The precast concrete piles engineering essay

2. 1 introduction

2. 1. 1 Introduction of pile

Piles are the very common elements in a foundation. Pile foundation have the function that transfer loads from superstructure through through water or through the weak compressible strata, onto rock, less compressible soils or onto stiffer. This type of foundation need to carry uplift loads when it is used to support tall structures. Not only that, it is also to overturning the forces from winds or waves. Thus, piles used in marine structures are also the subjected to lateral loads from the waves and impact of berthing ships. The combinations of horizontal and vertical loads are to carry where the piles are used to support, bridge piers and abutments, retaining walls and machinery foundations.

In the late of nineteenth years, reinforced concrete was developed as a structural medium. This is the replacement of timber for high-capacity piling of works into soil on land. This can be precast in structural forms and also suitable for ground conditions and the imposed loading. The durability of pile was satisfactory for immersion conditions and most of the soil. Replacement of the driven of precast concrete of cast in-situ piles had due to most of the development of highly efficient machines. This is for drilling pile boreholes of rock conditions, great depth in wide range of soil and the large diameter of pile than to other deficiency in performance of the precast concrete element.

Steel is used to increase when extension for pile due to ability to withstand hard driving, handling, to its ease of fabrication. The corrosion problem in marine structures have had solved by the introduction of cathode protection and durable coatings.(Michael Tomlinson, 2008)

2. 1. 2 Type of pile

2. 1. 2. 3 displacement piles

Precast concrete pile

Precast concrete piles have their principal use in marine and river structures, i. e. in situations where the use of driven and cast-in-place piles is impracticable or uneconomical. For land structures unjoint precast concrete piles are frequently more costly than driven and casting- place types for two main reasons:

1. Reinforcement must be provided in the precast concrete pile to withstand the bending and tensile stresses which occur during handling and driving. Once the pile is in the ground, and if mainly compressive loads are carried, the majority of this steel is redundant.

2. The precast concrete pile is not readily cut down or extended to suit variations in the level of the bearing stratum to which the piles are driven.

However, there are many situations for land structures where the precast concrete pile can be more economical. Where large numbers of piles are to be installed in easy driving conditions the savings in cost due to the rapidity of driving achieved may outweigh the cost of the heavier reinforcing steel necessary. Reinforcement may be needed in any case to resist bending stresses due to lateral loads or tensile stresses from uplift loads. Where high-capacity piles are to be driven to a hard stratum, savings in the overall quantity of concrete compared with cast-in-place piles can be achieved since higher working stresses can be used. Where piles are to be driven in sulphate-bearing ground or into aggressive industrial waste materials,

the provision of sound high-quality dense concrete is ensured. The problem of varying the length of the pile can be overcome by adopting a jointed type.

From the above remarks it can be seen that there is still quite a wide range of employment for the precast concrete pile, particularly for projects where the costs of establishing a precasting yard can be spread over a large number of piles. The piles can be designed and manufactured in ordinary reinforced concrete, or in the form of pre-tensioned or post-tensioned

prestressed concrete members. The ordinary reinforced concrete pile is likely to be preferred for a project requiring a fairly small number of piles, where the cost of establishing a production line for prestressing work on site is not justifiable and where the site is too far from an established factory to allow the economical transportation of prestressed units from the factory to the site.

Precast concrete piles in ordinary reinforced concrete are usually square or hexagonal and of solid cross-section for units of short or moderate length, but for saving weight long piles are usually manufactured with a hollow interior in hexagonal, octagonal, or circular sections. The interiors of the piles can be filled with concrete after driving. This is necessary to avoid bursting where piles are exposed to severe frost action. Alternatively, drainage holes can be provided to prevent water from accumulating in the hollow interior. To avoid excessive flexibility while handling and driving the usual maximum lengths of square section

piles, and the range of working loads applicable to each size are shown in table 2. 1 . Where piles are designed to carry the applied loads mainly in end-bearing, for example, piles driven through soft clays into medium-dense or dense sands, economies in concrete and reductions in weight for handling can be achieved by providing the piles with an enlarged toe. This is practised widely in the Netherlands where the standard enlargements are 1. 5 to 2. 5 times the shaft width with a length equal to or greater than the width of the enlargement.

