ANALYSIS AND DESIGN OF PILE FOUNDATION AND ITS ABUTMENT FOR RAILWAY GIRDER BRIDGE

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ABSTRACT
A Newly Broad Gauge Doubling Project Bridge was proposed between Jaroli – Jakhapura in Orissa, India under East Coast Railway. In this project a number of cross drainage structures are proposed, for canals, streams, etc. to cross the Railway. A deep study is made on one structure proposed at Bridge No.133 which is a major important bridge and the same is submitted as Project Thesis and which in later the drawings so developed using design are used for construction of bridge (On-going Project). All the necessary data was collected, studied, analyzed and designed to serve the purpose. But this thesis only deal with the design of abutment and its sub-structure, rest was also designed but to present the same become tedious.

INTRODUCTION
This thesis mainly deals with Analysis and Design of newly proposed Bridge No.133 which is a major important bridge on the proposed Broad Gauge Doubling Project, Jaroli – Jakhapura in Orissa, India under East Coast Railway at Chainage: 39078.2 m (39.078 Km), according to relevant Indian Railway Codes (IRS). Prior to Design the decision on levels and location of Abutments and Piers, Number of spans, Type of bridge & superstructure, type of sub-structure were decided in MOM meeting along with East Coast Railway Officials, RVNL Officials and Project Management and Consultancy (PMC). In this thesis only design of Abutment, Abutment Pile cap and Abutment piles are analysed and designed, rest were also designed but to present the same becomes Cumbersome but the concept being similar.

INVESTIGATION OF BRIDGES
Need for Investigation
The aim of the investigation is to select a suitable site at which a bridge can be built economically, at the same time satisfying the demands of traffic, the stream, safety and aesthetics. The investigation for a minor bridge project should cover studies on technical
feasibility and economic considerations and should result in an investigation report. The success of the final design will depend on the thoroughness of the information furnished by the officer in charge of the investigation.

Selection of Bridge site
The characteristics of an ideal site for a bridge across a river are:
(a) A straight reach of the river.
(b) Steady river flow without serious whirls and cross currents.
(c) A narrow channel with firm banks.
(d) Suitable high banks above high flood level on each side.
(e)Avoidance of excessive underwater construction.

Investigation of proposed bridge site
Detailed Topographic survey of stream i.e., cross section at site of crossing 100m, 150m, 300m and 500m on both upstream and downstream of the stream. Longitudinal section of the stream along the flow line of the stream up to 500m on upstream and downstream. Local enquiry of floods for the past 20 years.

Preliminary Data to be collected

The investigation for a bridge should collect the following information:
(a) Name of the stream, road and the identification mark allotted to the crossing and location in Km to centre of crossing.
(b) Location to the nearest GTS (Great Trigonometric Survey) bench mark with its reduced level.
(c) Present and anticipated future volume and nature of traffic on the road at the bridge site.
(d) Soil profile along the probable bridge sites over the length of the bridge and approaches.
(e) Need for large scale river training works.
(f) Means of transport for materials.
(g) Availability of electric power.

HYDRAULIC AND HYDROLOGICAL INVESTIGATION

This document contains detailed hydrologic/hydraulic report for a major important bridge on the proposed "Jaroli – Jakhapura Doubling" at Chainage: 39078.2 m (39.078 Km) which consists of 3 spans 18.3 m P.S.C. girder for 25T loading. The P.S.C superstructure is supported by MCC pier & RCC abutment which in turn transmits the loads through pile cap to the bored cast-in- situ pile of 1200mm dia.

BASIC REQUIREMENTS

AFFLUX (h) is the rise in water level upstream of a bridge as a result of obstruction to natural flow caused by the construction of the bridge and its approaches. CAUSEWAY or Irish bridge in a dip in the Railway track which allows floods to pass over it. CLEARANCE (C) is the vertical distance between the water level of the design discharge (Q) including afflux and the point on the bridge super-structure where the clearance is required to be measured. DEPTH OF SCOUR (D) is the depth of the eroded bed of the river, measured from the water level for the discharge considered. DESIGN DISCHARGE (Q) is the estimated discharge for the design of the bridge and its appurtenances. HIGHEST FLOOD LEVEL (HFL) is the highest water level Known to have occurred.

DATA COLLECTION

Topographic Survey for the longitudinal section and cross section To get the longitudinal and cross section for the bridge having definite course of Stream, survey has been done in accordance with IRS :Bridge sub-structures & Foundation code 2003.

