

CHAPTER: 2 - LITERATURE REVIEW

(1) Nanotechnology is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Interest in nanotechnology concept for Portland cement composites is steadily growing. Currently, the most active research areas dealing with cement and concrete are: understanding of the hydration of cement particles and the use of nano-size ingredients such as alumina and silica particles. If cement with nano-size particles can be manufactured and processed, it will open up a large number of opportunities in the fields of ceramics, high strength composites and electronic applications.

Perumalsamy Balaguru and Ken Chong, 2006, National Science Foundation, USA, NANOTECHNOLOGY AND CONCRETE: RESEARCH OPPORTUNITIES, Proceedings of ACI Session on “Nanotechnology of Concrete: Recent Developments and Future Perspectives” November 7, 2006, Denver, USA, p - 15-28

(2) Conventional concrete improved by applying nanotechnology aims at developing a novel, smart, eco- and environment- friendly construction material towards the green structure. In today's life, though utilization of cement based materials plays a vital role in the infrastructure development, it is polluting the environment by emitting CO₂. Based on this view, researchers have been pursuing to evolve new or alternate material towards a green and sustainable solution. It also discusses the application of nanotechnology in the area of cement based materials, their composites. . It has been observed that the inclusion of nano particles would improve the toughness, shear, tensile and compressive & flexural strength, durability of cement based materials, better understanding and engineering of complex structure of cement-based material at nano-level.

B. BHUVANESHWARI, SAPTARSHI SASMAL, NAGESH R.IYER , Nanoscience to Nanotechnology for Civil Engineering – Proof of Concepts, Recent Researches in Geography, Geology, Energy, Environment and Biomedicine ,230-235 , ISBN: 978-1-61804-022-0

(3) Nano-scale silica or nano silica is a material at level of individual atoms and molecules in the range of 0.1 to 100 nano meter (10⁻⁶ m). Adding nano-scale silica fume into concrete mixes improves durability of concrete structures. Understanding enactment that takes place in the cement particle at a nano-scale level can lead to improved industry standard for mixing and curing concrete. Material of nanotechnology product enables self-consolidating concrete (SCC) achieve consolidation without the need for vibration and to saving up 50% labour costs. The construction sector can benefit from this new construction material with ultra-high strength, ductility, and high durability, such as concrete. The research showed that

2.5% - 10% percentage weight nano silica to cement's as partial cement substitution increases the mechanics and physics properties of concrete.

**Saloma, Amrinsyah Nasution, Iswandi Imran and Mikrajuddin Abdullah,
MECHANICS PROPERTIES OF NANO-SILICA MATERIAL CONCRETE.**

(4) Nanotechnology is widely regarded as one of the twenty-first century's key technologies, and its economic importance is sharply on the rise. In the construction industry, nanomaterials has potentials that are already usable today, especially the functional characteristics such as increased tensile strength, self-cleaning capacity, fire resistance, and additives based on nano materials make common materials lighter, more permeable, and more resistant to wear. Nonomaterial are also considered extremely useful for roofs and facades in the built environment. Nano-insulating materials open up new possibilities for ecologically oriented sustainable infrastructure development. It has been demonstrated that nanotechnology could significantly provide solutions current construction issues and may change the requirement and organization of construction process.

Gammampila, R., Mendis, P., Ngo, T., Aye, L., Jayalath, A.S., Rupasinghe, R.A.M, 2010, APPLICATION OF NANOMATERIALS IN THE SUSTAINABLE BUILT ENVIRONMENT, International Conference on Sustainable Built Environment, 20-27

(5) One of the most interesting research fields of recent time is the study of reaction mechanism of nano embedment in cement composites. Cement composites prepared with river sand as per Indian standards with and without Nanoparticles showed an increase of 31% in compressive strength at 7 days & 32% at 28 days & 59% at 90 days respectively. Similarly, Nano Carbon tube embedment showed a decrease of 16% at 7 days, 37% increase at 28 days, 14% increase at 90 days & 3% increase at 180 days when compared to ordinary controlled cement composite after dispersion in Super.

