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The mechanical properties of dredged sludge matrices solidified by waste fiber compound binder

Wang Yuexiang[1,2], Zhao Wen[1]

Abstract. The recycle of dredged sludge become a concern in geo technique engineering. This study proposes a new way of solidifying dredged sludge with waste fiber compound binder. The mechanical properties of dredged sludge were discussed by the investigations of unconfined compressive strength and volume change of the solidified samples for different curing time. The results of mechanical test showed that adding waste fiber compound binder to dredged sludge improved the strength of solidified samples, but had little influence on the volume capacity of matrices, which is important to dredged sludge disposal. The results of the present work suggest that waste fiber compound binder can reduce the amount of cement and improve the mechanical properties of dredged sludge.

Key words. mechanical, dredged sludge, solidify, waste fiber, compound binder.

1. Introduction

In China, the dredged sludge increases significantly owing to rapid urbanization and improvement of dredged treatment capability. It was reported that about 2000×10^4 wet tons of dredged sludge were produced [1]. As is well known, more and more rivers have been contaminated which has caused that dredged sludge includes a large number of hazardous substances such as heavy metals and organic matters which are harmful to public health. To reduce the negative impacts, appropriate disposal of dredged sludge is required. The solidification/stabilization(S/S) technologies have been developed to reduce the release of toxic substance in sludge. In S/S matrices, the most ordinary fixing agents are cementitious materials such as porland cements, fly ash and lime. Calcium silicate hydrate, ettringite hydrate and monosulphate are formed in the stabilization process, and thus the pollutants are both chemically fixed

[1]Department of civil engineering, Suzhou University of Science and Technology, Suzhou, Jiangsu, China Corresponding Author, E Mail: wyxcy@sina.cn

[2]Nangjing Technology University, Civil engineering post doctoral mobile station, Nanjing, Jiangsu, China

and physically encapsulated in the matrices [2]. However, to traditioal binders, it is found that a large amount of cement must be consumed in S/S process , resulting in that the cost of sludge disposal is high. So, it is urgent to find a new binder to improve the S/S effect and reduce the disposal cost.

Waste fiber compound binder is produced in the process of construction debris treatment. As a large scale of construction is proceeding in China, a great deal of building materials have been used. Thus, the amount of construction debris has been larger and larger which causes the problem that there is nowhere to pile up. Hence, how to find a good outlet for construction debris has become a concern at present. It is found that construction debris can be used to produce a new material which is waste fiber compound binder. Waste fiber compound binder has special characteristics, and the mixture and co-disposition of waste fiber compound binder and dredged sludge may achieve better effectiveness on strength properties.

The objective of the work is to evaluate the feasibility of dredged sludge solidification using waste fiber compound binder and to investigate the solidified efficiency through the unconfined compressive strength of the matrices and volume change.

2. Methods and materials

2.1. Materials

Dredged sludge from the Nanjing dredged treatment plant, ordinary portland cement from a local cement plant and waste fiber compound binder provided by the Mabang material plant in Suzhou were used in the experiment. The dredged sludge was dehydrated sludge cake, and its main physical indices are shown in Table 1. Ordinary Portland cement was Grade 32.5 according to the Chinese standard. The chemical composition of waste fiber compound binder powder is listed in Table 2.

Table 1. The properties of the dredged sludge sample in the research

pH[a]	Water content(%)	Specific gravity	Density (g/cm^3)	Organic matter[b](%)	Plastic Limit(%)	Liquid Limit(%)
6.6	346.1	1.56	1.24	57.5	159	279

[a]The pH was measured at the ratio of 1:10 for air-dry sludge sample to distilled water

[b]The content of organic matter was acquired by the mass loss under combustion

Table 2. Chemical composition of waste fiber compound binder

Parameter	CaO	SiO_2	Al_2O_3	K_2O	MgO	Fe_2O_3	Waste fiber	others
Content(%)	13.51	35.82	13.71	2.14	3.35	1.10	30.20	0.17

