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Applied research on underpinning technology for protection of structure closed to deep excavation

Building structures are insecurity when it is closed to foundation pit, which likely to collapse or produce large deformation due to design or construction faults. Dead loads of structures applied on the top of pit slope and add the probability of circular sliding of slope. Underpinning technology can transfer loads to the deeper soil layer and deformation had been restrained effectively. With the development of foundation underpinning technique, more and more mini-pile should be drilled through the foundation inner or outer buildings structures. When the structures protected by underpinning method, the foundation pit supporting project can be designed more easily and flexibly. By one engineering example, underpinning technology and foundation pit supporting technology are combined and applied to protect the stability of structures near the pit. Using the united method, the loads of structures are transferred vertical and pressure on the top is reduced highly, active earth pressure is lower at the same time, so that the excavation stability can be achieved more easily. The engineering examples provide better technical references for similar projects.

Keywords: Underpinning technology, mini-pile; load transmission; deep excavation; structure protection; soil nail wall.

1. Introduction

With the speeding up of urbanization and reconstruction of old city area, many types of civil engineering and public transportation infrastructure increased rapidly. More and more projects are constructed near the old structures which are unsafe when the foundation pit had been excavated. How to protected the buildings closed to foundation pit are becoming an important problem by the large deformation induced by the loads of buildings on the top of slope. Deformation of slope lead to differential settlement of the building, even catastrophic consequences when collapse happened.

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Mini-piles are usually drilled through the existing footings to accommodate the additional load from the structures [1~3]. Most of the foundations were located under the earth surface, which bring difficulties for drilling of pile and the connection pile and old cushion cap. By one example, united technology by foundation underpinning using micropiles and excavation supporting are introduced and some advantages are reflected intuitively.

2.0 Foundation underpinning with mini-pile

Foundation underpinning is an important technology of civil engineering and applied to structure protection and function updating broadly, such as the foundation of original structure reinforcement or changed, or to improve the base work state, such as uneven settlement, or the load increased of the building, etc.

Independent foundation is one common kind of foundation styles and as shown in Fig.1. Because large diameter pile have difficulties to pass through this kind of concrete foundation without disturbing the use of building, mini-pile had been presented to solve the problem, which only has little vibration happened during work. Therefore foundation underpinning should be given sufficient consideration of construction technology and machine of pile type selected to meet the construction conditions.

Steel pipe micropile using steel pipe had become the research focus and get more engineering application in recent years [4~6]. The steel pipe pile is a kind of small diameter pile, the diameter is less than 350mm, generally is 200mm and pile length does not exceed 30m. The bearing capacity of micropile is calculated similarly with ordinary piles by side and tip resistance. Fig.2 is a schematic diagram of an independent foundation underpinning by steel pipe mini-pile, pile top and

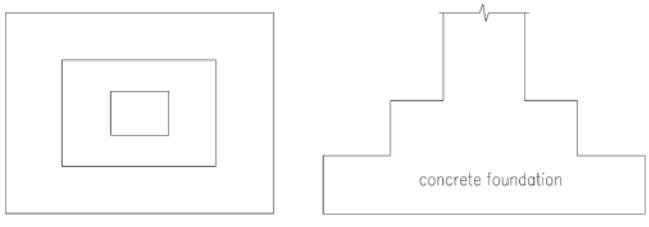

Fig.1: The plan and section of independent foundation

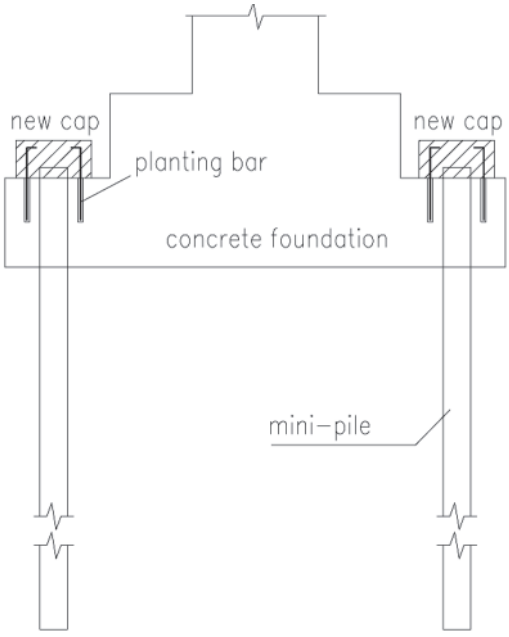

Fig.2: Foundation underpinning with mini-pile

independent foundation are connected effectively by planting bar technology, which one end built in the old foundation and another end bond in the new cap.

