**Nanotechnology:**

Nanotechnology is the study and use of structures between 1 nanometer (nm) and 100 nanometers in size. The word Nano is a scientific prefix that stands for $10^{-9}$ or one-billionth; the word itself comes from the Greek word nanos, meaning dwarf. Nanotechnology is the science of engineering that deals with particle which are less than 100 nm in size. It is the study of manipulating matter at molecular and atomic scale. As particles become nano-sized, the proportion of atoms on the surface increases relative to those inside leads to "nano-effects", however, that ultimately determine all the properties that we are familiar with at our "macro-scale" and this is where the power of nanotechnology comes in.

Nanotechnology is especially relevant in the field of civil engineering. Nanotechnology is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. With the power of nanotechnology, steel cables and joints can be strengthened. Coatings and paints can be given insulating properties. The main way this science is being utilized in civil engineering is through the improvement of materials such as glass, steel, and lastly, concrete.

There are various ways to incorporate nanotechnology into concrete that will greatly improve its desirable properties, such as durability, strength, ductility, and cleanliness etc. Currently, the most active research areas in terms of nanotechnology is it's dealing with cement and concrete are: understanding of the hydration of cement particles and the use of nano-size ingredients. Nanotechnology has changed our vision, expectations, and abilities to control the material world. The developments in Nanoscience can also have a great impact on the field of construction materials. Portland cement, one of the largest commodities consumed by mankind, is obviously the product with great, but not completely explored, potential. Better understanding and engineering of complex structure of cement-
based materials at nanolevel will definitely result in a new generation of concrete, stronger and more durable, with desired stress strain behaviour and, possibly, with the whole range of newly introduced “smart” properties.

**Nanotechnology and concrete:**

Cement is one of the most widely used materials in construction industry. In 2011, the expected total worldwide production of cement was 3,400 million tonnes and it is expected to increase the total worldwide production of cement to 6000 million tonnes up to 2050.

The major advantages of this material are: availability of raw materials for production all over the world, low cost, room temperature setting, ease of construction, readily available properties and performance data for design and construction. In addition modern day concrete has a very good performance record for a period of more than 175 years. China is the largest producer accounting for 2 billion tonnes in production with India in second position (210 million tonnes) followed by the USA (68 million tonnes).

Despite being widely used, cement-based materials have poor mechanical properties and are highly permeable to water and other aggressive chemicals, which reduces their durability and strength. If we can create chemical or mechanical tools to control nano-scale pores and the placement of calcium-silicate hydration products then concrete becomes a product of nanotechnology.
Concrete is a highly heterogeneous material produced by mixture of finely powdered cement, aggregates of various sizes and water with inherent physical, chemical and mechanical properties. A reaction between the cement and water yields calcium silicate hydrate, which gives concrete strength and other mechanical properties of concrete, as well as some by-products including calcium hydroxide [CH], ‘gel pores’ etc. Despite the hydrated cement and their by-product materials are available everywhere in the concrete, the reactions within the concrete as it sets and strengthens are difficult to control and this is an ongoing problem in the concrete industry.

The cracks in concrete structures and premature erosion are mainly due to alkali silica reaction, which is a chemical reaction that causes fissures in the concrete. Apart from the above, permeability of gases through pores and micro-cracks in the concrete, which leads to corrosion problem in the reinforcement of concrete causes further deterioration. Moreover, the expansion and shrinkage in concrete, which are also cause for crack in concrete at later ages, are mainly due to the sulphate attack, which causes disintegration in concrete, chemical leaching and both the events are mainly due to the excess calcium hydroxide [CH], the by-product during cement hydration as per the following chemical equations.

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\text{C-S-H} \quad \text{is the strength phase, whereas the by-product, CH is not having any cementitious properties, easily be leached out, prone to chemical attack. With the addition of suitable cementitious materials, mostly siliceous or aluminous, with cement which will react with excess CH and produce additional C-S-H with the replacement of porous CH and refines the pore structure and reduces permeability of gases and water in concrete. The reduction of the CH content during cement hydration associated with the possibilities of sulphate attack and chemical leaching can be reduced further, which will tackle to remediate the concrete cracking to some extent.}
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The researchers worldwide have attempted to tackle the above problem with various methods such as pozzolanic reactions of cement using cementitious
materials, by means of chemical reactions of the by-product CH to get additional C-S-H materials or by pore filling mechanism by using cementitious materials. The supplementary cementitious materials such as pulverized fly ash, ground granulated blast furnace slag, condensed micro silica fume, rice husk ash, metakaoline etc have been studied extensively in concrete as pozzolanic materials to enact the CH and get the additional C-S-H. The addition of supplementary cementitious materials in the concrete will not only improve the mechanical properties of concrete, but also its workability, alteration in setting times and durability.

![Figure: (a)](image1)
![Figure: (b)](image2)

(Density of concrete: figure (a) without nanomaterial and (b) with nanomaterial)

Moreover, the cement industry is one of the significant sources of CO$_2$ emissions, which accounts for 5-6% of global man-made CO$_2$ emission annually. However, the increasing demand for high performance structural materials and components has lead to the rapid development of new classes of materials. Nanotechnology can play a significant role in the construction industry and stands at eighth position in terms of most significant areas of applications in nanotechnology. Nano engineering of cement-based materials can result in outstanding or smart properties. Introduction of nanotechnology in cement industry has the potential to address some of the challenges such as CO$_2$ emissions, poor crack resistance, long curing time, low tensile strength, high water absorption, low ductility and many other mechanical performances. A remarkable improvement in the mechanical properties and durability of cementitious materials can be observed with incorporation of nano materials such as nano-SiO$_2$, ZnO$_2$, Al$_2$O$_3$, TiO$_2$, carbon nano tubes, nano-clays, carbon nano fibres and other nano materials.