Table 2. 1 Working loads and maximum lengths for ordinary precast

concrete piles of square section

Jointed precast concrete piles

The disadvantages of having to adjust the lengths of precast concrete piles either by cutting off the surplus or casting on additional lengths to accommodate variations in the depth to a hard bearing stratum will be evident. These drawbacks can be overcome by employing jointed piles in which the adjustments in length can be made by adding or taking away short lengths of pile which are jointed to each other by devices capable of developing the same bending and tensile resistance as the main body of the pile. BS EN 12794 defines pile joints in four classes, Class A to Class D, depending on whether the pile is used in compression, tension, or bending and the impact load test to be applied to verify the static design calculations. If the pile joint satisfies the impact and bending tests then the ultimate capacity of the joint is ‘ identical’ to the calculated static bearing capacity. Annex ZA to this standard deals with the CE marking of foundation pile units and the presumption of fitness for the intended use.

The ‘ Hercules’ pile, originally developed in Sweden, is available in the UK from Stent Foundations Ltd in two square sizes with standard lengths of 6. 1, 9. 2, and 12. 2 m, and properties as shown in Table 2. 6. C45/55 concrete is normally used. The precast concrete units are locked together by a steel bayonet-type joint to obtain the required bending and tensile resistance and a rock shoe incorporating an Oslo point seating pile into hard rock. A length is chosen for the initial driving which is judged to be suitable for the shallowest predicted penetration in a given area. Additional lengths are locked on if deeper penetrations are necessary, or if very deep penetrations requiring multiples of the standard lengths are necessary.

Other types of jointed precast concrete piles include the ‘ Centrum’ pile manufactured and installed by Aarslef Piling in the UK using C40/50 concrete and rigid welded reinforcement cages in varying lengths from 4 to 18 m in square sections from 200 to 600 mm. Lengths greater than 4 m for the 200 and 250 mm sections can be jointed using a single locking pin driven horizontally into locking rings in the joint box (four locking pins for the larger sections), which are designed to provide a degree of pre-tensioning to the typical locking pin joint. Depending on the length, section, and joint used and the ground conditions, working loads

up to 1200 kN in compression and 180 kN in tension are possible.

‘ RB’ precast square concrete piles made and installed by Roger Bullivant Ltd are available in four sizes with working load capabilities (depending on ground conditions) from 200 kN for the nominal 150 mm square section to 1200 kN for the 355 mm square pile, in lengths of 1. 5, 3, and 4 m. The standard joint for the limited tensile and bending capability is a simple spigot and socket type bonded with epoxy resin with each pile length bedded on a sand/cement mortar. Special joints and pile reinforcement can be provided as needed to resist bending moments and tension forces.

Precast concrete piles which consist of units joined together by simple steel end plates with welded butt joints are not always suitable for hard driving conditions, or for driving on to a sloping hard rock surface. Welds made in exposed site conditions with the units held in the leaders of a piling frame may not always be sound. If the welds break due to tension waves set up during driving or to bending caused by any deviation from alignment, the pile may break up into separate units with a complete loss of bearing capacity. This type of damage can occur with keyed or locked joints when the piles are driven heavily, for example, to break through thin layers of dense gravel. The design of the joint is, in fact, a critical factor in the successful employment of these piles, and tests to check bending, tension, and compression capabilities should be carried out for particular applications. However, even joints made from steel castings require accurate contact surfaces to ensure that stress concentrations are not transferred to the concrete.

The ‘ Presscore’ pile developed and installed by Abbey Pynford plc is a jointed precast concrete pile consisting of short units which are jacked into the soil. The concrete in the pile units and precast pile cap is 60 N/mm2 and a reinforcing bar can be placed through the centre of the units of Presscore pile. On reaching the required bearing depth the annulus around the pile is grouted through ports in the units. The use of jacked-in piles for underpinning work is described in Chapter 9.

A high strength cylindrical precast pile, 155 mm diameter and 1m long, was developed in Canada for underpinning a 90-year-old building in Regina. The segments were cast using steel fibre reinforced concrete with a 28-day compressive strength of 90 N/mm2 and steel fibre content of 40 kg/m3. Each segment was reinforced with four steel wires (9 mm) welded to a steel wire circumferential coil. Recesses were provided at each end of the segment and stainless steel rods connected each segment to form the joint. Hydraulic jacks with a capacity of 680 kN reacted against a new pile cap and as each segment was jacked down the next segment was screwed and tensioned onto the connecting rod. The required

600 kN pile capacity was achieved at depths ranging from 11 to 13 m.

