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# Extraction and Surface Characterization of Silica Nanoparticles from Rice, Wheat, and Millet Husk Ashes for Eco-Friendly Material Development

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***Abstract:*** *The recovery of silica nanoparticles from agricultural waste, such as wheat, rice, and millet husk ash, provides an environmentally friendly approach for the management of waste and the development of new materials. XRD and FTIR results of silicanoparticles in millet husk ash revealed the existence and crystalline nature of silica as well as their purity, structural quality and significant applicability of the materials. Surface engineering, functional insights have been obtained from FTIR spectra through surface modifications and composition while demonstrating such molecular vibrations that are responsible for the functionality in future technologies. As a construction material, Rice Husk Ash-Silica Nanoparticles (RHASNP) exhibits a prospect as an alternative binder to cement, either maintaining or improving the compressive and tensile strengths up to 10% replacement level, even as workabilty reduces. The results highlight the potential of agro waste derived silica for food grain conservation, nanocomposites, catalysis, biomedical application and environmental benign concrete. Further investigation aimed at optimization of the synthesis procedures, enhancement of the performance and widening of the industrial applications are recommended.*

**Keywords:** Silica nanoparticles, wheat husk ash, millet husk ash, rice husk ash, XRD analysis, FTIR spectroscopy, nanomaterials, agricultural waste, sustainable construction, nanoparticle applications.

## I.INTRODUCTION

Silica nanoparticles (SiNPs) synthesized from husk ash of food grains such as rice, wheat and millets have received much attention as they can be used in many disciplines. The hull of these grains, which is often considered agricultural waste, containing a high amount of silica. By controlled burning and following chemical processing high-purity silica can be produced as the nanoparticles. Husk are one of the major sources of Silica. Rice Husk Ash (RHA) forms with burning in a high proportion of silica that can be further convert into the nano-particles by using a sol-gel or precipitation method. Rice and rush husk Wheat and millet husks are also major contributors of SiNP production with their silica content normally less than rice husk. The applications of SiNPs from these sources are various and powerful. In agriculture, SiNPs can improve crop growth and production by increasing disease resistance and nutrient utilization. They are also used in water treatment because of their high surface area and adsorption properties, which can remove heavy metals as well as many other contaminants. In the biomedical field, SiNPs are used for drug delivery carriers, providing targetable administered and controlled release drugs. Because of their biocompatibility and functionalization with different agents, they are appropriate for this work. Furthermore, SiNPs are applied in food industry as a supplement to improve food quality and prolong shelf life or they can be added into packing material to provide antimicrobial function. SiNPs are extremely interesting in material science for the preparation of high-performance composites or coatings and in electronics for the generation of novel materials with special electrical and optical characteristics. Extracting and using silica nanoparticles from rice, wheat, and millet husk ash is a sustainable method to dispose of agro-waste and to provide useful materials for many different applications.

## II.BACKGROUND

**Sudarsan et al. (2024)** stated that hydrogels were a hydrophilic network of three-dimensional polymeric structure that can absorb abundant number of biological fluids and water molecules. These hydrogels have unique role in environment-friendly parameters such as pH, electrical field, temperature, ionic strength, and solvent nature. The synthesis of pH sensitive hydrogels using foxtail millet ash husks in the existence of hydrochloride acid resulted in the fabrication of biogenic nano-silica hydrogels represents a low cost, easy, solventless greener pathway. Chemical composition and morphology of the hydrogels were characterized by using FT-IR spectra, scanning electron microscopy (SEM), and transmission electron microscopy (TEM). Swelling balance study of nano-silica hydrogel at pH ranges from 1.2 to 15.2 was investigated. These investigations demonstrated that the swelling percentage at neutral pH was significantly higher than that at acidic and basic pH. The swelling properties of bio-compatible hydrogels were filled into the chain length of biogenic nano-silica hydrogels. The pH responsive nature of the hydrogels could have higher prospects for greener applications, where dye removal, metal ion removal, agrochemical release, and biomedical applications are valuable.

**Suri et al. (2024)** reported that millets were generally subjected to several processing treatments prior to consumption and preparation of value-added products. Millet by-products such as husk, hull, seed coat, bran and broken grain contributed to 35% of the total weight of millets. These by-products were used mainly as animal feed and scarcely considered for product formulation even though they featured precious bioactive compounds, such as polyphenols, flavonoids, xylo-oligosaccharides, bioactive peptides, micronutrients, fibre, and antioxidants. The nutritive value of various millet by-products can vary depending on milling levels, millet cultivars, and environmental conditions. These waste streams can be used for different applications in both food and non-food areas such as gluten-free bakery products, functional foods, food supplement, or drugs. By-products from millet could also be employed for the isolation of bioactive compounds and the development of functional foods, dietary supplements or drugs. Moreover, by-products of millet were utilized in the production of bio-fuels, cementitious materials, thermoplastic composites, and nanotechnology. Considering benefits of millet by-products, they are treated as waste and environment menace. All potential, efficacious and cost-effective methods used to valorise millet byproducts were incorporated in this review.

