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## DEEP FOUNDATION CONSTRUCTION IN BOULDERY BED AN OVER VIEW

BY

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### ABSTRACT

Deep foundation has been used for number of bridge piers in various parts of the world. Construction of deep foundation in case of sandy soil strata is a very easy task however to construct deep foundation in case of bouldery bed is really a challenge for bridge engineers. There are number of cases where this type of foundation has used in the form of caisson of different shapes and it has posed a challenge to bridge engineer due to heterogeneous character of the soil strata underneath. Deep foundations in such strata have been completed using pneumatic sinking based on the site requirements. A case study of a deep foundation construction on bridges over bouldery bed strata has been discussed in this paper.

**Key words:** Caisson, foundation, soil strata, sinking, soil properties, anchoring of foundation

### INTRODUCTION

1. Foundation design and construction in bouldery bed has its own challenges firstly due to none availability of any reliable formula for bouldery bed scour and sinking problem there on due to tough strata. Normally difficulties are faced when the depth is initially finalised with Indian road congress : 78 code formula method and revision is planned based on tough strata. As the revision involved sizable financial affect on either side, need has been felt to finalised depth in such strata based on greater examination. Foundation depth be finalised keeping in view the construction technique available viz, safety and stability requirement. Infact in case variation in strata is encountered it should be considered accordingly and revision on either side be considered. Also the tough strata be considered engineering friendly in different soil condition, which are mostly on bouldery bed. When ever there is change in properties of the soil the design be amended accordingly for completion of final sinking as per the design requirement, Pneumatic sinking has also been used at various bridges. Based on the experience two bridges with deep foundation on bouldery bed strata has been discussed in this paper.

### CAISSON FOUNDATION AN OUR VIEW

2. Correct assessment of scour is key task for the over all safety of the bridge. Normally no tension is permitted at the base of caisson foundation as per codal guidelines. In case the soil strata is comprises of rock underneath the caisson is sunk into rock and rock level is assumed as scour level, design is finalised based on the codal provisions. However, in case of rock 20% tension is permitted if need arises and caisson is suitably anchored with the rock as per codal provisions. Normally when deeper depths are anticipated and soil strata is also possible to excavate. , Caisson foundation are used to ensure design and hydraulic requirement. Shape of caisson can be square, circular, double D depending upon the site requirement and construction methodology available in the area. Circular caisson foundation is preferred. Foundations are taken to a sufficient level below the maximum scour level to satisfy design and stability requirement of caisson. However during the process of sinking if change in strata is observed, an action is taken according to engineering

consideration and economics of the design. There are cases in caisson foundation where based on the difficulties faced for sinking the caisson, pneumatic sinking technique has been used to expedite the process of sinking. In fact the pneumatic sinking is used when the soil strata is tougher and is not possible to excavate with conventional sinking arrangement.

### ESSENCE OF DESIGN PARAMETERS

3. Design parameters to be considered for foundation are hydraulic and soil parameters. Stratification of soil underneath plays key role in finalising the design and expediting the construction of foundation. Hydraulic parameters are discharge, velocity, bed slope and soil properties are silt factor, bulk density, angle of internal friction, angle of wall friction and cohesion which are assessed based on geological condition of the strata. On finalisation this data, foundation levels are decided. Correct assessment of scour in soil is very important and the same is decided with the help of available formula followed by judicious judgment and if required model study is also carried out to assess the likely scour during the service life of the bridge. This will have vital bearing on completion and serviceability of the bridge at later date. Case study of two bridges has are as under.

