World Academy of Science, Engineering and Technology
International Journal of Geological and Environmental Engineering
Vol:10, No:2, 2016

Construction Technology of Modified Vacuum Pre-Loading Method for Slurry Dredged Soil

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International Science Index, Geological and Environmental Engineering Vol:10, No:2, 2016 waset.org/Publication/10004254

Abstract—Slurry dredged soil at coastal area has a high water content, poor permeability, and low surface intensity. Hence, it is infeasible to use vacuum preloading method to treat this type of soil foundation. For the special case of super soft ground, a floating bridge is first constructed on muddy soil and used as a service road and platform for implementing the modified vacuum preloading method. The modified technique of vacuum preloading and its construction process for the super soft soil foundation improvement is then studied. Application of modified vacuum preloading method shows that the technology and its construction process are highly suitable for improving the super soft soil foundation in coastal areas.

Keywords—Super soft foundation, dredger fill, vacuum preloading, foundation treatment, construction technology.

I. Introduction

THE concept of vacuum preloading method was introduced in the middle of the last century by Kjellman [1]. Since then, the technology of vacuum preloading method has been applied by several researchers around the world. The vacuum preloading method has been successfully used at various engineering projects in China for improving the soil foundation of expressways, sea embankments, and airports [2]-[6]. Initially, vertical sand drains [8]-[10] were used and more recently, the prefabricated vertical drains (PVDs) have been used [2]-[5], [10], [11]. In this study, a complex composite drainage mattresses and drainage networks [2]-[4], [12]-[14] were used instead of sand cushion, mainly due to the shortage of sand resources. Special technology is being used for treating large amount of muddy soil in Wenzhou Yongxin, China. The ground improvement techniques are often difficult to use as the unskilled construction workers are unable to use the construction equipment properly. In this scenario, the modified vacuum preloading is likely to improve the slurry dredge significantly [7], [15].

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II. Project Overview

A. Geological Conditions

The soil profile are recorded from top to bottom as: (1) Thin grayish yellow loose sandbags of man-made backfill are locally distributed along the east side of the river bank and directly exposed at the surface with a thickness of 0.80 to 2.50 m. (2) Soft plastic clay of medium to high compressibility with thickness of 0.50 to 1.60 m. (3) Layer of sand containing silt with medium - high compressibility is located at depth of 0 to 2.50 m with a thickness of 7.00 to 17.80 m, (4) Layer of silt of high compressibility is found at depth 8.20 to 17.80 m with a thickness of 7.40 to 20.60 m. The super-soft soil with clay content of 78.8-99.7% has a thickness of 2.0 to 3.5 m. The moisture content and void ratio of the super soft clay were 124% and 2.56, respectively. The reclamation site after six months is shown in Fig. 1, whereas the particle size distribution curve is shown in Fig. 2.

Fig. 1 Foundation soil of recent dredger

B. Ground Reclamation Requirements

The upper part of the proposed reclamation site originally consisted of fill sediment of muddy soil. In addition to muddy soil, the soil profile was found to consist of clay, fine sand and silt. Slurry dredge fill was found to have a high water content, high clay content and high liquidity index.

Due to the complex geological conditions, the traditional ground improvement techniques could not be applied to the site. The initial treatment of soil foundation mainly consisted of slurry dredge accompanied by consolidation by vacuum preloading. Slurry dredge fill strengthening is generally carried out for roads construction with the aim to increase the bearing capacity of the soil.

