International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 11 Issue 4 ǁ April 2023 ǁ PP. 36-42

Experimental study on influence factors of foam light soil

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Abstract: *This paper studied the effects of water-binder ratio, fly ash and foam content on the working and mechanical properties of foamed light soil. Different water-binder ratios were adopted (water-binder ratio 0.37, 0.40, 0.43, 0.46, 0.49). Fly ash replacement rate (fly ash replacement rate is 0, 10%, 20%, 30%, 40%), foam content (foam content is 9.5 kg/m³, 14.25 kg/m³, 19 kg/m³, 23.75 kg/m³, 28.5 kg/m³), to make standard sample of light foam soil. The effects on compressive strength, dry density and wet weight of foamed light soil were studied. The test results show that when the water-binder ratio is between 0.37 and 0.49, the compressive strength, dry density and wet weight of foamed lightweight soil increase with the increase of water-binder ratio. To some extent, fly ash can strengthen the strength of foamed light soil and reduce its dead weight. With the increase of foam content, the compressive strength, dry density and wet weight of foamed light soil decreased obviously.*
Key words: *light foamed soil; dry apparent density; compressive strength: wet intensity*

Date of Submission: 20-03-2023 Date of acceptance: 04-04-2023

I. Introduction

Foam lightweight soil [1] ~ [2] has some advantages, such as high mobility, strong sound insulation, good seismic resistance, and easy construction, which has attracted more and more domestic and foreign experts and scholars' attention and research [3] ~ [5], and quite a lot of research results have been gradually applied in various fields related to civil engineering and achieved good results. Compared with ordinary concrete, Foam lightweight soil is more energy saving and environmental protection, saves a lot of resources, and conforms to the concept of human sustainable development [6].

In 2018, Zhou Zihao [6] et al. studied the effects of water-cement ratio, sand-cement ratio and water reducing agent content on the shrinkage properties of foamed lightweight soil with a dry density of 800 kg/m3 by using orthogonal test method, and obtained the optimal mix ratio conducive to the shrinkage properties of foamed concrete. In 2019, Wang Rong et al. [7] studied the effects of foam content, rubber crumb content and fly ash content on the waterproof performance of foam lightweight soil. The results show that a small amount of detrital rubber can improve the waterproof performance of the foamed light soil, and the content of foamed material is the main factor affecting the waterproof performance of the foamed light soil. There is a strong correlation between permeability and mechanical properties of foamed light soil. In 2021, Bai Yinghua et al. [9] studied the influence of thickener and water-reducing agent on the performance and pore structure of lightweight foam soil with the same density, and explored the relationship among fluidity, pore structure stability and density of lightweight foam soil. The results show that the structure of the foam light pore has a great relationship with its mobility. If the liquidity is too good, the foam will have strong aggregation and rupture, while if the liquidity is too poor, the mixed slurry will become hard and a large number of bubbles will be damaged in the stirring process. However, there are few studies on the foam lightweight soil with good weight, high strength and water resistance. In order to prepare the foam lightweight soil with good water resistance, this paper studies the effects of different water-binder ratio, fly ash replacement rate and foam content on various properties of the foam lightweight soil.

1 Test raw materials and test plan

The cement is P.O42.5 ordinary Portland cement, and its physical performance indicators are shown in Table 1. Fly ash is selected as Grade II fly ash, and its parameters are shown in Table 2. The parameters of mineral powder are shown in Table 3.

