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FOUNDATION DESIGN AND CONSTRUCTION OF RAIL-CUM-ROAD BRIDGE ACROSS RIVER DAMODAR NEAR MEJIA

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SUMMARY

This paper highlights the special features of planning , design and construction of the foundations for the road-cum-rail bridge across river Damodar along the alignment of the Raniganj-Mejia dedicated railway line for the Thermal Power Plant of Damodar Valley Corporation. This bridge provides a vital link for rail as also road transport between the Burdwan and Bankura districts of West Bengal, which earlier had inadequate connectors. The experiences on this bridge are being effectively utilized in other bridges being built in eastern region and north-eastern region, as this was the first major road bridge built on pile foundation in this part of the country.

1. PREFACE

Damodar Valley Corporation (DVC) set up a captive railway system for transportation of coal by rail to their Thermal Power Plant at Mejia in the district of Bankura of West Bengal. This railway line is designed to carry 7,000 tonnes of coal daily for meeting the requirements of the 630 MW power plant. The line is a major crossing on the river Damodar near Raniganj.

The railway bridge was initially envisaged to have 9 nos. of through type steel girders of clear span 76.2 m and two shore spans of 30.5 m. This arrangement of girders had been recommended by the consultant appointed by DVC for preparation of project report for the captive railway line[1].

2. NECESSITY OF RAIL-CUM-ROAD BRIDGE

The river divides the neighbouring districts of Burdwan & Bankura in West Bengal over long stretches during the flood season and, except the Durgapur barrage, there is no direct road link between these two neighbouring districts. In deference to the popular demand for additional link between the two neighbouring districts by road over the river, it was decided to introduce a 2-lane road superstructure of National Highway standard on the common foundations with the rail bridge.

3. SPAN ARRANGEMENT

The span arrangement of the rail-cum-road bridge was adopted as 15 x 48.5m + 2 x 33.062m after comparing the cost economy for various span arrangements, taking into account the varying costs of rail and road superstructure and the common foundation.

The superstructure was made structurally isolated with the roadway deck and railway track, located side by side on common substructure.

The superstructure for the railway has 15 nos. 45.7 m (clear span) standard through type steel truss span as per standard drawings adopted by the Railways with two shore spans of 30.5m (clear span) of similar nature. The roadway superstructure consists of three girder, precast, post-tensioned concrete T-beams with composite R.C. deck slab, carrying 7.5m-wide carriageway and 2m-wide footpath on one side only.

4. DESIGN CONSIDERATIONS

4.1 Hydraulic parameters

As a prelude to the construction of a permanent bridge, the hydrulic parameters for the bridge were first established. The location of the bridge site is approximately 15 km upstream of the Durgapur barrage in the district of Burdwan, West Bengal. The value of the discharge for this bridge was considered to be 18400 cumec[2]. , which is same as the design flood discharge of the Durgapur barrage.

The effective width of waterway for the above discharge works out to be around 656 m, which is less than the effective width of waterway provided from topographical considerations.

4.2 Soil investigation & profile

Soil investigation work for the foundation along the same alignment was carried out ahead of the decision to have a rail-cum-road bridge. Soil investigation had, therefore, been carried out at the locations of two abutments , and the ten pier locations as per the originally envisaged scheme, i.e. for 2 x 33 m + 9 x 80.1 m span pier arrangement. The bore hole positions, therefore, did not match with the new span arrangement, but a clear picture of soil profile distribution along the alignment was established from the soil investigation report, before undertaking the design of the foundations for this bridge.