2.2. Preparation of monolithic matrices

The binder materials were mixed in a definite ratio as given in Table 3. Two groups of solidified waste matrices were prepared by mixing different proportions of binder materials. For preparation of solid matrices, the materials were mixed uniformly, and the solidified samples were put into moulds with a diameter of 3.91cm and a height of 8 cm. The samples were demould after 2 days and kept at a temperature of 20^{o}C and relative humidity of 100% . After having been cured for 7, 14, 21, 28, 60 days, the specimens were tested for unconfined compressive strength.

Table 3. Different mixture proportions of S/S samples

Sample[a]	Weight ratio			Sample[a]	Weight ratio		
	Binder materials		Sludge		Binder materials		Sludge
Group1	cement	Waste fiber compound binder		Group2	cement	Waste fiber compound binder	
C0.2SMW0.5S1	0.2	0.5	1	C0.4SMW0.5S1	0.4	0.5	1
C0.2SMW0.6S1	0.2	0.6	1	C0.3SMW0.5S1	0.3	0.5	1
C0.2SMW0.7S1	0.2	0.7	1	C0.2SMW0.5S1	0.2	0.5	1
C0.2SMW0.8S1	0.2	0.8	1	C0.1SMW0.5S1	0.1	0.5	1

[a]C:ordinary portland cement, SMW:waste fiber compound binder, S:sludge

2.3. Unconfined compressive strength(UCS)

According to the preparation of monolithic matrices, the specimens were taken out from the curing room after having been cured for 7, 14, 21, 28, 60 days. The sizes of specimens (length and diameter) were measured by vernier caliper. Before the test began, a thin layer of vaseline was brushed on the surface of specimens to prevent the moisture volatilizing. After the specimen was placed on the underneath plate of the test instrument, the wheel was turned by hand to make the specimen touch the upper plate and the indication of dialgauge was adjusted to zero. Then, the wheel was turned at a speed of 0.06mm/min to test the specimen, and the indication of dialgauge was read per 0.5% strain. The test procedure was completed in 8-20 minutes. For each mixture, three specimens were tested, the average is the unconfined compressive strength.

2.4. Volume change

According to the methods in the literature [3], the sludge was mixed with the binders in a iron container and transferred into four 39.1 mm diameter copper molds for quantifying the volume change. After 2 days the specimens were demould. One of the specimens continued to be cured at 100% relative humidity and controlled temperature (21±2°C) for 28 days and its final volume was measured. The other three remained as control specimens. The length and diameter of specimens were measured by vernier caliper. Contrasted to the cured specimen, the volume change was acquired.

3. Results and discussion

3.1. Unconfined compressive strength of solidified matrices

3.1.1. Effect of waste fiber compound binder and cement content

In any cases, compressive strength is important to the performance of S/S matrices. A minimum compressive strength of 345kPa at 28 days of age is generally recommended for landfill to support earthmoving machinery [4, 5]. If the S/S matrices are proposed as a motar [6] and concrete [7, 8] to support foundations or road works, a higher strength of 1.034MPa is specified [9]. In this study, the values of 345kPa and 1034 kPa were adopted to analyze the solidified matrices. The unconfined compressive strengths of 28 days for various S/S matrices are given in Figure 1.

