



National Highways & Infrastructure Development Corporation Limited
(Ministry of Road Transport & Highway)
Government of India

SPECIALISED CONSULTANCY SERVICES FOR 'GOOD FOR TENDER' DESIGN BASED ON DETAILED SURVEY, INVESTIGATIONS, ESTIMATION, COSTING AND PREPARATION OF TECHNICAL SCHEDULES OF EPC DOCUMENTS FOR CONSTRUCTION OF 1200 METRE. LONG NEW 4-LANE BRIDGE WITH APPROACHES AND RIVER TRAINING WORKS OVER RIVER JIA BHARALI IN THE STATE OF ASSAM



VOLUME-I
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TABLE OF CONTENTS

VOLUME-I

Item No.	Description	Page No.
1.0	CHAPTER-1:INTRODUCTION	
1.1	Project Background	1
1.2	Scope of Work	1
1.3	Site Visit	2
1.4	GAD	2
1.4	Organization of Report	3
2.0	CHAPTER-2:REVIEW OF MODEL STUDY	
2.1	General	4
2.2	Characteristics of River Jia Bharali	4
2.3	Hydrological Observation	4
2.4	Model Scale	4
2.5	Summary of Results of Model Study	5
2.6	Observations in Protection Works	6
2.7	Proposed Remedial Measures in Protection Works	7
3.0	CHAPTER-3:SURVEY AND INVESTIGATION	
3.1	Site Profile	9
3.2	Topographical Survey	10
3.3	Geotechnical Investigation	14
4.0	CHAPTER-4:DESIGN OF STRUCTURES	
4.1	General Alignment Drawing of Bridge	25
4.2	Super Structure of Bridge	25
4.3	Foundation and Sub-Structure of Bridge	26
4.4	Design of Bank Protection	26
5.0	CHAPTER-5:COST ESTIMATE	
5.1	General	31
5.2	Rate Analysis and Unit Rate	31
5.3	Quantification	31
5.4	Project Costing	31
5.5	Points to be Noted	32
5.6	Summary	32

Annexure:

Annexure -A :	Overall Layout Plan
Annexure –B-1 :	River Protection Works(According to Model Study)
Annexure –B-2 :	River Protection Works (Proposed)
Annexure -C :	Survey Plan and River Cross Sections
Annexure -D :	General Alignment Drawing
Annexure -E :	Super Structure of Bridge
Annexure -F :	Sub-Structure of Bridge

VOLUME-II-GEOTECHNICAL

Annexure –G-1 :	Soil Profile and Bore Log, and Calculations
Annexure –G-2 :	Lab Test Results
Annexure –G-3 :	Silt Factor
Annexure –G-4 :	Bearing Capacity

VOLUME-III-COST ESTIMATE

Annexure -H:	Cost Estimate
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CHAPTER 1

INTRODUCTION

1.1 Project Background

The National Highway and Infrastructure Development Corporation Limited (NHIDCL) on behalf of the Ministry of Road Transport & Highway (MORTH&H), has decided to construct a New 4-Lane Carriageway Bridge (Approx. 1200m – Bridge proper) over river Jia Bharali, in district Tezpur in the state of Assam, at Km. 26.100, on the stretch between Dolabari junction on NH-37, to Jamugurihat junction on NH 52 under Engineering Procurement and Construction (EPC) Mode.

This is mostly a green field alignment and will serve as a link between the 2 national Highways namely, NH-52A and NH-37. River Jia Bharali is a tributary of the river Brhamaputra. It is prone to flash floods and high amount of soil deposition, causing meandering of the river.

This proposal includes the consultancy services for ‘good for tender’ design based on detailed investigations, estimation, survey, costing and preparation of technical schedules of EPC documents for construction of 1200 m. long new 4-lane bridge with approaches and river training works over river Jia Bharali in the state of Assam. M/s Xplorer Consultancy Services Pvt Ltd, Gurgaon has been appointed as technical consultants vide letter of Acceptance, Ref. no. NHIDCL/Assam/Dolabari-Jamugiri/2015/278, dated 16/05/2016 for preparation of report and related documents for this work.

The order to commence consultancy services was issued by General Manager (Technical) of National Highway and Infrastructure Development Corporation Limited (NHICL), New Delhi. The Consultants have commenced their services on 24th May, 2016.

1.2 Scope of Work

The broad scope of the assignment is to carry out geotechnical investigation and preparation of tender stage design, drawing and cost estimation of proposed 4-lane bridge including cost estimation for approach roads and river training works. The various activities as described in the OR are as under:

- i. Conduct due diligence on tests/survey conducted earlier by NEHARI, Brahmaputra Board.
- ii. Detailed reconnaissance survey with GPS.
- iii. Topographic survey for the bridge using Total Station as per guide line of latest IRC:SP-19.
- iv. Geotechnical Investigation for proposed 4-Lane Bridge which includes approximately 600 m of drilling/boring work.
- v. Preliminary Design of proposed 4-Line Bridge based on Model Study Report submitted by NEHARI, Brahmaputra Board.
- vi. Preparation of good for tender design/drawing of proposed 4 Lane Bridge.
- vii. Preparation of BOQ and Cost Estimates for Bridge.

- viii. Updating estimated cost for Road work, cross drainage works and river training works as per relevant / current SOR.
- ix. Preparation of bid document including EPC document, as per MORT&H
- x. Providing assistance in bidding process.

1.3 Site Visit

Immediately after receiving the Letter of Acceptance from NHIDCL, vide their letter dated 16.05.2016, a technical team from Xplorer carried out a reconnaissance survey and topographical survey of the project site from 24.05.16 to 30.05.16. This advance action to conduct topographical survey, was taken due to the onset of monsoon. Letter to proceed was received on 21.06.16. Subsequent to the receipt of letter to proceed, available data/reports were reviewed followed by preliminary planning and a site visit by Bridge expert and Geotechnical expert on 26.07.16. Although the right bank was accessible by walk, left bank and other areas of interest were not accessible due to peak monsoon season. The site was not found to be safe for geotechnical investigation due to heavy current and peak flood, which can be taken up only after the flood recedes in mid October. The photos of the visits are presented in Fig.1.1.



Fig.1.1.Site Visit

1.4 GAD of Proposed 4-Lane Bridge

Subsequent to the survey works and site visit a General Arrangement Drawing (GAD) for the proposed 4-lane bridge was prepared and submitted to NHIDCL on 30.08.16. The salient features of the bridge are given in Table 1.1.

Table 1.1. Salient Features

A. PROPOSED 4-LANE BRIDGE	
Type	Simply Supported PSC Box Girder
Waterway	1200 m
No. of Spans	25 nos x 48m each, 45.85m (clear)
Carriageway width	Dual Carriageway, 9.5 m each
Type of foundation	RCC well
No. of piers	24

Well diameter of foundation	12 m for abutments, 10 m for piers
Thickness of Well Cap	2.5 m
Thickness of Well Steining	2.6 m for abutments, 2.2 m for piers
Scour Level	54.76 m for abutments, 44.76 m for piers
Founding Level	30.1 m for abutments, 27.6 m for piers
B. RIVER PROTECTION WORKS	
GUIDE BUND	
Total Length	5464 m
Thickness of Pitching	0.9 m on river side, 0.45 m on country side
Thickness of Filter Media	0.3 m
Thickness of Apron	1.2 m
Width of Apron	31 m for curved part, 21 m for straight part
EMBANKMENT	
Total Length	17618 m
Thickness of Pitching	0.9 m on river side, turfing on country side
Thickness of Filter Media	0.3 m
Thickness of Apron	1.2 m
Width of Apron	12 m
CHANNEL CLOSING DYKE	
Total Length	1000 m
Thickness of Pitching	1.35 m on riverside, 0.9 m on countryside
Thickness of Filter Media	0.3 m
Thickness of Apron	2 m
Width of Apron	39 m
TOTAL PROJECT COST (Including Escalation, Contingency charges, Maintenance charges, etc)	Rs.1263.11 Crores

1.5 Organization of Report

The report is presented as follows

Chapter-I	Introduction
Chapter-II	Review of Model Study
Chapter-III	Survey and Geotechnical Investigation
Chapter-IV	Design of Bridge
Chapter-V	Cost Estimate

CHAPTER -2

REVIEW OF MODEL STUDY REPORT

2.1 General

To evolve a suitable road bridge alignment and its adequate waterway including river training measures, if any, required for the proposed bridge the model studies of river Jia Bhareli were undertaken at the North Eastern Hydraulic and Allied Research Institute (NEHARI). The model was laid out under the overall supervision of Mr.Borgohain, Chief Engineer (I&W), Brahmaputra Board and the model study was carried out under the leadership of Mr.R.K.Baruah, SRO, I/C, Hydraulic Laboratory, NEHARI and was assisted by hydraulic research members of NEHARI. The study was guided by former Chairman of Brahmaputra Board, Dr.T.G.Antony Balan and Shri. Rajan.Sh. M N Singh, CRO, CWPRS, Pune was also associated right from the design, construction and operational of the model. In line with the provision referred by the GREF, Vartak Tezpur, Assam, available data was analyzed and bridge alignment and river training measures were evolved.

2.2 Characteristics of River Jia Bharali

The following are the **Characteristics** of the river behavior:

- It is flashy in nature and braided in pattern.
- The river has a very steep slope, with average slope being 62.5cm per km resulting in high velocity.
- Since the river originates from hilly terrains of Arunachal Pradesh and flows mostly through hills (approximately 166 km out of a total of 229 km), it carries heavy silt from hilly catchment areas during floods and deposits the silt on its bed in plains.
- The width of the river at plain varies from 1 km to 7 km (at the proposed bridge site).

2.3 Hydrological Observation

The gauge, discharge and silt data of Jia Bharali river along the reach was collected for a period of 25 years (1969-1993). In addition to this flood gauge data of 2005 was also collected in four different sites including along the tentative bridge sites. The maximum observed discharge was reported to be 9939 cumecs during 1965 and maximum water level 80.89m during 1970 at NH-52 crossing as per Hydrometeorology of the Brahmaputra Basin prepared by Brahmaputra Board.

2.4 Model Scale

A small scale model of the river was created that included reproduction of flow processes, flow states and events. The following points were considered for setting up of the model,

- The river reach of 20 km length from 4 km upstream of NH-52 to the confluence of Jia Bharali with the Brahmaputra reproduced on the model.
- The scale was decided using Froude Model Law.
- The size of the model tray was 100m x 45m.

2.5 Summary of Results of Model Study

2.5.1 General

Based on the findings of the detailed studies of Jia Bharali river modeling programme at NEHARI, the report describes how the various elements of the proposed bridge and its associated river training works have been represented in the model. The river hydraulics, hydrological parameters, geotechnical characteristics and river morphology were reproduced and how they have contributed to the results of the study and recommendations. The following conclusions on the river behavior were made on the basis of the model study,

- When the flood subsides, the flow of sand is checked and large shoals and chars are formed.
- During flood stage, the position of shoals and chars change constantly.
- Since the fluctuation of flood discharge is very rapid, the transport power is substantially reduced; the chars cannot be washed away.
- Currents go round the chars, and the channels wander in new directions often attacking the banks squarely, causing bank erosion.
- Under the confinement of flow within a certain boundary is required to induce axial flow along the proposed bridge. Hence guide bund has to be supplemented with flood embankment for closure of few temporary flood channels.

2.5.2 Hydrological Parameters

- Design Discharge – 10000 cumecs
- Recommended Waterway – 1200 m
- HFL – 73.76 m
- Scour Level – 44.76 m
- Founding Level – 32.76 m
- Top of Well Cap – 65.10 m
- Silt Factor – 0.77

2.5.3 Bridge Specifications

Based on the findings of the detailed studies of model study, the specifications for bridge were,

- No. of Spans -25 x 48m each, 45.85m (clear)
- Type of foundation-RCC well
- No. of piers- 24
- Well diameter of foundation -6m
- Well Cap- 2.25m thick

2.5.4 River Training Measures

Based on the findings of the detailed studies of model study, the following river training measures were suggested:

➤ **Channel Closing Dyke and Deflecting Spur**

On the left bank of the river, a channel closing dyke of around 1.6 km length has been proposed across the channel at location 488630 E, 2960865 N with impervious core, slope pitching and apron towards river side. This dyke should also be provided with 1 no. solid deflecting spur of 80 m length. The 1.6 km channel closing dyke with 1 no. solid deflecting spur tested in model, produced desired result. However water spills from downstream of the dyke.

➤ **Flood Embankments**

Considering the extent and pattern of bank line shifting in the past, and the extent of spill observed in model, the proposed embankment has been aligned assigning a setback distance from the existing major discharge carrying channel. The spill water is controlled by means of an earthen flood embankment as:

Left Bank

- 1.5 km extension of channel closing dyke towards upstream.
- 5.1 km extension of channel closing dyke towards downstream (up to head of guide bund)

Right Bank

- 4.5 km upstream of proposed bridge (head of the guide bund)
- 4.2 km downstream of proposed bridge(end of the guide bund)

➤ **Guide Bunds**

Guide bunds are used to restrict the flow path of river waterway. It is provided at,

- Upstream guide bund is aligned at an angle 10° with the bridge axis towards right bank side to avoid deep channel. The length of guide bund is 1500m measured from bridge axis.
- Upstream left side guide bund is also aligned at an angle 33° with the bridge axis towards left side covering the confluence of two channels as well as avoiding deep channel. The length of guide bund is 1500m measured from bridge axis.
- A 1690m long guide bank at downstream of bridge beyond the point of avulsion of Jia Bharali into the Morabharali was found adequate to close the avulsion also at right bank.
- A 600m long guide bund at downstream of bridge on left bank.

2.6 Observations in Protection Works

Layout of embankments given in the report on model studies conducted by NEHARI, Brahmaputra Board has been reviewed keeping in view the changes in river alignment as per survey conducted by the consultants and present morphology.

It is presumed that the purpose of constructing the embankments on right and left bank of the river upstream and downstream at the bridge is to protect the habitations, agricultural land and guide the river to the bridge waterway. However the following anomalies have been observed:

- Embankment on right bank in upstream of bridge is not tied to any high ground and ends abruptly on right bank of tributary.
- Since the embankment is tied to upstream of guide bund, there is an area where eddies would form at the junction and may lead to erosion and failure.
- The guide bund on the downstream of the bridge in right bank is in the deep channel of the river. The alignment needs to be shifted towards right on the bank.
- On the left bank the embankment, starts from the end of the guide bund, resulting in formation of a pocket where eddies are likely to be formed during floods.
- Left bank guide bund in downstream of the bridge abruptly ends in the river.
- Embankment on left bank upstream of the bridge ends in the upstream by giving a kink on the river which is likely to act as a attracting spur and the river is likely to get diverted along the embankment.
- A deflecting spur aligned towards upstream of the river is proposed. It appears that the objective is to divert the flow away from the embankments. Though it may be right at this stage, the river Jia Bharali is known to change its flow abruptly and as such this spur may act as an attracting spur.
- It is observed that the stability analysis of the embankment sections have not been carried out, even though the design criteria have been given in Model Study (Pages 10 and 11).
- Protection by way of apron and pitching to embankments and guide bunds.
 - No protection of embankment has been proposed in Model study. However, pitching and apron have been considered on the river side of the left bank, no such provision has been made for right bank. It is observed that both the embankments are vulnerable to erosion by the river.
 - River closing dyke has been provided with pitching of same thickness and apron of same width and height as the rest of the embankment. Since vulnerability of both is of different order, the design should be different. Higher thickness of pitching and wider and thicker apron is required for channel closing dyke.
 - It has been observed that thickness of pitching and width and thickness of apron do not match with the design given in Model Study (Pages 24 & 25)
- Survey:
Even though Brahmaputra Board has carried out topographic and bathymetric survey of the river right from upstream NH-15 bridge up to confluence with the River Brahmaputra, (64 nos of Cross sections at 300 m c/c) data is not available.

2.7 Proposed Remedial Measures in Protection Works

It is proposed to adopt following remedial measures to take care of the above anomalies

- To realign the right bank upstream guide bund and right bank embankment upstream of the end of the guide bund to avert formation of eddies at their junction and tie the



upstream end to the NH-15 embankment to prevent outflanking of the embankment and the bridge from the right bank.

- Similarly realign the left embankment and the left guide bund so as to avoid eddy formation at their junction and extend the embankment and tie up with NH-15 road embankment.
- Eliminate the kink in the embankment at the upstream and eliminate the proposed spur.
- Redesign the protection works to take care of the importance of the structure and also likely erosion.
- Realign the right bank guide bund such that it has to be away from the active river channel.
- Realign the left embankment d/s of end of the d/s left guide bund and tie it up with NH-15 road embankment.
- Stone pitching and apron on the embankments and guide bunds are to be provided on the river side. On the country side provide protection against rain cuts by planting grass.
- Thickness of stone pitching and width and height of apron need to be redesigned as per relevant BIS and IRC codes and standard practices.

The drawing giving old layout plan and proposed layout plan is attached in Annexure-A and the drawings of River protection works are attached in Annexure-B-1.

CHAPTER 3

SURVEY AND GEOTECHNICAL INVESTIGATION

3.1 Site Profile

The place Tezpur, where the bridge is proposed on Jia Bharali river, is a city and Urban Agglomeration and the administrative headquarters and municipal board of Sonitpur district in the state of Assam in northeastern India.



Fig 3.1: Proposed Bridge Location

The **Kameng River** (previously named Bhareli River), now called Kameng in Arunachal Pradesh and Jia Bharali in Assam, originates in Tawang district from the glacial lake below snow-capped Gori Chen mountain. on the India-Tibet border in South Tibet and population exceeding 100,000. It is 175 kilometers (109 mi) northeast of Guwahati, considered to be the "Cultural Capital of Assam". Tezpur is also known as the Most Clean City of Assam because of its clean and green view. It flows through Bhalukpong circle of West Kameng District, Arunachal Pradesh and Sonitpur District of Assam. It is one of the major tributaries of the Brahmaputra River, joining it at Tezpur, just east of the Kolia Bhomora Setu bridge.

3.1.1 Climate

The climatic features of the area covered by the project road are:

Table 3.1: Climatic Condition

1.	Summer	Summer starts from the month of April. This season occupies a major portion of the seasonal calendar, lasting till the month of September. The average temperature during this time of the year is usually 18°C to 36°C. But the highest temperature is recorded during the month of May or early June, just before the start of the monsoon.
2.	Monsoon	The moisture laden southwest monsoon is responsible for the heavy rains in Tezpur, occurring primarily from late June to early September. The average annual rainfall during this time is about 160 cm.
3.	Winter	Winter starts from the month of October till the month of February and are usually cold and dry, with scanty rainfall. It usually tends to get a little foggy or misty during this season, especially during the early morning or in the afternoons. The mercury reading during this time is around 7°C to 22°C.
4.	Spring	Winter season is followed by the spring season, in the month of March and April. A typical feature seen during these months is the occurrence of flash rains and thunderstorms, called Bordoichila in the local parlance.

3.1.2 Geography

The town is on the north bank of the Brahmaputra River. The rivers in and around Tezpur are fast flowing, especially from the Himalayas foothills. Tezpur has a number of small hillocks, so that flooding doesn't occur during the monsoons.

3.1.3 Topography of Site

The proposed bridge to is be constructed over River Jia Bharali, a tributary of river Brahmaputra, in district Tezpur in the state of Assam, at Km. 26.100, on the stretch between Dolabari junction on NH-37, to Jamugurihat junction on NH 52. Entire Project location is generally plain terrain.

3.2 Topographical Survey of Proposed Bridge Site

3.2.1 Reconnaissance Survey

Immediately on the receipt of Letter of Acceptance, pending letter to proceed, a team was sent to site for reconnaissance survey and detailed topographical survey of the proposed 4-lane bridge.

3.2.2 Detailed Survey

The basic objective of the topographic survey is to capture all the essential ground features in the vicinity of the proposed bridge. Detailed survey of the entire area covering the proposed bridge has been carried out by using Electronic Total Stations (ETS). Adequate points were picked up sufficient to generate contours and bridge alignment. Cross-section survey was

performed by using Total station/DGPS and Ecosounder along the selected locations of river Jia Bhareli (i.e.3 nos at upstream, 3 nos at downstream and one at proposed bridge location), using boat as means of conveyance. However, for low water depths, cross section survey was carried out manually. Sufficient numbers of points were taken to draw a representative section. Raw survey data downloaded from ETS were processed using Civil3D software to generate Digital Terrain Model (DTM). Contours were generated from DTM. Plan showing topographic features are developed in AutoCAD and represented as drawings with suitable scale. The survey plan and the cross section drawing are given in Annexure-C. Photo of survey work is given below in Fig.3.2



Fig.3.2. Survey work near proposed bridge location

3.2.3 Reference Pillars

Eight numbers of reference pillars of size 150mmx150mmx1200mm have been constructed for future reference. Reference pillars are made of plain cement concrete of M-20 grade with 20mm and down size graded stone aggregates. The coordinates and photos of reference pillars are given in Table 3.2.

Table 3.2: Co-ordinates and photos of reference pillars

SI No.	BM No.	Northing	Easting	RL	Photos
1	BM1	2954131.355	485294.741	70.272	
2	BM2	2954336.818	485258.456	69.559	
3	BM3	2954064.875	485057.677	69.654	
4	BM4	2954031.842	484923.743	69.561	

Sl No.	BM No.	Northing	Easting	RL	Photos
5	BM5	2954419.662	486879.402	70.649	
6	BM6	2954401.450	487104.956	70.428	
7	BM7	2954513.825	487248.786	70.479	
8	BM8	2954557.689	487415.799	70.928	

3.2.4 Survey of River Protection Works

After consultation with client, it was decided that the protection works suggested by Brahmaputra board in its model study report in the year 2007, called for a review with respect to present scenario. Accordingly, a new alignment was proposed. To assess the alignment of the

river protection works, survey of the proposed alignment and existing embankment was done. The survey of proposed alignment was conducted to acquire the ground levels along the alignment at fixed intervals. For existing embankment, cross section was taken along the alignment at fixed intervals. Since there was an embankment already present, a more feasible option was to consider the existing embankment in the proposed alignment as much as possible. Accordingly, the alignment of proposed embankment was fixed. The photos are given below in Fig 3.3. The L-section of proposed alignment and typical cross section of the proposed embankment is given in Annexure-B-2.



Fig 3.3.a) Existing Embankment

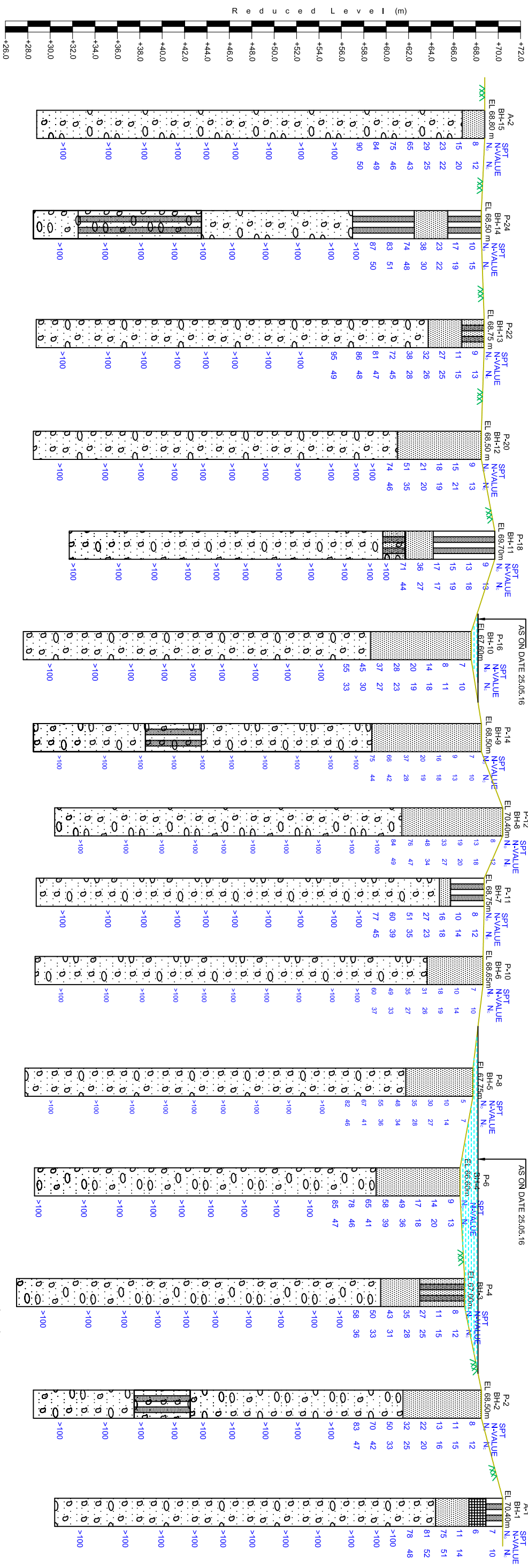
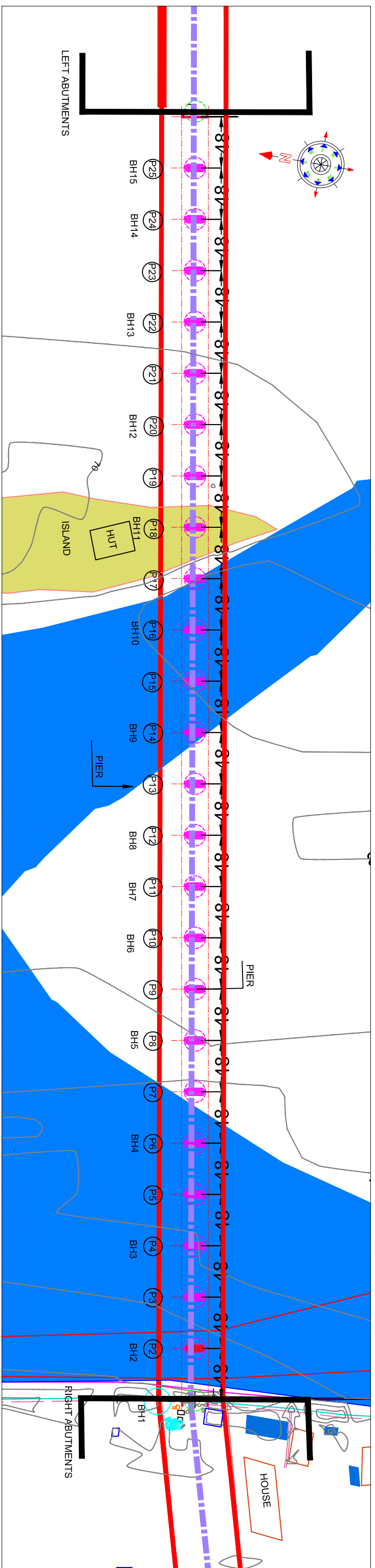
b) Survey along the proposed alignment

3.3 Geotechnical Investigation

To assess the founding strata the TOR required 15 boreholes of 40 m deep, i.e., a total of about 600m of boring/drilling. As the river is flashy in nature it was not safe to carry out geotechnical investigation in the river bed during monsoon which extends up to end of October. Two drilling machines have been mobilized at site on 30.09.16.

3.3.1 Boring/Drilling

Boreholes are sunk by deploying mechanical/hydraulic rotary drilling machine conforming to IS: 1892. Boring is being effected by rotating of bit providing casing at the top layer, to stabilize the side of the bore. Boreholes are taken up to the desired depth of 40.0m. SPTs are conducted at regular intervals. Since the strata from about 6 m depths consists of pebbles/boulders, diamond bits are being used wherever needed along with installation of casing. Wherever possible, undisturbed samples are collected at regular intervals. Borelog are presented in Annexure-G-1 and Soil profile is presented in drawing below.



Legends:

	Silty SAND (SM)		Poorly Graded SAND with Pebbles (SP)
	Silty CLAY (CL)		Well Graded SAND with SILT (SW-SM)
	Poorly Graded SAND (SP)		

CLIENT:

National Highways and Infrastructure Development Corporation Limited

PROJECT:

4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4-Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamaighat Road Junction, KM 182.00 of NH-52) in Sonpur District in the State of Assam.

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REVISION		SCALE	
DATE		NTS	
DRAWN		SHEET SIZE	
DESIGNED			
CHECKED			
APPROVED			

BOREHOLE LOCATION PLAN AND SOIL PROFILE

Photos of boring at different locations are shown in Fig 3.3.



Fig 3.3a) Boring at Right abutment (BH-1)



b) Boring at Pier -18 (BH-11)



Fig 3.3 c) Boring at Pier -14 (BH-9)



d) Boring at Pier -2 (BH-2)

3.3.2 Undisturbed Sampling

As the soil strata are non plastic in nature undisturbed samples could not be collected at this location. However sufficient disturbed samples were collected for relevant laboratory tests.

3.3.3 Standard Penetration Tests (SPT)

The first SPT was conducted at 0.5m depth from the existing ground level and thereafter at 1.5 m intervals, conducting last SPT at termination depth. SPT has been conducted as per IS 2131-1981 “Method of standard penetration tests for soils”.

The split spoon sampler used is of standard design and dimension. The spoon is advanced by driving with a drop hammer weighing 63.5 kg falling freely through a height of 75 cm. A record of the number of blows required to penetrate every 15 cm to a depth of 45cm is recorded. The

number of blows required for the last 30 cm penetration of the split spoon sampler is recorded as 'N'-value. On completion of the test, the sampler is lifted to the ground, opened and the specimen of the soil sample is stored in double polythene bags with proper identification mark. The penetration number, 'N' has been shown against the corresponding depths in bore logs.

3.3.4. Laboratory tests

Following laboratory tests have been conducted.

- Specific Gravity
- Grain size analysis
- Direct shear test
- Chemical analysis of soil

3.3.5 Laboratory Test Procedure

All the laboratory tests have been performed in the NABL accredited laboratory of M/S XPLORER, as per relevant IS Codes and in accordance with the terms of accreditation. The briefed methodology of laboratory tests is furnished below:

➤ Specific Gravity

The sample is dried overnight in an oven at 110° C, cooled in desiccators, grind and sieved through 425 μ IS Sieve. About 10gm of sieved sample is taken in a specific gravity bottle and sufficient distilled water is added to just cover the soil and left for soaking for 10-15 minutes. After which it is shaken well and more distilled water added to fill the bottle about half. It is then placed in a sand bath to de-air. After air is totally removed, it is cooled and filled completely with water.

Various weights, i.e. weight of empty bottle, weight of bottle filled with water, weight of bottle filled with water and sample, etc. are taken, from which specific gravity is calculated.

➤ Grain size Analysis

The grain size analysis is carried out utilizing both sieve and hydrometer analysis. The sieve analysis is carried out by wet sieving method in which the material is first washed through a 4.75 mm test sieve nested in a 75 μ m test sieve. The soil passing through the 4.75mm sieve is dried in an oven. The dried soil then sieved by passing through a series of square mesh sieves, which become progressively finer down to 75 μ m mesh. Each fraction thus collected then weighed and the percentage retained on each sieve is calculated, dividing individual weights by the total sample weight.

The soil passing through 75 μ m mesh is analysed by sedimentation, using hydrometer method. The hydrometer method involves measuring the rate of settlement of fine particles suspended in a solution. Utilizing the principle of Stokes' law, particle size can be directly related to its rate of settlement in a fluid such as water. From this process, the particle diameter and percentage finer is calculated



Fig 3.4 Grain Size analysis

➤ **Direct Shear Test**

This test is performed on remolded sandy soil. The specimens for the test are prepared to estimate density, based on SPT values. Three specimens are tested to get the shear strength profile. The tests are performed under normal stresses of 50, 100 and 150 kPa.



Fig 3.5: Performing Direct Shear

➤ **Chemical Analysis of Soil and water**

Chemical analysis of soil samples were carried out to determine of pH, total SO₃ and Chloride contents. The tests were carried out as per relevant IS code.

Measurement of pH

20gm of soil sample is mixed with 50ml of distilled water. The suspension is stirred for few seconds and is allowed to stand for 1 hour with occasional stirring. It is stirred again, immediately before testing.

The pH meter is calibrated with standard buffers and the pH of the soil suspension is measured.

Determination of Chloride Contents

40 gm of soil sample passing 2mm sieve is mixed with 200 ml of distilled water adding a pinch of potassium nitrate. The solution is allowed to stand for 16 hours.

The solution is then filtered and 25 ml of filtered sample is taken in a conical flask. The pH value of the solution is adjusted to 7 to 8 by adding sulphuric acid or Sodium Hydroxide solution. 1 ml of Potassium chromate is added to the solution to develop yellow color. The solution is then titrated by using 0.014N Silver Nitrate solution till brick red color develops. Note down the burette reading V1 and V2. The chloride content is then calculated as follows:

$$\text{Chloride (mg/l)} = (V2-V1) \times 35.46 \times 1000 \times N / (\text{ml of sample taken})$$

V1 = Initial burette reading

V2= Final burette reading

Determination of Sulphate Contents

10 gm of 425 μ passing soil samples is taken in a 250 ml reagent bottle and 100 ml of distilled water is added to it. The mixture is given occasional shaking for 2 hours and the suspension is allowed to stand overnight. The solution is then filtered with Whatman No. 1 filter paper. 25ml of the filtrate is taken in a beaker and concentrated Hydrochloric acid is added and boiled. Barium Chloride Solution is then added to it and allowed precipitate to settle and digest the ppt. at low temperature on a hot plate for 30 minutes. The precipitate is then filtered with Whatman No. 42 filter paper and wash with hot water till it is chloride free. The filter paper is then ignited at 700°C in a muffle furnace in a weighed crucible (W1). Cool the crucible in desiccators and weigh (W2).

$$\text{Sulphates (as SO}_4\text{), by mass} = (W2-W1) * 41.15$$

3.3.6 Design Subsoil Profile

Based on the perusal of field conditions and laboratory test as shown in Annexure-G-2, subsurface profile along with design parameters have been selected duly considering all the field and laboratory test results and presented in Table 3.4

Table 3.4.Subsoil Profile

Profile No.	Soil layer	Depth(m)		Thickness	Soil Type	SPT Value		C	°
		From (m)	To (m)	(m)		Obs.	Corr.	KPa	
	Layer No.	Depth below G.L	Depth below G.L						
PROFILE 1 (For Abutment)	I	0	2	2	Loose Grey Silty Sand	7	10	0	29
	II	2	4	2	Silty Clay with pocket of Sand	6		30	0
	III	4	10	6	Grey Fine Sand	11	14	0	32
	IV	10	20	10	Very Dense coarse to medium SAND with boulders and small pebbles	>100		0	34
	V	20	30	10	Very Dense coarse to medium SAND with boulders and small pebbles	>100		0	36
	VI	30	40	10	Very Dense coarse to medium SAND with boulders and small pebbles	>100		0	38
PROFILE 2 (For Pier)	I	0	3	3	Loose Grey Silty Sand	8	12	0	29
	II	3	10	7	Medium Dense to Dense Poorly graded SAND	30	27	0	33
	III	10	20	10	Very Dense coarse to medium SAND with boulders and small pebbles	>100		0	34
	IV	20	30	10	Very Dense coarse to medium SAND with boulders and small pebbles	>100		0	36
	V	30	40	10	Very Dense coarse to medium SAND with boulders and small pebbles	>100		0	38

3.3.7 Silt Factor

The silt factor (f) has been computed as per IRC:5-1998, using weighted average particle size obtained from grain size distribution of soil samples collected.

$$f = 1.76 * (d_m)^{0.5}$$

Where d_m is weighted mean diameter in mm. The computed silt factor is presented in Table 3.5.

Table 3.5: Silt Factor

Sl. No.	Location	Sample No.	Depth(m)	Weighted Mean Diameter (mm)	Silt factor at various depths
1	Abutment-A1-BH-1	SPT 4	6.00-6.45	0.77	1.54
		SPT 6	9.00-9.45	1.35	2.05
		SPT 8	12.00-12.35	1.65	2.26
		SPT 10	18.00-18.20	1.60	2.23
		SPT 11	21.00-21.26	1.40	2.09
		SPT 12	24.00-24.28	1.39	2.07
2	Pier-P2-BH-2	SPT 2	3.00-3.45	1.67	2.27
		SPT 3	4.50-4.95	1.28	1.99
		SPT 5	7.50-7.95	1.34	2.04
		SPT 7	10.50-10.95	2.66	2.87
		SPT 9	15.00-15.20	1.62	2.24
		SPT 11	21.00-21.05	2.53	2.80
3	Pier-P4-BH-3	SPT 2	3.00-3.45	0.51	1.25
		SPT 4	6.00-6.45	1.23	1.95
		SPT 6	9.00-9.45	0.91	1.68
		SPT 7	10.50-10.95	0.63	1.40
		SPT 9	15.00-15.20	2.70	2.89
		SPT 11	21.00-21.05	3.10	3.10
4	Pier-P6-BH-4	SPT 2	3.00-3.45	1.17	1.90
		SPT 4	6.00-6.45	1.59	2.22
		SPT 6	9.00-9.45	1.24	1.96
		SPT 7	10.50-10.95	2.12	2.56
		SPT 9	15.00-15.20	2.28	2.66
		SPT 11	21.00-21.05	2.29	2.67
5	Pier-P8-BH-5	SPT 1	1.50-1.95	0.90	1.67
		SPT 3	4.50-4.95	0.79	1.56
		SPT 5	7.50-7.95	1.73	2.32
		SPT 7	10.50-10.95	1.56	2.20
		SPT 9	15.00-15.20	1.43	2.10
		SPT 11	21.00-21.05	1.53	2.18
6	Pier-P10-BH-6	SPT 1	1.50-1.95	1.76	2.33
		SPT 3	4.50-4.95	1.93	2.44
		SPT 5	7.50-7.95	1.74	2.32
		SPT 7	10.50-10.95	1.84	2.39
		SPT 9	15.00-15.20	1.64	2.25
		SPT 11	21.00-21.05	1.20	1.92
7	Pier-P11-BH-7	SPT 4	6.00-6.45	1.58	2.21
		SPT 5	7.50-7.95	1.71	2.30
		SPT 6	9.00-9.45	1.06	1.81
		SPT 8	12.00-12.35	1.89	2.42
		SPT 9	15.00-15.20	2.15	2.58
		SPT 10	18.00-18.20	2.19	2.60

Sl. No.	Location	Sample No.	Depth(m)	Weighted Mean Diameter (mm)	Silt factor at various depths
8	Pier-P12-BH-8	SPT 2	3.00-3.45	0.39	1.10
		SPT 4	6.00-6.45	0.41	1.13
		SPT 7	10.50-10.95	0.50	1.25
		SPT 8	12.00-12.25	0.56	1.32
		SPT 10	18.00-18.22	0.52	1.27
		SPT 11	21.00-21.05	0.85	1.62
		SPT 13	25.00-25.15	0.51	1.26
9	Pier-P14-BH-9	SPT 2	3.00-3.45	0.39	1.10
		SPT 4	6.00-6.45	0.41	1.13
		SPT 6	9.00-9.45	0.97	1.73
		SPT 9	15.00-15.25	0.67	1.44
		SPT 11	21.00-21.26	0.48	1.22
10	Pier-P16-BH-10	SPT 2	3.00-3.45	1.15	1.89
		SPT 4	6.00-6.45	0.63	1.40
		SPT 6	9.00-9.45	1.09	1.84
		SPT 9	15.00-15.25	0.67	1.44
		SPT 11	21.00-21.26	2.34	2.69
11	Pier-P18-BH-11	SPT 3	4.50-4.95	0.81	1.59
		SPT 5	7.50-7.95	0.37	1.07
		SPT 6	9.00-9.45	1.01	1.77
		SPT 9	15.00-15.25	1.42	2.10
		SPT 10	18.00-18.25	0.59	1.35
		SPT 12	24.00-24.28	1.39	2.07
12	Pier-P20-BH-12	SPT 2	3.00-3.45	0.32	0.99
		SPT 4	6.00-6.45	0.95	1.72
		SPT 7	10.50-10.95	1.65	2.26
		SPT 9	15.00-15.25	1.62	2.24
		SPT 10	18.00-18.25	0.98	1.74
		SPT 12	24.00-24.28	0.96	1.72
13	Pier-P22-BH-13	SPT 1	1.50-1.95	0.40	1.12
		SPT 3	4.50-4.95	0.40	1.12
		SPT 6	9.00-9.45	1.34	2.04
		SPT 8	12.00-12.25	0.87	1.64
		SPT 10	18.00-18.22	1.04	1.80
14	Pier-P24-BH-14	SPT 2	3.00-3.45	1.07	1.82
		SPT 4	6.00-6.45	2.26	2.65
		SPT 6	9.00-9.45	0.37	1.07
		SPT 8	12.00-12.35	2.30	2.67
		SPT 10	18.00-18.20	1.48	2.14
		SPT 12	24.00-24.28	1.23	1.95
15	Abutment-A2-BH-15	SPT 2	3.00-3.45	1.91	2.43
		SPT 4	6.00-6.45	1.76	2.34
		SPT 6	9.00-9.45	1.81	2.37
		SPT 8	12.00-12.35	2.79	2.94
		SPT 10	18.00-18.20	1.64	2.25

Detailed Calculations are presented in **Annexure-D-3**

3.3.8 Well Foundation

Well capacity has been calculated as circular open foundations resting at deeper depths in bouldery strata. The design angle of friction has been restricted to 35°. No skin friction has been taken into account while estimating bearing capacity. The recommended bearing capacity of well foundation is presented in table 3.6

Table 3.6 Recommended Well Capacities

Structure	Design Scour Level (m)	Depth of Foundation Below Scour Level (m)	Founding Level (m)	Founding Strata	Well Diameter (m)	Net Safe Bearing capacity (kPa)	Recommended Safe Bearing capacity (kPa)
Jia Bhareli Bridge- Abutment	54	12	30	Very dense Poorly graded Sand with gravels and pebbles	10	2200	800
					12	2200	800
Jia Bhareli Bridge- Pier	44	7	27	Very dense Poorly graded Sand with gravels and pebbles and pebbles	10	1300	800
					12	1330	800

Detailed Calculations are presented in **Annexure-D-4**

3.3.9 Recommendation on Chemical Analysis of Subsoil

A summary of chemical analysis results of soil is presented in Table 3.7.

Table 3.7: Summary of Chemical Analysis Results

S.No	Location	Sample. No.	Soil		
			SO ₃ (mg/l)	Cl (mg/l)	pH value
1	A-1- BH-1	SPT-8 (12.00-12.35)	Nil	139	7.69
		SPT-13(26.00-26.10)	Nil	258.15	7.51
2	P-2 BH-2	SPT-3 (4.50-4.95)	NIL	99.29	7.53
3	P-4 BH-3	SPT-9 (15.00-15.38)	NIL	89.36	7.08
4	P-6 BH-4	SPT-9 (15.00-15.38)	NIL	109.22	7.01
5	P-8 BH-5	SPT-9 (15.00-15.38)	17.15	119.15	7.28

S.No	Location	Sample. No.	Soil		
			SO ₃ (mg/l)	Cl (mg/l)	pH value
6	P-10 BH-6	SPT-3 (4.50-4.95)	NIL	99.29	7.13
2	P-11, BH-7	SPT-8 (12.00-12.35)	Nil	139	6.92
		SPT-14 (29.00-29.18)	Nil	129.07	7.09
3	P-12, BH-8	SPT-7 (10.50-10.95)	Nil	129.07	6.87
		SPT-13(26.00-26.10)	Nil	99.29	6.97
4	P-14, BH-9	SPT-6 (9.00-9.45)	Nil	119.15	6.69
		SPT-14(29.00-29.18)	Nil	109.22	6.48
5	P-16, BH-10	SPT-6 (9.00-9.45)	Nil	119.15	6.89
		SPT-13 (26.00-26.10)	Nil	109.22	6.82
6	P-18, BH-11	SPT-6 (9.00-9.45)	Nil	119.15	6.37
		SPT-12 (24.00-24.35)	Nil	99.29	6.42
7	P-20, BH-12	SPT-7 (10.50-10.95)	Nil	99.29	6.64
		SPT-14 (29.00-29.18)	Nil	139	7.28
8	P-22, BH-13	SPT-6 (9.00-9.45)	Nil	59.57	7.2
		SPT-12 (24.00-24.35)	Nil	139	6.9
9	P-24, BH-14	SPT-6 (9.00-9.45)	Nil	119.15	7.05
		SPT-12 (24.00-24.35)	Nil	139	6.95
10	A-2, BH-15	SPT-6 (9.00-9.45)	Nil	129.07	7.12
		SPT-13 (26.00-26.10)	Nil	129.07	6.71

As per Table 3, IS: 456-2000, the exposure conditions for foundation works is low. As seen from the chemical analysis results in Table 6.5 the pH value is in near neutral condition (Between 6 to 9) and sulphate contents fall in Class 1 of Table 4 of IS: 456-2000. Hence, no special precaution is envisaged for underground structures.

There is no specific recommendation in IS: 456 as regard to allowable limits of chloride in ground water or soil. Warnings on chlorides in concrete are given in terms of chlorides coming from mix



constituents like use of chloride based admixtures or contaminated aggregates rather than penetration of chlorides into concrete from environment. However, the chloride contents are found to be generally low (<0.1% in soil).

CHAPTER 4

DESIGN OF BRIDGE

4.1 GAD (General Alignment Drawing)

The design of various components of the proposed bridge is carried out as per the findings of the various surveys and investigations, carried out and in consonance with relevant IRC and IS codes. Based on the design, the GAD for the proposed bridges has been developed. The GAD has been presented in Annexure-D

4.2 Super Structure

The design note pertains to design of simply supported PSC Box Girder of span length 48.0m with 9.5m carriageway.

GEOMETRIC DATA

Statical Scheme	Simply Supported Box Girder
Span Length	48.0m
Carriageway Width	9.5m
Wearing Coat Thickness	65.0mm
Crash Barrier Width one sided	0.5m
Crash Barrier Width two sided	1.2m
Height of the Crash Barrier	1.0m
Length of the Cantilever	4.0m
Deck Slab Width	25.2m
Soffit Slab Width	14.6m
Deck Slab Thickness (at mid span)	0.30m
Soffit Slab Thickness (at mid span)	0.36m
Web Thickness (at mid span)	0.4m
Haunch at Deck Slab	450X150
Haunch at Soffit Slab	450X150
Depth of Box-Girder (at center)	3.0m
Live Load	As per IRC:6-2014
Seismic Zone	v
Type of Bearing	Spherical Bearing

REFERENCES:

IRC :6-2014
IRC : 112-2011

STRUCTURAL DESIGN DATA:

Grade of Concrete	M-45
Grade of Reinforcement Steel	HYSDFe-500D
Pre stressing Steel	High Tensile Strands of 15.2mm dia conforming to Class:2 of IS:14268-1995

4.2.1 Design Basis and Assumptions

The design for Box Girder is based on the following assumptions:

- a. Simply supported, single cell, Pre-stressed concrete (post tensioned) box girder is proposed. A uniform wearing coat of 65 mm (40mm BC and 25mm mastic asphalt) is considered for design over deck slab in carriageway portion.
- b. The bending moment and shear forces due to Dead Load, Superimposed Dead Load and Live Loads shall be worked out based on Simple Beam Theory, considering centre to centre of bearing as span length.
- c. Four Lane of Class-A or Two Lane of 70-R or One lane of 70-R and Two lane of Class A along with uniform load of 500kg/m^2 has been considered as live load for design of PSC Box Girder as per IRC: 6-2014.
- d. To account for torsion, distortion and warping the live load bending moments and shear forces are increased by 10%.
- e. It is proposed to use 19 T 15 cables conforming to IS: 14268 with corrugated HDPE sheathing for pre-stressing.
- i. The friction and Wobble co-efficient for pre-stressing strands considered in the design are $\mu=0.17$ and $k= 0.002$ respectively.
- f. All instantaneous and time dependent losses due to pre-stressing have been calculated as per Clauses specified in IRC: 112.
- g. Stress check of PSC Box Girder has been done considering both Superior (Factor 1.1) and Inferior (Factor 0.9) effects of pre-stressing as specified in IRC: 112.
- h. Permissible values of stresses in different stages have been taken as specified in IRC: 112-2011.
- i. Ultimate resistance of box girder in flexure has been checked as per Clauses specified in IRC: 112.
- j. Section cracked or uncracked in flexure has been decided based on whether the maximum ultimate shear capacity of the sections governs by cracked or uncracked capacity. At locations where uncracked capacity governs there life due to vertical component of pre-stress has been considered.
- k. For temperature analysis along depth, box has been modeled as an equivalent T Beam and analysis has been done accordingly.
- l. In the transverse direction the box has been analyzed as R.C.C section. The box has been idealized as a plane considering unit width of box. The load intensities due to live load are applied on the frame considering the width over which they are dispersed as per I.R.C codes.
- m. Untensioned reinforcement has been provided as per calculation of reinforcement requirement derived from both Transverse as well as longitudinal analysis.
- n. End diaphragm has been analyzed considering Tie & Strut Model and reinforcement has been provided accordingly.
- o. Spherical Bearing has been designed as per IRC:83PartIV

The detailed drawing of super structure of the bridge is presented in Annexure-E

4.3 Foundation and Sub-Structure

The preliminary design calculations of foundation and sub structure along with design data, load combinations, etc. are presented in Annexure-F.

4.4 Design of Bank Protection

4.4.1 River Behavior Characteristics

The proposed bridge on river Jia Bharali is located at about 9 km u/s of its confluence with the river Brahmaputra. There are two existing bridges at about 12 km u/s of the proposed bridge; one road bridge (NH15) and the other is the railway bridge slightly u/s of the road bridge. The span

of U/S road bridge is of about 400 m. The river gradient is about 0.7m/km at U/S Road Bridge (NH15.Immediately D/S of the road bridge, it flattened down to 0.4m/km at the proposed bridge. The gradient further flattens and is zero at its confluence with river Brahmaputra.

The river carries a high sediment load and it deposits most of it on its way to the confluence with Brahmaputra. As a result river exhibits braiding and branching tendency. The river bank and bed are composed of poorly graded sand with silt, and as such is vulnerable to erosion at even slight concentration of flow.

4.4.2. River Training and Flood Control Works

Type of River Training works

For guiding the flow towards the bridge and to ensure that it remains concentrated between 1200 m span of bridge, following river training works are proposed:

- 1.Guide Bunds
- 2.Flood Embankments
- 3.Channel Closing Dyke

4.4.3. Sources of Data

Data for design of river training works are taken from the Report of Model studies of Jia Bharali, carried out by the Brahmaputra Board in the year 2007 and the actual topographic and geotechnical surveys carried out by the consultant.

4.4.3.1 Topographic Survey

The consultants have carried out topographic survey of the area around the bridge axis and the right and left guide bunds. The consultants have also carried out survey along the existing flood embankments and the alignment of the proposed embankment, both on the right and left bank in U/S, up to the existing NH Road bridge and in the D/S, up to the end of the proposed embankment. The consultants approached the Brahmaputra Board officials for obtaining the reference to the GTS benchmark they used for the survey of the river in 2005-2006 also the survey data collected by them in 2005-2006 and on the basis of which the physical model of the river from the u/s NH Bridge to the confluence with the Brahmaputra was developed by them. Reportedly they took 64 river cross sections .But they could not locate the data. We also approached the CWC officials, in charge of river gauge sites and also the CWC officials at their Guwahati office. But they refused to part with the information telling that the NHIDCL has to approach them with official requisition to them and they would be able to give the information to them only after approval by competent authority. However, CWC officials posted at the gauge site on river Brahmaputra and the NH 15 bridge on river Jia Bharali, showed us the locations of the Temporary Bench Marks (TBM) at the gauge sites. The values of RL's painted on top of the TBM's were obtained from field staff. The levels were carried out by leveling from the TBM on Brahmaputra gauge site and closed at NH 15 Road bridge on river Jia Bharali. The closing error was distributed over all the intermediate levels taken along the alignments of the proposed embankments as per principles of surveying in line with relevant Indian Standards.

The alignments of the proposed embankments were plotted and are enclosed at Annexure-A

4.4.3.2 Model Study

Based on the results of Model study report, 100 year return interval flood estimated on the basis of observed flood peaks during 1969 to 1993 and estimated discharge during the flood of year 1965, which is reportedly the highest observed flood. The model study boundaries extend in the U/S to existing Road Bridge and in the D/S to the confluence of river Jia Bharali with the river Brahmaputra. The results of model studies to be adopted for design of river training works are listed below,

4.4.3.3 Design Discharge

Hundred year return interval flood has been adopted as design flood. Estimated design flood is 10000 cumecs.

4.4.3.4 Design HFL

Design HFL corresponding to 10000 cumecs based on Model studies results at existing NH Road Bridge in u/s and other points in the d/s including on at bridge site has been adopted as design HFL. The design HFL along the left bank and right bank embankments including closure dyke has been obtained with straight line interpolation.

4.4.3.5 Alignment of Right Bank Embankment

The alignment of the right bank embankment u/s has been revised vis-à-vis that given in Model studies report. As discussed in the earlier meeting held on 21.10.16 with client's officials. This is also aligned along the existing flood embankment in u/s and d/s of the bridge to the extent feasible to minimize land acquisition. At the U/S end, it has been aligned such as to protect maximum number of habitations and tied with NH-17 embankment instead of just terminating on the right bank of the tributary of the river Jia Bharali just before joining the Jia Bharali river. Since the tributary is liable to erode its right bank, there is every possibility of the river flowing behind the embankment and flooding the habitations and damage the approach road to the proposed bridge.

The same is the case with D/S right bank embankment, except that there is no high ground in the d/s to which it can be tied and the NH-15 road is at about 12 km distance. However, it has been realigned to some extent to protect villages on river side of earlier alignments and D/S end is tied to locally available high ground (Not above HFL).

4.4.3.6 Alignment of Left Bank Embankment

The following are the highlights of the left bank embankments:

This starts from the U/S end of the left bank guide bund. The alignment has been revised slightly to protect the habitations and tied to the D/S end of the closure dyke. U/S end of the closure dyke has been extended to join the left bank of the NH 15 Road bridge. This prevents the possibility of the river taking a tilt towards the left and outflanking the U/S end of the closure dyke and damaging the habitations and the left bank approach roads to the proposed bridge.

4.4.3.7 Spill Channel Closure Dyke

The alignment of the Closure Dyke has been modified and taken towards the country side so as to cross at the least width of the channel. It has been extended to about 250 m on either end and tied to the left bank embankment. It

4.4.3.8 Right Bank Guide Bunds

U/S right bank guide bund alignment is virtually the same as in model studies. Its u/s end is tied to the left bank embankment. D/S right bank guide bund has been realigned slightly towards the country side because the alignment as given in Model studies report falls in the deep river channel. It is also to point out that deflecting spur near the U/S end of the dyke has been removed as it is considered necessary in view of tying to U/S end to NH-15 bridge. Further isolated spur are likely to impact stability of the river bank in U/S.

4.4.3.9 Left Bank Guide Bunds

The alignment of u/s and d/s left bank guide bunds have been kept unchanged.

4.4.4. Protection Works

4.4.4.1 General

Stone pitching in the form of stone pitching is laid over filter consisting of 300 mm coarse sand layer with launching apron at the toe of the embankment.

The thickness of stone pitching and weight of each stone or wire crate filled with stones and tied to each other, depends upon the velocity and direction of flow along the embankment and type of the bank material. Similarly size of wire mesh should be bigger than the size of the smallest stone in the crate. These parameters as well as the width and height of the launching apron depend upon the unit flow, type of river bed material and the likely scour along the embankments, the guide bunds and the Closure Dyke. These parameters are to be decided in accordance with IRC:89, CWC Handbook on Guide bunds and Flood protection embankments and relevant BIS codes.

4.4.4.2 Guide Bund

Top width of guide bunds has been kept as 6 m and side slopes of 2 horizontal:1 vertical (2H:1V) with height equal to the depth of flow over the river bed and freeboard of 2 m.

0.9 m thick stone pitching in wire crates of size 1m x 1m x 0.45m in two layers has been provided on river side slope of the guide bunds. Country side bank slope has been protected with 0.45 m thick stone pitching of river boulders and with toe drain of size 0.9m (depth) x 0.9m (bottom width) with slope of 1H:1V. Below the stone pitching filter layer comprising of 300 mm layer of coarse sand has been provided, both on river side as well as country side slope. Launching apron size is taken as 31m x 1.2m for curved portions and 21m x 1.2 m for straight portions in wire crates of size 1.5m x 1.5m x 0.45m in two layers.

River side of the embankments has to be designed considering a scour of 2.25R on the nose (crucial portion), 1.5R on the straight portion and 1.25 R on the country side of guide bund. R is Lacey's scour depth calculated from the formulae

$$R=0.473x\left(\frac{Q}{f}\right)^{1/3} \text{ or } R=1.34 x\left(\frac{q^2}{f}\right)^{1/3}$$

Where Q= Design discharge

q= unit discharge

f= silt factor, estimated from the formula $1.76(D_m)^{1/2}$ where D_m is the mean diameter of the bed material

4.4.4.3 Flood Protection Embankment

Top width of embankment has been kept as 6 m and side slopes of 2 horizontal:1 vertical with height equal to the depth of flow over the river bed and freeboard of 2 m. Size of Launching Apron considered for embankments is 12m x 1.2m along the length of the embankment on river side. Wire crate in 2 layers of size 1.5mx1.5mX 0.6m has been provided for the launching apron.

In addition to above on country side turfing with grass with stone filled toe drain of size of depth 0.9m, bottom width 0.9m and side slopes of drain 1H:1V, below the ground level along the embankment with discharge in to the river side of the embankments at regular intervals of 1 to 2 km.

4.4.4.4 Channel Closing Dyke

It has been extended to about 250 m on either end of the channel to be closed. The top width of embankment has been kept as 6 m and side slopes of 2 horizontal:1 vertical with height equal to the depth of flow over the river bed and freeboard of 2 m. The thickness of pitching on river side of dyke has been kept as 1.5 m in crates of size 1mx1mX 0.75m and on country side as 0.9 m with loose boulders. Size of Launching Apron considered for embankments is 39m x 2m along the length of the dyke. Wire crate in 2 layers of size 1.5m x1.5m x 1m has been provided for the launching apron.

CHAPTER 5

COST ESTIMATE

5.1 General

The cost estimates have been prepared for the bridge as well as the entire road from Dolabari Junction to Jamugurighat Junction including river protection works. Cost estimates are presented in Annexure-H.

The item of works for bridge and approach road have been identified and unit rates for principal items are arrived at using Standard Data Book of MOSRTH and rates for prime items such as labor, material etc. applicable to the concerned project area. The usage charges of important equipment of road and bridge items have been worked out from first principles using output, fuel consumption approaches.

5.2 Rate Analysis and Unit Rate

The item of works for bridge and approach road have been identified and unit rates for principal items are arrived at using Standard Data Book of MOSRTH and rates for prime items such as labor, material etc. applicable to the concerned project area.

The basic rates obtained were duly marked up for various allowances and cess charges.

5.3 Quantification

The quantification of the construction items has been carried out based on the detailed drawings.

5.4 Project Costing

The project cost at current cost level has been worked out. The cost is based on the unit rates analyzed for various items of work.

The following items have been considered for arriving at the quantities.

- Site Clearance and Dismantling
- Earthwork
- Base and Sub-base courses
- Bituminous Courses
- Drainage and Protective Works
- Safety Works(Traffic Island, Traffic Signs, Markings and Road Appurtenances)
- Miscellaneous
- Bridges and Structures

5.5 Points to be noted

The following points are to be noted

- The rates have been updated as per SOR of 2013-14.
- The rate and quantity of the proposed bridge has been updated as per the design.
- In river protection works, for embankment pitching has been considered only on river side. On country side, turfing has been considered.
- For guide bund and dyke , pitching has been considered on both sides.

