Queries / Request for Additional Information					**Date:19.02.2025**	
Project:	Improvement/Construction to 2-Lane with Paved Shoulder of old NH-40 (new NH-206) from Km 37+550 to Km 45+760 (Design Km 0+000 to Km 7+760, Design Length 7.760 Km) (Package-III) Pynursla Bypass on EPC Mode in the state of Meghalaya.					
Sr. No.	**Title**	**Volume, Clause, Page no.**	**Description**	**Existing condition**	**Modification requested / query**	**Reply**
Commercial points						
1	Tender document	DCA - Article 14	Maintenance payment	Clause 14.1 reads as : For the performance of its Maintenance obligations, the Contractor shall be paid (if not included in the Schedule - H) under either of th i.e. 14.1 - a, b, c, d, or e depending upon the category of proposed project.	We request you to kindly confirm that the subject project falls under which category i.e. 14.1 a or 14.1 d in regards to Maintenance payment.	Kindly refer corrigendum.
2	Tender document	Schedule H	% Breakup oF Contract Price (% weightage)	% Breakup of Contract Price (% weightage) is given upto 2 decimal points .	We would like to inform you that the Sub - Total of % weightages does not work out to exact 100.00% for Minor bridge, Major bridge & Other works.In view of above , we request you to kindly provide exact/correct figures of the % weightages of various heads so that the sum total for individual heads such as Minor Bridge, Major Bridge & Other works is equivalent to 100.00%.	Section Wise percentage has been checked and it is found in order.
Technical points						
1	Drawings	Tender Drawings Page 11 of 56			According to the tender drawings for the Extradosed bridge Single cell Box girder for 21 m width has been provided.We request you to allow the Bidder to modify the shape of the box section to meet the design requirements.	The Shape and size of the Box Girder can be Modified as per design requirement approved by authority engineer & Competent Authority. However, no change of

						scope will be permitted for this change.
2	Tender document	Schedule B			Bidder is **free to change the span arrangement (Increase or decrease)** for the Extradosed bridges. Please confirm.	Bidder can adopt suitable type of Span arrangement as per design requirement approved by authority engineer keeping total length as 400m. However, no change of scope will be permitted for this change.
3	Drawings	Tender Drawings Page 77 to 78			According to the tender drawings for the structure at Ch 6+812, a PSC I-girder is proposed for 50m Span. However, the schedule specifies a PSC Box Girder. Please clarify.	The type of girder as shown in GAD are for reference purpose only. Please refer Schedule.
4	Drawings	General	Shape of structural components	For all Structures	Kindly confirm that whether the shape of structural components such as superstructure, pier and pier cap can be changed from what is given in the tender drawings while ensuring the aesthetics of the bridge.	The type of Super-strucutre & Sub-structure as shown in GAD are for reference purpose. The Concessionaire can adopt as per design requirement approved by Authority's Engineer and Authority. However, no change of scope will be permitted for this change.
5	Drawing	Design	Design of Footpath		According to the tender drawings, Extradosed bridge is designed for three lane live load for a deck width of 21m (bridge has footpath on both sides). Please confirm that footpath will not be replaced by live load for future provision.	Bidders are Requested to follow Technical Schedules.

National Highways & Infrastructure Development Corporation Ltd. * New Delhi *

6	Tender document	Design	Geotech report	Geotech reports are not given for following structures:	Geotechanical Reports not available for the structures as mentioned in the schedule B. Please provide Geotechanical data.	Geotechnical report is enclosed for reference only. Bidders at his own cost conduct the Geotechnical investigation and accordingly design the type of foundation as per design requirement approved by Authority's Engineer and Authority. However, no change of scope will be permitted for this change.
7	Tender document	Design	Hydrological data		As per Schedule B, a major bridge is proposed at Ch 6+185, and its location is across a water body. However, hydrological data is not available. Please furnish the hydrology report prepared during DPR for correct assessment of discharge, HFL Levels , LWL and scour depth at Pier location.	Hydrology report is enclosed. All data provided are for reference only. Bidders are requested to perform their own survey and site investigation before bidding.
8	Tender document	Design	Hydrological data		As per Schedule B, a viaduct at Ch 6+812 of the bridge is situated across a water body. However, hydrological data is not available. Please furnish the hydrology report prepared during DPR for correct assessment of discharge, HFL Levels , LWL and scour depth at Pier location.	All data provided are for reference only. Bidders are requested to perform their own survey and site investigation before bidding.
9	Tender document	Design	Wind pressure		According to IRC guidelines, if the topography at the structure site (such as hills) can cause wind funneling, the wind pressure should be increased by 20%. Please confirm if this increment is required for the bridges.	Refer Codal provisions. In case of wind funneling, wind pressure be increased by 20% for the bridges. However, Bidders are requested to perform their own investigation before bidding.

National Highways & Infrastructure Development Corporation Ltd. New Delhi

10	Design	Exposure Condition		Not specified	Please confirm that the **exposure condition** to be considered for design of the subject project.	Refer Codal provisions. Bidders are requested to perform their own investigation before bidding.
11	Design	Seismic Zone		Not specified	Please confirm "seismic zone V" is to be considered for design of the subject project.	The project is under Seismic Zone-V. However, Bidders are requested to perform their own investigation before bidding.
12	Tender document	Design	Site specific response spectrum	Not provided	Extradosed bridge having individual span length 150m and height of pier more than 30m in zone 5 use of Site specific response spectrum is needed. Please provide Site specific spectra for proposed extradosed bridge.	All data provided are for reference only. Bidders are requested to perform their own survey and site investigation before bidding. Tentative Span Arrangement of Extradosed bridge shall be 100X200X100.
13	Tender document	Design	Type of foundation		Please confirm that the bidder is free to select any type of foundation (such as Open/Pile) for all proposed structures listed in Schedule B, based on the geotechnical data.	Bidders at his own cost conduct the Geotechnical investigation and accordingly design the type of foundation as per design requirement approved by Authority's Engineer and Authority. However, no change of scope will be permitted for this change.
14	Tender document	Design	Span arrangement for all bridges		Please confirm that bidder is free to change the span arrangement (Increase or decrease) for the all proposed I girder / box girder bridges.	The Total length shown in schedule are minimum & Contractor can adopt suitable type of Span arrangement as per design requirement approved by Authority's Engineer and Authority. However, no change of scope will be permitted for this change.

National Highways & Infrastructure Development Corporation Ltd. New Delhi

15	Tender document	Design	Span arrangement for Viaduct portion		Please confirm if the span arrangement for the viaduct of the Extradosed bridge can be changed (Increase or decrease).	The Total lengths shown in schedule are minimums. For exceptionally unavoidable conditions span variation may be accepted for few spans which shall be approved by Authority & Authority's Engineer. The design shall be vetted by IIT or equivalent institute at Contractor's own cost.
16	Tender document	Design	Type of bearings		Bidder is free to choose the type of bearings under superstructure i.e. Elastomeric, POT PTFE or Spherical as per design requirements. Please confirm.	Contractor can adopt suitable type of bearing as per design requirement approved by Authority's Engineer and Authority. However, no change of scope will be permitted for this change.
17	Tender document	Design	Type of wearing coat		Bidder is free to choose the type of wearing coat on deck as per Morth specifications. Please confirm.	65mm Wearing coat (Bitument conctere 40mm Thick overlaid with 25mm Thick Mastic Asphalt) as per MORT&H Standard 5th Revision.
18	Tender document	Design	Type of Superstructure for Major bridge		Is bidder allowed to change the type of superstructure for Extradosed bridge i.e. from Concrete to Steel- composite section?	Can be changed keeping over all span of 400m at their own cost after approval of Authority & Authority Engineer.
19	Tender document	Design	Nature of Superstructure for Major bridge		Is bidder allowed to change the nature of bridge from Extradosed bridge to Cable stay bridge? Please confirm.	Can be changed keeping over all span of 400m at their own cost after approval of Authority & Authority Engineer.
20	Tender document	Design	Exposure Condition	Not mentioned	Please confirm what "exposure condition" to be considered for the project.	Refer Codal provisions. Bidders are requested to perform their own investigation before bidding.

21	Tender document	Design	Seismic Zone	Not mentioned	Please confirm which "seismic zone is to be considered for the project.	Refer Codal provisions. Bidders are requested to perform their own investigation before bidding.
22	General	Importance factor			As per IRC 6, Importance factor for the extradosed bridge is 1.2. please confirm	Refer Codal provisions. Bidders are requested to perform their own investigation before bidding.
23	General	Congestion factor			As per our understanding congestion of vehicles is not expected for this project. Please confirm.	Refer Codal provisions. Bidders are requested to perform their own investigation before bidding.
24	Design	Techanical Schedule Sch B Clause 7(e) Page 34	Design Load of utilities		Kindly specify the load of utilities being carried over the elevated structure,if any.	Bidders are requested to perform their own investigation before bidding. Also, follow the codal provisions.
25	Design	Schedule D & Schedule B			As per Schedule D, it is stated that extra widening should be considered for curves. However, Schedule B, Clause 2(ii) specifies that no extra widening is to be considered for new minor bridges. Notably, as per the plan and profile, some proposed structures fall within curved sections. Kindly confirm whether bidders are required to consider extra widening in such cases.	The minimum required width of structure are shown in schedule, Extra widening at curve location will be taken as per the codal provision approved by Authority's Engineer and Authority. However, no change of scope will be permitted for this change.
26		Schedule B -Annex I	Scope of work - Noise barrier	Noise barriers: shall be provided in accordance with manual; Locations shall be decided as per site condition in consent with Authorit	Kindly confirm whether installtion of Noise barrier is in the scope of work . If yes , then kindly provide the excact location where the same is to be install. Please provide the total length , height above CB & specification for the same.	Bidder are requested to follow Schedule B.

27	General	Plan & Profile (CAD format)			Please provide Plan and Profile drawings in CAD format. Please also provide kmz file of the project alignment.	Bidder are requested to follow Tender documents.
28	General	CAD format			Please provide Topo Survey data in CAD format.	Bidder are requested to follow Tender documents.
29	General	Existing road pavement crust			Please provide Crust Thickness of existing road pavement.	Bidder are requested to follow Tender documents.
30	General	Schedule A	Minimum FRL		With respect to Annexure-III, Schedule A, the plan and profile should be left to the Contractor with the condition that the minimum vertical clearances as given in Manual and Schedule are to be maintained. Please confirm if minimum FRL criteria is applicable or not.	Kindly follow Tender documents.
31	Tender document	Design	CBR Test report		Provide trail pit data including CBR test report.	Kindly follow Tender documents.
32	Tender document	Design	Existing Ground level		Please provide the Ground Level (GL) at +15 and -15 offset from the proposed centre line (PCL).	Bidders are requested to follow Tender documents.
33	Tender document	Schedule B	Junction / Cross road development		As per Cl 3 (1) of Schedule B, please mentioned the extent of length and width to be considered for crossroad development	Bidders are requested to follow Schedule B.
34	Tender document	Schedule B	Utility Shifting	Shifting of Religious Sculpture / Common property resources: Contractor has to shift all such structures falling in the PROW to an appropriate location.	All the necessary clearances /NOCs /permission required for shifting of Religious Sculpture / Common property resources falling within the PROW shall be taken by the Department prior to handing over /award of work. Also, appropriate location/land for shifting these Religious Sculpture / Common property resources shall be provided by the department.	Bidder are requested to follow tender documents.

National Highways & Infrastructure Development Corporation Ltd. * New Delhi *

35	Tender document	Utility Shifting-Schedule-A - Annex V	Scope of work for Utility Shifting	Utility Shifting as per Schedule-A - Annex V	Existing Utility shifting quantities (item wise BOQ) will be taken as per given in schedule-A. Please clarify / confirm.	Item wise BOQ will be provided by utility owning department.
36	Tender document	Utility Shifting-Schedule-A - Annex V	Utility Shifting	Electrical	(i) We request department kindly indicate the followings: 1. We understand that the we need to shift LT, 11KV HT , 33 KV HT by Overhead type method. No underground cabling work is involved. 2. If Utility to be shifted with Under Ground Method then please specify the sizes of cable. 3. Name/ type of conductor/ cable to be shifted in the case of 11 kv/33kv line. 4. Electrical pole to be shifted is of PCC Type Or Rail pole, Kindly specify the numbers. 5. Technical specification 8 MTR/9 Mtr/11 mtr STP pole. 6. If it is RCC pole then please mention length of pole . (in the case of LT line /11 KV HT Line) 7. If Rail pole then please mention length of pole. (in the case of HT Line) 8. Type of 11 kv line to be shifted is Single circuit or Multi circuit type. 9. Type and size of LT cable to be shifted . OR configuration of LT line to be shifted (3phase -4wire system or 3 phase-5	Bidder are requested to follow Schedule A.

National Highways & Infrastructure Development Corporation Ltd. ★New Delhi★

					wire system), please also mention type of conductor. 10. Rating of Distribution transformer to be shifted.	
37	Tender document	Utility Shifting-Schedule-A - Annex V	Utility Shifting	Water Supply	(i) The details of existing water pipe line such as depth below GL is not clear. (ii) Also details of proposed water pipe line such as diameter , proposed materials (like Cast iron, Ductile... Etc) is not clear . Kindly provide the complete details.	Bidder are requested to follow Schedule A.
38					(iii) Please provide the water pressure in the pipeline.	
39					(iv) Please provide the spacing of air valve or no. of air valves in the project alignment.	
40	General	Access Road upto Pier P1 & P2 location			It has been noticed in "Plan & Profile" drawings that there is almost 81m & 46m level difference in Ground level (GL) and Finished Road level (FRL) at P1 and P2 location respectively of "Extradosed Bridge" at Ch 6+185. Further, during site visit, we could not access P1 & P2 foundation locations as there is no access roads. All resources (such as machines, manpowers) are required to be taken down from existing roads at top from both banks, these Access Roads are essentials to reach upto P1 & P2 foundations. Considering 80m level difference and required road gradient of 1 in	Temporary site road of length about 380m has been considered. It is responsibility of Contractor to arrange land for such access/site road.

National Highways & Infrastructure Development Corporation Ltd. ★New Delhi★

					10, Access Road of 800m to 1,000m is required towards P1 side and similarly for P2 side. Even the ROW to be provided at these locations are very less to accomodate the access roads. Therefore, we request to kindly **hand-over the land required for making the aforesaid access roads upto P1 and P2 foundation** locations prior to award of work to the Contractor.	
41	Tender Document	Bidder's Scope of Work - Slope protection			As observed during Site Visit, Abutment A1 & A2 may require Slope Protection to retain the loose exposed strata. Kindly confirm whether the same is in the Bidder's Scope of work or not. If yes, please include the appropriate payment of the same in Schedule 'H'. Please confirm.	Bidders are requested to follow technical schedule.
42	General	Land for Site Establishment / Casting Yard/ Labour hutment / Batching Plant ...etc		Not specified	We request Department to provide us land nearby to site for site establishment, Installation of Batching plant, Contractor Site office , labour camp (approx.4**.0 acres**) etc. free of cost nearby the site. Kindly provide the lead/distance of the same from site.	As per provisions of DCA. The Contractor has to make arrangement for land for site establishment, installation of batching plant, Contractor site office, labour camp etc at their own cost.
43	Tender Document	Schedule B	Dumping Ground	(c) Disposal of Debris: - 5. No Muck dumping sites will be Proposed within Reserved Forest area. The muck dumping sites have been identified at Ch. 3+700 (LHS), Ch. 4+900 (LHS) and Ch.	We request the department to provide necessary clearances /NOCs /permission shall be obtained by the Contractor in addition to the applicable permissions and clearances as stated in Schedule F for dumping of muck. Please confirm.	Kindly follow Technical Schedule.

National Highways & Infrastructure Development Corporation Ltd. ★ New Delhi ★

				7+200 (LHS). However, necessary permission for dumping of muck at the said locations needs to be obtained by the EPC contractor in consultation with the Local village head, District Administration & Forest department etc. In addition to this, the EPCC may identify additional dumping locations if required, for dumping of muck and necessary clearances/NOCs/permission shall be obtained by the Contractor in addition to the applicable permissions and clearances as stated in Schedule F.		
44	General	Obtaining permits, approvals, etc. from various Government bodies.			We request the Employer to arrange all the necessary permits, licenses, clearances & approvals as required from the various Government bodies prior to award of work/ during execution as required. Any deposit / cost shall be borne by the Employer.	As per provisions of DCA.
45	General	Bid submission date		Current Bid submission date 13/01/2025	Since the tender is based on "Design & Construction lump Sum Contract" and the tender estimate is to be based on pre-tender design, we request you to **extend the tender submission date by 03 weeks** from the current date.	Bidder are requested to follow Corrigendum.

National Highways & Infrastructure Development Corporation Ltd. ★New Delhi★

PYNURSLA BYPASS
GEO-TECHNICAL REPORT

Geotechnical Report Index

Sr No.	Chanage	pth of Bore	Page No.	Soil Details						Remark
1	1580m	15.00m	5 to 6	Filled up soil	(1.5-4.60) Silt Sand & Gravel (Hard Moorum)	(4.60-7.50) Medium dense to dense, grey Silty SAND (SM)	(7.50-24.00) Quartzite	-	-	MJB Viaduct
2	1620m	15.00m	7 to 8	Filled up soil	(1.5-5.10) Silt Sand & Gravel (Hard Moorum)	(5.10-8.20) Medium dense to dense, grey Silty SAND (SM)	(8.20-24.00) Quartzite	-	-	
3	1660m	15.00m	9 to 10	Filled up soil	(1.5-6.30) Silt Sand & Gravel (Hard Moorum)	(6.30-8.10) Medium dense to dense, grey Silty SAND (SM)	(8.10-24.00) Quartzite	-	-	
4	1700m	15.00m	11 to 12	Filled up soil	(1.5-6.45) Silt Sand & Gravel (Hard Moorum)	(6.45-8.90) Medium dense to dense, grey Silty SAND (SM)	(8.90-24.00) Quartzite	-	-	
5	1740m	15.00m	13 to 14	Filled up soil	(1.5-4.50) Silt Sand & Gravel (Hard Moorum)	(4.50-7.40) Medium dense to dense, grey Silty SAND (SM)	(7.40-24.00) Quartzite	-	-	
6	2210 m	15.00m	22 to 23	Filled up soil	(1.5-4.50) Silt Sand & Gravel (Hard Moorum)	(4.50-7.10) Medium dense to dense, grey Silty SAND (SM)	(7.10-24.00) Quartzite	-	-	MNB
7	2250 m	15.00m	24 to 25	Filled up soil	(1.5-4.65) Silt Sand & Gravel (Hard Moorum)	(4.65-7.75) Medium dense to dense, grey Silty SAND (SM)	(7.75-24.00) Quartzite	-	-	
8	2354 m	15.00m	33 to 34	Filled up soil	(1.5-4.60) Silt Sand & Gravel (Hard Moorum)	(4.60-8.15) Medium dense to dense, grey Silty SAND (SM)	(8.1524.00) Quartzite	-	-	VOP
9	2366 m	15.00m	35 to 36	Filled up soil	(1.5-4.65) Silt Sand & Gravel (Hard Moorum)	(4.65-7.75) Medium dense to dense, grey Silty SAND (SM)	(7.75-24.00) Quartzite	-	-	MNB
10	2790 m	15.00m	44 to 45	Filled up soi	(1.5-4.45) Silt Sand & Gravel (Hard Moorum)	(4.45-7.20) Medium dense to dense, grey Silty SAND (SM)	(7.20-24.00) Quartzite	-	-	
11	2830 m	15.00m	46 to 47	Filled up soil	(1.5-3.81) Silt Sand & Gravel (Hard Moorum)	(3.80-6.85) Medium dense to dense, grey Silty SAND (SM)	(6.85-24.00) Quartzite	-	-	
12	5020 m	15.00m	55 to 56	Filled up soil	(1.5-4.10) Silt Sand & Gravel (Hard Moorum)	(4.10-6.20) Medium dense to dense, grey Silty SAND (SM)	(6.20-24.00) Quartzite	-	-	Viaduct
13	5490m	15.00m	64 to 65	Filled up soil	(3.00-6.94m) Stiff Yellowish gray claye silt layer	(6.94m-10.40) Medium dense to dense, grey Silty SAND (SM)	(10.40-13.45) Very dense, grey fine SAND (SP SM)	(13.45-16.80) Dense, grey	(16.80-24.00) Quartzite	Cutting Section
14	5530m	15.00m	66 to 67	Filled up soil	(3.00-7.20m) Stiff Yellowish gray claye silt layer	(7.20m-10.50) Medium dense to dense, grey Silty SAND (SM)	(11.50-13.75) Very dense, grey fine SAND (SP-SM)	(13.75-18.70) Dense, grey	(18.70-24.00) Quartzite	
15	5775m	12.50m	79 to 79	Filled up soil	(1.5-4.15) Silt Sand & Gravel (Hard Moorum)	(4.15-7.95) Medium dense to dense, grey Silty SAND (SM)	(7.95-24.00) Quartzite	-	-	Extradosed (MJB)
16	5840m	13.00m	80 to 80	Filled up soil	(1.5-3.25) Silt Sand & Gravel (Hard Moorum)	(3.25-6.95) Medium dense to dense, grey Silty SAND (SM)	(6.95-24.00) Quartzite	-	-	
17	6050m	14.50m	81 to 82	Filled up soil	(1.5-5.26) Silt Sand & Gravel (Hard Moorum)	(5.26-7.20) Medium dense to dense, grey Silty SAND (SM)	(7.20-24.00) Quartzite	-	-	

Sr No.	Chanage	pth of Bore	Page No.	Soil Details						Remark
18	6140 m	15.00m	87 to 88	Filled up soil	(1.5-4.45) Silt Sand & Gravel (Hard Moorum)	(4.45-8.20) Medium dense to dense, grey Silty SAND (SM)	(8.20-24.00) Quartzite	-	-	Viaduct
19	6157 m	15.00m	89 to 90	Filled up soil	(1.5-4.85) Silt Sand & Gravel (Hard Moorum)	(4.85-9.85) Medium dense to dense, grey Silty SAND (SM)	(9.95-24.00) Quartzite	-	-	
20	6199 m	15.00m	91 to 92	Filled up soil	(1.5-5.95) Silt Sand & Gravel (Hard Moorum)	(5.95-8.80) Medium dense to dense, grey Silty SAND (SM)	(8.80-24.00) Quartzite	-	-	
21	6241 m	15.00m	93 to 94	Filled up soil	(1.5-4.65) Silt Sand & Gravel (Hard Moorum)	(4.65-7.60) Medium dense to dense, grey Silty SAND (SM)	(7.60-24.00) Quartzite	-	-	
22	6283 m	15.00m	95 to 96	Filled up soil	(1.5-4.70) Silt Sand & Gravel (Hard Moorum)	(4.70-7.90) Medium dense to dense, grey Silty SAND (SM)	(7.90-24.00) Quartzite	-	-	
23	6380 m	15.00m	104 to 105	Filled up soil	(1.5-4.55) Silt Sand & Gravel (Hard Moorum)	(4.55-6.35) Medium dense to dense, grey Silty SAND (SM)	(6.35-24.00) Quartzite	-	-	Viaduct
24	6540 m	15.00m	113 to 114	Filled up soil	(1.5-5.80) Silt Sand & Gravel (Hard Moorum)	(5.80-9.00) Medium dense to dense, grey Silty SAND (SM)	(9.00-24.00) Quartzite	-	-	Viaduct
25	6585 m	15.00m	115 to 116	Filled up soil	(1.5-4.80) Silt Sand & Gravel (Hard Moorum)	(4.80-10.30) Medium dense to dense, grey Silty SAND (SM)	(10.30-24.00) Quartzite	-	-	
26	6630 m	15.00m	117 to 118	Filled up soil	(1.5-6.00) Silt Sand & Gravel (Hard Moorum)	(6.00-9.50) Medium dense to dense, grey Silty SAND (SM)	(9.50-24.00) Quartzite	-	-	
27	6675 m	15.00m	119 to 120	Filled up soil	(1.5-4.40) Silt Sand & Gravel (Hard Moorum)	(4.40-8.95) Medium dense to dense, grey Silty SAND (SM)	(8.95-24.00) Quartzite	-	-	
28	7304 m	15.00m	128 to 129	Filled up soil	(1.5-4.20) Silt Sand & Gravel (Hard Moorum)	(4.20-6.65) Medium dense to dense, grey Silty SAND (SM)	(6.65-24.00) Quartzite	-	-	MNB
29	7316 m	15.00m	130 to 131	Filled up soil	(1.5-3.81) Silt Sand & Gravel (Hard Moorum)	(3.80-6.85) Medium dense to dense, grey Silty SAND (SM)	(6.85-24.00) Quartzite	-	-	
30	7476 m	15.00m	139 to 140	Filled up soil	(1.5-5.80) Silt Sand & Gravel (Hard Moorum)	(5.80-9.00) Medium dense to dense, grey Silty SAND (SM)	(9.00-24.00) Quartzite	-	-	MNB
31	7488 m	15.00m	141 to 142	Filled up soil	(1.5-4.60) Silt Sand & Gravel (Hard Moorum)	(4.60-8.15) Medium dense to dense, grey Silty SAND (SM)	(8.15-24.00) Quartzite	-	-	MNB

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 - W3) / (W3 - W1)) \times 100$

Where,

$W1$ = weight of container with lid, in g.

$W2$ = weight of container with wet soil, in g. $W3$ = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

F.S.I (%) = [(Vd – Vk) / Vk] x 100

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

TABLE –A-1, BORELOG

Location :-	**1580m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**04-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	10	150	35	Nil	Nil	(1.5-4.60) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	13	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	18	150	35	Nil	Nil	(4.60-7.50) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	22	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	28	150	35	Nil	Nil	(7.50-24.00) Quartzite	Rock	
9.00	10.50	Core	Refusal	10.50	>40	75	40	56	38			
10.50	12.00	Core	–	12.00	>40	75	40	61	34			
12.00	13.50	Core	–	13.50	>40	75	40	67	42			
13.50	15.00	Core	–	15.00	>40	75	40	69	43			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**1580m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**04-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	9	53	38	0	NL	NL	NP								
SPT-2	3.00	17	45	38	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	34	55	11	0	NL	NL	NP	-	9.53	1.89	2.75	0.53	29.36	0	33
SPT-5	7.50															
SPT-6	9.00	46	48	6	0	NL	NL	NP		8.69	2.15	2.77	0.62	32.36	0	34
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS
BHOPAL

TABLE –P-1, BORELOG

Location :-	**1620m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**04-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	9	150	35	Nil	Nil	(1.5-5.10) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	16	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	19	150	35	Nil	Nil	(5.10-8.20) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	22	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	27	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	54	36			
10.50	12.00	Core	–	12.00	>40	75	40	59	34	(8.20-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	65	39			
13.50	15.00	Core	–	15.00	>40	75	40	57	43			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-1, BORELOG

Location :-	**1620m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**04-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	12	46	42	0	NL	NL	NP								
SPT-2	3.00	18	44	38	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	30	65	5	0	NL	NL	NP	-	8.36	1.96	2.75	0.58	32.35	0	34
SPT-5	7.50															
SPT-6	9.00	46	47	7	0	NL	NL	NP		7.86	2.22	2.78	0.63	33.63	0	35
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-2, BORELOG

Location :-	**1660m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**04-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	8	150	35	Nil	Nil	(1.5-6.30) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	14	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	21	150	35	Nil	Nil	(6.30-8.10) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	27	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	31	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	59	41			
10.50	12.00	Core	–	12.00	>40	75	40	60	36			
12.00	13.50	Core	–	13.50	>40	75	40	68	46	(8.10-24.00) Quartzite	Rock	
13.50	15.00	Core	–	15.00	>40	75	40	70	48			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-2, BORELOG

Location :-	**1660m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**04-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	35	51	14	0	NL	NL	NP								
SPT-2	3.00	36	43	21	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	40	51	9	0	NL	NL	NP	-	12.32	1.98	2.75	0.52	32.36	0	28
SPT-5	7.50															
SPT-6	9.00	46	44	10	0	NL	NL	NP		9.66	2.36	2.76	0.63	33.25	0	34
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
SPT-11	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

TABLE –P-3, BORELOG	
Location :-	**1700m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**04-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	9	150	35	Nil	Nil	(1.5-6.45) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	15	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	22	150	35	Nil	Nil	(6.45-8.90) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	26	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	32	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	58	43			
10.50	12.00	Core	–	12.00	>40	75	40	61	45	(8.90-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	65	49			
13.50	15.00	Core	–	15.00	>40	75	40	69	48			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-3, BORELOG															
Location :-					**1700m**										
Ground Level:-					**1 m**										
Depth of Boring:-					**12 m**										
Date of Started:-					**04-03-2024**										
Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	10	50	40	0	NL	NL	NP								
SPT-2	3.00	21	49	30	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	33	53	14	0	NL	NL	NP	-	11.25	1.78	2.74	0.54	32.25	0	25
SPT-5	7.50															
SPT-6	9.00	49	46	5	0	NL	NL	NP		9.99	2.22	2.76	0.62	34.25	0	33
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
SPT-11	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**1740m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**05-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil	(1.5-4.50) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	16	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	24	150	35	Nil	Nil	(4.50-7.40) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	33	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	36	150	35	60	38			
9.00	10.50	Core	Refusal	10.50	>40	75	40	63	34			
10.50	12.00	Core	–	12.00	>40	75	40	65	39	(7.40-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	71	43			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**1740m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**05-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	9	53	38	0	NL	NL	NP								
SPT-2	3.00	17	45	38	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	34	55	11	0	NL	NL	NP	-	11.27	1.89	2.68	0.53	31.26	0	25
SPT-5	7.50															
SPT-6	9.00	46	48	6	0	NL	NL	NP		9.63	2.54	2.74	0.65	32.55	0	33
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.53	KN/m2
Angle of Internal Friction	=	33	degree
Bulk density of Soil	=	18.9	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.62	KN/m2
Angle of Internal Friction	=	34	degree
Bulk density of Soil	=	18.9	kN/m3
Soil Properties-3 (20-29.50 m)			
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	18.9	kN/m3
P_{Di}	=	9.45	kN/m2
ϕ	=	33	degree
$tan_{\delta i}$	=	0.650	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**231.36**	**kN**
α_i	=	1.20	
c_i	=	0.53	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**23.96448**	**kN**
SRF1	=	255.32	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	18.9	kN/m3
P_{Di}	=	141.75	kN/m2
ϕ	=	34	degree
$tan_{\delta i}$	=	0.675	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**720.90**	kN
α_i	=	1.20	
c_i	=	0.62	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.606784**	**kN**
SRF2	=	**726.51**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	981.83	kN
Ultimate Load Capacity Friction	=	981.83	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	392.73	kN
	=	39	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

