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SYNOPSIS A case study is presented concerning the design and construction of two retaining walls constructed with augercast piles. The paper describes the successful use of augercast piles for retaining walls with heights of 22.0 and 32.0 feet. The 22.0 foot permanent wall was tied back to an existing structure. The temporary wall used a circular configuration and vertical anchor piles to obtain a 32.0 foot wall height without tiebacks or bracing.

INTRODUCTION

Two retaining walls were required for an addition to a hospital in Michigan. The addition had three levels with two of the levels below grade. The retaining walls were needed to construct the lower levels. The specifications called for the contractor to provide retaining walls designed by a registered engineer. The author's firm was retained by the augercast pile contractor to provide the wall designs which consisted of drawings and submitting sealed calculations to the project engineer. Figure One shows the general site layout.

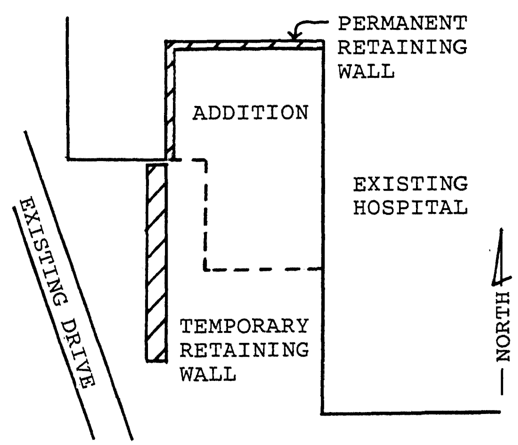

Figure One: Site Plan

One retaining wall was to be a permanent wall along the existing building to allow an excavation of approximately 22.0 feet below the basement floor. The basement floor was approximately 10.0 feet below the exterior ground surface. The existing building to the north of the addition was supported by caissons. The caissons extended below the bottom of the excavation. The existing building along the east side of the addition was supported by spread foundations.

A temporary retaining wall was required to protect an existing paved drive on the west. The excavation depth along the temporary wall was approximately 32.0 feet. The limited access, small site and presence of underground utilities dictated that bracing and tie backs could not be used for the temporary wall. A surcharge of 100 p.s.f. was included in the design of the temporary wall.

RETAINING SYSTEM

Augercast piles were selected for the retaining walls because they could be installed with minimal noise and essentially no vibration. In addition the proposed temporary wall avoided the use of both tiebacks and bracing. The temporary wall had to be buried and left in place after the project was completed because augercast piles can not be pulled.

Augercast piles are constructed by drilling a hole with hollow stem auger. After a specified depth is reached the auger is withdrawn as cement grout is pumped out the bottom of the auger through the hollow stem. The resulting pile is a cast in place concrete pile and is similar to a caisson. Reinforcing steel is pushed into the grout after the hole has been grouted and the auger removed. The construction of augercast piles is described more thoroughly by Hoener et al. (1990) and Neate (1989).

Other retaining systems such as sheet pile and soldier piles with lagging were ruled out for this project because of the difficulty in obtaining adequate embedment in the extremely stiff clay and because of the vibration and noise from driving.

SOIL PROFILE

The soil profile consisted of sand fill to a depth of 21.0 feet over clay which extended to a depth of at least 50.5 feet. Groundwater was not present.

The sand is a brown fine to medium sand with a trace of gravel (SP). The N value in the sand ranged from 6 to 13 which indicates that the sand is in a loose to compact state.

The clay is a glacial till and is sandy silty clay (CL) with interbedded layers of clayey silt and seams of fine sand. A particle size analysis indicates that relative amounts of each soil type are 29 percent clay, 43 percent silt and 28 percent sand. To a depth of approximately 27.5 feet the clay is stiff with N values in the range of 10 to 37.

Below a depth of 27.5 feet the clay is extremely stiff with N values ranging from 67 to over 100. This portion of the clay layer is heavily overconsolidated based on a correlation between the overconsolidation ratio and the N value and overburden pressure presented by Mayne and Kemper (1988). A limited number of penetrometer tests indicated that the shear strength of the extremely stiff clay was greater than 4500 p.s.f. The water content of the clay was in the range of 7 to 10 percent.

EARTH PRESSURE

For the sand an active earth pressure coefficient of 0.27 and a soil density of 115.0 p.c.f. were used to calculate the active earth pressure. For the clay earth pressures were calculated using a passive earth pressure coefficient of 2.05, an active earth pressure coefficient of 0.49, a soil density of 130.0 p.c.f. and a cohesion of 4500 p.s.f. The earth pressure coefficients were calculated using Rankine equations which do not include the effect of wall friction.

A surcharge of 100 p.s.f. was included in the design of the temporary wall.

PERMANENT WALL DESIGN

The permanent wall was designed assuming that each pile acted individually. The top of each pile was tied to the grade beam of the existing building. A pile diameter of 12.0 inches was used for the permanent wall. A minimum safety factor of 2.0 was used for the permanent wall.

