Compressive pile load tests on continuous flight auger piles and on a driven timber pile in silty clay soils in High Prairie, Alberta

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ABSTRACT
The geotechnical investigation for the proposed High Prairie Health Complex (HPHC) in the Town of High Prairie, Alberta, indicated that the subsurface conditions consisted of soft to stiff compressible clay extending at least 21m in depth. The clay was interbedded with water bearing sand layers. Due to heavy loads, constructability of piles in soft soils and the lack of availability of piling equipment in the province, Continuous Flight Auger (CFA) concrete piles were selected for foundations. The design capacity of the CFA piles was estimated based on conventional methods using the soil parameters from the geotechnical investigation program. In addition, the result from a driven timber pile load test, at a site with similar soil conditions, carried out in 1986 for the Provincial Building in High Prairie, was also utilized for the assessment. Due to the limited experience on CFA piles and in order to confirm the design parameters, and also to explore the possibility of higher capacity, a pile load test program was carried out on two 600 mm diameter CFA piles, 14m and 18m long each. The results indicated that the ultimate pile capacity of the CFA piles was about 19 to 41% greater than the theoretical ultimate pile capacity calculated with a total stress method if cast-in place concrete piles were considered. The HPHC site was also used to predict the pile capacity based on SCPTu and SDMT data and the results of this program are presented in a separate paper.

RÉSUMÉ
Les résultats d'une étude géotechnique effectuée au site choisi pour la construction du High Prairie Health Complex (HPHC), dans la ville de High Prairie en Alberta, ont révélés que les sols en place étaient constitués d'argiles silteuses ayant une consistance allant de molle à raide, et ceci jusqu'à une profondeur d'environ 21m . Cette couche d'argile est parsemée de lentilles de sable saturées d'eau. Vu le poids élevé de la structure à construire, de la consistance relativement molle des sols en place, des problèmes liés à la construction de fondations profondes en sols mou et du manque de disponibilités de plateformes de forage pour pieux forés dans la province, des pieux forés à tarière creuse (PFTC) ont été choisis pour construire les fondations profondes de ce projet. La capacité portante initiale des PFTC à été estimée en utilisant des méthodes de calculs conventionelles se basant sur des paramètres de sols obtenus lors du programme de forage durant l'étude géotechnique. De plus, le résultat obtenu lors d'un essai de chargement statique d'un pieu en bois battu, qui a eu lieu en 1986 à High Prairie pour le bâtiment provincial situé dans un site avec des conditions de sols similaires, a été utilisé pour l'interprétation initiale de la capacité portante des PFTC. Étant donné le manque d'expérience relatif à la détermination de la capacité portante des PFTC, et dans le but de confirmer les paramètres préliminaires de calcul, tout en espérant d'augmenter la capacité portante des PFTC, un programme d'essai de chargement statique a été entrepris sur deux PFTC ayant un diamètre de 600mm et des longueurs respectives de 14 m et 18 m. Les résultats de ces essais ont donné des valeurs de capacité portante allant de 19% à 41% plus élevées que les valeurs de capacité portante initiales déterminées par la méthode de contraintes totales en considérant des pieux forés cylindrinques conventionnels. Par la suite, la capacité portante des PFTC a été établie en se basant sur des résultats obtenus lors d'essais de résistance à la pénétration au cône (SCPTu) et d'essais entrepris au moyen d'une plaque dilatométrique sismique (SDMT). Les résultats de ces derniers essais font l'objet d'une autre étude et sont présentés sous un autre titre.

1 INTRODUCTION

The subsurface conditions encountered at the site of the proposed High Prairie Health Complex (HPHC) in High Prairie, Alberta, consisted of soft to stiff clay soils extending to at least 21m depth. The clay layer also contained sand layers of variable thickness at varying depths. Given the magnitude of the foundation loads, the low bearing capacity and the settlement potential of the surficial soils, shallow foundations were not feasible and a deep foundation system was proposed. However, the end bearing capacity of piles in soft to stiff clays is generally low and the load transfer from the pile to the soil is to be achieved mainly through skin friction. In constructability of end bearing piles was not feasible.

Continuous Flight Auger (CFA) piles were considered appropriate for this site as they appear to produce higher skin friction than conventional cast-in-place concrete piles and do not require casing. However, skin friction parameter correlations for CFA piles installed in soft clays are scarce and it was decided to proceed with a load test program to confirm the assumption. Furthermore, the Ultimate Limit State Design of the National Building Code will allow the use of a higher Geotechnical Resistance Factor (Φ of 0.6 instead of 0.4) therefore increasing the design loads of the piles.

In order to assess the capacity of the CFA pile system, the results of a pile load test on a driven timber pile carried out in 1986 for the Provincial Building in High Prairie was considered as the soil conditions were very similar to the HPHC site. The tested driven timber pile had a 0.28m diameter (average) and had an embedment length of 14.6m. Results of the pile load test on the timber pile are also presented herein.

