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FOUNDATION FAILURE OF BRIDGES IN ORISSA - TWO CASE STUDIES

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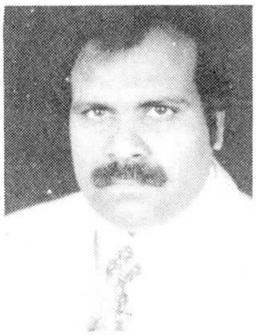

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SYNOPSIS :

The success of an engineer lies in planning, designing & construction of a durable structure. As such every engineer aspires to be crowned with "such success", but unfortunately at times, because of certain factors beyond comprehension, failure does occur. Failure of Bridges may be, either due to failure of superstructure or failure of foundation. In Orissa we have got rare experience of foundation failure. However two case-studies are depicted in this paper.

The first case refers to the famous Tel Bridge near Belgaon in Western Orissa. Originally in this location there used to exist a submersible bridge of total length 340.40 M. In 1967 because of exceptional flood and excessive scour, major part of the bridge was washed away. This necessitated construction of a new bridge, consisting of 12 spans each of 38.26M centre to centre having total length of 459.15M, at 393M down stream of the damaged bridge. By September,1977, when construction of major part of the bridge was completed, the pier well No.2, 3 & 4 alongwith 3 No. of superstructures between well No.5-4, 4-3 & 3-2 were completely washed away, because of another exceptional flood. On evaluation of the causes of failure, it was found that all the wells were plugged at 1.8M to 2.4m below the availability of rock level. Though Safe Bearing Capacity in each case far exceeds the design base pressure, **erodibility of the rock had not been tested**. In reality the foundation strata contains a whitish calcareous material, which leaches out by running water causing partial collapse of the rock strata, resulting in collapse of foundation and super-structure.

The second case refers to Surlake Cut Bridge on the famous Puri-Konark Marine Drive. This is a High Level Bridge of R.C.C. Box Culvert of 7 units of 4.88M centre to centre, with a central suspended span of 2.44M. There is discontinuity at the foundation level as well as deck slab level. Up stream & Down stream are protected by sheet pile. Because of a breach in a nearby river in 1997, its discharge found its way through this small channel & about 10 times the design discharge passed through the box culvert causing 325mm settlement on the Down stream end of the suspended span and bottom raft, leading to abolition of traffic movement on top of it.

1. Introduction :

The term "Failure", though creates despair & despondency in human mind, often leads to interesting findings, when the misty clouds of causes of failures are unravelled. Thus finding out causes of failure always represents an indicator of growth of technology. And hence the importance of highlighting the failure. Foundation failure is one of the most important modes of failures of any type of structure, more so incase of bridges. Two case studies are brought out here only for this purpose.

2. Brief History of Tel Bridge :

Originally the Tel Bridge near Belgaon, opened to traffic in 1957, was a submersible bridge of total length 340.40M consisting of 38 No. clear spans, each of 7.62M & 1 No. clear span of 6.10M. The deck level & Highest Flood Level of the bridge was at RL 165.85M & 170.25M respectively. This bridge was washed away partially during exceptional flood in 1967 because of the following reasons :

a) Trees hitting the bridge.
b) Excessive flood for which the bridge was not designed.
c) Excessive scour uprooting the pile foundation (smaller dia & length).

As this used to be an important link connecting Bolangir & Bhawanipatna, the two district head quarters on State Highway 2, immediately a bridge was planned at 393M Down Stream of the damaged bridge. The new proposed High Level Bridge consists of total length 459.15M with 12 spans each of 38.263M centre to centre; resting over foundation with twin-wells. The work was started in March, 1969 by one agency.

The salient features of the bridge are as follows :

Maxm. Discharge	:	11325 Cumec.
Velocity	:	3.19M/Sec.
Highest Flood Level	:	171.04M RL.
Maxm. scour level	:	146.32M RL.
Foundation level	:	137.20M RL.