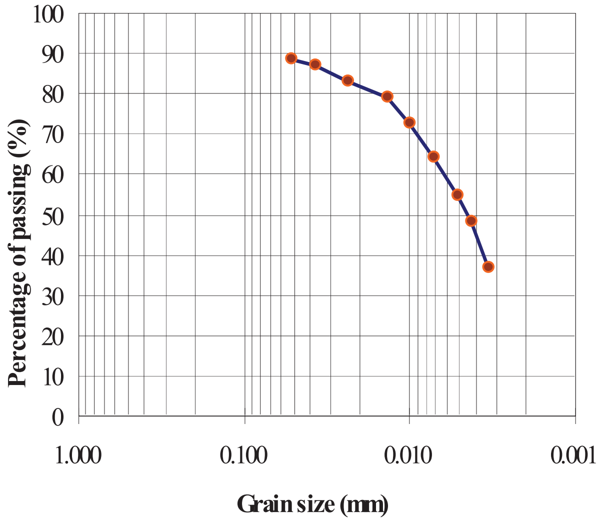

Fig. 2 Particle size distribution of dredged fill

III. Design of Soil Foundation Improvement

A. Construction Technology Program

Due to the geological and environmental conditions of proposed ground for improvement, the modified vacuum preloading technology employed a floating bridge to overcome construction problems on super soft soil. The technique consisted of two stages: In the first stage, a floating bridge was constructed to carry the workers and equipments. The technique of floating bridge is very effective in solving the problem of construction on large-area of dredged fill. The bridges were temporarily constructed by using polyethylene foam boards, bamboo plywood and steel tubes. Construction of temporary float bridge was carried out using rubber and plastic plates. Several bamboo sticks were driven vertically to the slurry soil and tied with others horizontal bamboo sticks using bamboo threads to construct a frame that can carry horizontal rubber foam boards (see Fig. 3) [7], [15]. The second stage involved the treatment of slurry dredged soil by vacuum preloading without sand cushion application because the super soft soil could not support the surcharge of sand cushion.

Fig. 3 Complete floating bridge

B. Design of Modified Vacuum Preloading

(1) Prefabricated vertical drains (PVDs) of 3.5m length were driven vertically in square distribution pattern with a spacing (S) of 80cm.
(2) Drainage plastic pipes of 63 mm diameter are laid horizontally as main pipes for water discharge and to support the corrugated filter. The pipes are arranged and connected with branch to form a drainage network frame as shown in Fig. 4.
(3) The initial loading was with 50% of the number of vacuum pumps. The vacuum operation was monitored at 10-15 day interval. Finally, the vacuum pressure was fixed at 80kPa, and maintained for not less than 60 days. When pumping is stopped the vacuum pressure shall not be less than desired pressure.
(4) The measured settlement for 4 days should be less than 1mm/d and the degree of consolidation should be 80% before stopping the vacuum pumping.

Fig. 4 Plastic pipes laid horizontally for water discharge and to support the membranes

IV. Construction Technology

Vacuum preloading mostly includes vertical drainage system (PVDs). The construction technology consists of drainage systems, vacuum pumps and monitoring equipments grouped together. The slurry dredge fill soil has surface strength equal to zero making it very difficult to treat. The following procedure is therefore, applied for the treatment:

(1) A plastic woven fabric is laid on the surface of muddy fill layer, (see Fig. 5) and then two opposite sides are fixed in the woven fabric on the floating bridge. The plastic woven fabric is wrapped on the floating board and inside the muddy soil.
(2) Plastic drainage (PVDs) are driven by bamboo sticks at a spacing of 80 cm × 80 cm and fixed to the horizontal plastic drain pipes network through orifice (Type A of 10 cm in width) made of exact size using blades. The orifice

should not be very large to prevent the flow of mud from the orifice at the upper level into the drainage system.

(3) The upper end of the PVDs is folded by 20 cm, and then inserted into the plastic drain pipes as shown in Fig. 6.

(4) Layer of vacuum membrane is laid instead of sand cushion. The membrane specification is 150 g/m^2 and the membrane is extended as shown in Fig. 7.

(5) The layer of vacuum membrane film is made of polyethylene with thickness of 0.14 mm. Vacuum membrane borders are made larger than the reinforced area by about 2.0 m on each side.

