRC: SP: 13-2004).

6. Design High Flood Level

The discharge computed by catchment area methods (as explained above) and observed gauging data, will be adopted as design discharge. After fixing the design discharge, design high flood level corresponding to the adopted design flood shall be determined by using Stage-Discharge Curve and adding afflux into the normal flood level obtained from stage discharge curve. The Stage-Discharge curve calculations will be done by using Manning’s equation;

$$Q_D = (1/n) * A * R^{2/3} * S^{1/2}$$

Where,

Q_D = Design Discharge in m^3/sec

A = Cross-sectional area of flow corresponding to design discharge in sq.m

R = Hydraulic mean depth in m = A/P

P = Wetted perimeter in m.

S = Mean longitudinal slope of the channel

n = Rugosity coefficient

7. Liner Waterway of the Bridge

IRC 5 - 2015 recommends for natural channels in alluvial beds but with well-defined banks and for all-natural channels in bed with rigid in-erodible boundaries, the linear waterway shall be distance between banks at HFL, at which the designed maximum discharge determined. As the channels in project are has defined banks, the above recommendation in clause 106.5.1.1 of IRC:5-2015 is adopted.

8. Scour Depth Calculation

Lacey's equation is generally adopted for estimating normal scour depth as recommended in IRC:5-2015

$$\mathbf{R = 1.34\ (Db^2/Ksf)^{1/3}}$$

Where,

R is the Lacey's regime scour depth, measured below HFL

q is the design dis- charge intensity under bridge in cumecs per meter

f is silt factor given by the equation

$$\mathbf{f = 1.76 * d_{50}^{\ 1/2}}$$

Where,

d_{50} is the mean sediment size in mm

Normal scour depth based on Lacey's equation and the actual observed depth. Higher of the two values is adopted for design. Maximum scour level for pier and abutment are to be calculated using a factor of safety of 2 and 1.27, respectively as per IRC: 5. for computing scour depth, design discharge is to be enhanced by 30% - 10% (as per catchment area) to provide for adequate margin of safety as per provision of IRC: 78 - 2014. The foundation level is to be fixed, depending upon the bore-hole data. Wherever the strata below the bed level are found to be rocky the foundation depth shall be restricted to that level keeping provision of anchoring as recommended in IRC.

9. Afflux Calculation

When the waterway area of the opening of a bridge is less than the unobstructed natural waterway area of the stream, i.e. when bridge contracts the stream, afflux occurs. The afflux will be calculated using Orifice formula as given below:

$$\mathbf{Q = C_0 * \sqrt{(2g)} * L * Dd * [\ h + (\ 1 + e) * (u^2/2g)\ ]^{1/2}}$$

Where,

L= Linear waterway of the bridge (m)

Dd = Downstream depth of water (m)

Q = Design discharge (cumecs)
h = Afflux (m)
u = velocity at bridge (m/s)
g = acceleration due to gravity (m/s^2)
C_0 & e = Factors depends on L/W (using graphs)

Minimum afflux provided as Per Moles worth & Orfiece formula. If h is more than ¼ Dd, Weir Formula is applied.

$$Q = 1.706 * Cw * L * H^{3/2}$$

$$Q = W * Du * u$$

10. Vertical Clearance

After fixing the afflux to the H.F.L, vertical clearance is provided according to the design discharge as shown in table below:

Table 1: Minimum vertical clearance above design HFL as per design discharge according to IRC:5-2015

Sr. No.	Discharge (m^3/s)	Minimum Vertical Clearance in mm
1	Upto 0.3	150
2	Above 0.3 & upto 3.0	450
3	Above 3.0 & upto 30	600
4	Above 30 & upto 300	900
5	Above 300 & upto 3000	1200
6	Above 3000	1500

11. Reference

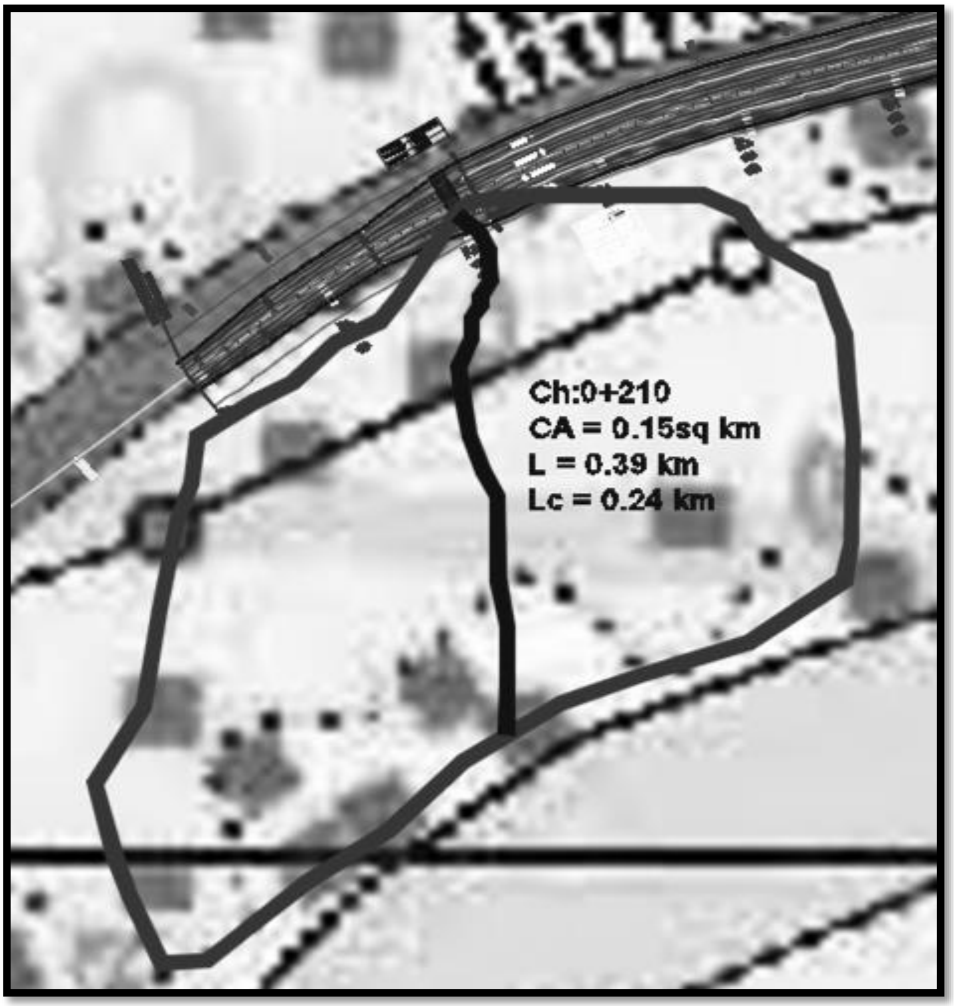
IRC: SP-13 (2004) - Guidelines for the design of small bridges and culverts
IRC: 5 (2015) - Code of practice for Road Bridges (General features of Design)
IRC: 78 (2014) – Code of Practice for Road Bridges (Design of substructure and Foundation).
IRC: SP-84 (2014) - Manual of Specifications and Standards for Four laning of Highways.
Flood Estimation Report by Central Water Commission for South Brahmaputra Sub-Zone 2(b)

Hydrology Design Calculation of MNB @ CH.0+210

Table 1: Details of Minor Bridge

S.No	Chainage (Km)	Proposed Span (m)	Catchment Area (Sq. Km)
1	0+210	1 x 10	0.15

Catchment Area



DISCHARGE BY EMPIRICAL & RATIONAL METHODS

General Information

Road	:	Silchar - Vairengte
Name of River/Nalla/Stream	:	Nala
Name of nearest Village/Town	:	Karatrigram
Proposed Chainage	:	0+210
GT Sheet NO.	:	G46U14
Hydrometerological Sub Zone	:	2 b

Details of proposed bridge site

Proposed span arrangement	:	1 x 10	m
Total width provided	:	11.6	m
Obstruction due toPier	:	0	m
Obstruction due to Abutment	:	1.6	m
Clear water way skew	:	10.000	m
Skew Angle	:	0	deg
Clear water way provided (Right)	:	10.000	m

<u>DISCHARGE BY DICKEN'S FORMULA :</u> (Refer SP-13, page 7)

Q = $CM^{3/4}$

C = 11 - 14 where the annual rainfall is 60 - 120 cm
= 14 - 19 where the annual rainfall is more than 120 cm
= 22 in Western Ghats

C adopted	(Annual rainfall is 125 cm - 250 cm)	=	19	
Catchments area (M)		=	0.15	sqkm
Q		**=**	**4.580**	***cums***

<u>DISCHARGE BY RATIONAL METHOD :</u>

Discharge by Rational Formula

Catchment area (A) = 0.15 sqkm	=	15	Hectares
Length of path from toposheet (L)	=	0.4	Km
Difference in levels from toposheet (H)	=	6	m
Maximum rain fall (F) (100 years return period)	=	176.0	mm
Storm Duration(Calculated as per CWC report for subzone 2b)	=	2.0	Hour
One hour rainfall (Io)	=	131.98	mm/hrs
Time of concentration (I.R.C.SP-13, page 11)	=	0.160	hrs
Critical rainfall intensity	=	227.50	

Discharge Q = 0.028 x P x f x A x Ic

P = (Rocky, Steep)	=	0.8	
f =	=	1.000	
A =	=	15	Hectares
Ic =	=	22.75	cm/hr
Q =	=	**7.64**	**cum/sec**

Here,

t_c = Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchments

= $(0.87*L3/H)^{0.385}$

I_o = One hour rainfall in cm.

= (F/T)*(T+1)/(1+1)

I_c = Critical intensity of rainfall in cm per hour

= Io*(2/(1+tc))

P = Coefficient of runoff for the catchments characteristics (Ref.TB-4.1, SP:13-2004)

A = Catchments area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in meter

DISCHARGE BY MANNING'S METHOD :

A = X-sectional Area

S = Slope considered

P = Wetted perimeter

R = Hydraulic mean radius = A/P

V = Velocity = $1/n\ R^{2/3}\ S^{1/2}$

n = Mannings rugosity coefficient = 0.05

Q = Discharge = A*V

HFL = 20.497 m

X-section at	HFL	A	P	R	S	u	Q
	m	m^2	m	m	m/m	m/sec	m^3/sec
Without afflux at Bridge location	20.50	7.74	14.18	0.55	0.0028	0.70	5.43
Without afflux at Upstream location	20.497	6.91	14.15	0.49	0.0028	0.65	4.50
Without afflux at Downstream location	20.50	9.77	14.15	0.69	0.0028	0.82	8.01
						0.820	8.01

DESIGN DISCHARGE :

Discharge by Dickens Formula = 4.6 cumecs

Discharge by Rational Formula = 7.6 cumecs

Discharge by Manning's Formula = 8.0 cumecs

Design discharge should be highest of above methods, limited to 1.5 times of second highest discharge. **= 8.01 cumecs**

AFFLUX CALCULATIONS:

i) Molesworth formula

By using molesworth Formula = $\left\{\left(\frac{V^2}{17.88}\right) + 0.015\right\} X \left\{\left(\frac{A}{a}\right)^2 -1\right\}$

where,

Velocity of water prior to obstruction (V) = **Discharge / wetted area**

= 1.03 m/s

Unobstructed sectional area of the river (A) = 7.743 m^2

Obstructed sectional area of the river (a) = 5.699 m^2

Hence, Actual afflux of the river = 0.06 m

ii) Oriface Formula

Obstructed length of bridge	L	=	10.000 m
Unobstructed width of the stream	W	=	13.586 m
	RV	=	0.590
Depth of flow	D_d	=	0.570
	L/W	=	**0.74**

From clause 17.2 of IRC SP:13, (page 65)

Discharge, **Q** = $\mathbf{Co \sqrt{2g} L D_d [h+ (1+e) u^2 / 2g]^{1/2}}$

Where,

Co	=	**0.867**
e	=	**0.871**
g	=	9.81 kg/m^2
D_d	=	0.570 m

Substituting the values

$C_o \sqrt{2g} L D_d$ = 21.880

{(1+e)/2g} = 0.095

Q = 8.01

Substituting,

$8.011 = 21.880 \times \text{sqrt} (h + 0.0954 u^2)$

$0.366 = \text{sqrt} (h + 0.0954 U^2)$

$0.134 = (h + 0.0954 U^2)$

$h = -0.0954 U^2 + 0.134$ → Equation 1

Discharge, Q = $W (D_d + h) u$

$8.011 = (0.57 + h) \; 13.586 \; U$

$0.590 = (0.57 + h) \; U$

$h = \dfrac{0.59 - 0.570 U}{U}$ → Equation 2

Equating Equation 1 and Equation 2

$-0.0954 U^2 + 0.134 = \dfrac{0.59 - 0.570 U}{U}$

$-0.095 U^3 + 0.13 U = 0.59 - 0.570 U$

$-0.095 U^3 + 0.70 U - 0.59 = 0$

Adopting Trial and Error method for solving the equation

Trial value of "U" = **0.9550** m/s

-0.0004 ≈ 0

OK

Hence, velocity U = 0.96 m/s

Substituting the value of U in equation 1

h = 0.047 m **<** 0.142

Oriface formula is applicable

iii) Weir Formula

Cw = 0.96 (IRC: SP:13-2004, Page 53, Clause 15.2)

$Q = 1.706\ Cw\ L\ H^{3/2}$

$8.01 = 16.378\ H^{3/2}$

H = **0.6** m

$H = D_u + u^2/2g$

Assume

Du = H

$Q = W\ d_u\ u$

u = 0.950

Du = 0.575 m

h = Du - Dd

= 0.005 m > 0.142

Oriface formula is applicable

Hence design afflux adopted = 0.063 m

AHFL = 20.560

HFL = 20.497

Bed level = 19.627

<u>VERTICAL CLEARANCE</u>

Design Discharge = 8.01 cumecs

Vertical Clearance = 0.60 m

Depth of Superstructure = 1.215 m

Minimum FRL required = 22.375 m

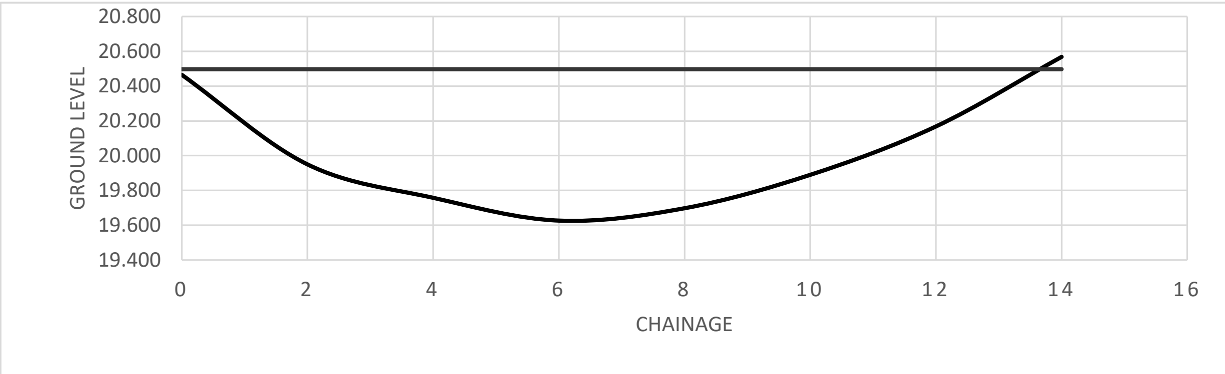
Proposed FRL = 22.952 m SAFE

Cross-sectional area of Stream

HFL 20.50 m

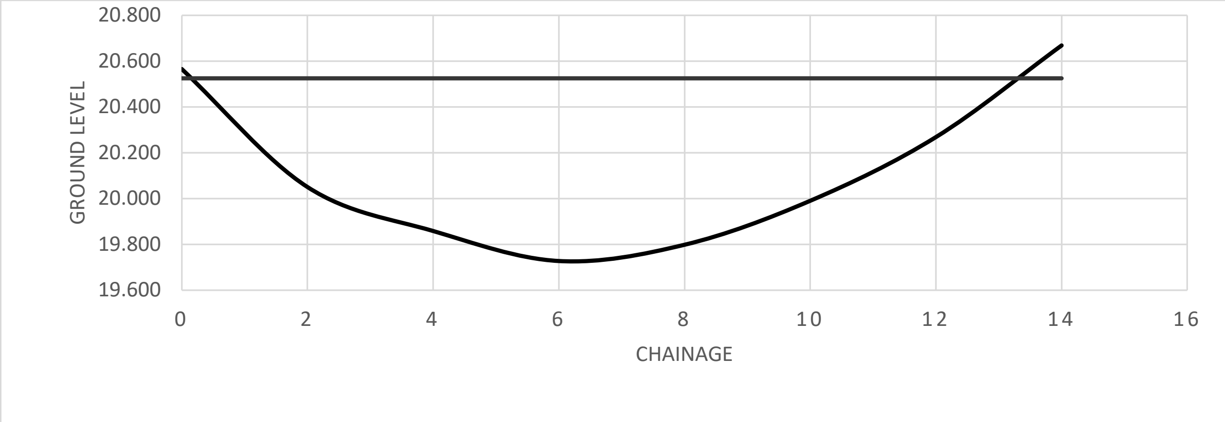
1. Bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**20.465**	20.50	0.0320				
2	**19.950**	20.50	0.5470	0.290	2	0.579	2.121
4	**19.758**	20.50	0.7390	0.643	2	1.286	2.026
6	**19.627**	20.50	0.8700	0.805	2	1.609	2.001
8	**19.698**	20.50	0.7990	0.835	2	1.669	2.004
10	**19.890**	20.50	0.6070	0.703	2	1.406	2.001
12	**20.168**	20.50	0.3290	0.468	2	0.936	2.009
14	**20.568**	20.50	-0.0710	0.129	2	0.258	2.019
	19.627					**7.74**	**14.182**



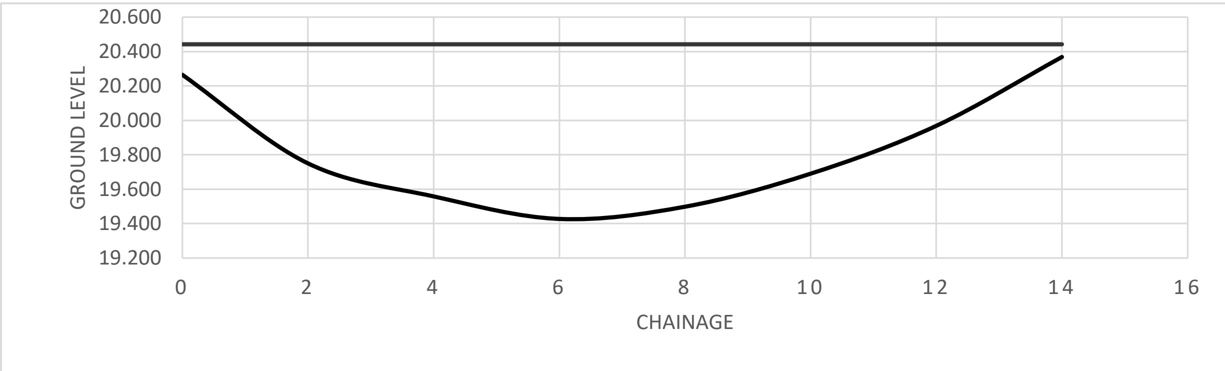
2. 10m Upstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**20.565**	20.52	0.0000				
2	**20.050**	20.52	0.4745	0.237	2	0.47	2.065
4	**19.858**	20.52	0.6665	0.571	2	1.14	2.009
6	**19.727**	20.52	0.7975	0.732	2	1.46	2.004
8	**19.798**	20.52	0.7265	0.762	2	1.52	2.001
10	**19.990**	20.52	0.5345	0.631	2	1.26	2.009
12	**20.268**	20.52	0.2565	0.396	2	0.79	2.019
14	**20.668**	20.52	0.0000	0.128	2	0.26	2.040
	19.727					**6.91**	**14.148**