Mainak Ghosal , Prof. Arun Kumar Chakroborty ,2015, STUDY OF NANO- EMBEDMENTS ON ORDINARY CEMENT COMPOSITES, ELK ASIA PACIFIC JOURNAL OF CIVIL ENGINEERING AND STRUCTURAL DEVELOPMENT, volume -1 , issue -2, ISSN 2394-9341

(6) Nanotechnology is a research area that has revolutionized mechanical and chemical properties of materials. Recently, focusing on concrete as a porous material with micro-scale and nano-scale pores, researchers developed investigations to find microstructure and mechanical properties of concrete. The effect of nano-silica as an addition on new concrete generation called self consolidating concrete, (SCC) and high strength SCC. The results were compared with SCC specimens without nano-silica addition. In order to investigate the development on the microstructure of SCCs, the scanning electron microscopy (SEM) imaging on specimens were also performed. Results show that use of nano-silica with micro-silica can improve the engineering properties of hardened SCC.

A.A. Maghsoudi, M. Maghsoudi, and M. Noori, 2010, Effect of Nano Particles on SCC , Second International conference on Sustainable Construction Materials and Technologies , ISBN 978-1-4507-1488-4

(7) 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 on molecular and atomic scale. In civil engineering and construction, the nanotechnology is applied in (i) concrete for reducing segregation in self compacted concrete, (ii) the use of copper nano-particles in low carbon HPS is remarkable, (iii) the use of nano sensors in construction phase to know the early age properties of concrete is very useful.

Amit Srivastava, Kirti Singh, 2011, NANOTECHNOLOGY IN CIVIL ENGINEERING AND CONSTRUCTION: a REVIEW ON STATE OF THE ART AND FUTURE PROSPECTS, Indian Geotechnical society, 1077-1080.

(8) Nanotechnology is one of the most active research areas that encompass a number of disciplines, including civil engineering and construction materials. The potential for application of many of the developments in the nanotechnology field in the area of construction engineering has been growing. It also discusses the application of instruments to reach material properties of nano-scale. Furthermore, it has been observed that better understanding and engineering of complex structures made by cement, steel or composite materials at nano-level will definitely result in a new generation of construction materials with higher performance in strength, durability, and other properties.

Ali Akbar Firoozi, Mohd Raihan Taha, Ali Asghar Firoozi, 2014, Nanotechnology in Civil Engineering, EJEg, volume -19 ,4673-4682.

(9) Nanotechnology is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Traditionally, nanotechnology has been concerned with developments in the fields of microelectronics, medicine and materials sciences. However, the potential for application of many of the developments in the nanotechnology field in the area of construction engineering is growing. The potential application of various nanotechnology developments in the construction engineering field is discussed, and the potential for further basic research that may lead to improved systems is evaluated.

Ashwani K. Rana, Shashi B Rana, Anjna Kumari³ and Vaishnav Kiran, 2009, Significance of Nanotechnology in Construction Engineering, International Journal of Recent Trends in Engineering, volume-4, no-1, 46-48.

(10) The significance of nanotechnology for construction industry is future of construction industry. The introduction and application of important nano building products are presented. Some prominent world construction projects using nanotechnology shows the trends at global level and importance of nanotechnology. Along with benefits, some serious health risks are also associated with the use of nano technology. These risks should be known and remedied so that the nano building products could be fully exploited for the benefit of the mankind.

Anwar Khitab and Muhammad Tausif Arshad, 2014, NANO CONSTRUCTION MATERIALS: REVIEW, Advance Material Science, 181-189.

(11) Carbon nano-materials, especially Carbon Nanotubes (CNT) and Carbon Nanofibers (CNF), are two of the most prospective advanced materials for application in cement based products for the construction industry. Both CNT and CNF composites demonstrated significant increase in compressive strengths, as compared to plain mortar control samples. Water/cement ratios in the range of 0.35-0.4 were found to produce the higher strengths, together with a 0.1% dosage rate for the CNT/CNF. Statistical analysis of the test results showed the significance of the enhanced strengths. It seemed that the CNT was better dispersed in the cement matrix than the CNF, because a correlation between the flow test results and the compressive strengths was detected for the CNT samples. SEM (Scanning Electron Microscope) images showed fair to good dispersion of CNT/CNF in the hardened samples.