Table 1
Physical Performance Indicators of Cement

Cement type	strength grade	density (g/mc ³)	compressive strength/MPa		Water consumption for standard consistency of 3d and 28d/%
			3d	28d	
Ordinary Portland cement	42.5	2.95	26.4	48.5	28.5

Table 2
Physical Performance Index of Fly Ash

Product name	Grade	density (g/cm³)	Burn vector/%	45 μ M square mesh sieve Sieve residue/%	water content (%)
Fly Ash	Ⅱ	2.21	2.72	19.8	0.7

Table 3
Physical Performance Indicators of Mineral Powder

Product name	density (g/mc ³)	Surface area (㎡/kg)	7-day activity index/%	28-day activity index/%	mobility ratio/%	Water content/%
Slag powder	3	465	78	95	110	0.08

1.2 Test plan

The total mass of the cementitious material in this test remains unchanged (cement+fly ash+mineral powder is 360kg/m ³), The water binder ratio, replacement rate of fly ash and foam content are mainly studied. See Table 4 for specific mix proportion.

Table 4
Mix proportion of foam light soil

No.	Water glue ratio	water/ kg/m ³	Cementitious material /kg/m ³	Cement/ kg/m ³	Fly ash/ kg/m ³	Mineral powder/kg/m ³	Foam/ kg/m ³
A1	0.37	133.2	360	252	72	36	19
A2	0.4	144	360	252	72	36	19
A3	0.43	154.8	360	252	72	36	19
A4	0.46	165.6	360	252	72	36	19
A5	0.49	176.4	360	252	72	36	19
A3-B1	0.43	154.8	360	324	0	36	19
A3-B2	0.43	154.8	360	288	36	36	19
A3	0.43	154.8	360	252	72	36	19
A3-B4	0.43	154.8	360	216	108	36	19
A3-B5	0.43	154.8	360	180	144	36	19
A3-C1	0.43	154.8	360	252	72	36	9.5
A3-C2	0.43	154.8	360	252	72	36	14.25
A3	0.43	154.8	360	252	72	36	19
A3-C4	0.43	154.8	360	252	72	36	23.75
A3-C5	0.43	154.8	360	252	72	36	28.5

2 Test method

2.1 Preparation method

First, fully dry mix the weighed cement, fly ash and mineral powder in the mixer, then add the pre weighed water to mix and mix into cement slurry, and use the foaming machine to prepare foam of corresponding quality to add into the cement slurry for mixing and mixing. After the mixing is uniform, prepare a size of 100mm × 100mm × 100mm foam light soil standard specimen. The test block is poured for about 48 hours (at this time, the test block has high strength, and it is not easy to damage the test block during formwork removal). After formwork removal, it is placed in a curing box for curing until the corresponding age of each index is reached [7].

2.2 Wet weight test

The volumetric cylinder method is used to measure the wet weight of foam light soil. The volume of the measuring cylinder is 1L. First peel the measuring cylinder, then put the mixed slurry into the measuring cylinder, slightly higher than the cylinder mouth, scrape the sample at the cylinder mouth with a scraper, and wipe the slurry on the outer wall of the measuring cylinder clean. Weigh its mass, accurate to 0.1g. Repeat the above test process three times, take the arithmetic mean of the test and calculate the wet weight.

2.3 Dry density

After the standard cube specimen has reached the age of 28 days, take out 3 specimens and place them in an electric blast drying oven. Dry them to constant weight at (60 ± 5 ℃) (the difference between the two weighing weights before and after an interval of 4 hours is less than 1 g). After cooling, take out the specimen and measure the dry density of the specimen.

2.4 Compressive strength test

Take out three test pieces with standard curing for 7d, 14d, and 28d, and test their compressive strength using a loading speed of 0.1 to 0.3kN/s. Take the arithmetic mean of the compressive strength of the three test pieces as their compressive strength for 7d, 14d, and 28d, respectively.

