Study on mix proportion design of cement foam concrete

Jingwen Zhang[1,a], Ningshan Jiang[1,b*], Hui Li[1,c] and Chengyou Wu[1,d]

[1]School of civil engineering, Qinghai University, Xining, Qinghai, 810016, China

[a]zhangjingwenm@sohu.com, [b]qhjns@163.com, [c]1992808903@qq.com,
[d]djwsry@hotmail.com

[*]Corresponding author's e-mail: qhjns@163.com

Abstract. In this paper, the influence of four main factors on the compressive strength of cement-based foam concrete is studied by orthogonal test with L_9 (3 ^ 4) orthogonal table. They are the amount of foam agent, the amount of water reducing agent, the amount of foam stabilizer and the water cement ratio. The results show that the main factors affecting the 7-day compressive strength of cement-based foam concrete are: water cement ratio > foam agent content > water reducer content > foam stabilizer content. The best test mix is: water cement ratio 0.41, foam agent 0.66%, water reducer 0.20%, foam stabilizer 0.021%. Its 7-day compressive strength is 2.65 MPa, dry density is 444 kg/m^3, water absorption rate is 23%, in line with JG/T 266-2011 "foam concrete" and JGJ/T 341-2014 "foam concrete application technical specification" stipulated in the performance requirements.

1. Introduction

Foam concrete is a new type of lightweight building material. It not only has excellent heat preservation and fire protection performance, but also is not easy to burn and aging[1]. Foam concrete is a kind of porous material made by mixing prefabricated foam and cement slurry evenly and hardening. It has the characteristics of light weight, heat insulation, low modulus of elasticity and high fluidity. It is widely used in roof, wall, cushion, floor heating and backfilling engineering, and it is also the most popular substitute for organic thermal insulation material at present. Good choice. At present, there are still many shortcomings in the mix proportion design of foamed concrete in China, which still need to be solved. These shortcomings and defects affect the quality control and technical development of foamed concrete[2]. Based on a large number of experiments, this paper studies the main factors affecting the performance of foamed concrete, and finds out the best design scheme of foamed concrete mix proportion, so as to provide some reference for the research and production of foamed concrete.

2. Test

2.1. Raw material

Cement:The early strength of foamed concrete is very important. The cement should be hydrated sufficiently before defoaming due to the action of gravity, extrusion and drying shrinkage, so as to avoid the phenomena of collapse of test blocks and pore connection. This experiment uses Chun Jiang brand P O42.5 common portland cement.

2.2. Mix proportion design of foam concrete

2.2.1. Basic principles of mix design. Dry density and strength are two very important performance parameters of foamed concrete. The next design method of mix proportion is to determine the dry density of foamed concrete to achieve effective control of foamed concrete strength:

1) Cement density is determined by dry density of foam concrete.

2) According to the water cement ratio, the amount of foam concrete water is determined.

3) Determine the volume of the paste according to the amount of cement and the amount of water.

4) Calculate the volume of the foam according to the volume of cement paste.

5) According to the volume of foam and the density of measured foam, the quality of foam solution is calculated.

6) Calculate the quality of the foaming agent through the quality of the foam and the dilution ratio of the foam agent.

In determining the proportion of each material, we should take into account the characteristics of slow solidification of some materials, these materials may cause great changes in the early strength of foamed concrete, such as slurry initial setting effect, excessive dosage will affect the stability of pouring, serious may lead to collapse, so it is necessary to control the dosage. However, there is always a certain amount of deviation between any theoretical calculation and actual production. Therefore, in the actual production and application process, the foam concrete mix ratio needs to be constantly adjusted and improved [2].

2.2.2. Mix proportion calculation of foam concrete. The dry density of foam concrete design and the water consumption of foam concrete are calculated according to the following formula:

$$\rho_d = S_a m_c \qquad (1)$$
$$m_w = B m_c \qquad (2)$$

In the form: ρ_d—Design density of foam concrete (kg/m^3);

S_a—After 28 days of foamed concrete curing, the coefficient of mass determined by the total amount of dry materials and the total amount of non-evaporative materials in the finished products is 1.2 for the ordinary Portland cement.

m_c—The cement dosage of 1m^3 foam concrete (kg);

m_w—Water consumption of 1m^3 foam concrete (kg);

B—Water cement ratio can be selected according to 0.5~0.6;

In 1m ^ 3 foamed concrete, the grout volume and foam addition of cement and water can be calculated by the following formula:

$$V_1 = \frac{m_c}{\rho_c} + \frac{m_w}{\rho_w} \qquad (3)$$
$$V_2 = K(1 - V_1) \qquad (4)$$

In the form: V_1—The total volume of slurry is composed of cement and water (m^3);

ρ_c—The cement density (kg/m^3) was 3100 kg/m^3;

ρ_w—The density of water (kg/m^3) was 1000 kg/m^3;

V_2—Foam addition (m^3);

K—Redundancy factor: depends on the quality of foaming agent, foaming time and foam added to the slurry when the loss of re-mixing and so on. For the foam agent with good stability, 1.1 ~ 1.3.

