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Application of Smart Nano Materials in Construction Industry- A Review

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Abstract
For sustainable development use of the new, innovative materials and technology in construction is the need of the hour. To meet the infrastructure demand for ever growing population, materials' demand is increasing. For infrastructure construction and operation, it requires large volume of materials, large energy inputs and generates large pollution and waste flows. Nano-technology is a technology that enables to develop materials with improved or totally new properties. Materials reduced to Nano-scale materials can suddenly show very different properties compared to what they exhibit on a macro scale, enabling unique applications. The chemical and physical properties of materials at the Nano materials enable novel applications ranging from structural strength enhancement and energy conservation, fire protective and heat insulating coatings wear and abrasion resistance and self-cleaning surfaces.
Concrete is a material most widely used in construction industry. Since the use of finer particles (higher surface area) has advantages in terms of filling the cement matrix, densifying the structure, resulting in higher strength and faster chemical reactions, hence, the materials such Nano-Titania (TiO_2), Carbon nanotubes, Nano-silica (SiO_2) and Nano-alumina (Al_2O_3) are being combined with Portland cement to improve the quality of concrete. Present paper discusses the applications of nano materials in construction industry based on literature and research. The results of research carried out at Central Soil and Materials Research Station using Nano-silica in geopolymer concrete is also discussed showing positive effects of Nano silica addition on the strength of concrete.
Keywords: *Nano composites, Nano-silica , Nano-Titania, Carbon nanotubes , Geo-polymer, Compressive Strength.*

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I. INTRODUCTION

Nanotechnology has changed and will pursue to change our perception, expectations and abilities to control the materials world. Several applications have been developed for this specific sector to improve the energy efficiency, durability of construction elements, and safety of the buildings, delivering the ease of maintenance and to provide increased living comfort. The role of nanotechnology in conceiving of innovative infrastructure systems has the potential to transform the civil engineering practice. At the moment, the ever-increasing need of the society to houses and buildings has made the need for applying new methods and building materials with the purpose of increasing the construction speed, using lighter materials, the useful life of buildings and strengthening them against earthquakes more urgent. Therefore, the construction industry is one of the important industries in which nanotechnology and nanomaterials can have extensive applications[1-8]. Nanotechnology covers all research, surveying, producing and application activities which are related to molecular structures that range from inner to outer surfaces of a substance, where at least one of its dimensions have a tolerance level of less than 100nm. Construction industry is one of those industries in which nanotechnology can have many applications. With its requirements in terms of strength, resistance, durability and high efficiency, this industry is considered as one of the main users of nanostructures. It is expected that in a not too distant future, nanotechnology would make the functional extent of building materials take a huge leap in areas like energy conservation, light, safety and being smart. As a whole, some of the areas of the construction industry in which nanotechnology can cause developments could be summarized as follows:

- Producing strong and smart building materials besides repairing and reconstructing the existing structures.

- New methods to produce substances and building materials that have a significant effect on reducing water and energy consumption and would produce much less wastes. Moreover, developing environment sustainability-based production methods that can recycle constructional products and by-products is one of the areas which nanotechnology has influenced.

- Increased understanding of architects of the Nano scale and its effects.
- Modified Nano scale substances and building materials.
- Strong and super-strong structural building materials.
- Multi-purpose thin films, coatings and paint
- Smart structures and using micro sensors.
- Integrated monitoring and diagnosis systems.

1.1 Applications of Nanotechnology in Structural Building Materials

Concrete

"Concrete is one of the most common and frequently used building materials. Consumption of energy and the carbon dioxide which is produced during the production processes of cement, concrete and wastes are the most important environmental issues related to concrete production and use. Nanotechnology has been a great help to researchers in the field of concrete industry. In fact, it has led to the production of new cements, concretes, additives and Nano composites. According to conducted studies, adding nanoparticles would improve the durability of concrete through physical and chemical interactions like concrete pore fillers. By adding fibers that are nanometers to micrometers long and are made of carbon, steel or polymers, researchers have reinforced concrete. Experiments have shown that after 28 days, the compressive strength of these concretes is doubled compared with ordinary concretes that are traditionally reinforced. Also, the developments of such materials guide building constructors to reduce their cement consumption by 50 percent compared with normal conditions.

