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Water and chloride permeability research on ordinary cement mortar and concrete with compound admixture and fly ash

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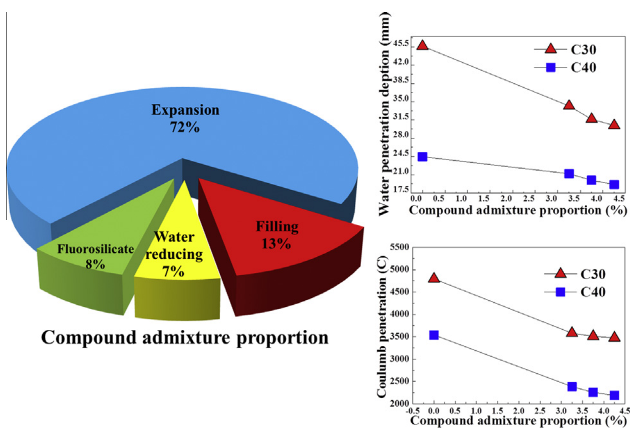
HIGHLIGHTS

- Study of cement mortar and ordinary cement concrete permeability.
- Study on newly designed fluorosilicate based compound admixture.
- Compound admixture effect study on mortar and ordinary concrete compressive strength.
- Study of external hydraulic water intrusion and chloride ion invasion resistance.
- Strength and permeability influence study of compound admixture together with FA.

GRAPHICAL ABSTRACT



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ABSTRACT

Worldwide use of ordinary cement concrete (OCC) faced with permeability problems causing significantly negative influence on construction and infrastructure, shortening the lifespan and increasing the related maintenance fee. To overcome these weaknesses, this paper focused on the improvement of OCC impermeability by combining a newly designed compound admixture consisting of four kinds of chemical admixtures including filling agent (F), water reducing agent (WR), fluorosilicate based agent (FB), and expansion agent (E) into the fresh concrete. Subsequent impermeable investigations showed that as adding average 3.75% compound admixture into C30 and C40 OCC, the external hydraulic water intrusion results decreased 30% and 18% respectively, chloride ion invasion number decreased 27% and 38% separately, the maximum water absorption decreased 57% and 55% meanwhile reaching saturated status obviously earlier. With evident impermeability improvement effect and partially strength loss, well-predesigned strength offsetting and appropriate fly ash combining dosage are suggested to generate remarkable workability in practical application.

1. Introduction

At present the concrete has become the most widely used construction material because of its low cost, the easily found raw material and the most valuable property that the strong resistance to the external load and corrosions. While the durability and long term lifespan problem attract more and more researchers and engineers, especially after a lot of deteriorating phenomena were recorded and investigated which make this great material become some sort of the weakness of the workability [1–3]. Besides in the field application the ordinary concrete is conventionally designed

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without high performance strength or excellent admixture and consumed a large amount as the main ingredient which may have the same urgent but worse problem [4–6]. Meanwhile the base of buildings or pile foundations are often designed and made with ordinary concrete, so its properties affect the infrastructure workability and safety significantly. To better develop the initial virtue of this beneficial material and keep its long life resistance, the improvement on ordinary concrete need to be the primary.

As the progressing of modern city, the development of urbanization occupies more and more lands of city for the infrastructures which makes the underground regions become more valuable for relieving the pressure of the congested ground space. But the permeable problems of no matter the buildings in some moist environments or the underground constructions are always bothering the engineers, especially when they face the main construction ingredient which is of originally porous and non-homogeneous material, Portland Cement Concrete [7]. Because most of the aggressive materials are transferred in solute form, the resistance to them needs to be improved primarily [8]. Then, taking the concrete workability and resistance into consideration, many engineering designers have mixed polymers to improve the viscosity and density making it some sort of waterproof and also sprayed hydrophobic agent making it hard to be wetted from the external surface by the moisture outside, but these external methods will eventually encounter the aging and flaking problem after long lifespan [9–12].

