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Effect Of Variation In Geotechnical Data On Stability Of Well Foundation

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Abstract
One of the major thrust areas in bridge development in future will be the strengthening of weak bridges and rehabilitation of distressed bridges. Attention in the next few decades needs to be focused on preservation and rational management of large stock of bridges built in the past.This paper enumerates a submersible bridge showing sign of distress after five years of its completion. Subsequent investigations have shown that the bridge distress is related to large settlement of well foundation at particular location. Comparison of geotechnical parameter obtained from pre design geotechnical investigation and actual strata obtained during the sinking of well at that location suggests that the size of sand particle in original investigation is significantly more than size of sand particle encounter during sinking operation. Because of this silt factor was overestimated and the scour depth which is inversely proportional to silt factor was underestimated. To get more grip length and adequate lateral stability well at particular location has settled.

Introduction

Movement of bridge supports can affect all aspects of bridge performance, from visual appearance to vehicle ride quality, and in extreme cases can affect the structural integrity of the bridge. The main design aspects of well foundation are the design of grip length, steining thickness, curb and bottom plug. A well foundation should be sunk below the maximum scour depth, such that there is adequate lateral stability, and this embedded length is called the grip length. Grip length is required for developing sufficient passive resistance to counteract the overturning moment due to horizontal force at well top. Other criterion is that the well should be taken deep enough to rest on strata of adequate bearing capacity in relation to the force being transmitted.

The Bridge

The bridge under consideration is a submersible, balance cantilever deck type bridge with thirteen spans. A number of submersible bridges were constructed in central India. This bridge deviate substantially from the sound practices of submersible bridge as per IRC SP 82 in two principle matters, first permitting suspended span which is likely to be uprooted during floods and the second is the sharp corners which are likely to be damaged during submergence. Because of the floods and the carbonations there will be a lot of damages. The bridge may not get seriously damaged on this account but durability will be affected. Following are the details of Bridge

Table 1

Length and Width	450 m, width 8.4 m.
Span	2 spans of 19.025 m. + 11 spans 37.450 m.
No of piers	12
Type of pier deck	Rigid Frame structure with two wall type Piers(4.5m c/c) on well cap & small suspended span(3.7m) supported on Cantilever deck(16.85m) on both sides of pier. Wall type pier are 400 mm thick 7 m high with rigidly connected box over it (PSC Box type of deck) Figure 6
Formation Level:	R.L. 98.500
Well cap top	R.L. 88.900
Well Foundation Level	R.L. 63.650
H.F.L.	R.L. 103.500
Foundation type	Single circular well

Observations

Detailed observations of the said Bridge were carried out along with the Assistant engineer in charge. Following observations were made

1. The bridge consists of rigid frame structure with two wall type Piers on well cap & small suspended span (solid slab) supported on Cantilever deck (PSC Box type) on both sides of pier. Wall type pier were rigidly connected with box over it (PSC Box type of deck) Figure1& Figure 6.

2. The bridge when observed as a whole showed that out of 13 spans, the suspended spans (second and third suspended spans) supported on cantilever from pier unit p10 disturbed.

3. Affected second and third suspended span were critically observed. It is supported on the end of the cantilever span from pier unit P10. Cantilever span is prestressed concrete box span. The cantilever prestressed concrete deck rigidly connected with the two wall type piers unit P10 spaced at 4.5 m centre to centre and cantilevered on both sides (figure 6 & Figure1).

4. Levels were taken at both the ends of second and third suspended span. For both the suspended span deflection was 11cm Figure 7, Figure 4 and 5.

5. As there were no difference in levels along the width of suspended span, tilting of well

can be ruled out and deflection of suspended span is due to settlement of substructure only.

6. Suspended span supported on cantilever is 3.7m solid slab type.

7. Three PTFE bearings are provided in the width at each end of suspended span (Figure2). To prevent displacement of the suspended span due to submergence two vertical RCC posts are erected at the end of box structure.

8. It was observed that the vertical post has come out 50 mm. beyond the end of the cross girder on which it is supporting (Figure3). This may be due to improper workmanship Figure3.

9. There are depressions and honey combs in the surface of concrete. A large chunk of concrete was found loosely placed on the surface of cantilever span Figure2. This was removed, the surface of concrete was not of proper quality.

