

PAPER • OPEN ACCESS

Effect of VOCs pollutants on strength of cemented soil

To cite this article: Xing-sen Fang *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **242** 052008

View the [article online](#) for updates and enhancements.



IOP | ebooks™

Bringing you innovative digital publishing with leading voices to create your essential collection of books in STEM research.

Start exploring the [collection](#) - download the first chapter of every title for free.

Effect of VOCs pollutants on strength of cemented soil

Xing-sen Fang, Peng-ming Jiang, Xian-wen Huang*, Pan Yang, Jin-hua Ding, Zhi-Hua Yuan

Jiangsu University of Science and Technology, Zhen jiang, Jiang-su, 212000, China

*Corresponding author's e-mail: 994310735@qq.com

Abstract. Based on the soil conservation project of a chemical plant in Zhenjiang, the effects of volatile organic compounds (VOCS) pollutants on the strength of cement soil were studied experimentally. Xylene was utilized for indoor experiment. The specimen was made of water, xylene solvent, gray yellow clay and 42.5 ordinary Portland cement in a certain proportion. Firstly, the influence of the content of xylene on the unconfined compressive strength of cemented soil with time was analyzed, and then the effect of cement blending ratio on the unconfined compressive strength of samples containing xylene was studied with the increase of time. The results showed that the unconfined compressive strength of cement-soil samples increase with the increase of time and decreased with the increase of xylene content in similar curing time; the same xylene incorporation and the unconfined compressive strength of cement soil samples increased with the increase of cement incorporation ratio. In addition, the author also verified the impact of VOCs pollutants on cement-soil retaining walls by simulating actual engineering, and proposed two solutions which were expected to advise the engineering.

1. Introduction

With the rapid development of human society, the collision between man and nature is more and more frequent, and the influence of human beings on the natural environment is getting bigger and bigger, but in turn, the influence of the natural environment on human beings is getting bigger and bigger. In order to cope with the impact of the natural environment on human geotechnical engineering, environmental geotechnical engineering came into being.

Cement soil is a mixture of cement slurry and soil. Because of its convenient material, simple construction, good performance and low price, it is widely used in soil reinforcement and soil seepage prevention projects. Because of its importance in engineering, there are many scholars who conduct related research, and there are many research results. The results show that there are many factors affecting the mechanical properties of cement soil, among which the main factors are cement content, cement properties, age, soil quality, curing conditions, initial moisture content and compactness[1]. At present, many studies on these factors have yielded many valuable research results [2-4], but most of these studies focus on the influence of physical properties of cement soil on cement soil, along with environmental rocks in recent years. With the establishment of soil, the influence of some special environments on cement soil has been paid more and more attention by scholars. For example, Yan Nan et al[5] studied the attenuation of seawater on cement soil through laboratory tests; Liu Xin et al [6] studied the change of strength of cement soil under erosive environment through indoor simulation, and analyzed the erosion mechanism of erosion solution on cement soil; Zhang Shaohua et al. [7] revealed the influence of AC frequency on the resistivity of cement-solidified cadmium-contaminated soils through experiments of resistivity and corrosion unconfined compressive strength of cement-solidified



cadmium-contaminated soils. Han Peng-ju[8] studied the effect of magnesium chloride on the early strength of cemented soil; Fu Xiaoyan et al. [9] studied the effect of sulfate erosion environment on the strength, elastic modulus and stress-strain relationship of cement soil; Liu Xin et al.[8] studied the influence of erosion environment on cement soil strength and microstructure through indoor simulation test. Chen Si-li, et al. [10-11] studied the effects of various specific chemical environments on the mechanical properties of cement soils; In addition to domestic, foreign scholars have also done a lot of related research [12-14]. These studies have not only promoted the development of environmental geology, but also played a very important guiding role in practical engineering. However, although these studies are full of content and involve a wide range of issues, over time we will find that there are some problems in the research, such as the current research on the impact of VOCs polluted environment on cement soil is limited.

