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The Research on Process and Application of Self-Compacting Concrete

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Abstract
Self-compacting concrete (SCC) is one kind of concrete with high workability and durability. First of all, this paper introduces the definition and history of Self-compacting concrete (SCC). Secondly, it introduces the raw material selection, equipped technology and the mix proportion design method of Self-compacting concrete. Finally, it analyzes the problems and countermeasures of self-compacting concrete and look ahead the application prospect of it.

Keywords: Self-compacting concrete; raw material selection; mix proportion design; application prospect

I. Introduction

Concrete is one of the most important elements for any kind of construction work and composed of mainly cement, aggregate, water and chemical admixtures. Generally, concrete is compacted by a vibrator or steel bar after being placed inside the formwork to remove the entrapped air after which it becomes a dense and homogeneous material. Compaction is very important in order to produce a uniform concrete mix with desired strength and durability properties.

As one of the great innovations in concrete technology, self-compacting concrete (SCC) is in the process of casting without imposing additional vibrating forces, and only gravity is necessary to completely fill the mold cavity to form a uniform dense concrete. Compared with traditional vibrated concrete, SCC has obvious advantages in terms of reducing construction costs and improving the construction environment, which are significant steps in the direction of sustain ably developed concrete.

The concept of Self-compacting concrete was firstly presented in 1986 by Okamura, a scholar from the University of Tokyo. He pointed out that the reduction of Japanese skilled workers has a negative impact on the durability of the concrete structure, and proposed developing self-compacting concrete which can avoid the impact of construction quality. Self - compacting concrete is a kind of concrete which is characterized by high - workability. Soon after, Ozawa, a scholar from the University of Tokyo, carried out the study of self-compacting concrete, and make up self - compacting concrete successfully in 1988[1,2].

Many people regard it as the most revolutionary development tin the construction sector in recent decades, essentially thanks to the new production and casting process. Since this is based on the elimination of vibration, the final product is of higher quality, with the additional benefit that the overall cost of casting is lower.

Because many of the problems of current structural concrete are related to execution quality issues during casting, a concrete that does not need manual labor at this stage is much less likely to suffer such problems.

II. raw material selection and equipped technology

2.1raw materials selection

2.1.1Aggregate

The water consumption and slurry content of Self-compacting concrete are directly influenced by the elongated particles content in coarse aggregate and coarse aggregate graduation. Therefore, limit in gel on gated particles content, using full shape particle and good coarse aggregate graduation is very important to Self-compacting concrete. To ensure that self-compacting concrete can pass through the dense steel smoothly, achieve its uniform and self-compacting, the coarse aggregate particle size is no more than 25 mm. The mud content of the aggregate greatly affected the strength and workability of the self-compacting concrete, so the fine aggregate content should not be more than 1.5%. Experiments shows using sand can easily meet the work requirement of self-compacting concrete, the fineness modulus of sand should be more than 2. 5.

2.1.2active admixture

Mixing mineral admixture in self-compacting concrete can meet the workability requirements and reduce the cement consumption. At present, the ash is most commonly used. The micro aggregate effect, active effect and morphological effect of ash played an important role in mixture workability and mechanical property of hardened concrete of self-compacting concrete. In addition, the ash fineness is good to avoid a premature second hydration, and its volume stability is good when mixing with concrete. The carbon content in ash should be less because of the low water-cement ratio of self-compacting concrete. The water consumption of ash should be small enough to meet the workability of self-compacting concrete.

2.1.3Colloid material

The pure Portland cement with low content of C3A and ordinary Portland cement is suitable for the preparation of self-compacting concrete. The cement used in the preparation of self-compacting concrete is not too fine, in order to ensure the workability of self-compacting concrete until it into the mold. The fluctuation of cement quality has a significant effect on the quality of self-compacting concrete.

2.1.4admixture

Self-compacting concrete can be prepared by compounding admixture with high efficiency water reducing agent. According to the project requirements of self-compacting concrete performance, climate conditions and the construction technology, combined with concrete raw materials performance, adaptability to cement and mix proportion and other factors, the species and dosage of admixture can be determined through the test.

