DESIGN AND CONSTRUCTION OF DEEP FOUNDATION

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ABSTRACT

The design of deep foundation is a specialist subject requiring both structural and geotechnical input, as it must also consider the condition for the execution of the deep foundation. Construction issues that are presented including deep foundation are not so easy in comparison to other foundation. Deep Foundations are those in which the depth of the foundation is very large in comparison to its width which is not constructed by ordinary methods of open pit excavations. It is used in cases where the strata of good bearing capacity are not available near the ground. The space is restricted to allow for spread footings. In these cases, the foundation of the structure has to be taken deep with the purpose of attaining a bearing stratum which is suitable and which ensures stability and durability of a structure. The bearing stratum is not the only case. There may be many other cases. For example, the foundation for a bridge pier must be placed below the scour depth, although suitable bearing stratum may exist at a higher level.

KEY WORDS: *Construction, Pile foundation, well foundation, Bearing Piles.*

INTRODUCTION

The foundations constructed below ground level with some arrangements such as piles, wells, etc. at their base are called deep foundations. Deep foundations are classified into the following
types:
– Pile foundation
– Well foundation

Well foundation

Well foundations also called as Caissons, have been in use for foundations of bridges. Well foundation has its origin in India. Well foundations have been used in India for hundreds of years for providing deep foundation below the water level for monuments, bridges and aqueducts. Caisson foundations have been used for most of the major bridges in India. Materials generally used for construction are reinforced concrete, brick or stone masonry. Well foundation is a type of deep foundation which is generally provided below the water level for bridges.

Depth of Foundations

The depth of deep foundations below the high flood level shall be determined as according to bearing capacity of soil. The choice of type and shape of well foundation will depend upon the soil, type, the size and shape of pier or abutment, depth of foundation and available construction material. Where major obstructions such as uneven rocky strata are likely to be encountered, provision for pneumatic sinking may be made. Small obstructions can be removed either with the help of divers or by chiseling.

Shape and Cross-Section of Wells:

The horizontal cross-section should satisfy the following requirements

(a) The dredge hole should be large enough to permit dredging.

(b) The staining thickness should be sufficient to enable sinking without excessive kentledge and provide adequate strength against forces acting on the staining, both during sinking and service.

(c) The overall size should be sufficient to transmit the loads safely to the soil without exceeding its allowable bearing pressure.

Tilt and Shifts:

As far as possible wells shall be sunk without any tilt and shift. A tilt of 1 in 100 and shift of D/40 subject to a minimum of 150 mm shall be taken into account in the design of well foundation (D is the width or diameter of well). If greater tilts and shifts occur, their effects on bearing pressure on soil, staining `stresses, change in span etc. should be examined individually.

Cutting Edges

Cutting edge shall be properly anchored to the well curb. When there are two or more compartments in a well the bottom of the cutting edge of the intermediate walls may be kept about 300 mm above the cutting edge of the outer wall to prevent rocking.

Well Curb

It should transmit the superimposed load to the bottom plug without getting overstressed and it should offer minimum resistance to sinking. The slope to the vertical of the inner faces of the curb shall preferably be not more than 30 degrees. In sandy strata, it may be up to 45 degrees. An offset on the outside (about 50 mm) may be provided to ease sinking.

Well Staining

Well staining shall be built of masonry or cement concrete not weaker than M-100 grade. Sufficient bond rods shall be provided to bond the units of the staining during the progress of construction. Bond rods shall be distributed evenly on both faces of staining and tied up by providing adequate horizontal hoop reinforcement.

Bottom Plug

A bottom plug shall be provided for all wells and its top shall be kept 300 mm above the top edge of the inclined face of the curb. The concrete used for the bottom plug when placed under dry conditions shall generally be of 1:3:6 proportions and it shall be placed gently in one operation. When the concrete is placed under water, the quantity of cement shall be increased by 10% and it shall be placed by tremie or skip boxes under still water condition.

Top Plug

A 300 mm thick plug of cement concrete 1:3:6 shall be provided over the hearting which shall normally be done with sand. Sometimes only water is filled to reduce the weight.

Well Cap

The bottom of the well cap shall, as far as possible, be located 300 mm above low water level. All the longitudinal bars from the well staining shall be anchored into the well cap. The well cap shall be designed as a slab resting on the well.

Pneumatic Sinking of Wells

Where boring data indicate pneumatic sinking, it will be necessary to decide the method of such sinking and location of air lock. The side wall and roof of the working chamber shall be designed to withstand the maximum air pressure envisaged with the use of pneumatic sinking equipment. The design air pressure for design shall be higher than the pressure due to the depth of water above the bottom of the well.

