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Foundations Failures of Bridges and Geotechnical Investigations

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SYNOPSIS In the present paper two cases of foundation failures due to which the complete bridge structure have failed are reported. The 93m long Palakmati high level brick masonry arch bridge on Hoshangabad - Piparia Road was constructed in year 1910. This bridge has shallow well brick masonry foundation with brick masonry wall type piers. Foundations of piers were on two circular shallow independent wells. The wells are resting on yellow soil. During floods of 1989, the pier No.3 sunk. This brought down 5 spans. Two well foundations were up-rooted. Cracks were developed in other arches also.

The 90.5m long submersible R.C.C. trough slab type Mand bridge in 60/8 km on Ambikapur-Pathalgaon Road of 5.5m width was constructed in the year 1945-46. The bridge has open foundation resting on rock whereas superstructure consist of R.C.C. portal framed structure. The foundation of first pier towards Ambikapur side sunk by about 0.4m in August 1991. Due to this abrupt settlement the abutment and all the three piers have developed through cracks below the supports and severe cracks in all spans. Geotechnical investigations are carried out in these two cases and remedial measures are suggested for reconstruction of new bridges.

INTRODUCTION

Foundation Engineering solely depends upon knowledge of geology, soil mechanics & precedents. Whether a particular type of foundation & its depths has proved to be successful over years could be known through previous experience. In addition to this geological and geotechnical investigations of the site are important factors to decide the type and the proper positioning of foundations and to give as insight to the sub-stratum through which the foundation is to be taken. These investigations could give a detailed picture of the underlying subsoil and rock and can result in considerable economy.

In India about 40 years ago the practice of geotechnical investigation was limited to taking trial pit for foundation for a depth of 3m to 4m. In respect of deep foundations the depth was decided by calculating scour depth by imperial formulae on the basis of bore hole data. If rock was available in river bed no investigations was considered necessary. Investigation of some of old bridges showed that the same are resting within 3m from bed level. The Arch. bridges has been rested on soil and these bridges have withstood for 100 years without settlement. The soil investigations for these bridges have been carried out and scour depth have been calculated from standard formulae and it is found that the depth of the foundation should be more than 6m. Thus there are good number of contradictions in the matter of foundations.

The present study deals two cases of foundation failures of Palakmati and Mand bridges.

PALAKMATI BRIDGE

This bridge is situated in Km. 208/4 of Hoshangabad - Piparia Road (State Highway-22) near Sohagpur Road. The bridge was constructed in year 1910.

Salient Features of the old bridge are:

- | | |
|---------------------------|---------------------------------|
| 1. Catchment area | : 87 Sq.Km. |
| 2. Formation level | : R.L. 103.91 |
| 3. H.F.L. | : R.L. 100.86 |
| 4. Lowest bed level | : R.L. 96.33 |
| 5. Length of bridge | : 93 m. |
| 6. Span arrangement | : 9 spans of 10.35m c/c |
| 7. Type of superstructure | : Brick Masonry Arches |
| 8. Type of foundation | : Twin shallow well foundation. |

Details of Foundation and Founding Strata

This bridge has shallow well brick masonry foundation with brick masonry wall type piers. Foundation of piers were on two circular shallow independent wells. Each well has 2000mm diameter and 600mm brick masonry steining thickness. The dredge hole is only 800mm diameter. The depth of well is 3000 mm below lowest bed level. Well cap consisted of thick stone slab and lime concrete. Entire bridge structure is in lime mortar/ lime concrete.

Foundation Strata

- (a) Bores are taken at 5 places and it was found that rock is available at 15m to 20m depth.
- (b) There is a top layer of @ 2m sand.
- (c) Below this there exists a yellow soil layer of @ 3m to 4m depth.
- (d) Below this yellow soil layer, yellow soil mixed with kankar and below this hard rock is available.

Cantilever + 13.40m
+15.15m
+13.40RCC
Frame structure.

7. Type of superstructure : Through slab.
8. Type of foundation : Open foundation.

Details of Foundation and Founding Strata

The bridge has open foundation resting on rock/hard strata. The superstructure consist of two units of R.C.C. framed structure (3.3m cantilever + 13.40m + 15.15m + 13.40m). The details are shown in fig.1. The foundations are resting at a depth 3.5m to 5m below the lowest bed level.