2.2 Equipped technology

The practice shows that: the properties and content of aggregate and slurry decide mixture performance. When aggregate content and properties is certain, you can get a good concrete mixture by improving the viscosity of the slurry. Okamura said: to make the mixture meet the requirements, you can choose low water-cement ratio, control aggregate content and adding additives. Okamura gives the following technical rules:

(1)Fine aggregate accounts for about 40% of the volume of mortar.

(2) Coarse aggregate can account for 50% of the total aggregate volume.

(3) The volume ratio of the gelled material and water can be adjusted through the gelled material properties.

(4) The final water-cement ratio and the amount of admixture can be decided by self- compacting ability of mixture.

With the appearance and application of mineral admixture and polymer synthesis technology, there are three kinds of preparation method of self-compacting concrete, thickener system, mineral admixture system and a combination of two systems[3~6].

III. Mix proportion design of self-compacting concrete

Mix proportion design method of self-compacting concrete is different from normal vibrated concrete. If the work performance can meets the requirements is the first condition of successful preparation. Work performance of concrete mixture is often affected by aggregate properties, particle size graduation, void ratio, slurry consumption and viscosity. There are 4 ways of mix proportion design of self-compacting concrete shows as follows:

(1) The calculation method. The calculation method is obtained by improving the method of calculating mix proportion of the high performance concrete.

(2) The calculation method of fixed sand volume content. The calculation method is as follows: ①The content of mortar and stones can be obtained by assuming the stone accumulation volume of $1m^3$ concrete; ②Assuming the content of sand in the mortar to obtain slurry content and sand consumption; ③ the amount of cementing material and water can be calculated by admixture ratio and the ratio of water to cement , then you can calculate admixture and cement consumption. But there is no specific provisions of how to determine water-cement ratio and admixture consumption.

(3)The factorial method. using orthogonal experiments or so-called "factorial method " to study the influence of different factors, such as mineral admixture dosage, total amount of colloid material, water-cement ratio, sand content, slurry volume and admixture dosage to concrete strength and workability. Determining the proper dosage range of parameters, and then design mix proportion with ordinary terms.

(4) Experience derivation method. Water consumption, the amount of coarse aggregates and colloid material content can be obtained by empirical data calculation, the volume of fine aggregates is equal to all volume minus other material volume. the admixture dosage can be determined by mortar experiment or debugging, then determine the initial mixture ratio and compound concrete, and test its performance, then adjust the mixture ratio, and finally obtained the ratio. It is easy to use the method, but need large amounts of data, and when the new material or quality changes, the material component of the dosage range need new test to determine[7~10].

IV. working performance test method and evaluation index

4.1 working performance test method

At present, there are many methods can be used to evaluate the performance of self-compacting concrete. Slump expansion experiment, L type tester, V-shaped funnel test, U type or box type tests and GTM sieve stability test, orimet velocity instrument method and penetration test are used in the test method[11,12]. Various test methods and test performance are shown in Table 1.

Table 1 Test properties and methods for evaluating SCC

Detection performance	Method
1. With Abrams cone on filling the slump flow test	Filling
2 T_{50}cm slump flow method	Filling
3.J type ring clearance	Gap passing
4 V funnel test filling	Filling
5. V funnel test segregation resistance	Segregation resistance
6 L type flow meter clearance through	Gap passing

7 U type fill test gap through	Gap passing
8 box type fill test gap through	Gap passing
9 GTM screen anti segregation stability test	Segregation resistance
10.Orimet flow meter method filling	Filling
11 penetration test Segregation resistance	Segregation resistance

4.2 working performance evaluation index

There is no single method can fully reflect the performance of self-compacting concrete so far, only by using a variety of methods can we get parameter of each batch of concrete when design the mix ratio.

In 2012, China released "Technical specification for self-compacting concrete". Make the evaluation index more detail to evaluate the working performance of self-compacting concrete, and the testing method is more scientific, standardized, useful and practical, provisions are shown in table 2.