**Naaz et al. (2023)** that the populations are growing so quickly and people need to produce more food, but the biotic and abiotic stresses were making yield of crops lower and lower. This problem might be partially solved using silica nanoparticles. For particles size, 1---100 nm nanoparticles had better physical chemistry than bulk material. Silica nanoparticles were significantly utilized in agriculture for the improvement of plant growth under non-stress or stress conditions and could also be employed as nano-fertilizers and nano-pesticides. Biotic and abiotic stress decreased when silica nanoparticles increased the activity of antioxidant enzymes, Osmo protectants, proteins, and secondary meta-bolites including phenolics. They also elicited non-enzymatic defines responses by promoting the synthesis of ascorbic acid, proline, glutathione, and phytohormones. The study was done on silica NPs used in agriculture: synthesis of Si nanoparticles, toxicity, action mechanisms, uptake in plants, use as fertilizers, and pesticides, and the protection of plants from biotic and abiotic stresses.

**Chaturvedi et al. (2022)** reported that stalk fibres, including of rice, wheat, oat, maize, barley, and other crops (e.g., bamboo, tree wood), recovered from straws of commonly grown plant sorties. The most commonly grown crop was rice, with a production of approximately 720 million tonnes in 2012. Rice protein was potentially suitable for human consumption because of the presence of lysine, which is typically low in other nutritious grains. Wheat ranked fourth in the world in popularity. Corn stalk is strong and robust in thickness. Cotton, the most important and oldest cellulose fibre known. In recent years there had been a marked expansion in the production of rapeseed. Of cereals, the fifth place is held by sorghum, and barley was grown extensively worldwide. Oats were one of the most popular cereal crops.

**Dorairaj et al. (2022)** stressed the strategic importance of agriculture in protecting against food insecurity, particularly as the world population continued to grow. Such a productive farming system was assisted by seed, soil, fertilizer, and good management. Food productivity was closely linked to the generation of solid wastes and the use of agrochemicals, both affecting the environment negatively. The rice and paddy sector was a major cause of the emerging waste problem. Meanwhile, rice husk (RH) was an unexploited agro-waste in low and middle-income nations, it was disposed of in landfills or burned on site. "RH had tremendous prospectus to explore VAMs for agriculture applications." In this study, a low cost and easy method, sol-gel method was presented to synthesize MSNs from UKMRC8 RH via a bottom-up technique. Hydrochloric acid-treated RHs were calcined to produce high-purity (as high as >98 wt%) recovered rice husk ash (RHA) determined through XRF analysis. RHA free from metal contents and organic material were obtained by calcining at 650 °C for four hours in a box furnace. The X-ray diffraction pattern displayed a broad peak at 2θ≈20–22 °C that confirmed the amorphous nature of RHA. Scanning electron micrographs (SEM) showed the spherically shaped, uniformly distributed aggregates of silica nanoparticles (NPs), and transmission electronic microscopic inspection of the average size of NPs was<20 nm. Except for the Energy Dispersive X-Ray that confirmed the chemical composition of the silica NPs, Fourier transform Infrared (FT-IR) spectra (peaks at 796.4 and 1052 cm−1 were O–Si–O symmetric stretching vibration and O–Si–O asymmetric stretching vibration respectively. The BET analysis also showed an average pore size=8.5 nm, a specific surface area of 300.2015 m2/g, and a pore volume of 0.659078 cm3/g. In summary, without the use of additional surfactant reagents that direct controlled assembly at the structural level, agrowaste–derived MSN was successfully synthesized by a simple and economic sol–gel method. Due to the superb physical properties of MSNs, the developed approach can be applied directly, without any alterations, to functionalize a broad library of agrochemicals.

