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Case Histories of Two Kinds of Composite Function – Constructing Buildings Over-crossing Canals

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CASE HISTORIES OF TWO KINDS OF COMPOSITE FOUNDATION

—— Constructing buildings over-crossing canals

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ABSTRACT

Two kinds of ground treatment methods of two buildings with 6 stories over-crossing irrigation canal will be inquired in the paper. The author analyses and compares respectively the design methods , action mechanisms, construction methods and treatment effects of sand column, powder deep mixing method(PDM), and chooses the best ground treatment method from the two. Moreover, the reason why the effects of obliterating liquefaction with PDM are little is discussed in the paper.

KEYWORDS

Composite foundation, sand column, powder deep mixing method, liquefaction, soft soil

INTRODUCTION

At present, there are a lot of ground treatment methods in China. According to reinforcing materials and construction methods, they are crushed: stone pillar, pebble pile, sand column, earth pile, lime soil pile, deep mixing method(PDM or GDM), low grade concrete pile, jet grouting, cement fly-ash gravel pile (CFG), geofabric cushion, slag stone chip pile, steel sediment pile and so on. The most of them are designed according to composite foundation, that is to say, the bearing capacity of composite foundation consists of the bearing capacity and settlement of reinforcer and soil according to certain order. These methods have two common traits: ①. The reinforcing area consists of soil and reinforcer and it is non-homogeneous and anisotropic. ②. The reinforcer and soil undertakes the load together.

The design methods, action mechanism, construction methods and the treatment effects of sand column, PDM of two buildings are analysed and compared in the paper with the help of test data. Therefore, the best treatment method is chosen. The derelict land over-crossing the irrigation canal area can be reutilized.

CONSTRUCTION SCALE AND HYDROGEOLOGICAL CONDITIONS

The two buildings are all 6 – story residences, and they are constructed over-crossing municipal or irrigation canals. The depth of canals is more than 3m. The canals are still needed to drain after the construction. (Fig. 1)

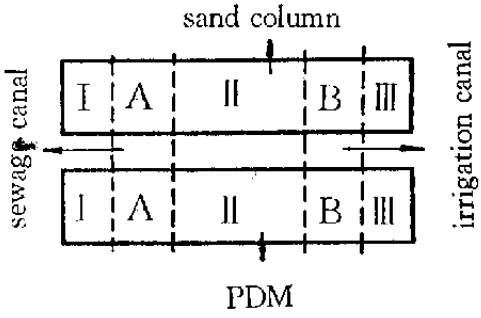

Fig. 1. Diagrammatic plan

The site soil strata consist of Quaternary Period alluvial deposit mainly. Liquified index I_{LE} of the site is 9.15, the site belongs to medium liquidity site according to (*the Code of Aseismatic Design in Construction*) (GBJ11 – 89) (China). The soil properties indexes of main bearing strata are listed in Table 1. The earthquake intensity of

Table 1 Properties indexes of main bearing strata

Soil Strata	ω (%)	γ (kN/m^3)	e	S_r (%)	a_{1-2} (MPa^{-1})	E_s (MPa)	ω_L (%)	ω_p (%)	$N_{63.5}$	f_k (kPa)
Silt	23.1	19.2	0.73	85.5	0.23	9.19	24.6	15.1	5.4	90
Sand				loose	state				11.2	120

the field is 8°. Therefore, the liquefaction of site need be eliminated, and the ground bearing capacity need be raised. The water level is about 6m underground.

THE ANALYSES AND COMPARISONS OF ACTION MECHANISM, CONSTRUCTION METHOD, MECHANICS CHARACTERISTICS OF SAND COLUMN, PDM

The Comparisons of Action Mechanism, Construction Methods of Sand Column, PDM

At first, sand column was used to reinforce loose sand ground, its action mechanism is compaction of sand columns on soils around columns during construction. The compactness and bearing capacity are raised and the liquefaction is eliminated. Second, sand columns are developed to reinforce soft clay ground, its action mechanism is a comprehensive function of replacement and dewatering consolidation, so that the consolidation settlement of soil is speeded up and the bearing capacity of composite foundation is raised. Sand column is a kind of discrete material column, its construction methods are mainly vibratory pile driving and percussion drilling. (They have been introduced in many other papers, so they aren't discussed here).