During the construction, the high flood of 1973 necessitated construction of one additional span of 15.24M on right side (Kesinga side). By 1973, 8 intermediate wells, 1 abutment well & 7 piers were completed when the first agency left the work. The bridge was started by the second agency in October, 1975. By September, 1977, the major portion of the bridge work was completed except the following components :

i) Sinking of pier well No.1 on right side (Kesinga side) was in progress (well has been numbered from right to left bank).

ii) Casting of superstructure span 11 & 12 were to be taken up (superstructure has been numbered from left to right bank).

Suddenly again on 13.09.77 the Highest Flood Level rose as high as 171.63M RL & the discharge, calculated corresponding to the Highest Flood Level came out to be 15289 Cumec i.e. about 35% excess over the Design discharge of 11325 Cumec. The wells under each pier were twin circular wells each of 4.27M external dia with 0.75M steining thickness. Because of such unprecedented flood, pier well No.2, 3 & 4 towards right side (Kesinga side) along with superstructure span No.8, 9, 10 between well No.5-4, 4-3 & 3-2 respectively were washed away. The rest of the bridge remained in tact, although the river bank of left side (Belgaon side) was eroded considerably both in Up stream & Down stream & was submerged under water. No distinct bank used to exist on this side possibly due to considerable erosion and deposition of thick pile of river born sediments. However the right bank (Kesinga side) is firm with steep bank slope & the tendency of water is to flow in this portion.

3. Causes of failure of Tel Bridge :

After the above disaster, a High Power Committees (HPC) consisting of some eminent engineers of the country was formed to find out the causes of failure. After a careful study of the available records, data & the evidence received from various officers, the committee was of the opinion that the damage to the bridge had occurred on account of -

i) Increased discharge than that for which the bridge was designed.

ii) Concentration of flow with high velocity towards Kesinga side (right side).

iii) Erosion of the strata on which the wells were founded.

The location of the site was not an ideal one as it was just below a constricted section of the river channel resulting in concentration of flow, high velocity & turbulence towards the right bank. However, if the rocky strata on which the foundation was located, was strong enough, even the turbulence and high velocity should not have affected the safety of the structure. This site, however, has the advantage of having the shortest bridge length. It seems that the siting of the bridge was done on the assumption that the rock is hard and inerodible, giving a false sense of safety.

It was found from the records that rock was available at a much higher level than the stipulated founding R.L. In almost all the cases the wells were taken 1.8M to 2.4M inside the rock and then founded.

The rock samples from each well were sent to the laboratory for test. As the Safe Bearing Capacity of rock reported by laboratory was much more than the design base pressure, those were presumed to be suitable for founding the wells. As such the wells were not taken to the stipulated founding level. The table below would explain the same in details. Since each pier is supported below by twin circular wells, the wells are designated in each location as Up Stream(U/S) & Down Stream(D/S) well.

Well No.	Founding RL in metre.	Safe Bearing Capacity (MPa)	Calculated Base Pressure (MPa)
2	U/S 152.91	1.03	1.01
	D/S 152.91	1.03	
3	U/S 152.65	4.30	0.86
	D/S 152.79	2.92	

Well No.	Founding RL in metre.	Safe Bearing Capacity (MPa)	Calculated Base Pressure (MPa)
4	U/S 151.51	4.41	2.34
	D/S 151.51	4.41	
5	U/S 151.17	6.13	2.34
	D/S 151.17	6.13	
6	U/S 151.40	4.98	2.34
	D/S 151.40	4.98	
7	U/S 150.81	8.40	1.96
	D/S 149.70	3.65	
8	U/S 148.37	2.22	1.82
	D/S 148.45	2.22	
9	U/S 138.08	3.45	1.20
	D/S 138.08	3.01	
10	U/S 146.64	7.86	1.97
	D/S 146.00	7.68	
11	U/S 152.44	1.42	1.31
	D/S 152.44	2.99	

The only short coming in the project was that Geological investigation of the rock by an expert Geologist was not conducted which would have revealed a typical nature of the rock. The actual reason of the failure was the founding of the well on a peculiar type of rock formation.

On the advise of the High Power Committee, a Geologist was deputed for the purpose of investigation of rock strata. According to him, the rock strata is dipping at 45^0 to the horizontal sloping towards left bank & Up stream side. The rock layers are intervened with a thick layer of whitish powdered chalky material which get leached out when absorbed in water. Some percentage of white mass which is found within the layers of the rock, rather get disintegrated by coming in contact with water and lead to the collapse of the rock layers. This caused the collapse of foundation & superstructure of 3 spans of the bridge. Hence it may be stated that the rock on which the wells have been founded are partially erodible.

