

Nanotechnology & Nano Material in Civil Infrastructure & Construction

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Abstract— The recent analysis and development in nanomaterial and nanotechnology have highlighted the potential importance similarly as use of those materials in varied fields such as construction, industry, medicine, energy, telecommunications as well as information processing. However, in recent times the potential for the appliance of the many of the developments within the nanotechnology trade within the space of construction and engineering science has been growing. Building materials may be one among the key beneficiaries of those researches in nanotechnology, with applications which will facilitate to enhance the characteristics of concrete, steel, glass etc. Use of nanotechnology in construction aims at developing novel, smart, eco-friendly and environment- friendly construction materials that successively can facilitate within the development towards the green structure. Usually speaking, the highest quantity of pollutants are because of the production of various construction materials as well as due to the energy needed throughout their usage and repair. Rising the materials resistance and after increasing their durability will certainly scale back the environmental pollution by reducing carbon footprint of the structures. On the opposite hand, it's ascertained that the higher understanding of advanced structure of cement-based material at nano-level can lead to a brand new developments within the field of construction materials. It'll positively improve the characteristics similarly as properties of the infrastructures, viz., strength and durability.

Key words: Nanotechnology, Nano Material

I. INTRODUCTION

Because technology continues to be evolving, there doesn't appear to be any definition that everyone agrees on. Technology is that the creation of materials and devices by dominant matter at the amount of atoms, molecules and supramolecular (nanoscale) structures. In different words, it's the employment of terribly little particles of materials to form new massive scale materials. Betting on the scale technology is outline because the study and use of structures between one nanometer (nm) and a hundred nanometers in size. The word Nano stands for 10⁻⁹ or one-billionth; the word itself comes from the Greek word NANOS, which means dwarf.

Different things begin to happen at nano level e.g. gravity becomes unimportant, electricity forces take over and quantum effects get in. Another necessary side is that, as particles become nano-sized, the proportion of atoms on the surface will increase relative to those within and this results in amendment within the properties.

Nanotechnology helps in producing better construction materials with improved properties : lighter and stronger structural composites, low maintenance coatings, higher building materials, lower thermal transfer rate of fireside agent and insulation, higher sound absorption of acoustic absorbers and higher reflectivity of glass. The use of nano materials within the composition of some materials, like cement, can end in important reductions of CO₂ pollution and

also the use of performance thermal insulations can end in economical use of energy for air con. Moreover, nano materials applied to the surfaces of structural components of the building will contribute to environmental cleansing by photo catalytic reactions. With the assistance of technology, concrete is stronger, additional sturdy and additional simply placed, steel is formed harder, glass is self-cleansing and paints square measure created additional insulating and water loathsome.

Nanomaterials and nanotechnologies have attracted right smart scientific interest thanks to the new potential uses of particles in micro millimeter scale and, consequently, great deal of funds and energy have being used. Compared with different major industrial sectors, industry has lagged behind in awareness of the potential for exploitation of technology. Each the notice and actual exploitation in construction are currently increasing, However progress is uneven, particularly within the current early stages of its sensible exploitation. In nano-level, gravity becomes unimportant, electricity forces take over, and quantum effects are available. Moreover, as particles become nano-sized, the proportion of atoms on the surface will increase relative to those within, and this results in novel properties. Nanotechnology, therefore, permits the look of systems with high purposeful density, high sensitivity, special surface effects, massive expanse, high strain resistance, and chemical process effects. All attributes square measure directly or indirectly the results of the little dimensions of nanoparticles

Nanotechnology has many applications within the engineering field, particularly within the space of technology. A massive range of materials is increased by the employment of nanotechnology, a number of that embody glass, concrete, and steel. Nanoparticles may be utilized in coatings admire paints to convey the coating "self-healing capabilities and corrosion protection below insulation. Since these coatings square measure hydrophobic and repel water from the metal pipe and might conjointly shield metal from salt water attack." The consolidation of technology in technology and construction is vastly useful to the sector. Technology is accustomed increase the lifetime of concrete, create fire-resistant materials admire steel, and provides building materials qualities admire "self-healing" and "self-cleaning." On a private level, we tend to square measure terribly fascinated by the look, construction, and engineering of buildings and different infrastructure. As a toddler we tend to use to design and create buildings out of paper, and also the plan of the look and construction of buildings. As a future engineer we might prefer to be in position to do analysis on finding new materials to assist produce stronger, better, longer lasting buildings and structures. Technology will, and has revolutionized the manner civil engineering is conducted by gap new prospects for materials and is a vital aspect to the sector of technology. It's for this reason that we tend to believe that nanotechnology ought to be additional wide incorporated into engineering curriculums around the country. Currently, solely a number of schools and Universities teach technology within their engineering