5.6 Summary

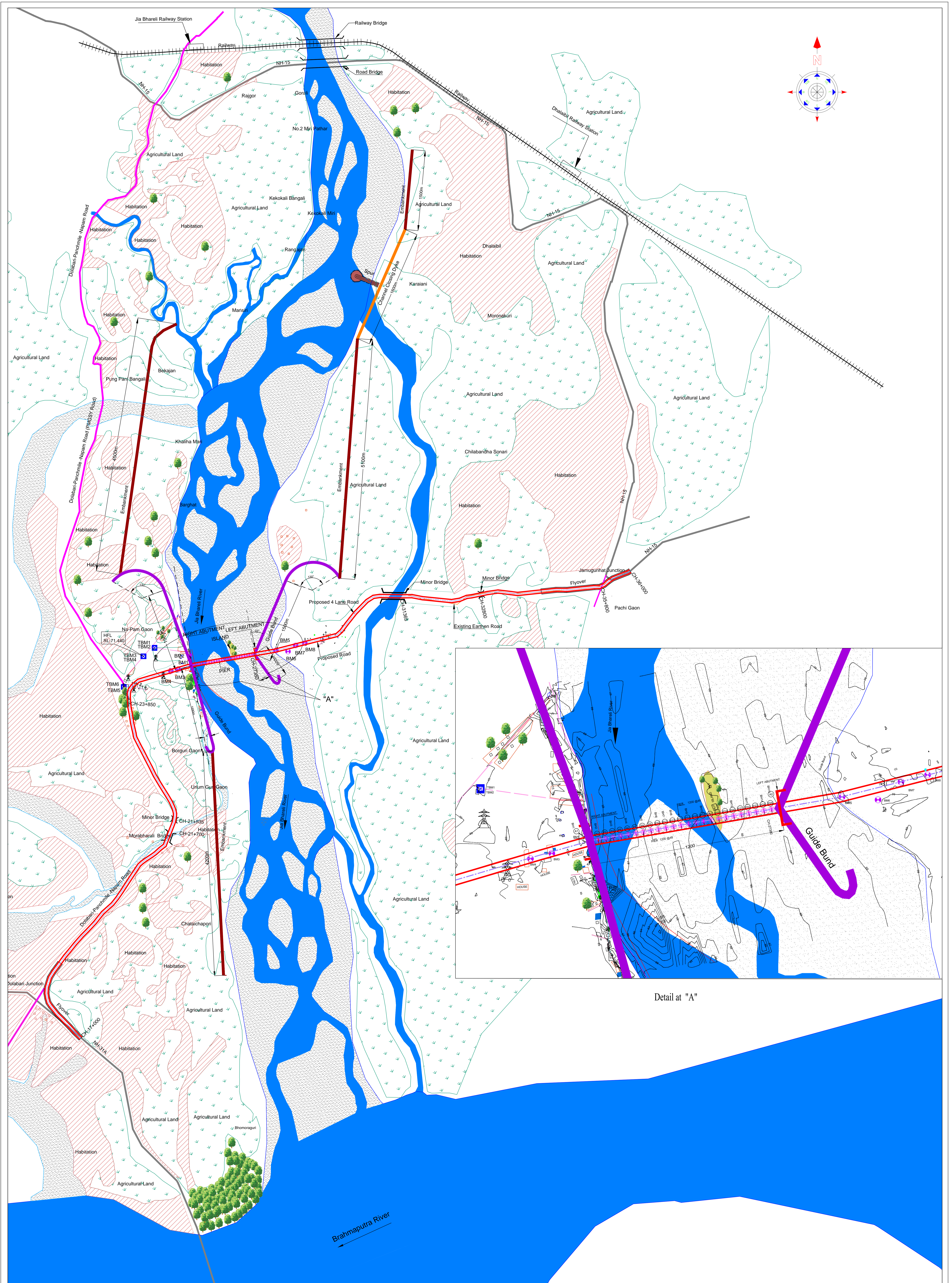
As per the cost estimate total project cost including a comparison between previous and present estimate is shown below in Table 5.1

Table 5.1 Abstract of Cost

Bill No.	Description of Items	Amount(Rs.)
1	SITE CLEARANCE & DISMANTLING	4646961
2	EARTHWORK	513002996
3	BASE AND SUBBASE COURSES	595113786
4	BITUMINOUS COURSES	643092029
5	DRAINAGE AND CULVERT WORKS	373343678
6	SAFETY WORKS: TRAFFIC ISLAND, TRAFFIC SIGNS, MARKINGS AND ROAD APPURTENANCES	52162287
7	MISCELLANEOUS	19217636
8	BRIDGES AND STRUCTURES	
8.1	Jia Bharali Bridge	1811031076
	RIVER TRAINING/PROTECTION WORKS	
8.2	Guide Bund, Embankment and Channel Closing Dyke	3316769312
8.3	Morabharali Bridge	261854926.6
8.4	Flyover(2 nos)	491719020.8
8.5	Minor Bridge(3 nos)	143429620.1
	TOTAL ESTIMATED COST(AS PER SOR 2013-2014) (A)	8225383329
9	Add Escalation @ 15% on(A)	1233807499
	TOTAL (B)	9459190828
10	Add Maintenance Cost @ 5% on (B)	472959541
11	Add Escalation during construction @ 12.5 % for 3.5 years on(B)	1182398854
12	Add Contingency @ 2.8% on (B)	264857343
	TOTAL (C)	11379406566
13	Add Construction Supervision Charge @ 3% on (C)	341382197
14	Add Administrative/Agency Charges @ 3% on (C)	341382197
15	Add Quality control @ 0.25% on (C)	284485164
16	Add Road Safety Audit Charges 0.25% on (C)	284485164
17	Add Environmental Impact Assessment, LA and others	0
	TOTAL PROJECT COST(TPC)	12631141289
	Say(in Rs.Crores)	1263.11

(Rupees One thousand two hundred sixty three crores eleven lakhs)only

ANNEXURE-A
OVERALL LAYOUT PLAN

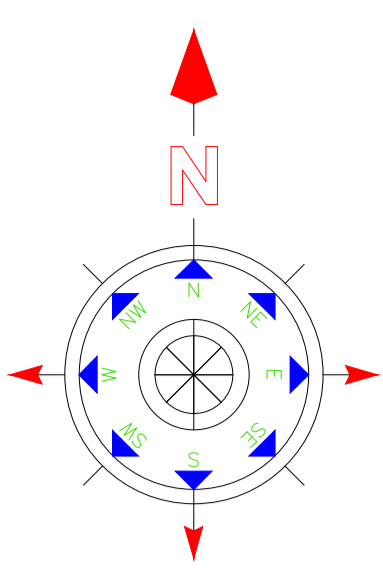
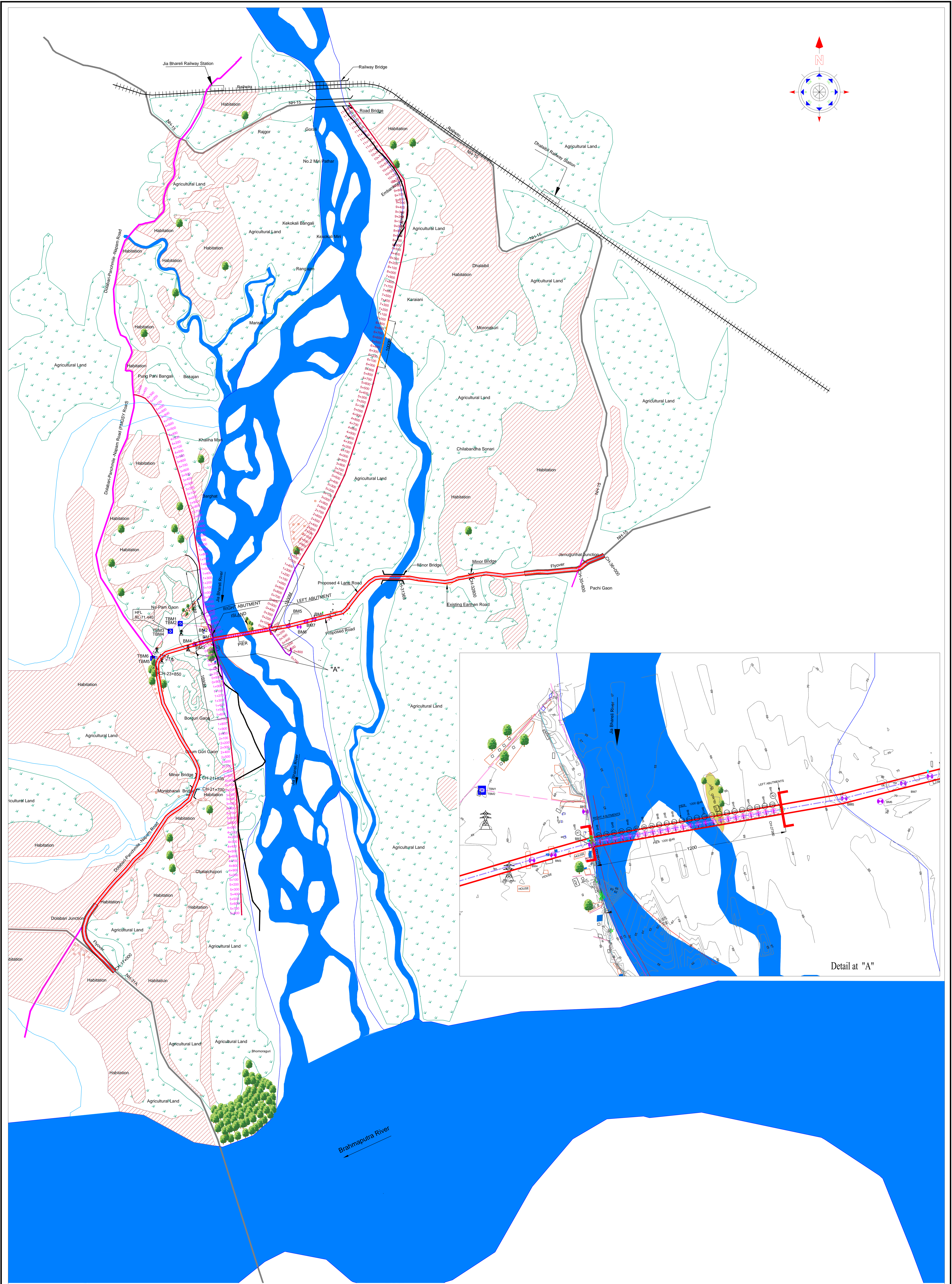


SL.NO.	DESCRIPTION	SYMBOL	SL.NO.	DESCRIPTION	SYMBOL	SL.NO.	DESCRIPTION	SYMBOL
1.	NH	—	9.	Channel Closing Dyke	—	17.	HUT	□
2.	Earthen Road	—	10.	Proposed 4 Lane Road	—	18.	ISLAND	■
3.	PMGSY Road	—	11.	Bridge	—	19.	POND	■
4.	Railway	—	12.	Contour	—	20.	TBM	■
5.	River	—	13.	HIGH TENTION TOWER	—	21.	Station	■
6.	Sand Area	—	14.	LOW TENTION POLE	—	22.	TREE	■
7.	Guide Bund	—	15.	TELEPHONE POLE	—	23.	Habitation	■
8.	Embankment	—	16.	House	—	24.	Agricultural Land	■

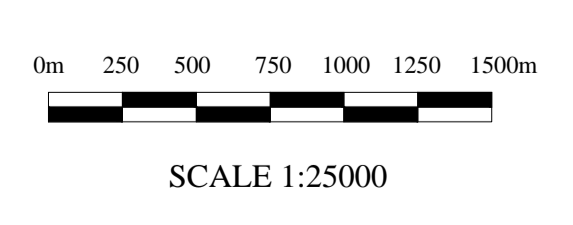
REV.	DATE	APPROVED BY	REVISIONS	DM	IN	SK	IN	DATE
1	SEPTEMBER, 2016							

CLIENT: National Highways and Infrastructure Development Corporation Limited
 CONSULTANT: Xplor Consulting Services Pvt. Ltd.
 PROJECT: 4 Lane Capital Connectivity to Sarangarh in Karanprasth under SARD NE Work (Phase A) - 4 Laning from KM 17.300 (Dolabari Road Junction) to NH 37A to KM 18.170 (Jamaghat Road Junction) KM 18.00 of NH 62 in Sarangarh in the State of Assam.
 DRAWING TITLE: OVERALL LAYOUT PLAN OF TEZPUR

SCALE	SIZE	DWG. NO.	REV.
NTS	A0	001	0



LEGEND											
SL.NO.	DESCRIPTION	SYMBOL	SL.NO.	DESCRIPTION	SYMBOL	SL.NO.	DESCRIPTION	SYMBOL	SL.NO.	DESCRIPTION	SYMBOL
1.	NH		9.	CHANNEL CLOSING DYKE		17.	HUT		25.	EXISTING EMBANKMENT	
2.	EARTHEN ROAD		10.	PROPOSED 4 LANE ROAD		18.	ISLAND				
3.	PMGSY ROAD		11.	BRIDGE		19.	POND				
4.	RAILWAY		12.	CONTOUR		20.	TBM				
5.	RIVER		13.	HIGH TENSION TOWER		21.	STATION				
6.	SAND AREA		14.	LOW TENSION POLE		22.	TREE				
7.	GUIDE BUND		15.	TELEPHONE POLE		23.	HABITATION				
8.	EMBANKMENT		16.	HOUSE		24.	AGRICULTURAL LAND				

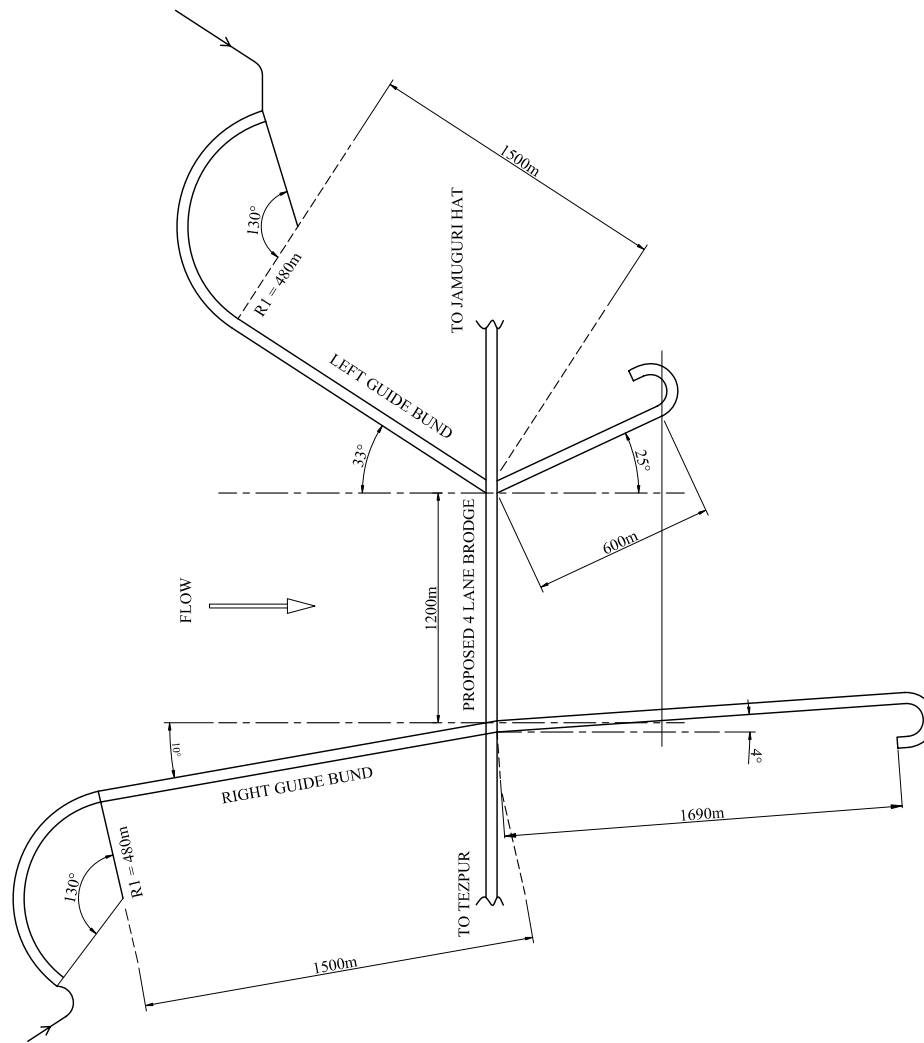


REV.	DATE	ISSUED FOR APPROVAL	REVISIONS	DRG	SK.	B.N.SEN
0	DEC. 2016			001	SK.	B.N.SEN
				002	SK.	B.N.SEN
				003	SK.	B.N.SEN
				004	SK.	B.N.SEN

CLIENT	National Highways and Infrastructure Development Corporation Limited
CONSULTANT	Xplorers Consultancy Services Pvt. Ltd. B-10/30/1st Floor, Sector-10, Gurgaon Phone: +91 122 438887 Fax: +91 122 431962 www.xplorers.com

PROJECT	4 Lane Capital Connectivity to Itanagar in Assam under SARDI NE Work Phase A1.4. Laying from NH 17.300 (Dolabari Road Junction) to NH-270 to NH-54 (Jangrahar Road Junction) KM 162.00 of NH-52 in Sonpur District in the State of Assam.
DRAWING TITLE	OVERALL LAYOUT PLAN OF TEZPUR
SCALE	1:25000
SIZE	A0
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REV.	0

ANNEXURE-B-1
RIVER PROTECTION WORKS(ACCORDING TO
MODEL STUDY)

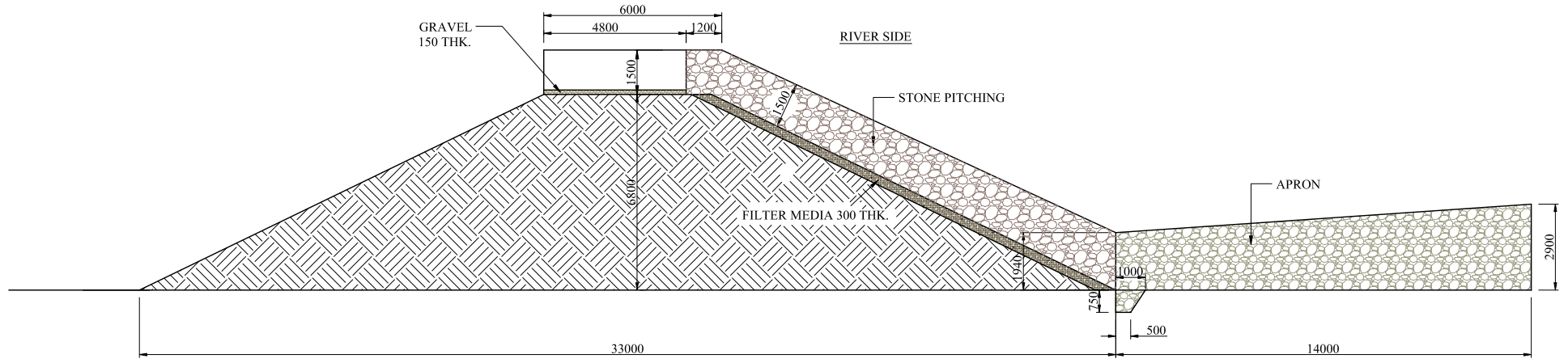


Note : All Dimension in 'm' unless noted otherwise.

Note :-
This drawing has been redrawn from
Ref.-DRG-4 of Report on Physical Model Study
of River Jia Bharali, NEHARI, Brahmaputra
Board received from NHIDCL.

**DETAILS POSITION AND SPECIFICATION OF GUIDE BUND AND ALIGNMENT OF BRIDGE
AS PER MODEL STUDY REPORT**






REV.	DATE	REVISIONS	DM	SK	R.N.SEN
0	SEPTEMBER, 2016	ISSUED FOR APPROVAL			
			DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. HPA Sarhad Gurgaon 122001 (Haryana) Ph: 0124-4388659 Fax: 0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT 4 Lane Capital Connectivity to Itanagar In Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17,300 (Dolabari Road Junction on NH-37A) to KM 36,110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.					
DRAWING TITLE DETAILS POSITION AND SPECIFICATION OF GUIDE BUND AND ALIGNMENT OF BRIDGE					
SEPTEMBER, 2016		SCALE	SIZE	DWG. NO.	REV.
		NTS	A4	001	0





TYPICAL SECTION OF GUIDE BUND

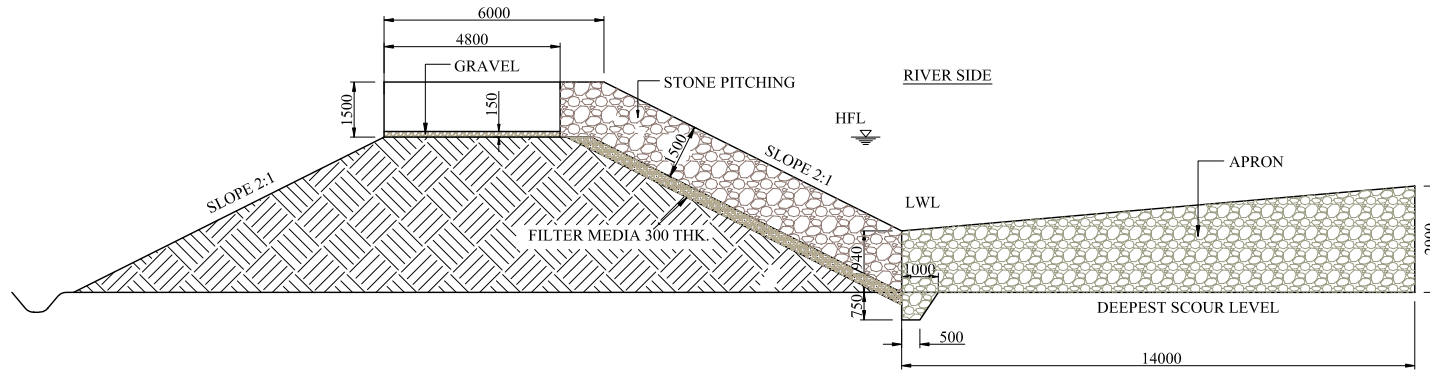
AS PER MODEL STUDY REPORT

LEGENDS :

-  APRON
-  EARTH FILL
-  GRAVEL
-  FILTER MEDIA
-  STONE PITCHING






Note : All Dimension in 'mm' unless noted otherwise.

0	SEPTEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. HPA Sarhad Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax: 0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT: 4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17,300 (Dolabari Road Junction on NH-37A) to KM 36,110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.					
DRAWING TITLE: Design Section of Guide Bund					
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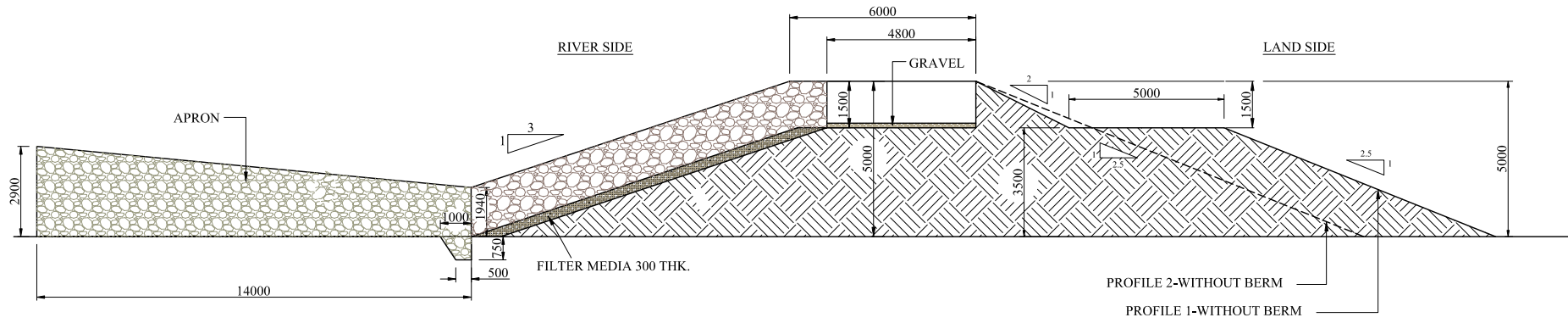
**TYPICAL SECTION OF CHANNEL CLOSING DYKE
AS PER MODEL STUDY REPORT**

LEGENDS :

-  APRON
-  EARTH FILL
-  GRAVEL
-  FILTER MEDIA
-  STONE PITCHING






Note : All Dimension in 'mm' unless noted otherwise.

0	SEPTEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. HPA Sarhad, Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax: 0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT: 4 Lane Capital Connectivity to Itanagar In Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17,300 (Dolabari Road Junction on NH-37A) to KM 36,110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.					
DRAWING TITLE: Typical Section of Channel Closing dyke					
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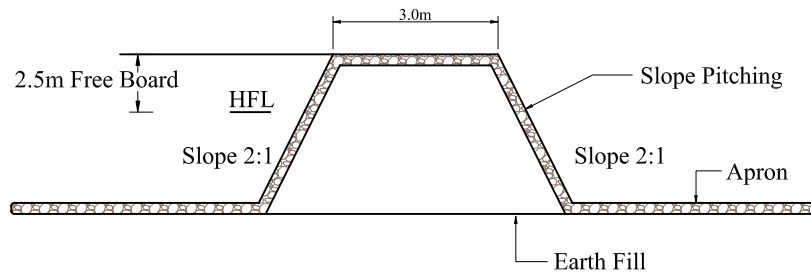
**TYPICAL SECTION OF EMBANKMENT
AS PER MODEL STUDY REPORT**

LEGENDS :

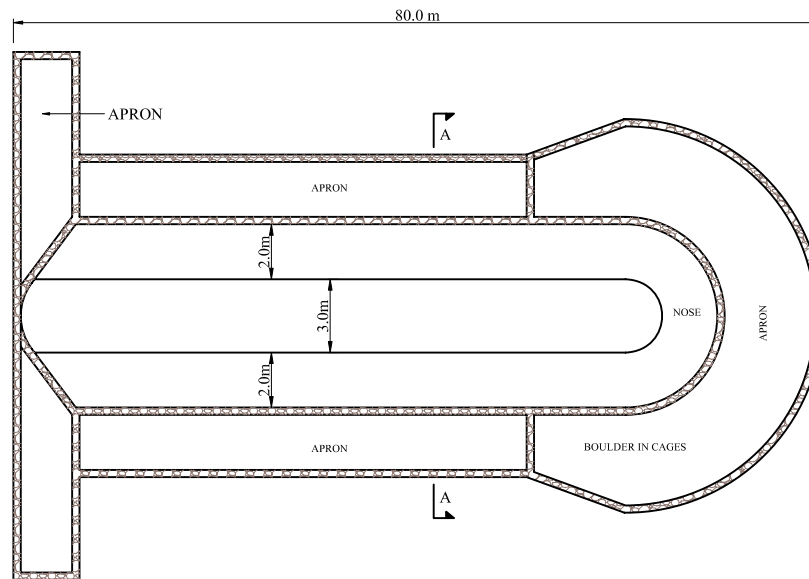
-  APRON
-  EARTH FILL
-  GRAVEL
-  FILTER MEDIA
-  STONE PITCHING

Note : All Dimension in 'mm' unless noted otherwise.

0	SEPTEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. HPA Sarhad, Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax: 0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT: 4 Lane Capital Connectivity to Itanagar In Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17,300 (Dolabari Road Junction on NH-37A) to KM 36,110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.					
DRAWING TITLE: Design Section of Embankment					
SEPTEMBER, 2016	SCALE	SIZE	DWG. NO.	REV.	
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Section A -A

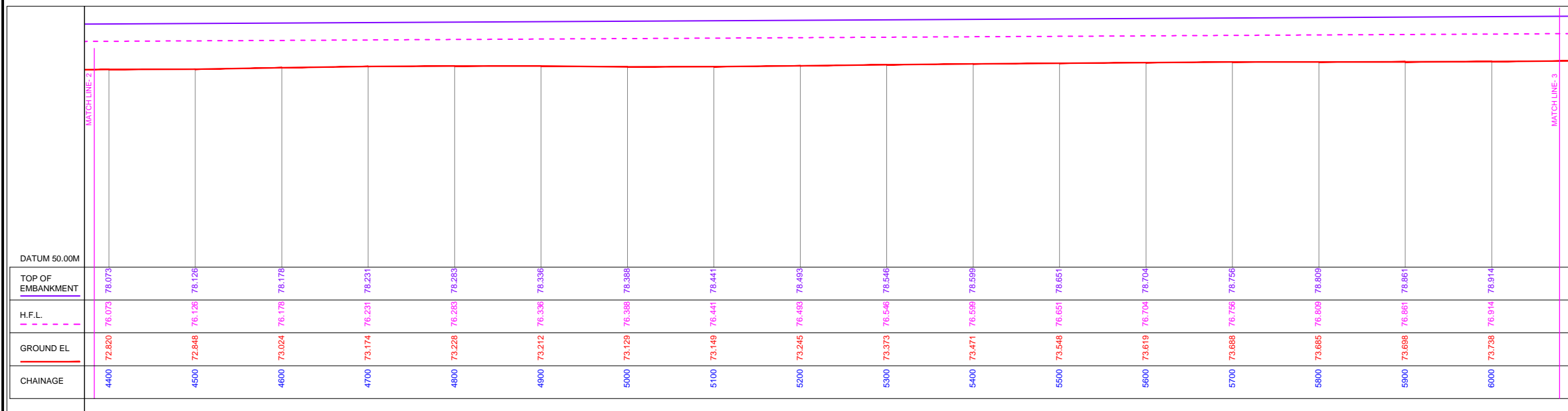
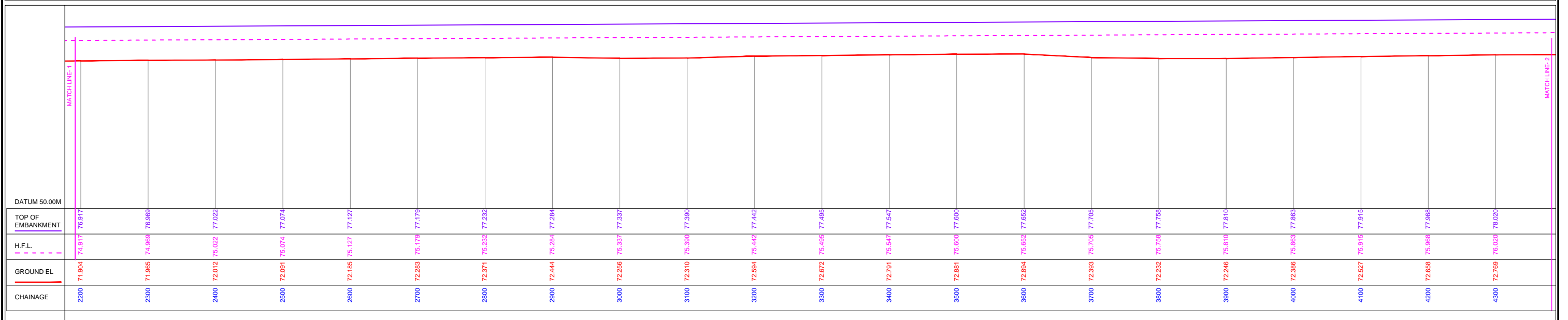
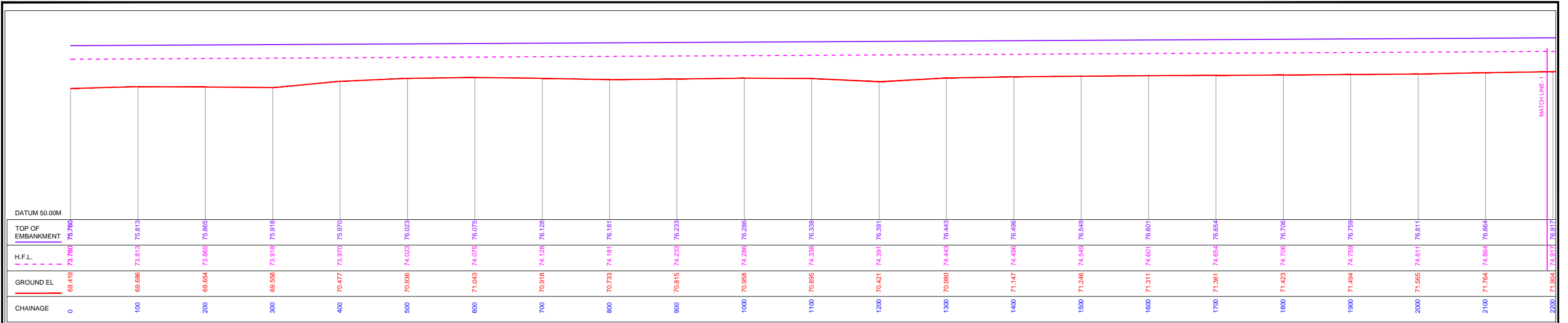




TYPICAL SECTION OF SPUR
AS PER MODEL STUDY REPORT

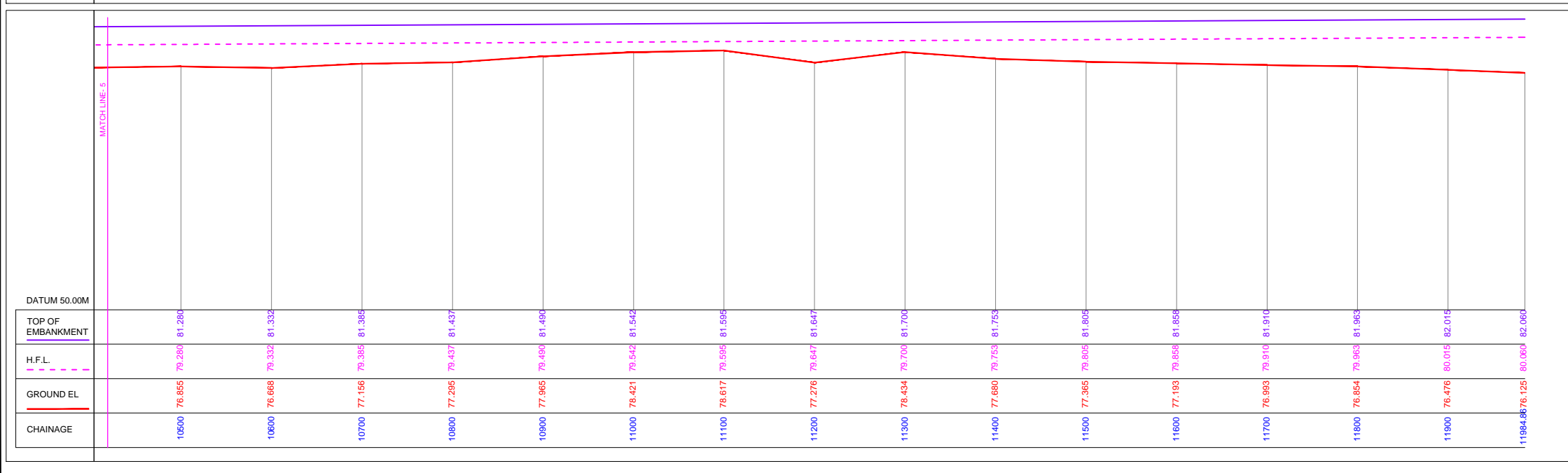
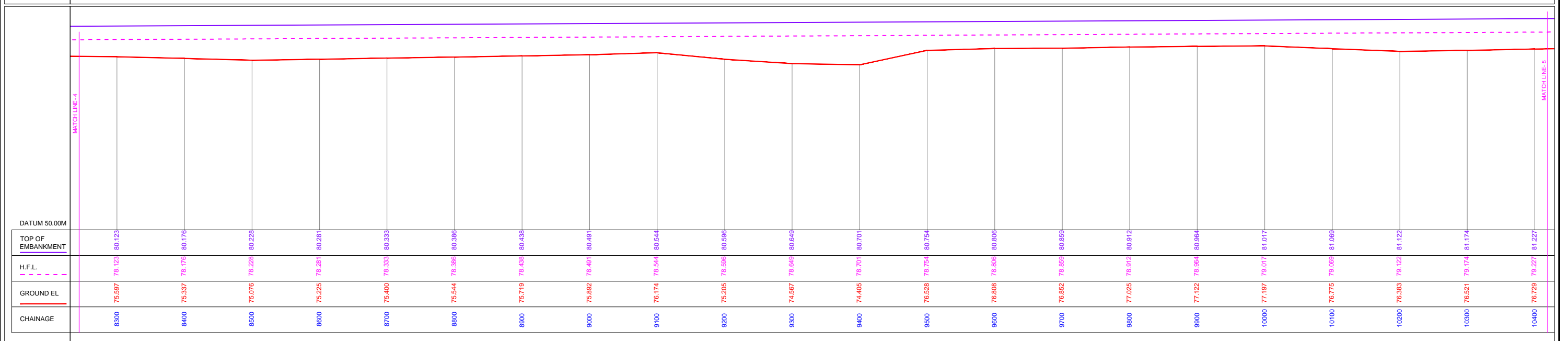
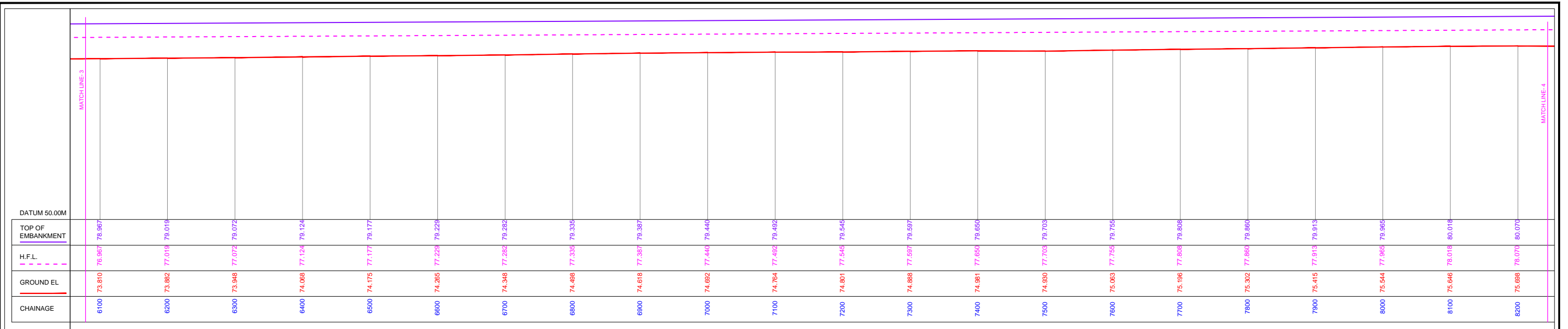
Note : All Dimension in 'mm' unless noted otherwise.



REV.	DATE	REVISIONS	DRN	CHKD	APPD
0	SEPTEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. HPA Sarhad, Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax: 0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT 4 Lane Capital Connectivity to Itanagar In Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17,300 (Dolabari Road Junction on NH-37A) to KM 36,110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.					
DRAWING TITLE Typical section of spur					
SEPTEMBER, 2016		SCALE NTS	SIZE A4	DWG. NO. 005	REV. 0

ANNEXURE-B-2
RIVER PROTECTION WORKS (PROPOSED)





0	DEC. 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. HIPA Sarhau, Gurgaon 122001 (Haryana) Ph: 0124-4386659, Fax: 0124-4241982 www.xplorer.in, Email: xplorer@xplorer.in			
PROJECT: 4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.					
DRAWING TITLE: L-SECTION OF PROPOSED EMBANKMENT LEFT BANK (U/S)					
DEC. 2016		SCALE	SIZE	DWG. NO.	REV.
		NTS	A3	001	0

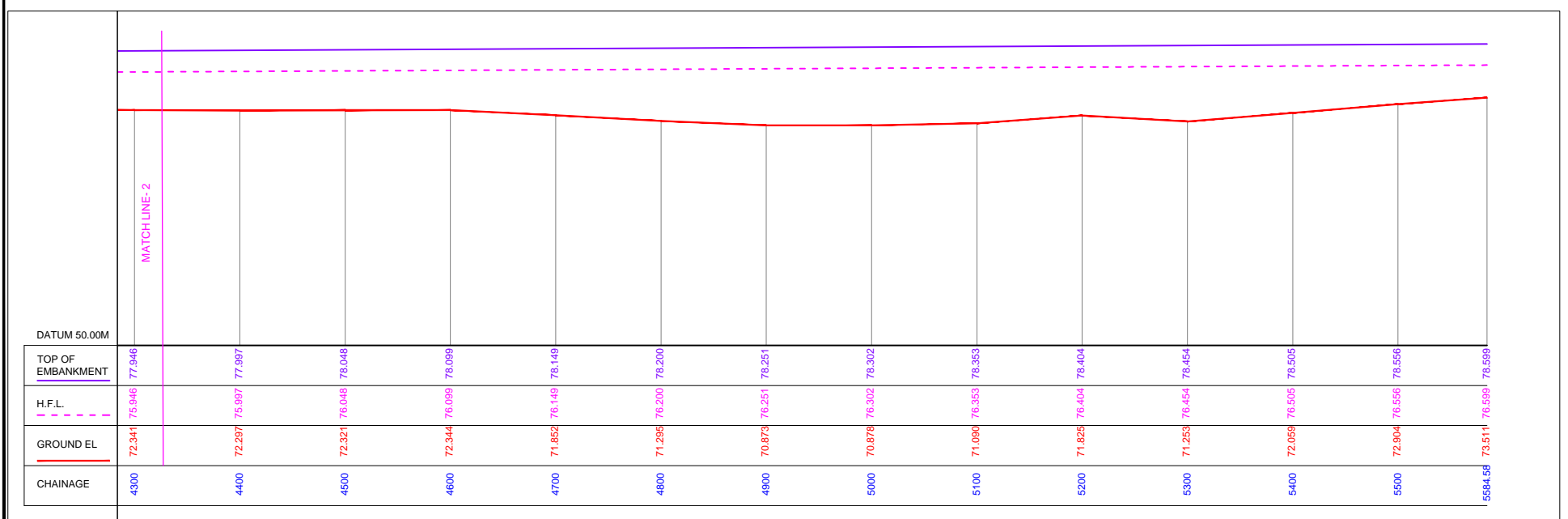
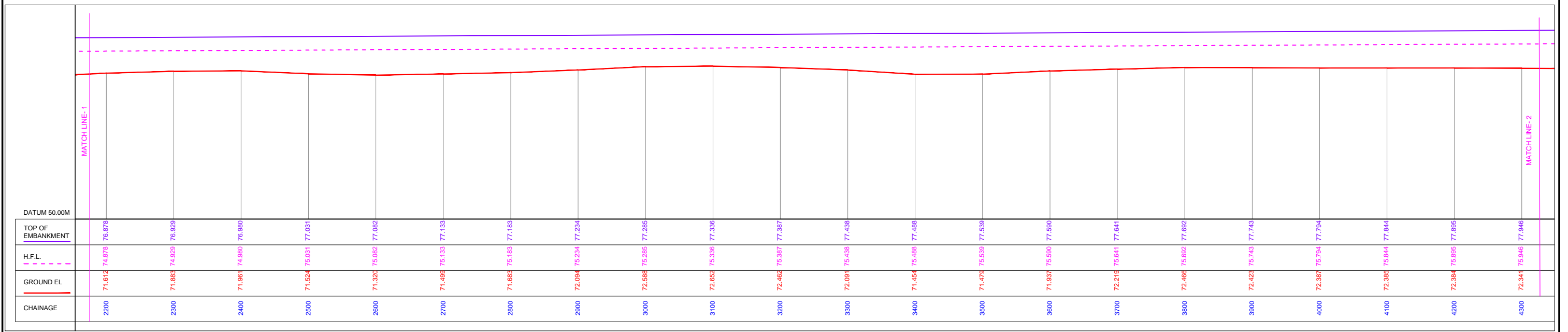
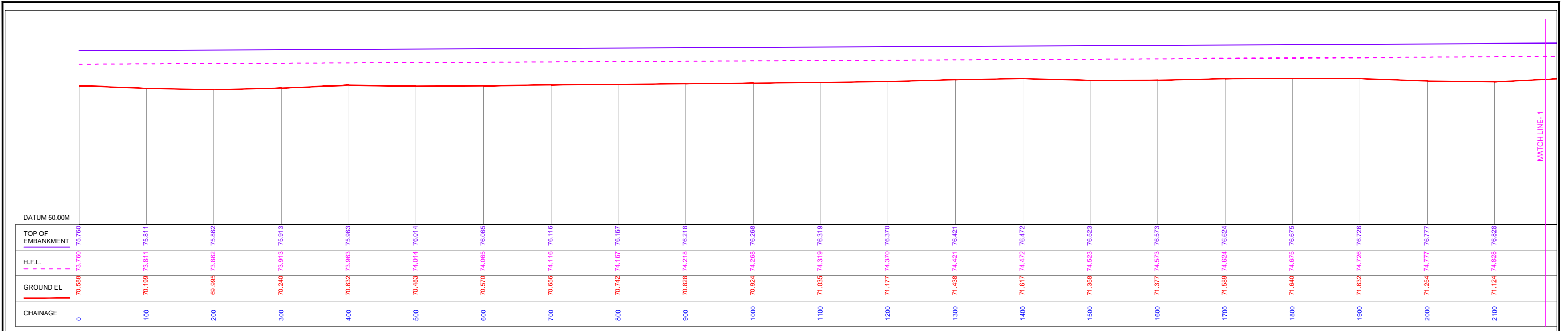




0	DEC. 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03,First Floor, Sector-18,Opp.HIPA Sarhau, Gurgaon 122001(Haryana) Ph: 0124-4388659, Fax: 0124-4241362 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		L-SECTION OF PROPOSED EMBANKMENT LEFT BANK (U/S)			
DEC. 2016	SCALE	SIZE	DWG. NO.	REV.	
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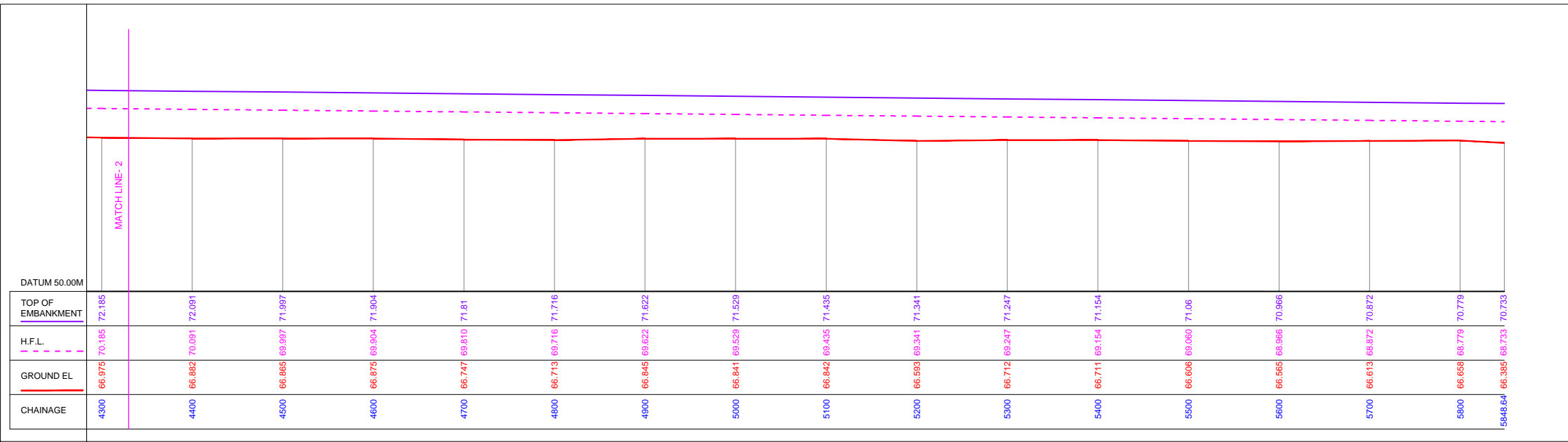
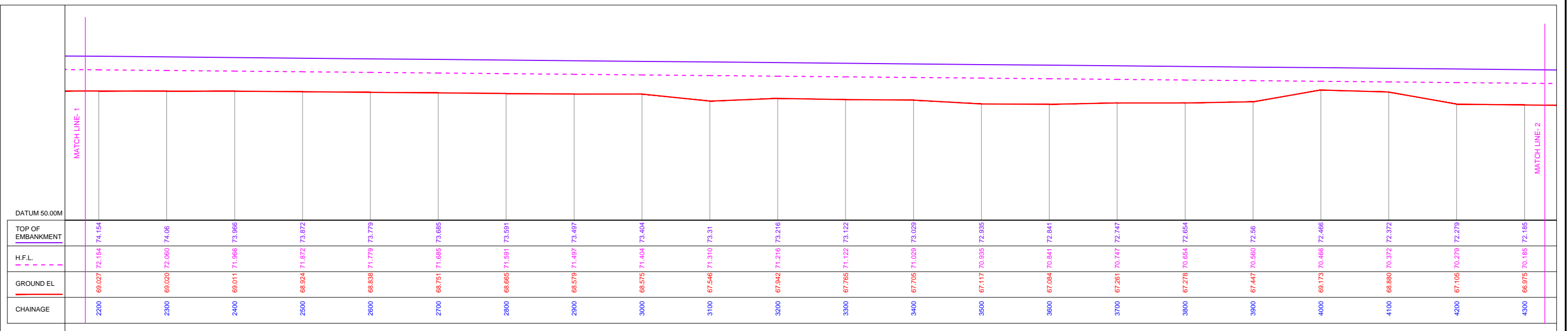
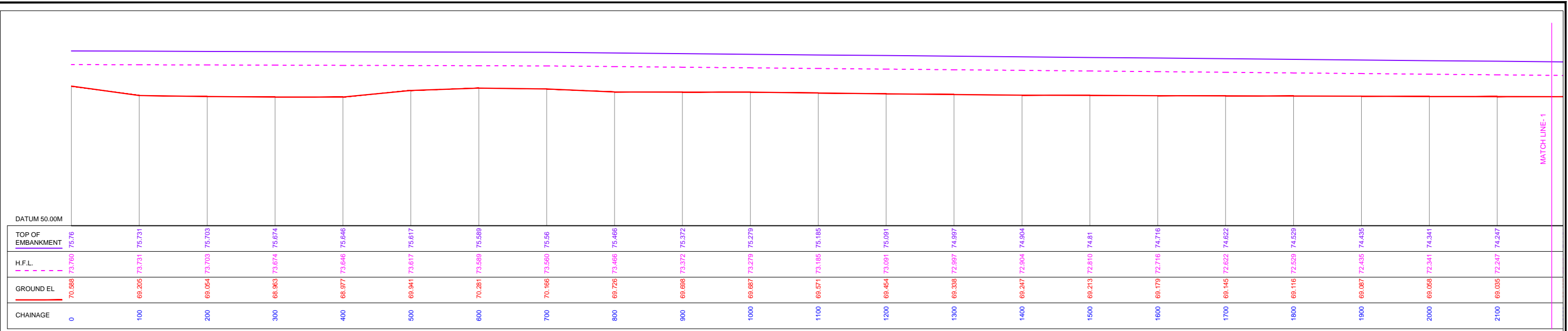
DATUM 50.00M



CHAINAGE	GROUND EL	H.F.L.	TOP OF EMBANKMENT
0	69.419	73.760	75.760
100	69.311	73.737	75.737
200	69.203	73.714	75.714
300	69.287	73.691	75.691
400	69.491	73.668	75.668
500	69.559	73.644	75.644
600	69.318	73.621	75.621
700	69.077	73.598	75.598
800	69.019	73.575	75.575
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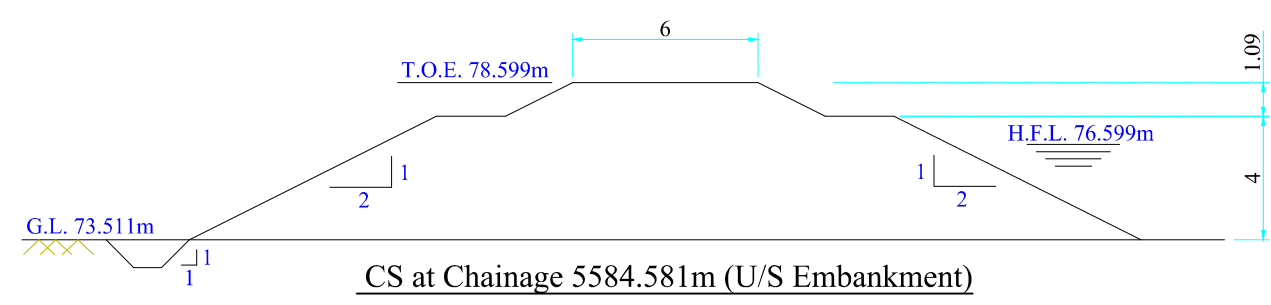
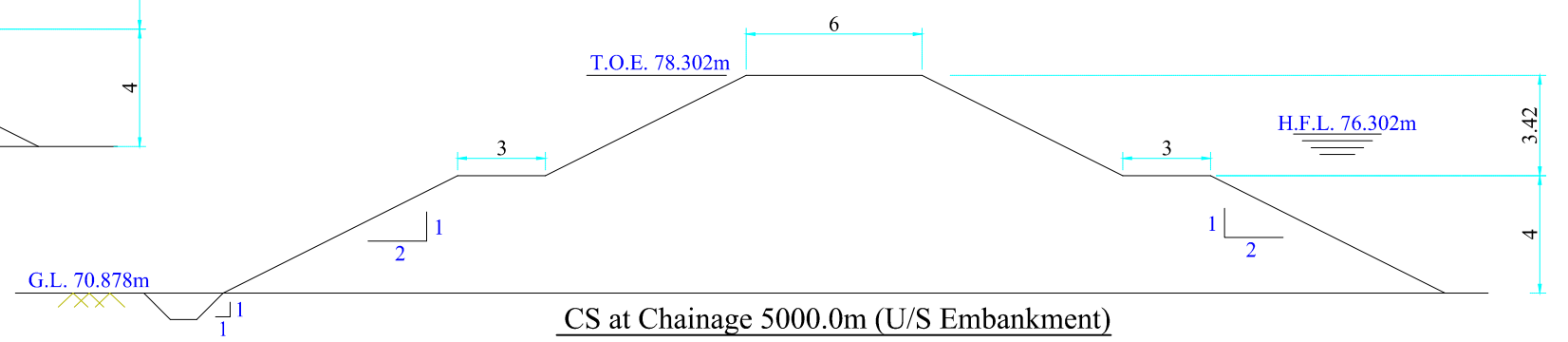
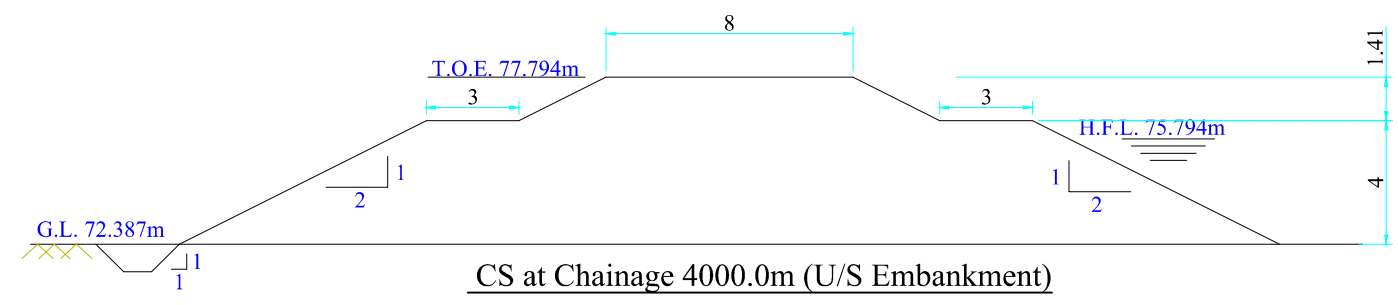
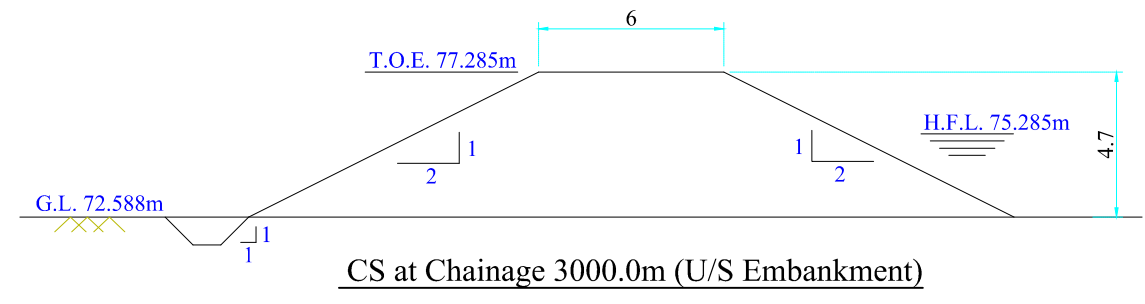
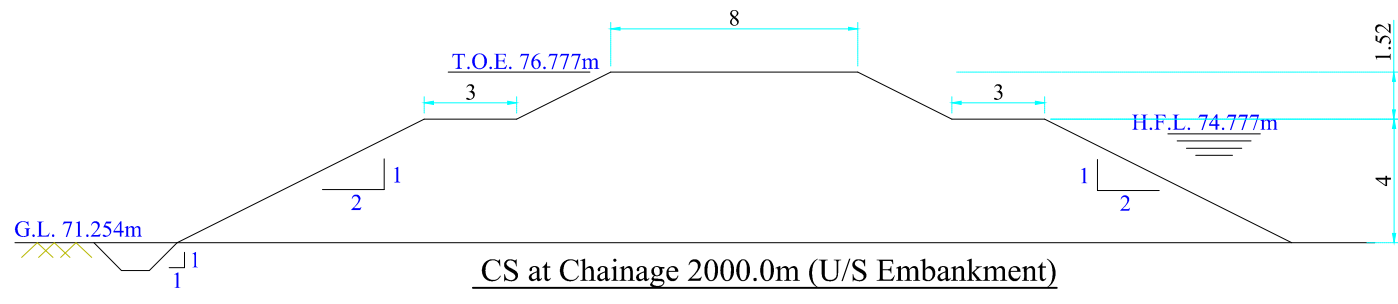
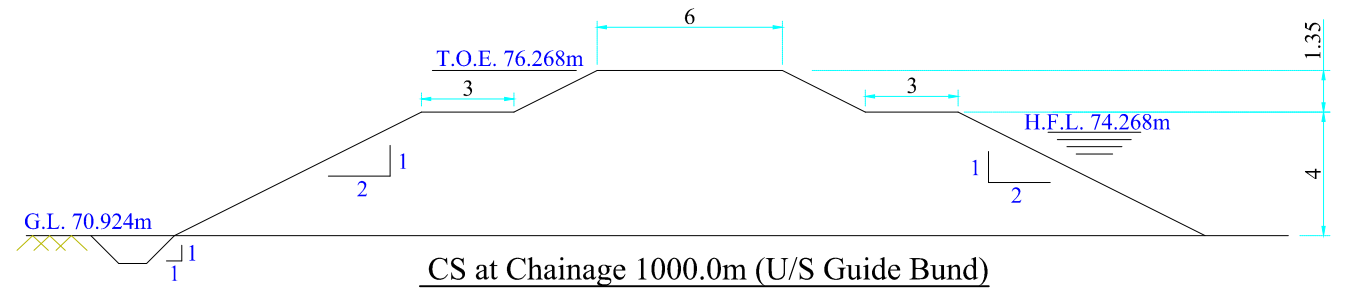
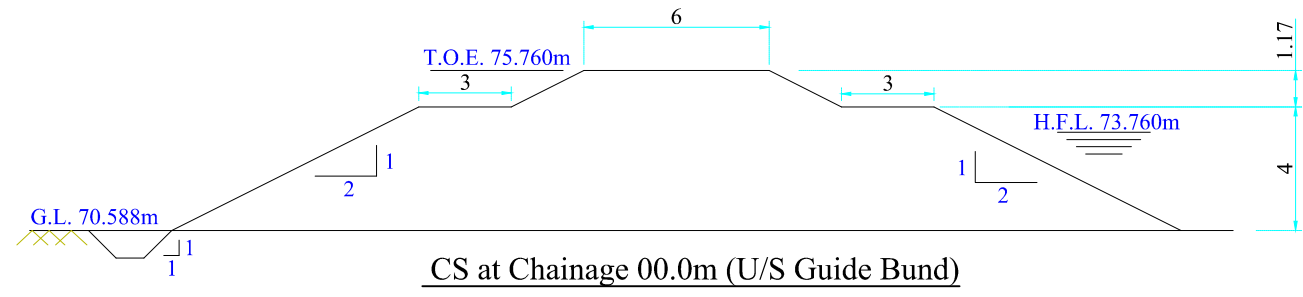
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REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03,First Floor, Sector-18,Opp.HIPA Sarhau, Gurgaon 122001(Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		L-SECTION OF PROPOSED EMBANKMENT LEFT BANK (D/S)			
DEC. 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	003	0	





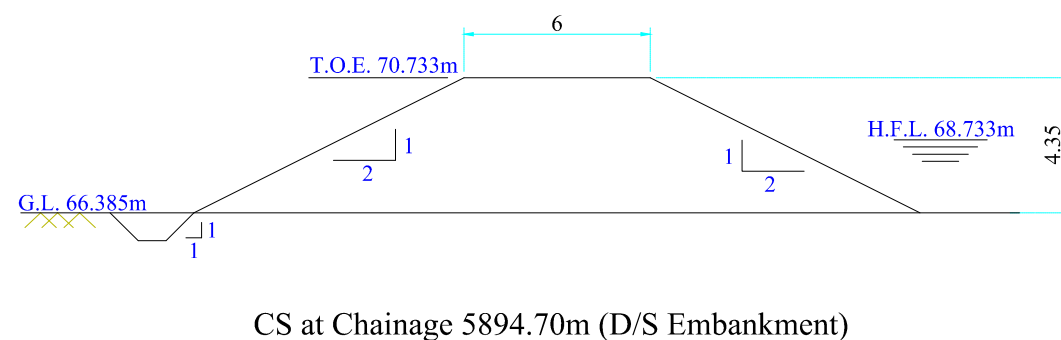
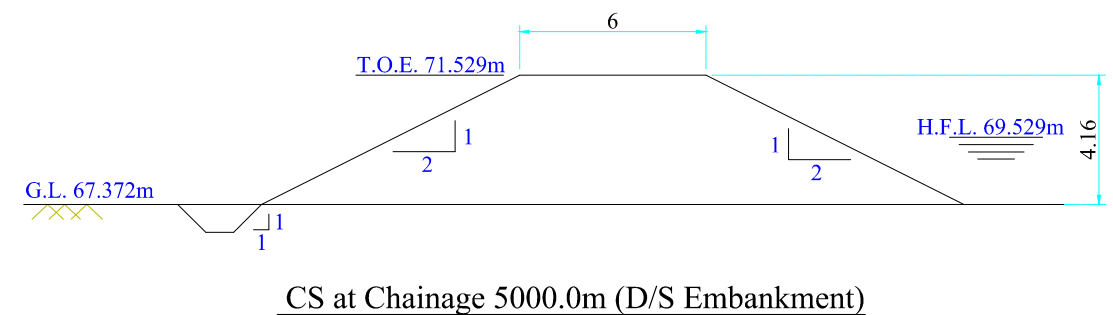
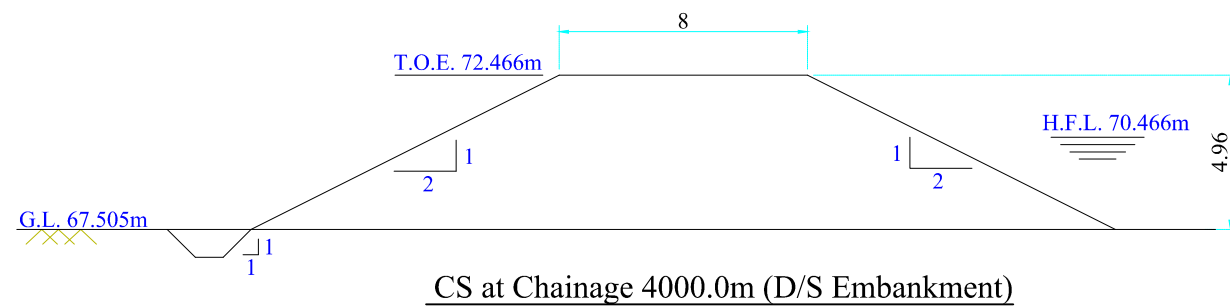
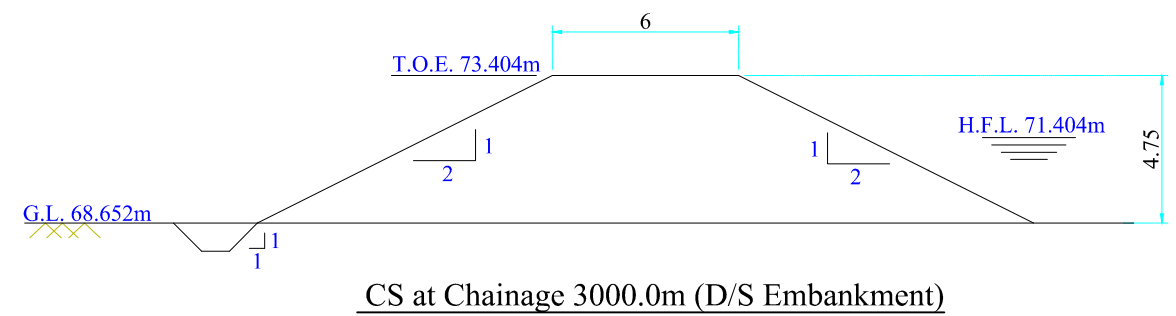
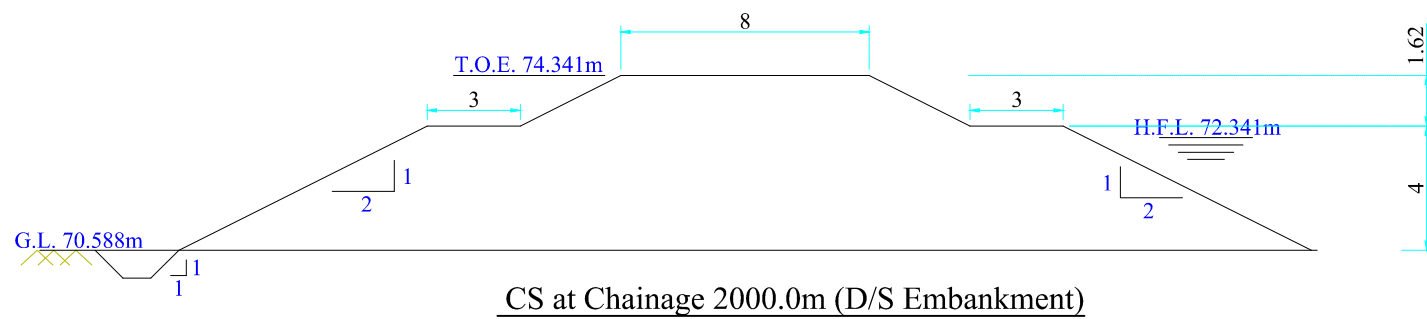
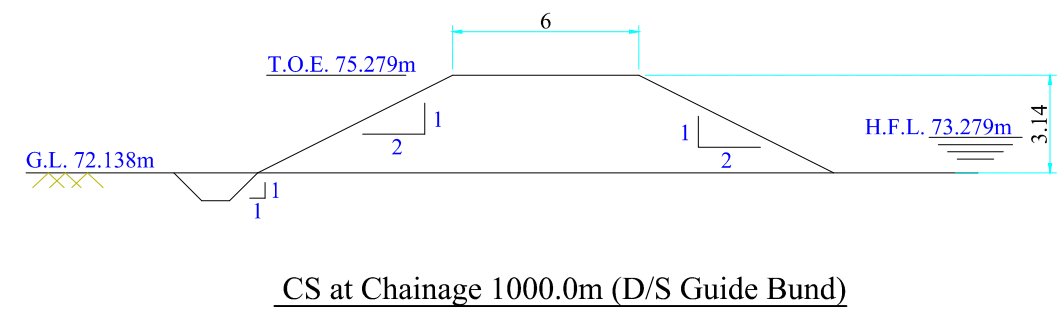
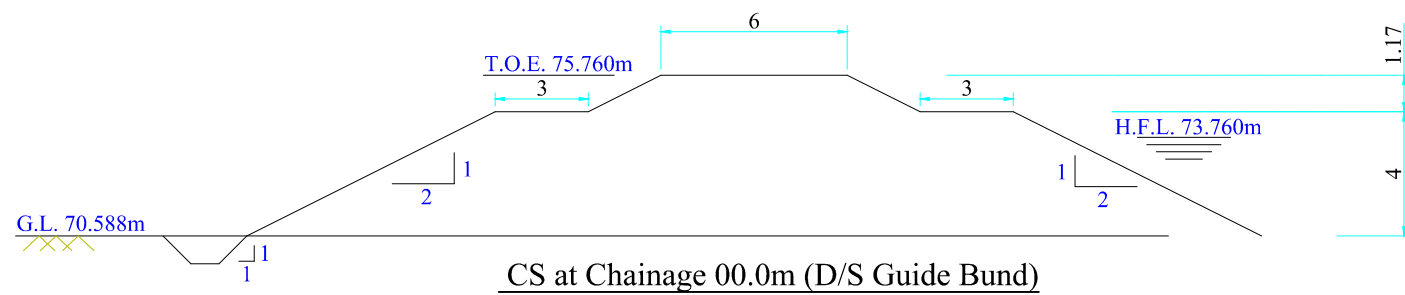
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REV.	DATE	REVISIONS	DRN	CHKD	APPD
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		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03,First Floor, Sector-18,Opp.HIPA Sarhaul,Gurgaon 122001(Haryana) Ph: 0124-4388659,Fax:0124-4241962 www.xplorer.in, Email: xplorer@xplorer.in			
PROJECT: 4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.					
DRAWING TITLE: L-SECTION OF PROPOSED EMBANKMENT RIGHT BANK (U/S)					
DEC. 2016		SCALE	SIZE	DWG. NO.	REV.
		NTS	A3	004	0