DATA FOR HYDROLOGICAL CALCULATIONS:

A comprehensive outline of hydrological investigations for collecting the necessary field data for the design of a bridge is given below. The nature and extent of investigations and data to be collected will depend upon the type and importance of the bridge. In the case of minor bridges, the scope of data collection may be reduced.

APPLICABLE STANDARDS/CODES

IRS specifications and codes followed for the hydraulic analysis and designing are given below.
IS : 1892-1962-Code of Practice for site investigations for foundations
IRS :Bridge sub-structures & Foundation code 2003.

METHODOLOGY FOR HYDROLOGIC ANALYSIS

Investigation and data collection regarding hydraulic design has been carried out to decide hydraulic parameters for new structure and also to check the adequacy of existing cross drainage structure. This hydrological/ hydraulic report has been prepared with objective
to assess the hydraulic and drainage capacity of the existing structure and check for requirement of additional drainage waterway to convey the peak flow of water satisfactorily.

Estimation of Design Discharge (Q)

The estimation of design discharge for waterway shall preferably be based, wherever possible, on procedures evolved from actual hydro meteorological observations of the same or similar catchments.

Lacey's formula:

$$P_w = 1.811\ C\sqrt{Q}$$

Where, Pw = wetted perimeter in metres which can be taken as the effective width of waterway in case of large streams.

Q = design discharge in cum/sec.

C = a Coefficient normally equal to 2.67, but which may vary from 2.5 to 3.5 according to local conditions depending upon bed slope and bed material.

Estimation of Depth of Scour

In the case of natural channels flowing in alluvial beds where the width of waterway provided is not less than Lacey's regime width, the normal depth or Scour (D) below the foundation design discharge (Qf) level may be estimated from Lacey's formula as indicated below

$$D = 0.473\left(\frac{Q_f}{f}\right)^{1/3}$$

Where due to constriction of waterway, the width is less than Lacey's regime width for Qf or where it is narrow and deep as in the case of incised rivers and has sandy bed, the normal depth of scour may be estimated by the following formula:

$$D = 1.338\left(\frac{Q_f^{\,2}}{f}\right)^{1/3}$$

Where 'Q f ' is the discharge intensity in cubic metre per second per metre width and f is silt factor.

LOADS AND STRESSES

Dead load is the weight of the structure itself together with the permanent loads carried thereon. For design of ballasted deck bridges, a ballast cushion of 400mm for BG and 300mm for MG shall be considered. However, ballasted deck bridges shall also be checked for a ballast cushion of 300mm on BG and 250mm on MG.

IRS Standard Live Loads

Railway Bridges including combined rail and road bridges shall be designed for one of the following standards of railway loading which are in Cl.2.3 "Rules Specifying the loads for Design of Superstructure and Sub-structure of Bridges and for assessment of the strength of Existing bridges-2008"

Dynamic Effect

The augmentation in load due to dynamic effects should be considered by adding a load Equivalent to a Coefficient of Dynamic Augment (CDA) multiplied by the live load giving the maximum stress in the member under consideration.

Forces due to curvature and eccentricity of Track

The horizontal load due to centrifugal force which may be assumed to act at a height of 1830mm for "25t Loading-2008" for BG, 3000mm for "DFC loading (32.5t axle load)" for BG and 1450mm for MG above rail level is:

C = (WV2) / (12.95 R)

Where, C= Horizontal effect in kN/m run (t/m run) of span.

W= Equivalent Distributed live load in kN/m run (t/m run).

V= Maximum speed in km per hour and

R= Radius of the curve in m.

WIND PRESSURE EFFECT

Table 4.1 Wind Pressures

Broad Gauge bridges	1.47 kN/m2 (150 kg/m2)
Metre and Narrow Gauge Bridges	0.98 kN/m2 (100kg/m2)
Foot-bridges	0.74 kN/m2 (75 kg/m2)

FORCES AND EFFECTS DUE TO EARTHQUAKE

Zones I to III - Seismic forces shall be considered in case of bridges of overall-length more than 60m or spans more than 15m.