With the development of industrialization in contemporary society, the chemical pollution of the soil is becoming more and more serious. Especially in recent years, as people pay more and more attention to environmental protection, President Xi has put forward the idea that “Clear waters and green mountains are as good as mountains of gold and silver”. Many chemical plants have been demolished, and many cities are facing the development and utilization of the old sites of chemical plants.

A chemical plant in Zhenjiang is a medium-sized enterprise that produces chemical pesticides for the country, covering a total area of 257 mu and about 200,000 square meters. As the area is located within the scenic area, it is planned to build a tourist service center, a water market, a polar snow park, a magic show, a sailing yacht club, a waterfront amphitheatre and a city waterfront park. However, according to the report of investigation and assessment and the technical scheme of remediation, the soil and groundwater in the site are polluted and need to be remedied. The remediation mode is ectopic remediation in situ. It was found that the main pollution types at the site were VOCs pollution and VOCs combined pollution. Because of the deep pollution, in order to control the diffusion of polluted groundwater and the volatilization of pollutants into the atmosphere, it is necessary to reinforce the site with cement and soil.

Whether VOCs pollutants will affect the strength and permeability of cement soil, there is no relevant research results. For the consideration of engineering safety, it is necessary to carry out experimental research on the influence of VOCs pollutants on the engineering properties of cement soil.

This paper mainly studies the influence of VOCs pollutants on the strength of cement soil. In order to verify whether the VOCs pollutants will affect the strength of cement soil, this experiment uses tap water, xylene, gray yellow clay and 42.5 ordinary Portland cement in a certain proportion. The cement soil sample was taken as the research object. Through the indoor simulation experiment, the influence of the content of VOCs pollutants on the unconfined compressive strength of cement soil with the change of age and the amount of cement incorporation of VOCs-containing pollutants were studied. The influence of the unconfined compressive strength of cement soil samples with age changes.

There are three reasons for choosing xylene as the experimental material: 1. Xylene is a typical volatile organic compound, which has the common characteristics of many volatile organic compounds and is one of the main pollutants in soil remediation. 2. Xylene is a less toxic volatile organic compound, which can be photolysed and biodegraded, therefore, a small number of experimental samples produced during the experiment need not worry about secondary pollution. 3. Xylene is widely used as a diluent in pigments and paints, and as an organic solvent in printing, rubber and leather industries.

2. Experimental materials and solution

2.1. Experimental materials

The materials used in this test are mainly clay, ordinary Portland cement, xylene solvent and water. See Table 1 below for details:

Table 1 Experimental materials

Experimental Materials	Type and parameter	source
cement	42.5 ordinary Portland cement	Jiang-su he-lin cement co., LTD
Gray-yellow clay	WL=12.5 WP=35.6	A construction site in zhen-jiang city
water	Tap water	Zhen-jiang city tap water
Xylene	Solvent grade	Ji-ning Shun-yuan Chemical Co., Ltd.

2.2. Test plan

First, the soil sample was air-dried and crushed through a 2 mm sieve, and then the water content was measured and sealed and stored. Then refer to the relevant specification[15] to determine the mix ratio of the sample. The specific mix ratio is shown in Table 2 below.

Table 2 Sample ratio

Sample	Design mix ratio Soil: cement: water	Xylene addition g / per kilogram of soil	Sample	Design mix ratio Soil: cement: water	Xylene addition g / per kilogram of soil
Group 1	1: 0.2:0.6	0	Group 7	1: 0.2:0.6	9
Group 2	1: 0.2:0.6	1.5	Group 8	1: 0.15:0.6	6
Group 3	1: 0.2:0.6	3	Group 9	1: 0.175:0.6	6
Group 4	1: 0.2:0.6	4.5	Group 10	1: 0.225:0.6	6
Group 5	1: 0.2:0.6	6	Group 11	1: 0.25:0.6	6
Group 6	1: 0.2:0.6	7.5			



