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IMPROVING THE QUALITY AND PERFORMANCE OF CONCRETE USING NANO TECHNOLOGY: A COMPREHENSIVE REVIEW

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Abstract

Nanotechnology has become a widespread practice in the 21st century. The constant search and research for improved production of high-quality concrete have led to the use of smaller particle materials in scale of 1-100 mm to enhance of concrete. This includes durability, workability, improved porosity, strength, and self-healing cracks and sensory systems in concrete structures. However, the study reviewed various related works in nanotechnology in production of high quality concrete. It also delves into various types of Nano materials used in production of concrete the study explore the challenges facing the use of Nanotechnology. The paper revealed that Nanotechnology improves the properties of concrete, it also reduces the use of natural aggregates thereby resulted in sustainability of concrete materials and also protect environmental degradation. The study concludes by making practical recommendations for effective use of nanotechnology in concrete industry; there is need to create awareness on the needs to improve concrete properties through Nano technology. Constant training and re-training is needed by construction personals to provide the needed skills in the practicability and application of Nanotechnology and application by building related professionals. Further study needs to be taken on the areas of chemical composition of nano materials and its effects on human health as well as promulgation of rules and regulation related for the application of Nano technology

Key words: Nanotechnology, Nano science, environmental sustainability, property, additives and high quality concrete.

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Introduction

Nano technology has been in existence for many years but lack of awareness and technical skills have been the major factors that confronting the use of nanotechnology in production of high quality concrete. Recently nanotechnology has become of convert the Nanoscience theory to useful applications by observing, manipulating, assembling, controlling and manufacturing matter at the nanometer scale of [1-100nm] [Bayda et al 2019]

Nanotechnology initiative [NTI] in the united State define nanotechnology as a science, engineering and technology conducted at the Nanoscale where unique phenomena enable novel application in a wide range of fields from chemistry, physics, biology and medicine, engineering and electronics.

Nano technology was introduced by American physicist and Nobel Prize Laurel; Feyman introduced the concept of nanotechnology in 1959.In 1974 Norio Tainguli, a Japannes scientist became the first to use and define the term Nanotechnology. Nano technology can be used in concrete for self-treat crack; sustainability of materials by reduces the materials used for a certain construction and improves the property of concrete products.

Nano increases life time of a building to five times the normal life of concrete without deputing resources and create environmental pollution (Obaid2021]. Its improving workability, cracks resistance, self –healing capabilities and energy efficiency [Rekhla, 2020]. Inability of traditional ways of concrete production that has been static in nature which cannot effectively produce a high – quality concept and constant researching on the use of nanotechnology that cut across various disciplines and professions necessitate of study on the impact of nanotechnology on production of high quality concrete product. This study intend to investigate the types of nanotechnology on production that has been static in nature which cannot effectively produce a high quality concrete and constant researching on the use of nanotechnology that cut across various disciplines and professions necessitates a research study on the impact of nanotechnology on production of high quality concrete product.

The study intend to investigate the types of nanomaterial, process involved in the use of nanotechnology and prevalence challenges that may hinder its effectiveness. This is the gap the study is intend to bridge

Purpose of the study

The purposes of this study are:

1. to identify various types of Nanomaterials that can be used in production of high quality concrete
2. to explore ways in which Nanomaterial can be used in production of high quality concrete
3. to Identify challenges involved in production of high quality concrete

Related Studies

Metro and Prevean (2015) carried out experimental study on performance of concrete using Sio2 nanoparticle to improve the mechanical properties of concrete specimen, water absorption test was also performed by investigate the complete absorption capacity OF CONCRETE WITH PARTICLES AND THE MICRO structure of the interfacial transaction zone (IT2) and concrete durability. Rekha, (2020) Reviewed article on nanotechnology in structural engineering strength and durability. The study looked into the cases and

experimental data to demonstrate the practical application of nanotechnology in the real world of construction projects the. The finding of the study emphasised its transformative impact on the construction industry and paved way for sustainable materials. Obaid,(2021).ExplainedIn the role of nanotechnology application in construction as a tool to reduce concrete materials. The paper identified that nanotechnology prevent dust and waste and also create self-treat cracks. It provides sustainability and offer ability to increase life span of the building to five times the normal life span.

Xi chen, (2022) carried out a study on the application of Nano additives reinforcement towards concrete with excellent mechanical properties. The study carried out using different categories of Nano materials. The finding revealed that the large surface materials reduces workability while smaller surface increases workability of concrete and conclude that despite the excellent improvement in strength. The over use of Nano materials can lead to increase in shrinkage that can make concrete vulnerable to tensile crack.

Santosh (2025) study title, enhancement of concrete properties using Nano technology: A Comprehensive. The review focuses on Nano materials to improve the qualities of concrete with the associated challenges such as: cost, scalability and safety. The study needs further research. Jackher, Kumah, Nagappan, and Sigh, (2024) carried out a research study on Nanotechnology and high performance concrete evaluating mechanical transformation. The finding revealed that using different Nanotechnology materials will improve the properties of high performance concrete but can decrease the flexibility of concrete. The study also identified that the use of Nano materials will reduce concrete materials there by reduces the use of natural materials and provide ecological friendly environment.

