

Strength and Shrinkage Property of Nano Silica Powder Concrete

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Abstract. Through indoor test to explore the compressive strength, bending tensile strength and shrinkage property of nano silica powder cement concrete. The test results show that in ordinary cement concrete mixed with an appropriate amount of nano silica powder, and bending tensile strength has increased, but the shrinkage increased significantly. When the nano silicon powder mixing content is 0.5%, 0.75% and 1.0%, compared with ordinary cement concrete, 28 days bending tensile strength were increased by 3.2%, 7.5%, 4.0%, the shrinkage rate of 28 days, respectively, an increase of 75.5%, 127.1 %, 163.0%. Based on the experimental study, the reason leads to the shrinkage rate increase of nano silica powder cement concrete are analyzed. Combined with the engineering practice experience, providing shrinkage compensate measures and construction key technology of nano silica powder cement concrete.

Introduction

In recent years, using a variety of blending materials more widely to improve the performance of cement concrete [1-3], the nano silica powder is one of the blended material. Studies have shown [4-7], the existence of silica powder, in the early cement hydration product $\text{Ca}(\text{OH})_2$ content along with the growth of the age becoming less and less, even complete reacted, generate new material which will jam channel, big pores will less, cohesion between aggregate and plaster will be strengthen, compactness will be improved. At the same time ultra-fine grain is mixed it could play role as mineral decrease water and increase the cohesion, make the fluidity and stability of concrete get harmonious. As the improvement of mixture stability can effectively avoid segregation and secrete water phenomenon, help to improve stress modes of the concrete. So mixed with nano silicon powder to the concrete bending tensile strength and durability has obviously improved [8,9]. But engineering experience shows that as with silicon powder, also bring two problems, on the one hand is the cohesiveness increase of concrete to construction cause certain difficult, on the other hand is shrinkage rate increases can lead early crack. This paper through the indoor test discussed about the compressive strength, bending tensile strength and shrinkage property of nano silica powder cement concrete, combined with the engineering practice experience presented construction key technology of nano silicon powder concrete.

Raw Materials and Test Methods

Cement. 42.5 ordinary Portland cement produced by Shandong cement plant, its quality qualified.

Aggregate. Fine aggregate is natural sand in Taian, quality of a material is good. Coarse aggregate is gravel in Taian, two kinds 5-20mm and 20-40mm, the ratio is 40%:60%.

Nano Silicon Powder. The high quality nano silica powder used in experiment produced by the Gansu Lee Xinyuan limited liability company, which is light gray, density 2.2 g/cm^3 , average grain diameter is about 100nm.

Chemical admixture and Mixing Water. Using the water reducing agent FDN-1 that decrease water more than 10% and its amount is about 1.0% cement. The mixing and maintenance water is tap water in test room.

Test Methods. Firstly, mix the high efficiency water reducing agent and part of the water uniformly, secondly put into the nano silicon powder, lastly mix them uniformly. Originally nano

silicon powder do not soluble in water. It could mostly soluble in the solution of high efficiency water reducing agent and water because of the dispersion effect of the high efficiency water reducing agent. In the forced mixer, mix the cement, sand, stone uniformly, then add water mixing for 30 seconds, lastly add the mixed solution of water, the water reducing agent and nano silicon powder mixing for another 60 seconds. According to the “Test Methods of Cement and Concrete Highway Engineering (JTG E30-2005)”, make ordinary cement concrete standard specimens whose mix proportion is shown in Table1. Adjust the water consumption to satisfy workability on the basis of mix proportion of ordinary cement concrete. The content of nano silicon powder to cement respectively are 0.5%,0.75%,1.0%,1.5%. When the specimens are completed, put them in standard curing room to cure for the requirement age.

Table 1 Ordinary concrete proportion

Water-cement ratio	Cement content (kg/m ³)	Sand content (kg/m ³)	Gravel content (kg/m ³)	Water reducing agent content (kg/m ³)
0.42	350	720	1300	4.2

Analysis of Test Results

Compressive Strength and Bending Tensile Strength. The relationship between compressive strength and content of nano silica powder is shown in Fig. 1. The relationship between bending tensile strength and content of nano silica powder is shown in Fig. 2. The experimental results indicate that nano silicon powder can not improve the compressive strength of concrete significantly. When the mixed contents of nano silicon powder are respectively 0.5%, 0.75%,1.0%,1.5% and the bending tensile strength improved by 3.2%,7.5%,4.0%,3.6%. The improvement is most obvious when the content is 0.75%. What’s more, the admixture of nano silicon powder lead to brittleness reducing and flexiblensess enhancing.