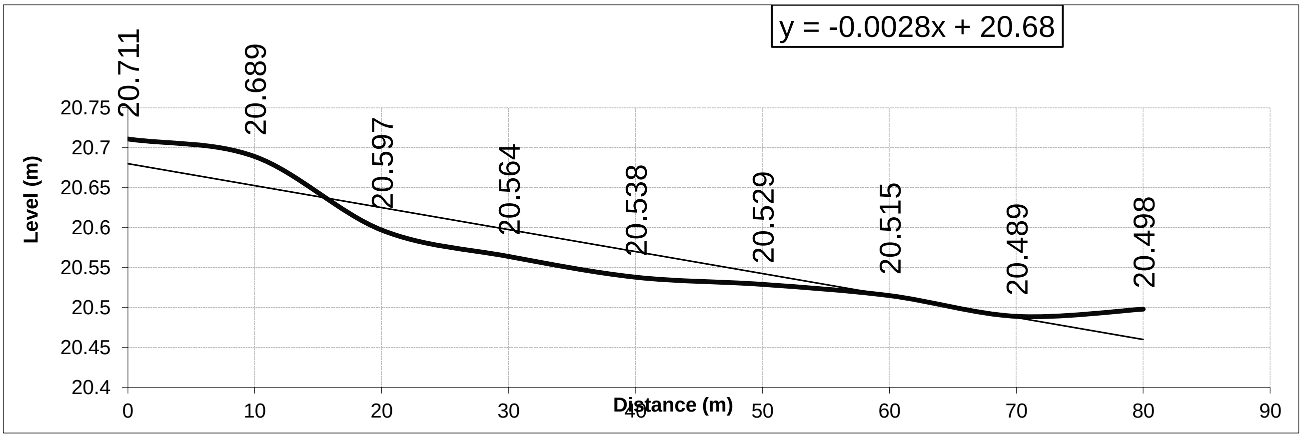


3. 10m Downstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**20.265**	20.44	0.1770				
2	**19.750**	20.44	0.6920	0.434	2	0.87	2.065
4	**19.558**	20.44	0.8840	0.788	2	1.58	2.009
6	**19.427**	20.44	1.0150	0.949	2	1.90	2.004
8	**19.498**	20.44	0.9440	0.979	2	1.96	2.001
10	**19.690**	20.44	0.7520	0.848	2	1.70	2.009
12	**19.968**	20.44	0.4740	0.613	2	1.23	2.019
14	**20.368**	20.44	0.0740	0.274	2	0.55	2.040
	19.427					**9.8**	**14.148**



Stream Slope in Longitudinal direction



Average Slope = 0.00275 m/m 0.002752

Hydrology Design Calculation of MJB @ CH.7+660

Table 1: Details of Major Bridge

S.No	Chainage (Km)	Proposed Span (m)	Catchment Area (Sq. Km)
1	7+660	2 x 40	108.00

Catchment Area

DISCHARGE BY EMPIRICAL & RATIONAL METHODS

General Information

Road	:	Silchar - Vairengte
Name of River/Nalla/Stream	:	Badri
Name of nearest Village/Town	:	Kashipur
Proposed Chainage	:	7+660
GT Sheet NO.	:	G46U13
Hydrometerological Sub Zone	:	2 b

Details of proposed bridge site

Proposed span arrangement	:	2 x 40	m
Total width provided	:	80	m
Obstruction due toPier	:	0.9	m
Obstruction due to Abutment	:	2	m
Clear water way skew	:	77.100	m
Skew Angle	:	0	deg
Clear water way provided (Right)	:	77.100	m

DISCHARGE BY DICKEN'S FORMULA : (Refer SP-13, page 7)

Q = $CM^{3/4}$

C = 11 - 14 where the annual rainfall is 60 - 120 cm
= 14 - 19 where the annual rainfall is more than 120 cm
= 22 in Western Ghats

C adopted	(Annual rainfall is 125 cm - 250 cm)	=	19	
Catchments area (M)		=	108.00	sqkm
Q		**=**	**636.534**	***cums***

DISCHARGE BY RATIONAL METHOD :

Discharge by Rational Formula

Catchment area (A) = 108 sqkm	=	10800	Hectares
Length of path from toposheet (L)	=	30.0	Km
Difference in levels from toposheet (H)	=	35	m
Maximum rain fall (F) (100 years return period)	=	240.3	mm
Storm Duration(Calculated as per CWC report for subzone 2b)	=	9.0	Hour
One hour rainfall (Io)	=	133.50	mm/hrs
Time of concentration (I.R.C.SP-13, page 11)	=	12.232	hrs
Critical rainfall intensity	=	20.18	

Discharge Q = 0.028 x P x f x A x Ic

P = (Rocky, Steep)	=	0.8	
f =	=	0.724	
A =	=	10800	Hectares
Ic =	=	2.02	cm/hr
Q =	=	**353.60**	**cum/sec**

Here,

t_c = Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchments

= $(0.87*L3/H)^{0.385}$

I_o = One hour rainfall in cm.

= (F/T)*(T+1)/(1+1)

I_c = Critical intensity of rainfall in cm per hour

= Io*(2/(1+tc))

P = Coefficient of runoff for the catchments characteristics (Ref.TB-4.1, SP:13-2004)

A = Catchments area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in meter

DISCHARGE BY MANNING'S METHOD :

A = X-sectional Area

S = Slope considered

P = Wetted perimeter

R = Hydraulic mean radius = A/P

V = Velocity = $1/n\ R^{2/3}\ S^{1/2}$

n = Mannings rugosity coefficient = 0.05

Q = Discharge = A*V

HFL = 19.474 m

X-section at	HFL	A	P	R	S	u	Q
	m	m^2	m	m	m/m	m/sec	m^3/sec
Without afflux at Bridge location	19.47	299.21	103.72	2.88	0.0019	1.77	528.70
Without afflux at Upstream location	19.474	261.89	85.21	3.07	0.0019	1.84	482.73
Without afflux at Downstream location	19.474	314.14	103.88	3.02	0.0019	1.82	572.80
						1.843	572.80

DESIGN DISCHARGE :

Discharge by Dickens Formula = 636.5 cumecs

Discharge by Rational Formula = 353.6 cumecs

Discharge by Manning's Formula = 572.8 cumecs

Discharge by SUG = 573.6 cumecs

As per IRC : 5-2015, Clause 106.3 for catchment areas more than 25 sq.Km SUG method shall be followe asscement of maximum discharge of bridge. **= 573.62 cumecs**

AFFLUX CALCULATIONS:

i) Molesworth formula

By using molesworth Formula = $\left\{ \left(\frac{V^2}{17.88} \right) + 0.015 \right\} X \left\{ \left(\frac{A}{a} \right)^2 -1 \right\}$

where,

Velocity of water prior to obstruction (V)	=	**Discharge / wetted area**	
	=	1.92	m/s
Unobstructed sectional area of the river (A)	=	299.21	m^2
Obstructed sectional area of the river (a)	=	200.666	m^2
Hence, Actual afflux of the river	=	0.27	m

ii) Oriface Formula

Obstructed length of bridge	L	=	77.100	m
Unobstructed width of the stream	W	=	115.0	m
	RV	=	4.990	
Depth of flow	D_d	=	2.603	
	L/W	=	**0.67**	

From clause 17.2 of IRC SP:13, (page 65)

Discharge, **Q** = $\mathbf{Co \sqrt{2g} L D_d [h+ (1+e) u^2 / 2g]^{1/2}}$

Where,	Co	=	**0.866**	
	e	=	**0.954**	
	g	=	9.81	kg/m^2
	D_d	=	2.603	m

Substituting the values

$C_o \sqrt{2g} L D_d$	=	769.736
{(1+e)/2g}	=	0.100
Q	=	573.62

Substituting,

573.620 = 769.736 X sqrt (h + 0.0996 u^2)

0.745 = sqrt (h + 0.0996 U^2)

0.555 = (h + 0.0996 U^2)

h = -0.0996 U^2 + 0.555 ⟶ Equation 1

Discharge, Q = W (D_d + h) u

573.620 = (2.60 + h) 114.962 U

4.990 = (2.60 + h) U

h = $\frac{4.99 - 2.603\ U}{U}$ ⟶ Equation 2

Equating Equation 1 and Equation 2

$$-0.0996\,U^2 + 0.555 = \frac{4.99 - 2.603\,U}{U}$$

$$-0.100\,U^3 + 0.56\,U = 4.99 - 2.603\,U$$

$$-0.100\,U^3 + 3.16\,U - 4.99 = 0$$

Adopting Trial and Error method for solving the equation

Trial value of "U" = **1.75** m/s

0.0008 ≈ 0

OK

Hence, velocity U = 1.75 m/s

Substituting the value of U in equation 1

h = 0.251 m **<** 0.651

Oriface formula is applicable

iii) Weir Formula

Cw = 0.98 (IRC: SP:13-2004, Page 53, Clause 15.2)

Q = $1.706\ Cw\ L\ H^{3/2}$

573.62 = $128.902\ H^{3/2}$

H = **2.7** m

H = $D_u + u^2/2g$

Assume

Du = H

Q = $W\ d_u\ u$

u = 1.844

Du = 2.532 m

h = Du - Dd

= -0.071 m > 0.651

Oriface formula is applicable

Hence design afflux adopted = 0.270 m

AHFL	=	19.744		
HFL	=	19.474		
Bed level	=	13.434		

VERTICAL CLEARANCE

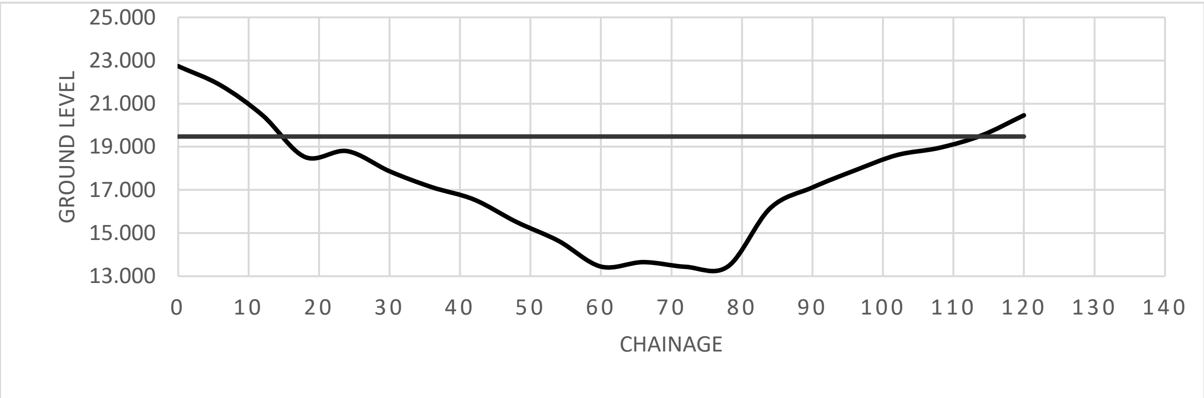
Design Discharge	=	573.62	cumecs	
Vertical Clearance	=	1.20	m	
Depth of Superstructure	=	3.130	m	
Minimum FRL required	=	24.074	m	
Proposed FRL	=	26.278	m	SAFE

Cross-sectional area of Stream

HFL 19.47 m

1. Bridge Location

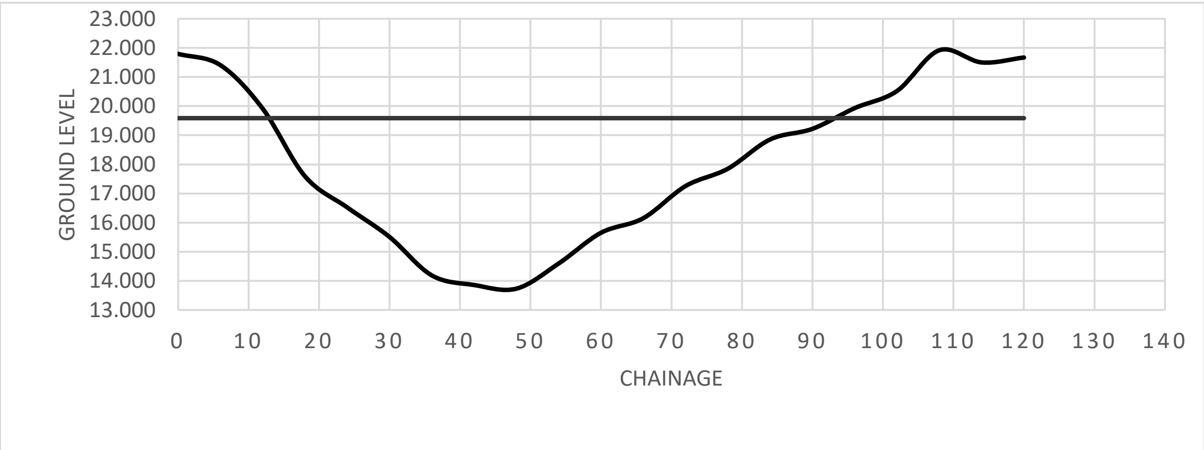
Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**22.738**	19.47	0.0000				
6	**21.856**	19.47	0.0000	0.000	6	0.000	0.000
12	**20.456**	19.47	0.0000	0.000	6	0.000	0.000
18	**18.526**	19.47	0.9480	0.474	6	2.844	6.225
24	**18.797**	19.47	0.6770	0.813	6	4.875	6.303
30	**17.865**	19.47	1.6090	1.143	6	6.858	6.006
36	**17.126**	19.47	2.3480	1.979	6	11.871	6.072
42	**16.552**	19.47	2.9220	2.635	6	15.810	6.045
48	**15.514**	19.47	3.9600	3.441	6	20.646	6.027
54	**14.631**	19.47	4.8430	4.402	6	26.409	6.089
60	**13.444**	19.47	6.0300	5.437	6	32.619	6.065
66	**13.651**	19.47	5.8230	5.927	6	35.559	6.116
72	**13.434**	19.47	6.0400	5.932	6	35.589	6.004
78	**13.448**	19.47	6.0260	6.033	6	36.198	6.004
84	**16.148**	19.47	3.3260	4.676	6	28.056	6.000
90	**17.113**	19.47	2.3610	2.844	6	17.061	6.580
96	**17.901**	19.47	1.5730	1.967	6	11.802	6.077
102	**18.616**	19.47	0.8580	1.216	6	7.293	6.052
108	**18.950**	19.47	0.5240	0.691	6	4.146	6.042
114	**19.526**	19.47	0.0000	0.262	6	1.572	6.009
120	**20.459**	19.47	0.0000	0.000	6	0.000	0.000
	13.434					**299.21**	**103.716**



Project:	Silchar-Vairengte Section of NH306 (Package SA-1, km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MJB CH: 7+660		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

2. 60m Upstream of bridge Location

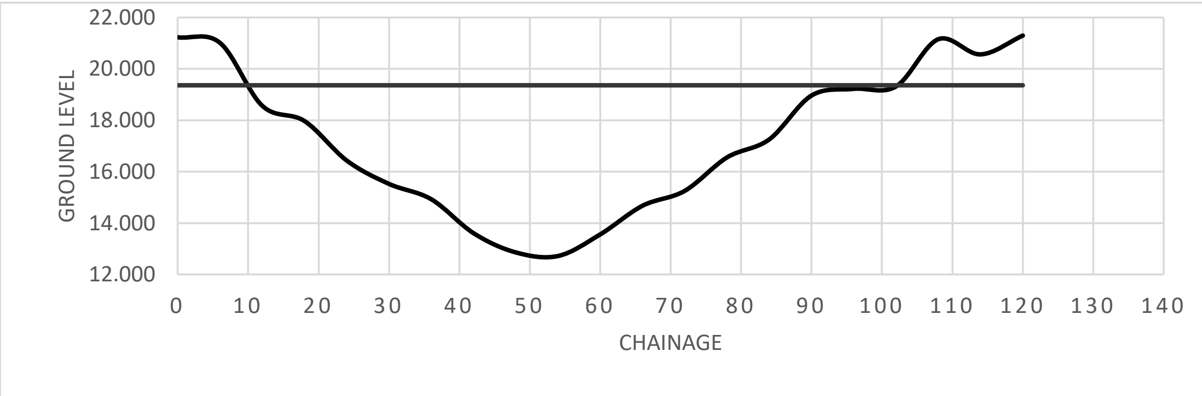
Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**21.795**	19.59	0.0000				
6	**21.409**	19.59	0.0000	0.000	6	0.00	0.000
12	**19.918**	19.59	0.0000	0.000	6	0.00	0.000
18	**17.593**	19.59	1.9950	0.998	6	5.99	6.435
24	**16.523**	19.59	3.0650	2.530	6	15.18	6.095
30	**15.510**	19.59	4.0780	3.572	6	21.43	6.085
36	**14.189**	19.59	5.3990	4.739	6	28.43	6.144
42	**13.859**	19.59	5.7290	5.564	6	33.38	6.009
48	**13.734**	19.59	5.8545	5.792	6	34.75	6.001
54	**14.598**	19.59	4.9900	5.422	6	32.53	6.062
60	**15.652**	19.59	3.9360	4.463	6	26.78	6.092
66	**16.152**	19.59	3.4360	3.686	6	22.12	6.021
72	**17.256**	19.59	2.3320	2.884	6	17.30	6.101
78	**17.852**	19.59	1.7360	2.034	6	12.20	6.030
84	**18.857**	19.59	0.7310	1.234	6	7.40	6.084
90	**19.221**	19.59	0.3670	0.549	6	3.29	6.011
96	**19.932**	19.59	0.0000	0.184	6	1.10	6.042
102	**20.521**	19.59	0.0000	0.000	6	0.00	0.000
108	**21.920**	19.59	0.0000	0.000	6	0.00	0.000
114	**21.501**	19.59	0.0000	0.000	6	0.00	0.000
120	**21.669**	19.59	0.0000	0.000	6	0.00	0.000
	13.734					**261.89**	**85.210**



Project:	Silchar-Vairengte Section of NH306 (Package SA-1, km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MJB CH: 7+660		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

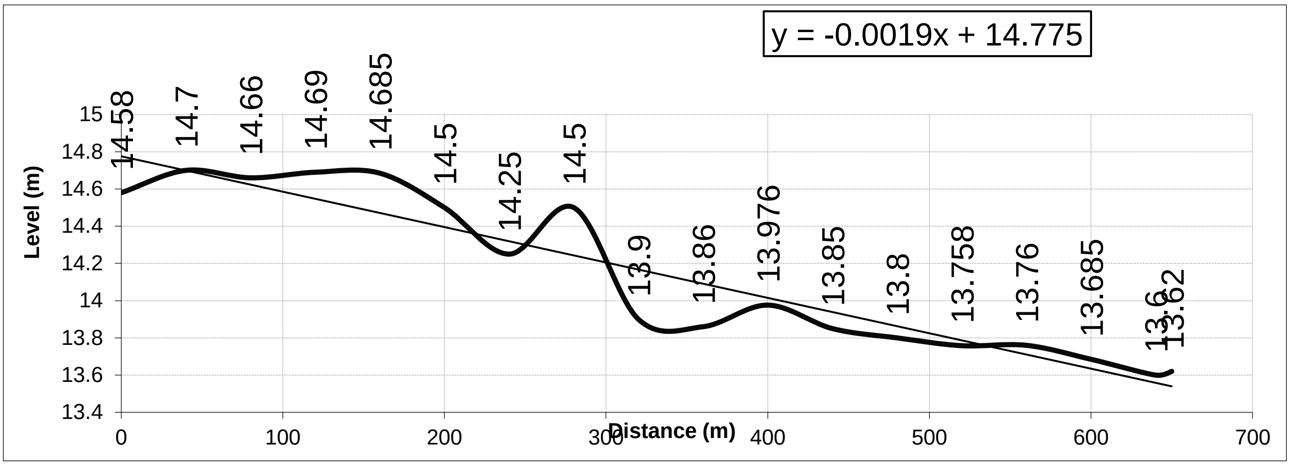
3.60m Downstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**21.226**	19.36	0.0000				
6	**21.010**	19.36	0.0000	0.000	6	0.00	0.000
12	**18.562**	19.36	0.7980	0.399	6	2.39	6.480
18	**17.969**	19.36	1.3910	1.094	6	6.57	6.029
24	**16.431**	19.36	2.9290	2.160	6	12.96	6.194
30	**15.524**	19.36	3.8360	3.382	6	20.29	6.068
36	**14.928**	19.36	4.4320	4.134	6	24.80	6.030
42	**13.608**	19.36	5.7520	5.092	6	30.55	6.143
48	**12.860**	19.36	6.5000	6.126	6	36.76	6.046
54	**12.720**	19.36	6.6400	6.570	6	39.42	6.002
60	**13.562**	19.36	5.7980	6.219	6	37.31	6.059
66	**14.675**	19.36	4.6850	5.241	6	31.45	6.102
72	**15.254**	19.36	4.1060	4.395	6	26.37	6.028
78	**16.555**	19.36	2.8050	3.455	6	20.73	6.139
84	**17.256**	19.36	2.1040	2.454	6	14.73	6.041
90	**18.962**	19.36	0.3980	1.251	6	7.51	6.238
96	**19.222**	19.36	0.1385	0.268	6	1.61	6.006
102	**19.315**	19.36	0.0450	0.092	6	0.55	6.001
108	**21.152**	19.36	0.0000	0.022	6	0.13	6.275
114	**20.562**	19.36	0.0000	0.000	6	0.00	0.000
120	**21.293**	19.36	0.0000	0.000	6	0.00	0.000
	12.720					**314.1**	**103.881**



Project:	Silchar-Vairengte Section of NH306 (Package SA-1, km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MJB CH: 7+660		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

Stream Slope in Longitudinal direction



Average Slope = 0.0019 m/m 0.0019

DISCHARGE BY SYNTHETIC UNIT HYDROGRAPH

General Information

Road : **Silchar - Vairengte**
Name of River/Nalla/Stream : **Badri**
Name of nearest Village/Town : **Kashipur**
Proposed Chainage : **7+660**
GT Sheet NO. : **G46U13**
Hydrometerological Sub Zone : **2 b**

Determination of Physiographic parameters :

i) Catchment area A = **108.00** Km^2
ii) Length of longest stream. L = **29.95** Km
iiI) Lc = **19.00** Km
iii) Equivalent stream slope

$$Se = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2}$$

Li = Length of each river segment
Di = Height above datum
Datum as RL at bridge site
L1 = Distance from Bridge site
RL = Reduced level

TABLE -A-1: COMPUTATION OF 'S'

Along main stream						
S.N.	RD	RL	Li	Di	$(D_{i-1}+D_i)$	$L_i (D_{i-1} + D_i)$
	(Km)	m	Km	m	m	Km.m
1	**0**	**15**				
2	**5**	**20**	5	5	5	25.00
3	**10**	**21**	5	6	11	55.00
4	**15**	**27**	5	12	18	90.00
5	**20**	**28**	5	13	25	125.00
6	**25**	**31**	5	16	29	145.00
7	**30**	**50**	5	35	51	255.00
					$\Sigma L_i (D_{i-1} + D_i)$ =	695.00

$$Se1 = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} = 0.77 \text{ m/km}$$

$$Se = \frac{S L * Se}{S L} = 0.77 \text{ m/km}$$

iv) $L*L_c / \sqrt{S}$ = 29.95 * 19.00 / √ 0.77
= 647.58

Determination of Synthetic Unitgraph Parameter :

One hour unit duration for the unitgraph i.e. unitgraph produced due to one cm depth of rainfall excess in one hour duration has been considered.