$Q\ Allow = (R_e/3) + (R_{af}/6)$

Qu	=	Ultimate Capacity of Pile		
QAllow	=	Allowable capacity of Pile		
R_e	=	Ultimate end bearing		
R_{af}	=	Ultimate side socket shear		
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength		
		(CR+RQD)/2	K_{sp}	
		30%	0.3	
		100%	1.2	
CR	=	Core Recovery in percent		
RQD	=	Rock Quality Designation in percentage		
q_c	=	Average unconfined compressive strength of rock core below base of pile for		
		The depth twice the diameter/least lateral dimension of pile in MPa.		
A_b	=	Cross Sectional Area Base of Pile		
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20		
A_s	=	Surface Area of Socket		
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014		
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for		
		M 35 concrete in confined condition, which for other strength of concrete can be		
		modified by a factor V(fck/35)		
Site Data				
Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**28.63**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4$ X D^2**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**2 X π R**	**3768000**	**mm^2**
C_{us}	=	**0.225 x vq_c**	**1.204**	
R_e	=	**Ksp.qc.df.Ab**	**11650807**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4536324**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4639656**	**Newtons**
Q Allow	=	**464**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**39**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**464**		**Tonne**
Total Load Carrying Capacity of Pile	=	**503**		**Tonne**

Annexure-1C

Lateral Load Carrying Capacity of Pile						
(As per IS 2911 (Part 1/Sec 2) : 2010)						
Type of Pile =			Bored Cast in situ, Fix Head Concrete Pile			
Pile Diameter			D (mm)	=	1200	
Grade of Concrete			N/mm2	=	35	
Modulus of Elasticity of Concrete			N/mm2	=	29580.39892	
5000√ fck			kN/m2	=	29580398.92	
Moment of Inertia (I)			m4	=	0.101736	
Modulus of Subgrade Reaction			ηh ($kN/m^3 x 10^3$)	=	8	
Soil Classification			Granular Soil			
Water Level						
Embedded Length (Le)			12m			
Stiffness factor			**T**			
$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	5	MN/m3	Subgrade modulus (IS 2911)	
		I	0.101736	m4	Moment of Inertia of Pile	
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete	
		T	**3.60**	m		
Pile Top RL (m)		(Data received from hydraulic engineer of project)				
Scour Level (m)						
L1	=	2.00	Point of lateral load application Length of virtual fixity or			2.00
Lf	=	Depth to point of fixity (m) zf				5.89
L1/T	=	0.56				
Lf/T	=	2.09				
		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$	
		E	29580.39892	kN/m2		
		I	0.101736	m4		
zf	Lf	Lf	7.517060095	m		
e	L1	L1	2.00	m	as per IS 2911 P-1	
			377.046	kN		
		H	38	Tons		
Depth of virtual fixity below Pile cut off (m)				9.52		

GLOBAL INFRA SOLUTIONS BHOPAL

4.0 LABORATORY TEST

A. Laboratory Test for Soil

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 - W3) / (W3 - W1)) \times 100$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I\ (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**2210 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**22-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil	(1.5-4.50) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	18	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	12	150	35	Nil	Nil	(4.50-7.10) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	34	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	37	150	35	Nil	Nil	(7.10-24.00) Quartzite	Rock	
9.00	10.50	Core	Refusal	10.50	>40	75	40	54	42			
10.50	12.00	Core	–	12.00	>40	75	40	61	43			
12.00	13.50	Core	–	13.50	>40	75	40	64	44			
13.50	15.00	Core	–	15.00	>40	75	40	69	47			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**2210 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**22-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	17	42	41	0	NL	NL	NP								
SPT-2	3.00	25	48	27	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	41	45	14	0	NL	NL	NP	-	11.36	1.85	2.67	0.51	27.63	0	24
SPT-5	7.50															
SPT-6	9.00	56	41	3	0	NL	NL	NP		9.86	2.22	2.74	0.62	33.41	0	32
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

TABLE –A-2, BORELOG

Location :-	**2250 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**22-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	12	150	35	Nil	Nil	(1.5-4.65) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	17	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	27	150	35	Nil	Nil	(4.65-7.75) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	32	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	39	150	35	60	35			
9.00	10.50	Core	Refusal	10.50	>40	75	40	64	40			
10.50	12.00	Core	–	12.00	>40	75	40	67	51	(7.75-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	72	42			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG	
Location :-	**2250 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**22-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	21	42	37	0	NL	NL	NP								
SPT-2	3.00	28	41	31	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	37	44	19	0	NL	NL	NP	-	10.36	1.75	2.75	0.54	28.65	0	27
SPT-5	7.50															
SPT-6	9.00	51	43	6	0	NL	NL	NP		9.35	2.15	2.77	0.61	34.68	0	35
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.51	KN/m2
Angle of Internal Friction	=	24	degree
Bulk density of Soil	=	18.5	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.62	KN/m2
Angle of Internal Friction	=	32	degree
Bulk density of Soil	=	18.5	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	18.5	kN/m3
P_{Di}	=	9.25	kN/m2
ϕ	=	24	degree
$tan_{\delta i}$	=	0.445	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**155.25**	**kN**
α_i	=	1.20	
c_i	=	0.51	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**23.06016**	**kN**
SRF1	=	178.31	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	18.5	kN/m3
P_{Di}	=	138.75	kN/m2
ϕ	=	32	degree
$tan_{\delta i}$	=	0.625	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**653.70**	kN
α_i	=	1.20	
c_i	=	0.62	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.606784**	**kN**
SRF2	=	**659.31**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	837.62	kN
Ultimate Load Capacity Friction	=	837.62	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	335.05	kN
	=	34	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

Q Allow=$(R_e/3)+(R_{af}/6)$

Qu	=	Ultimate Capacity of Pile		
QAllow	=	Allowable capacity of Pile		
R_e	=	Ultimate end bearing		
R_{af}	=	Ultimate side socket shear		
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength		
		(CR+RQD)/2	K_{sp}	
		30%	0.3	
		100%	1.2	
CR	=	Core Recovery in percent		
RQD	=	Rock Quality Designation in percentage		
q_c	=	Average unconfined compressive strength of rock core below base of pile for		
		The depth twice the diameter/least lateral dimension of pile in MPa.		
A_b	=	Cross Sectional Area Base of Pile		
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20		
A_s	=	Surface Area of Socket		
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014		
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for		
		M 35 concrete in confined condition, which for other strength of concrete can be		
		modified by a factor V(fck/35)		

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**27.63**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4$ X D^2**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**2 X π R**	**3768000**	**mm^2**
C_{us}	=	**0.225 x √q_c**	**1.183**	
R_e	=	**Ksp.qc.df.Ab**	**11243863**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4456397**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4490687**	**Newtons**
Q Allow	=	**449**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**34**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**449**		**Tonne**
Total Load Carrying Capacity of Pile	=	**483**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile

(As per IS 2911 (Part 1/Sec 2) : 2010)

Type of Pile =	Bored Cast in situ, Fix Head Concrete Pile		
Pile Diameter	D (mm)	=	1200
Grade of Concrete	N/mm2	=	35
Modulus of Elasticity of Concrete 5000√ fck	N/mm2	=	29580.39892
	kN/m2	=	29580398.92
Moment of Inertia (I)	m4	=	0.101736
Modulus of Subgrade Reaction	ηh (kN/m^3x 10^3)	=	8
Soil Classification	Granular Soil		
Water Level			
Embedded Length (Le)	12m		
Stiffness factor	**T**		

$T = \sqrt[5]{\frac{EI}{\eta_h}}$	ηh	5	MN/m3	Subgrade modulus (IS 2911)
	I	0.101736	m4	Moment of Inertia of Pile
	E	29580.39892	MN/m2	Modulus of Elasticity of Concrete
	T	**3.60**	m	
Pile Top RL (m)	(Data received from hydraulic engineer of project)			
Scour Level (m)				

L1	=	2.00	Point of lateral load application Length of virtual fixity or	2.00
Lf	=		Depth to point of fixity (m) zf	5.89
L1/T	=	0.56		
Lf/T	=	2.14		

		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$
		E	29580.39892	kN/m2	
		I	0.101736	m4	
zf	Lf	Lf	7.696894068	m	
e	L1	L1	2.00	m	as per IS 2911 P-1
			356.455	kN	
		H	34	Tons	
Depth of virtual fixity below Pile cut off (m)				9.13	

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$$W = ((W2 – W3) / (W3 – W1)) \times 100$$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**2354 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**19-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	12	150	35	Nil	Nil	(1.5-4.60) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	19	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	25	150	35	Nil	Nil	(4.60-8.15) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	33	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	37	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	55	41			
10.50	12.00	Core	–	12.00	>40	75	40	62	45	(8.1524.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	66	41			
13.50	15.00	Core	–	15.00	>40	75	40	68	46			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**2354 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**19-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	16	43	41	0	NL	NL	NP								
SPT-2	3.00	21	45	34	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	34	35	31	0	NL	NL	NP	-	10.85	1.92	2.76	0.55	27.86	0	25
SPT-5	7.50															
SPT-6	9.00	55	43	2	0	NL	NL	NP		10.23	2.23	2.79	0.63	32.63	0	33
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

TABLE –A-2, BORELOG

Location :-	**2366 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**20-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	10	150	35	Nil	Nil	(1.5-4.65) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	18	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	26	150	35	Nil	Nil	(4.65-7.75) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	36	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	38	150	35	60	35			
9.00	10.50	Core	Refusal	10.50	>40	75	40	64	40			
10.50	12.00	Core	–	12.00	>40	75	40	67	51	(7.75-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	72	42			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**2366 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**20-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	15	42	43	0	NL	NL	NP								
SPT-2	3.00	21	48	31	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	35	47	18	0	NL	NL	NP	-	11.36	1.78	2.76	0.53	28.63	0	25
SPT-5	7.50															
SPT-6	9.00	44	48	8	0	NL	NL	NP		9.63	2.11	2.76	0.62	34.63	0	37
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.55	KN/m2
Angle of Internal Friction	=	25	degree
Bulk density of Soil	=	19.2	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.63	KN/m2
Angle of Internal Friction	=	33	degree
Bulk density of Soil	=	19.2	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	19.2	kN/m3
P_{Di}	=	9.6	kN/m2
ϕ	=	25	degree
$\tan_{\delta i}$	=	0.467	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**168.75**	**kN**
α_i	=	1.20	
c_i	=	0.55	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**24.8688**	**kN**
SRF1	=	193.62	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	19.2	kN/m3
P_{Di}	=	144	kN/m2
ϕ	=	33	degree
$\tan_{\delta i}$	=	0.650	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**705.08**	kN
α_i	=	1.20	
c_i	=	0.63	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.697216**	**kN**
SRF2	=	**710.78**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	904.40	kN
Ultimate Load Capacity Friction	=	904.40	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	361.76	kN
	=	36	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

Q Allow=$(R_e/3)+(R_{af}/6)$

Qu	=	Ultimate Capacity of Pile		
QAllow	=	Allowable capacity of Pile		
R_e	=	Ultimate end bearing		
R_{af}	=	Ultimate side socket shear		
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength		
		(CR+RQD)/2	K_{sp}	
		30%	0.3	
		100%	1.2	
CR	=	Core Recovery in percent		
RQD	=	Rock Quality Designation in percentage		
q_c	=	Average unconfined compressive strength of rock core below base of pile for		
		The depth twice the diameter/least lateral dimension of pile in MPa.		
A_b	=	Cross Sectional Area Base of Pile		
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20		
A_s	=	Surface Area of Socket		
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014		
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for		
		M 35 concrete in confined condition, which for other strength of concrete can be		
		modified by a factor V(fck/35)		

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**27.86**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4 \times D^2$**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**$2 \times \pi$ R**	**3768000**	**mm^2**
C_{us}	=	**0.225 x vq_c**	**1.188**	
R_e	=	**Ksp.qc.df.Ab**	**11337460**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4474907**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4524971**	**Newtons**
Q Allow	=	**452**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**36**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**452**		**Tonne**
Total Load Carrying Capacity of Pile	=	**489**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile			
(As per IS 2911 (Part 1/Sec 2) : 2010)			
Type of Pile =	Bored Cast in situ, Fix Head Concrete Pile		
Pile Diameter	D (mm)	=	1200
Grade of Concrete	N/mm2	=	35
Modulus of Elasticity of Concrete 5000√ fck	N/mm2	=	29580.39892
	kN/m2	=	29580398.92
Moment of Inertia (I)	m4	=	0.101736
Modulus of Subgrade Reaction	ηh ($kN/m^3 x 10^3$)	=	8
Soil Classification	Granular Soil		
Water Level			
Embedded Length (Le)	12m		
Stiffness factor	**T**		

$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	5	MN/m3	Subgrade modulus (IS 2911)
		I	0.101736	m4	Moment of Inertia of Pile
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete
		T	**3.60**	m	
Pile Top RL (m)		(Data received from hydraulic engineer of project)			
Scour Level (m)					
L1	=	2.00 Point of lateral load application Length of virtual fixity or			2.00
Lf	=	Depth to point of fixity (m) zf			5.89
L1/T	=	0.56			
Lf/T	=	2.14			

		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$
		E	29580.39892	kN/m2	
		I	0.101736	m4	
zf	Lf	Lf	7.696894068	m	
e	L1	L1	2.00	m	as per IS 2911 P-1
			356.455	kN	
		H	34	Tons	
Depth of virtual fixity below Pile cut off (m)				9.11	

GLOBAL INFRA SOLUTIONS BHOPAL

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)

2. Grain Size Analysis (IS: 2720, 1992 Part 4)

3. Atterberg's Limits Test (IS: 2720, Part 5 1992)

4. Specific Gravity Test (IS: 2720, Part 3 1992)

5. Free Swell Value Test (IS: 2720, Part 40 1977)

6. Swell Pressure Test (IS: 2720, Part 41, 1977)

7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

8. Direct Shear Test (IS: 2720, Part 13, 1992)

9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

W = ((W2 – W3) / (W3 – W1)) x 100

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**2790 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**23-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	14	150	35	Nil	Nil	(1.5-4.45) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	17	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	25	150	35	Nil	Nil	(4.45-7.20) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	37	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	39	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	55	41			
10.50	12.00	Core	–	12.00	>40	75	40	59	42	(7.20-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	62	51			
13.50	15.00	Core	–	15.00	>40	75	40	67	40			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**2790 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**23-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	18	43	39	0	NL	NL	NP								
SPT-2	3.00	24	46	30	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	44	41	15	0	NL	NL	NP	-	10.26	1.79	2.64	0.53	27.89	0	26
SPT-5	7.50															
SPT-6	9.00	52	35	13	0	NL	NL	NP		9.63	2.10	2.79	0.64	32.56	0	33
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**2830 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**23-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	12	150	35	Nil	Nil	(1.5-3.81) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	17	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	27	150	35	Nil	Nil	(3.80-6.85) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	32	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	39	150	35	60	35			
9.00	10.50	Core	Refusal	10.50	>40	75	40	64	40			
10.50	12.00	Core	–	12.00	>40	75	40	67	51	(6.85-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	72	42			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**2830 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**23-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	25	41	34	0	NL	NL	NP								
SPT-2	3.00	31	46	23	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	41	45	14	0	NL	NL	NP	-	10.25	1.78	2.76	0.51	29.63	0	25
SPT-5	7.50															
SPT-6	9.00	45	47	8	0	NL	NL	NP		8.96	2.18	2.79	0.66	33.56	0	33
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.53	KN/m2
Angle of Internal Friction	=	26	degree
Bulk density of Soil	=	17.9	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.64	KN/m2
Angle of Internal Friction	=	33	degree
Bulk density of Soil	=	17.9	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	17.9	kN/m3
P_{Di}	=	8.95	kN/m2
ϕ	=	26	degree
$tan_{\delta i}$	=	0.488	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**164.56**	**kN**
α_i	=	1.20	
c_i	=	0.53	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**23.96448**	**kN**
SRF1	=	188.52	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	17.9	kN/m3
P_{Di}	=	134.25	kN/m2
ϕ	=	33	degree
$tan_{\delta i}$	=	0.650	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**657.34**	kN
α_i	=	1.20	
c_i	=	0.64	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.787648**	**kN**
SRF2	=	**663.13**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	851.65	kN
Ultimate Load Capacity Friction	=	851.65	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	340.66	kN
	=	34	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

$Q\ Allow = (R_e/3) + (R_{af}/6)$

Qu	=	Ultimate Capacity of Pile
QAllow	=	Allowable capacity of Pile
R_e	=	Ultimate end bearing
R_{af}	=	Ultimate side socket shear
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength
		(CR+RQD)/2 — K_{sp}
		30% — 0.3
		100% — 1.2
CR	=	Core Recovery in percent
RQD	=	Rock Quality Designation in percentage
q_c	=	Average unconfined compressive strength of rock core below base of pile for
		The depth twice the diameter/least lateral dimension of pile in MPa.
A_b	=	Cross Sectional Area Base of Pile
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20
A_s	=	Surface Area of Socket
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for
		M 35 concrete in confined condition, which for other strength of concrete can be
		modified by a factor V(fck/35)

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**27.89**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4 \times D^2$**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**$2 \times \pi R$**	**3768000**	**mm^2**
C_{us}	=	**0.225 x vq_c**	**1.188**	
R_e	=	**Ksp.qc.df.Ab**	**11349668**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4477315**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4529442**	**Newtons**
Q Allow	=	**453**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**34**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**453**		**Tonne**
Total Load Carrying Capacity of Pile	=	**487**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile

(As per IS 2911 (Part 1/Sec 2) : 2010)

Type of Pile =	Bored Cast in situ, Fix Head Concrete Pile		
Pile Diameter	D (mm)	=	1200
Grade of Concrete	N/mm2	=	35
Modulus of Elasticity of Concrete 5000√ fck	N/mm2	=	29580.39892
	kN/m2	=	29580398.92
Moment of Inertia (I)	m4	=	0.101736
Modulus of Subgrade Reaction	ηh (kN/m^3x 10^3)	=	8
Soil Classification	Granular Soil		
Water Level			
Embedded Length (Le)	12m		
Stiffness factor	**T**		

$$T = \sqrt[5]{\frac{EI}{\eta_h}}$$

ηh	5	MN/m3	Subgrade modulus (IS 2911)
I	0.101736	m4	Moment of Inertia of Pile
E	29580.39892	MN/m2	Modulus of Elasticity of Concrete
T	**3.60**	m	

Pile Top RL (m)		(Data received from hydraulic engineer of project)	
Scour Level (m)			
L1	=	2.00 Point of lateral load application Length of virtual fixity or	2.00
Lf	=	Depth to point of fixity (m) zf	5.89
L1/T	=	0.56	
Lf/T	=	2.18	

		y	9	mm
		E	29580.39892	kN/m2
		I	0.101736	m4
zf	Lf	Lf	7.840761247	m
e	L1	L1	2.00	m
			341.049	kN
		H	34	Tons
Depth of virtual fixity below Pile cut off (m)			9.11	

$$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$$

as per IS 2911 P-1

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 - W3) / (W3 - W1)) \times 100$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One

cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.
The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

TABLE –A-2, BORELOG

Location :-	**5020 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**27-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	15	150	35	Nil	Nil	(1.5-4.10) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	19	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	30	150	35	Nil	Nil	(4.10-6.20) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	31	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	38	150	35	60	37			
9.00	10.50	Core	Refusal	10.50	>40	75	40	63	45			
10.50	12.00	Core	–	12.00	>40	75	40	67	49	(6.20-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	69	45			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**5020 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**27-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	21	40	39	0	NL	NL	NP								
SPT-2	3.00	39	26	35	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	48	35	17	0	NL	NL	NP	-	12.36	1.78	2.69	0.53	28.96	0	25
SPT-5	7.50															
SPT-6	9.00	51	33	16	0	NL	NL	NP		10.75	2.19	2.71	0.68	33.65	0	36
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.54	KN/m2
Angle of Internal Friction	=	29	degree
Bulk density of Soil	=	18.7	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.67	KN/m2
Angle of Internal Friction	=	35	degree
Bulk density of Soil	=	18.7	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	18.7	kN/m3
P_{Di}	=	9.35	kN/m2
ϕ	=	29	degree
$tan_{\delta i}$	=	0.555	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**195.38**	**kN**
α_i	=	1.20	
c_i	=	0.54	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**24.41664**	**kN**
SRF1	=	219.80	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	18.7	kN/m3
P_{Di}	=	140.25	kN/m2
ϕ	=	35	degree
$tan_{\delta i}$	=	0.701	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**740.45**	kN
α_i	=	1.20	
c_i	=	0.67	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**6.058944**	**kN**
SRF2	=	**746.51**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	966.31	kN
Ultimate Load Capacity Friction	=	966.31	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	386.52	kN
	=	39	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e+R_{af}=K_{sp}.q_c.d_f.A_b+A_s.C_{us}$

$Q\ Allow=(R_e/3)+(R_{af}/6)$

Qu	=	Ultimate Capacity of Pile
QAllow	=	Allowable capacity of Pile
R_e	=	Ultimate end bearing
R_{af}	=	Ultimate side socket shear
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength
		(CR+RQD)/2 — K_{sp}
		30% — 0.3
		100% — 1.2
CR	=	Core Recovery in percent
RQD	=	Rock Quality Designation in percentage
q_c	=	Average unconfined compressive strength of rock core below base of pile for
		The depth twice the diameter/least lateral dimension of pile in MPa.
A_b	=	Cross Sectional Area Base of Pile
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20
A_s	=	Surface Area of Socket
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for
		M 35 concrete in confined condition, which for other strength of concrete can be
		modified by a factor V(fck/35)

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**27.86**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4 \times D^2$**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**$2 \times \pi$ R**	**3768000**	**mm^2**
C_{us}	=	**0.225 x $\sqrt{q_c}$**	**1.188**	
R_e	=	**Ksp.qc.df.Ab**	**11337460**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4474907**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4524971**	**Newtons**
Q Allow	=	**452**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**39**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**452**		**Tonne**
Total Load Carrying Capacity of Pile	=	**491**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile

(As per IS 2911 (Part 1/Sec 2) : 2010)

Type of Pile =			Bored Cast in situ, Fix Head Concrete Pile			
Pile Diameter			D (mm)	=	1200	
Grade of Concrete			N/mm2	=	35	
Modulus of Elasticity of Concrete 5000√ fck			N/mm2	=	29580.39892	
			kN/m2	=	29580398.92	
Moment of Inertia (I)			m4	=	0.101736	
Modulus of Subgrade Reaction			ηh ($kN/m^3 x 10^3$)	=	8	
Soil Classification			Granular Soil			
Water Level						
Embedded Length (Le)			12m			
Stiffness factor			**T**			
$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	5	MN/m3	Subgrade modulus (IS 2911)	
		I	0.101736	m4	Moment of Inertia of Pile	
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete	
		T	**3.60**	m		
Pile Top RL (m)		(Data received from hydraulic engineer of project)				
Scour Level (m)						
L1	=	2.00	Point of lateral load application Length of virtual fixity or			2.00
Lf	=	Depth to point of fixity (m) zf				5.89
L1/T	=	0.56				
Lf/T	=	2.14				
		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$	
		E	29580.39892	kN/m2		
		I	0.101736	m4		
zf	Lf	Lf	7.696894068	m		
e	L1	L1	2.00	m	as per IS 2911 P-1	
			356.455	kN		
		H	36	Tons		
Depth of virtual fixity below Pile cut off (m)				9.15		

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 - W3) / (W3 - W1)) \times 100$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One

cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I\ (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS
BHOPAL

Location :-	5+490m
Ground Level:-	1m
Depth of Boring:-	24m
Date of Started:-	11-03-2024

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	10	150	35	Nil	Nil			
3.00	4.50	SPT-3	1.50	4.50	15	150	35	Nil	Nil	(3.00-6.94m) Stiff Yellowish gray claye silt layer	CL	
4.50	6.00	SPT-4	1.50	6.00	24	150	35	Nil	Nil			
6.00	7.50	SPT-5	1.50	7.50	32	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	36	150	35	Nil	Nil	(6.94m-10.40) Medium dense to dense, grey Silty SAND (SM)	CL	
9.00	10.50	SPT-7	1.50	10.50	38	150	35	Nil	Nil			
10.50	12.00	SPT-8	1.50	12.00	38	150	35	Nil	Nil	(10.40-13.45) Very dense, grey fine SAND (SP-SM)	SM	
12.00	13.50	SPT-9	1.50	13.50	40	150	35	Nil	Nil			
13.50	15.00	SPT-10	1.50	15.00	40	150	35	Nil	Nil	(13.45-16.80) Dense, grey poorly graded Sandy GRAVELS	Rock	
15.00	16.50	Core	Refusal	16.50	>40	75	40	56	38			
16.50	18.00	Core	–	18.00	>40	75	40	61	34			
18.00	19.50	Core	–	19.50	>40	75	40	67	42			
19.50	21.00	Core	–	21.00	>40	75	40	69	43	(16.80-24.00) Quartzite	Rock	
21.00	22.50	Core	–	22.50	-	75	40					
22.50	24.00	Core	–	24.00	-	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

Location :-		5+490m														
Ground Level:-		1m														
Depth of Boring:-		24m														
Date of Started:-		11-03-2024														
Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	7	14	46	33	38.35	22.43	15.92								
SPT-2	3.00															
SPT-3	4.50															
SPT-4	6.00	12	19	35	34	35.19	22.14	13.05								
SPT-5	7.50	18	29	30	23	33.18	21.32	11.86	0.13	23.16	1.83	2.65	0.63	1.57	0.33	10
SPT-6	9.00															
SPT-7	10.50	32	22	27	19	32.58	21.25	11.33	0.8	22.35	2.06	2.73	0.56	2.32	0.26	17
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50	34	29	23	14	30.26	25.32	4.94	0.6	19.53	2.15	2.81	0.52	2.23	0	36
Core	18.00															
Core	19.50	42	16	39	3	NL	NL	NP								
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

Location :-	5+530m
Ground Level:-	1m
Depth of Boring:-	24m
Date of Started:-	11-03-2024

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil			
3.00	4.50	SPT-3	1.50	4.50	14	150	35	Nil	Nil	(3.00-7.20m) Stiff Yellowish gray claye silt layer	CL	
4.50	6.00	SPT-4	1.50	6.00	19	150	35	Nil	Nil			
6.00	7.50	SPT-5	1.50	7.50	20	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	24	150	35	Nil	Nil	(7.20m-10.50) Medium dense to dense, grey Silty SAND (SM)	CL	
9.00	10.50	SPT-7	1.50	10.50	25	150	35	Nil	Nil			
10.50	12.00	SPT-8	1.50	12.00	17	150	35	Nil	Nil	(11.50-13.75) Very dense, grey fine SAND (SP-SM)	SM	
12.00	13.50	SPT-9	1.50	13.50	32	150	35	Nil	Nil			
13.50	15.00	SPT-10	1.50	15.00	33	150	40	Nil	Nil			
15.00	16.50	Core	Refusal	16.50	35	75	40	60	38	(13.75-18.70) Dense, grey poorly graded Sandy GRAVELS	Rock	
16.50	18.00	Core	–	18.00	>40	75	40	63	34			
18.00	19.50	Core	–	19.50	>40	75	40	65	39			
19.50	21.00	Core	–	21.00	>40	75	45	71	43	(18.70-24.00) Quartzite	Rock	
21.00	22.50	Core	–	22.50	-	75	45					
22.50	24.00	Core	–	24.00	-	75	45					

GLOBAL INFRA SOLUTIONS BHOPAL

Location :-					**5+530m**											
Ground Level:-					**1m**											
Depth of Boring:-					**24m**											
Date of Started:-					**11-03-2024**											
Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	11	16	43	30	35.26	21.96	13.3								
SPT-2	3.00															
SPT-3	4.50															
SPT-4	6.00	18	21	36	25	34.26	21.86	12.4								
SPT-5	7.50	25	31	24	20	34.26	22.63	11.63	0.14	20.36	1.88	2.68	0.62	1.56	0.43	9
SPT-6	9.00															
SPT-7	10.50	34	26	31	9	32.58	21.25	11.33	0.90	18.36	2.10	2.72	0.54	2.34	0.28	19
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50	36	35	24	5	30.26	25.32	4.94	0.70	17.63	2.17	2.83	0.51	2.21	0.16	37
Core	18.00															
Core	19.50															
Core	21.00	41	17	40	2	NL	NL	NP								
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS
BHOPAL

Annexure-1A			
Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.33	KN/m2
Angle of Internal Friction	=	10	degree
Bulk density of Soil	=	18.3	kN/m3
Soil Properties-2 (10-20 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.26	KN/m2
Angle of Internal Friction	=	17	degree
Bulk density of Soil	=	2.06	kN/m3
Soil Properties-3 (20-24 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.00	KN/m2
Angle of Internal Friction	=	36	degree
Bulk density of Soil	=	28.1	kN/m3
Pile Dimensions			
Pile Diameter	=	1.20	m
Pile Length	=	20.00	m
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	18.3	kN/m3
P_{Di}	=	91.5	kN/m2
ϕ	=	32	degree
$\tan_{\delta i}$	=	0.625	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**2155.45**	**kN**
α_i	=	1.20	
c_i	=	0.33	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**14.92128**	**kN**
SRF1	=	2170.37	kN
Skin Friction Resistance (2), SFR2 (for 10-20 m Pile Length)			
K_i	=	1	-
γ	=	2.06	kN/m3
P_{Di}	=	228.75	kN/m2
ϕ	=	17	degree
$\tan_{\delta i}$	=	0.306	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF2a	=	**2636.31**	kN
α_i	=	1.20	
c_i	=	0.26	kN/m2
A_{si}	=	37.68	m2

GLOBAL INFRA SOLUTIONS BHOPAL

SRF1b	=	**11.75616**	**kN**
SRF2	=	**2648.07**	**kN**
Skin Friction Resistance (3), SFR3 (for 20-25 m Pile Length)			
K_i	=	1	-
γ	=	28.1	kN/m3
P_{Di}	=	152.7	kN/m2
ϕ	=	36	degree
$\tan_{\delta i}$	=	0.7269	-
Depth of Layer	=	0.00	m
A_{si}	=	5	m2
SRF3a	=	**555.01**	kN
α_i	=	1.20	
c_i	=	0.00	kN/m2
A_{si}	=	5	m2
SRF3b	=	**0.00**	**kN**
SRF3	=	**555.01**	**kN**
Total SRF	=	5373.45	kN
Ultimate Load Capacity Friction	=	5373.45	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	2149.38	kN
	=	215	T

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

$Q\ Allow = (R_e/3) + (R_{af}/6)$

Qu	=	Ultimate Capacity of Pile
QAllow	=	Allowable capacity of Pile
R_e	=	Ultimate end bearing
R_{af}	=	Ultimate side socket shear
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength

(CR+RQD)/2	K_{sp}
30%	0.3
100%	1.2

CR	=	Core Recovery in percent
RQD	=	Rock Quality Designation in percentage
q_c	=	Average unconfined compressive strength of rock core below base of pile for
		The depth twice the diameter/least lateral dimension of pile in MPa.
A_b	=	Cross Sectional Area Base of Pile
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20
A_s	=	Surface Area of Socket
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for
		M 35 concrete in confined condition, which for other strength of concrete can be
		modified by a factor V(fck/35)

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**25.98**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4 \times D^2$**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**$2 \times \pi R$**	**3768000**	**mm^2**
C_{us}	=	**$0.225 \times \surd q_c$**	**1.147**	
R_e	=	**Ksp.qc.df.Ab**	**10572405**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4321286**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4244349**	**Newtons**
Q Allow	=	**424**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**223**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**424**		**Tonne**
Total Load Carrying Capacity of Pile	=	**647**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile

(As per IS 2911 (Part 1/Sec 2) : 2010)

Type of Pile =			Bored Cast in situ, Fix Head Concrete Pile			
Pile Diameter			D (mm)	=	1200	
Grade of Concrete			N/mm2	=	35	
Modulus of Elasticity of Concrete 5000√ fck			N/mm2	=	29580.39892	
			kN/m2	=	29580398.92	
Moment of Inertia (I)			m4	=	0.101736	
Modulus of Subgrade Reaction			ηh (kN/m^{3}x 10^3)	=	8	
Soil Classification			Granular Soil			
Water Level						
Embedded Length (Le)			20m			
Stiffness factor			**T**			
$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	8	MN/m3	Subgrade modulus (IS 2911)	
		I	0.101736	m4	Moment of Inertia of Pile	
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete	
		T	**3.27**	m		
Pile Top RL (m)		(Data received from hydraulic engineer of project)				
Scour Level (m)						
L1	=	2.00 Point of lateral load application Length of virtual fixity or				2.00
Lf	=	Depth to point of fixity (m) zf				5.89
L1/T	=	0.61				
Lf/T	=	2.12				
		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$	
		E	29580.39892	kN/m2		
		I	0.101736	m4		
zf	Lf	Lf	6.940865049	m		
e	L1	L1	2.00	m	as per IS 2911 P-1	
			454.741	kN		
		H	45	Tons		
Depth of virtual fixity below Pile cut off (m)				8.94		

GLOBAL INFRA SOLUTIONS BHOPAL

Calculation of Load carrying capacity.

