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A Literature Survey on Impact of Nano Silica Mixing Methods on Recycled Aggregate Concrete Properties

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Abstract: This literature survey examines the impact of different nano silica mixing methods on the properties of recycled aggregate concrete. With the increasing demand for sustainable construction materials, the utilization of recycled aggregates in concrete production has gained significant attention. However, the use of recycled aggregates can lead to lower mechanical properties and durability issues in concrete. To address these concerns, researchers have explored the incorporation of nano silica as a supplementary material in recycled aggregate concrete. Nano silica, with its unique properties such as high surface area and reactivity, has the potential to enhance the mechanical and durability characteristics of concrete. This literature survey analyzes various studies conducted on the effect of different mixing methods of nano silica on recycled aggregate concrete properties. The methods investigated include pre-mixing nano silica with cementitious materials, direct mixing of nano silica with concrete mix, and post-mixing of nano silica with concrete. The findings from the surveyed studies indicate that the mixing method of nano silica significantly influences the properties of recycled aggregate concrete. The dispersion and uniform distribution of nano silica particles in the concrete matrix are crucial for achieving improved mechanical strength, reduced porosity, enhanced durability, and enhanced microstructure. The survey provides insights into the benefits and drawbacks of different nano silica mixing methods and highlights the need for further research to optimize the mixing techniques and dosage of nano silica in recycled aggregate concrete. The knowledge gathered from this survey can aid researchers and engineers in developing sustainable concrete mixtures with enhanced properties by incorporating nano silica in the production of recycled aggregate concrete.

Keywords: Nano silica, Recycled aggregate concrete, mixing methods, Mechanical properties, Durability, Sustainable construction materials.

1. INTRODUCTION

The utilization of recycled aggregates in concrete production has gained significant attention as a solution for construction and demolition waste. Concrete made with recycled aggregates, known as recycled aggregate concrete (RAC), offers a sustainable alternative to traditional concrete. However, the properties of RAC can be negatively affected by the presence of poor-quality recycled aggregates, which contain natural aggregates and attached old mortar. The attached old mortar contributes to the inferior properties of the new concrete. To improve the quality of recycled aggregates, researchers have investigated various processing methods to remove the attached mortar. These methods include ultrasonic cleaning, ball milling, heating and rubbing, and microwave heating technology. These techniques aim to separate the attached mortar from the original aggregates, reducing the porosity and enhancing the properties of the recycled aggregates. However, many of these methods require a significant amount of energy and may pose challenges in terms of practical implementation. Therefore, further research is needed to develop more efficient and feasible methods for processing recycled aggregates. By improving the quality of recycled aggregates, the properties of recycled aggregate concrete can be enhanced, promoting sustainable construction practices while reducing waste.

2. NANO-TECHNOLOGY IN CONCRETE

The term "nano" originates from the Greek word meaning "dwarf," representing a billionth of a meter. It refers to a very small scale of measurement. Nanotechnology is a broad term used to describe applications at this tiny scale. It involves understanding, controlling, and manipulating matter on the nanoscale, which is less than 100 nanometers, to create materials with entirely new properties and functions. Nanotechnology encompasses two main approaches. The first is the top-down method, where larger structures are reduced in size to the nanoscale while preserving their unique properties. This approach does not involve atomic-level control and may also involve breaking down larger structures into smaller components. The second approach is the bottom-up method, also known as molecular nanotechnology or molecular manufacturing. In this approach, materials and structures are engineered from individual atoms or molecular constituents through processes of assembly or self-assembly. This method allows for precise control and manipulation at the atomic and molecular levels. Both top-down and bottom-up approaches in nanotechnology offer opportunities to create innovative materials and devices with remarkable properties and functionalities. These advancements have the potential to revolutionize various fields, including electronics, medicine, energy, and materials science.