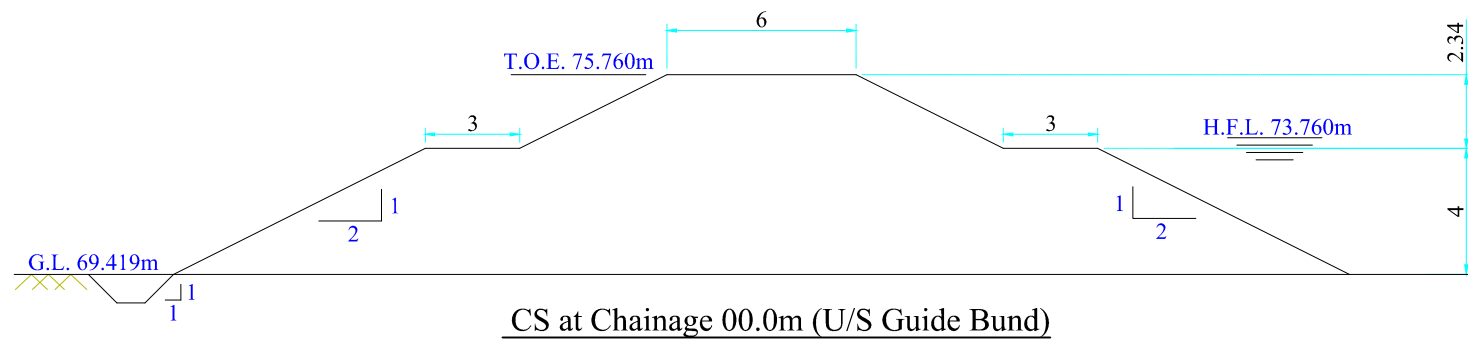
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REV.	DATE	REVISIONS	DRN	CHKD	APPD
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		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp.HIPA Sairahul, Gungson, 122001(Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		L-SECTION OF PROPOSED EMBANKMENT RIGHT BANK (D/S)			
DEC. 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	005	0	



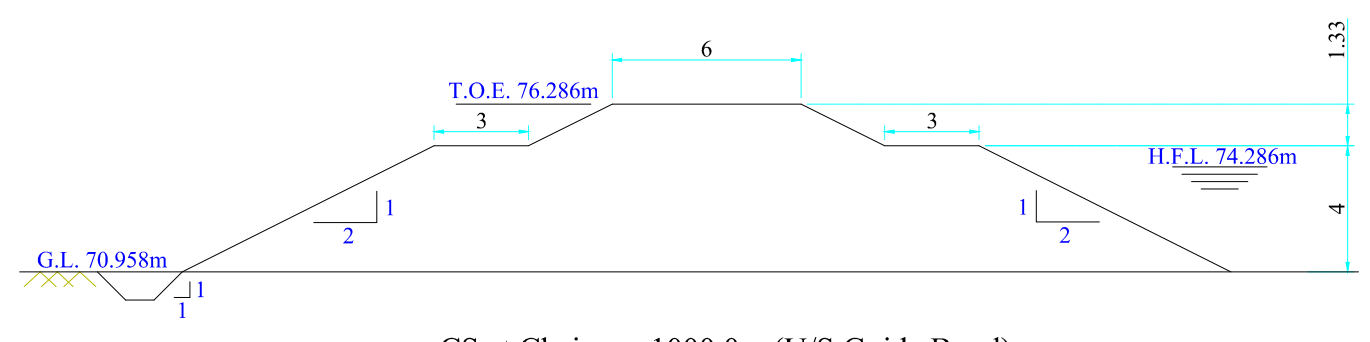
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PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		U/S TYPICAL CROSS SECTIONS (RIGHT BANK)			
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	001	0	



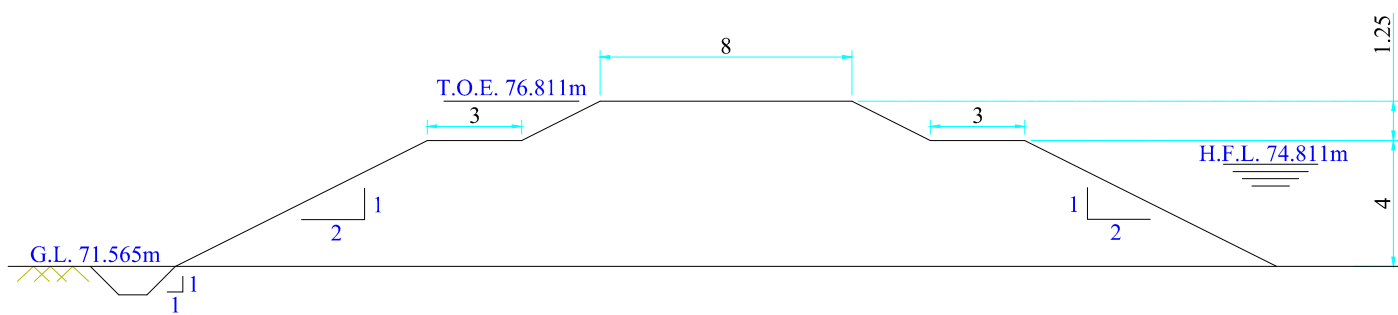
REV.	DATE	REVISIONS	DM	SK	R.N.SEN
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		CONSULTANT:	Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp.HIPA Sarhau, Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax:0124-4241952 www.xplorer.in, Email- xplorer@xplorer.in		
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		D/S TYPICAL CROSS SECTIONS (RIGHT BANK)			
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	002	0	



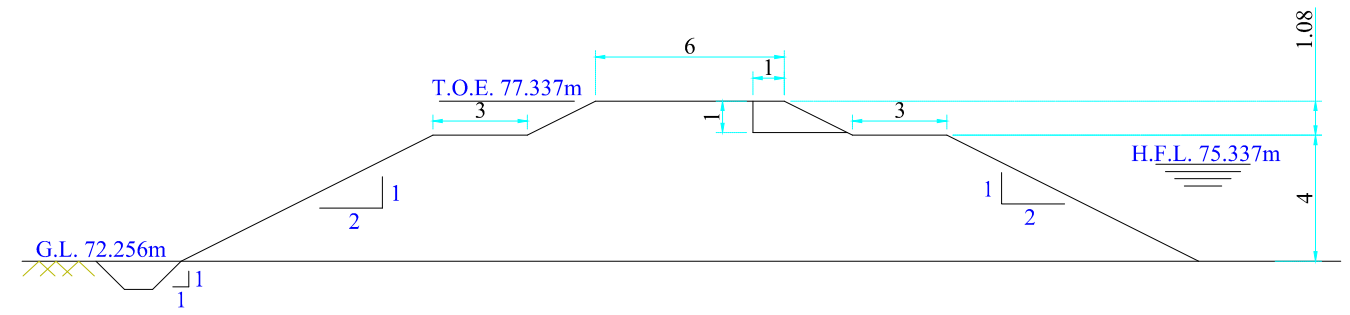
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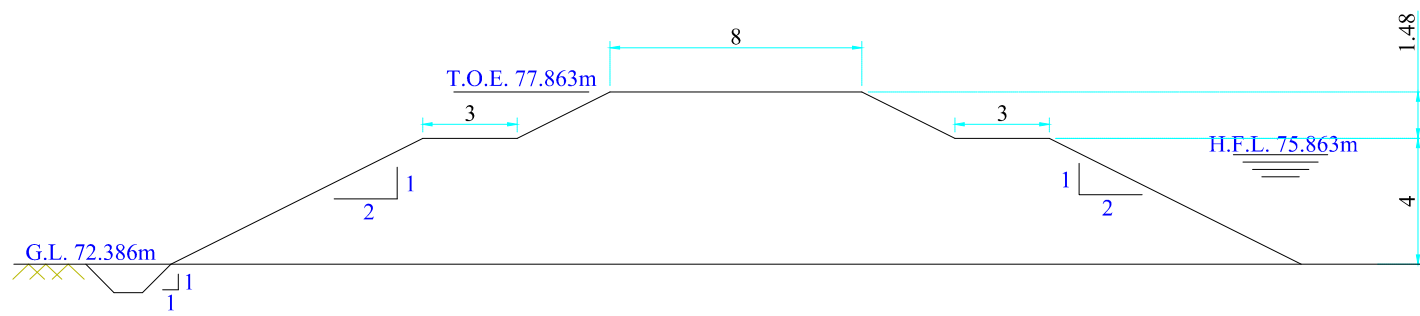
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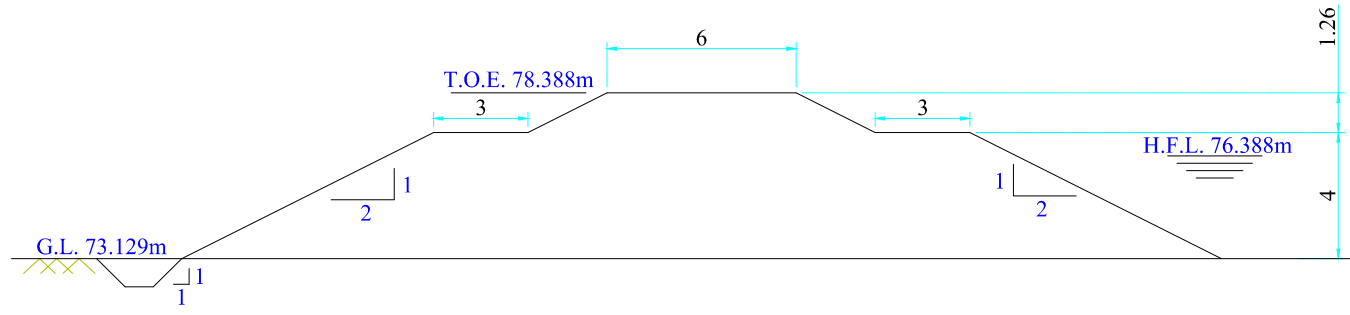
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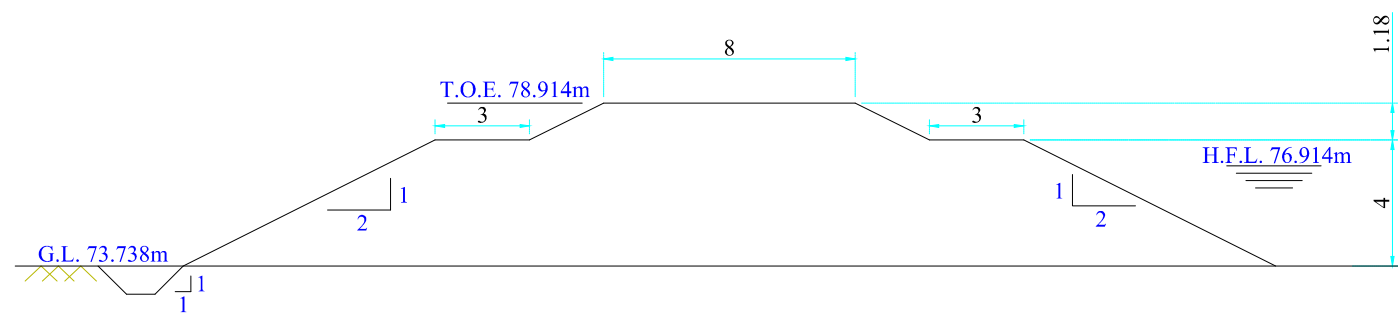
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CS at Chainage 4000.0m

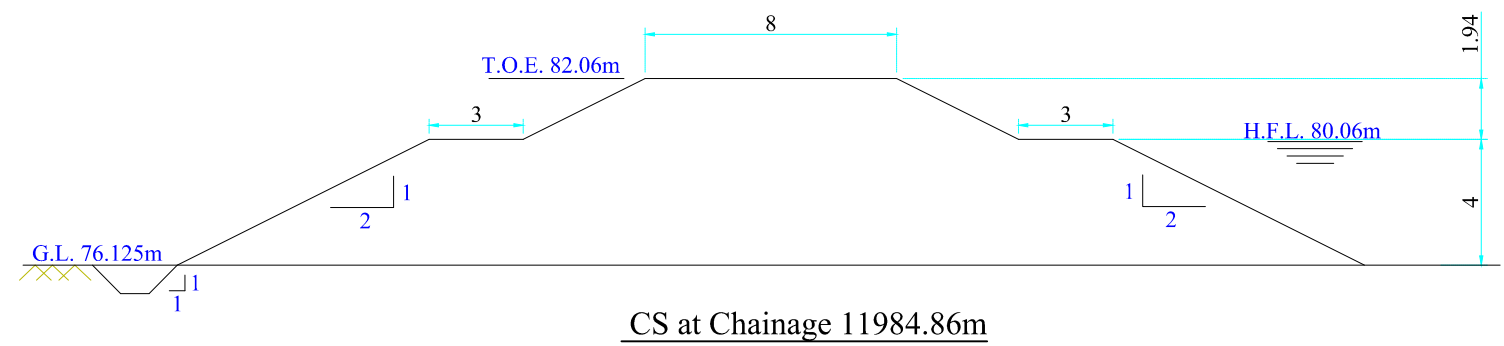
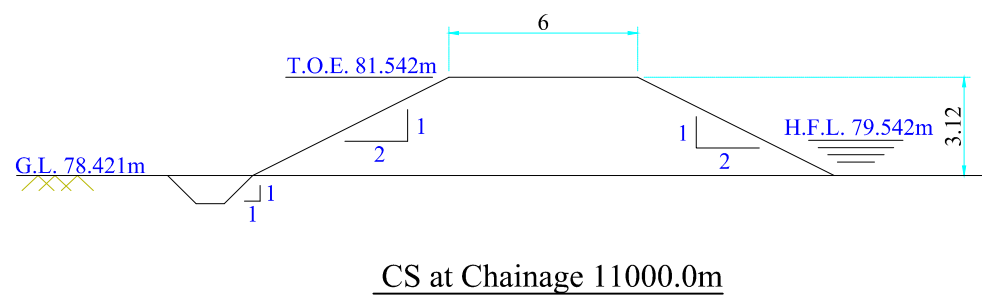
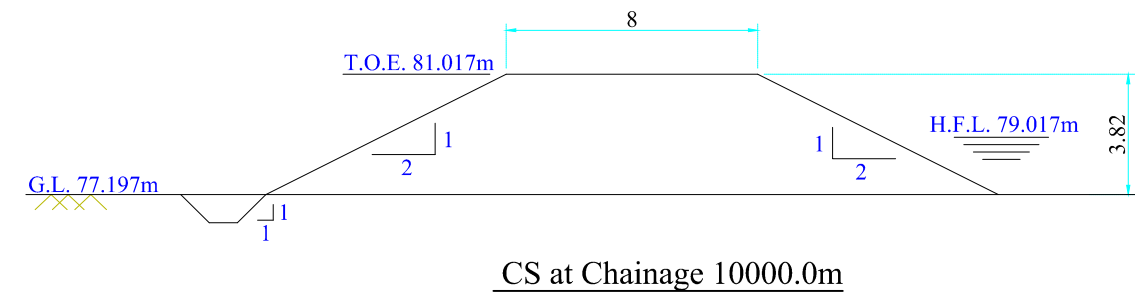
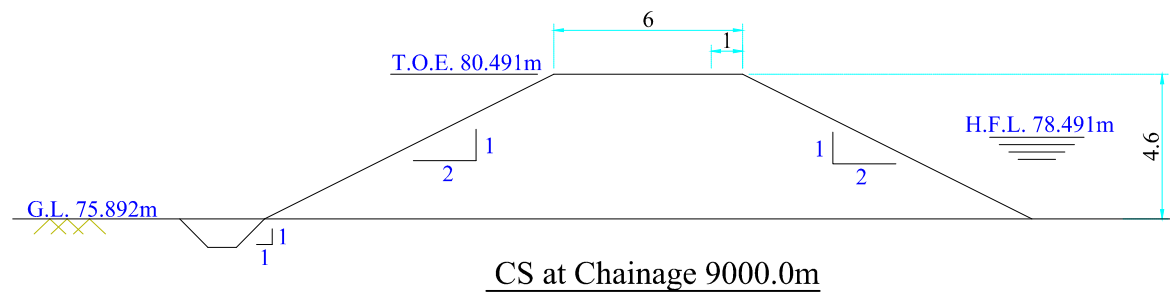
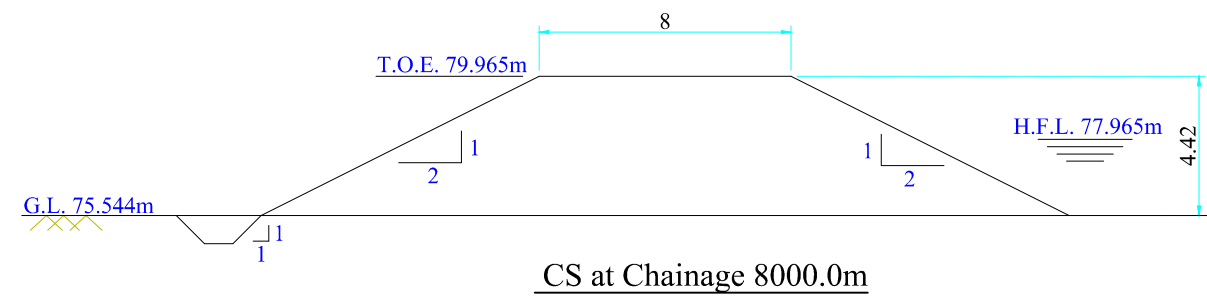
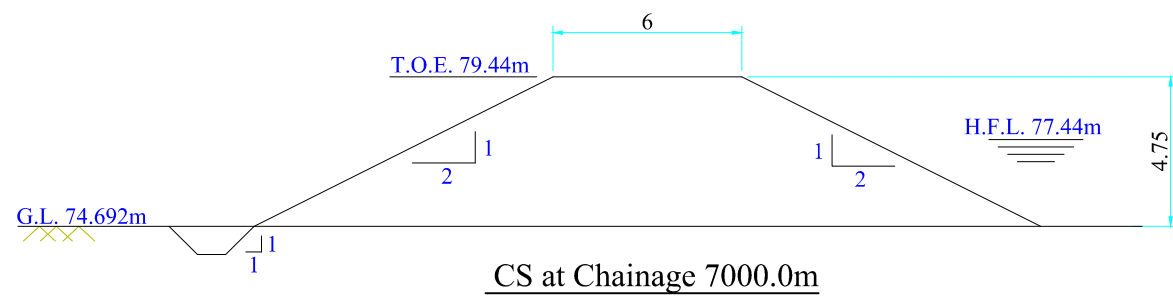


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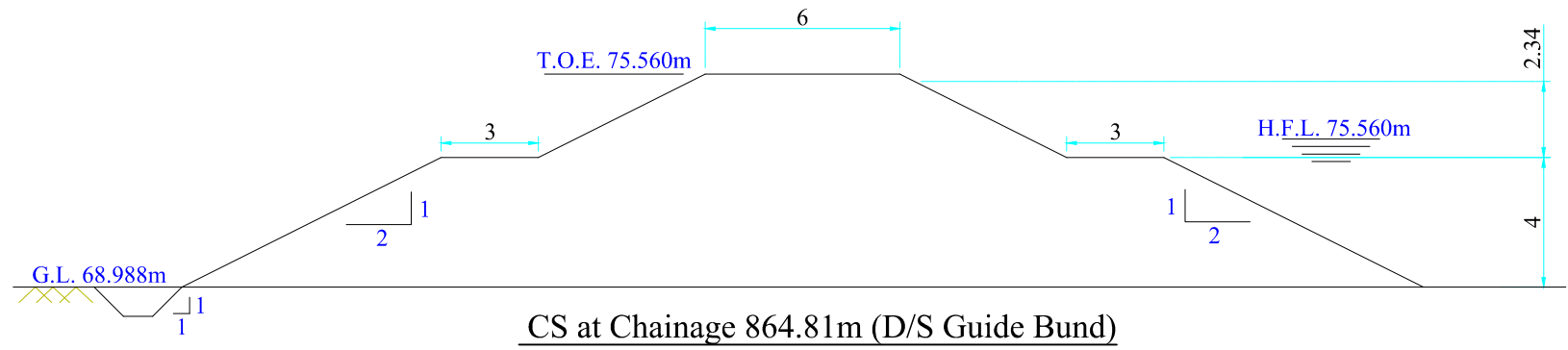
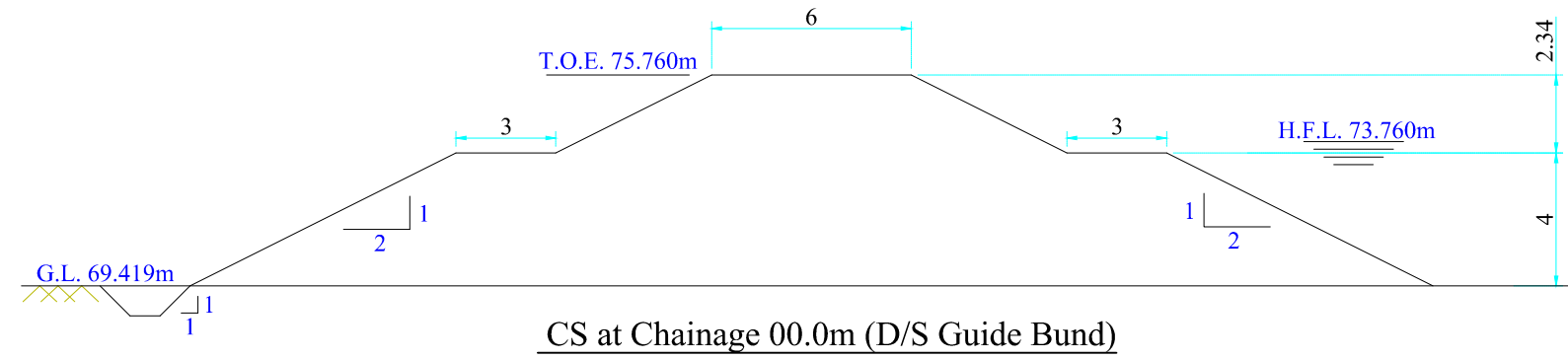




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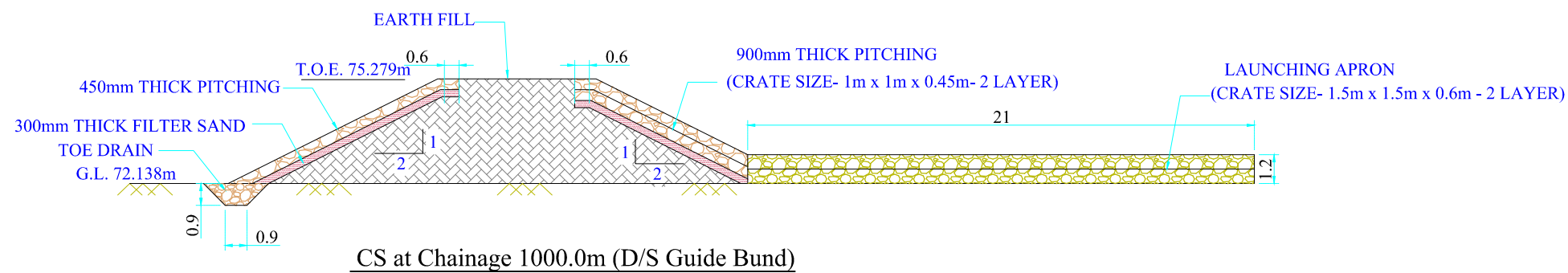
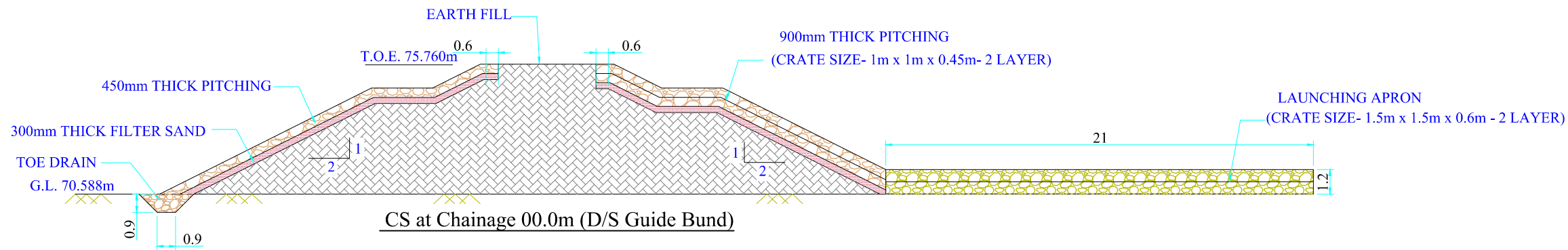
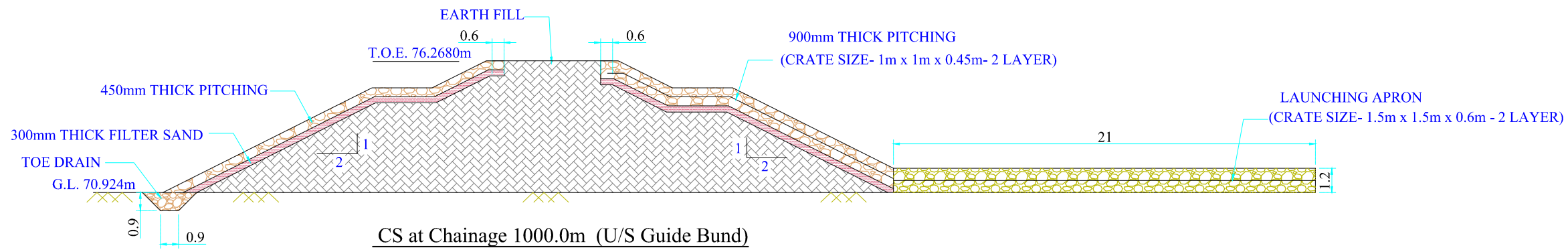
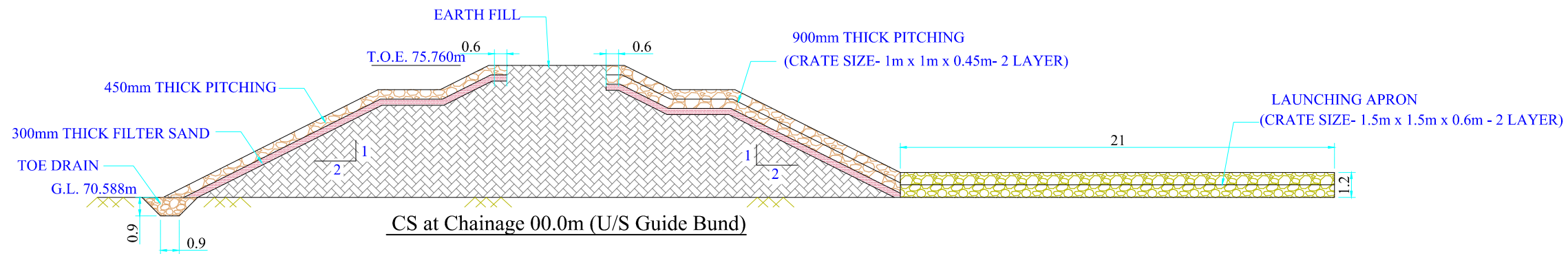
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REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp.HIPA Sarhau, Gurgaon 122001(Haryana) Ph: 0124-4388659 Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		U/S TYPICAL CROSS SECTIONS (LEFT BANK)			
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	003	0	



REV.	DATE	REVISIONS	DM	SK	R.N.SEN
0	DECEMBER, 2016	ISSUED FOR APPROVAL	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03,First Floor, Sector-18,Opp.HIPA Sarhau, Gurgaon 122001(Haryana) Ph: 0124-4388659,Fax:0124-4241962 www.xplorer.in, E-mail- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		U/S TYPICAL CROSS SECTIONS (LEFT BANK)			
DEC, 2016	SCALE NTS	SIZE A3	DWG. NO. 004	REV. 0	



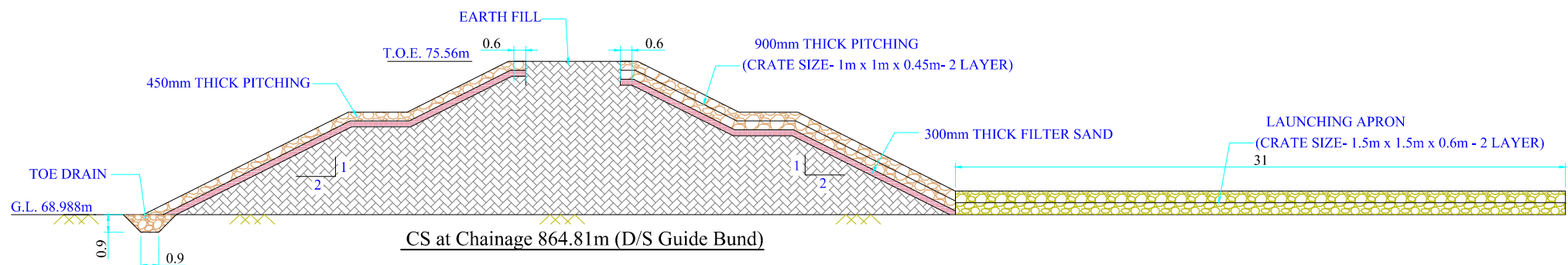
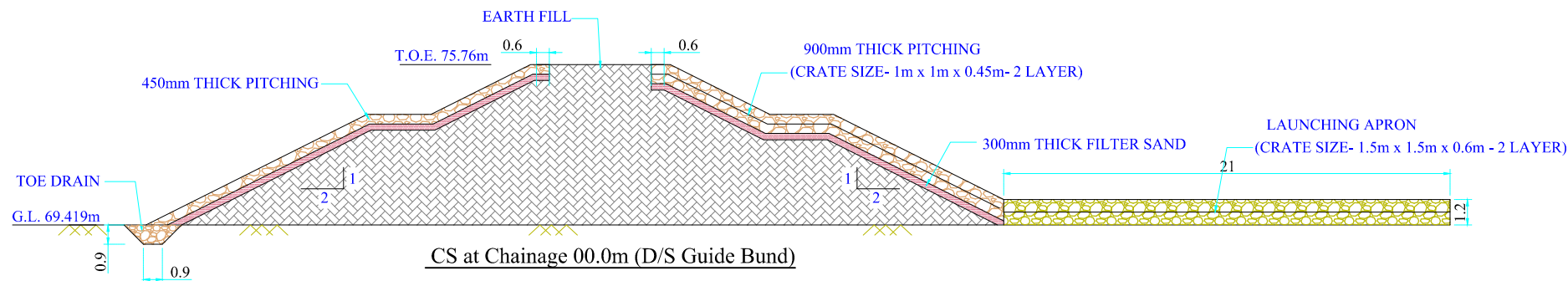
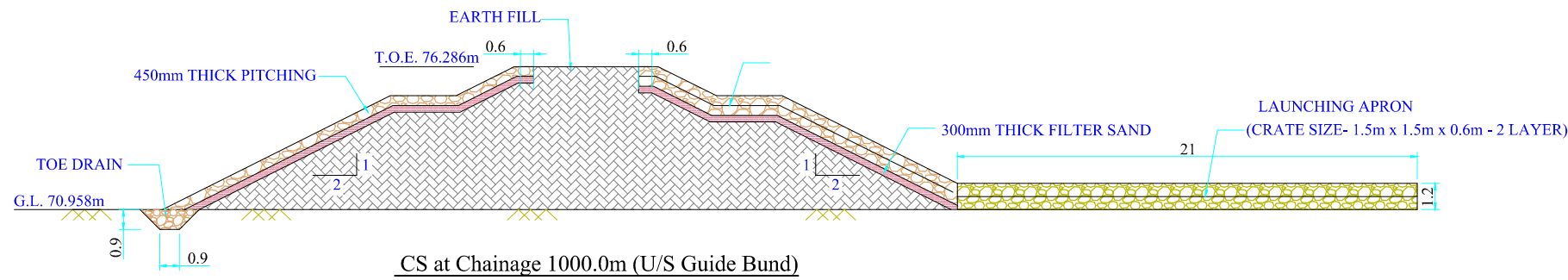
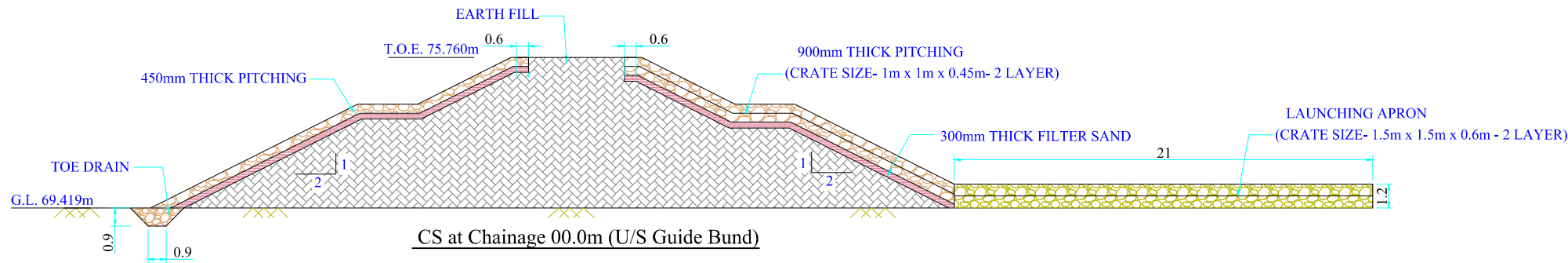
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REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03,First Floor, Sector-18,Opp.HIPA Sarhau, Gurgaon 122001(Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		D/S TYPICAL CROSS SECTIONS (LEFT BANK)			
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	005	0	



NOTES:

1. THICKNESS OF PITCHING ON RIVER SIDE 0.9m
2. SIZE OF WIRECRATE-1m x 1m x 0.45m- 2 LAYER.
3. THICKNESS OF PITCHING ON COUNTRY SIDE 0.45M.
4. THICKNESS OF FILTER SAND-0.3M.
5. SIZE OF LAUNCHING APRON-31m x 1.2m.
6. SIZE OF WIRECRATE-1.5m x 1.5m x 0.6m- 2 LAYER.

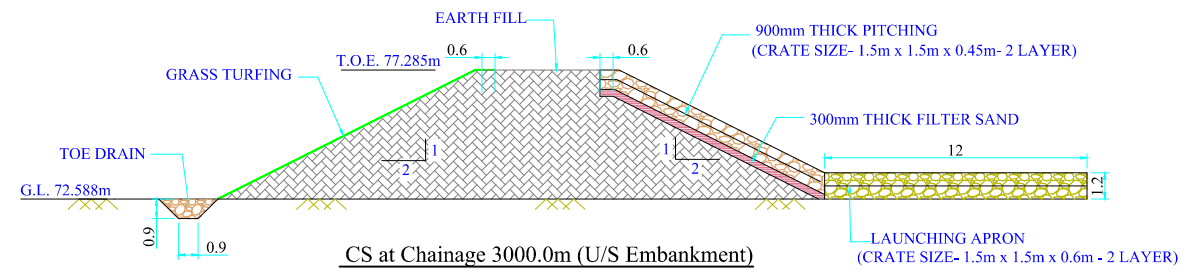
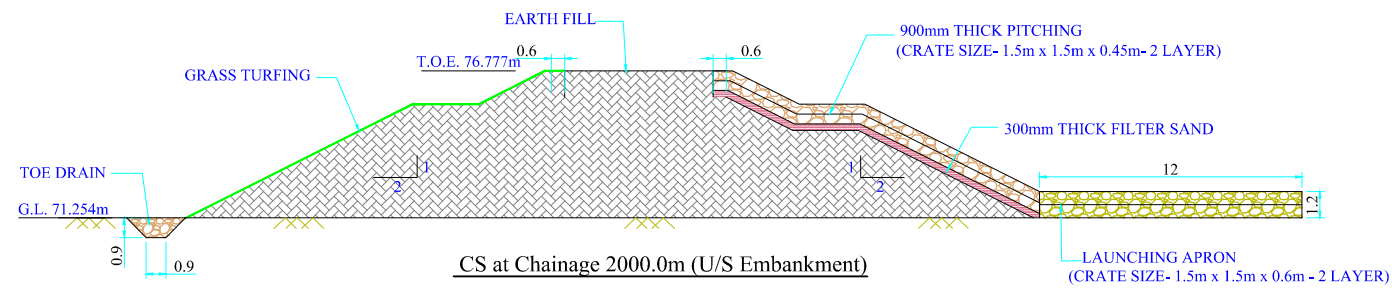
REV.	DATE	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
0	DECEMBER, 2016	ISSUED FOR APPROVAL			
		REVISIONS	DRN	CHKD	APPD
		CLIENT:	National Highways and Infrastructure Development Corporation Limited		
		CONSULTANT:	Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp.HIPA Safedui, Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in		
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE		TYPICAL CROSS SECTION WITH PITCHING AND LAUNCHING APRON GUIDE BUND (RIGHT BANK)			
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	006	0	



NOTES:

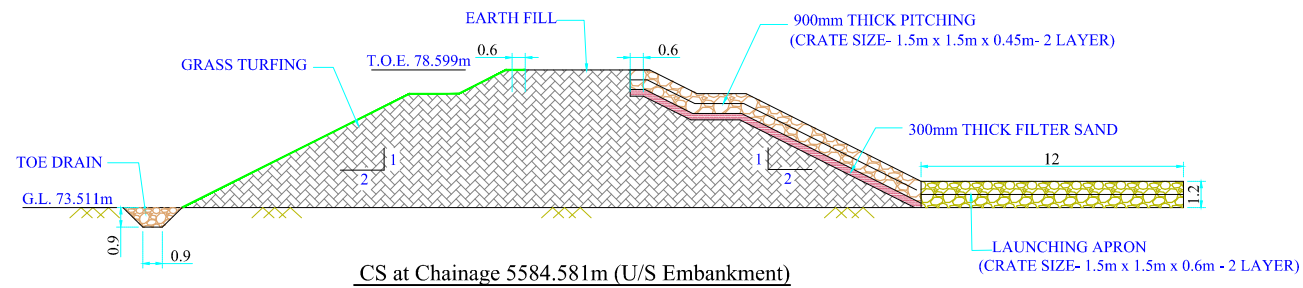
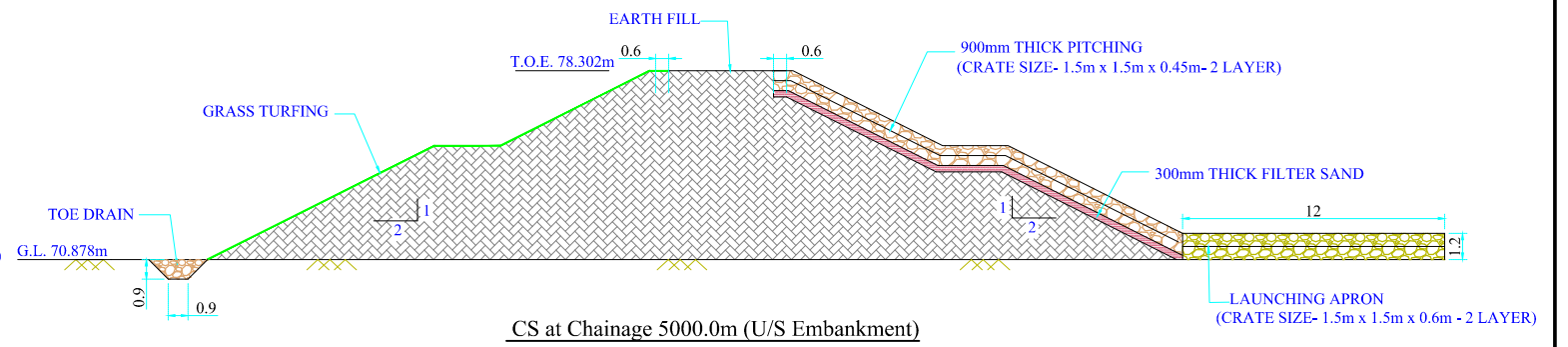
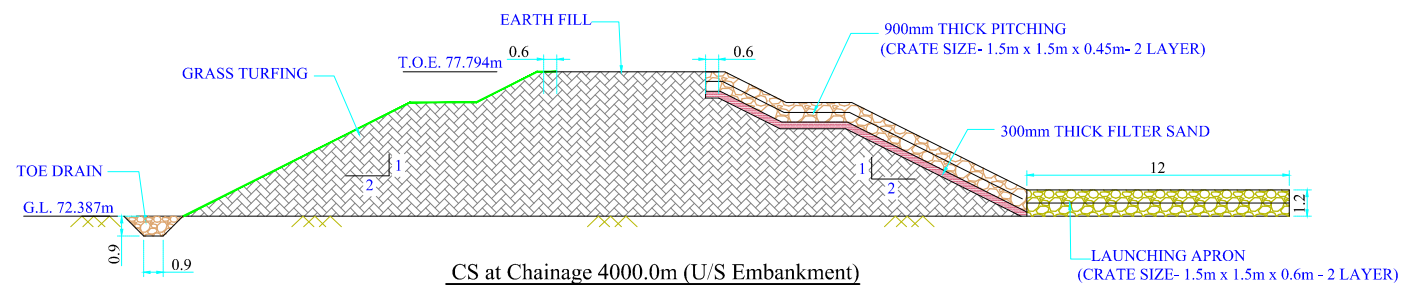
1. THICKNESS OF PITCHING ON RIVER SIDE 0.9m
2. SIZE OF WIRECRATE-1m x 1m x 0.45m- 2 LAYER.
3. THICKNESS OF PITCHING ON COUNTRY SIDE 0.45M.
4. THICKNESS OF FILTER SAND-0.3M.
5. SIZE OF LAUNCHING APRON-31m x 1.2m.
6. SIZE OF WIRECRATE-1.5m x 1.5m x 0.6m- 2 LAYER.

REV.	DATE	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
0	DECEMBER, 2016	ISSUED FOR APPROVAL			
		CLIENT:	National Highways and Infrastructure Development Corporation Limited		
		CONSULTANT:	Xplorer Consultancy Services Pvt. Ltd. Plot No.03,First Floor, Sector-18,Opp.HIPA Sarhau, Gurgaon 122001(Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in		
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE					
TYPICAL CROSS SECTION WITH PITCHING AND LAUNCHING APRON GUIDE BUND (LEFT BANK)					
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	007	0	

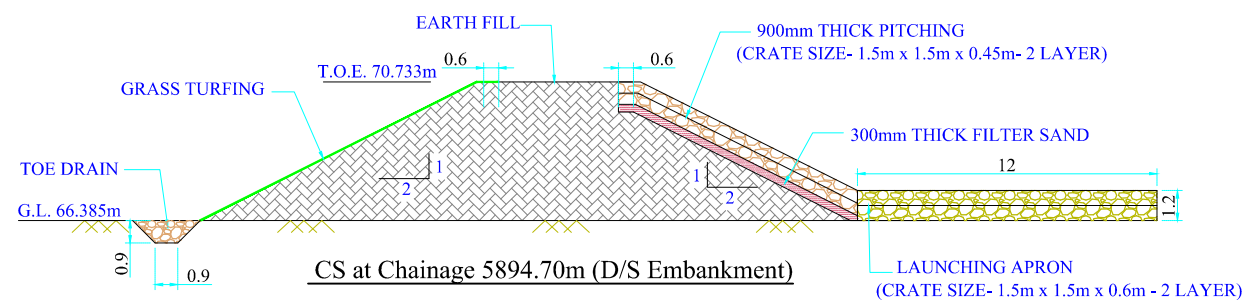
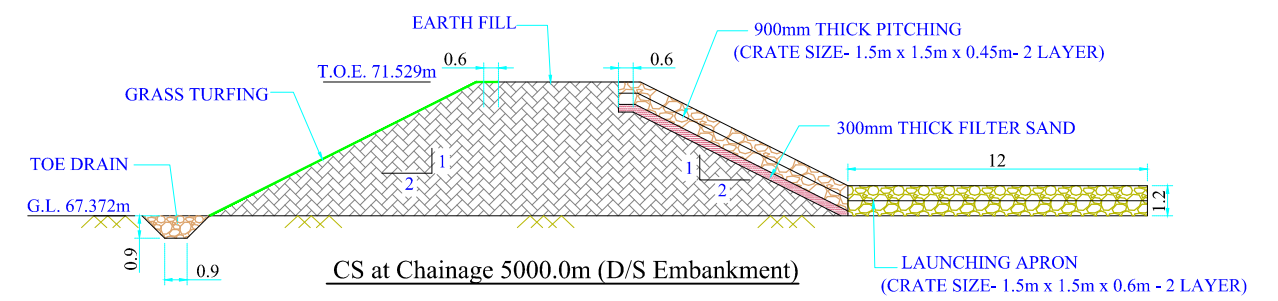
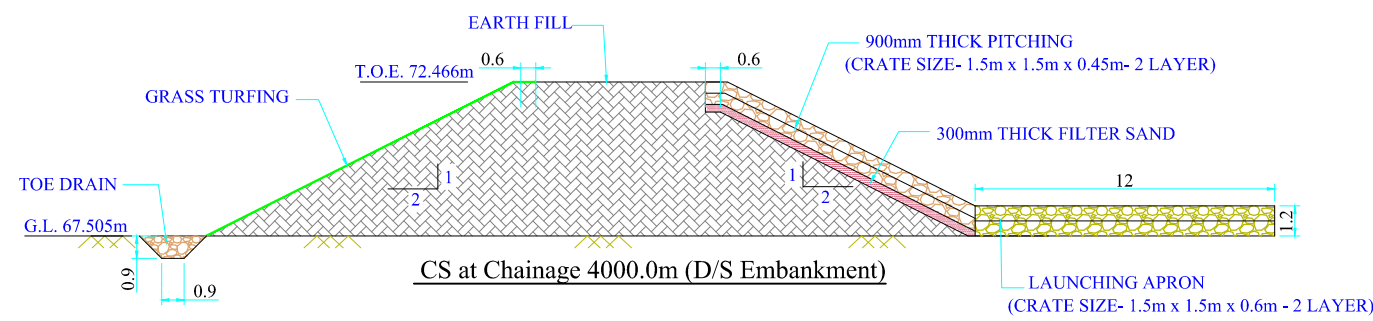
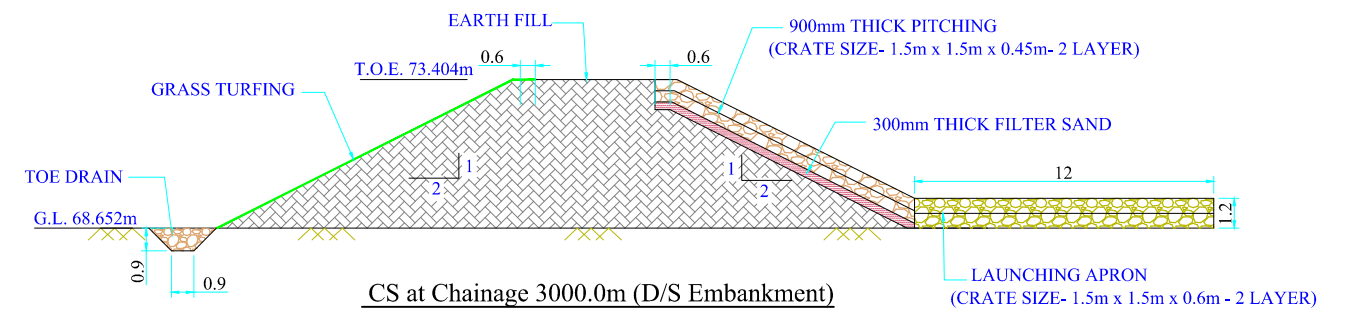
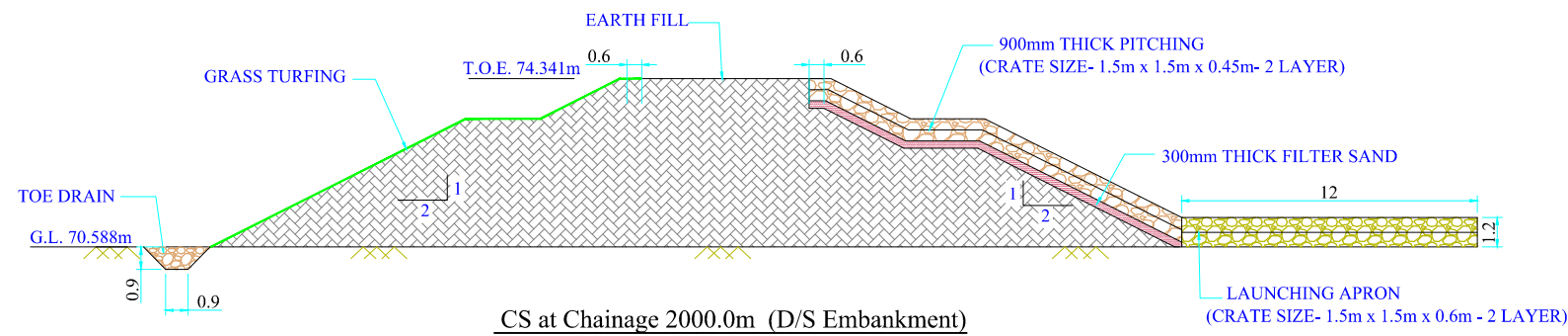


NOTES:

1. THICKNESS OF PITCHING 0.9m
2. SIZE OF WIRECRATE-1.5m x 1.5m x 0.45m- 2 LAYER
3. THICKNESS OF FILTER SAND-0.3M
4. SIZE OF LAUNCHING APRON-31m x 1.2m
5. SIZE OF WIRECRATE-1.5m x 1.5m x 0.6m- 2 LAYER
6. TURFING ON COUNTRY SIDE.





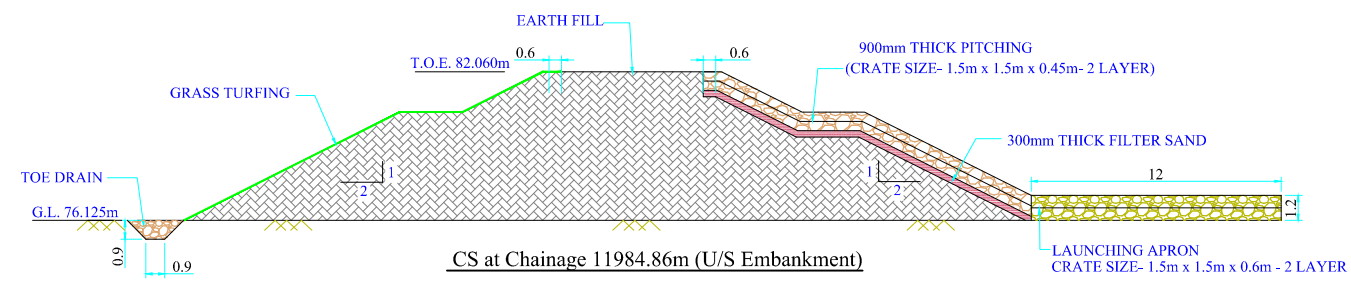
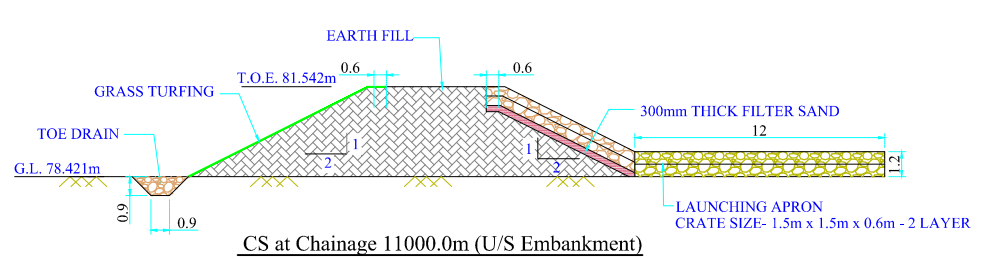
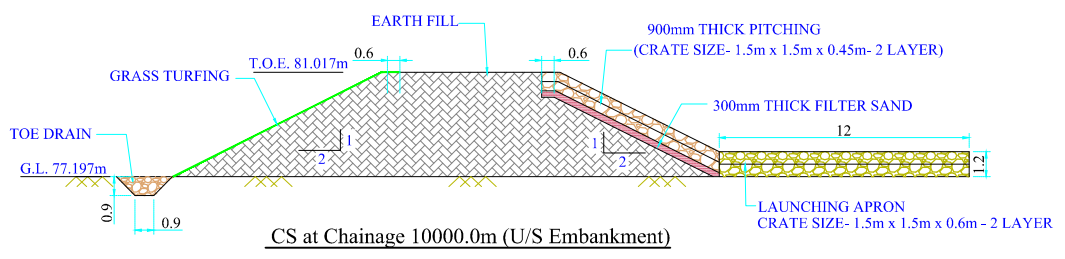
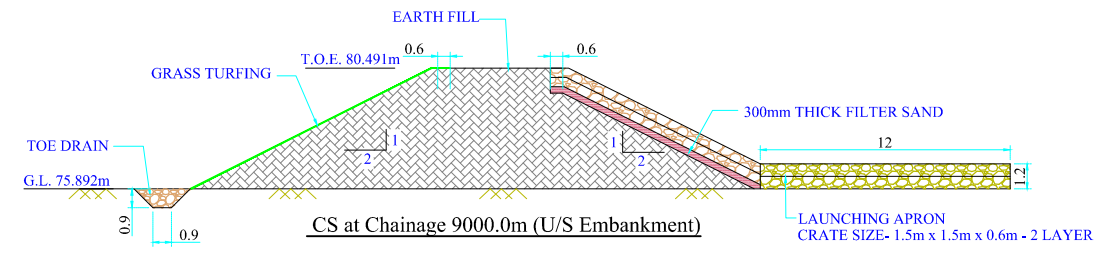
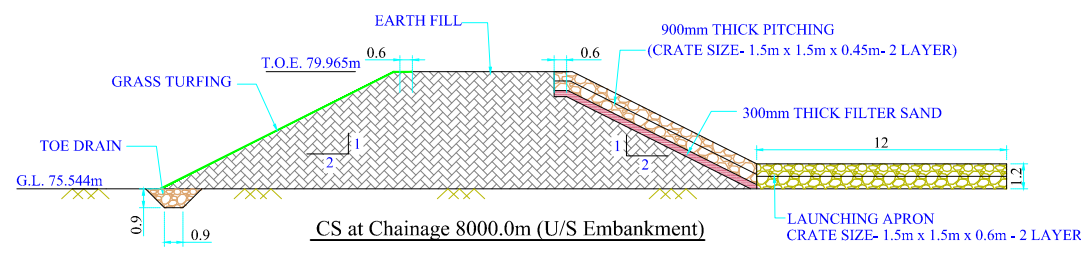
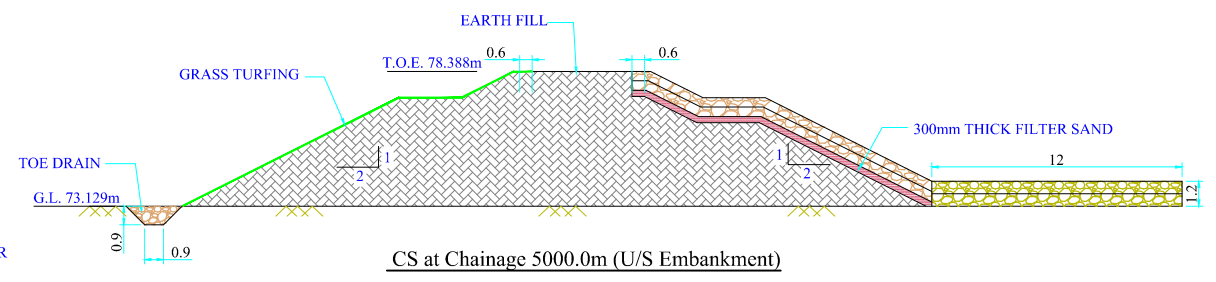
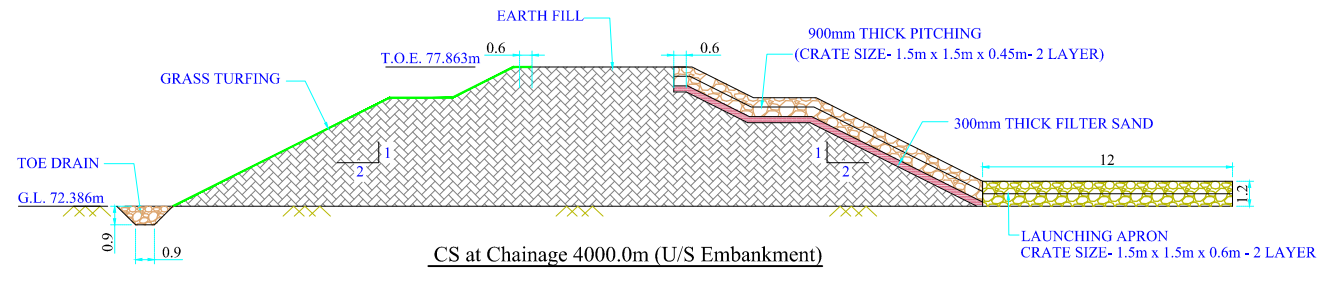
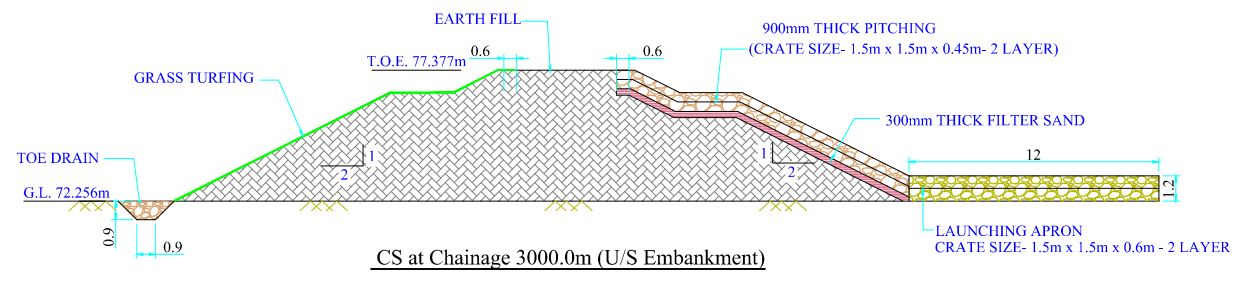
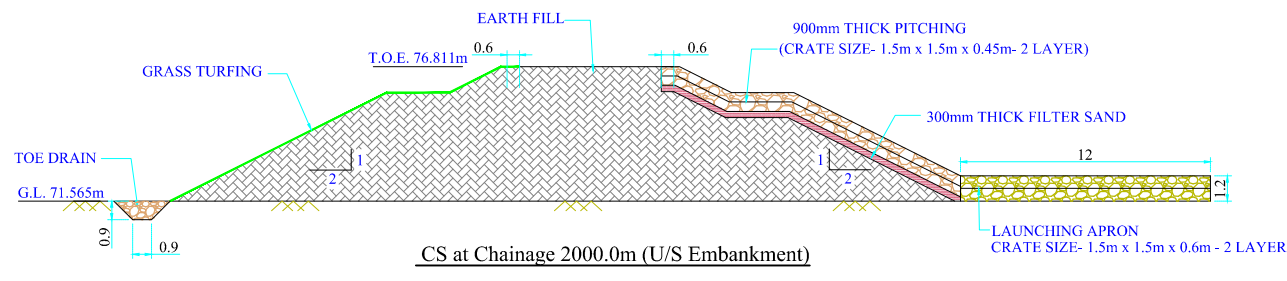
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			DRN	CHKD	APPD
		CLIENT:	National Highways and Infrastructure Development Corporation Limited		
		CONSULTANT:	Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp.HIPA Sarhau, Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in		
PROJECT:		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE:		TYPICAL CROSS SECTION WITH PITCHING AND LAUNCHING APRON EMBANKMENT (U/S RIGHT BANK)			
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	008	0	



NOTES:

1. THICKNESS OF PITCHING 0.9m
2. SIZE OF WIRECRATE-1.5m x 1.5m x 0.45m- 2 LAYER
3. THICKNESS OF FILTER SAND-0.3M
4. SIZE OF LAUNCHING APRON-31m x 1.2m
5. SIZE OF WIRECRATE-1.5m x 1.5m x 0.6m- 2 LAYER
6. TURFING ON COUNTRY SIDE.

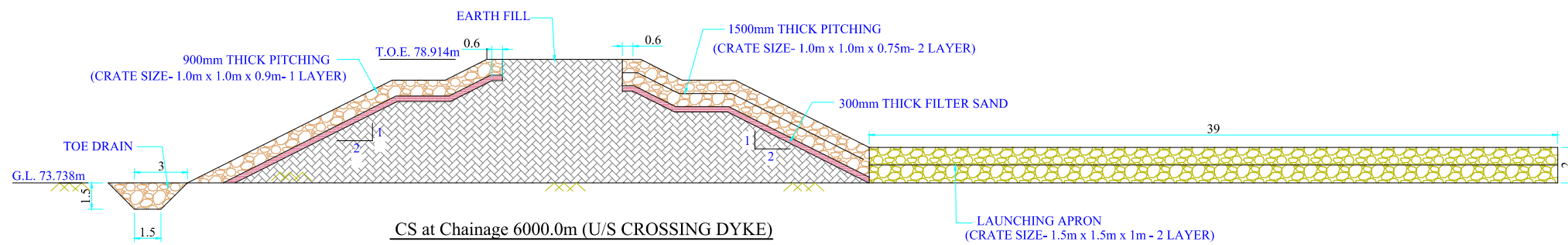
0	DECEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp.HIPA Sarhau, Gurgaon-122001(Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE					
TYPICAL CROSS SECTION WITH PITCHING AND LAUNCHING APRON EMBANKMENT (D/S RIGHT BANK)					
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	009	0	



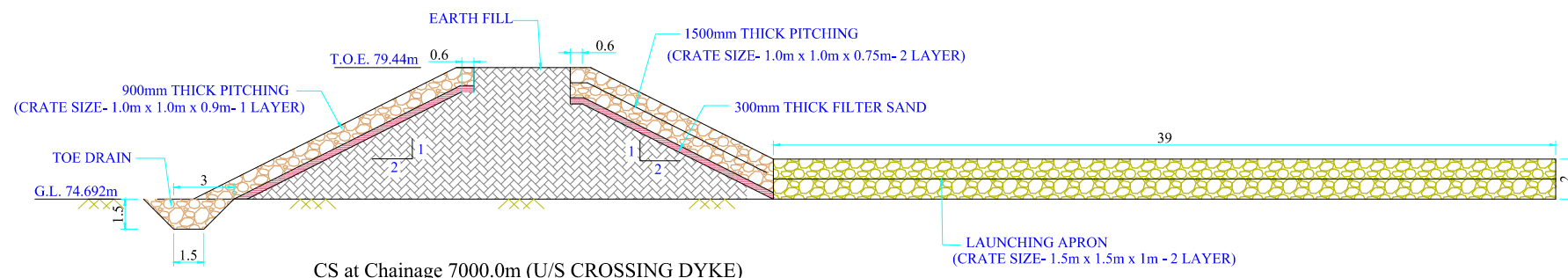
NOTES:

1. THICKNESS OF PITCHING 0.9m
2. SIZE OF WIRECRATE-1.5m x 1.5m x 0.45m- 2 LAYER
3. THICKNESS OF FILTER SAND-0.3M
4. SIZE OF LAUNCHING APRON-31m x 1.2m
5. SIZE OF WIRECRATE-1.5m x 1.5m x 0.6m- 2 LAYER
6. TURFING ON COUNTRY SIDE.