The maximum moment in the pile was calculated to be 319 kip-inches. The reinforcing in each pile consisted of two number eleven bars placed in the outside face. The top of each pile was tied to the grade beam of the existing building with a hooked number four bar doweled into the grade beam. A new grade beam was constructed over top of the augercast piles. A guide made of 0.25 inch steel rod was used to place the number eleven bars in the specified location. The piles were embedded 13.0 feet below the bottom of the excavation and had a total length of 35.0 feet.

For the piles in both walls a center to center spacing equal to the pile diameter plus 2.0 inches was used. This spacing allowed the piles to be placed without interference with the adjacent piles and still provide a continuous wall.

The specified grout and concrete strength was 4000 p.s.i.

TEMPORARY WALL DESIGN

The temporary wall was designed by assuming that a semicircular group of piles acted in unison. The basic assumption was that each pile is in contact with the adjacent piles for its full length. In addition to interlock the arch arrangement compresses each pile against the adjacent pile. A pile diameter of 16.0 inches was used for the temporary wall. A minimum safety factor of 1.5 was used with the temporary wall. The pile layout and cross section is shown in Figure Two.

The active earth pressure is resisted by both the embedded portion of the piles and the anchor piles. The anchor piles act as a tie back to restrain the top of the wall. The relatively large width of the semicircular pile arrangement allows the force at the top of the wall to be resisted by a vertical tension pile rather than a horizontal tieback.

One aspect of this wall which is shown in Figure Two is that the back piles of the wall are in tension and the front piles are in compression or bearing. The intermediate piles retain the earth above the bottom of the excavation and complete the arch. The uplift capacity of the anchor or tension piles was calculated to be 141 kips per pile. The maximum axial load on the outermost piles was calculated to be 25 kips. The outer two piles on each side of the semicircle were calculated to be in bearing.

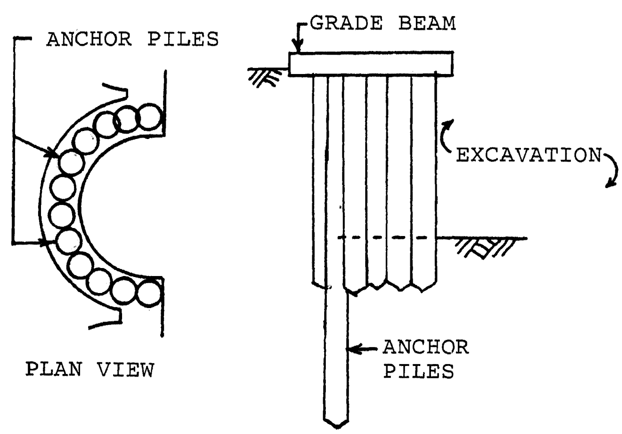

Figure Two: Temporary Wall Cross Section

The components of the temporary wall which had to be designed were the tension piles, bearing piles, intermediate piles and grade beam.

The anchor piles were designed using a cohesion value of 4500 p.s.f. which resulted in 28 feet of embedment below the bottom of the excavation. The reinforcing in the anchor piles consisted of a single high strength bar with a capacity of 150 kips in the full length of the pile. The safety factor against overturning was 1.65 with two anchor piles. During construction the shear strength of the clay was reevaluated as the result of the long drilling times, 30 to 45 minutes, required to drill from 50 to 60 feet. This review indicated that the shear strength of the clay was significantly in excess of 4500 p.s.f. Consequently the length of the tension piles was reduced to 55 feet.

The bearing capacity of the piles was calculated using the procedure outlined in Bowles (1977). Only end bearing was considered in determining the capacity of these piles. The safety factor against a bearing failure was greater than 2.0.

The length of the intermediate piles had to be sufficient to prevent a failure at the toe of the pile. The intermediate piles were designed assuming the grade beam restrained the top of the pile. The embedment depth of 13 feet provided a safety factor of greater than 3.0 against failure at the toe.

The bearing and intermediate piles were reinforced with a single number eleven bar for the entire length of the pile.

A grade beam was constructed at the top of the wall. In theory the grade beam is not needed if the piles are in contact with each other for their full length and form an arch. However, if a pile is mislocated or misaligned the arch effect is lost and a backup system is needed. The grade beam was designed by assuming that one of the intermediate piles was missing and the grade beam would have to carry the moment developed between the tension and bearing piles.

A center to center spacing of 18.0 inches was used which is the pile diameter plus 2.0 inches.

The specified grout and concrete strength was 4000 p.s.i.

QUALITY CONTROL

Quality control consisted of compressive tests, measuring the grout volume in each pile, crack monitors on the existing building and visual inspection of the partially excavated walls.

The compressive strength of the grout was measured using 2.0 inch cubes. The compressive strength ranged from 4220 to 6570 p.s.i. with an average of 5200 p.s.i. which met the design requirement of 4000 p.s.i. The grout consisted of 8.5 sacks of cement with fly ash and MDOT 2NS sand. MDOT 2NS designates a sand with equal amounts of fine, medium and coarse size particles with less than 3.0 percent fines.