The following equations were used to calculate the pile loading capacity.

a) For Stratified Soil (Cϕ Soil)

For Stratified Piles the ultimate load Capacity of Piles Should be determined by calculating the skin friction and end bearing in different strata.
(Ref: As per IS: 2911 – (p-1/Sec-2)-2010 code of practice for design and construction of pile Foundation)

b) For ϕ soil

$Qu = Ap(0.5D\ \gamma N\gamma + PDNq) + \sum KiPDi\tan\delta Asi$

Where
Ap = cross sectional area of pile tip, in m2;
D = diameter of Pile Shaft, in m;
γ = effective unit weight of soil at pile tip in (t/m)3
Z = depth (from EBL to nth layer) (m);
Nq, N γ = bearing capacity factors depending on ø;
PD = effective overburden pressure at pile tip;
Ki = coff. Of earth pressure;
δ = Angle of friction between pile and soil;
Asi = Surface area of Pile Shaft in the ith layer;
PDi = effective overburden pressure for the ith layer;

C) For Cohesive Soil

$Qu = ApNcCp + \sum \alpha iCiAsi$

Where,
Ap = cross sectional area of pile tip, in m2;
Nc = bearing capacity factor, may be taken as 9;
Cp = Average cohesion at Pile tip, in T/m2;
αi = adhesion factor for the ith layer depending on the consistency of soil;Ci = Average cohesion for the ith layer in T/m2;
Asi = Surface area of Pile Shaft in the ith layer,in m2.

GLOBAL INFRA SOLUTIONS BHOPAL

Uplift Resistance (Uplift Load)

The resistance of circular and straight sided piles to uplift is calculated exactly the same way as the skin friction resistance on compression. Therefore, the equation is given to assess the ultimate uplift capacity of pile.

$Q_{up} = \sum (K_i P_{Di} \tan\delta A_{si} + \alpha_i C_i A_{si})$ (For Cϕ Soil)

1.0 FOUNDATION ANALYSIS: -

Allowable Bearing Capacity

Shear Consideration

Typical Calculation for Square Footing Using Shear failure consideration (CH.5+775)

Size of Footing	2.0m x 2.0m		**Depth of Foundation**		1.50m	
Bearing Capacity factors :	N_c' =	17.25	N_q' =	8.08	N_γ' =	7.46
Depth factors :	d_c =	1.22	d_q =	1.11	d_γ =	1.11
Shape factors :	S_c =	1.3	S_q =	1.2	S_γ =	0.80
Inclination factors :	ic'=	1.0	iq=	1.0	i_γ =	1.0
Cohesion , c	-					
Angle of internal friction ,ø	31.5^o					
Bulk Density (γ)	1.82 g/cc					
Water Correction factor, W'	1.00					

$$q_{ult} = 2/3c\ N_c\ S_c\ d_c\ i_c + q\ (N_q-1)\ S_q\ d_q\ i_q + 0.5\ B\ \gamma\ N_\gamma\ S_\gamma\ d_\gamma\ i_\gamma\ \omega'$$

= 1.82 x 1.5 x (8.08-1) x 1.2 x 1.11 x 1.0 + 0.5 x 2.0 x 1.82 x 7.46 x 0.80 x 1.11 x 1.0 x 1.0

= 25.79 + 12.07

Ultimate bearing capacity (Q_{ult}) **= 37.87t/m²**

Safe bearing capacity (q's) t/m² **= 37.87/2.5 = 15.15t/m²**

2.1 Calculation for Square Footing Using Settlement consideration CH.5+775

Depth of foundation : 1.5m below existing ground level

Size of foundation : 2.0m x 2.0m

Weighted average minimum corrected 'N' value = 39.50

Settlement Undergone by footing
for (1 kg/ cm2 or 10.0 T/m^2) Pressure, = 5.98mm (Refer Fig 9, IS-8009, Part-1, 1976)

Depth Factor = 0.78
Final Settlement = 0.78 x 5.98 = 4.67mm

Allowable Bearing Pressure Corresponding
to 50mm Allowable settlement

= 50.0*10.0/ (4.67) t/m^2
= 107.14 t/m^2

Date of Boring: 20/02/2024 -20/02/2024	PROJECT:- DETAILED SOIL INVESTIGATION FOR PYNURSLA BYPASS		BH-1 (CH.5+775)
	Termination Depth- 12.50M		Water table - NIL

Soil details							Grain Size Distribution				Atterberg Limit			Soil density (gm/cc)					Moisture Content		Triaxial/ Direct Shear Test							
Depth	Sample nos. & type	Hatching	IS Classification of soil	Description of layers	N – Value (observed)	Specific Gravity	Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index	Bulk / Natural Density	DRY DENSITY gm/cc	Submerged Density	Proctor Density	Void Ratio	Natural	Optimum	Type of test	Confining Pressure (kg/cm^2)	Co-hesion (kg/cm^2)	Angle of Internal Friction	Compression Index	Swell Pressure	Free swelling index %	Remarks
0.50	DS-1		SM																									
1.00	DS-2		SM	SILTY SAND MIX GRAVEL		2.64	3.0	52.0	45.0	0.0	-	-	NP	1.82	1.68	1.05	-	0.57	8.17	-	DST	.5,1,1.5	0.00	31.5^0	-	-	-	
1.50	SPT-1		SM		29.0																							
2.00	DS-3		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.68	52.0	26.0	22.0	0.0	-	-	NP															
3.00	SPT-2		GM		>100																							
4.00	DS-4		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.68	56.0	23.0	21.0	0.0	-	-	NP	1.91	1.82	1.14	-	0.47	4.88	-	DST	.5,1,1.5	0.00	33^0	-	-	-	
4.50	SPT-3		GM		>100																							
6.00	DS-5		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.69	60.0	20.0	20.0	0.0	-	-	NP															
8.00	DS-6		GM																									
10.00	DS-7		GM																									
12.00	DS-8		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.69	63.0	19.0	18.0	0.0	-	-	NP	1.94	1.85	1.16	-	0.45	4.93	-	DST	.5,1,1.5	0.00	34.5^0	-	-	-	
12.50																												

TYPE OF TEST:- UUT- Unconsolidated Undrained Tri-axial Test, DST- Direct Shear Test

GLOBAL INFRA SOLUTIONS BHOPAL

Date of Boring: 21/02/2024 -21/02/2024 | PROJECT:- DETAILED SOIL INVESTIGATION FOR PYNURSLA BYPASS | BH-2 (CH.5+840)

Termination Depth- 13.00M | Water table - NIL

Soil details							Grain Size Distribution				Atterberg Limit			Soil density (gm/cc)					Moisture Content		Triaxial/ Direct Shear Test							
Depth	Sample nos. & type	Hatching	IS Classification of soil	Description of layers	N – Value (observed)	Specific Gravity	Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index	Bulk / Natural Density	DRY DENSITY gm/cc	Submerged Density	Proctor Density	Void Ratio	Natural	Optimum	Type of test	Confining Pressure (kg/cm^2)	Co-hesion (kg/cm^2)	Angle of Internal Friction	Compression Index	Swell Pressure	Free swelling index %	Remarks
0.50	DS-1		SM																									
1.00	DS-2		SM	SILTY SAND MIX GRAVEL		2.63	2.0	56.0	42.0	0.0	-	-	NP	1.80	1.66	1.03	-	0.59	8.74	-	DST	.5,1,1.5	0.00	30.5^0	-	-	-	
1.50	SPT-1		SM		21.0																							
2.00	DS-3		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.68	51.0	25.0	24.0	0.0	-	-	NP															
3.00	SPT-2		GM		135.0																							
4.00	DS-4		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.68	53.0	24.0	23.0	0.0	-	-	NP	1.88	1.79	1.12	-	0.50	5.13	-	DST	.5,1,1.5	0.00	32.5^0	-	-	-	
4.50	SPT-3		GM		>100																							
6.00	DS-5		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.68	56.0	22.0	22.0	0.0	-	-	NP															
8.00	DS-6		GM																									
10.00	DS-7		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.69	59.0	21.0	20.0	0.0	-	-	NP															
12.00	DS-8		GM																									
12.50	DS-8		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.69	60.0	20.0	20.0	0.0	-	-	NP	1.92	1.83	1.15	-	0.47	4.99	-	DST	.5,1,1.5	0.00	33.5^0	-	-	-	
13.00																												

TYPE OF TEST:- UUT- Unconsolidated Undrained Tri-axial Test, DST- Direct Shear Test

GLOBAL INFRA SOLUTIONS BHOPAL

Date of Boring: 22/02/2024 -22/02/2024					PROJECT:- DETAILED SOIL INVESTIGATION FOR PYNURSLA BYPASS																	BH-3 (CH.6+050)						
					Termination Depth- 14.50M																Water table - NIL							
Soil details						Grain Size Distribution				Atterberg Limit			Soil density (gm/cc)					Moisture Content		Triaxial/ Direct Shear Test							
Depth	Sample nos. & type	Hatching	IS Classification of soil	Description of layers	N – Value (observed)	Specific Gravity	Gravel	Sand	Silt	Clay	Liquid Limit	Plastic Limit	Plasticity Index	Bulk / Natural Density	DRY DENSITY gm/cc	Submerged Density	Proctor Density	Void Ratio	Natural	Optimum	Type of test	Confining Pressure (kg/cm^2)	Co-hesion (kg/cm^2)	Angle of Internal Friction	Compression Index	Swell Pressure	Free swelling index %	Remarks
0.50	DS-1		SM-SC																									
1.00	DS-2		SM-SC	SILTY SAND WITH LOW PLASTIC CLAY & GRAVEL		2.65	4.0	54.0	37.0	5.0	25	20	5	1.78	1.62	1.01	-	0.64	10.02	-	DST	.5,1,1.5	0.14	25^0	-	-	-	
1.50	SPT-1		SM-SC		18.0																							
2.00	DS-3		SM	COMPACTED SILTY SAND MIX GRAVEL & BOULDER		2.65	10.0	55.0	35.0	0.0	-	-	NP	1.79	1.68	1.04	-	0.58	6.74	-	DST	.5,1,1.5	0.00	30^0	-	-	-	
3.00	SPT-2		SM		65.0																							
4.00	DS-4		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE		2.68	50.0	26.0	24.0	0.0	-	-	NP	1.87	1.77	1.11	-	0.51	5.45	-	DST	.5,1,1.5	0.00	32^0	-	-	-	
4.50	SPT-3		GM		129.0																							
6.00	SPT-4		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE	>100	2.68	53.0	25.0	22.0	0.0	-	-	NP															
8.00	DS-5		GM																									
10.00	DS-6		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE (SOFT ROCK)		2.68	55.0	23.0	22.0	0.0	-	-	NP															
12.00	DS-7		GM																									
12.50	DS-8		GM																									
14.00	DS-9		GM	COMPACTED SILTY GRAVEL & BOULDER/COBBLE (SOFT ROCK)		2.70	68.0	18.0	14.0	0.0	-	-	NP	1.95	1.88	1.18	-	0.44	3.87	-	DST	.5,1,1.5	0.00	35^0	-	-	-	

14.50																												

TYPE OF TEST:- UUT- Unconsolidated Undrained Tri-axial Test, DST- Direct Shear Test

GLOBAL INFRA SOLUTIONS
BHOPAL

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 – W3) / (W3 – W1)) \times 100$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I\ (\%) = [(V_d - V_k) / V_k] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**6140 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**08-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	13	150	35	Nil	Nil	(1.5-4.45) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	18	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	22	150	35	Nil	Nil	(4.45-8.20) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	35	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	40	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	55	41			
10.50	12.00	Core	–	12.00	>40	75	40	62	45	(8.20-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	66	41			
13.50	15.00	Core	–	15.00	>40	75	40	68	46			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**6140 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**08-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	12	45	43	0	NL	NL	NP								
SPT-2	3.00	18	42	40	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	35	42	23	0	NL	NL	NP	-	10.25	1.89	2.75	0.56	28.63	0	25
SPT-5	7.50															
SPT-6	9.00	53	42	5	0	NL	NL	NP		9.98	2.22	2.78	0.63	33.26	0	35
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-1, BORELOG

Location :-	**6157 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**09-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	15	150	35	Nil	Nil	(1.5-4.85) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	25	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	32	150	35	Nil	Nil	(4.85-9.85) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	34	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	40	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	52	37			
10.50	12.00	Core	–	12.00	>40	75	40	57	33	(9.95-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	63	38			
13.50	15.00	Core	–	15.00	>40	75	40	56	42			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-1, BORELOG																
Location :-					**6157 m**											
Ground Level:-					**1 m**											
Depth of Boring:-					**12 m**											
Date of Started:-					**09-03-2024**											
Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	15	38	47	0	NL	NL	NP								
SPT-2	3.00	21	38	41	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	35	45	20	0	NL	NL	NP	-	11.25	1.89	2.65	0.54	32.25	0	26
SPT-5	7.50															
SPT-6	9.00	40	43	17	0	NL	NL	NP		9.98	2.22	2.78	0.63	33.25	0	34
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-2, BORELOG

Location :-	**6199 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**10-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil	(1.5-5.95) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	16	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	23	150	35	Nil	Nil	(5.95-8.80) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	35	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	40	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	56	42			
10.50	12.00	Core	–	12.00	>40	75	40	59	38	(8.80-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	65	44			
13.50	15.00	Core	–	15.00	>40	75	40	68	49			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-2, BORELOG	
Location :-	**6199 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**10-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	33	45	22	0	NL	NL	NP								
SPT-2	3.00	35	51	14	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	41	45	14	0	NL	NL	NP	-	13.25	1.78	2.75	0.54	32.22	0	28
SPT-5	7.50															
SPT-6	9.00	42	55	3	0	NL	NL	NP		8.62	2.55	2.78	0.65	33.26	0	35
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
SPT-11	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

TABLE –P-3, BORELOG

Location :-	**6241 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**11-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	15	150	35	Nil	Nil	(1.5-4.65) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	24	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	29	150	35	Nil	Nil	(4.65-7.60) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	35	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	40	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	55	44			
10.50	12.00	Core	–	12.00	>40	75	40	63	46	(7.60-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	67	51			
13.50	15.00	Core	–	15.00	>40	75	40	68	49			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

TABLE –P-3, BORELOG

Location :-	6241 m
Ground Level:-	1 m
Depth of Boring:-	12 m
Date of Started:-	11-03-2024

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	12	46	42	0	NL	NL	NP								
SPT-2	3.00	23	45	32	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	35	47	18	0	NL	NL	NP	-	12.32	1.79	2.75	0.64	31.25	0	22
SPT-5	7.50															
SPT-6	9.00	42	52	6	0	NL	NL	NP		9.63	2.45	2.78	0.66	34.65	0	33
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
SPT-11	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG	
Location :-	**6283 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**12-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil	(1.5-4.70) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	19	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	27	150	35	Nil	Nil	(4.70-7.90) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	34	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	39	150	35	62	38			
9.00	10.50	Core	Refusal	10.50	>40	75	40	65	41			
10.50	12.00	Core	–	12.00	>40	75	40	68	52	(7.90-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	73	43			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**6283 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**12-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	11	46	43	0	NL	NL	NP								
SPT-2	3.00	19	51	30	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	36	51	13	0	NL	NL	NP	-	12.25	1.88	2.77	0.54	29.63	0	22
SPT-5	7.50															
SPT-6	9.00	43	51	6	0	NL	NL	NP		10.36	2.14	2.79	0.68	33.98	0	36
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS
BHOPAL

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.56	KN/m2
Angle of Internal Friction	=	25	degree
Bulk density of Soil	=	18.9	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.63	KN/m2
Angle of Internal Friction	=	35	degree
Bulk density of Soil	=	18.9	kN/m3
Soil Properties-3 (20-29.50 m)			
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	18.9	kN/m3
P_{Di}	=	9.45	kN/m2
ϕ	=	25	degree
$\tan_{\delta i}$	=	0.467	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**166.12**	**kN**
α_i	=	1.20	
c_i	=	0.56	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**25.32096**	**kN**
SRF1	=	191.44	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	18.9	kN/m3
P_{Di}	=	141.75	kN/m2
ϕ	=	35	degree
$\tan_{\delta i}$	=	0.701	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**748.37**	kN
α_i	=	1.20	
c_i	=	0.63	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.697216**	**kN**
SRF2	=	**754.07**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	945.51	kN
Ultimate Load Capacity Friction	=	945.51	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	378.20	kN
	=	38	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e+R_{af}=K_{sp}.q_c.d_f.A_b+A_s.C_{us}$

Q Allow=(R_e/3)+(R_{af}/6)

Qu	=	Ultimate Capacity of Pile	
QAllow	=	Allowable capacity of Pile	
R_e	=	Ultimate end bearing	
R_{af}	=	Ultimate side socket shear	
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength	
		(CR+RQD)/2	K_{sp}
		30%	0.3
		100%	1.2
CR	=	Core Recovery in percent	
RQD	=	Rock Quality Designation in percentage	
q_c	=	Average unconfined compressive strength of rock core below base of pile for	
		The depth twice the diameter/least lateral dimension of pile in MPa.	
A_b	=	Cross Sectional Area Base of Pile	
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20	
A_s	=	Surface Area of Socket	
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014	
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for	
		M 35 concrete in confined condition, which for other strength of concrete can be	
		modified by a factor V(fck/35)	

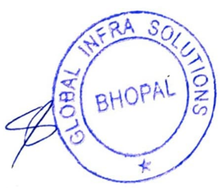
Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**28.63**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4$ X D^2**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**2 X π R**	**3768000**	**mm^2**
C_{us}	=	**0.225 x vq_c**	**1.204**	
R_e	=	**Ksp.qc.df.Ab**	**11650807**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4536324**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4639656**	**Newtons**
Q Allow	=	**464**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**38**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**464**		**Tonne**
Total Load Carrying Capacity of Pile	=	**502**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile						
(As per IS 2911 (Part 1/Sec 2) : 2010)						
Type of Pile =			Bored Cast in situ, Fix Head Concrete Pile			
Pile Diameter			D (mm)	=	1200	
Grade of Concrete			N/mm2	=	35	
Modulus of Elasticity of Concrete 5000√ fck			N/mm2	=	29580.39892	
			kN/m2	=	29580398.92	
Moment of Inertia (I)			m4	=	0.101736	
Modulus of Subgrade Reaction			ηh ($kN/m^3 x 10^3$)	=	8	
Soil Classification			Granular Soil			
Water Level						
Embedded Length (Le)			12m			
Stiffness factor			**T**			
$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	5	MN/m3	Subgrade modulus (IS 2911)	
		I	0.101736	m4	Moment of Inertia of Pile	
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete	
		T	**3.60**	m		
Pile Top RL (m)		(Data received from hydraulic engineer of project)				
Scour Level (m)						
L1	=	2.00 Point of lateral load application Length of virtual fixity or				2.00
Lf	=	Depth to point of fixity (m) zf				5.89
L1/T	=	0.56				
Lf/T	=	2.18				
		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$	
		E	29580.39892	kN/m2		
		I	0.101736	m4		
zf	Lf	Lf	7.840761247	m		
e	L1	L1	2.00	m	as per IS 2911 P-1	
			341.049	kN		
		H	34	Tons		
Depth of virtual fixity below Pile cut off (m)				9.65		



4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 – W3) / (W3 – W1)) \times 100$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I\ (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG												
Location :-					6380 m							
Ground Level:-					1 m							
Depth of Boring:-					12 m							
Date of Started:-					26-03-2024							
Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA	Soil Classification	Log
From	To	Type	Pit	Depth						(Description of core rock type color grain size texture mineral composition degree of weathering)		
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil	(1.5-4.55) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	22	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	24	150	35	Nil	Nil	(4.55-6.35) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	31	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	37	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	51	48			
10.50	12.00	Core	–	12.00	>40	75	40	55	45	(6.35-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	62	50			
13.50	15.00	Core	–	15.00	>40	75	40	67	49			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG																
Location :-				**6380 m**												
Ground Level:-				**1 m**												
Depth of Boring:-				**12 m**												
Date of Started:-				**26-03-2024**												
Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P. L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	18	45	37	0	NL	NL	NP								
SPT-2	3.00	27	51	22	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	51	43	6	0	NL	NL	NP	-	12.75	1.87	2.67	0.54	27.86	0	29
SPT-5	7.50															
SPT-6	9.00	52	32	16	0	NL	NL	NP		10.75	2.32	2.78	0.67	32.63	0	35
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.54	KN/m2
Angle of Internal Friction	=	29	degree
Bulk density of Soil	=	18.7	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.67	KN/m2
Angle of Internal Friction	=	35	degree
Bulk density of Soil	=	18.7	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	18.7	kN/m3
P_{Di}	=	9.35	kN/m2
ϕ	=	29	degree
$\tan_{\delta i}$	=	0.555	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**195.38**	**kN**
α_i	=	1.20	
c_i	=	0.54	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**24.41664**	**kN**
SRF1	=	219.80	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	18.7	kN/m3
P_{Di}	=	140.25	kN/m2
ϕ	=	35	degree
$\tan_{\delta i}$	=	0.701	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**740.45**	kN
α_i	=	1.20	
c_i	=	0.67	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**6.058944**	**kN**
SRF2	=	**746.51**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	966.31	kN
Ultimate Load Capacity Friction	=	966.31	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	386.52	kN
	=	39	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

$Q\ Allow = (R_e/3) + (R_{af}/6)$

Qu	=	Ultimate Capacity of Pile	
QAllow	=	Allowable capacity of Pile	
R_e	=	Ultimate end bearing	
R_{af}	=	Ultimate side socket shear	
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength	
		(CR+RQD)/2	K_{sp}
		30%	0.3
		100%	1.2
CR	=	Core Recovery in percent	
RQD	=	Rock Quality Designation in percentage	
q_c	=	Average unconfined compressive strength of rock core below base of pile for	
		The depth twice the diameter/least lateral dimension of pile in MPa.	
A_b	=	Cross Sectional Area Base of Pile	
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20	
A_s	=	Surface Area of Socket	
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014	
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for	
		M 35 concrete in confined condition, which for other strength of concrete can be	
		modified by a factor V(fck/35)	

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**27.86**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4 \times D^2$**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**2 X π R**	**3768000**	**mm^2**
C_{us}	=	**0.225 x $\sqrt{q_c}$**	**1.188**	
R_e	=	**Ksp.qc.df.Ab**	**11337460**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4474907**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4524971**	**Newtons**
Q Allow	=	**452**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**39**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**452**		**Tonne**
Total Load Carrying Capacity of Pile	=	**491**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile

(As per IS 2911 (Part 1/Sec 2) : 2010)

Type of Pile =	Bored Cast in situ, Fix Head Concrete Pile		
Pile Diameter	D (mm)	=	1200
Grade of Concrete	N/mm2	=	35
Modulus of Elasticity of Concrete 5000√ fck	N/mm2	=	29580.39892
	kN/m2	=	29580398.92
Moment of Inertia (I)	m4	=	0.101736
Modulus of Subgrade Reaction	ηh (kN/m^{3}x 10^3)	=	8
Soil Classification	Granular Soil		
Water Level			
Embedded Length (Le)	12m		
Stiffness factor	**T**		

$T = \sqrt[5]{\dfrac{EI}{\eta_h}}$			
ηh	5	MN/m3	Subgrade modulus (IS 2911)
I	0.101736	m4	Moment of Inertia of Pile
E	29580.39892	MN/m2	Modulus of Elasticity of Concrete
T	**3.60**	m	

Pile Top RL (m)		(Data received from hydraulic engineer of project)	
Scour Level (m)			
L1	=	2.00 Point of lateral load application Length of virtual fixity or	2.00
Lf	=	Depth to point of fixity (m) zf	5.89
L1/T	=	0.56	
Lf/T	=	2.18	

		y	9	mm	$y = \left(\dfrac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$
		E	29580.39892	kN/m2	
		I	0.101736	m4	
zf	Lf	Lf	7.840761247	m	
e	L1	L1	2.00	m	as per IS 2911 P-1
			341.049	kN	
		H	34	Tons	
Depth of virtual fixity below Pile cut off (m)				9.10	

GLOBAL INFRA SOLUTIONS BHOPAL

4.0 LABORATORY TEST

A. Laboratory Test for Soil

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 - W3) / (W3 - W1)) \times 100$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I\ (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG												
Location :-					**6540 m**							
Ground Level:-					**1 m**							
Depth of Boring:-					**12 m**							
Date of Started:-					**14-03-2024**							
Drill Depth (m)		**SAMPLES**			**SPT 'N' Value / Remarks**	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	**% Core Recovery**	Rock Quality Designation **(RQD)** %	**DESCRIPTION OF STRATA** (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	**To**	**Type**	**Pit**	**Depth**								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil	(1.5-5.80) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	17	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	21	150	35	Nil	Nil	(5.80-9.00) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	36	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	39	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	54	40	(9.00-24.00) Quartzite	Rock	
10.50	12.00	Core	–	12.00	>40	75	40	61	42			
12.00	13.50	Core	–	13.50	>40	75	40	65	43			
13.50	15.00	Core	–	15.00	>40	75	40	63	47			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**6540 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**14-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	11	43	46	0	NL	NL	NP								
SPT-2	3.00	21	41	38	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	34	46	20	0	NL	NL	NP	-	11.24	1.78	2.75	0.51	27.86	0	22
SPT-5	7.50															
SPT-6	9.00	52	40	8	0	NL	NL	NP		10.32	2.14	2.79	0.62	32.63	0	34
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-1, BORELOG

Location :-	6585 m
Ground Level:-	1 m
Depth of Boring:-	12 m
Date of Started:-	15-03-2024

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	15	150	35	Nil	Nil	(1.5-4.80) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	25	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	32	150	35	Nil	Nil	(4.80-10.30) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	34	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	40	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	50	35			
10.50	12.00	Core	–	12.00	>40	75	40	52	34	(10.30-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	61	37			
13.50	15.00	Core	–	15.00	>40	75	40	55	41			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-1, BORELOG

Location :-	**6585 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**15-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	17	35	48	0	NL	NL	NP								
SPT-2	3.00	23	34	43	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	37	43	20	0	NL	NL	NP	-	10.36	1.79	2.69	0.55	31.26	0	24
SPT-5	7.50															
SPT-6	9.00	46	53	1	0	NL	NL	NP		8.63	2.11	2.77	0.69	32.63	0	35
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-2, BORELOG

Location :-	**6630 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**16-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	13	150	35	Nil	Nil	(1.5-6.00) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	21	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	24	150	35	Nil	Nil	(6.00-9.50) Medium dense to dense, grey Silty SAND (SM)	Rock	
6.00	7.50	SPT-5	1.50	7.50	38	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	39	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	55	41			
10.50	12.00	Core	–	12.00	>40	75	40	54	34	9.50-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	62	42			
13.50	15.00	Core	–	15.00	>40	75	40	67	48			
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –P-2, BORELOG