0	DECEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp.HIPA Sarhau, Gurgaon-122001 (Haryana) Ph: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE TYPICAL CROSS SECTION WITH PITCHING AND LAUNCHING APRON EMBANKMENT (U/S LEFT BANK)					
DEC, 2016	SCALE NTS	SIZE A3	DWG. NO. 010	REV. 0	





CS at Chainage 6000.0m (U/S CROSSING DYKE)



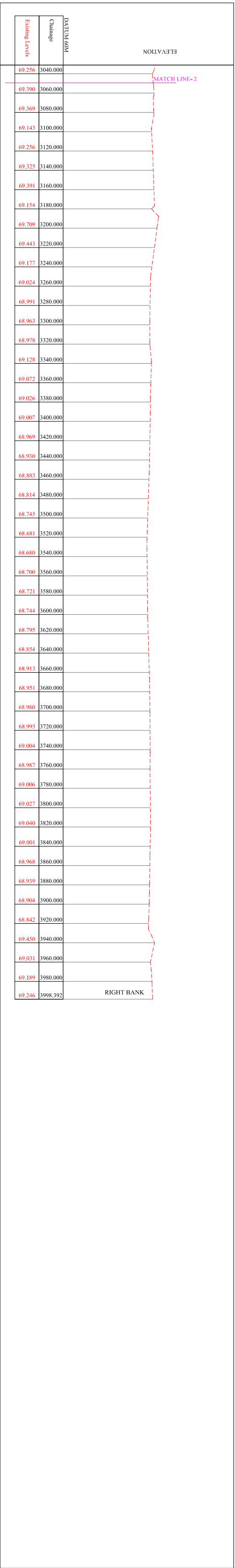
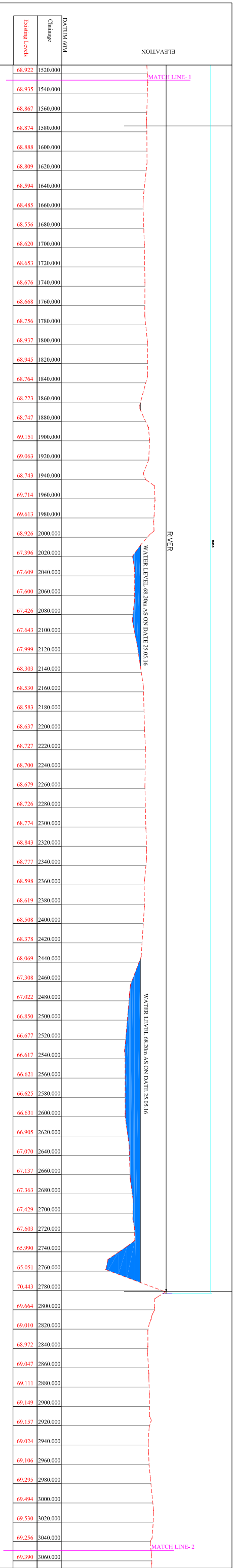
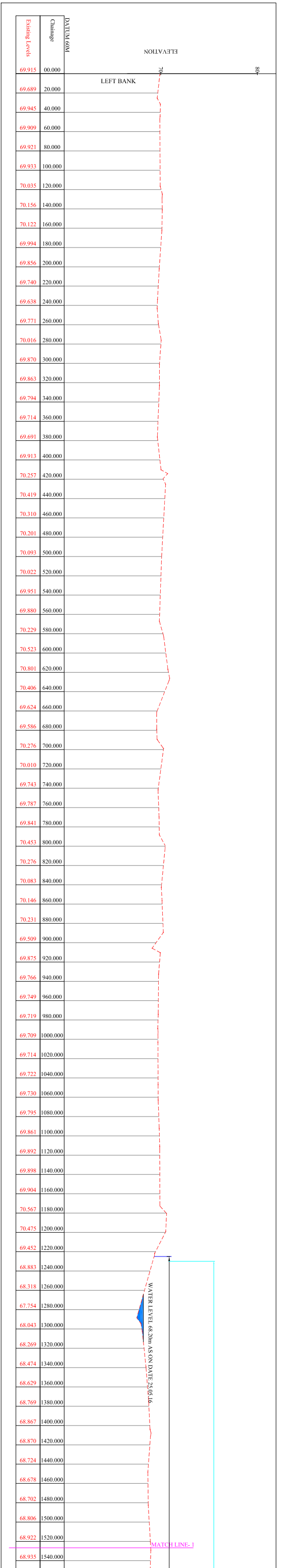
CS at Chainage 7000.0m (U/S CROSSING DYKE)

NOTES:

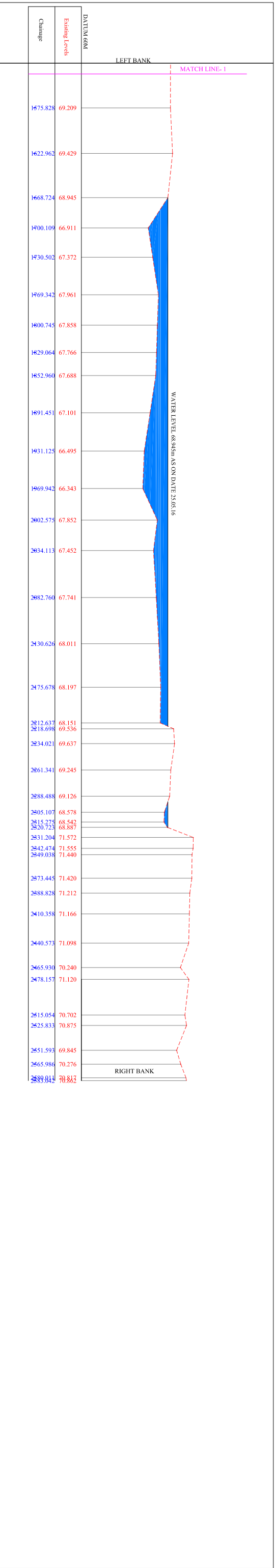
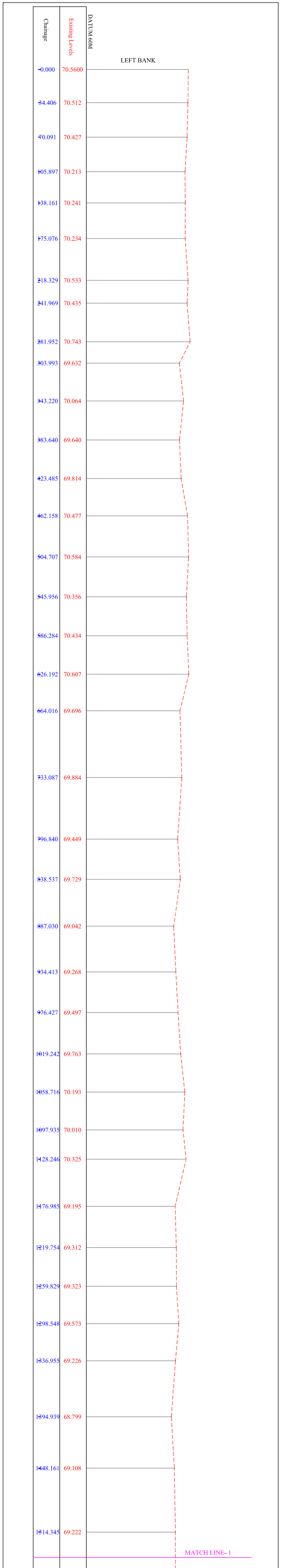
1. THICKNESS OF PITCHING ON RIVER SIDE 1.5m
2. SIZE OF WIRECRATE-1.0m x 1.0m x 0.75m- 2 LAYER
3. THICKNESS OF PITCHING ON COUNTRY SIDE 0.9m
4. SIZE OF WIRECRATE-1m x 1m x 0.9m- 1 LAYER
5. THICKNESS OF FILTER SAND-0.3M
4. SIZE OF LAUNCHING APRON-39m x 2m
5. SIZE OF WIRECRATE-1.5m x 1.5m x 1m- 2 LAYER

0	DECEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.N.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
		CLIENT: National Highways and Infrastructure Development Corporation Limited			
		CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. HIPA Sarhau, Gurgaon 122001 (Haryana) Ph: 0124-4388659, Fax: 0124-4241962 www.xplorer.in, Email- xplorer@xplorer.in			
PROJECT		4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A). 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagurihat Road Junction: KM 182.00 of NH-52) in Sonipur District in the State of Assam.			
DRAWING TITLE					
TYPICAL CROSS SECTION WITH PITCHING AND LAUNCHING APRON CROSSING DYKE (U/S LEFT BANK)					
DEC, 2016	SCALE	SIZE	DWG. NO.	REV.	
	NTS	A3	011	0	

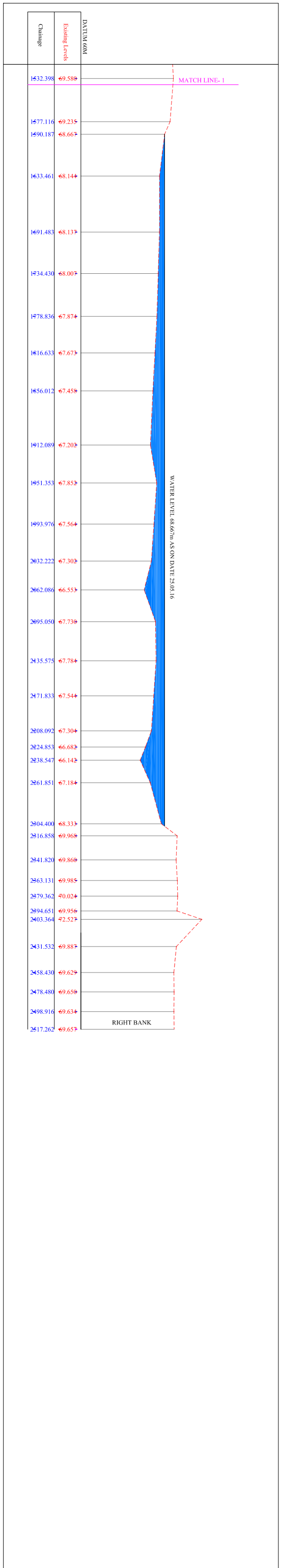
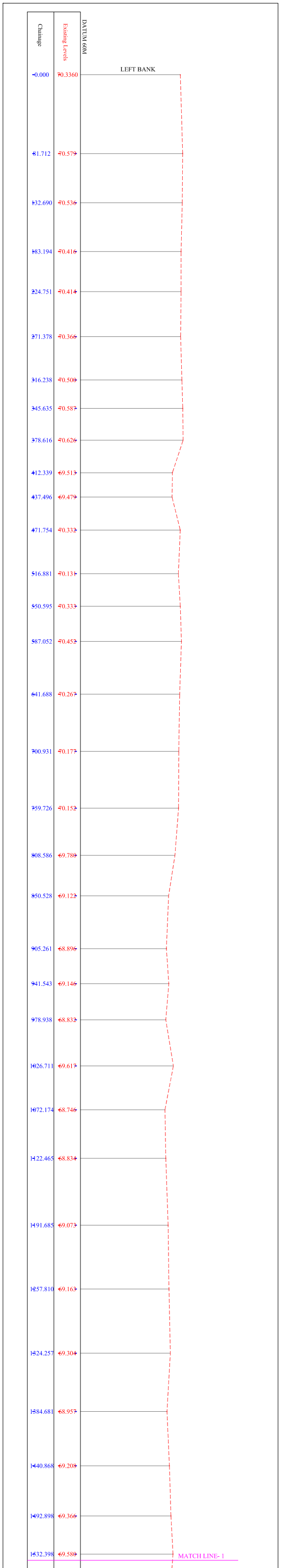
ANNEXURE-C
SURVEY PLAN AND RIVER CROSS SECTION
DRAWINGS



Rev	Date	PARTICULARS	WARCOS
CLIENT: National Highways and Infrastructure Development Corporation Limited			
PROJECT: 4 Lane Capital Connectivity to Manager in Aravalli Pradesh under SMO NE Work (Phase A) - Lining from KM 17.200 (Dabai Road Junction on NH-37A) to KM 38.170 (Lamangan Road Junction, KM 18.200 of NH-52) in Sargol District in the State of Assam.			
DRAWING TITLE: X-SECTION AT PROPOSED BRIDGE			
SURVEY BY: XPI OPER CONSULTANCY SERVICES PRIVATE LIMITED 12000/Highway, Plot 12/40/8693/Ar/24/24/18/2		REVIEWED BY: APPROVED BY	
DRAWN BY:		APPROVED BY	
SCALE DEC. 2016 NTS	DRG. No. XPI/TE/PUR/SECTION-02	SHEET NO. I	REV 1/7 0



Rev	Date	PARTICULARS	WARCOS
CLIENT: National Highways and Infrastructure Development Corporation Limited			
PROJECT: 4.1km Capital Connectivity to Bangalore in Anaparthi Pradesh under S&B NE Work (Phase A)-4-Landing from KM 17.200 (Dudhesh Road Junction on NH-37A) to KM 35.110 (Jainmangal Road Junction, KM 18.200 of NH-523) in Sangar District in the State of Assam.			
DRAWING TITLE: X-SECTION OF RIVER AT CH. 1+000KM AT US FROM PROPOSED BRIDGE			
SURVEY BY: XPLORER CONSULTANCY SERVICES PRIVATE LIMITED 12020, Hyderabad, Tel. 020-26089971, 020-24241882			
DRAWN BY:		REVIEWED BY:	APPROVED BY:
DEC. 2016 SCALE NTS DRG. No. XPL/TEJ/R/SECTION-42 SHEET NO. 27 REV 0			



Rev	Date	PARTICULARS	WARCOS

CLIENT: **National Highways and Infrastructure Development Corporation Limited**

PROJECT: 4 Lane Capital Connectivity to Interop in Assam at Assam Road under S&B NE Work (Phase A), 4-Laning from KM 17.200 (Dakshin Road Junction on NH-37A) to KM 35.110 (Samantpur Road Junction, KM 18.200 of NH-52) in Samantpur District in the State of Assam.

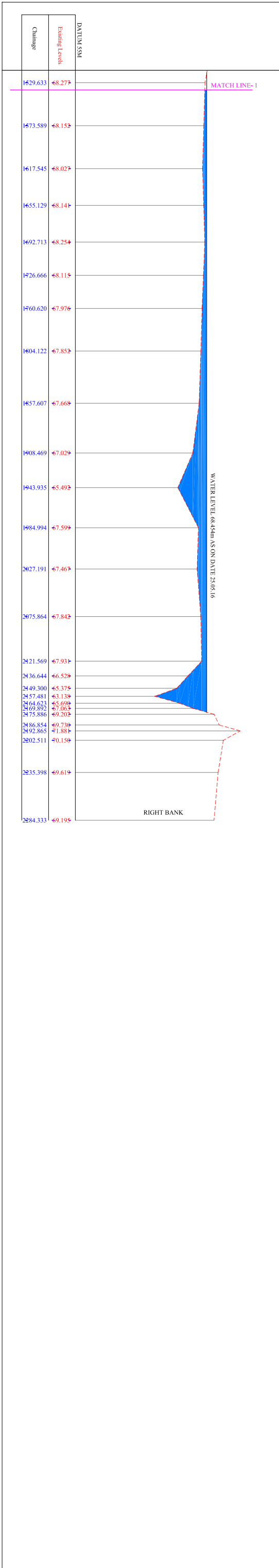
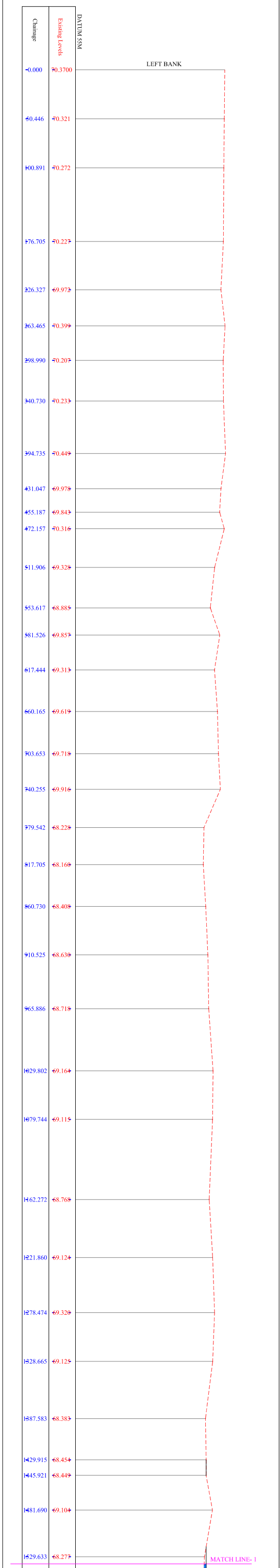
DRAWING TITLE: **X-SECTION OF RIVER AT CH. 0+600KM AT US FROM PROPOSED BRIDGE**

SURVEY BY: **XPLORER CONSULTANCY SERVICES PRIVATE LIMITED**

DRAWN BY: **REVIEWED BY: APPROVED BY:**

SCALE: DRG. No. XPL/TEZ/IR/SECTION-42

DATE: DEC. 2016



CLIENT:
 National Highways and Infrastructure
 Development Corporation Limited

PROJECT:
 4 Lane Capital Connectivity to Bangalore in Anaparthi Pradesh under S&B
 NE Work (Phase A), 4-Laning from KM 17.200 (Dakshin Road Junction
 on NH-37A) to KM 36.110 (Samantpur Road Junction, KM 18.200 of
 NH-52) in Sampur District in the State of Andhra.

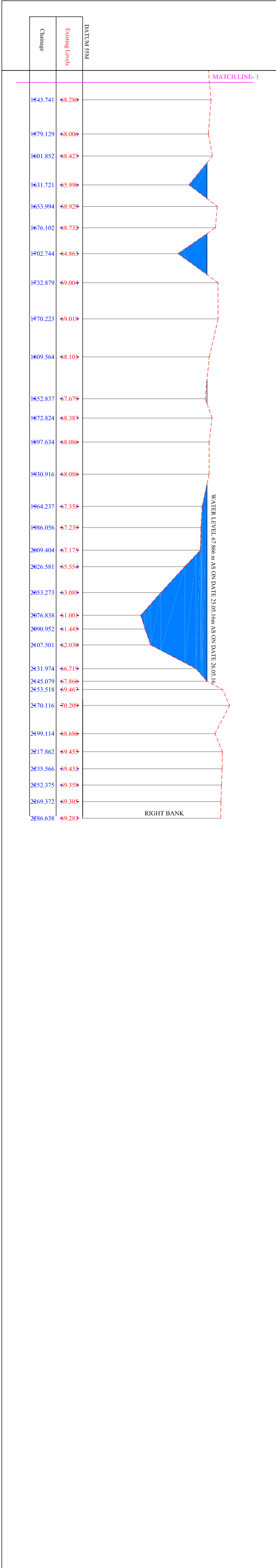
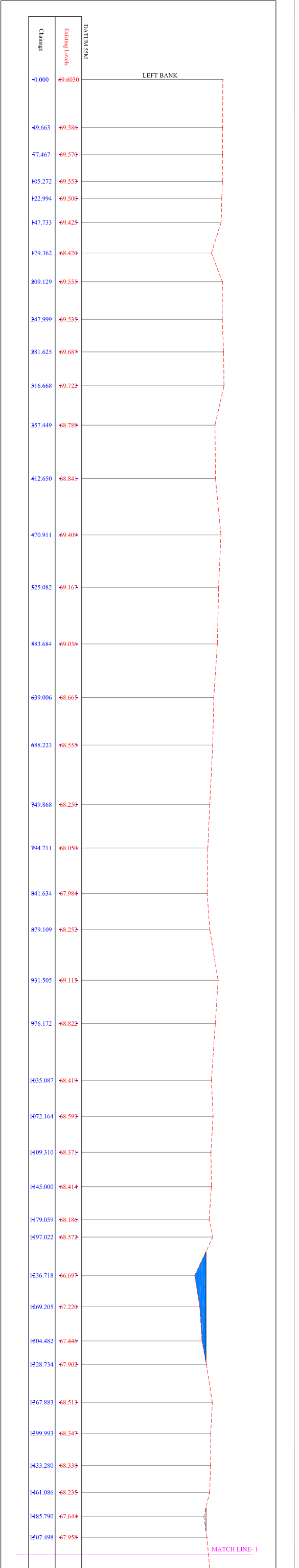
DRAWING TITLE:
 X-SECTION OF RIVER AT CH. 0+300km AT US
 FROM PROPOSED BRIDGE

SURVEY BY:
 XPLORER CONSULTANCY
 SERVICES PRIVATE LIMITED
 12020/Pradesh Rd, P.O: 520008/001, Rajahmundry, Andhra Pradesh, India.

DRAWN BY: REVIEWED BY: APPROVED BY:

Rev	Date	PARTICULARS	WARCOS

DEC. 2016 SCALE NTS DRG. No. XPL/TEZ/IR/SECTION-02 SHEET NO. 47 REV 0



Rev	Date	PARTICULARS	WARCOS

CLIENT:
NIPDA
 National Highways and Infrastructure
 Development Corporation Limited

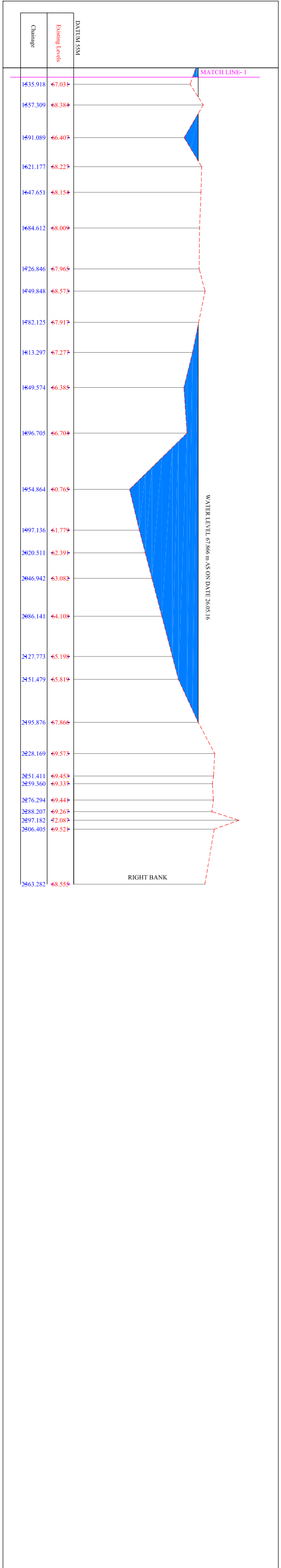
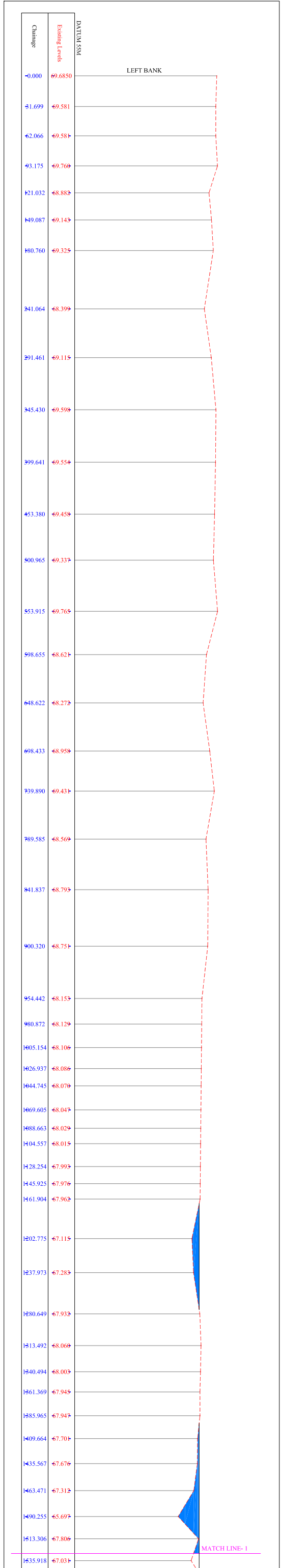
PROJECT:
 4 Lane Capital Connecting to Itanagar to Anantpur Pradesh under S&P
 NE Work (Phase A)-4-Laning from KM 17.200 (Dakshin Road Junction
 on NH-37A) to KM 36.110 (Jammigunta Road Junction; KM 182.00 of
 NH-52) in Sripur District in the State of Assam.

DRAWING TITLE:
**X-SECTION OF RIVER AT CH. 0+400Km AT DS
 FROM PROPOSED BRIDGE**

SURVEY BY:
**XPLORER CONSULTANCY
 SERVICES PRIVATE LIMITED**
7th Floor, 7th Main Road, Sector 10, Connaught Place, New Delhi - 110028, India
 Tel: +91 11 2610 0200, Fax: +91 11 2610 0201, Email: info@xplorer.in

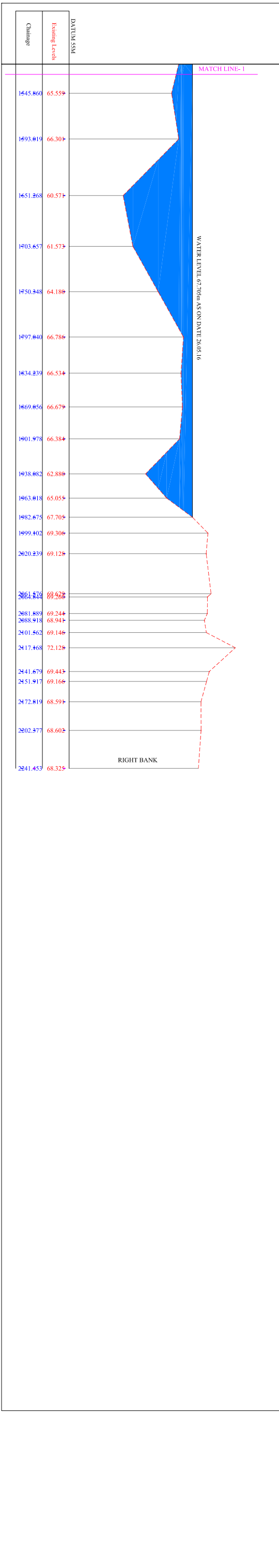
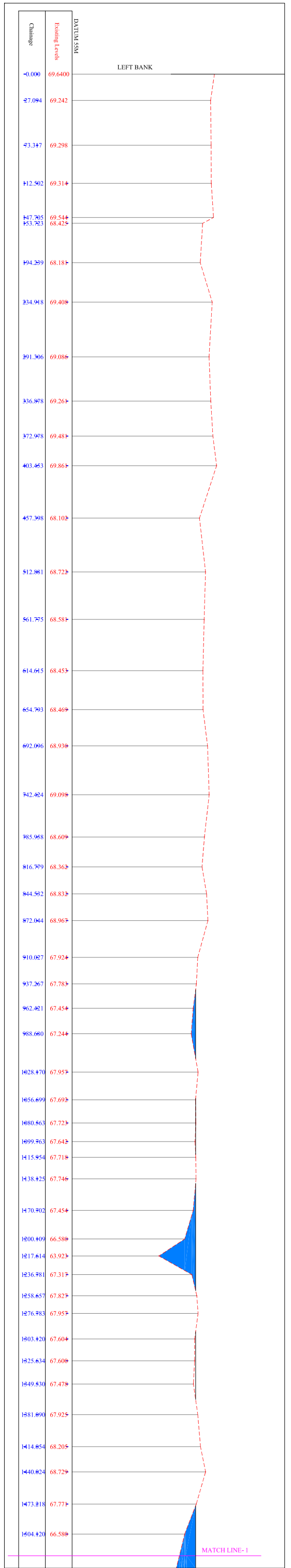
DRAWN BY: _____ REVIEWED BY: _____ APPROVED BY: _____

SCALE	DWG. No.	SHEET NO.	REV
1:1	XPL/TEZ/R/SECTION-02	57	0



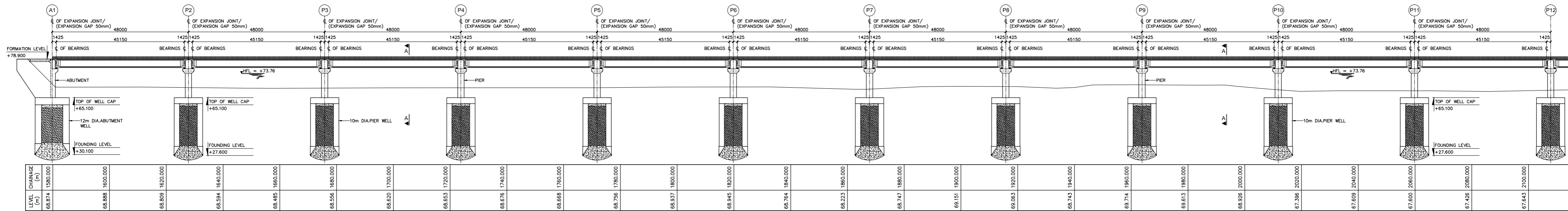
Rev	Date	PARTICULARS	WARCOS
CLIENT: National Highways and Infrastructure Development Corporation Limited			
PROJECT: 4 Lane Capital Connectivity to Interceptor in Anapurna Pradesh under S&P NE Work (Phase A), 4-Laning from KM 17.200 (Older Road Junction on NH-37A) to KM 35.110 (Junctional Road Junction, KM 18.200 of NH-52) in Sonapat District in the State of Assam.			
DRAWING TITLE: X-SECTION OF RIVER AT CH. 0+700km AT D/S FROM PROPOSED BRIDGE			
SURVEY BY: XPLORER CONSULTANCY SERVICES PRIVATE LIMITED			
DRAWN BY: REVIEWED BY:			
APPROVED BY:			

DEC. 2016	SCALE	DRG. No. XPL/TE/PIR/SECTION-02	SHEET NO.	REV
	NTS		6/7	0

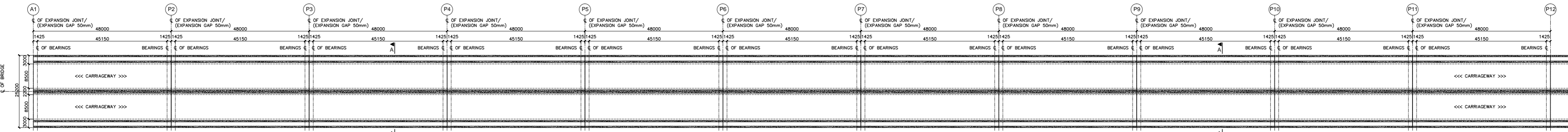


Rev	Date	PARTICULARS	WAPCOS
CLIENT: National Highways and Infrastructure Development Corporation Limited			
PROJECT 4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work Phase A, & Linking from KM 17.200 (Dakshin Road Junction on NH57) to NH 55 (10 km) under Phase 2 of the project. (NH 57) on NH 55 (10 km) under Phase 2 of the project. (NH 57) on NH 55 (10 km) under Phase 2 of the project.			
DRAWING TITLE X-SECTION OF RIVER AT CH. 1+000km AT D/S FROM PROPOSED BRIDGE			
SURVEY BY: XPLORER CONSULTANCY SERVICES PRIVATE LIMITED		DRAWN BY: XPLORER CONSULTANCY SERVICES PRIVATE LIMITED	
DRAWN BY:		REVIEWED BY:	
DRAWN BY:		APPROVED BY:	
DEC 2016	SCALE NTS	DRG. No. XPL/TEPR/SECTION-02	SHEET NO. 1 REV 0

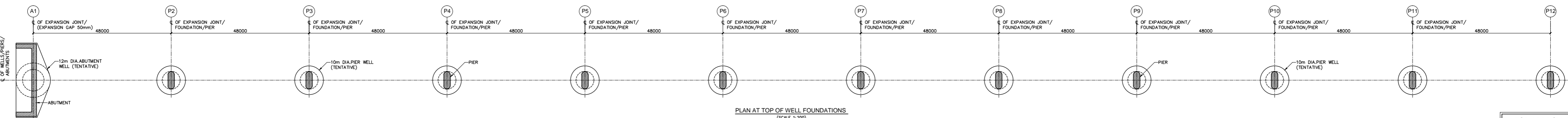
ANNEXURE-D
GENERAL ALIGNMENT DRAWING



SECTIONAL ELEVATION OF BRIDGE
(SCALE 1:200)

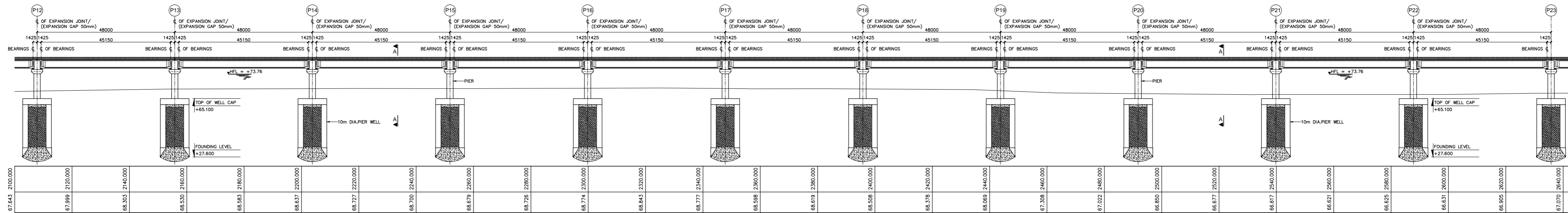


PLAN AT TOP OF DECK SLAB
(SCALE 1:200)

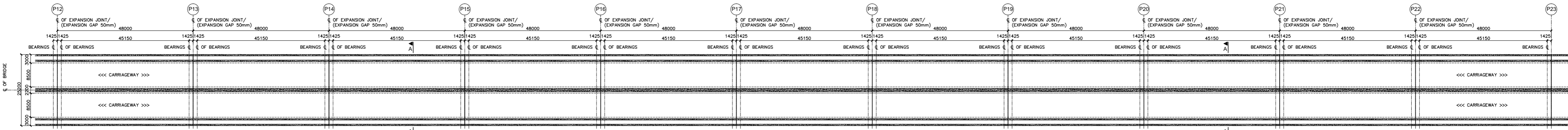


PLAN AT TOP OF WELL FOUNDATIONS
(SCALE 1:200)

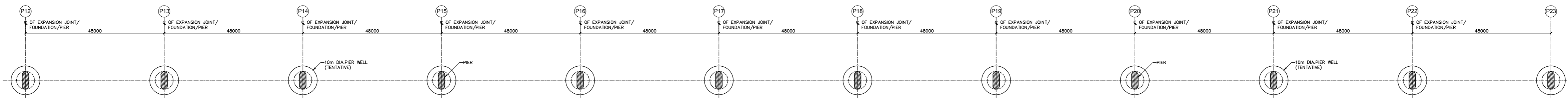
<table border="1"> <tr> <td>R1</td> <td>OCT 2016</td> <td>GENERAL REVISION</td> </tr> <tr> <td>REVISION</td> <td>DATE</td> <td>DESCRIPTION</td> </tr> </table>		R1	OCT 2016	GENERAL REVISION	REVISION	DATE	DESCRIPTION	CONSULTANT XPLORER CONSULTANCY SERVICES PRIVATE LIMITED First Floor, Plot No.03, Sector-18, Opp.HIPA, Sarbajit, Gurgaon-122001 (Haryana) Phone: 0124 - 4388659, www.xploreronline.com, email - xplorer@xplorer.in	PROJECT CONSTRUCTION OF JIA-BHARALI BRIDGE IN ASSAM OWNER NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LIMITED	TITLE GENERAL ARRANGEMENT DRAWING OF THE BRIDGE (SHEET 1 OF 3)	FOR APPROVAL <table border="1"> <tr> <td>SCALE</td> <td>DATE</td> <td>DRAWN</td> <td>APPROVED</td> <td>DRAWING NO.</td> <td>REV.</td> </tr> <tr> <td>AS SHOWN</td> <td>AUGUST 2016</td> <td>SANDEEP</td> <td>AP</td> <td>XPLR-226/2016/101</td> <td>R1</td> </tr> </table>	SCALE	DATE	DRAWN	APPROVED	DRAWING NO.	REV.	AS SHOWN	AUGUST 2016	SANDEEP	AP	XPLR-226/2016/101	R1
R1	OCT 2016	GENERAL REVISION																					
REVISION	DATE	DESCRIPTION																					
SCALE	DATE	DRAWN	APPROVED	DRAWING NO.	REV.																		
AS SHOWN	AUGUST 2016	SANDEEP	AP	XPLR-226/2016/101	R1																		



SECTIONAL ELEVATION OF BRIDGE
(SCALE 1:200)

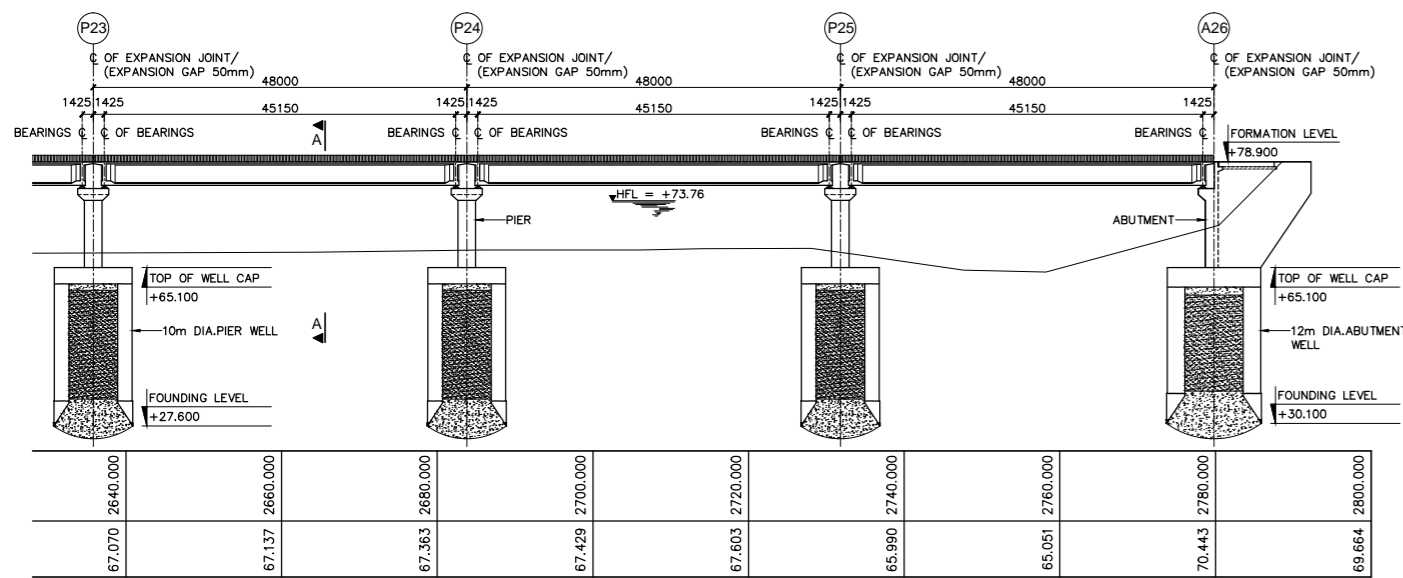


PLAN AT TOP OF DECK SLAB
(SCALE 1:200)

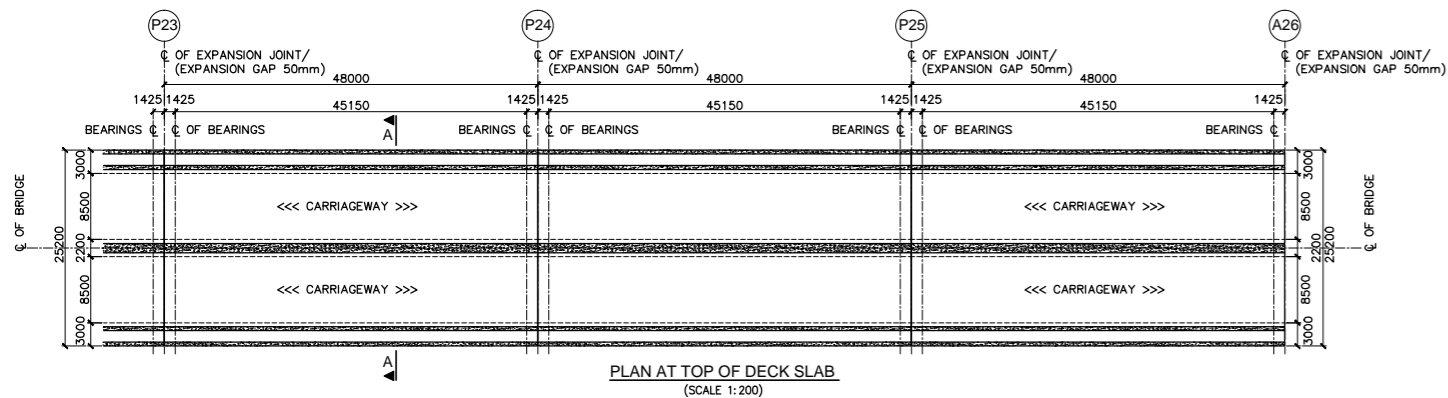


PLAN AT TOP OF WELL FOUNDATIONS
(SCALE 1:200)

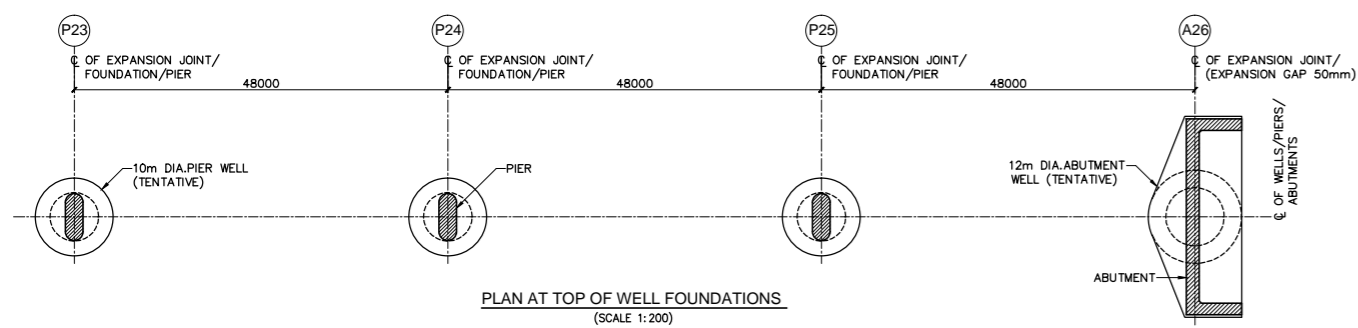
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R1	OCT 2016	GENERAL REVISION																					
REVISION	DATE	DESCRIPTION																					
SCALE	DATE	DRAWN	APPROVED	DRAWING NO.	REV.																		
AS SHOWN	AUGUST 2016	SANDEEP	AP	XPLR-226/2016/102	R1																		



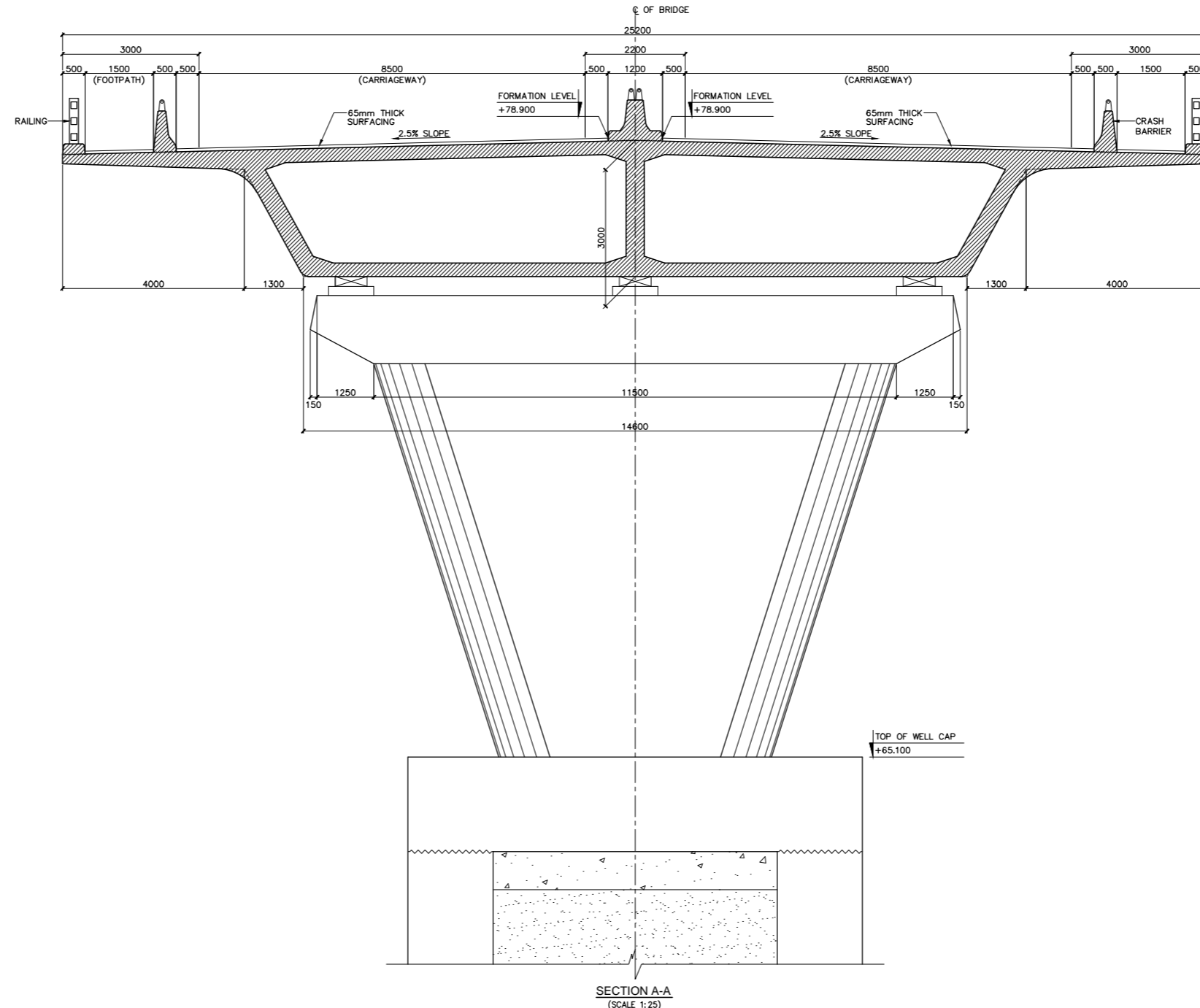
SECTIONAL ELEVATION OF BRIDGE
(SCALE 1:200)



PLAN AT TOP OF DECK SLAB
(SCALE 1:200)



PLAN AT TOP OF WELL FOUNDATIONS
(SCALE 1:200)



SECTION A-A
(SCALE 1:25)

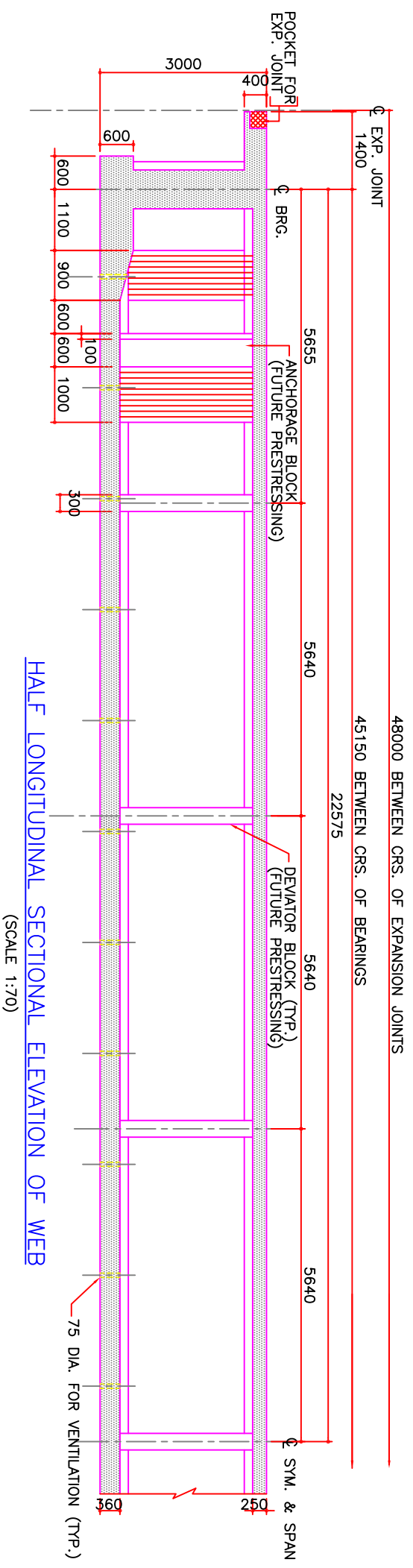
NOTE:

- ALL DIMENSIONS ARE IN mm & LEVELS ARE IN m UNLESS NOTED OTHERWISE.
- CLEAR COVER FOR VARIOUS STRUCTURAL ELEMENTS SHALL BE AS FOLLOWS:
WELL & WELL CAPS: 75mm TO MAIN REINFORCEMENT
PIERS: 50mm TO ANY REINFORCEMENT
OTHER ELEMENTS: 40mm TO ANY REINFORCEMENT
- GRADE OF CONCRETE FOR VARIOUS STRUCTURAL ELEMENTS SHALL BE AS FOLLOWS:
WELL STENING: M25
WELL CURB & CAP: M35
SUPERSTRUCTURE & CRASH BARRIER: M50
ABUTMENT, PIER, PIER CAP, BEARING PEDESTAL & RAILING: M35
BOTTOM PLUG: M25
INTERMEDIATE/TOP PLUG: M25
- ALL REINF. BARS SHALL BE OF HIGH YIELD STRENGTH DEFORMED (GRADE Fe500) BARS CONFORMING TO IS 1786-1985
- LOADS CONSIDERED FOR BRIDGE DESIGN (AS PER IRC-6):
(i) DEAD LOAD: CONSISTING OF SELFWEIGHT OF STRUCTURE AND SUPERIMPOSED DEAD LOADS
(ii) LIVE LOAD IN EACH CARRIAGEWAY: CONSISTING OF THREE LANES OF CLASS-A VEHICLES OR ONE LANE OF CLASS 70R TRACKED/WHEELED VEHICLES ALONG WITH ONE LANE OF CLASS-A VEHICLES AS PER IRC-6
(iii) ANY OTHER LIVE LOADS I.e. SPECIAL VEHICLES, FATIGUE VEHICLES AS PER IRC-6
(iv) FOOTPATH LOAD AS PER IRC-5
(v) WATER CURRENT FORCES AS PER IRC-6
(vi) TRACTIVE/BRAKING FORCES: AS PER IRC-6
(vii) BEARING FRICTION: AS PER IRC-6
(viii) EARTH PRESSURE
(ix) SEISMIC FORCES: AS PER IRC-6 FOR ZONE V (ZONE FACTOR=0.36 AND IMPORTANCE FACTOR=1.5)
(x) ANY OTHER LOADS AS PER IRC-6
- LOADS COMBINATIONS FOR BRIDGE DESIGN
LOAD COMBINATIONS SHALL BE AS PER IRC-78 FOR FOUNDATION DESIGN AND IRC-6 FOR STRUCTURAL DESIGN.
- DETAILS SHOWN IN THIS DRAWING ARE TENTATIVE AND SUBJECT TO CHANGE DURING DETAILED DESIGN.

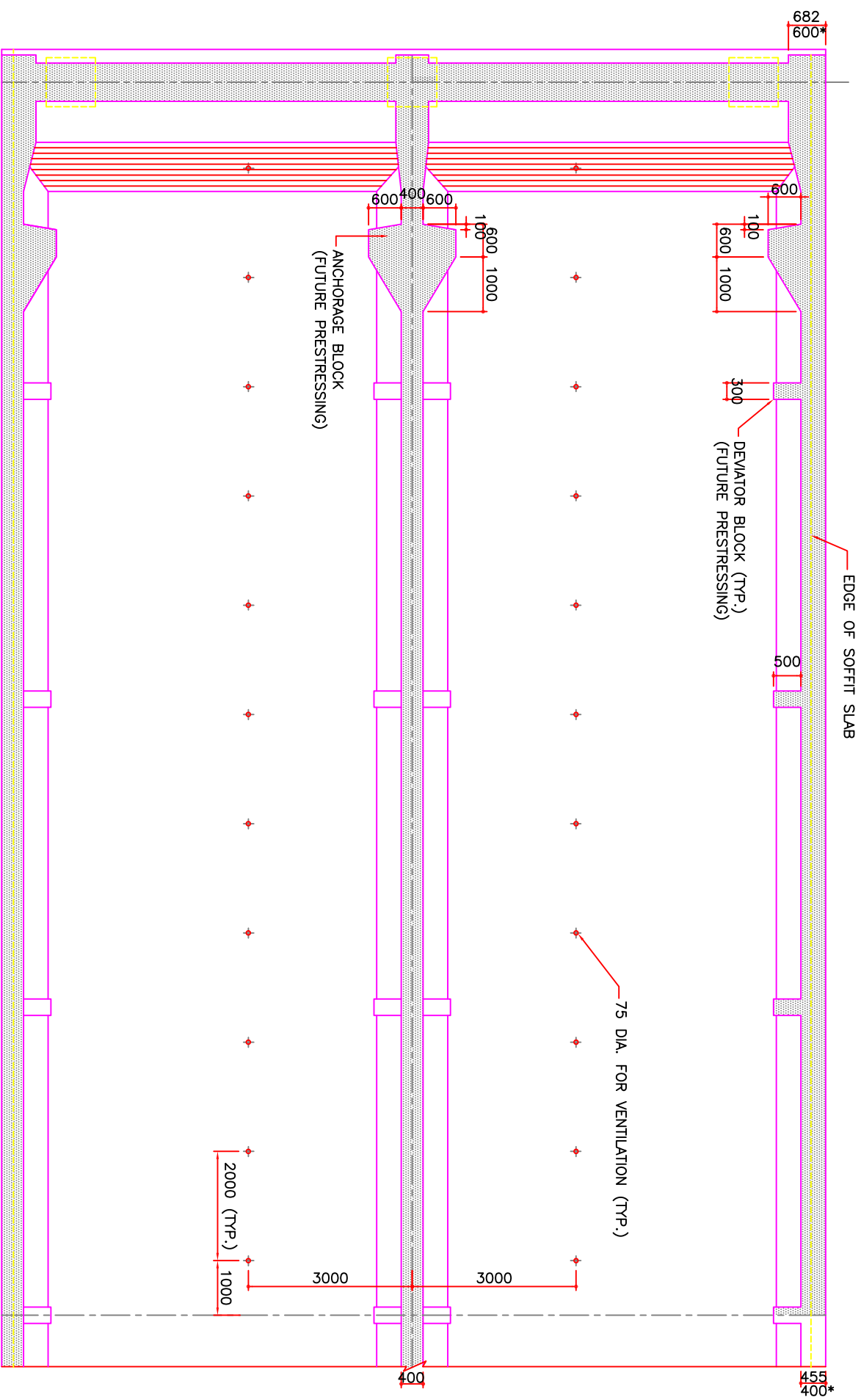
FOR APPROVAL

CONSULTANT XPLORER CONSULTANCY SERVICES PRIVATE LIMITED First Floor, Plot No.03, Sector-18, Opp.HIPA,Sarhau,Gurgaon-122001 (Haryana) Phone: 0124 - 4388659, www.xploreronline.com, email - xplorer@xplorer.in		PROJECT CONSTRUCTION OF JIA-BHARALI BRIDGE IN ASSAM		TITLE GENERAL ARRANGEMENT DRAWING OF THE BRIDGE (SHEET 3 OF 3)					
R1 REVISION	OCT 2016 DATE	GENERAL REVISION DESCRIPTION	OWNER NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LIMITED	SCALE AS SHOWN	DATE AUGUST 2016	DRAWN SANDEEP	APPROVED AP	DRAWING NO. XPLR-226/2016/103	REV. R1

ANNEXURE-E
SUPER STRUCTURE



- NOTES:**
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED.
 2. DIMENSIONS ARE NOT TO BE SCALED, ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.
 3. GRADE OF CONCRETE SHALL BE M45.
 4. ALL REINFORCING BARS SHALL BE H.Y.S.D. BARS HAVING SPECIFIED MINIMUM 0.2% PROOF STRESS OF 500D MPa CONFORMING TO IS: 1786.



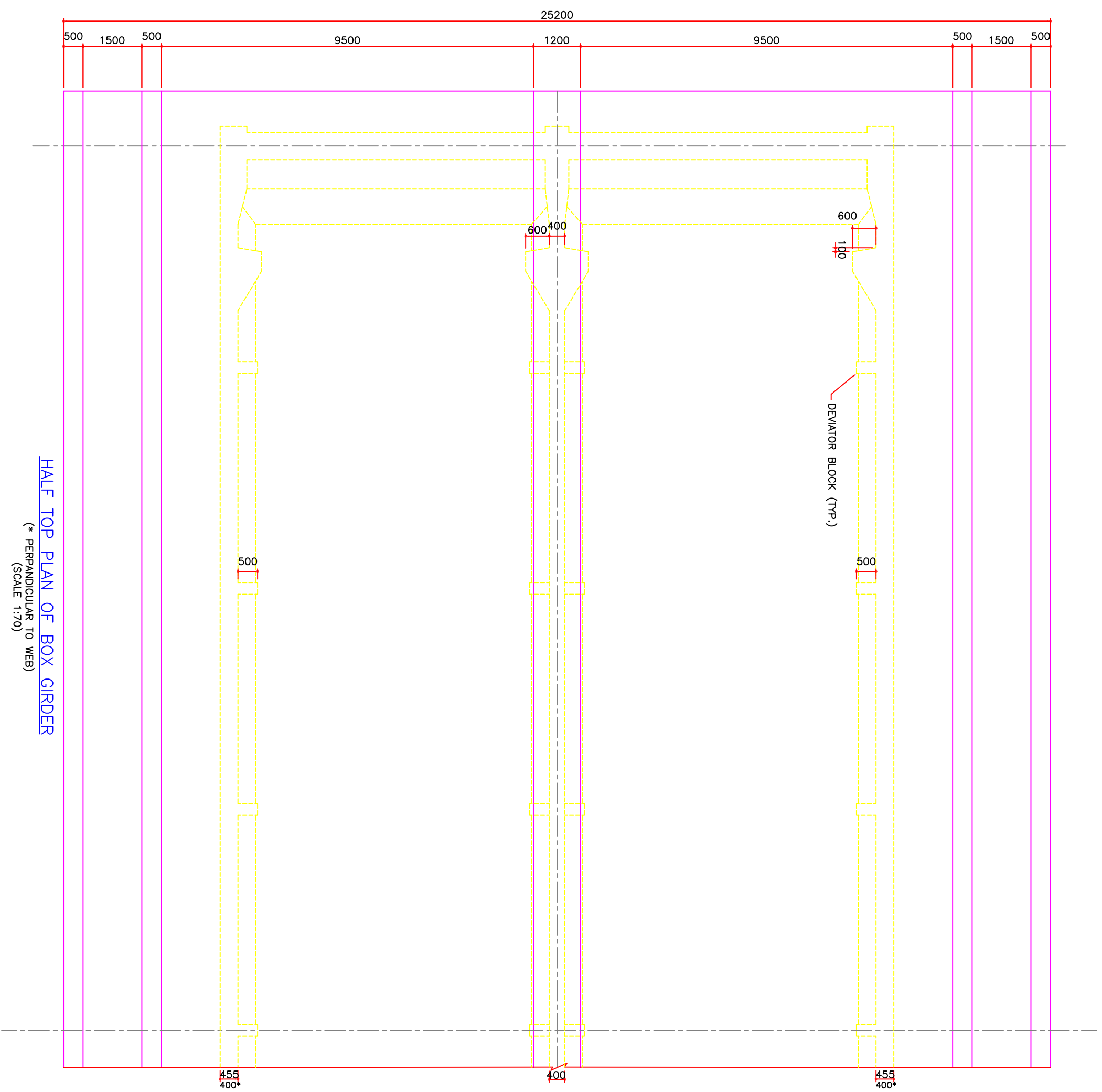
0	DECEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.M.SEN
REV.	DATE	REVISIONS	DRN	CHKD	APPD
CLIENT:			National Highways and Infrastructure Development Corporation Limited		
CONSULTANT:			Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, GPO, H.P.A Sarnaul, Gurgaon 122001 (Haryana) Ph: 0124-4388659 Fax:0124-241962 www.xplorer.in, Email: xplorer@xplorer.in		

PROJECT
4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Lamagunhat Road Junction: KM 182.00 of NH-52) in Sonpur District in the State of Assam.



