Study on Strength Characteristics of Straw (EPS Particles)-Sparse Sludge Unburned Brick

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Study on Strength Characteristics of Straw (EPS Particles)-Sparse Sludge Unburned Brick

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Abstract. The recycling of dredged sludge is an economical and environmentally friendly technology. In this paper, the sludge produced by river dredging is used as the main material, which are mixed with discarded straw or EPS granules, cement, gypsum, etc. as additives. The cement content, the content of the blended materials and the age of the bricks are tested by orthogonal experiment. The influence of strength determines the optimal mix ratio of straw (EPS particles)-dried sludge-free bricks. The results show that the cement content has the most significant influence on the compressive strength of the material, followed by the incorporation of materials and age; when 20% cement, 5% mixing materials, and the curing is 28d, the compressive strength of the brick meets the standard of MU7.5.

1. Introduction

In recent years, China has begun large-scale dredging projects of lakes and rivers. Taking Jiangsu Province as an example, in 2017, Jiangsu Province issued the “Jiangsu Province Ecological Rivers and Lakes Action Plan” (2017-2020), it is estimated that about 250 million cubic meters of rural river dredging earth will be completed each year, and it is proposed to properly dispose of river silt, prevent secondary pollution, and improve the utilization level of silt resources. Zheng et al. [1] studied the effect of two filamentous fungi on the dewatering ability of sludge. Experiments showed that one of the fungi was confirmed to not only improve the mud dewatering ability but also can effectively reduce the toxicity of dissolved organic matter in the sludge. In China, many researchers have carried out various researches on the recycling of silt resources. Zhu Wei et al. [2] studied different treatment methods for sludge solidification, and obtained an economical, practical and feasible chemical method for adding solidified materials to dredged sludge to improve the strength of dredged sludge. Zhu Wei, Ji Fengling, Ma Dianguang, Li Mingdong [3] studied the occurrence of microcracks in lightweight mixed soil samples under axial loading conditions. Experiments have shown that the internal crack of the sample starts from the joint surface of the EPS particles and the solidified soil. With the addition of different amounts of EPS particles and cement, its Mohr damage envelope has both linear and polygonal forms. The shear strength mechanism considers the gradual damage effect of the cemented structure of the lightweight mixed soil sample is different from the general soil. Peng Bo, Li Bixiong, Fang Yong, Chen Jian et al [4] studied the effect of sludge content on the compressive strength of silt-free bricks. The test shows that: 1 With the increase of sludge content, the compressive strength of the silt-free bricks tends to rise first and then decrease; 2 The maximum compressive strength of the three unfired brick test groups is that the sludge content is 15% to 20% of the sandstone replacement rate. Most of the use of sludge materials in China is mainly based on sintering, which not only consumes a lot of energy, but also easily causes air pollution.

In this paper, the dredged sludge is used as the main raw material, and the waste straw and plastic are blended as the blending materials to make the bricks with certain mechanical properties. The compressive strength is used as the index, and the orthogonal experiment method is used to determine the optimal material coordination. The purpose is to form a set of technical lines for the treatment of dredged silt-free bricks containing straw or EPS particles, to achieve reuse of waste materials, reduce energy consumption and protect the ecological environment.

2. Materials and methods

2.1.Test materials

The experimental materials were made from the sludge produced by environmental dredging in a river in Nanjing, collected, placed in plastic buckets and let it stand for natural drainage. The collected straw and waste plastics are pulverized, wherein the average length of the straw powder formed by the crushing is 2 to 3 mm; the average particle diameter of the discarded plastic formed after the crushing is 1 to 1.5 mm, and the formed plastic particles are all washed with water and then dry. 42.5# ordinary Portland cement produced by Taicang Conch Cement Co., Ltd. as curing agent, bonding dredged sludge and blending materials, using gelling agent to improve the bonding between particles and increase the final compressive strength [5].

Table1. Basic physical properties of dredged sediment.