4. Recommendation of High Power Committee(HPC) to protect the undamaged portion:

As the damaged wells were lying along the bridge axis, these could not have been reconstructed at the same location. Therefore the wells were sunk at suitably shifted positions along the bridge axis resulting in change of superstructure spans. The flood protection in the form of garlanding ring with the help of concrete blocks of 1.2M x 1.2M x 1.2M interconnected with 32mm dia hook bars with loose chain for easy launching, both in Up stream & Down stream of the bridge axis were provided to resist the water current of high velocity of the order of 4.27 M/Sec in accordance with the suggestion of the High Power Committee. The cost of such protection work was high. However this type of floor protection was considered essential for the safety of the bridge, particularly for the undamaged spans whose foundations can also be eroded, if the concentration of flow shifted to left side.

It was observed during the flood of 1977 that apart from the damage to 3 spans of the bridge, water spilled on the bank causing a breach of about 122M on the Belgaon side (left side) approach road to the bridge. A suitably designed spill portion was provided as per the suggestion of the High Power Committee on the left side with proper pitching such that provision was made for passing 11325 Cumec discharge through the bridge proper and balance through the spill portion on left side (Belgaon side) and it was made in such a way that in the normal flood, the communication system is not disrupted by more than one or two days.

The bridge was completed by a third agency after many hurdles & finally opened to traffic in the year 1994.

5. Brief History of Surlake Cut Bridge :

Surlake Cut Bridge is located at 10 KM from Puri on the famous Puri-Konark marine drive. It was completed in the year 1982 during the construction of Puri-Konark Marine drive, which was made to complete the Golden Triangle of Orissa consisting of Puri, Konark & Bhubaneswar. The traffic density of foreign tourist is quite high on this road and hence its importance.

Unlike the Tel Bridge, Surlake Cut Bridge is a small, but important High Level Bridge, consisting of R.C.C. box culvert of 7 units of 4.88M Centre to Centre each with a central suspended span of 2.44M. There is discontinuity at the foundation level as well as the deck slab level. Up stream & Down stream end are protected by sheet pile.

6. Causes of Failure of Surlake Cut Bridge :

The bridge was designed for a discharge of 85 Cumecs. Suddenly in the rainy season of 1997, because of a breach in the nearby River, Nuanai, discharge of about 850 Cumecs (i.e. 10 times the design discharge) passed through the box culvert. Because of such exceptionally high discharge, the velocity of water increased to a great extent and it displaced the sheet pile cut-off provided earlier and caused heavy local scour, forming deep gorge to the tune of about 5M in the Down stream end from Left Bank (Konark side) to the centre of the bridge and its depth gradually reduces towards the Up stream. The raft has been cracked & displaced in the central portion of the bridge. Near the joint of the suspended span there is a settlement of about 325mm on Down stream end. Thus the portion of the Box Structure of Left Bank (Konark side) has been tilted towards the Down stream end. As a deep gorge has been created in the Down stream end and the raft has settled to a great extent, it is quite risky to jack up the superstructure to restore the relative settlement of 325mm of the superstructure. A Baily Bridge type arrangement was made to restore the traffic on such an important route.

7. **Conclusion** :

Fixing of the founding level in case of bridge depends on the discharge, waterway provided and type of strata of the river bed. For different types of soil the maximum scour level & founding level can be calculated depending on the silt factor, flow concentration & water way etc.. But in case a sound hard inerodible rock is encountered at a level, higher than the Maximum Scour Level, then the scour line is considered to be the top of the rock level and founding level can be fixed by keeping the structure below the rock with some minimum grip length as per relevant code. But to take a decision, whether a rock is hard & inerodible, is a tricky one. In such cases, it is always preferable to take the help of an experienced geologist to find out the nature of rock and the rock profile (Dip & fault), along with field testing of the quality of rock (both Safe Bearing Capacity & erodibility). Then only the decision on foundation can be safe & suitable.

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