Location :-	**6630 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**16-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	31	45	24	0	NL	NL	NP								
SPT-2	3.00	36	38	26	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	42	49	9	0	NL	NL	NP	-	11.24	1.76	2.57	0.55	28.63	0	27
SPT-5	7.50															
SPT-6	9.00	50	43	7	0	NL	NL	NP		9.63	2.14	2.69	0.61	32.54	0	35
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
SPT-11	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG	
Location :-	**6675 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**17-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	11	150	35	Nil	Nil	(1.5-4.40) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	19	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	27	150	35	Nil	Nil	(4.40-8.95) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	34	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	39	150	35	61	36			
9.00	10.50	Core	Refusal	10.50	>40	75	40	64	39			
10.50	12.00	Core	–	12.00	>40	75	40	67	56			
12.00	13.50	Core	–	13.50	>40	75	40	71	42	(8.95-24.00) Quartzite	Rock	
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG	
Location :-	**6675 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**17-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	12	42	46	0	NL	NL	NP								
SPT-2	3.00	21	47	32	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	33	43	24	0	NL	NL	NP	-	10.36	1.78	2.75	0.55	28.63	0	26
SPT-5	7.50															
SPT-6	9.00	51	43	6	0	NL	NL	NP		9.45	2.14	2.76	0.67	32.36	0	33
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.51	KN/m2
Angle of Internal Friction	=	22	degree
Bulk density of Soil	=	17.8	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.62	KN/m2
Angle of Internal Friction	=	34	degree
Bulk density of Soil	=	17.8	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	17.8	kN/m3
P_{Di}	=	8.9	kN/m2
ϕ	=	22	degree
$\tan_{\delta i}$	=	0.404	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**135.55**	**kN**
α_i	=	1.20	
c_i	=	0.51	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**23.06016**	**kN**
SRF1	=	158.61	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	17.8	kN/m3
P_{Di}	=	133.5	kN/m2
ϕ	=	34	degree
$\tan_{\delta i}$	=	0.675	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**678.94**	kN
α_i	=	1.20	
c_i	=	0.62	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.606784**	**kN**
SRF2	=	**684.55**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	843.16	kN
Ultimate Load Capacity Friction	=	843.16	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	337.26	kN
	=	34	T

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

$Q\ Allow = (R_e/3) + (R_{af}/6)$

Qu	=	Ultimate Capacity of Pile		
QAllow	=	Allowable capacity of Pile		
R_e	=	Ultimate end bearing		
R_{af}	=	Ultimate side socket shear		
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength		
		(CR+RQD)/2	K_{sp}	
		30%	0.3	
		100%	1.2	
CR	=	Core Recovery in percent		
RQD	=	Rock Quality Designation in percentage		
q_c	=	Average unconfined compressive strength of rock core below base of pile for		
		The depth twice the diameter/least lateral dimension of pile in MPa.		
A_b	=	Cross Sectional Area Base of Pile		
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20		
A_s	=	Surface Area of Socket		
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014		
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for		
		M 35 concrete in confined condition, which for other strength of concrete can be		
		modified by a factor V(fck/35)		

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**28.63**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4 \times D^2$**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**$2 \times \pi R$**	**3768000**	**mm^2**
C_{us}	=	**0.225 x $\sqrt{q_c}$**	**1.204**	
R_e	=	**Ksp.qc.df.Ab**	**11650807**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4536324**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4639656**	**Newtons**
Q Allow	=	**464**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**34**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**464**		**Tonne**
Total Load Carrying Capacity of Pile	=	**498**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile						
(As per IS 2911 (Part 1/Sec 2) : 2010)						
Type of Pile =			Bored Cast in situ, Fix Head Concrete Pile			
Pile Diameter			D (mm)	=	1200	
Grade of Concrete			N/mm2	=	35	
Modulus of Elasticity of Concrete 5000√ fck			N/mm2	=	29580.39892	
			kN/m2	=	29580398.92	
Moment of Inertia (I)			m4	=	0.101736	
Modulus of Subgrade Reaction			ηh (kN/m^{3}x 10^3)	=	8	
Soil Classification			Granular Soil			
Water Level						
Embedded Length (Le)			12m			
Stiffness factor			**T**			
$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	5	MN/m3	Subgrade modulus (IS 2911)	
		I	0.101736	m4	Moment of Inertia of Pile	
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete	
		T	**3.60**	m		
Pile Top RL (m)		(Data received from hydraulic engineer of project)				
Scour Level (m)						
L1	=	2.00 Point of lateral load application Length of virtual fixity or				2.00
Lf	=	Depth to point of fixity (m) zf				5.89
L1/T	=	0.56				
Lf/T	=	2.14				
		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$	
		E	29580.39892	kN/m2		
		I	0.101736	m4		
zf	Lf	Lf	7.696894068	m		
e	L1	L1	2.00	m	as per IS 2911 P-1	
			356.455	kN		
		H	34	Tons		
Depth of virtual fixity below Pile cut off (m)				9.64		

GLOBAL INFRA SOLUTIONS BHOPAL

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$$W = ((W2 – W3) / (W3 – W1)) \times 100$$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75µ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**7304 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**24-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	10	150	35	Nil	Nil	(1.5-4.20) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	20	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	27	150	35	Nil	Nil	(4.20-6.65) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	32	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	38	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	54	45			
10.50	12.00	Core	–	12.00	>40	75	40	58	43	(6.65-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	61	52			
13.50	15.00	Core	–	15.00	>40	75	40	64	46			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**7304 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**24-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	16	42	42	0	NL	NL	NP								
SPT-2	3.00	25	47	28	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	46	39	15	0	NL	NL	NP	-	11.29	1.81	2.65	0.55	28.96	0	30
SPT-5	7.50															
SPT-6	9.00	51	38	11	0	NL	NL	NP		9.61	2.12	2.77	0.61	31.78	0	34
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**7316 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**24-03-2024**

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	15	150	35	Nil	Nil	(1.5-3.81) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	19	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	30	150	35	Nil	Nil	(3.80-6.85) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	31	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	38	150	35	59	38			
9.00	10.50	Core	Refusal	10.50	>40	75	40	62	41			
10.50	12.00	Core	–	12.00	>40	75	40	65	49	(6.85-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	70	47			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**7316 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**24-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	18	38	44	0	NL	NL	NP								
SPT-2	3.00	35	44	21	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	45	49	6	0	NL	NL	NP	-	11.25	1.75	2.65	0.50	28.63	0	28
SPT-5	7.50															
SPT-6	9.00	47	36	17	0	NL	NL	NP		9.98	2.23	2.69	0.65	32.56	0	32
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.55	KN/m2
Angle of Internal Friction	=	30	degree
Bulk density of Soil	=	18.1	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.61	KN/m2
Angle of Internal Friction	=	34	degree
Bulk density of Soil	=	18.1	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	18.1	kN/m3
P_{Di}	=	9.05	kN/m2
ϕ	=	30	degree
$\tan_{\delta i}$	=	0.578	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**196.97**	**kN**
α_i	=	1.20	
c_i	=	0.55	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**24.8688**	**kN**
SRF1	=	221.84	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	18.1	kN/m3
P_{Di}	=	135.75	kN/m2
ϕ	=	34	degree
$\tan_{\delta i}$	=	0.675	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**690.39**	kN
α_i	=	1.20	
c_i	=	0.61	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.516352**	**kN**
SRF2	=	**695.90**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	917.75	kN
Ultimate Load Capacity Friction	=	917.75	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	367.10	kN
	=	37	T

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

$Q\ Allow = (R_e/3) + (R_{af}/6)$

Qu	=	Ultimate Capacity of Pile	
QAllow	=	Allowable capacity of Pile	
R_e	=	Ultimate end bearing	
R_{af}	=	Ultimate side socket shear	
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength	
		(CR+RQD)/2	K_{sp}
		30%	0.3
		100%	1.2
CR	=	Core Recovery in percent	
RQD	=	Rock Quality Designation in percentage	
q_c	=	Average unconfined compressive strength of rock core below base of pile for	
		The depth twice the diameter/least lateral dimension of pile in MPa.	
A_b	=	Cross Sectional Area Base of Pile	
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20	
A_s	=	Surface Area of Socket	
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014	
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for	
		M 35 concrete in confined condition, which for other strength of concrete can be	
		modified by a factor V(fck/35)	

Site Data

Dia of Pile (D)	=	**1200**		**mm**
Socket Length (L)	=	**1000**		**mm**
q_c	=	**28.96**		**Mpa**
(CR+RQD)/2	=	**30**		**%**
K_{sp}	=	**0.3**		
A_b	=	**$\pi/4 \times D^2$**	**1130400**	
d_f	=	**1 + 0.4 x (L/D)**	**1.33**	
		But maximum value of **df** should not taken more then 1.20, Hence Take	**1.20**	
A_s	=	**$2 \times \pi R$**	**3768000**	**mm^2**
C_{us}	=	**$0.225 \times \sqrt{q_c}$**	**1.211**	
R_e	=	**Ksp.qc.df.Ab**	**11785098**	**Newtons**
R_{af}	=	**Raf=As.Cus**	**4562393**	**Newtons**
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	**4688765**	**Newtons**
Q Allow	=	**469**		**Tonne**
Friction Capacity of Pile (As per Annexure-1A)	=	**37**		**Tonne**
End Bearing Capacity of Pile (As per Annexure-1B)	=	**469**		**Tonne**
Total Load Carrying Capacity of Pile	=	**506**		**Tonne**

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile					
(As per IS 2911 (Part 1/Sec 2) : 2010)					
Type of Pile =			Bored Cast in situ, Fix Head Concrete Pile		
Pile Diameter			D (mm)	=	1200
Grade of Concrete			N/mm2	=	35
Modulus of Elasticity of Concrete 5000√ fck			N/mm2	=	29580.39892
			kN/m2	=	29580398.92
Moment of Inertia (I)			m4	=	0.101736
Modulus of Subgrade Reaction			ηh (kN/m^3x 10^3)	=	8
Soil Classification			Granular Soil		
Water Level					
Embedded Length (Le)			12m		
Stiffness factor			**T**		
$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	5	MN/m3	Subgrade modulus (IS 2911)
		I	0.101736	m4	Moment of Inertia of Pile
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete
		T	**3.60**	m	
Pile Top RL (m)		(Data received from hydraulic engineer of project)			
Scour Level (m)					
L1	=	2.00	Point of lateral load application Length of virtual fixity or		2.00
Lf	=	Depth to point of fixity (m) zf			5.89
L1/T	=	0.56			
Lf/T	=	2.14			
		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$
		E	29580.39892	kN/m2	
		I	0.101736	m4	
zf	Lf	Lf	7.696894068	m	
e	L1	L1	2.00	m	as per IS 2911 P-1
			356.455	kN	
		H	36	Tons	
Depth of virtual fixity below Pile cut off (m)				9.05	

GLOBAL INFRA SOLUTIONS BHOPAL

4.0 LABORATORY TEST

A. **Laboratory Test for Soil**

1. Natural Moisture Content Test (IS: 2720, 1992 Part 2)
2. Grain Size Analysis (IS: 2720, 1992 Part 4)
3. Atterberg's Limits Test (IS: 2720, Part 5 1992)
4. Specific Gravity Test (IS: 2720, Part 3 1992)
5. Free Swell Value Test (IS: 2720, Part 40 1977)
6. Swell Pressure Test (IS: 2720, Part 41, 1977)
7. Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)
8. Direct Shear Test (IS: 2720, Part 13, 1992)
9. One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

4.A.1 Natural Moisture Content Test (IS: 2720, 1992 Part 2)

Test procedure conforms to IS: 2720 - Part - 2. A moisture cup is loosely filled with soil sample and weighed with lid. It is then kept in oven with lid removed and maintained at temperature of oven at 110oC for 24 hours. The lid of the container is then replaced and the dry weight found out. The percentage of water content is calculated using the formula.

$W = ((W2 – W3) / (W3 – W1)) \times 100$

Where,

W1 = weight of container with lid, in g.

W2 = weight of container with wet soil, in g. W3 = weight of container with dry soil, in g. W = moisture content (%)

4.A.2 Grain Size Analysis (IS: 2720, 1992 Part 4)

Testing procedure generally conforms to IS: 2720 Part 4. Both sieve and hydrometer analysis has been carried out.

Sieve Analysis: Sieve analysis is done by wet sieving method. Oven dried soil is washed through 75m IS sieve. Fraction retained was oven dried and particle size analysis carried out using sieve shaker by passing through the IS sieve.

Hydrometer Analysis : 50 g of soil 75μ passing IS sieve was mixed with 33 g passing sodium hexa-

meta-phosphate and 7g sodium carbonate and soil suspension prepared. Suspension was made up to 1000 ml distilled water and then shaken thoroughly. Hydrometer is immersed to a depth slightly below its floating position and then allowed to float freely. Hydrometer readings are taken at 10, 20, 30 and 45 sec, subsequently at 1, 2, 4, 8,15 and 30 minutes and finally at 1, 2, 4, 8 and 24 hour interval. Diameter of the particle in suspension at any sampling time't' is calculated using "Stokes" formula and the percentage finer was calculated. In the semi log graph, silt and clay fractions are indicated along with coarser fractions.

4.A.3 Atterberg's Limits Test (IS: 2720, Part 5 1992)

Liquid limit and plastic limit test on cohesive and semi cohesive samples has been done as per procedure in IS 2720 (Part 5).

Liquid Limit: Liquid limit and plastic limit test on cohesive has been done as per procedure in IS 2720 (Part 5) using the more reliable "cone penetrometer", method where errors of grove cutting involved in Casagrande's device are minimized. In cone penetrometer test about 200 g of passing 425µ sieve is taken mixed with requisite water, placed in cup and compacted lightly in 3layers.

The tip of penetrometer is adjusted such that it just touches soil surface. The needle is allowed to plunge slowly under its own weight for 5 seconds and penetration in mm is recorded. The water content is adjusted such that penetration is between 16-26mm. The following relationship is used to evaluate liquid limit.

Plastic Limit: About 20g of oven dried soil passing through 425µ sieve is mixed with sufficient quantity of water to become plastic enough to be easily shaped into a ball. A portion of this ball is rolled on a glass plate with the palm into a thread of uniform diameter of 3mm. The corresponding water content represents the plastic limit of the soil.

Plastic Index: PI = Liquid limit – Plastic limit.

Shrinkage Limit (IS : 2720, Part 6, 1992): It is the maximum water content expressed as percentage of oven-dry weight at which any further reduction in water content will not cause a decrease in volume of the soil mass is calculated as follows:

$SL = W - ((V - V_0) / W_0) \times 100$

Where,

SL = Shrinkage limit in %.

W = Moisture content of wet soil pat in %.

V = Volume of wet soil pat in ml. V_0 = Volume of dry soil pat in ml.

W_0 = Weight of oven-dried soil pat in gm.

4.A.4 Specific Gravity Test (IS: 2720, Part 3 1992)

The specific gravity of soil solids is determined by a 50 ml density bottle. The weight (W1) of the empty dry bottle is taken first. A sample of oven-dried soil about 10-20 g cooled in a desiccators, is put in the bottle, and weight (W2) of the bottle and the soil taken. The bottle is then filled with distilled water gradually removing the entrapped air either by applying Veccume of 20mmhg & weighted as (W3) of the bottle, soil and water (full up to the top) is then taken. Finally the bottle is emptied completely and thoroughly washed and clean water is filled to the top and the weight (W4) is taken.

$G = (W2 - W1) / [(W4 - W1) - (W3 - W2)]$

4.A.5 Free Swell Value Test (IS: 2720, Part 40 1977)

Free Swell Index Test was conformed as per IS: 2720 – Part – 40 - 1977. In this test 10 gm of soil passing IS sieve 425 µ is taken. Two graduated cylinders of 100 ml capacity are taken. One cylinder is filled with Kerosene oil and the other with distilled water and soil. Remove entrapped air by shaking well and stirring using a glass rod. Allow the soil in both the jars to settle for a sufficient time (not less than 24 hours) for the soil sample to attain equilibrium state of volume without any further changes. Free swell index is calculated as follows:

$F.S.I (\%) = [(Vd - Vk) / Vk] \times 100$

Where,

Vd = The volume of soil sample read from the graduated cylinder containing distilled water.

Vk = The volume of soil sample read from the graduated cylinder containing Kerosene.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.6 Swell Pressure Test (IS: 2720, Part 41, 1977)

The swell pressure tests are carried out at field dry density with zero percent moisture content and by constant and volume method. An oven dry soil specimen is compacted into the specimen ring with the specimen kept in between two porous stone saturated in boiling water providing a filter paper between the soil specimen and the porous stones. The loading block is then positioned centrally on the top of the porous stone. The assembly is then placed on the platen of loading unit. The load measuring proving ring is attached to the load frame and placed in contact with the consolidation cell without any eccentricity. A direct strain measuring dial gauge is fitted to the cell. The specimen is then inundated with distilled water and allowed to swell. The initial reading of the proving ring s noted. The swelling of the specimen with increasing volume is obtained in the strain measuring load gauge. The specimen is kept at constant volume by adjusting the strain dial gauge always at original reading. This adjustment is done at every 0.1mm of swell or earlier. The swell pressure is then calculated frm the difference between the final and initial dial readings of the proving ring. Swell pressure (Kg/cm2) is calculated as follows: SP = ((Final Dial Gauge reading - Initial Dial Gauge reading) / Area of specimen) x Calibration factor of the proving ring.

4.A.7 Triaxial Shear Test (UU) (IS: 2720 Part 11, 1992)

The extracted specimen is then placed in triaxial cell pedestal. The cell is assembled and placed on loading machine. A cell pressure through an operating fluid (oil) was applied. The plunger was made to have proper contact with specimen. A compressive force at a constant strain rate of 1.25 mm/min is applied, till the failure occurred within a period of 5-15 minutes or rill the failure of 20% strain was removed, cell chamber cleaned and test continued on a new specimen.

The test was repeated on three different specimens at three different cell pressures as per standard practice. Mohr-Coulomb envelopes were drawn for three stress values recorded and total stress parameters interpreted from the Mohr-Coulomb graph.

4.A.8 Direct Shear Test (IS: 2720, Part 13, 1992)

Direct shear test is carried out using shear box with the specimens (60mm x 60mm). Specimen with plain grid plate at the bottom of the specimen and plain grid plate at the top of the specimen is fitted into position in the shear box housing and assembly placed on the load frame. The serrations of the grid plates are kept at right angle to the direction of shear. The loading pad is kept on the top grid plate. The required normal stress is applied and the rate of longitudinal displacement shear stress application so adjusted that no drainage can occur in the sample during the test (1.25mm/min.). The upper part of the shear box is raised such that a gap of about 1mm is left between the two parts of the box. The test is conducted by applying horizontal shear load to failure or to 20 percent longitudinal displacement whichever occurs first. The test is repeated on identical specimens.

GLOBAL INFRA SOLUTIONS BHOPAL

4.A.9 One Dimensional Consolidation Test (IS: 2720 Part 15, 1992)

Consolidation test was done to evaluate compressibility behavior of stiff / hard clayey silt. Procedure is described below. The empty consolidation ring W1 is weighed. Representative sample for testing is extruded and cut off, care being taken to ensure that the two plane faces of the resulting soil disc are parallel to each other. The soil sample thus obtained is trimmed flush with the top and bottom edges of the ring. A sample of soil similar to that in the ring taken from the trimmings is used for determining moisture content. The thickness of the specimen (Ho) is measured and it is weighed immediately (W2). The bottom porous stone is centered on the base of the consolidation cell. The ring and specimen is placed centrally on the bottom porous stone and then the loading cap is placed on top. The consolidometer is placed in position in the loading device and suitably adjusted. The dial gauge is then clamped into position for recording the relative movement between the base of the consolidation cell and the loading cap. A seating pressure of 0.05 kg/cm2 is applied to the specimen. The consolidation cell is filled with distilled water. The specimen is then allowed to reach equilibrium for 24 hrs. The test is continued using a loading sequence, which would successively apply stress of 0.25, 0.5, 1.0, 2.0 , 4.0, 8.0 kg/cm2 etc on the soil specimen For each loading increment, after application of load, readings of the dial gauge are taken using a time sequence such as 0, 0.25, 4, 6.25, 9, 12.25, 16, 20.25, 25, 36, 49, 64, 81, 100, 121, 144, 169, 196, 225 min etc. up to 24 hr or 1. 1/4, 1/2, 1, 2, 4, 8, 15, 30, 60min, 2, 4, 8 and 24hr. These time sequences facilitate plotting of thickness or change of thickness of specimen against square root of time or against log time. The loading increment is left until readings become more or less constant. On completion of the final loading stage the specimen is unloaded by suitable pressure decrements. Dial gauge readings are taken as necessary during each stage of unloading. On completion of the decrement, the water is siphoned out of the cell and the consolidometer is rapidly dismantled after release of the final load. The specimen, preferably within the ring, is wiped free of water, weighed (W3) and thereafter placed in the oven for drying. Following drying, the specimen plus ring is reweighed (W4). E-log P curve is drawn and consolidation parameters deduced.

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**7476 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**18-03-2024**

Drill Depth (m)		**SAMPLES**			**SPT 'N' Value / Remarks**	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	**% Core Recovery**	Rock Quality Designation **(RQD)** %	**DESCRIPTION OF STRATA** (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	**To**	**Type**	**Pit**	**Depth**								
0.00	1.50	SPT-1	1.5	1.50	4	150	35	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	10	150	35	Nil	Nil	(1.5-5.80) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	18	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	25	150	35	Nil	Nil	(5.80-9.00) Medium dense to dense, grey Silty SAND (SM)	(SM)	
6.00	7.50	SPT-5	1.50	7.50	34	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	38	150	35	Nil	Nil			
9.00	10.50	Core	Refusal	10.50	>40	75	40	55	42	(9.00-24.00) Quartzite	Rock	
10.50	12.00	Core	–	12.00	>40	75	40	58	45			
12.00	13.50	Core	–	13.50	>40	75	40	63	48			
13.50	15.00	Core	–	15.00	>40	75	40	62	46			
15.00	16.50	Core	–	24.00	>40	75	40					
16.50	18.00	Core	–	25.50	>40	75	40					
18.00	19.50	Core	–	27.00	>40	75	40					
19.50	21.00	Core	–	28.50	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-1, BORELOG

Location :-	**7476 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**18-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	13	39	48	0	NL	NL	NP								
SPT-2	3.00	23	43	34	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	36	49	15	0	NL	NL	NP	-	12.63	1.77	2.74	0.53	27.63	0	23
SPT-5	7.50															
SPT-6	9.00	56	38	6	0	NL	NL	NP		10.63	2.16	2.8	0.63	29.65	0	34
Core	10.50															
Core	12.00															
Core	13.50															
Core	15.00															
Core	24.00															
Core	25.50															
Core	27.00															
Core	28.50															
Core	22.50															
Core	24.00															

TABLE –A-2, BORELOG

Location :-	7488 m
Ground Level:-	1 m
Depth of Boring:-	12 m
Date of Started:-	18-03-2024

Drill Depth (m)		SAMPLES			SPT 'N' Value / Remarks	Dia of Bore / Casing Used (mm)	Time taken for boring for each 30cm in minutes	% Core Recovery	Rock Quality Designation (RQD) %	DESCRIPTION OF STRATA (Description of core rock type color grain size texture mineral composition degree of weathering)	Soil Classification	Log
From	To	Type	Pit	Depth								
0.00	1.50	SPT-1	1.5	1.50	4	150	30	Nil	Nil	Filled up soil		Filling
1.50	3.00	SPT-2	1.50	3.00	10	150	35	Nil	Nil	(1.5-4.60) Silt Sand & Gravel (Hard Moorum)	GC-SC	
3.00	4.50	SPT-3	1.50	4.50	17	150	35	Nil	Nil			
4.50	6.00	SPT-4	1.50	6.00	26	150	35	Nil	Nil	(4.60-8.15) Medium dense to dense, grey Silty SAND (SM)		
6.00	7.50	SPT-5	1.50	7.50	36	150	35	Nil	Nil			
7.50	9.00	SPT-6	1.50	9.00	38	150	35	60	35			
9.00	10.50	Core	Refusal	10.50	>40	75	40	63	41			
10.50	12.00	Core	–	12.00	>40	75	40	64	57	(8.15-24.00) Quartzite	Rock	
12.00	13.50	Core	–	13.50	>40	75	40	68	41			
13.50	15.00	Core	–	15.00	>40	75	40					
15.00	16.50	Core	–	16.50	>40	75	40					
16.50	18.00	Core	–	18.00	>40	75	40					
18.00	19.50	Core	–	19.50	>40	75	40					
19.50	21.00	Core	–	21.00	>40	75	40					
21.00	22.50	Core	–	22.50	>40	75	40					
22.50	24.00	Core	–	24.00	>40	75	40					

GLOBAL INFRA SOLUTIONS BHOPAL

TABLE –A-2, BORELOG

Location :-	**7488 m**
Ground Level:-	**1 m**
Depth of Boring:-	**12 m**
Date of Started:-	**18-03-2024**

Type of Sample	Depth (m)	Mechanical Analysis				Consistency Limit			Compression index Cc	Natural Moisture containt	Field Density	SPECIFIC GRAVITY	Void Ratio	Unconfined compressive strength kg/cm2	SHEARING STRENGTH CHARACTERISTIC	
		Gravel %	Sand%	Silt%	Clay%	L.L %	P.L. %	Plastic index							COHESON 'C' IN kg/cm2	ANGLE OF SHEARING RESISTANCE
SPT-1	1.50	15	53	32	0	NL	NL	NP								
SPT-2	3.00	35	41	24	0	NL	NL	NP								
SPT-3	4.50															
SPT-4	6.00	45	41	14	0	NL	NL	NP	-	11.25	1.75	2.76	0.54	28.36	0	25
SPT-5	7.50															
SPT-6	9.00	53	45	2	0	NL	NL	NP		9.63	2.15	2.78	0.69	33.56	0	35
SPT-7	10.50															
SPT-8	12.00															
SPT-9	13.50															
SPT-10	15.00															
Core	16.50															
Core	18.00															
Core	19.50															
Core	21.00															
Core	22.50															
Core	24.00															

Annexure-1A

Load Carrying Capacity of Pile (Friction Pile)			
(As per IRC 78:2014 & IS 2911)			
Pile Load Capacity			
Type of Pile	=	Concrete Pile	
Type of Construction	=	Bored Cast-in-situ	
Soil Properties-1 (0-10 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.53	KN/m2
Angle of Internal Friction	=	23	degree
Bulk density of Soil	=	17.7	kN/m3
Soil Properties-2 (10-12 m)			
Soil Type	ϕ soil	Value	Unit
Cohesion	=	0.63	KN/m2
Angle of Internal Friction	=	34	degree
Bulk density of Soil	=	17.7	kN/m3
Calculation considering ϕ-soil			
End Bearing Resistance (EBR1) Granular Soil			
Skin Friction Resistance (1), SFR1 (for 0-10 m Pile Length)			
K_i	=	1	-
γ	=	17.7	kN/m3
P_{Di}	=	8.85	kN/m2
ϕ	=	23	degree
$\tan_{\delta i}$	=	0.425	-
Depth of Layer	=	10	m
A_{si}	=	37.68	m2
SRF1a	=	**141.61**	**kN**
α_i	=	1.20	
c_i	=	0.53	kN/m2
A_{si}	=	37.68	m2
SRF1b	=	**23.96448**	**kN**
SRF1	=	165.58	kN
Skin Friction Resistance (2), SFR2 (for 10-12 m Pile Length)			
K_i	=	1	-
γ	=	17.7	kN/m3
P_{Di}	=	132.75	kN/m2
ϕ	=	34	degree
$\tan_{\delta i}$	=	0.675	-
Depth of Layer	=	2	m
A_{si}	=	7.536	m2
SRF2a	=	**675.13**	kN
α_i	=	1.20	
c_i	=	0.63	kN/m2
A_{si}	=	7.536	m2
SRF1b	=	**5.697216**	**kN**
SRF2	=	**680.83**	**kN**
SRF3	=	**0.00**	**kN**
Total SRF	=	846.40	kN
Ultimate Load Capacity Friction	=	846.40	kN
Factor of Safety	=	2.5	-
Safe load capacity	=	338.56	kN
	=	34	T

Annexure-1B

Load Carrying Capacity of Pile (End Bearing)

(As per IRC 78:2014)

$Q_u = R_e + R_{af} = K_{sp}.q_c.d_f.A_b + A_s.C_{us}$

$Q\ Allow = (R_e/3) + (R_{af}/6)$

Qu	=	Ultimate Capacity of Pile	
QAllow	=	Allowable capacity of Pile	
R_e	=	Ultimate end bearing	
R_{af}	=	Ultimate side socket shear	
K_{sp}	=	An empiricalco-efficient whose value ranges from 0.3 to 1.2 as per the table below for the rocks where core recovery is reported, and cores tested for uniaxial compressive strength	
		(CR+RQD)/2	K_{sp}
		30%	0.3
		100%	1.2
CR	=	Core Recovery in percent	
RQD	=	Rock Quality Designation in percentage	
q_c	=	Average unconfined compressive strength of rock core below base of pile for	
		The depth twice the diameter/least lateral dimension of pile in MPa.	
A_b	=	Cross Sectional Area Base of Pile	
d_f	=	Depth factor=1+0.4 x (Length of Socket/Diameter of Socket)Maximum should not taken more then 1.20	
A_s	=	Surface Area of Socket	
C_{us}	=	Ultimate shear strength of rock along socket length, 0.225vq_c IRC:78-2014	
		but restricted to shear capacity of concreteof the pile,to be taken as 3.0 MPa for	
		M 35 concrete in confined condition, which for other strength of concrete can be	
		modified by a factor V(fck/35)	

Site Data

Dia of Pile (D)	=	1200		mm
Socket Length (L)	=	1000		mm
q_c	=	**28.63**		Mpa
(CR+RQD)/2	=	30		%
K_{sp}	=	0.3		
A_b	=	**$\pi/4 \times D^2$**	1130400	
d_f	=	**1 + 0.4 x (L/D)**	1.33	
		But maximum value of **df** should not taken more then 1.20, Hence Take	1.20	
A_s	=	**2 X π R**	3768000	mm^2
C_{us}	=	**0.225 x $\sqrt{q_c}$**	1.204	
R_e	=	**Ksp.qc.df.Ab**	11650807	Newtons
R_{af}	=	**Raf=As.Cus**	4536324	Newtons
Q Allow	=	**Q Allow=(Re/3)+(Raf/6)**	4639656	Newtons
Q Allow	=	464		Tonne
Friction Capacity of Pile (As per Annexure-1A)	=	34		Tonne
End Bearing Capacity of Pile (As per Annexure-1B)	=	464		Tonne
Total Load Carrying Capacity of Pile	=	498		Tonne