Moisture content (%)	Severe (KN/m^3)	saturation (%)	Pore ratio e	proportion G_s	Liquid limit (%)	Plastic limit (%)
52.1	17.2	96	1.509	2.74	46.0	26.9

2.2.Test plan

The dosage was 2% gypsum and 1% gelling agent. The optimum ratio of the unfired bricks mixed with straw and EPS particles was determined by orthogonal experiment. In this study, the three factors of the content of the mixed materials (straw, EPS particles), cement content and age were selected for orthogonal test. The orthogonal design table is shown below.

Table 2. Factor level table.

Level	Test factor		
	(A) Cement /%	(B) Incorporation of materials /%	(C) age
One level	20	5	7
Second level	15	10	14
Three levels	10	15	28

2.3.Preparation steps

The sludge produced by dredging the river is dehydrated to make the moisture content of the dredged sludge less than 25%. After removing the granules such as gravel, the pre-treated materials (straw and EPS granules), cement, gypsum and gelling agent are mixed with the dredged sludge according to the ratio shown in Figure 1, stirring for 10 minutes and putting into the mold. The sample size is 50mm*100mm*200mm. After curing for 24 hours under dry conditions, watering is carried out under natural conditions on the 2nd to 14th day, and it is under natural conservation from 8 to 28 days. After 28 days, the mold was removed and the dredged sludge-free brick containing the material was added.

Figure 1. Preparation of the sample

Figure 2. Sample formation

3. Results and analysis

3.1. Orthogonal results analysis

Table 3. Orthogonal test results

Test number	(A) cement/%	(B) Incorporation material /%	(C) Age	Straw compression resistance Strength / MPa	EPS particle resistance Compressive strength / MPa
1	20	5	7	8.2	6.9
2	20	10	14	8.1	5.7
3	20	15	28	6.7	5.8
4	15	5	7	7.4	4.2
5	15	10	14	6.9	4.7
6	15	15	28	6.2	3.2
7	10	5	7	6.4	3.4
8	10	10	14	5.1	2.6
9	10	15	28	4.2	2.2
k_1	7.67 （5.8）	7.3 （4.83）	6.5 (4.23)		
k_2	6.83 （4.03）	6.7 （4.33）	6.56 (4.03)		
k_3	5.33 （2.73）	5.7 （3.73）	6.67 (4.63)		
R	2.34 （3.07）	1.6 (1.1)	01.7 (0.4)		
Primary and secondary order	A＞B＞C（A＞B＞C）				
Excellent level	$A_1B_1C_3(A_1B_1C_3)$				

In summary, among the three factors including age, incorporation of materials and cement, the content of cement has the greatest influence on the compressive strength of bricks, followed by the incorporation of materials, and finally the age. The greater the cement content, the longer the curing time, and the greater the compressive strength of the resulting unfired brick.

3.2. Single factor analysis

3.2.1. Effect of cement dosage on compressive strength of straw (EPS granule)-dried sludge-free brick

Figure3. shows the relationship between the amount of cement and the compressive strength of straw (EPS granule)-dried sludge-free brick. It can be seen that with the increase of the amount of cement added, the compressive strength of straw-dried sludge-free bricks shows a significant upward trend. When the cement is incorporated in an amount of about 12%, the compressive strength of the unfired bricks just reaches the standard of the compressive strength of the bricks MU7.5. It varies within the range between 12% and 20%, which meets the requirements for the compressive strength of the bricks. When the cement is added in an amount of 20%, the compressive strength of the sample is the highest in different amounts, and the highest compressive strength is about 11.7 MPa. The intensity of Straw-dried silt free brick is mainly determined by the amount of cement mixed and the degree of uniformity of mixing. The introduction of cement can effectively improve the structural stability of straw and sludge and improve its compressive strength. With the increase of the amount of cement added, the compressive strength of EPS granules-dried sludge-free bricks showed an upward trend, but it did not rise in a straight line. When the cement is incorporated in an amount of about 17.5%, the compressive

strength of the unfired bricks just reaches the standard of the compressive strength of the bricks MU7.5. It varies within the range of 17.5%~20%, which meets the requirements of the engineering for the compressive strength of the bricks, but the highest strength is about 8MPa. Experiments have shown that the effect of cement addition on the compressive strength of dredged sludge-free bricks is obvious. In the case of age, the amount of cement added and the amount of blended materials not changing, the different types of blended materials have great influences on the compressive strength of dredged silt-free bricks. The compressive strength of the blending of straw dredged sludge is greater than the compressive strength of the dredged silt-free bricks blended with EPS particles, which is generally 1.43~1.46 times of the compressive strength of the dredged silt-free bricks blended with EPS particles, indicating that the effect of straw on the compressive strength of dredged silt-free bricks is more obvious.