Zone IV & V - Seismic forces shall be considered for all spans

Design Seismic Coefficient

The design values of horizontal seismic

coefficient (α h) shall be computed by the following expression

α h =δ I α 0

δ= a coefficient depending upon the soil-foundation,

Where,

I = a coefficient depending upon the importance of the structure

α 0 = Basic horizontal seismic coefficient

HYDRAULIC DESIGN CALCULATIONS

The Hydrological Data was supplied by RVNL from concerned Irrigation Authorities and Geo-technical Investigation was done by local Sub-Contractors both have been studied by Architecture and Engineering Consultancy (P) Ltd. and required parameters involved in design such as Depth of embedment of piles/pile group, Depth of scour etc. where been worked out prior to design.

Table 5.1 CALCULATION OF SCOUR DEPTH

1	HFL	434.2 m
2	Discharge = (Data supplied by RVNL) Q	280 m3/s
3	Provided number of spans	3 Nos.
4	Each span length	18.3 m
5	Linear water way	54.9 m
6	Unit discharge = Designed discharge/ linear water way	5.1 m3/s/m
7	Silt factor	1.92
8	Normal scour depth= dsm	3.19 m
9	Maximum scour depth at abutment =1.27x dsm	4.0513 m
	= RL	430.149 m
10	Maximum scour depth at pier =2.00x dsm	6.38 m
	= RL	427.82 m

STRUCTURAL DESIGN CALCULATIONS

New Bridge No.133 is a major important bridge on the proposed "Jaroli – Jakhapura Doubling at Orissa State under East Coast Railway of India" at Chainage: 39078.2 m (39.078 Km). It consists of 3 spans 18.3 m P.S.C. girder for 25T loading. The P.S.C superstructure is supported by MCC pier & RCC abutment which in turn transmits the loads through pile cap to the bored cast-in- situ pile of 1200mm dia.

The MSL for pier has been taken as RL 427.300 m.

The pile cap top of P1 is at RL .431.638 m which is lower than that of P2.

For pier cap, pile cap & piles M35 grade of concrete and

For pier MCC of M25 grade concrete has been adopted.

In the design the critical load combinations, IRS standards have been considered.

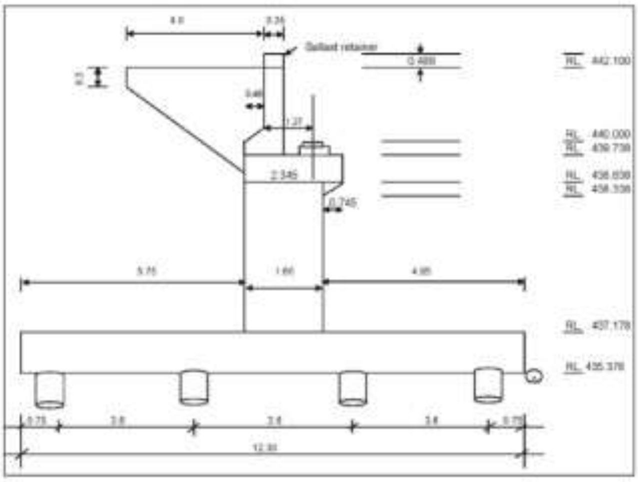

Figure 6.1 General details of Abutment and its Sub-structure

Load Calculation

1. DL from Super structure: [Ref: Drg.No.RDSO/B-10262]

Self Wt. of super structure = Wt. of (Span + Bearings) = 210.00 T

Reaction on abutment = 210.00 / 2 = 105.00T

This will act a distance, 4.96+1.6-1.27 = 5.28m from point 'A' in Fig.

Transverse Eccentricity of reaction, e₁ = 0.00 m

(Since superstructure is symmetric about CL of soffit)

2. SIDL from Superstructure: (SIDL)

Equivalent UDL of SIDL = 6.15 T/m

Reaction due to SIDL on abutment

intensity of SIDL = 6.15 T/m

SIDL Reaction from 18.00 m span (6.15)x19.76) / 2 = 60.76 T

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This will act at a distance 4.95+1.6-1.27= 5.28 m from point 'A' in Fig: 6.1

Transverse Eccentricity of reaction, e₁ = 0.00 m

(Since superstructure is symmetric about CL of soffit)

3. DL from Abutment Cap, Dirt Wall, Platform & Railing

Self wt of abutment cap = 6.65x2.35x0.90x2.5 = 17.082 T

This will act at a distance, 4.95-0.745+2.345/2= 5.3775 m from point 'A' in Fig. 6.1

Self wt of dirt Wall = 6.65x0.35x2.85x2.5 = 17.082T

This will act at a distance, 4.95+1.6-0.48-0.35/2= 5.895 m from point 'A' in Fig. 6.1