1.2 Nano-silica and Self-healing Concretes

"In the concrete industry, silica is one of the best known substances that play an important role in a concrete's cohesion and pore-filling properties with a high degree performance. To get a better result, nanoconcrete is included in the concrete-cement mixture which besides being more cohesive, it increases its adhesion and integrity as well. Adding Nano-silica

(SiO_2) to concrete can improve its mechanical properties by creating more compressed micro particles and nanostructures. In fact, Nano-silica increases the durability of concrete by reducing the calcium level in the water that is needed for soaking the cement and also, by decreasing water penetration. Moreover, it helps adding more fly ashes to the concrete without affecting its strength and curing speed which in turn, causes the durability and strength of concrete to increase and the cement consumption to reduce.

"Self-healing concrete is another achievement of nanotechnology. There are researches that are still being conducted on this type of concrete. When this concrete cracks, microcapsules that are placed in it are broken and release the healing agent into the damaged area through the capillary action. The said agent contacts the catalyzer embedded inside the concrete and releases a polymer, which fills the crack's surface. In test cracks, self-healing composites regained their initial strength up to 75%. Usually, they can double or triple the life of structural compounds compared with normal conditions. This concrete can be used for repairing microcracks in bridge and dock columns.

1.3 Carbon Nanotubes

One of the greatest discoveries relevant to nanotechnology is nanotubes. These tubes are plates made of carbon atoms that move inside a roller-like compartment and they seem like wire screens that are coated on one side. Carbon nanotubes are hollow and usually made of carbon sources such as graphite. Due to characteristics such as their vast specific surface area, great strength of up to several times more than steel and also, exceptional electric and electronic properties, they have applications like being a catalyst and a mechanical booster of polymers and composites and are used in manufacturing electronic parts. They are ten times stronger than steel, while weighing one sixth of its weight. In the concrete industry, these nanomaterials can be used as fibers for flattening and modifying the mechanical function of concrete. In this field, carbon nanotubes can play an important role as multi-purpose building materials of high degree performances compared with steel and aluminum. Stress and compressive resistances of the said nanotubes are much higher compared with those of other building materials.

1.4 Nano-Titania (TiO_2),

Anatase, rutile, brookite are some of the crystalline forms in which TiO_2 exists in nature. High refraction index is one of the properties of TiO_2. When exposed as a coating on the tiles of pavements, concrete, self cleaning glasses, outdoor paints, TiO_2 exhibit photo catalysis, whereby on absorption of UV rays electronhole pair are created, which undergo further reaction to create hydroxyl radicals which oxidize pollutants such as oxides of nitrogen into nitrates thus helping to reduce pollution.

1.5 Nano coatings

Smart Nano coatings are one of the most important achievements of nanotechnology in the field of producing materials. In addition to their various and multi-purpose functions, nanocoatings are quite effective in saving energy and in reducing the costs. They can turn every surface to a smart, anti-corrosion, anti-radar, anti-fog (and mist), air purifier, surface cleaning and an active biological coating. Benefiting from active nanoparticles such as titanium dioxide in their structures, these coatings are capable of showing smart protective, healing, absorbing, repulsive and neutralizing reactions to environmental stimuli such as light, heat or sensitivity to some chemical changes like corrosion.