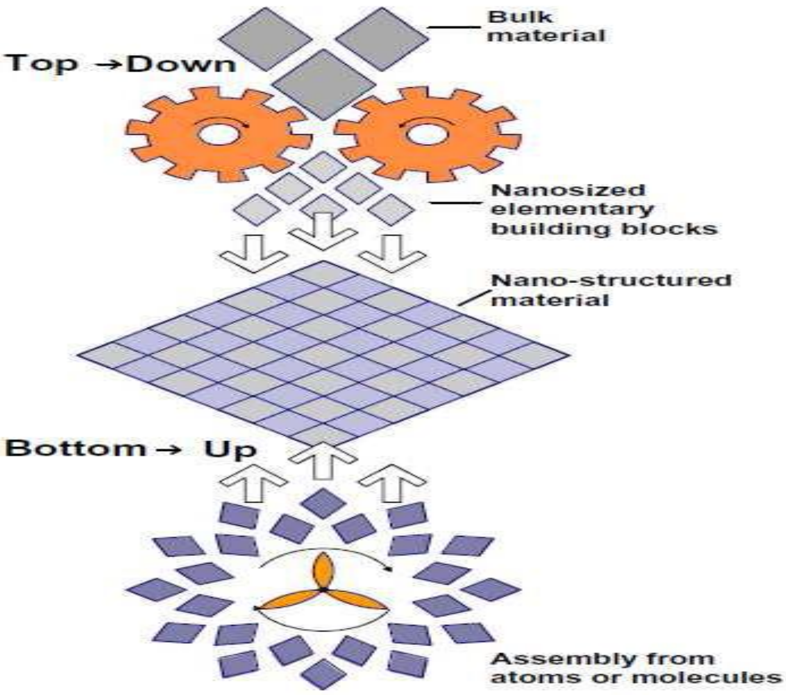

Figure 1: Approaches to Nanotechnology (Sanchez & Sobolev)

3. DEFINITION OF NANOTECHNOLOGY WITH CONCRETE

The nanoscience and nanotechnologyare the mainly used terms that describe two key promenades of application of nanotechnology in concrete exploration. Nano-science is basically related to dimension and characterization of nano and microscale materials to greater understanding for how this structure affects performance and macro-scale properties through the use of advanced classification techniques and atomic or molecular level modeling. Nanoengineering covers the approaches of managing the structure at the nanometers to build up a new improved generation of tailored, multifunctional, cementitiouscomposites with better mechanical performance and durability, potentially having a range of novel properties such as: little electrical resistivity, self-sensing capabilities, self-cleaning, self-healing, high ductility, and self-control of cracks. Concrete can be nano-engineered by addition of nanosized building blocks or objects (e.g., nanoparticles and nanotubes) to handle material behavior and improve different properties by the embedment of molecules onto cement particles, cement phases, aggregates, and additives (includingnano-sized additives) to require surface functionality, which can be adapted to improve particular interfacial interactions.

4. LITERATURE REVIEW

Several research studies have focused on the on impact of nano silica mixing methods on recycled aggregate concrete properties. The following provides an overview of various studies conducted in these areas.

Lee and Ryou (2014) The focus of the study was on characterizing recycled coarse aggregate (RCA) using a surface coating method. When RCA was utilized in concrete, the high porosity of the recycled aggregate required the addition of water, which led to a decrease in workability during transportation. Consequently, the workability of recycled aggregate concrete (RAC) was found to be lower compared to other materials. The results demonstrated that as the replacement percentage of crushed recycled coarse aggregate (CRCA) increased, the changes in slump values became less pronounced. In terms of mechanical properties, all the concrete mixes, except for the control using 100% natural aggregates (RCA), exhibited comparable or higher compressive and tensile strengths. This suggests that incorporating CRCA in concrete did not significantly compromise the overall strength performance. The findings highlight the potential of utilizing recycled coarse aggregates in concrete production, as the modified surface coating method helped improve the workability and maintain or enhance the mechanical properties of the RAC. This research contributes to advancing sustainable construction practices by promoting the use of recycled materials, reducing waste, and minimizing the environmental impact associated with concrete production.

Ismail and Ramli (2014) The objective of the study was to examine the impact of surface-treated coarse recycled concrete aggregate (RCA) on the compressive strength of concrete. The researchers employed calcium metasilicate (CM) and nanosilica (NS) at various concentrations for the surface treatment of RCA. It was observed that as the concentration of the material solution used for treating RCA increased, the slump of the concrete with treated RCA decreased.

In terms of compressive strength, the study revealed that the RAC treated with CM exhibited higher values compared to the RAC treated with NS. Additionally, it was found that a concentration of 10% for the CM solution yielded the optimum results when treating the coarser RCA. These findings indicate that surface treatment of coarse recycled concrete aggregate can have a significant influence on the properties of concrete, particularly in relation to compressive strength. The use of CM as a surface treatment material showed better performance compared to NS in enhancing the compressive strength of RAC. The optimal concentration of 10% CM solution provided the most favorable outcome for treating the coarser RCA. The results of this study contribute to the understanding of the potential benefits of surface-treated recycled concrete aggregate in concrete production, highlighting the importance of appropriate treatment methods and concentrations to optimize the performance of recycled materials in concrete applications.