Vol. of inspection platform = 6.65x0.9x0.15 = 0.925 m³

Wt. of inspection platform = 2.312 T

Self wt of Railing = (2x0.9+6.65) x.05) = 0.433 T

S/S of (inspection+Platform) = 2.31 + 0.4325 = 2.744 T

This will act at a distance, 4.95-0.745-0.9/2 = 3.755 m from point 'A' in Fig. 6.1

Seismic Loads:

Design Horizontal Seismic Coefficient α_h $= \beta \times I \times \alpha_0$

$= 1.2*1.5*0.04$ $= 0.072\ T/m^2$

ON ABUTMENT CAP

3 ON ABUTMENT CAP:

Horizontal Seismic Force = 0.072x36.142

Distance of C.G. of Abut. Cap from B/O of Abut. Cap =0.9/2

This will act at RL 0.45 + 438.838 = RL

ON ABUTMENT

Horizontal Seismic Force = 0.072 x 45.48 =

Distance of C.G. of Abut. from Base of Abut. = (438.838 - 437.178) /2

This will act at RL 0.830 + 437.178 = RL

Forces due to earth pressure:

(Refer Cl: 5.7.1 of IRS Sub structure & foundation code)

Ø= 30, I= 0, α= 0
δ= 10, γ= 1.80 T/m³,
L= 6.85, H= 4.922

$$K_a = \frac{\cos^2(\phi - \alpha)}{\cos^2\alpha \cdot \cos(\alpha + \delta)\left(1 + \sqrt{\frac{\sin(\phi + \delta) \cdot \sin(\phi - \ldots}{\cos(\alpha + \delta) \cdot \cos(\alpha \ldots}}\right)}$$

K_a = 0.3085, K_s = 0.3038

AEP at base of abutment wall = K_a g

DYNAMIC INCREMENT ON EARTH PRESSURE

(Ref Cl 5.12.6.1 of IRS Substructure & Foundation Code)

Active Earth Pressure due to Back fill

Ø= 30, I =0, 0,
δ= 10,
α_h =0.072, α_v =0.036

For +ve α_v: λ = tan⁻¹ α_h / 1+α_v = 0.0694 radian = 3.976 degrees
For -ve α_v: λ = tan⁻¹ α_h / 1+α_v = 0.0746 radian = 4.271 degrees

CALCULATION OF LOAD & MOMENT AND LOAD & MOMENT COMBINATIONS

All the calculated loads & their moments about centre line (CL) of pile cap base (acting at a distance from 'A' in Fig: 6.1) have been calculated and shown in Tabular form, Table 6.2(A) for Vertical Load and Table 6.2(B) for Longitudinal and Transverse Load.

The summary of all forces and moments which are calculated from Table 6.3(A), Table 6.3(B) and Table 6.3(C) at pile cap base are presented in Table 6.4.

TABLE NO – 6.2(A) SUMMARY OF LOADS & MOMENTS AT C/L OF PILE CAP BASE

Bottom of pile cap level = 426.488 m		Vertical load (Tonnes)	Dist. from 'A'	Lever arm		Longitudinal Moment		Trans. Mom. for LL load
1	2							
1	Dead Load							
1.1	DL Superstructure	126.000	6.260	6.150	-0.87	-81.38		
1.2	DL SIDL	60.783	6.260	6.150	-0.87	-52.88		
1.3	DL Abutment Cap	36.142	5.376	6.150	-0.77	-27.92		
1.4	DL Dirt Wall	17.682	5.886	6.150	-0.28	-4.38		
1.5	DL Abutment	45.464	5.750	6.150	-0.40	-18.19		
1.6	DL wing wall	10.287	7.626	6.150	1.36	17.98		
1.7	DL Pile Cap	461.848	6.150	6.150	0.00	0.00		
2	Live Load							
2.1	LL Longer span loaded	116.338	5.260	6.150	-0.87	-101.21	3.100	11.834
2.1.1	Tractive/Braking Force							
2.2	50% LL Longer span loaded	58.169	5.260	6.150	-0.87	-50.61	3.100	5.917
2.2.1	Tractive/Braking Force							
2.3	Foot Path Live Load							
2.3.1	FPLL Longer span loaded	5.492	5.260	6.150	-0.87	-4.78		
2.3.2	60% FPLL Longer span loaded	2.746	5.260	6.150	-0.87	-2.39		
3	Active Earth pressure force							
3.1	Back fill earth							
3.1.1	On abutment							
3.1.2	On pile cap							
3.2	Due to DL & LL Surcharge							
3.2.1	On abutment							
3.2.2	On pile cap							
4	Vertical load due to Earth							
4.1	Due to backfill on pile cap	443.221	9.425	6.150	3.28	1451.49		
4.2	Due to DL & LL surcharge on pile cap	144.993	9.425	6.150	3.28	474.79		
5	Seismic Forces							
5.1	Longitudinal Seismic Forces							
5.1.1	Superstructure - DL	3.780	5.260	6.150	-0.87	-3.29		
5.1.2	SIDL - DL	2.187	5.260	6.150	-0.87	-1.90		
5.1.3	Abutment Cap	1.881	5.376	6.150	-0.77	-1.61		
5.1.4	Dirt wall	0.818	5.886	6.150	-0.26	-0.18		
5.1.5	Abutment	1.637	5.750	6.150	-0.40	-0.66		
5.1.6	Wing wall	0.470	7.626	6.150	1.36	0.68		
5.1.7	Pile cap	17.336	6.150	6.150	0.00	0.00		