programs, or perhaps supply a degree in technology. This needs to be modified, particularly for the sector of technology as technology is significant to the advancement of the sector. Current researchers handling nanoscience and technology square measure exploring these novel properties since at nanoscale, we are able to alter the macro-properties and manufacture considerably new materials and processes. Discussion on the appliance of technology in technology, specifically in construction, is very necessary.

II. NEED OF NANOTECHNOLOGY IN CONSTRUCTION

Nanotechnology has changed and may pursue to vary our perception, expectations and skills to manage the materials world. Several applications square measure developed for this specific sector to spice up the energy efficiency, sturdiness of construction elements and safety of the buildings, providing the convenience of maintenance and to provide increased living comfort. Nanotechnology helps in innovative infrastructure systems and it's potential to transform the technology follow and dilate the vision of Civil engineering in many disciplines of technology, in conjunction with vogue and construction processes is benefited from this technology, like new structural materials with distinctive properties, stronger and lighter composites, sound absorbent, fireplace non-conductor, nano-clay stuffed polymers, self-disinfecting surfaces, water repellents, air cleaners, nano-sized sensors, star cells, radical thin-strong-conductive wafers etc. This text introduces, in brief, the areas of application of this technology in subject and conjointly the science & technology behind the improved performance.

III. NATURAL NANO MINERAL – CLAY

Due to exponential growth of population and convenience of restricted natural resources, intensive scientific explorations are carried out to find out obtainable raw materials that are designed and used. It's been found that the foremost obtainable raw mineral equivalent to clay contains an immense potential to be employed in the development business each as an artifact and as a foundation for structures. The tremendous developments within the space of "wet" mixture chemical synthesis of nano-sized and nano-structured materials, that was mimicked by "bio mineralization and hierarchically organized self-assembly", is giving a brand new entranceway to resolve the environmental and energy downside to keep up social property development in construction sector. The alternating layer-by-layer (LBL) deposition method was the essential principle behind the wet synthesis. The Nano-fiber nature of NMK and their filler result in cement mortar was unconcealed by morphological study through SEM. within the management specimen, a needle like hydrates were fashioned round the CSH gel and deposited CH crystals were distributed within the cement paste. The feel of hydrate merchandise was found to be denser, compact and with uniform microstructure. It indicates the uniform distribution of nano-particles within the cement mortar thanks to their high surface energy throughout association. The reportable study has additionally cautioned on non-uniform dispersion of nano-particles that could lead on to particles aggregation and development of voids through weak zone.

IV. CLAY/POLYMER NANO COMPOSITES

One of the foremost fascinating knowledge domain areas in engineering discipline is clay/polymer composites. This technology has received nice attention within the space of nano composites analysis. It offers tremendous improvement in an exceedingly big selection of physical and engineering properties for polymers with lower proportion of filler. This nano composite approach has blessings over the thus known as fiber reinforced composites within the low filler loading vary, however still it desires a lot of analysis for more applications to overtake the standard composites.

V. PROPERTIES & USES

Clay/polymer nano composites have improved physical and engineering properties embody hearth retardancy, barrier resistance and particle physical phenomenon. This chemical compound composite technique may be helpful for soluble hydrophilic/hydrophobic useful compound systems for the preparation of polymer/silicate hybrid nano materials.

VI. NANO MATERIALS FOR CONSTRUCTION

Because the scale of the particles is an important issue, the fabric properties vital dissent at the nano scale from that at larger scales. Physical phenomena begin to occur otherwise below the boundary limit: gravity becomes unimportant, static forces and quantum effects begin to prevail. In the same time, the proportion of atoms on the surface will increase relative to those within, making alleged "nano-effect". These nano-properties really affect the materials behavior at macro-scale and, from this time, the facility of nanotechnology is emphasized: if the weather square measure correct manipulated at the nanoscale, the macro-properties square measure affected and new materials and processes can be developed.

