Good historical review of continuous flight augers in granular soils research pap...

Law, Security

Engineering

Abstract

Continuous Flight Augers (CFA) require special expertise to construct but done properly they are economical and very successful for areas with inconsistent load carrying capacities. Examples include using CFA pilings for guard rails, highway reinforcement, highway junction improvements and buildings. The CFA pilings are similar to driven and bored piles but offer different advantages when working in good to marginal soils and in projects where the load capacity needs vary. An auger with a hollow tube is used to bore the hole and then when the auger tip reaches the final depth concrete is added as the auger is carefully pulled out of the hole. The concrete mixture is especially designed for withstanding the stress and strains in its final use as a piling. No casing is necessary. The main disadvantage is that the CFA process is temperature dependent so cold temperatures are not as easy to work in because the concrete needs to be carefully handled in order to set properly. Proper testing of the piling is highly recommended because the economic savings are large if using a CFA with the optimum resistance. CFAs have been successfully used across the UK even adjacent to high volumes of traffic during reinforcement and improvements of highway junctions. Safety is a critical factor because the auger can be dangerous if not turned off when construction workers are in the adjacent area. Also the cleaning of the auger can allow large amount of tailings to be dumped and this must be done in an empty space or it could create an unsafe situation for workers. Future research can be done on safer cleaning processes for the CFA. Two new models which are being designed are Cased Auger Piling (CAP)

and a Cased Secant Piling (CSP).

1. 0 Historical review of CFA in Granular Soils

1. 1 Background

Continuous Flight Auger (CFA) pilings are suitable for use for a variety of situations including buildings, earth wall retention, and transportation structures (like guard rails), process units, and ground improvement (stabilizing, prevention of erosion). In the UK historical examples of driving bearing piles to build foundations to support structures are evident from the time of the Roman Empire and during the Middle Ages. The examples from the Romans are the timber pilings used to support bridges and in the Roman settlements located next to rivers. Mediaeval architects used piles formed from oak and alder; some of the most impressive examples were used in monasteries. In China during the Han dynasty (about 2000 years ago) architects of the great Chinese bridges also used timber piling. Timber had the advantages of availability, " strength combined with lightness, durability and ease of cutting and handling, remained the only material used for piling" (Woodward 2008: 2) until recently when concrete and steel materials were developed. Load bearing piles are used when soil for bearing is not deep, when loading is not consistent across the area, and when clay soils that shrink are in top horizons are drilled through so the bearing piles can carry the load below the shrinkage zone. A feature of load bearing piles is that their tension capacity and compression capacity are higher than that for lateral loads.

1. 2 Definition

A CFA pile is defined as " any foundation that is made by rotating a hollow-stem auger into the ground to the specified pile depth” (Brown et al., 2007: 218) After the location and depth have been established at the construction site the CFA is drilled at the correct location to the design depth. The hollow stem of the auger is used as a delivery system; grout or a mortar made from cement-sand is pumped down the stem; as the auger is slowly raised back out of the hole while dispensing the cement-sand mortar in the empty space left as the auger is removed. (See fig. 1) The bore the drilling makes is supported by the auger and soil until the mortar is injected (or pumped) into the bore hole. The concrete (or grout) is injected “ through the auger shaft under continuous positive pressure, as the auger is being withdrawn” because this in turn exerts “ a positive upward pressure on the earth-filled auger flights as well as lateral pressure on the soil surrounding the placed grout or concrete column” (Brown et al., 2007: 218). Before the mortar sets a cage of reinforcement can be placed into the fluid mortar to approximately 12 meters in depth from the surface. (Brown 2012) Reinforcing steel is the material used for strengthening the top metres of the piling. The three types of conventional CFA piles are

“ . . . (a) traditional continuous flight auger piles, (b) drilled displacement piles intended to install a cast-in-place pile with full displacement and minimal soil spoil; and (c) partial displacement piles which may displace some soil but not act as a full displacement pile.” (Brown et al., 2007: 218) The concrete or grout is pumped into the bore hole through the injection tube after the design depth is reached. “ The stem plug is ejected under concrete pressure” (Greider 2010: 6) No de-consolidation is wanted so the auger is not rotating, or if still rotating the auger is pulled slightly forward.