PDM is such a method that the reinforcer – cement powder and soil are forced to be mixed on site along the direction of depth with the help of a special machine – deep mixing machine. Through a series of physical and chemical reactions between the reinforcer and soil, the structure of disturbed soil are changed, and the cement-soil piles are coagulated, which have integrity, water stability and certain strength. PDM form the composite foundation of deep mixing piles. They belong to half – rigid and half – flexible composite foundation. They have no so much compacting actions on soil as in sand columns.

Comparison of Mechanics Properties of Sand Column, PDM

Depending on the lateral resistance from the around soil, sand columns keep their shapes and support the load. The bearing capacity of the composite foundation with sand columns depends mainly on the lateral resistance of soil and on the properties and the density of column -material. The bearing capacity of the composite foundation with PDM relies on the comprehensive function that consists of the strength of material, lateral and end-bearing resistance of column. The effect of the PDM on increasing the bearing capacity of soil around columns are not notable, and the effect on eliminating liquefactin is not good, which are inquired in following engineering examples.

ENGINEERING EXAMPLES OF SAND COLUMN, PDM

Sand Column

Diameter – 400mm, length – 6m, column spacing – 1.1m and in triangular arrangment. The stuffing is medium coarse sand (5% stone). Vibratory pile driving was adopted as its construction method. After the pile pipe is reached the design depth, sand is filled in it, then the pipe is lifted in $\leqslant$0.5m high, and then the pipe is stoped lifting and vibrated 20s. Repeat the above process until the pipe is lifted out of the ground. The lifted velocity of the pipe should be controlled very well, then reconstruction. The bearing capacity is required to$\geqslant$140kPa. Liquified index is required to $\leqslant$5. Through the site investigation and laboratory test, the following data, in Table 2, have been obtained.

After the treatment, the liquified index $I_{LE} = 3.5 < 5$. The bearing capacity and liquefaction satisfy the requirements of design.

Table 2 Comparison of effects between before and after treatment

Index	before	after	increasing percent
$N_{63.5}$	5.4	9.0	66%
f_k(kPa)	90	135	50%
$f_{sp,k}$(kPa)	90	140.9	56%

f_k: the bearing capacity of the ground

$f_{sp,k}$: the bearing capacity of the composite foundaiton

Powder Deep Mixing Method (PDM)

Diameter – 500mm, pile spacing-1.1m, additive cement60kg/m, length – 4.278m. Their bearing capacity is required to≥140kPa, and liquified index is required to< 5.

In order to examine and compare the treatment effects of PDM and sand column, the soil around piles is investigated with SPT (standard penetration test) and laboratory geotechnical test, and the pile – selves are investigated with drilling cores to test their compressive strength.

Table 3. Comparison of effects the treatment methods

Index	sand column	PDM
$N_{63.5}$	9.0	8.2
f_k(kPa)	135	125
$f_{sp,k}$(kPa)	140.9	143.2
ω(%)	18.5	19.8
I (%)	56%	59%

Where I: increasing percent of the bearing capacity of the ground

The compressive strength of unconfined test cube of pile core $f_{cu,k}$ is 2.5MPa. R_k^d (uni-pile bearing capacity) = $\eta f_{cu,k} A_p$ = 171.7kN, liquified index of soil around piles is 6.8, thus this site is still medium liquidity site.

In the Table 2 and Table 3, it is found that the increasing extent of the strength of soil around sand columns is larger than that of PDM. The one cause is that the sand columns have the compaction function on the soil around columns. The other cause is that sand columns can be applied as good drain path so that the consolidation settlement is speeded up. For PDM after cement powder is mixed with soils, the cement-soil piles with certain strength are formed with the help of the physical and chemical reactions between cement and soil, and the function of setting and hardening. The reasons why the increasing extent of the strength of soil around PDM pile is smaller are that the soil can not be compacted effectively, and the effect of eliminating liquefaction isn't ideal.

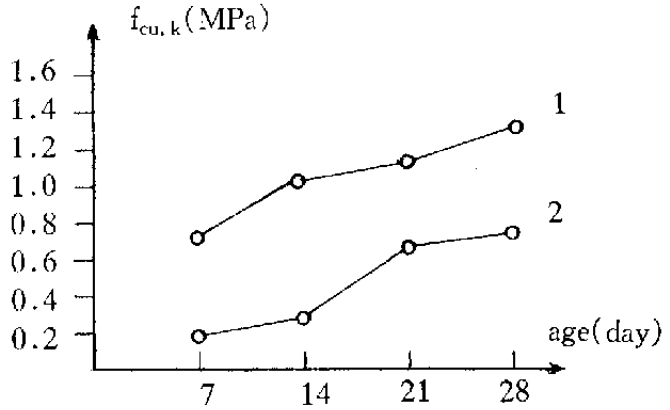

Figure 2. Water quality affecting on the strength of cement-soil

curve 1: cemennt – soil mixed with tap water [organic matter content (OMC) = 0.28%]

curve 2: cement – soil mixed with water in drain canal (OMC = 3.8%)