In what follows the foremost vital nano materials with potential use in construction are bestowed:

A. Carbon Nanotubes

Carbon nanotubes are a variety of carbon having a cylindrical form, the name coming back from their metric linear unit diameter. They will be many millimeters in length and might have one "layer" or wall (single walled nanotube) or quite one wall (multi walled nanotube). Nanotubes are members of the C structural family and exhibit extraordinary strength and distinctive electrical properties, being economical thermal conductors. Let's say, they need 5 times the Young's modulus and eight times (theoretically a hundred times) the strength of steel, while being 1/6th the density.

Expected advantages of carbon nanotubes are:

- Mechanical sturdiness and crack interference in concrete.
- Increased mechanical and thermal properties in ceramics and period of time structural health observation capability.

B. Oxide Nanoparticles (TiO₂)

The oxide nanoparticles square measure added to concrete to boost its properties. This white pigment is employed as a superb reflective coating. Or added to paints, cements and windows for its sterilizing properties. The metallic element

dioxide breaks down organic pollutants, volatile organic compounds and bacterial membranes through powerful photo catalytic reactions, reducing air pollutants once it's applied to out of doors surfaces. Being deliquescent offers self-cleaning properties to surfaces to that it's applied, as a result of the rain water is attracted to the surface and forms sheets that collect the pollutants and dirt particles antecedently de-escalated and washes them off. The ensuing concrete surface includes a white color that retains its white terribly effectively.

C. Silica Nanoparticles (SiO₂)

Nano-SiO₂ might considerably increase the compressive strength of concretes containing massive ash volume at early age, by filling the pores between massive ash and cement particles. Nano-silica decreases the setting time of mortar when put next with silicon oxide fume (micro silica) and reduces bleeding water and segregation by the advance of the cohesiveness.

D. Oxide Nanoparticles (ZnO)

Zinc oxide may be a distinctive material that exhibits semi conductive and piezoelectric twin properties. It's added into varied materials and product, including plastics, ceramics, glass, cement, rubber, paints, adhesive, sealants, pigments, fireplace retardants. Used for concrete producing, ZnO improves the processing time and therefore the resistance of concrete against water.

E. Silver Nanoparticles (Ag)

The nano silver can have an effect on, in reality with microorganism, viruses and fungi, the cellular metabolism and inhibit cells growth. The nano silver inhibits multiplication and growth of microorganism and fungi that causes infection, odor, itchiness and sores. The core technology of nano silver is that the ability to provide particles as tiny as potential and to distribute these particles terribly uniformly. When the nanoparticles square measure coated on the surface of any material, the surface area is increasing many million times than the conventional silver foil.

F. Corundum Nanoparticles (Al₂O₃)

Alumina (Al₂O₃) element reacts with hydroxide created from the association of metallic element silicates. The speed of the pozzolanic reaction is proportional to the number of extent out there for reaction. The addition of nano-Al₂O₃ of high purity improves the characteristics of concretes, in terms of higher split tensile and flexural strength. The cement may be advantageously replaced within the concrete mixture with nano-Al₂O₃ particles up to maximum limit of two.0% with average particle sizes of fifteen nm, the best level of nano-Al₂O₃ particles content being achieved with one.0% replacement.

G. Zirconium Dioxide Nanoparticles (ZrO₂)

Zirconium oxide (or Zirconia) nano powder or nanoparticles square measure white high extent particles with typical dimensions of 5...100 nanometers and specific extent within the 25...50 m²/g vary. Nano metal shows smart aesthetics (translucency), superior physical resistance (hardness, flexibility durability), and chemical resistance (practically inert) and may be an excellent material.

H. Atomic Number 74 (Tungsten) Compound Nanoparticles (WO₃)

In recent years, metallic element oxide has been utilized within the production of electro chromic windows, or sensible windows. These windows square measure electrically switchable glass that modification lightweight transmission properties with associate degree applied voltage. This permits the user to tint their windows, dynamic the number of warmth or lightweight passing through.