DRAWING TITLE
GENERAL ARRANGEMENT OF DECK

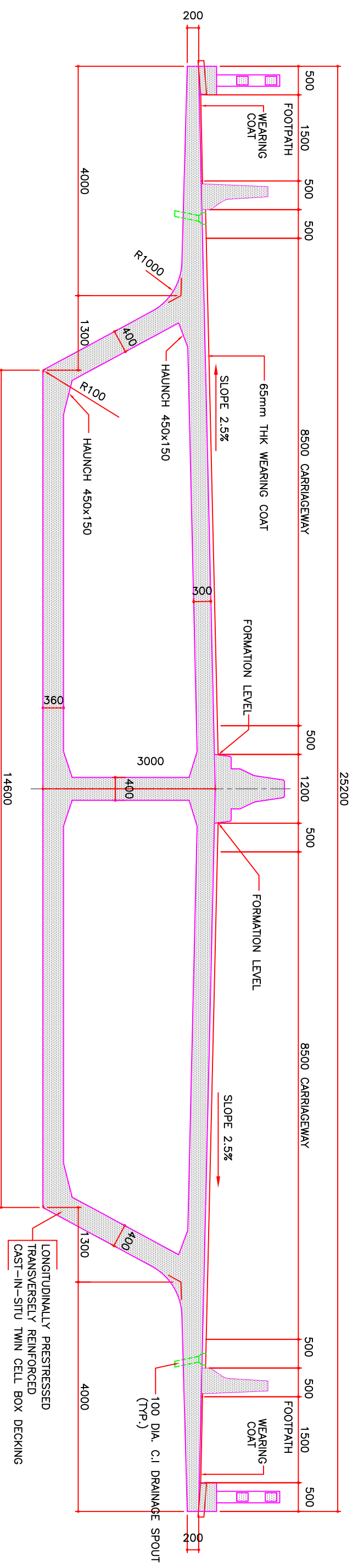
DECEMBER, 2016	SCALE	SIZE	DWG. NO.	REV.
	NTS	A3	1 OF 3	0

- NOTES:**
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED.
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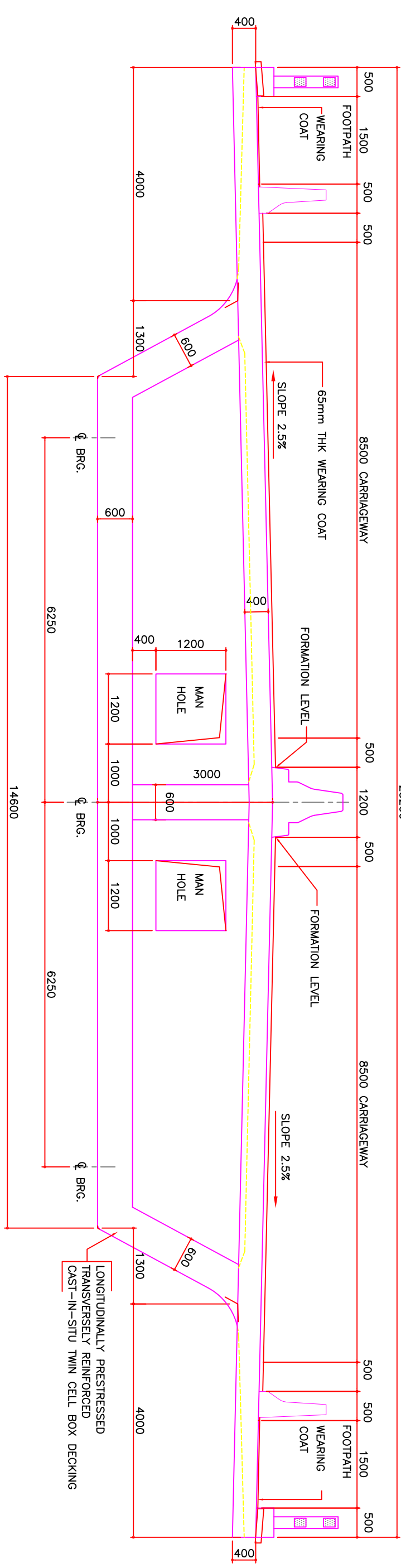
HALF TOP PLAN OF BOX GIRDER
 (* PERPENDICULAR TO WEB)
 (SCALE 1:70)

REV. 0	DATE	DECEMBER, 2016	ISSUED FOR APPROVAL	DM	SK	R.M. SEN
			REVISIONS	DRN	CHKD	APPD
			CLIENT: National Highways and Infrastructure Development Corporation Limited			
			CONSULTANT: Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, GPO, HJP A Sarhail, Gurgaon 122001(Haryana) Ptc: 0124-4388659, Fax:0124-4241962 www.xplorer.in, Email: xplorer@xplorer.in			
PROJECT: 4 Lane Capital Connectivity to Itanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4- Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamagunhat Road Junction: KM 182.00 of NH-62) in Sonipur District in the State of Assam.						
DRAWING TITLE GENERAL ARRANGEMENT OF DECK						
DECEMBER, 2016	SCALE	SIZE	DWG. NO.	REV.		
	NTS	A3	2 OF 3	0		



CROSS SECTION NEAR MID SPAN

(SCALE 1:50)



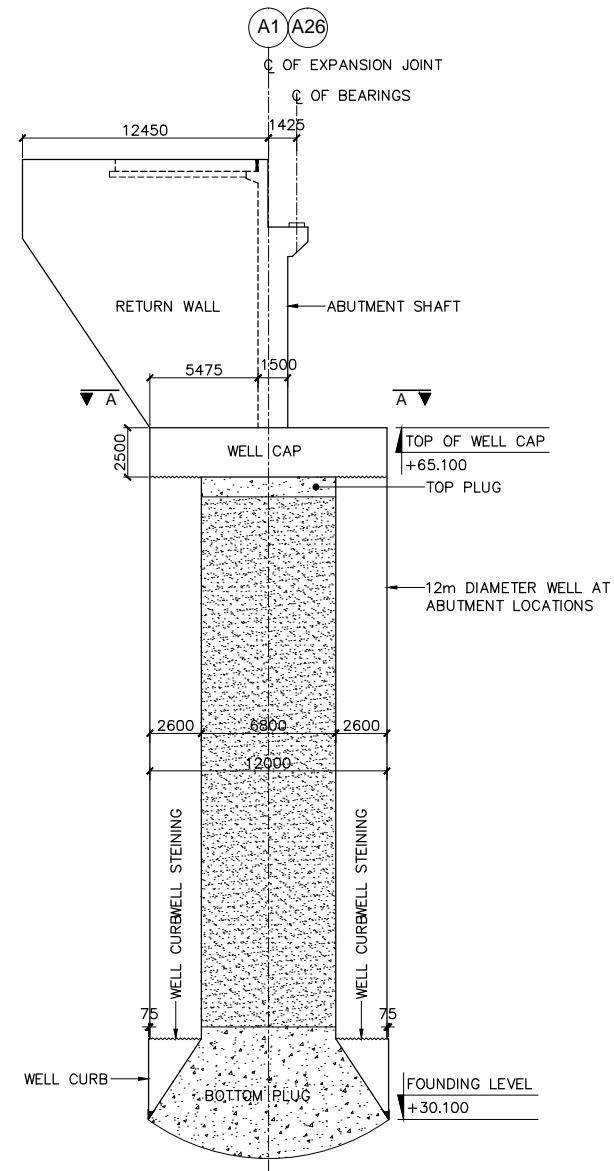
CROSS SECTION NEAR SUPPORT

(SCALE 1:50)

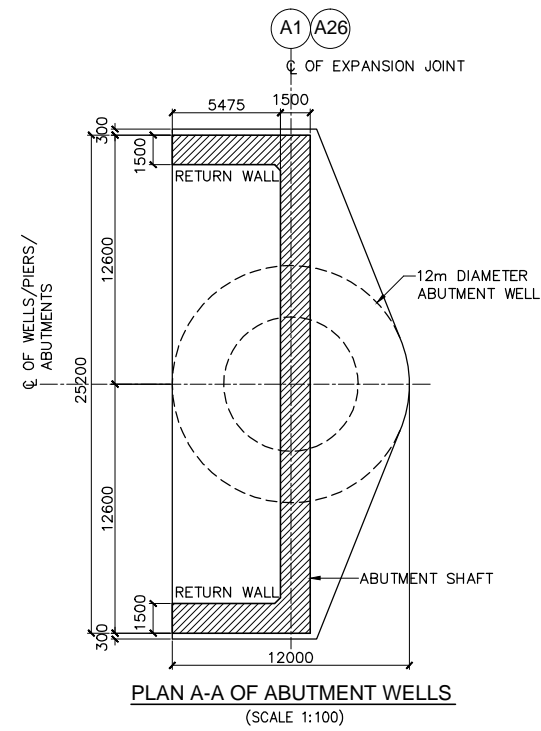
- NOTES:**
1. ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED.
 2. DIMENSIONS ARE NOT TO BE SCALED, ONLY WRITTEN DIMENSIONS ARE TO BE FOLLOWED.
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 4. ALL REINFORCING BARS SHALL BE H.Y.S.D. BARS HAVING SPECIFIED MINIMUM 0.2% PROOF STRESS OF 5000 MPa CONFORMING TO IS: 1786.

PROJECT 4 Lane Capital Connectivity to Hanagar in Arunachal Pradesh under SARD NE Work (Phase A), 4-Laning from KM 17.300 (Dolabari Road Junction on NH-37A) to KM 36.110 (Jamgurnhat Road Junction: KM 182.00 of NH-52) in Sonpur District in the State of Assam.	CLIENT: National Highways and Infrastructure Development Corporation Limited	CONSULTANT Xplorer Consultancy Services Pvt. Ltd. Plot No.03, First Floor, Sector-18, Opp. JHPA, Sarbajit, Guwahati 781001 (Haryana) Ph: 0124-4388559, Fax: 0124-4241962 www.xplorer.in, Email: xplorer@xplorer.in	REVISIONS
REV. 0	DATE SEPTEMBER, 2016	ISSUED FOR APPROVAL	DM SK R.N.SEN
REV.	DATE	REVISIONS	DRN SK R.N.SEN CHKD SK R.N.SEN APPD
DRAWING TITLE GENERAL ARRANGEMENT OF DECK			
DECEMBER, 2016	SCALE NTS	SIZE A3	DWG. NO. 3 OF 3
REV.	0	0	0

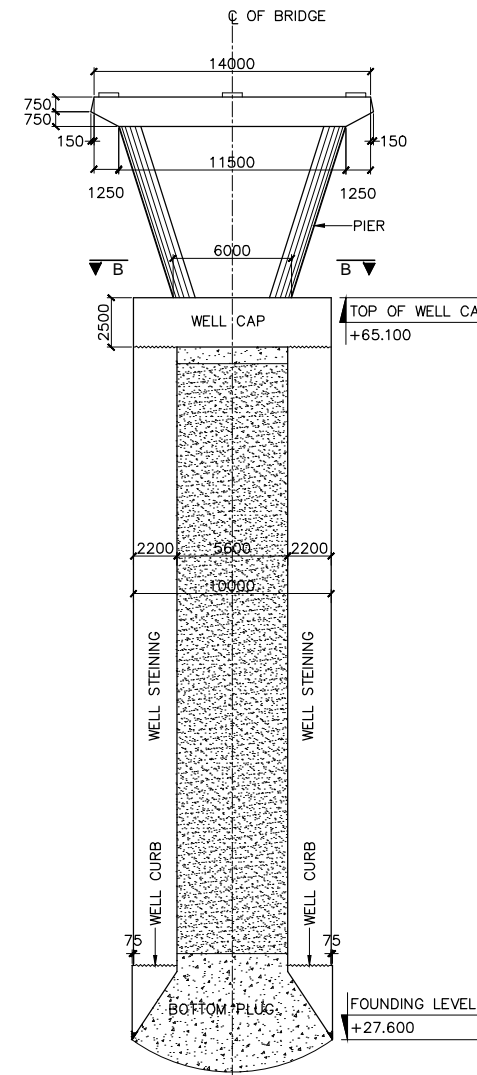
ANNEXURE-F
SUB STRUCTURE



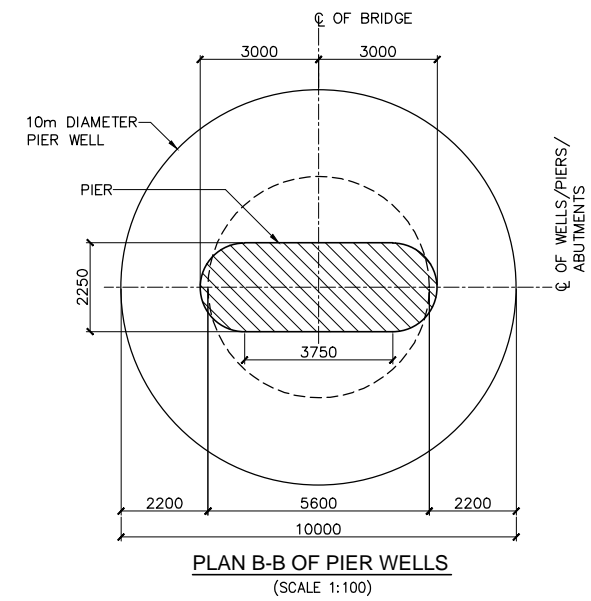
SECTIONAL ELEVATION OF ABUTMENT WELLS
(SCALE 1:100)



PLAN A-A OF ABUTMENT WELLS
(SCALE 1:100)



SECTIONAL ELEVATION OF PIER WELLS
(SCALE 1:100)



PLAN B-B OF PIER WELLS
(SCALE 1:100)

NOTE:

1. ALL DIMENSIONS ARE IN mm & LEVELS ARE IN m UNLESS NOTED OTHERWISE.
2. DIMENSIONS ARE NOT TO BE SCALED. ONLY WRITTEN DIMENSIONS SHALL BE FOLLOWED.

FOR APPROVAL

REVISION	DATE	DESCRIPTION

CONSULTANT
XPLORER
 XPLORER CONSULTANCY SERVICES PRIVATE LIMITED
 First Floor, Plot No.03, Sector-18, Opp.HIPA,Sarhau,Gurgaon-122001 (Haryana)
 Phone: 0124 - 4388659, www.xploreronline.com, email - xplorer@xplorer.in

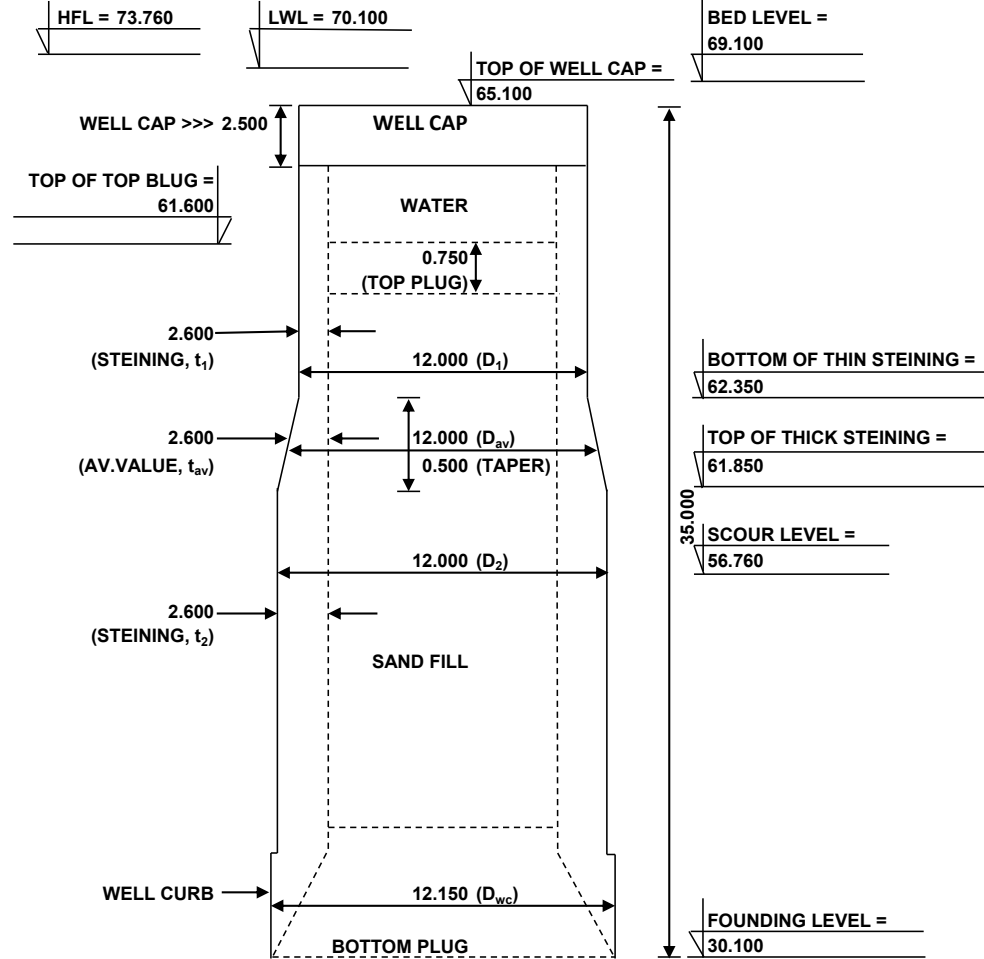
PROJECT
CONSTRUCTION OF JIA-BHARALI BRIDGE IN ASSAM
 OWNER
NATIONAL HIGHWAYS & INFRASTRUCTURE DEVELOPMENT CORPORATION LIMITED

TITLE DETAILS OF FOUNDATIONS AND SUBSTRUCTURE					
SCALE	DATE	DRAWN	APPROVED	DRAWING NO.	REV.
AS SHOWN	OCT 2016	SANDEEP	AP	XPLR-226/2016/104	R0

DESIGN OF CIRCULAR WELL FOUNDATION

(AS PER PROVISIONS OF IRC: 78)

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM
 LOCATION: WELL SUPPORTING ABUTMENTS
 LOAD CASE: SEISMIC



TYPICAL ELEVATION OF WELL

A. DESIGN DATA:

WELL SUPPORTING ABUTMENTS

1. LOAD CASE CONSIDERED:

SEISMIC

2. LEVELS:

High flood level (HFL)	=	73.760	m	
Low water level (LWL)	=	70.100	m	
Top level of well cap	=	65.100	m	
Bed level	=	69.100	m	
Top level of top/intermediate plug	=	61.600	m	
Level at the bottom of top steining having less thickness, t_1	=	62.350	m	
should be above top of top plug in such a way that tapering is done above top plug				
Level at the top of bottom steining having more thickness, t_2	=	61.850	m	
Scour level	=	56.760	m	(conservative value)
should be below the bottom of top/intermediate plug				
Bottom level of well (founding level)	=	30.100	m	

3. WELL PROPERTIES:

Outer diameter of well near top having thin steining, D_1	=	12.000	m	
Outer diameter of well near bottom having thick steining, D_2	=	12.000	m	
Average outer diameter of well at location where steining tapers, D_{av}	=	12.000	m	
Outer diameter of well at founding level (well curb), D_{wc}	=	12.150	m	
Coefficient 'K' for calculating steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2014)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2014)
Steining thickness near top (should be above scour depth), t_1	=	2.600	m	(taper not steeper than 1H:3V)
Steining thickness near bottom, t_2	=	2.600	m	(taper not steeper than 1H:3V)
Average steining thickness in taper portion, t_{av}	=	2.600	m	
Thickness of well cap	=	2.500	m	
Thickness of top/intermediate plug	=	0.750	m	
Thickness of bottom plug	=	4.000	m	(above founding level of well)
Density of RCC	=	2.500	t/m ³	
Density of PCC	=	2.200	t/m ³	
Density of sand fill	=	2.000	t/m ³	
Density of water	=	1.000	t/m ³	

4. SOIL PROPERTIES:

Net safe bearing capacity	=	100.00	t/m ²	(at founding level)
Gross bearing capacity	=	150.00	t/m ²	(Net SBC + overburden)
F.O.S in assessing passive resistance	=	1.600		(as per appendix-3 of IRC:78-2014)

Top of Layer	Bottom of Layer	ϕ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³ (submerged, if applicable)	Intensity of active earth pressure at top, p_a , t/m ²	Intensity of passive earth pressure at top, p_p , t/m ²
56.760	50.000	34.00	22.50	0.00	1.00	0.000	0.000
50.000	45.000	34.00	22.50	0.00	1.00	(conservative)	(conservative)
45.000	40.000	34.00	22.50	0.00	1.00	(see below)	(see below)
40.000	35.000	34.00	22.50	0.00	1.00		
35.000	30.100	34.00	22.50	0.00	1.00		

5. EXTERNAL LOADS:

External vertical load at top of well cap	=	8,000.00	t	(at top of well cap)
External moment at top of well cap	=	12000.00	t-m	(at top of well cap)
External horizontal load at top of well cap	=	4,100.00	t	(at top of well cap)
Horizontal seismic coefficient	=	0.300		(resultant of long.& trans.seismic)
Vertical seismic coefficient	0.300*2/3 =	0.200		
Velocity of flow at well top	=	3.600	m/s	(at top of well cap)
Coefficient 'K' to calculate water pressure	=	0.660		(as per clause 210.2 of IRC:6-2014)
Intensity of water pressure at scour level	=	0.000	kg/m ²	

6. TILTS AND SHIFTS:

Maximum shift considered for well design	=	0.150	m	(as per clause 708.5.1of IRC:78-2014)
Maximum tilt considered for well design	=	1.250	%	(as per clause 708.5.1of IRC:78-2014)

7. OTHERS:

Inclination of wall from horizontal, α	=	90.000	degree	
Inclination of backfill from horizontal, β	=	0.000	degree	
Surcharge considered for active earth pressure	=	30.000	t/m ²	(acting over the well)
Factor of safety, F	(for steining stress, see below) =	2.00		
Submerged density of soil, γ_b	(for steining stress, see below) =	1.00	t/m ³	
Coefficient of active earth pressure, K_a	(for steining stress, see below) =	0.254		
Coefficient of passive earth pressure, K_p	(for steining stress, see below) =	8.901		

B. SUMMARY OF FINDINGS & RESULTS:

Minimum steining thickness required near top	=	1.446	m	
Steining thickness provided near top	=	2.600	m	Hence O.K.
Minimum steining thickness required near bottom	=	2.505	m	
Steining thickness required near bottom	=	2.600	m	Hence O.K.
Maximum base pressure, σ_{max}	=	114.03	t/m ²	
Allowable gross bearing capacity	=	150.00	t/m ²	Hence O.K.
Minimum base pressure, σ_{min}	=	114.03	t/m ²	Hence O.K.

C. OUTPUT FOR WELL STABILITY:

1. CHECK FOR MINIMUM STEINING THICKNESSES:

(As per clause 708.2.3 of IRC:78)

Coefficient 'K' for steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2000)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2000)
Outer diameter of well near top, D_1	=	12.000	m	
Depth of well below well top or LWL till scour level whichever is more	=	13.340	m	
Minimum steining thickness required near top				
$0.030 \times 1.100 \times 12.000 \times 13.340^{0.5}$	=	1.446	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

Outer diameter of well near bottom, D_2	=	12.000	m	
Depth of well below well top or LWL till founding level whichever is more	=	40.000	m	
Minimum steining thickness required near bottom				
$0.030 \times 1.100 \times 12.000 \times 40.000^{0.5}$	=	2.505	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

2. VERTICAL FORCES AT BASE LEVEL:

Thickness of well cap	=	2.500	m	
Diameter of well cap	=	12.000	m	
Density of RCC	=	2.500	t/m ³	
Weight of well cap	$3.14 \times 12.000^2 \times 2.500 \times 2.500 / 4$	=	707.14	t
Outer diameter of well near top, D_1	=	12.000	m	
Area corresponding to outer diameter, A_1	$3.14 \times 12.000^2 / 4$	=	113.143	m ²
Steining thickness near top, t_1	=	2.600	m	
Inner diameter of well near top, D_1'	$12.000 - 2 \times 2.600$	=	6.800	m
Area corresponding to inner diameter, A_1'	$3.14 \times 6.800^2 / 4$	=	36.331	m ²
Net area of steining near top, $A_1 - A_1'$	$113.143 - 36.331$	=	76.812	m ²
Depth of this portion of well	$65.100 - 62.350 - 2.500$	=	0.250	m
Density of RCC	=	2.500	t/m ³	
Weight of this portion of well steining	$76.812 \times 0.250 \times 2.500$	=	48.01	t

Outer diameter of well near bottom, D_2		=	12.000	m
Area corresponding to outer diameter, A_2	$3.14 \times 12.000^2 / 4$	=	113.143	m^2
Steining thickness near bottom, t_2		=	2.600	m
Inner diameter of well near bottom, D_2'	$12.000 - 2 \times 2.600$	=	6.800	m
Area corresponding to inner diameter, A_2'	$3.14 \times 6.800^2 / 4$	=	36.331	m^2
Net area of steining near bottom, $A_2 - A_2'$	$113.143 - 36.331$	=	76.812	m^2
Depth of this portion of well	$61.850 - 30.100$	=	31.750	m
Weight of this portion of well steining	$76.812 \times 31.750 \times 2.500$	=	6,096.95	t
Outer diameter of well in tapering portion, D_{av}	$(12.000 + 12.000) / 2$	=	12.000	m
Area corresponding to outer diameter, A_{av}	$3.14 \times 12.000^2 / 4$	=	113.143	m^2
Steining thickness in tapering portion, t_{av}		=	2.600	m
Inner diameter of well in tapering portion, D_{av}'	$12.000 - 2 \times 2.600$	=	6.800	m
Area corresponding to inner diameter, A_{av}'	$3.14 \times 6.800^2 / 4$	=	36.331	m^2
Net area of steining near bottom, $A_2 - A_2'$	$113.143 - 36.331$	=	76.812	m^2
Depth of this portion of well	$62.350 - 61.850$	=	0.500	m
Weight of this portion of well steining	$76.812 \times 0.500 \times 2.500$	=	96.02	t
Total weight of well steining	$48.01 + 6,096.95 + 96.02$	=	6,240.98	t
Depth of water above top/intermediate plug	$65.100 - 61.600 - 2.500$	=	1.000	m
Inner diameter of well		=	6.800	m
Density of water		=	1.000	t/m^3
Weight of water	$3.14 \times 6.800^2 \times 1.000 \times 1.000 / 4$	=	36.33	t
Thickness of intermediat/top plug		=	0.750	m
Inner diameter of well		=	6.800	m
Density of PCC		=	2.200	t/m^3
Weight of intermediat/top plug	$3.14 \times 6.800^2 \times 0.750 \times 2.200 / 4$	=	59.95	t
Depth of sand fill below top plug	$61.600 - 30.100 - 0.750 - 4.000$	=	26.750	m
Inner diameter of well		=	6.800	m
Density of sand		=	2.000	t/m^3
Weight of sand fill below top plug	$3.14 \times 6.800^2 \times 26.750 \times 2.000 / 4$	=	1,943.73	t
Thickness of bottom plug		=	4.000	m
Inner diameter of well		=	6.800	m
Density of PCC		=	2.200	t/m^3
Weight of bottom plug	$3.14 \times 6.800^2 \times 4.000 \times 2.200 / 4$	=	319.72	t

Total weight of well including top & bottom plugs and filling		=	9,307.85	t	
	$707.14+6,240.98+36.33+59.95+1,943.73+319.72$	=	8,000.00	t	
External vertical load over well		=	8,000.00	t	
Total vertical load including external load	$9,307.85+8,000.00$	=	17,307.85	t	(at founding level)
Vertical load of well components upto scour level	2,222.07	=	2,222.07	t	(see calculations below)
Vertical downward seismic force on this	$2,222.07*0.200$	=	444.41	t	(downward seismic governs the design)
Buoyancy on well	$3.14*12.000^2*(70.100-30.100)*1.000/4$	=	4,525.71	t	(diameter at the top is taken on safer side)
Net vertical load at base level	$17,307.85+444.41-4,525.71$	=	13,226.55	t	(including buoyancy & vertical seismic)

3. HORIZONTAL FORCES AND MOMENTS AT SCOUR & FOUNDING LEVELS:

3.1 EXTERNAL HORIZONTAL LOAD ACTING ON WELL:

External horizontal load on well		=	4,100.00	t	(at top of well cap)
C.G. of this above scour level	65.100-56.760	=	8.340	m	
Moment at scour level	$4,100.00*8.340$	=	34,194.00	t-m	
C.G. of this above founding level	$8.340+56.760-30.100$	=	35.000	m	
Moment at founding level	$4,100.00*35.000$	=	143500.00	t-m	

3.2 EXTERNAL MOMENT ACTING ON WELL:

External moment acting on well		=	12000.00	t-m	
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3.3 SEISMIC FORCES ON WELL:

Horizontal seismic coefficient		=	0.300		
Weight of well cap		=	707.14	t	
Seismic force on this weight	$0.300*707.14$	=	212.14	t	
C.G. of this above scour level	$65.100-56.760-1.25$	=	7.090	m	
Moment at scour level	$212.14*7.090$	=	1,504.07	t-m	
C.G. of this above founding level	$7.090+56.760-30.100$	=	33.750	m	
Moment at founding level	$212.14*33.750$	=	7,159.73	t-m	
Weight of well steining near top (with reduced thickness of steining)		=	48.01	t	
Seismic force on this weight	$0.300*48.01$	=	14.40	t	
C.G. of this above scour level	$62.350-56.760+0.250/2$	=	5.715	m	
Moment at scour level	$14.40*5.715$	=	82.30	t-m	
C.G. of this above founding level	$62.350-30.100+0.250/2$	=	32.375	m	
Moment at founding level	$14.40*32.375$	=	466.20	t-m	

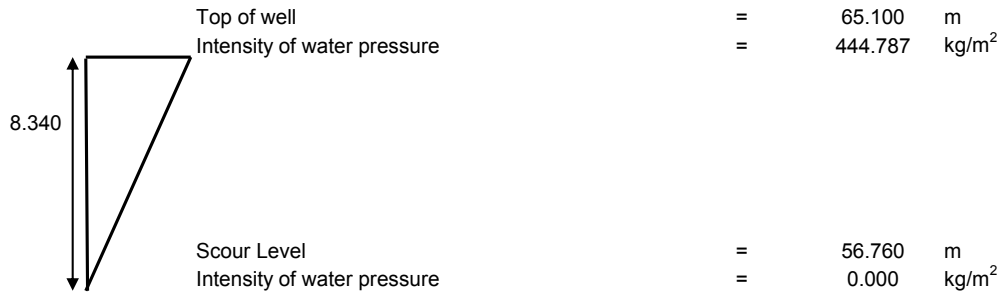
Height of thicker well steining above scour level	$61.850-56.760$	=	5.090	m
Weight of thicker well steining upto scour level	$76.812*5.090*2.500$	=	977.43	t
Seismic force on this weight	$0.300*977.43$	=	293.23	t
C.G. of this above scour level	$0.5*5.090$	=	2.545	m
Moment at scour level	$293.23*2.545$	=	746.27	t-m
C.G. of this above founding level	$(61.850-30.100)/2$	=	15.875	m
Moment at founding level	$293.23*15.875$	=	4,655.03	t-m
Weight of tapering well steining		=	96.02	t
Seismic force on this weight	$0.300*96.02$	=	28.81	t
C.G. of this above scour level	$61.850-56.760+0.500/2$	=	5.340	m
Moment at scour level	$28.81*5.340$	=	153.85	t-m
C.G. of this above founding level	$61.850-30.100+0.500/2$	=	32.000	m
Moment at founding level	$28.81*32.000$	=	921.92	t-m
Weight of water fill		=	36.33	t
Seismic force on this weight	$0.300*36.33$	=	10.90	t
C.G. of this above scour level	$(65.100-61.600-2.500)*0.5+(61.600-56.760)$	=	5.340	m
Moment at scour level	$10.90*5.340$	=	58.21	t-m
C.G. of this above founding level	$5.340+56.760-30.100$	=	32.000	m
Moment at founding level	$10.90*32.000$	=	348.80	t-m
Weight of intermediat/top plug		=	59.95	t
Seismic force on this weight	$0.300*59.95$	=	17.99	t
C.G. of this above scour level	$61.600-56.760-0.750*0.5$	=	4.465	m
Moment at scour level	$17.99*4.465$	=	80.33	t-m
C.G. of this above founding level	$4.465+56.760-30.100$	=	31.125	m
Moment at founding level	$17.99*31.125$	=	559.94	t-m
Depth of sand fill upto scour level	$61.600-56.760-0.750$	=	4.090	m
Weight of sand fill upto scour level	$3.14*6.800^2*4.090*2.000/4$	=	297.19	t
Seismic force on this weight	$0.300*297.19$	=	89.16	t
C.G. of this above scour level	$4.090/2$	=	2.045	m
Moment at scour level	$89.16*2.045$	=	182.33	t-m
C.G. of this above founding level	$2.045+56.760-30.100$	=	28.705	m
Moment at founding level	$89.16*28.705$	=	2,559.34	t-m
Weight of well components above scour level	$707.14+48.01+977.43+96.02+36.33+59.95+297.19$ (including top plug, sandfill & waterfill)	=	2,222.07	t
Horizontal seismic forces on well components	$2,222.07*0.300$ (including top plug, sandfill & waterfill)	=	666.62	t

Moment at scour level due to this
 $1,504.07+82.30+746.27+153.85+58.21+80.33+182.33$ = 2,807.36 t-m
(including top plug, sandfill & waterfill)

Moment at founding level due to this
 $7,159.73+466.20+4,655.03+921.92+348.80+559.94+2,559.34$ = 16,670.96 t-m
(including top plug, sandfill & waterfill)

3.4 WATER PRESSURE: (As per clause 210.2 of IRC:6-2010)

Intensity of water pressure at well top $52 \times 0.660 \times 3.600^2$ = 444.787 kg/m² (as per cl 210.2 of IRC:6-2010)
 Intensity of water pressure at scour level = 0.000 kg/m²
 Outer diameter of well = 12.000 m (diameter near base taken on safer side)
 Height of well above scour level $65.100-56.760$ = 8.340 m



Total water pressure acting over well $0.5 \times 444.787 \times 12.000 \times 8.340 / 1000$ = 22.26 t
 C.G. of this above scour level $2 \times 8.340 / 3$ = 5.560 m
 Moment at scour level 22.26×5.560 = 123.77 t-m
 C.G. of this above founding level $5.560 + 56.760 - 30.100$ = 32.220 m
 Moment at founding level 22.26×32.220 = 717.22 t-m

Net forces including those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$4,100.00+666.62+22.26$	=	4,788.88	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$34,194.00+12000+2,807.36+123.77$	=	49,125.13	t-m	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at base level	$143500+12000+16,670.96+717.2172$	=	172,888.18	t-m	(3.1 + 3.2 + 3.3 + 3.4)

Net forces excluding those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$4,100.00+212.14+14.40+293.23+28.81+22.26$	=	4,670.84	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$34,194.00+12000+1,504.07+82.30+746.27+153.85+123.77$	=	48,804.26	t-m	(3.1 + 3.2 + 3.3 + 3.4)

4. MOMENT AT BASE LEVEL DUE TO TILT & SHIFT:

(As per clause 708.5.1 of IRC:78)

Shift considered for well design		=	0.150	m
Vertical load at top of the well		=	8,000.00	t
Moment due to shift	$0.150 \times 8,000.00$	=	1,200.00	t-m
Tilt considered for well design		=	1.250	%
Vertical load at top of the well		=	8,000.00	t
C.G. of this above founding level	$65.100-30.100$	=	35.000	m
Lateral shift of this C.G. due to tilt	$1.250 \times 35.000/100$	=	0.438	m
Moment due to lateral shift due to tilt	$8,000.00 \times 0.438$	=	3,504.00	t-m
Weight of well cap		=	707.14	t
C.G. of this above founding level	$65.100-30.100-2.500 \times 0.5$	=	33.750	m
Lateral shift of this C.G. due to tilt	$1.250 \times 33.750/100$	=	0.422	m
Moment due to lateral shift due to tilt	707.14×0.422	=	298.41	t-m
Weight of well steining near top		=	48.01	t
C.G. of this above founding level	$62.350-30.100+0.250/2$	=	32.375	m
Lateral shift of this C.G. due to tilt	$1.250 \times 32.375/100$	=	0.405	m
Moment due to lateral shift due to tilt	48.01×0.405	=	19.44	t-m
Weight of well steining near bottom		=	6,096.95	t
C.G. of this above founding level	$(61.850-30.100)/2$	=	15.875	m
Lateral shift of this C.G. due to tilt	$1.250 \times 15.875/100$	=	0.198	m
Moment due to lateral shift due to tilt	$6,096.95 \times 0.198$	=	1,207.20	t-m
Weight of well steining in tapering portion		=	96.02	t
C.G. of this above founding level	$61.850-30.100+0.500/2$	=	32.000	m
Lateral shift of this C.G. due to tilt	$1.250 \times 32.000/100$	=	0.400	m
Moment due to lateral shift due to tilt	96.02×0.400	=	38.41	t-m

Weight of water fill	=	36.33	t
C.G. of this above founding level			
	$65.100-30.100-2.500-(65.100-2.500-61.600)/2$	=	32.000 m
Lateral shift of this C.G.due to tilt	$1.250*32.000/100$	=	0.400 m
Moment due to lateral shift due to tilt	$36.33*0.400$	=	14.53 t-m
Weight of intermediat/top plug	=	59.95	t
C.G. of this above founding level	$61.600-30.100-0.750*0.5$	=	31.125 m
Lateral shift of this C.G.due to tilt	$1.250*31.125/100$	=	0.389 m
Moment due to lateral shift due to tilt	$59.95*0.389$	=	23.32 t-m
Weight of sand fill	=	1,943.73	t
C.G. of this above founding level	$(61.600-30.100-0.750-4.000)/2+4.000$	=	17.375 m
Lateral shift of this C.G.due to tilt	$1.250*17.375/100$	=	0.217 m
Moment due to lateral shift due to tilt	$1,943.73*0.217$	=	421.79 t-m
Weight of bottom plug	=	319.72	t
C.G. of this above founding level	$4.000/2$	=	2.000 m
Lateral shift of this C.G.due to tilt	$1.250*2.000/100$	=	0.025 m
Moment due to lateral shift due to tilt	$319.72*0.025$	=	7.99 t-m

Total moment at base due to tilt & shift			
$1,200.00+3,504.00+298.41+19.44+1,207.20+38.41+14.53+23.32+421.79+7.99$	=	6735.09	t-m

5. RESISTING MOMENT AT FOUNDING LEVEL:

(As per Appendix-3 of IRC:78)

The resisting moment is acting because of difference in passive and active earth pressure

F.O.S in assessing passive resistance	=	1.600	(r appendix-3 of IRC78)
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The active and passive earth pressure at any depth has been calculated by following equations:

Active earth pressure, p_a :	=	$K_a \gamma h + K_a q - 2c(K_a)^{1/2}$	
	=	$K_a \gamma h + K_a q$	(ignoring the effect of cohesion conservatively)

Passive earth pressure, p_p :	=	$K_p \gamma h + K_p q + 2c(K_p)^{1/2}$	(q = 0 considered for well design)
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where,

Coefficient of active earth pressure, K_a	=	$\frac{\sin^2(\alpha + \varphi)}{\sin^2 \alpha \sin(\alpha - \delta) [1 + \{\sin(\varphi + \delta) \sin(\varphi - \beta) / \sin(\alpha - \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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Coefficient of passive earth pressure, K_p	=	$\frac{\sin^2(\alpha - \varphi)}{\sin^2 \alpha \sin(\alpha + \delta) [1 - \{\sin(\varphi + \delta) \sin(\varphi + \beta) / \sin(\alpha + \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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γ'	=	Submerged density of earth
h	=	Thickness of layer considered
q	=	Surcharge at top of the layer considered
Inclination of Wall from Horizontal, α	=	90.000 degree
φ	=	Angle of Internal Friction
δ	=	Angle of Wall Friction
Inclination of Backfill from Horizontal, β	=	0.000 degree

5.1 GENERAL CALCULATIONS:

Surcharge considered for active earth pressure	=	30.000 t/m ²
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Top of Layer	Bottom of Layer	$\sin^2(\alpha+\varphi)$	$\sin^2\alpha$	$\sin(\alpha-\delta)$	$\sin(\varphi+\delta)$	$\sin(\varphi-\beta)$	$\sin(\alpha+\beta)$	$\sin^2(\alpha-\varphi)$	$\sin(\alpha+\delta)$	$\sin(\varphi+\beta)$
56.760	50.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
50.000	45.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
45.000	40.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
40.000	35.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
35.000	30.100	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559

Top of Layer	Bottom of Layer	φ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³	Coefficient, Ka	Coefficient, Kp	Thickness, h, m	Height above well bottom, m
56.760	50.000	34.00	22.50	0.00	1.000	0.254	8.901	6.76	19.90
50.000	45.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	14.90
45.000	40.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	9.90
40.000	35.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	4.90
35.000	30.100	34.00	22.50	0.00	1.000	0.254	8.901	4.90	0.00

5.2 FORCES & MOMENTS DUE TO ACTIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_a at top, t/m ²	p_a at bottom, t/m ²	Dia of well, m	Total Active Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
56.760	50.000	0.000	9.333	12.000	378.5	22.153	8386.08
50.000	45.000	9.333	10.602	12.000	598.06	17.347	10374.58
45.000	40.000	10.602	11.872	12.000	674.23	12.353	8328.74
40.000	35.000	11.872	13.141	12.000	750.40	7.358	5521.21
35.000	30.100	13.141	14.385	12.000	809.3	2.413	1952.89
Total Moment, M_a							34,563.50

5.3 FORCES & MOMENTS DUE TO PASSIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_p at top, t/m ²	p_p at bottom, t/m ²	Dia of well, m	Total Passive Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
56.760	50.000	0.000	60.170	12.000	2440.48	22.153	54064.86
50.000	45.000	60.170	104.674	12.000	4945.31	17.175	84935.81
45.000	40.000	104.674	149.178	12.000	7615.57	12.254	93320.41
40.000	35.000	149.178	193.682	12.000	10285.82	7.292	75002.46
35.000	30.100	193.682	237.297	12.000	12670.78	2.367	29996.25
Total Moment, M_p							337,319.79

Total moment due to active earth pressure, M_a = 34,563.50 t-m

Total moment due to passive earth pressure, M_p = 337,319.79 t-m

Factor of safety = 1.600 (as per appendix-3 of IRC:78)

Net resisting moment, $(M_a - M_p)/F.O.S$	$(337,319.79 - 34,563.50)/1.600$	=	189222.68 t-m
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6. DESIGN MOMENT AT BASE LEVEL:

External moment at top of well cap = 12000.00 t-m

Moment due to external horizontal load = 143500.00 t-m

Moment due to seismic forces on well
 $7,159.73 + 466.20 + 4,655.03 + 921.92 + 348.80 + 559.94 + 2,559.34$ = 16670.96 t-m

Moment due to water pressure on well = 717.22 t-m

Moment due to tilt and shift = 6735.09 t-m

Resisting moment = 189222.68 t-m
 (due to passive earth pressure)

Net moment at base level	=	0.00 t-m
<small>(resisting moment is more than moment acting)</small>		

7. CHECK FOR BASE PRESSURE:

(As per provisions of IRC:78-2014)

Outer diameter of well at well bottom/curb		=	12.150	m
Area at well bottom, A	$3.14 \times 12.150^2 / 4$	=	115.989	m ²
Section modulus, Z	$3.14 \times 12.150^3 / 32$	=	176.158	m ³
Net vertical load at well bottom, P (including buoyancy & vertical seismic forces)		=	13,226.55	t
Net moment at well bottom, M		=	0.00	t-m
Maximum base pressure, σ_{\max}	$13,226.55 / 115.989 + 0.00 / 176.158$	=	114.03	t/m ²
Allowable gross bearing capacity		=	150.00	t/m ²
Which is more than the maximum base pressure, hence O.K.				
Minimum base pressure, σ_{\min}	$13,226.55 / 115.989 - 0.00 / 176.158$	=	114.03	t/m ²
Which is more than zero, hence O.K.				

D. OUTPUT FOR STEINING STRESS CHECK:

1. DEPTH OF ZERO SHEAR BELOW SCOUR LEVEL:

Depth of zero shear below scour level, x		=	$\{2FH / \gamma_b(K_p-K_a)D\}^{1/2}$	
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)				
where,				
Factor of safety, F		=	2.00	
Resultant horizontal force at scour level, H		=	4,670.84	t
Submerged density of soil, γ_b		=	1.00	t/m ³
Coefficient of active earth pressure, K_a		=	0.254	
Coefficient of passive earth pressure, K_p		=	8.901	
Outer diameter of well steining, D		=	12.000	m
Now, depth of zero shear, x				
	$2*2.00*4,670.84/(1.00*(8.901-0.254)*12.000)^{0.5}$	=	13.419	m
Level at the depth of zero shear	56.760-13.419	=	43.341	m

2. VERTICAL LOAD & MOMENT DUE TO TILT & SHIFT AT DEPTH OF ZERO SHEAR:

Shift considered for well design		=	0.150	m
Tilt considered for well design		=	1.250	%
External vertical load over well		=	8,000.00	t
Moment due to shift	8,000.00*0.150	=	1,200.00	t-m
C.G. of this above depth of zero shear	65.100-43.341	=	21.759	m
Lateral shift of this C.G.due to tilt	1.250*21.759/100	=	0.272	m
Moment due to lateral shift due to tilt	0.272*8,000.00	=	2176.00	t-m
Weight of well cap		=	707.14	t
C.G. of this above depth of zero shear	7.090+13.419	=	20.509	m
Lateral shift of this C.G.due to tilt	1.250*20.509/100	=	0.256	m
Moment due to lateral shift due to tilt	0.256*707.14	=	181.03	t-m
Weight of well steining near top (with reduced thickness of steining)		=	48.01	t
C.G. of this above depth of zero shear	5.715+13.419	=	19.134	m
Lateral shift of this C.G.due to tilt	1.250*19.134/100	=	0.24	t-m
Moment due to lateral shift due to tilt	0.24*48.01	=	11.52	t-m
Height of thicker well steining above depth of zero shear		=		
	61.850-43.341	=	18.509	m
Weight of thicker well steining upto depth of zero shear		=		
	76.812*18.509*2.500	=	3,554.28	t
C.G. of this above depth of zero shear	0.5*18.509	=	9.255	m

Lateral shift of this C.G.due to tilt	$1.250 \times 9.255 / 100$	=	0.12	t-m
Moment due to lateral shift due to tilt	$0.12 \times 3,554.28$	=	426.51	t-m
Weight of tapering well steining		=	96.02	t
C.G. of this above depth of zero shear	$5.340 + 13.419$	=	18.759	m
Lateral shift of this C.G.due to tilt	$1.250 \times 18.759 / 100$	=	0.23	t-m
Moment due to lateral shift due to tilt	0.23×96.02	=	22.08	t-m

Total vertical load at depth of zero shear	$8,000.00 + 707.14 + 48.01 + 3,554.28 + 96.02$	=	12,405.45	t	(excluding those due to top plug, sandfill & waterfill)
Tilt & shift moment at depth of zero shear	$1,200.00 + 2176 + 181.03 + 11.52 + 426.51 + 22.08$	=	4,017.14	t-m	

3. DESIGN VERTICAL LOAD & MOMENT AT DEPTH OF ZERO SHEAR:

Total vertical load at depth of zero shear		=	12,405.45	t	(excluding buoyancy & seismic forces)
Vertical load of well components at scour level	$707.14 + 48.01 + 3,554.28 + 96.02$	=	4405.45	t	(excluding those due to top plug, sandfill & waterfill)
Vertical upward seismic force on this	0.200×4405.45	=	881.09	t	(upward seismic governs the design)
Height of well upto the depth of zero shear	$65.100 - 43.341$	=	21.76	t	
Buoyancy on well upto the depth of zero shear	$113.143 \times 21.759 \times 0.15$	=	369.28	t	(15% buoyancy as per cl.216.5 of IRC: 6)
Net vertical load at depth of zero shear	$12,405.45 - 881.09 - 369.28$	=	11155.08	t	(including buoyancy & vertical seismic forces)
Tilt & shift moment at depth of zero shear, M1		=	4,017.14	t-m	
Resultant horizontal force at scour level, H		=	4,670.84	t	(excluding those due to top plug, sandfill & waterfill)
Net moment at scour level, M ₀		=	48,804.26	t-m	(excluding those due to top plug, sandfill & waterfill)
Moment at depth of zero shear, M2		=	$M_0 + 2Hx/3$		
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)	$48,804.26 + (2 \times 4,670.84 \times 13.419) / 3$	=	90,589.59	t-m	

Now,

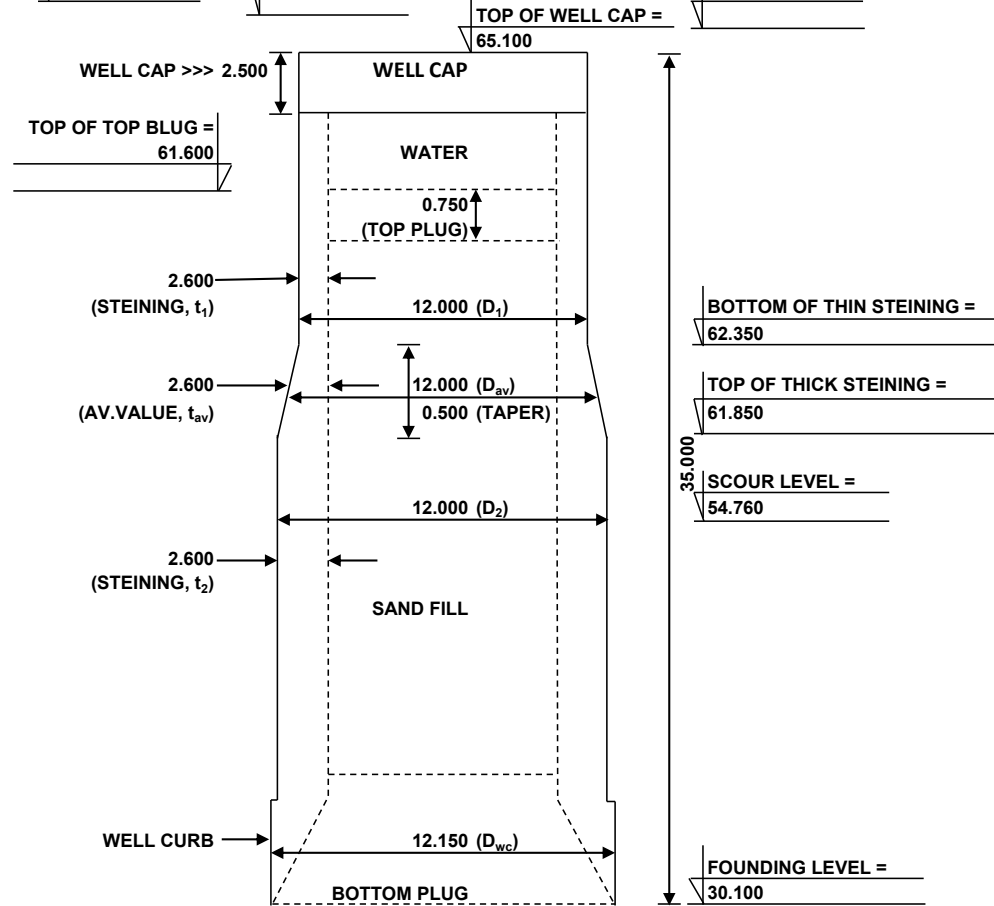
Net vertical load for steining design		=	11155.08	t	
Net moment for steining design	$4,017.14 + 90,589.59$	=	94606.73	t-m	(M1 + M2)

DESIGN OF CIRCULAR WELL FOUNDATION

(AS PER PROVISIONS OF IRC: 78)

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM
 LOCATION: WELL SUPPORTING ABUTMENTS
 LOAD CASE: NORMAL

HFL = 73.760 LWL = 70.100 BED LEVEL = 69.100



TYPICAL ELEVATION OF WELL

A. DESIGN DATA:

WELL SUPPORTING ABUTMENTS

1. LOAD CASE CONSIDERED:

NORMAL

2. LEVELS:

High flood level (HFL)	=	73.760	m	
Low water level (LWL)	=	70.100	m	
Top level of well cap	=	65.100	m	
Bed level	=	69.100	m	
Top level of top/intermediate plug	=	61.600	m	
Level at the bottom of top steining having less thickness, t_1	=	62.350	m	
should be above top of top plug in such a way that tapering is done above top plug				
Level at the top of bottom steining having more thickness, t_2	=	61.850	m	
Scour level	should be below the bottom of top/intermediate plug	=	54.760	m (conservative value)
Bottom level of well (founding level)	=	30.100	m	

3. WELL PROPERTIES:

Outer diameter of well near top having thin steining, D_1	=	12.000	m	
Outer diameter of well near bottom having thick steining, D_2	=	12.000	m	
Average outer diameter of well at location where steining tapers, D_{av}	=	12.000	m	
Outer diameter of well at founding level (well curb), D_{wc}	=	12.150	m	
Coefficient 'K' for calculating steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2014)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2014)
Steining thickness near top (should be above scour depth), t_1	=	2.600	m	(taper not steeper than 1H:3V)
Steining thickness near bottom, t_2	=	2.600	m	(taper not steeper than 1H:3V)
Average steining thickness in taper portion, t_{av}	=	2.600	m	
Thickness of well cap	=	2.500	m	
Thickness of top/intermediate plug	=	0.750	m	
Thickness of bottom plug	=	4.000	m	(above founding level of well)
Density of RCC	=	2.500	t/m ³	
Density of PCC	=	2.200	t/m ³	
Density of sand fill	=	2.000	t/m ³	
Density of water	=	1.000	t/m ³	

4. SOIL PROPERTIES:

Net safe bearing capacity	=	80.00	t/m ²	(at founding level)
Gross bearing capacity	=	120.00	t/m ²	(Net SBC + overburden)
F.O.S in assessing passive resistance	=	2.000		(as per appendix-3 of IRC:78-2014)

Top of Layer	Bottom of Layer	ϕ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³ (submerged, if applicable)	Intensity of active earth pressure at top, p_a , t/m ²	Intensity of passive earth pressure at top, p_p , t/m ²
54.760	50.000	34.00	22.50	0.00	1.00	0.000	0.000
50.000	45.000	34.00	22.50	0.00	1.00	(conservative)	(conservative)
45.000	40.000	34.00	22.50	0.00	1.00	(see below)	(see below)
40.000	35.000	34.00	22.50	0.00	1.00		
35.000	30.100	34.00	22.50	0.00	1.00		

5. EXTERNAL LOADS:

External vertical load at top of well cap	=	7,500.00	t	(at top of well cap)
External moment at top of well cap	=	5000.00	t-m	(at top of well cap)
External horizontal load at top of well cap	=	2,500.00	t	(at top of well cap)
Horizontal seismic coefficient	=	0.000		(resultant of long.& trans.seismic)
Vertical seismic coefficient	0.000*2/3	=	0.000	
Velocity of flow at well top	=	3.600	m/s	(at top of well cap)
Coefficient 'K' to calculate water pressure	=	0.660		(as per clause 210.2 of IRC:6-2014)
Intensity of water pressure at scour level	=	0.000	kg/m ²	

6. TILTS AND SHIFTS:

Maximum shift considered for well design	=	0.150	m	(as per clause 708.5.1of IRC:78-2014)
Maximum tilt considered for well design	=	1.250	%	(as per clause 708.5.1of IRC:78-2014)

7. OTHERS:

Inclination of wall from horizontal, α	=	90.000	degree	
Inclination of backfill from horizontal, β	=	0.000	degree	
Surcharge considered for active earth pressure	=	30.000	t/m ²	(acting over the well)
Factor of safety, F	(for steining stress, see below)	=	2.00	
Submerged density of soil, γ_b	(for steining stress, see below)	=	1.00	t/m ³
Coefficient of active earth pressure, K_a	(for steining stress, see below)	=	0.254	
Coefficient of passive earth pressure, K_p	(for steining stress, see below)	=	8.901	

B. SUMMARY OF FINDINGS & RESULTS:

Minimum steining thickness required near top	=	1.551	m	
Steining thickness provided near top	=	2.600	m	Hence O.K.
Minimum steining thickness required near bottom	=	2.505	m	
Steining thickness required near bottom	=	2.600	m	Hence O.K.
Maximum base pressure, σ_{max}	=	105.89	t/m ²	
Allowable gross bearing capacity	=	120.00	t/m ²	Hence O.K.
Minimum base pressure, σ_{min}	=	105.89	t/m ²	Hence O.K.

C. OUTPUT FOR WELL STABILITY:

1. CHECK FOR MINIMUM STEINING THICKNESSES:

(As per clause 708.2.3 of IRC:78)

Coefficient 'K' for steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2000)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2000)
Outer diameter of well near top, D ₁	=	12.000	m	
Depth of well below well top or LWL till scour level whichever is more	=	15.340	m	
Minimum steining thickness required near top				
$0.030 \times 1.100 \times 12.000 \times 15.340^{0.5}$	=	1.551	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

Outer diameter of well near bottom, D ₂	=	12.000	m	
Depth of well below well top or LWL till founding level whichever is more	=	40.000	m	
Minimum steining thickness required near bottom				
$0.030 \times 1.100 \times 12.000 \times 40.000^{0.5}$	=	2.505	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

2. VERTICAL FORCES AT BASE LEVEL:

Thickness of well cap	=	2.500	m	
Diameter of well cap	=	12.000	m	
Density of RCC	=	2.500	t/m ³	
Weight of well cap	$3.14 \times 12.000^2 \times 2.500 / 4$	=	707.14	t
Outer diameter of well near top, D ₁	=	12.000	m	
Area corresponding to outer diameter, A ₁	$3.14 \times 12.000^2 / 4$	=	113.143	m ²
Steining thickness near top, t ₁	=	2.600	m	
Inner diameter of well near top, D ₁ '	$12.000 - 2 \times 2.600$	=	6.800	m
Area corresponding to inner diameter, A ₁ '	$3.14 \times 6.800^2 / 4$	=	36.331	m ²
Net area of steining near top, A ₁ -A ₁ '	$113.143 - 36.331$	=	76.812	m ²
Depth of this portion of well	$65.100 - 62.350 - 2.500$	=	0.250	m
Density of RCC	=	2.500	t/m ³	
Weight of this portion of well steining	$76.812 \times 0.250 \times 2.500$	=	48.01	t

Outer diameter of well near bottom, D_2		=	12.000	m
Area corresponding to outer diameter, A_2	$3.14 \times 12.000^2 / 4$	=	113.143	m^2
Steining thickness near bottom, t_2		=	2.600	m
Inner diameter of well near bottom, D_2'	$12.000 - 2 \times 2.600$	=	6.800	m
Area corresponding to inner diameter, A_2'	$3.14 \times 6.800^2 / 4$	=	36.331	m^2
Net area of steining near bottom, $A_2 - A_2'$	$113.143 - 36.331$	=	76.812	m^2
Depth of this portion of well	$61.850 - 30.100$	=	31.750	m
Weight of this portion of well steining	$76.812 \times 31.750 \times 2.500$	=	6,096.95	t
Outer diameter of well in tapering portion, D_{av}	$(12.000 + 12.000) / 2$	=	12.000	m
Area corresponding to outer diameter, A_{av}	$3.14 \times 12.000^2 / 4$	=	113.143	m^2
Steining thickness in tapering portion, t_{av}		=	2.600	m
Inner diameter of well in tapering portion, D_{av}'	$12.000 - 2 \times 2.600$	=	6.800	m
Area corresponding to inner diameter, A_{av}'	$3.14 \times 6.800^2 / 4$	=	36.331	m^2
Net area of steining near bottom, $A_2 - A_2'$	$113.143 - 36.331$	=	76.812	m^2
Depth of this portion of well	$62.350 - 61.850$	=	0.500	m
Weight of this portion of well steining	$76.812 \times 0.500 \times 2.500$	=	96.02	t
Total weight of well steining	$48.01 + 6,096.95 + 96.02$	=	6,240.98	t
Depth of water above top/intermediate plug	$65.100 - 61.600 - 2.500$	=	1.000	m
Inner diameter of well		=	6.800	m
Density of water		=	1.000	t/m^3
Weight of water	$3.14 \times 6.800^2 \times 1.000 \times 1.000 / 4$	=	36.33	t
Thickness of intermediat/top plug		=	0.750	m
Inner diameter of well		=	6.800	m
Density of PCC		=	2.200	t/m^3
Weight of intermediat/top plug	$3.14 \times 6.800^2 \times 0.750 \times 2.200 / 4$	=	59.95	t
Depth of sand fill below top plug	$61.600 - 30.100 - 0.750 - 4.000$	=	26.750	m
Inner diameter of well		=	6.800	m
Density of sand		=	2.000	t/m^3
Weight of sand fill below top plug	$3.14 \times 6.800^2 \times 26.750 \times 2.000 / 4$	=	1,943.73	t
Thickness of bottom plug		=	4.000	m
Inner diameter of well		=	6.800	m
Density of PCC		=	2.200	t/m^3
Weight of bottom plug	$3.14 \times 6.800^2 \times 4.000 \times 2.200 / 4$	=	319.72	t

Total weight of well including top & bottom plugs and filling		=	9,307.85	t	
	$707.14+6,240.98+36.33+59.95+1,943.73+319.72$	=	7,500.00	t	
External vertical load over well		=			
Total vertical load including external load	$9,307.85+7,500.00$	=	16,807.85	t	(at founding level)
Vertical load of well components upto scour level	2,751.46	=	2,751.46	t	(see calculations below)
Vertical downward seismic force on this	$2,751.46*0.000$	=	0.00	t	(downward seismic governs the design)
Buoyancy on well	$3.14*12.000^2*(70.100-30.100)*1.000/4$	=	4,525.71	t	(diameter at the top is taken on safer side)
Net vertical load at base level	$16,807.85+0.00-4,525.71$	=	12,282.14	t	(including buoyancy & vertical seismic)

3. HORIZONTAL FORCES AND MOMENTS AT SCOUR & FOUNDING LEVELS:

3.1 EXTERNAL HORIZONTAL LOAD ACTING ON WELL:

External horizontal load on well		=	2,500.00	t	(at top of well cap)
C.G. of this above scour level	65.100-54.760	=	10.340	m	
Moment at scour level	$2,500.00*10.340$	=	25,850.00	t-m	
C.G. of this above founding level	$10.340+54.760-30.100$	=	35.000	m	
Moment at founding level	$2,500.00*35.000$	=	87500.00	t-m	

3.2 EXTERNAL MOMENT ACTING ON WELL:

External moment acting on well		=	5000.00	t-m	
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3.3 SEISMIC FORCES ON WELL:

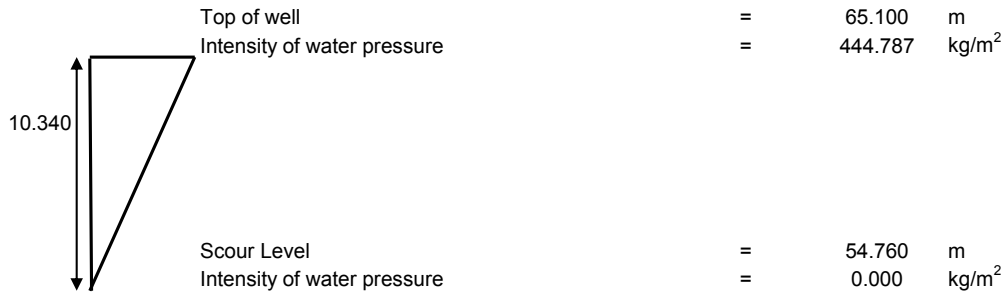
Horizontal seismic coefficient		=	0.000		
Weight of well cap		=	707.14	t	
Seismic force on this weight	$0.000*707.14$	=	0.00	t	
C.G. of this above scour level	$65.100-54.760-1.25$	=	9.090	m	
Moment at scour level	$0.00*9.090$	=	0.00	t-m	
C.G. of this above founding level	$9.090+54.760-30.100$	=	33.750	m	
Moment at founding level	$0.00*33.750$	=	0.00	t-m	
Weight of well steining near top (with reduced thickness of steining)		=	48.01	t	
Seismic force on this weight	$0.000*48.01$	=	0.00	t	
C.G. of this above scour level	$62.350-54.760+0.250/2$	=	7.715	m	
Moment at scour level	$0.00*7.715$	=	0.00	t-m	
C.G. of this above founding level	$62.350-30.100+0.250/2$	=	32.375	m	
Moment at founding level	$0.00*32.375$	=	0.00	t-m	

Height of thicker well steining above scour level	$61.850-54.760$	=	7.090	m
Weight of thicker well steining upto scour level	$76.812*7.090*2.500$	=	1,361.49	t
Seismic force on this weight	$0.000*1,361.49$	=	0.00	t
C.G. of this above scour level	$0.5*7.090$	=	3.545	m
Moment at scour level	$0.00*3.545$	=	0.00	t-m
C.G. of this above founding level	$(61.850-30.100)/2$	=	15.875	m
Moment at founding level	$0.00*15.875$	=	0.00	t-m
Weight of tapering well steining		=	96.02	t
Seismic force on this weight	$0.000*96.02$	=	0.00	t
C.G. of this above scour level	$61.850-54.760+0.500/2$	=	7.340	m
Moment at scour level	$0.00*7.340$	=	0.00	t-m
C.G. of this above founding level	$61.850-30.100+0.500/2$	=	32.000	m
Moment at founding level	$0.00*32.000$	=	0.00	t-m
Weight of water fill		=	36.33	t
Seismic force on this weight	$0.000*36.33$	=	0.00	t
C.G. of this above scour level	$(65.100-61.600-2.500)*0.5+(61.600-54.760)$	=	7.340	m
Moment at scour level	$0.00*7.340$	=	0.00	t-m
C.G. of this above founding level	$7.340+54.760-30.100$	=	32.000	m
Moment at founding level	$0.00*32.000$	=	0.00	t-m
Weight of intermediat/top plug		=	59.95	t
Seismic force on this weight	$0.000*59.95$	=	0.00	t
C.G. of this above scour level	$61.600-54.760-0.750*0.5$	=	6.465	m
Moment at scour level	$0.00*6.465$	=	0.00	t-m
C.G. of this above founding level	$6.465+54.760-30.100$	=	31.125	m
Moment at founding level	$0.00*31.125$	=	0.00	t-m
Depth of sand fill upto scour level	$61.600-54.760-0.750$	=	6.090	m
Weight of sand fill upto scour level	$3.14*6.800^2*6.090*2.000/4$	=	442.52	t
Seismic force on this weight	$0.000*442.52$	=	0.00	t
C.G. of this above scour level	$6.090/2$	=	3.045	m
Moment at scour level	$0.00*3.045$	=	0.00	t-m
C.G. of this above founding level	$3.045+54.760-30.100$	=	27.705	m
Moment at founding level	$0.00*27.705$	=	0.00	t-m
Weight of well components above scour level	$707.14+48.01+1,361.49+96.02+36.33+59.95+442.52$	=	2,751.46	t
	(including top plug, sandfill & waterfill)			
Horizontal seismic forces on well components	$2,751.46*0.000$	=	0.00	t
	(including top plug, sandfill & waterfill)			

Moment at scour level due to this	$0.00+0.00+0.00+0.00+0.00+0.00+0.00$ (including top plug, sandfill & waterfill)	=	0.00	t-m
Moment at founding level due to this	$0.00+0.00+0.00+0.00+0.00+0.00+0.00$ (including top plug, sandfill & waterfill)	=	0.00	t-m

3.4 WATER PRESSURE: (As per clause 210.2 of IRC:6-2010)

Intensity of water pressure at well top	$52 \times 0.660 \times 3.600^2$	=	444.787	kg/m ²	(as per cl 210.2 of IRC:6-2010)
Intensity of water pressure at scour level		=	0.000	kg/m ²	
Outer diameter of well		=	12.000	m	(diameter near base taken on safer side)
Height of well above scour level	$65.100 - 54.760$	=	10.340	m	



Total water pressure acting over well	$0.5 \times 444.787 \times 12.000 \times 10.340 / 1000$	=	27.59	t
C.G. of this above scour level	$2 \times 10.340 / 3$	=	6.893	m
Moment at scour level	27.59×6.893	=	190.18	t-m
C.G. of this above founding level	$6.893 + 54.760 - 30.100$	=	31.553	m
Moment at founding level	27.59×31.553	=	870.55	t-m

Net forces including those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$2,500.00+0.00+27.59$	=	2,527.59	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$25,850.00+5000+0.00+190.18$	=	31,040.18	t-m	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at base level	$87500+5000+0.00+870.54727$	=	93,370.55	t-m	(3.1 + 3.2 + 3.3 + 3.4)

Net forces excluding those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$2,500.00+0.00+0.00+0.00+27.59$	=	2,527.59	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$25,850.00+5000+0.00+0.00+0.00+190.18$	=	31,040.18	t-m	(3.1 + 3.2 + 3.3 + 3.4)

4. MOMENT AT BASE LEVEL DUE TO TILT & SHIFT:

(As per clause 708.5.1 of IRC:78)

Shift considered for well design		=	0.150	m
Vertical load at top of the well		=	7,500.00	t
Moment due to shift	$0.150 \times 7,500.00$	=	1,125.00	t-m
Tilt considered for well design		=	1.250	%
Vertical load at top of the well		=	7,500.00	t
C.G. of this above founding level	$65.100-30.100$	=	35.000	m
Lateral shift of this C.G. due to tilt	$1.250 \times 35.000/100$	=	0.438	m
Moment due to lateral shift due to tilt	$7,500.00 \times 0.438$	=	3,285.00	t-m
Weight of well cap		=	707.14	t
C.G. of this above founding level	$65.100-30.100-2.500 \times 0.5$	=	33.750	m
Lateral shift of this C.G. due to tilt	$1.250 \times 33.750/100$	=	0.422	m
Moment due to lateral shift due to tilt	707.14×0.422	=	298.41	t-m
Weight of well steining near top		=	48.01	t
C.G. of this above founding level	$62.350-30.100+0.250/2$	=	32.375	m
Lateral shift of this C.G. due to tilt	$1.250 \times 32.375/100$	=	0.405	m
Moment due to lateral shift due to tilt	48.01×0.405	=	19.44	t-m
Weight of well steining near bottom		=	6,096.95	t
C.G. of this above founding level	$(61.850-30.100)/2$	=	15.875	m
Lateral shift of this C.G. due to tilt	$1.250 \times 15.875/100$	=	0.198	m
Moment due to lateral shift due to tilt	$6,096.95 \times 0.198$	=	1,207.20	t-m
Weight of well steining in tapering portion		=	96.02	t
C.G. of this above founding level	$61.850-30.100+0.500/2$	=	32.000	m
Lateral shift of this C.G. due to tilt	$1.250 \times 32.000/100$	=	0.400	m
Moment due to lateral shift due to tilt	96.02×0.400	=	38.41	t-m

Weight of water fill	=	36.33	t
C.G. of this above founding level			
		$65.100-30.100-2.500-(65.100-2.500-61.600)/2$	= 32.000 m
Lateral shift of this C.G.due to tilt		$1.250*32.000/100$	= 0.400 m
Moment due to lateral shift due to tilt		$36.33*0.400$	= 14.53 t-m
Weight of intermediat/top plug	=	59.95	t
C.G. of this above founding level		$61.600-30.100-0.750*0.5$	= 31.125 m
Lateral shift of this C.G.due to tilt		$1.250*31.125/100$	= 0.389 m
Moment due to lateral shift due to tilt		$59.95*0.389$	= 23.32 t-m
Weight of sand fill	=	1,943.73	t
C.G. of this above founding level		$(61.600-30.100-0.750-4.000)/2+4.000$	= 17.375 m
Lateral shift of this C.G.due to tilt		$1.250*17.375/100$	= 0.217 m
Moment due to lateral shift due to tilt		$1,943.73*0.217$	= 421.79 t-m
Weight of bottom plug	=	319.72	t
C.G. of this above founding level		$4.000/2$	= 2.000 m
Lateral shift of this C.G.due to tilt		$1.250*2.000/100$	= 0.025 m
Moment due to lateral shift due to tilt		$319.72*0.025$	= 7.99 t-m

Total moment at base due to tilt & shift			
	=	$1,125.00+3,285.00+298.41+19.44+1,207.20+38.41+14.53+23.32+421.79+7.99$	6441.09 t-m

5. RESISTING MOMENT AT FOUNDING LEVEL:

(As per Appendix-3 of IRC:78)

The resisting moment is acting because of difference in passive and active earth pressure

F.O.S in assessing passive resistance	=	2.000	(r appendix-3 of IRC78)
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The active and passive earth pressure at any depth has been calculated by following equations:

Active earth pressure, p_a :	=	$K_a \gamma h + K_a q - 2c(K_a)^{1/2}$	
	=	$K_a \gamma h + K_a q$	(ignoring the effect of cohesion conservatively)

Passive earth pressure, p_p :	=	$K_p \gamma h + K_p q + 2c(K_p)^{1/2}$	(q = 0 considered for well design)
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where,

Coefficient of active earth pressure, K_a	=	$\frac{\sin^2(\alpha + \varphi)}{\sin^2 \alpha \sin(\alpha - \delta) [1 + \{\sin(\varphi + \delta) \sin(\varphi - \beta) / \sin(\alpha - \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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Coefficient of passive earth pressure, K_p	=	$\frac{\sin^2(\alpha - \varphi)}{\sin^2 \alpha \sin(\alpha + \delta) [1 - \{\sin(\varphi + \delta) \sin(\varphi + \beta) / \sin(\alpha + \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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γ'	=	Submerged density of earth
h	=	Thickness of layer considered
q	=	Surcharge at top of the layer considered
Inclination of Wall from Horizontal, α	=	90.000 degree
φ	=	Angle of Internal Friction
δ	=	Angle of Wall Friction
Inclination of Backfill from Horizontal, β	=	0.000 degree

5.1 GENERAL CALCULATIONS:

Surcharge considered for active earth pressure	=	30.000 t/m ²
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Top of Layer	Bottom of Layer	$\sin^2(\alpha+\varphi)$	$\sin^2\alpha$	$\sin(\alpha-\delta)$	$\sin(\varphi+\delta)$	$\sin(\varphi-\beta)$	$\sin(\alpha+\beta)$	$\sin^2(\alpha-\varphi)$	$\sin(\alpha+\delta)$	$\sin(\varphi+\beta)$
54.760	50.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
50.000	45.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
45.000	40.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
40.000	35.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
35.000	30.100	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559

Top of Layer	Bottom of Layer	φ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³	Coefficient, Ka	Coefficient, Kp	Thickness, h, m	Height above well bottom, m
54.760	50.000	34.00	22.50	0.00	1.000	0.254	8.901	4.76	19.90
50.000	45.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	14.90
45.000	40.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	9.90
40.000	35.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	4.90
35.000	30.100	34.00	22.50	0.00	1.000	0.254	8.901	4.90	0.00

5.2 FORCES & MOMENTS DUE TO ACTIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_a at top, t/m ²	p_a at bottom, t/m ²	Dia of well, m	Total Active Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
54.760	50.000	0.000	8.825	12.000	252.0	21.487	5415.69
50.000	45.000	8.825	10.095	12.000	567.60	17.344	9844.46
45.000	40.000	10.095	11.364	12.000	643.76	12.351	7950.95
40.000	35.000	11.364	12.634	12.000	719.93	7.356	5295.76
35.000	30.100	12.634	13.878	12.000	779.4	2.412	1879.73
Total Moment, M_a							30,386.59

5.3 FORCES & MOMENTS DUE TO PASSIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_p at top, t/m ²	p_p at bottom, t/m ²	Dia of well, m	Total Passive Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
54.760	50.000	0.000	42.368	12.000	1210.03	21.487	25999.54
50.000	45.000	42.368	86.872	12.000	3877.21	17.113	66350.84
45.000	40.000	86.872	131.377	12.000	6547.46	12.230	80075.95
40.000	35.000	131.377	175.881	12.000	9217.72	7.279	67098.51
35.000	30.100	175.881	219.495	12.000	11624.04	2.360	27431.73
Total Moment, M_p							266,956.56

Total moment due to active earth pressure, M_a = 30,386.59 t-m

Total moment due to passive earth pressure, M_p = 266,956.56 t-m

Factor of safety = 2.000 (as per appendix-3 of IRC:78)

Net resisting moment, $(M_a - M_p)/F.O.S$	$(266,956.56 - 30,386.59)/2.000$	=	118284.99 t-m
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6. DESIGN MOMENT AT BASE LEVEL:

External moment at top of well cap = 5000.00 t-m

Moment due to external horizontal load = 87500.00 t-m

Moment due to seismic forces on well
 $0.00+0.00+0.00+0.00+0.00+0.00+0.00$ = 0.00 t-m

Moment due to water pressure on well = 870.55 t-m

Moment due to tilt and shift = 6441.09 t-m

Resisting moment = 118284.99 t-m

(due to passive earth pressure)

Net moment at base level	=	0.00 t-m
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(resisting moment is more than moment acting)

7. CHECK FOR BASE PRESSURE:

(As per provisions of IRC:78-2014)

Outer diameter of well at well bottom/curb		=	12.150	m
Area at well bottom, A	$3.14 \times 12.150^2 / 4$	=	115.989	m ²
Section modulus, Z	$3.14 \times 12.150^3 / 32$	=	176.158	m ³
Net vertical load at well bottom, P (including buoyancy & vertical seismic forces)		=	12,282.14	t
Net moment at well bottom, M		=	0.00	t-m
Maximum base pressure, σ_{\max}	$12,282.14 / 115.989 + 0.00 / 176.158$	=	105.89	t/m ²
Allowable gross bearing capacity		=	120.00	t/m ²
Which is more than the maximum base pressure, hence O.K.				
Minimum base pressure, σ_{\min}	$12,282.14 / 115.989 - 0.00 / 176.158$	=	105.89	t/m ²
Which is more than zero, hence O.K.				