GLOBAL INFRA SOLUTIONS BHOPAL

Annexure-1C

Lateral Load Carrying Capacity of Pile						
(As per IS 2911 (Part 1/Sec 2) : 2010)						
Type of Pile =			Bored Cast in situ, Fix Head Concrete Pile			
Pile Diameter			D (mm)	=	1200	
Grade of Concrete			N/mm2	=	35	
Modulus of Elasticity of Concrete 5000√ fck			N/mm2	=	29580.39892	
			kN/m2	=	29580398.92	
Moment of Inertia (I)			m4	=	0.101736	
Modulus of Subgrade Reaction			ηh (kN/m^{3}x 10^3)	=	8	
Soil Classification			Granular Soil			
Water Level						
Embedded Length (Le)			12m			
Stiffness factor			**T**			
$T = \sqrt[5]{\frac{EI}{\eta_h}}$		ηh	5	MN/m3	Subgrade modulus (IS 2911)	
		I	0.101736	m4	Moment of Inertia of Pile	
		E	29580.39892	MN/m2	Modulus of Elasticity of Concrete	
		T	**3.60**	m		
Pile Top RL (m)		(Data received from hydraulic engineer of project)				
Scour Level (m)						
L1	=	2.00	Point of lateral load application Length of virtual fixity or			2.00
Lf	=	Depth to point of fixity (m) zf				5.89
L1/T	=	0.56				
Lf/T	=	2.18				
		y	9	mm	$y = \left(\frac{H\,(e + z_f)^3}{12EI}\right) \times 10^3$	
		E	29580.39892	kN/m2		
		I	0.101736	m4		
zf	Lf	Lf	7.840761247	m		
e	L1	L1	2.00	m	as per IS 2911 P-1	
			341.049	kN		
		H	34	Tons		
Depth of virtual fixity below Pile cut off (m)				9.61		

GLOBAL INFRA SOLUTIONS BHOPAL

INDEX

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Sr. No.	Design Chainage	Type of Proposal	Type of Structure	Span Arrangement (m)	CA (km^2)
1	2+222	New Proposal	Minor Bridge	1 X 34.61	1.73
2	2+815	New Proposal	Minor Bridge	1 X 34.61	1.47
3	4+930	New Proposal	Minor Bridge	1 X 15	0.85
4	7+498	New Proposal	Minor Bridge	1 X 15	0.65
5	7+675	New Proposal	Minor Bridge	1 X 15	0.72

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Minor Bridge at Chainage 2+222 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -
3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges
	Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	1.730	Sq.km.
Design Discharge		=	91.67	m^3/s
Required Linear Waterway		=	45.96	m
Provided Effective Linear Waterway		=	32.64	m
Design Velocity		=	1.07	m/s
Lowest Bed Level		=	1418.260	M
Max. Scour Level		=	1418.157	M
Highest Flood Level	(Observed)	=	1421.506	M
Highest Flood Level	(Designed)	=	1421.656	M
Formation Level		=	1430.811	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	173.00 Ha
Dickens Constant	C_D^*	=	19
Discharge	$C_D \times (A)^{3/4}$	=	28.66 m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	173.00 Ha
Length of Longest Stream		L	=	10.50 km
The Fall in Level between source and site		H	=	95.00 m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90 cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49 cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	2.48 hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	50.83 cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	170.63 m^3/s

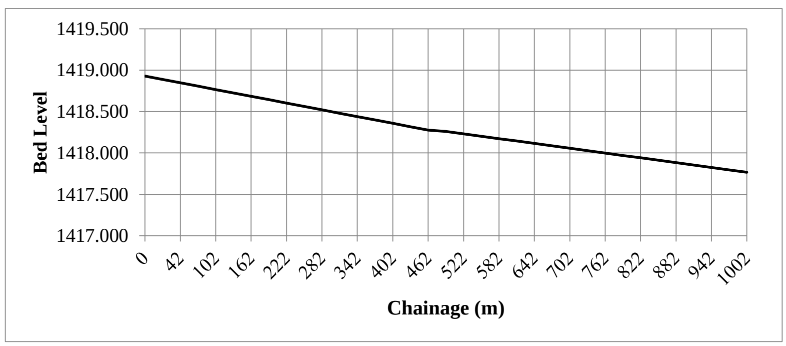
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1421.506 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1418.929	Upstream
12	1418.888	
42	1418.847	
72	1418.807	
102	1418.766	
132	1418.725	
162	1418.684	
192	1418.643	
222	1418.603	
252	1418.562	
282	1418.521	
312	1418.480	
342	1418.439	
372	1418.399	
402	1418.358	
432	1418.317	
462	1418.276	
492	1418.260	Bridge
522	1418.231	
552	1418.202	
582	1418.173	
612	1418.144	
642	1418.115	
672	1418.086	
702	1418.057	
732	1418.028	
762	1417.999	
792	1417.970	
822	1417.941	
852	1417.912	
882	1417.883	
912	1417.854	
942	1417.825	
972	1417.796	
1002	1417.767	Downstream



Location	H.F.L.	Bed Level	Interval
At Bridge Location	1421.506	1418.260	0.00
At U/S from Bridge Location	1422.175	1418.929	492.00
At D/S from Bridge Location	1421.013	1417.767	510.00

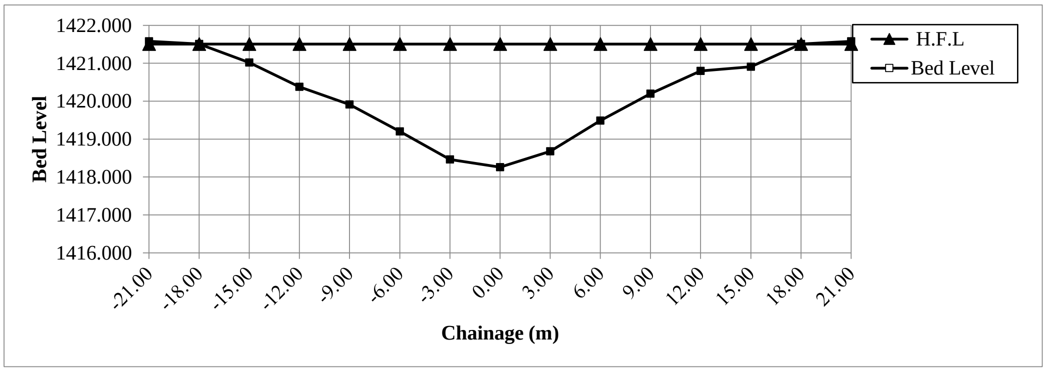
From the longitudinal section of the stream, the Bed Slope is obtained as S = 0.0012

Rugosity co-efficient according to bed material n = 0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-21.00	1421.506	1421.581					
-18.00	1421.506	1421.506	3.00	0.000	0.000	0.00	0.00
-15.00	1421.506	1421.022	3.00	0.484	0.484	3.04	0.73
-12.00	1421.506	1420.380	3.00	1.126	0.642	3.07	2.42
-9.00	1421.506	1419.910	3.00	1.596	0.470	3.04	4.08
-6.00	1421.506	1419.200	3.00	2.306	0.710	3.08	5.85
-3.00	1421.506	1418.460	3.00	3.046	0.740	3.09	8.03
0.00	1421.506	1418.260	3.00	3.246	0.200	3.01	9.44
3.00	1421.506	1418.680	3.00	2.826	0.420	3.03	9.11
6.00	1421.506	1419.490	3.00	2.016	0.810	3.11	7.26
9.00	1421.506	1420.200	3.00	1.306	0.710	3.08	4.98
12.00	1421.506	1420.800	3.00	0.706	0.600	3.06	3.02
15.00	1421.506	1420.910	3.00	0.596	0.110	3.00	1.95
18.00	1421.506	1421.506	3.00	0.000	0.596	0.00	0.00
21.00	1421.506	1421.580	3.00	0.000	0.000	0.00	0.00
	Average =	**1420.232**		**1.750**	**Total =**	**33.60**	**56.87**

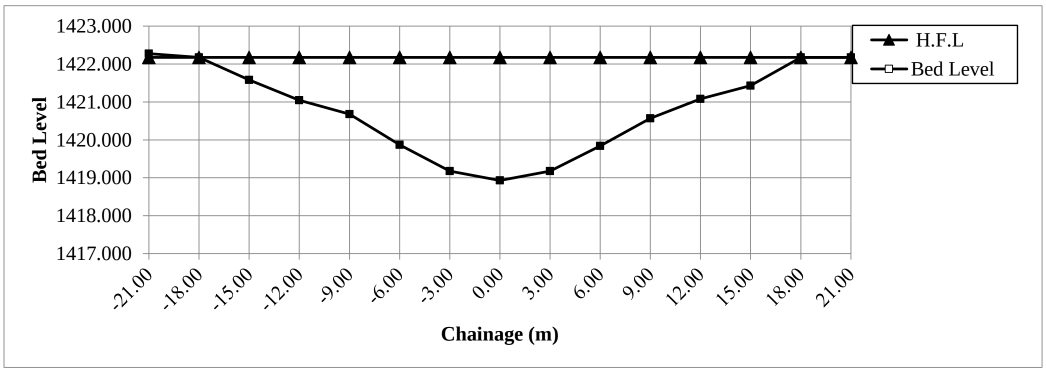


Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		R = A / P	=	1.69
Slope of River Bed		S	=	0.0012
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.07 m/sec
and	Discharge	**Q = A x V**	=	**61.11 m^3/s**

Cross-Section at 492 m U/S from Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-21.00	1422.175	1422.274					
-18.00	1422.175	1422.175	3.00	0.000	0.000	3.00	0.00
-15.00	1422.175	1421.579	3.00	0.596	0.596	3.06	0.89
-12.00	1422.175	1421.044	3.00	1.131	0.535	3.05	2.59
-9.00	1422.175	1420.679	3.00	1.496	0.365	3.02	3.94
-6.00	1422.175	1419.869	3.00	2.306	0.810	3.11	5.70
-3.00	1422.175	1419.179	3.00	2.996	0.690	3.08	7.95
0.00	1422.175	1418.929	3.00	3.246	0.250	3.01	9.36
3.00	1422.175	1419.179	3.00	2.996	0.250	3.01	9.36
6.00	1422.175	1419.843	3.00	2.332	0.664	3.07	7.99
9.00	1422.175	1420.569	3.00	1.606	0.726	3.09	5.91
12.00	1422.175	1421.083	3.00	1.092	0.514	3.04	4.05
15.00	1422.175	1421.429	3.00	0.746	0.346	3.02	2.76
18.00	1422.175	1422.175	3.00	0.000	0.746	3.09	1.12
21.00	1422.175	1422.175	3.00	0.000	0.000	3.00	0.00
	Average =	**1420.812**		**1.467**	**Total =**	**42.65**	**61.63**

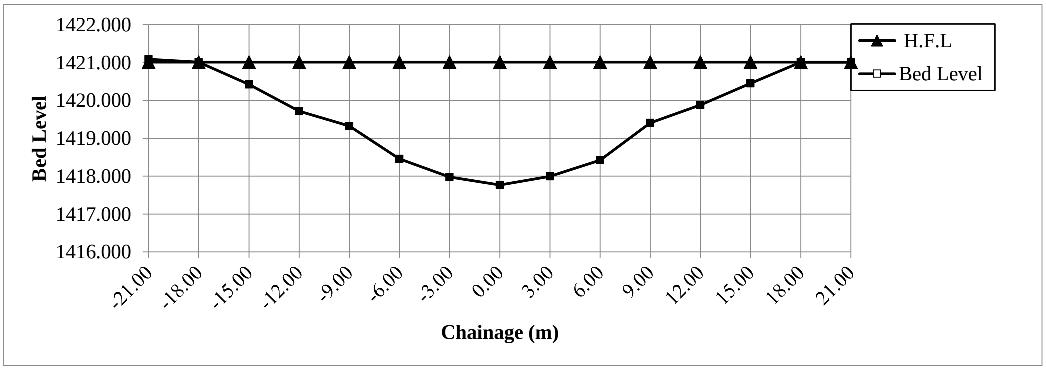


Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	1.45
Slope of River Bed		S	=	0.0012
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	0.97 m/sec
and	Discharge	**$Q = A \times V$**	=	**59.61 m^3/s**

Cross-Section at 510 m D/S from Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-21.00	1421.013	1421.088					
-18.00	1421.013	1421.013	3.00	0.000	0.000	3.00	0.00
-15.00	1421.013	1420.422	3.00	0.591	0.591	3.06	0.89
-12.00	1421.013	1419.717	3.00	1.296	0.705	3.08	2.83
-9.00	1421.013	1419.327	3.00	1.686	0.390	3.03	4.47
-6.00	1421.013	1418.457	3.00	2.556	0.870	3.12	6.36
-3.00	1421.013	1417.977	3.00	3.036	0.480	3.04	8.39
0.00	1421.013	1417.767	3.00	3.246	0.210	3.01	9.42
3.00	1421.013	1417.997	3.00	3.016	0.230	3.01	9.39
6.00	1421.013	1418.421	3.00	2.592	0.424	3.03	8.41
9.00	1421.013	1419.407	3.00	1.606	0.986	3.16	6.30
12.00	1421.013	1419.877	3.00	1.136	0.470	3.04	4.11
15.00	1421.013	1420.451	3.00	0.562	0.574	3.05	2.55
18.00	1421.013	1421.013	3.00	0.000	0.562	3.05	0.84
21.00	1421.013	1421.013	3.00	0.000	0.000	3.00	0.00
	Average =	**1419.596**		**1.523**	**Total =**	**42.67**	**63.97**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	1.50
Slope of River Bed		S	=	0.0012
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	0.99 m/sec
and	Discharge	**$Q = A \times V$**	=	**63.41 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula	=	28.66	m^3/s
Discharge Calculated by Rational Formula Formula	=	170.63	m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method	=	61.11	m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q)	=	**91.67**	**m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**45.96**	**m**
Bank to bank distance		=	**34.00**	**m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	: Minor Bridge		
Span Arrangement	=	1 Span(s) of 34 m.	
No. of Spans	=	1	
Overall Span Length	=	34.00	m
Bearing Center to Deck End	=	0.40	m
Effective Span (center to center of bearings)	=	33.20	m
Total Bridge Length (between inner faces of dirt wall)	=	**34.00**	**m**
No. of Expansion Gap at bridge portion	=	2	
Expansion Gap between two adjacent span	=	0.02	m
Total Bridge Length (i/c Expansion Gap)	=	**34.04**	**m**
No. of Piers	=	0	
Thickness of One Pier	=	0.00	m
No. of Abutments	=	2	
Distance from dirt wall inner face to Abutment inner face	=	0.70	m
Total Obstruction caused due to Sub-Structure	=	1.40	m
Provided Effective Linear Waterway	**=**	**32.64**	**m**
Clear Vertical Height	**=**	**10.50**	**m**
Provided Area of Opening	**=**	**342.75**	**m^2**
Velocity of Stream	**=**	**1.07**	**m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**368.35**	**m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**	
Required Linear Waterway	**=**	**45.96**	**m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1421.506 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1421.656 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.900 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1422.556 M**
Depth of Top Slab+Girder		=	1.985 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level due to Profile correction		=	6.205
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1430.811 M**
Formation Level as per hydarulic			**1430.811 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	91.67 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	119.17 m^3/s
Provided Effective Linear Waterway		=	32.64 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	3.65 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	2.637 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	2.556 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	2.637 m
Highest Flood Level (H.F.L.)		=	1421.506 M
Normal Scour Level (H.F.L.-d_{sm})		=	1418.869 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	3.349 m
Max. Scour level *		=	1418.157 M
Avg. Bed Level		=	1420.232 M
Min. Foundation Level #		=	1416.157 M or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Minor Bridge at Chainage 2+815 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -

3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	1.470	Sq.km.
Design Discharge		=	161.78	m^3/s
Required Linear Waterway		=	61.05	m
Provided Effective Linear Waterway		=	32.64	m
Design Velocity		=	1.92	m/s
Lowest Bed Level		=	1397.876	M
Max. Scour Level		=	1397.233	M
Highest Flood Level	(Observed)	=	1402.122	M
Highest Flood Level	(Designed)	=	1402.272	M
Formation Level		=	1409.571	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	147.00 Ha
Dickens Constant	C_D^*	=	19
Discharge	$C_D \times (A)^{3/4}$	=	25.37 m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	147.00 Ha
Length of Longest Stream		L	=	11.20 km
The Fall in Level between source and site		H	=	105.00 m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90 cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49 cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	2.57 hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	49.54 cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	141.30 m^3/s

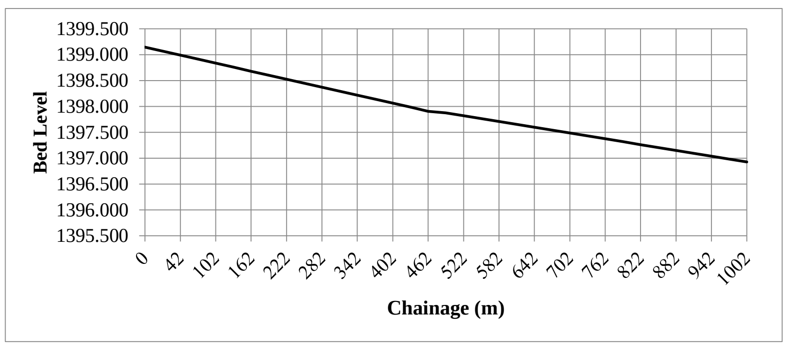
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1402.122 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1399.145	Upstream
12	1399.068	
42	1398.990	
72	1398.913	
102	1398.835	
132	1398.758	
162	1398.681	
192	1398.603	
222	1398.526	
252	1398.449	
282	1398.371	
312	1398.294	
342	1398.216	
372	1398.139	
402	1398.062	
432	1397.984	
462	1397.907	
492	1397.876	Bridge
522	1397.820	
552	1397.764	
582	1397.708	
612	1397.653	
642	1397.597	
672	1397.541	
702	1397.485	
732	1397.429	
762	1397.373	
792	1397.318	
822	1397.262	
852	1397.206	
882	1397.150	
912	1397.094	
942	1397.038	
972	1396.983	
1002	1396.927	Downstream



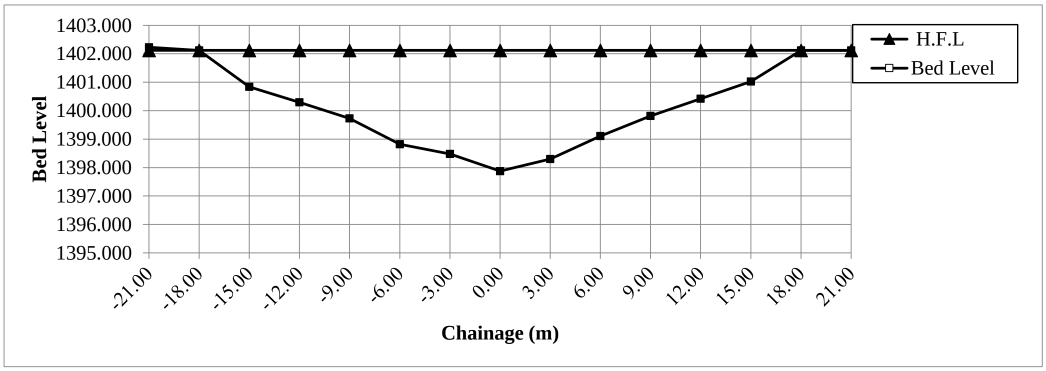
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1402.122	1397.876	0.00
At U/S from Bridge Location	1403.391	1399.145	492.00
At D/S from Bridge Location	1401.173	1396.927	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0022
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-21.00	1402.122	1402.230					
-18.00	1402.122	1402.122	3.00	0.000	0.000	0.00	0.00
-15.00	1402.122	1400.838	3.00	1.284	1.284	3.26	1.93
-12.00	1402.122	1400.296	3.00	1.826	0.542	3.05	4.67
-9.00	1402.122	1399.726	3.00	2.396	0.570	3.05	6.33
-6.00	1402.122	1398.816	3.00	3.306	0.910	3.13	8.55
-3.00	1402.122	1398.476	3.00	3.646	0.340	3.02	10.43
0.00	1402.122	1397.876	3.00	4.246	0.600	3.06	11.84
3.00	1402.122	1398.296	3.00	3.826	0.420	3.03	12.11
6.00	1402.122	1399.106	3.00	3.016	0.810	3.11	10.26
9.00	1402.122	1399.816	3.00	2.306	0.710	3.08	7.98
12.00	1402.122	1400.416	3.00	1.706	0.600	3.06	6.02
15.00	1402.122	1401.026	3.00	1.096	0.610	3.06	4.20
18.00	1402.122	1402.122	3.00	0.000	1.096	0.00	0.00
21.00	1402.122	1402.122	3.00	0.000	0.000	0.00	0.00
	Average =	**1400.219**		**2.600**	**Total =**	**33.92**	**84.32**

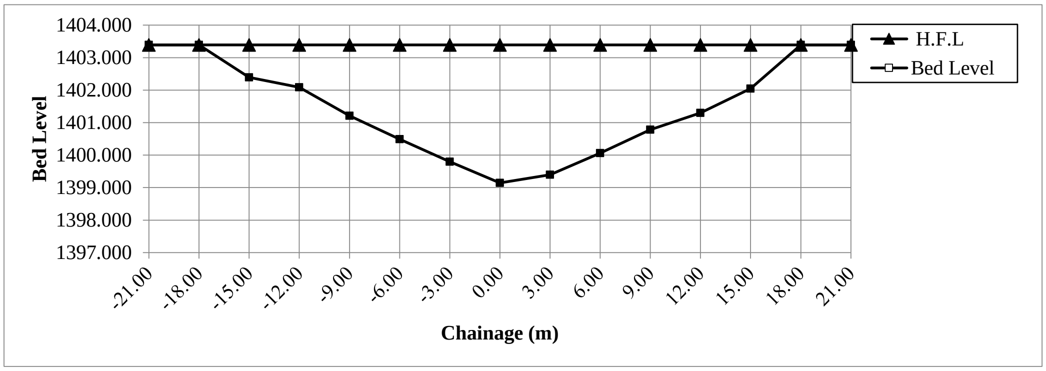


Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		R = A / P	=	2.49
Slope of River Bed		S	=	0.0022
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.92 m/sec
and	Discharge	**Q = A x V**	=	**161.78 m^3/s**

Cross-Section at 492 m U/S from Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-21.00	1403.391	1403.391					
-18.00	1403.391	1403.391	3.00	0.000	0.000	3.00	0.00
-15.00	1403.391	1402.395	3.00	0.996	0.996	3.16	1.49
-12.00	1403.391	1402.087	3.00	1.304	0.309	3.02	3.45
-9.00	1403.391	1401.210	3.00	2.181	0.876	3.13	5.23
-6.00	1403.391	1400.489	3.00	2.902	0.721	3.09	7.62
-3.00	1403.391	1399.795	3.00	3.596	0.694	3.08	9.75
0.00	1403.391	1399.145	3.00	4.246	0.650	3.07	11.76
3.00	1403.391	1399.395	3.00	3.996	0.250	3.01	12.36
6.00	1403.391	1400.059	3.00	3.332	0.664	3.07	10.99
9.00	1403.391	1400.785	3.00	2.606	0.726	3.09	8.91
12.00	1403.391	1401.299	3.00	2.092	0.514	3.04	7.05
15.00	1403.391	1402.045	3.00	1.346	0.746	3.09	5.16
18.00	1403.391	1403.391	3.00	0.000	1.346	3.29	2.02
21.00	1403.391	1403.391	3.00	0.000	0.000	3.00	0.00
	Average =	**1401.485**		**2.043**	**Total =**	**43.13**	**85.79**

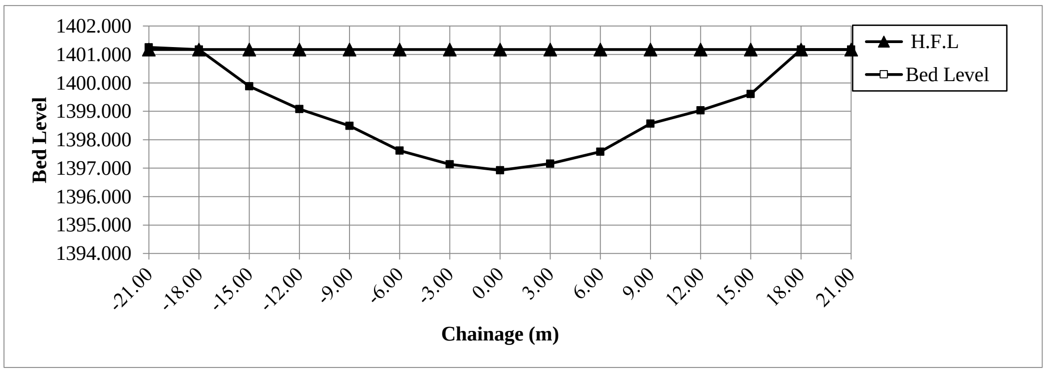


Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	1.99
Slope of River Bed		S	=	0.0022
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.65 m/sec
and	Discharge	$\mathbf{Q = A \times V}$	=	**141.88 m^3/s**

Cross-Section at 510 m D/S from Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-21.00	1401.173	1401.248					
-18.00	1401.173	1401.173	3.00	0.000	0.000	3.00	0.00
-15.00	1401.173	1399.882	3.00	1.291	1.291	3.27	1.94
-12.00	1401.173	1399.077	3.00	2.096	0.805	3.11	5.08
-9.00	1401.173	1398.487	3.00	2.686	0.590	3.06	7.17
-6.00	1401.173	1397.617	3.00	3.556	0.870	3.12	9.36
-3.00	1401.173	1397.137	3.00	4.036	0.480	3.04	11.39
0.00	1401.173	1396.927	3.00	4.246	0.210	3.01	12.42
3.00	1401.173	1397.157	3.00	4.016	0.230	3.01	12.39
6.00	1401.173	1397.581	3.00	3.592	0.424	3.03	11.41
9.00	1401.173	1398.567	3.00	2.606	0.986	3.16	9.30
12.00	1401.173	1399.037	3.00	2.136	0.470	3.04	7.11
15.00	1401.173	1399.611	3.00	1.562	0.574	3.05	5.55
18.00	1401.173	1401.173	3.00	0.000	1.562	3.38	2.34
21.00	1401.173	1401.173	3.00	0.000	0.000	3.00	0.00
	Average =	**1399.056**		**2.273**	**Total =**	**43.27**	**95.47**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		R = A / P	=	2.21
Slope of River Bed		S	=	0.0022
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.77 m/sec
and	Discharge	**Q = A x V**	=	**169.18 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	25.37 m^3/s
Discharge Calculated by Rational Formula Formula		=	141.30 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	161.78 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **161.78 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**61.05 m**
Bank to bank distance		=	**34.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 34 m.
No. of Spans	=	1
Overall Span Length	=	34.00 m
Bearing Center to Deck End	=	0.40 m
Effective Span (center to center of bearings)	=	33.20 m
Total Bridge Length (between inner faces of dirt wall)	=	**34.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**34.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Distance from dirt wall inner face to Abutment inner face	=	0.70 m
Total Obstruction caused due to Sub-Structure	=	1.40 m
Provided Effective Linear Waterway	**=**	**32.64 m**
Clear Vertical Height	**=**	**9.65 m**
Provided Area of Opening	**=**	**314.81 m^2**
Velocity of Stream	**=**	**1.92 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**604.04 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**61.05 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1402.122 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1402.272 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.900 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1403.172 M**
Depth of Top Slab+Girder		=	1.985 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level due to Profile correction		=	4.349
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1409.571 M**
Formation Level as per hydarulic			**1409.571 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	161.78 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	210.32 m^3/s
Provided Effective Linear Waterway		=	32.64 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	6.44 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	3.850 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	3.343 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	3.850 m
Highest Flood Level (H.F.L.)		=	1402.122 M
Normal Scour Level (H.F.L.-d_{sm})		=	1398.272 M
Max. scour depth = (1.27 x d_{sm})		=	4.890 m
Max. Scour level *		=	1397.233 M
Avg. Bed Level		=	1400.219 M
Min. Foundation Level #		=	1395.233 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Minor Bridge at Chainage 4+930 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.
The following methods are used for the estimation of flood discharge:
1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -
3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges
	Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.850	Sq.km.
Design Discharge		=	119.52	m^3/s
Required Linear Waterway		=	52.48	m
Provided Effective Linear Waterway		=	13.64	m
Design Velocity		=	2.36	m/s
Lowest Bed Level		=	1297.063	M
Max. Scour Level		=	1293.060	M
Highest Flood Level	(Observed)	=	1300.209	M
Highest Flood Level	(Designed)	=	1300.359	M
Formation Level		=	1303.309	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	85.00	Ha
Dickens Constant	C_D^*	=	19	
Discharge	$C_D \times (A)^{3/4}$	=	16.82	m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	85.00	Ha
Length of Longest Stream		L	=	5.00	km
The Fall in Level between source and site		H	=	42.00	m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70	
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90	cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49	cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99	
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	1.44	hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	72.46	cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	119.52	m^3/s

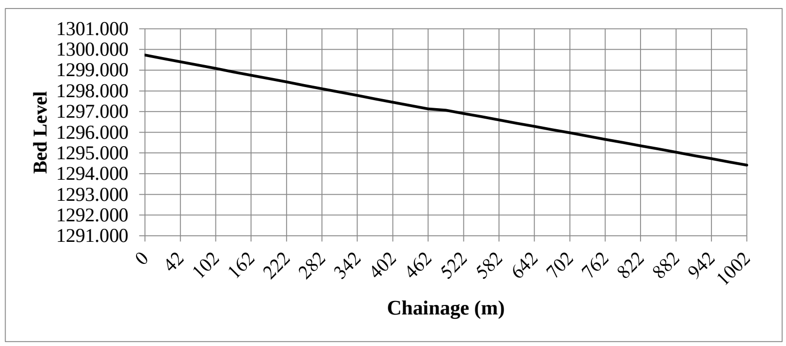
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1300.209 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1299.732	Upstream
12	1299.569	
42	1299.407	
72	1299.244	
102	1299.081	
132	1298.918	
162	1298.756	
192	1298.593	
222	1298.430	
252	1298.267	
282	1298.105	
312	1297.942	
342	1297.779	
372	1297.616	
402	1297.454	
432	1297.291	
462	1297.128	
492	1297.063	Bridge
522	1296.907	
552	1296.751	
582	1296.595	
612	1296.440	
642	1296.284	
672	1296.128	
702	1295.972	
732	1295.816	
762	1295.660	
792	1295.505	
822	1295.349	
852	1295.193	
882	1295.037	
912	1294.881	
942	1294.725	
972	1294.570	
1002	1294.414	Downstream