So the small-diameter pile can better solve such problems encountered in foundation underpinning construction: (1) micropile construction machinery is simple, can use small drilling machine to pore-creating and strong adaptability to the surrounding environment; (2) the pile hole diameter is small, pore forming process on the original foundation and subfoundation soil almost do not produce additional stress, noise and vibration caused by the construction is very small, and does not affect the normal use of structure [7, 8]; (3) Upper load force can be downward transfer clearly. Meanwhile the soil mechanical characteristics can be improved through the secondary high pressure grouting of pile, which can effectively improve the bearing capacity of single pile and the ability to resist overturning.

When foundation underpinning construction using mini-pile, firstly, pile will not effectively come into working after construction. But if the foundation even produces minimal subsidence, micropile will play a role quickly and take part of the structure loads, at the same time lower base pressure on soil layer. If structure continues to sink, micropile will assume the loads gradually, until almost all the loads undertaken by the micropiles.

3.0 Composite soil nailing support for excavation

Soil nailing wall is developed in more than 30 years to maintain stability of deep excavation [9]. Because of passive performance of soil nail, the capability of deformation control is weak. Take the prestressed anchor or micropile into account, the soil nail supporting can have a great improvement on global stability and restrain deformation of slope. Generally composite soil nailing support section is as shown in Fig.3. There are several kinds of components such as soil nail, prestressed anchor, micropiles and concrete surface, water-stopping curtain wall will be added at the engineering site of higher underground water level.

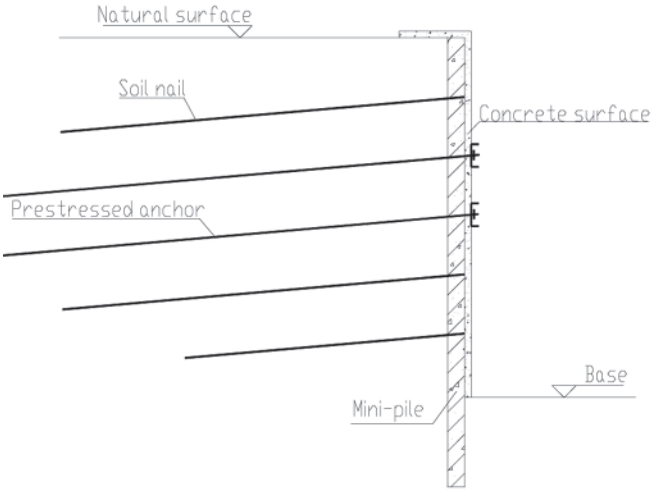

Fig.3 the profile of micropile-soil nailing support

By the role of soil nail, the surface layer and the combined action of undisturbed soil, formed on the basis of the active restriction mechanism of complex, has greatly improved the structure of the slope soil strength and resistance to deformation ability, decrease the lateral deformation of soil, enhance the stability of the slope. Supporting effect is mainly obtained by the length and density of soil nail, the top load and excavation depth factors. One successful excavation supporting engineering completed in 2002, which is the largest vertical opening of digging depth of 19m, anchor cable composite soil nailing wall had been used, marked the soil nailing wall technology has reached a very high level [10].

Failure morphology and mechanical properties of the support, can be used for the analysis of the principle of the combined minipile. In order to make the micropile can play an important role of a whole, usually at the top of the pile setting crown beam. In general, the greater the stiffness of pile is and the less deformation of composite soil nailing wall [11] will be. When steel pipe pile stiffness is bigger, which can significantly reduce the levels of slope displacement and ground settlement, therefor stiffness of pipe is important point in the design work.

The scheme of composite soil nailing wall with micropile is often used in vertical digging segment. Mini-pile composite soil nailing wall has flexible, wide applicable range, low cost, short construction period and the characteristics of safe and reliable. In practical engineering, the composite soil nailing wall is simple, economic and reasonable, comprehensive performance of which is outstanding, and deformation is proved to be little [12].

