Different effects of steel fiber and nano-SiO$_2$ on epoxy resin concrete

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Abstract. Epoxy resin is a thermosetting resin, which has excellent mechanical, electrical and chemical properties, and is widely used in mechanical, chemical, electronic and other fields. Epoxy resin has the characteristics of high strength, good adhesion, good wear resistance, low price and so on, and has good adhesion with ordinary concrete, but epoxy resin also has some shortcomings. It has the defects of brittle crosslinking curing, poor impact resistance, poor stress cracking resistance and the like [1-3]. The effects of steel fiber and nano-SiO$_2$ on the mechanical properties of epoxy resin were compared in this paper.

1. Adding nano-SiO$_2$ experimental part

1.1 Material

The epoxy resin takes WSR6101(E-44) which has double A made in Wuxi Resin Industry. Nano silica is provided by Hangzhou Wan Jing new material Co. Ltd. The Performance is showed in table 1.

| Properties   | Value          |
|--------------|----------------|
| Surface area | 250 ± 30 m$^2$/g |
| Average particle diameter | 15 ± 5nm |

It can be seen from Table 1 that nanophase SiO$_2$ which surface area is 250 ± 30 m$^2$/g and average particle diameter is 15 ± 5nm. Curing agent (ethylenediamine) is made by Shanghai Reagent Factory; Acetone is produced by Xi'an Reagent Factory.

1.2 Preparation of test specimens

The powdered nano-SiO$_2$ is added to a solution of an appropriate amount of acetone, and treated with ultrasonic waves for 30 minutes. The pot in an oil bath is heated to about 130 $^\circ$C after stirring the solution and an epoxy resin mixed solvent removed, the epoxy resin and nano-SiO$_2$ reaction is about 1H. A curing agent (ethylenediamine) stoichiometric is mixed and poured into the vacuum degassing of steel mold coated with a release agent after cooling, the cured completely is cooled after demoulding, the mechanical properties of the test piece.

1.3 The performance testing

1.3.1 The tensile properties are tested according to GB1040-79 standard test. The machine used is LJ-500 type.

1.3.2 The impact properties are tested according to GB1043-79 standard test. The machine used is CHARPY XCJ-40-type.
1.3.3 *The Particle morphology of material is observed by Transmission electron microscope and scanning electron microscope.* The machine type is S-570 scanning electron microscope (Hitachi Ltd., Japan).

2 Experimental part of adde steel fiber

2.1 Material

Epoxy resin: WSR6101 (E 44), bisphenol A type was used in this experiment, curing agent: ethylene diamine, diluent: obutanol, toughening agent: dibutyl phthalate, polysulfide rubber: JLY-124 liquid polysulfide rubber, organic fibers: PP fiber; micro aggregates: P.O 42.5 cement, fine aggregate: ordinary sand.

2.2 Preparation of test specimens

The basic polymer mortar ratio of mixing is like this: the epoxy resin: ethylenediamine: isobutanol: Dibutyl: middle sand: polysulfide rubber: cement = 1:0.08:0.15:0.1:5:0.01:1.15. The isobutanol which different butanol according the workability and the mixture can be suitably changed. The mixture of polymer mortar was poured into standard test mode 40 x 40 x 160 mm at 20 ℃. After stripping, the mechanical property testing was carried out after 6 days[4-5].

3. Results and discussion

3.1. The mechanical properties of E-44/nm SiO₂ composite material

Nano-SiO₂ with different amounts effects mechanical properties of E-44/nm SiO₂ composite. It takes the epoxy resin as the base to be incorporated material SiO₂ to find five points dosage of 0%, 2%, 4%, 6%, 8%, which are measured impact values and the tensile value and the test piece is observed nano-SiO₂ ash on PC impact, tensile impact. Table 1 is about the mechanical properties of nm SiO₂ composite material.

| Table 1. The mechanical properties of nm SiO₂ composite material |
|---------------------------------------------------------------|
| SiO₂ Contents (%)  | 0  | 2  | 4  | 6  | 8  |
|---------------------|----|----|----|----|----|
| Tensile value (MPa) | 0.26 | 1.43 | 0.38 | 0.47 | 0.36 |
| Impact values (J/m²) | 0.65 | 1.24 | 0.75 | 0.64 | 0.60 |

