The Future of Civil Engineering with the Influence and Impact of Nanotechnology on Properties of Materials

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Abstract

It is true that nanotechnology has become one of the influential technologies in this century since it has been successful in fascinating all most all manifolds of technology, like that it has also embraced the field of Civil Engineering. More particularly the construction sector finds its advantage with nanotechnology, construction industry needs more material and energy resources. Among all the materials used in construction, concrete occupies nearly 70\% of the materials by volume and shows significant impact. The advent of nanotechnology helped in producing more strong and durable material than conventional materials. Nanotechnology in making concrete refers to the production and addition of nanosized particles in to concrete at suitable proportions by appropriate methods. The basic purpose of using nanosized materials in concrete is to improve compressive and flexural strengths at early age, it is possible due to the high surface – to volume ratio. It also helps to improve the pore structure of concrete. Nanosized materials help to reduce porosity as they absorb less water compared to traditional cementitious materials. The presence of nanomaterials reduces the amount of cement content in concrete than the conventional concrete. This can be achieved without sacrificing strength characteristics, thereby it is possible to produce eco friendly concrete called green concrete. This paper tries to review how nanotechnology is used in civil engineering and its effects on various nanomaterials viz. steel, glass, wood and the paper also throws a special focus on concrete how does it affect various properties of materials.

Keywords: Nanomaterials; concrete; flexural strength; porosity; green concrete; Durability

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1. Introduction

In fact the term nanotechnology offers very much elaborate meaning and vast scope that may be changed from field to field. Generally it refers to the process of understanding, controlling and restructuring of matter on the basis of size (0.1 to 100nm) to develop materials with fresh (new) properties and functions. Nanotechnology has many folds and applications in almost all engineering fields. As far as its application concerned with civil engineering is very significant since the branch itself deals with various types of construction materials. The properties of various materials may be enhanced by the applications of nanotechnology. Nanotechnology paves the path for getting most economical infrastructure, offers longer durability with low cost maintenance. The advent of nanotechnology has revolutionized the growth of the civil engineering in the areas like application of protective coatings to prevent corrosion and salt water attacks to the pipes, reducing heat transfer (fire retarders). The application of nanotechnology has been proved successful in making insulators, nano sensors, smart and eco friendly materials. In fact nanotechnology is not either a new science or technology but an enhancement of existing technology. The word “Nano” was derived from the Greek word dwarf which indicates a billionth part. Nanometer means billionth of a meter. There are two approaches to the nano scale one is from the top down another is from the bottom up. The top down approach refers to reduction of size from large to smallest size where as bottom up approach refers to the construction of materials from atomic or molecular components.

2. Nanotechnology in Civil Engineering

According to the surveys conducted in Sweden and UK it came to know nanotechnology has been emerged as a promising technology in the construction industry. More importantly its influence is very much significant in concrete products. It was also identified that construction industry is one of the important sectors which will be influenced by nanotechnology. A lot of research and development initiations are being organized to bring out many more innovations in nanotechnology relevant to construction industry. A lot of investments were made by venture capitalist and industrial corporations to unleash the potential in construction sector by the applications of nanotechnology. By identifying those potential European commission in late 2002 allotted huge funds for initiating research by name GMA1-2002-72160 “NANOCONEX”. Nanotechnology is identified as a vital application to the advancement of Civil Engineering field. Its applications are very much significant in the construction portfolio of Civil Engineering.

3. Nanotechnology in Concrete

Compared to the other form of materials used in construction concrete is one of the most common and predominantly used constructional materials. Concrete is a heterogeneous, nano structured, multi phase, construction material consist of various sizes of small crystals. It is widely used in almost all construction activities. We can’t assume any construction without concrete. It occupies nearly 70% of the volume of the structure. Cement is one of the vital components used in manufacturing of concrete, but cement has some disadvantages. A lot of research has been carried out in order to reduce the proportion of cement in the concrete. Nanotechnology has been emerged as a best tool to address many problems associated with ingredients of concrete. Nanotechnology is used to study many properties of concrete like heat of hydration, alkali aggregate reaction particularly alkali silicate reaction. The presence of alkali and silica in cement and aggregates causes ASR. If the amount of cement content is replaced by the use of Pozzolona it reduces the occurring and severity of alkali silicate reaction. The properties of concrete may be altered in so many ways, one of the best ways is the incorporation of nano particles. Nano particles in terms of nano silica, nano clays, nano titanium Oxide (TiO₂), Nano Iron (Fe₂O₃), Nano alumina (Al₂O₃), CuO, ZnO₂ and ZrO₂. Nanomaterials in concrete will improve the pore structure of concrete, speed up the C-S-H gel formation and improve the concrete mechanical and durability properties. More particularly fly ash improves durability and strength of the concrete to the maximum extent but due to the addition of fly ash the early strength of the concrete may be reduced. The problem of low strength at early stage may be overcome by the incorporation of Nano-Silica which improves the density and structure of the concrete. The addition of Nano- Silica improves resistance to segregation and also augments the strength of hardened concrete and offers more repulsion towards water
absorption and prevents calcium leaching. Nano iron imparts the ability of self-sensing and also improves its compressive and flexural strength. Nano titanium helps the concrete for self-cleaning. It is experimentally proved that how nanotechnology enhanced the life span of bridges. As per the study conducted by National Institute of Standards and technology, US, in 2007, it came to know that almost one quarter of all bridges in the country were damaged because of the attack of chloride and sulfate ions on concrete. The ions of sulfate and chloride that entered concrete caused cracks led to internal structural damage. They made an experiment to double the life span of structures by changing the viscosity of the solution in concrete at the micro scale in order to reduce the speed of entry of chlorides and sulfates into concrete. In fact cracking in concrete is a major problem leads to the failure of structures. The University of Illinois Urbana worked on healing polymers the study also focused on micro capsule healing agent and catalytic chemical agent. The microcapsules are broken by cracks developed in concrete at that time the healing agent is released in to the crack and contact the catalytic chemical agent. During the process polymerization happens and bond the crack faces. This is mostly suitable for filling the micro cracks formed in piers and columns of bridges. Protection of existing structures from decay also become a challenge to the engineers. Fibre wrapping in this regard has become a common technique for increasing the strength and durability of existing structures. The technology involves, use of fibre sheet containing nano silica particles and hardeners. When the fibre sheet is wrapped with the concrete surface the nano particles enter into the concrete cracks and they close the cracks on the surface of the concrete. It is also proved experimentally that self consolidating nano fibre concrete column failed at higher loads with larger deflections that the columns made up of steel confined reinforced concrete. It is also understood that the self compacting concrete column with nano fibre is stiffer than steel reinforced concrete column.