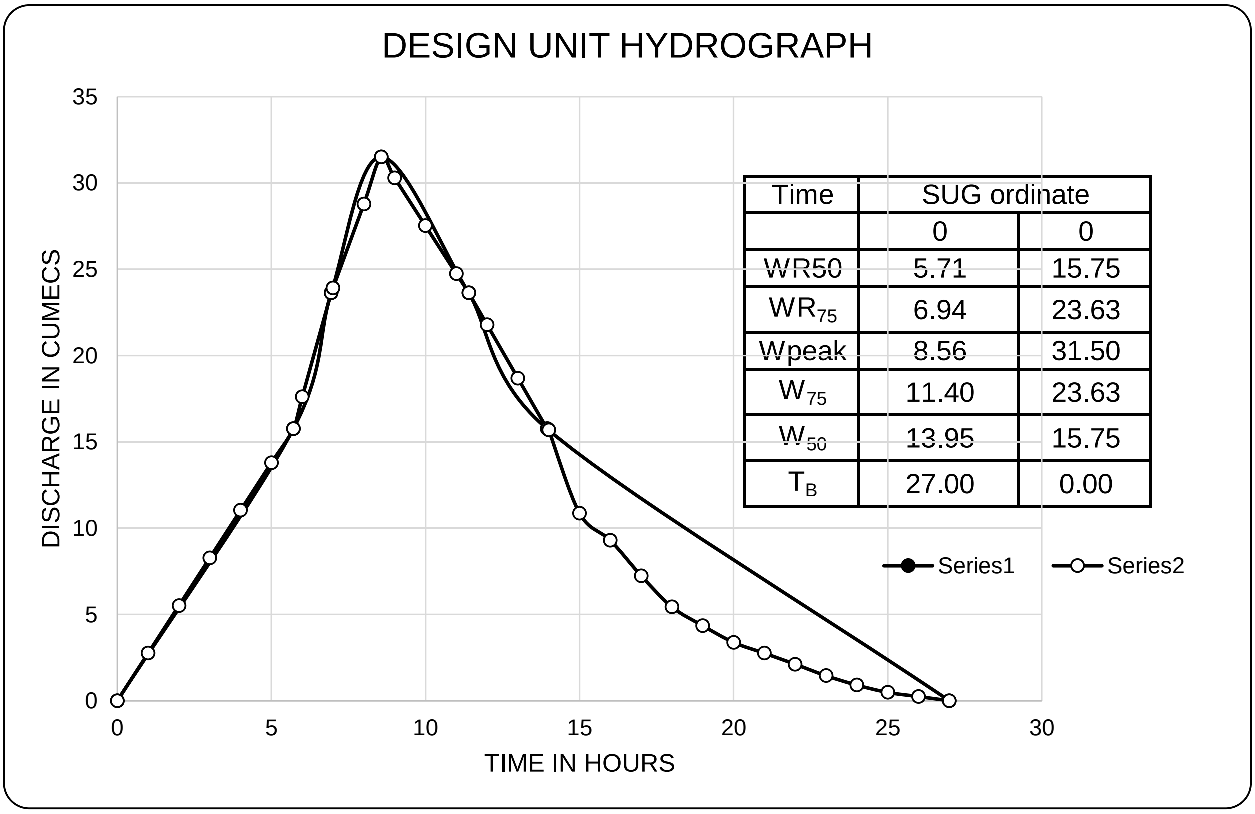
The one hour synthetic U.G parameters may be found out by using Synthetic Relations

The unit duration t_r = **1** hours

TABLE-A-2: COMPUTATION OF PARAMETERS OF 1- HOUR SYNTHETIC UNITGRAPH

Sl.No.	Known Parameter	Unknown Parameter	Synthetic Relationship	Calculated Value	Adopted Value
1	2	3	4	5	6
1	A	Q_p (Cumecs)	$Q_p=0.905*A^{0.758}$	31.48	31.50
2	Qp	q_p (Cumec/Sq.km)	$q_p=Q_p/A$	0.2917	0.292
3	q_p	t_p (Hours)	$t_p=2.87/(q_p)^{0.839}$	8.062	8.06
4	t_p	T_m (Hours)	$T_m = t_p + t_r / 2$	8.56	8.56
5	q_p	W_{50} (Hours)	$W_{50}=2.304/ (q_p)^{1.035}$	8.24	8.24
6	q_p	W_{75} (Hours)	$W_{75}=1.339 /(q_p)^{0.978}$	4.46	4.46
7	q_p	WR_{50} (Hours)	$W_{R50}=0.814/(q_p)^{1.018}$	2.85	2.85
8	q_p	WR_{75} (Hours)	$W_{R75}=0.494 /(q_p)^{0.966}$	1.62	1.62
9	t_p	T_B (Hours)	$T_B=2.447(t_p)^{1.157}$	27.38	27.00

Preparation of 1-hr. Synthetic Unitgraph :



Time	SUG ordinate	
	0	0
WR50	5.71	15.75
WR_{75}	6.94	23.63
Wpeak	8.56	31.50
W_{75}	11.40	23.63
W_{50}	13.95	15.75
T_B	27.00	0.00

One hours Synthetic Unit hydrograh

	SUG ordinates			
Time	Calculated		Modified	by factor
0	0.000		0.0000	1
1.00	2.757		2.7574	1
2.00	5.515		5.5149	1
3.00	8.272		8.2723	1
4.00	11.030		11.0298	1
5.00	13.787		13.7872	1
5.71	15.750	WR_{50}	15.7500	1
6.00	17.599		17.5986	1
6.94	23.625	WR_{75}	23.6250	1
7.00	23.919		23.9186	1
8.00	28.772		28.7723	1
8.56	31.500	W_{PEAK}	31.5000	1
9.00	30.286		30.2861	1
10.00	27.515		27.5147	1
11.00	24.743		24.7433	1
11.40	23.625	W_{75}	23.6250	1
12.00	21.780		21.7800	1
13.00	18.687		18.6871	1
13.95	15.750	W_{50}	15.7500	1
14.00	15.689		15.6892	1
15.00	14.482		10.8617	0.75
16.00	13.275		9.2928	0.7
17.00	12.069		7.2412	0.6
18.00	10.862		5.4309	0.5
19.00	9.655		4.3447	0.45
20.00	8.448		3.3792	0.4
21.00	7.241		2.7516	0.38
22.00	6.034		2.1120	0.35
23.00	4.827		1.4482	0.3
24.00	3.621		0.9051	0.25
25.00	2.414		0.4827	0.2
26.00	1.207		0.2414	0.2
27.00	0.000	T_B	0.0000	0.15

*/ Calculated values are suitably changed, to equate theoretical sum total of ordinates to sum total of plotted SUG

Actual sum total of SUG Ordinates (at 1 hrs interval) after adjustment

= 298.8 Cumecs (from graph)

Theoretical sum total of SUH ordinates : Net surface runoff for 1 cm rain fall

= A / 0.36 tr

= 300.00

As theoretical sum total of ordinates nearly equals the sum total of Plotted SUG (Modified) & hence The SUG is in order.

Estimation of Design Storm duration :

The design storm Duration (TD) is equal to 1.1 times tp , as recommended in flood estimation report subzone- 2b

T_D = 8.87 Hrs @ 8.87

Adjusting the design storm duration to nearest even hour the adopted design storm duration is **9.00**

Estimation of point rainfall and Areal Rainfall for storm duration:

Estimation of Point rain fall & arial Rainfall :

Point Rainfall = **32** cm

For 100 Years 24 Hours (From Plate 10, sub-zone-2b)

Point Rainfall' for 9 Hrs. = 25.92 cm

For 100 Years return period

Arial rainfall / Point rainfall = **0.93** *Catchment Area

From Annexure 4.3, sub zone 2b

Arial Rainfall = **24.03** cm

For 100 Years return period

Hourly effective rainfall increments :

Loss rate = **0.35** cm/Hour

Loss rate for one hour = 0.35 x 1

= 0.35 cm / hour

Hr	Percentage of Storm duration	Distribution Co-efficient	Storm Rainfall	Rainfall Increments	Loss Rate/ Hour	Effective Hourly Rainfall
(hr)		(cm)	(cm)	(cm)	(cm)	(cm)
1	11.11	38	9.13	9.13	0.35	8.78
2	22.22	59	14.18	5.05	0.35	4.70
3	33.33	71	17.06	2.88	0.35	2.53
4	44.44	80	19.22	2.16	0.35	1.81
5	55.56	86	20.67	1.44	0.35	1.09
6	66.67	91	21.87	1.20	0.35	0.85
7	77.78	95	22.83	0.96	0.35	0.61
8	88.89	98	23.55	0.72	0.35	0.37
9	100.00	100	24.03	0.48	0.35	0.13

Estimation of base flow :

Base flow = **0.05** cumecs / sq Km

Total base flow = 0.05 x 108.0
= 5.40 cumecs

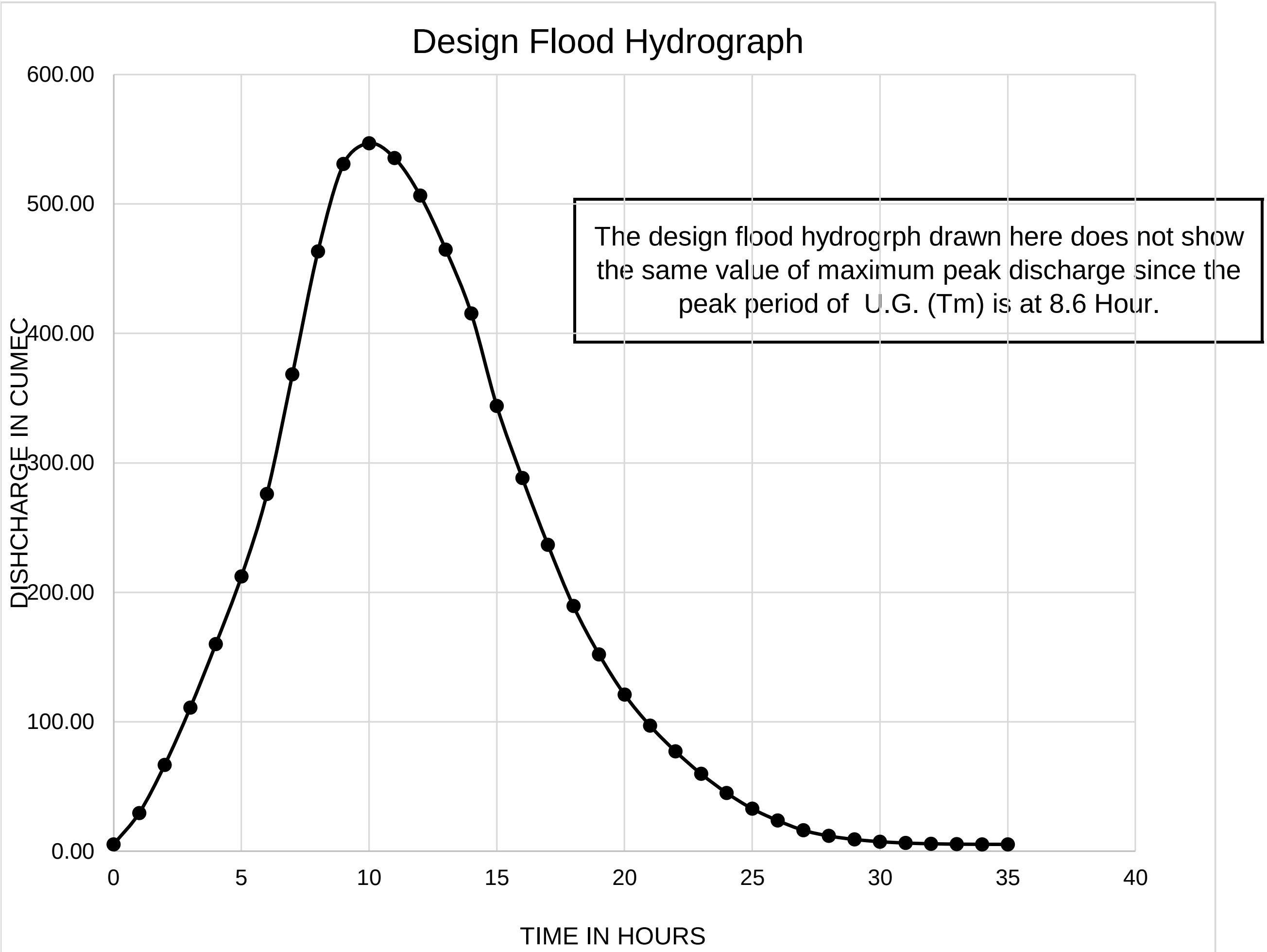
Estimation of Design Flood (peak only) :

For estimation of peak discharge, the rainfall excess units have to be rearranged against the unitgraph ordinates such that maximum rainfall excess is placed against the maximum unitgraph ordinate, the next maximum value of rainfall excess comes against the next lower value of unit graph ordinate & so on.

Hour	U.G. ordinate	1-Hr. rainfall excess	Direct runoff	Rearranging Data	
	Cumecs	cm.	cumecs		
				31.500	8.78
8.562	31.500	8.78	276.60	28.729	4.70
9.562	28.729	4.70	134.91	25.957	2.53
10.562	25.957	2.53	65.76	23.135	1.81
11.562	23.135	1.81	41.93	20.042	1.09
12.562	20.042	1.09	21.88	16.949	0.85
13.562	16.949	0.85	14.43	12.976	0.61
14.562	12.976	0.61	7.93	9.980	0.37
15.562	9.980	0.37	3.70	8.140	0.13
16.562	8.140	0.13	1.06		
		Total	568.22		

Design Discharge = Direct Runoff + Base flow
= 568.22 + 5.40
= 573.62 cumecs

Computation of Design Flood Hydrograph:

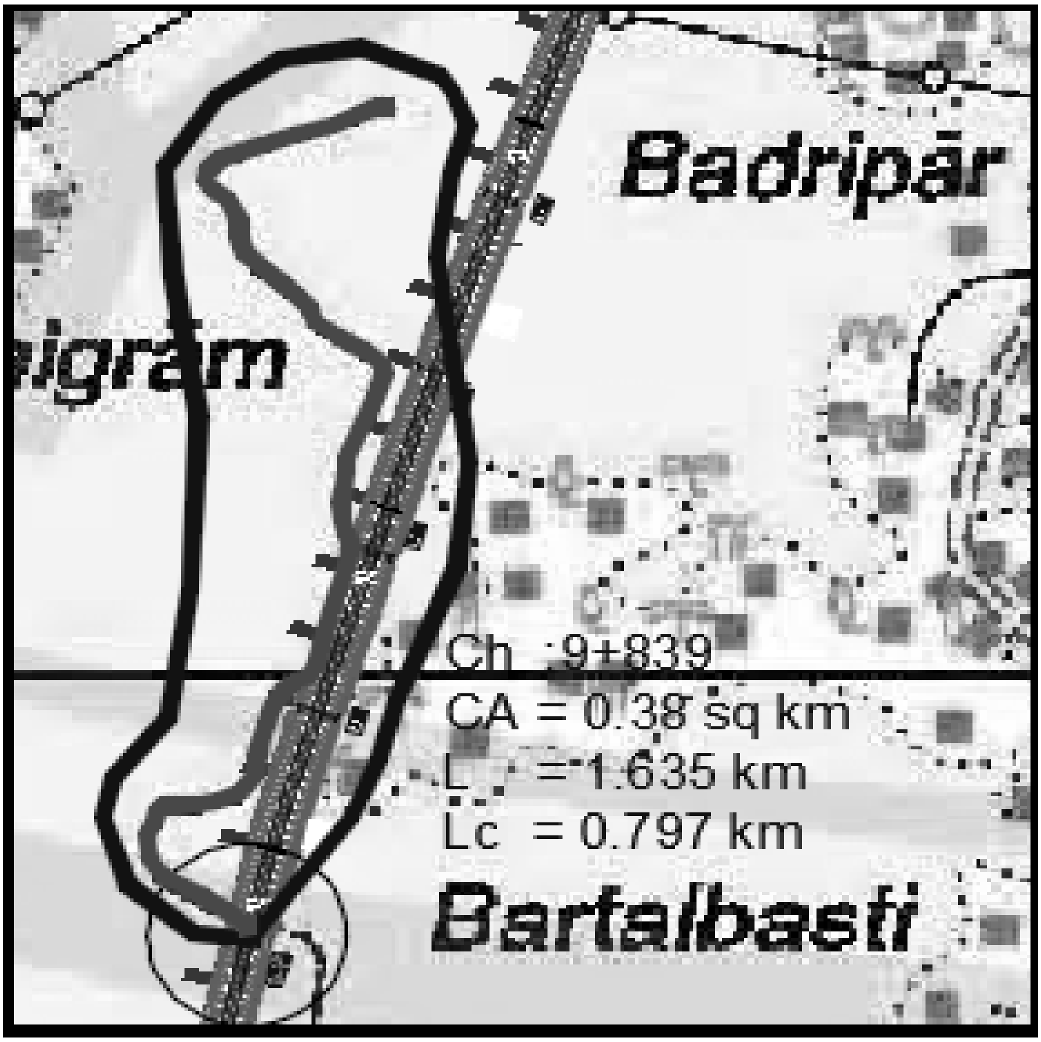


Hydrology Design Calculation of MNB @ CH.9+839

Table 1: Details of Minor Bridge

S.No	Chainage (Km)	Proposed Span (m)	Catchment Area (Sq. Km)
1	9+839	1 x 10	0.38

Catchment Area



DISCHARGE BY EMPIRICAL & RATIONAL METHODS

General Information

Road	:	Silchar - Vairengte
Name of River/Nalla/Stream	:	Nala
Name of nearest Village/Town	:	Narsingpur
Proposed Chainage	:	9+839
GT Sheet NO.	:	G46U14
Hydrometerological Sub Zone	:	2 b

Details of proposed bridge site

Proposed span arrangement	:	1 x 10	m
Total width provided	:	11.6	m
Obstruction due toPier	:	0	m
Obstruction due to Abutment	:	1.6	m
Clear water way skew	:	10.000	m
Skew Angle	:	0	deg
Clear water way provided (Right)	:	10.000	m

DISCHARGE BY DICKEN'S FORMULA : (Refer SP-13, page 7)

Q = $CM^{3/4}$

C = 11 - 14 where the annual rainfall is 60 - 120 cm
= 14 - 19 where the annual rainfall is more than 120 cm
= 22 in Western Ghats