According to some studies [13–16], adding various kinds of admixtures and miners to change the microstructure of hardened concrete is a feasible method to obtain the lower pervious, and generally in field application complex compound admixture had been used successfully in engineering.

Otherwise many researchers introduce industrial by-product powders like the fly ash (FA) into concrete to replace portion of the cement material which will reduce the early age hydration and the related physical strength but commonly obtain better latter compactness and permeability [17].

FA as one by-product of coal-fired electric power plants in which a large amount of ash residual staying in the chimney or spreading in the air is widely used in blended cements. The current annual worldwide production of coal ash is estimated about 700 million tons of which at least 70% is FA. As for today, the annual FA production is about 20 million tones [18]. No matter considering the economy of plants, the air-protection or the hazards, the collection and utilization of this by-product ash should be big problems needing to be disposed. And with the concerns on the resource utilization, the FA is also used among the experiments in this paper.

Overall experimental study on the compound admixture applied in ordinary cement concrete was performed in this paper to evaluate the physical and permeable properties with or without the by-product mineral admixture – fly ash (FA). Several measurements on the water impermeability and chloride ion resistance characteristic were made to research the differences within various concrete groups. Much attention was paid to enhance the impermeability of the bulk matrix itself to resist the corrosive substance especially those kinds transferring by liquid across connecting pores, and such is the reason of designing the fluorosilicate based compound admixture.

2. Materials and orthogonal method

Portland Cement Ordinary, Brand: Swan/P.O 42.5, according to the Chinese Standards GB175 [19] was used; its content of clinker plus gypsum was in the range of 80–95% by weight. The Blaine fineness of cement was 0.45 m^2/g and its relative specific gravity was 3.1 g/cm^3.

Moreover, FA (65.9%SiO_2, 19.0%Al_2O_3, 4.5%Fe_2O_3 and other minor constituents) was used as proportional replacement of the cement material obtained from by-product of coal fired power plants.

The limestone gravel and silica sand were used as the aggregate. The gradation of both aggregate fractions and their physical properties, evaluated according to GB/T14685 [20] are shown in Tables 1 and 2, respectively.

A water reducing agent was used, which consisted of solid calcium lignosulfonate powder about 95%, and the burnt lime was used as the expansion agent.

As the filling agent, zinc stearate was employed, while fluorosilicate based agent was introduced as the constituent modifying the performance.

In Table 3, the mix proportion of four additives in the cement mortar was shown and with these levels they were designed by orthogonal method to make up from NO.1 to NO.9 groups for the next samples production and testing.

The name scheme of the three levels of filling agent (F), water reducing agent (WR), fluorosilicate based agent (FB), and expansion agent (E) were named by 1, 2 and 3 respectively and shown as the subscript of each abbreviation (see Tables 5 and 6).

There are two water-to-cement ratios adopted for two designed compressive strength which would present a better relationship between concrete properties and compound admixture in different levels.

And orthogonal test design method is used in this paper as one kind of experimental predesigning and analyzing method to reduce the testing numbers and simplify the arrangement with multiple numerous testing groups array [21]. Generally the determining factors within this method should be quantitative like the strength

Table 2
Coarse aggregate diameter distribution.

Sieve diameter (mm)	Differential residue (%)	Cumulative residue (%)
26.5	0	0
19	28.8	28.8
16	31.1	59.9
9.5	12.1	72.0
4.75	25.7	97.7
2.36	1.9	99.6

Table 3
mix proportion levels of four kinds additives in cement mortar (%).

Levels	Category			
	F	WR	FB	E
1	0.3	0.15	0.3	2.2
2	0.4	0.2	0.4	2.7
3	0.5	0.25	0.5	3.2

Table 1
Fine aggregate physical property.

Fineness modulus	Clay content (%)	Pebble content (%)	Diameter (mm)	Apparent density (g/cm^3)
2.71	5.6	2.58	$<$5.00	2.8