5.2	Transverse Seismic Forces										
5.2.1	Superstructure - DL						7.560	441.088	5.672	42.883	42.883
5.2.2	SIDL - DL						4.375	442.768	7.410	32.418	32.418
5.2.3	Abutment Cap						2.602	439.288	3.910	10.175	10.175
5.2.4	Dirt wall						1.230	445.263	4.666	6.008	6.008
5.2.5	Abutment						3.275	438.008	2.630	8.613	8.613
5.2.6	Wing wall						0.941	441.288	5.910	5.583	5.583
5.2.7	Pile cap						34.671				
								439.278	0.900	31.204	31.204
5.2.8	50% LL Longer(one) span loaded						4.183	448.463	10.085	42.237	42.237
5.2.9	50% FPLL Longer span loaded						0.395	440.000	4.622	1.826	1.826
6	Dynamic increment of Earth pressure										
6.1.1	Due to AEP on abutment	8.959	438.639	-4.251	-38.176	-38.176					
6.1.2	Due to AEP on pile cap	9.845	426.739	-3.351	-33.088	-33.088					
6.2.1	Due to DL & LL surcharge on abutment	12.830	440.469	-5.081	-65.196	-65.196					
6.2.2	Due to DL & LL surcharge on pile cap	41.213	426.889	-4.491	-184.888	-184.888					
5	Wind Forces										
5.1	On Superstructure						3.112	441.088	5.672	17.652	17.652
5.2	On LL Longer span loaded						6.150	448.463	10.585	62.028	62.028

	abutment					
	AEP due to DL & LL surcharge on pile cap	58.362	1.7	1	99.215	58.362
	Due to Longitudinal Seismic Forces up					
	Superstructure - DL					
	SIDL - DL	7.560	1.25	1	9.450	7.560
	Abutment Cap	4.375	2	1.2	8.750	5.250
	Dirt wall	2.602	1.25	1	3.253	2.602
	Abutment	1.230	1.25	1	1.537	1.230
	Wing wall	3.275	1.25	1	4.094	3.275
	Pile cap	0.941	1.25	1	1.176	0.941
	Due to Dynamic increment of Earth pressure	34.671	1.25	1	43.339	34.671
	AEP on abutment					
	AEP on pile cap					
	AEP due to DL & LL surcharge on abutment					
	AEP due to DL & LL surcharge on pile cap	8.959	1.7	1	15.231	8.959
		9.845	1.7	1	16.736	9.845
	Total Longitudinal Force (HL)	12.830	1.7	1	21.812	12.830
	Horizontal Force in Transverse Direction = HT					
	FPLL Longer span 50% loaded	41.213	1.7	1	70.062	41.213
	Total Transverse Force (HT)					
					561.051	346.750
5						
		2.746	1.4	1	3.845	2.746
					3.845	2.746

