# X-Section Cast-in-Situ Concrete Pile: A Review

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*Abstract*--- X-section cast-in-place concrete (XCC) pile is a new type of foundation that uses piles with X-shaped cross-sections as compared to a traditional circular cast-in-place concrete (CCC) pile.
*Keywords:* XCC Pile, CCC Pile, Under reamed Pile, Pile Driving.

## I. INTRODUCTION

If any engineering structure going to construct on thick deposit soft soil it has great problem of low bearing capacity ,excessive total and differential settlement, lateral spreading etc. So generally to mitigate this type of problem we have two methods. In first method we can enhance the soil strength by using different soil improvement methods such as vacuum preloading and surcharge preloading. The other is installing structure with high stiffness into the soil so that it can help to support the surrounding soil. For this pile technology has been widely used in soft ground improvement.

Number of special shaped piles are used to improve the stiffness of foundation such as H-pile, I-pile, barrette, tapered pile, belled pile, squeezed branch pile, pipe pile, Y-section pile, and XCC pile. From the list of above piles H and I piles are made of steel. H-piles and I-piles generally referred as displacement piles which are having very strong to resist the penetration and also good to withstand in vertical and horizontal pressure of soil.(Burdette et al. 2004; Yang et al. 2006).For improving the bearing capacity the depth and length of flange must be enlarged.(Lin 1998; William et al. 2010).

For increasing section modulus, horizontal shear strength of pile there are number of cross-section such as rectangle, H-shape, I-shape etc. are used. As per the requirement of bearing capacity, section of pile can be modified. (Lei 2001).As compared with traditional piles tapered piles are more economical one. It can reduce required material by 80% under the same bearing capacity (Sakr et al. 2005). In belled piles the enlarge diameter at tip is taking place due to this enlarge diameter at tip the skin friction is very high at tip. Under reamed piles are bored cast-in-situ concrete piles having one or more bulbs formed by enlarging the pile stem with a suitable cutting tool. The provision of bulbs is useful in two ways. It provides larger bearing area at greater depths which are more firm and stable. It also serves as an anchor and keeps the foundation stable in the event of any upward drag of the pile stem.(S.Neha& B. Nikhil.2008)Squeezed branch pile with specific property of frictional end-bearing pile bears load mainly by bearing disks, and the ultimate load of the pile is 150 - 200 percent of straight pile.(D. Qian et al. 2006). Compared with a belled pile, a squeezed branch pile has multiple expanding diameters. Having higher bearing capacity, it can adjust pile-soil load-sharing to effectively decrease the settlement and cost (Zhang et al. 2004).

Professor Hanlong Liu and others at Hohai University in China developed a new pipe pile named cast-in-place concrete pipe pile. This type of pile produced their strength by pipe as well as concrete. In this tubes are immersed with vibration in the ground and poring of concrete is take place inside it. Due to simple in construction it will save the cost.(Liu et al. 2009; Xu et al. 2006).One other type of pile named Y-section pile is also have good skin friction because of its perimeter. It was developed by professor Lu.(Lu and Lu 2002).

A new XCC pile developed by the Geotechnical Research Institute of Hohai University has been patented in China (patent number ZL200720036892.6). The method of construction is same as Y-shape pile. In this, cross-section steel mold drives in ground which is protected by a valve pile shoe or precast pile tip. The procedure includes immersing the tube, pouring concrete, vibratory extubation, and curing of the concrete.(Yaru lu. et al.2012). Compared with a circular pile, the XCC pile with the same cross-sectional area shows improve in bearing capacity and also good frictional resistance, because of increasing in pile perimeter.(Yaru lu. et al.2012,Liu 2008; Wang 2009; Yuan 2009).

## II. INSTALLATION METHOD AND EQUIPMENT

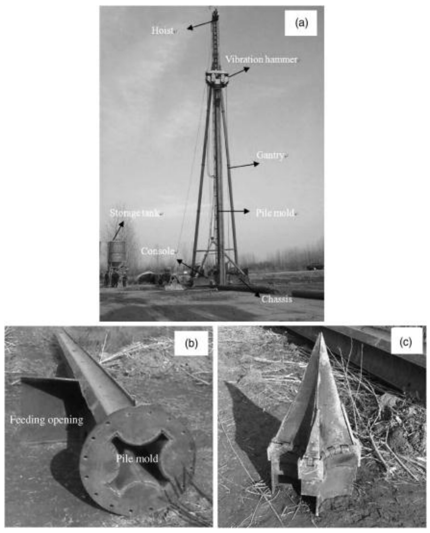


Fig. 1: Construction equipment: pile driving machine; (b) the mold of XCC pile; (c) valve pile shoe for the XCC pile.

During the construction some important point should be kept in mind.Chen et al. (2010)

 

The pile is formed by driving the cross-section steel mold, which is protected by a valve pile shoe or precast pile tip. Yaru Lu discuss in their paper that there are some requirements of installation equipment for XCC pile. The perimeter of mold can be taken as 0.25 to 1 m and the capacity of mold which was immersed in the ground can take as depth of 25 m. Further they stated that the static lifting power should be larger than 200 kN and static load plus the high frequency vibration load must be larger than 1000 kN. Equipment is made up of many parts such as chassis, gantry, vibration hammer, pile mold, valve pile shoe, hoist, and console (Fig-1, a, b, c).

