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Study on anti-permeability of specified density concrete

Shuaishuai Yan[1,2] and Ming Zhang[1,2]

[1]State Key Laboratory of Green Building Materials, Beijing, China
[2]College of Civil Science and Engineering, Yangzhou University, Yangzhou, China
E-mail: zhangmingjob@sina.com

Abstract. Anti-permeability is one of critical properties of concrete, as a porous material, ceramsite in specified density concrete leads to many performance changes compare with ordinary concrete, such as mechanical properties, volume stability, durability, et al. combined with micro-test technology, this study investigated the effect of replacement rate and pre-wetting degree of ceramsite, water to binder (W/B) ratio, the content of fly ash, and the composite of aggregate on specified density concrete, and concluded appropriate range of above narrated factors.

1. Introduction

Concrete is the largest amount of building materials, with the advantages of a wide range of raw material sources, low production energy consumption as well as good durability, concrete is widely used in civil engineering, traffic engineering, hydraulic engineering, nuclear power plant engineering and other fields [1]. Specified density concrete is the concrete with a range of apparent density between 1950 kg/m^3 ~ 2300 kg/m^3 by replacing an amount of ordinary aggregate with light weight aggregate [2]. Due to high weight, difficult in transportation and hoisting, Ordinary concrete members are more and more not satisfied the requirement of prefabrication industry. Apparent density of light weight aggregate concrete is not higher than 1900 kg/m^3, light weight makes its prefabricated members easy to transportation and construction [3]. But due to low strength of light weight aggregate concrete, its member prone to damaged during the transportation, storage as well as hoisting. Compare with ordinary concrete, the addition of light weigh aggregate makes specified density concrete lower weight, and compare with light weight aggregate concrete, specified density concrete improves mechanical properties, the light weight and high strength of specified density concrete match the requirement of prefabrication members, which leads to the specified density concrete has broad application prospect.

Permeability refers to how difficulty that air and liquid permeate, diffuse, or migrate in concrete under influence of external environment. Anti-permeability of concrete is related to pore structure, some factors of specified density of concrete, such as aggregate, mineral admixtures, W/B ratio, et al, effect the size of and distribution of internal pore, and then effect the anti-permeability of concrete.

2. Materials and methods

2.1. Materials and mix design

The raw materials were P·O 42.5 ordinary Portland cement, grade Ⅰ fly ash, medium particle size river sand, clay ceramsite (5~10 mm and 5~15 mm particle size) and crushed stone (5~10 mm and 5~20 mm particle size). The initial mix proportion of ordinary concrete is shown in Table 1, and specified density concrete obtained by replacing certain amount of crushed stone with ceramsite.

Table 1. Mix proportion of specified density concrete (kg)

Cement	Fly ash	sand	Crushed stone	ceramsite	water
320	80	730	1191	-	118

2.2. Methods

Preparing and anti-permeability test of specified density concrete samples were carried out according to GB/T50082-2009 [4].

3. Results and discussion

3.1. Effect of volume replacement rate of ceramsite on anti-permeability of concrete

figure 1 is water permeability height of specified density concrete mixed with 0% ～ 40% of ceramsite, as shown in Figure 1, when the volume replacement rate is between 0% and 20%, the water permeability height decreases, which means the anti-permeability is improved. Ceramsite has the function of backwater effect, and beneficial to the interfacial transaction zone (ITZ), consequently concrete become more compact and anti-permeability is improved. When the volume replacement rate of ceramsite is between 20% and 40%, with the volume replacement rate of ceramsite from 20% up to 40%, the water permeability height is from 50 mm rises up to 96 mm, which means anti-permeability of specified density concrete is reduced.

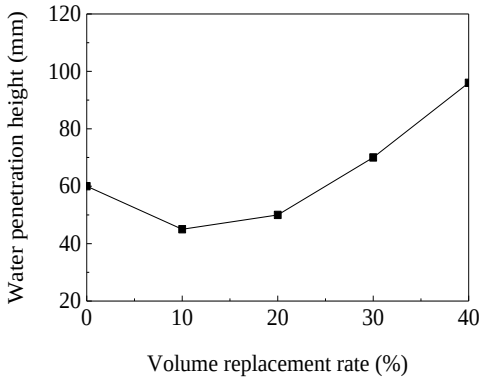
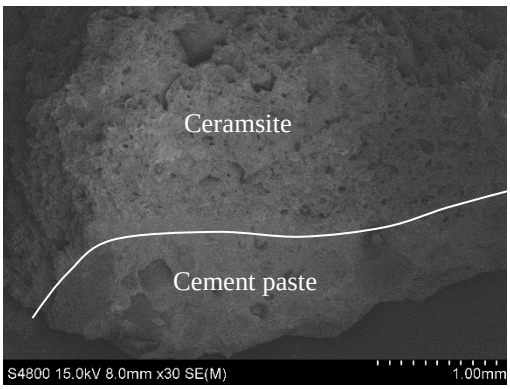
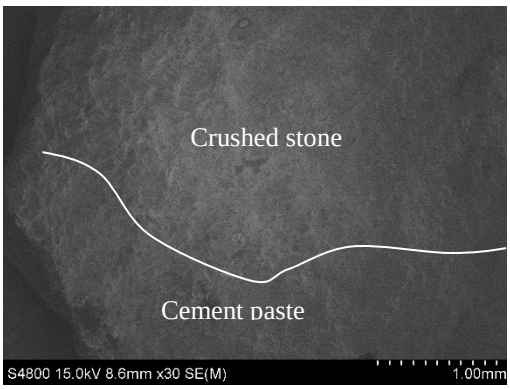