4.0 Project example

4.1 Project background

One hospital building foundation pit is closed to an existing two-storey voltage transformation room, which cannot be removed or replaced and provide electric power for the hospital operation normally. The horizontal space between excavating line and outer wall of the room is only 1.2m and the depth of pit is nearly 15m, therefor the room is very dangerous with the deep excavation if no underpinning pile had been drilled. Fig.4 shows the profile of the project, the slab foundation is used in this building and underpinning piles are assumed built under the foundation slab in the pictures. If no underpinning pile is taken into account in this project, the safety of the building and slope are hard to get guarantee.

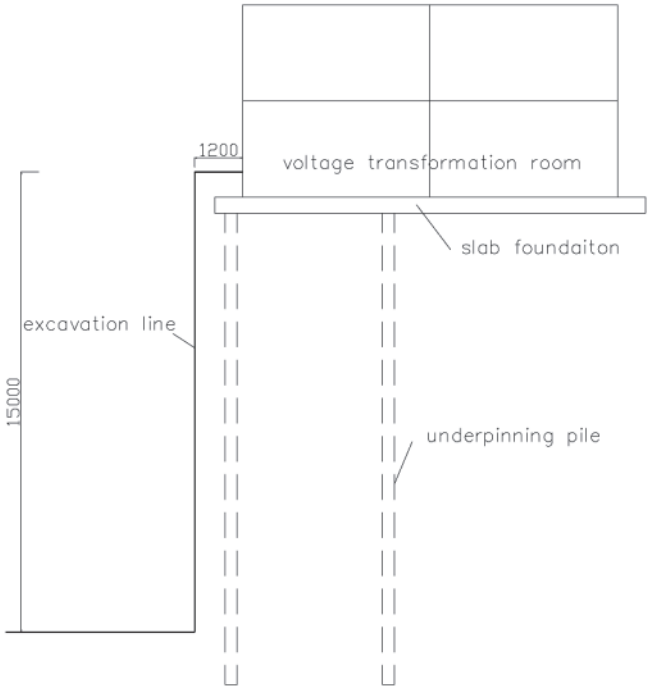

Fig.4: The profile of project

4.2 Subsurface conditions

Fig.5 is a subsurface profile based on the results of the survey holes. The good news from the subsurface investigation were that the soils are harder and with better parameters, especially the rock buried depth is shallow. Therefor the tip of pile can be embedded into hard rock and almost no settlement is generated after room underpinning using mini-pile.

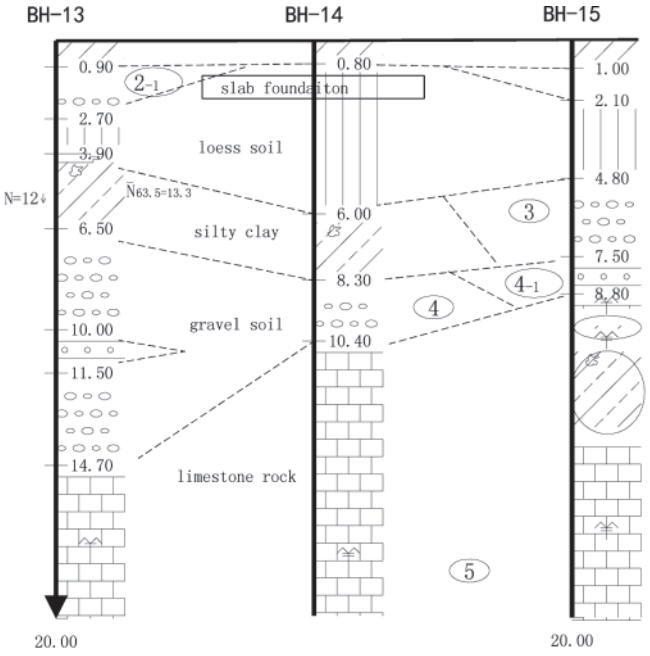

Fig.5: The profile of subsurface

4.3 Underpinning design and construction using minipile

Minipiles are small diameter deep foundation piles. The equipment used to install them is fairly small which makes them ideal for situations that offer low overhead clearance and tight working conditions. The kind of underpinning method even have better anti-seismic properties [13, 14]. In this project, the micropiles were spaced 0.75m apart, which is intensively due to the excavation is too deep, while the norml space is 1.5m. The bearing capacity design value of the micropiles is 400kN with 1.0m embedded into intact rock and the drilling depth of the micropiles varied from 11.4 m to 15.7 m. The plan and section of underpinning are shown as Fig.6.