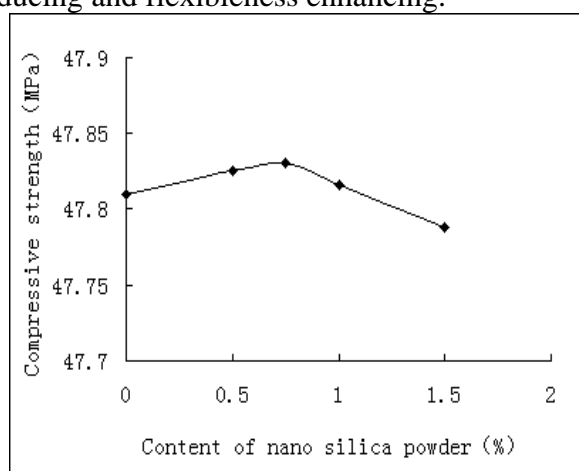


Fig. 1 The relationship between compressive strength and content of nano silica powder

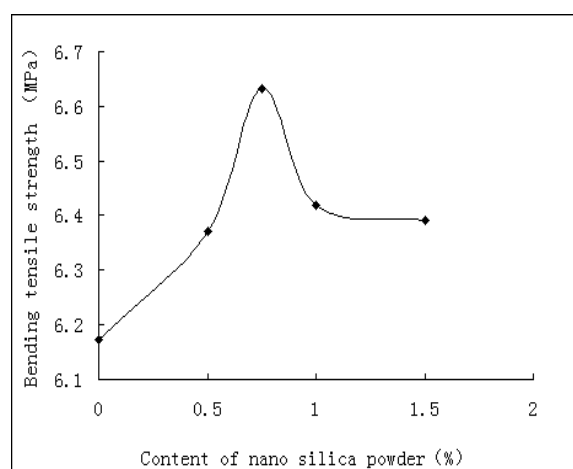


Fig. 2 The relationship between bending tensile strength and content of nano silica powder

The Dry shrinkage Ratio. The dry shrinkage ratio of nano silicon powder concrete is shown in Table 2. Through test result find that ordinary cement concrete dry shrinkage in 7-28 days is significant, the dry shrinkage of concrete mixed with nano silicon powder in 3-7 days is significant, which increases with the increasing content of nano silicon powder. The 28 days dry shrinkage ratio compared with ordinary concrete respectively developed by 75.5%, 127.1% ,163.0% when the mixed contents of nano silicon powder are 0.5%, 0.75%, 1.0%.The result indicates the admixture of nano silicon powder enlarged the dry shrinkage of concrete significantly.

The Analysis of Shrinkage Reasons. The first, Plastic shrinkage. It is mainly resulted by the water loss on the surface of new mixed concrete, in theory it is helpful to enhance density, but in fact deformation of volume could lead to cracks due to its uniformity the tensile strength. The secrete water of concrete mixed with nano silicon powder decreases, especially when the quantity of the content is large. The increase of uniformity between inner part and surface can lead to shrinking and

