

# Improvement of Performance of Ultra-high Performance Concrete Based Composite Material Added with Nano Materials

Jinchang Pang

Architecture and Civil Engineering, Nantong Polytechnic College ,nantong 226000 , Jiangsu

**Abstract.** UHPC is a kind of composite material characterized by ultra high strength, high toughness and high durability. It has a wide application prospect in engineering practice. But there are some defects in concrete. How to improve strength and toughness of UHPC remains to be the target of researchers. To obtain UHPC with better performance, this study introduced nano-SiO<sub>2</sub> and nano-CaCO<sub>3</sub> into UHPC. Moreover, hydration heat analysis, X-Ray Diffraction (XRD), mercury intrusion porosimetry and nanoindentation tests were used to explore hydration process and microstructure. Double-doped nanomaterials can further enhance various mechanical performances of materials. Nano-SiO<sub>2</sub> can promote early progress of cement hydration due to its high reaction activity and C-S-H gel generates when it reacts with cement hydration product Ca(OH)<sub>2</sub>. Nano-CaCO<sub>3</sub> mainly plays the role of crystal nucleus effect and filling effect. Under the combined action of the two, the composite structure is more dense, which provides a way to improve the performance of UHPC in practical engineering.

**Keywords:** UHPC; composite material; nano material; SiO<sub>2</sub>.

Human society is developing constantly, and the human living space is also becoming smaller. The development trend of living space is high-rise and large span. The residential buildings with concrete structure are often corroded by the external environment[1,2]Therefore, the performance of concrete materials must be improved. Ultra-high performance cement matrix composite material (UHPCC) has many excellent properties, which has been accepted and applied in engineering practice, and is obviously superior to ordinary concrete in the subsequent testing.

## 1. The trial process

### 1.1 Raw materials

Cement: P·II,42.5R, ordinary Portland cement, density of 3.4g / cm<sup>3</sup>

Fly ash: Grade I fly ash of Nantong thermal power Plant, with a specific surface area of 400m<sup>2</sup>And / kg, density of 2.0 g / cm<sup>3</sup>

The specific components of the above materials are shown in Table 1.

nanometre SiO<sub>2</sub>: Yancheng optical machine institute crystal center production, porous surface, particle size of about 15nm, high purity (SiO<sub>2</sub>More than 99% of the content).

nanometre CaCO<sub>3</sub>: Produced by Suzhou Nanomaterials Co., LTD., particle size about 30nm, high purity (CaCO<sub>3</sub>Content is above 99.9%).

According to the relevant literature studies<sup>[3]</sup>, Nano-SiO in UHPCC concrete<sub>2</sub>Of 2.5%, 40% fly ash and 50% cement, so nano SiO was used in this study<sub>2</sub>Of 2.5%, fly ash at 40%, cement at 50%, the corresponding change of nano CaCO<sub>3</sub>See Table 2.

Table 1 Composition of cement and fly ash Table (%)

material	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	CaO	SO <sub>3</sub>	K <sub>2</sub> O	other
cement	20.80	4.52	3.50	64.82	2.02	1.03	3.31
flyash	54.20	28.90	6.54	5.30	1.45	1.55	2.06

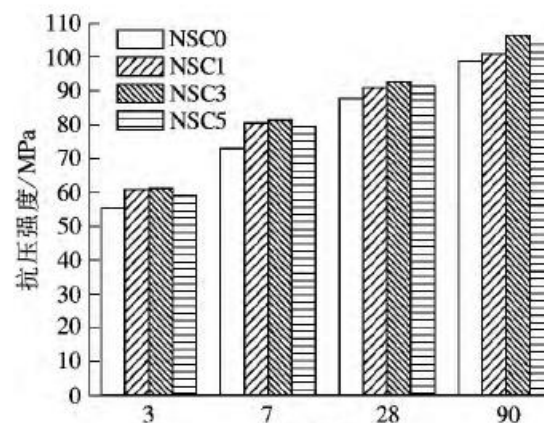
Table 2 UHPCC Composition mix ratio of the test material, (%)

test-piece	cement	flyash	nanometre SiO <sub>2</sub>	nanometre CaCO <sub>3</sub>	other
NSC0	50	40	2.5	0	7.5
NSC1	50	40	2.5	1	6.5
NSC3	50	40	2.5	3	4.5
NSC5	50	40	2.5	5	2.5

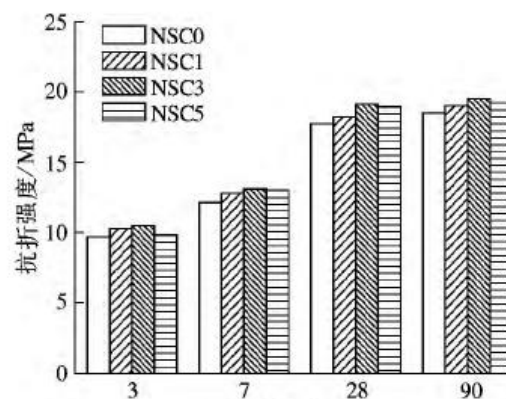
## 1.2 Results and analysis

In this study, the hydrostatic properties of UHPCC concrete were examined at different curing ages, as shown in Figure1

As shown:



(1) compression strength



(2) rupture strength

Figure 1 Compression and folding strength of UHPCC concrete at different ages

## 2. Numerical simulation of the concrete flow field

### 2.1 Grid division and solution method

The generation of the grid is a pre-processing process in the numerical simulation of the flow field. Meshing of the model is the premise and a key step for numerical calculation. The quality of the grid will not only affect the accuracy of the calculation results, but also seriously distort the results and get the wrong simulation results.