VII. APPLICATION OF NANOTECHNOLOGY IN CIVIL ENGINEERING

A. Concrete

Concrete is one amongst the foremost common and widely used construction materials is, a macro-material powerfully influenced by its nano-properties. Addition of nano scale materials into cement might improve its performance. Nano material like SiO₂ may significantly increase the compressive strength of concrete in early stage. The dispersion through powerful chemical change reactions. It provides self-cleaning properties to surfaces to that it's applied. The ensuing concrete, already employed incomes round the world, contains a white color that /slurry of amorphous nano silica is employed to enhance segregation resistance for self-compacting concrete. Addition of nano-silica to cement based mostly materials can even control the degradation of the basic C-S-H (calcium-silicate hydrate) reaction of concrete caused by metallic element leach in water additionally as block water penetration and so improve its sturdiness. Nano-silica particles, higher referred to as oxide fume, improve the general raceme packing in concrete matrix leading to terribly high compressive strengths (>15,000 psi).

Another variety of nano particle adscititious to concrete to enhance its properties is pigment (TiO₂). These in concrete will provide ability to interrupt down dirt or pollution then permit it to be washed off by rain water on everything from concrete to glass. TiO₂ may be a white pigment and might be used as a superb reflective coating. TiO₂ in concrete provide shielding against ultraviolet rays and it's adscititious to paints, cements and windows for its sterilizing properties since TiO₂ breaks down organic pollutants, volatile organic compounds, and microorganism membranes retains its white terribly effectively in contrast to the stained buildings of the material's pioneering past.

A further variety of nanoparticle, that has exceptional properties, is that the carbon nano tube (CNT). The addition of tiny amounts (1% wt) of CNT's will improve the mechanical properties of samples consisting of the most cement section and water. Change multi-walled nanotubes show the simplest enhancements each in compressive strength (+ twenty five N/mm²) and flexural strength (+ eight N/mm) compared to the reference samples while not the reinforcement. Expected edges of carbon nanotubes are: mechanical sturdiness and crack interference in concrete, increased mechanical and thermal properties in ceramics and period structural health observation capability.

Finally, fiber wrapping of concrete is sort of common these days for increasing the strength of pre-existing concrete structural parts. Associate in nursing advancement within the procedure involves the employment of a fiber sheet

(matrix) containing nano-silica particles and hardeners. These nanoparticles enter in pores of concrete and stop little cracks on the concrete surface and also improve the strength, the matrices type a sturdy bond between the surface of the concrete and also the fibre reinforcement.

B. Nanotechnologies for Structural Observance

Nano and micro electrical mechanical systems (MEMS) sensors are developed and employed in construction to watch the setting condition and also the structure performance. Nanosensor ranges from 10⁻⁹ to 10⁻⁵ m. These sensors might be embedded into the structure during the development method and will monitor internal stresses, cracks and other physical forces within the structures throughout the structures' life.

C. Nano Cement

Portland cement is that the most generally used construction material. It is argued that concrete utilizes engineering science as a result of it contains nano-particles as ingredients together with nano-water particles and nano-air voids. But, it's not the applying of the technology at nano level. If it's attainable to form the technological tools and organize the number and locations of those nano-ingredients during a scientific approach, then concrete will expertise the advances of engineering science. Concrete is, after all, a macro-material powerfully influenced by its nano-properties and understanding it at nano level will give the avenues for improvement of strength and sturdiness. The particle size of cement is reduced to nano-size or is changed by adding nanotubes and reactive nano-size silicon dioxide particles. variety of investigations are dispensed for developing good concrete victimization carbon fibers and it's been found that rather than carbon fibers, nano-carbon tubes added with nano-cement are more practical. It's conjointly envisaged that the micro-thick nano-cement with flexibility might not be Associate in nursing not possible task.

D. Nano composites

Nano-composites is developed by victimization nano-tubes which might implant a number of the outstanding properties of the nano-tubes. Alumino-silicates area unit being mixed with carbon nanotubes which might turn out sturdy, sturdy semiconducting films. Further, the present sizes of alumino-silicates (50 to one hundred nm) will any be reduced to five to ten nm vary and a bit volume p.c of nano-tubes (\approx zero.5%) will turn out extraordinary composites. Further, fibre wrapping unremarkably used for strengthening of existing concrete structures, has witnessed Associate in nursing advancement by victimization fibre sheet (matrix) containing nano-silica particles and hardeners. These nanoparticles penetrate and shut tiny cracks on the concrete surface and, in strengthening applications, the matrices kind a powerful bond between the surface of the concrete and also the fibre reinforcement. An in depth discussion on totally different sort of nano-cement composites is bestowed later.