### DIMWE BRIDGE

4. Dimwe bridge is located in North East part of the India and span arrangement of this bridge is two spans of length 65.5 and 22.8 respectively. Central pier is on caisson foundation in the main channel of the river and both the abutments are on open foundation. Construction of the bridge took more time than the planned period which include delay due to logistic reasons and channel problems working period was also very less and to high rainfall and unprecedented flood. Salient feature of the bridge are as under :-

- (i) Total length of bridge : 87.30m (65.50 + 22.50)
- (ii) Type of structure : Simply supported
- (iii) Velocity : 5 m/sec
- (iv) Design HFL : RL 238 m
- (v) Vertical clearance : 8.5 m
- (vi) Maximum scour level : RL 222.0 m
- (vii) River Bed Level : RL 232.00 m
- (viii) Foundation Level : RL 207.00 m
- (ix) Silt Factor : 1.4
- (x) Design Parameters
  - (a) Coefficient of lateral friction : 30°

- (b) Angle of wall friction : 20°
- (c) Bulk density of soil : 1.8t/cum
- (d) Submerged weight of soil : 0.8 t/cum
- (e) Buoyancy : 100%
- (f) Cutting edge placed RL : 232.00 m
- (g) Sump below cutting edge on date : 1.5 m
- (h) Top RL of steining : RL 237.425 m
- (i) Tilt along alignment : 1 in 300
- (j) Tilt along transverse : 1 in 200

4.2 Work on this bridge started smoothly. Sinking of caisson from RL 237.45 to RL 224.00 was through loose boulders embedded in silty/sandy matrix. Below RL 224.00 to RL 222.59 m rock was moderately hard closely spaced lightly jointed and represented by feebly weathered strained banded quartz, grandiorite, gneisses. Fresh rock occurred below RL 222.59 to RL 219.00 m. Rock was traversed by falling prominent sets of joints viz (D-1).

- (a) N 30 E S 53 W Dipping vertical
- (b) N 70 E S 57 E Dipping 60 on NE
- (c) Transverse joints N 20 E, S 20 W sub vertical.

4.3. Besides The two parallel gougy seam of 8 to 9 cm thick striking NE-SW dipping SE were recorded. The intersection of different joints was deloping cubical block which were blocked to crushed rock but there were no evidence of crushing. Geologist recommended that anchoring should be provided for the depth of 3 to 5 mtr in the direction perpendicular to the bending plane (D2). The foundation RL 219.00 consisting of fresh hard quartz, granodiorite, gneiss is lies within the permissible limit.

### CONSTRUCTION PROBLEMS

- 4.4. (a) Due to tough strata the sinking of caisson became very difficult due to large size of boulders and led to slow down the over all progress of the bridge.
- (b) Basically there are difficulties of finally deciding the foundation level on such strata and this put the decision making body into dilemma and led to delay in progress.

### DALAI BRIDGE

5. Dalai bridge is of total length is 129.65 mtrs prestressed concrete bridge and is also located North East part of India. Both the piers are resting on well foundations are in the main channel of the river and both the abutments are on open foundations. Salient features of the bridge are as under :-

- (i) Span - 129.65m  
(69.52m + 45.12m + 15.00m)
- (ii) Deck Level (RL) - RL 35.60m
- (iii) HFL (RL) - RL 29.60m
- (iv) LWL (RL) - RL 23.20m
- (v) Velocity - RL 8.83 M/Sec
- (vi) Discharge - 5714 M<sup>3</sup>/Sec
- (vii) Silt Factor (taken for design) - 9
- (viii) Maximum Scour Level - RL 11.90m
- (ix) Foundation Level (Final)
  - A1 (RL) - RL 29.00m
  - P1 (RL) - RL (-) 3.400m
  - P2 (RL) - RL 6.000m
  - A2 (RL) - RL 29.00m
- (x) Dia of circular well
  - P1 - 12.00 m
  - P2 - 9.00 m

### CONSTRUCTION OF CAISSON FOUNDATION

5.1. Work was started as per approved bridge scheme. Both the abutments A1 & A2 are open foundation and piers P1 & P2 are on the caisson foundation. Initial sinking was started on both the caisson locations with conventional sinking only. There was no problem in construction of both the abutment and both were completed up to designed RLs. However in case o caisson foundation sinking difficulties were faced. Accordingly after reaching RL 18.300m in case of P1, sinking difficulty was faced due tough strata. However, case was examined in greater details in term of cost aspects and further efforts were made with open grabbing. On further examining difficulties faced on cost and time aspect, the pneumatic sinking was used and work was restarted accordingly. The scope of work for sinking was also examined in terms of tough strata which was considered to be less scourable and revised RL of foundation were also given to utilise the available strata in a better way (tough strata considered as technically stronger). Pneumatic sinking at this location was started from RL 18.300m. Soil strata details encountered were kept. After reaching at RL 12.000m, there was problem in sinking the foundation specially for excavating the strata even in pneumatic condition. A close watch was kept for soil strata and SBC got checked at RL 7.490m which was found out in order and plugging was done at this RL since the soil strata

