MATERIALS TO IMPROVE TENSILE STRENGTH OF CONCRETE AT MICRO LEVEL

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ABSTRACT

Concrete is defined as a composite material, which is weak in tension and strong in compression. It becomes very essential to improve the tensile strength of concrete at micro level, to make durable concrete structures. Researchers from various countries are using various materials to improve the mechanical properties of concrete at micro and nano level. In this study, past studies of using various materials are analyzed. This literature survey is to summarize the past experimental data on the properties of concrete with nano particles, nano tubes, nano fibers and waste steel wires. As a solution tensile strength of concrete can be improved up to certain limit with the use of all these materials. Apart from this utilization of waste steel wires is also an eco-friendly phenomenon to improve the mechanical properties of concrete.

KEYWORDS: Tensile Strength, Nano Materials, Nano Tubes, Nano Fibers, Waste Steel Wires

INTRODUCTION

Concrete is the most common material used in the construction industry in India and all over the world. Concrete mixes are designed to provide a wide range of mechanical properties to meet the design requirements of a structure. As concrete is used in the design of several tensions conditioned structures, though it is not a potential material due to very inadequate tensile strength compared to its compressive strength. In the recent century, very wide and effective research has seen on improving the mechanical properties of the concrete with incorporating wide range of supplementary cementing material such as pozzolans and nano particles due to increasing the use of concrete. Fibers can also be used in concrete to achieve tensile strength.

Concrete is a complex material consisting of several phases. In order to effectively reinforce and improve the response of concrete to loading, crack growth must be abated at the macro, micro, and nano. The use of pozzolonic materials, fibers and nano particles, is not only effective but also provides insight into the nanostructure of these composites. The hybridization was found to enhance the split tensile strength of the concrete. The tensile strength of concrete is much lower than the compressive strength, largely because of the ease with which cracks can propagate under tensile loads. Although tensile strength is usually not considered directly in design, while its value is still needed because cracking in concrete tends to be of tensile behavior. Concrete can be considered as a brittle material, and the tensile strength of a brittle material is due to the rapid propagation of a single flaw or micro crack.
Researchers from all over the world are focusing on improving the mechanical properties of the concrete with incorporating wide range of supplementary material such as fibers, steel wires and nano particles due to increasing the use of concrete. The use of steel wires, fibers and nano particles, is not only effective but also provides insight into the nanostructure of these composites.

So, the aim of this review paper is to spread awareness of using different materials to improve the mechanical properties of concrete.

**NANO PARTICLES**

**Ferric Oxide Nano particles (Fe$_2$O$_3$)**

Ferric oxide nano particles can be use in cement concrete or mortar to improve the mechanical properties. The characteristics of the Fe$_2$O$_3$ nano particles are shown in Table 1.

<table>
<thead>
<tr>
<th>Nano Particles Type</th>
<th>Diameter(Nm)</th>
<th>Specific Surface Area (M$^2$/G)</th>
<th>Purity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fe$_2$O$_3$</td>
<td>30</td>
<td>60</td>
<td>99</td>
</tr>
</tbody>
</table>

Yazdi et al (2011) studied the mechanical properties of cement mortar. The authors have studied the tensile as well as compressive strength of cement mortar by replacing Fe$_2$O$_3$ nanoparticles by 1%, 3% and 5% weight of binder. It is quite obvious from the data that there were desirable mechanical properties in samples containing 1% and 3% Fe$_2$O$_3$ nanoparticles compared to control mix. At 1% replacement level, the structure of mortar is compacted as compared to reference mix while large Ca(OH)$_2$ crystals were still observed. As the replacement reaches to 3% the Ca(OH)$_2$ crystals were removed and the microstructure of the mortar becomes completely compacted. The mechanism of Fe$_2$O$_3$ nanoparticles which increases the strength of cement mortar was the addition of Fe$_2$O$_3$ nanoparticles, this addition reduces the quantity and size of Ca(OH)$_2$ crystals and fills the voids of C-S-H gel structure and ultimately the structure of hydrated products become denser and compact. In contrast, as Fe$_2$O$_3$ nanoparticles increased up to 5%, the mechanical properties become critical. The main cause behind this stage was their high surface energy and has the tendency towards agglomeration. As nanoparticles were added more than this level the non uniform distribution was observed in mortar and due to agglomeration, weak zone appear in the cement mortar.
Nazari et al. 2010b conducted the study by replacing of nano-Fe$_2$O$_3$ particles up to maximum replacement level of 2.0%. The authors have concluded that there was improvement in split tensile strength. However, the ultimate strength of concrete was gained at 1.0% of cement replacement. Authors studied the influences of nano Fe$_2$O$_3$ on tensile strength of binary blended concrete. Nanoparticles react with calcium hydroxide produced from the hydration of calcium silicates. The rate of the pozzolanic reaction was proportional to the amount of surface area available for reaction. In nutshell it can be concluded that it is possible to add nano- Fe$_2$O$_3$ of a high purity (99.9%) and a high Blaine fineness value (60 m$^2$/g) in order to improve the characteristics of cement mortars at significant level.