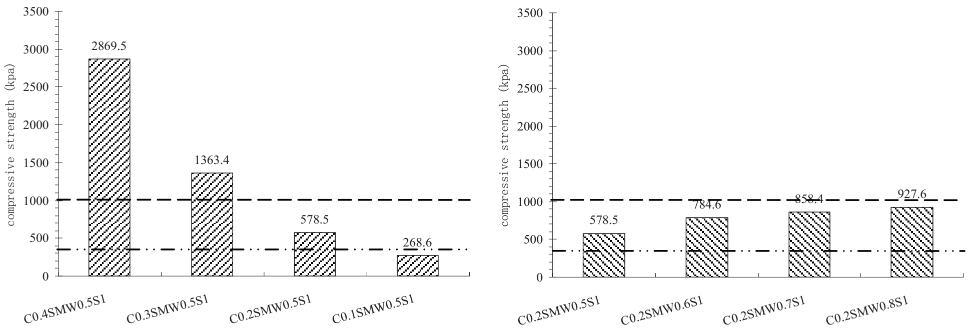

Fig. 1. UCS at 28 days age

As shown in Fig.1, a majority of the S/S matrices met with the requirement of compressive strength (345 kPa) as landfill disposal except the strength of the sample (C0.1SMW0.5S1) which was 268.6 kPa. To a high value of 1034 kPa specified as a motar and concrete, there were two samples which can attain the standard. One was the matrice (C0.3SMW0.5S1) which strength was 1363.4 kPa, the other was the matrice (C0.4SMW0.5S1) which strength was 2869.5 kPa and exceeded the standard almost two times.

Fig.1(a) shows the effect of cement content on UCS while the contents of waste fiber compound binder and dredged sludge were kept unchanged. As the content of cement decreased, there was a decrease of UCS of the S/S matrices. For example, when the mass of cement reduced from 0.3 kg to 0.2 kg, UCS of the S/S matrices remarkably decreased from 1363.4 kPa to 578.5 kPa. These results suggest that the content of cement had a far-reaching influence on UCS.

Fig.1(b) shows the effect of waste fiber compound binder content on UCS while the contents of cement and dredged sludge were kept unchanged. The datas indicate that UCS of the matrices increased as the content of waste fiber compound binder increased, suggesting that the addition of waste fiber compound binder as substitute part of cement can achieve a fine solidifying effect.

Based on the above analysis, it can be concluded that sludge mixed with an appropriate amount of cement and waste fiber compound binder after 28d of curing time had an adequate unconfined compressive strength for landfill disposal or as building material.

3.1.2. Influence of curing time

Fig.2 depicts the variation of UCS of the matrices with curing time. It was observed that the compressive strength of the S/S samples increased with an increase in curing time. Fig.2 (b) dedicates that the addition of waste fiber compound binder can increase the UCS, however, as shown in Figure.2(a), the effect of cement on the increase of the UCS was more significant.

To evaluate the long term strength of the S/S matrices, the percentage of increment in the UCS from 28 to 60 days was calculated. The results were shown in Table 4 and Table 5 according to Fig 2. Table 4 and Table 5 show that the matrices still can develop their strength after 28 days. The strength increment for the sample (C0.2SMW0.8S1) reached the maximum value of 66.90% at 60 days. It is implied that the strength development in a longer time may benefit from the reasonable addition of waste fiber compound binder and it was still a considerable improvement on the UCS of matrices with time.

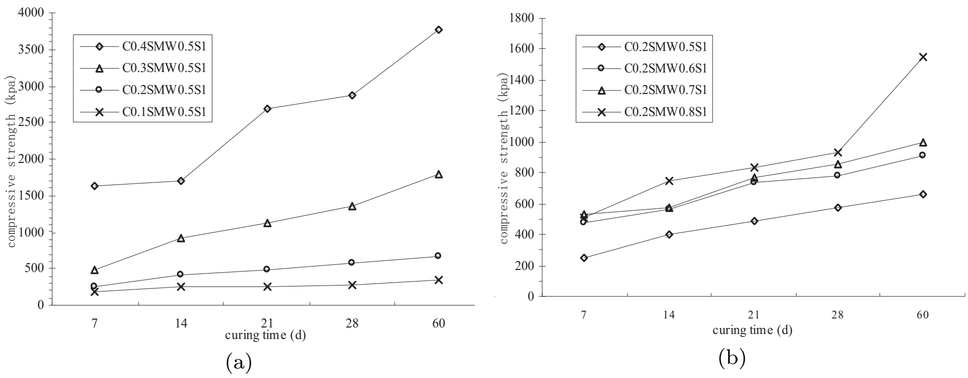

Fig. 2. Influence of curing time on UCS

Table 4. Percentage of increase in UCS between 28 and 60 days according to Figure.3 (a)

sample	C0.4SMW0.5S1	C0.3SMW0.5S1	C0.2SMW0.5S1	C0.1SMW0.5S1
Percentage of increase in UCS	31.73%	30.90%	13.42%	28.22%