was tough, blasting was resorted to and approximately 1.50 tones gelatin was used while sinking the wells. Details of various RLs for foundation are as under:-

S No	Description	A1 (RL)	P1 (RL)	P2 (RL)	A2 (RL)
1	NIT FL	29.00	(-) 3.40	6.00	29.00
2	Design FL	29.00	(-) 12.00	2.10	--
3	First Revision	--	6.00	(+) 8.00	--
4	Final FL	29.00	7.49	11.50	29.00

### STRATA REPORT OF EXCAVATED MATERIALS : P1 WELL

Sl	Date	Sample collected at RL	Distribution by percentage	Remark
1	04 Feb 98	19.56	(a) Boulder :- (i) size 1000 to 2000 mm - 10% (ii) size 500 to 1000 mm - 25% (iii) size upto 500 mm - 25% (b) Sand & Gravel - 40%	
2	07 Mar 98	16.90	(a) Boulder :- (i) size 1000 to 3000 mm - 15% (ii) size 500 to 1000 mm - 30% (iii) size upto 500 mm - 30% (b) Sand & Gravel - 25%	
3	31 Mar 98	15.47	(a) Boulder :- (i) size 1m x 2 m - 25% (ii) size 0.5 m x 1 m - 25% (iii) size upto 0.5 m - 30% (b) Sand & shingle - 20%	Width 20 to 50 cm
4	21 Apr 98	14.50	(a) Boulder :- (i) size 1m x 2 m - 25%	Width varying from

			(ii) size 0.5 m x 1 m - 23% (iii) size upto 0.5 m - 32% (b) Sand & shingle - 20%	20 to 50 cm
5	19 May 98	13.50	(a) Boulder :- (i) size 1m x 1.5 m - 20% (ii) size 1m x 0.8m - 22% (iii) size 0.8mx0.5m - 23% (iv) size below 0.5 m - 12% (b) Sand & shingle - 23%	

Efforts made for pneumatic sinking plant viz-a-viz output are as under :-

**EFFORTS IN PNEUMATIC SINKING FROM APR 1998 TO FEB 1999 : WELL P1**

Month	Man Power		Explosive consumed		Sinking achieved (Mtrs)
	Sup	Labour	Gel Kg	E/D Nos	
Apr 98	145	2426	85.78	587	1.310
May 98	114	2007	44.59	334	1.035
Jun 98	65	1109	13.13	58	0.100
Jul 98	102	1561	58.98	266	0.680
Aug 98	57	1918	46.44	255	0.785
Sep 98	102	1578	29.42	154	0
Oct 98	66	768	11.46	60	0.220
Nov 98	96	1234	23.72	170	0.150
Dec 98	116	1884	43.12	424	0.160
Jan 99	98	1850	21.14	130	0.280
*Feb 99	69	1330	14.17	102	0.400

1030      17665      391.95      2540      5.120

**TOTAL**

\* Present cutting edge RL 10.250m

(a) The soil strata plan at RL 7.50 is indicated in Fig.(D3).

(b) Well Curb was anchored with the ground with anchor bar as indicated in sketch. Fig (D4).

**RECOMMENDATIONS**

6. All the bridge schemes be planned based on the construction method planned or equipment/plant to be deployed. With the past experience and to overcome the delay the variation in strata is given due consideration keeping in view of the safety and serviceability requirement of the structure. However the following points be given due consideration while planning bridges in bouldery bed.

