RENOVATION OF AN OLD SALES CENTER
FOR ADDITIONAL UNDERGROUND PARKING

GUANGLEI LIU\textsuperscript{1}, PETER CHOI\textsuperscript{2}, QI WANG\textsuperscript{3}, JIA MA\textsuperscript{4}

ABSTRACT

Due to the automotive vehicles increase, available parking lots become a new type of limited resources in central cities in China, especially in those old districts without visionary urban planning. Additional mechanical parking is an efficient solution to provide sufficient parking lots under the situation where the space is constrained. More severely, if there is no space on the ground, parking garage under an existing building may be the only way to fix the problem. One project is introduced in this paper about the renovation work of an old sales center in central Shijiazhuang urban area, China. The sales center was in a logistic park and no parking was designed for this building. The biggest challenge was to keep the upper level of building operating during the construction. The renovation work started from the beginning of 2016 and finished in May 2016, including the parking equipment installation and interior decoration. The new parking garage is currently in operation and satisfies the requirements by the client. The design work, details, construction consideration, load test and monitor results of this renovation work will be presented in this paper.

Keywords: building renovation, screw anchor pile, micro-pile, underground parking
INTRODUCTION

Lack of parking is severe in many cities in China, especially for those old districts in central cities. Traffic condition gets worse when cars park on the street or move slowly to find parking spaces. Study shows that the normal ratio of available parking space to automotive vehicle number is about 1.2 in most major cities such as New York, Tokyo and Hong Kong. However this ratio is only 0.5 in Beijing. One possible solution is to move cars out of the central city. But still there are plenty of parking requirements for the residents in the central city.

Additional mechanical parking is an efficient solution to provide more parking lots where there is rare space. This paper presents one renovation project in Shijiazhuang city to add one basement to the existing old sales center for car parking consideration. SAP piles were used to support the super structure during the construction. The screw anchor piles were drilled into the ground and worked as permanent piles after grouting. The design work, details, construction considerations, load test and monitor results of the renovation work will be presented in this paper.

PROJECT DESCRIPTION

The logistic park is in Luquan district, Shijiazhuang city. The sales center is close to the entrance of this logistic park. It is a 2-storey steel structure building without basement. No car parking garages were planned for the building. There are many important persons every day and the owner found it inconvenient without exclusive parking places on site. After scheme study, the client decided to build an extra basement with mechanical parking equipment to solve this problem in September 2015. The design and construction work was conducted by Zhongyan Technology Co., Ltd. and SE EXT Co., Ltd. The GFA of the original building is about 1300m². The new basement was 8m x 10m in plan and 7.65m deep. Automatic mechanical car parking equipment with four parking lots were proposed. The demolishing work of partition structure was conducted in December 2015. The under-pinning work started from the beginning of 2016 and the main structure was accomplished in March 2016. All work finished in May 2016 including the installation and testing of the parking equipment. Before the excavation, each column was under-pinned by four SAP piles and the piles length were 24m or 25m. The sales center was kept open to public and the rooms at level two above the construction zone were also kept operational during the construction.
Figure 1. Plan of the sales center

Figure 2. Section of the sales center

New basement under this area
SITE CONDITIONS

The site is on a flat ground and the ground water level was lower than -40m, which means there was no ground water impact during the construction period. The site conditions are shown in Table 1 and Table 2 in accordance with the geotechnical investigations.

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>f_{ak} (kPa)</th>
<th>Tensile Modulus (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>100~200 (kPa)</td>
</tr>
<tr>
<td>loess like silt(1)</td>
<td>115</td>
<td>7.4</td>
</tr>
<tr>
<td>loess like silt clay(2)</td>
<td>130</td>
<td>6.1</td>
</tr>
<tr>
<td>Silt(3)</td>
<td>150</td>
<td>8.0</td>
</tr>
<tr>
<td>silt clay(4)</td>
<td>170</td>
<td>8.3</td>
</tr>
<tr>
<td>Medium Sand(4)1</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>silt clay(5)</td>
<td>190</td>
<td>9.3</td>
</tr>
<tr>
<td>Gravel(6)</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>Round gravel(7)</td>
<td>210</td>
<td></td>
</tr>
<tr>
<td>Gravel(8)</td>
<td>260</td>
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</table>