In this paper, the grid generation software Gambit2.1.6 is used for pre-processing. After a large number of model calculation, it proves that the 3 D tetrahedral hybrid grid is more suitable for the requirements, the grid domain is too sparse to accurately describe the characteristics of the flow field, and the calculation error is large. When the grid number reaches a certain degree, the grid can reflect the actual situation and reduce the calculation speed. The grid model is shown in Figure 2:

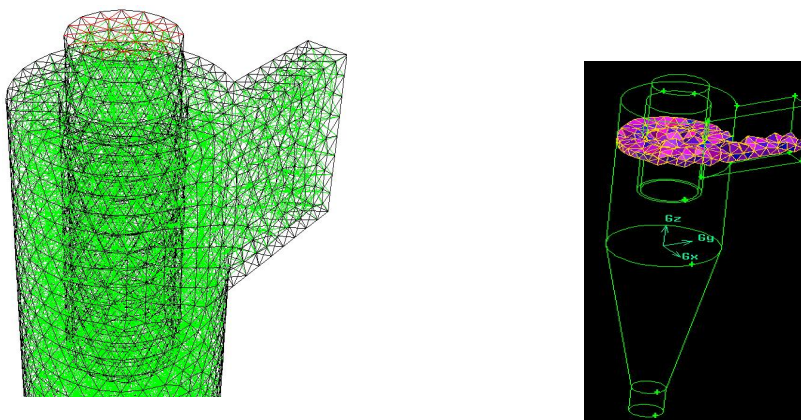
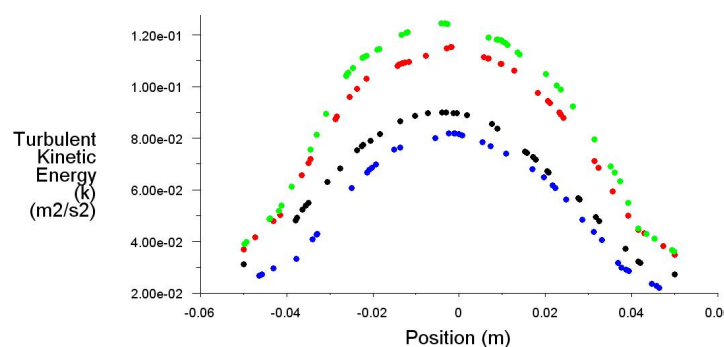


Figure 2 A. Numerical simulation of the grid model

### 2.2 Simulation results and discussion of turbulence degree

Turbulence is an important indicator to measure the strength of a material<sup>[4]</sup>, Is an important aspect of the flow field characteristics, which is mainly related to the imported Reynolds number, and ultimately affects the material separation efficiency. The simulation of turbulence is shown in Figure3:



$z = 0mm$   $z = 50mm$   $z = 75mm$   $z = 100mm$  Distribution curve along the radial turbulence direction in Figure 3

### 3. The development status of structural reliability analysis method

At present, the theoretical research on time-invariant reliability both at home and abroad has been relatively mature, while the time-varying reliability theory is more complicated due to more consideration factors, which needs to be further studied. Therefore, many scholars have conducted a series of studies on the time-varying reliability of reinforced concrete structure. And Czarnecki et al<sup>[4]</sup>It is found that the resistance of reinforced concrete structure changes significantly with time. A time-varying reliability model of reinforced concrete structure is put forward and predicts the service life of the structure. Frangopol<sup>[5]</sup>The degradation performance of the structure and the prior knowledge of the structure. Madsen<sup>[6]</sup>A new method for structural time-varying reliability and sensitivity analysis is proposed. Similarly, many domestic scholars are also actively exploring to promote the development of structural time-varying reliability analysis. Cheng Shoushan et al<sup>[7]</sup>Through the analysis of the structural resistance decay process caused by steel corrosion, the reliability evaluation and prediction method of the future state of the structure are established.