D. OUTPUT FOR STEINING STRESS CHECK:

1. DEPTH OF ZERO SHEAR BELOW SCOUR LEVEL:

Depth of zero shear below scour level, x		=	{2FH / $\gamma_b(K_p-K_a)D$ } ^{1/2}	
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)				
where,				
Factor of safety, F		=	2.00	
Resultant horizontal force at scour level, H		=	2,527.59 t	(excluding those due to top plug, sandfill & waterfill)
Submerged density of soil, γ_b		=	1.00 t/m ³	
Coefficient of active earth pressure, K_a		=	0.254	
Coefficient of passive earth pressure, K_p		=	8.901	
Outer diameter of well steining, D		=	12.000 m	
Now, depth of zero shear, x				
	$2*2.00*2,527.59/(1.00*(8.901-0.254)*12.000)^{0.5}$	=	9.871 m	
Level at the depth of zero shear	54.760-9.871	=	44.889 m	

2. VERTICAL LOAD & MOMENT DUE TO TILT & SHIFT AT DEPTH OF ZERO SHEAR:

Shift considered for well design		=	0.150 m	
Tilt considered for well design		=	1.250 %	
External vertical load over well		=	7,500.00 t	
Moment due to shift	7,500.00*0.150	=	1,125.00 t-m	
C.G. of this above depth of zero shear	65.100-44.889	=	20.211 m	
Lateral shift of this C.G.due to tilt	1.250*20.211/100	=	0.253 m	
Moment due to lateral shift due to tilt	0.253*7,500.00	=	1897.50 t-m	
Weight of well cap		=	707.14 t	
C.G. of this above depth of zero shear	9.090+9.871	=	18.961 m	
Lateral shift of this C.G.due to tilt	1.250*18.961/100	=	0.237 m	
Moment due to lateral shift due to tilt	0.237*707.14	=	167.59 t-m	
Weight of well steining near top (with reduced thickness of steining)		=	48.01 t	
C.G. of this above depth of zero shear	7.715+9.871	=	17.586 m	
Lateral shift of this C.G.due to tilt	1.250*17.586/100	=	0.22 t-m	
Moment due to lateral shift due to tilt	0.22*48.01	=	10.56 t-m	
Height of thicker well steining above depth of zero shear		=		
	61.850-44.889	=	16.961 m	
Weight of thicker well steining upto depth of zero shear		=		
	76.812*16.961*2.500	=	3,257.02 t	
C.G. of this above depth of zero shear	0.5*16.961	=	8.481 m	

Lateral shift of this C.G.due to tilt	$1.250 \times 8.481 / 100$	=	0.11	t-m
Moment due to lateral shift due to tilt	$0.11 \times 3,257.02$	=	358.27	t-m
Weight of tapering well steining		=	96.02	t
C.G. of this above depth of zero shear	$7.340 + 9.871$	=	17.211	m
Lateral shift of this C.G.due to tilt	$1.250 \times 17.211 / 100$	=	0.22	t-m
Moment due to lateral shift due to tilt	0.22×96.02	=	21.12	t-m

Total vertical load at depth of zero shear	$7,500.00 + 707.14 + 48.01 + 3,257.02 + 96.02$	=	11,608.19	t	(excluding those due to top plug, sandfill & waterfill)
Tilt & shift moment at depth of zero shear	$1,125.00 + 1897.5 + 167.59 + 10.56 + 358.27 + 21.12$	=	3,580.04	t-m	

3. DESIGN VERTICAL LOAD & MOMENT AT DEPTH OF ZERO SHEAR:

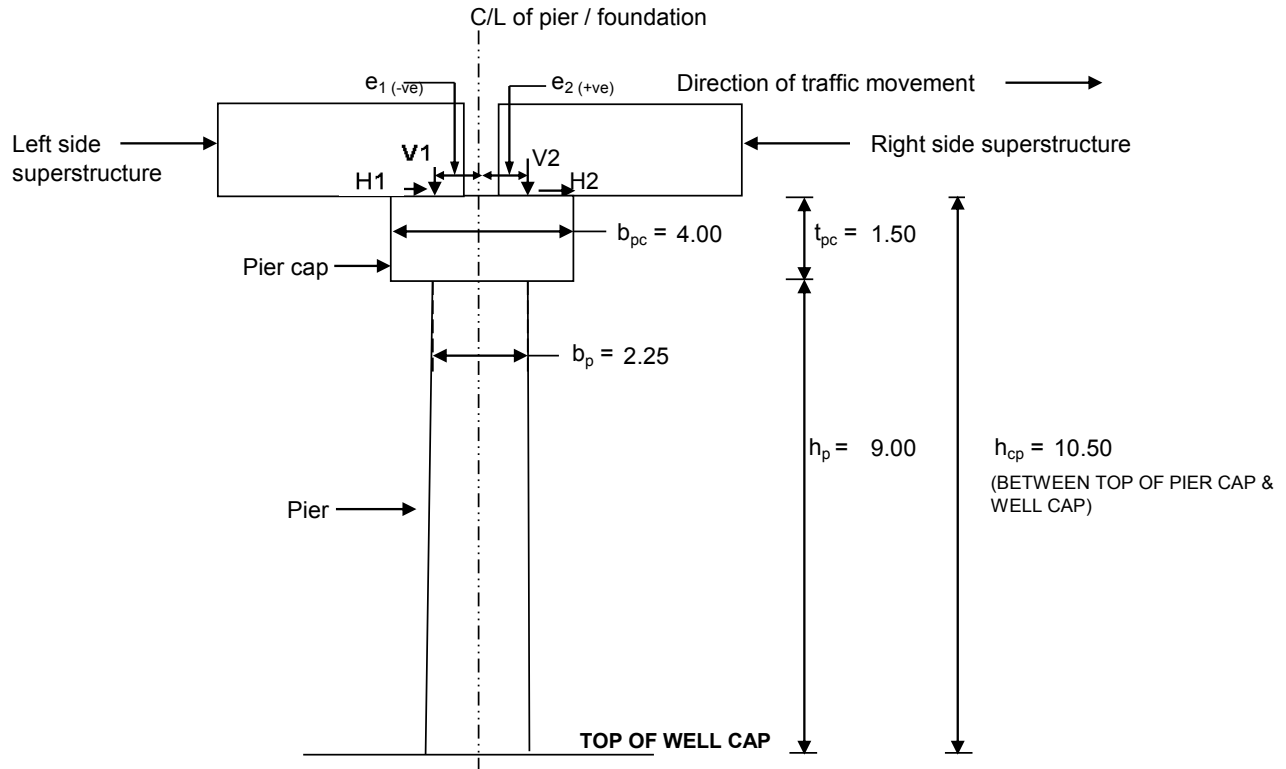
Total vertical load at depth of zero shear		=	11,608.19	t	(excluding buoyancy & seismic forces)
Vertical load of well components at scour level	$707.14 + 48.01 + 3,257.02 + 96.02$	=	4108.19	t	(excluding those due to top plug, sandfill & waterfill)
Vertical upward seismic force on this	0.000×4108.19	=	0.00	t	(upward seismic governs the design)
Height of well upto the depth of zero shear	$65.100 - 44.889$	=	20.21	t	
Buoyancy on well upto the depth of zero shear	$113.143 \times 20.211 \times 0.15$	=	343.01	t	(15% buoyancy as per cl.216.5 of IRC: 6)
Net vertical load at depth of zero shear	$11,608.19 - 0.00 - 343.01$	=	11265.18	t	(including buoyancy & vertical seismic forces)
Tilt & shift moment at depth of zero shear, M1		=	3,580.04	t-m	
Resultant horizontal force at scour level, H		=	2,527.59	t	(excluding those due to top plug, sandfill & waterfill)
Net moment at scour level, M ₀		=	31,040.18	t-m	(excluding those due to top plug, sandfill & waterfill)
Moment at depth of zero shear, M2		=	$M_0 + 2Hx/3$		
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)	$31,040.18 + (2 \times 2,527.59 \times 9.871) / 3$	=	47,673.41	t-m	

Now,

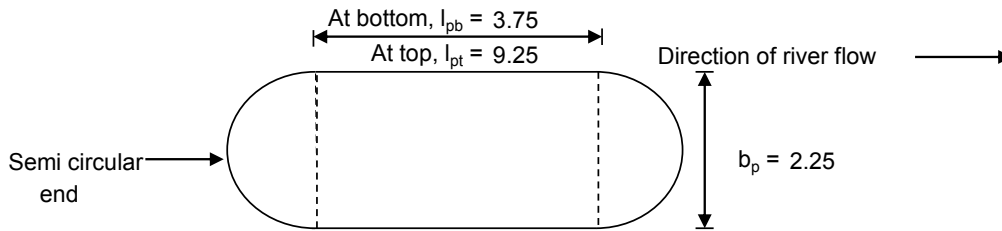
Net vertical load for steining design		=	11265.18	t	
Net moment for steining design	$3,580.04 + 47,673.41$	=	51253.45	t-m	(M1 + M2)

DESIGN OF RCC PIER

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM **JOB NO.** XPLR-226
LOCATION: PIERS ON GRIDS 'P2' TO 'P25' **DATE:** 2016 OCT
LOAD CASE: SEISMIC (LIVE LOADS ON BOTH SPANS)
 (ALLOWABLE STRESSES GIVEN BELOW ARE CORRESPONDING TO THIS LOAD CASE)
INPUT DATA: (ALL DIMENSIONS SHOWN IN THE FIGURES BELOW ARE IN METER)



ELEVATION OF PIER



PLAN OF PIER

1 DIMENSIONS:

PIER CAP:

Length of pier cap over pier (along river flow), l_{pc}	=	14.50	m	(slightly on higher side)
Width of pier cap (along bridge), b_{pc}	=	4.00	m	
Thickness of pier cap, t_{pc} (average thickness)	=	1.50	m	(conservative value)
Thickness of bearing & bearing pedestal, $t_{b\&p}$	=	0.50	m	(for design purpose only)

PIER:

Length of rectangular portion of pier at bottom, l_{pb}	=	3.75	m	(6.00-2.25)
Length of rectangular portion of pier at top, l_{pt}	=	9.25	m	(11.50-2.25)
Width of pier, b_p	=	2.25	m	
Height of pier, h_p	=	9.00	m	(conservative value)
Height " h_{cp} " between top of pier cap & pier base	=	1.50+9.00	=	10.50 m

2 PROPERTIES OF CONCRETE & STEEL:

Permissible stresses given below are corresponding to

Density of concrete, γ_c (as per clause 203 of IRC: 6- 2014)	=	2.50	t/m ³	SEISMIC load case
Grade of concrete & steel	=	M35	&	Fe500
Permissible stress in concrete, σ_{cb} (table A4.2 of IRC: 112- 2011)	=	17.505	N/mm ²	
Permissible stress in tension steel, σ_{st} (table A4.4 of IRC: 112- 2011)	=	360.00	N/mm ²	
Permissible stress in compression steel, σ_{sc} (table A4.4 of IRC: 112)	=	307.50	N/mm ²	

3 LOADS:

Live loads defined below are corresponding to

Load Combination:		SEISMIC	(LIVE LOADS ON BOTH SPANS)
Horizontal seismic coefficient, α_h (clause 219 of RC: 6- 2014)	=	0.240	(resul.of long.& trans.seismic)
Vertical seismic coefficient, α_v (clause 219 of RC: 6- 2014)	=	0.160	(2/3 of the horizontal seismic)
Enhancement factor for seismic forces for foundation design	=	1.250	(clause 219 of RC: 6- 2014)
Dead load " V_{1DL} " from left side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Dead load " V_{2DL} " from right side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Live load " V_{1LL} " from left side superstructure, including FPLL	=	75.00	t (70R-W in each C.W.)
Live load " V_{2LL} " from right side superstructure, including FPLL	=	75.00	t (70R-W in each C.W.)
Vertical seismic " V_{1SE} " from left side superstructure	=	212.00	t $\alpha_v*(DL+LL)$
Vertical seismic " V_{2SE} " from right side superstructure	=	212.00	t $\alpha_v*(DL+LL)$
Eccentricity of left side vertical load w.r.t C/L of pier/ foundation, e_1 (taken as -ve below)	=	1.425	m
Eccentricity of right side vertical load w.r.t C/L of pier/ foundation, e_2 (taken as +ve below)	=	1.425	m
Horizontal force " H_1 " from left side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	10.000	t (70R-W in each C.W.)
Horizontal force " H_2 " from right side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	10.000	t (70R-W in each C.W.)
Horizontal seismic " H_{1SE} " from left side superstructure	=	300.00	t $\alpha_h*(DL)$
Horizontal seismic " H_{2SE} " from right side superstructure	=	300.00	t $\alpha_h*(DL)$

1 SECTIONAL PROPERTIES AND WEIGHT:

PIER CAP:

X-sectional area of pier cap	1.50×4.00	=	6.000	m ²
Length of pier cap		=	14.500	m
Weight of pier cap, W_{pc}	$6.000 \times 14.500 \times 2.50$	=	217.500	t

PIER:

Area of rectangular portion of pier at bottom	3.75×2.25	=	8.438	m ²
Area of circular portion at bottom	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at bottom, A_{pb}	$8.438 + 3.976$	=	12.414	m ²
Area of rectangular portion of pier at top	9.25×2.25	=	20.813	m ²
Area of circular portion at top	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at top, A_{pt}	$20.813 + 3.976$	=	24.789	m ²
Average X-section area of pier, A_p	$(12.414 + 24.789) / 2$	=	18.602	m ²
Height of pier, h_p		=	9.000	m
Weight of pier, W_p	$18.602 \times 9.000 \times 2.50$	=	418.545	t

2 VERTICAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>ECC.*</u> (m)	<u>MOMENT</u> (t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	75.00	-1.425	-106.88
Live load (right side)	75.00	1.425	106.88
Vertical seismic (left side superstructure)	212.00	-1.425	-302.10
Vertical seismic (right side superstructure)	212.00	1.425	302.10
Vertical seismic on weight of pier	66.967	0.000	0.00
Vertical seismic on weight of pier cap	34.800	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p	=	3,811.81	t
Moment due to vertical load at the base of pier, M_{vp}	=	0.00	t-m

3 HORIZONTAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>LEVER</u> <u>ARM**</u> (m)	<u>MOMENT</u> (t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	10.000	11.00	110.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	10.000	11.00	110.00
Horizontal seismic, H_{1SE} (left side superstructure)	300.00	11.00	3300.00
Horizontal seismic, H_{2SE} (right side superstructure)	300.00	11.00	3300.00
Horizontal seismic on weight of pier	100.45	5.13	515.78
Horizontal seismic on weight of pier cap	52.20	9.75	508.95

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is height between top of bearing & base of pier).

Total horizontal load at the base of pier, H_p	=	772.65	t
Moment due to horizontal load at the base of pier, M_{hp}	=	7,844.73	t-m

4 RECAP OF FORCES FOR PIER DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,811.81	t
Total horizontal load at the base of pier, H_p	=	772.65	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	7,844.73	t-m

5 STRESSES AT PIER BASE:

Refer following pages for calculation of stresses in concrete & steel at pier base.

6 VERTICAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u>	<u>ECC.*</u>	<u>MOMENT</u>
	(t)	(m)	(t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	75.00	-1.425	-106.88
Live load (right side)	75.00	1.425	106.88
Vertical seismic (left side superstructure)	265.000	-1.425	-377.63
Vertical seismic (right side superstructure)	265.000	1.425	377.63
Vertical seismic on weight of pier	83.709	0.000	0.00
Vertical seismic on weight of pier cap	43.500	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p	=	3,943.25	t
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Moment due to vertical load at the base of pier, M_{vp}	=	0.00	t-m
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7 HORIZONTAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u>	<u>LEVER</u>	<u>MOMENT</u>
	(t)	<u>ARM**</u> (m)	(t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	10.000	11.00	110.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	10.000	11.00	110.00
Horizontal seismic, H_{1SE} (left side superstructure)	375.00	11.00	4125.00
Horizontal seismic, H_{2SE} (right side superstructure)	375.00	11.00	4125.00
Horizontal seismic on weight of pier	125.56	5.13	644.72
Horizontal seismic on weight of pier cap	65.25	9.75	636.19

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is

Total horizontal load at the base of pier, H_p	=	960.81	t
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Moment due to horizontal load at the base of pier, M_{hp}	=	9,750.91	t-m
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8 RECAP OF FORCES FOR FOUNDATION DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,943.25	t
Total horizontal load at the base of pier, H_p	=	960.81	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	9,750.91	t-m

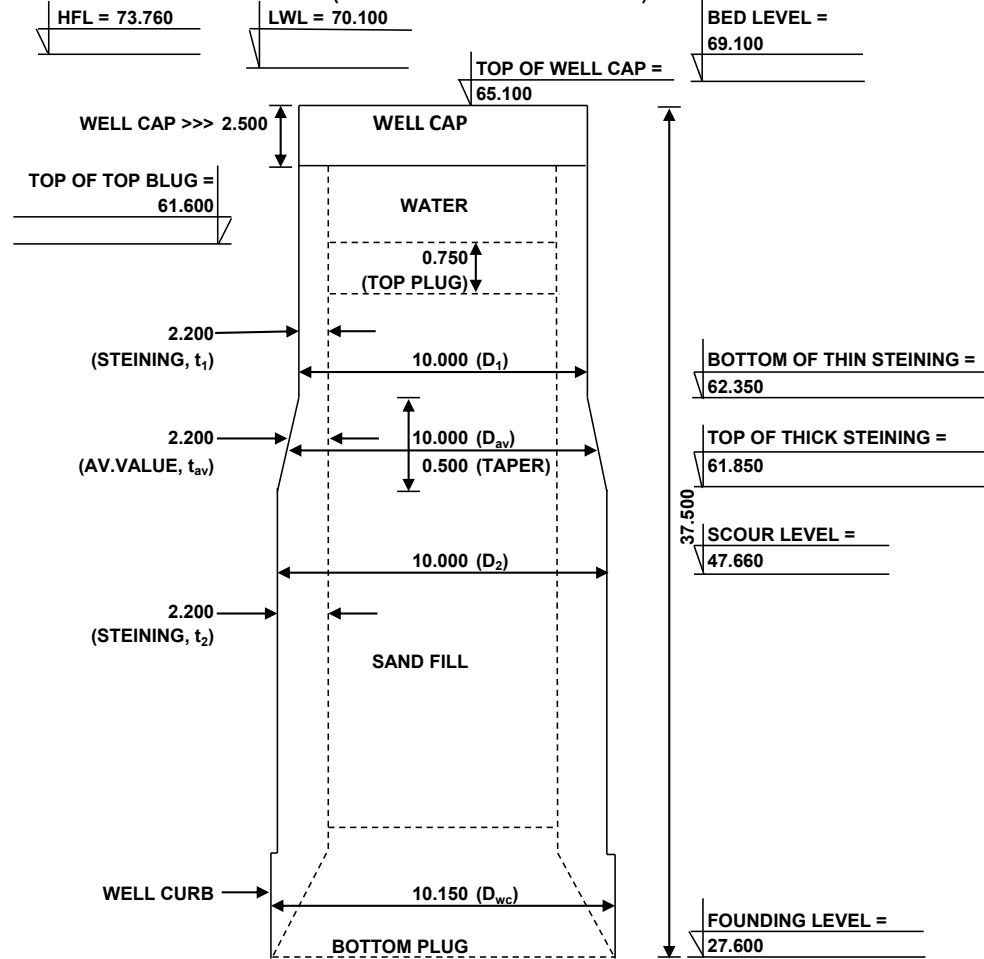
9 DESIGN OF FOUNDATION:

Refer following pages for design of foundation.

DESIGN OF CIRCULAR WELL FOUNDATION

(AS PER PROVISIONS OF IRC: 78)

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM
 LOCATION: WELL SUPPORTING PIERS
 LOAD CASE: SEISMIC (LIVE LOADS ON BOTH SPANS)



TYPICAL ELEVATION OF WELL

A. DESIGN DATA:

WELL SUPPORTING PIERS

1. LOAD CASE CONSIDERED:

SEISMIC (LIVE LOADS ON BOTH SPANS)

2. LEVELS:

High flood level (HFL)	=	73.760	m	
Low water level (LWL)	=	70.100	m	
Top level of well cap	=	65.100	m	
Bed level	=	69.100	m	
Top level of top/intermediate plug	=	61.600	m	
Level at the bottom of top steining having less thickness, t_1	=	62.350	m	
<input type="text" value="should be above top of top plug in such a way that tapering is done above top plug"/>				
Level at the top of bottom steining having more thickness, t_2	=	61.850	m	
Scour level <input type="text" value="should be below the bottom of top/intermediate plug"/>	=	47.660	m	(conservative value)
Bottom level of well (founding level)	=	27.600	m	

3. WELL PROPERTIES:

Outer diameter of well near top having thin steining, D_1	=	10.000	m	
Outer diameter of well near bottom having thick steining, D_2	=	10.000	m	
Average outer diameter of well at location where steining tapers, D_{av}	=	10.000	m	
Outer diameter of well at founding level (well curb), D_{wc}	=	10.150	m	
Coefficient 'K' for calculating steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2014)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2014)
Steining thickness near top (should be above scour depth), t_1	=	2.200	m	(taper not steeper than 1H:3V)
Steining thickness near bottom, t_2	=	2.200	m	(taper not steeper than 1H:3V)
Average steining thickness in taper portion, t_{av}	=	2.200	m	
Thickness of well cap	=	2.500	m	
Thickness of top/intermediate plug	=	0.750	m	
Thickness of bottom plug	=	4.000	m	(above founding level of well)
Density of RCC	=	2.500	t/m ³	
Density of PCC	=	2.200	t/m ³	
Density of sand fill	=	2.000	t/m ³	
Density of water	=	1.000	t/m ³	

4. SOIL PROPERTIES:

Net safe bearing capacity	=	100.00	t/m ²	(at founding level)
Gross bearing capacity	=	150.00	t/m ²	(Net SBC + overburden)
F.O.S in assessing passive resistance	=	1.600		(as per appendix-3 of IRC:78-2014)

Top of Layer	Bottom of Layer	ϕ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³ (submerged, if applicable)	Intensity of active earth pressure at top, p_a , t/m ²	Intensity of passive earth pressure at top, p_p , t/m ²
47.660	40.000	34.00	22.50	0.00	1.00	0.000	0.000
40.000	35.000	34.00	22.50	0.00	1.00	(conservative)	(conservative)
35.000	30.000	34.00	22.50	0.00	1.00	(see below)	(see below)
30.000	25.000	34.00	22.50	0.00	1.00		
25.000	27.600	34.00	22.50	0.00	1.00		

5. EXTERNAL LOADS:

External vertical load at top of well cap	=	3,943.25	t	(at top of well cap)
External moment at top of well cap	=	9,750.91	t-m	(at top of well cap)
External horizontal load at top of well cap	=	960.81	t	(at top of well cap)
Horizontal seismic coefficient	=	0.300		(resultant of long.& trans.seismic)
Vertical seismic coefficient	0.300*2/3 =	0.200		
Velocity of flow at well top	=	3.600	m/s	(at top of well cap)
Coefficient 'K' to calculate water pressure	=	0.660		(as per clause 210.2 of IRC:6-2014)
Intensity of water pressure at scour level	=	0.000	kg/m ²	

6. TILTS AND SHIFTS:

Maximum shift considered for well design	=	0.150	m	(as per clause 708.5.1of IRC:78-2014)
Maximum tilt considered for well design	=	1.250	%	(as per clause 708.5.1of IRC:78-2014)

7. OTHERS:

Inclination of wall from horizontal, α	=	90.000	degree	
Inclination of backfill from horizontal, β	=	0.000	degree	
Surcharge considered for active earth pressure	=	0.000	t/m ²	(acting over the well)
Factor of safety, F	(for steining stress, see below) =	2.00		
Submerged density of soil, γ_b	(for steining stress, see below) =	1.00	t/m ³	
Coefficient of active earth pressure, K_a	(for steining stress, see below) =	0.254		
Coefficient of passive earth pressure, K_p	(for steining stress, see below) =	8.901		

B. SUMMARY OF FINDINGS & RESULTS:

Minimum steining thickness required near top	=	1.563	m	
Steining thickness provided near top	=	2.200	m	Hence O.K.
Minimum steining thickness required near bottom	=	2.151	m	
Steining thickness required near bottom	=	2.200	m	Hence O.K.
Maximum base pressure, σ_{max}	=	101.08	t/m ²	
Allowable gross bearing capacity	=	150.00	t/m ²	Hence O.K.
Minimum base pressure, σ_{min}	=	101.08	t/m ²	Hence O.K.

C. OUTPUT FOR WELL STABILITY:

1. CHECK FOR MINIMUM STEINING THICKNESSES:

(As per clause 708.2.3 of IRC:78)

Coefficient 'K' for steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2000)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2000)
Outer diameter of well near top, D_1	=	10.000	m	
Depth of well below well top or LWL till scour level whichever is more	=	22.440	m	
Minimum steining thickness required near top				
$0.030 \times 1.100 \times 10.000 \times 22.440^{0.5}$	=	1.563	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

Outer diameter of well near bottom, D_2	=	10.000	m	
Depth of well below well top or LWL till founding level whichever is more	=	42.500	m	
Minimum steining thickness required near bottom				
$0.030 \times 1.100 \times 10.000 \times 42.500^{0.5}$	=	2.151	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

2. VERTICAL FORCES AT BASE LEVEL:

Thickness of well cap	=	2.500	m	
Diameter of well cap	=	10.000	m	
Density of RCC	=	2.500	t/m ³	
Weight of well cap	$3.14 \times 10.000^2 \times 2.500 \times 2.500 / 4$	=	491.07	t
Outer diameter of well near top, D_1	=	10.000	m	
Area corresponding to outer diameter, A_1	$3.14 \times 10.000^2 / 4$	=	78.571	m ²
Steining thickness near top, t_1	=	2.200	m	
Inner diameter of well near top, D_1'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_1'	$3.14 \times 5.600^2 / 4$	=	24.640	m ²
Net area of steining near top, $A_1 - A_1'$	$78.571 - 24.640$	=	53.931	m ²
Depth of this portion of well	$65.100 - 62.350 - 2.500$	=	0.250	m
Density of RCC	=	2.500	t/m ³	
Weight of this portion of well steining	$53.931 \times 0.250 \times 2.500$	=	33.71	t

Outer diameter of well near bottom, D_2		=	10.000	m
Area corresponding to outer diameter, A_2	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness near bottom, t_2		=	2.200	m
Inner diameter of well near bottom, D_2'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_2'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$61.850 - 27.600$	=	34.250	m
Weight of this portion of well steining	$53.931 \times 34.250 \times 2.500$	=	4,617.84	t
Outer diameter of well in tapering portion, D_{av}	$(10.000 + 10.000) / 2$	=	10.000	m
Area corresponding to outer diameter, A_{av}	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness in tapering portion, t_{av}		=	2.200	m
Inner diameter of well in tapering portion, D_{av}'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_{av}'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$62.350 - 61.850$	=	0.500	m
Weight of this portion of well steining	$53.931 \times 0.500 \times 2.500$	=	67.41	t
Total weight of well steining	$33.71 + 4,617.84 + 67.41$	=	4,718.96	t
Depth of water above top/intermediate plug	$65.100 - 61.600 - 2.500$	=	1.000	m
Inner diameter of well		=	5.600	m
Density of water		=	1.000	t/m^3
Weight of water	$3.14 \times 5.600^2 \times 1.000 \times 1.000 / 4$	=	24.64	t
Thickness of intermediat/top plug		=	0.750	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of intermediat/top plug	$3.14 \times 5.600^2 \times 0.750 \times 2.200 / 4$	=	40.66	t
Depth of sand fill below top plug	$61.600 - 27.600 - 0.750 - 4.000$	=	29.250	m
Inner diameter of well		=	5.600	m
Density of sand		=	2.000	t/m^3
Weight of sand fill below top plug	$3.14 \times 5.600^2 \times 29.250 \times 2.000 / 4$	=	1,441.44	t
Thickness of bottom plug		=	4.000	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of bottom plug	$3.14 \times 5.600^2 \times 4.000 \times 2.200 / 4$	=	216.83	t

Total weight of well including top & bottom plugs and filling		=			
	$491.07+4,718.96+24.64+40.66+1,441.44+216.83$	=	6,933.60	t	
External vertical load over well		=	3,943.25	t	
Total vertical load including external load	$6,933.60+3,943.25$	=	10,876.85	t	(at founding level)
Vertical load of well components upto scour level	3,220.69	=	3,220.69	t	(see calculations below)
Vertical downward seismic force on this	$3,220.69*0.200$	=	644.14	t	(downward seismic governs the design)
Buoyancy on well	$3.14*10.000^2*(70.100-27.600)*1.000/4$	=	3,339.29	t	(diameter at the top is taken on safer side)
Net vertical load at base level	$10,876.85+644.14-3,339.29$	=	8,181.70	t	(including buoyancy & vertical seismic)

3. HORIZONTAL FORCES AND MOMENTS AT SCOUR & FOUNDING LEVELS:

3.1 EXTERNAL HORIZONTAL LOAD ACTING ON WELL:

External horizontal load on well		=	960.81	t	(at top of well cap)
C.G. of this above scour level	65.100-47.660	=	17.440	m	
Moment at scour level	$960.81*17.440$	=	16,756.53	t-m	
C.G. of this above founding level	$17.440+47.660-27.600$	=	37.500	m	
Moment at founding level	$960.81*37.500$	=	36030.38	t-m	

3.2 EXTERNAL MOMENT ACTING ON WELL:

External moment acting on well		=	9,750.91	t-m	
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3.3 SEISMIC FORCES ON WELL:

Horizontal seismic coefficient		=	0.300		
Weight of well cap		=	491.07	t	
Seismic force on this weight	$0.300*491.07$	=	147.32	t	
C.G. of this above scour level	$65.100-47.660-1.25$	=	16.190	m	
Moment at scour level	$147.32*16.190$	=	2,385.11	t-m	
C.G. of this above founding level	$16.190+47.660-27.600$	=	36.250	m	
Moment at founding level	$147.32*36.250$	=	5,340.35	t-m	
Weight of well steining near top (with reduced thickness of steining)		=	33.71	t	
Seismic force on this weight	$0.300*33.71$	=	10.11	t	
C.G. of this above scour level	$62.350-47.660+0.250/2$	=	14.815	m	
Moment at scour level	$10.11*14.815$	=	149.78	t-m	
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m	
Moment at founding level	$10.11*34.875$	=	352.59	t-m	

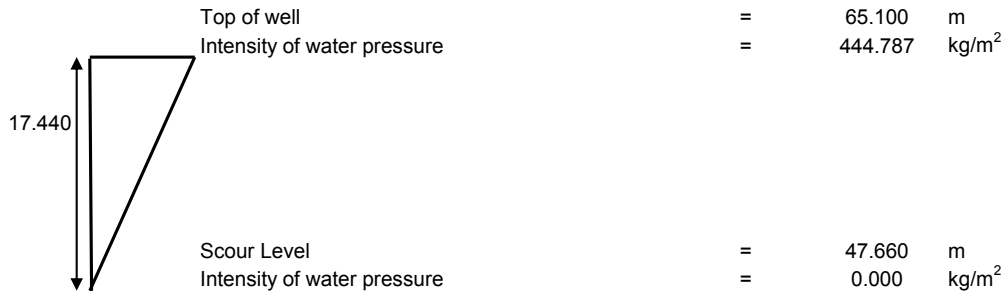
Height of thicker well steining above scour level	$61.850-47.660$	=	14.190	m
Weight of thicker well steining upto scour level	$53.931*14.190*2.500$	=	1,913.20	t
Seismic force on this weight	$0.300*1,913.20$	=	573.96	t
C.G. of this above scour level	$0.5*14.190$	=	7.095	m
Moment at scour level	$573.96*7.095$	=	4,072.25	t-m
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Moment at founding level	$573.96*17.125$	=	9,829.07	t-m
Weight of tapering well steining		=	67.41	t
Seismic force on this weight	$0.300*67.41$	=	20.22	t
C.G. of this above scour level	$61.850-47.660+0.500/2$	=	14.440	m
Moment at scour level	$20.22*14.440$	=	291.98	t-m
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Moment at founding level	$20.22*34.500$	=	697.59	t-m
Weight of water fill		=	24.64	t
Seismic force on this weight	$0.300*24.64$	=	7.39	t
C.G. of this above scour level	$(65.100-61.600-2.500)*0.5+(61.600-47.660)$	=	14.440	m
Moment at scour level	$7.39*14.440$	=	106.71	t-m
C.G. of this above founding level	$14.440+47.660-27.600$	=	34.500	m
Moment at founding level	$7.39*34.500$	=	254.96	t-m
Weight of intermediat/top plug		=	40.66	t
Seismic force on this weight	$0.300*40.66$	=	12.20	t
C.G. of this above scour level	$61.600-47.660-0.750*0.5$	=	13.565	m
Moment at scour level	$12.20*13.565$	=	165.49	t-m
C.G. of this above founding level	$13.565+47.660-27.600$	=	33.625	m
Moment at founding level	$12.20*33.625$	=	410.23	t-m
Depth of sand fill upto scour level	$61.600-47.660-0.750$	=	13.190	m
Weight of sand fill upto scour level	$3.14*5.600^2*13.190*2.000/4$	=	650.00	t
Seismic force on this weight	$0.300*650.00$	=	195.00	t
C.G. of this above scour level	$13.190/2$	=	6.595	m
Moment at scour level	$195.00*6.595$	=	1,286.03	t-m
C.G. of this above founding level	$6.595+47.660-27.600$	=	26.655	m
Moment at founding level	$195.00*26.655$	=	5,197.73	t-m
Weight of well components above scour level	$491.07+33.71+1,913.20+67.41+24.64+40.66+650.00$ (including top plug, sandfill & waterfill)	=	3,220.69	t
Horizontal seismic forces on well components	$3,220.69*0.300$ (including top plug, sandfill & waterfill)	=	966.21	t

Moment at scour level due to this
 $2,385.11+149.78+4,072.25+291.98+106.71+165.49+1,286.03 = 8,457.35 \text{ t-m}$
 (including top plug, sandfill & waterfill)

Moment at founding level due to this
 $5,340.35+352.59+9,829.07+697.59+254.96+410.23+5,197.73 = 22,082.52 \text{ t-m}$
 (including top plug, sandfill & waterfill)

3.4 WATER PRESSURE: (As per clause 210.2 of IRC:6-2010)

Intensity of water pressure at well top $52 \times 0.660 \times 3.600^2 = 444.787 \text{ kg/m}^2$ (as per cl 210.2 of IRC:6-2010)
 Intensity of water pressure at scour level = 0.000 kg/m^2
 Outer diameter of well = 10.000 m (diameter near base taken on safer side)
 Height of well above scour level $65.100 - 47.660 = 17.440 \text{ m}$



Total water pressure acting over well $0.5 \times 444.787 \times 10.000 \times 17.440 / 1000 = 38.79 \text{ t}$
 C.G. of this above scour level $2 \times 17.440 / 3 = 11.627 \text{ m}$
 Moment at scour level $38.79 \times 11.627 = 451.01 \text{ t-m}$
 C.G. of this above founding level $11.627 + 47.660 - 27.600 = 31.687 \text{ m}$
 Moment at founding level $38.79 \times 31.687 = 1229.14 \text{ t-m}$

Net forces including those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$960.81+966.21+38.79$	=	1,965.81	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$16,756.53+9,750.91+8,457.35+451.01$	=	35,415.80	t-m	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at base level	$36030.375+9,750.91+22,082.52+1229.13873$	=	69,092.94	t-m	(3.1 + 3.2 + 3.3 + 3.4)

Net forces excluding those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$960.81+147.32+10.11+573.96+20.22+38.79$	=	1,751.21	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$16,756.53+9,750.91+2,385.11+149.78+4,072.25+291.98+451.01$	=	33,857.57	t-m	(3.1 + 3.2 + 3.3 + 3.4)

4. MOMENT AT BASE LEVEL DUE TO TILT & SHIFT:

(As per clause 708.5.1 of IRC:78)

Shift considered for well design		=	0.150	m
Vertical load at top of the well		=	3,943.25	t
Moment due to shift	$0.150 \times 3,943.25$	=	591.49	t-m
Tilt considered for well design		=	1.250	%
Vertical load at top of the well		=	3,943.25	t
C.G. of this above founding level	$65.100-27.600$	=	37.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 37.500/100$	=	0.469	m
Moment due to lateral shift due to tilt	$3,943.25 \times 0.469$	=	1,849.38	t-m
Weight of well cap		=	491.07	t
C.G. of this above founding level	$65.100-27.600-2.500 \times 0.5$	=	36.250	m
Lateral shift of this C.G. due to tilt	$1.250 \times 36.250/100$	=	0.453	m
Moment due to lateral shift due to tilt	491.07×0.453	=	222.45	t-m
Weight of well steining near top		=	33.71	t
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.875/100$	=	0.436	m
Moment due to lateral shift due to tilt	33.71×0.436	=	14.70	t-m
Weight of well steining near bottom		=	4,617.84	t
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Lateral shift of this C.G. due to tilt	$1.250 \times 17.125/100$	=	0.214	m
Moment due to lateral shift due to tilt	$4,617.84 \times 0.214$	=	988.22	t-m
Weight of well steining in tapering portion		=	67.41	t
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.500/100$	=	0.431	m
Moment due to lateral shift due to tilt	67.41×0.431	=	29.05	t-m

Weight of water fill	=	24.64	t
C.G. of this above founding level			
	$65.100-27.600-2.500-(65.100-2.500-61.600)/2$	=	34.500 m
Lateral shift of this C.G.due to tilt	$1.250*34.500/100$	=	0.431 m
Moment due to lateral shift due to tilt	$24.64*0.431$	=	10.62 t-m
Weight of intermediat/top plug	=	40.66	t
C.G. of this above founding level	$61.600-27.600-0.750*0.5$	=	33.625 m
Lateral shift of this C.G.due to tilt	$1.250*33.625/100$	=	0.420 m
Moment due to lateral shift due to tilt	$40.66*0.420$	=	17.08 t-m
Weight of sand fill	=	1,441.44	t
C.G. of this above founding level	$(61.600-27.600-0.750-4.000)/2+4.000$	=	18.625 m
Lateral shift of this C.G.due to tilt	$1.250*18.625/100$	=	0.233 m
Moment due to lateral shift due to tilt	$1,441.44*0.233$	=	335.86 t-m
Weight of bottom plug	=	216.83	t
C.G. of this above founding level	$4.000/2$	=	2.000 m
Lateral shift of this C.G.due to tilt	$1.250*2.000/100$	=	0.025 m
Moment due to lateral shift due to tilt	$216.83*0.025$	=	5.42 t-m

Total moment at base due to tilt & shift			
$591.49+1,849.38+222.45+14.70+988.22+29.05+10.62+17.08+335.86+5.42$	=	4064.27	t-m

5. RESISTING MOMENT AT FOUNDING LEVEL:

(As per Appendix-3 of IRC:78)

The resisting moment is acting because of difference in passive and active earth pressure

F.O.S in assessing passive resistance	=	1.600	(r appendix-3 of IRC78)
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The active and passive earth pressure at any depth has been calculated by following equations:

Active earth pressure, p_a :	=	$K_a \gamma h + K_a q - 2c(K_a)^{1/2}$	
	=	$K_a \gamma h + K_a q$	(ignoring the effect of cohesion conservatively)

Passive earth pressure, p_p :	=	$K_p \gamma h + K_p q + 2c(K_p)^{1/2}$	(q = 0 considered for well design)
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where,

Coefficient of active earth pressure, K_a	=	$\frac{\sin^2(\alpha + \varphi)}{\sin^2 \alpha \sin(\alpha - \delta) [1 + \{\sin(\varphi + \delta) \sin(\varphi - \beta) / \sin(\alpha - \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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Coefficient of passive earth pressure, K_p	=	$\frac{\sin^2(\alpha - \varphi)}{\sin^2 \alpha \sin(\alpha + \delta) [1 - \{\sin(\varphi + \delta) \sin(\varphi + \beta) / \sin(\alpha + \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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γ'	=	Submerged density of earth
h	=	Thickness of layer considered
q	=	Surcharge at top of the layer considered
Inclination of Wall from Horizontal, α	=	90.000 degree
φ	=	Angle of Internal Friction
δ	=	Angle of Wall Friction
Inclination of Backfill from Horizontal, β	=	0.000 degree

5.1 GENERAL CALCULATIONS:

Surcharge considered for active earth pressure	=	0.000 t/m ²
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Top of Layer	Bottom of Layer	$\sin^2(\alpha+\varphi)$	$\sin^2\alpha$	$\sin(\alpha-\delta)$	$\sin(\varphi+\delta)$	$\sin(\varphi-\beta)$	$\sin(\alpha+\beta)$	$\sin^2(\alpha-\varphi)$	$\sin(\alpha+\delta)$	$\sin(\varphi+\beta)$
47.660	40.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
40.000	35.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
35.000	30.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
30.000	25.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
25.000	27.600	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559

Top of Layer	Bottom of Layer	φ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³	Coefficient, Ka	Coefficient, Kp	Thickness, h, m	Height above well bottom, m
47.660	40.000	34.00	22.50	0.00	1.000	0.254	8.901	7.66	12.40
40.000	35.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	7.40
35.000	30.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	2.40
30.000	25.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	-2.60
25.000	27.600	34.00	22.50	0.00	1.000	0.254	8.901	-2.60	0.00

5.2 FORCES & MOMENTS DUE TO ACTIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_a at top, t/m ²	p_a at bottom, t/m ²	Dia of well, m	Total Active Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
47.660	40.000	0.000	1.945	10.000	74.5	14.953	1113.81
40.000	35.000	1.945	3.214	10.000	128.98	9.695	1250.42
35.000	30.000	3.214	4.484	10.000	192.45	4.763	916.55
30.000	25.000	4.484	5.753	10.000	255.92	-0.203	-52.04
25.000	27.600	5.753	5.093	10.000	-141.0	-1.326	187.02
Total Moment, M_a							3,415.76

5.3 FORCES & MOMENTS DUE TO PASSIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_p at top, t/m ²	p_p at bottom, t/m ²	Dia of well, m	Total Passive Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
47.660	40.000	0.000	68.180	10.000	2611.31	14.953	39047.83
40.000	35.000	68.180	112.685	10.000	4521.63	9.695	43836.97
35.000	30.000	112.685	157.189	10.000	6746.84	4.763	32132.36
30.000	25.000	157.189	201.693	10.000	8972.05	-0.203	-1824.38
25.000	27.600	201.693	178.551	10.000	-4943.17	-1.326	6556.50
Total Moment, M_p							119,749.28

Total moment due to active earth pressure, M_a = 3,415.76 t-m

Total moment due to passive earth pressure, M_p = 119,749.28 t-m

Factor of safety = 1.600 (as per appendix-3 of IRC:78)

Net resisting moment, $(M_a - M_p)/F.O.S$	(119,749.28-3,415.76)/1.600	=	72708.45 t-m
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6. DESIGN MOMENT AT BASE LEVEL:

External moment at top of well cap = 9,750.91 t-m

Moment due to external horizontal load = 36030.38 t-m

Moment due to seismic forces on well
 $5,340.35+352.59+9,829.07+697.59+254.96+410.23+5,197.73$ = 22082.52 t-m

Moment due to water pressure on well = 1229.14 t-m

Moment due to tilt and shift = 4064.27 t-m

Resisting moment = 72708.45 t-m
 (due to passive earth pressure)

Net moment at base level	=	0.00 t-m
<small>(resisting moment is more than moment acting)</small>		

7. CHECK FOR BASE PRESSURE:

(As per provisions of IRC:78-2014)

Outer diameter of well at well bottom/curb		=	10.150	m
Area at well bottom, A	$3.14 \times 10.150^2 / 4$	=	80.946	m ²
Section modulus, Z	$3.14 \times 10.150^3 / 32$	=	102.701	m ³
Net vertical load at well bottom, P (including buoyancy & vertical seismic forces)		=	8,181.70	t
Net moment at well bottom, M		=	0.00	t-m
Maximum base pressure, σ_{\max}	$8,181.70 / 80.946 + 0.00 / 102.701$	=	101.08	t/m ²
Allowable gross bearing capacity		=	150.00	t/m ²
Which is more than the maximum base pressure, hence O.K.				
Minimum base pressure, σ_{\min}	$8,181.70 / 80.946 - 0.00 / 102.701$	=	101.08	t/m ²
Which is more than zero, hence O.K.				

D. OUTPUT FOR STEINING STRESS CHECK:

1. DEPTH OF ZERO SHEAR BELOW SCOUR LEVEL:

Depth of zero shear below scour level, x		=	$\{2FH / \gamma_b(K_p - K_a)D\}^{1/2}$	
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)				
where,				
Factor of safety, F		=	2.00	
Resultant horizontal force at scour level, H		=	1,751.21 t	(excluding those due to top plug, sandfill & waterfill)
Submerged density of soil, γ_b		=	1.00 t/m ³	
Coefficient of active earth pressure, K_a		=	0.254	
Coefficient of passive earth pressure, K_p		=	8.901	
Outer diameter of well steining, D		=	10.000 m	
Now, depth of zero shear, x				
	$2 \times 2.00 \times 1,751.21 / (1.00 \times (8.901 - 0.254) \times 10.000)^{0.5}$	=	9.000 m	
Level at the depth of zero shear	47.660 - 9.000	=	38.660 m	

2. VERTICAL LOAD & MOMENT DUE TO TILT & SHIFT AT DEPTH OF ZERO SHEAR:

Shift considered for well design		=	0.150 m
Tilt considered for well design		=	1.250 %
External vertical load over well		=	3,943.25 t
Moment due to shift	$3,943.25 \times 0.150$	=	591.49 t-m
C.G. of this above depth of zero shear	65.100 - 38.660	=	26.440 m
Lateral shift of this C.G. due to tilt	$1.250 \times 26.440 / 100$	=	0.331 m
Moment due to lateral shift due to tilt	$0.331 \times 3,943.25$	=	1305.22 t-m
Weight of well cap		=	491.07 t
C.G. of this above depth of zero shear	16.190 + 9.000	=	25.190 m
Lateral shift of this C.G. due to tilt	$1.250 \times 25.19 / 100$	=	0.315 m
Moment due to lateral shift due to tilt	0.315×491.07	=	154.69 t-m
Weight of well steining near top (with reduced thickness of steining)		=	33.71 t
C.G. of this above depth of zero shear	14.815 + 9.000	=	23.815 m
Lateral shift of this C.G. due to tilt	$1.250 \times 23.815 / 100$	=	0.30 t-m
Moment due to lateral shift due to tilt	0.30×33.71	=	10.11 t-m
Height of thicker well steining above depth of zero shear	61.850 - 38.660	=	23.190 m
Weight of thicker well steining upto depth of zero shear	$53.931 \times 23.190 \times 2.500$	=	3,126.65 t
C.G. of this above depth of zero shear	0.5×23.190	=	11.595 m

Lateral shift of this C.G.due to tilt	$1.250 \times 11.595 / 100$	=	0.14	t-m
Moment due to lateral shift due to tilt	$0.14 \times 3,126.65$	=	437.73	t-m
Weight of tapering well steining		=	67.41	t
C.G. of this above depth of zero shear	$14.440 + 9.000$	=	23.440	m
Lateral shift of this C.G.due to tilt	$1.250 \times 23.440 / 100$	=	0.29	t-m
Moment due to lateral shift due to tilt	0.29×67.41	=	19.55	t-m

Total vertical load at depth of zero shear

$$3,943.25 + 491.07 + 33.71 + 3,126.65 + 67.41 = 7,662.09 \text{ t}$$

(excluding those due to top plug, sandfill & waterfill)

Tilt & shift moment at depth of zero shear

$$591.49 + 1305.21575 + 154.69 + 10.11 + 437.73 + 19.55 = 2,518.79 \text{ t-m}$$

3. DESIGN VERTICAL LOAD & MOMENT AT DEPTH OF ZERO SHEAR:

Total vertical load at depth of zero shear		=	7,662.09	t	(excluding buoyancy & seismic forces)
Vertical load of well components at scour level		=			
	$491.07 + 33.71 + 3,126.65 + 67.41$	=	3718.84	t	(excluding those due to top plug, sandfill & waterfill)
Vertical upward seismic force on this	0.200×3718.84	=	743.77	t	(upward seismic governs the design)
Height of well upto the depth of zero shear	$65.100 - 38.660$	=	26.44	t	
Buoyancy on well upto the depth of zero shear	$78.571 \times 26.44 \times 0.15$	=	311.61	t	(15% buoyancy as per cl.216.5 of IRC: 6)
Net vertical load at depth of zero shear	$7,662.09 - 743.77 - 311.61$	=	6606.71	t	(including buoyancy & vertical seismic forces)
Tilt & shift moment at depth of zero shear, M1		=	2,518.79	t-m	
Resultant horizontal force at scour level, H		=	1,751.21	t	(excluding those due to top plug, sandfill & waterfill)
Net moment at scour level, M ₀		=	33,857.57	t-m	(excluding those due to top plug, sandfill & waterfill)
Moment at depth of zero shear, M2		=	$M_0 + 2Hx/3$		
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)		=			
	$33,857.57 + (2 \times 1,751.21 \times 9.000) / 3$	=	44,364.83	t-m	

Now,

Net vertical load for steining design		=	6606.71	t	
Net moment for steining design	$2,518.79 + 44,364.83$	=	46883.62	t-m	(M1 + M2)

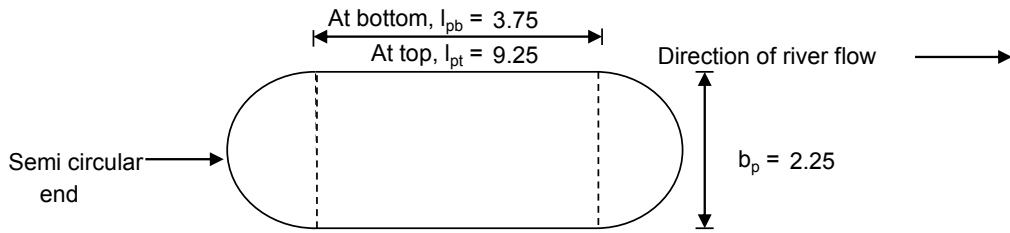
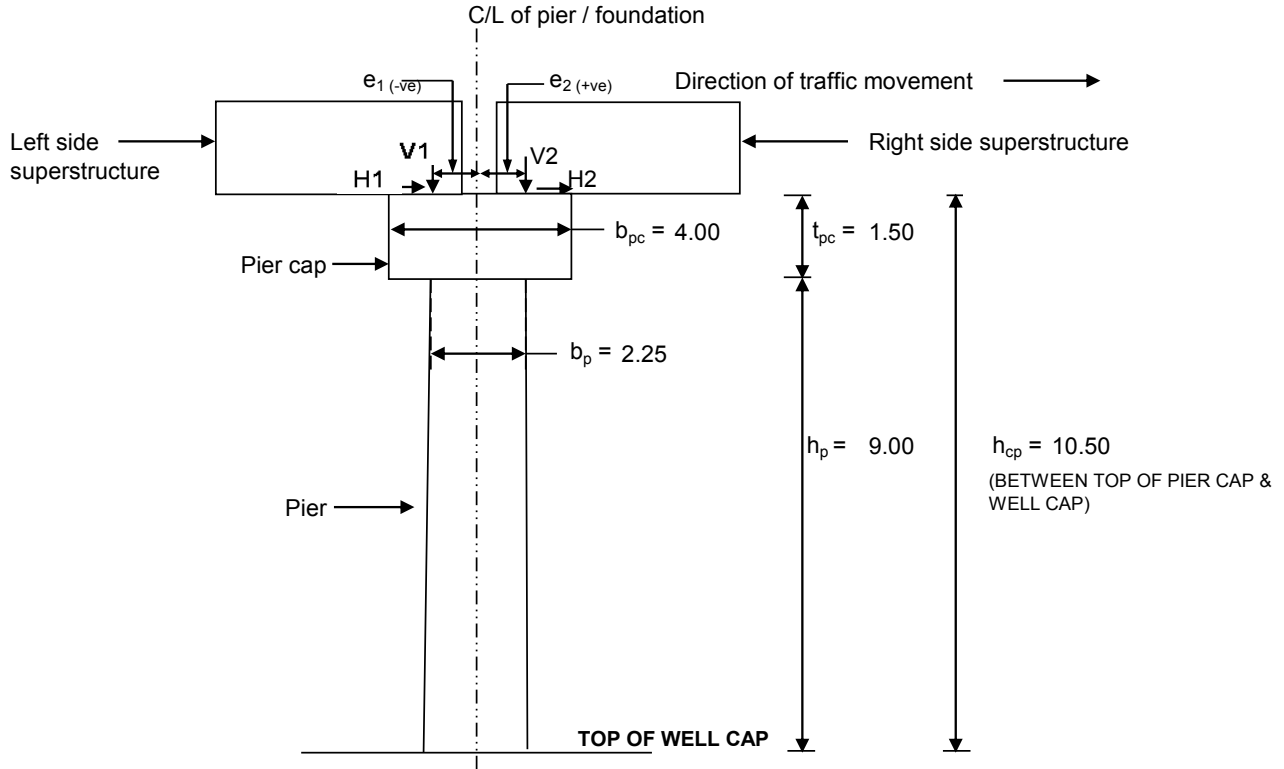
DESIGN OF RCC PIER

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM **JOB NO.** XPLR-226

LOCATION: PIERS ON GRIDS 'P2' TO 'P25' **DATE:** 2016 OCT

LOAD CASE: SEISMIC (LIVE LOADS ON ONE SPAN)
 (ALLOWABLE STRESSES GIVEN BELOW ARE CORRESPONDING TO THIS LOAD CASE)

INPUT DATA: (ALL DIMENSIONS SHOWN IN THE FIGURES BELOW ARE IN METER)



1 DIMENSIONS:

PIER CAP:

Length of pier cap over pier (along river flow), l_{pc}	=	14.50	m	(slightly on higher side)
Width of pier cap (along bridge), b_{pc}	=	4.00	m	
Thickness of pier cap, t_{pc} (average thickness)	=	1.50	m	(conservative value)
Thickness of bearing & bearing pedestal, $t_{b\&p}$	=	0.50	m	(for design purpose only)

PIER:

Length of rectangular portion of pier at bottom, l_{pb}	=	3.75	m	(6.00-2.25)
Length of rectangular portion of pier at top, l_{pt}	=	9.25	m	(11.50-2.25)
Width of pier, b_p	=	2.25	m	
Height of pier, h_p	=	9.00	m	(conservative value)
Height " h_{cp} " between top of pier cap & pier base	=	1.50+9.00	=	10.50 m

2 PROPERTIES OF CONCRETE & STEEL:

Permissible stresses given below are corresponding to

Density of concrete, γ_c (as per clause 203 of IRC: 6- 2014)	=	2.50	t/m ³	SEISMIC load case
Grade of concrete & steel	=	M35	&	Fe500
Permissible stress in concrete, σ_{cb} (table A4.2 of IRC: 112- 2011)	=	17.505	N/mm ²	
Permissible stress in tension steel, σ_{st} (table A4.4 of IRC: 112- 2011)	=	360.00	N/mm ²	
Permissible stress in compression steel, σ_{sc} (table A4.4 of IRC: 112)	=	307.50	N/mm ²	

3 LOADS:

Live loads defined below are corresponding to

Load Combination:		SEISMIC	(LIVE LOADS ON ONE SPAN)
Horizontal seismic coefficient, α_h (clause 219 of RC: 6- 2014)	=	0.240	(resul.of long.& trans.seismic)
Vertical seismic coefficient, α_v (clause 219 of RC: 6- 2014)	=	0.160	(2/3 of the horizontal seismic)
Enhancement factor for seismic forces for foundation design	=	1.250	(clause 219 of RC: 6- 2014)
Dead load " V_{1DL} " from left side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Dead load " V_{2DL} " from right side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Live load " V_{1LL} " from left side superstructure, including FPLL	=	0.00	t (LL on one span only)
Live load " V_{2LL} " from right side superstructure, including FPLL	=	75.00	t (70R-W in each C.W.)
Vertical seismic " V_{1SE} " from left side superstructure	=	200.00	t $\alpha_v*(DL+LL)$
Vertical seismic " V_{2SE} " from right side superstructure	=	212.00	t $\alpha_v*(DL+LL)$
Eccentricity of left side vertical load w.r.t C/L of pier/ foundation, e_1 (taken as -ve below)	=	1.425	m
Eccentricity of right side vertical load w.r.t C/L of pier/ foundation, e_2 (taken as +ve below)	=	1.425	m
Horizontal force " H_1 " from left side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	0.000	t (LL on one span only)
Horizontal force " H_2 " from right side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	10.000	t (70R-W in each C.W.)
Horizontal seismic " H_{1SE} " from left side superstructure	=	300.00	t $\alpha_h*(DL)$
Horizontal seismic " H_{2SE} " from right side superstructure	=	300.00	t $\alpha_h*(DL)$

1 SECTIONAL PROPERTIES AND WEIGHT:

PIER CAP:

X-sectional area of pier cap	1.50×4.00	=	6.000	m ²
Length of pier cap		=	14.500	m
Weight of pier cap, W_{pc}	$6.000 \times 14.500 \times 2.50$	=	217.500	t

PIER:

Area of rectangular portion of pier at bottom	3.75×2.25	=	8.438	m ²
Area of circular portion at bottom	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at bottom, A_{pb}	$8.438 + 3.976$	=	12.414	m ²
Area of rectangular portion of pier at top	9.25×2.25	=	20.813	m ²
Area of circular portion at top	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at top, A_{pt}	$20.813 + 3.976$	=	24.789	m ²
Average X-section area of pier, A_p	$(12.414 + 24.789) / 2$	=	18.602	m ²
Height of pier, h_p		=	9.000	m
Weight of pier, W_p	$18.602 \times 9.000 \times 2.50$	=	418.545	t

2 VERTICAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>ECC.*</u> (m)	<u>MOMENT</u> (t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	0.00	-1.425	0.00
Live load (right side)	75.00	1.425	106.88
Vertical seismic (left side superstructure)	200.00	-1.425	-285.00
Vertical seismic (right side superstructure)	212.00	1.425	302.10
Vertical seismic on weight of pier	66.967	0.000	0.00
Vertical seismic on weight of pier cap	34.800	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p	=	3,724.81	t
Moment due to vertical load at the base of pier, M_{vp}	=	123.98	t-m

3 HORIZONTAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>LEVER</u> <u>ARM**</u> (m)	<u>MOMENT</u> (t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	0.000	11.00	0.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	10.000	11.00	110.00
Horizontal seismic, H_{1SE} (left side superstructure)	300.00	11.00	3300.00
Horizontal seismic, H_{2SE} (right side superstructure)	300.00	11.00	3300.00
Horizontal seismic on weight of pier	100.45	5.13	515.78
Horizontal seismic on weight of pier cap	52.20	9.75	508.95

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is height between top of bearing & base of pier).