Table 2. Soil parameters (Continue)

<table>
<thead>
<tr>
<th>Soil Type</th>
<th>q_{sik} (kPa)</th>
<th>q_{pk} (kPa)</th>
<th>γ (kN/m³)</th>
<th>C_{k} (kPa)</th>
<th>φ_{k} (°)</th>
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</thead>
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<tr>
<td>loess like silt(1)</td>
<td>30</td>
<td>19.2</td>
<td>23.8</td>
<td>16.1</td>
<td></td>
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<tr>
<td>loess like silt clay(2)</td>
<td>40</td>
<td>19.1</td>
<td>25.2</td>
<td>14.5</td>
<td></td>
</tr>
<tr>
<td>Silt(3)</td>
<td>44</td>
<td>19.5</td>
<td>22.9</td>
<td>14.8</td>
<td></td>
</tr>
<tr>
<td>silt clay(4)</td>
<td>50</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium Sand(4)1</td>
<td>50</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>silt clay(5)</td>
<td>60</td>
<td></td>
<td>1400</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gravel(6)</td>
<td>80</td>
<td></td>
<td>2000</td>
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</table>
STRUCTURAL AND FOUNDATION DESIGN CONSIDERATIONS

Structural and foundation scheme

The super structure is designed to be temporarily supported by 16 SAP piles. There are four steel columns to be under-pinned. Each one is supported by four SAP piles. The SAP piles under the east two columns are 24m long and the designed characteristic bearing capacity is 20T. The SAP piles under the two columns are 25m long and the designed characteristic bearing capacity is 35T. The new basement is 8m x 10m in plan and 7.65m deep. The retaining structure are micro steel piles with 12m length, 168mm@750. Top ring beams are concrete and the second ring beams are steel, supported by soil nails and horizontal bracing respectively. The retaining structures and under-pinned structure are shown in Figure 3 to Figure 5.

Figure 3. Plan of the excavation zone and temporary structures
SAP pile design

The conception of SAP is to make the boring rod a permanent pile. That is, the boring rod excavates to the ground at the beginning, and then it will perform as a permanent pile with grouting.

After SAP is placed to desired depth using air or T4 drilling, grouting will be injected through both in and out of SAP. The attained frictional resistance between the grouting bulge and the ground should exceed design bearing capacity. Figure 6 illustrates the typical soil-pile interaction.
Vertical loads, material stress, buckling stress, buckling reinforcement, joint stress, etc. are considered in the SAP design.

(1) Calculate the compression loads applied at the top of the SAP and determine the screw length – which is equal to the bond zone. The SAP must be resisted by the grout to ground bond through the screw length.

Typical SAP piles transfer axial load through end bearing and pile-soil friction. In this case, however, end bearing capacity is not considered due to negligible toe area compared to surface area of the shaft. Only surface friction is considered in the design. To determine surface friction, it is assumed that soil/grout around the screw act as one body together with the pile.

Equation (1) is used to calculate allowable bearing capacity of pile under axial compression and tension loads according to FHWA NHI-05-039.

\[
P_a = \frac{\pi \times D \times L \times \tau}{F.S} \quad (1)
\]

- \(D\) – Screw Diameter (mm)
- \(L\) – Length of Screw Section (mm)
- \(\tau\) – Frictional Resistance (N/mm²)
- \(F.S\) – Factor of Safety

Consider that current screw pile design methodologies use safety factor of 2 or less, as well as screw and grout interaction increases stability, safety factor of 2 is used in our design.

In addition, frictional resistance shall be based on \(N\) value for weathering soil. The length of screw section shall be determined by engineer’s judgment.