4. Nanotechnology in Steel

Steel is one of the most vital and indispensable material in construction activity. Though steel is good in tension it has a problem with fatigue. Fatigue is a major problem leads to the failure when it is subjected to cyclic loading. Fatigue of the steel will be reduced by adding copper nano particles. When copper nano particles are added to the steel the surface of the finished steel become smooth and even. This evenness of the surface may reduce the stress, hence the steel may have less stress risers and fatigue cracking is also limited. New generation steel is also developed with higher corrosion resistance. New stainless steel is also developed and will be suitable in light weight structures and rigid bridges. MFX steel corporation U.S.A. has developed a nano-structure – modified steel. By virtue of its modified structure it has attained higher strength, ductility and fatigue resistance over normal strength of steel. These properties enhance the longevity of the structure even in most adverse corrosive environment. Nanotechnology is also used in producing carbon nano fibres which are very much stronger than steel. Besides being very much light in weight they exhibit very high strength. CNTs also have high thermal and electrical conductivity. Under compressive loads carbon fibres are more prone to fracture but carbon nano tubes are more flexible and compressed without failures. It is experimentally proved that reinforced structures made of CNTs are excellent in tensile strength compared to conventional steel – reinforced structures.

5. Nanotechnology in Glass

Nanotechnology may be applied to the different materials used in construction. Cleaning of the glass is a continuous problem may be solved if the glass is able to clean itself. The glass made of Nano titanium dioxide is a best solution to this problem. Titanium dioxide disintegrates the organic wastes. The glass made of titanium dioxide attracts rain water, thus water cleans the dirt on the glass. Nanotechnology is also successfully used to make fire protection glass. When the small layer of the silica nano particles is sandwiched between glass panels, the layer between glass panels acts as a fire proof when heated, various types of protective coatings are developed by applying nano particles to different chemical compounds. Nano TiO₂ coatings are applied to outside of buildings to prevent sticking of pollutants it reduces the maintenance costs. As TiO₂ exhibits hydrophobic properties it can be used in anti fogging coatings.
6. Nanotechnology in Sensors

To detect the distress of the structures self sensing and self actuating sensors are developed with the application of nanotechnology. By using nanotechnology accidental protective air bags arranged in cars are being made. Sophisticated sensors are being developed with the application of nanotechnology. Nanotechnology is also used in electrical and mechanical systems to control the external environment (Temperature, moisture, smoke, smog and noise). Some of the sensors fixed in structures indicate the stress, strain vibrations acting on the structures. Some of the sophisticated devices are also designed to monitor early age concrete properties such as moisture, temperature etc. these sensors are very much useful as they provide early information about structures helps for initiating timely corrective measures.

7. Nanotechnology in Concrete Pavements

Nanotechnology is found best suitable in making pavements. Pavements should be very strong, durable, resistant to weathering, wearing and skid resistant. The pavements with all these features were successfully possible with the applications of ZnO2 nano silica particles. Water logging on roads causes weathering it can be avoided by means of proper drainage and quick run-off. Hydrophobic roads, made of nano particles facilitate fast run-off. Nanotechnology is also used for water purification. The quality and availability of water can also be improved by nanotechnology. By using advanced methods and materials water can be made fit for reuse. The salinity of water can also be reduced. With the application of nanotechnology carbon fibre reinforced plastics are also made. As they are very light in weight they don’t exhibit good electric properties. Plastic solar cells are also made to produce solar energy which is very cheaper than conventional silicon semi conductors. By using these cells energy can be saved and they are also eco friendly since they reduce emission of carbon particles. Almost all developed countries are trying to use LED lamps instead of conventional lamps. Many more smart materials are produced with the application of nanotechnology. Smart materials have the influence of external stimuli like temperature, moisture, electric and magnetic fields etc.

Conclusion

The initiative of nanotechnology has tremendous impact on engineering and its influence is profound and promising on civil engineering. Its presence is very much significance as civil engineering is mostly related to building materials such as concrete, steel, glass and wood. Nanotechnology has helped in creating most efficient and effective materials with excellent engineering properties. The maintenance cost of structures has drastically reduced due to the advent of nanotechnology in making self cleaning, self repairing concretes. Nanotechnology has also helped to improve the durability of materials by providing fire resistance and anti corrosive paintings. The scope of nanotechnology is being extended to the every nook and corner of civil engineering field, still a lot of awareness and research should be carried out to exploit its benefits. No doubt nanotechnology will help to bring out the materials with new properties and excellent functional ability. The materials made of nanotechnology also enhance the life span of the structures to the longer periods. A paradigm has already started in construction industry with the application of nanotechnology and the technology will totally transforms the construction industry. It will create a big impact on technology and business if the nanotechnology is used properly in the lines of technology and business as it has a huge market potential and economic impact.

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