The grout volume for each pile was determined from the number of pump strokes and the pump stroke volume. The pump was equipped with a counter to automatically record the number of strokes. The ratio of the actual grout volume to the theoretical volume is referred to as the grout factor or grout ratio. For the temporary wall the grout ratio was approximately 1.5 for each pile.

The crack monitors indicated no measurable movement of the existing structure during both the pile installation and excavation. When augercast piles are placed soil is pulled out of the ground which may result in settlement to nearby structures.

An inspection of the walls was specified after an elevation of 751.5 feet was reached. This elevation corresponds to an excavation depth of 24.0 feet along the temporary wall. The purpose of the inspection was to check pile alignment, continuity, shape, damage and distress.

OBSERVATIONS

As the building area was excavated several aspects of augercast piles were observed. In the temporary wall one pile was misaligned resulting in a gap in the lower portion of one of the cells. The adjacent piles were examined for cracking and signs of distress. The completed walls are shown in Figure Three and Four.

Figure Three: Photograph of Permanent Wall

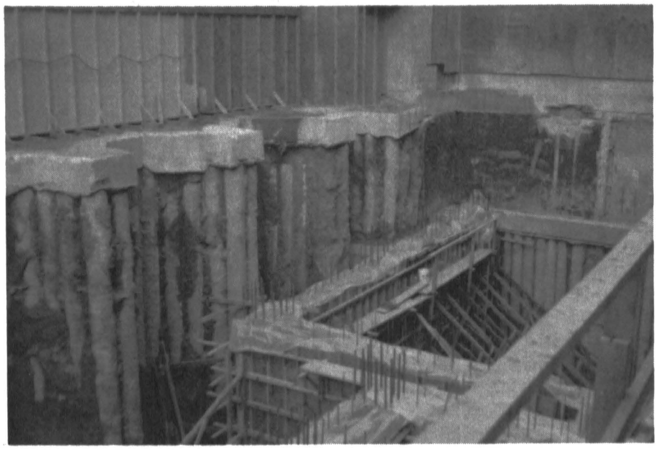

Figure Four: Photograph of the Temporary Wall

The contact between the piles was examined. The piles were found to not be in contact as the result of a smear zone along the length of the piles. The smear zone consisted of approximately 2.0 inches of clay around the outside of the pile that extended along the entire exposed length and through the entire 20 foot thick sand layer. The smear zone resulted because the cuttings coming up the auger were forced into the sides of the hole. The smear zone had not been anticipated and was not observed on piles in previous projects. A photograph of the smear zone is shown in Figure Five.

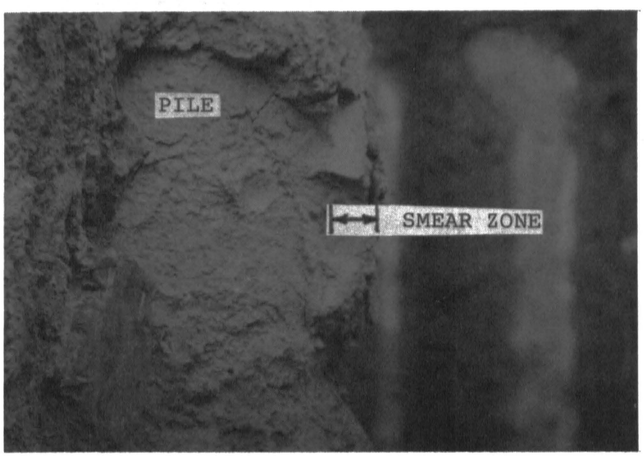

Figure Five: Smear Zone Along The Pile Length

The strength of the clay in the smear zone in between the piles was checked with a hand penetrometer and possessed a shear strength of 3000 p.s.f and greater. The clay was estimated to provide sufficient interlock between the piles to complete the arch effect.

A zone of disturbed clay between the sand and pile would reduce the friction angle between the wall and sand potentially increasing the active earth pressure. However, the friction angle at the wall was assumed to be zero for the design and therefore no adjustments were necessary because of the smear zone. Consequently the excavation was allowed to proceed.

The shape of the piles was circular with no significant bulges or necked down portions. The diameter of the piles was slightly larger, within 1.0 inches, of the auger diameters of 12.0 and 16.0 inches.

The cell with the misaligned pile did not exhibit distress so the excavation was allowed to proceed. The void would have been filled with concrete had erosion begun to occur through the void.

CONCLUSIONS

Augercast piles were used successfully to construct both a permanent and temporary retaining wall. The use of augercast piles minimized vibration and avoided the use of tie backs or bracing.

The design of an augercast pile retaining wall should include an adequate safety factor, redundant members and provisions for inspection of both the wall and soil during construction. The suggested minimum safety factors are 1.5 for temporary walls and 2.0 for permanent walls. Redundant members are needed to compensate for mislocated members and unforseen conditions.

Augercast pile retaining walls will provide the an economical retaining system in certain situations and should be considered when selecting a retaining system.

Additional research on augercast piles would be of use to the practicing engineer because of the relative scarcity of technical information on augercast piles.

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