C adopted	(Annual rainfall is 125 cm - 250 cm)	=	19	
Catchments area (M)		=	0.38	sqkm
Q		**=**	**9.178**	***cums***

DISCHARGE BY RATIONAL METHOD :

Discharge by Rational Formula

Catchment area (A) = 0.379 sqkm	=	37.9	Hectares
Length of path from toposheet (L)	=	1.6	Km
Difference in levels from toposheet (H)	=	2	m
Maximum rain fall (F) (100 years return period)	=	198.3	mm
Storm Duration(Calculated as per CWC report for subzone 2b)	=	3.0	Hour
One hour rainfall (Io)	=	132.21	mm/hrs
Time of concentration (I.R.C.SP-13, page 11)	=	1.281	hrs
Critical rainfall intensity	=	115.94	

Discharge Q = 0.028 x P x f x A x Ic

P = (Rocky, Steep)	=	0.8	
f =	=	0.999	
A =	=	37.9	Hectares
Ic =	=	11.59	cm/hr
Q =	=	**9.83**	**cum/sec**

Here,

t_c	=	Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchments
	=	$(0.87*L3/H)^{0.385}$
I_o	=	One hour rainfall in cm.
	=	(F/T)*(T+1)/(1+1)
I_c	=	Critical intensity of rainfall in cm per hour
	=	Io*(2/(1+tc))
P	=	Coefficient of runoff for the catchments characteristics (Ref.TB-4.1, SP:13-2004)
A	=	Catchments area in hectare
Q	=	Maximum discharge in cumecs.
L	=	Distance from the critical point to the structure in Km.
H	=	The fall in level from the critical point to the structure in meter

DISCHARGE BY MANNING'S METHOD :

A	=	X-sectional Area		
S	=	Slope considered		
P	=	Wetted perimeter		
R	=	Hydraulic mean radius	=	A/P
V	=	Velocity	=	$1/n\ R^{2/3}\ S^{1/2}$
n	=	Mannings rugosity coefficient	=	0.05
Q	=	Discharge	=	A*V

HFL = 20.113 m

X-section at	HFL	A	P	R	S	u	Q
	m	m^2	m	m	m/m	m/sec	m^3/sec
Without afflux at Bridge location	20.11	9.97	12.13	0.82	0.0021	0.80	7.95
Without afflux at Upstream location	20.113	9.29	12.16	0.76	0.0021	0.76	7.06
Without afflux at Downstream location	20.11	11.15	12.09	0.92	0.0021	0.86	9.61
						0.861	9.61

DESIGN DISCHARGE :

Discharge by Dickens Formula = 9.2 cumecs

Discharge by Rational Formula = 9.8 cumecs

Discharge by Manning's Formula = 9.6 cumecs

Design discharge should be highest of above methods, limited to 1.5 times of second highest discharge. **= 9.83 cumecs**

AFFLUX CALCULATIONS:

i) Molesworth formula

By using molesworth Formula = $\left\{\left(\frac{V^2}{17.88}\right) + 0.015\right\} X \left\{\left(\frac{A}{a}\right)^2 -1\right\}$

where,

Velocity of water prior to obstruction (V)	=	**Discharge / wetted area**	
	=	0.99	m/s
Unobstructed sectional area of the river (A)	=	9.965	m^2
Obstructed sectional area of the river (a)	=	6.621	m^2
Hence, Actual afflux of the river	=	0.09	m

ii) Oriface Formula

Obstructed length of bridge	L	=	10.000	m
Unobstructed width of the stream	W	=	15.051	m
	RV	=	0.653	
Depth of flow	D_d	=	0.662	
	L/W	=	**0.66**	

From clause 17.2 of IRC SP:13, (page 65)

Discharge, **Q** = $\mathbf{Co \sqrt{2g}\, L\, D_d\, [\, h + (1+e)\, u^2 / 2g\,]^{1/2}}$

Where,	Co	=	**0.866**	
	e	=	**0.961**	
	g	=	9.81	kg/m^2
	D_d	=	0.662	m

Substituting the values

$C_o \sqrt{2g}\, L\, D_d$	=	25.396
{(1+e)/2g}	=	0.100
Q	=	9.83

Substituting,

9.833 = 25.396 X sqrt (h + 0.0999 u^2)

0.387 = sqrt (h + 0.0999 U^2)

0.150 = (h + 0.0999 U^2)

h = -0.0999 U^2 + 0.150 ⟶ Equation 1

Discharge, Q = W (D_d + h) u

9.833 = (0.66 + h) 15.051 U

0.653 = (0.66 + h) U

h = $\dfrac{0.65 - 0.662\ U}{U}$ ⟶ Equation 2

Equating Equation 1 and Equation 2

-0.0999 U^2 + 0.150 = $\dfrac{0.65 - 0.662\ U}{U}$

-0.100 U^3 + 0.15 U = 0.65 - 0.662 U

$-0.100\, U^3 + 0.81\, U - 0.65 = 0$

Adopting Trial and Error method for solving the equation

Trial value of "U" = **0.8920** m/s

0.0001 ≈ 0

OK

Hence, velocity U = 0.89 m/s

Substituting the value of U in equation 1

h = 0.070 m **<** 0.166

Oriface formula is applicable

iii) Weir Formula

Cw = 0.96 (IRC: SP:13-2004, Page 53, Clause 15.2)

Q = $1.706\ Cw\ L\ H^{3/2}$

9.83 = $16.378\ H^{3/2}$

H = **0.7** m

H = $D_u + u^2/2g$

Assume

Du = H

Q = $W\ d_u\ u$

u = 0.918

Du = 0.669 m

h = Du - Dd

= 0.007 m > 0.166

Oriface formula is applicable

Hence design afflux adopted = 0.09 m

AHFL	=	20.201	
HFL	=	20.113	
Bed level	=	18.953	

VERTICAL CLEARANCE

Design Discharge	=	9.83	cumecs	
Vertical Clearance	=	0.60	m	
Depth of Superstructure	=	1.003	m	
Minimum FRL required	=	21.803	m	
Proposed FRL	=	26.614	m	SAFE

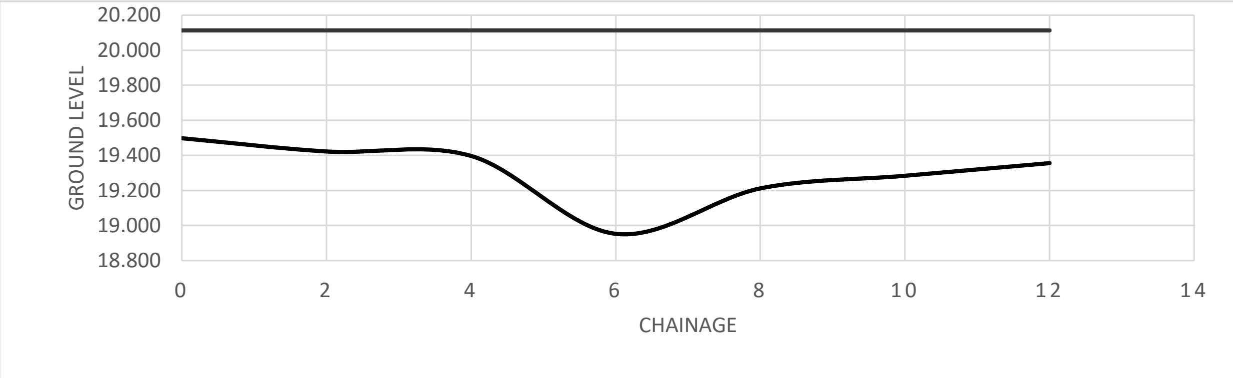
Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MNB CH: 9+839		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

Cross-sectional area of Stream

HFL 20.11 m

1. Bridge Location

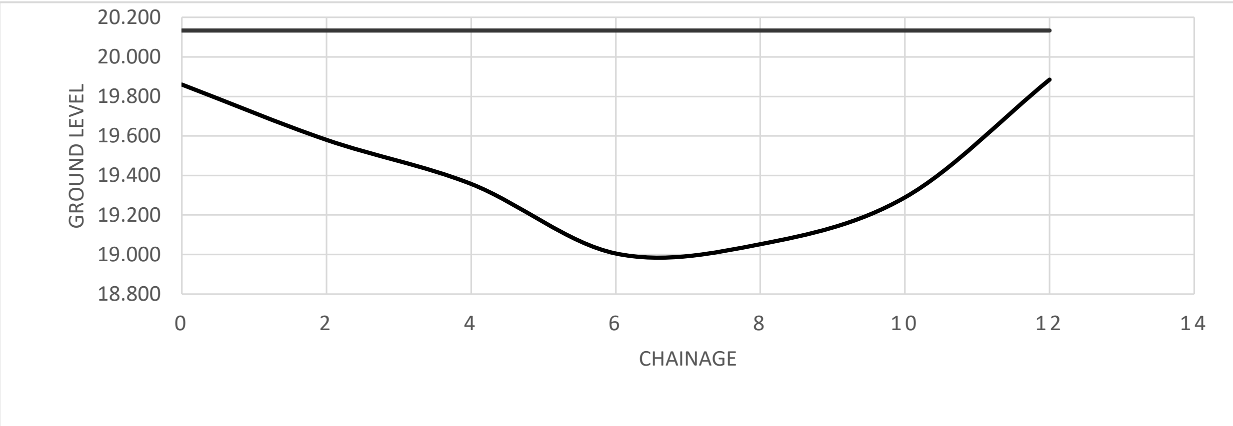
Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**19.498**	20.11	0.6150				
2	**19.423**	20.11	0.6905	0.653	2	1.306	2.003
4	**19.397**	20.11	0.7160	0.703	2	1.407	2.054
6	**18.953**	20.11	1.1600	0.938	2	1.876	2.009
8	**19.212**	20.11	0.9010	1.031	2	2.061	2.049
10	**19.284**	20.11	0.8290	0.865	2	1.730	2.017
12	**19.356**	20.11	0.7570	0.793	2	1.586	2.001
	18.953					**9.97**	**12.132**



Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MNB CH: 9+839		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

2. 10m Upstream of bridge Location

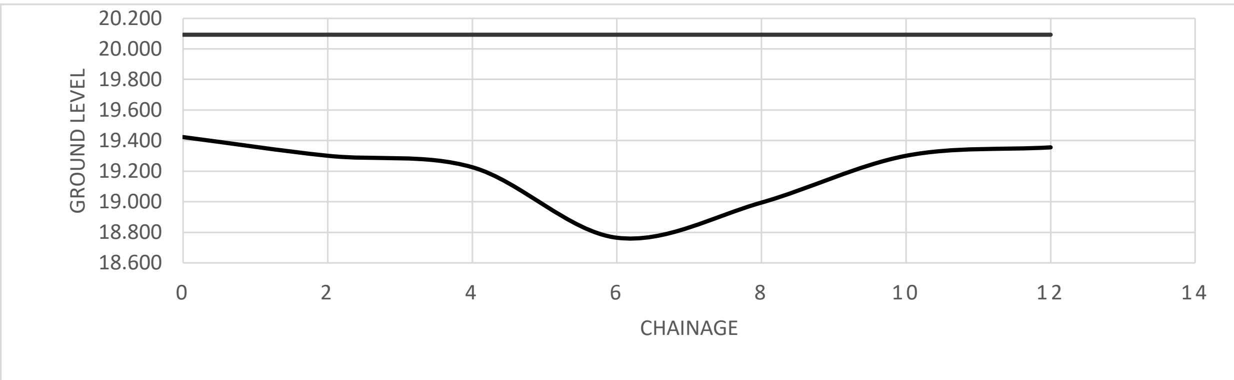
Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**19.860**	20.13	0.2737				
2	**19.580**	20.13	0.5537	0.414	2	0.83	2.020
4	**19.357**	20.13	0.7767	0.665	2	1.33	2.012
6	**19.005**	20.13	1.1287	0.953	2	1.91	2.031
8	**19.052**	20.13	1.0817	1.105	2	2.21	2.001
10	**19.289**	20.13	0.8447	0.963	2	1.93	2.014
12	**19.885**	20.13	0.2487	0.547	2	1.09	2.087
	19.005					**9.29**	**12.164**



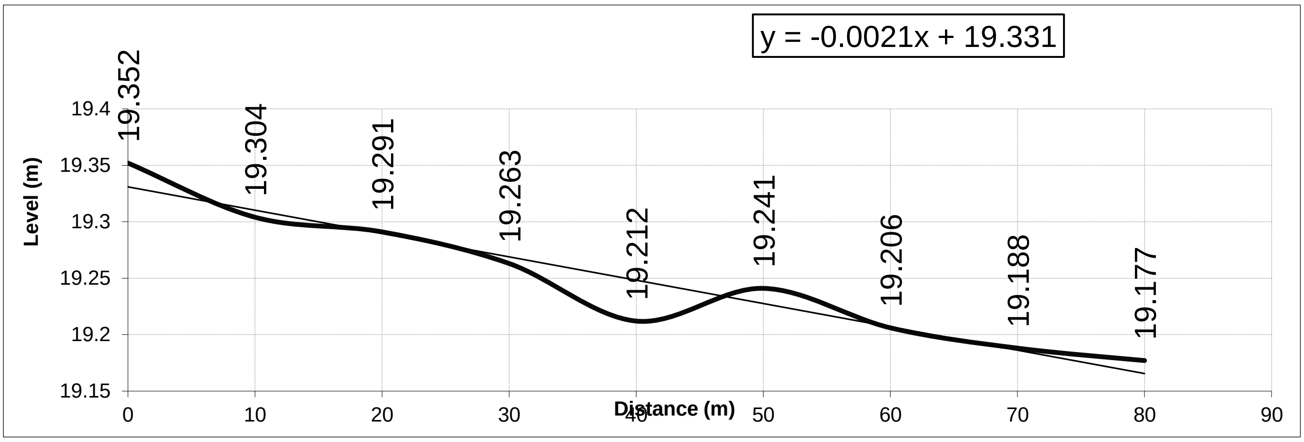
Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MNB CH: 9+839		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

3. 10m Downstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**19.423**	20.09	0.6693				
2	**19.301**	20.09	0.7913	0.730	2	1.46	2.004
4	**19.226**	20.09	0.8663	0.829	2	1.66	2.001
6	**18.765**	20.09	1.3273	1.097	2	2.19	2.052
8	**18.995**	20.09	1.0973	1.212	2	2.42	2.013
10	**19.301**	20.09	0.7913	0.944	2	1.89	2.023
12	**19.356**	20.09	0.7363	0.764	2	1.53	2.001
	18.765					**11.2**	**12.095**



Stream Slope in Longitudinal direction



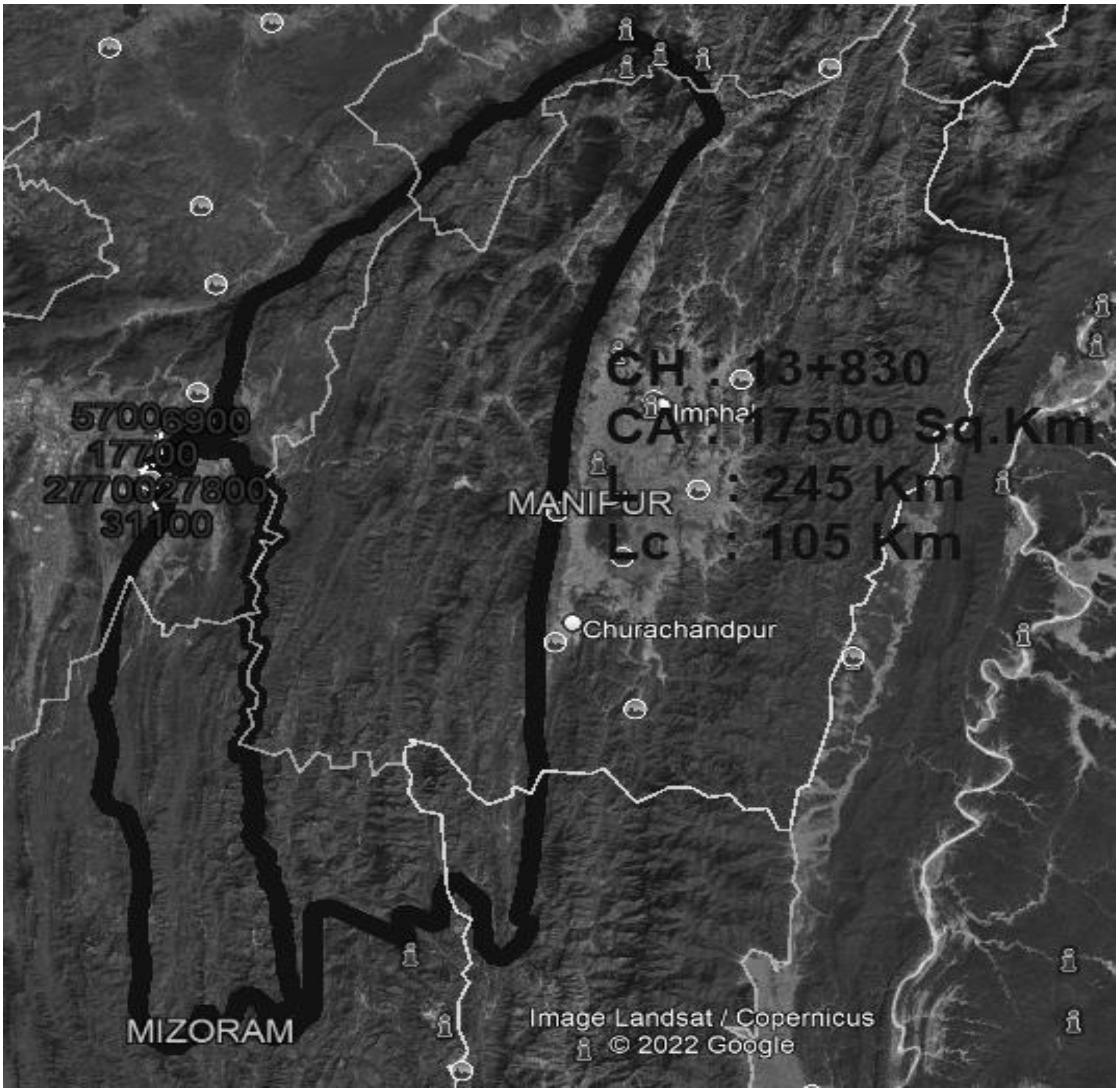
Average Slope = 0.00207 m/m 0.002067

Hydrological calculation of MJB @ CH.13+830

Table 1: Details of Major Bridge

S.No	Chainage (Km)	Proposed Span (m)	Catchment Area (Sq. Km)
1	13+830	16 x 30	17500.00

Catchment Area



DISCHARGE BY EMPIRICAL & RATIONAL METHODS

General Information

Road	:	Silchar - Vairengte
Name of River/Nalla/Stream	:	Barak River
Name of nearest Village/Town	:	Baghpur
Proposed Chainage	:	13+830
GT Sheet NO.	:	-
Hydrometerological Sub Zone	:	2 b

Details of proposed bridge site

Proposed span arrangement	:	16 x 30	m
Total width provided	:	480	m
Obstruction due toPier	:	22.5	m
Obstruction due to Abutment	:	1.6	m
Clear water way skew	:	455.900	m
Skew Angle	:	0	deg
Clear water way provided (Right)	:	455.900	m

DISCHARGE BY DICKEN'S FORMULA : (Refer SP-13, page 7)

Q = $CM^{3/4}$

C	=	11 - 14 where the annual rainfall is 60 - 120 cm			
	=	14 - 19 where the annual rainfall is more than 120 cm			
	=	22 in Western Ghats			
C adopted		(Annual rainfall is 125 cm - 250 cm)	=	19	
Catchments area (M)			=	17500	sqkm
Q			**=**	**28909**	***cums***

DISCHARGE BY RATIONAL METHOD :

Discharge by Rational Formula

Catchment area (A) = 17500 sqkm	=	2E+06	Hectares
Length of path from toposheet (L)	=	245.0	Km
Difference in levels from toposheet (H)	=	845	m
Maximum rain fall (F) (100 years return period)	=	248.0	mm
Storm Duration(Calculated as per CWC report for subzone 2	=	24.0	Hour
One hour rainfall (Io)	=	129.17	mm/hrs
Time of concentration (I.R.C.SP-13, page 11)	=	40.678	hrs
Critical rainfall intensity	=	6.20	

Discharge Q = 0.028 x P x f x A x Ic

P = (Rocky, Steep)	=	0.8	
f =	=	0.660	
A =	=	2E+06	Hectares
Ic =	=	0.62	cm/hr
Q =	=	**16036**	**cum/sec**

Here,

t_c = Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchments

= $(0.87*L3/H)^{0.385}$

I_o = One hour rainfall in cm.