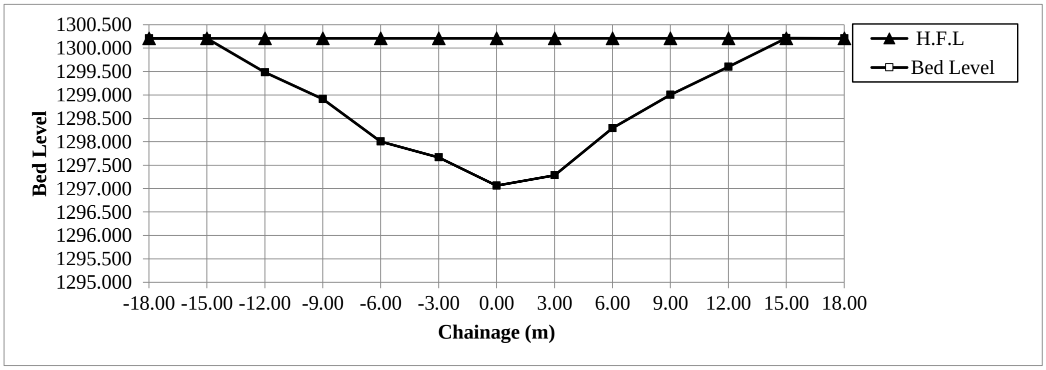
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1300.209	1297.063	0.00
At U/S from Bridge Location	1302.878	1299.732	492.00
At D/S from Bridge Location	1297.560	1294.414	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0053
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-18.00	1300.209	1300.209					
-15.00	1300.209	1300.209	3.00	0.000	0.000	0.00	0.00
-12.00	1300.209	1299.483	3.00	0.726	0.726	3.09	1.09
-9.00	1300.209	1298.913	3.00	1.296	0.570	3.05	3.03
-6.00	1300.209	1298.003	3.00	2.206	0.910	3.13	5.25
-3.00	1300.209	1297.663	3.00	2.546	0.340	3.02	7.13
0.00	1300.209	1297.063	3.00	3.146	0.600	3.06	8.54
3.00	1300.209	1297.283	3.00	2.926	0.220	3.01	9.11
6.00	1300.209	1298.293	3.00	1.916	1.010	3.17	7.26
9.00	1300.209	1299.003	3.00	1.206	0.710	3.08	4.68
12.00	1300.209	1299.603	3.00	0.606	0.600	3.06	2.72
15.00	1300.209	1300.213	3.00	0.000	0.606	0.00	0.00
18.00	1300.209	1300.209	3.00	0.000	0.000	0.00	0.00
	Average =	**1298.934**		**1.840**	**Total =**	**27.67**	**48.81**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	1.76	
Slope of River Bed		S	=	0.0053	
Rugosity Co-efficient		n	=	0.045	
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	2.36	m/sec
and	Discharge	**Q = A x V**	=	**115.38**	**m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula	=	16.82	m^3/s
Discharge Calculated by Rational Formula Formula	=	119.52	m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method	=	115.38	m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **119.52 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**52.48**	**m**
Bank to bank distance		=	**15.00**	**m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge : Minor Bridge

Span Arrangement	=	1 Span(s) of 15 m.	
No. of Spans	=	1	
Overall Span Length	=	15.00	m
Bearing Center to Deck End	=	0.40	m
Effective Span (center to center of bearings)	=	14.20	m
Total Bridge Length (between inner faces of dirt wall)	=	**15.00**	**m**
No. of Expansion Gap at bridge portion	=	2	
Expansion Gap between two adjacent span	=	0.02	m
Total Bridge Length (i/c Expansion Gap)	=	**15.04**	**m**
No. of Piers	=	0	
Thickness of One Pier	=	0.00	m
No. of Abutments	=	2	
Distance from dirt wall inner face to Abutment inner face	=	0.70	m
Total Obstruction caused due to Sub-Structure	=	1.40	m
Provided Effective Linear Waterway	**=**	**13.64**	**m**
Clear Vertical Height	**=**	**4.20**	**m**
Provided Area of Opening	**=**	**57.23**	**m^2**
Velocity of Stream	**=**	**2.36**	**m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**135.28**	**m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**	
Required Linear Waterway	**=**	**52.48**	**m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1300.209**	**M**
Afflux		=	0.150	m
Designed Highest Flood Level (De. H.F.L.)		=	**1300.359**	**M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.900	m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1301.259**	**M**
Depth of Top Slab+Girder		=	1.985	m
Wearing Course on Deck Slab		=	0.065	m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1303.309**	**M**
Formation Level as per hydarulic			**1315.551**	**M**
Formation Level due to Profile correction				

9. Scour Depth Calculation :

Design Discharge		=	119.52	m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30	%
Incremented Design Discharge	*(for scour calculation only)*	=	155.37	m^3/s
Provided Effective Linear Waterway		=	13.64	m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	11.39	$m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75	
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*			
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	5.629	m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	2.477	m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	5.629	m
Highest Flood Level (H.F.L.)		=	1300.209	M
Normal Scour Level (H.F.L.-d_{sm})		=	1294.580	M
Max. scour depth = ($1.27 \times d_{sm}$)		=	7.149	m
Max. Scour level *		=	1293.060	M
Avg. Bed Level		=	1298.934	M
Min. Foundation Level #		=	1291.060	M
			or upto Rock Lvl	

 # Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Minor Bridge at Chainage 7+498 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -

3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.650	Sq.km.
Design Discharge		=	124.11	m^3/s
Required Linear Waterway		=	53.47	m
Provided Effective Linear Waterway		=	13.64	m
Design Velocity		=	2.43	m/s
Lowest Bed Level		=	1211.549	M
Max. Scour Level		=	1208.163	M
Highest Flood Level	(Observed)	=	1215.495	M
Highest Flood Level	(Designed)	=	1215.645	M
Formation Level		=	1218.595	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	65.00 Ha
Dickens Constant	C_D^*	=	19
Discharge	$C_D \times (A)^{3/4}$	=	13.75 m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	65.00 Ha
Length of Longest Stream		L	=	3.50 km
The Fall in Level between source and site		H	=	37.00 m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90 cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49 cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	1.00 hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	88.35 cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	111.44 m^3/s

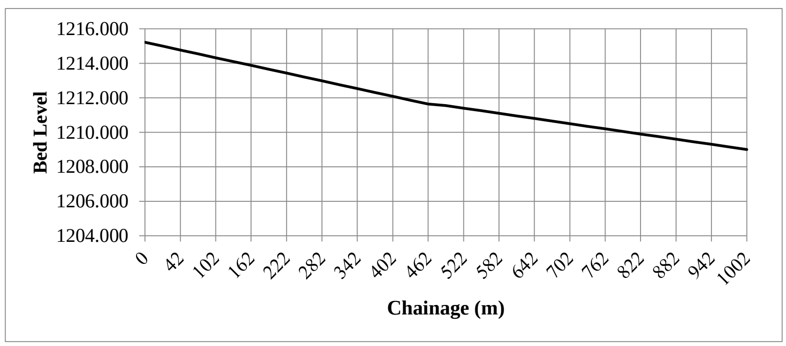
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1215.495 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1215.218	Upstream
12	1214.994	
42	1214.771	
72	1214.547	
102	1214.323	
132	1214.099	
162	1213.876	
192	1213.652	
222	1213.428	
252	1213.205	
282	1212.981	
312	1212.757	
342	1212.533	
372	1212.310	
402	1212.086	
432	1211.862	
462	1211.638	
492	1211.549	Bridge
522	1211.399	
552	1211.249	
582	1211.099	
612	1210.949	
642	1210.799	
672	1210.649	
702	1210.499	
732	1210.349	
762	1210.199	
792	1210.049	
822	1209.899	
852	1209.749	
882	1209.600	
912	1209.450	
942	1209.300	
972	1209.150	
1002	1209.000	Downstream



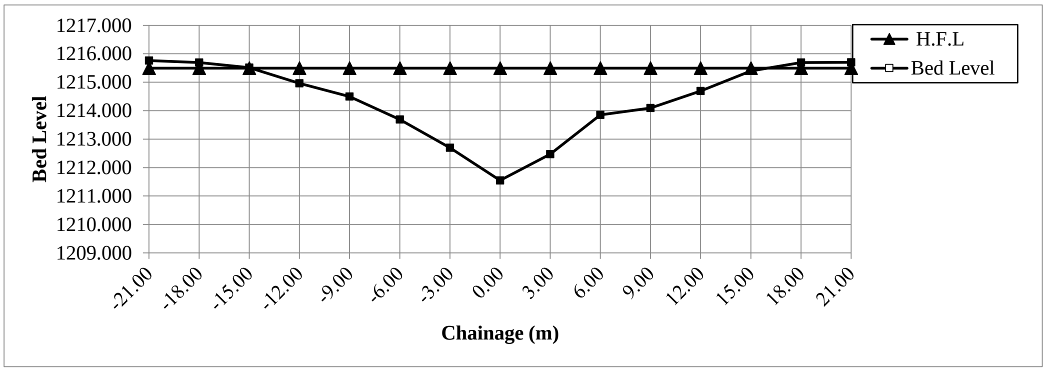
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1215.495	1211.549	0.00
At U/S from Bridge Location	1219.164	1215.218	492.00
At D/S from Bridge Location	1212.946	1209.000	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0062
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-21.00	1215.495	1215.763					
-18.00	1215.495	1215.695	3.00	0.000	0.000	0.00	0.00
-15.00	1215.495	1215.511	3.00	0.000	0.000	0.00	0.00
-12.00	1215.495	1214.959	3.00	0.536	0.536	3.05	0.80
-9.00	1215.495	1214.499	3.00	0.996	0.460	3.04	2.30
-6.00	1215.495	1213.689	3.00	1.806	0.810	3.11	4.20
-3.00	1215.495	1212.699	3.00	2.796	0.990	3.16	6.90
0.00	1215.495	1211.549	3.00	3.946	1.150	3.21	10.11
3.00	1215.495	1212.469	3.00	3.026	0.920	3.14	10.46
6.00	1215.495	1213.849	3.00	1.646	1.380	3.30	7.01
9.00	1215.495	1214.089	3.00	1.406	0.240	3.01	4.58
12.00	1215.495	1214.693	3.00	0.802	0.604	3.06	3.31
15.00	1215.495	1215.399	3.00	0.096	0.706	3.08	1.35
18.00	1215.495	1215.695	3.00	0.000	0.096	0.00	0.00
21.00	1215.495	1215.701	3.00	0.000	0.000	0.00	0.00
	Average =	**1214.417**		**1.710**	**Total =**	**31.15**	**51.02**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		R = A / P	=	1.64
Slope of River Bed		S	=	0.0062
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	2.43 m/sec
and	Discharge	**Q = A x V**	=	**124.11 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	13.75 m^3/s
Discharge Calculated by Rational Formula Formula		=	111.44 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	124.11 m^3/s
As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q)		=	**124.11 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**53.47 m**
Bank to bank distance		=	**15.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 15 m.
No. of Spans	=	1
Overall Span Length	=	15.00 m
Bearing Center to Deck End	=	0.40 m
Effective Span (center to center of bearings)	=	14.20 m
Total Bridge Length (between inner faces of dirt wall)	=	**15.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**15.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Distance from dirt wall inner face to Abutment inner face	=	0.70 m
Total Obstruction caused due to Sub-Structure	=	1.40 m
Provided Effective Linear Waterway	**=**	**13.64 m**
Clear Vertical Height	**=**	**5.00 m**
Provided Area of Opening	**=**	**68.15 m^2**
Velocity of Stream	**=**	**2.43 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**165.76 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**53.47 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1215.495**	**M**
Afflux		=	0.150	m
Designed Highest Flood Level (De. H.F.L.)		=	**1215.645**	**M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.900	m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1216.545**	**M**
Depth of Top Slab+Girder		=	1.985	m
Wearing Course on Deck Slab		=	0.065	m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1218.595**	**M**
Formation Level as per hydarulic			**1228.940**	**M**
Formation Level due to Profile correction				

9. Scour Depth Calculation :

Design Discharge		=	124.11	m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30	%
Incremented Design Discharge	*(for scour calculation only)*	=	161.34	m^3/s
Provided Effective Linear Waterway		=	13.64	m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	11.83	$m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75	
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*			
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	5.773	m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	3.107	m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	5.773	m
Highest Flood Level (H.F.L.)		=	1215.495	M
Normal Scour Level (H.F.L.-d_{sm})		=	1209.722	M
Max. scour depth = (1.27 x d_{sm})		=	7.332	m
Max. Scour level *		=	1208.163	M
Avg. Bed Level		=	1214.417	M
Min. Foundation Level #		=	1206.163	M
			or upto Rock Lvl	

 # Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Minor Bridge at Chainage 7+675 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.
The following methods are used for the estimation of flood discharge:
1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -
3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.720	Sq.km.
Design Discharge		=	114.08	m^3/s
Required Linear Waterway		=	51.27	m
Provided Effective Linear Waterway		=	13.64	m
Design Velocity		=	1.97	m/s
Lowest Bed Level		=	1218.275	M
Max. Scour Level		=	1215.291	M
Highest Flood Level	(Observed)	=	1222.221	M
Highest Flood Level	(Designed)	=	1222.371	M
Formation Level		=	1225.321	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	72.00	Ha
Dickens Constant	C_D^*	=	19	
Discharge	$C_D \times (A)^{3/4}$	=	14.85	m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	72.00	Ha
Length of Longest Stream		L	=	5.00	km
The Fall in Level between source and site		H	=	25.00	m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70	
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90	cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49	cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99	
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	1.76	hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	64.10	cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	89.55	m^3/s

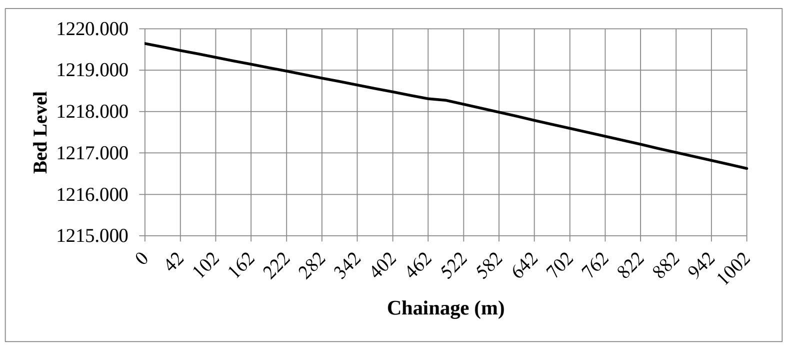
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1222.221 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1219.644	Upstream
12	1219.561	
42	1219.477	
72	1219.394	
102	1219.310	
132	1219.227	
162	1219.143	
192	1219.060	
222	1218.976	
252	1218.893	
282	1218.809	
312	1218.726	
342	1218.642	
372	1218.559	
402	1218.475	
432	1218.392	
462	1218.308	
492	1218.275	Bridge
522	1218.178	
552	1218.081	
582	1217.984	
612	1217.887	
642	1217.790	
672	1217.693	
702	1217.596	
732	1217.499	
762	1217.402	
792	1217.305	
822	1217.208	
852	1217.111	
882	1217.014	
912	1216.917	
942	1216.820	
972	1216.723	
1002	1216.626	Downstream



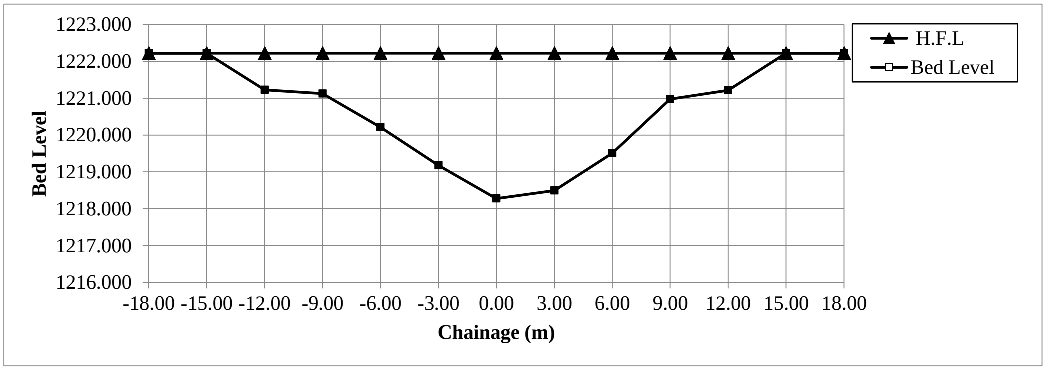
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1222.221	1218.275	0.00
At U/S from Bridge Location	1223.590	1219.644	492.00
At D/S from Bridge Location	1220.572	1216.626	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0030
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-18.00	1222.221	1222.221					
-15.00	1222.221	1222.221	3.00	0.000	0.000	0.00	0.00
-12.00	1222.221	1221.225	3.00	0.996	0.996	3.16	1.49
-9.00	1222.221	1221.125	3.00	1.096	0.100	3.00	3.14
-6.00	1222.221	1220.215	3.00	2.006	0.910	3.13	4.65
-3.00	1222.221	1219.175	3.00	3.046	1.040	3.18	7.58
0.00	1222.221	1218.275	3.00	3.946	0.900	3.13	10.49
3.00	1222.221	1218.495	3.00	3.726	0.220	3.01	11.51
6.00	1222.221	1219.505	3.00	2.716	1.010	3.17	9.66
9.00	1222.221	1220.975	3.00	1.246	1.470	3.34	5.94
12.00	1222.221	1221.215	3.00	1.006	0.240	3.01	3.38
15.00	1222.221	1222.222	3.00	0.000	1.006	0.00	0.00
18.00	1222.221	1222.221	3.00	0.000	0.000	0.00	0.00
	Average =	**1220.699**		**2.200**	**Total =**	**28.13**	**57.84**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		R = A / P	=	2.06
Slope of River Bed		S	=	0.0030
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.97 m/sec
and	Discharge	**Q = A x V**	=	**114.08 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	14.85 m^3/s
Discharge Calculated by Rational Formula Formula		=	89.55 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	114.08 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **114.08 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**51.27 m**
Bank to bank distance		=	**15.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 15 m.
No. of Spans	=	1
Overall Span Length	=	15.00 m
Bearing Center to Deck End	=	0.40 m
Effective Span (center to center of bearings)	=	14.20 m
Total Bridge Length (between inner faces of dirt wall)	=	**15.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**15.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Distance from dirt wall inner face to Abutment inner face	=	0.70 m
Total Obstruction caused due to Sub-Structure	=	1.40 m
Provided Effective Linear Waterway	**=**	**13.64 m**
Clear Vertical Height	**=**	**5.00 m**
Provided Area of Opening	**=**	**68.15 m^2**
Velocity of Stream	**=**	**1.97 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**134.40 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**51.27 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1222.221 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1222.371 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.900 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1223.271 M**
Depth of Top Slab+Girder		=	1.985 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1225.321 M**
Formation Level as per hydarulic			**1228.940 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	114.08 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	148.31 m^3/s
Provided Effective Linear Waterway		=	13.64 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	10.87 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	5.457 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	3.107 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	5.457 m
Highest Flood Level (H.F.L.)		=	1222.221 M
Normal Scour Level (H.F.L.-d_{sm})		=	1216.764 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	6.930 m
Max. Scour level *		=	1215.291 M
Avg. Bed Level		=	1220.699 M
Min. Foundation Level #		=	1213.291 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

INDEX

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Sr. No.	Design Chainage	Type of Proposal	Type of Structure	Span Arrangement (m)	CA (km^2)
1	2+650	New Proposal	Rcc Slab Culvert	1 X 5	0.15
2	3+035	New Proposal	Rcc Slab Culvert	1 X 5	0.12
3	3+120	New Proposal	Rcc Slab Culvert	1 X 5	0.14
4	5+115	New Proposal	Rcc Slab Bridge	1 X 10	0.25
5	5+205	New Proposal	Rcc Slab Bridge	1 X 10	0.27
6	5+435	New Proposal	Rcc Slab Culvert	1 X 5	0.10
7	6+655	New Proposal	Rcc Slab Culvert	1 X 5	0.12
8	7+395	New Proposal	Rcc Slab Culvert	1 X 5	0.14

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Culvert at Chainage 2+650 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -

3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.150	Sq.km.
Design Discharge		=	6.87	m^3/s
Required Linear Waterway		=	12.58	m
Provided Effective Linear Waterway		=	5.04	m
Design Velocity		=	0.88	m/s
Lowest Bed Level		=	1409.908	M
Max. Scour Level		=	1408.686	M
Highest Flood Level	(Observed)	=	1410.754	M
Highest Flood Level	(Designed)	=	1410.904	M
Formation Level		=	1411.969	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	15.00 Ha
Dickens Constant	C_D^*	=	19
Discharge	$C_D \times (A)^{3/4}$	=	4.58 m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	15.00 Ha
Length of Longest Stream		L	=	1.50 km
The Fall in Level between source and site		H	=	15.00 m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90 cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49 cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.53 hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	115.39 cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	33.59 m^3/s

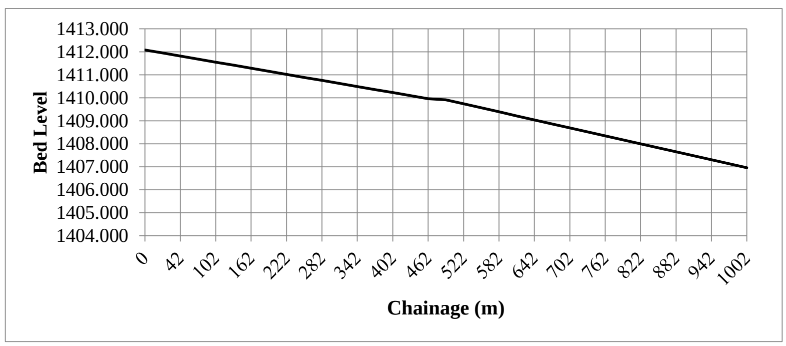
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1410.754 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1412.078	Upstream
12	1411.946	
42	1411.813	
72	1411.681	
102	1411.549	
132	1411.416	
162	1411.284	
192	1411.152	
222	1411.019	
252	1410.887	
282	1410.755	
312	1410.623	
342	1410.490	
372	1410.358	
402	1410.226	
432	1410.093	
462	1409.961	
492	1409.908	Bridge
522	1409.734	
552	1409.561	
582	1409.387	
612	1409.214	
642	1409.040	
672	1408.867	
702	1408.693	
732	1408.520	
762	1408.346	
792	1408.173	
822	1407.999	
852	1407.826	
882	1407.652	
912	1407.479	
942	1407.305	
972	1407.132	
1002	1406.958	Downstream



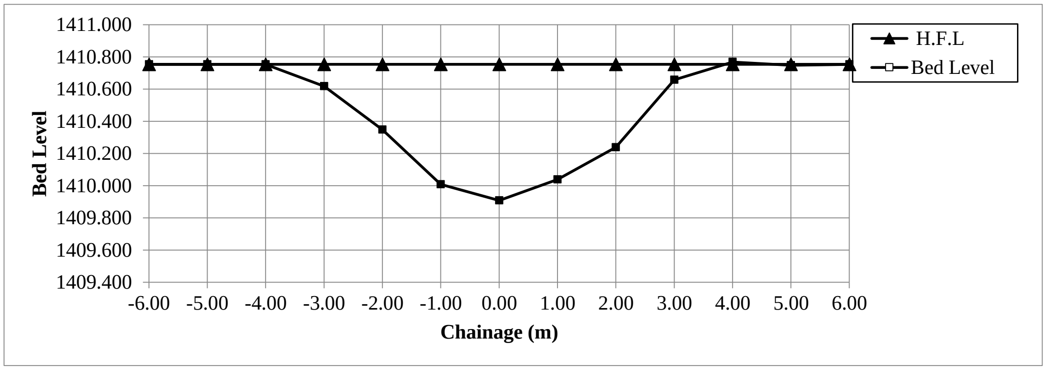
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1410.754	1409.908	0.00
At U/S from Bridge Location	1412.924	1412.078	492.00
At D/S from Bridge Location	1407.804	1406.958	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0051
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.00	1410.754	1410.754					
-5.00	1410.754	1410.754	1.00	0.000	0.000	0.00	0.00
-4.00	1410.754	1410.754	1.00	0.000	0.000	0.00	0.00
-3.00	1410.754	1410.618	1.00	0.136	0.136	1.01	0.07
-2.00	1410.754	1410.348	1.00	0.406	0.270	1.04	0.27
-1.00	1410.754	1410.008	1.00	0.746	0.340	1.06	0.58
0.00	1410.754	1409.908	1.00	0.846	0.100	1.00	0.80
1.00	1410.754	1410.038	1.00	0.716	0.130	1.01	0.78
2.00	1410.754	1410.238	1.00	0.516	0.200	1.02	0.62
3.00	1410.754	1410.658	1.00	0.096	0.420	1.08	0.31
4.00	1410.754	1410.768	1.00	0.000	0.096	0.00	0.00
5.00	1410.754	1410.748	1.00	0.006	0.006	1.00	0.00
6.00	1410.754	1410.754	1.00	0.000	0.006	0.00	0.00
	Average =	**1410.488**		**0.430**	**Total =**	**8.22**	**3.42**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.42
Slope of River Bed		S	=	0.0051
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	0.88 m/sec
and	Discharge	**$Q = A \times V$**	=	**3.02 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	4.58 m^3/s
Discharge Calculated by Rational Formula Formula		=	33.59 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	3.02 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **6.87 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**12.58 m**
Bank to bank distance		=	**5.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	: Minor Bridge		
Span Arrangement		=	1 Span(s) of 5 m.
No. of Spans		=	1
Overall Span Length		=	5.00 m
Bearing Center to Deck End		=	0.30 m
Effective Span (center to center of bearings)		=	4.40 m
Total Bridge Length (between inner faces of dirt wall)		=	**5.00 m**
No. of Expansion Gap at bridge portion		=	2
Expansion Gap between two adjacent span		=	0.02 m
Total Bridge Length (i/c Expansion Gap)		=	**5.04 m**
No. of Piers		=	0
Thickness of One Pier		=	0.00 m
No. of Abutments		=	2
Total Obstruction caused due to Sub-Structure		=	0.00 m
Provided Effective Linear Waterway		**=**	**5.04 m**
Clear Vertical Height		**=**	**1.60 m**
Provided Area of Opening		**=**	**8.04 m^2**
Velocity of Stream		**=**	**0.88 m/sec**
Quantum of Discharge which can be passed through Provided Opening		**=**	**7.12 m^3/s**
Quantum of Discharge which can be passed through Provided Opening			**Hence Safe**
Required Linear Waterway		**=**	**12.58 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1410.754 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1410.904 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1411.504 M**
Depth of Top Slab+Girder		=	0.400 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1411.969 M**
Formation Level as per hydarulic			**1413.811 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	6.87 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	8.93 m^3/s
Provided Effective Linear Waterway		=	5.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	1.77 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	1.628 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	0.666 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	1.628 m
Highest Flood Level (H.F.L.)		=	1410.754 M
Normal Scour Level (H.F.L.-d_{sm})		=	1409.126 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	2.068 m
Max. Scour level *		=	1408.686 M
Avg. Bed Level		=	1410.488 M
Min. Foundation Level #		=	1406.686 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Culvert at Chainage 3+035 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.
The following methods are used for the estimation of flood discharge:
1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -
3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.120	Sq.km.
Design Discharge		=	5.81	m^3/s
Required Linear Waterway		=	11.57	m
Provided Effective Linear Waterway		=	5.04	m
Design Velocity		=	0.80	m/s
Lowest Bed Level		=	1400.478	M
Max. Scour Level		=	1399.575	M
Highest Flood Level	(Observed)	=	1401.424	M
Highest Flood Level	(Designed)	=	1401.574	M
Formation Level		=	1402.639	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	12.00	Ha
Dickens Constant	C_D^*	=	19	
Discharge	$C_D \times (A)^{3/4}$	=	3.87	m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	12.00	Ha
Length of Longest Stream		L	=	1.10	km
The Fall in Level between source and site		H	=	18.00	m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70	
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90	cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49	cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99	
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.35	hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	131.32	cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	30.58	m^3/s

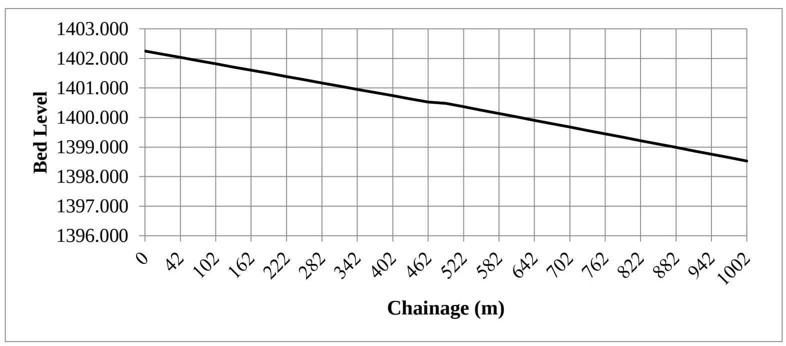
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1401.424 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1402.248	Upstream
12	1402.140	
42	1402.032	
72	1401.924	
102	1401.816	
132	1401.708	
162	1401.600	
192	1401.493	
222	1401.385	
252	1401.277	
282	1401.169	
312	1401.061	
342	1400.953	
372	1400.845	
402	1400.737	
432	1400.629	
462	1400.521	
492	1400.478	Bridge
522	1400.363	
552	1400.249	
582	1400.134	
612	1400.019	
642	1399.904	
672	1399.790	
702	1399.675	
732	1399.560	
762	1399.446	
792	1399.331	
822	1399.216	
852	1399.102	
882	1398.987	
912	1398.872	
942	1398.757	
972	1398.643	
1002	1398.528	Downstream



