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Design of Pile Foundation at GALANDER-KANDIZAL Bridge in J&K

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Abstract

Design of a pile foundation involves solving the complex problem of transferring loads from the structure through the piles to the underlying soil. It involves the analysis of a structure-pile system, the analysis of a soil-pile system, and the interaction of the two systems, which is highly nonlinear. Close cooperation between the structural engineers and geotechnical engineers is essential to the development of an effective design.

Many factors must be considered when selecting an appropriate foundation for a hydraulic structure. Information is presented to identify the feasible foundation alternatives for more detailed study. The final selection should be based on an evaluation of engineering feasibility and comparative costs for the potential alternatives considering such factors as safety, reliability, constructability, and life cycle performance. T Such criteria pertain to the type and function of the structure, the nature of the applied loads, and the type of foundation material. The requirements for a subsurface investigation program are also presented.

Structural and Geotechnical Coordination A fully coordinated effort from

geotechnical and structural engineers and geologists should ensure that the result of the pile foundation analysis is properly integrated into the overall foundation design. This coordination extends through plans and specifications, preconstruction meetings, and construction. Some of the critical aspects of the design process which require coordination are:

- Preliminary and final selection of pile type.
- Allowable deflections at the groundline.
- Preliminary evaluation of geotechnical data and subsurfaceconditions.
- Selection of loading conditions, loading effects, potential failure mechanisms, and other related features of the analytical models.
- Minimum pile spacing and maximum batter.
- Lateral resistance of soil.

- Required pile length and axial capacity.

Introduction

General design requirements

Piles must be designed to withstand stresses caused during their installation, and subsequently when they function as supporting members in a foundation structure. Such piles must be capable of withstanding bending stresses when they are lifted from their fabrication bed and pitched in the piling rig. They are then subjected to compressive, and sometimes to tensile, stresses as they are being driven into the ground, and may also suffer bending stresses if they deviate from their true alignment. Piles of all types may be subjected to bending stresses caused by eccentric loading, either as a designed loading condition or as a result of the pile heads deviating from their intended positions. Differential settlement between adjacent piles or pile groups can induce bending moments near the pile heads as a result of distortion of the pile caps or connecting beams.

The working stresses adopted for piles should take into account the effects of unseen breakage and the long-term effects of corrosion or biological decay. Pile caps, capping beams, and ground beams are designed to transfer loading from the superstructure to the heads of the piles, and to withstand pressures from the soil beneath and on the sides of the capping members. These soil pressures can be caused by settlement of the piles, by swelling of the soil, and by the passive resistances resulting from lateral loads transmitted to the pile caps from the superstructure. In addition to guidance on structural design and detailing, matters of relevance to the design of piled foundations include the following:

- Partial factors for the ultimate limit state of materials
- The influence of soil–structure interaction caused by differential settlement
- Strength classes of concrete and reinforcement cover for various exposure conditions
- Slenderness and effective lengths of isolated members
- Punching shear and reinforcement in pile caps
- Limits for crack widths and
- Minimum reinforcement for bored piles.

Pile Construction

Design criteria

a. Applicability and Deviations.

The design criteria set forth in this paragraph are applicable to the design and analysis of a broad range of piles, soils and structures. Conditions that are site-specific may necessitate variations which must be substantiated by extensive studies and testing of both the structural properties of the piling and the geotechnical properties of the foundation.

b. Loading Conditions.

- **Usual**. These conditions include normal operating and frequent flood conditions. Basic allowable stresses and safety factors should be used for this type of loading condition.

- **Unusual**. Higher allowable stresses and lower safety factors may be used for unusual loading conditions such as maintenance, infrequent floods, barge impact, construction, or hurricanes. For these conditions allowable stresses may be increased up to 33 percent. Lower safety factors for pile capacity may be used, as described in paragraph **4-2c.**

- **Extreme.** High allowable stresses and low safety factors are used for extreme loading conditions such as accidental or natural disasters that have a very remote probability of occurrence and that involve emergency

maintenance conditions after such disasters. For these conditions allowable

stresses may be increased up to 75 percent. Low safety factors for pile

capacity may be used. Special provisions (such as field instrumentation, frequent or continuous field monitoring of performance, engineering studies and analyses, constraints on operational or rehabilitation activities, etc.) are required to ensure that the structure will not catastrophically fail during or after extreme loading

conditions. Deviations from these criteria for extreme loading conditions

should be formulated in consultation with and approved by CECW-ED.