= (F/T)*(T+1)/(1+1)

I_c = Critical intensity of rainfall in cm per hour

= Io*(2/(1+tc))

P = Coefficient of runoff for the catchments characteristics (Ref.TB-4.1, SP:13-2004)

A = Catchments area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in meter

DISCHARGE BY MANNING'S METHOD :

A = X-sectional Area

S = Slope considered

P = Wetted perimeter

R = Hydraulic mean radius = A/P

V = Velocity = $1/n\ R^{2/3}\ S^{1/2}$

n = Mannings rugosity coefficient = 0.05

Q = Discharge = A*V

HFL = 24.686 m

X-section at	HFL	A	P	R	S	u	Q
	m	m^2	m	m	m/m	m/sec	m^3/sec
Without afflux at Bridge location	24.69	6112.25	701.57	8.71	0.0015	3.32	20270.62
Without afflux at Upstream location	24.69	5697.21	701.29	8.12	0.0015	3.17	18033.70
Without afflux at Downstream location	24.69	6107.30	700.95	8.71	0.0015	3.32	20255.15
						3.317	20270.62

DESIGN DISCHARGE :

Discharge by Dickens Formula = 28908.9 cumecs

Discharge by Rational Formula = 16036.2 cumecs

Discharge by Manning's Formula = 20270.6 cumecs

Discharge by SUG = 20420.1 cumecs

As per IRC : 5-2015, Clause 106.3 for catchment areas more than 25 sq.Km SUG method shall be follov asscement of maximum discharge of bridge. **= 20420.08 cumecs**

AFFLUX CALCULATIONS:

i) Molesworth formula

By using molesworth Formula = $\left\{\left(\frac{V^2}{17.88}\right) + 0.015\right\} X \left\{\left(\frac{A}{a}\right)^2 - 1\right\}$

where,

Velocity of water prior to obstruction (V)	=	**Discharge / wetted area**	
	=	3.34	m/s
Unobstructed sectional area of the river (A)	=	6112.25	m^2
Obstructed sectional area of the river (a)	=	4062.569	m^2
Hence, Actual afflux of the river	=	0.81	m

ii) Oriface Formula

Obstructed length of bridge	L	=	456	m
Unobstructed width of the stream	W	=	686	m
	RV	=	29.771	
Depth of flow	D_d	=	8.911	
	L/W	=	**0.67**	

From clause 17.2 of IRC SP:13, (page 65)

Discharge, **Q** = $\mathbf{Co \sqrt{2g}\, L\, D_d\, [\, h + (1+e)\, u^2 / 2g\,]^{1/2}}$

Where,	Co	=	**0.866**	
	e	=	**0.955**	
	g	=	9.81	kg/m^2
	D_d	=	8.911	m

Substituting the values

$C_o \sqrt{2g}\, L\, D_d$	=	15583.612
{(1+e)/2g}	=	0.100
Q	=	20420.08

Substituting,

20420 = 15583.612 X sqrt (h + 0.0996 u^2)

1.310 = sqrt (h + 0.100 U^2)

1.717 = (h + 0.100 U^2)

h = -0.0996 U^2 + 1.717 ⟶ Equation 1

Discharge, Q = W (D_d + h) u

20420 = (8.91 + h) 685.914 U

29.771 = (8.91 + h) U

h = $\frac{29.77 - 8.911\ U}{U}$ ⟶ Equation 2

Equating Equation 1 and Equation 2

$$-0.0996\ U^2 + 1.717 = \frac{29.77 - 8.911\ U}{U}$$

$$-0.100\ U^3 + 1.72\ U = 29.77 - 8.911\ U$$

$$-0.10\ U^3 + 10.6\ U - 29.77 = 0$$

Adopting Trial and Error method for solving the equation

Trial value of "U" = **3.07** m/s

0.000 ≈ 0

OK

Hence, velocity U = 3.07 m/s

Substituting the value of U in equation 1

h = 0.776 m **<** 2.228

Oriface formula is applicable

iii) Weir Formula

Cw = 0.98 (IRC: SP:13-2004, Page 53, Clause 15.2)

Q = $1.706\ Cw\ L\ H^{3/2}$

20420 = $762.21\ H^{3/2}$

H = **9.0** m

H = $D_u + u^2/2g$

Assume

Du = H

Q = $W\ d_u\ u$

u = 3.325

Du = 8.390 m

h = Du - Dd

= -0.521 m > 2.228

Oriface formula is applicable

Hence design afflux adopted = 0.808 m

AHFL	=	25.494	m	
HFL	=	24.686	m	
Bed level	=	9.386	m	

<u>VERTICAL CLEARANCE</u>

Design Discharge	=	20420	cumecs	
Vertical Clearance	=	1.50	m	
Depth of Superstructure	=	2.540	m	
Minimum FRL required	=	29.534	m	
Proposed FRL	=	29.600	m	SAFE

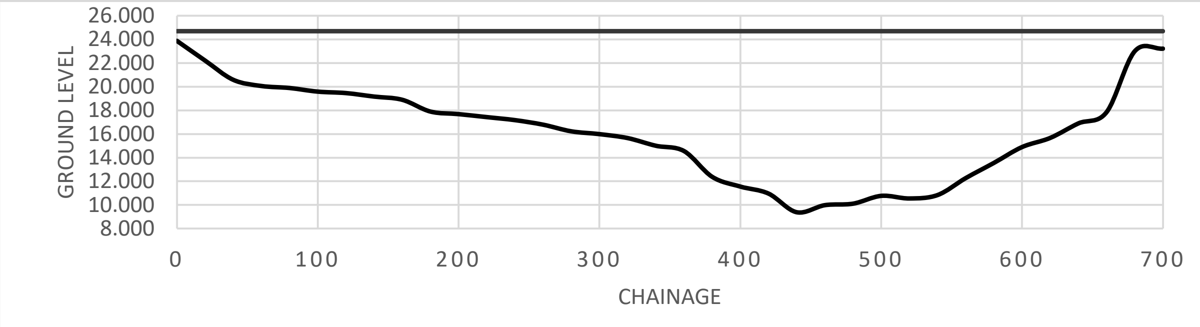
Cross-sectional area of Stream

HFL 24.686 m

1. Bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**23.872**	24.69	0.8140				
20	**22.206**	24.69	2.4800	1.647	20	32.94	20.269
40	**20.578**	24.69	4.1080	3.294	20	65.88	20.115
60	**20.056**	24.69	4.6300	4.369	20	87.38	20.012
80	**19.886**	24.69	4.8000	4.715	20	94.30	20.007
100	**19.579**	24.69	5.1070	4.954	20	99.07	20.001
120	**19.456**	24.69	5.2300	5.169	20	103.37	20.002
140	**19.160**	24.69	5.5260	5.378	20	107.56	20.000
160	**18.889**	24.69	5.7970	5.662	20	113.23	20.002
180	**17.895**	24.69	6.7910	6.294	20	125.88	20.002
200	**17.679**	24.69	7.0070	6.899	20	137.98	20.025
220	**17.425**	24.69	7.2610	7.134	20	142.68	20.001
240	**17.170**	24.69	7.5160	7.389	20	147.77	20.002
260	**16.785**	24.69	7.9010	7.709	20	154.17	20.002
280	**16.225**	24.69	8.4610	8.181	20	163.62	20.004
300	**15.987**	24.69	8.6990	8.580	20	171.60	20.008
320	**15.654**	24.69	9.0320	8.866	20	177.31	20.001
340	**15.005**	24.69	9.6810	9.357	20	187.13	20.003
360	**14.556**	24.69	10.1300	9.906	20	198.11	20.011
380	**12.379**	24.69	12.3070	11.219	20	224.37	20.005
400	**11.556**	24.69	13.1300	12.719	20	254.37	20.118
420	**10.963**	24.69	13.7230	13.427	20	268.53	20.017
440	**9.386**	24.69	15.3000	14.512	20	290.23	20.009
460	**9.984**	24.69	14.7020	15.001	20	300.02	20.062
480	**10.110**	24.69	14.5760	14.639	20	292.78	20.009
500	**10.771**	24.69	13.9150	14.246	20	284.91	20.000
520	**10.551**	24.69	14.1350	14.025	20	280.50	20.011
540	**10.839**	24.69	13.8470	13.991	20	279.82	20.001
560	**12.271**	24.69	12.4150	13.131	20	262.62	20.002
580	**13.556**	24.69	11.1300	11.773	20	235.45	20.051
600	**14.895**	24.69	9.7910	10.461	20	209.21	20.041
620	**15.668**	24.69	9.0180	9.405	20	188.09	20.045
640	**16.895**	24.69	7.7910	8.405	20	168.09	20.015
660	**17.846**	24.69	6.8400	7.316	20	146.31	20.038

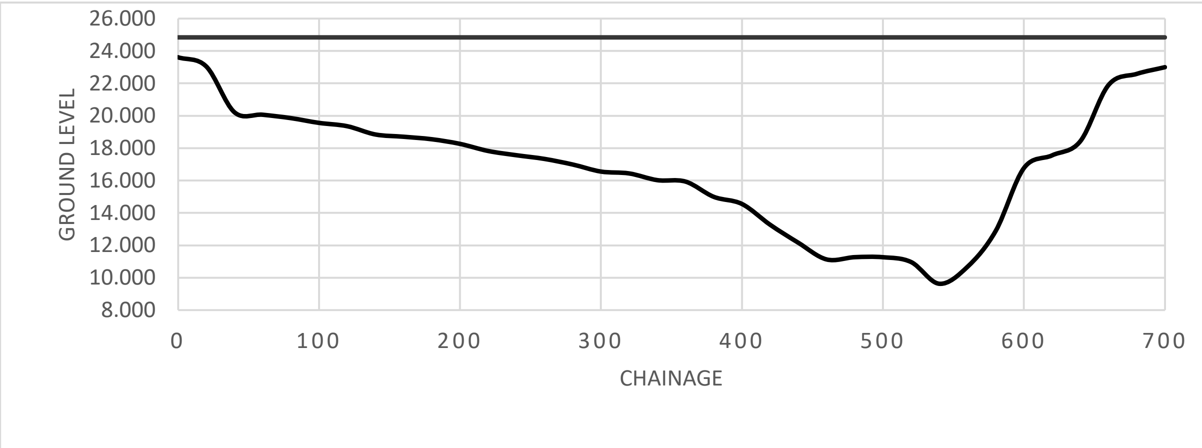
680	**22.995**	24.69	1.6910	4.266	20	85.31	20.023
700	**23.211**	24.69	1.4750	1.583	20	31.66	20.652
	9.386					**6112**	**701.565**



2. 40m Upstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**23.611**	24.84	1.2284				
20	**23.047**	24.84	1.7924	1.510	20	30.21	20.008
40	**20.218**	24.84	4.6214	3.207	20	64.14	20.199
60	**20.065**	24.84	4.7744	4.698	20	93.96	20.001
80	**19.856**	24.84	4.9834	4.879	20	97.58	20.001
100	**19.561**	24.84	5.2784	5.131	20	102.62	20.002
120	**19.356**	24.84	5.4834	5.381	20	107.62	20.001
140	**18.846**	24.84	5.9934	5.738	20	114.77	20.007
160	**18.705**	24.84	6.1344	6.064	20	121.28	20.000
180	**18.551**	24.84	6.2884	6.211	20	124.23	20.001
200	**18.265**	24.84	6.5744	6.431	20	128.63	20.002
220	**17.826**	24.84	7.0134	6.794	20	135.88	20.005
240	**17.565**	24.84	7.2744	7.144	20	142.88	20.002
260	**17.335**	24.84	7.5044	7.389	20	147.79	20.001
280	**16.990**	24.84	7.8494	7.677	20	153.54	20.003
300	**16.556**	24.84	8.2834	8.066	20	161.33	20.005
320	**16.441**	24.84	8.3984	8.341	20	166.82	20.000
340	**16.025**	24.84	8.8144	8.606	20	172.13	20.004
360	**15.936**	24.84	8.9034	8.859	20	177.18	20.000
380	**14.996**	24.84	9.8434	9.373	20	187.47	20.022
400	**14.556**	24.84	10.2834	10.063	20	201.27	20.005
420	**13.271**	24.84	11.5684	10.926	20	218.52	20.041
440	**12.160**	24.84	12.6794	12.124	20	242.48	20.031
460	**11.133**	24.84	13.7064	13.193	20	263.86	20.026
480	**11.271**	24.84	13.5684	13.637	20	272.75	20.000
500	**11.268**	24.84	13.5714	13.570	20	271.40	20.000

520	**10.970**	24.84	13.8694	13.720	20	274.41	20.002
540	**9.630**	24.84	15.2094	14.539	20	290.79	20.045
560	**10.680**	24.84	14.1594	14.684	20	293.69	20.028
580	**12.895**	24.84	11.9444	13.052	20	261.04	20.122
600	**16.771**	24.84	8.0684	10.006	20	200.13	20.372
620	**17.556**	24.84	7.2834	7.676	20	153.52	20.015
640	**18.428**	24.84	6.4114	6.847	20	136.95	20.019
660	**21.898**	24.84	2.9414	4.676	20	93.53	20.299
680	**22.586**	24.84	2.2534	2.597	20	51.95	20.012
700	**22.998**	24.84	1.8414	2.047	20	40.95	20.004
	9.630					**5697.2**	**701.286**

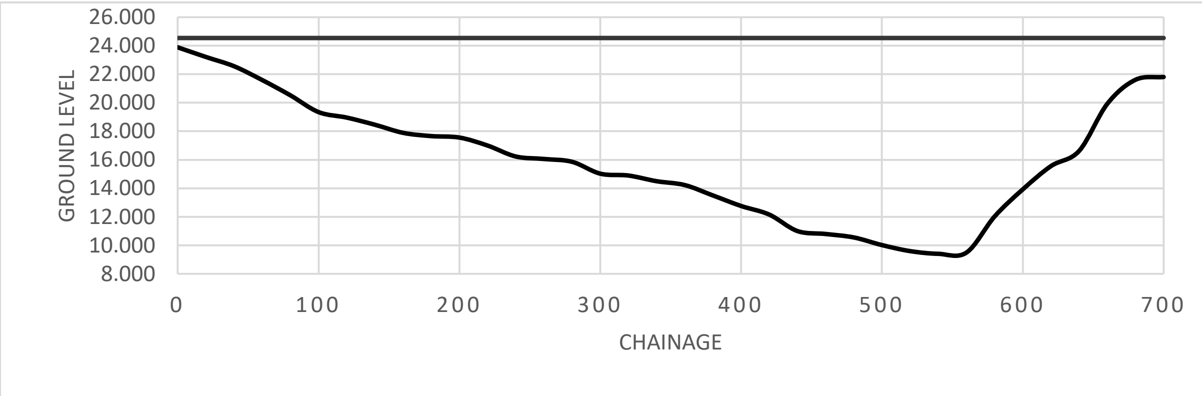


3.40m Downstream of bridge Location

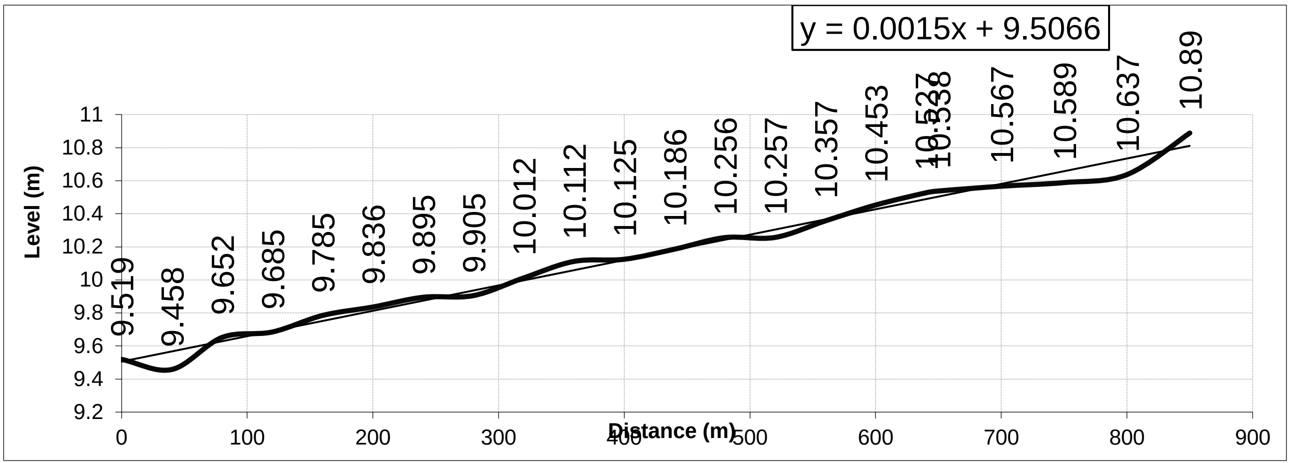
Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	**(m)**	**(m)**	**(m)**		**(m)**	**(m^2)**	**(m)**
0	**23.880**	24.53	0.6526				
20	**23.205**	24.53	1.3276	0.990	20	19.80	20.011
40	**22.554**	24.53	1.9786	1.653	20	33.06	20.011
60	**21.585**	24.53	2.9476	2.463	20	49.26	20.023
80	**20.514**	24.53	4.0186	3.483	20	69.66	20.029
100	**19.341**	24.53	5.1916	4.605	20	92.10	20.034
120	**18.956**	24.53	5.5766	5.384	20	107.68	20.004
140	**18.456**	24.53	6.0766	5.827	20	116.53	20.006
160	**17.886**	24.53	6.6466	6.362	20	127.23	20.008
180	**17.659**	24.53	6.8736	6.760	20	135.20	20.001
200	**17.556**	24.53	6.9766	6.925	20	138.50	20.000
220	**16.996**	24.53	7.5366	7.257	20	145.13	20.008
240	**16.228**	24.53	8.3046	7.921	20	158.41	20.015
260	**16.056**	24.53	8.4766	8.391	20	167.81	20.001
280	**15.856**	24.53	8.6766	8.577	20	171.53	20.001

Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology for Major Bridge CH: 13+830		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

300	**15.025**	24.53	9.5076	9.092	20	181.84	20.017
320	**14.895**	24.53	9.6376	9.573	20	191.45	20.000
340	**14.497**	24.53	10.0356	9.837	20	196.73	20.004
360	**14.225**	24.53	10.3076	10.172	20	203.43	20.002
380	**13.497**	24.53	11.0356	10.672	20	213.43	20.013
400	**12.759**	24.53	11.7736	11.405	20	228.09	20.014
420	**12.156**	24.53	12.3766	12.075	20	241.50	20.009
440	**11.002**	24.53	13.5306	12.954	20	259.07	20.033
460	**10.798**	24.53	13.7346	13.633	20	272.65	20.001
480	**10.556**	24.53	13.9766	13.856	20	277.11	20.001
500	**10.019**	24.53	14.5136	14.245	20	284.90	20.007
520	**9.598**	24.53	14.9346	14.724	20	294.48	20.004
540	**9.408**	24.53	15.1246	15.030	20	300.59	20.001
560	**9.495**	24.53	15.0376	15.081	20	301.62	20.000
580	**12.027**	24.53	12.5056	13.772	20	275.43	20.160
600	**13.927**	24.53	10.6056	11.556	20	231.11	20.090
620	**15.556**	24.53	8.9766	9.791	20	195.82	20.066
640	**16.621**	24.53	7.9116	8.444	20	168.88	20.028
660	**19.921**	24.53	4.6116	6.262	20	125.23	20.270
680	**21.606**	24.53	2.9266	3.769	20	75.38	20.071
700	**21.802**	24.53	2.7306	2.829	20	56.57	20.001
	9.408					**6107.3**	**700.947**



Stream Slope in Longitudinal direction



Average Slope = 0.0015 m/m 0.0015

DISCHARGE BY SYNTHETIC UNIT HYDROGRAPH

General Information

Road	:	**Silchar - Vairengte**
Name of River/Nalla/Stream	:	**Barak River**
Name of nearest Village/Town	:	**Baghpur**
Proposed Chainage	:	**13+830**
GT Sheet NO.	:	**-**
Hydrometerological Sub Zone	:	**2 b**

<u>Determination of Physiographic parameters :</u>

i) Catchment area	A	=	**17500**	Km^2
ii) Length of longest stream.	L	=	**245.00**	Km
iiI) Lc		=	**105.00**	Km

iii) Equivalent stream slope

$$Se = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2}$$

Li	=	Length of each river segment
Di	=	Height above datum
		Datum as RL at bridge site
L1	=	Distance from Bridge site
RL	=	Reduced level

TABLE -A-1: COMPUTATION OF 'S'

Along main stream						
S.N.	RD	RL	Li	Di	$(D_{i-1}+ D_i)$	$L_i (D_{i-1} + D_i)$
	(Km)	m	Km	m	m	Km.m
1	**0**	**15**				
2	**43.6**	**20**	43.6	5	5	218.00
3	**61.2**	**25**	17.6	10	15	264.00
4	**119**	**30**	57.8	15	25	1445.00
5	**129**	**35**	10	20	35	350.00
6	**132**	**40**	3	25	45	135.00
7	**140**	**50**	8	35	60	480.00
8	**145**	**65**	5	50	85	425.00
9	**151**	**100**	6	85	135	810.00
10	**152**	**110**	1	95	180	180.00
11	**153**	**120**	1	105	200	200.00
12	**155**	**140**	2	125	230	460.00
13	**156**	**150**	1	135	260	260.00
14	**158**	**160**	2	145	280	560.00
15	**160**	**170**	2	155	300	600.00
16	**161**	**200**	1	185	340	340.00
17	**165**	**210**	4	195	380	1520.00
18	**170**	**250**	5	235	430	2150.00
19	**172**	**300**	2	285	520	1040.00

20	**173**	**330**	1	315	600	600.00
21	**176**	**360**	3	345	660	1980.00
22	**183**	**400**	7	385	730	5110.00
23	**187**	**450**	4	435	820	3280.00
24	**220**	**500**	33	485	920	30360.00
25	**226**	**520**	6	505	990	5940.00
26	**230**	**550**	4	535	1040	4160.00
27	**237**	**600**	7	585	1120	7840.00
28	**240**	**680**	3	665	1250	3750.00
30	**242**	**850**	2	835	1500	3000.00
31	**243**	**860**	1	845	1680	1680.00
					$\Sigma L_i (D_{i-1} + D_i)$ =	79137.00

$$Se1 = \frac{\Sigma L_i (D_{i-1} + D_i)}{L^2} = 1.34 \text{ m/km}$$

$$Se = \frac{S L * Se}{S L} = 1.34 \text{ m/km}$$

iv) $L*L_c / \sqrt{S}$ = 245.00 * 105.00 / √ 1.34
= 22221

Determination of Synthetic Unitgraph Parameter :

One hour unit duration for the unitgraph i.e. unitgraph produced due to one cm depth of rainfall excess in one hour duration has been considered.