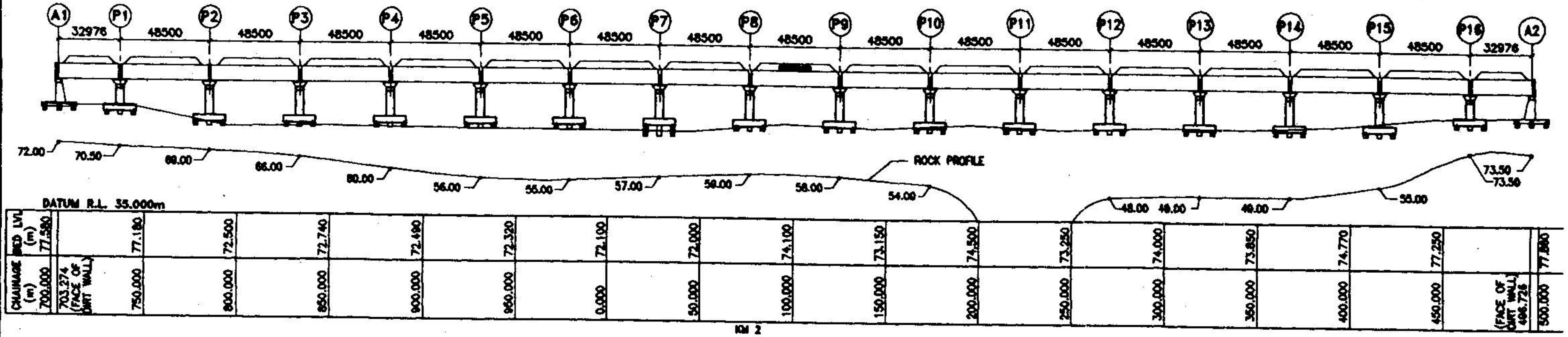
During construction, boreholes were installed at each pier location, which the substrata confirmed the existence of sandstone at designed levels overtopped by loose-to-medium dense sand or silty sand with traces of gravels. It was seen from the generalized soil profile that the rock slopes down towards the centre of the river from either abutment end and no rock layer could be struck at the central region (pier locations 11, 12, 13 & 14) where boring was continued as much as 35.00 m below the bed level without reaching rock strata. This indicates the possible existence of a geological rift along the river alignment.

5. SELECTION OF FOUNDATION

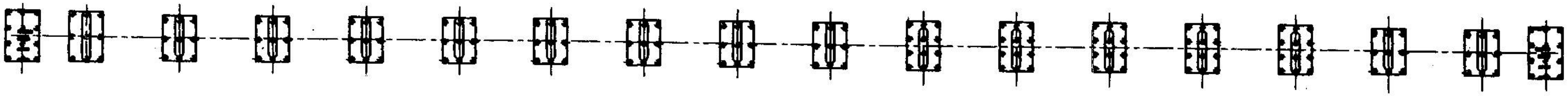
The availability of rock at a depth of around 15 m average from the bed level and existence of high groundwater level eliminated the adoption of open foundations. Acceptable options for foundation were