Figure 1. Water permeability height of specified density concrete with different volume replacement rate of ceramsite

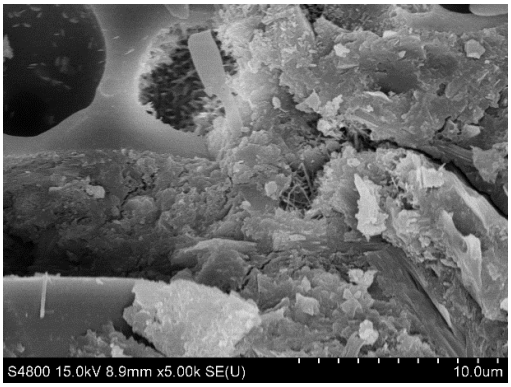
The figure 2 is ITZ between aggregate and hardened cement paste, as shown in the Figure 2, the ITZ



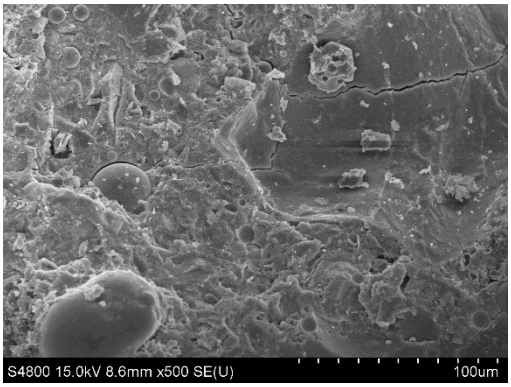
(a) ITZ between ceramsite and cement paste (×30)



(b) ITZ between crushed stone and cement paste (×30)



(c) Micro structure of ITZ between ceramsite and cement paste (×5000)



(d) Micro structure of ITZ between crushed stone and cement paste (×5000)

Figure 2. ITZ of between aggregate and cement paste

between crushed stone and hardened cement paste is obvious, and the bonding is loose. But the ITZ between ceramsite and hardened cement paste exists a large amount of hydration products such as C-S-H and a small amount of AFm, the hydration products form the compact three-dimensional structure, and thereby improve anti-permeability of specified density concrete.

3.2. Effect of pre-wetting degree of ceramsite on anti-permeability of concrete

Figure 3 is water penetration height of specified density concrete mixed ceramsite of pre-wetting time, as shown in the figure, the effect degree of pre-wetting degree on water penetration height of concrete are different with curing age. To the specified density concrete cured 7 d, the concrete mixed ceramsite of pre-wetting 0 h has lowest water penetration height. To the specified density concrete crued 28 d, the water penetration height of the concrete mixed ceramsite of pre-wetting 0 h do not change obviously, but that of concrete mixed ceramsite of pre-wetting 24 h obtains lowest water penetration height, and the anti-permeability of concrete reach to best.

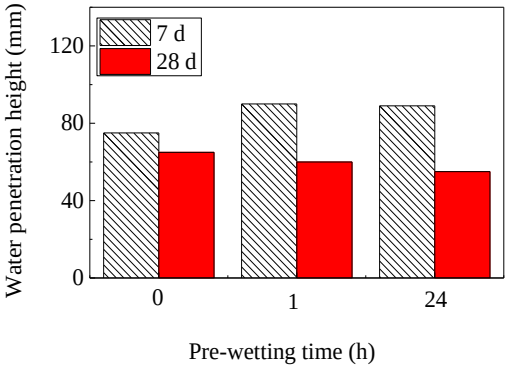
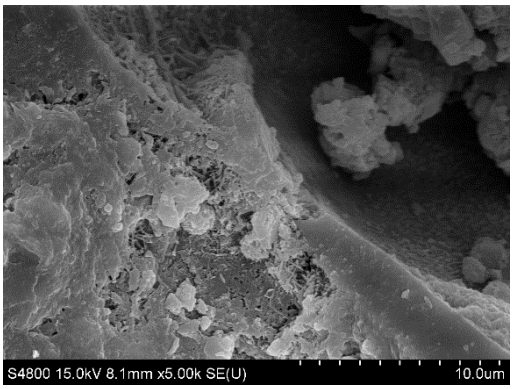