**Copper Oxide Nanoparticles (CuO)**

Incorporation of other nanoparticles is rarely reported. Therefore, introducing some other nanoparticles which probably could improve the mechanical and physical properties of cementitious composites is inherent. CuO nanoparticles with the average particle size of 15 nm were used.

<table>
<thead>
<tr>
<th>Nano Particles Type</th>
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<th>Specific Surface Area (M$^2$/G)</th>
<th>Purity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CuO</td>
<td>15</td>
<td>60</td>
<td>99.9</td>
</tr>
</tbody>
</table>

Nazari and Riahi 2011 studied that CuO nanoparticles were able to improve the split tensile strength of concrete. The authors have concluded that the replacement of CuO nanoparticles partially with cement up to 4% by weight of cement would accelerate the formation of C-S-H gel, as a result of increased crystalline Ca(OH)$_2$ amount at the early ages of hydration. As the replacement was further increased beyond 4% by weight of cement causes unsuitable dispersion of nanoparticles in concrete matrix. This will ultimately decrease the split tensile strength.

**Carbon Nano Tubes**

Carbon nanotubes are a form of carbon having a cylindrical shape, the name coming from their nanometer diameter. They can be several millimeters in length and can have one “layer” or wall (single walled nanotube) or more than one wall (multi walled nanotube).

![Figure 2](image)

Abinayaa et al. 2014 studied the replacement of Multi Walled Carbon Nano Tubes (MWCNT) by weight of cement in 0.015%, 0.03%, and 0.045% percentages respectively. The authors have summarized the experimental data on the properties of concrete with MWCNT. As a solution carbon nanotubes, which consists of multiple sheets of graphite rolled...
to form a cylindrical structure and stacked concentrically was used. It can be conclude that due to strong Van de Waals forces & electrostatic forces MWCLT tend to aggregate. The ultrasonic dispersion techniques were adopted to disperse them uniformly. Tensile tests have been conducted on the specimens in the past experimental programs. There was about 66.3% increase in the split tensile strength of concrete increased for 0.045% of multiwalled carbon nanotubes.

CARBON NANO FIBERS

The carbon nano fibers (CNFs) which exhibit a cylindrical nanostructure with graphite planes when extend beyond the diameter of the nanofiber are mainly used. The morphology of the nanofibers with the graphite planes are presented in Figure. The graphite edges which exhibit along the circumference of the fiber can be used to effectively embed the nanofibers in the cement matrix, improving the interfacial bond and enabling more sufficient load transfer across nanocrack and pores.

![Figure 3](image)

Figure 3

Generally it can be observed that the addition of carbon fibers cause a significant increase in the splitting tensile strength relative to the reference specimen (without fiber). The percentage increase is about 45% for concrete with fiber volume fraction 0.5% at age of 28 days. It can also be seen that the splitting tensile strength increases as the fiber volume fraction increases for all ages. It was observed that the splitting tensile strength increases with age, especially for concrete with fiber volume fraction 0.5%.

WASTE STEEL WIRES

Waste steel wires are obtained from reinforcement and formwork which are previously utilized in construction projects. These can be used as reinforcement in structural light weight concrete. The shape of the wires was almost straight.

![Figure 4](image)

Figure 4
Aghae K and Yazdi M A conducted the study on the use of waste steel wires in lightweight concrete. The authors have cut down waste wires of the length and diameter of 50 ± 10 mm and 1.2 mm, respectively. In experimental work three mixes with volume fractions of 0.25%, 0.5% and 0.75% of waste wire reinforced concrete were prepared. It can be concluded from the results shown that the utilization of waste steel wires in lightweight concrete, the splitting tensile strength of concrete increases effectively. The splitting tensile strength of waste steel fibers reinforced concrete (WFRC) was increased by approximately 28% on average through the addition of fibers at ratio of 0.25%, 0.5% and 0.75% in volume fraction of the concrete. On the whole, the addition of waste steel wires just by 0.25% volume fraction of fiber into lightweight concrete, splitting tensile strength of WFRC increases, significantly.

CONCLUSIONS

- Carbon nano tubes are very effective to enhance the tensile strength of concrete, with their use of 0.045 % by weight of cement; we can increase tensile strength up to 66%.
- With the help of nano particles, we can increase the tensile strength at nano level.
- For concrete with Carbon fiber volume fraction 0.5%, best results of tensile strength are achieved. It is increased up to 45%.
- Waste steel wires are also effective; as their percentage is increased strength is also increased.

REFERENCES