Table 2 Acceptance criteria for SCC

Detection performance	Test method for performance index	Test value	Performance level	Performance index
Filling	The slump	The slump	*SF1*	550 mm～650 mm
			SF2	660 mm～750 mm
			SF3	760 mm～850 mm
	T_{50}	Extended time	*VS*	2 s≤T_{50}≤5 s
Gap passing	J ring expansion	The difference of slump and ring expansion	*PA1*	25 mm≤*PA1*≤50mm
			PA2	0 mm≤*PA2*≤25mm
Segregation resistance	Sieve analysis	Percentage of floating pulp	*SR1*	≤20%
			SR2	≤15%
	Jump table method	Segregation rate	f_m	≤10%

V. Advantages and disadvantages of self-compacting concrete

5.1 advantages

1) Improve the quality of concrete effectively: good mechanical performance, density and durability; 2) use industrial wastes as admixture, it's favorable for environmental protection; 3) save electric energy; 4) reduce environmental noise, improve the working environment and safety; 5) greatly reduced the labor; 6) a high degree of automation of the construction, improve production efficiency, shorten the construction period; 7)solve the vibration problems of traditional concrete construction , ensure that the embedded parts, reinforced, pre-stressed hole position do not shift in vibration; 8) increase the freedom of the structure design. The structure of complex shape, thin wall and dense reinforced can be cast without vibration. 9) The engineering cost may be decreased.

5.2 problems

(1)Slump changes with time: self-compacting concrete slump losses larger than other types of concrete as the change of time, high efficiency water reducing agent is used in engineering to solve this problem. But this method is adverse to quality control and quality management, and it also reducing

productivity.

(2)Cognition of the physical mechanical properties and durability: the construction performance of self-compacting concrete has been fully studied. Whether it's physical and mechanical properties and durability changes and its change rule is uncertain after self-compacting concrete mixed into super plasticizer and pumping.

5.3 countermeasures

(1) Study on quality control measures: including the selection of raw materials, mixture ratio design and construction technology and so on.

(2)Study on the mechanism of slump loss: to suppress the slump loss, we need to study the mechanism of it.

(3) Explore the feasibility of using mineral admixtures: by adding excess fine slag and micro-Silica fume to improve the self-compacting concrete strength and control its slump losses with time[13~18].

VI. Application prospect of self-compacting concrete

Germany adopted the self-compacting concrete so they improve the performance of concrete construction, reduces the power concrete needed when pouring and vibrating, improve the construction efficiency, reduce the amount of labor and shorten the construction period, therefore reduce the cost. In order to improve the concrete quality and maintain the original construction scheme, Japanese use self-compacting concrete to reduce the cement content and water.

With the development of the west of China, the amount of concrete used in road, bridge, railway, increasing rapidly. These structures are constructed in difficult conditions, the continuity of its project progress and its efficiency is the most critical issue. Self-compacting concrete can be used to solve these problems.

self-compacting concrete that used in the following aspects can achieve better technical and economic effect: ①the pump sending concrete; ②steel dense parts, difficult vibrating parts; ③when the concrete must be uniform and compact[19~21].

VII. conclusions and prospects

(1) In order to control self-compacting concrete construction quality and promote the engineering application, we should strengthen the study of assurance system of construction quality, survey the relationship of self-compacting concrete structure performance and other concrete performance in the same condition.

(2) As the workability is the key performance of self-compacting concrete, so the study should focus on it, and also should develop more scientific, standardized and practical structural performance test methods.

(3)Self-compacting concrete is different from ordinary concrete in the composition and requirements of raw materials, so strengthening the environmental service behavior of self-compacting concrete is needful, such as the carbonation resistance, shrinkage cracking performance of self-compacting concrete, which benefit to the life of self-compacting concrete.

(4) Strengthening the study of design methods and the preparation technical of self-compacting concrete in common used strength, then further study should be taken on the design method and preparation techniques of that in moderate intensity, and develop the self-compacting concrete of medium strength. These will be beneficial to expand engineering applications of self-compacting concrete.

References

[1] Caijun Shi, Zemei Wu, KuiXi Lv, et al. A review on mixture design methods for self-compacting concrete [R]. Construction and Building Materials, 84 (2015): 387–398.