Total horizontal load at the base of pier, H_p	=	762.65	t
Moment due to horizontal load at the base of pier, M_{hp}	=	7,734.73	t-m

4 RECAP OF FORCES FOR PIER DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,724.81	t
Total horizontal load at the base of pier, H_p	=	762.65	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	7,858.71	t-m

5 STRESSES AT PIER BASE:

Refer following pages for calculation of stresses in concrete & steel at pier base.

6 VERTICAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>ECC.*</u> (m)	<u>MOMENT</u> (t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	0.00	-1.425	0.00
Live load (right side)	75.00	1.425	106.88
Vertical seismic (left side superstructure)	250.000	-1.425	-356.25
Vertical seismic (right side superstructure)	265.000	1.425	377.63
Vertical seismic on weight of pier	83.709	0.000	0.00
Vertical seismic on weight of pier cap	43.500	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p	=	3,853.25	t
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Moment due to vertical load at the base of pier, M_{vp}	=	128.25	t-m
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7 HORIZONTAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>LEVER</u> <u>ARM**</u> (m)	<u>MOMENT</u> (t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	0.000	11.00	0.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	10.000	11.00	110.00
Horizontal seismic, H_{1SE} (left side superstructure)	375.00	11.00	4125.00
Horizontal seismic, H_{2SE} (right side superstructure)	375.00	11.00	4125.00
Horizontal seismic on weight of pier	125.56	5.13	644.72
Horizontal seismic on weight of pier cap	65.25	9.75	636.19

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is

Total horizontal load at the base of pier, H_p	=	950.81	t
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Moment due to horizontal load at the base of pier, M_{hp}	=	9,640.91	t-m
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8 RECAP OF FORCES FOR FOUNDATION DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,853.25	t
Total horizontal load at the base of pier, H_p	=	950.81	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	9,769.16	t-m

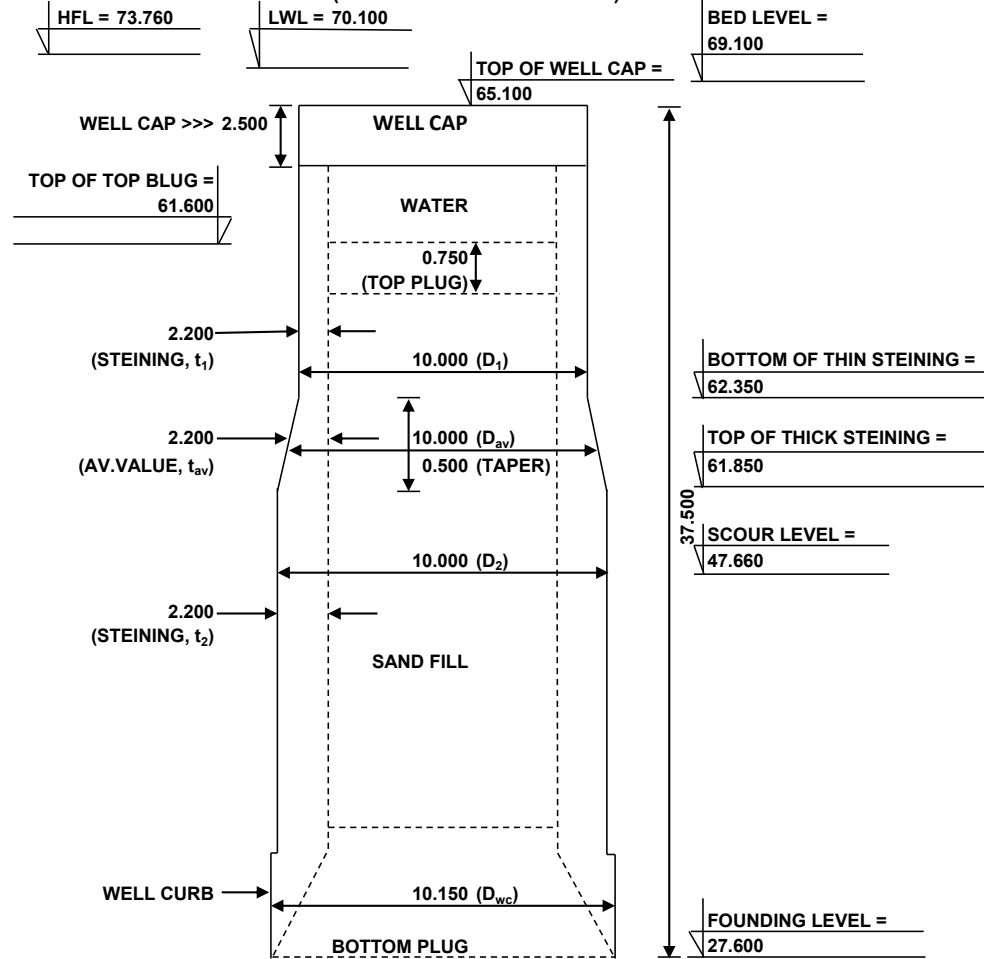
9 DESIGN OF FOUNDATION:

Refer following pages for design of foundation.

DESIGN OF CIRCULAR WELL FOUNDATION

(AS PER PROVISIONS OF IRC: 78)

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM
 LOCATION: WELL SUPPORTING PIERS
 LOAD CASE: SEISMIC (LIVE LOADS ON ONE SPAN)



TYPICAL ELEVATION OF WELL

A. DESIGN DATA:

WELL SUPPORTING PIERS

1. LOAD CASE CONSIDERED:

SEISMIC (LIVE LOADS ON ONE SPAN)

2. LEVELS:

High flood level (HFL)	=	73.760	m	
Low water level (LWL)	=	70.100	m	
Top level of well cap	=	65.100	m	
Bed level	=	69.100	m	
Top level of top/intermediate plug	=	61.600	m	
Level at the bottom of top steining having less thickness, t_1	=	62.350	m	
should be above top of top plug in such a way that tapering is done above top plug				
Level at the top of bottom steining having more thickness, t_2	=	61.850	m	
Scour level	should be below the bottom of top/intermediate plug	=	47.660	m (conservative value)
Bottom level of well (founding level)	=	27.600	m	

3. WELL PROPERTIES:

Outer diameter of well near top having thin steining, D_1	=	10.000	m	
Outer diameter of well near bottom having thick steining, D_2	=	10.000	m	
Average outer diameter of well at location where steining tapers, D_{av}	=	10.000	m	
Outer diameter of well at founding level (well curb), D_{wc}	=	10.150	m	
Coefficient 'K' for calculating steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2014)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2014)
Steining thickness near top (should be above scour depth), t_1	=	2.200	m	(taper not steeper than 1H:3V)
Steining thickness near bottom, t_2	=	2.200	m	(taper not steeper than 1H:3V)
Average steining thickness in taper portion, t_{av}	=	2.200	m	
Thickness of well cap	=	2.500	m	
Thickness of top/intermediate plug	=	0.750	m	
Thickness of bottom plug	=	4.000	m	(above founding level of well)
Density of RCC	=	2.500	t/m ³	
Density of PCC	=	2.200	t/m ³	
Density of sand fill	=	2.000	t/m ³	
Density of water	=	1.000	t/m ³	

4. SOIL PROPERTIES:

Net safe bearing capacity	=	100.00	t/m ²	(at founding level)
Gross bearing capacity	=	150.00	t/m ²	(Net SBC + overburden)
F.O.S in assessing passive resistance	=	1.600		(as per appendix-3 of IRC:78-2014)

Top of Layer	Bottom of Layer	ϕ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³ (submerged, if applicable)	Intensity of active earth pressure at top, p_a , t/m ²	Intensity of passive earth pressure at top, p_p , t/m ²
47.660	40.000	34.00	22.50	0.00	1.00	0.000	0.000
40.000	35.000	34.00	22.50	0.00	1.00	(conservative)	(conservative)
35.000	30.000	34.00	22.50	0.00	1.00	(see below)	(see below)
30.000	25.000	34.00	22.50	0.00	1.00		
25.000	27.600	34.00	22.50	0.00	1.00		

5. EXTERNAL LOADS:

External vertical load at top of well cap	=	3,853.25	t	(at top of well cap)
External moment at top of well cap	=	9,769.16	t-m	(at top of well cap)
External horizontal load at top of well cap	=	950.81	t	(at top of well cap)
Horizontal seismic coefficient	=	0.300		(resultant of long.& trans.seismic)
Vertical seismic coefficient	0.300*2/3 =	0.200		
Velocity of flow at well top	=	3.600	m/s	(at top of well cap)
Coefficient 'K' to calculate water pressure	=	0.660		(as per clause 210.2 of IRC:6-2014)
Intensity of water pressure at scour level	=	0.000	kg/m ²	

6. TILTS AND SHIFTS:

Maximum shift considered for well design	=	0.150	m	(as per clause 708.5.1of IRC:78-2014)
Maximum tilt considered for well design	=	1.250	%	(as per clause 708.5.1of IRC:78-2014)

7. OTHERS:

Inclination of wall from horizontal, α	=	90.000	degree	
Inclination of backfill from horizontal, β	=	0.000	degree	
Surcharge considered for active earth pressure	=	0.000	t/m ²	(acting over the well)
Factor of safety, F	(for steining stress, see below) =	2.00		
Submerged density of soil, γ_b	(for steining stress, see below) =	1.00	t/m ³	
Coefficient of active earth pressure, K_a	(for steining stress, see below) =	0.254		
Coefficient of passive earth pressure, K_p	(for steining stress, see below) =	8.901		

B. SUMMARY OF FINDINGS & RESULTS:

Minimum steining thickness required near top	=	1.563	m	
Steining thickness provided near top	=	2.200	m	Hence O.K.
Minimum steining thickness required near bottom	=	2.151	m	
Steining thickness required near bottom	=	2.200	m	Hence O.K.
Maximum base pressure, σ_{max}	=	99.96	t/m ²	
Allowable gross bearing capacity	=	150.00	t/m ²	Hence O.K.
Minimum base pressure, σ_{min}	=	99.96	t/m ²	Hence O.K.

C. OUTPUT FOR WELL STABILITY:

1. CHECK FOR MINIMUM STEINING THICKNESSES:

(As per clause 708.2.3 of IRC:78)

Coefficient 'K' for steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2000)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2000)
Outer diameter of well near top, D_1	=	10.000	m	
Depth of well below well top or LWL till scour level whichever is more	=	22.440	m	
Minimum steining thickness required near top				
$0.030 \times 1.100 \times 10.000 \times 22.440^{0.5}$	=	1.563	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

Outer diameter of well near bottom, D_2	=	10.000	m	
Depth of well below well top or LWL till founding level whichever is more	=	42.500	m	
Minimum steining thickness required near bottom				
$0.030 \times 1.100 \times 10.000 \times 42.500^{0.5}$	=	2.151	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

2. VERTICAL FORCES AT BASE LEVEL:

Thickness of well cap	=	2.500	m	
Diameter of well cap	=	10.000	m	
Density of RCC	=	2.500	t/m ³	
Weight of well cap	$3.14 \times 10.000^2 \times 2.500 \times 2.500 / 4$	=	491.07	t
Outer diameter of well near top, D_1	=	10.000	m	
Area corresponding to outer diameter, A_1	$3.14 \times 10.000^2 / 4$	=	78.571	m ²
Steining thickness near top, t_1	=	2.200	m	
Inner diameter of well near top, D_1'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_1'	$3.14 \times 5.600^2 / 4$	=	24.640	m ²
Net area of steining near top, $A_1 - A_1'$	$78.571 - 24.640$	=	53.931	m ²
Depth of this portion of well	$65.100 - 62.350 - 2.500$	=	0.250	m
Density of RCC	=	2.500	t/m ³	
Weight of this portion of well steining	$53.931 \times 0.250 \times 2.500$	=	33.71	t

Outer diameter of well near bottom, D_2		=	10.000	m
Area corresponding to outer diameter, A_2	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness near bottom, t_2		=	2.200	m
Inner diameter of well near bottom, D_2'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_2'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$61.850 - 27.600$	=	34.250	m
Weight of this portion of well steining	$53.931 \times 34.250 \times 2.500$	=	4,617.84	t
Outer diameter of well in tapering portion, D_{av}	$(10.000 + 10.000) / 2$	=	10.000	m
Area corresponding to outer diameter, A_{av}	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness in tapering portion, t_{av}		=	2.200	m
Inner diameter of well in tapering portion, D_{av}'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_{av}'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$62.350 - 61.850$	=	0.500	m
Weight of this portion of well steining	$53.931 \times 0.500 \times 2.500$	=	67.41	t
Total weight of well steining	$33.71 + 4,617.84 + 67.41$	=	4,718.96	t
Depth of water above top/intermediate plug	$65.100 - 61.600 - 2.500$	=	1.000	m
Inner diameter of well		=	5.600	m
Density of water		=	1.000	t/m^3
Weight of water	$3.14 \times 5.600^2 \times 1.000 \times 1.000 / 4$	=	24.64	t
Thickness of intermediat/top plug		=	0.750	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of intermediat/top plug	$3.14 \times 5.600^2 \times 0.750 \times 2.200 / 4$	=	40.66	t
Depth of sand fill below top plug	$61.600 - 27.600 - 0.750 - 4.000$	=	29.250	m
Inner diameter of well		=	5.600	m
Density of sand		=	2.000	t/m^3
Weight of sand fill below top plug	$3.14 \times 5.600^2 \times 29.250 \times 2.000 / 4$	=	1,441.44	t
Thickness of bottom plug		=	4.000	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of bottom plug	$3.14 \times 5.600^2 \times 4.000 \times 2.200 / 4$	=	216.83	t

Total weight of well including top & bottom plugs and filling		=			
	$491.07+4,718.96+24.64+40.66+1,441.44+216.83$	=	6,933.60	t	
External vertical load over well		=	3,853.25	t	
Total vertical load including external load	$6,933.60+3,853.25$	=	10,786.85	t	(at founding level)
Vertical load of well components upto scour level	3,220.69	=	3,220.69	t	(see calculations below)
Vertical downward seismic force on this	$3,220.69*0.200$	=	644.14	t	(downward seismic governs the design)
Buoyancy on well	$3.14*10.000^2*(70.100-27.600)*1.000/4$	=	3,339.29	t	(diameter at the top is taken on safer side)
Net vertical load at base level	$10,786.85+644.14-3,339.29$	=	8,091.70	t	(including buoyancy & vertical seismic)

3. HORIZONTAL FORCES AND MOMENTS AT SCOUR & FOUNDING LEVELS:

3.1 EXTERNAL HORIZONTAL LOAD ACTING ON WELL:

External horizontal load on well		=	950.81	t	(at top of well cap)
C.G. of this above scour level	65.100-47.660	=	17.440	m	
Moment at scour level	$950.81*17.440$	=	16,582.13	t-m	
C.G. of this above founding level	$17.440+47.660-27.600$	=	37.500	m	
Moment at founding level	$950.81*37.500$	=	35655.38	t-m	

3.2 EXTERNAL MOMENT ACTING ON WELL:

External moment acting on well		=	9,769.16	t-m	
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3.3 SEISMIC FORCES ON WELL:

Horizontal seismic coefficient		=	0.300		
Weight of well cap		=	491.07	t	
Seismic force on this weight	$0.300*491.07$	=	147.32	t	
C.G. of this above scour level	$65.100-47.660-1.25$	=	16.190	m	
Moment at scour level	$147.32*16.190$	=	2,385.11	t-m	
C.G. of this above founding level	$16.190+47.660-27.600$	=	36.250	m	
Moment at founding level	$147.32*36.250$	=	5,340.35	t-m	
Weight of well steining near top (with reduced thickness of steining)		=	33.71	t	
Seismic force on this weight	$0.300*33.71$	=	10.11	t	
C.G. of this above scour level	$62.350-47.660+0.250/2$	=	14.815	m	
Moment at scour level	$10.11*14.815$	=	149.78	t-m	
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m	
Moment at founding level	$10.11*34.875$	=	352.59	t-m	

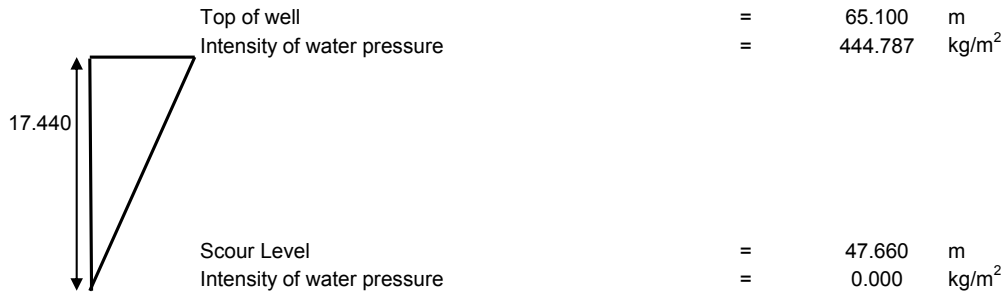
Height of thicker well steining above scour level	$61.850-47.660$	=	14.190	m
Weight of thicker well steining upto scour level	$53.931*14.190*2.500$	=	1,913.20	t
Seismic force on this weight	$0.300*1,913.20$	=	573.96	t
C.G. of this above scour level	$0.5*14.190$	=	7.095	m
Moment at scour level	$573.96*7.095$	=	4,072.25	t-m
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Moment at founding level	$573.96*17.125$	=	9,829.07	t-m
Weight of tapering well steining		=	67.41	t
Seismic force on this weight	$0.300*67.41$	=	20.22	t
C.G. of this above scour level	$61.850-47.660+0.500/2$	=	14.440	m
Moment at scour level	$20.22*14.440$	=	291.98	t-m
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Moment at founding level	$20.22*34.500$	=	697.59	t-m
Weight of water fill		=	24.64	t
Seismic force on this weight	$0.300*24.64$	=	7.39	t
C.G. of this above scour level	$(65.100-61.600-2.500)*0.5+(61.600-47.660)$	=	14.440	m
Moment at scour level	$7.39*14.440$	=	106.71	t-m
C.G. of this above founding level	$14.440+47.660-27.600$	=	34.500	m
Moment at founding level	$7.39*34.500$	=	254.96	t-m
Weight of intermediat/top plug		=	40.66	t
Seismic force on this weight	$0.300*40.66$	=	12.20	t
C.G. of this above scour level	$61.600-47.660-0.750*0.5$	=	13.565	m
Moment at scour level	$12.20*13.565$	=	165.49	t-m
C.G. of this above founding level	$13.565+47.660-27.600$	=	33.625	m
Moment at founding level	$12.20*33.625$	=	410.23	t-m
Depth of sand fill upto scour level	$61.600-47.660-0.750$	=	13.190	m
Weight of sand fill upto scour level	$3.14*5.600^2*13.190*2.000/4$	=	650.00	t
Seismic force on this weight	$0.300*650.00$	=	195.00	t
C.G. of this above scour level	$13.190/2$	=	6.595	m
Moment at scour level	$195.00*6.595$	=	1,286.03	t-m
C.G. of this above founding level	$6.595+47.660-27.600$	=	26.655	m
Moment at founding level	$195.00*26.655$	=	5,197.73	t-m
Weight of well components above scour level	$491.07+33.71+1,913.20+67.41+24.64+40.66+650.00$ (including top plug, sandfill & waterfill)	=	3,220.69	t
Horizontal seismic forces on well components	$3,220.69*0.300$ (including top plug, sandfill & waterfill)	=	966.21	t

Moment at scour level due to this
 $2,385.11+149.78+4,072.25+291.98+106.71+165.49+1,286.03$ = 8,457.35 t-m
 (including top plug, sandfill & waterfill)

Moment at founding level due to this
 $5,340.35+352.59+9,829.07+697.59+254.96+410.23+5,197.73$ = 22,082.52 t-m
 (including top plug, sandfill & waterfill)

3.4 WATER PRESSURE: (As per clause 210.2 of IRC:6-2010)

Intensity of water pressure at well top $52 \times 0.660 \times 3.600^2$ = 444.787 kg/m² (as per cl 210.2 of IRC:6-2010)
 Intensity of water pressure at scour level = 0.000 kg/m²
 Outer diameter of well = 10.000 m (diameter near base taken on safer side)
 Height of well above scour level $65.100 - 47.660$ = 17.440 m



Total water pressure acting over well $0.5 \times 444.787 \times 10.000 \times 17.440 / 1000$ = 38.79 t
 C.G. of this above scour level $2 \times 17.440 / 3$ = 11.627 m
 Moment at scour level 38.79×11.627 = 451.01 t-m
 C.G. of this above founding level $11.627 + 47.660 - 27.600$ = 31.687 m
 Moment at founding level 38.79×31.687 = 1229.14 t-m

Net forces including those due to top/intermediate plug, sandfill & water fill:				
Net horizontal force at scour/base level	$950.81+966.21+38.79$	=	1,955.81	t (3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$16,582.13+9,769.16+8,457.35+451.01$	=	35,259.65	t-m (3.1 + 3.2 + 3.3 + 3.4)
Net moment at base level	$35655.375+9,769.16+22,082.52+1229.13873$	=	68,736.19	t-m (3.1 + 3.2 + 3.3 + 3.4)

Net forces excluding those due to top/intermediate plug, sandfill & water fill:				
Net horizontal force at scour/base level	$950.81+147.32+10.11+573.96+20.22+38.79$	=	1,741.21	t (3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$16,582.13+9,769.16+2,385.11+149.78+4,072.25+291.98+451.01$	=	33,701.42	t-m (3.1 + 3.2 + 3.3 + 3.4)

4. MOMENT AT BASE LEVEL DUE TO TILT & SHIFT:

(As per clause 708.5.1 of IRC:78)

Shift considered for well design		=	0.150	m
Vertical load at top of the well		=	3,853.25	t
Moment due to shift	$0.150 \times 3,853.25$	=	577.99	t-m
Tilt considered for well design		=	1.250	%
Vertical load at top of the well		=	3,853.25	t
C.G. of this above founding level	$65.100-27.600$	=	37.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 37.500/100$	=	0.469	m
Moment due to lateral shift due to tilt	$3,853.25 \times 0.469$	=	1,807.17	t-m
Weight of well cap		=	491.07	t
C.G. of this above founding level	$65.100-27.600-2.500 \times 0.5$	=	36.250	m
Lateral shift of this C.G. due to tilt	$1.250 \times 36.250/100$	=	0.453	m
Moment due to lateral shift due to tilt	491.07×0.453	=	222.45	t-m
Weight of well steining near top		=	33.71	t
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.875/100$	=	0.436	m
Moment due to lateral shift due to tilt	33.71×0.436	=	14.70	t-m
Weight of well steining near bottom		=	4,617.84	t
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Lateral shift of this C.G. due to tilt	$1.250 \times 17.125/100$	=	0.214	m
Moment due to lateral shift due to tilt	$4,617.84 \times 0.214$	=	988.22	t-m
Weight of well steining in tapering portion		=	67.41	t
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.500/100$	=	0.431	m
Moment due to lateral shift due to tilt	67.41×0.431	=	29.05	t-m

Weight of water fill	=	24.64	t
C.G. of this above founding level			
	$65.100-27.600-2.500-(65.100-2.500-61.600)/2$	=	34.500 m
Lateral shift of this C.G.due to tilt	$1.250*34.500/100$	=	0.431 m
Moment due to lateral shift due to tilt	$24.64*0.431$	=	10.62 t-m
Weight of intermediat/top plug	=	40.66	t
C.G. of this above founding level	$61.600-27.600-0.750*0.5$	=	33.625 m
Lateral shift of this C.G.due to tilt	$1.250*33.625/100$	=	0.420 m
Moment due to lateral shift due to tilt	$40.66*0.420$	=	17.08 t-m
Weight of sand fill	=	1,441.44	t
C.G. of this above founding level	$(61.600-27.600-0.750-4.000)/2+4.000$	=	18.625 m
Lateral shift of this C.G.due to tilt	$1.250*18.625/100$	=	0.233 m
Moment due to lateral shift due to tilt	$1,441.44*0.233$	=	335.86 t-m
Weight of bottom plug	=	216.83	t
C.G. of this above founding level	$4.000/2$	=	2.000 m
Lateral shift of this C.G.due to tilt	$1.250*2.000/100$	=	0.025 m
Moment due to lateral shift due to tilt	$216.83*0.025$	=	5.42 t-m

Total moment at base due to tilt & shift			
$577.99+1,807.17+222.45+14.70+988.22+29.05+10.62+17.08+335.86+5.42$	=	4008.56	t-m

5. RESISTING MOMENT AT FOUNDING LEVEL:

(As per Appendix-3 of IRC:78)

The resisting moment is acting because of difference in passive and active earth pressure

F.O.S in assessing passive resistance	=	1.600	(r appendix-3 of IRC78)
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The active and passive earth pressure at any depth has been calculated by following equations:

Active earth pressure, p_a :	=	$K_a \gamma h + K_a q - 2c(K_a)^{1/2}$	
	=	$K_a \gamma h + K_a q$	(ignoring the effect of cohesion conservatively)

Passive earth pressure, p_p :	=	$K_p \gamma h + K_p q + 2c(K_p)^{1/2}$	(q = 0 considered for well design)
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where,

Coefficient of active earth pressure, K_a	=	$\frac{\sin^2(\alpha + \varphi)}{\sin^2 \alpha \sin(\alpha - \delta) [1 + \{\sin(\varphi + \delta) \sin(\varphi - \beta) / \sin(\alpha - \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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Coefficient of passive earth pressure, K_p	=	$\frac{\sin^2(\alpha - \varphi)}{\sin^2 \alpha \sin(\alpha + \delta) [1 - \{\sin(\varphi + \delta) \sin(\varphi + \beta) / \sin(\alpha + \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$
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γ' = Submerged density of earth
 h = Thickness of layer considered
 q = Surcharge at top of the layer considered
 Inclination of Wall from Horizontal, α = 90.000 degree
 φ = Angle of Internal Friction
 δ = Angle of Wall Friction
 Inclination of Backfill from Horizontal, β = 0.000 degree

5.1 GENERAL CALCULATIONS:

Surcharge considered for active earth pressure = 0.000 t/m²

Top of Layer	Bottom of Layer	$\sin^2(\alpha+\varphi)$	$\sin^2\alpha$	$\sin(\alpha-\delta)$	$\sin(\varphi+\delta)$	$\sin(\varphi-\beta)$	$\sin(\alpha+\beta)$	$\sin^2(\alpha-\varphi)$	$\sin(\alpha+\delta)$	$\sin(\varphi+\beta)$
47.660	40.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
40.000	35.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
35.000	30.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
30.000	25.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
25.000	27.600	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559

Top of Layer	Bottom of Layer	φ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³	Coefficient, Ka	Coefficient, Kp	Thickness, h, m	Height above well bottom, m
47.660	40.000	34.00	22.50	0.00	1.000	0.254	8.901	7.66	12.40
40.000	35.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	7.40
35.000	30.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	2.40
30.000	25.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	-2.60
25.000	27.600	34.00	22.50	0.00	1.000	0.254	8.901	-2.60	0.00

5.2 FORCES & MOMENTS DUE TO ACTIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_a at top, t/m ²	p_a at bottom, t/m ²	Dia of well, m	Total Active Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
47.660	40.000	0.000	1.945	10.000	74.5	14.953	1113.81
40.000	35.000	1.945	3.214	10.000	128.98	9.695	1250.42
35.000	30.000	3.214	4.484	10.000	192.45	4.763	916.55
30.000	25.000	4.484	5.753	10.000	255.92	-0.203	-52.04
25.000	27.600	5.753	5.093	10.000	-141.0	-1.326	187.02
Total Moment, M_a							3,415.76

5.3 FORCES & MOMENTS DUE TO PASSIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_p at top, t/m ²	p_p at bottom, t/m ²	Dia of well, m	Total Passive Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
47.660	40.000	0.000	68.180	10.000	2611.31	14.953	39047.83
40.000	35.000	68.180	112.685	10.000	4521.63	9.695	43836.97
35.000	30.000	112.685	157.189	10.000	6746.84	4.763	32132.36
30.000	25.000	157.189	201.693	10.000	8972.05	-0.203	-1824.38
25.000	27.600	201.693	178.551	10.000	-4943.17	-1.326	6556.50
Total Moment, M_p							119,749.28

Total moment due to active earth pressure, M_a = 3,415.76 t-m

Total moment due to passive earth pressure, M_p = 119,749.28 t-m

Factor of safety = 1.600 (as per appendix-3 of IRC:78)

Net resisting moment, $(M_a - M_p)/F.O.S$	(119,749.28-3,415.76)/1.600	=	72708.45 t-m
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6. DESIGN MOMENT AT BASE LEVEL:

External moment at top of well cap = 9,769.16 t-m

Moment due to external horizontal load = 35655.38 t-m

Moment due to seismic forces on well
 $5,340.35+352.59+9,829.07+697.59+254.96+410.23+5,197.73$ = 22082.52 t-m

Moment due to water pressure on well = 1229.14 t-m

Moment due to tilt and shift = 4008.56 t-m

Resisting moment = 72708.45 t-m
 (due to passive earth pressure)

Net moment at base level	=	0.00 t-m
<small>(resisting moment is more than moment acting)</small>		

7. CHECK FOR BASE PRESSURE:

(As per provisions of IRC:78-2014)

Outer diameter of well at well bottom/curb		=	10.150	m
Area at well bottom, A	$3.14 \times 10.150^2 / 4$	=	80.946	m ²
Section modulus, Z	$3.14 \times 10.150^3 / 32$	=	102.701	m ³
Net vertical load at well bottom, P (including buoyancy & vertical seismic forces)		=	8,091.70	t
Net moment at well bottom, M		=	0.00	t-m
Maximum base pressure, σ_{\max}	$8,091.70 / 80.946 + 0.00 / 102.701$	=	99.96	t/m ²
Allowable gross bearing capacity		=	150.00	t/m ²
Which is more than the maximum base pressure, hence O.K.				
Minimum base pressure, σ_{\min}	$8,091.70 / 80.946 - 0.00 / 102.701$	=	99.96	t/m ²
Which is more than zero, hence O.K.				

D. OUTPUT FOR STEINING STRESS CHECK:

1. DEPTH OF ZERO SHEAR BELOW SCOUR LEVEL:

Depth of zero shear below scour level, x		=	{2FH / $\gamma_b(K_p - K_a)D$ } ^{1/2}	
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)				
where,				
Factor of safety, F		=	2.00	
Resultant horizontal force at scour level, H		=	1,741.21 t	(excluding those due to top plug, sandfill & waterfill)
Submerged density of soil, γ_b		=	1.00 t/m ³	
Coefficient of active earth pressure, K_a		=	0.254	
Coefficient of passive earth pressure, K_p		=	8.901	
Outer diameter of well steining, D		=	10.000 m	
Now, depth of zero shear, x				
	$2 \times 2.00 \times 1,741.21 / (1.00 \times (8.901 - 0.254) \times 10.000)^{0.5}$	=	8.975 m	
Level at the depth of zero shear	47.660 - 8.975	=	38.685 m	

2. VERTICAL LOAD & MOMENT DUE TO TILT & SHIFT AT DEPTH OF ZERO SHEAR:

Shift considered for well design		=	0.150 m	
Tilt considered for well design		=	1.250 %	
External vertical load over well		=	3,853.25 t	
Moment due to shift	3,853.25*0.150	=	577.99 t-m	
C.G. of this above depth of zero shear	65.100 - 38.685	=	26.415 m	
Lateral shift of this C.G. due to tilt	1.250*26.415/100	=	0.330 m	
Moment due to lateral shift due to tilt	0.330*3,853.25	=	1271.57 t-m	
Weight of well cap		=	491.07 t	
C.G. of this above depth of zero shear	16.190 + 8.975	=	25.165 m	
Lateral shift of this C.G. due to tilt	1.250*25.165/100	=	0.315 m	
Moment due to lateral shift due to tilt	0.315*491.07	=	154.69 t-m	
Weight of well steining near top (with reduced thickness of steining)		=	33.71 t	
C.G. of this above depth of zero shear	14.815 + 8.975	=	23.790 m	
Lateral shift of this C.G. due to tilt	1.250*23.790/100	=	0.30 t-m	
Moment due to lateral shift due to tilt	0.30*33.71	=	10.11 t-m	
Height of thicker well steining above depth of zero shear		=		
	61.850 - 38.685	=	23.165 m	
Weight of thicker well steining upto depth of zero shear		=		
	53.931*23.165*2.500	=	3,123.28 t	
C.G. of this above depth of zero shear	0.5*23.165	=	11.583 m	

Lateral shift of this C.G.due to tilt	$1.250 \times 11.583 / 100$	=	0.14	t-m
Moment due to lateral shift due to tilt	$0.14 \times 3,123.28$	=	437.26	t-m
Weight of tapering well steining		=	67.41	t
C.G. of this above depth of zero shear	$14.440 + 8.975$	=	23.415	m
Lateral shift of this C.G.due to tilt	$1.250 \times 23.415 / 100$	=	0.29	t-m
Moment due to lateral shift due to tilt	0.29×67.41	=	19.55	t-m

Total vertical load at depth of zero shear	$3,853.25 + 491.07 + 33.71 + 3,123.28 + 67.41$	=	7,568.72	t	(excluding those due to top plug, sandfill & waterfill)
Tilt & shift moment at depth of zero shear	$577.99 + 1271.5725 + 154.69 + 10.11 + 437.26 + 19.55$	=	2,471.17	t-m	

3. DESIGN VERTICAL LOAD & MOMENT AT DEPTH OF ZERO SHEAR:

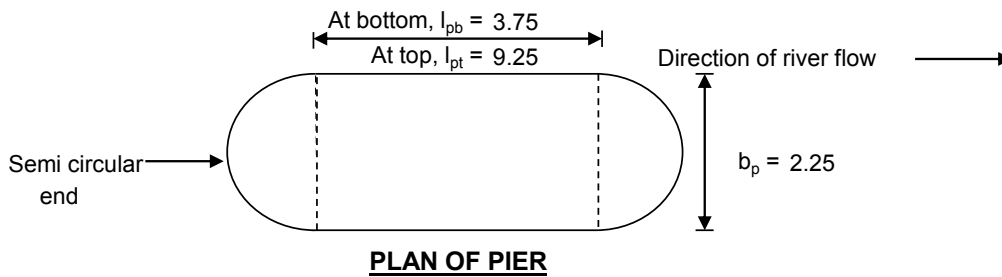
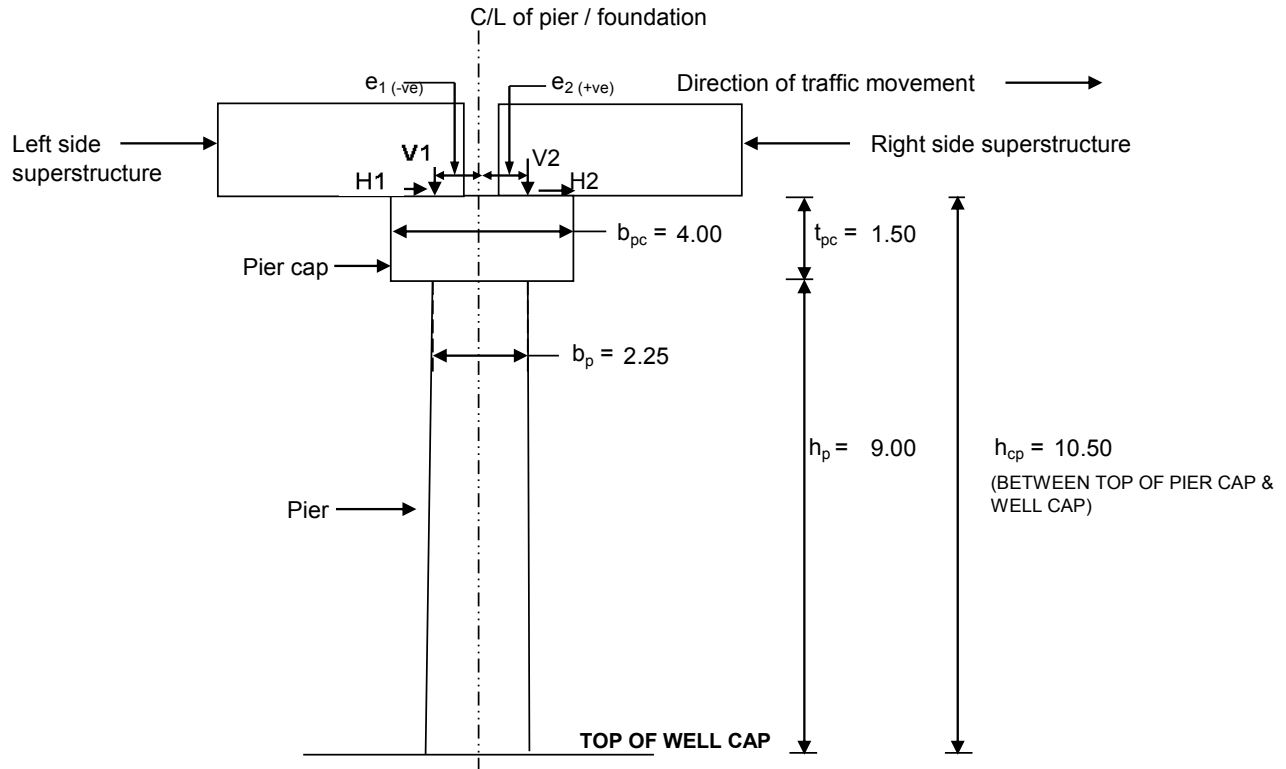
Total vertical load at depth of zero shear		=	7,568.72	t	(excluding buoyancy & seismic forces)
Vertical load of well components at scour level	$491.07 + 33.71 + 3,123.28 + 67.41$	=	3715.47	t	(excluding those due to top plug, sandfill & waterfill)
Vertical upward seismic force on this	0.200×3715.47	=	743.09	t	(upward seismic governs the design)
Height of well upto the depth of zero shear	$65.100 - 38.685$	=	26.42	t	
Buoyancy on well upto the depth of zero shear	$78.571 \times 26.415 \times 0.15$	=	311.32	t	(15% buoyancy as per cl.216.5 of IRC: 6)
Net vertical load at depth of zero shear	$7,568.72 - 743.09 - 311.32$	=	6514.31	t	(including buoyancy & vertical seismic forces)
Tilt & shift moment at depth of zero shear, M1		=	2,471.17	t-m	
Resultant horizontal force at scour level, H		=	1,741.21	t	(excluding those due to top plug, sandfill & waterfill)
Net moment at scour level, M ₀		=	33,701.42	t-m	(excluding those due to top plug, sandfill & waterfill)
Moment at depth of zero shear, M2		=	$M_0 + 2Hx/3$		
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)	$33,701.42 + (2 \times 1,741.21 \times 8.975) / 3$	=	44,119.66	t-m	

Now,

Net vertical load for steining design		=	6514.31	t	
Net moment for steining design	$2,471.17 + 44,119.66$	=	46590.83	t-m	(M1 + M2)

DESIGN OF RCC PIER

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM **JOB NO.** XPLR-226
LOCATION: PIERS ON GRIDS 'P2' TO 'P25' **DATE:** 2016 OCT
LOAD CASE: NORMAL (LIVE LOADS ON BOTH SPANS)
 (ALLOWABLE STRESSES GIVEN BELOW ARE CORRESPONDING TO THIS LOAD CASE)
INPUT DATA: (ALL DIMENSIONS SHOWN IN THE FIGURES BELOW ARE IN METER)



1 DIMENSIONS:

PIER CAP:

Length of pier cap over pier (along river flow), l_{pc}	=	14.50	m	(slightly on higher side)
Width of pier cap (along bridge), b_{pc}	=	4.00	m	
Thickness of pier cap, t_{pc} (average thickness)	=	1.50	m	(conservative value)
Thickness of bearing & bearing pedestal, $t_{b\&p}$	=	0.50	m	(for design purpose only)

PIER:

Length of rectangular portion of pier at bottom, l_{pb}	=	3.75	m	(6.00-2.25)
Length of rectangular portion of pier at top, l_{pt}	=	9.25	m	(11.50-2.25)
Width of pier, b_p	=	2.25	m	
Height of pier, h_p	=	9.00	m	(conservative value)
Height " h_{cp} " between top of pier cap & pier base	1.50+9.00	=	10.50	m

2 PROPERTIES OF CONCRETE & STEEL:

Permissible stresses given below are corresponding to

NORMAL load case

Density of concrete, γ_c (as per clause 203 of IRC: 6- 2014)	=	2.50	t/m ³
Grade of concrete & steel	=	M35	& Fe500
Permissible stress in concrete, σ_{cb} (table A4.2 of IRC: 112- 2011)	=	11.670	N/mm ²
Permissible stress in tension steel, σ_{st} (table A4.4 of IRC: 112- 2011)	=	240.00	N/mm ²
Permissible stress in compression steel, σ_{sc} (table A4.4 of IRC: 112)	=	205.00	N/mm ²

3 LOADS:

Live loads defined below are corresponding to

NORMAL load case

Load Combination:		NORMAL	(LIVE LOADS ON BOTH SPANS)
Horizontal seismic coefficient, α_h (clause 219 of RC: 6- 2014)	=	0.000	(resul.of long.& trans.seismic)
Vertical seismic coefficient, α_v (clause 219 of RC: 6- 2014)	=	0.000	(2/3 of the horizontal seismic)
Enhancement factor for seismic forces for foundation design	=	0.000	(clause 219 of RC: 6- 2014)
Dead load " V_{1DL} " from left side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Dead load " V_{2DL} " from right side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Live load " V_{1LL} " from left side superstructure, including FPLL	=	300.00	t (70R-W in each C.W.)
Live load " V_{2LL} " from right side superstructure, including FPLL	=	300.00	t (70R-W in each C.W.)
Vertical seismic " V_{1SE} " from left side superstructure	=	0.00	t $\alpha_v*(DL+LL)$
Vertical seismic " V_{2SE} " from right side superstructure	=	0.00	t $\alpha_v*(DL+LL)$
Eccentricity of left side vertical load w.r.t C/L of pier/ foundation, e_1 (taken as -ve below)	=	1.425	m
Eccentricity of right side vertical load w.r.t C/L of pier/ foundation, e_2 (taken as +ve below)	=	1.425	m
Horizontal force " H_1 " from left side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	25.000	t (70R-W in each C.W.)
Horizontal force " H_2 " from right side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	25.000	t (70R-W in each C.W.)
Horizontal seismic " H_{1SE} " from left side superstructure	=	0.00	t $\alpha_h*(DL)$
Horizontal seismic " H_{2SE} " from right side superstructure	=	0.00	t $\alpha_h*(DL)$

1 SECTIONAL PROPERTIES AND WEIGHT:

PIER CAP:

X-sectional area of pier cap	1.50×4.00	=	6.000	m ²
Length of pier cap		=	14.500	m
Weight of pier cap, W_{pc}	$6.000 \times 14.500 \times 2.50$	=	217.500	t

PIER:

Area of rectangular portion of pier at bottom	3.75×2.25	=	8.438	m ²
Area of circular portion at bottom	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at bottom, A_{pb}	$8.438 + 3.976$	=	12.414	m ²
Area of rectangular portion of pier at top	9.25×2.25	=	20.813	m ²
Area of circular portion at top	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at top, A_{pt}	$20.813 + 3.976$	=	24.789	m ²
Average X-section area of pier, A_p	$(12.414 + 24.789) / 2$	=	18.602	m ²
Height of pier, h_p		=	9.000	m
Weight of pier, W_p	$18.602 \times 9.000 \times 2.50$	=	418.545	t

2 VERTICAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>ECC.*</u> (m)	<u>MOMENT</u> (t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	300.00	-1.425	-427.50
Live load (right side)	300.00	1.425	427.50
Vertical seismic (left side superstructure)	0.00	-1.425	0.00
Vertical seismic (right side superstructure)	0.00	1.425	0.00
Vertical seismic on weight of pier	0.000	0.000	0.00
Vertical seismic on weight of pier cap	0.000	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p	=	3,736.05	t
Moment due to vertical load at the base of pier, M_{vp}	=	0.00	t-m

3 HORIZONTAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>LEVER</u> <u>ARM**</u> (m)	<u>MOMENT</u> (t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	25.000	11.00	275.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	25.000	11.00	275.00
Horizontal seismic, H_{1SE} (left side superstructure)	0.00	11.00	0.00
Horizontal seismic, H_{2SE} (right side superstructure)	0.00	11.00	0.00
Horizontal seismic on weight of pier	0.00	5.13	0.00
Horizontal seismic on weight of pier cap	0.00	9.75	0.00

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is height between top of bearing & base of pier).

Total horizontal load at the base of pier, H_p	=	50.00	t
Moment due to horizontal load at the base of pier, M_{hp}	=	550.00	t-m

4 RECAP OF FORCES FOR PIER DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,736.05	t
Total horizontal load at the base of pier, H_p	=	50.00	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	550.00	t-m

5 STRESSES AT PIER BASE:

Refer following pages for calculation of stresses in concrete & steel at pier base.

6 VERTICAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>ECC.*</u> (m)	<u>MOMENT</u> (t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	300.00	-1.425	-427.50
Live load (right side)	300.00	1.425	427.50
Vertical seismic (left side superstructure)	0.000	-1.425	0.00
Vertical seismic (right side superstructure)	0.000	1.425	0.00
Vertical seismic on weight of pier	0.000	0.000	0.00
Vertical seismic on weight of pier cap	0.000	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p	=	3,736.05	t
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Moment due to vertical load at the base of pier, M_{vp}	=	0.00	t-m
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7 HORIZONTAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>LEVER</u> <u>ARM**</u> (m)	<u>MOMENT</u> (t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	25.000	11.00	275.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	25.000	11.00	275.00
Horizontal seismic, H_{1SE} (left side superstructure)	0.00	11.00	0.00
Horizontal seismic, H_{2SE} (right side superstructure)	0.00	11.00	0.00
Horizontal seismic on weight of pier	0.00	5.13	0.00
Horizontal seismic on weight of pier cap	0.00	9.75	0.00

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is

Total horizontal load at the base of pier, H_p	=	50.00	t
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Moment due to horizontal load at the base of pier, M_{hp}	=	550.00	t-m
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8 RECAP OF FORCES FOR FOUNDATION DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,736.05	t
Total horizontal load at the base of pier, H_p	=	50.00	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	550.00	t-m

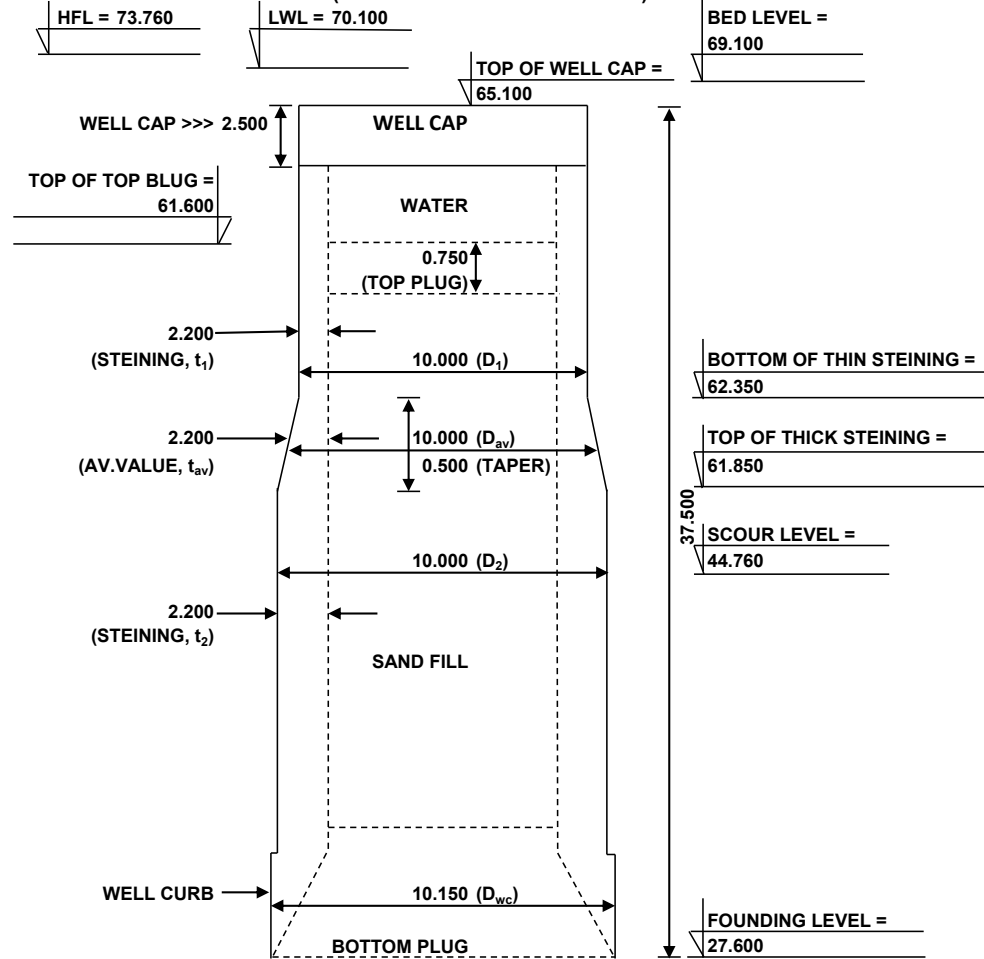
9 DESIGN OF FOUNDATION:

Refer following pages for design of foundation.

DESIGN OF CIRCULAR WELL FOUNDATION

(AS PER PROVISIONS OF IRC: 78)

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM
 LOCATION: WELL SUPPORTING PIERS
 LOAD CASE: NORMAL (LIVE LOADS ON BOTH SPANS)



TYPICAL ELEVATION OF WELL

A. DESIGN DATA:

WELL SUPPORTING PIERS

1. LOAD CASE CONSIDERED:

NORMAL (LIVE LOADS ON BOTH SPANS)

2. LEVELS:

High flood level (HFL)	=	73.760	m	
Low water level (LWL)	=	70.100	m	
Top level of well cap	=	65.100	m	
Bed level	=	69.100	m	
Top level of top/intermediate plug	=	61.600	m	
Level at the bottom of top steining having less thickness, t_1	=	62.350	m	
<input type="text" value="should be above top of top plug in such a way that tapering is done above top plug"/>				
Level at the top of bottom steining having more thickness, t_2	=	61.850	m	
Scour level <input type="text" value="should be below the bottom of top/intermediate plug"/>	=	44.760	m	(conservative value)
Bottom level of well (founding level)	=	27.600	m	

3. WELL PROPERTIES:

Outer diameter of well near top having thin steining, D_1	=	10.000	m	
Outer diameter of well near bottom having thick steining, D_2	=	10.000	m	
Average outer diameter of well at location where steining tapers, D_{av}	=	10.000	m	
Outer diameter of well at founding level (well curb), D_{wc}	=	10.150	m	
Coefficient 'K' for calculating steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2014)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2014)
Steining thickness near top (should be above scour depth), t_1	=	2.200	m	(taper not steeper than 1H:3V)
Steining thickness near bottom, t_2	=	2.200	m	(taper not steeper than 1H:3V)
Average steining thickness in taper portion, t_{av}	=	2.200	m	
Thickness of well cap	=	2.500	m	
Thickness of top/intermediate plug	=	0.750	m	
Thickness of bottom plug	=	4.000	m	(above founding level of well)
Density of RCC	=	2.500	t/m ³	
Density of PCC	=	2.200	t/m ³	
Density of sand fill	=	2.000	t/m ³	
Density of water	=	1.000	t/m ³	

4. SOIL PROPERTIES:

Net safe bearing capacity	=	80.00	t/m ²	(at founding level)
Gross bearing capacity	=	120.00	t/m ²	(Net SBC + overburden)
F.O.S in assessing passive resistance	=	2.000		(as per appendix-3 of IRC:78-2014)

Top of Layer	Bottom of Layer	ϕ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³ (submerged, if applicable)	Intensity of active earth pressure at top, p_a , t/m ²	Intensity of passive earth pressure at top, p_p , t/m ²
44.760	40.000	34.00	22.50	0.00	1.00	0.000	0.000
40.000	35.000	34.00	22.50	0.00	1.00	(conservative)	(conservative)
35.000	30.000	34.00	22.50	0.00	1.00	(see below)	(see below)
30.000	25.000	34.00	22.50	0.00	1.00		
25.000	27.600	34.00	22.50	0.00	1.00		

5. EXTERNAL LOADS:

External vertical load at top of well cap	=	3,736.05	t	(at top of well cap)
External moment at top of well cap	=	550.00	t-m	(at top of well cap)
External horizontal load at top of well cap	=	50.00	t	(at top of well cap)
Horizontal seismic coefficient	=	0.000		(resultant of long.& trans.seismic)
Vertical seismic coefficient	0.000*2/3 =	0.000		
Velocity of flow at well top	=	3.600	m/s	(at top of well cap)
Coefficient 'K' to calculate water pressure	=	0.660		(as per clause 210.2 of IRC:6-2014)
Intensity of water pressure at scour level	=	0.000	kg/m ²	

6. TILTS AND SHIFTS:

Maximum shift considered for well design	=	0.150	m	(as per clause 708.5.1of IRC:78-2014)
Maximum tilt considered for well design	=	1.250	%	(as per clause 708.5.1of IRC:78-2014)

7. OTHERS:

Inclination of wall from horizontal, α	=	90.000	degree	
Inclination of backfill from horizontal, β	=	0.000	degree	
Surcharge considered for active earth pressure	=	0.000	t/m ²	(acting over the well)
Factor of safety, F	(for steining stress, see below) =	2.00		
Submerged density of soil, γ_b	(for steining stress, see below) =	1.00	t/m ³	
Coefficient of active earth pressure, K_a	(for steining stress, see below) =	0.254		
Coefficient of passive earth pressure, K_p	(for steining stress, see below) =	8.901		

B. SUMMARY OF FINDINGS & RESULTS:

Minimum steining thickness required near top	=	1.661	m	
Steining thickness provided near top	=	2.200	m	Hence O.K.
Minimum steining thickness required near bottom	=	2.151	m	
Steining thickness required near bottom	=	2.200	m	Hence O.K.
Maximum base pressure, σ_{max}	=	90.56	t/m ²	
Allowable gross bearing capacity	=	120.00	t/m ²	Hence O.K.
Minimum base pressure, σ_{min}	=	90.56	t/m ²	Hence O.K.