Nur Yazdani, Vinoth Mohanam, 2014, Carbon Nano-Tube and Nano-Fiber in Cement Mortar: Effect of Dosage Rate and Water-Cement Ratio, International Journal of Material Science, Volume 4 Issue 2, 45-52

(12) Important feats in the construction industry were the invention of concrete in ancient Rome. What is nanotechnology? What can nanotechnology mean for the construction industry? Are there presently any commercialized products in construction that make use of nanotechnology? Construction can be defined as a process of converting the basic civil engineering raw materials to the final civil engineering product. Hence if the performance of the basic civil engineering raw materials is enhanced anyhow, the productivity will get increased as to work with those modified materials and the performance of the final civil engineering product will also be improved.

Patel Abhiyan S. , Rathod Hiren A.Neeraj SharmaD.3,2013, An Overview on Application of Nanotechnology in Construction Industry, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, Issue 11,6094-6098, ISSN: 2319-8753

(13) The recent researches on nanomaterials and nanotechnologies have highlighted the potential use of these materials construction informatics. This is due to the special characteristics of materials at the nano scale. Improving the materials resistances and the increasing of their durability will reduce environmental pollution by reducing the carbon footprint of the building because largest amount of pollutants are due to the production of various construction materials and to the energy required during their service. The use of nanomaterials in the composition of some materials, such as cement, will result in significant reductions of CO₂ pollution.

RADU OLAR, 2011, NANOMATERIALS AND NANOTECHNOLOGIES FOR CIVIL ENGINEERING, CONSTRUC II. ARHITECTUR , 109-117

(14) Nanotechnology will help us control and conquer the smallest of the material, therefore, eliminating the limitations in the field of civil engineering helping to improve this difficulties. We get an in-depth of the real-time application of nanotechnology in building materials like concrete, carbon nanotube, steel, wood, coating, glass etc. Nanotechnology can also be used in the new emerging trend of green building, especially in India.

Somnath Ganguli, Vikas Julius Ganesh, P. Shenick Jain, Manoj Nallanathel, S. Needhidasan, 2015, Nanotechnology in Civil Engineering Present Scenario with Practical Application, INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH, volume -4 issue -5, 3-7, ISSN No 2277 – 8179.

(15) Nanotechnology is the use of very small particles of material either by themselves or by their manipulation to create new large scale materials. The size of the particles, though, is very important because at the length scale of the nanometre, 10-9m, the properties of the material actually become affected. The size of the particles is the critical factor. At the nano scale, material properties are altered from that of larger scales. One of the fundamental aspects of nanotechnology is its interdisciplinary nature and there has already been cross over research between the mechanical modelling of bones for medical engineering to that of concrete which has enabled the study of chloride diffusion in concrete (which causes corrosion of reinforcement). Concrete is, after all, a macro-material strongly influenced by its nano-properties and understanding it at this new level is yielding new avenues for improvement of strength, durability.

Surinder Mann, 2006, Nanotechnology and Construction, European Nanotechnology Gateway, 1-55

(16) In this study, first, different mix design of four types of Self-Compacting Concrete (SCC), 1. SCC consisted of only nanosilica, 2. SCC included only microsilica, 3. SCC consisted of both microsilica and nanosilica and 4. SCC without microsilica and nanosilica called as control mix, were casted and tested to find out the values of the Slump Flow, L-Box and 7 and 28 days compressive strength. For selected mixes, the fresh concrete properties such as values of the Slump Flow, L-Box, V-Funnel, J-Ring and hardened engineering properties such as compressive and flexural strength, shrinkage and swelling values were investigated for three curing conditions at short and long term. The results showed that the engineering properties of SCC mixes could not be improved by adding only nanosilica. However, a satisfactory behaviour can be achieved using microsilica in the SCC mixes. However, by adding both microsilica and nanosilica to the SCC mixtures, the best effect on the engineering properties was reported while comparing to the control mixes.

A.A. Maghsoudi, and F. Arabpour Dahoei, 2009, APPLICATION OF NANOTECHNOLOGY IN SELF COMPACTING CONCRETE DESIGN, IJE Transactions B: Applications, volume – 2, no- 3, 229-244

(17) A common question in the minds of all of us living in today's world is about how the mechanism of nanotechnology can be used in the healthy compatibility with the constructional structures like that of massive buildings and bridges, which have been thought to encroach upon huge masses of land, leading to the destroying of homes of wildlife and putting pressure in the limited reserves of energy. Paper focuses on the sustainable usage of nano based materials like carbon nanotube, nanoclays, titanium dioxide, nanoceramic coating, nanocrystalline materials, nanosilica, nano composites, MMFX2 steel, nanometals, nanofibres, nano cement, which could be used for providing singular or multiple functions of potential reinforcement, corrosion resistance, insulation, fire protection, temperature resistance, reducing air conditioning loads, pollution control, UV ray absorption, lighting, when used as a part of building materials.