i) Caissons or well foundation

ii) Large diameter pile foundation

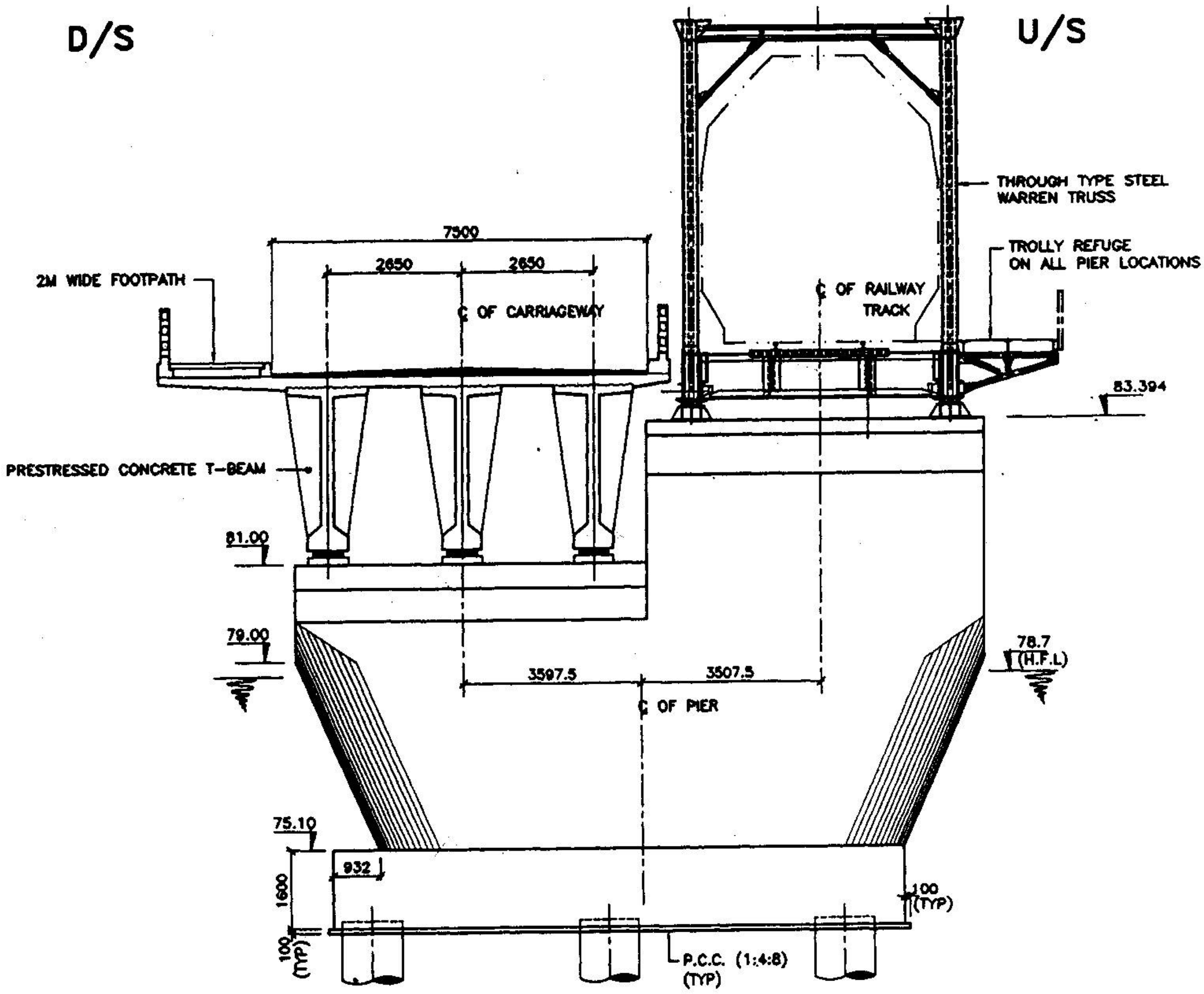


GENERAL ARRANGEMENT AND GEOTECHNICAL PROFILE OF RAIL–CUM–ROAD BRIDGE ACROSS RIVER DAMODAR

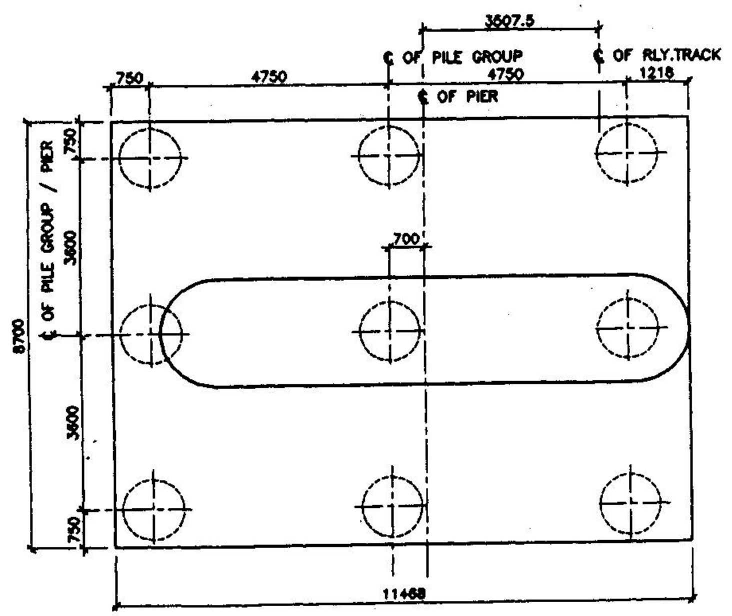


PLAN AT PILECAP LEVEL

FIGURE :1



TYPICAL CROSS SECTION OF RAIL-CUM-ROAD BRIDGE OVER RIVER DAMODAR NEAR MEJIA



PLAN OF PILECAP

FIGURE:2

Both these systems have inherent functional characteristics which were closely weighed before making the final selection.