E. Coatings

Surface coatings of nanomaterial are applied in order to selectively change or influence distinct particle properties including: protective or anti-corrosion coatings for

mechanism; self-cleaning, thermal management, energy saving, anti-reflection coatings for windows; easy-to-clean, a great deal of durable paints and anti-graffiti coating for buildings and structures. This coating works in 2 stages. First, using a photograph chemical process technique, nano sized TiO₂ particles inside the coating react with ultra-violet rays from natural daylight to interrupt down and disintegrate organic dirt. Secondly, the surface coating is hydrophilic, that lets water unfold equally over the surface and „sheet“ down the glass to scrub the untangled dirt away. It'll therefore reduce mobile pollutants once applied to out of doors surfaces. Coating of seven000 pecuniary resource of horizontal surface with such a cloth in metropolis in 2002 has semiconductor to a 60 minutes reduction in number 7 oxides concentration at street level. Analysis has put together incontrovertible that bimetallic Nano particles, love Fe/Pd, Fe/Ag, or Zn/Pd, can operate potent reductants and catalysts reductants and catalysts for an outsized type of environmental contaminants .

F. Glass

Fire-protective glass is another application of engineering science. this may be reach by transparent in puffy layer sandwiched between glass panel (an interlayer) shaped of treated oxide (SiO₂) nanoparticles that turns into a rigid and opaque fireplace protect once heated. The electro chromic coatings area unit being urbanized that react to changes in applied voltage by employing a wolfram chemical compound layer; thereby turning into a lot of opaque at the bit of a button. As a result of the hydrophobic properties of TiO₂, it is applied in antifogging coatings or in self-cleaning windows. Nano titanium-dioxide coatings may also be applied to exteriors to stop jutting of pollutants, and therefore scale back a facility's maintenance prices.

G. Steel

Steel has been wide out there since the second age within the late a {part of} } the nineteenth and early part of the twentieth Century and has vie a serious part within the housing industry since that point. Fatigue may be an important issue which will cause the structural failure of steel subject to cyclic loading, comparable to in bridges or towers. This could happen at stresses considerably below the yield stress of the fabric and cause a major shortening of helpful lifetime of the structure. The present style philosophy entails one or a lot of of 3 limiting measures: a style supported a dramatic reduction within the allowable stress, a shortened allowable service life or the necessity for an everyday examination regime. Stress risers area unit answerable for initiating cracks from that fatigue failure results and analysis has shown that the addition of copper nanoparticles reduces the surface unevenness of steel that then limits the amount of stress risers and thus fatigue cracking.

H. Nano Technology in Waterproofing Building Materials

Water proofing of building materials has been a tangle since last a thousand years. The matter has not been addressed fully because of lack of understanding at nano level of the artefact. The new development in science & technology has allowed exploitation the newest nano technology to supply eco-friendly Organo-Silicon merchandise to waterproof much all

the various types of building materials. The nano technology has ensured that service lifetime of this approach can cause life cycles on the far side twenty to thirty years at terribly economic value. Building materials area unit better-known to possess water ooze, water leakages because of inherent porousness and micro cracks may be a treatment that is anticipated to create the fabric moth-resistant to water. Various technology development has taken place in varied waterproofing products for the last fifty years, significantly exploitation compound backbone and type of different materials. Another issue waterproofing addresses is to stop loss of structural strength of concrete building materials, significantly because of ASR (alkali silica reaction), acid rain, salt attacked. It conjointly prevents chloride penetration which might end in corrosion of the strengthened steel bars

I. Nano Sensors

Nanotechnology enabled sensors/devices that exhibit 'self-sensing' and 'self-actuating' capability additionally supply nice potential for developing good materials and structures. The monitoring and controlling of the condition of the environment and materials structure, performance in construction could be implemented by Nano and micro electrical mechanical system (MEMS) sensors. MEMS sensors range from 10-9 m to 10-5 m which could be embedded into the structure during the construction process. Nano sensors also be used to check the corrosion and cracking of concrete. This sensor can indicate the internal stresses, cracks, and other physical forces in the structures during the whole life cycle of a structure. Also it can provide an early indication before a failure of the structure occurs. Thus the sensors are able to work as self-health monitoring system.