(2) Evaluate the axial capacity of pile and calculate the compression loads applied at the top of the SAP. Even if the capacity of the ground is sufficient, the material failure may occur in conditions such as lack of material allowable strength. In this case, stability evaluation with calculating material allowable strength is necessary. The allowable compression loads for the cased length of the SAP is given by equation (2) according to German Standard.

\[
P_a = \frac{f_{y-casing} \times A_{casing}}{F.S} \quad (2)
\]

- \(f_y\) – Yield strength of material (N/mm²)
- \(A\) – Effective area of material (mm²)
- \(F.S\) – Factor of Safety
### Table 3. Axial Capacity of Pile Shaft by Material Rating

(Including couplers for steel splice)

<table>
<thead>
<tr>
<th>Material</th>
<th>Rating</th>
<th>Yielding Load (MPa)</th>
<th>Tensile Load (MPa)</th>
<th>External Diameter (mm)</th>
<th>Thickness (mm)</th>
<th>Weight (kg/m)</th>
<th>Cross Sectional Area (cm²)</th>
<th>Allowable Load of material (tf/ea)</th>
<th>Section Modulus (cm³)</th>
<th>Radius of gyration of area (cm)</th>
<th>Moment of inertia (cm⁴)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AP15CT</td>
<td>N80</td>
<td>552</td>
<td>689</td>
<td>73</td>
<td>11</td>
<td>16.7</td>
<td>21.42</td>
<td>70.53</td>
<td>29.0</td>
<td>2.22</td>
<td>106</td>
</tr>
<tr>
<td>AP15CT</td>
<td>P110</td>
<td>758</td>
<td>862</td>
<td>73</td>
<td>9.5</td>
<td>16.7</td>
<td>21.42</td>
<td>96.85</td>
<td>29.0</td>
<td>2.22</td>
<td>106</td>
</tr>
</tbody>
</table>

(3) The center to center spacing between individual SAP Piles should be at least 750mm or more than 5 times of the SAP Pile diameter. This spacing criterion is for potential deviations in drilling and reducing group effects between SAP Piles.

(4) Evaluate the buckling of cased length of the SAP Piles and exposed length of the SAP Piles because of excavating to the ground. The cased length of the SAP Piles may be evaluated in very weak ground.

Considering the ground condition, if the lateral elastic modulus of specific ground is smaller than the limit value of $E_s$, buckling effect must be reviewed.

The buckling of cased length of the SAP Piles is given by Equation (3) according to Cadden and Gómez, 2002.

$$
E_s \geq \frac{1}{4 I_{casing} \left(\frac{E_{steel}}{A_{casing}^2 f_y^2-casing}\right)} = E_s^{\text{limit}} \quad (3)
$$

- $I$ – Moment of inertia (mm⁴)
- $A$ – Effective area of material (mm²)
- $E$ – Elastic modulus of material (N/mm²)
- $f_y$ – Yield strength of material (N/mm²)

Also, the exposed length of the SAP Piles requires the anti-buckling system for safety of the SAP Piles. The anti-buckling system and the center to center spacing of anti-buckling beam should be evaluated. X-bracing and horizontal bar are used in this project with 1m spacing.

**Numerical Simulation**

3D finite element software MIDAS/GTS was used to conduct the numerical simulation of the whole construction procedure and to be the reference of the design. Modified Mohr-Coulomb is used as the soil model in the analysis. The numerical simulation included 12 steps:
Step 1: Free field simulation
Step 2: Original steel structure construction
Step 3: Excavate to -1m level to expose the original pad foundation of columns
Step 4: Retaining steel piles, SAP piles installation
Step 5: Top ring beam construction
Step 6: Excavate to -3.35m, second ring beam and horizontal bracing construction
Step 7: Excavate to -7.65 (bottom of the basement)
Step 8: Base slab construction
Step 9: Lower part basement wall construction
Step 10: Remove second ring beam and horizontal bracing
Step 11: Upper part basement wall construction
Step 12: Remove SAP and finish the construction

The SAP axial forces, lateral displacements of the excavation zone, settlement of the columns and ground around the excavation zone were discussed basing on the simulation results.

Figure 7. 3D soil-structure interaction modeling
The maximum column axial force is about 460kN, which is similar to the evaluation. The maximum axial force in the SAP piles is 138kN, which is smaller than the design pile capacity and all piles have enough capacity to resist upper structure loads.