Table 2. 2Dimensions and properties of square section ‘ Hercules’ piles as

manufactured

Driven and cast-in-place displacement piles

In the Cementation Foundations Skanska version of the withdrawal tube pile, the heavy wall section tube has its lower end closed by an expendable steel plate or shoe and is driven from the top by a five-tone hydraulic hammer. On reaching the required to level, as predetermined by calculation or as determined by measurements of driving resistance, the hammer is lifted off and a reinforcing cage is lowered down the full length of the tube. A highly workable self-compacting concrete is then placed in the tube through a hopper, followed by raising the tube by a hoist rope operated from the pile frame. The tube may be filled completely with concrete before it is lifted or it may be lifted in stages depending on the risks of the concrete jamming in the tube. The length of the pile is limited by the ability of the rig to pull out the drive tube. This restricts the length to about 20 to 30 m. Pile diameters range from 285 to 525 mm with working loads up to 1500 kN.

In a further variation of the Franki technique, the gravel plug (or dry concrete plug) can be hammered out at several intermediate stages of driving to form a shell of compact material around the pile shaft. This technique is used in very soft clays which are liable to squeeze inwards when withdrawing the tube. Composite Franki piles are formed by inserting a precast concrete pile or steel tube into the driving tube and anchoring it to the base concrete plug by light hammer blows. The drive tube is then withdrawn.

A full-length reinforcing cage is always advisable in the driven and cast-in-place pile. It acts as a useful tell-tale against possible breaks in the integrity of the pile shaft caused by arching and lifting of the concrete as the tube is withdrawn. BS EN 12699 requires minimum reinforcement of 0. 5% of the pile cross-section or four 12 mm diameter bars over the top 4 m of all such piles; with minimum cover of 50 mm where the casing is withdrawn, 75 mm where reinforcement is installed after concreting (or where subject to ground contaminants), and 40 mm where there is permanent lining.

The problem of inward squeezing of soft clays and peats or of bulging of the shafts of piles from the pressure of fluid concrete in these soils is common to cast-in-place piles both of the driven and bored types. A method of overcoming this problem is to use a permanent light gauge steel lining tube to the pile shaft. However, great care is needed in withdrawing the drive tube to prevent the permanent liner being lifted with the tube. Even a small amount of lifting can cause transverse cracks in the pile shaft of sufficient width to result in excessive settlement of the pile head under the working load. The problem is particularly difficult in long piles when the flexible lining tube tends to snake and jam in the drive tube. Also where piles are driven in large groups, ground heave can lift the lining tubes off their seating on the unlined portion of the shaft. Snaking and jamming of the permanent liner can be avoided by using spacers such as rings of sponge rubber.

In most cases the annulus left outside the permanent liner after pulling the drive tube will not close up. Hence, there will be no frictional resistance available on the lined portion. This can be advantageous because drag down forces in the zone of highly compressible soils and fill materials will be greatly reduced. However, the ability of the pile shaft to carry the working load as a column without lateral support below the pile cap should be checked.

Allowable stresses on the shafts of these piles are influenced by the need to use easily workable self-compacting mixes with a slump in the range of 130 to 180 mm and to make allowances for possible imperfections in the concrete placed in unseen conditions. BS EN 12699 for driven displacement piles requires the rules on the concreting of bored piles using self-compacting concrete as recommended in BS EN 1536 to apply to all cast-in-place displacement piles unless otherwise specified. BS 8004 limits the working stress to 25% of the 28-day cube strengths, but BS EN 12699 specifies concrete strength classes of C20/25 to C30/37 which are 25% stronger than the cube strengths usually adopted in the UK under BS 8004, that is, a range of 20-30 N/mm2. EC2-1-1 Clause 3 refers to characteristic cylinder strengths for the determination of design compressive strengths, and if the 25% limit is applied the allowable stresses range from 5 to 7. 5 N/mm2 (i. e. similar to the BS 8004 limits, but for the stronger mixes). For these values, allowable loads for piles of various shaft diameters are as shown in the following table:

The higher ranges in the above table should be adopted with caution, particularly in difficult ground conditions.

Maximum working loads are as shown in the following table:

The spacing of bars in the reinforcing cage should give ample space for the flow of

concrete through them. Bars of 5 mm diameter in the form of a spiral or flat steel hoops used for lateral reinforcement should not be spaced at centres closer than 100 mm (80 mm when using 20 mm aggregate).