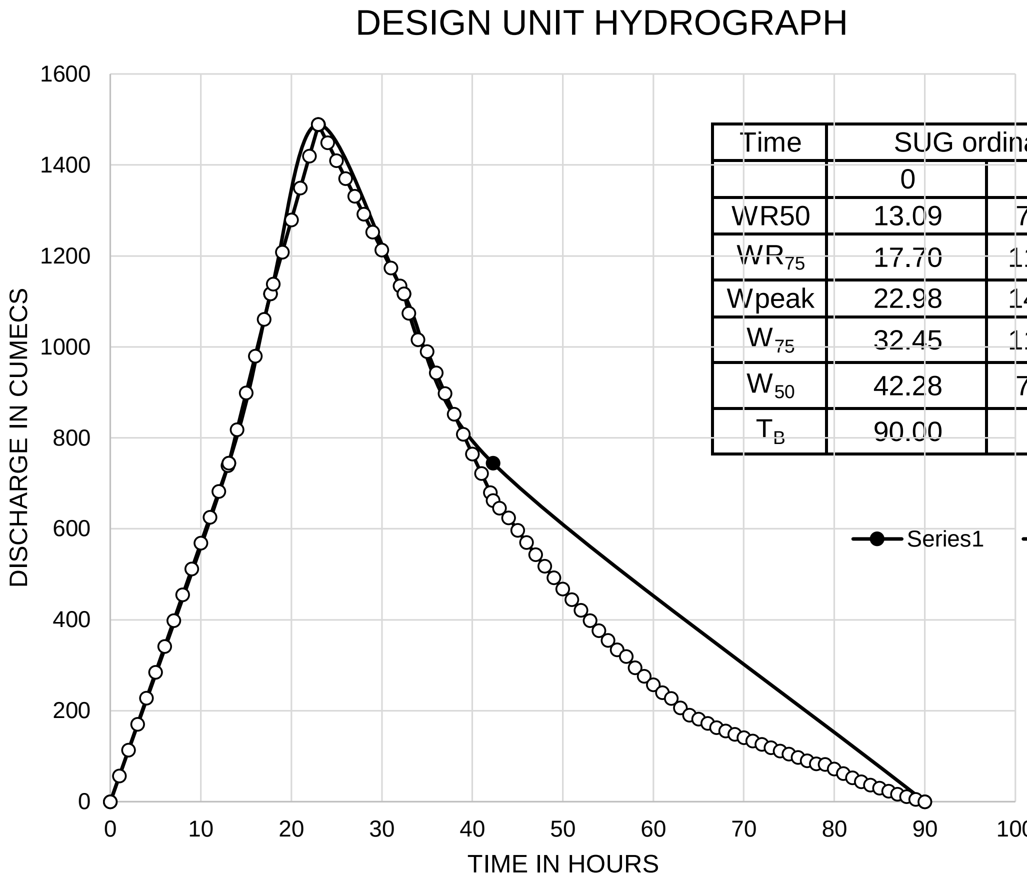
The one hour synthetic U.G parameters may be found out by using Synthetic Relations

The unit duration t_r = **1** hours

TABLE-A-2: COMPUTATION OF PARAMETERS OF 1- HOUR SYNTHETIC UNITGRAPH

Sl.No.	Known Parameter	Unknown Parameter	Synthetic Relationship	Calculated Value	Adopted Value
1	2	3	4	5	6
1	A	Q_p (Cumecs)	$Q_p=0.905*A^{0.758}$	1488.92	1489.00
2	Qp	q_p (Cumec/Sq.km)	$q_p=Q_p/A$	0.0851	0.086
3	q_p	t_p (Hours)	$t_p=2.87/(q_p)^{0.839}$	22.482	22.48
4	t_p	T_m (Hours)	$T_m = t_p + t_r / 2$	22.98	22.98
5	q_p	W_{50} (Hours)	$W_{50}=2.304/ (q_p)^{1.035}$	29.19	29.19
6	q_p	W_{75} (Hours)	$W_{75}=1.339 /(q_p)^{0.978}$	14.75	14.75
7	q_p	WR_{50} (Hours)	$W_{R50}=0.814/(q_p)^{1.018}$	9.89	9.89
8	q_p	WR_{75} (Hours)	$W_{R75}=0.494 /(q_p)^{0.966}$	5.28	5.28
9	t_p	T_B (Hours)	$T_B=2.447(t_p)^{1.157}$	89.69	90.00

Preparation of 1-hr. Synthetic Unitgraph :



Time	SUG ordinate	
	0	0
WR50	13.09	744.50
WR_{75}	17.70	1116.75
Wpeak	22.98	1489.00
W_{75}	32.45	1116.75
W_{50}	42.28	744.50
T_B	90.00	0.00

One hours Synthetic Unit hydrograh

	SUG ordinates			
Time	Calculated		Modified	by factor
0	0.000		0.00	1
1.00	56.873		56.87	1
2.00	113.747		113.75	1
3.00	170.620		170.62	1
4.00	227.493		227.49	1
5.00	284.367		284.37	1
6.00	341.240		341.24	1
7.00	398.113		398.11	1
8.00	454.986		454.99	1
9.00	511.860		511.86	1
10.00	568.733		568.73	1
11.00	625.606		625.61	1
12.00	682.480		682.48	1
13.00	739.353		739.35	1
13.09	744.500	WR_{50}	744.50	1

14.00	817.973		817.97	1
15.00	898.756		898.76	1
16.00	979.539		979.54	1
17.00	1060.323		1060.32	1
17.70	1116.750	WR_{75}	1116.75	1
18.00	1137.988		1137.99	1
19.00	1208.430		1208.43	1
20.00	1278.872		1278.87	1
21.00	1349.314		1349.31	1
22.00	1419.756		1419.76	1
23.00	1488.332		1488.33	1
22.98	1489.000	W_{PEAK}	1489.00	1
24.00	1449.013		1449.01	1
25.00	1409.694		1409.69	1
26.00	1370.375		1370.38	1
27.00	1331.057		1331.06	1
28.00	1291.738		1291.74	1
29.00	1252.419		1252.42	1
30.00	1213.101		1213.10	1
31.00	1173.782		1173.78	1
32.00	1134.463		1134.46	1
32.45	1116.750	W_{75}	1116.75	1
33.00	1095.947		1074.03	0.98
34.00	1058.090		1015.77	0.96
35.00	1020.232		989.63	0.97
36.00	982.374		943.08	0.96
37.00	944.517		897.29	0.95
38.00	906.659		852.26	0.94
39.00	868.802		807.99	0.93
40.00	830.944		764.47	0.92
41.00	793.086		721.71	0.91
42.00	755.229		679.71	0.9
42.28	744.500	W_{50}	662.61	0.89
43.00	733.319		645.32	0.88
44.00	717.717		624.41	0.87
45.00	702.114		596.80	0.85
46.00	686.512		569.80	0.83
47.00	670.909		543.44	0.81
48.00	655.307		517.69	0.79
49.00	639.704		492.57	0.77
50.00	624.101		468.08	0.75
51.00	608.499		444.20	0.73
52.00	592.896		420.96	0.71
53.00	577.294		398.33	0.69
54.00	561.691		376.33	0.67
55.00	546.089		354.96	0.65

56.00	530.486		334.21	0.63
57.00	514.884		319.23	0.62
58.00	499.281		294.58	0.59
59.00	483.679		275.70	0.57
60.00	468.076		257.44	0.55
61.00	452.474		239.81	0.53
62.00	436.871		227.17	0.52
63.00	421.268		206.42	0.49
64.00	405.666		190.66	0.47
65.00	390.063		181.38	0.465
66.00	374.461		172.25	0.46
67.00	358.858		163.28	0.455
68.00	343.256		155.84	0.454
69.00	327.653		148.43	0.453
70.00	312.051		141.05	0.452
71.00	296.448		133.70	0.451
72.00	280.846		126.38	0.45
73.00	265.243		119.09	0.449
74.00	249.641		111.84	0.448
75.00	234.038		105.01	0.4487
76.00	218.436		97.42	0.446
77.00	202.833		90.26	0.445
78.00	187.230		83.13	0.444
79.00	171.628		82.38	0.48
80.00	156.025		71.77	0.46
81.00	140.423		61.79	0.44
82.00	124.820		52.42	0.42
83.00	109.218		43.69	0.4
84.00	93.615		36.51	0.39
85.00	78.013		29.64	0.38
86.00	62.410		23.09	0.37
87.00	46.808		16.85	0.36
88.00	31.205		10.92	0.35
89.00	15.603		5.30	0.34
90.00	0.000		0.00	0.33

*/ Calculated values are suitably changed, to equate theoretical sum total of ordinates to sum total of plotted SUG

Actual sum total of SUG Ordinates (at 1 hrs interval) after adjustment
= 48166 Cumecs (from graph)

Theoretical sum total of SUH ordinates : Net surface runoff for 1 cm rain fall
= A / 0.36 tr
= 48611.11

As theoretical sum total of ordinates nearly equals the sum total of Plotted SUG (Modified) & hence The SUG is in order.

Estimation of Design Storm duration :

The design storm Duration (TD) is equal to 1.1 times tp , as recommended in flood estimation report subzone- 2b

T_D = 24.73 Hrs @ 24.73

Adjusting the design storm duration to nearest even hour the adopted design storm duration is **24.00**

Estimation of point rainfall and Areal Rainfall for storm duration:

Estimation of Point rain fall & arial Rainfall :

Point Rainfall = **32** cm

For 100 Years 24 Hours (From Plate 10, sub-zone-2b)

Point Rainfall' for 24 Hrs. = 32 cm

For 100 Years return period

Arial rainfall / Point rainfall = **0.78** *Catchment Area

From Annexure 4.3, sub zone 2b

Arial Rainfall = **24.80** cm

For 100 Years return period

Hourly effective rainfall increments :

Loss rate = **0.35** cm/Hour

Loss rate for one hour = 0.35 x 1

= 0.35 cm / hour

Hr	Percentage of Storm duration	Distribution Co-efficient	Storm Rainfall	Rainfall Increments	Loss Rate/ Hour	Effective Hourly Rainfall
(hr)		(cm)	(cm)	(cm)	(cm)	(cm)
1	4.17	12	2.98	2.98	0.35	2.63
2	8.33	24	5.95	2.98	0.35	2.63
3	12.50	34	8.43	2.48	0.35	2.13
4	16.67	42	10.42	1.98	0.35	1.63
5	20.83	49	12.15	1.74	0.35	1.39
6	25.00	55	13.64	1.49	0.35	1.14
7	29.17	60	14.88	1.24	0.35	0.89
8	33.33	64	15.87	0.99	0.35	0.64
9	37.50	68	16.86	0.99	0.35	0.64
10	41.67	71	17.61	0.74	0.35	0.39
11	45.83	75	18.60	0.99	0.35	0.64
12	50.00	77	19.10	0.50	0.35	0.15
13	54.17	80	19.84	0.74	0.35	0.39

14	58.33	83	20.58	0.74	0.35	0.39
15	62.50	86	21.33	0.74	0.35	0.39
16	66.67	88	21.82	0.50	0.35	0.15
17	70.83	90	22.32	0.50	0.35	0.15
18	75.00	92	22.82	0.50	0.35	0.15
19	79.17	94	23.31	0.50	0.35	0.15
20	83.33	96	23.81	0.50	0.35	0.15
21	87.50	97	24.06	0.25	0.35	-0.10
22	91.67	98	24.30	0.25	0.35	-0.10
23	95.83	99	24.55	0.25	0.35	-0.10
24	100.00	100	24.80	0.25	0.35	-0.10

Estimation of base flow :

Base flow = **0.05** cumecs / sq Km

Total base flow = 0.05 x 17500

= 875.00 cumecs

Estimation of Design Flood (peak only) :

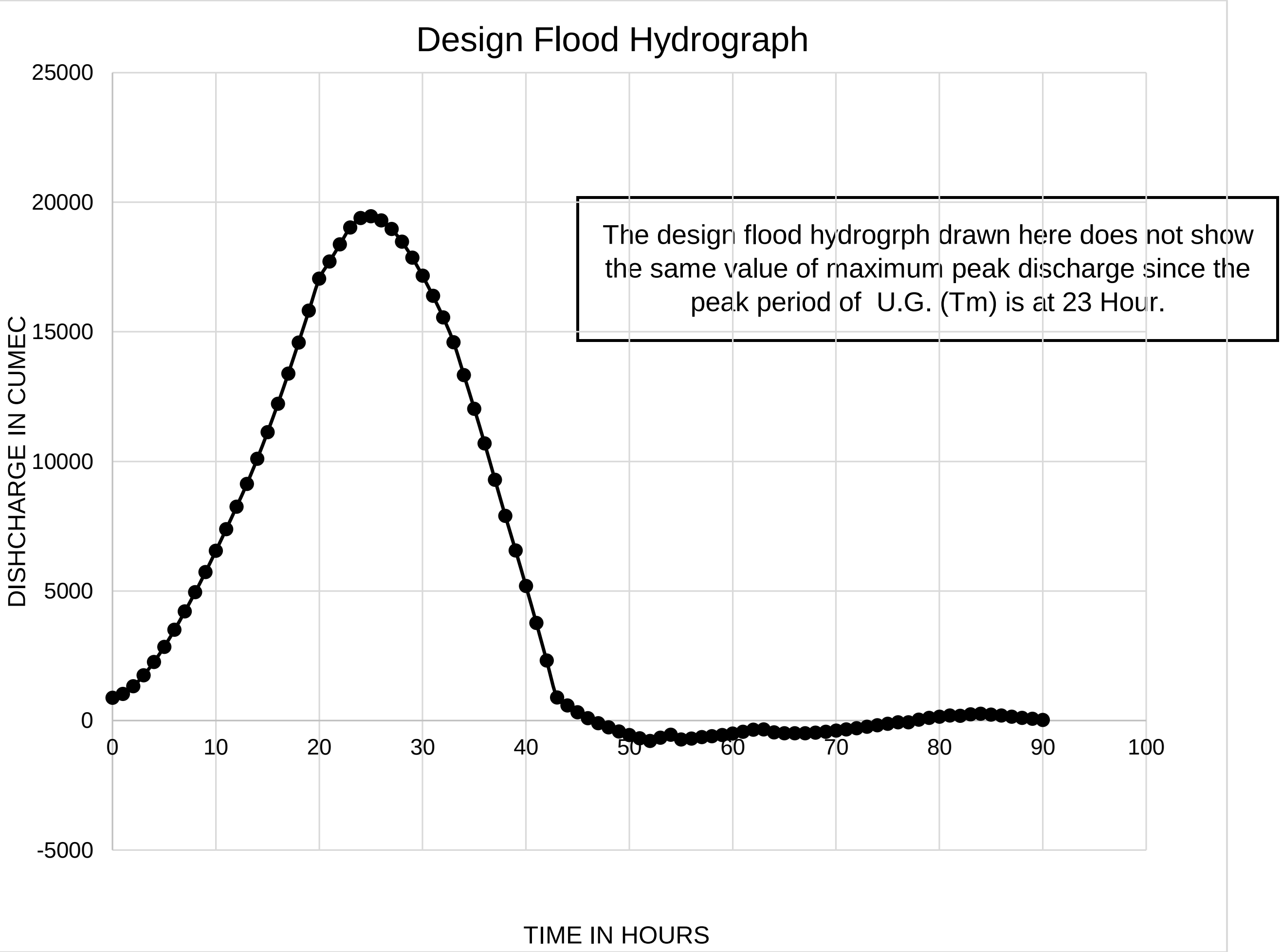
For estimation of peak discharge, the rainfall excess units have to be rearranged against the unitgraph ordinates such that maximum rainfall excess is placed against the maximum unitgraph ordinate, the next maximum value of rainfall excess comes against the next lower value of unit graph ordinate & so on.