Foundation Strata

Bores are taken near each foundation location and the results are as tabulated below

S.No.	Location	Type of soil
1.	A ₁	3.00m Soil (R.L.97.00 to 94.00) 8.00m Silt 2.00m fine sand 2.50m coarse sand hard rock
2.	P ₁	5.00m fine sand 3.60m Gravel 6.00m silt
3.	P ₂	3.3m coarse sand hard rock.
4.	P ₃	5.4m coarse sand & gravel hard rock.
5.	P ₄	6.50m coarse sand & gravel hard rock.
6.	P ₅	7.00m coarse sand & gravel hard rock.
7.	A ₂	7.00m fine & coarse sand hard rock.

Rock is not available upto 15m below the bed level in pier P-1. Foundation were resting on gravel. There was a layer of silt below gravel layer.

Failure of Foundations

The river channel is flat with defined banks. The abutments are resting on high ground near banks. Pier P-1 is resting on gravel and below gravel it is only silt. The foundation of pier P-1 towards Ambikapur side sunk by about 0.4m in August 1991. Due to this abrupt settlement the abutment and all the three piers have developed through cracks below the supports. Similarly the slabs at 0.2 L. from support have developed severe cracks in all spans as shown in figure-1. The traffic on bridge has been stopped.

Causes of Failures

The investigation have shown that failure occur partly due to consolidation of silt

Failure of Shallow Well Foundation

The wells were resting on yellow soil @3m below the lowest bed level. Concentration of flow is mainly in span Nos.3,4,5 & 6. During floods of 1989, there was heavy scouring at pier-3 which collapsed and the shallow well was uprooted (Photo-1). This brought down 5 spans i.e. spans 3 to 7 as there was no abutment pier. Two well foundations were uprooted. Cracks developed in other arches (Photo-2). There exists a Railway bridge @ 300m U/S on the same river has about 5.5m deep open foundation resting on similar type of foundation. No distress is observed on Railway bridge.

Causes of Failure

The investigation shows that heavy floods in this small river caused scour which extended gradually over years below founding level. The bridge did not collapse during high flood but on receding floods when a heavy tanker passed over the bridge. Pier p-3 which settled and gone way.

Reconstruction of Bridge

Investigations have been done and it is found that good founding strata, yellow soil mixed with kankar is available at a depth 4m to 5m below the lowest bed level with S.B.C. of @ 30 T/Sq.m. Now a new bridge is proposed at the existing site with 5 spans of 19.2m c/c and the foundations are kept at R.L. 91.00 i.e. 5.5m below lowest bed level on yellow soil mixed with kankar.

This brings out the need to critically examine every year the foundations of old bridges particularly resting on soil.

MAND BRIDGE

This bridge is situated in Km.60/8 on Ambikapur - Pathalgaon Road. The bridge was constructed in the year 1945-46.

Salient Features of the bridge are :

1. Catchment are : 523 Sq.Km.
2. Formation level : R.L. 100.00
3. H.F.L. : R.L. 98.500
4. Lowest bed level : R.L. 94.000
5. Length of bridge : 90.500m
6. Span arrangement : Two units of 3.30m

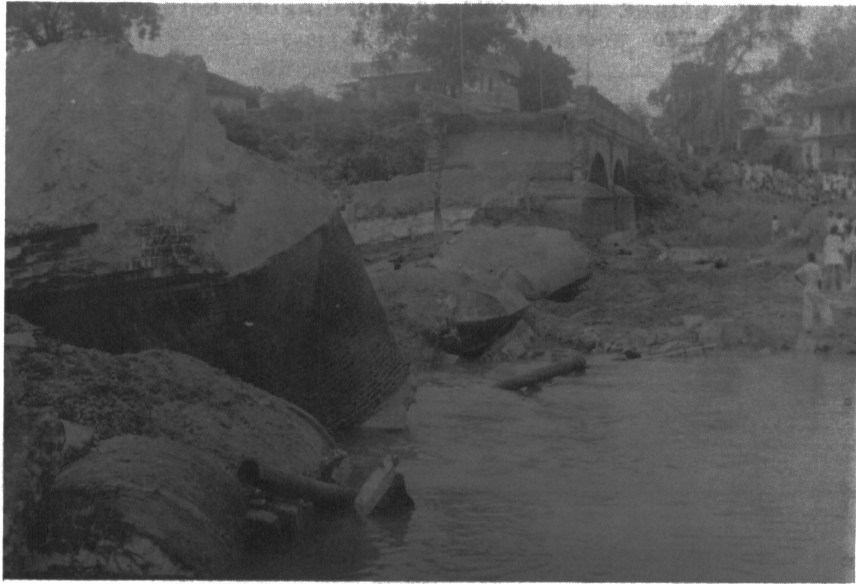


Photo 1 Pier No.3 from Piparia side of Palakmati Bridge.