- **Foundation Properties**.Determination of foundation properties ispartially dependent on types of loadings. Soil strength or stiffness, and therefore pile capacity or stiffness, may depend on whether a load is vibratory, repetitive, or static and whether it is of long or short duration. Soil-pile properties should, therefore, be determined for each type of loading to be considered.

c.Allowable Stresses in reinforced Concrete Piles

Reinforced concrete piles shall be designed for strength in accordance with the general requirements of ACI 318.Load factors prescribed in ACI 318 should be directly applied to hydraulic structures with one alteration. The factored load combination "U" should be increased by a hydraulic load factor (Hf).The hydraulic load factor shall be 1.3 for reinforcement calculations in flexure or compression, 1.65 for reinforcement in direct tension, and 1.3 for reinforcement in diagonal

tension (shear). The shear reinforcement calculation should deduct the shear carried by the concrete prior to application of the hydraulic load factor. As an alternate to the prescribed ACI load factors, a single load factor of 1.7 can be used. The 1.7 should then be multiplied by Hf. The axial compression strength of the pile shall be limited to 80 percent of the ultimate axial strength, or the pile shall be designed for a minimum eccentricity equal to 10 percent of the pile width. Strength interaction diagrams for reinforced concrete piles may be developed using the Corps computer program CASTR. Slenderness effects can be approximated using the ACI moment magnification procedures.

Pile Capacity

Pile capacities are computed by experienced designers thoroughly familiar with the various types of piles, how piles behave when loaded, and the soil conditions that exist at the site.

Axial Pile Capacity. The axial capacity of a pile may be represented

by the following formula:

Q = Qf + Qq
Qf = fAf
Qq = qAq

where
Q = ultimate pile capacity.
Qf = shaft resistance of the pile due to skin friction.
Qq = tip resistance of the pile due to end bearing.
f = average unit skin resistance.
Af = surface area of the shaft in contact with the soil.
q = unit tip-bearing capacity.
Aq = effective (gross) area of the tip of the pile in contact with the soil.

Skin Friction.
Skin friction is the resistance is due to the cohesion or adhesion of the clay to the pile shaft.

- fs = ca
- ca = □s
- Qs = fsAs

where
ca = adhesion between the clay and the pile
□= adhesion factor
S = undrained shear strength of the clay from a Q test

Design procedure

a. General. The following paragraphs outline a step-by-step procedure to design an economical pile foundation. The steps range from selection of applicable loads and design criteria through use of rigid and flexible base analyses. Identification and evaluation of foundation alternatives, including selection of the type of pile.

b.Selection of Pile-Soil Model. A computer model (CPGS) is currently being developed and its capabilities for analyzing the nonlinear interaction of the pile and surrounding soil. This model represents the lateral and axial behavior of a single pile under loading and accounts for layered soil, water table, skin friction, end bearing, and group effects.Deformations computed in the pile group analysis should be limited to this assumed deflection. If site conditions are such that the foundation properties are not well defined, then a parametric approach should be used. A parametric analysis is performed by using stiff and weak values for the elastic springs based on predicted limits of pile group deflections.

c. Selection of Pile Structure Model. The selection of the pilestructure model for analysis and design of a pile-founded structure must consider the following three critical items:

Type of structure (concrete or steel).

Type of analysis (rigid or flexible base).

Pile-head fixity (fixed, pinned, or partially fixed).