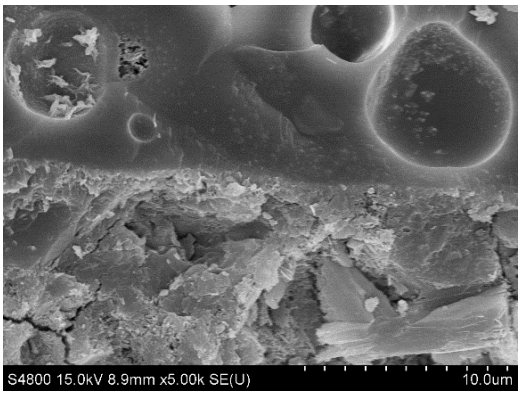
Figure 3. Water penetration height of specified density concrete mixed ceramsite of different pre-wetting time

Figure 4 is SEM images of specified density concrete mixed ceramsite of different pre-wetting time, according to figure 4(a), to the concrete mixed ceramsite of pre-wetted 0 h, the quantity of hydration products at ITZ is few so that the microstructure is loose. As shown in figure 4(b), with the pre-wetting time prolong, the quantity of hydration products at ITZ increase, and C-S-H begins fill into ITZ, results in microstructure of ITZ become compact. As shown in figure 4(c), ceramsite of pre-wetting 24 h make the quantity of hydration products increase obviously, those hydration products fill into ITZ, and form compact spatial network, and which indicates the pathway of water penetration decrease and anti-permeability increase. The change of the microstructure of ITZ can explain the

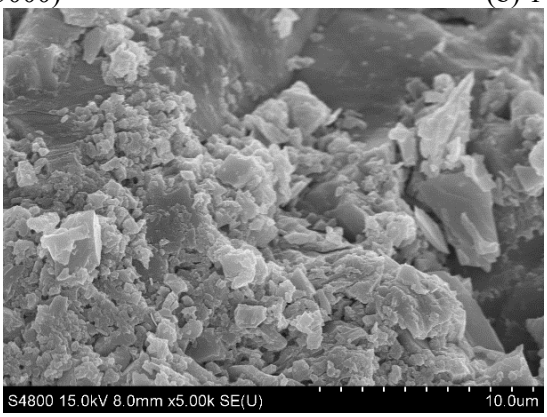
internal reason that anti-permeability of specified density concrete increases with the increase of pre-wetting degree.



(a) 0 h (×5000)



(b) 1 h (×5000)



(c) 24 h (×5000)

Figure 4. SEM images of specified density concrete mixed ceramsite of different pre-wetting time

3.3. Effect of W/B on anti-permeability of concrete

Figure 5 is water penetration height of specified density concrete with different W/B, as shown in the figure, when W/B is 0.30, water penetration height is lowest, which means the anti-permeability is best. With the increase of W/B, the anti-permeability decrease, the low W/B of concrete has less free water inside, and the connected pores caused by free water migration and bleeding are also reduced, and the interior is become dense and anti-permeability is improved [5]. With the increase of W/B, excessive moisture exists in ceramsite as free water, and after evaporating, the free water generates

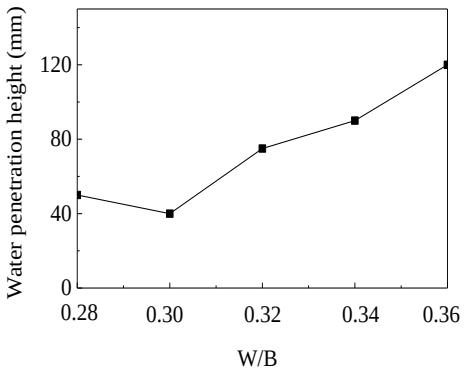


Figure 5. Water penetration of specified density concrete with different W/B

pores, and the penetration paths increase, which is disadvantage to anti-permeability. The higher W/B, the lower anti-permeability.

3.4. Effect of fly ash on anti-permeability of concrete

Figure 6 is water penetration height of specified density concrete mixed with different content of fly ash, as shown in the figure, with the content of fly ash between 0% and 30%, water penetration height decreases and anti-permeability improves, however, the rule is inversed when the content of fly ash over 30%.

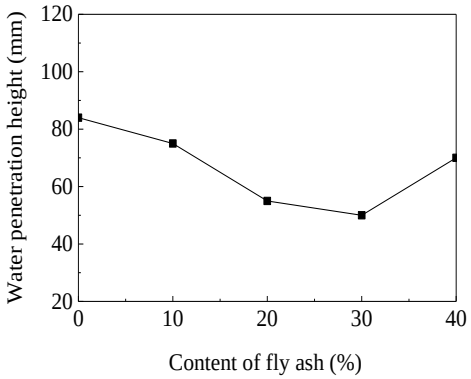


Figure 6. Water penetration height of specified density concrete mixed different content of fly ash

4. Conclusions

With the replacement rate of ceramsite between 0% and 20%, the anti-permeability of specified density concrete improves with the replacement rate of ceramsite, and the rule inverses when the replacement rate over 20%.

To the concrete cured 7 d, the anti-permeability of specified density concrete mixed ceramsite of pre-wetted 0 h is highest, and to the concrete cured 28 d, that of the concrete mixed ceramsite of pre-wetted 24 h is highest.

Anti-permeability of specified density concrete in inverse proportional with W/B.

Acknowledgments

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