B. B. Das and Arkadeep Mitra, 2014, Nanomaterials for Construction Engineering-A Review, International Journal of Materials, Mechanics and Manufacturing, volume-2 No-1, 41-46

(18) Ground and Unground micro-silica with concrete in 5, 10, and 15% as a partial substitute to cement and results were compared with conventional concrete. Concrete specimens were cast in the laboratory and tested for compressive and tensile strength at different ages of concrete. The morphology of the ground and unground micro-silica for different time durations were studied using scanning electron microscope. More irregular shapes were observed after 6 hrs of grinding. Results were observed that the specimens cast with microsilica with 6hrs grinding and 5% of replacement of cement showed improvement in strength of 30%. Resistance to permeability was also higher in concrete specimens.

B. Karthikeyan, G. Dhinakaran, 2014, Effect of Grinding on Physico-Mechanical Properties of Ultra-Fine Micro-Silica, Asian Journal of Applied Sciences, 182-193, ISSN 1996-3343

(19) Nano-scale silica or nanosilica is a material at level of individual atoms and molecules in the range of 0.1 to 100 nanometre (10⁻⁶ m). Adding nano-scale silica fume into concrete mixes improves durability of concrete structures. Understanding enaction that takes place in the cement particle at a nano-scale level can lead to improved industry standard for mixing and curing concrete. Material of nanotechnology product as part of concrete ingredient enables self-consolidating concrete (SCC) of which the concrete may achieve consolidation without the need for vibration and to saving up 50% labour costs. The research showed that 2.5% - 10% weight nanosilica to cement's as partial cement substitution increases the mechanics and physics properties of concrete.

Saloma, Amrinsyah Nasution, Iswandi Imran and Mikrajuddin Abdullah, 2013, Mechanics Properties of nano-silica material concrete, International Journal of Engineering & sciences.

(20) The use of nanotechnology controls the topic at the minute level; the properties of matter are sincerely affected. Strength, durability and other properties of materials are dramatically affected under a scale of nano meter (10⁻⁹ m). The use of nano technology makes concrete more stronger, durable and more easily placed. Following this the analysis were carried out in ductile structural composites along with its improved properties, low repairs coatings, better properties of cementitious materials, reduction of the thermal transfer rate of fire retardant and insulation, various nanosensors, smart materials, intellectual construction technology.

Syed Sabihuddin, 2014, Application of Nanotechnology in Civil Infrastructure, Int. Journal of Engineering Research and Applications, Vol. 4, Issue 3 (Version 1), 92-95, ISSN: 2248-9622.

(21) Exploring and manipulating inner characteristics at nano-meter scale of matter in order to obtain exceptional properties and performance of materials is one of the most active research areas of the present time. The potential for application of nanotechnology in cement-based materials is huge. Currently, applications of nanotechnology in cement-based materials in several areas including construction of concrete roads are being explored. Nanotechnology has immense potential to 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 properties. Enhanced flexural behaviour of the concrete may lead a reduction in the concrete slab thickness used in the construction of concrete pavements.

Dr Rakesh Kumar, Dr Renu Mathur, and Dr Arun Kumar Mishra, 2011, Opportunities & Challenges for Use of Nanotechnology in Cement-Based Materials, NBMCW

(22) Nanotechnology involves the investigation of matter at the level down to individual atoms. Portland cement, one of the commodities consumed by mankind, is obviously the product with great, but not completely explored, potential. 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, “smart” properties. It was proposed that this process is governed by the solid state interaction between the organic modifiers and cement. During this process, the surface of cement particles attaches the functional groups introduced from the modifiers so the organo-mineral nano-layers or nano-grids are formed on the surface of cement. The developed high-performance cements demonstrate the 28-day compressive strength higher than the strength of reference cements.

K. Sobolev, I. Flores, R. Hermosillo, and L.M. Torres-Martínez, 2008, Nanomaterials and Nanotechnology for High-Performance Cement Composites, American Concrete Institute, 93-120, ISBN: 978-0-87031-299-1.