Replacement piles

Bored and cast-in-place piles

In stable ground an unlined hole can be drilled by hand or mechanical auger. If reinforcement is required, a light cage is then placed in the hole, followed by the concrete. In loose or water-bearing soils and in broken rocks casing is needed to support the sides of the borehole, this casing being withdrawn during or after placing the concrete. In stiff to hard clays and in weak rocks an enlarged base can be formed to increase the end-bearing resistance of the piles. The enlargement is formed by a rotating expanding tool. Hand excavation is now uneconomic because of stringent statutory health and safety regulations, even in piles with a large shaft diameter. A sufficient cover of stable fine-grained soil must be left over the top of the enlargement in order to avoid a ‘ run’ of loose or weak soil into the unlined cavity.

Bored piles drilled by hand auger are limited in diameter to about 355 mm and in depth to about 5 m. They can be used for light buildings such as dwelling houses, but even for these light structures hand methods are used only in situations where mechanical augers.

The versatile, light cable percussion tripod rigs can bore piles up to 600 mm diameter 10 m deep with working loads up to 1200 kN in suitable ground conditions. Temporary casing can be driven to cut off unstable ground and reinforcement inserted prior to concreting.

Bored piles drilled by mechanical spiral-plate or bucket augers or by grabbing rigs can drill piles with a shaft diameter up to 7. 3 m. Standard plate auger boring tools for use with kelly bar rigs range from 600 to 3650 mm. Rigs with telescopic kelly bars can reach 70 m depth and 102 m exceptionally. Under-reaming tools can form enlarged bases in stable soils up to 7. 3 m in diameter. Rotary drilling equipment consisting of drill heads with multiple rock roller bits have been manufactured for drilling shafts up to 8 m in diameter.

In a stable dry bore, concreting is carried out from a hopper over the pile with a short length of pipe to direct flow into the centre of the reinforcement, ensuring that segregation does not occur. When concreting boreholes under flooded conditions or under stabilizing fluid a full length tremie pipe (6 times the maximum diameter of the aggregate or 150 mm diameter whichever is the greater) is essential. For reasons of economy and the need to develop shaft friction, it is the normal practice to withdraw the casing during or after placing the concrete. As in the case of driven and cast-in-place piles this procedure requires care and conscientious workmanship by the operatives in order to prevent the concrete being lifted by the casing, and resulting in voids in the shaft or inclusions of

collapsed soil.

Reinforcement is not always needed in bored and cast-in-place piles unless uplift loads are to be carried (uplift may occur due to the swelling and shrinkage of clays). Reinforcement may also be needed in the upper part of the shaft to withstand bending moments caused by any eccentricity in the application of the load, or by bending moments transmitted from the ground beams. However, it is often a wise precaution to use a full-length reinforcing cage in piles where temporary support by casing is required over the whole pile depth. The cage acts as a warning against the concrete lifting as the casing is extracted. The need to allow ample space between the bars for the flow of concrete is again emphasized.

2. 2 Procedure of driving precast pile and cast in-situ pile.

2. 2. 1 Driving precast concrete piles

A helmet for precast concrete piles are carefully centered on the

pile, and the hammer position should be checked to ensure that it delivers a concentric blow. The hammer should preferably weigh not less than the pile. BS 8004 requires that the weight or power of the hammer should be sufficient to ensure a final penetration of about 5 mm per blow unless rock has been reached. Damage to the pile can be avoided by using the heaviest possible hammer and limiting the stroke. BS 8004 states that the stroke of a single-acting or drop hammer should be limited to 1. 2 m and preferably to not more than 1 m. The

Swedish piling code requires a drop hammer to weigh at least 3 tonne, except that 2-tonne hammers can be used for piles with a maximum length of 10 m and a maximum load of 450 kN, but a 4-tonne hammer should be used for long piles in compact materials. This code recommends that the drop of the hammer should be limited to 300 to 400 mm in soft or loose soils to avoid damage by tensile stresses. The drop should be limited to 300 mm when driving through compact granular soils.

The driving of the piles should be carefully watched, and binding by toggle bolts due to the pile rotating or moving off line should be eased. The drop of the hammer should be reduced if cracking occurs, and if necessary the hammer should be changed for a heavier one. After the completion of driving the pile heads should be prepared for bonding into the pile caps. Hollow piles with a solid end may burst under the impact of the hammer if they become full of water, and holes should therefore be provided to drain off accumulated water. Where a soil plug is formed at the toe of an open-ended pile, water accumulation or arching of the soil within the pile may also result in bursting during driving.

The installation of withdrawable-tube types of driven and cast-in-place piles