1) The center of the pile should be marked and should not deviate more than 2 mm. Datum lines should be set up along both sides for verification of alignment as necessary

Fig. 2: XCC pile head

2) When placing the pile-driver, the valve pile shoe or precast pile tip should be adjusted to align the center of the hole, and the verticality bias should not be larger than 1%,
3) The material must be filled incrementally to avoid isolation resulting from vibration. Pouring concrete and vibration extubation should be done alternatively. The ratio of actual section area to designed section area is delimited as the filling coefficient. The height of the concrete must be above the ground surface to avoid breaking the pile. The filling coefficient must be larger than 1 and no more than 1.25, and the pile cap must be conserved, and the piled foundation must be tested.

## III. MODEL TESTING AND CASE STUDY

(LÜ Ya-ruet al.2012) carried out in-situ static load tests based on the foundation treatment project in Qiaobei sewage treatment plant in Nanjing. They discuss ultimate bearing capacity considering some factors including elastic modulus of pile, modulus of surrounding soil, pile length, cushion thickness and cushion modulus. The result which they have discussed shows that XCC single-pile composite foundation can increase the bearing capacity by 20% more than that of traditional pile. And also the ultimate bearing capacity of XCC four-pile composite foundation can increase the bearing capacity by 12.35% more than that of traditional pile. From their experimental and finite element analysis they shows that ultimate bearing capacity increases with the increase of pile modulus, cushion modulus surrounding soil modulus and pile length. They carried out the CPT tests and static load tests for their study. Fig (3).

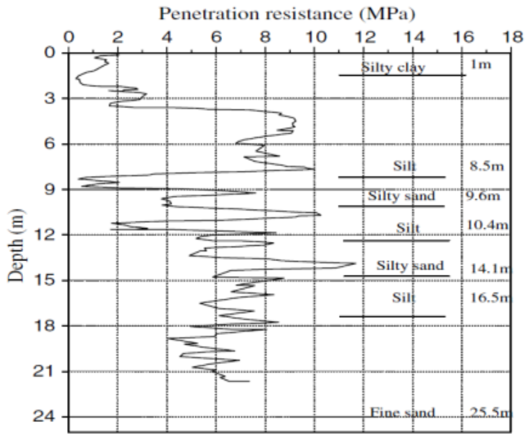


Fig. 3: Result of CPT test for the test site

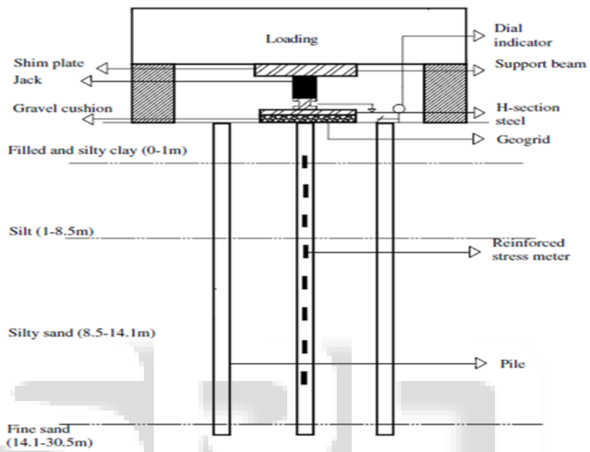


Fig. 4: Layout of test equipment for the static load tests

(DING Xuan-ming et al.2012) carried out comparative study between circular and XCC pile and measured the load-settlement, pile-soil load sharing, pile-soil stress ratio, and the distributions of axial force of pile shaft. They have also done pile-soil interaction analysis of XCC pile under different conditions. In order to do comparative analysis,they done the static load tests for circular pile which has the same concrete amount with that of XCC pile. Result shows that the maximum value of positive skin friction is about 140 % of those of negative skinfriction and also pile-soil stress ratio of XCC pile in composite foundation is increased with the decreasing of pile spacing under the same pile length.

## IV. NUMERICAL ANALYSIS

(Yaru Lv et al 2013) done the Three-dimensional numerical analysis of the stress transfer mechanism of XCC piled raft foundation. They concluded that for a given applied load, the total side resistance mobilised on the XCC pile is usually larger than the total side resistance of the CCC pile, by a factor that ranges from 0.5 to 10, dependingon the pile depth. According to this study approximately 66% and 46% of the applied load is carried by the XCC and CCC piles respectively, and simultaneously, approximately 45% and 24% of the applied load is taken by the side resistance of the XCC and CCC piles, respectively. This is due to cross-sectional geometry of XCC pile, which results in a larger perimeter and arching effects.

Ding Xuanming 2012 study the dynamic responses of XCC pile supported embankment under lateral seismic excitation by 3DFEM and concluded that absolute acceleration, relative dynamic displacement and dynamic stress, maximal acceleration response locates at the top of embankment when XCC pile was used.

LÜ Ya-ru 2012 also shows in their numerical analysis that XCC single-pile composite foundation can increase the bearing capacity by 20% more than that of traditional pile and also ultimate bearing capacity of XCC four-pile composite foundation can increase the bearing capacity by 12.35% more than that of traditional pile.The maximum stress distribution increased with the decreasing of outsourcing diameter, the decreasing of open arc angle, and the increasing of open space with the same area.(KONG Gang-qiang 2012).

## V. CONCLUSION

From the brief review on XCC pile it is concluded that XCC pile shows the more side frictional resistance than normal CCC pile. Because the perimeter of XCC pile is more than CCC pile. So the bearing capacity improve by XCC pile is more than that of CCC pile.

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