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Research on Fracture and Durability of High Performance Concrete

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The building structure is the main frame of the building and whose optimization and development promotes the renewal and development of building materials. Concrete has become more and more popular construction materials that are widely used in modern times. With the development of science and technology, all kinds of concrete structures emerge in an endless stream. These concrete structures should not only meet the requirements of structural load design but also the long-term work in a specific environment capacity. This produces a great demand of adequate durability of the concrete structure and this is the future direction of the development of concrete technology. Since the middle of twentieth Century, a number of accidents have happened at home and abroad. The cause of these accidents is the poor durability of concrete structures. It also makes people pay more and more attention to the durability of concrete structure. High performance concrete is a kind of concrete with a new type of high tech that has been widely used in all over the world in recent years, which can not only guarantee the durability and workability but also meet the requirements of application and economy. The high-performance concrete prepared by the eight groups was studied in this paper and the fracture and durability of high performance concrete were studied by two experiments of compressive strength and frost resistance.

1. Introduction

High performance concrete is a kind of concrete with a new type of high tech and high durability, high workability and high strength and other characteristics. The performance of ordinary concrete can be greatly improved by the use of modern concrete technology. Traditional concrete structures and special structures built in harsh environments is replaced by high performance concrete. It is helpful to increase the safe service life of concrete structure. What's more, it has significant economic benefits (Cusson et al., 2012; Vejmelková et al, 2010). Alon.g with the progress of construction technology, the increase of the scale of the project construction and the change of construction technology, a variety of main concrete structures used under brutal conditions such as cross sea bridge, subsea tunnel, offshore oil platforms, etc. make the application of high performance concrete become more popular (Wang et al., 2016; Meira et al., 2010). Therefore, it is important to study the fracture and durability of high performance concrete to avoid or reduce the construction safety accidents caused by the failure of durability of concrete structure.

Many people at home and broad have always attached great importance to the research on the durability of high performance concrete. For instance, an international conference named future of concrete was held by International Society for bridge and structure in Paris in 1987 (Idiart et al., 2011). Since 1976 companies like RILEM would hold International Conference on the durability of building materials and components every three years (Lulu et al., 2011). In addition, many experts and scholars have studied durability of high performance concrete. For example, the Effect of silica fume on durability of concrete composite was studied by Zhang P with four different content of silica fume 3%, 6%, 9% and 12% (Zhang et al., 2001). In this paper, the high-performance concrete mainly works in the cold environment, based on the two experiments of the compressive strength and frost resistance, the high-performance concrete with different mix ratio of eight groups was the object of the study and its fracture and durability was studied based on the above situation in order to find the right mix for the cold environment.

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2. Configuration of high performance

2.1 Material selection

(1) Cement: Because of the high-performance concrete is more sensitive to the performance of cement we should pay special attention to it in the choice of cement. At the same time, we should determine the compatibility of cement and admixture in the choice of cement especially the superplasticizer (Konsta-Gdoutos et al., 2010). Under the condition of satisfying the strength it is the same as the ordinary strength concrete, it is neccessary to limit the amount of cement used in cement concrete and take the minimum value. Grade 42.5 ordinary portland cement was chosen from Shaanxi coal chemical industry group ecological cement Limited by Share Ltd in this paper and all indicators have reached the national standard.
(2) Aggregate: The compressive strength of concrete is high and the workability is good. So, we should strictly control the content of fine silt and mud content. River sand produced from the Yanhe River of Yan'An city was used in this experiment. It is Medium sand of Grade II which can be used to make concrete. It is generally agreed that with the increase of the size of coarse aggregate, the compressive strength of high strength concrete will be reduced. Gravel was chosen from a certain gravel factory of Yan'An city in this paper. 5mm ~ 20mm continuous gradation of crushed stone was obtained by using square hole sieve. It was regarded as coarse aggregate.
(3) Fly ash: Fly ash is often used as mineral admixture in high strength concrete. For high strength concrete, adding fly ash helps to improve the early and long term strength. And it is much cheaper than cement (Zhang et al., 2013). Grade II Fly ash produced by Portland Shaanxi Electronic Science and Technology Co., Ltd was used in the paper.
(4) Admixture: Adding high efficiency water reducing agent can increase the working performance. In the meanwhile it reduces the amount of water and cement. Compared with the traditional water reducing agent, carboxylic acids with low molecular weight comb polymer grafting is widely used since it has the following advantages. It has low content, good dispersion, high ability of slump retaining. Formaldehyde and strong corrosive concentrated sulfuric acid are not used in the synthesis and it doesn't cause any pollution to the environment. PC poly carboxylic acid series high efficiency water reducing agent (powder) produced by Shanghai Hanford company was used in the paper.