The maximum settlement of the top of SAP piles is 1.79mm according to the simulation. The maximum settlement measured during the construction was 2.5mm. No wall crack was observed during the construction period.

**CONSTRUCTION CONSIDERATIONS**

Considering the constraints of the site, small equipment is required to do the drilling work. ‘SE-SAP-MR13 SAP’ is the dedicated equipment of SAP method and its size is 0.8x3.1x2.3m. The boring equipment consists of Main Machine as a role of drilling, Power Pack for Main Machine power supply, and Remote Controller such as attached component for Main Machine’s operation.
Besides those three components, Air-Compressor for boring, Mixer-Pump Plant for grouting, and Diesel-Engine Generator for electric power are needed as additional devices.

Figure 10. The components of SAP-drilling

The SAP is located in its place after mounting connection between the auger of the boring machine and the pile screw tab, and it is maintained verticality using a vertical measuring device. The rotary pressure is applied while putting high pressure air/water by operating compressor/hydraulic motor based on the ground and maintain proper penetration speed to prevent SAP from bending.

The piling work of the SAP pile using the screw tab continues until the design length. After boring, the air hose is prevented in order to pump the cement mortar into the SAP pile with grouting hose attached by SAP-drilling.

The cement mortar is pumped into the SAP pile through its top, and it is filled up to the ground level. After the Over-Flow of grout is checked at the ground surface, stop grouting and move the equipment to next construction location.

Once the grouting completes, SAP cutting work and joint work between column and SAP with wing plate should be followed at least 1 to 3 days after.

At this time, the amount of load transfer and increase of loads are checked by instruments in selective areas. After the installation of joint, boring work of lower ground is continued, and also connect SAP(partial) to SAP(partial) to minimize bucking while boring work.

If the boring depth is complete as scheduled, the joint is separated after pouring concrete at foundation and inside of the wall.
And then, set up new structures in extended area and proceed overground finishing work to complete the SAP construction. It took one week to finish the SAP pile drilling work and the whole procedure of the construction please refer to Figure 11.

<table>
<thead>
<tr>
<th>1. Move to the point</th>
<th>2. Set the equip.</th>
<th>3. Set the pile</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Image 1]</td>
<td>![Image 2]</td>
<td>![Image 3]</td>
</tr>
<tr>
<td>4. Pile drilling</td>
<td>5. Grouting</td>
<td>6. Joint (column to pile)</td>
</tr>
<tr>
<td>![Image 7]</td>
<td>![Image 8]</td>
<td>![Image 9]</td>
</tr>
<tr>
<td>![Image 10]</td>
<td>![Image 11]</td>
<td>![Image 12]</td>
</tr>
</tbody>
</table>

Figure 11. Construction sequences
MONITORING AND LOAD TEST

The pile axial forces were monitored by four load cells and no axial forces exceeded the expected loads.

Three piles were tested after the basement construction. The super structure was supported by the new basement wall and the base slab formed a raft foundation. The SAP piles were no longer required supports and they were intentionally separated from the base slab to conduct the test. The test results show that all piles have sufficient bearing capacity comparing to the design.

Strain gages were used to monitor the forces in the columns, piles and anti-buckling members. Settlements of the column bottom were also monitored periodically and the maximum value was 2.5mm, which was very small as the actual load was far away from the pile capacity.
CONCLUSIONS

This small project lasts about half year because of the limitation of the working space and working hours. However there were no safety problems during the construction and the client was satisfied with the result. The building was fully operational during the construction. The exterior of the renovated building is exactly the same except the additional entrance of the mechanical parking. More studies are required to confirm the performance of SAP technology to different site conditions. This project indicates that parking garage under an existing building may be one good solution to solve the problems in central cities.

ACKNOWLEDGEMENTS

We are grateful to Mr. Gary Koo, Mr. Un-Moo Lee, Mr. Myoung-Su Jo form SE EXT Co., Ltd.; Mr. Jianguo Liu, Mr. Siyu Wu, Mr. Wubao Li, Mr. Zengzhu Kang from Zhongyan Technology Co., Ltd. for their support during this project and in preparation of this paper.

REFERENCES