2 GEOLOGICAL SETTING

The HPHC site is located near the east end of High Prairie, Alberta. Based on the Alberta Geological Survey (Atkinson, 2008) the surficial geology of the High Prairie area consists of fluvial sediments transported and deposited by streams and rivers in a generally flat to gently rolling topography. These sediments include stratified sand and gravel, silt, clay and organic sediments occurring in a channel and overbank deposits (post glacial flood plains, terraces, fans and deltas). Test drilling conducted in 1978 by The Alberta Research Council (Borneuf, 1979) indicated the presence of an east-west, buried bedrock valley about 10km wide and 170m deep underlying the High Prairie area. The infill of the bedrock channel in the High Prairie area consist mostly of clay but sand and gravel deposits were also found at the base of the bedrock channel at an elevation of 425m above mean sea level. The bedrock below the channel is of the Smoky Group of Upper Cretaceous age, which consists mainly of shale.

The subsurface conditions at the HPHC site were determined from the results of 14 test holes drilled at the site. The generalized soil stratigraphy was very uniform and consisted of topsoil overlying a thick, soft to firm, silty clay deposit interbedded with loose to very loose silty sand layers. The stiffness of the clay deposit increased with depth. The stratigraphy as determined from two test holes nearest to the pile load test locations was as follows:

- Soft to firm, medium to high plastic clay, with an uncorrected number of blows from the standard penetration test (SPT-N) ranging from 4 to 7 with an average of 5, extending to about 5.5 to 8.5m depth, overlying;
- Loose to compact sand layers with uncorrected SPT-N ranging from 4 to 13 with an average of 6, ranging in thickness from 2.8 to 7.8m, extending to depths of about 13.3 to 17.7m, overlying;
- Firm to stiff, high plastic clay with uncorrected SPT-N ranging from 6 to 15 with an average of 12, starting at about 8.5m depth to the termination of the test holes (21m depth).
- The groundwater table was located between 4.4 and 6.1m below existing ground surface.

3 CFA PILE CONSTRUCTION METHOD

A CFA pile is constructed by rotating a hollow-stem auger into the ground to the specified pile depth. Grout or concrete is then injected through the auger shaft under continuous pressure, as the auger is withdrawn. The concrete or grout under pressure forms the shaft of the pile while creating a lateral pressure against the surrounding soils; in addition this pressure exerts a positive upward pressure on the earth-filled auger flights as they are withdrawn. Reinforcing steel, as specified, is inserted into the column of concrete or fluid grout following the completion of concrete or grout placement.

4 TEST PILES DESCRIPTION

The test pile layout consisted of two test piles TP1 (14m long) and TP2 (18m long) and six reaction piles (RP1 to RP6), as shown on Figure 1. The selected pile layout allowed the use of reaction piles RP3 and RP4 in both load tests.

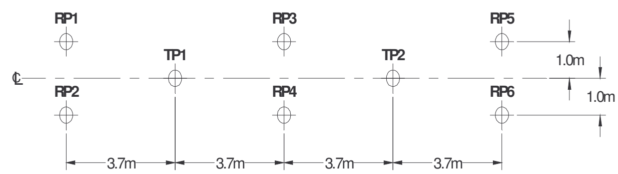


FIGURE 1

Each static pile load test consisted of one CFA test pile, four CFA reaction piles and one steel reaction beam supported on two transverse reaction beams at each end. The ends of the transverse beams were secured to the anchor piles using a 36mm diameter Dywidag steel rebar embedded in the complete reaction pile length.

The CFA piles were installed on November 1, 2007. The concrete used for the construction of the test piles and reaction piles had a compressive strength of 33 and 39 MPa at 14 and 28 days, respectively. The pile load tests were carried out 14 days after the construction of the piles for the load test set up.

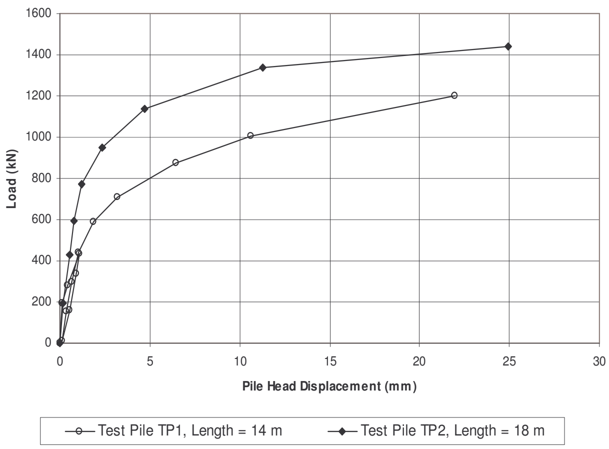
5 LOAD TESTING

In the preliminary geotechnical investigation carried out at the HPHC site, a theoretical ultimate skin friction of 32 kPa was calculated for an 18 m long straight shaft cast-in-place pile using a total stress analysis (α-method). This skin friction was used to design the load increments to be applied to the CFA test piles.