2.2 High performance concrete mix proportion and preparation

Compared with ordinary concrete, high performance concrete mix design must first ensure durability requirements. At the same time due to its various components, the mix design is more complex than the design. Some achievements have been made in the design method of high performance concrete. Some even reach the level of the design of the computer. But most of the high performance concrete design is still based on the requirements of the project, existing mix design methods and practical experience to ratio initially while designing and the final mix ratio will be determined after adjustment through the trial (Deepa et al., 2010; Ozbay et al., 2011). To make the experimental results be more comparable and feasible, this paper classified the design of high performance concrete for the two groups of experiments. Each concrete mixture ratio of the test is shown in Table 1.

Table 1: Concrete mix ratio of each number

Number	Cement (kg/m3)	Fly ash FA (kg/m3)	Water (kg/m3)	Coarse aggregate (kg/m3)	Fine aggregate (kg/m3)	Admixture (amount of cement used)	Water binder ratio
30FA0	400	0	160	1100	700	1.0%	0.30
35FA0	400	0	160	1100	700	1.0%	0.35
35FA10	360	40	160	1100	700	1.0%	0.35
35FA20	320	80	160	1100	700	1.0%	0.35
35FA30	280	120	160	1100	700	1.0%	0.35
35FA40	240	160	160	1100	700	1.0%	0.35
40FA0	400	0	160	1100	700	1.0%	0.40
45FA0	400	0	160	1100	700	1.0%	0.45

The concrete was mixed by HJW60 type mixer for the production of this series of tests. The fiber concrete mixing procedure in laboratory was as follows. Putting in successively the fine aggregate, cement, fly ash, coarse aggregate and then adding water and admixture after stirring 20s. 1min later it should still be vibrated for 60s on the shaking table to make a standard test block cube of 150mm side length. It should be immediately put in the standard curing room for maintenance after test piece is formed.

3. Compressive strength test of high performance

3.1 Experiment methods

Generally speaking, the strength of concrete refers to its ability to resist external forces (Habert et al., 2012). In this paper, the sample made from above test are used as the experimental objects; the compressive strength with 95% guaranteed rate, that measured in accordance with standard experimental method, is used as the cube compressive strength of high performance concrete. The whole experiment is carried out at room temperature, the detailed steps are as following:

(1) To put the test sample that mentioned above in the humid air for separately 5d, 10d, 25d, and 50d, the temperature is (20±3)□ and its relative humidity is over 95%, then test their compressive strength.

(2) To put the test parts on the type of TYE-2000B pressure testing machine (shown in Figure 1), place the specimen in the center of the press base, then run the test machine. When the pressure plate is close to the sample, adjust its position to make the touching surface balance between them. At the same time, speed the machine according to the loading speed until the sample is finally destroyed. Then we can record the maximum damage load.

Figure 1: The type of TYE-2000B pressure testing machine

3.2 Result analysis

Eight groups of high performance concrete with different mix rate that were maintained for separately 5d, 10d, 25d and 50d were tested their compressive strength, the result is shown as Figure 2.

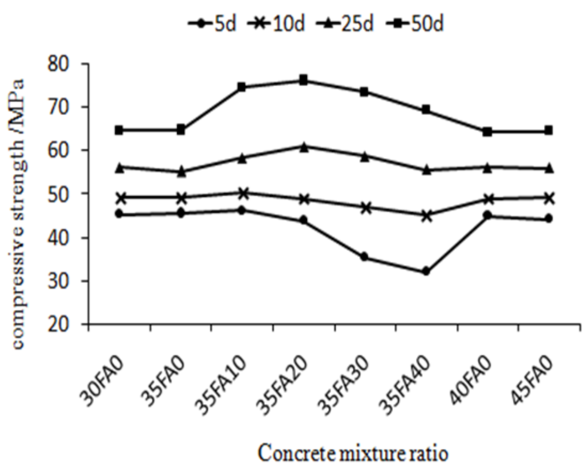

Figure 2: Comparison of compressive strength of concrete with different mix ratio