(a) Bridge scheme be finalized based on idealization of the pros and con of the data and guidelines exists. Also the numbers of foundation be so decided that there is less sinking efforts involved considering other factors.

(b) Construction difficulties be given greater attention from execution point of view.

(c) Change in soil strata properties be considered or examined with due consideration.

(d) Since there is no formula for finalization of scour depth in boulder bed, efforts should be made to co-relate system based on the statistical approach and for this data of existing bridge be collected and same be analyzed.

(e) Sinking should be done in a systematic way to avoid the over tilting of any structure.

**CONCLUSION**

7. Numbers of bridges has been made on bouldery bed and a few bridges led to delay in completion due to foundation problems. There is need to review the soil strata based on the pragmatic approach keeping in view the requirement of design

of bridge. Documentation of experience of the past bridges on bouldery bed is very-very helpful for caisson foundation design and construction of a bouldery bed. Soil strata record should be kept systematically.

**References :**

(a) Dhiman RK & DK Mohapatra [2000] 'Construction Challenge of Bridges in Hilly Terrain – A Practical Review' Indian Institution of Bridge Engineering National Seminar – 2000, New Delhi

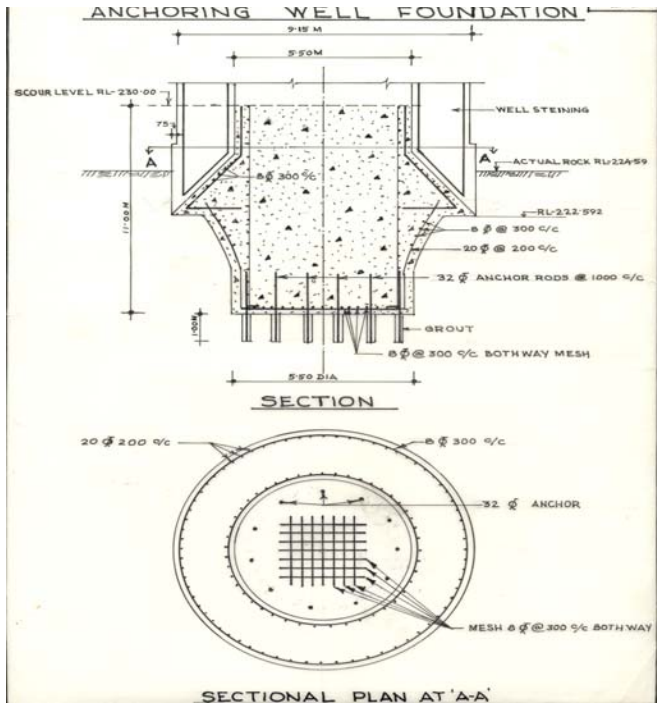


Figure : D1

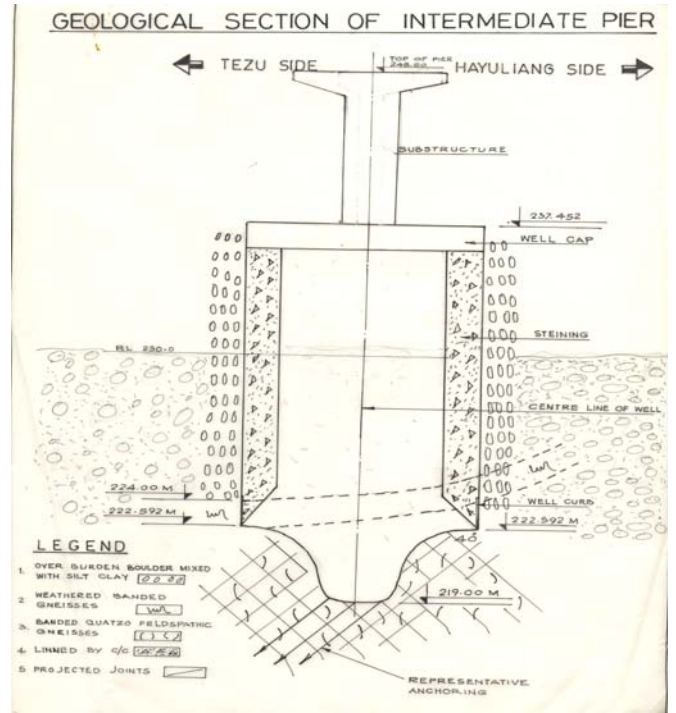


Figure : D2

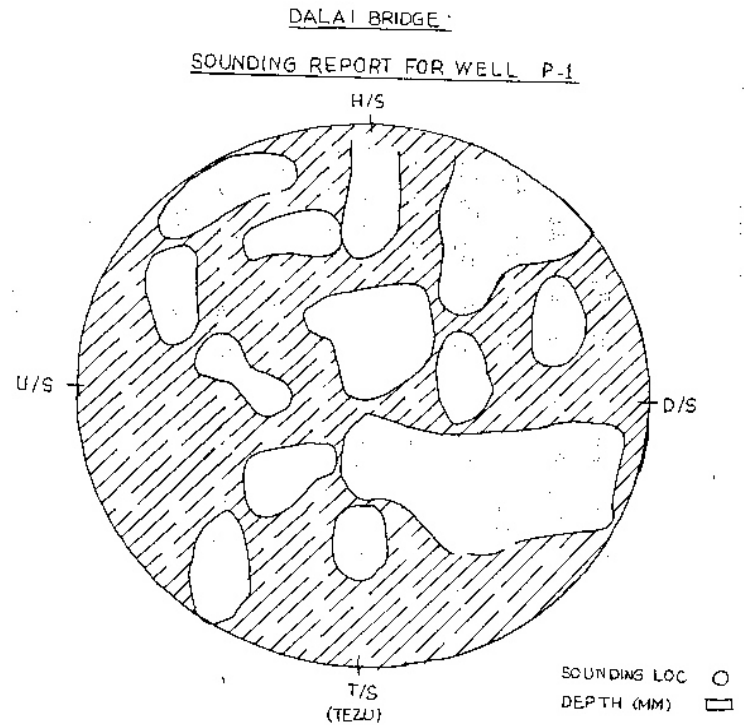


Figure : D3

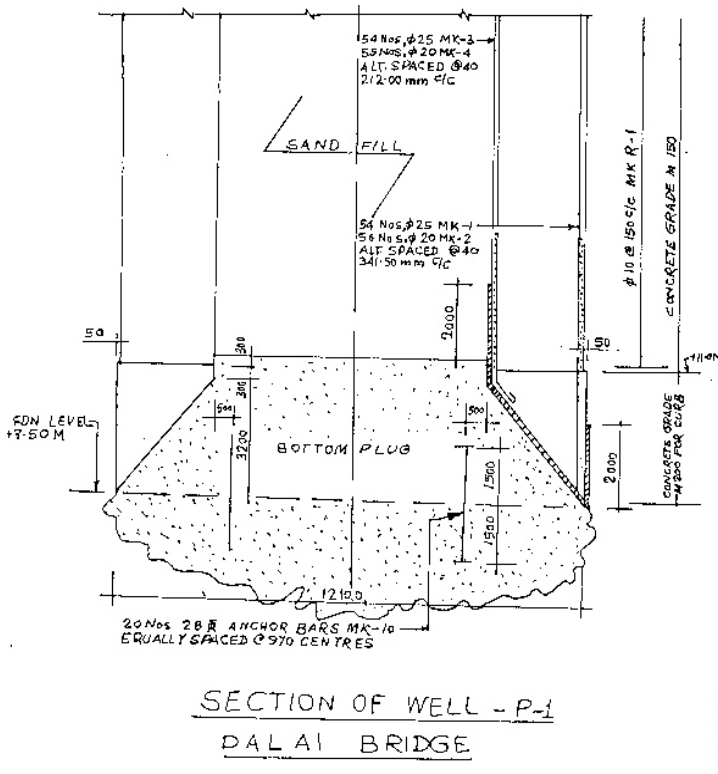


Figure : D4