TABLE NO - 6.4 SUMMARY OF FORCES & MOMENTS AT PILE CAP BASE

DESCRIPTION	Normal case	Normal case with + Long Seismic +Vert. Seismic up	Normal case with + Tran Seismic +Vert. Seismic up
	Case 1	Case 2	Case 3
A. ULS CONDITION			
V(T)	2207.50	2043.78	2040.58
ML (T - m)	1198.93	1097.88	1492.14
MT (T - m)	64.79	25.91	282.99
MR (T - m)	1200.68	1098.19	1518.74
HL (T)	404.975	61.05	365.61
HT (T)	9.61	3.84	81.86
B. SLS CONDITION			
V(T)	1493.41	1392.55	1390.26
ML (T - m)	651.52	611.94	819.06
MT (T - m)	40.72	18.51	205.92
MR (T - m)	652.79	612.22	844.55
HL (T)	240.86	346.75	218.37
HT (T)	6.04	2.75	62.86

DESIGN OF PILE FOUNDATION

1. Length of pile cap along Longitudinal direction = 12.3 m
2. Length of pile cap along transverse direction = 8.7 m
3. Thickness of pile cap = 1.8 m
4. Diameter of Pile = 1.2 m
5. Total No. of piles in the pile cap = 12 nos.

Levels

1. Top of pile cap = 437.178 m
2. Pile Cut off level = 435.428 m
3. Bottom of pile cap = 435.378 m
4. Pile fixity level = 421.079 m
5. Founding level = 416.878 m

PILE REACTION FOR DIFFERENT CASES

Table No: 6.6 ULS Condition –Summary of Forces & moments at Pile cap base

Description	Normal case	Normal case with + Long Seismic +Vert. Seismic up	Normal case with + Tran Seismic +Vert. Seismic up
	Case - 1	Case - 2	Case - 3
V(T)	2207.502	2043.784	2040.575
ML (T - m)	1198.933	1097.882	1492.141
MT (T - m)	64.786	25.915	282.991
MR (T - m)	1200.682	1098.187	1518.739
HL (T)	404.972	561.051	365.613
HT (T)	9.612	3.846	81.860
HR (T)	405.086	561.064	374.665

P10	119.832	111.022	115.421
P11	131.897	122.355	130.589
P12	143.962	133.687	145.756
Max. Value	143.962	133.687	145.756
Min. value	104.939	98.405	85.953
Self wt. of pile			
upto fixity level Max. value with self wt. of	24.258	24.258	24.258
pile. Min. value with self wt. of pile.	168.220	157.945	170.014
HR (T)	129.197	122.662	110.211
	20.078	28.897	18.937

Pile Reaction

Vertical load on each pile P1 = (V / Σ n) + (ML x X_i / Σ X_i2) + (MT x y_i / Σ y_i2)

HR = HR / Σn

Using above formula, Pile Reaction for 3 cases in SLS condition i.e., Table No: Table No: 6.8 derived from Table No: 6.4 has been worked out and presented in Table No: 6.9 below

Table No: 6.9 SLS Condition –Pile Reaction for Three cases

Pile reaction (T)	Case - 1	Case - 2	Case - 3
P1	104.939	98.405	85.953
P2	117.004	109.737	101.121
P3	129.069	121.069	116.289
P4	141.135	132.401	131.457
P5	106.353	99.047	93.103
P6	118.418	110.380	108.271
P7	130.483	121.712	123.439
P8	142.548	133.044	138.607
P9	107.767	99.690	100.253

Calculation of load carrying capacity of pile (Under Abut)

Soil exploration data under A2 is only available.

Hence the same date will be used for A1.

It is observed that N-value from RL 437.283 m to RL 416.283 m is very low Weathered rock strata starts at RL 416.283m and continues up to 410.283 m.

$$Qa = Cu_1\ Nc \frac{p\ B^2}{4Fs} + \alpha Cu_2 \frac{p\ B\ L}{Fs}$$

Calculating pile head deflection

Ref. Clause C 4.2 IS 2911 (Part 1/Sec 2) : 2010 Page 16

For fixed head pile –

$$\text{deflection } y = \frac{H\ (e + Zf)^3}{12\ EI} \times 10^3$$

H = Lateral load = 52.371T, Load Case V with seismic,

e = Cantilever length of pile = 332.1 cm,

Zf = Depth to point of fixity = 692 cm,

E = Young's modules of pile material = 295804 Kg/cm2

I = M.I. of material of pile = 10182857 cm4

y= (52371(332 + 692)3)/(12 x 295804 x 10182857) = 1.56 cm

= 15.6 mm < 15.96 mm, Hence OK

DESIGN OF PILE CAP

Size of Pile Cap

Pile Cap dimension along Longitudinal direction	= 12.300 m
Pile Cap dimension along Transverse direction	= 8.700 m
Pile cap depth	= 1.800 m
Pile dia.	= 1.200 m
Clear cover	= 0.075 m
Distance of extre edge of pile cap in transverse direction	= 0.925 m
ULS factor for dead wt. of pile cap	= 1.250