The caisson or well foundation provides welcome stability when the foundation is subjected to large lateral forces at a high leverage. Construction of the well foundation, however, is time consuming and involves considerable preparatory time. Sinking of well is an uncertain process, particularly in bouldery layers.

Construction of large-diameter bored cast-in-situ pile is a relatively assured process. Large depths can be achieved with bored cast-in-situ pile in almost all soil strata, including bouldery layers. With the adoption of large-diameter piles it is possible to overcome the limitations of achieving higher load carrying capacity, both vertically and laterally. In Damodar river, the rock qualities are heterogeneous in nature and there can be observed a rapid change of rock levels within a short distance. Adoption of end-bearing bored cast-in-situ pile was the preferred foundation element for this bridge, after comparing installation cost and time cost.

6. SUBSTRUCTURE

6.1 Pier

Wall type R.C.C. pier was adopted for this bridge for supporting the isolated superstructures for both railway and roadway. The railway formation level at the bridge location was finalized keeping in view the overall economy of the project. The roadway formation level was fixed at the same level as railways to reduce approach viaducts. The railway traffic moves on deck system supported on the bottom chord of trussed girders, whereas the roadway live load moves on the top of T-beam superstructure. This resulted in a stepped pier cap as seen in figure-2.

The pier was designed to withstand the permanent dead load and a wide variation of live loads in addition to the longitudinal forces due to braking/traction, water current and wind. The variations of the live load combination which were considered are as follows:

Case-1	One side railway span loaded
Case-2	Both side railway span loaded
Case-3	Both side railway span loaded + One side roadway span loaded
Case-4	Both side railway span loaded + Both side roadway span loaded
Case-5	One side railway span loaded + Both side roadway span loaded
Case-6	Both side roadway span loaded
Case-7	One side roadway span loaded
Case-8	One side railway span loaded + One side roadway span loaded

It is important to note that while the deadweight of the roadway span is much higher than that for the railway span, the railway live load effect is significantly greater than that of the roadway live load. The combined effect of these loads results in wide variations of stresses on the foundation elements as can be seen from the figure-3. The pier configuration was made eccentric with respect to the geometrical centre of the two superstructures and the pile groups for partially compensating for this loading pattern