3 Test Results and Discussion

3.1 Effect of water glue ratio

Table 5

The performance test results of foam light soil under different water binder ratios

Water-binder ratio	compressive strength（MPa）			Wet weight（kN/m³）	Dry density（kg/m³）
	7d	14d	28d		
0.37	0.15	0.16	0.17	6.02	473.77
0.4	0.69	0.95	1.01	6.17	475.60
0.43	1.05	1.32	1.51	6.37	474.30
0.46	1.46	1.80	1.88	7.09	525.80
0.49	1.33	1.89	2.29	7.24	537.40

Figure 1 shows the change trend of compressive strength of foam light soil with water binder ratio. It can be seen from the figure that the longer the age, the greater the compressive strength of foam light soil; When the water-binder ratio is 0.49, the compressive strength at 14 days and 28 days is the highest, 1.89 MPa and 2.29 MPa, respectively. The 7-day compressive strength is slightly lower than the 7-day compressive strength when the water-binder ratio is 0.46; When the water binder ratio is 0.37, the compressive strength of each age is the lowest, and its 28d compressive strength is only 16.8% of the 28d compressive strength when the water binder ratio is 0.4. This is because when the water binder ratio is small, the water consumption is less, which makes the foam light soil mixture too dry and thick. At this time, the workability is poor. During mixing, the friction between the dry and thick mixture is relatively high, which makes the foam deform and burst significantly, and the foam water will be absorbed to burst the foam after pouring, The uneven dispersion of pores and the connection of many cracked pores ultimately lead to lower compressive strength.

Figure 2 shows the change trend of wet weight and dry density of foam light soil with water binder ratio. It can be seen from the figure that when the water binder ratio is between 0.37 and 0.43, the change trend of wet weight and dry density curve of foam light soil is not obvious, and the dry density is 474.30 Kg/m ³ Floating up and down, the wet weight slowly rises; When the water binder ratio is between 0.43 and 0.46, the curve of wet weight and dry density rises sharply, up to about 11%, and the curve change trend of the first two stages of wet weight and dry density of foam light soil is significantly more moderate than that of the last two stages; When the

water-binder ratio is 0.37～0.49, the trend of wet weight and dry density of foam light soil is basically the same.

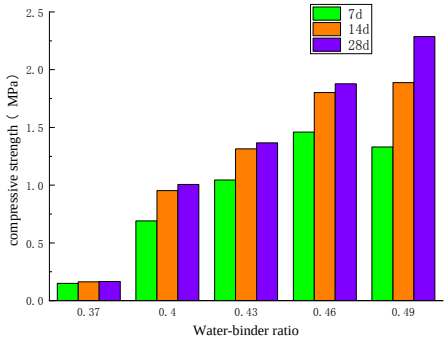

Fig.1 Effect of water binder-ratio on compressive strength

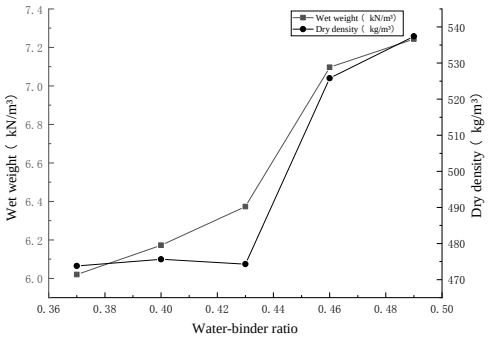

Fig.2 Effect of water-binder ratio on wet and dry density

Through the research and analysis of the above test results, it can be concluded that when the water binder ratio is 0.40~0.46, it is a more appropriate range. When the water binder ratio is 0.43, the dry density of foam light soil is 474.30kg/m ^{3}， The wet weight is relatively small. Therefore, considering the three indicators of foam light soil, the best water binder ratio of foam light soil is 0.43 in this test. The water glue ratio in subsequent tests was 0.43.

3.2 Effect of fly ash content

The performance test results of foam light soil with different fly ash content are shown in Table 6.