It is can be seen from figure 1 that for sample part produced by the same mix ratio were maintained with four kinds of different time, their compressive strength changed accordingly, that is 5d＞10d＞25d＞50d, which means that the compressive strength of high performance concrete increases with the curing time. Meanwhile, it is not hard to see from above figure that the compressive strength of concrete with curing time 5d, 10d, 25d and 50d all firstly increases and then decreases, which is possible for that the using of a large of fly ash reduces the amount of cement and this makes the hydration rate of cement in the early stage of concrete has slowed down. After 10 d, the compressive strength of high performance with 10% fly ash content is higher than that without fly ash; after 25 d, the strength increase of high performance concrete with fly ash has a little change, which even is equal to that not mixed fly ash in the case of small volume (here refers to that FA<40). When curing for 50d, the compressive strength of high performance concrete with fly ash increased obviously, whose compressive strength is over that without missing fly ash (the details in this paper are shown as 35FA20＞35FA10＞35FA30＞35FA40＞35FA0). That is to say that Fly ash contributes greatly to the increase of the strength of concrete in the later period. The results of this study are consistent with the active effect of fly ash: the active components in fly ash can react with the hydration products of cement and generate C-S-H gel. At the begging, due to the less hydration products of cement, the chemical reaction between them is weak, which leads to the low compressive strength of the high performance concrete in the early stage; after that, with the increase of hydration products of cement, it promotes the reaction and greatly improve the performance of high performance concrete.

4. Test of frost resistance of high performance

4.1 Test method frost resistance of concrete

The frost resistance of concrete is one of the most important parts in the research field of the durability of concrete. Because of a large area of China's territory is in the cold zone, freezing and thawing damage is the main damage caused by the local hydraulic concrete construction in the course of operation (Etxeberria et al., 2007; TBibhuti et al., 2014). In this study, the slow freezing method is used to study the frost resistance of high performance concrete (the experimental setup is shown in Figure 3), the specific steps are as follows:

Figure 3: The testing machine TDR-28 of rapid freezing and thawing of concrete

(1) The prepared specimen is placed in water with (20 + 2)°C for 4 d, and the water surface is higher than the specimen (255) mm;
(2) Taking the specimen out from water, wipe its surface moisture with a damp cloth and placing them into the specimen holder by number. What is noted is that the contacting area between the specimen and the holder is less than 1/5 of the base area. At the same time, the distance for the specimen and the inner wall of the holder is >20mm and the distance between the specimen is >30mm;
(3) The test piece is frozen and the temperature of the freezing chamber should be -18°C around. The time from loading test piece to temperature down to -18□ should be within two hours. The freezing temperature should be kept to (-19±1)°C. And the freezing time is not less than 4 hours for each recycle freezing.
(4) After freezing, putting water that with temperature 20°C, and making the test piece enter into the melting state within 15 minutes to let the temperature increase rapidly and ensure that it adds up to 10°C at the first 30 minutes. Then, keep the temperature adds up to 20°C after the following 30 minutes. Finally, keep the temperature is 20°C. In this process, the water surface should always be 20mm higher than the spicemen and the melting time is not less than 4 hours.

(5) The melting end means the end of the freeze-thaw cycle, then it entered into the next freeze thaw cycle, the cycle of the maximum limit is 400 times. At the end of each 50 cycles, the appearance detection and weighing detection for the frozen thawed specimens are tested. The test should be stopped when the following three situations occur: the number of cycles has reached the limit; the loss rate of compressive strength has reached 25%; the quality loss rate has reached 5%.

4.2 Results and analysis of frost resistance of concrete

Test results of freeze-thaw resistance of concrete are shown as Figure 4 and Figure 5. It can be found from Figure 4 that the quality loss rate in the process freezing is very low and most of cases are that when the concrete is frozen, the quality is destroyed immediately.