Hour	U.G. ordinate	1-Hr. rainfall excess	Direct runoff	Rearranging Data	
	Cumecs	cm.	cumecs		
				1487.17	2.63
	0.000	-0.10	0.00	1418.56	2.63
0.983	55.906	-0.10	-5.70	1348.12	2.13
1.983	112.780	-0.10	-11.50	1277.67	1.63
2.983	169.653	-0.10	-17.30	1207.23	1.39
3.983	226.526	0.15	33.07	1136.79	1.14
4.983	283.400	0.15	41.38	1058.95	0.89
5.983	340.273	0.15	49.68	978.17	0.64
6.983	397.146	0.15	57.98	897.38	0.64
7.983	454.020	0.15	66.29	816.60	0.64
8.983	510.893	0.15	74.59	738.39	0.39
9.983	567.766	0.39	223.70	681.51	0.39
10.983	624.640	0.39	246.11	624.64	0.39
11.983	681.513	0.39	268.52	567.77	0.39
12.983	738.386	0.39	290.92	510.89	0.15
13.983	816.599	0.64	524.26	454.02	0.15
14.983	897.383	0.64	576.12	397.15	0.15
15.983	978.166	0.64	627.98	340.27	0.15
16.983	1058.949	0.89	942.47	283.40	0.15
17.983	1136.791	1.14	1293.67	226.53	0.15

18.983	1207.233	1.39	1673.22	169.65	-0.10
19.983	1277.674	1.63	2087.72	112.78	-0.10
20.983	1348.116	2.13	2871.49	55.91	-0.10
21.983	1418.558	2.63	3725.13	0.00	-0.10
22.983	1487.166	2.63	3905.30		
		Total	19545		

Design Discharge	=	Direct Runoff	+	Base flow
	=	19545.08	+	875.00
	=	20420.08 cumecs		

Computation of Design Flood Hydrograph:

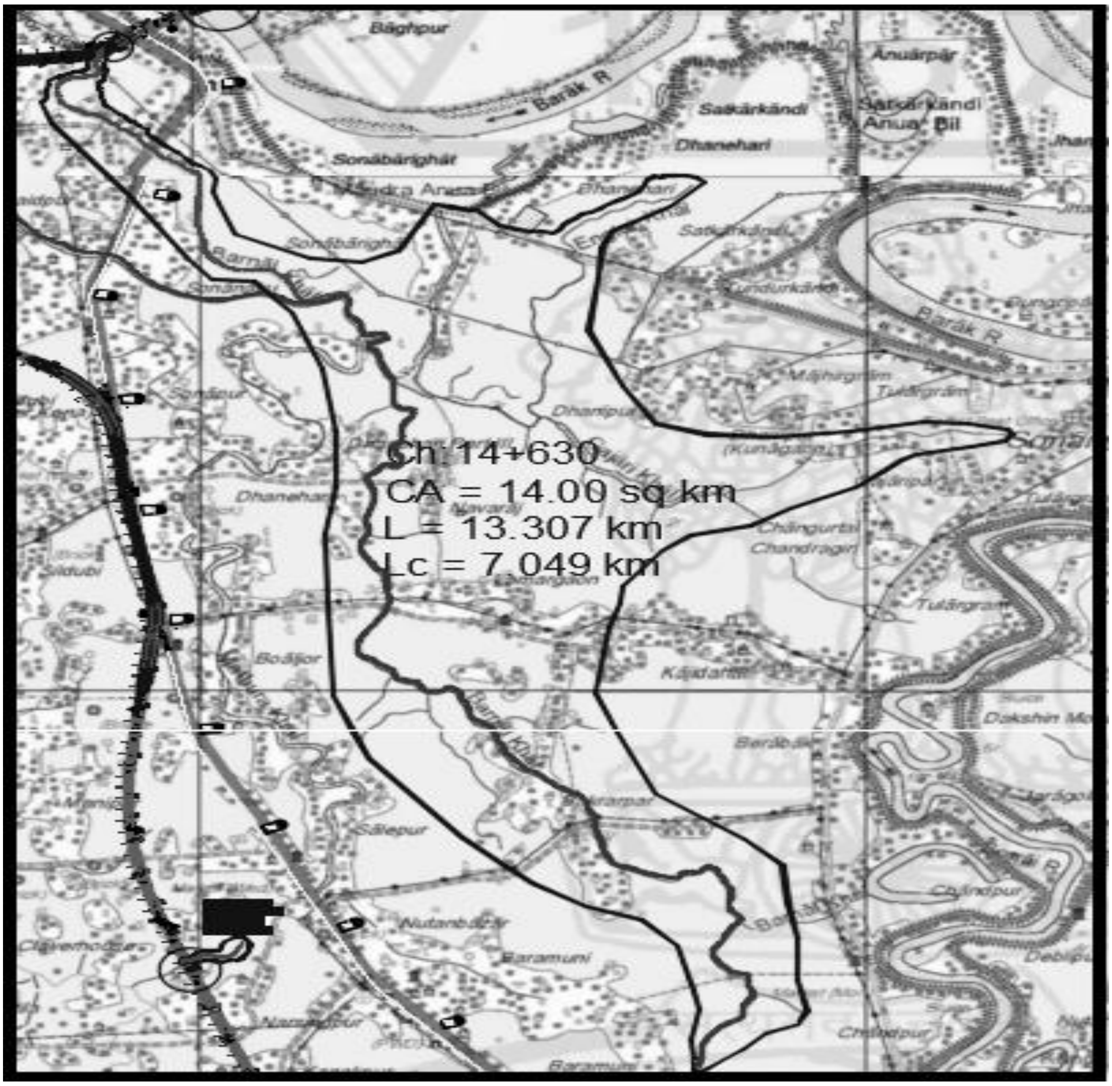


Hydrology Design Calculation of MNB @ CH.14+630

Table 1: Details of Minor Bridge

S.No	Chainage (Km)	Proposed Span (m)	Catchment Area (Sq. Km)
1	14+630	2 x 20	14.00

Catchment Area



DISCHARGE BY EMPIRICAL & RATIONAL METHODS

General Information

Road	:	Silchar - Vairengte
Name of River/Nalla/Stream	:	Barnal khal
Name of nearest Village/Town	:	Saidpur
Proposed Chainage	:	14+630
GT Sheet NO.	:	G46U14
Hydrometerological Sub Zone	:	2 b

Details of proposed bridge site

Proposed span arrangement	:	2 x 20	m
Total width provided	:	40	m
Obstruction due toPier	:	1	m
Obstruction due to Abutment	:	1.6	m
Clear water way skew	:	37.501	m
Skew Angle	:	4.214	deg
Clear water way provided (Right)	:	37.400	m

DISCHARGE BY DICKEN'S FORMULA : (Refer SP-13, page 7)

Q = $CM^{3/4}$

C = 11 - 14 where the annual rainfall is 60 - 120 cm
= 14 - 19 where the annual rainfall is more than 120 cm
= 22 in Western Ghats

C adopted	(Annual rainfall is 125 cm - 250 cm)	=	19	
Catchments area (M)		=	14.00	sqkm
Q		**=**	**137.515**	***cums***

DISCHARGE BY RATIONAL METHOD :

Discharge by Rational Formula

Catchment area (A) = 14 sqkm	=	1400	Hectares
Length of path from toposheet (L)	=	13.3	Km
Difference in levels from toposheet (H)	=	8	m
Maximum rain fall (F) (100 years return period)	=	234.0	mm
Storm Duration(Calculated as per CWC report for subzone 2b)	=	6.0	Hour
One hour rainfall (Io)	=	136.49	mm/hrs
Time of concentration (I.R.C.SP-13, page 11)	=	8.459	hrs
Critical rainfall intensity	=	28.86	

Discharge Q = 0.028 x P x f x A x Ic

P = (Rocky, Steep)	=	0.8	
f =	=	0.962	
A =	=	1400	Hectares
Ic =	=	2.89	cm/hr
Q =	=	**87.08**	**cum/sec**

Here,

t_c = Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchments

= $(0.87*L3/H)^{0.385}$

I_o = One hour rainfall in cm.

= (F/T)*(T+1)/(1+1)

I_c = Critical intensity of rainfall in cm per hour

= Io*(2/(1+tc))

P = Coefficient of runoff for the catchments characteristics (Ref.TB-4.1, SP:13-2004)

A = Catchments area in hectare

Q = Maximum discharge in cumecs.

L = Distance from the critical point to the structure in Km.

H = The fall in level from the critical point to the structure in meter

DISCHARGE BY MANNING'S METHOD :

A = X-sectional Area

S = Slope considered

P = Wetted perimeter

R = Hydraulic mean radius = A/P

V = Velocity = $1/n\ R^{2/3}\ S^{1/2}$

n = Mannings rugosity coefficient = 0.05

Q = Discharge = A*V

HFL = 21.063 m

X-section at	HFL	A	P	R	S	u	Q
	m	m^2	m	m	m/m	m/sec	m^3/sec
Without afflux at Bridge location	21.06	87.64	57.81	1.52	0.0027	1.38	121.27
Without afflux at Upstream location	21.063	84.21	56.51	1.49	0.0027	1.37	115.19
Without afflux at Downstream location	21.06	96.58	61.18	1.58	0.0027	1.42	137.29
						1.421	137.29

DESIGN DISCHARGE :

Discharge by Dickens Formula = 137.5 cumecs

Discharge by Rational Formula = 87.1 cumecs

Discharge by Manning's Formula = 137.3 cumecs

Design discharge should be highest of above methods, limited to 1.5 times of second highest discharge. **= 137.51 cumecs**

AFFLUX CALCULATIONS:

i) Molesworth formula

By using molesworth Formula = $\left\{\left(\frac{V^2}{17.88}\right) + 0.015\right\} X \left\{\left(\frac{A}{a}\right)^2 -1\right\}$

where,

Velocity of water prior to obstruction (V) = **Discharge / wetted area**

= 1.57 m/s

Unobstructed sectional area of the river (A) = 87.641 m^2

Obstructed sectional area of the river (a) = 58.232 m^2

Hence, Actual afflux of the river = 0.19 m

ii) Oriface Formula

Obstructed length of bridge	L	=	37.400	m
Unobstructed width of the stream	W	=	56.3	m
	RV	=	2.443	
Depth of flow	D_d	=	1.557	
	L/W	=	**0.67**	

From clause 17.2 of IRC SP:13, (page 65)

Discharge, **Q** = **Co √2g L D_d [h+ (1+e) u^2 / 2g]$^{1/2}$**

Where,	Co	=	**0.866**	
	e	=	**0.955**	
	g	=	9.81	kg/m^2
	D_d	=	1.557	m

Substituting the values

C_o √2g L D_d	=	223.372
{(1+e)/2g}	=	0.100
Q	=	137.51

Substituting,

137.515 = 223.372 X sqrt (h + 0.0996 u^2)

0.616 = sqrt (h + 0.100 U^2)

0.379 = (h + 0.100 U^2)

h = -0.0996 U^2 + 0.379 ⟶ Equation 1

Discharge, Q = W (D_d + h) u

137.515 = (1.56 + h) 56.288 U

2.443 = (1.56 + h) U

h = $\frac{2.44 - 1.557\ U}{U}$ ⟶ Equation 2

Equating Equation 1 and Equation 2

$$-0.0996\ U^2 + 0.379 = \frac{2.44 - 1.557\ U}{U}$$

$$-0.100\ U^3 + 0.38\ U = 2.44 - 1.557\ U$$

$$-0.100\ U^3 + 1.94\ U \ -2.44 = 0$$

Adopting Trial and Error method for solving the equation

Trial value of "U" = **1.40** m/s

0.0000 ≈ 0

OK

Hence, velocity U = 1.40 m/s

Substituting the value of U in equation 1

h = 0.182 m **<** 0.389

Oriface formula is applicable

iii) Weir Formula

Cw = 0.96 (IRC: SP:13-2004, Page 53, Clause 15.2)

Q = $1.706\ Cw\ L\ H^{3/2}$

137.51 = $61.252\ H^{3/2}$

H = **1.7** m

H = $D_u + u^2/2g$

Assume

Du = H

Q = $W\ d_u\ u$

u = 1.425

Du = 1.611 m

h = Du - Dd

= 0.054 m > 0.389

Oriface formula is applicable

Hence design afflux adopted = 0.193 m

AHFL = 21.256

HFL = 21.063

Bed level = 16.665

VERTICAL CLEARANCE

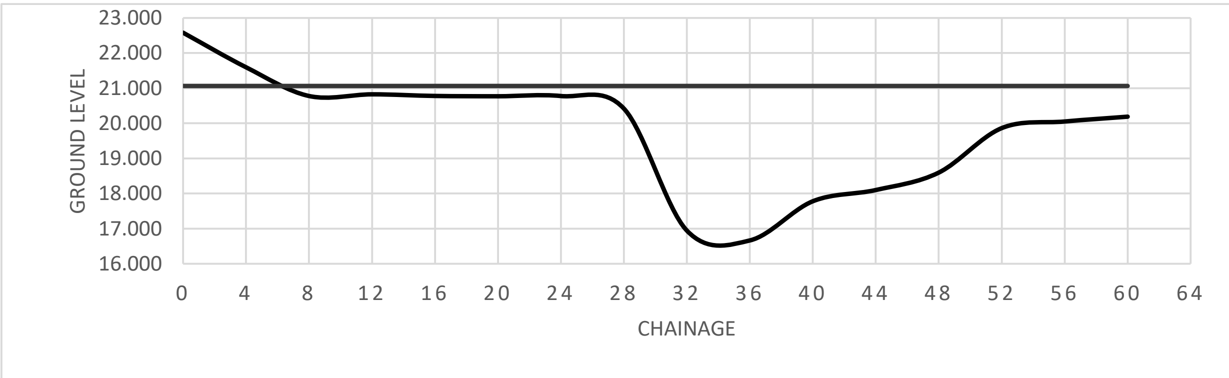
Design Discharge	=	137.51	cumecs	
Vertical Clearance	=	0.90	m	
Depth of Superstructure (Main Carriage way)	=	2.400	m	
Depth of Superstructure (Service Road)	=	2.093	m	
Minimum FRL required (Main Carriage way)	=	24.556	m	
Minimum FRL required (Serviece Road)	=	24.249	m	
Proposed FRL (Main Carriage way)	=	27.849	m	SAFE
Proposed FRL (Serviece Road)	=	24.300	m	SAFE

Cross-sectional area of Stream

HFL 21.06 m

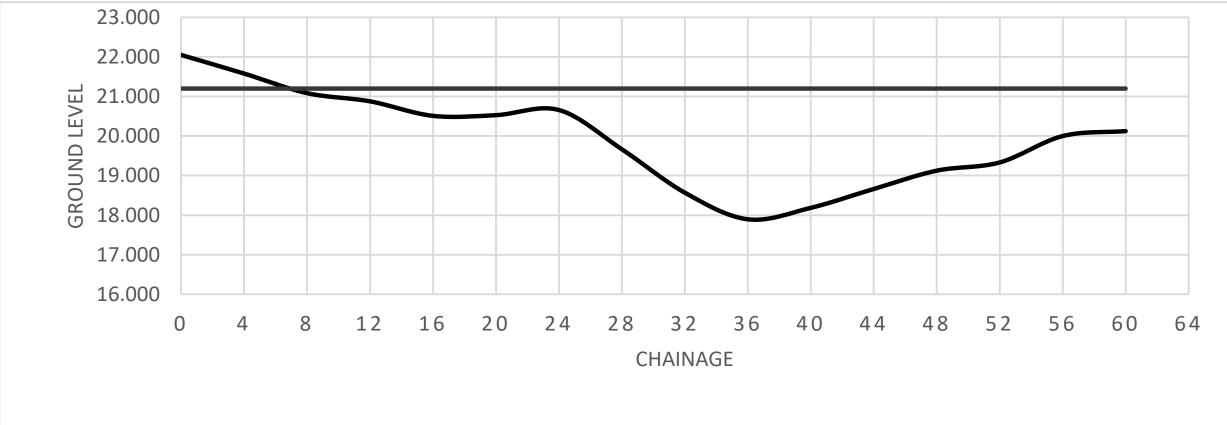
1. Bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**22.580**	21.06	0.0000				
4	**21.595**	21.06	0.0000	0.000	4	0.000	0.000
8	**20.777**	21.06	0.2861	0.143	4	0.572	4.083
12	**20.825**	21.06	0.2383	0.262	4	1.049	4.000
16	**20.779**	21.06	0.2843	0.261	4	1.045	4.000
20	**20.770**	21.06	0.2931	0.289	4	1.155	4.000
24	**20.777**	21.06	0.2864	0.290	4	1.159	4.000
28	**20.419**	21.06	0.6440	0.465	4	1.861	4.016
32	**16.945**	21.06	4.1180	2.381	4	9.524	5.298
36	**16.665**	21.06	4.3980	4.258	4	17.032	4.010
40	**17.780**	21.06	3.2830	3.841	4	15.362	4.152
44	**18.100**	21.06	2.9630	3.123	4	12.492	4.013
48	**18.596**	21.06	2.4670	2.715	4	10.860	4.031
52	**19.863**	21.06	1.2000	1.834	4	7.334	4.196
56	**20.051**	21.06	1.0120	1.106	4	4.424	4.004
60	**20.189**	21.06	0.8740	0.943	4	3.772	4.002
	16.665					**87.64**	**57.806**



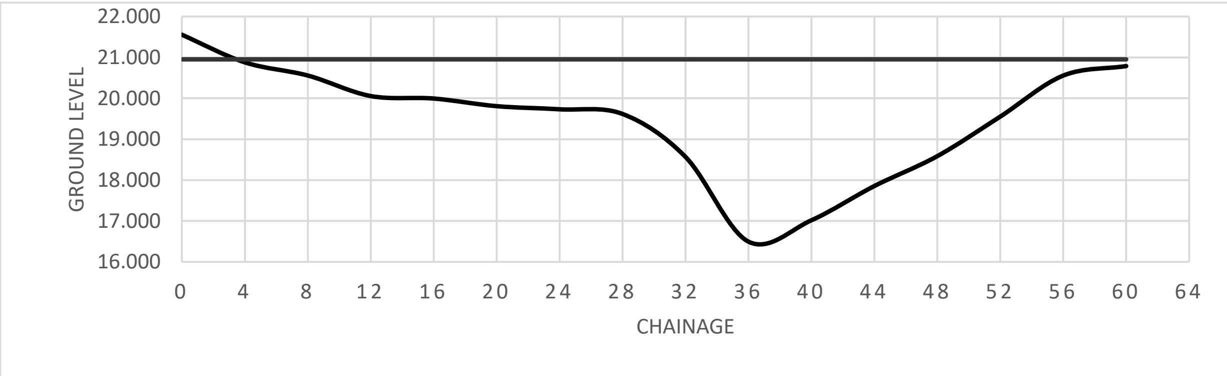
2. 50m Upstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**22.050**	21.20	0.0000				
4	**21.580**	21.20	0.0000	0.000	4	0.00	0.000
8	**21.085**	21.20	0.1154	0.058	4	0.23	4.031
12	**20.877**	21.20	0.3234	0.219	4	0.88	4.005
16	**20.511**	21.20	0.6899	0.507	4	2.03	4.017
20	**20.528**	21.20	0.6724	0.681	4	2.72	4.000
24	**20.658**	21.20	0.5424	0.607	4	2.43	4.002
28	**19.665**	21.20	1.5354	1.039	4	4.16	4.121
32	**18.568**	21.20	2.6324	2.084	4	8.34	4.148
36	**17.895**	21.20	3.3054	2.969	4	11.88	4.056
40	**18.185**	21.20	3.0154	3.160	4	12.64	4.010
44	**18.662**	21.20	2.5384	2.777	4	11.11	4.028
48	**19.125**	21.20	2.0754	2.307	4	9.23	4.027
52	**19.333**	21.20	1.8679	1.972	4	7.89	4.005
56	**20.000**	21.20	1.2009	1.534	4	6.14	4.055
60	**20.125**	21.20	1.0754	1.138	4	4.55	4.002
	17.895					**84.21**	**56.508**



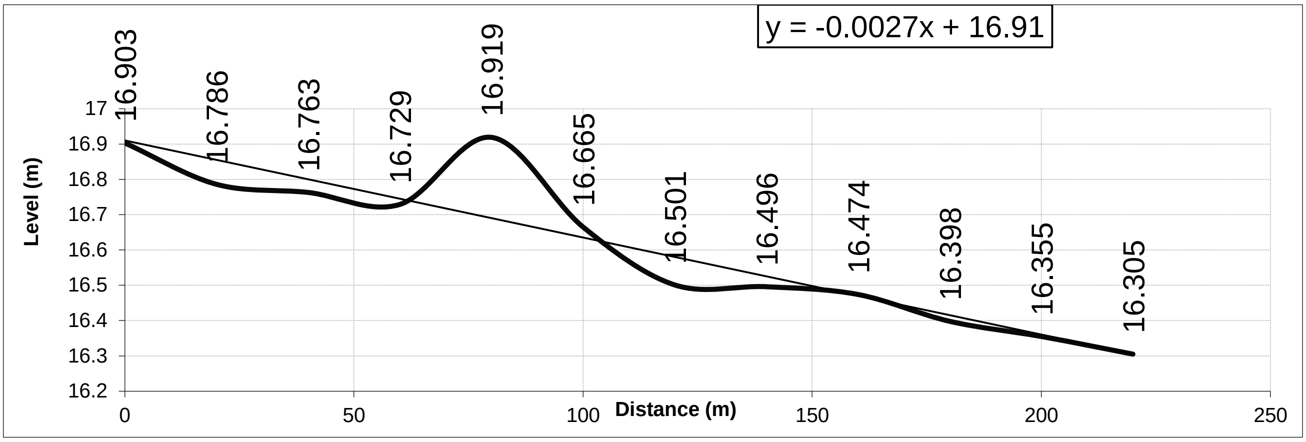
3. 40m Downstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**21.556**	20.95	0.0000				
4	**20.880**	20.95	0.0731	0.037	4	0.15	4.057
8	**20.558**	20.95	0.3951	0.234	4	0.94	4.013
12	**20.056**	20.95	0.8971	0.646	4	2.58	4.031
16	**19.995**	20.95	0.9581	0.928	4	3.71	4.000
20	**19.808**	20.95	1.1447	1.051	4	4.21	4.004
24	**19.732**	20.95	1.2211	1.183	4	4.73	4.001
28	**19.618**	20.95	1.3351	1.278	4	5.11	4.002
32	**18.568**	20.95	2.3851	1.860	4	7.44	4.136
36	**16.495**	20.95	4.4581	3.422	4	13.69	4.505
40	**17.018**	20.95	3.9351	4.197	4	16.79	4.034
44	**17.855**	20.95	3.0981	3.517	4	14.07	4.087
48	**18.586**	20.95	2.3671	2.733	4	10.93	4.066
52	**19.554**	20.95	1.3991	1.883	4	7.53	4.115
56	**20.556**	20.95	0.3971	0.898	4	3.59	4.124
60	**20.789**	20.95	0.1641	0.281	4	1.12	4.007
	16.495					**96.6**	**61.182**



Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys
Doc. Title	Hydrology Design Calculation of MNB CH: 14+630	
Doc. no.	HYDROLOGY-DDPR-R1	Rev. R0