(23) Nano science and technology is a new field of emergence in materials science and engineering, which forms the basis for evolution of novel technological materials. Nano technology finds application in various fields of science and technology. A critical review of the literature on the influence of nano silica in concrete and its application for the development of sustainable materials in the construction industry and to study the pour filling effect and its pozzolanic activity with cement towards improvement of mechanical properties and durability aspects. Thus, there is a scope for development of crack free concrete towards sustainable construction.

Maheswaran S., Bhuvaneshwari B., Palani G.S., Nagesh R Iyer¹ and Kalaiselvam S.2012, An Overview on the Influence of Nano Silica in Concrete and a Research Initiative, Research Journal of Recent Sciences, Vol. 2,17-24, ISSN 2277-2502

(24) Nanotechnology is one of the most active research areas that encompass a number of disciplines including civil engineering and construction materials. Interest in nanotechnology concept for Portland cement composites is steadily growing. It is important to understanding of the hydration of cement particles and the use of nano-size ingredients such as alumina and silica particles. If cement with nano-size particles can be manufactured and processed, it will open up a large number of opportunities in the fields of ceramics, high strength composites and electronic applications. This will elevate the status of Portland cement to a high tech material in addition to its current status of the most widely used construction material.

Perumalsamy Balaguru and Ken Chong, 2006, NANOTECHNOLOGY AND CONCRETE: RESEARCH OPPORTUNITIES, Nanotechnology of Concrete: Recent Developments and Future, Perspectives, 15-28.

(25) The nanostructure and micro structural behaviour of concrete plays a decisive role in determining the properties of a material. The pore structure of paste, mortar,

or concrete affects the behaviour of the material and can give insight into the material's nanostructure and microstructure and their performance. Permeability and other durability-related properties of concrete are directly affected by pore structure. The pore structure also influences strength, modulus of elasticity, volume stability, and environmental resistance. The pore structure study was conducted by using mercury intrusion porosimetry on the cement mortar incorporating fly ash and silica fume as partial cement replacements for the preparation of various combinations of blended systems. It was observed that incorporation of fly ash has a slight pore refinement effect, while inclusion of silica fume significantly improved pore refinement.

Mohammad Khan, 2010 Nanostructure and Microstructure of Cement Concrete Incorporating Multicementitious Composites, Journal of the Transportation Research Board, 21-27.

(26) The intelligent combining of mineral oxides, which are found in clinker, slag, fly ashes etc., is designated as mineral oxide engineering. It results among others in environmentally friendly binders, recipes for soil stabilization and impermeable/durable concretes. Subsequently, the mix design of concrete is treated, whereby distinction is made between self-compacting concrete and earth-moist concrete. By combining the particle sizes of all components, so including the powders, optimum mixes in regard to workability/compactability and hardened state properties are obtained.

H.J.H. Brouwers, 2006, THE ROLE OF NANOTECHNOLOGY FOR THE DEVELOPMENT OF SUSTAINABLE CONCRETE, Nanotechnology of Concrete: Recent Developments and Future Perspectives, 69-91.

(27) Concrete as a material is the most commonly used material (other than water) on the planet. As increasingly higher performance demands are placed on the product, the limitations of modern concrete as a construction material become increasingly apparent. Significant need of the concrete construction material is to significantly increase reliability. It is estimated that up to 10% of concrete placed in a given year fails prematurely or is below standard from the beginning. Even a small reduction in the number of problems would amount to significant economic savings and performance benefits. As computing capabilities grow and nano techniques are developed, we now are starting to improve the tools and skills that we need to take a fundamental look at the hydrated cementitious system. Based on this new knowledge, it is therefore feasible to consider how to modify the cementitious system to address the issues confronting working construction sites, including shrinkage and knowing/controlling the degree of hydration.

Peter Taylor, Krishna Rajan, Bjorn Birgisson, Tom Cackler, 2007, Nanotechnology for cement and concrete, National Nanotechnology Coordination Office, 1-69.

(28) It has been observed that the inclusion of nano particles would improve the toughness, shear, tensile and flexural strength of cement based materials. Some of the widely reported Nanoparticles in cement concrete industries are based on Titanium dioxide (TiO_2), Nanosilica (SiO_2), Alumina (Al_2O_3), ZrO_2 , Carbon nanotube (CNT) nanoclays, etc. Research areas dealing with cement and concrete are: understanding of the hydration of cement particles and the use of nano-size

ingredients such as alumina and silica particles. Further, we have discussed the latest reliable properties like waterproofing, acid resistive and self healing qualities of nanocement. This paper will be very much useful those would like to work in the field of nanocement technology.