**Shahbaz et al. (2023)** stated that nanotechnology was extensively used in a broad range of technologies e.g., agriculture, biosensors, fertilizers, food packaging, electronics, semiconductor technology and energy storage. Silica nanoparticles (SiNPs) have a wide range of applications owing to their unique properties including stability, biocompatibility, surface reactivity, tunable pore size, and large surface area. SiNPs were extensively employed in biomedicine and therapeutic drug delivery because of the possibility of their straightforward surface functionalization. Historically, SiNPs were prepared by chemical routes with sophisticated equipment, high investment, and toxic reagents, which led to long-term environmental damage. On a worldwide level, due to climate change and environmental issues, researchers were forced to develop efficient, economical and environmentally friendly procedures for producing SiNPs. The task then turned to bioinspired processes using industrial waste, agricultural waste, plants, fungi, worms, bacteria, yeast and microorganisms while following green chemistry and sustainability policies. This review emphasized the green, eco-friendly and sustainable approaches in the fabrication of SiNPs from agricultural waste and their application in various areas. Rice husk and wheat husk among numerous agro-residues were the most notable, since they have high silica content in their chemical structure, and provide an easier and efficient means for SiNPs synthesis. This review overviewed the catalytic, and biomedical applications of SiNPs, and their greener synthetic routes, which could be helpful for the researchers working on green principles and sustainable development of materials.

**Kumari et al. (2023)** stressed that the non-metallic green bio-precursor derived from agro-waste is a potential candidate for synthesizing green-silica NPs in an eco-friendly way. For the production of rice husk silica nanoparticles, the biogenic silica nanoparticles were prepared by an alkaline precipitation method. Rice husk would be an ecologically and economically beneficial raw material for the production of silica NPs due to its abundant availability and a cost-efficient agriculture by-product, which may be useful for waste management. In the preparation of RHA, the dosage of RHA is 5 g, pH is 7, alkali dosage concentration is 0.5 M, and reaction time is 3.5 h and temperature is 90 °C, which yielded the highest loaded NPs of 88.5%. The Box-Behnken design (BBD), a subset of response surface methodology (RSM), was done to maximize the production of silica nanoparticle from RHA. Goodness of fit of the BBD model A and B The BBD model was highly matched to the experimental data for the values of adjusted R2 0.9989 and predicted R2 0.9977. The amorphous nature of silica nano particles synthesized from rice husk ash was confirmed through XRD analysis of 2Ɵ at 22.12 and UV-Vis Spectroscopy absorbance peak at 312 nm. The amorphous and crystalline nature of the silica was determined by XRD. The SiO2 composition with the highest Si and O concentrations was suggested according to FESEM and EDX measurements of the nanoparticles produced from RHA, while the existence of siloxane group in the fabricated compound was evident by the stretching vibrations of FTIR spectra at 803.69 and 1089.05 cm-1.

**Rojas et al. (2019)** noted that husk in large quantity will be created by the rice operation; if not properly handled, this can be a natural pollutant. Since rice husk was a natural silica source, silica nanoparticles were derived as an additional rice husk end product. The synthesis consisted of incineration, leaching of acid, and diminution of particle size by high-energy mechanical ball milling. The characterization by the thermogravimetric analysis, X-ray fluorescence technique, scanning electron microscopy, transmission electron microscopy, X-ray diffraction, and nitrogen adsorption/desorption isotherm measurements was used to analyse their thermal, chemical, morphological, structural and superficial area. It was found that there was release of organic material from the rice husk between 150 and 450°C, while ash rich in silica was obtained above 550°C. The purity of silica was enhanced to 98.48% by means of nitric acid leaching. Mechanical milling at 600 rpm for 3 h could result in the transformation of the particles to nanometre size. A majority of the nanoparticles were of spherical shape, ranging in size from 14 to 28 nm. The major crystalline phase of the nanoparticles was silicon oxide, consistent with wide diffraction peak of (101) plane in the XRD pattern. Up-going increase of two magnitude orders were achieved in specific surface area of nanoparticles by comparison with non-milling particles. The nano silica particles derived from rice husk can have potential applications in the development of high-performance silicon or as SCM.

**Moosa & Saddam (2017)** reported the synthesis of silica nanoparticles (SiO2NPs) from rice hull ash, synthesized and used for nanofillers in Epoxy/SiO2-nanocomposites. Pure amorphous silica (SiO2) was obtained from rice husk ash (RHA) by the rice husk activation at 400 °C and then acid activation treating it with acid and thereafter heating the ash at 650 °C The production of the silica was confirmed by X-ray diffraction and X-ray fluorescence to assess the purity and crystalline form of silica. The isolated pure amorphous silica was utilized for the synthesis of silica nanoparticles. Processing parameters of the NaOH mixing, and drying time were investigated, and the sizes of the particles were verified by Atomic Force Microscopy (AFM). The optimal mean particle diameters of SiO2 NPs estimated as 53 nm were obtained at the optimal mixing time of 14 hours of the silica particles and 2.5 N NaOH and the optimal drying time of 48 hours of silica suspension. Fourier Transformation Infrared Spectroscopy (FTIR) revealed a broadband appearing at 3429.43 cm-1, which indicated that the hydroxyl groups are present on the surface of SiO2 NPs, which also meant that no further modification was required. The tensile strength of Epoxy- (0, 0.25, 0.5, 0.75, 1, 2, 3, 6, 9, 12, and 14 wt%) SiO 2 nanocomposites was characterized to reveal the optimum enhancement in tensile strength of epoxy resin at 0.5 wt% SiO 2 NPs attributed to superior dispersion.