Shaikh et al. (2017) The study focused on investigating the effects of two distinct mixing methods on the properties of recycled aggregate concrete. The first method involved presoaking the recycled aggregates in a Nano silica (NS) solution, while the second method involved direct mixing of NS during the concrete ingredient blending process. The results revealed that the presoaking method of recycled aggregates in NS solution led to a 5% enhancement in compressive strength compared to the direct mixing method. Moreover, when both mixing methods of NS were employed, the recycled aggregate concrete exhibited a substantial improvement of 20-25% in compressive strength. However, it is worth noting that the recycled aggregate concrete prepared using the presoaking method of NS demonstrated a 12% lower compressive strength in comparison to the control concrete. These findings suggest that both mixing methods of NS can positively influence the compressive strength of recycled aggregate concrete. The presoaking method showed a slight advantage over the direct mixing method, leading to a modest improvement in compressive strength. However, when both methods were combined, a more significant enhancement in compressive strength was achieved. The study highlights the importance of careful consideration and selection of the appropriate mixing method when incorporating NS in recycled aggregate concrete. These findings provide valuable insights for researchers and engineers in optimizing the mixing techniques of NS and improving the overall performance of recycled aggregate concrete.

Adday et al.(2018) This research involved conducting experimental investigations on four types of concrete mixtures to assess the production of high-early strength concrete pavement using recycled coarse aggregates (RCA) with the addition of virgin silica. The objective of the study was to examine the impact of incorporating virgin silica into recycled concrete pavement aggregate on concrete properties and determine the maximum percentage that can be used in concrete. The investigations focused on evaluating the mechanical and physical properties of recycled concrete aggregate with and without silica, comparing them to natural aggregate concrete. Based on the obtained density of 24 kN/m3, the concrete was classified as dense concrete. Compressive strength and split tensile strength tests were performed on the materials, and the results were recorded at 7, 14, and 28 days of curing. The use of RCA and natural aggregate (NA) mixed with virgin silica resulted in an early strength of 37.5 MPa after 7 days of curing. For road construction, slump values ranging from 25 to 50 mm were recommended. The results showed variations in slump values between 38 and 47 mm for concrete mixtures with different compositions of RCA ranging from 0 to 75%. Overall, the findings of the study demonstrated the influence of incorporating virgin silica into recycled concrete pavement aggregate on the mechanical properties of the resulting concrete. The past tense of the research findings indicates that the experiments and analyses have already been conducted and the results have been obtained.

Kien et al.(2018) This study aimed to enhance the quality of 100% coarse recycled concrete aggregate (RCA) by introducing new treatment solutions involving pozzolanic materials and sodium silicate solution. The performance of the treated RCA was evaluated using a new mixing procedure, and its mechanical properties were assessed under various conditions. The study focused on investigating the impact of the new treatment solutions on the mechanical abilities of the RCA. The results of the study revealed significant improvements in the mechanical properties of the 100% coarse RCA when treated with a combination of sodium silicate and pozzolanic materials. By utilizing a 20% concentration of sodium silicate and silica fume, the compressive strength of the treated RCA increased by up to 36%. These findings highlight the effectiveness of the approach in enhancing the strength of RAC and suggest its potential application in treating RCA for concrete production in the future. Overall, this study provides valuable insights into the use of novel treatment solutions and a modified mixing procedure to enhance the mechanical properties of 100% coarse RCA. The results indicate the feasibility of implementing this approach to improve the quality and performance of recycled concrete aggregates, offering promising prospects for the utilization of RCA in concrete applications.

Agarwal et al.(2020) This paper focused on investigating the properties of recycled aggregate concrete using laboratory concrete waste as a replacement for natural aggregate (NA) and incorporating nano silica (NS) as a partial replacement for cement. The study examined the compressive strength, split tensile strength, and flexural strength as mechanical properties, as well as water sorptivity and rapid chloride penetration to evaluate durability characteristics. Concrete specimens were prepared with different combinations, including control concrete with NA, and 20%, 40%, and 60% replacement of NA with recycled aggregate (RA). Additionally, the effects of replacing 1%, 3%, and 5% of cement with nano silica were examined for each RA concrete mix. The results demonstrated that the absence of nano silica in the specimens, with only RA and NA, resulted in a decrease in strength. Conversely, when nano silica replaced cement, an improvement in strength was observed. The mix containing 3% nano silica and 40% RA exhibited optimal results for both strength and durability properties. The use of nano silica as a cement additive not only enhanced the microstructure of the concrete but also contributed to reducing CO2 emissions associated with high cement consumption, addressing environmental concerns such as the greenhouse effect. Therefore, it was concluded that up to a 3% replacement level of cement with nano silica, along with 40% replacement of natural aggregate with RA, improved the strength and durability characteristics, promoting sustainability in concrete production.