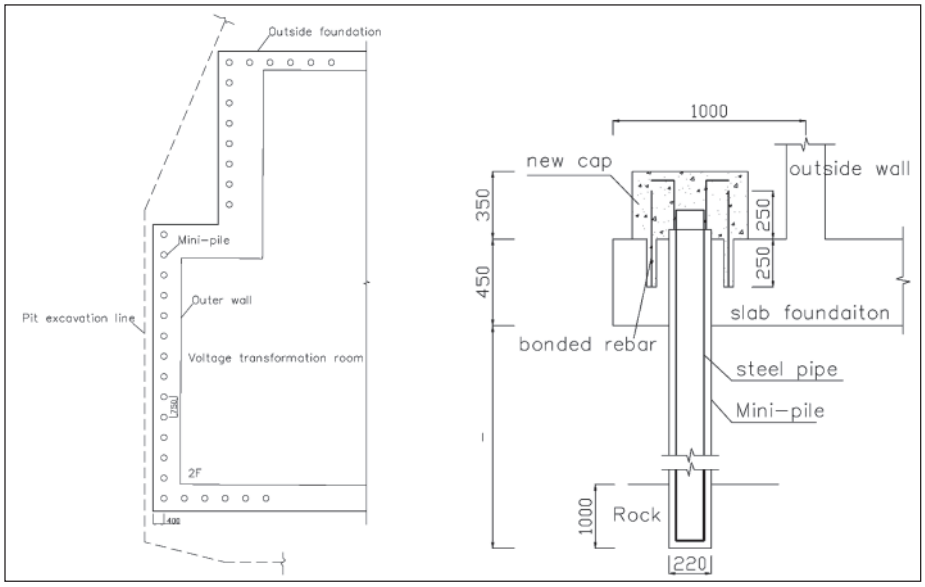

Fig.6: The plan and profile of underpinning pile

Fig.7: The drilling machine worked near the building

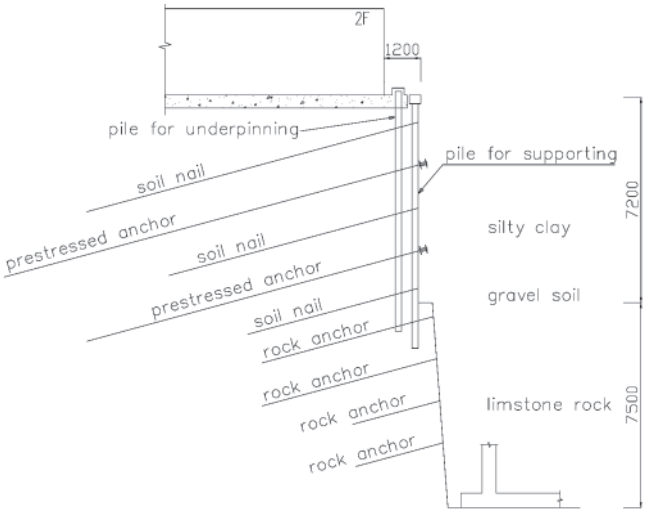

Fig.8: Profile of united method about supporting and underpinning

Because of many instruments worked in the room, the underpinning pile cannot be arranged in the room and only constructed outside of the wall, the drilling machine is shown in Fig.7.

4.4 Supporting scheme of excavation

According to the geological data, half of the slope consists of rock layer, end-suspended pile are designed in this construction site, the profile of supporting is shown in Fig.8. The suspended pile were still produced using mini-pile, by which the composite soil nailing wall supporting scheme formed with soil nail and prestressed anchor. Rock bolt were used when excavation at limestone rock layer and the gradient of slope is about 1:0.1. Fig.9 showed the status of

Fig.9: Pictures of construction site

construction site, the left picture is just excavation to rock layer and the right picture is excavation to the basal elevation nearly. Although underpinning pile drilled only single row outside of the building wall, the overall stability of slope is reached expectation and the room maximum settlement is 4mm during construction.

5.0 Conclusion

For the protection of structures closed to the excavation of foundation pit, the effect and design method of an underpinning plan with minipiles has been analyzed. Accroding to one example, by underpinning micropiles the load transmission were worked well and offered supporting for the safety of excavation.

The foundation underpinning design makes full use of characteristics of micropile, such as lower requirement of construction space, little impact on the normal use of building and clearly transmission of load, ensure the smooth implementation of the foundation underpinning, have created favourable conditions for the retaining and protection of deep excavation.

6.0 Acknowledgements

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