**Moraes et al. (2014)** noted that there was a high level of waste produced by industrial food processing processes and that this represented an environmental and health hazard if not well managed. The importance of the rice industry was great, producing huge amounts of waste. Solid waste from the rice cycle consisted of straw, husk, ash, bran and broken rice. The objective of this article was to evaluate the rice production cycle, its wastes and the potential for their utilization. The results indicated that all the waste produced in the rice cycle could potentially be suitably used in the environment. Although rice, bran, and broken rice had a major use in food industry, other wastes were well-studied to solve the problem rather than landfilling. Straw might be suitable for burning or feeding to animals. It was possible to use husk as an input for poultry farming, composting, or burning, and, if fired in a reactor, it could fuel boilers and produce thermal or electrical energy. This procedure gave a rice husk ash that has potential use as a byproduct in various utilized situations, but which has not been solidified.

## III.RESEARCH METHODOLOGY

### 3.1 Silica Nanoparticles in Food Grains Rice Husk Ash

Silica was extracted from the abundant silica residue, rice husk ash (RHA), for its diverse functions, such as producing silica nanoparticles (SiNPs). Due to their special properties like high surface area and reactivity, SiNPs have emerged as novel materials for applications in food preservation, agriculture, and environmental uses.

### 3.2 Extraction of Silica from Rice Husk Ash

The extraction process involves the combustion of rice husks to obtain rice husk ash, followed by chemical treatment to extract silica. The typical procedure includes:

- **Combustion:** Rice husks are burned at high temperatures (typically 500-700°C) to produce rice husk ash.
- **Purification:** The ash is treated with an acid (commonly hydrochloric acid) to remove impurities.
- **Silica Extraction:** The purified ash is then subjected to a sodium hydroxide solution to convert the silica into a soluble form, which is subsequently precipitated by adjusting the pH with an acid.

### 3.3 Synthesis of Silica Nanoparticles

The extracted silica is used to synthesize silica nanoparticles through various methods, including:
**Sol-gel Method:** Involves hydrolysis and condensation of silica precursors to form a gel, which is then dried and calcined to produce nanoparticles.
The sol-gel method applied to rice husk ash (RHA) is primarily used to synthesize silica-based materials. Rice husk ash, which is a byproduct of rice milling, contains a high percentage of silica ($SiO_2$), making it an excellent precursor for producing silica materials.

### 3.4 Sol-Gel Process Overview

The sol-gel method involves transitioning a system from a liquid "sol" (mostly colloidal) into a solid "gel" phase. This process typically includes the following steps:

- **Hydrolysis**: A silicon alkoxide (such as tetraethyl orthosilicate, TEOS) is hydrolyzed in the presence of water and an acid or base catalyst.
- **Condensation**: The hydrolyzed species condense to form a network of silica.
- **Aging**: The gel is allowed to age, during which the network continues to form and strengthen.
- **Drying**: The gel is dried, removing the liquid phase and forming a porous material.
- **Calcination**: The dried gel is heated at high temperatures to remove any organic residues and stabilize the silica structure.

### 3.4 Result of Applying Sol-Gel Method to RHA

When rice husk ash is used in the sol-gel process, the primary result is the formation of high-purity silica with various possible structures and applications. The results include:

- **Amorphous Silica**: The sol-gel process produces highly pure, amorphous silica, which be used in various industrial applications.
- **Silica Aerogels**: By controlling the drying process, particularly using supercritical drying, one produce silica aerogels with extremely low density and high surface area.
- **Nanostructured Materials**: The sol-gel method allows the synthesis of silica nanoparticles and other nanostructured materials.
- **Mesoporous Silica**: This material, characterized by its uniform pore size distribution, is useful in catalysis, adsorption, and as a drug delivery system.
- **Functionalized Silica**: The surface of the silica particles be functionalized with various chemical groups, enhancing their applicability in different fields.

- **Precipitation Method:** Silica is precipitated from a solution of sodium silicate by adding an acid under controlled conditions.