A reinforced concrete structure will require a rigid or flexible base analysis with the pile heads fixed or pinned. The decision regarding which type of base analysis to use is determined from the parametric analysis. A rigid base analysis should use the program CPGA.A flexible base analysis should use one of the general purpose finite element computer programs, such as STRUDL or SAP, which have a pile element similar to the one used in CPGA. Pile forces and moments and structure forces and moments are obtained from these analyses. An analysis of a steel frame on a pile foundation is accomplished in a similar manner.

d. Selection of Design Criteria. Criteria for ultimate pile capacity may be applied to most pile foundation designs. However, uncertainty about pile-soil behavior may require modification of some criteria to ensure a conservative design. The magnitude of the lateral or axial pile stiffness may significantly affect the results of any pile analysis. Combining limiting values of lateral and axial pile stiffnesses may result in significantly different percentages of the applied loads being resisted by pile bending or axial force.This is particularly important for flexible base analyses because the applied loads are distributed to the piles based on the relative stiffness of the structure and the piles. Therefore realistic variations in pile stiffnesses should usually be evaluated, and the pile group should be designed for the critical condition.

e.Initial Layout. The simplest pile layout is one without batter piles. Such a layout should be used if the magnitude of lateral forces is small. Since all piles do not carry an equal portion of the load, axial pile capacity can be reduced to 70 percent of the computed value to provide a good starting point to determine an initial layout. In this case, the designer begins by dividing the largest vertical load on the structure by the reduced pile capacity to obtain the approximate number of piles. If there are large applied lateral forces, then batter piles are usually required. Piles with flat batters provide greater resistance to lateral loads and the less resistance to vertical loads. Piles with steep batters, provide greater vertical resistance and less lateral resistance.The number of batter piles required to resist a given lateral load can also be estimated by assuming that the axial and lateral resistances are approximately 70 percent of computed capacity. This should be done for the steepest and flattest batters that are practical for the project, which will provide range estimate of the number of batter piles required. For a single load case this method is not difficult.

f. Final Layout. After the preliminary layout has been developed the remaining load cases should be investigated and the pile layout revised to provide an efficient layout. The goal should be to produce a pile layout in which most piles are loaded as near to capacity as practical for the critical loading cases with tips located at the same elevation for the various pile groups within a given monolith. Adjustments to the initial layout by the addition, deletion, or relocation of piles within the layout grid system may be required. Generally, revisions to the pile batters will not be required because they were optimized during the initial pile layout. The designer is cautioned that the founding of piles at various elevations or in different strata may result in monolith instability and differential settlement.

A funnel connected with a tremie pipe used for pouring concrete into the pile

Special consideration

a. Soil-Structure Interaction. Pile-supported structures should be

analyzed based on the axial and lateral resistance of the piles alone.

Additional axial or lateral resistance from contact between the base slab and the foundation material should be neglected for the following reasons. Vibration of the structure typically causes densification of the foundation material and creates voids between the base slab and foundation material. Also, consolidation or piping of the foundation material can create voids beneath the structure.

b. Deep Seated Lateral Movement and Settlement. The soil mass surrounding a pile group must be stable without relying on the resistance of the pile foundation. In actual slides, 48-inch diameter piles have failed. Deep seated stability of the soil mass should be analyzed by neglecting the piles. Potential problems of inducing a deep seated failure due to excess pore water pressures generated during pile driving or liquefaction due to an earthquake should be recognized and accounted for in the design. The probable failure mechanism for piles penetrating a deep seated weak zone is due to formation of plastic hinges. A second mechanism is a shear failure of the piles which can only occur if the piles penetrate a very thin, weak zone which is confined by relatively rigid strata.

c. Effects of Changes in the Pile Stiffness.

Rigid Base. For a pile group that contains only vertical piles, the

rigid cap assumption requires that the plane of the pile heads remains plane when loads are applied. Therefore, since the axial and lateral components of the pile reactions are independent, changes in the axial or lateral pile stiffnesses will have predictable results. If the pile layout contains a combination of vertical and batter piles, then the interaction of lateral and axial components of the pile reactions can have significant and often unforeseen effects on the distribution of pile forces. Therefore, changes in the lateral stiffnesses could have a profound effect on the axial pile forces, and the sensitivity of the pile forces to changes in the pile stiffnesses would not be predictable without using a computer analysis.

d. Effects of Adjacent Structures.

