Analysis of construction technology and technical advantages of a kind of environmental homogeneous plastic pile

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Abstract. Environmental Homogeneous Plastic (EHP) Pile is an improved cement-soil mixing pile with controllable and adjustable physical and mechanical properties. It is formed by completely replacing and filling while forming holes, so as to solve the disadvantages of traditional cement-soil mixing piles, such as insufficient mixing, uneven pile body and low pile strength. The construction technology of EHP piles was introduced and field standard penetration tests were carried out on EHP piles with different cement contents. It is found that the number of blows required to penetrate a 30cm depth increases with the increase of cement content at the same pile depth. At the same cement content, the number of blows of the EHP pile is greater than that of the traditional cement-soil mixing pile. The change in the number of blows along the pile depth of the EHP pile is also much smaller. Finally, the technical advantages of EHP piles are summarized: uniform and integrated pile body, quality-assured admixture, controllable pile material, and environmental protection.

1. Introduction

Cement soil mixing is a technique that mixes soil with a binder (usually based on cement or lime) mechanically or hydraulically in situ and injects it through a pump system [1]. Cement-soil mixing piles can be produced in slurry (wet mix) or powder (dry mix). The improvement of soft soil foundation by cement mixing piles is a soil stabilization technology, which has been widely used to enhance the performance of ground and underground facilities, such as embankments, drainage channels and deep foundation pits [2-3]. It is proved in many practical construction cases that the advantages of cement-soil mixing piles include improving bearing capacity, reducing differential settlement, minimizing lateral movement and increasing slope stability [4].

However, when traditional cement-soil mixing (hereinafter referred to as TCM) piles are used to treat complex multi-layered soil foundations, the physical and chemical reaction effects of soils and cements with different soil properties are different. Using the same cement mixing ratio of the same pile in different soil layer will cause uneven pile strength, and even the strength segmentation phenomenon appears. In China, the disadvantages of TCM piles are found in practical engineering applications, such as insufficient mixing, grouting spill and decrease of strength along column depth [5-7]. In addition, during deep foundation reinforcement, the cement mixing method takes a long time and the construction efficiency is low, which largely restrains the construction progress.
Aiming at the above problems, a kind of environmental homogeneous plastic (hereinafter referred to as EHP) pile construction method was improved on the basis of the TCM pile to form a pile with controllable and adjustable physical and mechanical properties. In this paper, the construction technology of EHP piles was introduced and a series of field standard penetration tests were carried out on EHP piles with different cement contents to compare the pile uniformity with TCM piles. The technical advantages of EHP piles were also summarized.

2. Construction technology

The construction technology of EHP piles abandons the traditional cement pile construction technology, combines the soil properties of the reinforced foundation. By means of factory production, the soil material and the curing agent are forcibly mixed outside the in-situ foundation by using agitating machinery, and the mixture is poured while forming holes. The EHP pile mixing process is separated from the interior of the reinforced foundation, and a wide range of additive materials for mixing piles are available. The parameters of the mixing material can be adjusted according to the soil properties of the reinforced foundation, and certain construction waste can be used in the mixing process to achieve the effect of environmental protection.

The EHP pile construction process is: while the soil material and the curing agent are forcibly stirred, the long screw pile machine drills to the designed depth, and after the mixture is evenly mixed, it is pumped to the central tube of the screw rod. While drilling to form a hole, the mixture is used for filling and filling in the borehole. The long screw pile driver is drilling to form a hole, and the mixture is used for pouring and filling in the borehole. When the drill rod is completely raised out of the ground, the pile is formed. The ground soil carried by the auger drill pipe is homogenized and can be used for pouring the next pile. The site construction process diagram is shown in Figure 1.

![Figure 1. EHP pile construction process diagram](image)

3. In-situ standard penetration test

The basic method of the standard penetration test is as follows: a 63.5kg penetrating hammer is used to fall freely from a height of 0.76m, and the hammer seat is hit. The standard penetrator is vertically driven into the soil layer by a probe, the number of blows required to penetrate a 30cm depth is measured in this method. In order to discuss the number of blows at different depths, standard
penetration tests were carried out at the depth of - 2m, - 4m, - 6m, - 8m, - 10m, - 12m of EHP piles with cement content of 8%, 10% and 13% respectively. In these tests, two standard penetration holes were tested for each type of pile, and the average of two numbers at the same depth of the same type of pile was used as the number of blows of this type of pile. Figure 3 shows the on-site standard penetration test process.