We can see from Fig2 and Tab.3: ①If the organic matter content in ground is large, the hydration action of cement powder of PDM cannot be fully completed, the $f_{cu,k}$ will be reduced, which leads to the decrease of the bearing capacity of composite foundation $f_{sp,k}$ of PDM. Thus, PDM is not suited to the ground with large the organic matter content. ②The reason why the effect of eliminating liquefaction isn't ideal is that the permeability of cement – soil is bad after setting and hardening, therefore, cement – soil piles aren't able to act as the drain path.

SPECIAL DESIGN OF GROUND – FOUNDATION SYSTEM

The difficult point in designing the ground – foundation system over-crossing canals is that the system must satisfy the requirements of blowdown during and after the construction. Moreover, the sewage water in the canals must not seep into the ground, otherwise, the contamination of ground made by the sewage water is a source of endless trouble. For this reason, two types of foundations are designed as Fig.3, Fig.4.

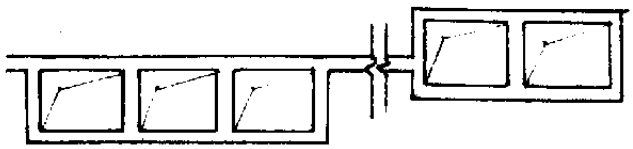

Fig.3. PDM foundation

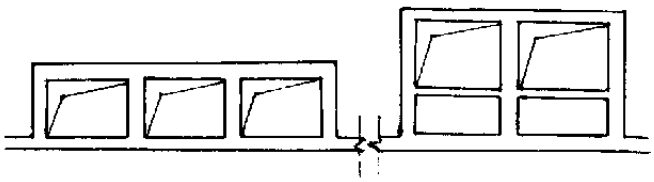

Fig.4. Sand columns foundation

THE CONSTRUCTION MANAGEMENT MEASURES OF THE GROUND－FOUNDATION

Because of the particularity of the two buildings, good design intention can be realized only by means of good construction management measures. The construction management measures are inquired as follows:

In order to make the blowdown not be influenced, the scope of ground treatment is divided into a few of areas: Ⅰ Ⅱ Ⅲ and canals area A, B from Fig. 1 The temporary sewage canal is constructed on Ⅰ area. After the sewage canal is changed, the ground in area A－original sewage canal area is reinforced. With the same method, the temporary irrigation canal is constructed on Ⅲ area. After the irrigation canal is changed, the ground in the area B－original irrigation canal is reinforced. After the ground treatment of A, B areas is considered qualified through checking, special ground-foundation systems are made according to the types in Fig. 3, Fig. 4. The ground treatment and the construction of the foundation in Ⅰ Ⅱ Ⅲ areas are made at last.

The waterproof measures must be adopted during whole construction of ground-foundation and after buildings are completed and used. The water in the canals must not seep into the ground. Othervise, superfluous water makes the ground contaminated or softened so that the bearing capacity of the ground will be decreased. Therefore, material of canals are made up of seepage－resisting concrete, its grade of seepage－resisting is required to $\geqslant S_6$

CONCLUSIONS

1. In the above stated two kinds of ground treatment methods. Various ground treatment methods and construction experiences (successful and non-successful) for constructing over-crossing irrigation canal are supplied. A great deal of derelict land will be redeveloped as long as the suitable ground treatment methods can be chosen.

2. It is one of effectual measures to use sand column for reinforcing loose, soft and liquidity ground with large water content. First, with the help of the comprehensive effects of compaction, replacement and drain consolidation of the columns, the composite foundation of column－soil is formed. Further, the ground strength can be enhanced and liquefaction can be eliminated.

3. If the construction quality of PDM is good, the ground strength can be heightened more than 50%. The key points pledging the quality consist in sufficient quantity of spraying－cement and lifting velocity of pipe. The effect of PDM on eliminating liquefaction isn't very good. Other, PDM is not suited to the ground with large the organic matter content.

4. Choosing more reasonable construction organization plans not only can assure the drain of the canals under buidlings during the wholl construction but also can raise construction efficiency.

5. The sucessful experences of constructing multi-story buildings over-crossing the canals supply a good example for lots of land reutilized on drain net.

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