1.6 Nano cement

A combination of Nano silica, sodium aluminate, and sodium hydroxide gives Nano cement. Reducing carbon-dioxide emissions alongside providing high compressive strength (50% replacement of nanocement along with mortar gives strength up to 86.97 N/mm2 at the end of 21 days) and avoiding air gaps by virtue of large specific surface area (3582400 cm2/gm) are some of the properties offered by addition of Nano cement to the construction materials. Reduction of penetration of water, filling up air spaces, increasing compressive strength over a prolonged period of time are some of the positive results obtained on mixing nanoparticles like carbon nano tubes and composites, in the conventional cement. High magnitudes of tensile and flexular strength that is strong enough to withstand vibrations due to earthquakes with a prolonged longevity coupled with immunity against attack of corrosion, chemicals, penetration of water, is obtained on incorporation of nanocement fibers in the ultra high performance materials

II. MATERIALS

2.1 Materials and Mix Proportion

1. Fly ash: - Low Calcium (ASTM Class F) dry fly ash obtained from N.T.P.C Thermal Power plant (Rasulpur) Dadri, district- G.B Nagar, U P. has been used as the base material.
2. Aggregates:- Locally available aggregates, comprising 10 mm coarse aggregates in saturated surface dry condition, were used. The coarse aggregates were crushed to granite-type aggregates.
3. Alkaline liquid:- The alkaline liquid used was a combination of sodium silicate solution and sodium hydroxide solution.
4. Nano silica:-CemSyn®-XTX, is a series of silica based binders /fillers obtained from Bee-chem Chemicals Ltd., Kanpur.

State - Dispersed in water
Active Nano Content (%W/W) - 30.0-32.0%
pH (20°c) - 9.0-10.0
Specific gravity – 1.20-1.22
Particle size - 10 nm

5. Mix proportions and curing:- From the different trial mixes, this mix proportion has been adopted for study.

- Total aggregates percent taken as 70%.
- Alkaline to fly ash ratio taken as 0.45.
- Sodium hydroxide (NaOH) molar concentration 12M.
- Sodium hydroxide solution(NaOH) to sodium silicate solution (Na_2SiO_3)ratio taken as 2.5.
- Heat curing in oven, at 60˚C.
- Nano silica with 2%, 4%, 6% and 8% of fly ash by weight.

III. EXPERIMENTAL

3.1 Preparation of alkaline liquids

The sodium hydroxide (NaOH) solids in form of pellets were dissolved in water to make the 12 M .The sodium silicate solution and the sodium hydroxide solution were mixed together at least 24 hrs prior to use to prepare the alkaline liquid. On the day of casting of the specimens, the alkaline liquid was mixed together with the super plasticizer and the extra water (if any) to prepare the liquid component of the mixture.

3.2 Manufacture of Fresh geo-polymer Concrete and Casting.

First, step is that the fly ash and the aggregates were first mixed together in the 10-litre capacity laboratory concrete pan mixer for about 4-5 minutes. Then secondly, the liquid component(alkaline liquids) of the mixture was then added to the dry materials and the mixing continued for further about 6-8 minutes to manufacture the fresh concrete .Before the fresh concrete was cast into the molds, the slump value of the fresh concrete was measured. Then the fresh concrete was cast into the molds. For compaction of the specimens, each layer was given 60 to 80 manual strokes using a rod bar, and then vibrated for 40-50 seconds on a vibrating table. Casting of cubes are presented in Figure 1 & 2.


Figure 1: Casting on Vibrator **Figure 2: Casted Molds**

3.3. Curing of test specimens

After casting, the test specimens were covered with aluminum foil film to minimize the water evaporation during curing at an elevated temperature. The specimens were heat-cured at 60°C for 24 hours. After the required curing period, the test specimens were left in the molds for at least 4-6 hours in order to avoid a drastic change in the environmental conditions. After demoulding, the specimens were further heat-cured at 60°C for 72 hours to gain their desired strength. Cubes and curing procedure are presented in figure 3 & 4.

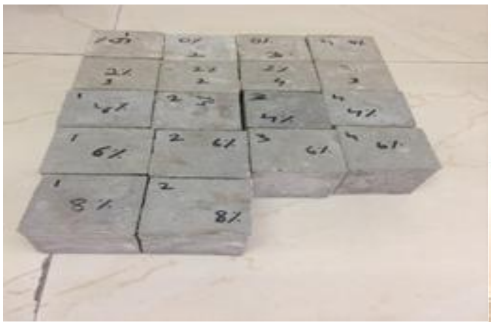


Figure 3: Casted Cubes **Figure 4: Curing of Cubes**

3.4 Compressive Strength Test

For each series of tests, a set of standard size of 15 cubes were manufactured. The cubes are of 70.5 mm X 70.5 mm dimensions. All The specimens were tested at 3days after casting to determine the compressive strength at different ages in accordance with the test procedures given in the Indian Standard Codes. Compressive strength test with CTM is presented in figure 5.