[2] OZAWA K，MAEKAWA K, KUNISHIMA M, et a1. Development of high performance concrete based on the durability design of

concrete structures[C].The Second East-Asia and Pacific Concrete on Structural Engineering and Construction (EASEC-2), 96 (1989): 445-450.

[3] Mostafa Jalal, Alireza Pouladkhan , Omid Fasihi Harandi, et al. Comparative study on effects of Class F fly ash, nano silica and silica fume on properties of high performance self compacting concrete[R]. Construction and Building Materials, 94 (2015) :90–104.

[4] O.R. Kavitha, V.M. Shanthi , G. Prince Arulraj , et al. Fresh, micro- and macrolevel studies of metakaolin blended self-compacting concrete[R]. Applied Clay Science, 114 (2015): 370–374

[5] Rahmat Madandoust , Malek Mohammad Ranjbar, Reza Ghavidel, et al. Assessment of factors influencing mechanical properties of steel fiber reinforced self-compacting concrete[R]. Materials & Design, 83 (2015) :284–294.

[6] Song Wenjun. Experimental study on the mixture ratio of self compacting concrete [J]. Shanxi water conservancy science and technology, 4 (2011) :7l-73.

[7] M.G. Alberti, A. Enfedaque, J.C. Galvez .Comparison between polyolefin fibre reinforced vibrated conventional concrete and self-compacting concrete[R]. Construction and Building Materials, 85 (2015) :182–194.

[8] P.R. da Silva , J. de Brito . Experimental study of the porosity and microstructure of self-compacting concrete (SCC) with binary and ternary mixes of fly ash and limestone filler[R]. Construction and Building Materials ,86 (2015): 101–112

[9] Youcef Ghernouti , Bahia Rabehi , Tayeb Bouziani , et al. Fresh and hardened properties of self-compacting concrete containing plastic bag waste fibers (WFSCC) [R]. Construction and Building Materials ,82 (2015) :89–100.

[10] Guangcheng Long , Yu Gao, Youjun Xie. Designing more sustainable and greener self-compacting concrete[R]. Construction and Building Materials ,84 (2015) :301–306

[11] EFNARC . Specification and guidelines for self – compacting concrete［R］. EFNARC, 2002.

[12] GUI Miaomiao. Standard survey and comparison of self compacting concrete at home and abroad [J]. Materials review, 25 (2011):97-100.

[13] Efstratios G. Badogiannis, Ioannis P. Sfikas , Dimitra V. Voukia , et al. Durability of metakaolin Self-Compacting Concrete [R]. Construction and Building Materials, 82 (2015) :133–141.

[14] Disc business customers. Pan Ying passenger dedicated CRTS type ballastless track self filling concrete tentative technical requirements [S]. disc business customers. 18(2011): 56–58.

[15] Wang Guoqing, Cheng Liping. Self compacting concrete historical development and research status [J]. China waterway, 8 (2011): 33–36

[16] Eehab Khalil, Mostafa Abd-Elmohsen, Ahmed M. Anwar. Impact Resistance of Rubberized Self-Compacting Concrete[R]. Water Science ,29 (2015): 45–53.

[17] Japanese Ready - Mixed Concrete Association . Manual of producing High Fluidity（Self - Compacting）Concrete［S］

[18] Sun Wei, Zhao Qingxin, Yang Zhenghui, et al. Study on the control accuracy of self compacting concrete production [J]. construction technology, 37 (2006):52 – 54.

[19] Mohsen Tennich, Abderrazek Kallel , Mongi Ben Ouezdou . Incorporation of fillers from marble and tile wastes in the composition of self-compacting concretes [R]. Construction and Building Materials, 91 (2015) :65–70

[20] Reza Ghavidel, Rahmat Madandoust, Malek Mohammad Ranjbar. Reliability of pull-off test for steel fiber reinforced self-compacting concrete[R]. Measurement, 73 (2015): 628–639

[21] Hui Zhao, Wei Sun , Xiaoming Wu , et al. The properties of the self-compacting concrete with fly ash and ground granulated blast furnace slag mineral admixtures[R]. Journal of Cleaner Production, 95 (2015) :66–74