Effect of Nano-CaCO₃ on Concrete Compressive Strength

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Abstract: By comparing and analyzing the compressive test data of different content of nano-CaCO₃ concrete, the method of optimizing the compressive performance of nano-CaCO₃ concrete is proposed. Based on this, the influence of fly ash content on the compressive strength of nano-CaCO₃ concrete is studied, which provides a reference for improving the durability of concrete. Improve the recycling efficiency of building materials and accelerate the practical application of nano-CaCO₃ material concrete in engineering industry.

1. Introduction
Nanomaterials refer to at least one dimension in a three-dimensional space ranging from 1 nm to 100 nm. Because of its small size, it exhibits the small size effect, quantum size effect, surface interface effect and macroscopic quantum tunneling effect that macroscopic objects do not have, and is praised by scientists as "the most promising material in the 21st century" [1]. There are many researches on the replacement of cement by nanomaterials as admixtures. Li Guh ua et al. [2] studied the properties of nano-CaCO₃ and nano-SiO₂ and concrete mixed with silica fume. Ye Qing [3] of Zhejiang University of Technology has shown that nano-SiO₂ has higher volcanic ash activity than silica fume. Shaikh et al. [4] concluded that the fluidity of mortar, fly ash mortar and fly ash concrete decreased with the increase of nano-CaCO₃ content. Fuzhou University Jitao et al. [5] added nano-SiO₂ to fly ash coagulation, and carried out preliminary experimental research on its physical and mechanical properties. The results show that the addition of nano-SiO₂ can improve the compressive strength and flexural strength of 7d and 28d on the coagulation of fly ash.

In addition, after the fly ash is blended, although the total porosity of the concrete is not greatly reduced, the influence on the pore size distribution is large, and the edge pore diameter of the concrete is reduced. The relative number of harmful holes with a pore diameter greater than 100 mm is significantly reduced. The pore size is effectively refined, and the connectivity of the pore structure network of the slurry is deteriorated. While the fly ash is used to reduce the diffusion of chloride ions in the nano-concrete, the adsorption effect of capillary is also reduced.

2. The effect of nano materials on the performance of concrete
The research of nano-CaCO₃ in cement concrete is still in the exploration stage, and there are few reports at home and abroad. Therefore, the effect of CaCO₃ content on the mechanical properties of concrete is studied. The mechanical properties of concrete at 28 days of age is compared by group test. In-depth analysis is carried out to study the effect of adding nano-CaCO₃ on the mechanical properties of concrete, in order to provide a scientific basis for the application of nano-CaCO₃ in the concrete field. The addition of some nano-materials to concrete can affect the performance of concrete and adapt to the needs of some special buildings. Therefore, the application of nanomaterials in concrete has become a research hotspot in the current concrete industry.
In our experiment, we should study the effect of nano-CaCO$_3$ on the performance of concrete. In order to study the influence of nano-CaCO$_3$ on concrete, we adopted the control variable method. Maintaining the water-cement ratio, strength, sanding rate and cement strength of concrete at a certain level, only change the amount of nano-CaCO$_3$, so as to observe its influence on concrete. In order to carry out a comparative test, we changed the type of concrete, no longer plain concrete, and changed to fly ash concrete. The remains were unchanged. The amount of nano-CaCO$_3$ was changed to observe the effect of nano-CaCO$_3$ on fly ash concrete.

2.1. Effect of nano-CaCO$_3$ on the strength of concrete
Zu Tianyi believes that the incorporation of nano-calcium carbonate in ultra-high performance concrete can improve the compressive strength of ultra-high performance concrete (UHPC) and significantly improve its flexural strength. The reason may be that after the nano-CaCO$_3$ is incorporated, the CSH gel uses nano-CaCO$_3$ as the nucleus to bond on the surface of the nano-CaCO$_3$. The hydrated calcium silicate gel forms a network structure with nano-CaCO$_3$ as the core, which makes the interior of the concrete structure denser. The incorporation of a small number of nano-CaCO$_3$ particles can significantly reduce the orientation and dense distribution of Ca(OH)$_2$ at the matrix interface. From a physical point of view, nano-CaCO$_3$ can act as a micro-aggregate, filling between cement and other mineral micro-powder particles, improving the bulk density, reducing the porosity, reducing the internal defects of UHPC, and improving the mechanical properties of UHPC.

| Nano admixture (%) | Cement Content (kg) | Water Content (kg) | Sand Content (kg) | Cobble Content (kg) | Nano Content (g) |
|--------------------|---------------------|--------------------|-------------------|---------------------|------------------|
| 0.0%               | 1.282               | 1.519              | 4.658             | 0.642               | 0                |
| 0.5%               | 1.276               | 1.511              | 4.634             | 0.638               | 40.50            |
| 1.0%               | 1.269               | 1.504              | 4.611             | 0.635               | 81.00            |
| 1.5%               | 1.263               | 1.496              | 4.588             | 0.632               | 121.50           |
| 2.0%               | 1.256               | 1.488              | 4.564             | 0.629               | 162.00           |
| 2.5%               | 1.250               | 1.481              | 4.541             | 0.625               | 202.50           |
| 3.0%               | 1.244               | 1.473              | 4.518             | 0.622               | 243.00           |

After research, it is found that fly ash can play a favorable role in concrete, and the high-quality fly ash can be used reasonably in concrete, which can partially replace cement and make the engineering cost lower and improve the performance of concrete. So, in the experiment, we added fly ash as an aggregate, added different levels of nanomaterials, and observed how the resistance of compression will
Compressive strength is the main bearing capacity of buildings, so studying the compressive pressure is very helpful in understanding how to improve the performance of concrete.