Abdulrahman et al.(2020) This research conducted an experimental study to evaluate the performance of reinforced recycled aggregate concrete (RAC) incorporating two types of recycled coarse aggregate: one obtained from normal concrete and the other from self-compacting concrete (SCC). The replacement percentages of natural coarse aggregate with recycled coarse aggregate were varied at 0%, 33.3%, 66.7%, and 100% by weight. Additionally, Silica Fume was used as an admixture in all RAC mixtures. The mechanical properties of the concrete, including compressive strength, split tensile strength, and flexural strength, were examined for both the reference and RAC mixtures after 28 days of curing. Concrete cubes, cylinders, and reinforced concrete slab specimens were tested to assess these properties. The results revealed that the use of recycled waste concrete as aggregate significantly reduced the flexural strength of the slabs. However, when recycled SCC mixtures were employed, the reduction in flexural strength was relatively minor. Furthermore, the addition of silica fume to the concrete mixture increased the flexural strength of the slabs, with a greater improvement observed in the case of recycled SCC aggregate mixtures compared to recycled concrete aggregate mixtures.

Sahu et al.(2021) In this experimental study, the focus was on enhancing the mechanical and microstructural properties of recycled aggregate concrete (RAC) by incorporating a colloidal nano-silica (CNS) admixture. CNS particles are highly reactive and can generate C-S-H gel when combined with hydrated cement. This gel effectively fills microvoids and cracks in RAC, leading to an improved interfacial transition zone (ITZ). The experimental investigation involved 100% replacement of natural coarse aggregate (NCA) with recycled coarse aggregate (RCA) and partial replacement of cement with CNS at varying percentages (0%, 1%, 2%, and 4% by weight). Through detailed analysis of the experimental results, it was observed that the substitution of cement with CNS, both in NAC and RAC mixes, had a positive impact on the mechanical and microstructural characteristics of the concrete. Significant improvements were observed, including a reduction in voids and enhancement of the ITZ. Even with 100% RCA and partial replacement of cement with CNS, the concrete mixes met the design requirements for construction industry applications.

Tam et al.(2021) This paper presented an overview of various methods employed in the past to enhance the properties of recycled aggregate. These methods included autogenous healing, autonomous healing, bacterial and micro-encapsulation techniques, as well as two-stage mixing approaches. The aim of these methods was to improve the permeability, durability, and nanomechanical properties of the recycled aggregate. Different strategies were explored to reduce voids and the calcium hydroxide (Ca(OH)2) content in the recycled aggregate. Mechanical grinding, heat grinding, pre-soaking in water or acid, and microwave-assisted mortar removal were some of the techniques used to remove or strengthen weak parts and mortar layers in the recycled aggregate. Furthermore, the utilization of mineral admixtures such as fly ash, silica fume, metakaolin, and ground granulated blast furnace slag was investigated to enhance the properties of the recycled aggregate. These admixtures were found to contribute to improved interfacial transition zones and nanomechanical properties. Each method had its own set of advantages and disadvantages, and their effectiveness varied depending on the specific application. The research provided insights into the potential of these methods in the past for improving the performance of recycled aggregate.

Wang et al.(2021) This study presented a comprehensive review of recycled aggregate (RA) and recycled aggregate concrete (RAC), focusing on their historical background, recycling and reuse processes, manufacturing methods, as well as inherent defects such as the presence of additional interfacial transition zones in RAC. The review also examined the properties of RAC, including its workability in fresh concrete, physical and chemical characteristics such as density, carbonation depth, and chloride ion penetration, mechanical properties including compressive, flexural, and splitting tensile strength, as well as elastic modulus, and long-term performance factors such as resistance to freezing-thawing, alkali-silica reaction, creep, and dry shrinkage. Through the review, various aspects of RAC and RA were evaluated based on past research and findings. The study discussed the challenges and limitations associated with these materials, as well as their potential benefits in sustainable construction practices. By analyzing the properties and performance of RAC, the review aimed to provide a comprehensive understanding of the material and its suitability for different applications in the construction industry.