Location	H.F.L.	Bed Level	Interval
At Bridge Location	1401.424	1400.478	0.00
At U/S from Bridge Location	1403.194	1402.248	492.00
At D/S from Bridge Location	1399.474	1398.528	510.00

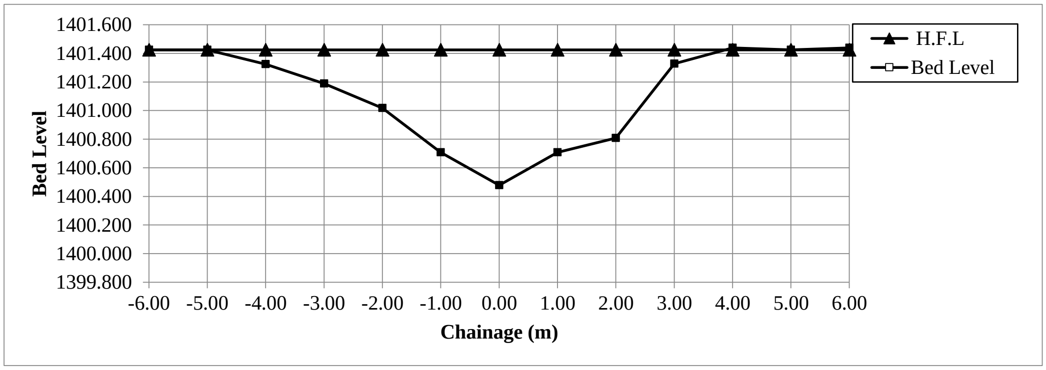
From the longitudinal section of the stream, the Bed Slope is obtained as S = 0.0037

Rugosity co-efficient according to bed material n = 0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.00	1401.424	1401.424					
-5.00	1401.424	1401.424	1.00	0.000	0.000	0.00	0.00
-4.00	1401.424	1401.324	1.00	0.100	0.100	1.00	0.05
-3.00	1401.424	1401.188	1.00	0.236	0.136	1.01	0.17
-2.00	1401.424	1401.018	1.00	0.406	0.170	1.01	0.32
-1.00	1401.424	1400.708	1.00	0.716	0.310	1.05	0.56
0.00	1401.424	1400.478	1.00	0.946	0.230	1.03	0.83
1.00	1401.424	1400.708	1.00	0.716	0.230	1.03	0.83
2.00	1401.424	1400.808	1.00	0.616	0.100	1.00	0.67
3.00	1401.424	1401.328	1.00	0.096	0.520	1.13	0.36
4.00	1401.424	1401.438	1.00	0.000	0.096	0.00	0.00
5.00	1401.424	1401.424	1.00	0.000	0.000	0.00	0.00
6.00	1401.424	1401.438	1.00	0.000	0.000	0.00	0.00
	Average =	**1401.131**		**0.480**	**Total =**	**8.26**	**3.78**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.46
Slope of River Bed		S	=	0.0037
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	0.80 m/sec
and	Discharge	**$Q = A \times V$**	=	**3.04 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	3.87 m^3/s
Discharge Calculated by Rational Formula Formula		=	30.58 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	3.04 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **5.81 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**11.57 m**
Bank to bank distance		=	**5.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 5 m.
No. of Spans	=	1
Overall Span Length	=	5.00 m
Bearing Center to Deck End	=	0.30 m
Effective Span (center to center of bearings)	=	4.40 m
Total Bridge Length (between inner faces of dirt wall)	=	**5.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**5.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Total Obstruction caused due to Sub-Structure	=	0.00 m
Provided Effective Linear Waterway	**=**	**5.04 m**
Clear Vertical Height	**=**	**1.70 m**
Provided Area of Opening	**=**	**8.55 m^2**
Velocity of Stream	**=**	**0.80 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**6.88 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**11.57 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1401.424 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1401.574 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1402.174 M**
Depth of Top Slab+Girder		=	0.400 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1402.639 M**
Formation Level as per hydarulic			**1405.171 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	5.81 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	*7.55* m^3/s
Provided Effective Linear Waterway		=	5.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	1.50 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	1.456 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	0.745 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	1.456 m
Highest Flood Level (H.F.L.)		=	1401.424 M
Normal Scour Level (H.F.L.-d_{sm})		=	1399.968 M
Max. scour depth = (1.27 x d_{sm})		=	1.849 m
Max. Scour level *		=	1399.575 M
Avg. Bed Level		=	1401.131 M
Min. Foundation Level #		=	1397.575 M or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Culvert at Chainage 3+120 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -

3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.140	Sq.km.
Design Discharge		=	9.79	m^3/s
Required Linear Waterway		=	15.02	m
Provided Effective Linear Waterway		=	5.04	m
Design Velocity		=	1.04	m/s
Lowest Bed Level		=	1397.392	M
Max. Scour Level		=	1396.019	M
Highest Flood Level	(Observed)	=	1398.638	M
Highest Flood Level	(Designed)	=	1398.788	M
Formation Level		=	1399.853	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	14.00	Ha
Dickens Constant	C_D^*	=	19	
Discharge	$C_D \times (A)^{3/4}$	=	4.35	m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	14.00	Ha
Length of Longest Stream		L	=	0.91	km
The Fall in Level between source and site		H	=	14.00	m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70	
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90	cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49	cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99	
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.31	hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	135.34	cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	36.77	m^3/s

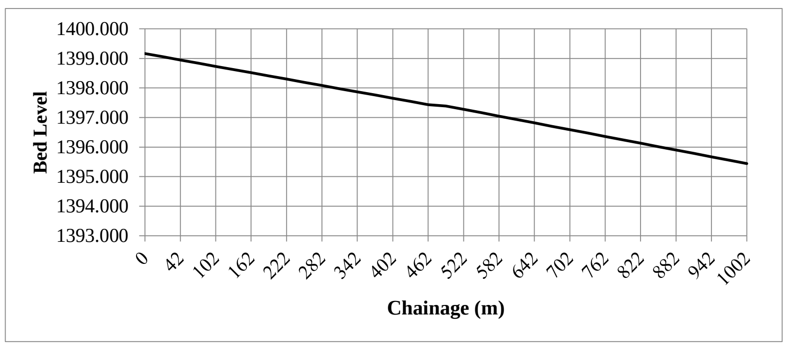
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1398.638 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1399.162	Upstream
12	1399.054	
42	1398.946	
72	1398.838	
102	1398.730	
132	1398.622	
162	1398.514	
192	1398.407	
222	1398.299	
252	1398.191	
282	1398.083	
312	1397.975	
342	1397.867	
372	1397.759	
402	1397.651	
432	1397.543	
462	1397.435	
492	1397.392	Bridge
522	1397.277	
552	1397.163	
582	1397.048	
612	1396.933	
642	1396.818	
672	1396.704	
702	1396.589	
732	1396.474	
762	1396.360	
792	1396.245	
822	1396.130	
852	1396.016	
882	1395.901	
912	1395.786	
942	1395.671	
972	1395.557	
1002	1395.442	Downstream



Location	H.F.L.	Bed Level	Interval
At Bridge Location	1398.638	1397.392	0.00
At U/S from Bridge Location	1400.408	1399.162	492.00
At D/S from Bridge Location	1396.688	1395.442	510.00

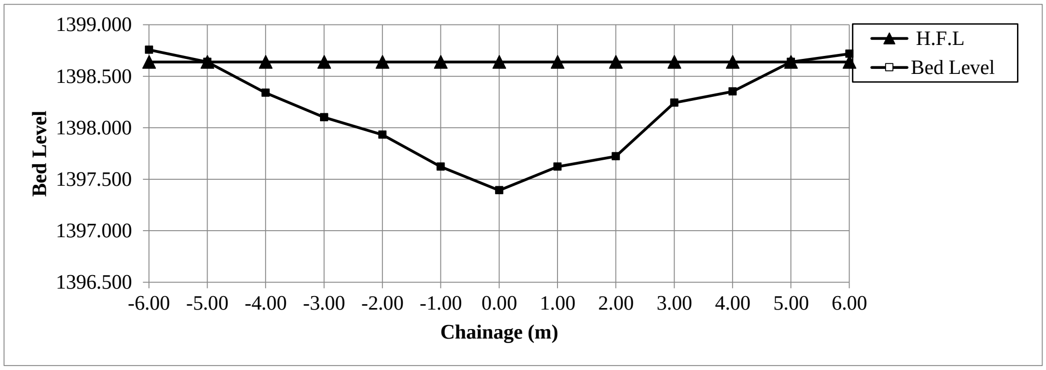
From the longitudinal section of the stream, the Bed Slope is obtained as S = 0.0037

Rugosity co-efficient according to bed material n = 0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.00	1398.638	1398.757					
-5.00	1398.638	1398.638	1.00	0.000	0.000	0.00	0.00
-4.00	1398.638	1398.338	1.00	0.300	0.300	1.04	0.15
-3.00	1398.638	1398.102	1.00	0.536	0.236	1.03	0.42
-2.00	1398.638	1397.932	1.00	0.706	0.170	1.01	0.62
-1.00	1398.638	1397.622	1.00	1.016	0.310	1.05	0.86
0.00	1398.638	1397.392	1.00	1.246	0.230	1.03	1.13
1.00	1398.638	1397.622	1.00	1.016	0.230	1.03	1.13
2.00	1398.638	1397.722	1.00	0.916	0.100	1.00	0.97
3.00	1398.638	1398.242	1.00	0.396	0.520	1.13	0.66
4.00	1398.638	1398.352	1.00	0.286	0.110	1.01	0.34
5.00	1398.638	1398.638	1.00	0.000	0.286	0.00	0.00
6.00	1398.638	1398.718	1.00	0.000	0.000	0.00	0.00
	Average =	**1398.160**		**0.710**	**Total =**	**9.32**	**6.28**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.67
Slope of River Bed		S	=	0.0037
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.04 m/sec
and	Discharge	**$Q = A \times V$**	=	**6.53 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula	=	4.35 m^3/s
Discharge Calculated by Rational Formula Formula	=	36.77 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method	=	6.53 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **9.79 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**15.02 m**
Bank to bank distance		=	**5.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 5 m.
No. of Spans	=	1
Overall Span Length	=	5.00 m
Bearing Center to Deck End	=	0.30 m
Effective Span (center to center of bearings)	=	4.40 m
Total Bridge Length (between inner faces of dirt wall)	=	**5.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**5.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Total Obstruction caused due to Sub-Structure	=	0.00 m
Provided Effective Linear Waterway	**=**	**5.04 m**
Clear Vertical Height	**=**	**2.00 m**
Provided Area of Opening	**=**	**10.06 m^2**
Velocity of Stream	**=**	**1.04 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**10.46 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**15.02 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1398.638 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1398.788 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1399.388 M**
Depth of Top Slab+Girder		=	0.400 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1399.853 M**
Formation Level as per hydarulic			**1403.471 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	9.79 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	12.72 m^3/s
Provided Effective Linear Waterway		=	5.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	2.52 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	2.062 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	0.981 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	2.062 m
Highest Flood Level (H.F.L.)		=	1398.638 M
Normal Scour Level (H.F.L.-d_{sm})		=	1396.576 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	2.619 m
Max. Scour level *		=	1396.019 M
Avg. Bed Level		=	1398.160 M
Min. Foundation Level #		=	1394.019 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Bridge at Chainage 5+115 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -

3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.250	Sq.km.
Design Discharge		=	14.73	m^3/s
Required Linear Waterway		=	18.42	m
Provided Effective Linear Waterway		=	10.04	m
Design Velocity		=	1.17	m/s
Lowest Bed Level		=	1298.383	M
Max. Scour Level		=	1297.557	M
Highest Flood Level	(Observed)	=	1299.729	M
Highest Flood Level	(Designed)	=	1299.879	M
Formation Level		=	1301.044	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	25.00 Ha
Dickens Constant	C_D^*	=	19
Discharge	$C_D \times (A)^{3/4}$	=	6.72 m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	25.00 Ha
Length of Longest Stream		L	=	1.20 km
The Fall in Level between source and site		H	=	35.00 m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90 cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49 cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.30 hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	136.39 cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	66.16 m^3/s

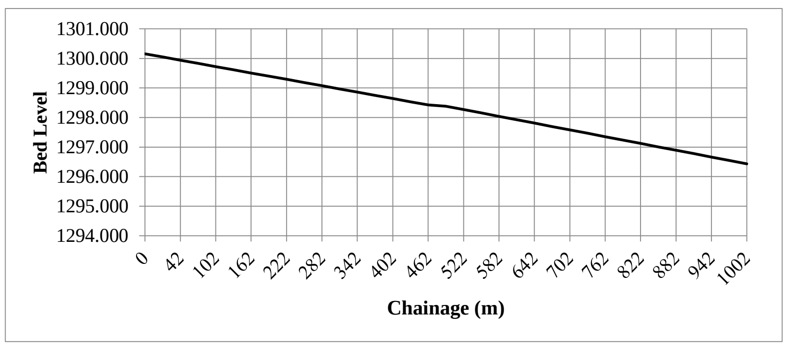
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1299.729 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1300.153	Upstream
12	1300.045	
42	1299.937	
72	1299.829	
102	1299.721	
132	1299.613	
162	1299.505	
192	1299.398	
222	1299.290	
252	1299.182	
282	1299.074	
312	1298.966	
342	1298.858	
372	1298.750	
402	1298.642	
432	1298.534	
462	1298.426	
492	1298.383	Bridge
522	1298.268	
552	1298.154	
582	1298.039	
612	1297.924	
642	1297.809	
672	1297.695	
702	1297.580	
732	1297.465	
762	1297.351	
792	1297.236	
822	1297.121	
852	1297.007	
882	1296.892	
912	1296.777	
942	1296.662	
972	1296.548	
1002	1296.433	Downstream



Location	H.F.L.	Bed Level	Interval
At Bridge Location	1299.729	1298.383	0.00
At U/S from Bridge Location	1301.499	1300.153	492.00
At D/S from Bridge Location	1297.779	1296.433	510.00

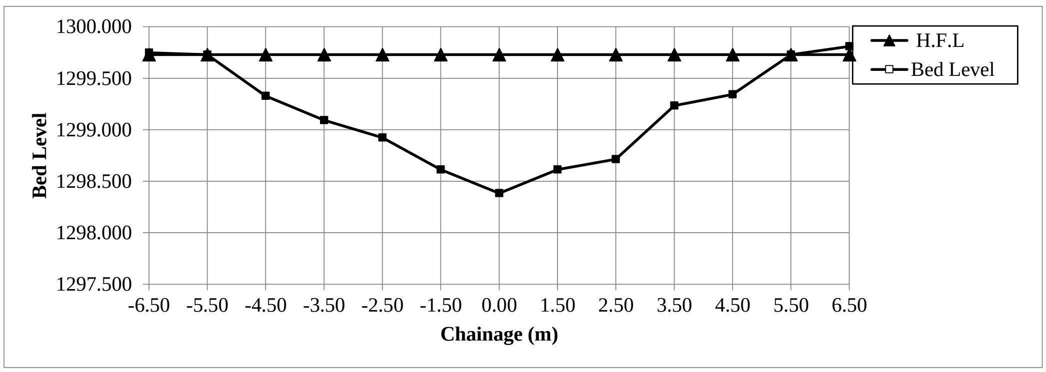
From the longitudinal section of the stream, the Bed Slope is obtained as S = 0.0037

Rugosity co-efficient according to bed material n = 0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.50	1299.729	1299.748					
-5.50	1299.729	1299.729	1.00	0.000	0.000	0.00	0.00
-4.50	1299.729	1299.329	1.00	0.400	0.400	1.08	0.20
-3.50	1299.729	1299.093	1.00	0.636	0.236	1.03	0.52
-2.50	1299.729	1298.923	1.00	0.806	0.170	1.01	0.72
-1.50	1299.729	1298.613	1.00	1.116	0.310	1.05	0.96
0.00	1299.729	1298.383	1.50	1.346	0.230	1.52	1.85
1.50	1299.729	1298.613	1.50	1.116	0.230	1.52	1.85
2.50	1299.729	1298.713	1.00	1.016	0.100	1.00	1.07
3.50	1299.729	1299.233	1.00	0.496	0.520	1.13	0.76
4.50	1299.729	1299.343	1.00	0.386	0.110	1.01	0.44
5.50	1299.729	1299.729	1.00	0.000	0.386	0.00	0.00
6.50	1299.729	1299.809	1.00	0.000	0.000	0.00	0.00
	Average =	**1299.174**		**0.810**	**Total =**	**10.34**	**8.36**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.81
Slope of River Bed		S	=	0.0037
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.17 m/sec
and	Discharge	**Q = A x V**	=	**9.82 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	6.72 m^3/s
Discharge Calculated by Rational Formula Formula		=	66.16 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	9.82 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **14.73 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**18.42 m**
Bank to bank distance		=	**10.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 10 m.
No. of Spans	=	1
Overall Span Length	=	10.00 m
Bearing Center to Deck End	=	0.30 m
Effective Span (center to center of bearings)	=	9.40 m
Total Bridge Length (between inner faces of dirt wall)	=	**10.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**10.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Total Obstruction caused due to Sub-Structure	=	0.00 m
Provided Effective Linear Waterway	**=**	**10.04 m**
Clear Vertical Height	**=**	**2.10 m**
Provided Area of Opening	**=**	**21.04 m^2**
Velocity of Stream	**=**	**1.17 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**24.72 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**18.42 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1299.729 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1299.879 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1300.479 M**
Depth of Top Slab+Girder		=	0.500 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1301.044 M**
Formation Level as per hydarulic			**1306.764 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	14.73 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	19.14 m^3/s
Provided Effective Linear Waterway		=	10.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	1.91 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	1.710 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	1.060 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	1.710 m
Highest Flood Level (H.F.L.)		=	1299.729 M
Normal Scour Level (H.F.L.-d_{sm})		=	1298.019 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	2.172 m
Max. Scour level *		=	1297.557 M
Avg. Bed Level		=	1299.174 M
Min. Foundation Level #		=	1295.557 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Bridge at Chainage 5+206 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -

3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.270	Sq.km.
Design Discharge		=	12.29	m^3/s
Required Linear Waterway		=	16.83	m
Provided Effective Linear Waterway		=	10.04	m
Design Velocity		=	1.22	m/s
Lowest Bed Level		=	1297.070	M
Max. Scour Level		=	1296.491	M
Highest Flood Level	(Observed)	=	1298.416	M
Highest Flood Level	(Designed)	=	1298.566	M
Formation Level		=	1299.631	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	27.00	Ha
Dickens Constant	C_D^*	=	19	
Discharge	$C_D \times (A)^{3/4}$	=	7.12	m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	27.00	Ha
Length of Longest Stream		L	=	0.75	km
The Fall in Level between source and site		H	=	27.00	m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70	
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90	cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49	cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99	
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.19	hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	148.58	cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	77.84	m^3/s

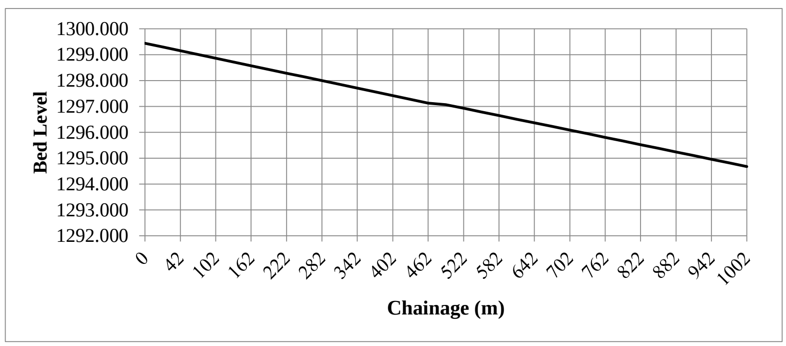
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1298.416 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1299.440	Upstream
12	1299.295	
42	1299.151	
72	1299.006	
102	1298.862	
132	1298.717	
162	1298.573	
192	1298.428	
222	1298.284	
252	1298.139	
282	1297.995	
312	1297.850	
342	1297.706	
372	1297.561	
402	1297.417	
432	1297.272	
462	1297.128	
492	1297.070	Bridge
522	1296.929	
552	1296.788	
582	1296.647	
612	1296.506	
642	1296.366	
672	1296.225	
702	1296.084	
732	1295.943	
762	1295.802	
792	1295.661	
822	1295.520	
852	1295.379	
882	1295.239	
912	1295.098	
942	1294.957	
972	1294.816	
1002	1294.675	Downstream



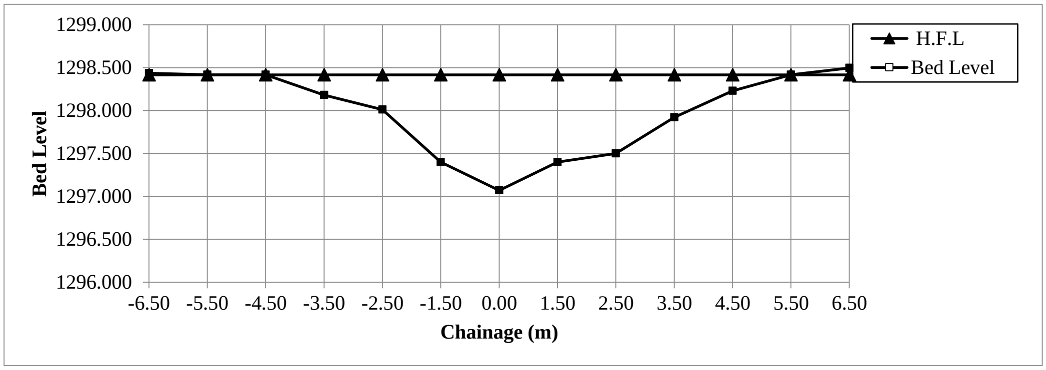
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1298.416	1297.070	0.00
At U/S from Bridge Location	1300.786	1299.440	492.00
At D/S from Bridge Location	1296.021	1294.675	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0048
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.50	1298.416	1298.435					
-5.50	1298.416	1298.416	1.00	0.000	0.000	0.00	0.00
-4.50	1298.416	1298.416	1.00	0.000	0.000	0.00	0.00
-3.50	1298.416	1298.180	1.00	0.236	0.236	1.03	0.12
-2.50	1298.416	1298.010	1.00	0.406	0.170	1.01	0.32
-1.50	1298.416	1297.400	1.00	1.016	0.610	1.17	0.71
0.00	1298.416	1297.070	1.50	1.346	0.330	1.54	1.77
1.50	1298.416	1297.400	1.50	1.016	0.330	1.54	1.77
2.50	1298.416	1297.500	1.00	0.916	0.100	1.00	0.97
3.50	1298.416	1297.920	1.00	0.496	0.420	1.08	0.71
4.50	1298.416	1298.230	1.00	0.186	0.310	1.05	0.34
5.50	1298.416	1298.416	1.00	0.000	0.186	0.00	0.00
6.50	1298.416	1298.496	1.00	0.000	0.000	0.00	0.00
	Average =	**1297.991**		**0.700**	**Total =**	**9.42**	**6.71**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.71
Slope of River Bed		S	=	0.0048
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.22 m/sec
and	Discharge	**$Q = A \times V$**	=	**8.19 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	7.12 m^3/s
Discharge Calculated by Rational Formula Formula		=	77.84 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	8.19 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **12.29 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**16.83 m**
Bank to bank distance		=	**10.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 10 m.
No. of Spans	=	1
Overall Span Length	=	10.00 m
Bearing Center to Deck End	=	0.30 m
Effective Span (center to center of bearings)	=	9.40 m
Total Bridge Length (between inner faces of dirt wall)	=	**10.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**10.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Total Obstruction caused due to Sub-Structure	=	0.00 m
Provided Effective Linear Waterway	**=**	**10.04 m**
Clear Vertical Height	**=**	**2.10 m**
Provided Area of Opening	**=**	**21.04 m^2**
Velocity of Stream	**=**	**1.22 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**25.71 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**16.83 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1298.416 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1298.566 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1299.166 M**
Depth of Top Slab+Girder		=	0.400 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1299.631 M**
Formation Level as per hydarulic			**1306.764 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	12.29 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	15.98 m^3/s
Provided Effective Linear Waterway		=	10.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	1.59 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	1.516 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	1.060 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	1.516 m
Highest Flood Level (H.F.L.)		=	1298.416 M
Normal Scour Level (H.F.L.-d_{sm})		=	1296.900 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	1.925 m
Max. Scour level *		=	1296.491 M
Avg. Bed Level		=	1297.991 M
Min. Foundation Level #		=	1294.491 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Culvert at Chainage 5+435 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.

The following methods are used for the estimation of flood discharge:

1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -

3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.100	Sq.km.
Design Discharge		=	7.63	m^3/s
Required Linear Waterway		=	13.26	m
Provided Effective Linear Waterway		=	5.04	m
Design Velocity		=	0.77	m/s
Lowest Bed Level		=	1283.787	M
Max. Scour Level		=	1282.914	M
Highest Flood Level	(Observed)	=	1285.133	M
Highest Flood Level	(Designed)	=	1285.283	M
Formation Level		=	1286.348	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	10.00 Ha
Dickens Constant	C_D^*	=	19
Discharge	$C_D \times (A)^{3/4}$	=	3.38 m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	10.00 Ha
Length of Longest Stream		L	=	0.60 km
The Fall in Level between source and site		H	=	18.00 m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90 cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49 cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.17 hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	150.92 cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	29.29 m^3/s

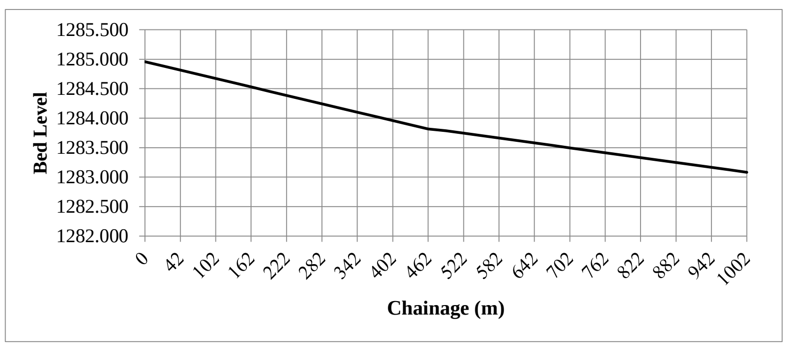
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1285.133 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1284.957	Upstream
12	1284.886	
42	1284.814	
72	1284.743	
102	1284.672	
132	1284.600	
162	1284.529	
192	1284.458	
222	1284.386	
252	1284.315	
282	1284.244	
312	1284.172	
342	1284.101	
372	1284.030	
402	1283.958	
432	1283.887	
462	1283.816	
492	1283.787	Bridge
522	1283.746	
552	1283.704	
582	1283.663	
612	1283.621	
642	1283.580	
672	1283.538	
702	1283.497	
732	1283.455	
762	1283.414	
792	1283.372	
822	1283.331	
852	1283.289	
882	1283.248	
912	1283.206	
942	1283.165	
972	1283.123	
1002	1283.082	Downstream



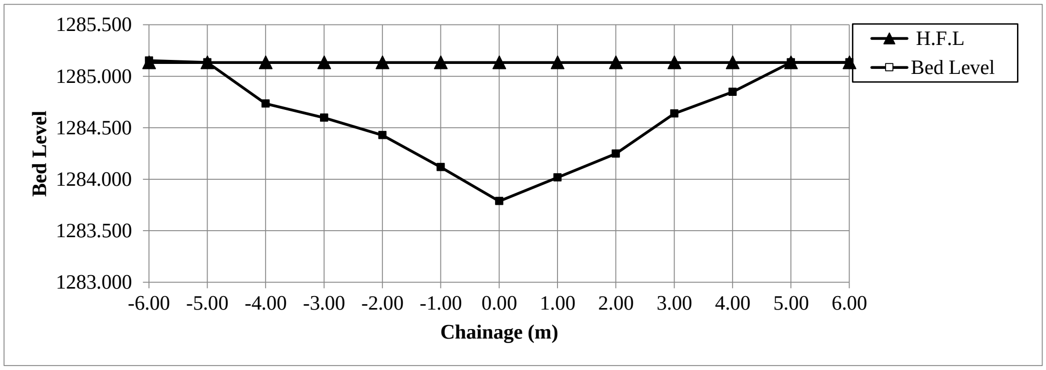
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1285.133	1283.787	0.00
At U/S from Bridge Location	1286.303	1284.957	492.00
At D/S from Bridge Location	1284.428	1283.082	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0019
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.00	1285.133	1285.152					
-5.00	1285.133	1285.133	1.00	0.000	0.000	0.00	0.00
-4.00	1285.133	1284.733	1.00	0.400	0.400	1.08	0.20
-3.00	1285.133	1284.597	1.00	0.536	0.136	1.01	0.47
-2.00	1285.133	1284.427	1.00	0.706	0.170	1.01	0.62
-1.00	1285.133	1284.117	1.00	1.016	0.310	1.05	0.86
0.00	1285.133	1283.787	1.00	1.346	0.330	1.05	1.18
1.00	1285.133	1284.017	1.00	1.116	0.230	1.03	1.23
2.00	1285.133	1284.247	1.00	0.886	0.230	1.03	1.00
3.00	1285.133	1284.637	1.00	0.496	0.390	1.07	0.69
4.00	1285.133	1284.847	1.00	0.286	0.210	1.02	0.39
5.00	1285.133	1285.133	1.00	0.000	0.286	0.00	0.00
6.00	1285.133	1285.133	1.00	0.000	0.000	0.00	0.00
	Average =	**1284.612**		**0.750**	**Total =**	**9.35**	**6.65**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.71
Slope of River Bed		S	=	0.0019
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	0.77 m/sec
and	Discharge	**Q = A x V**	=	**5.09 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	3.38 m^3/s
Discharge Calculated by Rational Formula Formula		=	29.29 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	5.09 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **7.63 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**13.26 m**
Bank to bank distance		=	**5.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 5 m.
No. of Spans	=	1
Overall Span Length	=	5.00 m
Bearing Center to Deck End	=	0.30 m
Effective Span (center to center of bearings)	=	4.40 m
Total Bridge Length (between inner faces of dirt wall)	=	**5.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**5.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Total Obstruction caused due to Sub-Structure	=	0.00 m
Provided Effective Linear Waterway	**=**	**5.04 m**
Clear Vertical Height	**=**	**2.10 m**
Provided Area of Opening	**=**	**10.56 m^2**
Velocity of Stream	**=**	**0.77 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**8.09 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**13.26 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1285.133 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1285.283 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1285.883 M**
Depth of Top Slab+Girder		=	0.400 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1286.348 M**
Formation Level as per hydarulic			**1292.594 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	7.63 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	9.92 m^3/s
Provided Effective Linear Waterway		=	5.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	1.97 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	1.747 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	1.060 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	1.747 m
Highest Flood Level (H.F.L.)		=	1285.133 M
Normal Scour Level (H.F.L.-d_{sm})		=	1283.386 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	2.219 m
Max. Scour level *		=	1282.914 M
Avg. Bed Level		=	1284.612 M
Min. Foundation Level #		=	1280.914 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Culvert at Chainage 6+655 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.
The following methods are used for the estimation of flood discharge:
1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -
3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.120	Sq.km.
Design Discharge		=	5.81	m^3/s
Required Linear Waterway		=	11.57	m
Provided Effective Linear Waterway		=	5.04	m
Design Velocity		=	0.62	m/s
Lowest Bed Level		=	1260.803	M
Max. Scour Level		=	1260.100	M
Highest Flood Level	(Observed)	=	1261.949	M
Highest Flood Level	(Designed)	=	1262.099	M
Formation Level		=	1263.164	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	12.00	Ha
Dickens Constant	C_D^*	=	19	
Discharge	$C_D \times (A)^{3/4}$	=	3.87	m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	12.00	Ha
Length of Longest Stream		L	=	0.50	km
The Fall in Level between source and site		H	=	15.00	m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70	
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90	cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49	cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99	
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.15	hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	153.89	cm/hr
Discharge	$0.028 \, P \, f \, A \, I_c$		=	35.83	m^3/s