It can be seen nm SiO₂ epoxy resin concrete has a toughening effect, within a certain range From Figure 1 to Figure 2. The impact strength and tensile strength of the composite material obtained gradually increased with the nmSiO₂ increasing of the content, when nm SiO₂/E-44 is 2/100 (mass ratio), these two properties have reached a maximum value (1.24 J / m, 1.43MPa), and the material of two kinds of performance declines with nm SiO₂ increasing in the amount.
Nano silica is a light amorphous white powder. It is non-toxic, tasteless, and non-polluting. The microstructure of nano-silica is flocculent and mesh. This special structure makes it has unique properties, especially its dispersion in the material when combined with polymer chains to form a three-dimensional network structure. So it can improve the basic properties of the material, such as strength, elastic etc.

3.2 Electron microscopic analysis of E-44/nm SiO2 composite material

Fig. 3 is an epoxy resin nano-composite material by the impact of the SEM photos. It can be seen from the figure, when the nano-composite epoxy system force will produce a lot of crazing. Nano-SiO2 particles are added to the epoxy resin, the surface of nano-SiO2 particles is serious lack of coordination, a large specific surface area characteristics, so that it is showed strong activity with the oxygen atoms of the epoxy-like molecules which are prone to key cooperation with, and enhance the bond force between the molecules. As part of nano-SiO2 particles are distributed in the gap of the polymer chain, and a high degree of liquidity, so the strength and toughness of epoxy adds and nano-SiO2 particles are increased greatly.

3.2.1 Effect of steel fiber content on mechanical properties of polymer mortar

The effect of dosage of steel on the mechanical properties of mortar was shown in table 2. steel was added according to the ratio of epoxy resin content in mass percentage, from 0% to 6%. The flexural strength and compressive strength were measured for each specimen and the ratio of flexural strength and compressive strength was also shown in Table 2.
Table 2. Effect of dosage of steel on the mechanical properties of mortar

| Dosage of Polysulfide rubber (%) | Flexural strength (MPa) | Compressive strength (MPa) | R   |
|----------------------------------|-------------------------|----------------------------|-----|
| 0                                | 24.3                    | 66.3                       | 0.37|
| 1.5                              | 27.2                    | 68.1                       | 0.40|
| 3.0                              | 30.5                    | 70.5                       | 0.43|
| 4.5                              | 28.1                    | 66.9                       | 0.42|
| 6.0                              | 23.9                    | 65.6                       | 0.36|

*R = flexural strength / compressive strength

Fig. 4 Effect of dosage of steel on the flexural strength of mortar

Fig. 5 Effect of dosage of steel on the compressive strength of mortar

Fig. 6 Effect of dosage of steel on the R of mortar
It can be seen from figure 4 to figure 6 that both the flexural strength and compressive strength of the mortar increased first and then decreased along with the steel fiber content increases\cite{6}. When the steel fiber PC content is 3\%, the bending strength of PC increased by 26\% and the compressive strength increases 6\%. The fluctuation of the ratio between flexural strength and compressive strength of PC is very small\cite{7}. This stable performance is in need in practice.

3.2.2 Micrographs of mortar

\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{fig7.png}
\includegraphics[width=0.4\textwidth]{fig8.png}
\caption{Micrographs of mortar (without fiber) \hspace{1cm} Micrographs of mortar (with fiber)}
\end{figure}

In can seen from figure 7 and figure 8 that steel fiber surface is smooth and without apparent attachment. This indicated that the combination between polypropylene fiber and polymer concrete surface was loose\cite{8}.

4. Results

It can be seen from the above experiments that nano-SiO$_2$ particles have certain compatibility with epoxy resin, and proper addition of nano-SiO$_2$ can enhance the strength and toughness of epoxy resin. When the content of nano-SiO$_2$ is low, the tensile strength of epoxy resin is not obviously affected. When the content of nano-SiO$_2$ increases, the tensile strength of epoxy resin decreases, but the modulus of elasticity increases obviously.

For adding steel fiber into epoxy resin concrete, the incorporation of steel fiber changes the force transmission path in PC, which inhibits the expansion of cracks in concrete to a certain extent, thus improving the compressive strength, flexural strength and flexibility of polymer concrete. However, when the content of steel fiber is too small, the strength of concrete is not obviously improved. The excessive amount of steel fiber will lead to the generation of internal voids in concrete, that is, the increase of internal crack sources, and ultimately lead to premature failure and strength reduction of specimens.

Acknowledgments

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