10. The corners of the cross girders and the box type deck are not chamfered and streamlined. The corners of the wall type pier are chamfered but not rounded as is usually provided for piers. Thus a lack of stream lining at corners of the two wall type piers exist in this submersible structure. All these corners may not stand the fury of floods during submergence and they are likely to get damage during submergence. The bridge is going to be submerged by 5 m. during high floods.

11. The deck appears to have been cast not true to the approved drawing. This appears to be at defect in workmanship. The bridge is completed 5 years ago but the full traffic is not allowed as yet.

12. Expansion joints are provided of angle and plate type (Open type of joints). The alignment of bridge was not given properly during construction. So many deviations are observed in the alignment.

Subsoil investigation

Before starting the work, contractor carried out subsoil investigation at all the well locations as proposed by his Consultants. The bore data contain in the departmental file shows brown coarse sand mixed with boulder (Annexure I). But the actual strata encountered during sinking of well was only fine sand at well for pier p10. design consultant was also reported to have visited the site during construction and observed that the strata encountered was fine sand with some small quantity of large pieces of sand but not pebbles or boulders, contractor has also confirmed this.

The sample of strata of founding level of P5 & P6 sent to NIT for ascertaining the S.B.C. NIT recommended S.B.C. of 74 T/m^2. at depth of 24.25 m.

Codal provision for well foundation

Clause 2.4 of Appendix – 4 of I.R.C. – 78 page 85 states as follows " boring chart shall be referred to constantly during sinking for taking adequate care while piercing different types of strata by keeping the boring chart at the site and plotting the soil as obtained for well steining and comparing it with earlier bore data to take prompt decision.

This particular clause is applicable for the departmental Engineer as well as the contractor. No such record of comparison has been reported to be sent by the site Engineer to the design office. Design office decided the design factor on the basis of old bore data. After visiting the site and observing the settlement of one of the foundation, it is very clear that such settlement might have been avoided by properly following the codal provisions.

Causes of settlement

The newly constructed Bridge was submerged up to the top of deck during first monsoon and one of the well foundations have been settled. The maximum settlement of well no. 10 is 11 cm Figure 6. This may be due to weak soil at the founding level not capable of bearing the load or the calculated scour depth is inadequate.

As per initial bore log the strata is brown coarse sand mixed with boulder (annexure I). for this type of soil silt factor taken as 1.5 and for this value scour depth is calculated as per the clause 703.2 of IRC 78-2000. As already stated the contractor and his consultant observed fine sand during sinking of well. For such a soil silt factor will not be more than 1. In that case the scour depth will be R.L. 67.45 m. The foundation level is at R.L. 63.65 therefore the grip length is only 3.8m. This depth does not neutralize the flood movements.

This is unsafe and the well may settle on that account. Thus due to inadequate assessment of scour and the passive resistance the well is subjected to overstress and got settled by 11 cm (Figure4, 5 and 7).

Conclusion

The calculation shows that the pressure on the foundation will be more than the capacity of founding strata (annexure II) if the scour depth is more than the calculated. The passive resistance will be reduced and more pressure will come on the foundations which are likely to settle. Silt factor has to be assessed by taking bore up to depth of foundation and ascertaining sizes of particles. This is necessary. After observing the settlement of one well it is very clear that the calculations of scour depth considering the silt factor of 1.5 may be not correct for foundation P10. Hence scour depth may vary if we get different soil strata at different foundation location for same bridge. Boring chart should be constantly compare with the actual soil strata encounter during the sinking of well as scour depth is a function of silt factor which depends on type and size of bed material. This river meets another major river which is on the downstream side at the distance of 1.0 Km. The discharge of major river is much higher and the flood back water of the major river could increase the flood level in this river. During the recession of the flood the velocity at the said bridge site may increase appreciably. These effects have been properly considered by the department by increasing the calculated discharge by 50% as per codal provisions and further increase it by 50% perhaps for back water effect.