Table 6

Test Results of foam Light Soil with Different Fly Ash Content

Fly ash content (%)	Compressive strength (MPa)			Wet weight (kN/m ^{3})	Dry density (kg/m ^{3})
	7d	14d	28d		
0	1.27	1.34	1.48	7.31	537.43
10	1.66	1.75	2.07	6.90	524.97
20	1.05	1.32	1.51	6.37	474.30
30	1.08	1.11	1.42	6.51	471.63
40	1.15	1.40	1.83	6.14	468.87

Figure 3 shows the change trend of the compressive strength of foam light soil with the amount of fly ash. It can be seen from the figure that a certain amount of fly ash can enhance the compressive strength of foam light soil. When the amount of fly ash is 10%, the compressive strength of foam light soil at each age is significantly greater than the compressive strength of other amounts; The 28d compressive strength of foam light soil with 20% and 30% fly ash is close to the 28d compressive strength with 0 fly ash.

Figure 4 shows the change trend of wet weight and dry density of foam light soil with the content of fly ash. It can be seen from the figure that when the content of fly ash is 10%~20%, the change trend of wet weight and dry density curve is very obvious, and the decline rate is fast; When the content of fly ash is between 20% and 40%, the dry density curve has a small downward trend and is almost unchanged; With the increase of fly ash content, the wet weight and dry density curve of foam light soil also decreases. When the fly ash content is 40%, the wet weight and dry density of foam light soil reach the minimum value, 6.14 kN/m respectively ^{3}、 468.87 Kg/m ^{3}， The decrease was 19% and 14.6%, respectively. This is mainly because the density of fly ash is only about 3/4 of the density of cement. Under the condition that the quality of the cementitious material remains unchanged, the more fly ash is used, the smaller the amount of cement is used, resulting in a smaller weight per unit volume of the test block. Therefore, the self weight of the specimen can be reduced by adding fly ash to foam light soil.

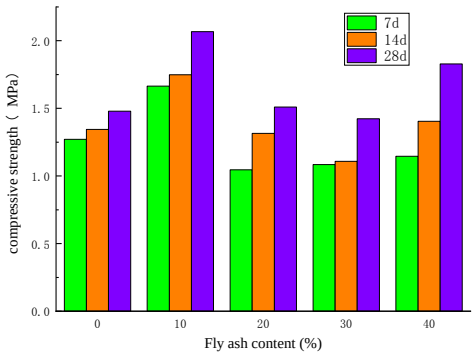

Fig.3 Effect of fly ash content on compressive strength

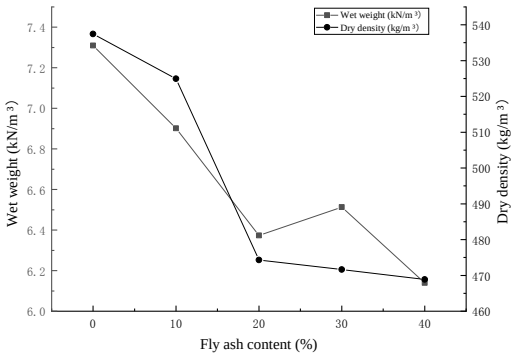

Fig.4 Effect of fly ash on wet weight and dry density

According to the research and analysis of the above test results, when the content of fly ash is 10%, the performance of foam light soil is obviously better than that of other fly ash content, which is the best content of fly ash. However, as fly ash is the main solid waste produced by coal-fired power plants, the emissions increase year by year, and if not treated, it may produce a lot of dust, pollute the environment, and endanger human health, Adding fly ash to foam light soil can reduce the cost. Therefore, after comprehensive consideration, the optimal content of fly ash in this test is 20%. At this time, the four test indicators of foam light soil are in a good range, which not only improves economic benefits, but also strengthens environmental protection, so that waste materials can be reasonably developed and utilized. The content of fly ash in subsequent tests is 20%.

3.3 Influence of foam content

The performance test results of foam light soil with different foam content are shown in Table 7.