Figure 3. Field standard penetration test

Figure 4 shows the change in the number of blows along the pile depth for different cases. The cases include EHP piles with cement content of 8%, 10%, 13% (EHP-8%, EHP-10%, EHP-13%) and a TCM pile with cement content of 13% (TCM-13%). As can be seen from the figure, the numbers of blows of EHP piles and MIP piles show a slight downward trend along the pile depth. The number of blows of EHP-13% is between 41 and 48, with an average of about 45, while the number of blows of MIP-13% is between 36 and 43, with an average of about 40. According to the relevant specifications in China, the number of blows of both types of piles is greater than 30, and the quality of the cement soil of the piles is hard. However, the number of blows of EHP-13% is greater than that of TCM-13% 5 blows. It can be seen that under the same circumstances, the pile quality of EHP piles is better than that of TCM piles. In addition, it can be seen from the figure that the number of blows of EHP piles with different cement contents is also quite different. EHP-13% has the largest number of blows, EHP-8% has the smallest number, and EHP-10% is somewhere in between. This fully shows that for EHP piles, the cement content is an important factor affecting the quality of the pile body. In addition, compared to the TCM pile, the change in the number of blows at different depths of the EHP pile is much smaller than that of the TCM pile. It can be inferred that the EHP pile has better uniformity than the TCM pile.

Figure 4. The number of blows at different pile depths for different cases
4. Technology advantages of EHP piles

4.1. Pile homogeneity and integrity

Figure 5 and Figure 6 shows the core samples of a TCM pile and an EHP pile, respectively. It can be seen that there are a small number of pure cement blocks in the TCM pile core sample, and the pure cement blocks are scattered. The pure cement blocks are actually formed by the solidification of cement slurry, due to the insufficient mixing of the soil layer during the construction process of the TCM pile. If the number of pure cement blocks is greater or the volume is larger, it means that the stirring is more uneven. As for an EHP pile core sample, there is no pure cement block in the core sample, and the core sample is uniform in colour, indicating that it has better uniformity.

![Figure 5. TCM pile core sample](image)
![Figure 6. EHP pile core sample](image)

4.2. Guaranteed curing agent content

During the construction process of TCM piles, the phenomenon of grouting spill is common, which causes the curing agent to overflow, and the amount of curing agent does not reach the design value. The EHP pile curing agent is fully mixed with the earth material after forced stirring. The construction process of filling while lifting the screw rod is used to reduce the phenomenon of grouting spill during the construction process and the quality of the curing agent is guaranteed.

4.3. Easy-to-adjust physical and mechanical indexes of piles

During the construction of EHP piles, parameters such as the amount of curing agent can be obtained through laboratory tests according to the requirements of specific projects, so that the parameters of the mixing materials can be accurately adjusted according to different soils. In the construction, it is necessary to change the slump of the mix by adjusting the water-soil ratio, test the pumping of the mix under different slumps, and determine the optimal pumping slump. Then, the lifting speed of the screw rod of the pile driver is determined according to the pumped flow and pressure under the optimal pumping slump to ensure that the mixing material can be filled into the pile hole in time during the lifting of the screw rod of the pile driver. The filling speed is matched with lifting speed to prevent hole collapse or shrinkage.
4.4. Less pollution and more environmentally friendly
The grouting spill phenomenon is common in the construction of TCM piles. The solidifying agent slurry that is emitted causes pollution to the surrounding environment, especially in waterfront areas or underwater construction. The pollution is more serious and difficult to control. The construction equipment system of the EHP pile is composed of a mixing and conveying system and hole-forming equipment. The construction equipment is advanced and environmentally friendly. The curing agent is added and forcedly stirred in a mixer, and the mixture is pumped into the pile hole in the pipeline. This construction process is free of leakage and waste, which is conducive to environmental protection.

5. Conclusions
The construction technology of EHP piles was introduced and field standard penetration tests were carried out on EHP piles with different cement contents. Compared with the traditional cement-soil mixing pile, the following conclusions can be obtained:

(1) At the same cement content, the number of blows required to penetrate a 30cm depth for the EHP pile is greater.

(2) The change in the number of blows at different depths of the EHP pile is also much smaller, indicating that the EHP pile has better uniformity.

(3) The technical advantages of EHP piles include uniform pile body, quality-assured admixture, controllable pile material, and environmental protection.

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