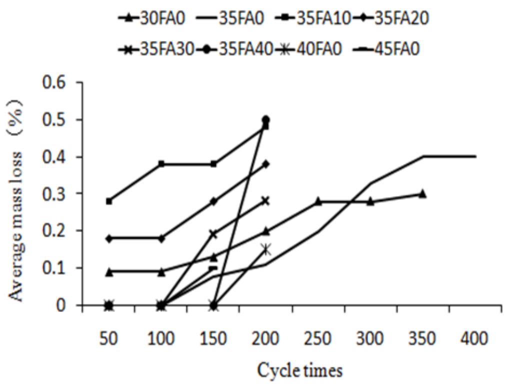

Figure 4: The quality loss rate of concrete with different mix ratio of freeze-thaw cycles

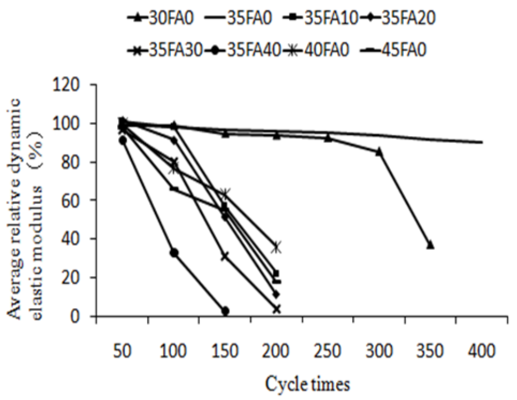

Figure 5: Relative dynamic modulus for freeze-thaw cycles of concrete with different mix ratio

So, it is not reasonable to use the quality loss rate to determine the times and numbers of freeze-thaw of high performance concrete. In this paper, the relative dynamic elastic modulus of concrete reduced to 50% is considered as the standard, seeing from figure 5, it is not hard to get the times and number of freeze-thaw that the high-performance concrete can stand. The times of freezing and thawing cycles that the 45FA0, 40FA0, 35FA0, 30FA0 high-performance concrete can stand is separately in the range of 100 to 150 times, 150 to 200 times, > 400 times and 300 to 350 times. Then it gets that the boundary for water cement rate is 0.35; when the ratio is greater than 0.35, accompany with the increasing rate of water cement, the frost resisting of high performance concrete decreased significantly (45FA0<40FA0<35FA0) but for the number of 350FA0 concrete, even if its freezing time reached up to 400 times, its relative dynamic modulus is still about 90%. The freezing and thawing cycles for concrete with number 35FA10, 35FA20, 35FA30, 35FA40 can withstand is in the interval range from 150 to 200 times, 100 to 150 times, 100 to 150 times and 50 to 100 times, therefore, it can be concluded that the frost resistance of concrete decreased with the increasing of fly ash, which refers to the fly ash is not good for concrete freezing resistance and should be used carefully. The frost resistance durability index DF of concrete with different mix ratio is calculated and its result is shown as figure 6. What we can see from figure 6 is that for concrete with different mix ratio but without fly ash, the durability index from high to low order is 35FA0 > 30FA0 > 40FA0 > 45FA0, which further proves the conclusions in this paper.

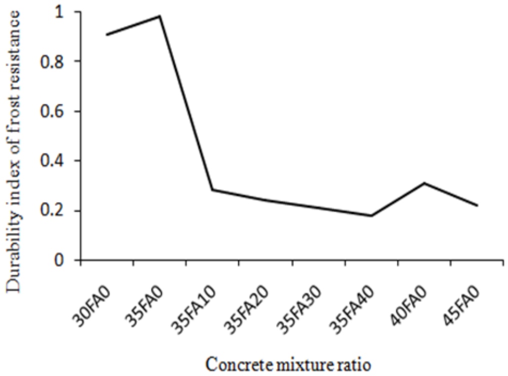

Figure 6: Freeze-thaw durability index of concrete with different mix ratio

5. Conclusions

After analyzing the eight groups of different mix ratio of high performance concrete compressive strength and frost resistance experiment, this paper got the following conclusions: the compressive strength of high performance concrete increases with the curing time. At the same time, the mix ratio of fly ash also has an effect on its compressive strength, with the increasing of the amount of fly ash, the compressive strength of high performance concrete is firstly increased and then decreased. Furthermore, the fly ash is not good for the frost resistance of concrete, for high performance concrete, its compressive strength decreased with the increasing of fly ash. Therefore, for construction of buildings in cold regions, when using high performance concrete, the mix ratio of fly ahs should be considered carefully. Finally, this paper found that the ratio 0.35 of water and cement is a boundary, when the ratio is higher than 0.35, the frost resistance of high performance concrete will decrease with the water cement ratio increasing. So, the ratio 0.35 is a reasonable reference value when using high performance concrete with high frost resistance.

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