Fig.1 Partial sample number



Fig.2 Sample loading

In order to ensure the accuracy of this test as much as possible, in this process of making cement soil samples, it is also necessary to consider the moisture contained in the soil sample. In this test, a total of 11 cement soil samples were produced, 15 in each group. The prepared cement soil is evenly stirred and placed in a cube test piece with a side length of 70.7mm. It is manually vibrated and compacted by a 10mm diameter rod, and then vibrated for 3 minutes through the vibrating table. The surface of the cement soil is cut and smoothed, and placed under standard curing conditions. After 48 hours, the mold number is removed, and then it is placed in the standard curing box to continue the maintenance. Then, when the cement soil sample maintenance age reached 7 days, 14 days, 28 days, 60 days, and 90 days,

three samples from each group were taken as experimental samples of each age, and the YAW-300C type was used. Automatic cement bending and compression testing machine test, measuring the unconfined compressive strength of cement soil samples at different ages

3. Experimental results and analysis

3.1. Influence of VOCs pollutants on cement soil strength

The relationship between the unconfined compressive strength of cement soil and the age is shown in Figure 3.1, where the abscissa is expressed as the curing age of the specimen and the ordinate is expressed as the unconfined compressive strength of the specimen. The legend shows the content of xylene per kilogram of soil sample in different groups of cement soil samples under the same mix ratio.

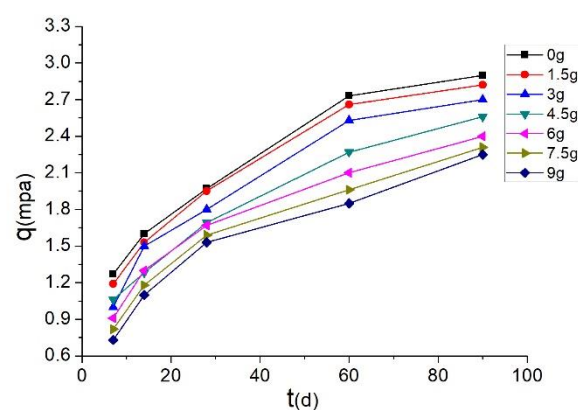


Fig.3 Relationship between unconfined compressive strength and pollutant content of VOCs contaminated cement soil with age

As can be seen from Figure 3.1: 1. Although the xylene content of each cement soil sample is different, the unconfined compressive strength of the cement soil sample will increase with the increase of age, and it can be seen from the figure. The intensity of the sample increased 60 days ago, and the growth rate was smaller after 60 days, and it was almost close to the peak in about 90 days. 2. Under the same age, the unconfined compressive strength of cement soil samples decreased with the increase of xylene content.

3.2. Influence of cement mixing ratio on the strength of contaminated cement soil

The relationship between the unconfined compressive strength of cement soil and age is shown in Figure 3.2, where the abscissa is expressed as the curing age of the specimen and the ordinate is expressed as the unconfined compressive strength of the specimen. The legend shows the different cement incorporation ratios of different sets of cement soil samples at the same xylene content.

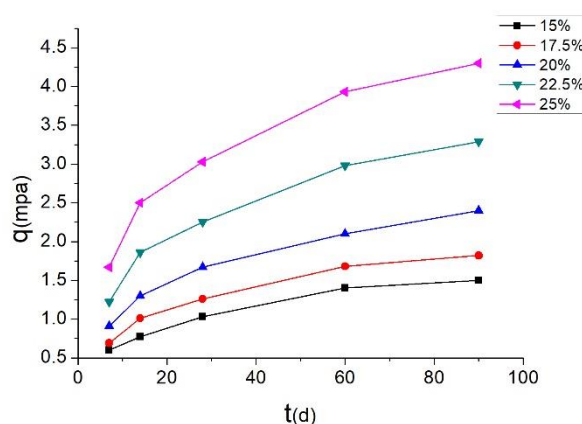


Fig.4 Relationship between unconfined compressive strength and cement incorporation ratio of VOCs contaminated cement soil with age

As can be seen from Fig. 3.2, when the xylene content of each sample is the same, only the cement mixing ratio of the cement soil sample is changed, we find that under the same age, the cement soil increases with the cement mixing ratio. The unconfined compressive strength of the sample also increases. Moreover, we can also see in the figure that the cement mixing ratio of the cement soil sample is longer, and the cement soil sample has a longer cement concrete soil mixing ratio. The earlier the sample strength can reach its maximum value.