(Greider 2010) The extraction of the auger also acts as the cleaning step of the auger because an auger cleaner is placed at the base of the mast in order to strip off the tailings from the flight. (Greider 2010: 9; Woodward 2008)

2. 0 CFA piling methodology

The capacity of CFA pilings are in the middle of the range between a drilled pile and a driven pile. In general the load-settlement behaviour is about the same as driven and drilled piles. For example the safety factors for CFA pilings fall between the values or are equal to the values for driven piles and bored piles. Greider (2010: 8) reports the CFA Pile Load Capacity as " 50 to 2, 000 kN Axial" and suitable for uplift loads and lateral/moment loads.

Regardless of the soil conditions at a piling location the soil is in contact with the pile face and supports it by shaft friction and which uses resistance to hold lateral loads. Under the vadose zone soil at the ' toe' of the pile the soil will be further compressed and/or bedrock cracked which

Figure 1 The process of using CFA

(Abebe and Smith 2004: 73)

loosens the material thereby decreasing the ability for end-bearing resistance. Over time the weather and seasonal environment impacts the skin-friction at the soil-pile interface. (See fig. 2) The changes over-ground impact the underground impacts from (a) dissipation of excess pore pressure set up by installing the pile, (b) to the relative effects of friction and cohesion which in turn depend on the relative pile-to-soil movement and to chemical or electro-chemical effects caused by the hardening of the concrete or the corrosion of the steel in contact with the soil” (Woodward)

The Cone Penetration Test (CPT) is used to measure bearing capacitcies for piles when they are used in granular soils. In figure 2 Q represents the load bearing resistance. The schematic on the left (See fig. 2) shows how soft compressible soil becomes more compressed and therefore more firm under the tip of the pile drill. On the right (See fig. 2) GWT stands for Ground Water Table; under the GWT soft soil becomes more stiff with depth and if bedrock is at the site it may become cracked and perhaps loosened.

Figure 2 End bearing pile (left) and friction/cohesion pile (right

(Brown et al., 2007: 6)

Equation 2 shows how to calculate the bearing capacity of a single pile. (Pusztai 2005: 45)

$Qu = Qb + Qs = Ab \cdot \bar{qc} + U \cdot L \cdot \bar{\tau s}$ Eqn. 2

where

Qu = ultimate (critical) bearing capacity of one pile

Qb = the ultimate (critical) resistance of shaft

Qs = Shaft capacity

Ab = nominal plan (the least amount) are at the pile base (m2)

$\bar{qc}$ = average cone resistance at the pile toe zone (MPa)

U = length of the periphery of the pile (m)

L = the pile Length (m)

$\bar{\tau s}$ = average ultimate (the highest amount) skin friction at the pile shaft surface (MPa)

An opened ended steel tube driven into a fine to medium sand has an Ultimate unit skin friction, τs, equal to 0. 0033 qc.. MiliPascal (MPa) is the unit used to report qc . which is the amount of pressure exerted on the ground.

A concrete mixture is used to form the finished piling placed in the bore hole. Greider 2010: 11) describes the proportions to use in CFA pilings construction as follows.

- “ 25 to 25 MPa Compressive Strength on Day 28
- Slump 200 mm + / -25
- W/C = 0. 45 Typical
- Up to 25% Flyash
- (addition of) air entrainment
- Hydration Stabiliser

2. 1 CFA and Load Testing

Load testing is performed because it is economical if the resistance factor is equal to 0. 4 versus 0. 6. This is a small increment that makes a lot of difference in costing out. High capacities may be reached due to the “ semi-displacement and construction process” (Grieder 2010: 15) Therefore the following tests have been developed.