cracking more easily. The second, Inner dry shrinkage. Italian Kohler Battie and others made research in mortar mixed with nano silicon powder finding the mixing method would affect the shrinkage. If mixing cement and nano silica powder with water together specimen will produce cracks before dismantling formwork in 24 hours when it is cured in damp air room. If mixing the nano silica powder and water firstly and then put cement into the mixture solution of silicon powder and water, there will be no cracks even it is exposed in dry air. This phenomenon is called inner dry shrinkage, it is caused by the silica powder draw water into its cavity in the initial wet. The third, Hydration shrinkage. Cement shrinks through hydration reaction. Generally, the shrinkage is very small and can be ignored. Silicon powder could react with $\text{Ca}(\text{OH})_2$ produced by cement during hydration which leads to the development of shrinkage. The research conducted by Q-Wald shows that the chemical shrinkage caused by pozzolan in silicon powder setting hard reaction is greater than that caused by cement hydration. As a consequence, when silicon powder concrete is cured without enough water, the self-dry effect of silicon powder will be enhanced, relatively water evaporation be low. The fourth, Dry shrinkage. Stomatal water and capillary water evaporation will lead negative pressure in the capillary porosity during the dry process of silicon powder concrete. The decrease of air humidity and the increase of negative pressure will cause shrinkage force which lead to concrete shrinking. If there is still dry after capillary water evaporated, the absorbed water of gelatinous will evaporate partly, because of the attraction of molecular, space between molecular will be narrow and make gelatinous grain tightening[10].

Table 2 Test results of dry shrinkage rate

Numbers	Nano silica powder cement (%)	Dry shrinkage rate ($\times 10^{-6}$)						
		1 days	3 days	7 days	14 days	28 days	60 days	90 days
0	0	18.81	24.00	38.84	62.14	100.05	137.78	162.31
1	0.5	33.21	58.67	97.01	133.33	175.56	227.63	285.66
2	0.75	48.25	68.31	128.93	179.21	227.18	302.69	370.45
3	1.0	59.36	89.87	160.15	208.23	263.09	351.12	450.24

Construction Technology of Nano Silicon Powder Concrete

Considering the difference between laboratory condition and the site conditions, to ensure strength and less shrinkage, during construction should pay attention to the problems as follows.

The Appropriate Mix Content of the Nano Silicon Powder. Test result show that when the content of silicon powder is increased significantly, its on concrete strength contribution rate decreases. What's more, when the content of silicon powder is too much, the new mixed concrete becomes so sticky that concrete compaction in construction is very difficult. Thus, in real project should add proper content of silicon powder according to test to satisfy concrete's property requirement.

Nano Silicon Powder must be Combined with High Efficiency Water Reducing Agent. When add nano silicon powder in concrete, at the same time should add high efficiency water reducing agent to ensure the necessary liquidity and enhancement effect of silicon powder to concrete. But should pay attention to the adaptability between water reducing agent and other materials. So must combine the engineering characteristics and properties of the raw materials and through try-mixing concrete test determine the content of silicon powder, chemical admixtures and gelatinous materials, and the best proportion corresponding.

Nano Silicon Powder Concrete Mixing and Transport. Firstly add coarse aggregate, 75% water, silicon powder, 50% fine aggregate, mixing 15 to 30s, then add cement, 50% fine aggregate, 25% water, admixtures, mixing 30 to 60s to uniform. Forced mixer should be applied. The mixing time should be extended 30 to 60 s than ordinary concrete. When the materials mixed uniformly in the

machine should try to shorten the delivery time, pave and vibrate in time. Try to reduce the loss of the slump.

Curing of Nano Silicon Powder Concrete. Curing of silicon powder concrete should ahead than the ordinary concrete. After the concrete pouring before final set must immediately use spray method to reduce evaporation of moisture or cover plastic film or spray concrete curing agent. Keep the concrete surface wet without water flow and visible water droplets. After final set should continue to cover plastic thin film or spray maintenance agent or in the surface cover wet sack and sprinkle water to cure the concrete. Keep concrete the wet state all the time and curing age should be not less than 28 days.

Shrinkage Compensation. During the construction of silicon powder concrete, different compensation methods can be applied in different shrinkages, such as plastic shrinkage covering maintenance should be in time, basal, template before casting should be appropriate wet. Such as inner dry shrinkage, silicon powder is mixed with water firstly, and so on. Sometimes several shrinkage phenomenons exist at same time, it should take effective measures to different shrinkage phenomenons. For example, adding appropriate expansion agent to ease the bad influence caused by severe dry shrinkage.

Conclusions

When adding proper content nano silicon powder in concrete, bending tensile strength can be improved but lead to a lager shrinkage rate and produce early crack easily. This paper suggests a series of shrinkage compensation measures available for reference. Due to many factors could lead to the nano silicon powder concrete dry shrinkage, the further research in dry shrinkage should be made.

Acknowledgements

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