REFERENCES

1. IRC-78-2000 of Indian Road Congress
2. IRC SP 82-2008 of Indian Road Congress

ANNEXURE I

GEOTECH Z

CLIENT :- RADHESHYAM BHAKAR & CO.
EXPLORATION :- CONSTRUCTION OF SUBMERSIBLE BRIDGE ACROSS RIVER TAWA ON BANDRABHAN - SANGAKHEDA ROAD. HOSHANGABAD.
BORE HOLE NO :- P-10
FINAL DEPTH :- 31.50 M
METHOD OF BORING :- ROTARY WASH METHOD
91.150 LOCATION :- PIER NO.10
GROUND WATER LEVEL:- 2.10M
DATE OF COMMENCEMENT:- 10-01-2006
DATE OF COMPLETION :- 12-01-2006

BORELOG

DEPTH (M)	R.L. (M)	THICKNESS OF LAYER	LOG	VISUAL DESCRIPTION OF STRATA	FIELD TEST	TYPE OF SAMPLE	CORE PIECES	CORE DRILLING RECOVERY % (25, 50, 75, 100)	CORE DRILLING R.Q.D. % (25, 50, 75, 100)	REMARKS WASH WATER COLOUR
0.00	91.150									
1.50	89.650			DARK BROWNISH COARSE SILTY SAND MIX GRAVELS	SPT1 1.50 TO 2.10 M	WS1				
2.10	89.050				CMS 15 15 15 15 BLS 03 04 [illegible] N=11	SPT1				
3.00	88.150				SPT2 3.00 TO 3.60 M	WS2				
3.60	87.550				CMS 15 15 15 15 BLS 03 03 [illegible] N=8	SPT2				
4.50	86.650				SPT3 4.50 TO 5.10 M	WS3				
5.10	86.050				CMS 15 15 15 15 BLS 04 07 [illegible] N=14	SPT3				
6.00	85.150				SPT4 6.00 TO 6.60 M	WS4				
6.60	84.550				CMS 15 15 15 15 BLS 05 [illegible] N=15	SPT4				
7.50	83.650				SPT5 7.50 TO 8.10 M	WS5				
8.10	83.050				CMS 15 15 15 15 BLS 05 06 [illegible] 14 N=20	SPT5				
9.00	82.150				SPT6 9.00 TO 9.04 M	WS6				
9.04	82.110				CMS 04 BLS 50 N>50	SPT6				
10.50	80.650	10.50				DS1				
12.00	79.150			BROWNISH COARSE SAND MIX BOULDERS		DS2				
13.50	77.650					WS7				
15.00	76.150	4.50				DS3				

A:- 75 MM Ø B:- 'NX' DOUBLE TUBE CORE BARREL

LOG: GRAVEL, CLAY, WEATHERED FORMATION / SOFT ROCK, SAND, FILLING, HARD ROCK, SILT, BOULDERS

ABBRV
DS :- DISTURBED SAMPLE
WS :- WASH SAMPLE
WO :- WATER SAMPLE
UDS :- UNDISTURBED SAMPLE
CP :- CORE PIECES
SP :- SMALL PIECES
SPT :- STANDARD PENETRATION TEST
VST :- VANE SHEAR TEST

SCALE :- VER :- 1:100, HOR :- N.T.S.
DATE :- 30-01-2006
DRN BY :- RAJIV
CHKD BY :- PRASAD
REFERENCE NO- BH NO.10 RAD TAW'05

Agency :- M/s Zed Geotechnics & Const. (Geotechnical Engineers)
We Undertake :- Soil Investigation (Land & Marine), Piling/Rotary Piling, Micropiling, Drilling & Grouting, Rock Anchoring
Address :- 4/8, Kamana CHS., K. Gadgil Marg, Prabhadevi, Mumbai 400 025.
Tel.Nos:- 022-24221574, 4315305 Fax:- 91-22-24221574 Mobile:- 09821[illegible] E-mail:- zantye@hotmail.com

ANNEXURE II

a) Calculation of grip length h for fine sand

Design discharge = 19875 m^3/sec

H.F.L.(highest flood level) = 103.5 m

Normal scour depth d_m = $1.34 \times \{ (Q/L)2 / Ksf \}^{1/3}$

(clause 703.2 of IRC 78 2000) Where

Q = Design discharge

Ksf = Silt factor = 1.5 for coarse sand

= 0.5 to 0.6 for fine sand

= 0.8 to 1.25 for medium sand

Taking Ksf = 0.8
(clause703.2.2.1 of IRC 78 200)

L = Total length of bridge = 450 m

Normal scour depth d_m = 18.03 m

Maximum scour depth for pier = 2 x d_m (clause703.3of IRC 78 2000)