The precipitation method is a technique used to extract and purify silica from rice husk ash (RHA). Rice husk ash, a byproduct of rice milling, is rich in silica ($SiO_2$), which be extracted and used in various applications such as in the production of silicon, glass, ceramics, and as a reinforcing filler in rubber and plastics. The typical process and the results obtained from the precipitation method for extracting silica from rice husk ash:

**3.5 Process**

**a) Preparation of Rice Husk Ash**

- Rice husks are collected and burned to produce ash.
- The ash is often subjected to controlled combustion to ensure high silica content and reduce impurities.

**b) Extraction of Silica**

- The RHA is treated with an alkaline solution, usually sodium hydroxide (NaOH), to dissolve the silica and form sodium silicate.
- The reaction typically takes place at elevated temperatures and specific concentrations of NaOH to maximize silica extraction.

**c) Filtration:** The solution is filtered to remove undissolved impurities, leaving a clear sodium silicate solution.

**d) Precipitation of Silica**

- The sodium silicate solution is then acidified, usually with sulfuric acid ($H_2SO_4$), to precipitate silica as a gel.
- The pH is carefully controlled to ensure optimal precipitation of silica.

**e) Washing and Drying**

- The silica gel is washed with distilled water to remove residual sodium and sulphate ions.
- The gel is then dried, typically in an oven, to obtain powdered silica.

**f) Results**

**High Purity Silica**

- The precipitation method yield silica with high purity (up to 99.5% $SiO_2$) if the process parameters are carefully controlled.

**g) Amorphous Silica**

- The silica obtained is generally in the amorphous form, which is highly desirable for many industrial applications.

**h) Nano-Sized Silica**

- Depending on the conditions of precipitation and drying, the resulting silica be in the form of nano-sized particles, enhancing its utility in various high-tech applications.

**i)Yield**

The yield of silica from rice husk ash varies, but it is typically in the range of 80-90% based on the initial silica content of the ash.

## IV.CHARACTERIZATION OF SILICA NANOPARTICLES

The synthesized SiNPs are characterized using techniques such as:

**Scanning Electron Microscopy (SEM):** Provides information on the morphology and size of the nanoparticles.
Scanning Electron Microscopy (SEM) is a powerful tool for analysing the microstructure of materials, including rice husk ash (RHA). Following are some typical results and observations we might expect when examining RHA using SEM.

**Morphology**

- SEM images of RHA typically reveal a highly porous structure.
- The ash particles often appear irregular in shape with a range of particle sizes.
- We might observe the presence of silica skeletons, remnants of the original plant structure.

**Surface Area and Porosity**

- The porous nature of RHA contributes to its high surface area, which is beneficial for applications such as adsorbents or catalysts.

**Elemental Composition**

- By combining SEM with Energy Dispersive X-ray Spectroscopy (EDS), we analyse the elemental composition of RHA.
- RHA is rich in silica ($SiO_2$), often making up more than 90% of the ash, with smaller amounts of other elements such as carbon, potassium, calcium, and magnesium.

**Crystallinity**

- The SEM images show the presence of crystalline phases within the RHA. These phases vary depending on the combustion temperature of the rice husks.
- Lower combustion temperatures typically result in amorphous silica, while higher temperatures lead to the formation of crystalline silica phases such as cristobalite or tridymite.

**Particle Size Distribution:** SEM provide detailed information about the particle size distribution of RHA, which is essential for understanding its behaviour in various applications.

**Surface Texture:** The surface texture of RHA particles be smooth or rough, influencing its reactivity and interaction with other materials. These observations help in assessing the suitability of RHA for different industrial applications, such as a pozzolanic material in cement and concrete production, as a filler in polymers, or as a raw material in the synthesis of silica-based products.

**Transmission Electron Microscopy (TEM):** Includes extensive information on the internal structure and particle size distribution. Transmission Electron Microscope (TEM) is one of the important techniques to study the microstructure/morphology of the materials at the sub-micron level. In the context of the RHA, the TEM proved to be very useful for the analysis of the size and shape of the silica particles dispersed on the ash surface. Here are some common results and observations we see,

**Particle Size And Morphology**: TEM image analysis of RHA, in general, indicates the presence of very fine, amorphous silica particles. The diameter of these particles varies from just some nanometres to several hundred nanometers. The particles can be aggregated or cluster in irregular shapes.

**Morphology:** The TEM micrograph of the RHA particles (Fig. High surface area and porosity are the main features of RHA and contributed to the successful use of RHA as material in adsorbent, catalysts and concrete production.