KURAPATI SRINIVAS, 2014, NANOMATERIALS FOR CONCRETE TECHNOLOGY, International Journal of Civil, Structural, Environmental and Infrastructure Engineering Research and Development (IJCSEIERD), Vol. 4, Issue 3, 79-90, ISSN (P): 2249-6866.

(29) The role of nanotechnology in conceiving of innovative infrastructure systems has potential to revolutionize the civil engineering practice. The properties like self-sensing, self-rehabilitation, self-structural health monitoring, self-vibration damping, self-cleaning and self-healing are studied. Following this the analysis were carried out in ductile structural composites along with its enhanced properties, low maintenance coatings, better properties of cementitious materials, reduction of the thermal transfer rate of fire retardant and insulation, various nanosensors, smart materials, intelligent structure technology etc. And also the possible consequences regarding its practicality and the most challenging economic factors concerned are discussed briefly. Its future trend and potential towards more economical, sustainable & eco-friendly infrastructure having longer durability are elucidated.

V. Kartik Ganesh, NANOTECHNOLOGY IN CIVIL ENGINEERING, European Scientific Journal, vol. 8, No.27,96-109 , ISSN: 1857 – 7881 (Print).

(30) Concrete is the most widely used construction material and given the current population growth, economic development, and need for repair/replacement of aging infrastructure. The production of one of its major constituents, cement, is associated with approximately 5–10% of the global anthropogenic carbon dioxide emissions and therefore the industry and the specific material is in urgent need for re-evaluation. The chemical reactions and resulting products that are produced when cement is mixed with water create a material that is highly complex. The dominant component, C-S-H gel, has a local structure of a precipitate with nanoscale features that are difficult to model and understand. Recent experimental and theoretical advancements in the field of Nanoscience and nanotechnology provide optimistic expectations for a refined understanding of the material that will create the scientific basis for a more sustainable and eco-efficient construction.

F. Pacheco-Torgal, M. V. Diamanti, A. Nazari and C-G. Granqvist, 2013, Nanotechnology in eco-efficient construction, Woodhead Publication in Materials, 1-428, ISBN 978-0-85709-544-2 (print).

(31) Nanotechnology is an emerging field of science related to the understanding and control of matter at the nanoscale, i.e., at dimensions between approximately 1 and 100 nm. Concrete, the most ubiquitous material in the world, is a nanostructured, multiphase, composite material. The mechanical behaviour of concrete materials depends to a great extent on structural elements and phenomena that are effective on a micro- and nanoscale. The size of the calcium silicate hydrate (C-S-H) phase, the primary component responsible for strength and other properties in cementitious systems, lies in the few nanometres range. The structure of C-S-H is much like clay, with thin layers of solids separated by gel pores filled with interlayer and adsorbed water (Mehta, 1986). This has significant impact on the performance of concrete because the structure is sensitive to moisture movement, at times

resulting in shrinkage and consequent cracking if accommodations in element sizes are not made. Hence, nanotechnology may have the potential to engineer concrete with superior properties through the optimization of material behaviour and performance needed to significantly improve mechanical performance, durability, and sustainability.

Bjorn Birgisson, Anal K. Mukhopadhyay ,Georgene Geary ,Mohammad Khan ,Konstantin Sobolev,2012, Nanotechnology in Concrete Materials, Transportation Research Circular E-C170, Task Force on Nanotechnology-Based Concrete Materials Transportation Research Board, 1-27, ISSN 097-8515.

(32) Multiwall carbon nanotube (CNT) effects on strength characteristics and durability of concrete. Sonication process is carried out by adding MWCNT with surfactants (super plasticizers - polycarboxylate 8H), 0.25% by weight of cement and also with water. 36 Specimens with MWCNTs of 0.015%, 0.03% and 0.045% of cement (by weight) were tested after 28 days of curing. Results show an increase in compressive and splitting-tensile strengths of the samples with increasing MWCNT. 0.045% of MWCNT has improved the 28 days compressive strength by 27 % while the split tensile strength increased by 45%. Crack propagation was reduced and water absorption decreased by 17% at 28 days curing.