C. OUTPUT FOR WELL STABILITY:

1. CHECK FOR MINIMUM STEINING THICKNESSES:

(As per clause 708.2.3 of IRC:78)

Coefficient 'K' for steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2000)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2000)
Outer diameter of well near top, D_1	=	10.000	m	
Depth of well below well top or LWL till scour level whichever is more	=	25.340	m	
Minimum steining thickness required near top				
$0.030 \times 1.100 \times 10.000 \times 25.340^{0.5}$	=	1.661	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

Outer diameter of well near bottom, D_2	=	10.000	m	
Depth of well below well top or LWL till founding level whichever is more	=	42.500	m	
Minimum steining thickness required near bottom				
$0.030 \times 1.100 \times 10.000 \times 42.500^{0.5}$	=	2.151	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

2. VERTICAL FORCES AT BASE LEVEL:

Thickness of well cap	=	2.500	m	
Diameter of well cap	=	10.000	m	
Density of RCC	=	2.500	t/m ³	
Weight of well cap	$3.14 \times 10.000^2 \times 2.500 \times 2.500 / 4$	=	491.07	t
Outer diameter of well near top, D_1	=	10.000	m	
Area corresponding to outer diameter, A_1	$3.14 \times 10.000^2 / 4$	=	78.571	m ²
Steining thickness near top, t_1	=	2.200	m	
Inner diameter of well near top, D_1'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_1'	$3.14 \times 5.600^2 / 4$	=	24.640	m ²
Net area of steining near top, $A_1 - A_1'$	$78.571 - 24.640$	=	53.931	m ²
Depth of this portion of well	$65.100 - 62.350 - 2.500$	=	0.250	m
Density of RCC	=	2.500	t/m ³	
Weight of this portion of well steining	$53.931 \times 0.250 \times 2.500$	=	33.71	t

Outer diameter of well near bottom, D_2		=	10.000	m
Area corresponding to outer diameter, A_2	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness near bottom, t_2		=	2.200	m
Inner diameter of well near bottom, D_2'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_2'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$61.850 - 27.600$	=	34.250	m
Weight of this portion of well steining	$53.931 \times 34.250 \times 2.500$	=	4,617.84	t
Outer diameter of well in tapering portion, D_{av}	$(10.000 + 10.000) / 2$	=	10.000	m
Area corresponding to outer diameter, A_{av}	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness in tapering portion, t_{av}		=	2.200	m
Inner diameter of well in tapering portion, D_{av}'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_{av}'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$62.350 - 61.850$	=	0.500	m
Weight of this portion of well steining	$53.931 \times 0.500 \times 2.500$	=	67.41	t
Total weight of well steining	$33.71 + 4,617.84 + 67.41$	=	4,718.96	t
Depth of water above top/intermediate plug	$65.100 - 61.600 - 2.500$	=	1.000	m
Inner diameter of well		=	5.600	m
Density of water		=	1.000	t/m^3
Weight of water	$3.14 \times 5.600^2 \times 1.000 \times 1.000 / 4$	=	24.64	t
Thickness of intermediat/top plug		=	0.750	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of intermediat/top plug	$3.14 \times 5.600^2 \times 0.750 \times 2.200 / 4$	=	40.66	t
Depth of sand fill below top plug	$61.600 - 27.600 - 0.750 - 4.000$	=	29.250	m
Inner diameter of well		=	5.600	m
Density of sand		=	2.000	t/m^3
Weight of sand fill below top plug	$3.14 \times 5.600^2 \times 29.250 \times 2.000 / 4$	=	1,441.44	t
Thickness of bottom plug		=	4.000	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of bottom plug	$3.14 \times 5.600^2 \times 4.000 \times 2.200 / 4$	=	216.83	t

Total weight of well including top & bottom plugs and filling		=	6,933.60	t	
	$491.07+4,718.96+24.64+40.66+1,441.44+216.83$	=	6,933.60	t	
External vertical load over well		=	3,736.05	t	
Total vertical load including external load	$6,933.60+3,736.05$	=	10,669.65	t	(at founding level)
Vertical load of well components upto scour level	3,754.61	=	3,754.61	t	(see calculations below)
Vertical downward seismic force on this	$3,754.61*0.000$	=	0.00	t	(downward seismic governs the design)
Buoyancy on well	$3.14*10.000^2*(70.100-27.600)*1.000/4$	=	3,339.29	t	(diameter at the top is taken on safer side)
Net vertical load at base level	$10,669.65+0.00-3,339.29$	=	7,330.36	t	(including buoyancy & vertical seismic)

3. HORIZONTAL FORCES AND MOMENTS AT SCOUR & FOUNDING LEVELS:

3.1 EXTERNAL HORIZONTAL LOAD ACTING ON WELL:

External horizontal load on well		=	50.00	t	(at top of well cap)
C.G. of this above scour level	65.100-44.760	=	20.340	m	
Moment at scour level	$50.00*20.340$	=	1,017.00	t-m	
C.G. of this above founding level	$20.340+44.760-27.600$	=	37.500	m	
Moment at founding level	$50.00*37.500$	=	1875.00	t-m	

3.2 EXTERNAL MOMENT ACTING ON WELL:

External moment acting on well		=	550.00	t-m	
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3.3 SEISMIC FORCES ON WELL:

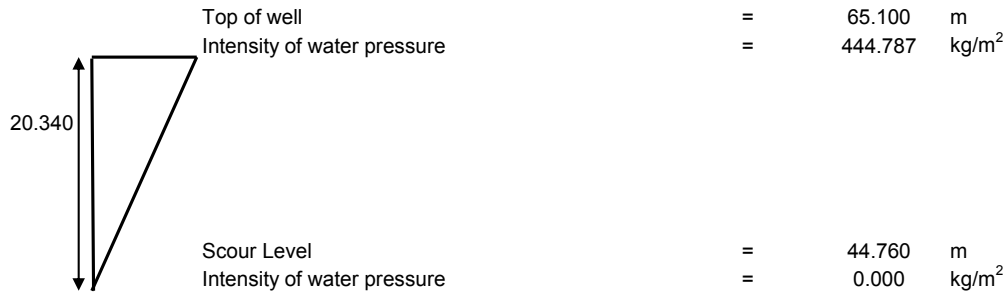
Horizontal seismic coefficient		=	0.000		
Weight of well cap		=	491.07	t	
Seismic force on this weight	$0.000*491.07$	=	0.00	t	
C.G. of this above scour level	$65.100-44.760-1.25$	=	19.090	m	
Moment at scour level	$0.00*19.090$	=	0.00	t-m	
C.G. of this above founding level	$19.090+44.760-27.600$	=	36.250	m	
Moment at founding level	$0.00*36.250$	=	0.00	t-m	
Weight of well steining near top (with reduced thickness of steining)		=	33.71	t	
Seismic force on this weight	$0.000*33.71$	=	0.00	t	
C.G. of this above scour level	$62.350-44.760+0.250/2$	=	17.715	m	
Moment at scour level	$0.00*17.715$	=	0.00	t-m	
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m	
Moment at founding level	$0.00*34.875$	=	0.00	t-m	

Height of thicker well steining above scour level	$61.850-44.760$	=	17.090	m
Weight of thicker well steining upto scour level	$53.931*17.090*2.500$	=	2,304.20	t
Seismic force on this weight	$0.000*2,304.20$	=	0.00	t
C.G. of this above scour level	$0.5*17.090$	=	8.545	m
Moment at scour level	$0.00*8.545$	=	0.00	t-m
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Moment at founding level	$0.00*17.125$	=	0.00	t-m
Weight of tapering well steining		=	67.41	t
Seismic force on this weight	$0.000*67.41$	=	0.00	t
C.G. of this above scour level	$61.850-44.760+0.500/2$	=	17.340	m
Moment at scour level	$0.00*17.340$	=	0.00	t-m
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Moment at founding level	$0.00*34.500$	=	0.00	t-m
Weight of water fill		=	24.64	t
Seismic force on this weight	$0.000*24.64$	=	0.00	t
C.G. of this above scour level	$(65.100-61.600-2.500)*0.5+(61.600-44.760)$	=	17.340	m
Moment at scour level	$0.00*17.340$	=	0.00	t-m
C.G. of this above founding level	$17.340+44.760-27.600$	=	34.500	m
Moment at founding level	$0.00*34.500$	=	0.00	t-m
Weight of intermediat/top plug		=	40.66	t
Seismic force on this weight	$0.000*40.66$	=	0.00	t
C.G. of this above scour level	$61.600-44.760-0.750*0.5$	=	16.465	m
Moment at scour level	$0.00*16.465$	=	0.00	t-m
C.G. of this above founding level	$16.465+44.760-27.600$	=	33.625	m
Moment at founding level	$0.00*33.625$	=	0.00	t-m
Depth of sand fill upto scour level	$61.600-44.760-0.750$	=	16.090	m
Weight of sand fill upto scour level	$3.14*5.600^2*16.090*2.000/4$	=	792.92	t
Seismic force on this weight	$0.000*792.92$	=	0.00	t
C.G. of this above scour level	$16.090/2$	=	8.045	m
Moment at scour level	$0.00*8.045$	=	0.00	t-m
C.G. of this above founding level	$8.045+44.760-27.600$	=	25.205	m
Moment at founding level	$0.00*25.205$	=	0.00	t-m
Weight of well components above scour level	$491.07+33.71+2,304.20+67.41+24.64+40.66+792.92$ (including top plug, sandfill & waterfill)	=	3,754.61	t
Horizontal seismic forces on well components	$3,754.61*0.000$ (including top plug, sandfill & waterfill)	=	0.00	t

Moment at scour level due to this	$0.00+0.00+0.00+0.00+0.00+0.00+0.00$ (including top plug, sandfill & waterfill)	=	0.00	t-m
Moment at founding level due to this	$0.00+0.00+0.00+0.00+0.00+0.00+0.00$ (including top plug, sandfill & waterfill)	=	0.00	t-m

3.4 WATER PRESSURE: (As per clause 210.2 of IRC:6-2010)

Intensity of water pressure at well top	$52 \times 0.660 \times 3.600^2$	=	444.787	kg/m ²	(as per cl 210.2 of IRC:6-2010)
Intensity of water pressure at scour level		=	0.000	kg/m ²	
Outer diameter of well		=	10.000	m	(diameter near base taken on safer side)
Height of well above scour level	$65.100 - 44.760$	=	20.340	m	



Total water pressure acting over well	$0.5 \times 444.787 \times 10.000 \times 20.340 / 1000$	=	45.23	t
C.G. of this above scour level	$2 \times 20.340 / 3$	=	13.560	m
Moment at scour level	45.23×13.560	=	613.32	t-m
C.G. of this above founding level	$13.560 + 44.760 - 27.600$	=	30.720	m
Moment at founding level	45.23×30.720	=	1389.47	t-m

Net forces including those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$50.00+0.00+45.23$	=	95.23	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$1,017.00+550.00+0.00+613.32$	=	2,180.32	t-m	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at base level	$1875+550.00+0.00+1389.4656$	=	3,814.47	t-m	(3.1 + 3.2 + 3.3 + 3.4)

Net forces excluding those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$50.00+0.00+0.00+0.00+45.23$	=	95.23	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$1,017.00+550.00+0.00+0.00+0.00+613.32$	=	2,180.32	t-m	(3.1 + 3.2 + 3.3 + 3.4)

4. MOMENT AT BASE LEVEL DUE TO TILT & SHIFT:

(As per clause 708.5.1 of IRC:78)

Shift considered for well design		=	0.150	m
Vertical load at top of the well		=	3,736.05	t
Moment due to shift	$0.150 \times 3,736.05$	=	560.41	t-m
Tilt considered for well design		=	1.250	%
Vertical load at top of the well		=	3,736.05	t
C.G. of this above founding level	$65.100-27.600$	=	37.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 37.500/100$	=	0.469	m
Moment due to lateral shift due to tilt	$3,736.05 \times 0.469$	=	1,752.21	t-m
Weight of well cap		=	491.07	t
C.G. of this above founding level	$65.100-27.600-2.500 \times 0.5$	=	36.250	m
Lateral shift of this C.G. due to tilt	$1.250 \times 36.250/100$	=	0.453	m
Moment due to lateral shift due to tilt	491.07×0.453	=	222.45	t-m
Weight of well steining near top		=	33.71	t
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.875/100$	=	0.436	m
Moment due to lateral shift due to tilt	33.71×0.436	=	14.70	t-m
Weight of well steining near bottom		=	4,617.84	t
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Lateral shift of this C.G. due to tilt	$1.250 \times 17.125/100$	=	0.214	m
Moment due to lateral shift due to tilt	$4,617.84 \times 0.214$	=	988.22	t-m
Weight of well steining in tapering portion		=	67.41	t
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.500/100$	=	0.431	m
Moment due to lateral shift due to tilt	67.41×0.431	=	29.05	t-m

Weight of water fill	=	24.64	t
C.G. of this above founding level			
	$65.100-27.600-2.500-(65.100-2.500-61.600)/2$	=	34.500 m
Lateral shift of this C.G.due to tilt	$1.250*34.500/100$	=	0.431 m
Moment due to lateral shift due to tilt	$24.64*0.431$	=	10.62 t-m
Weight of intermediat/top plug	=	40.66	t
C.G. of this above founding level	$61.600-27.600-0.750*0.5$	=	33.625 m
Lateral shift of this C.G.due to tilt	$1.250*33.625/100$	=	0.420 m
Moment due to lateral shift due to tilt	$40.66*0.420$	=	17.08 t-m
Weight of sand fill	=	1,441.44	t
C.G. of this above founding level	$(61.600-27.600-0.750-4.000)/2+4.000$	=	18.625 m
Lateral shift of this C.G.due to tilt	$1.250*18.625/100$	=	0.233 m
Moment due to lateral shift due to tilt	$1,441.44*0.233$	=	335.86 t-m
Weight of bottom plug	=	216.83	t
C.G. of this above founding level	$4.000/2$	=	2.000 m
Lateral shift of this C.G.due to tilt	$1.250*2.000/100$	=	0.025 m
Moment due to lateral shift due to tilt	$216.83*0.025$	=	5.42 t-m

Total moment at base due to tilt & shift			
	$560.41+1,752.21+222.45+14.70+988.22+29.05+10.62+17.08+335.86+5.42$	=	3936.02 t-m

5. RESISTING MOMENT AT FOUNDING LEVEL:

(As per Appendix-3 of IRC:78)

The resisting moment is acting because of difference in passive and active earth pressure

F.O.S in assessing passive resistance = 2.000 (As per appendix-3 of IRC78)

The active and passive earth pressure at any depth has been calculated by following equations:

$$\begin{aligned} \text{Active earth pressure, } p_a &= K_a \gamma h + K_a q - 2c(K_a)^{1/2} \\ &= K_a \gamma h + K_a q \quad \text{(ignoring the effect of cohesion conservatively)} \end{aligned}$$

$$\text{Passive earth pressure, } p_p = K_p \gamma h + K_p q + 2c(K_p)^{1/2} \quad (q = 0 \text{ considered for well design})$$

where,

$$\text{Coefficient of active earth pressure, } K_a = \frac{\sin^2(\alpha + \varphi)}{\sin^2 \alpha \sin(\alpha - \delta) [1 + \{\sin(\varphi + \delta) \sin(\varphi - \beta) / \sin(\alpha - \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$$

$$\text{Coefficient of passive earth pressure, } K_p = \frac{\sin^2(\alpha - \varphi)}{\sin^2 \alpha \sin(\alpha + \delta) [1 - \{\sin(\varphi + \delta) \sin(\varphi + \beta) / \sin(\alpha + \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$$

γ'	=	Submerged density of earth
h	=	Thickness of layer considered
q	=	Surcharge at top of the layer considered
Inclination of Wall from Horizontal, α	=	90.000 degree
φ	=	Angle of Internal Friction
δ	=	Angle of Wall Friction
Inclination of Backfill from Horizontal, β	=	0.000 degree

5.1 GENERAL CALCULATIONS:

Surcharge considered for active earth pressure	=	0.000 t/m ²
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Top of Layer	Bottom of Layer	$\sin^2(\alpha+\varphi)$	$\sin^2\alpha$	$\sin(\alpha-\delta)$	$\sin(\varphi+\delta)$	$\sin(\varphi-\beta)$	$\sin(\alpha+\beta)$	$\sin^2(\alpha-\varphi)$	$\sin(\alpha+\delta)$	$\sin(\varphi+\beta)$
44.760	40.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
40.000	35.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
35.000	30.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
30.000	25.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
25.000	27.600	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559

Top of Layer	Bottom of Layer	φ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³	Coefficient, Ka	Coefficient, Kp	Thickness, h, m	Height above well bottom, m
44.760	40.000	34.00	22.50	0.00	1.000	0.254	8.901	4.76	12.40
40.000	35.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	7.40
35.000	30.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	2.40
30.000	25.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	-2.60
25.000	27.600	34.00	22.50	0.00	1.000	0.254	8.901	-2.60	0.00

5.2 FORCES & MOMENTS DUE TO ACTIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_a at top, t/m ²	p_a at bottom, t/m ²	Dia of well, m	Total Active Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
44.760	40.000	0.000	1.209	10.000	28.8	13.987	402.29
40.000	35.000	1.209	2.478	10.000	92.16	9.613	885.96
35.000	30.000	2.478	3.747	10.000	155.63	4.730	736.16
30.000	25.000	3.747	5.017	10.000	219.11	-0.221	-48.36
25.000	27.600	5.017	4.357	10.000	-121.9	-1.331	162.13
Total Moment, M_a							2,138.19

5.3 FORCES & MOMENTS DUE TO PASSIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_p at top, t/m ²	p_p at bottom, t/m ²	Dia of well, m	Total Passive Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
44.760	40.000	0.000	42.368	10.000	1008.36	13.987	14103.58
40.000	35.000	42.368	86.872	10.000	3231.01	9.613	31059.81
35.000	30.000	86.872	131.377	10.000	5456.22	4.730	25808.31
30.000	25.000	131.377	175.881	10.000	7681.43	-0.221	-1695.31
25.000	27.600	175.881	152.739	10.000	-4272.05	-1.331	5684.03
Total Moment, M_p							74,960.42

Total moment due to active earth pressure, M_a = 2,138.19 t-m

Total moment due to passive earth pressure, M_p = 74,960.42 t-m

Factor of safety = 2.000 (as per appendix-3 of IRC:78)

Net resisting moment, $(M_a - M_p)/F.O.S$	$(74,960.42 - 2,138.19)/2.000$	=	36411.12 t-m
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6. DESIGN MOMENT AT BASE LEVEL:

External moment at top of well cap = 550.00 t-m

Moment due to external horizontal load = 1875.00 t-m

Moment due to seismic forces on well = 0.00 t-m

Moment due to water pressure on well = 1389.47 t-m

Moment due to tilt and shift = 3936.02 t-m

Resisting moment = 36411.12 t-m

(due to passive earth pressure)

Net moment at base level	=	0.00 t-m
<small>(resisting moment is more than moment acting)</small>		

7. CHECK FOR BASE PRESSURE:

(As per provisions of IRC:78-2014)

Outer diameter of well at well bottom/curb		=	10.150	m
Area at well bottom, A	$3.14 \times 10.150^2 / 4$	=	80.946	m^2
Section modulus, Z	$3.14 \times 10.150^3 / 32$	=	102.701	m^3
Net vertical load at well bottom, P (including buoyancy & vertical seismic forces)		=	7,330.36	t
Net moment at well bottom, M		=	0.00	t-m
Maximum base pressure, σ_{max}	$7,330.36 / 80.946 + 0.00 / 102.701$	=	90.56	t/m^2
Allowable gross bearing capacity		=	120.00	t/m^2
Which is more than the maximum base pressure, hence O.K.				
Minimum base pressure, σ_{min}	$7,330.36 / 80.946 - 0.00 / 102.701$	=	90.56	t/m^2
Which is more than zero, hence O.K.				

D. OUTPUT FOR STEINING STRESS CHECK:

1. DEPTH OF ZERO SHEAR BELOW SCOUR LEVEL:

Depth of zero shear below scour level, x		=	$\{2FH / \gamma_b(K_p - K_a)D\}^{1/2}$	
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)				
where,				
Factor of safety, F		=	2.00	
Resultant horizontal force at scour level, H		=	95.23	t
Submerged density of soil, γ_b		=	1.00	t/m ³
Coefficient of active earth pressure, K_a		=	0.254	
Coefficient of passive earth pressure, K_p		=	8.901	
Outer diameter of well steining, D		=	10.000	m
Now, depth of zero shear, x				
	$2 \times 2.00 \times 95.23 / (1.00 \times (8.901 - 0.254) \times 10.000)^{0.5}$	=	2.099	m
Level at the depth of zero shear	$44.760 - 2.099$	=	42.661	m

(excluding those due to top plug, sandfill & waterfill)

2. VERTICAL LOAD & MOMENT DUE TO TILT & SHIFT AT DEPTH OF ZERO SHEAR:

Shift considered for well design		=	0.150	m
Tilt considered for well design		=	1.250	%
External vertical load over well		=	3,736.05	t
Moment due to shift	$3,736.05 \times 0.150$	=	560.41	t-m
C.G. of this above depth of zero shear	$65.100 - 42.661$	=	22.439	m
Lateral shift of this C.G. due to tilt	$1.250 \times 22.439 / 100$	=	0.280	m
Moment due to lateral shift due to tilt	$0.280 \times 3,736.05$	=	1046.09	t-m
Weight of well cap		=	491.07	t
C.G. of this above depth of zero shear	$19.090 + 2.099$	=	21.189	m
Lateral shift of this C.G. due to tilt	$1.250 \times 21.189 / 100$	=	0.265	m
Moment due to lateral shift due to tilt	0.265×491.07	=	130.13	t-m
Weight of well steining near top (with reduced thickness of steining)		=	33.71	t
C.G. of this above depth of zero shear	$17.715 + 2.099$	=	19.814	m
Lateral shift of this C.G. due to tilt	$1.250 \times 19.814 / 100$	=	0.25	t-m
Moment due to lateral shift due to tilt	0.25×33.71	=	8.43	t-m
Height of thicker well steining above depth of zero shear		=		
	$61.850 - 42.661$	=	19.189	m
Weight of thicker well steining upto depth of zero shear		=		
	$53.931 \times 19.189 \times 2.500$	=	2,587.20	t
C.G. of this above depth of zero shear	0.5×19.189	=	9.595	m

Lateral shift of this C.G.due to tilt	$1.250 \times 9.595 / 100$	=	0.12	t-m
Moment due to lateral shift due to tilt	$0.12 \times 2,587.20$	=	310.46	t-m
Weight of tapering well steining		=	67.41	t
C.G. of this above depth of zero shear	$17.340 + 2.099$	=	19.439	m
Lateral shift of this C.G.due to tilt	$1.250 \times 19.439 / 100$	=	0.24	t-m
Moment due to lateral shift due to tilt	0.24×67.41	=	16.18	t-m

Total vertical load at depth of zero shear	$3,736.05 + 491.07 + 33.71 + 2,587.20 + 67.41$	=	6,915.44	t	(excluding those due to top plug, sandfill & waterfill)
Tilt & shift moment at depth of zero shear	$560.41 + 1046.094 + 130.13 + 8.43 + 310.46 + 16.18$	=	2,071.70	t-m	

3. DESIGN VERTICAL LOAD & MOMENT AT DEPTH OF ZERO SHEAR:

Total vertical load at depth of zero shear		=	6,915.44	t	(excluding buoyancy & seismic forces)
Vertical load of well components at scour level	$491.07 + 33.71 + 2,587.20 + 67.41$	=	3179.39	t	(excluding those due to top plug, sandfill & waterfill)
Vertical upward seismic force on this	0.000×3179.39	=	0.00	t	(upward seismic governs the design)
Height of well upto the depth of zero shear	$65.100 - 42.661$	=	22.44	t	
Buoyancy on well upto the depth of zero shear	$78.571 \times 22.439 \times 0.15$	=	264.46	t	(15% buoyancy as per cl.216.5 of IRC: 6)
Net vertical load at depth of zero shear	$6,915.44 - 0.00 - 264.46$	=	6650.98	t	(including buoyancy & vertical seismic forces)
Tilt & shift moment at depth of zero shear, M1		=	2,071.70	t-m	
Resultant horizontal force at scour level, H		=	95.23	t	(excluding those due to top plug, sandfill & waterfill)
Net moment at scour level, M ₀		=	2,180.32	t-m	(excluding those due to top plug, sandfill & waterfill)
Moment at depth of zero shear, M2		=	$M_0 + 2Hx/3$		
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)	$2,180.32 + (2 \times 95.23 \times 2.099) / 3$	=	2,313.58	t-m	

Now,

Net vertical load for steining design		=	6650.98	t	
Net moment for steining design	$2,071.70 + 2,313.58$	=	4385.28	t-m	(M1 + M2)

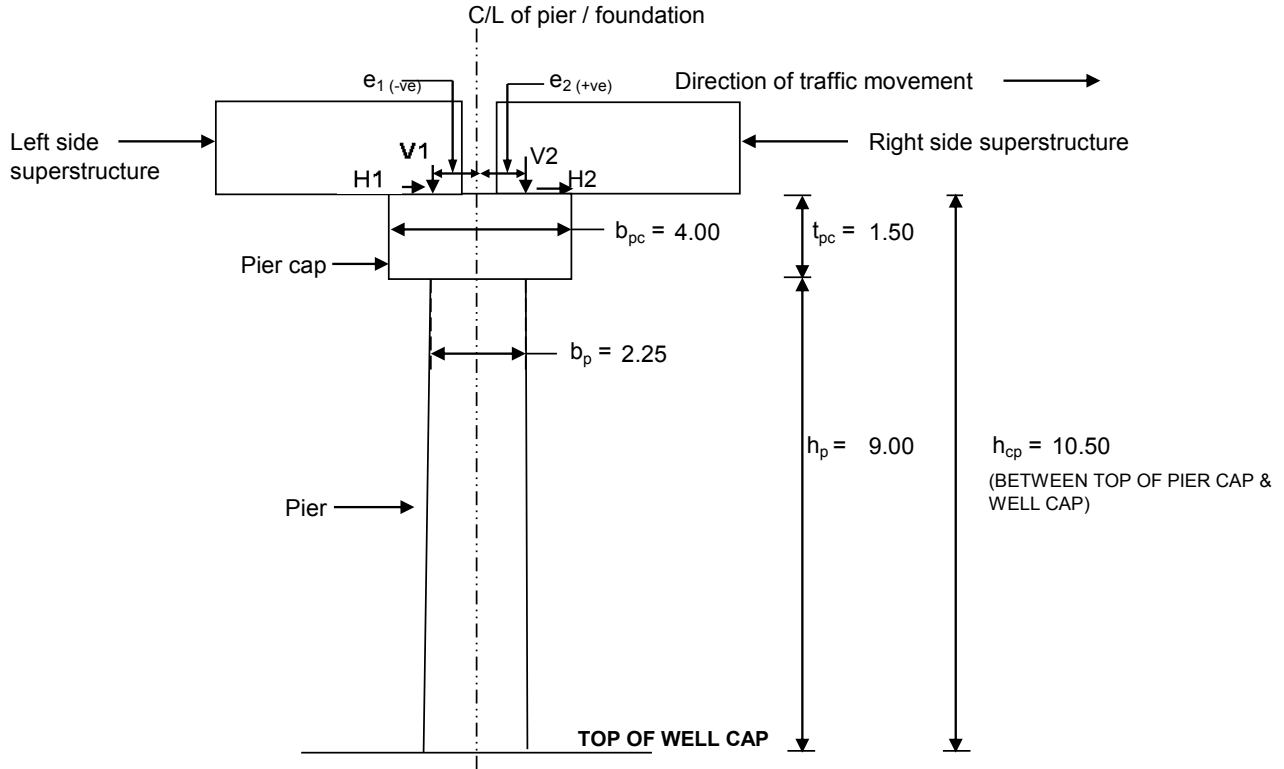
DESIGN OF RCC PIER

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM **JOB NO.** XPLR-226

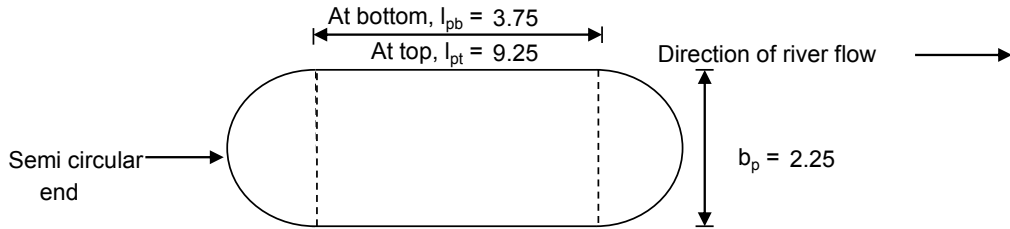
LOCATION: PIERS ON GRIDS 'P2' TO 'P25' **DATE:** 2016 OCT

LOAD CASE: NORMAL (LIVE LOADS ON ONE SPAN)
(ALLOWABLE STRESSES GIVEN BELOW ARE CORRESPONDING TO THIS LOAD CASE)

INPUT DATA: (ALL DIMENSIONS SHOWN IN THE FIGURES BELOW ARE IN METER)



ELEVATION OF PIER



PLAN OF PIER

1 DIMENSIONS:

PIER CAP:

Length of pier cap over pier (along river flow), l_{pc}	=	14.50	m	(slightly on higher side)
Width of pier cap (along bridge), b_{pc}	=	4.00	m	
Thickness of pier cap, t_{pc} (average thickness)	=	1.50	m	(conservative value)
Thickness of bearing & bearing pedestal, $t_{b\&p}$	=	0.50	m	(for design purpose only)

PIER:

Length of rectangular portion of pier at bottom, l_{pb}	=	3.75	m	(6.00-2.25)
Length of rectangular portion of pier at top, l_{pt}	=	9.25	m	(11.50-2.25)
Width of pier, b_p	=	2.25	m	
Height of pier, h_p	=	9.00	m	(conservative value)
Height " h_{cp} " between top of pier cap & pier base	1.50+9.00	=	10.50	m

2 PROPERTIES OF CONCRETE & STEEL:

Permissible stresses given below are corresponding to

NORMAL load case

Density of concrete, γ_c (as per clause 203 of IRC: 6- 2014)	=	2.50	t/m ³
Grade of concrete & steel	=	M35	& Fe500
Permissible stress in concrete, σ_{cb} (table A4.2 of IRC: 112- 2011)	=	11.670	N/mm ²
Permissible stress in tension steel, σ_{st} (table A4.4 of IRC: 112- 2011)	=	240.00	N/mm ²
Permissible stress in compression steel, σ_{sc} (table A4.4 of IRC: 112)	=	205.00	N/mm ²

3 LOADS:

Live loads defined below are corresponding to

NORMAL load case

Load Combination:		NORMAL	(LIVE LOADS ON ONE SPAN)
Horizontal seismic coefficient, α_h (clause 219 of RC: 6- 2014)	=	0.000	(resul.of long.& trans.seismic)
Vertical seismic coefficient, α_v (clause 219 of RC: 6- 2014)	=	0.000	(2/3 of the horizontal seismic)
Enhancement factor for seismic forces for foundation design	=	0.000	(clause 219 of RC: 6- 2014)
Dead load " V_{1DL} " from left side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Dead load " V_{2DL} " from right side superstructure (including SIDL) (based on the enclosed drawings & calculations of superstructure)	=	1,250.00	t (conservative value)
Live load " V_{1LL} " from left side superstructure, including FPLL	=	0.00	t (LL on one span only)
Live load " V_{2LL} " from right side superstructure, including FPLL	=	300.00	t (70R-W in each C.W.)
Vertical seismic " V_{1SE} " from left side superstructure	=	0.00	t $\alpha_v*(DL+LL)$
Vertical seismic " V_{2SE} " from right side superstructure	=	0.00	t $\alpha_v*(DL+LL)$
Eccentricity of left side vertical load w.r.t C/L of pier/ foundation, e_1 (taken as -ve below)	=	1.425	m
Eccentricity of right side vertical load w.r.t C/L of pier/ foundation, e_2 (taken as +ve below)	=	1.425	m
Horizontal force " H_1 " from left side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	0.000	t (LL on one span only)
Horizontal force " H_2 " from right side superstructure (excl.seismic) (as per clause 211 of IRC: 6- 2014)	=	25.000	t (70R-W in each C.W.)
Horizontal seismic " H_{1SE} " from left side superstructure	=	0.00	t $\alpha_h*(DL)$
Horizontal seismic " H_{2SE} " from right side superstructure	=	0.00	t $\alpha_h*(DL)$

1 SECTIONAL PROPERTIES AND WEIGHT:

PIER CAP:

X-sectional area of pier cap	1.50×4.00	=	6.000	m ²
Length of pier cap		=	14.500	m
Weight of pier cap, W_{pc}	$6.000 \times 14.500 \times 2.50$	=	217.500	t

PIER:

Area of rectangular portion of pier at bottom	3.75×2.25	=	8.438	m ²
Area of circular portion at bottom	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at bottom, A_{pb}	$8.438 + 3.976$	=	12.414	m ²
Area of rectangular portion of pier at top	9.25×2.25	=	20.813	m ²
Area of circular portion at top	$3.14 \times 2.25^2 / 4$	=	3.976	m ²
X-section area of pier at top, A_{pt}	$20.813 + 3.976$	=	24.789	m ²
Average X-section area of pier, A_p	$(12.414 + 24.789) / 2$	=	18.602	m ²
Height of pier, h_p		=	9.000	m
Weight of pier, W_p	$18.602 \times 9.000 \times 2.50$	=	418.545	t

2 VERTICAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>ECC.*</u> (m)	<u>MOMENT</u> (t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	0.00	-1.425	0.00
Live load (right side)	300.00	1.425	427.50
Vertical seismic (left side superstructure)	0.00	-1.425	0.00
Vertical seismic (right side superstructure)	0.00	1.425	0.00
Vertical seismic on weight of pier	0.000	0.000	0.00
Vertical seismic on weight of pier cap	0.000	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p = 3,436.05 t

Moment due to vertical load at the base of pier, M_{vp} = 427.50 t-m

3 HORIZONTAL LOADS FOR PIER DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>LEVER</u> <u>ARM**</u> (m)	<u>MOMENT</u> (t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	0.000	11.00	0.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	25.000	11.00	275.00
Horizontal seismic, H_{1SE} (left side superstructure)	0.00	11.00	0.00
Horizontal seismic, H_{2SE} (right side superstructure)	0.00	11.00	0.00
Horizontal seismic on weight of pier	0.00	5.13	0.00
Horizontal seismic on weight of pier cap	0.00	9.75	0.00

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is height between top of bearing & base of pier).

Total horizontal load at the base of pier, H_p = 25.00 t

Moment due to horizontal load at the base of pier, M_{hp} = 275.00 t-m

4 RECAP OF FORCES FOR PIER DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,436.05	t
Total horizontal load at the base of pier, H_p	=	25.00	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	702.50	t-m

5 STRESSES AT PIER BASE:

Refer following pages for calculation of stresses in concrete & steel at pier base.

6 VERTICAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>ECC.*</u> (m)	<u>MOMENT</u> (t-m)
Weight of pier	418.545	0.000	0.00
Weight of pier cap	217.500	0.000	0.00
Dead load including SIDL (left side)	1,250.00	-1.425	-1781.25
Dead load including SIDL (right side)	1,250.00	1.425	1781.25
Live load (left side)	0.00	-1.425	0.00
Live load (right side)	300.00	1.425	427.50
Vertical seismic (left side superstructure)	0.000	-1.425	0.00
Vertical seismic (right side superstructure)	0.000	1.425	0.00
Vertical seismic on weight of pier	0.000	0.000	0.00
Vertical seismic on weight of pier cap	0.000	0.000	0.00

* Eccentricity w.r.t C/L of pier/foundation

Total vertical load at the base of pier, V_p	=	3,436.05	t
Moment due to vertical load at the base of pier, M_{vp}	=	427.50	t-m

7 HORIZONTAL LOADS FOR FOUNDATION DESIGN: (AT BASE OF THE PIER)

<u>COMPONENT</u>	<u>LOAD</u> (t)	<u>LEVER</u> <u>ARM**</u> (m)	<u>MOMENT</u> (t-m)
Horizontal force, H_1 (left side superstructure) (excluding seismic forces)	0.000	11.00	0.00
Horizontal force H_2 (right side superstructure) (excluding seismic forces)	25.000	11.00	275.00
Horizontal seismic, H_{1SE} (left side superstructure)	0.00	11.00	0.00
Horizontal seismic, H_{2SE} (right side superstructure)	0.00	11.00	0.00
Horizontal seismic on weight of pier	0.00	5.13	0.00
Horizontal seismic on weight of pier cap	0.00	9.75	0.00

** Lever arm above base of the pier/top of the foundation (in case of forces from superstructure it is

Total horizontal load at the base of pier, H_p	=	25.00	t
Moment due to horizontal load at the base of pier, M_{hp}	=	275.00	t-m

8 RECAP OF FORCES FOR FOUNDATION DESIGN:

AT BASE OF PIER:

Total vertical load at the base of pier, V_p	=	3,436.05	t
Total horizontal load at the base of pier, H_p	=	25.00	t
Total moment at the base of pier, $M_p = (M_{vp} + M_{hp})$	=	702.50	t-m

9 DESIGN OF FOUNDATION:

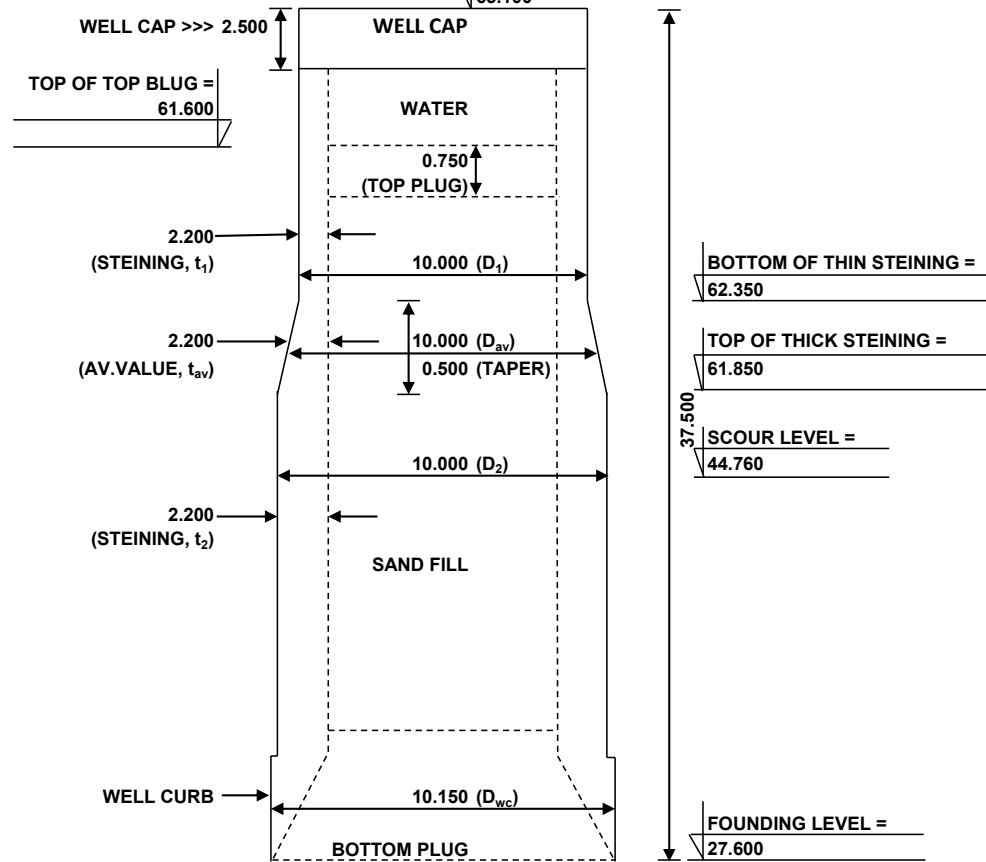
Refer following pages for design of foundation.

DESIGN OF CIRCULAR WELL FOUNDATION

(AS PER PROVISIONS OF IRC: 78)

PROJECT: BRIDGE OVER JIA-BHARALI RIVER NEAR TEZPUR IN ASSAM
 LOCATION: WELL SUPPORTING PIERS
 LOAD CASE: NORMAL (LIVE LOADS ON ONE SPAN)

HFL = 73.760 LWL = 70.100 TOP OF WELL CAP = 65.100 BED LEVEL = 69.100



TYPICAL ELEVATION OF WELL

A. DESIGN DATA:

WELL SUPPORTING PIERS

1. LOAD CASE CONSIDERED:

NORMAL (LIVE LOADS ON ONE SPAN)

2. LEVELS:

High flood level (HFL)	=	73.760	m	
Low water level (LWL)	=	70.100	m	
Top level of well cap	=	65.100	m	
Bed level	=	69.100	m	
Top level of top/intermediate plug	=	61.600	m	
Level at the bottom of top steining having less thickness, t_1	=	62.350	m	
<input type="text" value="should be above top of top plug in such a way that tapering is done above top plug"/>				
Level at the top of bottom steining having more thickness, t_2	=	61.850	m	
Scour level <input type="text" value="should be below the bottom of top/intermediate plug"/>	=	44.760	m	(conservative value)
Bottom level of well (founding level)	=	27.600	m	

3. WELL PROPERTIES:

Outer diameter of well near top having thin steining, D_1	=	10.000	m	
Outer diameter of well near bottom having thick steining, D_2	=	10.000	m	
Average outer diameter of well at location where steining tapers, D_{av}	=	10.000	m	
Outer diameter of well at founding level (well curb), D_{wc}	=	10.150	m	
Coefficient 'K' for calculating steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2014)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2014)
Steining thickness near top (should be above scour depth), t_1	=	2.200	m	(taper not steeper than 1H:3V)
Steining thickness near bottom, t_2	=	2.200	m	(taper not steeper than 1H:3V)
Average steining thickness in taper portion, t_{av}	=	2.200	m	
Thickness of well cap	=	2.500	m	
Thickness of top/intermediate plug	=	0.750	m	
Thickness of bottom plug	=	4.000	m	(above founding level of well)
Density of RCC	=	2.500	t/m ³	
Density of PCC	=	2.200	t/m ³	
Density of sand fill	=	2.000	t/m ³	
Density of water	=	1.000	t/m ³	

4. SOIL PROPERTIES:

Net safe bearing capacity	=	80.00	t/m ²	(at founding level)
Gross bearing capacity	=	120.00	t/m ²	(Net SBC + overburden)
F.O.S in assessing passive resistance	=	2.000		(as per appendix-3 of IRC:78-2014)

Top of Layer	Bottom of Layer	ϕ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³ (submerged, if applicable)	Intensity of active earth pressure at top, p_a , t/m ²	Intensity of passive earth pressure at top, p_p , t/m ²
44.760	40.000	34.00	22.50	0.00	1.00	0.000	0.000
40.000	35.000	34.00	22.50	0.00	1.00	(conservative)	(conservative)
35.000	30.000	34.00	22.50	0.00	1.00	(see below)	(see below)
30.000	25.000	34.00	22.50	0.00	1.00		
25.000	27.600	34.00	22.50	0.00	1.00		

5. EXTERNAL LOADS:

External vertical load at top of well cap	=	3,436.05	t	(at top of well cap)
External moment at top of well cap	=	702.50	t-m	(at top of well cap)
External horizontal load at top of well cap	=	25.00	t	(at top of well cap)
Horizontal seismic coefficient	=	0.000		(resultant of long.& trans.seismic)
Vertical seismic coefficient	0.000*2/3	=	0.000	
Velocity of flow at well top	=	3.600	m/s	(at top of well cap)
Coefficient 'K' to calculate water pressure	=	0.660		(as per clause 210.2 of IRC:6-2014)
Intensity of water pressure at scour level	=	0.000	kg/m ²	

6. TILTS AND SHIFTS:

Maximum shift considered for well design	=	0.150	m	(as per clause 708.5.1of IRC:78-2014)
Maximum tilt considered for well design	=	1.250	%	(as per clause 708.5.1of IRC:78-2014)

7. OTHERS:

Inclination of wall from horizontal, α	=	90.000	degree	
Inclination of backfill from horizontal, β	=	0.000	degree	
Surcharge considered for active earth pressure	=	0.000	t/m ²	(acting over the well)
Factor of safety, F	(for steining stress, see below)	=	2.00	
Submerged density of soil, γ_b	(for steining stress, see below)	=	1.00	t/m ³
Coefficient of active earth pressure, K_a	(for steining stress, see below)	=	0.254	
Coefficient of passive earth pressure, K_p	(for steining stress, see below)	=	8.901	

B. SUMMARY OF FINDINGS & RESULTS:

Minimum steining thickness required near top	=	1.661	m	
Steining thickness provided near top	=	2.200	m	Hence O.K.
Minimum steining thickness required near bottom	=	2.151	m	
Steining thickness required near bottom	=	2.200	m	Hence O.K.
Maximum base pressure, σ_{max}	=	86.85	t/m ²	
Allowable gross bearing capacity	=	120.00	t/m ²	Hence O.K.
Minimum base pressure, σ_{min}	=	86.85	t/m ²	Hence O.K.

C. OUTPUT FOR WELL STABILITY:

1. CHECK FOR MINIMUM STEINING THICKNESSES:

(As per clause 708.2.3 of IRC:78)

Coefficient 'K' for steining thickness	=	0.030		(as per clause 708.2.3.1 of IRC:78-2000)
Factor for increase/decrease in steining thickness	=	1.100		(as per clause 708.2.3.2 of IRC:78-2000)
Outer diameter of well near top, D_1	=	10.000	m	
Depth of well below well top or LWL till scour level whichever is more	=	25.340	m	
Minimum steining thickness required near top				
$0.030 \times 1.100 \times 10.000 \times 25.340^{0.5}$	=	1.661	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

Outer diameter of well near bottom, D_2	=	10.000	m	
Depth of well below well top or LWL till founding level whichever is more	=	42.500	m	
Minimum steining thickness required near bottom				
$0.030 \times 1.100 \times 10.000 \times 42.500^{0.5}$	=	2.151	m	(as per clause 708.2.3.1 of IRC:78-2000)

Which is less than the actual thickness provided, hence O.K.

2. VERTICAL FORCES AT BASE LEVEL:

Thickness of well cap	=	2.500	m	
Diameter of well cap	=	10.000	m	
Density of RCC	=	2.500	t/m ³	
Weight of well cap	$3.14 \times 10.000^2 \times 2.500 \times 2.500 / 4$	=	491.07	t
Outer diameter of well near top, D_1	=	10.000	m	
Area corresponding to outer diameter, A_1	$3.14 \times 10.000^2 / 4$	=	78.571	m ²
Steining thickness near top, t_1	=	2.200	m	
Inner diameter of well near top, D_1'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_1'	$3.14 \times 5.600^2 / 4$	=	24.640	m ²
Net area of steining near top, $A_1 - A_1'$	$78.571 - 24.640$	=	53.931	m ²
Depth of this portion of well	$65.100 - 62.350 - 2.500$	=	0.250	m
Density of RCC	=	2.500	t/m ³	
Weight of this portion of well steining	$53.931 \times 0.250 \times 2.500$	=	33.71	t

Outer diameter of well near bottom, D_2		=	10.000	m
Area corresponding to outer diameter, A_2	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness near bottom, t_2		=	2.200	m
Inner diameter of well near bottom, D_2'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_2'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$61.850 - 27.600$	=	34.250	m
Weight of this portion of well steining	$53.931 \times 34.250 \times 2.500$	=	4,617.84	t
Outer diameter of well in tapering portion, D_{av}	$(10.000 + 10.000) / 2$	=	10.000	m
Area corresponding to outer diameter, A_{av}	$3.14 \times 10.000^2 / 4$	=	78.571	m^2
Steining thickness in tapering portion, t_{av}		=	2.200	m
Inner diameter of well in tapering portion, D_{av}'	$10.000 - 2 \times 2.200$	=	5.600	m
Area corresponding to inner diameter, A_{av}'	$3.14 \times 5.600^2 / 4$	=	24.640	m^2
Net area of steining near bottom, $A_2 - A_2'$	$78.571 - 24.640$	=	53.931	m^2
Depth of this portion of well	$62.350 - 61.850$	=	0.500	m
Weight of this portion of well steining	$53.931 \times 0.500 \times 2.500$	=	67.41	t
Total weight of well steining	$33.71 + 4,617.84 + 67.41$	=	4,718.96	t
Depth of water above top/intermediate plug	$65.100 - 61.600 - 2.500$	=	1.000	m
Inner diameter of well		=	5.600	m
Density of water		=	1.000	t/m^3
Weight of water	$3.14 \times 5.600^2 \times 1.000 \times 1.000 / 4$	=	24.64	t
Thickness of intermediat/top plug		=	0.750	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of intermediat/top plug	$3.14 \times 5.600^2 \times 0.750 \times 2.200 / 4$	=	40.66	t
Depth of sand fill below top plug	$61.600 - 27.600 - 0.750 - 4.000$	=	29.250	m
Inner diameter of well		=	5.600	m
Density of sand		=	2.000	t/m^3
Weight of sand fill below top plug	$3.14 \times 5.600^2 \times 29.250 \times 2.000 / 4$	=	1,441.44	t
Thickness of bottom plug		=	4.000	m
Inner diameter of well		=	5.600	m
Density of PCC		=	2.200	t/m^3
Weight of bottom plug	$3.14 \times 5.600^2 \times 4.000 \times 2.200 / 4$	=	216.83	t

Total weight of well including top & bottom plugs and filling		=	6,933.60	t	
	$491.07+4,718.96+24.64+40.66+1,441.44+216.83$	=	6,933.60	t	
External vertical load over well		=	3,436.05	t	
Total vertical load including external load	$6,933.60+3,436.05$	=	10,369.65	t	(at founding level)
Vertical load of well components upto scour level	3,754.61	=	3,754.61	t	(see calculations below)
Vertical downward seismic force on this	$3,754.61*0.000$	=	0.00	t	(downward seismic governs the design)
Buoyancy on well	$3.14*10.000^2*(70.100-27.600)*1.000/4$	=	3,339.29	t	(diameter at the top is taken on safer side)
Net vertical load at base level	$10,369.65+0.00-3,339.29$	=	7,030.36	t	(including buoyancy & vertical seismic)

3. HORIZONTAL FORCES AND MOMENTS AT SCOUR & FOUNDING LEVELS:

3.1 EXTERNAL HORIZONTAL LOAD ACTING ON WELL:

External horizontal load on well		=	25.00	t	(at top of well cap)
C.G. of this above scour level	$65.100-44.760$	=	20.340	m	
Moment at scour level	$25.00*20.340$	=	508.50	t-m	
C.G. of this above founding level	$20.340+44.760-27.600$	=	37.500	m	
Moment at founding level	$25.00*37.500$	=	937.50	t-m	

3.2 EXTERNAL MOMENT ACTING ON WELL:

External moment acting on well		=	702.50	t-m	
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3.3 SEISMIC FORCES ON WELL:

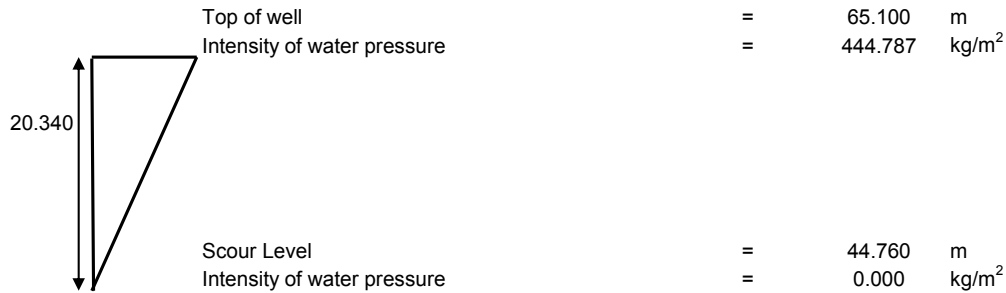
Horizontal seismic coefficient		=	0.000		
Weight of well cap		=	491.07	t	
Seismic force on this weight	$0.000*491.07$	=	0.00	t	
C.G. of this above scour level	$65.100-44.760-1.25$	=	19.090	m	
Moment at scour level	$0.00*19.090$	=	0.00	t-m	
C.G. of this above founding level	$19.090+44.760-27.600$	=	36.250	m	
Moment at founding level	$0.00*36.250$	=	0.00	t-m	
Weight of well steining near top (with reduced thickness of steining)		=	33.71	t	
Seismic force on this weight	$0.000*33.71$	=	0.00	t	
C.G. of this above scour level	$62.350-44.760+0.250/2$	=	17.715	m	
Moment at scour level	$0.00*17.715$	=	0.00	t-m	
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m	
Moment at founding level	$0.00*34.875$	=	0.00	t-m	

Height of thicker well steining above scour level	$61.850-44.760$	=	17.090	m
Weight of thicker well steining upto scour level	$53.931*17.090*2.500$	=	2,304.20	t
Seismic force on this weight	$0.000*2,304.20$	=	0.00	t
C.G. of this above scour level	$0.5*17.090$	=	8.545	m
Moment at scour level	$0.00*8.545$	=	0.00	t-m
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Moment at founding level	$0.00*17.125$	=	0.00	t-m
Weight of tapering well steining		=	67.41	t
Seismic force on this weight	$0.000*67.41$	=	0.00	t
C.G. of this above scour level	$61.850-44.760+0.500/2$	=	17.340	m
Moment at scour level	$0.00*17.340$	=	0.00	t-m
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Moment at founding level	$0.00*34.500$	=	0.00	t-m
Weight of water fill		=	24.64	t
Seismic force on this weight	$0.000*24.64$	=	0.00	t
C.G. of this above scour level	$(65.100-61.600-2.500)*0.5+(61.600-44.760)$	=	17.340	m
Moment at scour level	$0.00*17.340$	=	0.00	t-m
C.G. of this above founding level	$17.340+44.760-27.600$	=	34.500	m
Moment at founding level	$0.00*34.500$	=	0.00	t-m
Weight of intermediat/top plug		=	40.66	t
Seismic force on this weight	$0.000*40.66$	=	0.00	t
C.G. of this above scour level	$61.600-44.760-0.750*0.5$	=	16.465	m
Moment at scour level	$0.00*16.465$	=	0.00	t-m
C.G. of this above founding level	$16.465+44.760-27.600$	=	33.625	m
Moment at founding level	$0.00*33.625$	=	0.00	t-m
Depth of sand fill upto scour level	$61.600-44.760-0.750$	=	16.090	m
Weight of sand fill upto scour level	$3.14*5.600^2*16.090*2.000/4$	=	792.92	t
Seismic force on this weight	$0.000*792.92$	=	0.00	t
C.G. of this above scour level	$16.090/2$	=	8.045	m
Moment at scour level	$0.00*8.045$	=	0.00	t-m
C.G. of this above founding level	$8.045+44.760-27.600$	=	25.205	m
Moment at founding level	$0.00*25.205$	=	0.00	t-m
Weight of well components above scour level	$491.07+33.71+2,304.20+67.41+24.64+40.66+792.92$	=	3,754.61	t
	(including top plug, sandfill & waterfill)			
Horizontal seismic forces on well components	$3,754.61*0.000$	=	0.00	t
	(including top plug, sandfill & waterfill)			

Moment at scour level due to this	$0.00+0.00+0.00+0.00+0.00+0.00+0.00$ (including top plug, sandfill & waterfill)	=	0.00	t-m
Moment at founding level due to this	$0.00+0.00+0.00+0.00+0.00+0.00+0.00$ (including top plug, sandfill & waterfill)	=	0.00	t-m

3.4 WATER PRESSURE: (As per clause 210.2 of IRC:6-2010)

Intensity of water pressure at well top	$52 \times 0.660 \times 3.600^2$	=	444.787	kg/m ²	(as per cl 210.2 of IRC:6-2010)
Intensity of water pressure at scour level		=	0.000	kg/m ²	
Outer diameter of well		=	10.000	m	(diameter near base taken on safer side)
Height of well above scour level	$65.100 - 44.760$	=	20.340	m	



Total water pressure acting over well	$0.5 \times 444.787 \times 10.000 \times 20.340 / 1000$	=	45.23	t
C.G. of this above scour level	$2 \times 20.340 / 3$	=	13.560	m
Moment at scour level	45.23×13.560	=	613.32	t-m
C.G. of this above founding level	$13.560 + 44.760 - 27.600$	=	30.720	m
Moment at founding level	45.23×30.720	=	1389.47	t-m

Net forces including those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$25.00+0.00+45.23$	=	70.23	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$508.50+702.50+0.00+613.32$	=	1,824.32	t-m	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at base level	$937.5+702.50+0.00+1389.4656$	=	3,029.47	t-m	(3.1 + 3.2 + 3.3 + 3.4)

Net forces excluding those due to top/intermediate plug, sandfill & water fill:					
Net horizontal force at scour/base level	$25.00+0.00+0.00+0.00+45.23$	=	70.23	t	(3.1 + 3.2 + 3.3 + 3.4)
Net moment at scour level	$508.50+702.50+0.00+0.00+0.00+613.32$	=	1,824.32	t-m	(3.1 + 3.2 + 3.3 + 3.4)

4. MOMENT AT BASE LEVEL DUE TO TILT & SHIFT:

(As per clause 708.5.1 of IRC:78)

Shift considered for well design		=	0.150	m
Vertical load at top of the well		=	3,436.05	t
Moment due to shift	$0.150 \times 3,436.05$	=	515.41	t-m
Tilt considered for well design		=	1.250	%
Vertical load at top of the well		=	3,436.05	t
C.G. of this above founding level	$65.100-27.600$	=	37.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 37.500/100$	=	0.469	m
Moment due to lateral shift due to tilt	$3,436.05 \times 0.469$	=	1,611.51	t-m
Weight of well cap		=	491.07	t
C.G. of this above founding level	$65.100-27.600-2.500 \times 0.5$	=	36.250	m
Lateral shift of this C.G. due to tilt	$1.250 \times 36.250/100$	=	0.453	m
Moment due to lateral shift due to tilt	491.07×0.453	=	222.45	t-m
Weight of well steining near top		=	33.71	t
C.G. of this above founding level	$62.350-27.600+0.250/2$	=	34.875	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.875/100$	=	0.436	m
Moment due to lateral shift due to tilt	33.71×0.436	=	14.70	t-m
Weight of well steining near bottom		=	4,617.84	t
C.G. of this above founding level	$(61.850-27.600)/2$	=	17.125	m
Lateral shift of this C.G. due to tilt	$1.250 \times 17.125/100$	=	0.214	m
Moment due to lateral shift due to tilt	$4,617.84 \times 0.214$	=	988.22	t-m
Weight of well steining in tapering portion		=	67.41	t
C.G. of this above founding level	$61.850-27.600+0.500/2$	=	34.500	m
Lateral shift of this C.G. due to tilt	$1.250 \times 34.500/100$	=	0.431	m
Moment due to lateral shift due to tilt	67.41×0.431	=	29.05	t-m

Weight of water fill	=	24.64	t
C.G. of this above founding level			
	$65.100-27.600-2.500-(65.100-2.500-61.600)/2$	=	34.500 m
Lateral shift of this C.G.due to tilt	$1.250*34.500/100$	=	0.431 m
Moment due to lateral shift due to tilt	$24.64*0.431$	=	10.62 t-m
Weight of intermediat/top plug	=	40.66	t
C.G. of this above founding level	$61.600-27.600-0.750*0.5$	=	33.625 m
Lateral shift of this C.G.due to tilt	$1.250*33.625/100$	=	0.420 m
Moment due to lateral shift due to tilt	$40.66*0.420$	=	17.08 t-m
Weight of sand fill	=	1,441.44	t
C.G. of this above founding level	$(61.600-27.600-0.750-4.000)/2+4.000$	=	18.625 m
Lateral shift of this C.G.due to tilt	$1.250*18.625/100$	=	0.233 m
Moment due to lateral shift due to tilt	$1,441.44*0.233$	=	335.86 t-m
Weight of bottom plug	=	216.83	t
C.G. of this above founding level	$4.000/2$	=	2.000 m
Lateral shift of this C.G.due to tilt	$1.250*2.000/100$	=	0.025 m
Moment due to lateral shift due to tilt	$216.83*0.025$	=	5.42 t-m

Total moment at base due to tilt & shift			
	$515.41+1,611.51+222.45+14.70+988.22+29.05+10.62+17.08+335.86+5.42$	=	3750.32 t-m

5. RESISTING MOMENT AT FOUNDING LEVEL:

(As per Appendix-3 of IRC:78)

The resisting moment is acting because of difference in passive and active earth pressure

F.O.S in assessing passive resistance = 2.000 (As per appendix-3 of IRC78)

The active and passive earth pressure at any depth has been calculated by following equations:

$$\begin{aligned} \text{Active earth pressure, } p_a &= K_a \gamma h + K_a q - 2c(K_a)^{1/2} \\ &= K_a \gamma h + K_a q \quad \text{(ignoring the effect of cohesion conservatively)} \end{aligned}$$

$$\text{Passive earth pressure, } p_p = K_p \gamma h + K_p q + 2c(K_p)^{1/2} \quad (q = 0 \text{ considered for well design})$$

where,

$$\text{Coefficient of active earth pressure, } K_a = \frac{\sin^2(\alpha + \varphi)}{\sin^2 \alpha \sin(\alpha - \delta) [1 + \{\sin(\varphi + \delta) \sin(\varphi - \beta) / \sin(\alpha - \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$$

$$\text{Coefficient of passive earth pressure, } K_p = \frac{\sin^2(\alpha - \varphi)}{\sin^2 \alpha \sin(\alpha + \delta) [1 - \{\sin(\varphi + \delta) \sin(\varphi + \beta) / \sin(\alpha + \delta) \sin(\alpha + \beta)\}^{0.5}]^2}$$

γ'	=	Submerged density of earth
h	=	Thickness of layer considered
q	=	Surcharge at top of the layer considered
Inclination of Wall from Horizontal, α	=	90.000 degree
φ	=	Angle of Internal Friction
δ	=	Angle of Wall Friction
Inclination of Backfill from Horizontal, β	=	0.000 degree

5.1 GENERAL CALCULATIONS:

Surcharge considered for active earth pressure	=	0.000 t/m ²
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Top of Layer	Bottom of Layer	$\sin^2(\alpha+\varphi)$	$\sin^2\alpha$	$\sin(\alpha-\delta)$	$\sin(\varphi+\delta)$	$\sin(\varphi-\beta)$	$\sin(\alpha+\beta)$	$\sin^2(\alpha-\varphi)$	$\sin(\alpha+\delta)$	$\sin(\varphi+\beta)$
44.760	40.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
40.000	35.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
35.000	30.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
30.000	25.000	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559
25.000	27.600	0.686	1.00	0.924	0.834	0.559	1.00	0.688	0.924	0.559

Top of Layer	Bottom of Layer	φ , degree	δ , degree	Cohesion, c, t/m ²	Density, γ' , t/m ³	Coefficient, Ka	Coefficient, Kp	Thickness, h, m	Height above well bottom, m
44.760	40.000	34.00	22.50	0.00	1.000	0.254	8.901	4.76	12.40
40.000	35.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	7.40
35.000	30.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	2.40
30.000	25.000	34.00	22.50	0.00	1.000	0.254	8.901	5.00	-2.60
25.000	27.600	34.00	22.50	0.00	1.000	0.254	8.901	-2.60	0.00

5.2 FORCES & MOMENTS DUE TO ACTIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_a at top, t/m ²	p_a at bottom, t/m ²	Dia of well, m	Total Active Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
44.760	40.000	0.000	1.209	10.000	28.8	13.987	402.29
40.000	35.000	1.209	2.478	10.000	92.16	9.613	885.96
35.000	30.000	2.478	3.747	10.000	155.63	4.730	736.16
30.000	25.000	3.747	5.017	10.000	219.11	-0.221	-48.36
25.000	27.600	5.017	4.357	10.000	-121.9	-1.331	162.13
Total Moment, M_a							2,138.19

5.3 FORCES & MOMENTS DUE TO PASSIVE EARTH PRESSURE:

Top of Layer	Bottom of Layer	p_p at top, t/m ²	p_p at bottom, t/m ²	Dia of well, m	Total Passive Force, t	C.G. of this above well bottom, m	Moment at well bottom, tm
44.760	40.000	0.000	42.368	10.000	1008.36	13.987	14103.58
40.000	35.000	42.368	86.872	10.000	3231.01	9.613	31059.81
35.000	30.000	86.872	131.377	10.000	5456.22	4.730	25808.31
30.000	25.000	131.377	175.881	10.000	7681.43	-0.221	-1695.31
25.000	27.600	175.881	152.739	10.000	-4272.05	-1.331	5684.03
Total Moment, M_p							74,960.42

Total moment due to active earth pressure, M_a = 2,138.19 t-m

Total moment due to passive earth pressure, M_p = 74,960.42 t-m

Factor of safety = 2.000 (as per appendix-3 of IRC:78)

Net resisting moment, $(M_a - M_p)/F.O.S$	$(74,960.42 - 2,138.19)/2.000$	=	36411.12 t-m
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6. DESIGN MOMENT AT BASE LEVEL:

External moment at top of well cap = 702.50 t-m

Moment due to external horizontal load = 937.50 t-m

Moment due to seismic forces on well = 0.00 t-m

Moment due to water pressure on well = 1389.47 t-m

Moment due to tilt and shift = 3750.32 t-m

Resisting moment = 36411.12 t-m

(due to passive earth pressure)

Net moment at base level	=	0.00 t-m
<small>(resisting moment is more than moment acting)</small>		

7. CHECK FOR BASE PRESSURE:

(As per provisions of IRC:78-2014)

Outer diameter of well at well bottom/curb		=	10.150	m
Area at well bottom, A	$3.14 \times 10.150^2 / 4$	=	80.946	m^2
Section modulus, Z	$3.14 \times 10.150^3 / 32$	=	102.701	m^3
Net vertical load at well bottom, P (including buoyancy & vertical seismic forces)		=	7,030.36	t
Net moment at well bottom, M		=	0.00	t-m
Maximum base pressure, σ_{max}	$7,030.36 / 80.946 + 0.00 / 102.701$	=	86.85	t/m^2
Allowable gross bearing capacity		=	120.00	t/m^2
Which is more than the maximum base pressure, hence O.K.				
Minimum base pressure, σ_{min}	$7,030.36 / 80.946 - 0.00 / 102.701$	=	86.85	t/m^2
Which is more than zero, hence O.K.				

D. OUTPUT FOR STEINING STRESS CHECK:

1. DEPTH OF ZERO SHEAR BELOW SCOUR LEVEL:

Depth of zero shear below scour level, x		=	$\{2FH / \gamma_b(K_p - K_a)D\}^{1/2}$	
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)				
where,				
Factor of safety, F		=	2.00	
Resultant horizontal force at scour level, H		=	70.23	t
Submerged density of soil, γ_b		=	1.00	t/m ³
Coefficient of active earth pressure, K_a		=	0.254	
Coefficient of passive earth pressure, K_p		=	8.901	
Outer diameter of well steining, D		=	10.000	m
Now, depth of zero shear, x				
	$2 \times 2.00 \times 70.23 / (1.00 \times (8.901 - 0.254) \times 10.000)^{0.5}$	=	1.802	m
Level at the depth of zero shear	44.760 - 1.802	=	42.958	m

(excluding those due to top plug, sandfill & waterfill)

2. VERTICAL LOAD & MOMENT DUE TO TILT & SHIFT AT DEPTH OF ZERO SHEAR:

Shift considered for well design		=	0.150	m
Tilt considered for well design		=	1.250	%
External vertical load over well		=	3,436.05	t
Moment due to shift	$3,436.05 \times 0.150$	=	515.41	t-m
C.G. of this above depth of zero shear	65.100 - 42.958	=	22.142	m
Lateral shift of this C.G. due to tilt	$1.250 \times 22.142 / 100$	=	0.277	m
Moment due to lateral shift due to tilt	$0.277 \times 3,436.05$	=	951.79	t-m
Weight of well cap		=	491.07	t
C.G. of this above depth of zero shear	19.090 + 1.802	=	20.892	m
Lateral shift of this C.G. due to tilt	$1.250 \times 20.892 / 100$	=	0.261	m
Moment due to lateral shift due to tilt	0.261×491.07	=	128.17	t-m
Weight of well steining near top (with reduced thickness of steining)		=	33.71	t
C.G. of this above depth of zero shear	17.715 + 1.802	=	19.517	m
Lateral shift of this C.G. due to tilt	$1.250 \times 19.517 / 100$	=	0.24	t-m
Moment due to lateral shift due to tilt	0.24×33.71	=	8.09	t-m
Height of thicker well steining above depth of zero shear	61.850 - 42.958	=	18.892	m
Weight of thicker well steining upto depth of zero shear	$53.931 \times 18.892 \times 2.500$	=	2,547.16	t
C.G. of this above depth of zero shear	0.5 * 18.892	=	9.446	m

Lateral shift of this C.G.due to tilt	$1.250 \times 9.446 / 100$	=	0.12	t-m
Moment due to lateral shift due to tilt	$0.12 \times 2,547.16$	=	305.66	t-m
Weight of tapering well steining		=	67.41	t
C.G. of this above depth of zero shear	$17.340 + 1.802$	=	19.142	m
Lateral shift of this C.G.due to tilt	$1.250 \times 19.142 / 100$	=	0.24	t-m
Moment due to lateral shift due to tilt	0.24×67.41	=	16.18	t-m

Total vertical load at depth of zero shear	$3,436.05 + 491.07 + 33.71 + 2,547.16 + 67.41$	=	6,575.40	t	(excluding those due to top plug, sandfill & waterfill)
Tilt & shift moment at depth of zero shear	$515.41 + 951.78585 + 128.17 + 8.09 + 305.66 + 16.18$	=	1,925.30	t-m	

3. DESIGN VERTICAL LOAD & MOMENT AT DEPTH OF ZERO SHEAR:

Total vertical load at depth of zero shear		=	6,575.40	t	(excluding buoyancy & seismic forces)
Vertical load of well components at scour level	$491.07 + 33.71 + 2,547.16 + 67.41$	=	3139.35	t	(excluding those due to top plug, sandfill & waterfill)
Vertical upward seismic force on this	0.000×3139.35	=	0.00	t	(upward seismic governs the design)
Height of well upto the depth of zero shear	$65.100 - 42.958$	=	22.14	t	
Buoyancy on well upto the depth of zero shear	$78.571 \times 22.142 \times 0.15$	=	260.96	t	(15% buoyancy as per cl.216.5 of IRC: 6)
Net vertical load at depth of zero shear	$6,575.40 - 0.00 - 260.96$	=	6314.44	t	(including buoyancy & vertical seismic forces)
Tilt & shift moment at depth of zero shear, M1		=	1,925.30	t-m	
Resultant horizontal force at scour level, H		=	70.23	t	(excluding those due to top plug, sandfill & waterfill)
Net moment at scour level, M_0		=	1,824.32	t-m	(excluding those due to top plug, sandfill & waterfill)
Moment at depth of zero shear, M2		=	$M_0 + 2Hx/3$		
(refer "Analysis and Design of Substructures" by Prof.Swami Saran)	$1,824.32 + (2 \times 70.23 \times 1.802) / 3$	=	1,908.69	t-m	

Now,

Net vertical load for steining design		=	6314.44	t	
Net moment for steining design	$1,925.30 + 1,908.69$	=	3833.99	t-m	(M1 + M2)