Yan et al.(2022) In this study, the aim was to enhance the surface properties of recycled aggregates by treating them with a nano-silica slurry and applying them to concrete beam specimens. The self-healing performance of cracks and the resistance to chloride ingress in recycled concrete beams were investigated under the influence of cracks caused by continuous loading and drying-wetting cycles. The study examined the effects of different levels of recycled aggregate additions, nano-silica contents, and crack widths on the self-healing capability of cracks and the resistance to chloride ingress. It was observed that the self-healing rate of cracks initially increased and then decreased as the nano-silica content increased, with the maximum rate achieved at a content of 0.4%. Higher amounts of additive in the recycled aggregate led to increased concentrations of free chloride ions in cracks. However, this concentration was found to be mitigated in the case of nano-reinforced aggregate. Taking a comprehensive perspective, controlling the crack width to be smaller than 0.12 mm and utilizing improved recycled aggregates treated with 0.2% nano-silica material proved to be effective in reducing the relative chloride ion concentration. These findings highlight the potential of nano-silica treatment in enhancing the self-healing properties and chloride resistance of recycled concrete, offering insights for future applications and design considerations.

Chen et al.(2022) In this study, the focus was on investigating the properties of recycled aggregates (RAs) enhanced with nano-silica (NS) and the resulting concrete. The RAs were subjected to soaking in nano-SiO2 solutions with varying concentrations (0, 1.0, 1.5, 2.0, and 2.5 wt.%), and the crushing indices and water absorptions of the treated NS-RAs were measured to determine the optimal soaking conditions. The results obtained indicated that the optimal concentration of nano-silica was determined to be 2%. Under this condition, the NS-RAs exhibited a 28% reduction in the crushing index compared to untreated RAs, indicating improved strength. Subsequently, the NS-RAs with the optimal nano-silica content were incorporated into concrete during the mixing process. Upon evaluating the concrete's properties, it was found that the addition of NS-RAs at the determined concentration resulted in a 20% increase in compressive strength compared to concrete without treated aggregates. This improvement highlights the effectiveness of incorporating nano-silica-treated recycled aggregates in enhancing the performance of concrete. Overall, the findings of this study demonstrate the positive impact of utilizing NS-RAs on concrete properties, emphasizing their potential for sustainable construction practices.

Adetukasi et al.(2022) In this study, the focus was on investigating the impact of incorporating nano-silica (NS) on the strength characteristics of concrete containing recycled coarse aggregate (CRCA). The research involved adding nano-silica to CRCA in different proportions (0%, 5%, and 10% by weight of cement) and conducting various tests to evaluate the workability, density, compressive strength, flexural strength, tensile strength, porosity, and shrinkage deformation of the concrete. Additionally, the content of recycled coarse aggregate (RCA) was varied in increments of 25%, ranging from 0% to 100%. The results revealed that the addition of 5% nano-silica (by weight of cement) to CRCA improved the workability of the concrete, while the incorporation of RCA had an adverse effect on workability. The density of the concrete increased with higher percentages of nano-silica, while it decreased with increasing RCA content. This relationship can be attributed to the fine nature of the nano-silica, which effectively filled the voids within the concrete matrix, resulting in increased density. Furthermore, it was observed that the use of RCA in the concrete led to a reduction in compressive strength, tensile strength, and flexural strength. This indicates that the presence of recycled coarse aggregate had a negative impact on the overall strength properties of the concrete.

5. SUMMARY

The literature survey focused on investigating the impact of different nano-silica mixing methods on the properties of recycled aggregate concrete (RAC). The study aimed to gather and analyze existing research papers and publications related to this topic to provide a comprehensive summary of the findings. The survey revealed that various nano-silica mixing methods were employed in previous studies, including direct mixing, pre-soaking, and surface coating. These methods aimed to enhance the properties of RAC by improving the interfacial transition zone between the recycled aggregate and cement matrix, increasing the strength and durability of the concrete. The findings indicated that the choice of nano-silica mixing method significantly influenced the properties of RAC. Direct mixing of nano-silica during concrete preparation showed promising results in terms of enhancing the mechanical properties, such as compressive strength, flexural strength, and split tensile strength. It was observed that the presence of nano-silica improved the bonding between the recycled aggregate and cement matrix, leading to increased strength. Pre-soaking of recycled aggregates in nano-silica solution also exhibited positive effects on the properties of RAC. This method allowed the nano-silica to penetrate into the pores of the recycled aggregate, filling the voids and improving the interfacial transition zone. As a result, the RAC exhibited improved workability, reduced water absorption, and enhanced strength properties. Surface coating of recycled aggregates with nano-silica was another method explored in the literature survey. This technique involved applying a thin layer of nano-silica on the surface of the recycled aggregates, leading to improved bonding with the cement matrix and enhanced properties of the RAC. Overall, the literature survey highlighted the potential of nano-silica mixing methods to positively impact the properties of recycled aggregate concrete. The findings underscored the importance of selecting an appropriate mixing method based on the specific requirements and desired outcomes of the RAC application. Further research and experimentation are recommended to optimize the nano-silica mixing methods and fully understand their influence on the properties of RAC.

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