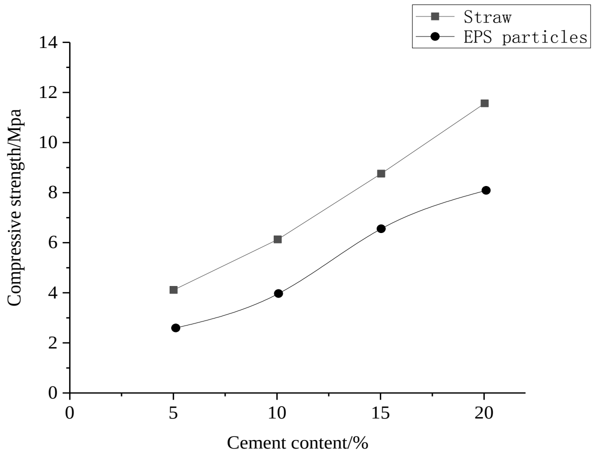

Figure 3. Effect of cement dosage on compressive strength of straw (EPS granule)-dried sludge unburned brick

3.2.2. Effect of age on the compressive strength of straw (EPS granule)-dried silt-free brick

Figure 4. shows the relationship between age and the compressive strength of straw (EPS particles)-dried sludge-free bricks. It can be seen that with the continuous increase of age, the compressive strength of straw (EPS granule)-dried silt-free bricks is on the rise. When the EPS granules are dredged with mud-free bricks, the compressive strength for curing for 28 days is about 7.6 MPa, and the compressive strength of the straw-dried sludge dredged with mud-free bricks for curing for 28 days is about 10.2 MPa. Compared with the addition of EPS particles, the compressive strength of the sample increased by about 34%. The results show that with the increase of age, the introduction of straw can increase the bond strength with the sludge than the introduction of EPS particles, making the structure of dredged sludge-free bricks more stable and its compressive strength higher.

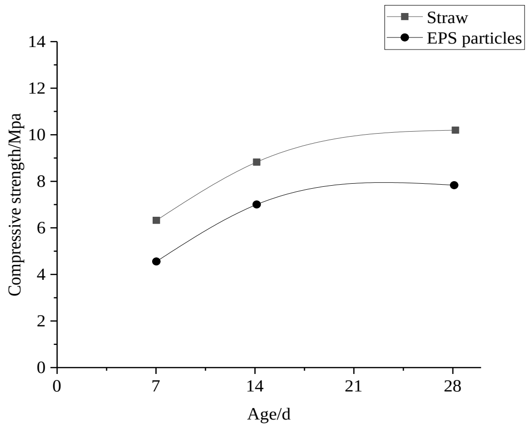

Figure 4. Effect of age on the compressive strength of straw (EPS granule)-dried sludge-free brick

In summary, the initial formulation of cement content is 20%, and the curing time is 28d as the optimal mix ratio. In order to further study the effect of the blended materials on the compressive strength of the burnt-free bricks, the blending is adjusted based on the blending ratio and exploring how the incorporated material participates in the cementation of the cement.

3.2.3. Influence of the amount of materials incorporated on the compressive strength of dredged silt-free bricks

Figure 5. shows the effect of the amount of material incorporated on the compressive strength of the dredged sludge-free brick.