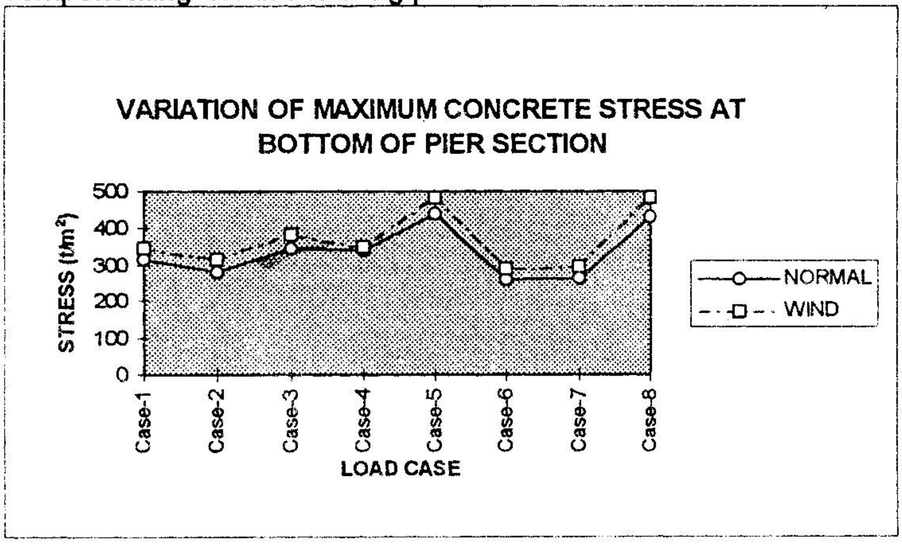


figure-3

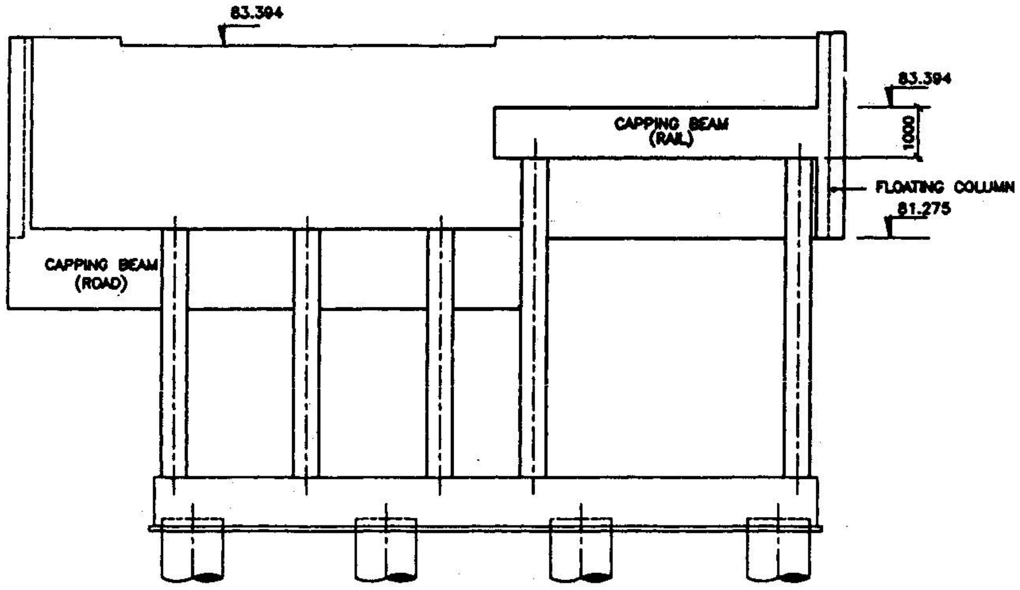
6.2 Abutment

Spill through type R.C. abutment with rectangular RC column was provided for this bridge with cantilever type wing wall and dirt wall (ref. figure-4). The level of the cap of abutment followed the same arrangement as for the pier. For reducing the abutment cap section, rectangular RC columns have been provided under each bearing location. The distribution of lateral forces on each column has been made on the basis of stiffness coefficient method taking into account the rigidity of columns. The column sections have subsequently been checked by 3-D frame analysis, considering the abutment as a framed structure subjected to vertical loads, lateral loads and moments. The bending moment at the base of columns compared and it was noted that the value obtained from 3-D frame analysis were 10% lower for columns under road superstructure and 18% lower for columns under rail superstructure. The design of sections, however, were prepared considering the higher values.