The amount of foaming agent is calculated according to the following formula:

$$m_f = \frac{m_y}{\beta + 1} \qquad (5)$$
$$m_y = V_2 \rho_f \qquad (6)$$

In the form: m_f—The amount of foaming agent for 1m^3 foam concrete (kg);

m_y—The quality of the foam liquid formed (kg);

β—Dilution ratio of foam agent;

ρ_f—Measured foam agent density (kg/m^3).

2.3. Instrument and equipment

Hebei Hongtaicheng Co., Ltd. produces foaming machine, cement mortar mixer, automatic pressure testing machine, air compressor, standard maintenance box, etc.

2.4. Sample preparation

Cement-based foam concrete sample preparation: (1) foaming: the preparation of foam solution into the foaming machine for foaming. (2) Sample preparation: ordinary Portland cement, water reducer and foam stabilizer are added to the mortar mixer for 20 seconds, then water is added to mix for 100 seconds during the mixing process, and then the prepared foam is added to the mortar in the mixing state and stirred for 1 minute; the stirred slurry is carefully poured into the mold with polished oil, Slightly sway one to two[5]. (3) After placing the finished sample in the curing room for 1-2 days, the sample was demoulded by air compressor, and then the sample was put into the standard curing box for curing to the prescribed age, and the relevant performance indexes of the sample were tested.

3. Orthogonal experimental design

Through a large number of trial-mixing tests, the basic parameters of preparing cement-based foam concrete are obtained: water-cement ratio of 0.39-0.41, foaming agent content of 0.66%-0.70%, foaming stabilizer content of 0.021%-0.025% and water reducer content of 0.20%-0.24% of cement quality.

Through the orthogonal test of 4 factors and 3 levels, we can get the optimum foam concrete mix proportion scheme. Four factors, such as the amount of foaming agent, water cement ratio, water reducer and stabilizer, were taken to study. The orthogonal table of L_9 (3 ^ 4) was selected for design.

Table 1. Factor and level table.

level	Factor			
	Stabilizer (A)	Foam agent (B)	Water reducing agent (C)	Water cement ratio (D)
1	0.021%	0.66%	0.20%	0.39
2	0.023%	0.68%	0.22%	0.40
3	0.025%	0.70%	0.24%	0.41

The test consisted of 9 groups of 27 specimens of 100×100×100. The dry density and water absorption of the specimens were 490 kg/m ^ 3 and 25% respectively, which met the requirements of JG/T 266-2011 and JGJ/T 341-2014. The test results of compressive strength through standard curing box to 7d specimens are shown in Table 2.

Table 2. Test results and analysis table.

Test number \ Factor	A	B	C	D	7d compressive strength/ MP_a
1	1	1	1	1	2.47
2	1	2	2	2	2.14
3	1	3	3	3	1.89
4	2	1	2	3	2.58
5	2	2	3	1	2.23
6	2	3	1	2	1.69

7	3	1	3	2	1.80
8	3	2	1	3	2.35
9	3	3	2	1	2.21
$\sum K_1$	6.50	6.85	6.85	6.91	
$\sum K_2$	6.50	6.72	6.72	5.63	
$\sum K_3$	6.36	5.79	5.92	6.82	
k_1	2.17	2.28	2.28	2.30	
k_2	2.17	2.24	2.24	1.88	
k_3	2.12	1.93	1.97	2.27	
Range R	0.05	0.35	0.31	0.42	

Notes:① $\sum K_i$ $(i = 1,2,3)$ is an arbitrary factor, the sum of the corresponding compressive strength when the horizontal number is i;

② $k_i (i = 1,2,3)$ is expressed as $\sum K_i/3$;

③ Range R= $k_{max} - k_{min}$.

4. Conclusion

⑴ Observing the above test results, the results show that the order of influencing the compressive strength of cement-based foam concrete is D > B > C > A, in which water-cement ratio is the most important factor affecting the compressive strength, and then the amount of foaming agent, superplasticizer, and the degree of influence of these three factors is similar, the amount of foam stabilizer is the least affected.

⑵ On the premise of meeting the design requirements and considering the economic cost, the optimal test scheme is $D_3B_1C_1A_1$, then the optimal scheme is: water-cement ratio is 0.41, foam agent is 0.66%, water reducer is 0.20%, foam stabilizer is 0.021%.

The compressive strength of the specimens was measured by the optimum proportion of the test. At the same age of 7 days, the compressive strength reached 2.65 MPa, the dry density decreased to 444 kg/m ^ 3, and the water absorption rate decreased to 23%.

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