Dr.T.Ch.Madhavi, Pavithra.P, Sushmita Baban Singh, S.B.Vamsi Raj, Surajit Paul, 2013, Effect of Multiwalled Carbon Nanotubes On Mechanical Properties of Concrete, IJSR - INTERNATIONAL JOURNAL OF SCIENTIFIC RESEARCH, Volvolume-2 issue -6, 166-168 , ISSN No 2277 – 8179.

(33) Application of nanotechnology in building materials for various civil engineering works is discussed. Since the use of nanotechnology controls the matter at the atomic level, the properties of matter are seriously affected. Strength, durability and other properties of materials are dramatically affected under a scale of nano meter (10⁻⁹m). The use of nano technology makes concrete more stronger, durable and more easily placed. Different types of nano materials used are discussed with its wide applications.

Saurav, 2012, Application of Nanotechnology in Building Materials, International Journal of Engineering Research and Applications, Vol. 2, Issue5, 1077-1082, ISSN: 2248- 9622.

(34) Nanotechnology is widely considered as one of the 21st century's important technologies, and its economic importance is gradually on the rise. It is the study of manipulating matter on molecular and atomic scale. Analysis of concrete is being done at the Nano-level in order to understand its structure using the various techniques developed for study at that scale such as Atomic Force Microscopy (AFM), Scanning Electron Microscopy (SEM) and Focused Ion Beam (FIB). Nano-silica addition to cement based materials can also control the degradation of the fundamental C-S-H (calcium-silicate hydrate) reaction of concrete caused by Calcium leaching in water as well as block water penetration and therefore leads to improvements in durability. Benefits of using Nano materials in Concrete Very high thermal conductivity along the tube axis, the finished product has 1% CNT's to the 99% standard concrete Can handle an additional 25 N/mm² , Strengthened concrete has 500% the tensile strength of normal concrete.

Kifayah Abbood Alsaffar, 2014, Review of the Use of Nanotechnology in Construction Industry, International Journal of Engineering Research and Development, Volume 10, Issue 8, 67-70, ISSN: 2278-800X.

(35) Concrete science is a multidisciplinary area of research where nanotechnology potentially offers the opportunity to enhance the understanding of concrete behaviour, to engineer its properties and to lower production and ecological cost of construction materials. Recent work in the area of concrete materials research has shown the potential of improving concrete properties by modifying the structure of cement hydrates, addition of Nanoparticles and nanotube and controlling the delivery of admixtures.

Laila Raki, James Beaudoin, Rouhollah Alizadeh, Jon Makar and Taijiro Sato, 2010, Cement and Concrete Nanoscience and Nanotechnology, Materials, 918-942, ISSN 1996-1944.

(36) Concrete, the most ubiquitous material in the world, is a nanostructured, Multi-phase, composite material those ages over time. It is composed of an amorphous phase, nanometre to micrometer size crystals, and bound water. Nanoscience deals with the measurement and characterization of the nano and micro scale structure of cement-based materials to better understand how this structure affects macro scale properties and performance through the use of advanced characterization techniques and atomistic or molecular level modelling. Nano-engineering encompasses the techniques of manipulation of the structure at the nanometre scale to develop a new generation of tailored, multifunctional, cementitious composites with superior mechanical performance and durability potentially having a range of novel properties such as: low electrical resistivity, self-sensing capabilities, self-cleaning, self healing, high ductility, and self-control of cracks.

Florence Sanchez, Konstantin Sobolev, 2010, Nanotechnology in concrete – a review, Construction and Building Materials, Science direct, 2060-2071.

(37) The development of nano technique has also influenced the concrete industry. Carbon nanotube (nanofibres) with 10-100 nm diameter and lengths of μm to some mm up to several cm are now available. The price is very high, but if extensive use can be found for the nanotube the price will fall dramatically. They have very good electric and heat conductive properties. Concrete with carbon nanotubes can obtain piezoresistivity enabling strain registration. The research on carbon nanotubes in concrete is just in starting phase. There has to be a follow up of controlling concrete structure on nano level to avoid porosity, disturbing bond of the tiny nanofibres. It is essential to investigate the carbon nanotube influence on human health and the recirculation of the fibers and the final deposition parallel with the application research.

RALEJS TEPFERS, 2008, Investigation of different types of fibers to Strengthen cement paste, mortar and concrete, CHALMERS UNIVERSITY OF TECHNOLOGY, 1-52, ISSN 1650-5166.