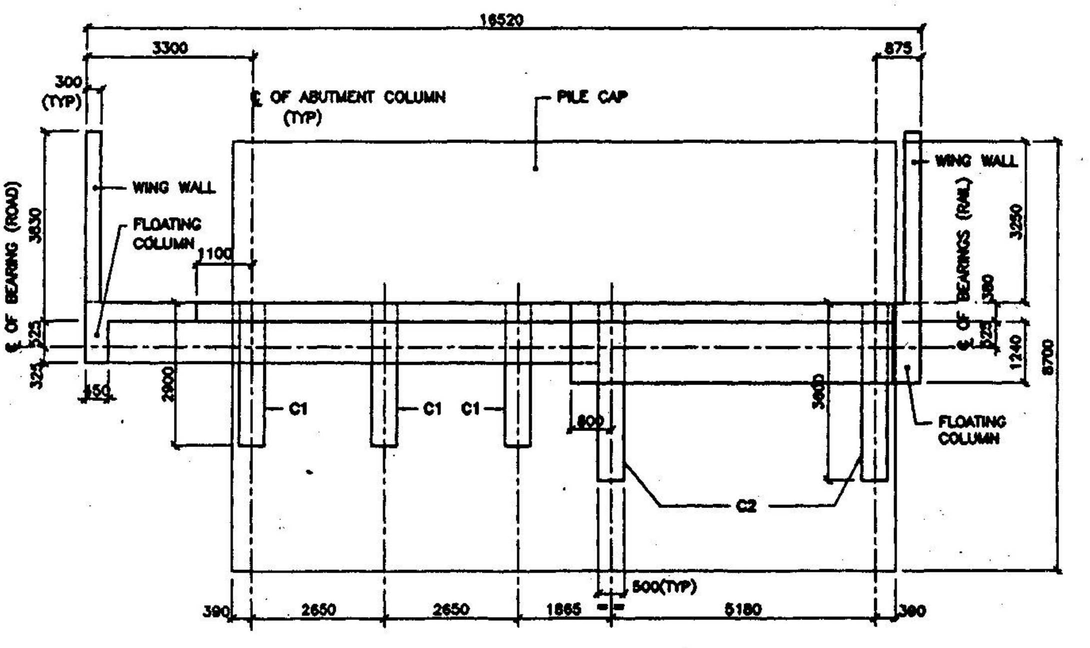
7. PILE FOUNDATION

Large-diameter piles of 1,200 mm dia have been used after examining the relative economy with possible alternative sizes. Considering the generalized soil profile of the river as reflected in figure-1, the pile groups are divided under two heads.

Group-A	:	Piles resting on rock
Group-B	:	Piles embedded in sandy strata



ELEVATION OF ABUTMENT



PLAN OF ABUTMENT

FIGURE:4

For the piles under group-A, vertical load carrying capacity was obtained by primarily considering the end-bearing on rock. Wherever the rock level was above the anticipated scour level, the rock layer was treated as strata not vulnerable to erosion. The piles were socketed inside hard rock by a length equivalent to three times the diameter. It was established that the horizontal load carrying capacity of the rock is adequate with the given embedment of pile. The structural design of pile was made considering the piles as free standing columns, fixed at the pile cap level and at rock level, with the point of contraflexure at centre.

For the piles under group-B, the vertical load carrying capacity was obtained considering end-bearing resistance and also skin friction offered by the sand strata in which the piles were rested. The piles were embedded in soil beyond the maximum scour depth by a minimum length of one-third the length up to scour level. The structural design of pile was made considering the piles as free standing columns, fixed at pile cap level and at the effective level of fixity inside sand, calculated from Reese and Matlock recommendation[3]..

The variations of vertical load in the most lightly loaded and heavily loaded piles are reflected in figures-5 & 6