Iman and Behnaz (2024)carried out study on Nanotechnology to increase properties of smart concrete. The paper delves in to environmental advantages and potentials application of Nanotechnology. The finding revealed that with the use of Nano concrete can achieve up to 20% reduction in cement and aggregates consumption there by lessoned environmental impact. The paper also revealed that additional inclusion of Nano materials boost energy efficiency in 25% heating and cooling energy required. Yang, et al (2025). In a study carried out by Zhang, et al (20@$) on assessment of me3chanical microstructur4al economic and durability of concrete using Ntio2in production of concrete. The findings revealed the dosage between 0.5% to 1%improves compressive and flexural strength. It also reduces chloride penetration. Adewale, et al (2024), carried out a study on the use of carbon nanotube and grapheme oxide. The study revealed that carbon nanotube and grapheme improves tensile and flexural performance of pavement concrete quality .CNT found to reduce micro cracks in concrete.

Types of Nano Materials Used To Improve Quality of Concrete

Nano materials available in many forms, this depends on the property of the concrete needed in a particular concrete. The following are the common ones:

Nano- silica (NS): This is one of the common additives that used to improve the workability and strength of concrete. When mixed with cement it is usually reacting with calcium hydroxide to form additional calcium silicate hydrate (CSH).

Carbon nanotubes: (CNTS):It serves as fibre that provides strength and made the concrete to demonstrate the property of ductility. Its act and connect the structure to bridge the cracks.

Nano calcium carbonate $caco_3$: its act and serves as a filler to fill the pores within the concrete materials. It increases the density of the structure.

Nanoclay/ Nano metal kaolin: it improves the property of binding. This gives concrete the ability to be properly binds together.

Process That Involved In Using Nanotechnology to Improve Quality of Concrete

The following are the suggested way for practical application of Nano technology: identification of concrete deficiencies: it is very important to identify the needs of concrete or purpose of concrete to be able to determine the kind of Nano materials to be used for a particular structure.

Selection of suitable materials: the kind of defects will dictate the kind of materials to be used. Materials must be carefully selected to suit the purpose of work.

Dispersion of Nano materials: This is very important to disperse the Nanomaterials because of its smaller molecules. At times it is very difficult because it will need the help of powerful instruments to disperse and the instruments are very costly usually by ultrasonic or by using chemical to make the mix thoroughly together.

Mix design modification: A shift from traditional means of concrete mix is also require and that is what Nano technology is all about. It involved a modification of mix to acquire the desire objective.

Hydration and pore redefine: hydration is the chemical reaction between cement and water. Without the chemical reaction setting cannot take place. In some cases chemical enhancer may be used to increase the hydrating power of cement especially in cold weather.

Testing performance evaluation and quality control. Safety and field application: It is very important before using any Nano materials it must be tested to determine the performance under the quality control. Safety must also be determined especially safety of effects of chemical on human health.

Nature of the interfacial transition zone (ITZ). Nano materials improves ITZ of the concrete. During setting time of cement particles tend to create gapes or porosity and produce weak concrete. At times it may lead to crack on the surface concrete. The use of Nano improve this, by produce more compact and dense concrete.

Challenges Facing the Use of Nano Technology to Produce High Quality Concrete

Difficulty in defining Nano technology materials: Majority of Nano materials are not in single shape, size and form therefore it makes it difficult to classify and define the Nano materials that fall within the range of 1-100nm.

Characterisation and identification problem: The nature of Nano material in terms of size, make it difficult to identify within concrete mix. As a result it required the use o9f sensitive instrument like; Transmission Electron Microscope (TEM) and Scanning Electron Microscope (STEM). These are very expensive in terms of cost of purchasing and importation.

Lack of standard testing methods and instruments: There is no clear cut standard method of testing materials and to get the instrument to test this material is another problem.

International standard organization of Nigeria has not come to standardise the method of testing Nano material

Difficulty in detecting dispersion materials in concrete: it is very difficult to identify and determine the distribution and chemical reaction of Nano materials of Nano materials once concrete is mixed together.

Inconsistence materials quality: some materials exhibit varying quality such as carbon Nanotube and titanium dioxide. The variation in the qualities and property make it difficult to predict their performance in production of high quality concrete.

Limited awareness and technical skills on the use of Nano technology. Nano technology is not new it has been in existence for long period of time but majority of people are not aware, those that aware lack technical application. The continues research shown the additional use of concrete sensory and the use of self- treat cracks in concrete this reduces the cost of maintenance and make concrete more durable

Regulations and safety identification issues. The use of Nano technology, the health hazards have not been identified, no clear safety regulation attached to the use. This is dangerous, the government and related bodies need to come out with clean and clear regulation that will guide the application of Nano technology.

Recommendations

The following were recommendations were made to make Nanotechnology more effective and improve the high quality of concrete structure.

There is need to create awareness on the needs to improve concrete property through Nano technology. Constant training and re-training is needed by construction personals to provide the needed skills in the practicability and application of Nanotechnology and application by building related professionals

Further study needs to be taken on the areas of chemical composition of nana materials and its effects on human health as well as promulgation of rules and regulation related for the application of Nano technology

Adequate provision of fund for purchasing of machine and instrument for testing and determine the dispersion of Nano materials when mixed with concrete.

Testing of Nano materials should be standardised and lay down procedurals should be established by relevant international organization.

Nano materials should be clearly define and classified for appropriate selection and application.

Conclusion

Nanotechnology has becomes inevitable tool to improve properties of concrete such as: durability, workability, and strength of concrete. It also helps in production of special concrete by improving porosity; sensory system and self- treat cracks. This reduces the maintenance cost of build structure. As excellent as Nanotechnology is, there are many challenges facing its application, if these challenges can be adequately addressed the quality of concrete will be proved and great achievement will be made. Further research is suggested to address the challenges.

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