3.3. Correspondence between xylene content and cement incorporation ratio

According to the above test results, VOCs pollutants can indeed lead to a decrease in the strength of cement soil, and in the case of VOCs pollutants, the cement blending ratio is increased, and the strength of cement soil can indeed be increased. Therefore, we can know that increasing the cement incorporation ratio of cement soil can solve the adverse effects of VOCs pollution on cement soil. However, there is still a lack of quantitative correspondence between the two. From the above results, it can be seen that the cement soil sample can basically reach or approach the final strength at 90 days of age, in order to obtain a relatively stable quantitative correspondence between the two, at 90 days of age. I separately select the intensity under the condition of the respective control variables, and obtain the relationship between the independent variable and the intensity. The specific results are as follows:

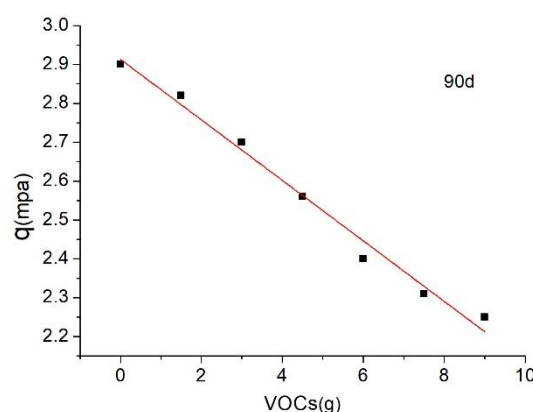


Fig.5 Relationship between strength of cement soil and pollutant content in 90 days of age

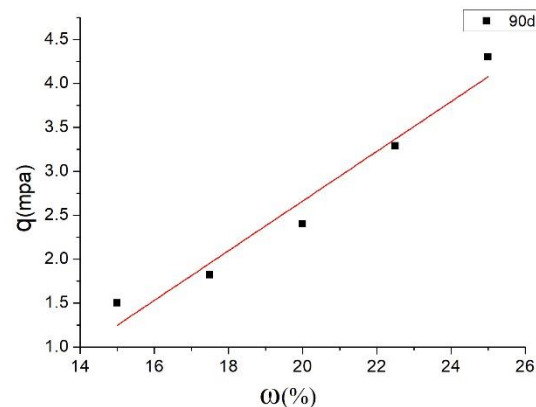


Fig.6 Relationship between strength of cement soil and cement mixing ratio in 90 days of age

The regression equations are as follows:

The relationship between the xylene content α on cement soil:

$$q_u = -0.078 * \alpha + 2.9 \quad R^2 = 0.98$$

Correspondence between xylene content α and sample strength change:

$$\Delta q_u = -0.078 * \alpha$$

The relationship between cement incorporation β and concrete on cement soil:

$$q_u = 0.28 * \beta - 3 \quad R^2 = 0.95$$

The relationship between cement incorporation ratio β and the change in strength of the sample:

$$\Delta q_u = 0.28 * \beta$$

From the fitting results, it can be seen that for every 1g increase of xylene content, the unconfined compressive strength of cement soil decreases by 0.078Mpa, and the cement incorporation ratio increases by 1%, and the unconfined compressive strength of cement soil sample increases by 0.28Mpa. Only by fitting the results, for every 1g increase in soil VOCs pollutant content, in order to solve the impact of pollutants, the cement incorporation ratio needs to increase by 0.28%.

4. Conclusion

(1) Under the same age, VOCs pollutant content is higher, the unconfined compressive strength of cement soil is low, which indicates that the VOCs pollutants have a degrading effect on the strength of cement soil, and the test results are passed. It can be seen that at the age of 90 days, the degree of deterioration is positively correlated with the content of VOCs pollutants within a certain range.