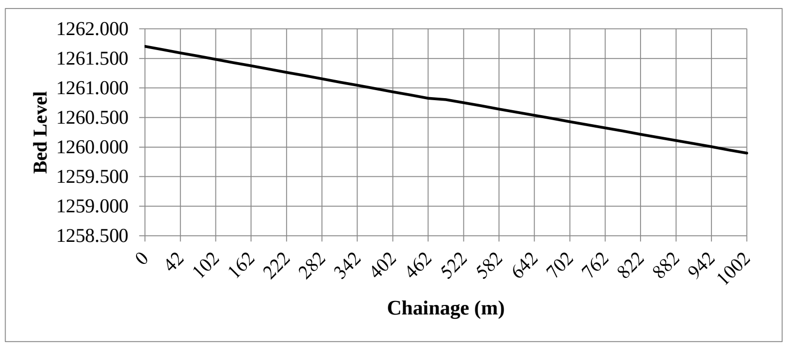
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1261.949 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1261.703	Upstream
12	1261.648	
42	1261.593	
72	1261.538	
102	1261.483	
132	1261.429	
162	1261.374	
192	1261.319	
222	1261.264	
252	1261.209	
282	1261.154	
312	1261.099	
342	1261.044	
372	1260.990	
402	1260.935	
432	1260.880	
462	1260.825	
492	1260.803	Bridge
522	1260.750	
552	1260.697	
582	1260.643	
612	1260.590	
642	1260.537	
672	1260.484	
702	1260.430	
732	1260.377	
762	1260.324	
792	1260.271	
822	1260.217	
852	1260.164	
882	1260.111	
912	1260.058	
942	1260.004	
972	1259.951	
1002	1259.898	Downstream



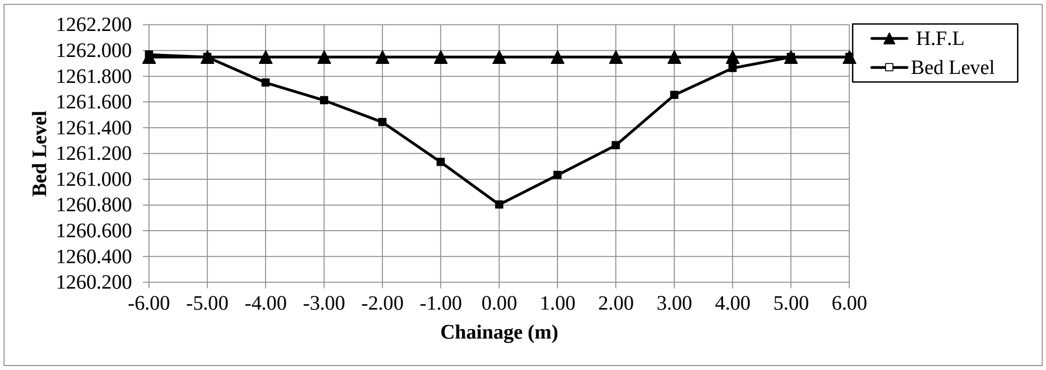
Location	H.F.L.	Bed Level	Interval
At Bridge Location	1261.949	1260.803	0.00
At U/S from Bridge Location	1262.849	1261.703	492.00
At D/S from Bridge Location	1261.044	1259.898	510.00

From the longitudinal section of the stream, the Bed Slope is obtained as	S	=	0.0018
Rugosity co-efficient according to bed material	n	=	0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.00	1261.949	1261.968					
-5.00	1261.949	1261.949	1.00	0.000	0.000	0.00	0.00
-4.00	1261.949	1261.749	1.00	0.200	0.200	1.02	0.10
-3.00	1261.949	1261.613	1.00	0.336	0.136	1.01	0.27
-2.00	1261.949	1261.443	1.00	0.506	0.170	1.01	0.42
-1.00	1261.949	1261.133	1.00	0.816	0.310	1.05	0.66
0.00	1261.949	1260.803	1.00	1.146	0.330	1.05	0.98
1.00	1261.949	1261.033	1.00	0.916	0.230	1.03	1.03
2.00	1261.949	1261.263	1.00	0.686	0.230	1.03	0.80
3.00	1261.949	1261.653	1.00	0.296	0.390	1.07	0.49
4.00	1261.949	1261.863	1.00	0.086	0.210	1.02	0.19
5.00	1261.949	1261.949	1.00	0.000	0.086	0.00	0.00
6.00	1261.949	1261.949	1.00	0.000	0.000	0.00	0.00
	Average =	**1261.567**		**0.550**	**Total =**	**9.29**	**4.94**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.53
Slope of River Bed		S	=	0.0018
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	0.62 m/sec
and	Discharge	**$Q = A \times V$**	=	**3.06 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	3.87 m^3/s
Discharge Calculated by Rational Formula Formula		=	35.83 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	3.06 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **5.81 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**11.57 m**
Bank to bank distance		=	**5.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	: Minor Bridge		
Span Arrangement		=	1 Span(s) of 5 m.
No. of Spans		=	1
Overall Span Length		=	5.00 m
Bearing Center to Deck End		=	0.30 m
Effective Span (center to center of bearings)		=	4.40 m
Total Bridge Length (between inner faces of dirt wall)		=	**5.00 m**
No. of Expansion Gap at bridge portion		=	2
Expansion Gap between two adjacent span		=	0.02 m
Total Bridge Length (i/c Expansion Gap)		=	**5.04 m**
No. of Piers		=	0
Thickness of One Pier		=	0.00 m
No. of Abutments		=	2
Total Obstruction caused due to Sub-Structure		=	0.00 m
Provided Effective Linear Waterway		**=**	**5.04 m**
Clear Vertical Height		**=**	**1.90 m**
Provided Area of Opening		**=**	**9.56 m^2**
Velocity of Stream		**=**	**0.62 m/sec**
Quantum of Discharge which can be passed through Provided Opening		**=**	**5.92 m^3/s**
Quantum of Discharge which can be passed through Provided Opening			**Hence Safe**
Required Linear Waterway		**=**	**11.57 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1261.949 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1262.099 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1262.699 M**
Depth of Top Slab+Girder		=	0.400 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1263.164 M**
Formation Level as per hydarulic			**1267.375 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	5.81 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	7.55 m^3/s
Provided Effective Linear Waterway		=	5.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	1.50 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	1.456 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	0.902 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	1.456 m
Highest Flood Level (H.F.L.)		=	1261.949 M
Normal Scour Level (H.F.L.-d_{sm})		=	1260.493 M
Max. scour depth = (1.27 x d_{sm})		=	1.849 m
Max. Scour level *		=	1260.100 M
Avg. Bed Level		=	1261.567 M
Min. Foundation Level #		=	1258.100 M
			or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Slab Culvert at Chainage 7+395 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.
The following methods are used for the estimation of flood discharge:
1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -
3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	0.140	Sq.km.
Design Discharge		=	6.52	m^3/s
Required Linear Waterway		=	12.26	m
Provided Effective Linear Waterway		=	5.04	m
Design Velocity		=	0.76	m/s
Lowest Bed Level		=	1227.036	M
Max. Scour Level		=	1226.184	M
Highest Flood Level	(Observed)	=	1228.182	M
Highest Flood Level	(Designed)	=	1228.332	M
Formation Level		=	1229.397	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	14.00	Ha
Dickens Constant	C_D^*	=	19	
Discharge	$C_D \times (A)^{3/4}$	=	4.35	m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	14.00	Ha
Length of Longest Stream		L	=	0.35	km
The Fall in Level between source and site		H	=	16.00	m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70	
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90	cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49	cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99	
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.10	hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	161.34	cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	43.83	m^3/s

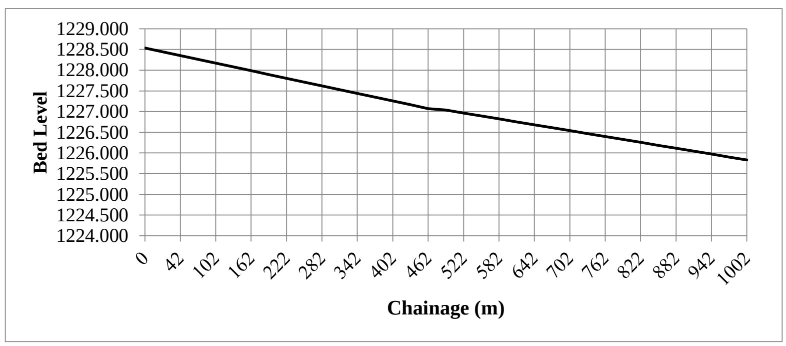
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream

From the survey data & local enquiry, we fix the observed H.F.L. = 1228.182 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1228.536	Upstream
12	1228.445	
42	1228.353	
72	1228.262	
102	1228.170	
132	1228.079	
162	1227.987	
192	1227.896	
222	1227.804	
252	1227.713	
282	1227.621	
312	1227.530	
342	1227.438	
372	1227.347	
402	1227.256	
432	1227.164	
462	1227.073	
492	1227.036	Bridge
522	1226.965	
552	1226.894	
582	1226.823	
612	1226.752	
642	1226.682	
672	1226.611	
702	1226.540	
732	1226.469	
762	1226.398	
792	1226.327	
822	1226.256	
852	1226.185	
882	1226.115	
912	1226.044	
942	1225.973	
972	1225.902	
1002	1225.831	Downstream



Location	H.F.L.	Bed Level	Interval
At Bridge Location	1228.182	1227.036	0.00
At U/S from Bridge Location	1229.682	1228.536	492.00
At D/S from Bridge Location	1226.977	1225.831	510.00

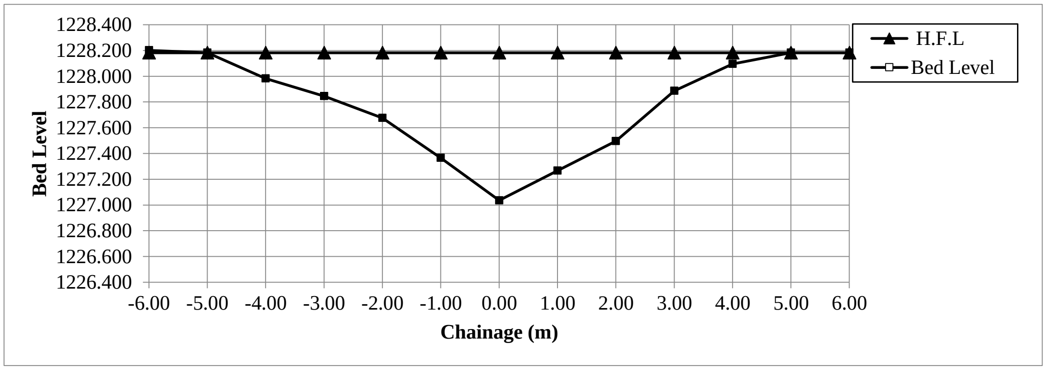
From the longitudinal section of the stream, the Bed Slope is obtained as S = 0.0027

Rugosity co-efficient according to bed material n = 0.045

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
-6.00	1228.182	1228.201					
-5.00	1228.182	1228.182	1.00	0.000	0.000	0.00	0.00
-4.00	1228.182	1227.982	1.00	0.200	0.200	1.02	0.10
-3.00	1228.182	1227.846	1.00	0.336	0.136	1.01	0.27
-2.00	1228.182	1227.676	1.00	0.506	0.170	1.01	0.42
-1.00	1228.182	1227.366	1.00	0.816	0.310	1.05	0.66
0.00	1228.182	1227.036	1.00	1.146	0.330	1.05	0.98
1.00	1228.182	1227.266	1.00	0.916	0.230	1.03	1.03
2.00	1228.182	1227.496	1.00	0.686	0.230	1.03	0.80
3.00	1228.182	1227.886	1.00	0.296	0.390	1.07	0.49
4.00	1228.182	1228.096	1.00	0.086	0.210	1.02	0.19
5.00	1228.182	1228.182	1.00	0.000	0.086	0.00	0.00
6.00	1228.182	1228.182	1.00	0.000	0.000	0.00	0.00
	Average =	**1227.800**		**0.550**	**Total =**	**9.29**	**4.94**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		R = A / P	=	0.53
Slope of River Bed		S	=	0.0027
Rugosity Co-efficient		n	=	0.045
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	0.76 m/sec
and	Discharge	**Q = A x V**	=	**3.75 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	4.35 m^3/s
Discharge Calculated by Rational Formula Formula		=	43.83 m^3/s
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	3.75 m^3/s

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **6.52 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**12.26 m**
Bank to bank distance		=	**5.00 m**

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	:	Minor Bridge
Span Arrangement	=	1 Span(s) of 5 m.
No. of Spans	=	1
Overall Span Length	=	5.00 m
Bearing Center to Deck End	=	0.30 m
Effective Span (center to center of bearings)	=	4.40 m
Total Bridge Length (between inner faces of dirt wall)	=	**5.00 m**
No. of Expansion Gap at bridge portion	=	2
Expansion Gap between two adjacent span	=	0.02 m
Total Bridge Length (i/c Expansion Gap)	=	**5.04 m**
No. of Piers	=	0
Thickness of One Pier	=	0.00 m
No. of Abutments	=	2
Total Obstruction caused due to Sub-Structure	=	0.00 m
Provided Effective Linear Waterway	**=**	**5.04 m**
Clear Vertical Height	**=**	**1.90 m**
Provided Area of Opening	**=**	**9.56 m^2**
Velocity of Stream	**=**	**0.76 m/sec**
Quantum of Discharge which can be passed through Provided Opening	**=**	**7.25 m^3/s**
Quantum of Discharge which can be passed through Provided Opening		**Hence Safe**
Required Linear Waterway	**=**	**12.26 m**

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1228.182 M**
Afflux		=	0.150 m
Designed Highest Flood Level (De. H.F.L.)		=	**1228.332 M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.600 m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1228.932 M**
Depth of Top Slab+Girder		=	0.400 m
Wearing Course on Deck Slab		=	0.065 m
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1229.397 M**
Formation Level as per hydarulic			**1234.175 M**
Formation Level due to Profile correction			

9. Scour Depth Calculation :

Design Discharge		=	6.52 m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30 %
Incremented Design Discharge	*(for scour calculation only)*	=	8.48 m^3/s
Provided Effective Linear Waterway		=	5.04 m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	1.68 $m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*		
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	1.573 m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	0.902 m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	1.573 m
Highest Flood Level (H.F.L.)		=	1228.182 M
Normal Scour Level (H.F.L.-d_{sm})		=	1226.609 M
Max. scour depth = ($1.27 \times d_{sm}$)		=	1.998 m
Max. Scour level *		=	1226.184 M
Avg. Bed Level		=	1227.800 M
Min. Foundation Level #		=	1224.184 M or upto Rock Lvl

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.

INDEX

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Sr. No.	Design Chainage	Type of Proposal	Type of Structure	Span Arrangement (m)	CA (km^2)
1	6+185	New Proposal	Viaduct (EXTRADOSE BRIDGE)	(1X100 + 1X200 + 1X100)	1.89

IMPROVEMENT TO 2-LANE WITH PAVED SHOULDER/4-LANING OF NH-40 BETWEEN SHILLONG TO DAWKI ROAD UPTO BANGLADESH BORDER INCLUDING DAWKI BRIDGE IN THE STATE OF MEGHALAYA FOR EXECUTION OF EPC MODE UNDER JICA FUNDING.(DESIGN LENGTH 7.760 KM (PACKAGE-III).

Hydraulic Calculation of Minor Bridge at Chainage 6+185 KM.

1. Introduction:

The length of a bridge, depth of foundation & formational level are dependent on the maximum recorded quantum of water or flood discharge which has passed through the river or the channel over which the bridge is proposed and as such the design discharge is very important not only from economic consideration but also from safety or stability consideration. Therefore, the design discharge, which might be the recorded discharge during the past 50-100 years, shall be ascertained very carefully.
The following methods are used for the estimation of flood discharge:
1. Peak Run-off from catchment by using Empirical Formulae.

2. Peak Run-of -
3. Flood discharge from Cross-Sectional Area-Velocity Method as observed on the stream at the bridge site.

2. Codes Referred for Design Purpose:

IRC: 5 - 2015	Standard Specifications and Code of Practice for Road Bridges Section - I, General Features of Design
IRC: SP: 13 - 2022	Guidelines for the design of small bridges & culverts

3. Abstract of Hydraulic Calculation:

Catchment Area		=	1.890	Sq.km.
Design Discharge		=	45.94	m^3/s
Required Linear Waterway		=	32.53	m
Provided Effective Linear Waterway		=	367.30	m
Design Velocity		=	1.37	m/s
Lowest Bed Level		=	1168.456	M
Max. Scour Level		=	1157.679	M
Highest Flood Level	(Observed)	=	1158.099	M
Highest Flood Level	(Designed)	=	1158.249	M
Formation Level		=	1251.099	M

4. Dickens Formula to Calculate Peak Run-off from Catchment:

Area of Catchment	A	=	189.00 Ha
Dickens Constant	C_D^*	=	19
Discharge	$C_D \times (A)^{3/4}$	=	30.63 m^3/s

5. Rational Formula to Calculate Peak Run-off from Catchment:

Area of Catchment		A	=	189.00 Ha
Length of Longest Stream		L	=	2.00 km
The Fall in Level between source and site		H	=	260.00 m
Co-efficient of Runoff	*(Refer IRC:SP:13-2004, Table 4.1)*	P	=	0.70
100 Years - 24 Hour Rainfall	*(Refer Plate-10 of subzone 2(b))*		=	226.90 cm
100 Years - 1 Hour Rainfall	*(39% of 24 Hour Rainfall)*	I_o	=	88.49 cm
Mean Intensity fraction	*(Refer IRC:SP:13-2004, Fig. 4.2)*	f	=	0.99
Concentration time	$t_c = (0.87 \times L^3 / H)^{0.385}$		=	0.25 hrs.
Critical Intensity of Rainfall	$I_c = I_o (2 / t_c + 1)$		=	141.80 cm/hr
Discharge	$0.028\ P\ f\ A\ I_c$		=	520.03 m^3/s

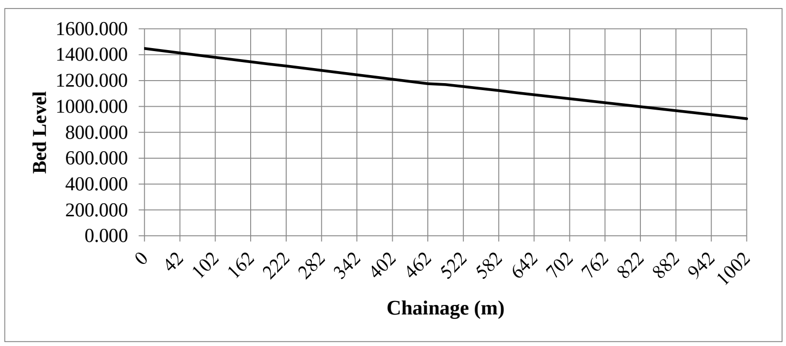
6. Cross-Sectional Area-Velocity Method to Calculate Flood Discharge:

Since the bridge is provided across a defined stream, we estimate flood discharge from the conveyance factor & slope of the stream applying

From the survey data & local enquiry, we fix the observed H.F.L. = 1158.099 M

Longitudinal Section of River/Stream :

Chainage	R. L.	
0	1448.000	Upstream
12	1430.955	
42	1413.909	
72	1396.864	
102	1379.819	
132	1362.773	
162	1345.728	
192	1328.682	
222	1311.637	
252	1294.592	
282	1277.546	
312	1260.501	
342	1243.456	
372	1226.410	
402	1209.365	
432	1192.320	
462	1175.274	
492	1168.456	Bridge
522	1152.959	
552	1137.461	
582	1121.964	
612	1106.466	
642	1090.969	
672	1075.472	
702	1059.974	
732	1044.477	
762	1028.979	
792	1013.482	
822	997.984	
852	982.487	
882	966.990	
912	951.492	
942	935.995	
972	920.497	
1002	905.000	Downstream



Location	H.F.L.	Bed Level	Interval
At Bridge Location	1158.099	1168.456	0.00
At U/S from Bridge Location	1437.643	1448.000	492.00
At D/S from Bridge Location	894.643	905.000	510.00

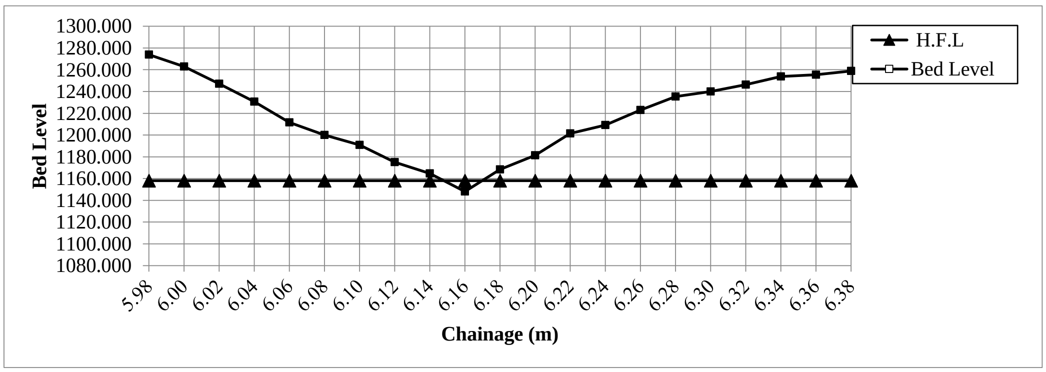
From the longitudinal section of the stream, the Bed Slope is obtained as S = 0.5419

Rugosity co-efficient according to bed material n = 0.025

(Refer IRC:SP:13-2004,Table 5.1)

Cross-Section at Bridge Location :

Chainage (m)	H.F.L	Bed Level	Distance (m)	Depth Below H.F.L. (m)	Vertical Difference (m)	Perimeter (m)	Area (m^2)
5.98	1158.099	1273.876					
6.00	1158.099	1262.943	0.02	0.000	0.000	0.00	0.00
6.02	1158.099	1247.211	0.02	0.000	0.000	0.00	0.00
6.04	1158.099	1230.631	0.02	0.000	0.000	0.00	0.00
6.06	1158.099	1211.610	0.02	0.000	0.000	0.00	0.00
6.08	1158.099	1200.043	0.02	0.000	0.000	0.00	0.00
6.10	1158.099	1190.838	0.02	0.000	0.000	0.00	0.00
6.12	1158.099	1175.084	0.02	0.000	0.000	0.00	0.00
6.14	1158.099	1164.837	0.02	0.000	0.000	0.00	0.00
6.16	1158.099	1148.099	0.02	10.000	10.000	10.00	0.10
6.18	1158.099	1168.456	0.02	0.000	10.000	0.00	0.00
6.20	1158.099	1181.411	0.02	0.000	0.000	0.00	0.00
6.22	1158.099	1201.367	0.02	0.000	0.000	0.00	0.00
6.24	1158.099	1209.184	0.02	0.000	0.000	0.00	0.00
6.26	1158.099	1223.008	0.02	0.000	0.000	0.00	0.00
6.28	1158.099	1235.362	0.02	0.000	0.000	0.00	0.00
6.30	1158.099	1240.101	0.02	0.000	0.000	0.00	0.00
6.32	1158.099	1246.247	0.02	0.000	0.000	0.00	0.00
6.34	1158.099	1253.742	0.02	0.000	0.000	0.00	0.00
6.36	1158.099	1255.510	0.02	0.000	0.000	0.00	0.00
6.38	1158.099	1258.895	0.02	0.000	0.000	0.00	0.00
	Average =	**1218.022**		**10.000**	**Total =**	**10.00**	**0.10**



Discharge Calculation by Area Velocity method (Using Mannings formula)

Hydraulic Radius		$R = A / P$	=	0.01
Slope of River Bed		S	=	0.5419
Rugosity Co-efficient		n	=	0.025
Therefore,	Velocity	$V = R^{2/3} \times S^{1/2} / n$	=	1.37 m/sec
and	Discharge	**$Q = A \times V$**	=	**0.14 m^3/s**

7. Linear Waterway Calculation:

Discharge Calculated by Dicken's Formula		=	30.63 m^3/s	
Discharge Calculated by Rational Formula Formula		=	520.03 m^3/s	
Discharge Calculated by Cross-Sectional Area-Velocity Method		=	0.14 m^3/s	

As per IRC:SP:13-2004, Clause 6.2.1*, Design Discharge (Q) = **45.94 m^3/s**

*The highest of these values should be adopted as the design discharge Q, provided it does not exceed the next highest discharge by more

As per Design Discharge, Linear Water Way Required	(4.8 x √Q)	=	**32.53 m**	
Bank to bank distance		=	**400.00 m**	

Considering all the above parameters, We are proposing a High Level Bridge, details of which are given below:

Type of Bridge	: Extradose Bridge			
Span Arrangement		=	3 Span(s) of 1x100+1x200+1x100"m.	
No. of Spans		=	2	1
Overall Span Length		=	100.00	200
Bearing Center to Deck End		=	0.40 m	
Effective Span (center to center of bearings)		=	99.20 m	
Total Bridge Length (between inner faces of dirt wall)		=	**400.00 m**	
No. of Expansion Gap at bridge portion		=	4	
Expansion Gap between two adjacent span		=	0.05 m	
Total Bridge Length (i/c Expansion Gap)		=	**400.00 m**	
No. of Piers		=	2	
Thickness of One Pier		=	5.25 m	
No. of Abutments		=	2	
Distance from dirt wall inner face to Abutment inner face		=	11.10 m	
Total Obstruction caused due to Sub-Structure		=	32.70 m	
Provided Effective Linear Waterway		**=**	**367.30 m**	
Clear Vertical Height		**=**	**74.35 m**	
Provided Area of Opening		**=**	**27309.86 `**	
Velocity of Stream		**=**	**1.37 m/sec**	
Quantum of Discharge which can be passed through Provided Opening		**=**	**37325.44 m^3/s**	
Quantum of Discharge which can be passed through Provided Opening			**Hence Safe**	
Required Linear Waterway		**=**	**32.53 m**	

8. Fixation of Formation Level:

Highest Flood Level (H.F.L.)		=	**1158.099**	**M**
Afflux		=	0.150	m
Designed Highest Flood Level (De. H.F.L.)		=	**1158.249**	**M**
Vertical Clearance *	*(Refer IRC:SP:13-2004,Table 12.1)*	=	0.900	m
Soffit Level	**(De. H.F.L. + Afflux + Vertical Clearance)**	=	**1159.149**	**M**
Depth of Top Slab+Girder		=	8.225	m
Wearing Course on Deck Slab		=	0.065	m
Formation Level due to Profile correction		=	83.660	
Formation Level	**(Soffit Level + Depth of S.S. + Wearing Course)**	**=**	**1251.099**	**M**
Formation Level as per hydarulic			**1252.000**	**M**
Formation Level due to Profile correction				

9. Scour Depth Calculation :

Design Discharge		=	45.94	m^3/s
%age Increment over Des. Discharge *(Refer IRC:78-2014, Clause 703.1.1)*		=	30	%
Incremented Design Discharge	*(for scour calculation only)*	=	59.72	m^3/s
Provided Effective Linear Waterway		=	367.30	m

Scour Depth Calculation :-

D_b	=	Inc. Design Discharge / Eff. Waterway	=	0.16	$m^3/sec/m$
K_{sf}	=	Silt Factor *(Refer IRC:78-2014, Clause 703.2.2.1)*	=	1.75	
d_{sm}	=	Mean Scour Depth *(As per IRC:78-2014, Clause 703.2)*			
d_{sm}	=	$1.34 \times (D_b^2 / K_{sf})^{1/3}$	=	0.331	m
d_{sm}	=	[(HFL - LBL) / 1.27 Criteria]	=	-8.155	m

Mean Scour Depth (d_{sm})	*(Max. of above two values)*	=	0.331	m
Highest Flood Level (H.F.L.)		=	1158.099	M
Normal Scour Level (H.F.L.-d_{sm})		=	1157.768	M
Max. scour depth = (1.27 x d_{sm})		=	0.420	m
Max. Scour level *		=	1157.679	M
Avg. Bed Level		=	1218.022	M
Min. Foundation Level #		=	1154.679	M
			or upto Rock Lvl	

Note: Foundation levels are calculated on the basis of maximum scour level. Final foundation levels are subjected to availability of rock and/or S.B.C. of founding strata.