The ultimate pile load capacities determined from the pile load tests were 1010 and 1350 kN for the 14 m and 18 m long piles, respectively, calculated using the Davisson Offset Method (CMFE 2008). Neglecting any end bearing contribution, the results of the two static axial compressive pile load tests indicate that the mobilized average ultimate skin friction from 0 to 14 m depth was about 38 kPa, and given that the difference in ultimate load capacities of piles TP1 and TP2 was 340 kN, the average ultimate shaft friction between 14 and 18 m depth was 45 kPa. Therefore there is a slight increase in skin friction with depth, which also corresponds with an increase in the shear strength of the clay at about that depth.

The pile load test results are presented in Figure 2.

FIGURE 2
HIGH PRAIRIE HEALTH COMPLEX
PILE LOAD TEST PROGRAM
TEST PILES TP1 AND TP2, 0.6 m DIAMETER



6 PREVIOUS PILE LOAD TEST ON DRIVEN TIMBER PILE

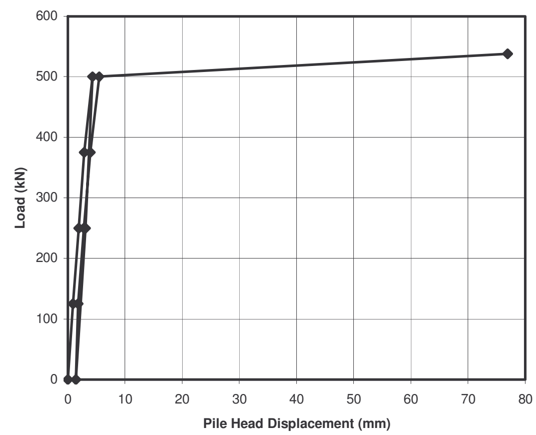
Given the magnitude of the proposed loads at the HPHC site, driven timber piles were not considered feasible. However, the results from a previous pile load test carried out in similar subsoil conditions in High Prairie was used for the initial assessment of the capacity of the CFA piles.

A pile load test was carried out in 1986 for the design of the foundation of the High Prairie Provincial Building. The test pile consisted of a 15.2 m long creosote treated fir pile of 0.355m butt and 0.203 m tip diameter driven to 14.6 m depth. The four reaction piles consisted of untreated lodgepine piles with butt diameters varying between 0.406 m and 0.431 m and end diameters between 0.254 and 0.267 m. A drop hammer of 14.2 kN weight and 1.52 m drop was used to install the piles. The test pile was retaped 24 hrs after its initial driving, recording 34 blows for a 150 mm penetration. The test pile and the reaction piles were installed on September 5, 1986 and tested on September 11 to 12, 1986.

Soil conditions at this site consisted of a soft to stiff clay deposit extending to 15 m depth, with uncorrected SPT-N values ranging from 5 to 13 and an average of 8, interbedded with loose to compact sand and silt layers. At 15 m depth a stiff to very stiff clay deposit was encountered, with uncorrected SPT-N values ranging from 7 to 17 and an average of 11, extending to the depth of investigation (22 m).

The results from the pile load test are presented in Figure 3. The pile failed when the 622 kN load was being applied. The ultimate pile load immediately prior to failure was 500 kN, equivalent to an ultimate skin friction of about 39 kPa, neglecting any end bearing contribution.

FIGURE 3
HIGH PRAIRIE PROVINCIAL BUILDING
PILE LOAD TEST ON TIMBER PILE 0.355 m BUTT AND 0.203 m TIP DIAMETER, 14.6 m DEPTH



7 CONCLUSIONS

(a) The results of the two CFA static axial compressive pile load tests indicate that the mobilized average ultimate skin friction was about 38 kPa from 0 to 14 m and about 45 kPa from 14 to 18 m depth, neglecting any end bearing contribution. A 32 kPa was considered for ultimate skin friction in the preliminary design prior to the results of the pile load tests.

(b) The benefit of the pile load tests to the owner was that because of the higher skin friction obtained from the pile load tests, the piles could be designed with an even higher skin friction when taking into account the Resistance Factor (Φ=0.6 instead of 0.4) as allowed for in Ultimate Limit State Design when a static pile load test is completed. The combined increase of the aforementioned items is 70% increase in the piles design capacity.

(c) The average skin friction mobilized by the CFA piles between 0 to 14 m and 14 to 18 m depth was about 19 and 41% greater than the theoretical skin friction for cast-in-place piles, calculated using a total stress analysis (α-method). From these results it appears that the skin friction determined with the traditional α-method was underestimated.

(d) The skin friction mobilized with CFA piles and timber piles at two High Prairie sites appear to have a similar magnitude (about 38 kPa) for depths ranging between 0 and 14 m depth.

8 ADDITIONAL SITE INVESTIGATIONS FOR PILE CAPACITY ESTIMATION

Additional in situ tests were carried out in the HPHC site to estimate the pile capacity of the CFA piles by direct methods and establish a comparison with some indirect methods commonly used in geotechnical practice. The results are presented in a companion paper by Cruz et. al. (2008).

9 ACKNOWLEDGEMENT

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