PILE FOUNDATIONS

Pile foundations are used extensively for the support of buildings, bridges, and other structures to safely transfer structural loads to the ground and to avoid excess settlement or lateral movement. They are very effective in transferring structural loads through weak or compressible soil layers into the more competent soils and rocks below. A “driven pile foundation” is a specific type of pile foundation where structural elements are driven into the ground using a large hammer.

Piles may be divided into the following categories depending upon the manner of transference of load:
(i) Friction Piles
(ii) Bearing Piles
(iii) Bearing-cum-friction piles

Piles may also be further divided into the following categories, depending upon the method of construction.

(i) Pre-cast driven piles.
(ii) In-situ driven piles (these are normally not used for Railway Bridges).
(iii) In-situ bored piles (only large diameter bored piles are normally used for Railway Bridge construction.)

Spacing of Piles

The spacing of piles shall be considered in relation to the nature of the ground and the manner in which piles transfer the load to the soil. The spacing is also decided by group behavior for total carrying capacity and settlement. Normally, center-to-center spacing shall not be more than 4 d where d is the diameter of the piles. In case of piles of non-circular section, `d’ will be the diameter of the circumscribing circle.

LOAD CARRYING CAPACITY OF A PILE

(a) The ultimate bearing capacity of a pile may be assessed by means of a dynamic pile formula, using data obtained during driving of piles or by a static formula on the basis of soil-test results or by a load test.
(b) For non-cohesive soils, Hiley’s formula is more reliable than other formulae. This formula is given in Appendix `E’ of IS: 2911(Part-I)-1969.
(c) Hiley’s formula is not reliable in cohesive soils.
(d) The static formula should be used with careful judgment as the mechanics of load transfer from pile to soil is very complex. This judgment is employed in selecting appropriate multiplying factors.
(e) In unknown areas, load test is therefore most desirable.

Factor of Safety for Pile Foundation

The factor of safety shall be judiciously chosen after considering the following:
(a) Reliability of the soil parameters used in the computation.
(b) Type of superstructure and nature of loading.
(c) Possible reduction in the strength of the sub-soil strata arising out of the installation technique.
(d) Experience of similar structures near the site.
The minimum factor of safety of static formula shall be 3. The final selection of the factor of safety shall take into consideration the total settlement and differential settlement of the structure.

Overloading
When a pile designed for a certain allowable load is found to be short of the load required to be carried by it, due to change in design during construction stage or due to construction inaccuracies or due to outcome of the actual load test an overloading up to 10% of the pile capacity may be allowed on each pile. For a group of piles, the maximum overloading on the group shall be restricted to 40% of the allowable load on a single pile of the group. This overloading shall not be allowed at the initial design stage.

Capacity of Pile against Lateral Loadings:

The lateral load due to tractive/braking effort is transferred to the cap level along with a moment. The bending moment transferred at the pile cap level is shared by the piles in the group.
The piles should be considered as partially restrained at the pile cap level.

LOAD TEST METHODS

Dynamic Load Test Methods
Approximately 160 dynamic pile load tests were performed to evaluate pile capacity, driving stresses, and hammer performance during the installation of test piles and production piles. The dynamic resistance is formulated using a viscous damping model that is a function of a damping parameter and the velocity.

Static Load Test Methods
Static load tests were performed during the test phase of each contract to verify the design assumptions and load-carrying capacity of the piles. Telltale rods installed at various depths within the piles were used to evaluate the load transfer behavior of the piles with regard to the surrounding soil and bearing stratum.

LOAD TEST RESULTS
More than 160 dynamic tests were performed on the selected contracts to evaluate pile capacity during both the testing and production phases. Of these 160 tests, the results of 28 tests are presented in this report because they correspond to static load tests on 15 piles. Information about each pile tested is shown in table.

Test pile name	Test type	Hammer type2	Embedment depth(m)	Minimum trasferred energy(kn-m)	Recorded penetration resistance (below 2,5 cm)	permanent set(cm)
ET4-C2	EOD	II	47.5	NI[3]	7,7,7	0.36
ET4-3B	EOD	II	41.1	NI	8,7,10	0.25
190 EB SA	EOD	III	46.6	25.8	12,10,10	0.25
12A1-1	EOD	III	41.8	20.7	4,4,5	0.51

12A2-1	EOD	III	38.7	15.3	3,4,4	0.64

CONCLUSION

This topic presents a summary of the lessons learned from driven piles on the project. The conclusions presented below are based on the evaluation of field records, project specifications, and pile load test data compiled from the project files.

. The dominant pile type used on the project was a 41-cm square PPC pile. Based on the contractor's bid estimates, the PPC piles were also the most economical pile type.

• Pile heave in excess of the 1.3-cm criteria was identified on one cut-and-cover tunnel structure requiring 445 restrike events for the 576 piles used in the structure. The heave occurred even though pre-auguring of the marine clay layer was performed. Pile heave issues were not identified at other structures where the pile spacing was greater than about 1.8 m.

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