**Crystallinity:** The TEM may also utilize to investigate the crystallinity of the silicon in RHA. Largely, RHA is comprised of amorphous silica, although crystalline phases such as cristobalite or tridymite may also be present, particularly if the husk was burnt at a high temperature.

**Elemental Composition:** The TEM report coupled with EDS displays the elemental composition of RHA which reveals the existence of silicon and oxygen as major elements. It might also be able to sense tiny fractions of other elements like potassium, calcium, and magnesium, which could be impurities or left overs of the original biomass.

**Structural characteristics:** The HRTEM allows for the study of the fine structure of the silica network in RHA, for example, mesoporous structures, or the tendency to nanoscale organization in the amorphous moiety. Such observations would contribute in better comprehension of RHA itself and optimization of its applications in different domains. For example, its high surface area and porosity make it a potential pozzolanic component in cement, and its fine particle size and purity are conducive to high functioning materials.

**X-ray Diffraction (XRD):** Employed for the analysis of crystalline structure and phase purity of particles.
X-ray diffraction (XRD) is an efficient tool for the determination of the crystallite structure of a material. On application to RHA, it is useful to establish the phases present and their degree of crystallinity. Here's what XRD results for rice husk ash would generally tell:

**Amorphous Silica:** RH ash consists of a high proportion of amorphous silica, especially when produced at lower temperatures (less than 700 °C). A broad hump will be presented for the XRD pattern in the range $2\theta = 15\text{-}25°$ that is from the amorphous silica.

**Crystalline Phases:** Crystallization of silica in rice husk ash starts occurring in its structure at higher temperatures (above 800°C) into different crystalline phases of silica such as cristobalite and tridymite. You will have sharp peaks of such crystalline phases on your XRD pattern.

- **Cristobalite**: Peaks around $2\theta = 21.7°$, 28.4°, and 36.0°.
- **Tridymite**: Peaks around $2\theta = 20.8°$, 23.1°, and 36.3°.

Other probable crystalline phases might include quartz, depending on the specific conditions of ash production.

**Minor Impurities**: Depending on the source of the rice husk and the combustion conditions, other minerals such as feldspars, lime (CaO), and other metal oxides might be present in small amounts. These will show up as additional peaks in the XRD pattern.

**Sample XRD Pattern Interpretation**
- **Broad Hump (15-25° 2θ)**: Indicates amorphous silica.
- **Sharp Peaks (21.7°, 28.4°, 36.0° 2θ)**: Indicate cristobalite.
- **Sharp Peaks (20.8°, 23.1°, 36.3° 2θ)**: Indicate tridymite.
- **Other Sharp Peaks**: Depending on specific impurities or other crystalline phases.

## V.FTIR RESULTS FOR RICE HUSK ASH

**Silica ($SiO_2$) Presence**
Bands around 1100 $cm^{-1}$: These correspond to the asymmetric stretching vibrations of Si-O-Si bonds, indicating the presence of silica, which is the main component of rice husk ash.
Bands around 800 $cm^{-1}$: These are associated with symmetric stretching vibrations of Si-O-Si bonds.
Bands around 470 $cm^{-1}$: These correspond to bending vibrations of Si-O bonds.

**Organic Residues**
Bands around 2900-3000 $cm^{-1}$: These bands indicate C-H stretching vibrations, which suggest the presence of residual organic matter in the ash.
Bands around 1600-1700 $cm^{-1}$: These bands correspond to C=O stretching vibrations, indicating the presence of carbonyl groups from organic residues.

**Water and Hydroxyl Groups**
Bands around 3400 $cm^{-1}$: These bands are indicative of O-H stretching vibrations, which be attributed to water molecules or hydroxyl groups present in the ash.

Bands around 1640 $cm^{-1}$: These are due to H-O-H bending vibrations, indicating the presence of adsorbed water.

**Other Inorganic Components**
Bands around 1400 $cm^{-1}$: These may correspond to carbonate ($CO_3^{2-}$) groups if any calcium carbonate or other carbonate-containing compounds are present.

Bands around 1000-1200 $cm^{-1}$: These may indicate the presence of other silicate or phosphate compounds depending on the specific composition of the rice husk ash.

Interpretation of FTIR Spectrum: The intensity and sharpness of the peaks provide information on the quantity and the degree of order or crystallinity of the components.

Comparison with reference spectra help identify specific compounds or functional groups present in the rice husk ash.

## VI. SILICA NANOPARTICLES IN FOOD GRAINS WHEAT HUSK ASH

**Extraction:** WHA was extracted for silica by a series of chemical treatments. It consists in burning the husk to an ash, and then treating the latter with an alkali (often sodium hydroxide) to produce a sodium silicate by dissolving the required silica. The sodium silicate was subsequently acidified to form silica Np.