Abutment section at bottom, Length = 6.850 m; Width = 1.600 m

Computation for Moment

Table No: 6.10 ULS - Summary of Pile Reactions – Case -01

P9	152.90	P10	175.11	P11	197.31	P12	219.51
P5	150.65	P6	172.86	P7	195.06	P8	217.26
P1	148.41	P2	170.61	P3	192.81	P4	215.01

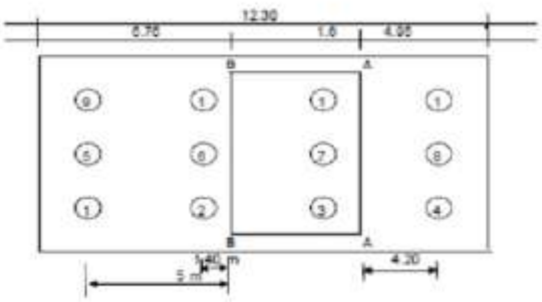

Figure: 6.3 Critical Section of Piles for Computing Moments

Since, A_{st} provided > A_{st} required, The section is safe in Shear

Computation of Two way Shear/Punching Shear

The critical section breadth calculated as per Figure 6.4

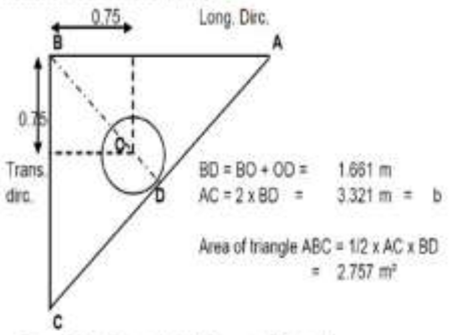

Figure 6.4 Critical Section of Pile for Computing Punching Shear

Data

Pile dia	= 1.2 m
Max. reaction on pile	= 221.3 T
Depth of pile cap	= 1.8 m
Wt. of concrete	= 2.5 t/m³

CALCULATION OF MOMENTS AND LOAD & MOMENT COMBINATIONS

All the calculated loads & their moments about centre line (CL) of Abutment base (RL Bottom level of abutment = 437.178 m) has been calculated and shown in Tabular form, Table 6.15(A) for Vertical Load and Table 6.15(B) for Longitudinal and Transverse Load.

Combination of these loads and moments about pile cap base for Ultimate Limit State (ULS) Design and Serviceability Limit State (SLS) Design with appropriate Partial Safety Factors for three Cases have been considered and shown in Table 6.16(A), Table 6.16(B) and Table 6.16(C)

Table No: 6.15(A) SUMMARY OF LOADS & MOMENTS AT C/L OF ABUTMENT BASE

Bottom level of abutment = 437.178 m

Sl No	Description of load	VERTICAL LOAD: Vertical load	Acting at a distance from 'A' in Fig: 6.1	Distance of CG of abutment from 'A' in Fig: 6.1	Lever arm	Long.mom. for vt. load	Trans. Eccn.	Trans. Mom. for vt. load
		(T)	(m)	(m)	(m)	(t-m)	eT (m)	(t-m)
1	2	3	4	5	6	7	8	9
1	Dead Load							
1.1	DL supstrucutre							
1.2	DL SIDL	105.000	5.280	5.750	-0.47	-49.35		
1.3	DL Abutment Cap	60.762	5.280	5.750	-0.47	-28.56		
1.4	DL dirt Cap	36.142	5.378	5.750	-0.37	-13.46		
1.5	DL Abutment	17.082	5.895	5.750	0.15	2.48		
1.6	DL wing wall	45.484	5.750	5.750	0.00	0.00		
2	Live Load	13.067	7.526	5.750	1.78	23.20		
2.1	LL Longer span loaded							
2.1.1	Tractive/Braking Force							
2.2	50% LL Longer span loaded							
2.2.1	Tractive/Braking Force	116.335	5.280	5.750	-0.47	-54.68	0.100	11.634
2.3	Foot Path Live Load							
2.3.1	FPLL Longer span loaded							
2.3.2	50% FPLL Longer span loaded	58.168	5.280	5.750	-0.47	-27.34	0.100	5.817
3	Active Earth pressure force							
		5.493	5.280	5.750	-0.47	-2.58		
		2.746	5.280	5.750	-0.47	-1.29		