CFA pile Load Testing Methods

- Dynamic Pile Testing (PDA)
- Top Load Static Load Tests (conventional Load Frame)
- Rapid Load Testing – Statnamic Testing
- Osterberg Cell Testing (O-cell Testing)

Top Load Static Testing:

- Compressive Loads Up to 6. 5 MN

- Tension Loads up to 5. 0 MN

- ASTM D-1184 Standard or Quick Load Test method

- Hydraulic Jack c/w Load Cell – Jack Runs Test, Load cell

- Confirms jack train Gauges for Load Transfer Down Pile Shaft

3. 0 Advantages and Limitations

3. 1 Advantages

The use of CFA piles instead of other traditionally used piles are advantageous because there is no vibration associated with the insertion, the noise levels are low and no temporary casing is necessary (the bore hole is fist supported by the auger and the soil). (Greider: 2010) Although in some cases vibrators are used during the construction process. The advantage of CFA pilings over conventionally bored pilings according to Chen (2006: 60) is mainly due to the use of them in " water-bearing and unstable soils by eliminating the need of casing and the problems of concrete underwater." The installation of CFA piles is quick and the cost is lower. (Greider 2010: 9; Woodward 2008) The

3. 2 Limitations

A disadvantage of using The CFA piles is that the temperature and weather conditions act as limitations on proper installation. The CFA cannot penetrate the hard-bearing bedrock layers. If the rocks can be penetrated they can become cracked or loosened which is not suitable for piling applications.

4. 0 Regulations

In the UK the FPS safety and training committee uses the input from the organisation’s members to develop improvements in dealing with accidents and problems. In 1994 any events and/or experiences are reported to the committee and then sent on to the HSE including age of worker, time of day, circumstances of problem or accidents. RIDDOR 2003 requires quarterly reporting to the HSA of appropriate events. The auger is required to be shut off if a worker needs to enter the area where the piling is being constructed. The most troubling safety issue according to the FPS (2012: 6) are preventing injuries that can occur during the process when workers are “ adjacent to the auger.” “ Of much greater seriousness is the incidence of spoil either being ejected or becoming detached from augers at various heights above ground and falling.” (FPS 2012: 6) The amount of spoil can be large and although excavators are used for spoil removal reports of problems and injuries are made. The FPS recommends that “ the bottom of the guard has to be above ground level to allow spoil to exit the excavation and the be remover the height of the top of the guard has to be such as to prevent personnel coming into contact with the auger” (FPS 2012: 6).

5. 0 Future studies

The process of cleaning the auger also leads to injuries so this area must receive continued research until a safe method for cleaning the auger has been devised. Many adaptations of CFAs have been patented. Two new types that are now being developed according to Greider (2010) are a Cased Auger Piling (CAP) and a Cased Secant Piling (CSP).

6. 0 Conclusion

CFA pilings have been successfully used across the UK. In Bedfordshore CFA piling was constructed next to the motorway in a joint project for improving the carriageway at the M1 junctions 10 – 13, Luton to Milton Keynes. The project was safely carried out next to high volumes of traffic, at times up to 135, 000 vehicles per day. (Bachy 2010: 2) The CRA were 750 mm in diameter and installed (using a vibrator) in lengths of up to 20 meters. The walls of steeply-faced slopes were reinforced with contiguous pile walls to create emergency refuge areas. (Bachy 2010: 2 The distance of the buffer of safety was at the very minimum half a line and a barrier was put in place. This is an important case to note because CFA pilings are practical for making improvements and this project demonstrate success is attained when appropriate safety precautions are used.

CFA pilings work well for marginal soils and for applications that fall between but do not match the capabilities of bored and driven piles. Good to marginal soils are the best suited for using CFA. CFA works the best and the most economically when appropriate resistance tests are carried out.

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