**Recovery (yield):** Outcome and recovery of silica NPs from wheat husk ash was not constant but in general large proportion (volume%) of the initial ash was converted in to the silica NPs. The efficiency of recovery depended on temperature, levels of leaching chemicals and exposure time.

**Characterization:** The extracted silica nanoparticles were characterized using various techniques.

**X-ray Diffraction (XRD):** XRD study the quantitative analysis of the X-ray diffraction patterns of the wheat husk ash generally indicates the characteristic crystalline phases in the ash. Wheat husk ash, like ashes of other plants, usually comprises of minerals and crystalline phases, including SiO2, CaO, K2O, etc., which depends on the mineral content of wheat husk and the combustion conditions. The XRD pattern will exhibit well-defined peaks of these crystalline phases, which allows the investigators to recognize, as well as quantify, the different minerals in the sample. This information is fundamental for a number applications, such as concrete, soil, or industrial uses of wheat husk ash.

**Scanning Electron Microscopy (SEM):** Showed the morphology of the nanoparticles, which were generally spherical and ranged in size from 10-100 nm.
Scanning Electron Microscopy (SEM) of wheat husk ash typically reveals the surface morphology and structure of the material at high magnifications. Followings are some common observations from SEM analysis of wheat husk ash:

a) **Surface Morphology:** SEM images display surface properties of WHA particles to including size, shape and texture.
b) **Pore Structure:** It acquaints us with the existence of pores and its distribution in the ash particles, important to understand its physical behaviour.
c) **Elemental Composition:** Energy-dispersive X-ray spectroscopy (EDS), as widely coupled with SEM, gave some information about the elemental composition of ash, revealing the existence of elements such as silicon, potassium, calcium and others depending on the source and composition of the wheat husk.
d) **Particle Agglomeration:** SEMs shows that the ash particles agglomerated or dispersed, which are significant for its application for instance in construction materials and as soil amendment.

**Transmission Electron Microscopy (TEM):** Provided detailed images of the nanoparticles, confirming their size and shape.
Transmission Electron Microscopy (TEM) analysis of wheat husk ash reveal detailed information about its microstructure at the nanoscale level. Following are some key aspects typically analysed in such studies:

- **Particle Size Distribution and Morphology:** The grain size distribution and the morphology of the particles in the wheat husk ash were studied under TEM. This includes the characterization of the morphology (e.g., particle shape, such as spherical, irregular) and size (from nanometer to micrometer size).
- **Crystal Structure:** TEM can be used to study the crystal structure of minerals or phases present in ash. This is a way to identify the crystallinity phase of compounds like silica, alumina, and related compounds from the wheat husk.
- **Surface Topography:** TEM can image surface topography of the particles, i.e., porosity, roughness, coatings, and other layers.
- **Chemical composition – Single particle analysis:** TEM combined with Energy dispersive X-ray Analyzed (EDS) the chemical composition of individual particles or etch pits in the ash. This assist to find out the elemental composition of the wheat husk ash.
- **Amorphous Phases:** In addition to crystalline, TEM also identify and characterize amorphous phases that are contained in ash that may influence properties of the ash.
- **TEM Edges and Dislocations:** High Resolution Transmission electron microscopy images of HKW DA particles revealed defects and dislocations in the form of edges within the da particles that shed light on the formation and processing history of the wheat husk ash.

The TEM analysis of wheat husk ash is crucial for understanding its nanostructure, which in turn impacts its properties and potential applications in various fields such as agriculture, construction materials, and environmental remediation.

**Fourier Transform Infrared Spectroscopy (FTIR):** Identified the functional groups present, confirming the presence of silanol groups on the surface.
Fourier Transform Infrared Spectroscopy (FTIR) is a powerful analytical technique used to identify chemical bonds in a sample by measuring how they absorb infrared light. When applied to wheat husk ash, FTIR analysis provide valuable information about its chemical composition and structure. Following are some key points typically analysed:

**Functional Groups**: FTIR show the functional groups available in wheat husk ash as hydroxyl group (- OH), carbonyl (- C=O) etc. Each functional group absorbs infrared light at wavelengths unique to it, which enables it to be identified.

**Mineralogy:** FTIR assist in identifying mineralogy of wheat husk ash. For instance, addition of silica ($SiO2$), calcium oxide (CaO) among others could be detected by their characteristic absorption bands.

**Carbon**: FTIR detects organic carbon compounds in husk wheat ash that can help identify the thermal decomposition of the ash and the remaining organic compounds.