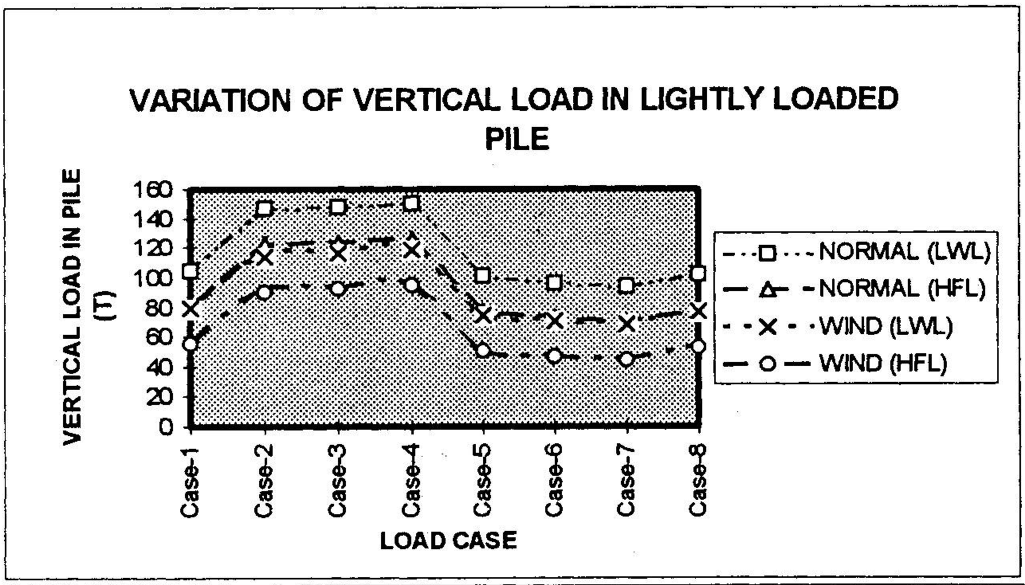


figure-5

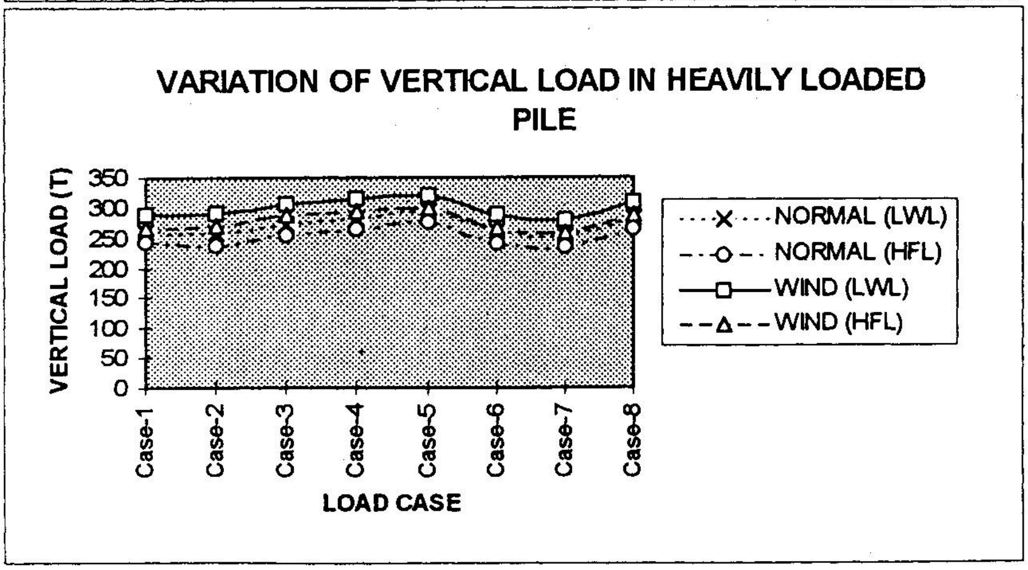


figure-6

8.0 CONSTRUCTION OF FOUNDATION AND SUBSTRUCTURE

During construction it was observed that the low water level (L.W.L.) as observed at site is 1 m higher than what had been reported during investigation and on the basis of which the execution drawings were prepared. It was, therefore, decided to raise the pile cap by 1 m, so that the same can be cast above water with better quality control. This resulted in an increased free standing length of pile at each pier location, requiring redesign of the pile reinforcements for most of the pier locations. The structural design of piles were progressively amended depending on the actual rock levels met at site. This regular interaction between the designers and the construction agency ensured uninterrupted progress at site. No other major problems were encountered in construction of piles and the substructure , thus avoiding the uncertainities met in foundation construction for most bridges in this region.

9.0 CONCLUSION

The foundation selection for this road-cum-rail bridge presented interesting alternatives to the designers. The solutions adopted were highly appropriate and allowed the foundation work to be completed within planned periods and without any major site problem.

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1. RITES, Preliminary report on Captive Railway System for Mejia, Thermal Power Plant
2. Completion report of Durgapur barrage - Vol.I
3. H.C. POULOS & E.H. DAVIS, Pile foundation analysis and design