Stream Slope in Longitudinal direction



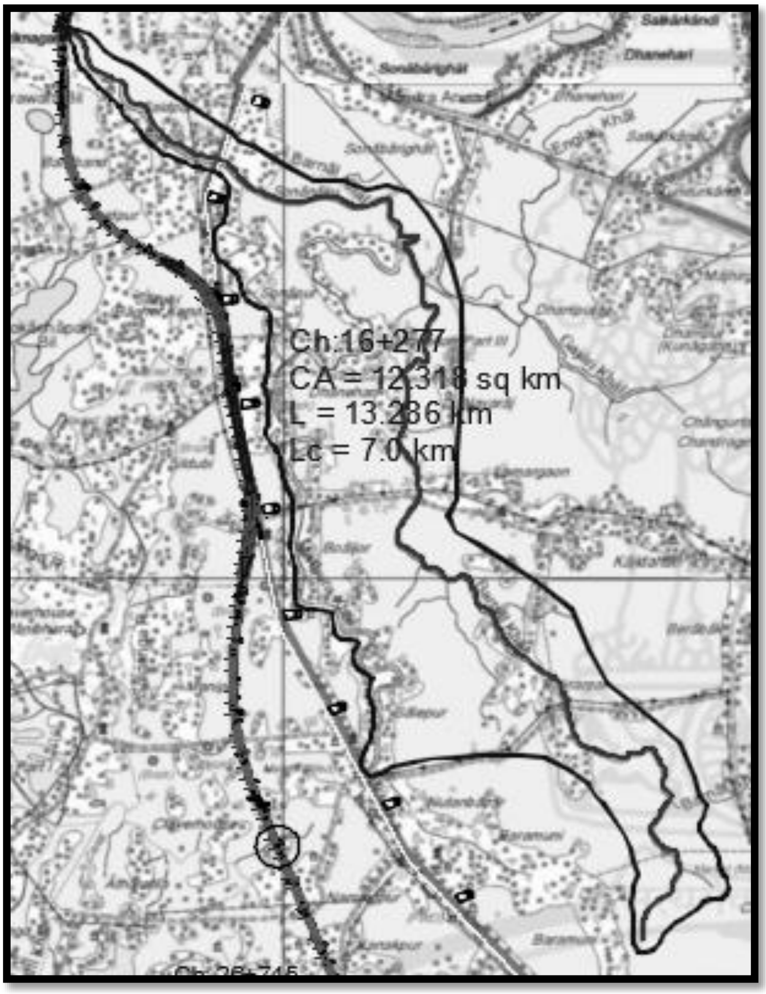
Average Slope = 0.003 m/m 0.003

Hydrology Design Calculation of MNB @ CH.16+277

Table 1: Details of Minor Bridge

S.No	Chainage (Km)	Proposed Span (m)	Catchment Area (Sq. Km)
1	16+277	3 x 12	12.32

Catchment Area



DISCHARGE BY EMPIRICAL & RATIONAL METHODS

General Information

Road	:	Silchar - Vairengte
Name of River/Nalla/Stream	:	Gungur Nala
Name of nearest Village/Town	:	Saidpur
Proposed Chainage	:	16+277
GT Sheet NO.	:	G46U14
Hydrometerological Sub Zone	:	2 b

Details of proposed bridge site

Proposed span arrangement	:	3 x 12	m
Total width provided	:	38.6	m
Obstruction due toPier	:	1	m
Obstruction due to Abutment	:	1.6	m
Clear water way skew	:	36.704	m
Skew Angle	:	11.238	deg
Clear water way provided (Right)	:	36.000	m

<u>DISCHARGE BY DICKEN'S FORMULA :</u> (Refer SP-13, page 7)

Q = $CM^{3/4}$

C = 11 - 14 where the annual rainfall is 60 - 120 cm
= 14 - 19 where the annual rainfall is more than 120 cm
= 22 in Western Ghats

C adopted	(Annual rainfall is 125 cm - 250 cm)	=	19	
Catchments area (M)		=	12.32	sqkm
Q		**=**	**124.93**	***cums***

<u>DISCHARGE BY RATIONAL METHOD :</u>

Discharge by Rational Formula

Catchment area (A) = 12.318 sqkm	=	1231.8	Hectares
Length of path from toposheet (L)	=	13.2	Km
Difference in levels from toposheet (H)	=	13	m
Maximum rain fall (F) (100 years return period)	=	234.2	mm
Storm Duration(Calculated as per CWC report for subzone 2b)	=	6.0	Hour
One hour rainfall (Io)	=	136.60	mm/hrs
Time of concentration (I.R.C.SP-13, page 11)	=	6.979	hrs
Critical rainfall intensity	=	34.24	

Discharge Q = 0.028 x P x f x A x Ic

P = (Rocky, Steep)	=	0.8	
f =	=	0.967	
A =	=	1231.8	Hectares
Ic =	=	3.42	cm/hr
Q =	=	**91.34**	**cum/sec**

Here,

t_c	=	Time of concentration i.e.time taken by the runoff from the farthest point on the periphery of catchments
	=	$(0.87*L3/H)^{0.385}$
I_o	=	One hour rainfall in cm.
	=	(F/T)*(T+1)/(1+1)
I_c	=	Critical intensity of rainfall in cm per hour
	=	Io*(2/(1+tc))
P	=	Coefficient of runoff for the catchments characteristics (Ref.TB-4.1, SP:13-2004)
A	=	Catchments area in hectare
Q	=	Maximum discharge in cumecs.
L	=	Distance from the critical point to the structure in Km.
H	=	The fall in level from the critical point to the structure in meter

DISCHARGE BY MANNING'S METHOD :

A	=	X-sectional Area		
S	=	Slope considered		
P	=	Wetted perimeter		
R	=	Hydraulic mean radius	=	A/P
V	=	Velocity	=	$1/n\ R^{2/3}\ S^{1/2}$
n	=	Mannings rugosity coefficient	=	0.05
Q	=	Discharge	=	A*V

HFL = 17.732 m

X-section at	HFL	A	P	R	S	u	Q
	m	m^2	m	m	m/m	m/sec	m^3/sec
Without afflux at Bridge location	17.73	106.50	70.27	1.52	0.0014	1.00	106.38
Without afflux at Upstream location	17.732	110.52	70.22	1.57	0.0014	1.02	113.21
Without afflux at Downstream location	17.73	116.40	70.25	1.66	0.0014	1.06	123.39
						1.060	123.39

DESIGN DISCHARGE :

Discharge by Dickens Formula	=	124.9 cumecs
Discharge by Rational Formula	=	91.3 cumecs
Discharge by Manning's Formula	=	123.4 cumecs

Design discharge should be highest of above methods, limited to 1.5 times of second highest asscement of maximum discharge of bridge. **= 124.93 cumecs**

AFFLUX CALCULATIONS:

i) Molesworth formula

By using molesworth Formula = $\left\{\left(\frac{V^2}{17.88}\right) + 0.015\right\} X \left\{\left(\frac{A}{a}\right)^2 - 1\right\}$

where,

Velocity of water prior to obstruction (V)	=	**Discharge / wetted area**	
	=	1.17	m/s
Unobstructed sectional area of the river (A)	=	106.500	m^2
Obstructed sectional area of the river (a)	=	71.463	m^2
Hence, Actual afflux of the river	=	0.11	m

ii) Oriface Formula

Obstructed length of bridge	L	=	36.000	m
Unobstructed width of the stream	W	=	53.650	m
	RV	=	2.329	
Depth of flow	D_d	=	1.985	
	L/W	=	**0.67**	

From clause 17.2 of IRC SP:13, (page 65)

Discharge, **Q** = $\mathbf{Co\ \sqrt{2g}\ L\ D_d\ [\ h + (1+e)\ u^2 / 2g\ ]^{1/2}}$

Where,	Co	=	**0.866**	
	e	=	**0.954**	
	g	=	9.81	kg/m^2
	D_d	=	1.985	m

Substituting the values

$C_o \sqrt{2g}\ L\ D_d$	=	274.125
{(1+e)/2g}	=	0.100
Q	=	124.93

Substituting,

124.93 = 274.125 X sqrt (h + 0.0996 u^2)

0.456 = sqrt (h + 0.0996 U^2)

0.208 = (h + 0.0996 U^2)

h = -0.0996 U^2 + 0.208 → Equation 1

Discharge, Q = W (D_d + h) u

124.928 = (1.99 + h) 53.650 U

2.329 = (1.99 + h) U

h = $\frac{2.33 - 1.985\ U}{U}$ → Equation 2

Equating Equation 1 and Equation 2

$$-0.0996\,U^2 + 0.208 = \frac{2.33 - 1.985\,U}{U}$$

$$-0.100\,U^3 + 0.21\,U = 2.33 - 1.985\,U$$

$$-0.100\,U^3 + 2.19\,U - 2.33 = 0$$

Adopting Trial and Error method for solving the equation

Trial value of "U" = **1.127** m/s

0.0001 ≈ 0

OK

Hence, velocity U = 1.13 m/s

Substituting the value of U in equation 1

h = 0.081 m **<** 0.496

Oriface formula is applicable

iii) Weir Formula

Cw = 0.96 (IRC: SP:13-2004, Page 53, Clause 15.2)

Q = $1.706\ Cw\ L\ H^{3/2}$

124.93 = $58.959\ H^{3/2}$

H = **1.6** m

H = $D_u + u^2/2g$

Assume

Du = H

Q = $W\ d_u\ u$

u = 1.412

Du = 1.548 m

h = Du - Dd

= -0.437 m > 0.496

Oriface formula is applicable

Hence design afflux adopted = 0.112 m

AHFL = 17.844

HFL = 17.732

Bed level = 15.132

VERTICAL CLEARANCE

Design Discharge	=	124.93	cumecs	
Vertical Clearance	=	0.90	m	
Depth of Superstructure	=	1.068	m	
Minimum FRL required	=	19.812	m	
Proposed FRL	=	22.153	m	SAFE
Minimum FRL required	=	19.784	m	
Proposed FRL	=	21.347	m	SAFE

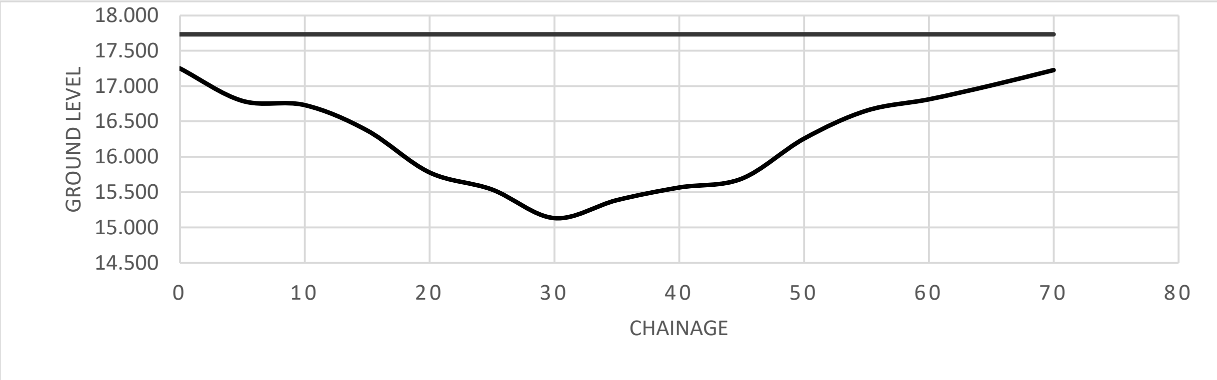
Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MNB CH: 16+277		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

Cross-sectional area of Stream

HFL 17.73 m

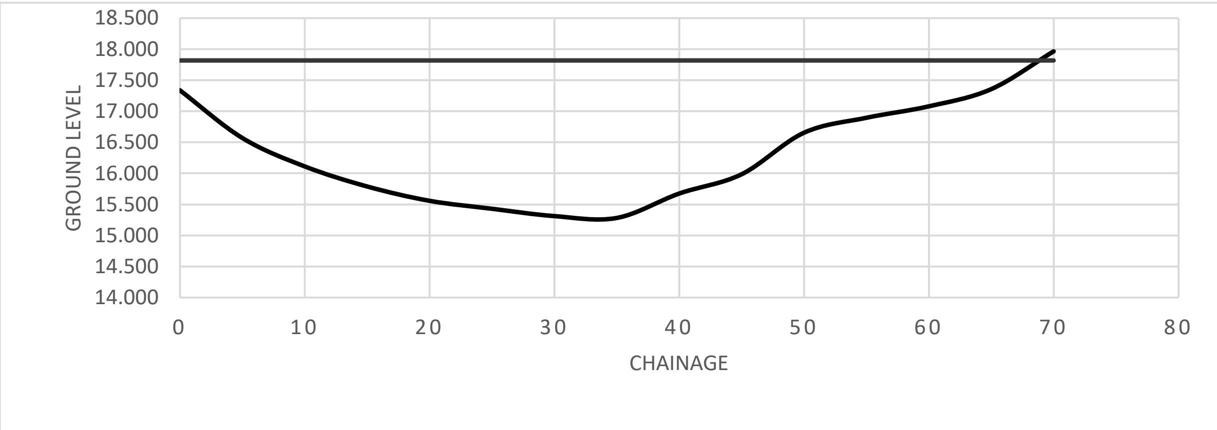
1. Bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**17.250**	17.73	0.4820				
5	**16.791**	17.73	0.9410	0.711	5	3.558	5.027
10	**16.731**	17.73	1.0010	0.971	5	4.855	5.018
15	**16.372**	17.73	1.3600	1.181	5	5.902	5.090
20	**15.778**	17.73	1.9540	1.657	5	8.285	5.013
25	**15.537**	17.73	2.1950	2.075	5	10.373	5.035
30	**15.132**	17.73	2.6000	2.398	5	11.988	5.006
35	**15.386**	17.73	2.3460	2.473	5	12.365	5.016
40	**15.565**	17.73	2.1670	2.257	5	11.283	5.006
45	**15.689**	17.73	2.0430	2.105	5	10.525	5.003
50	**16.256**	17.73	1.4760	1.760	5	8.798	5.002
55	**16.652**	17.73	1.0800	1.278	5	6.390	5.032
60	**16.812**	17.73	0.9200	1.000	5	5.000	5.016
65	**17.009**	17.73	0.7230	0.821	5	4.107	5.003
70	**17.226**	17.73	0.5060	0.615	5	3.073	5.004
	15.132					**106.50**	**70.270**



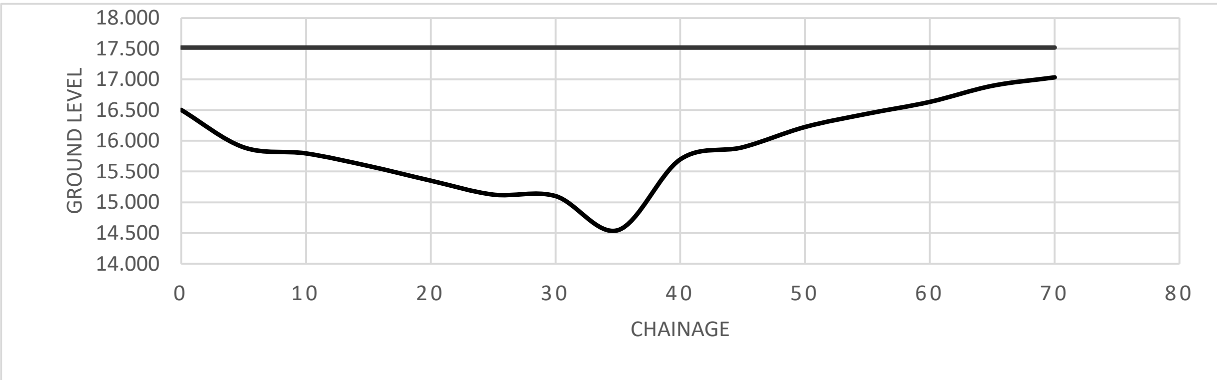
2. 60m Upstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**17.338**	17.82	0.4800				
5	**16.570**	17.82	1.2480	0.864	5	4.32	5.059
10	**16.112**	17.82	1.7060	1.477	5	7.38	5.021
15	**15.789**	17.82	2.0290	1.867	5	9.34	5.010
20	**15.558**	17.82	2.2600	2.144	5	10.72	5.005
25	**15.430**	17.82	2.3880	2.324	5	11.62	5.002
30	**15.312**	17.82	2.5060	2.447	5	12.23	5.001
35	**15.282**	17.82	2.5360	2.521	5	12.60	5.000
40	**15.675**	17.82	2.1430	2.339	5	11.70	5.015
45	**15.985**	17.82	1.8330	1.988	5	9.94	5.010
50	**16.654**	17.82	1.1640	1.498	5	7.49	5.045
55	**16.895**	17.82	0.9230	1.043	5	5.22	5.006
60	**17.079**	17.82	0.7390	0.831	5	4.15	5.003
65	**17.356**	17.82	0.4620	0.600	5	3.00	5.008
70	**17.964**	17.82	-0.1460	0.158	5	0.79	5.037
	15.282					**110.52**	**70.222**



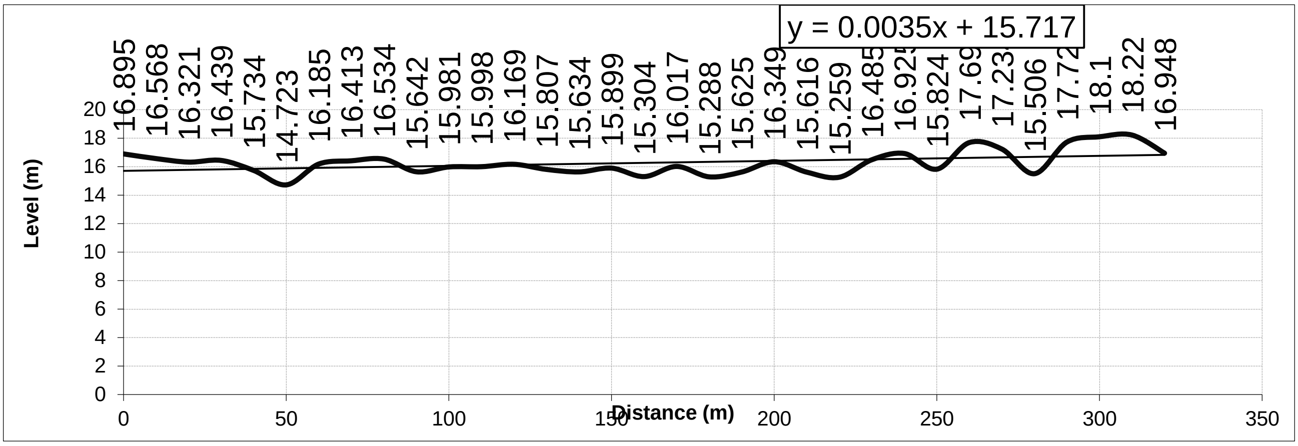
3. 60m Downstream of bridge Location

Chainage	Bed Level	HFL	Depth of water	Average depth of water	Distance	Area	Wetted Perimeter
(m)	(m)	(m)	(m)		(m)	(m^2)	(m)
0	**16.503**	17.52	1.0141				
5	**15.895**	17.52	1.6221	1.318	5	6.59	5.037
10	**15.795**	17.52	1.7221	1.672	5	8.36	5.001
15	**15.591**	17.52	1.9261	1.824	5	9.12	5.004
20	**15.352**	17.52	2.1651	2.046	5	10.23	5.006
25	**15.125**	17.52	2.3921	2.279	5	11.39	5.005
30	**15.101**	17.52	2.4161	2.404	5	12.02	5.000
35	**14.546**	17.52	2.9710	2.694	5	13.47	5.031
40	**15.698**	17.52	1.8191	2.395	5	11.98	5.131
45	**15.895**	17.52	1.6221	1.721	5	8.60	5.004
50	**16.225**	17.52	1.2921	1.457	5	7.29	5.011
55	**16.441**	17.52	1.0761	1.184	5	5.92	5.005
60	**16.633**	17.52	0.8841	0.980	5	4.90	5.004
65	**16.895**	17.52	0.6221	0.753	5	3.77	5.007
70	**17.032**	17.52	0.4851	0.554	5	2.77	5.002
	14.546					**116.4**	**70.246**



Project:	Silchar - Vairengte Section of NH306 (Package SA-1,km 0+000 to 21+000)	Transys	
Doc. Title	Hydrology Design Calculation of MNB CH: 16+277		
Doc. no.	HYDROLOGY-DDPR-R1	Rev.	R0

Stream Slope in Longitudinal direction



Average Slope = 0.0014 m/m 0.001433