VIII. NANOTECHNOLOGY IN SUSTAINABILITY AND ENVIRONMENT

Sustainability is outlined as “the ability to produce for the requirements of the world's current population while not damaging the power of future generations to produce for themselves”. A key side of property is conservation through the economical use of the resources that are tied up within the already designed atmosphere. As existing stock will increase thus can the necessity for effective maintenance and important edges are going to be offered by a sensible assessment of material lifetimes. Materials scientists have quantitative models that go from nanometres to millimetres and canopy half-dozen length scales (e.g. pore network models to check the porousness of concrete). Engineers have models that go from tenths of millimetres to tens of metres and therefore cover concerning half-dozen length scales (e.g. structural analysis). Along they'll, theoretically, cover twelve scale lengths and a model covering such a scale would be a strong tool for service life predictions. This is often one among the analysis areas presently below investigation and a part of its advancement depends on the event of computing power that itself is dependent on advances in engineering science within the natural philosophy field.

“In the sector of cement and its derivatives, property are going to be a significant issue. The management of the cement association may lead to a brand new generation of

products. These merchandise can have a much better quantitative relation (of) property to mass, that means, a similar or higher property may well be obtained with less material. Their production processes may well be a lot of environment-friendly. A similar may well be for different construction materials and therefore the elements created mistreatment them”

Another key side of property is that the economical use of energy. In the EU, over four-hundredth of total energy created is consumed by buildings. Insulation is a clear answer to cut back some of this energy use, however, restricted house for installation may be a major drawback for building renovation. Small and nanoporous aerogel (box eight, p17) materials are excellent candidates for being core materials of vacuum insulation panels however they're sensitive to moisture. This risk isn't acceptable for prime performance thermal insulation and therefore the next challenge is to develop a very airtight wrapping, taking into consideration the foil and therefore the welding. As a doable remedy, work by poplar Aerogels has created associate degree ultra-thin wall repels water thus it's mold free. Another intriguing application of aerogels is oxide primarily based products for clear insulation that ends up in the likelihood of super-insulating windows.

Micro or Nano Electro mechanical Systems (MEMS or NEMS) additionally supply the likelihood of monitoring and dominant the inner atmosphere of buildings (through a probably integrated network). This might cause energy savings abundant within the approach that current motion detectors put on lightweight only if required.

Sustainability and environmental considerations are closely coupled and clean water may be a key sustainable resource. Clean water has been one among the good leaps forward publically health provided by engineering and engineering science is getting used to additional this advance. In particular, iron nanoparticles that have a high surface area and high reactivity are being used to remodel and detoxify chlorinated hydrocarbons (some of that ar carcinogens) in groundwater. These nano-materials even have the potential to remodel significant metals admire soluble lead and mercury to insoluble forms, so limiting their transport and contamination.

IX. CHALLENGES

Though an enormous and tempting potential of nanotechnology in civil engineering has been envisaged and massive efforts throughout the world are being taken up to use nanotechnology in civil engineering applications, still few of grey areas need to be explored to make the technology more applicable. These are:

- Manufacture nano-size cement particles,
- Heat of hydration
- Influence of water-cement magnitude ratio,
- Performance of the (coating) and the interface between the film and the parent material,
- Analytical models to predict the initiation and growth of cracks and their contribution to final degradation,
- Agglomeration of nano tubes,
- Lack of cohesion between nano-tubes with concrete matrix,

- Optimum values of nano-tubes and dispersing agents in concrete mix design,
- High strength material with high ductility,
- Deterioration in mechanical properties and meager thermal stability of nano-composites due to high concentrations of organic surfactants for modification of nano-clay.

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X. CONCLUSION

Nanotechnology is one the most rapidly expanding area of research where the properties of materials manufactured on nano -scale can be utilized for the benefit of civil infrastructure. Also there are many concerns regarding unintended consequences. Though the field of nanotechnology is quite enormous, promising and it is moving extremely fast, there are some major challenges that need to be addressed by the scientists and engineers and solutions should be found at the earliest time possible so as to elevate nanotechnology to the one of biggest graces to the society and to the engineers. This highlights the need to research into safe design, production, use as well as disposal practices and consequently recycling, reusing, and remanufacturing initiatives that will help to enhance the sustainability of nanotechnology as well as civil engineering industries.

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