= 2 x 18.03= 36.1 m

Scour level = H.F.L. - maximum scour depth

= 103.5 – 36.1 = 67.45

Foundation level = R.L. 63.65

Grip length h =67.45 – 63.65 = 3.8 m

b) Calculation of Passive Moment

Earth pressure intensity at depth 'H' below formation = Kah X γ X H

Horizontal/ Shear force due to Earth pressure at depth 'H' below scour

(Pah) = (Kph-Kah)X γ X H X H /2

Passive Moment at depth 'h below scour

= ((Kph-Kah)) X γ X h X h /2) X Lever arm x D / f.o.s …………………(1)

Kph = horizontal component of passive earth pressure co-efficient

Kah = horizontal component of active earth pressure co-efficient

γ = unit weight of soil = 1t/m^2 below LWL

lever arm = 0.42 h

f.o.s. = factor of safety = 2 (IRC78 2000 appendix III)

From equation 1 Passive Moment is directly proportional to h^3 i.e. it reduces with grip length.

Photo no. 1 - settled pier P10

Photo no. 2 - Tip of cantilever span

Photo no. 3 – Protection of suspended span

Photo no. 4 - Deflected suspended span on right side

Photo no. 5 - Deflected suspended span on left side

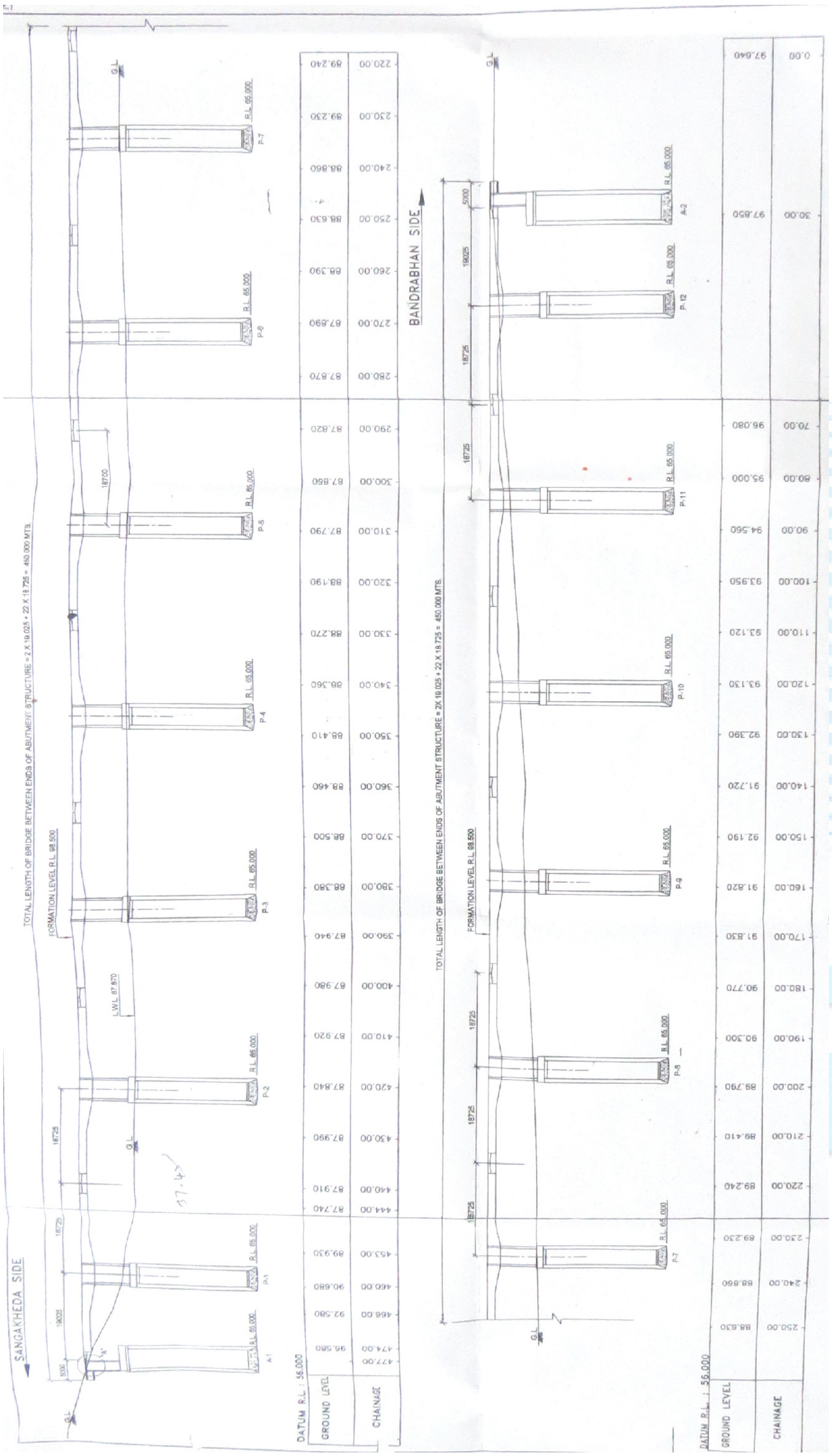

Figure 6 GAD of the bridge

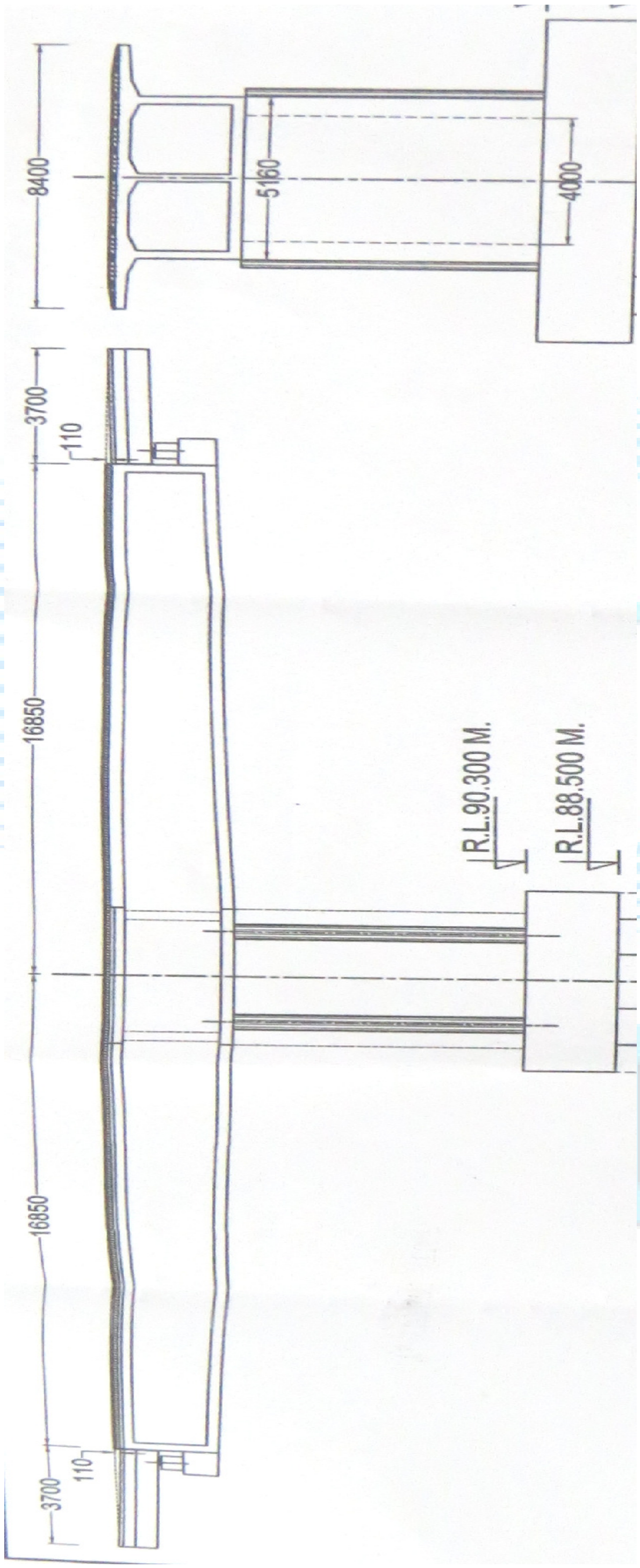

Figure 7 GAD of the bridge