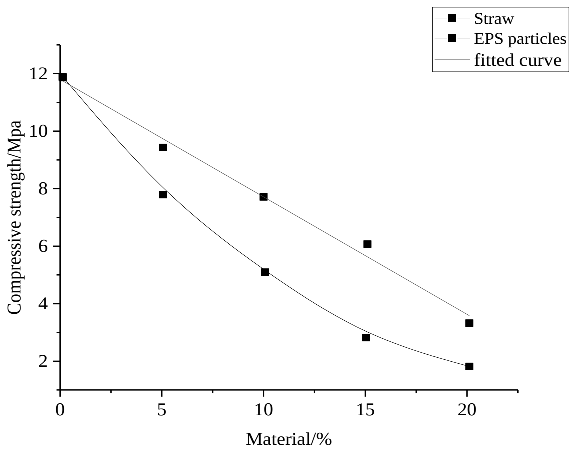

Figure 5. Effect of the amount of materials incorporated on the compressive strength of dredged sludge-free brick

The Straight line is the relationship between the content of straw material and the compressive strength of the brick. As far as the straw is concerned, the straw itself has better water permeability and flexibility, and can better exert the cementation performance of the cement as a curing agent. The results show that when the straw content varies from 0% to 11%, the compressive strength varies between 7.5MPa and 11.7Mpa, and the compressive strength of the bricks that are cured for 28 days meets the compressive strength of the brick （MU7. 5）.

The curve is the relationship between the content of EPS material and the compressive strength of the brick. It can be seen that with the increase of the amount of EPS material incorporation, the compressive strength of the burn-free bricks shows a significant downward trend. When the EPS particle content is between 0% and 7.5%, the compressive strength varies between 6.3Mpa and 11.7Mpa, which is approximately linear. When the EPS particle is greater than 7.5%, the volume of EPS particles increases in the pattern. The fluidity of the sample is deteriorated, and it is not easy to stir evenly during the mixing of the mixed materials, so that the sample has a partial section without forming a cement-soil skeleton, which reduces the compressive strength; on the other hand, with the amount of the incorporated material increasing, the bonding area between the colloid and the aggregate is reduced and the adhesion is lowered as well as fine cracks are generated when the concrete is hardened, thereby reducing the concrete strength [6]. When the blending amount of EPS material is 0%, the compressive strength of the burn-free brick for curing for 28 days is 11.7Mpa. When the blending amount of EPS material is about 6.5%, the compressive strength of the bricks for curing for 28 days just reaches the compressive strength of brick（MU7.5）. The results show that when the straw content varies from 0% to 6.5%, the compressive strength varies from 7.5MPa to 11.7Mpa, and the compressive strength of the bricks for 28 days of curing meets the compressive strength of brick （MU7. 5 ）.

It can be seen from the above analysis that the compressive strength of the unfired bricks tends to decrease as the amount of the incorporated material increases. However, as long as the blending amount of the blended material is controlled within a certain range, the prepared burnt-free brick performance can still meet the national standard, so that the prepared burnt-free brick can effectively utilize the waste materials in life and production, and has a far-reaching social and economic benefits. Therefore, in order to improve the utilization rate of resources and meet the national brick-free strength standard of MU7.5, 5% is selected as the optimal blending material ratio through comprehensive analysis.

4. Conclusion

Using straw and EPS particles as a blending material to produce dredged sludge-free bricks solves the environmental pollution problem of dredged sludge discharge and realizes resource reuse. The produced products can replace clay sintered bricks, which can not only protect the environment, but also save a lot of earth and stone resources, when obtaining environmental benefits, it can also obtain certain economic benefits and promote the development of building materials industry.

（1）Orthogonal experiment using straw and EPS granules as blending materials to make dredged silt-free bricks showed that the optimal mix ratio was 72% sludge, 20% cement, 5% blended material, 2% gypsum, 1% gelling agent. To meet the requirements of resource utilization and compressive strength, the overall performance of bricks is the best.

（2）The content of the blended material, the cement content and the age have an effect on the compressive strength of the unfired brick. Within a certain range, the compressive strength of the burnt-free brick increases with the increase of cement addition and age as well as the decrease of the amount of incorporated material. The orthogonal experimental data analysis shows that the cement content has the most significant influence on the compressive strength of the material, followed by the incorporation of materials and age.

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