(1) General. Most hydraulic structures are designed to function as independent monoliths. Sometimes it is necessary to design hydraulic structures which interact with adjacent monoliths or existing structures. Certain procedures and details should be used to assure that the actual structural performance is consistent with the design assumptions.

(2) New Structures Adjacent to Existing Structures. Special provisions

are appropriate for designing and installing piles adjacent to an existing structure.Existing structures include those under construction or already in service. During construction, pile

driving should not be allowed within 100 feet of concrete which has not attained its design strength. Pile driving within 100feet of concrete that has achieved the required design strength should be monitored for detrimental effects on the existing concrete.If piles are installed near an existing structure It is prudent to monitor and document effects of pile driving on the existing structure and foundation. Such provisions should be fully considered during design.

e. Pile Buckling.

Buckling of individual piles is related to the load level, the flexibility of the pile cap, the geometry of the pile group, and the properties of the soil and piles. Pile-soil stiffness and the degree of lateral support provided by the soil primarily depend on the following factors:

- **Embedment**. If the piles are fully embedded, then the lateral support provided by the soil is usually sufficient to prevent pile buckling. Even extremely weak soils may provide sufficient support to prevent buckling when fully embedded. Buckling may be critical if the piles project above the surface of soils that provide strong lateral support.

- **Rigidity**. The pile shape (radius of gyration), modulus of elasticity of the pile, the lateral and axial support provided by the soil, the degree of fixity of the pile head, and the flexibility of the pile cap all affect the relative pile rigidity. Buckling analysis is very complex because the axial and transverse loads and the pile stiff-nesses affect the deformation of the pile, and this behavior is related through interaction with the soil.

References

1. Massachusetts Turnpike Authority (2000), Project Summary, http://www.bigdig.com/thtml/ summary.htm.
2. Massachusetts Turnpike Authority (2000), Project Contract Lists, http://www.bigdig.com/ thtml/contlist.htm.
3. Massachusetts Turnpike Authority (2000), Maps and Plans, http://www.bigdig.com/thtml/ maps01.htm.
4. GZA GeoEnvironmental, Inc. (1991), *Central Artery (I-93)/Tunnel (I-90) Project, Geotechnical Data Report, South Bay Interchange, Design Sections D009B/D009C*, Boston, MA.
5. GZA GeoEnvironmental, Inc. (1992), *Central Artery (I-93)/Tunnel (I-90) Project, Geotechnical Data Report, South Bay Interchange, Design Section D009A*, Boston, MA.
6. Haley and Aldrich, Inc. (1991), *Final Geotechnical Data Report, Central Artery (I-;93)/Tunnel (I-90) Project, Design Sections D007C and D007D (C07D2)*, Boston, MA.
7. Haley and Aldrich, Inc. (1996), *Final Geotechnical Report, Central Artery (I-93)/Tunnel (I-;90) Project, Design Section D008A*, Boston, MA.
8. Maguire Group, Inc., and Frederic R. Harris, Inc. (1995), *Final Report on Soil Stabilization and Testing Program, Central Artery (I-93)/Tunnel (I-90) Project, D009A*, Boston, MA.
9. Maguire Group, Inc., and Frederic R. Harris, Inc. (1995), *Supplemental Geotechnical Data Report, Central Artery (I-93)/Tunnel (I-90) Project, Design Section D009A*, Boston, MA.
10. Stone and Webster, Inc. (1996), *Final Geotechnical Data Report, Central Artery (I-;93)/Tunnel (I-90) Project, Design Section D019B, I-93 Viaducts and Ramps North of Charles River*, Boston, MA.
11. Barosh, P.J.; Kaye, C.A.; and Woodhouse, D. (1989), "Geology of the Boston Basin and Vicinity." *Civil Engineering Practice: Journal of the Boston Society of Civil Engineers*, 4(1), 39-52.
12. McGinn, A.J., and O'Rourke, T.D. (2003), *Performance of Deep Mixing Methods at Fort Point Channel*, Cornell University, Ithaca, NY.
13. Commonwealth of Massachusetts (1997), *The Massachusetts State Building Code, Users Guide to 780 CMR* (6th Edition), William F. Galvin, Boston, MA.