(6) The borderline of vacuum preloading membrane in this current state is not needed to dig a groove for sealing, but membrane borders are inserted to depth of not less than 1.5m.

(7) A number of vacuum pumps are installed as a single pump cannot support an area of more than 1000m^2. Hence, for a very large area of the slurry dredge soil foundation under treatment, sufficient number of vacuum pumps were installed.

Fig. 5 Ground before foundation treatment

Fig. 6 Connection between drainage pipes and corrugated filter pipe

Fig. 7 Working photo of laying vacuum membrane

V. SITE MONITORING OF GROUND IMPROVEMENT

The monitoring of settlement under vacuum pressure is done and the monitoring curves are shown in Fig. 8. To meet the design requirements, the test time is 10-15 days under vacuum pump of 50% efficiency. The results showed that the characteristics of jumping is relatively stable at a vacuum pressure of 70-85 kPa. Each reinforced area during the settlement is observed daily. The settlement - time curve as shown in Fig. 9 indicates that even if the vacuum in the test stage is causing settlement rate of up to 4 mm/d, a greater total settlement of 376 mm to 557 mm has been achieved within 32 days. Pedestrians were able to walk conveniently on the treated soil as shown in Fig. 10. The settlement has not been stable so far. It is recommended that the vacuum pressure should continue maintaining the vacuum load.

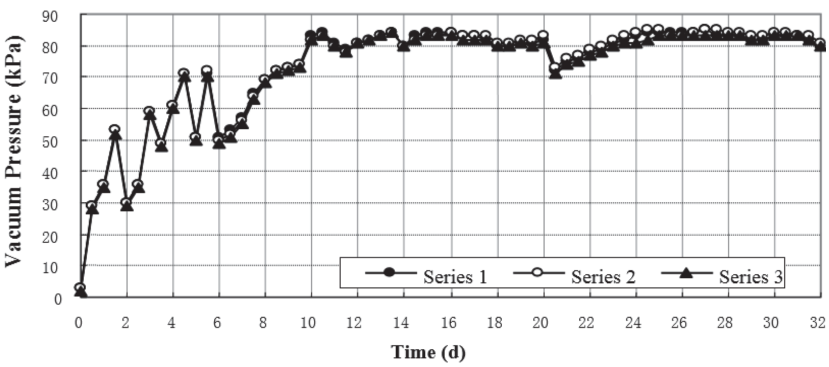

Fig. 8 Curves of vacuum pressure under the membrane

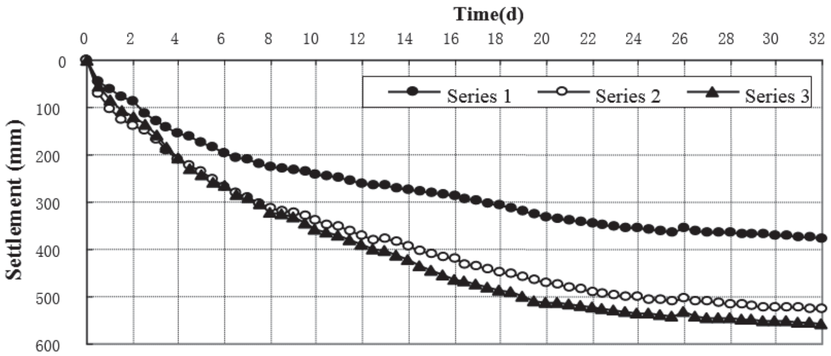

Fig. 9 Curves of settlement with time

Fig. 10 Ground in half way of foundation treatment

VI. Conclusion

In this study, a new construction technology of vacuum preloading for super soft soil improvement in Wenzhou Yongxin, China has been introduced. The construction technology is proposed as a platform for construction detour and for the improvement of super soft soil by using modified vacuum preloading construction technology. Results of construction technique described in this paper clearly showed that the proposed construction technology is technically feasible, convenient, economically advantageous, and leads to satisfactory results.