### 4. Parameters of the degradation model of reinforced concrete resistance

#### 4.1 Determination of the resistance parameters

The uncertainty of material performance mainly refers to the various variability caused by durability degradation, such as carbonization of concrete, section loss caused by corrosion of steel bar, rust swelling and cracking of concrete protective layer and mechanical performance degradation of corroded steel bar. Considering the uncertainty of the calculation mode, the resistance of the RC structure can be expressed by the following formula:

$$P(t) = K_r P_r(t) \quad (1)$$

$P(t)$  Where the ——— resistance stochastic process;

$K_r$  ——— Calculate the pattern uncertainty random variables.

$$\omega_{P_r}(t) = P[\omega_{f_{aj}}(t), \omega_{d_j}(t), \omega_{K_{sj}}(t)] \quad (2)$$

$$\sigma_{P_r}(t) = \frac{\beta_{P_r}(t)}{\omega_{P_r}(t)} \quad (3)$$

$$\beta_{P_r}(t) = \sqrt{\sum_j \left[ \frac{\partial \omega_{P_r}(t)}{\partial Z_j} \Big|_{\omega} \right]^2 \beta_{Z_j}^2(t)} \quad (4)$$

$Z_j$  In this equation, ——— affects the associated random variable of resistance

$\frac{\partial \omega_{P_r}(t)}{\partial Z_j} \Big|_{\omega}$  ——— The partial derivative is taken at the mean value.

It can be seen from the above derivation process that in order to get the statistical characteristics of the final resistance, we can first determine the statistical characteristics of some basic parameters included in the

resistance. With the current experimental means and research conditions, it is relatively easy for us to obtain the statistical characteristics of some parameters, and then through mathematical methods, we can obtain the uncertainty statistical law of the final model, so as to solve the problem that cannot be directly statistical.

#### 4.2 Statistical parameters of resistance to corrosion and bending members

Bending members are the most commonly used structural components in the service reinforced concrete structure. After many years of research, the bearing capacity calculation of corrosion bending members has been relatively mature. According to the relevant knowledge of concrete, the bending bearing capacity of the rectangular section positive section of the reinforced concrete structure corrosion member can be obtained from the following formula:

$$Y = \alpha_1 f_v l x (b - \frac{x}{2}) \quad (5)$$

$$x = \frac{B_{se} f_o}{\alpha_1 f_v l} \quad (6)$$

$Y$  Among them, the positive section bearing capacity of the —— structure (kN·m);

$f_v, f_o$  —— Axial compressive strength (MPa);

$\alpha_1$  —— Coefficient, its value according to the Code for Design of Concrete Structure;

$l, b$  —— Section width, section effective height (mm);

$B_{se}$  —— Equivalent section area of tensile reinforcement (mm<sup>2</sup>).

According to the above analysis, it is easy to know that through the parameter analysis of the model and starting from the uncertainty of the model parameters, we can finally obtain the relevant uncertainty statistical parameters of the resistance of the corroded bending members of the reinforced concrete structure.

### 5. Conclusion

The conclusion can be drawn from the above test and the simulation results

(1) UHPCC concrete materials in different circumstances, its compressive and folding strength change trend is the same, the strength is proportional to the age, at the same time. At a certain age, nanometer CaCO<sub>3</sub> was added. With the increase of incorporation, its compressive and folding strength will also be significantly improved, if nano CaCO<sub>3</sub>. If the amount is too high, the intensity of the increase is limited, and even the intensity will decrease.

(2) can be seen from figure 3, in the different radial position turbulence degree difference is obvious, its distribution and the tangential velocity distribution has a close relationship, distribution "hump" shape, in the center and the wall is small, and between the value, but the symmetry of the turbulence distribution, it also reflects the asymmetry of the flow field, related to the material size.

## Reference

- [1] Wang C, Yang C H, Liu F, et al. Preparation of ultra-high performance concrete with common technology and materials [J]. Cement and Concrete Composites, 2012, 34(4): 538-544.
- [2] Kang S T, Kim J K. The relation between fiber orientation and tensile behavior in an ultra high performance fiber reinforced cementitious composites ( UHPFRCC ) [J]. Cement and Concrete Research, 2011, 41(10):1001-1014.
- [3] Wang Dezhi, Meng Yunfang. Mechanical properties of concrete mixed with  $\text{SiO}_2$  and  $\text{CaCO}_3$  nanoparticles [J]. Ningxia Engineering Technology, 2011, 10(4):330-333.
- [4] Czarnecki AA, Nowak A S. Time-variant Reliability Profiles for Steel Girder Bridges[J]. Structural Safety, 2008, 30 (1): 49-64.
- [5] Okasha N M, Frangopol D M. Integration of Structural Health Monitoring in a System Performance based Life-cycle Bridge Management Framework[J]. Structure and Infrastructure Engineering, 2012, 8(11): 999-1016.
- [6] Madsen HO, Tvedt L. Methods for Time-Dependent Reliability and Sensitivity Analysis[J]. American Society of Civil Engineers, 2014, 116 (10): 2118-2135.
- [7] Cheng Shoushan, Zhang Jinquan, Li Wanheng. Reliability analysis of bridge structural performance degradation caused by steel bar corrosion [J]. Highway Traffic Technology, 2006, 23 (4): 33-36.