(2) When VOCs are contained in the soil, increasing the cement mixing ratio of the cement soil can increase the unconfined compressive strength of the cement soil sample, and the test results show that at the age of 90 days, the cement the degree of increase in the unconfined compressive strength of soil has a good correlation with the cement incorporation ratio.

(3) Due to the limited scale of the experiment, the conclusions obtained in this paper can only be used as a quantitative reference for related projects, but can not be directly used as the quantitative basis for the project. The specific project needs to be based on the specific test results.

Acknowledgments

The authors gratefully acknowledge the financial support of the National Natural Science Foundation of China(Grant no. 51579119) and the Natural Science Fund for Colleges Universities of Jiangsu Province (Grant no. 17KJB560003).

References

- [1] XIAO Lin. Building materials cement soil [M]. Beijing: Water Resources and Power Publishing House, 1987.
- [2] ZHAO Cheng, SHEN Xiang-dong, JIA Shang hua, ZHAO Chun-feng. Influence of density on strength of cemented soil[J]. Chinese Journal of Geotechnical Engineering, 2013, 35(S1): 360-365.
- [3] Liu shun-qing, Huang Xian-wen, Zhou Ai-zhao, et al. Soil-rock slope stability analysis by considering the Non-uniformity of rocks[J]. Mathematical Problems in engineering. 2018:1563-1578.
- [4] Huang Xian-wen, Liu Shun-qing, Sui Xiao-lan, et al. Earthquake response analysis of soil-rock slope based on distribution of rocks[J]. MATEC Web of Conferences, 2018, 175.
- [5] YAN Nan, YANG Jun-jie, LIU Qiang, DONG Meng-rong, Laboratory test on strength deterioration process of soil cement in seawater environment[J]. CHINA CIVIL ENGINEERING JOURNAL, 2017, 50(11):115-124.
- [6] LIU Xin, HONG Bao-ning, CHEN Yan-li, ZHANG Hua-jie, Research on the Shear Strength and Microstructure Change Regulation of Cement-mixed Soil Under Environmental Erosion[J]. Journal of wuhan university of technology, 2010, 32(10): 11-15+57
- [7] ZHANG Shao-hua, GAO Yi-tao, KOU Xiao-hui, DONG Xiao-qiang. Study on Electrical Resistivity and Strength Characteristics of Cadmium Contaminated Soil Solidified by Cement [J]. Journal of taiyuan university of technology, 2015, 46(06): 702-706.
- [8] HAN Peng-ju, ZHANG Wen-bo, LIU Xin, BAI Xiao-hong. Early strength of cemented soils polluted by magnesium chloride[J]. Chinese Journal of Geotechnical Engineering, 2014, 36(06):1173-1178.
- [9] FU Xiao-qian, FENG Jun-de, XIE You-jun. Mechanical behavior of soil cement under ambient with sulfate conditions[J]. Rock and Soil Mechanics, 2008, 29(S1):659-662.
- [10] Chen Si-li, Ning Bao-kuan. Environmental effects of Geotechnical materials [M]. Beijing: Metallurgical Industry Press, 2010.)
- [11] CHEN Si-li, YANG Yu-lin, ZHOU hui, HU Dawei, Effect of sewage environment on permeability of cemented soil[J]. Rock and Soil Mechanics, 2015, 36(11):3047-3054.
- [12] Kong sukprasert L, Lalana F, Tatsuoka H. Effects of curing period and stress conditions on the strength and deformation characteristics of cement-mixed soil [J]. Soils and Foundations, 2007, 47(3):577 — 596.
- [13] Hara h, hayashi s, suetsugu d, et al. Study on the property changes of Lime-treated soil under sea water[J]. Journal of Geotechnical Engineering C, JSCE, 2010, 66(1): 21–31.
- [14] Hara h, suetsugu d, hayashi s, et al. Calcium leaching properties of Lime-treated soil by infiltration of tidal river water[C] Proceedings of International Offshore and Polar Engineering Conference, 2008: 810–813.
- [15] Ministry of Housing and Urban-Rural Development of the People's Republic of China. Design rules for cement-soil mix ratio: JGJ/T 233-2011[S]. Beijing: China Building Industry Press