2.2. **Nano fly ash compression test**

| Nano admixture (%) | Total content of cement fly ash (kg) | Water Content (kg) | Sand Content (kg) | Cobble Content (kg) | Nano Content (g) |
|--------------------|-------------------------------------|-------------------|------------------|---------------------|-----------------|
| 0.0%               | 1.282                               | 1.519             | 4.658            | 0.642               | 0               |
| 0.5%               | 1.276                               | 1.511             | 4.634            | 0.638               | 40.50           |
| 1.0%               | 1.269                               | 1.504             | 4.611            | 0.635               | 81.00           |
| 1.5%               | 1.263                               | 1.496             | 4.588            | 0.632               | 121.50          |
| 2.0%               | 1.256                               | 1.488             | 4.564            | 0.629               | 162.00          |
| 2.5%               | 1.250                               | 1.481             | 4.541            | 0.625               | 202.50          |
| 3.0%               | 1.244                               | 1.473             | 4.518            | 0.622               | 243.00          |

Note: This experiment studies the effect of nano-materials on the performance of concrete with quantitative fly ash. A quantitative amount of fly ash is used instead of 1/3 of the proportion of cement and different amounts of nano-materials are added. The total content of cement fly ash is consistent with the original cement content to form a single variable.

![Concrete compressive strength of nanometer 1/3 fly ash replacement rate](image)

| Nano admixture (%) | Total content of cement fly ash (kg) | Water Content (kg) | Sand Content (kg) | Cobble Content (kg) | Nano Content (g) |
|--------------------|-------------------------------------|-------------------|------------------|---------------------|-----------------|
| 0.0%               | 1.282                               | 1.519             | 4.658            | 0.642               | 0               |
| 0.5%               | 1.276                               | 1.511             | 4.634            | 0.638               | 40.50           |
| 1.0%               | 1.269                               | 1.504             | 4.611            | 0.635               | 81.00           |
| 1.5%               | 1.263                               | 1.496             | 4.588            | 0.632               | 121.50          |
| 2.0%               | 1.256                               | 1.488             | 4.564            | 0.629               | 162.00          |
| 2.5%               | 1.250                               | 1.481             | 4.541            | 0.625               | 202.50          |
| 3.0%               | 1.244                               | 1.473             | 4.518            | 0.622               | 243.00          |

Note: This experiment studies the effect of nano-materials on the performance of concrete with quantitative fly ash. A quantitative amount of fly ash is used instead of 1/4 of the proportion of cement and different amounts of nano-materials are added. The total content of cement fly ash is consistent with the original cement content to form a single variable.
Table 4. Compressive test material content of fly ash nanometer concrete

| Nano admixture (%) | Total content of cement fly ash (kg) | Water Content (kg) | Sand Content (kg) | Cobble Content (kg) | Nano Content (g) |
|--------------------|-------------------------------------|-------------------|-------------------|---------------------|------------------|
| 0.0%               | 1.282                               | 1.519             | 4.658             | 0.642               | 0                |
| 0.5%               | 1.276                               | 1.511             | 4.634             | 0.638               | 40.50            |
| 1.0%               | 1.269                               | 1.504             | 4.611             | 0.635               | 81.00            |
| 1.5%               | 1.263                               | 1.496             | 4.588             | 0.632               | 121.50           |
| 2.0%               | 1.256                               | 1.488             | 4.564             | 0.629               | 162.00           |
| 2.5%               | 1.250                               | 1.481             | 4.541             | 0.625               | 202.50           |
| 3.0%               | 1.244                               | 1.473             | 4.518             | 0.622               | 243.00           |

Note: This experiment studies the effect of nano-materials on the performance of concrete with quantitative fly ash. A quantitative amount of fly ash is used instead of 1/5 of the proportion of cement and different amounts of nano-materials are added. The total content of cement fly ash is consistent with the original cement content to form a single variable.

Test data analysis: It can be seen from the compression test line diagram that when the other dosages are constant, when the nano CaCO₃ content is 2.5%, the concrete compressive strength is the maximum.
at this time. As the amount of nano-CaCO$_3$ is increased, the compressive strength is continuously reduced. Therefore, the nano-CaCO$_3$ content is controlled at about 2.50%, which can appropriately improve the compressive strength of the nano-concrete. In addition, the nanocomposite has the highest compressive strength when the fly ash blending ratio is 1/5.

3. Conclusion
According to the results of the compression test of concrete mixed with nano-CaCO$_3$, the summary of the factors affecting its performance is as follows:

1) The particle size and high activity of nano-CaCO$_3$ increase the reaction area and route of cement slurry and enhance surface effects. Therefore, compared with the concrete specimen, the hydration reaction inside the concrete specimen with nano-powder is fast and fully developed. However, the nano-yield should not be too large, because the nano-based material consumes a large amount of hydrated water, which hinders the hydration process of the cement particles, and controls the nano-CaCO$_3$ content to be 2.50%, which can appropriately improve the compressive strength of the nano-concrete.

2) Studies have shown that adding proper amount of fly ash to concrete can reduce water consumption and increase concrete strength. However, the influence of fly ash on the performance of concrete has a peak. When the proportion of fly ash is 1/5, the effect of fly ash can be fully utilized. When the amount of fly ash is too much, the strength is decreased.

4. Outlook
The influence of nano-CaCO$_3$ on the performance of concrete. Most of the domestic and foreign research is on the strength, durability and frost resistance as well as axial fracture. However, considering the variety of nanomaterials and the instability of components, all research results have a certain degree of limitations. In order to make nano-concrete widely used in China, it is necessary to conduct a multifaceted research on this topic, and research nanomaterials to take the path of green sustainable development and apply it to life.

References

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