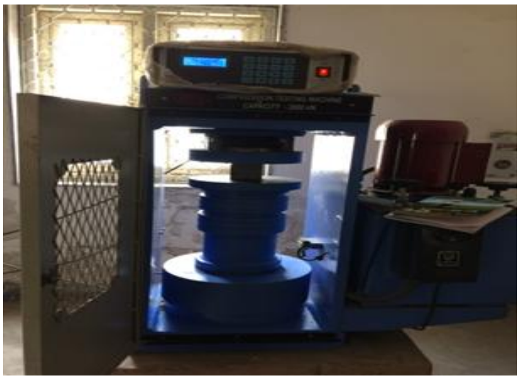

Figure 5: Compressive Strength Testing Machine. CTM

IV. RESULTS AND DISCUSSIONS

For each batch of geo-polymer concrete made in this study, 70.5x70.5 mm specimens were prepared. At least three of these cubes were tested for compressive strength at an age of three days after casting. The unit weight of specimens was also determined at the same time. For these numerous specimens made from Mix design and cured at 60^{o}C for 72 hours, the average results are presented in figure 6.

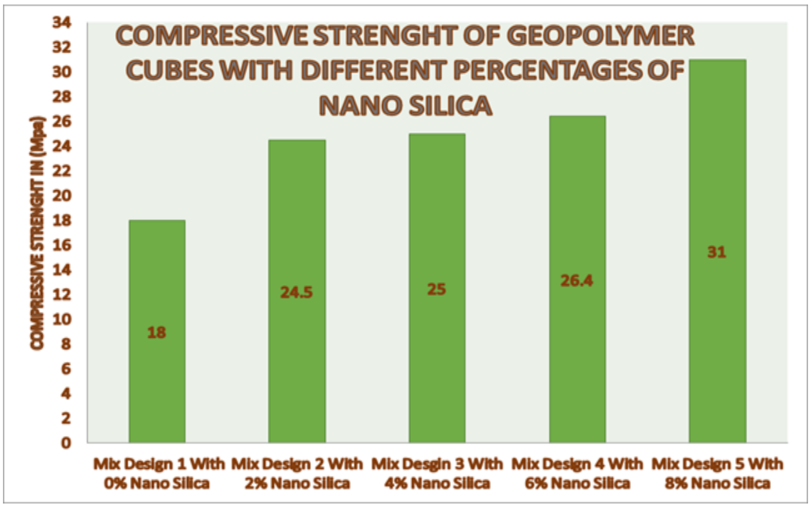

Figure 6: Compressive Strength

The test results shows that the geo-polymer concrete having 8% of Nano silica shows highest compressive strength with respect to 2%, 4%, 6% Nano silica. The compressive strength of fly ash-based geo-polymer concrete increased as the percent of Nano silica addition in concrete mix increased.

V. CONCLUSIONS

The application of nanotechnology in the field of construction industry has remarkable future. The development of new materials helps the civil engineers in tackling various challenges that encountered during various stages of building constructions. Using nanotechnology helps less energy consumption in a building, which is considered one of the main concerns of the world today. Nanotechnology reduces mankind's need to rare materials and by decreasing the level of pollutants in the process of producing building materials, eventually reduces environmental pollution. It is hoped that by providing necessary conditions, using nanotechnology in the construction industry would lead to creating safer buildings of higher qualities that are cost effective. The results obtained so far shows that geo-polymer with Nano silica addition possess good compressive strength which is almost comparable to cement concrete. The successful mixed design approach is another significant aspect of this study as the geo-polymerization required very selective materials and controlled conditions of curing. To achieve strength without cement will open new era of green concreting in future.

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