References

[1] Kjellman, w. 1952. Consolidation of clayey soils by atmospheric pressure. Proceedings of a conference on soil stabilization, Massachusetts institute of technology, Boston: 258-263.

[2] Liu H. L, Mahfouz, A. H., and Chen Yong-hui., 2004. Ground Treatment of sea embankment by vacuum preloading with PVDs. *Southeast University Journal, SEUJ,* Nanjing, China, 20(1): 96-101. (EI)

[3] Mahfouz, A.H., Liu Han-long, Gao Yu-feng, and Li Hao, 2004. Soil improvement for Hangzhou express highway – China by Using Vacuum Preloading Method and PVD Application. *J. of Petroleum and Mining Engineering, JPME*, Suez, Egypt, June 7(1): 115-125.

[4] Mahfouz, A.H. 2005. Study of combined vacuum-surcharge preloading mechanism for ground treatment. *PhD Thesis*, Hohai University, Nanjing, China.

[5] Mahfouz, A.H., Liu Han-long and Yu Xiang Juan. 2005. Soil improvement for Jing-Zhu expressway in Guangdong province–China by using vacuum preloading method. *Proc. of 3rd Int. Conf. on Geotech. Eng. combined with 9th Yearly Meeting of the Indonesian Society for Geotech. Eng. (ISGE) for Disaster Prevention and Rehabilitation.* Aug. 3-4, 2005, Semarang, Indonesia, 303-313.

[6] Mahfouz, A. H., Liu Hanlong, Mohammed A Sakr and Samir IShalaby. 2007. New technique of ground improvement by using vacuum preloading method with PVDs. *12th International Colloquium on Structural and Geotechnical Engineering (ICSGE)* 10-12 Dec. 2007, Cairo - Egypt.

[7] Mahfouz, A.H., Shen Yang, New. 2014. Technology of Vacuum Preloading for Super Soft Soil Foundation. MPM 12 International conference, 20-22 October 2014, Geo 1.

[8] CAO Yong Lang, Cong Jian, Wu Xiaopeng. 2003 Expressway super soft vacuum preloading of (J). Rock and Soil Mechanics, 24 (5):771-775.

[9] Zhao Weibing, Qian Huan. 1990. Preloading Sand foundation design. Journal of Waterway engineering, (9):5-10.

[10] Mahfouz, A.H Liu Han-long and Gao Yu-feng, 2002. Behaviour of soft soils under consolidation with applied surcharge and vacuum preloading. *Proc. of Symp. on Soil/Ground Improvement and Geosynthetic Application, 12-13 Dec. 2002, SEAGS,* Bangkok, Thailand, 2545, 199-211.

[11] Mahfouz, A. H, Liu Hanlong, and Gaoyufeng, 2004. Ground Improvement by Using Vacuum Preloading with Sand Drains. *IS-OSAKA 2004 International Symposium on Engineering Practice and Performance of Soft Deposits 2-4 June*, Osaka, Japan, 287-292.

[12] Ground Handling Manual prepared by the Committee. Ground Handling Manual (Second Edition) (M). Beijing: China Building Industry Press, 2000.

[13] Li Hao，Gao Yu-feng，Liu Han-long，Peng Jie, and Mahfouz, A.H. 2003. Simplified method for subsoil improved by vacuum combined with surcharge preloading, *Chinese Geotechnical Engineering Journal,* Nanjing, China, 25(1): 58-62, (in Chinese). (EI).

[14] Cai Xiaoguang, Liu Han. 2009. Composites reinforced embankment on soft soil drainage water cushion design method (J). Disaster Prevention and Mitigation Engineering, (3): 356-360.

[15] Y. Shen, M. Tao, H. L. Liu, Y. F. Gao, Y. Cui. 2012. The performance of super soft foundation under modified vacuum preloading method. Forensic Engineering, American Society of Civil Engineers (ASCE) 2012 pp. 708-715.