Table No: 6.17 SUMMARY OF FORCES & MOMENTS AT ABUTMENT BASE

DESCRIPTION	Normal case	Normal case with + Long Seismic +Vert. Seismic up	Normal case with + Tran Seismic +Vert. Seismic up
	Case 1	Case 2	Case 3
		A. ULS CONDITION	
V(T)	605.69	463.64	460.43
ML (T-m)	-887.13	-861.05	-819.47
MT (T-m)	47.48	18.99	174.65
MR (T-m)	888.40	861.26	837.87
HL (T)	219.70	245.64	180.34
HT (T)	9.61	2.75	38.52
		B. SLS CONDITION	
V(T)	423.70	340.17	337.88
ML (T-m)	-533.35	-521.63	-506.93
MT (T-m)	29.85	13.57	123.97
MR (T-m)	534.19	521.81	521.87
HL (T)	131.88	152.04	109.39
HT (T)	6.04	2.75	28.19

DESIGN OF ABUTMENT

The moment which are acting along abutment are shown in Figure: 6.5

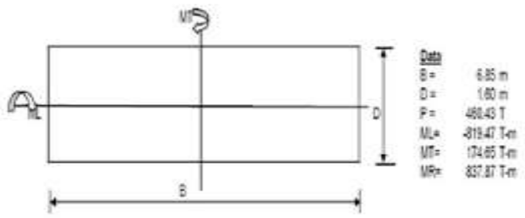

Figure: 6.5 Longitudinal and transverse moment Representation

Ac = B x D = 6.85 x 1.60 = 10.96 sq.m

Maximum Ultimate axial compressive Load , P_{max} = 460.43 T

0.10 x f_{ck} x A_c = 0.1 x 35 x 10.96 x 100 = 3836 T > 460.43 T

Since the Ultimate axial load is less than 0.1fck Ac, abutment can be designed as Cantilever slab and design will be done as per Cl. 14.4.2.1.2 of IRS: Concrete Bridge Code.

Resultant moment MR = 837.87 T-m

Design moment per unit width = 837.87 / 6.85 = 122 T-m/m

CONCLUSIONS & FUTURE SCOPE

The following steps were followed for the above presentation:

- Site investigation of the bridge location

i) Topographic survey for the stream and railway

ii) Geotechnical investigation for sub soil exploration at each support location.

- Data collection (Rainfall, HFL, Topographic sheets etc) from concerned department.
- Structural design and analysis.

i) Super structure: IRS – Bridge Rules and IRS-Concrete Bridge Rules are taken for analyzing the Bending Moments and Shear Forces and the following observations were made:

a) The maximum bending moment valves are observed in Normal case with Transverse Seismic & Vertical Seismic up load combination i.e., CASE-3 is taken for design in both ULS and SLS conditions.

ii) Sub structure: Manual analysis is carried out for design of Piles as per IS: 2911 and IRS provisions in relevant codes.

- Drawings are prepared based on the above results and are to be used for construction of the bridge.
- The above bridge design i.e., 3 span of 18.3 m span consisting of 2 piers (P1, P2), 1 Abutment (A1) which are partly submerged in water and 1 Abutment (A2) not being affected by flood was designed and detailed drawing done satisfactorily.
- It will take all the necessary Loads and Effects as prescribed in codes and design is done in accordance with it.
- The drawings were drawn based upon this design and they are good for construction.
- The design was made to Abutment (A1) only and same is followed to A2 as it is at higher level
- The bridge was completely designed and detailed drawing was also prepared incl. sub structure and superstructure, but presenting the design in this thesis will become cumbersome viz., part of it is submitted

FUTURE SCOPE

1. After designing it was found that much of "material strength" is not utilized to full extent as sections are provided in additional. But due to advancement in the technology, we can do rigorous analysis quite easily and save material and constructional time.

2. Using Advnaced analysis programs like ANSYS, using FEM we can find the stresses at any point and thereby "Optimization" can be done by using 2 or more variables with as many as parameters.
3. The analysis i.e., Bending Moment, Shear Forces, etc. part are done according to code values, if done by Model Analysis better designs could be developed.
4. By FEM programs we can evaluate the stress variation quite easily and same is used for design of shape, thus saving material rather following standard tables.

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