Photo 2. Showing 5 spans collapsed of Palakmati Bridge on Hoshangabad - Piparia Road.

under pier P-1 and partly due to creation of cavity and voids in the silty strata due to flow of water with high velocity during rains. The bridge was standing due to arch action and when this arch action was broken due to unbalancing of the underlying strata, the settlement took place under pier P-1 and the failure of one unit of three spans occurred.

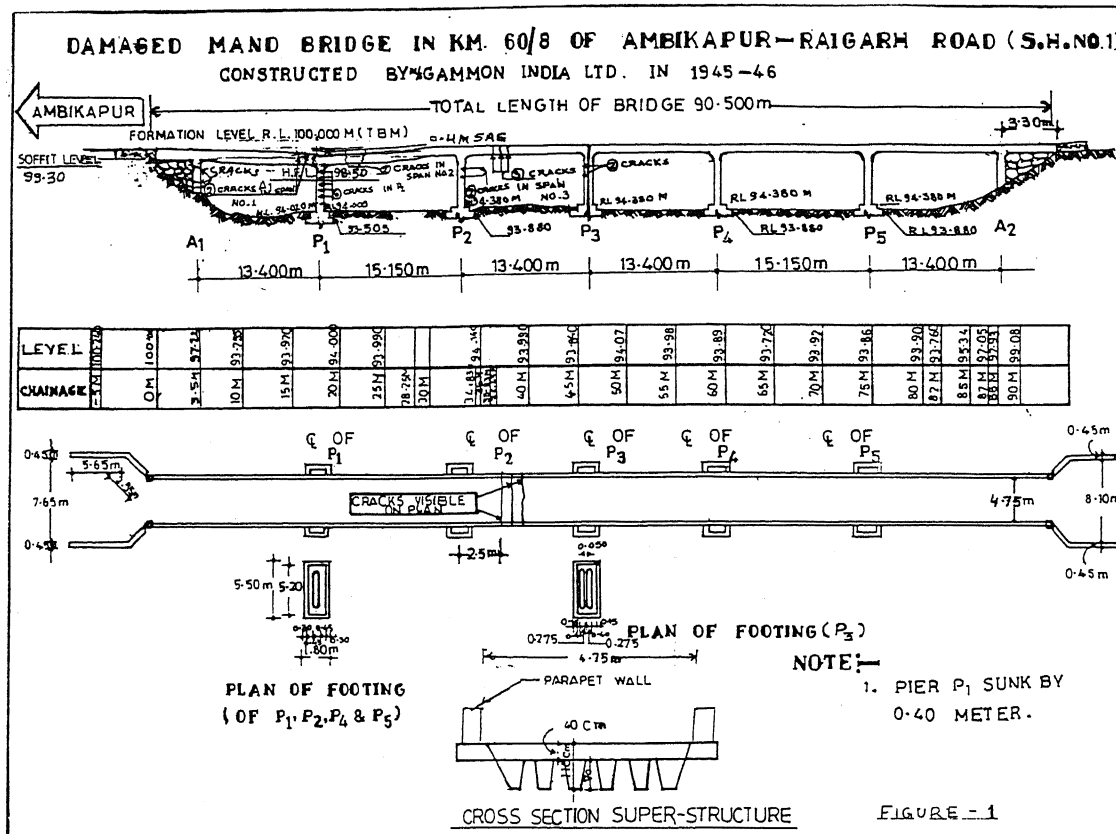
Reconstruction of Bridge

Detailed investigations have been done and it is found that foundation in unit-2

is also not reliable, so it is under consideration to dismantle complete bridge and provide a new bridge with 2 lane carriage way i.e. 7.5m width.

LESSONS DERIVED FROM FOUNDATION PROBLEMS

Besides the cases mentioned here, there are many cases of such problems. Detailed investigations of these cases have brought out some important lessons regarding design aspects, construction practice, sub-soil investigation and specifications for safety.



- Confirmatory bores must be taken at location of each pier before starting the work at site and type and depth of foundations be decided. If foundations are to rest on rock there must be rock in a depth atleast twice the width of foundation or 5.0m whichever is more below foundation level.
- The type of superstructure to be provided should commensurate with the type of sub-soil strata available for resting foundations.
- Arches, continuous type of superstructure or frame type structure should not be provided in settling type of foundation to avoid failure.
- Bouldery strata or conglomerate are not dependable for foundations. This strata scours and foundations are undermined.
- In respect of old bridges, foundation depths be ascertained and every year after flood scour around piers, settlement be kept under observation. Protection work be provided if necessary to avoid sudden failures.

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