Table 5. Percentage of increase in UCS between 28 and 60 days according to Figure.3 (b)

sample	C0.2SMW0.5S1	C0.2SMW0.6S1	C0.2SMW0.7S1	C0.2SMW0.8S1
Percentage of increase in UCS	13.42%	16.16%	16.78%	66.90%

3.1.3. Volume change analysis

The volume increased as a result of the solidification activity is presented in Fig.3. It is observed that cement and waste fiber compound binder caused small volume increase which is advantageous to solidification of waste material. Fig.3(a) and (b) show that the volume change was almost less than 10%, which was not significant compared to the volume change caused by the use of fly ash or lime as binders [10, 11, 12, 13, 14, 15]. In addition, it can be concluded from Fig.3(a) and (b) that waste fiber compound binder had less influence on the volume change of the matrices than cement. For example, when the same amount of binders was added to solidify 1 kg dredged sludge as the sample C0.3SMW0.5S1 and the sample C0.2SMW0.6S1, the volume change of the sample C0.3SMW0.5S1 was 10.50% and larger than the one of the sample C0.2SMW0.6S1 which was 6.28%. Similar observation can be made for the sample C0.4SMW0.5S1 with a 9.54% volume increase and C0.2SMW0.7S1 with a 6.68% volume change.

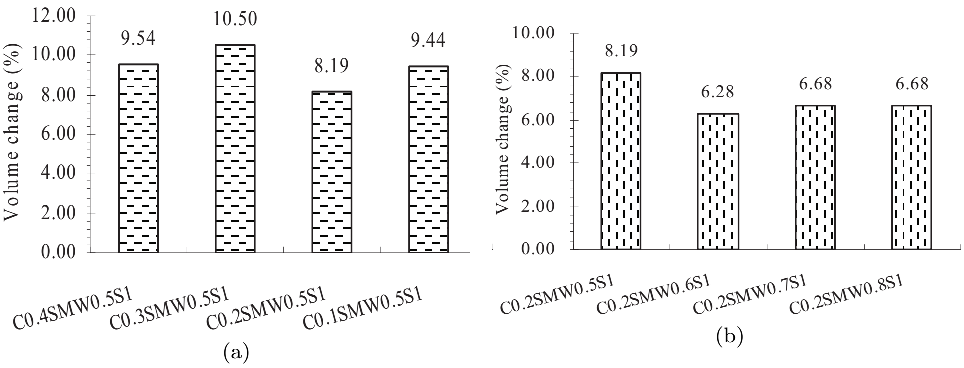

Fig. 3. Volume change of S/S matrices at 28 days age

4. Conclusion

The present study revealed the effect of different mixture proportion of binders (cement and waste fiber compound binder) on the unconfined compressive strength and volume change of the solidified sludge. All mixture proportion of binders produced positive effects on each of the measured parameters. The UCS of the solidified sludge varied with the content of binders and curing time. The more binders were added, the more UCS of the matrices was improved. The UCS of the matrices increased with curing time and continued to increase after 28 days, especially at a higher content of cement or waste fiber compound binder. The material constituted of cement and waste fiber compound binder caused small volume increase. Cement could have more influence on volume than waste fiber compound binder. The results of the present study confirmed that waste fiber compound binder can reduced the amount of cement and improve the property of all binder system. Further studies are needed to determine the leaching characteristics or mechanical behavior during solidification processes.

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