Table 7

Test results of foam light soil with different foam content

Foam content (kg/m³)	Compressive strength (MPa)			Wet weight (kN/m³)	Dry density (kg/m³)
	7d	14d	28d		
9.5	2.14	5.15	5.16	10.44	823.40
14.25	1.65	2.28	2.56	7.72	576.80
19	1.05	1.32	1.37	6.37	474.30
23.75	0.63	0.72	0.91	5.25	389.63
28.5	0.4	0.44	0.46	4.75	342.00

Figure 5 shows the change trend of compressive strength of foam light soil with foam content. It can be seen from the figure that the more foam is added, the smaller the compressive strength of foam light soil is; When the foam content is 9.5 kg/m³～ 14.25 kg/m³ The 14d and 28d compressive strength curves of foam light soil decreased significantly. This is because with the increase of foam content, a large number of small closed bubbles are introduced into the cement paste, so that a large number of small pores are formed inside the test piece during the setting process, which is equivalent to squeezing the corresponding volume of cementitious material, thus reducing the compressive strength of foam light soil.

Figure 6 shows the change trend of wet weight and dry density of foam light soil with foam content. It can be seen from the figure that the influence of different foam content on the wet weight and dry density of foam light soil is relatively obvious. With the gradual increase of foam content, the curve of wet weight and dry density of foam light soil continues to decline, and the change amplitude of wet weight and dry density curve is basically the same under different foam content; When the foam content is from 9.5 kg/m³ Increase to 14.25 kg/m³ The wet weight and dry density curve decreased the most, with a decrease of over 35%; With the continuous increase of foam content, the change range of wet weight and dry density curve tends to be flat. This is because the mass of foam per unit volume is far less than the mass of cementitious material and water, and the amount of micro closed bubbles introduced by the gradual increase of foam content will also increase, so that the amount of cementitious material and water contained in the unit volume specimen will be less, and the wet weight and dry

density will be reduced.

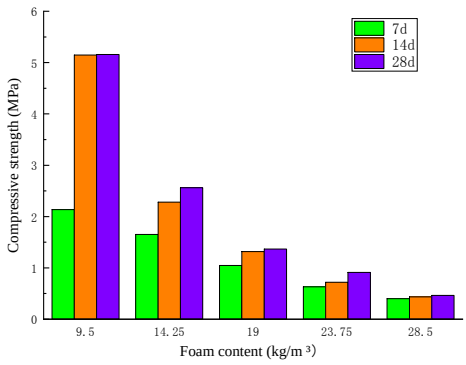

Fig. 5 Influence of foam content on compressive strength

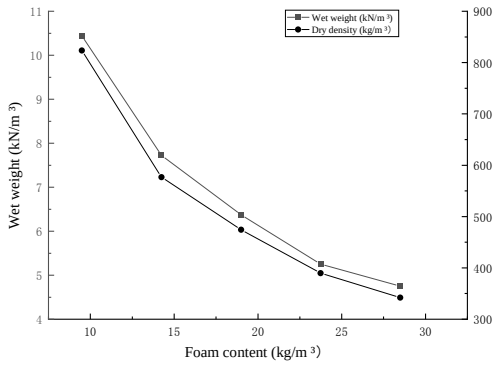

Fig. 6 Influence of foam content on wet weight and dry density

Through the research and analysis of the above test results, different foam content has a great impact on the performance of foam light soil. It is necessary to select foam content according to the actual needs of the project, which can not only reduce the weight of the structure, but also reduce the construction cost. The content of foam in subsequent tests is 19 kg/m ³。

4 Conclusion

(1) When the water binder ratio is between 0.37 and 0.49, the dry density, wet weight, and compressive strength of foam light soil show an overall upward trend; Considering the light weight, high strength and low permeability of foam light soil, the optimal water binder ratio in this test is 0.43.

(2) Adding proper amount of fly ash to foam concrete can not only improve the strength, reduce the weight of the structure, but also turn waste into treasure, so that waste resources can be reasonably utilized and developed, and reduce construction costs.

(3) The higher the foam content is, the lower the compressive strength, wet weight and dry density of foam light soil are. The content of foam is 9.5 kg/m ³～ 19 kg/m ³ The decrease is most obvious, and the decrease speed is relatively gentle with the continuous increase of foam content.

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