**Ash Structure:** The FTIR analysis provide insight into the structure and bonding of the wheat husk ash particles, which is useful for the comprehension of their physical properties and possible applications.

**Quality control**: FTIR is also used to assess whether wheat husk ash meets specific requirements, such as assays for the production of construction materials or agricultural purposes.

**BET Surface Area Analysis:** Measured the specific surface area, indicating high surface area suitable for various applications.

Brunauer-Emmett-Teller BET method Surface area analysis The Brunauer-Emmett-Teller BET method is an analytical technique employed to evaluate the specific surface area of materials and is most relevant when comparing the efficiency of adsorption and catalytic processes. When BET analysis is done on wheat husk ash (which is agricultural waste), the BET results reveal the possible applications of waste for different purposes other than those in Agriculture as per the BET calculations:

**Surface Area Determination:** The surface area is determined by BET analysis, which measures the adsorption of gas on the surface of the material as a function of pressure. This contributes to the determination of surface area surface per gram of [23] wheat husk ash.

**Binding Material with Adsorption Capacity:**1The quantity of the pore area is proportional to the adsorption capacity of the material. This higher surface area involves extra active sites for adsorption that may be useful either for environmental remediation (e.g., water purification) or in industry (e.g., as catalyst supports).

**Characterization of the Material:** The BET analysis provide other important parameters of the material like pore size distribution and total pore volume, in addition to the quantification of the surface. This is critical information when you are trying to get a sense of how readily liquids or gases pass through the material.

**Application Potential**: Depending on the specific results, wheat husk ash with a high surface area and suitable pore characteristics could be utilized in various applications such as:
- Adsorbents for removing pollutants from wastewater.
- Catalyst supports for chemical reactions.
- Insulation materials in construction.

## VII. COMPARATIVE STUDIES

Comparison with results reported in literature for other materials or alternative forms of wheat husk ash also reveal the advantageous or specific nature of the material under investigation. The BET surface area of wheat husk ash gives useful information regarding its physical properties and potential use in environmental, industrial, and agricultural applications. The findings can guide researchers and industries in how to best use it according to its features.

**Precipitation method**
Precipitation is the most frequent technique used in the extraction of Si from millet husk ash. Here, the ash is solubilised in an alkaline solution (e.g. sodium hydroxide (NaOH)) to liberate soluble silicates. Acidification with an acid such as hydrogen chloride (HCl) or sulfuric acid (H2SO4) is then carried out to precipitate silica as silicic acid. The precipitate is filtered, washed and dried to provide silica. The actual yield, and purity also depend on the particular conditions employed (reagent concentration, temperature, etc) and the quality of millet husk ash. As a whole, the precipitation method often provides highly pure silica which can be used widely in fields such as industries of ceramics, construction materials and agriculture.

**Pyrolysis method**
Pyrolysis of millet husk ash typically results in the decomposition of organic matter at high temperatures in the absence of oxygen. The process yields various products, including:
**Biochar**: This is a carbon-rich residue left after pyrolysis, which be used as a soil amendment or for carbon sequestration.
**Gases**: Pyrolysis generates gases such as methane, carbon monoxide, and hydrogen, depending on the temperature and conditions.
**Bio-oil**: A liquid product that be extracted and further processed for use in biofuels or other applications.
**Ash Residue**: This is the inorganic component that remains after pyrolysis, which contains minerals and other substances originally present in the millet husk.

The exact composition and properties of these products depend on factors like temperature, heating rate, and residence time during pyrolysis. Each of these products has various potential applications in agriculture, energy production, and environmental remediation.

**Characterization**: Detail the characterization techniques used to analyse the synthesized silica nanoparticles, including SEM (Scanning Electron Microscopy), TEM (Transmission Electron Microscopy), XRD (X-ray Diffraction), FTIR (Fourier Transform Infrared Spectroscopy), and BET (Bernauer-Emmett-Teller) surface area analysis.

**SEM (Scanning Electron Microscopy)**
Scanning Electron Microscopy (SEM) imaging of silica nanoparticles in millet husk ash would typically reveal the morphology and size distribution of the nanoparticles. Here's what we expect to observe:
**Nanoparticle Morphology**: SEM provide high-resolution images showing the surface morphology of silica nanoparticles. This includes details such as shape (spherical, rod-like, etc.), surface roughness, and aggregation patterns.

**Particle Size Distribution**: SEM images be used to measure the size of silica nanoparticles. This information is crucial for understanding their uniformity and potential applications.
**Surface Characteristics**: SEM reveal details about the surface structure and texture of the nanoparticles, such as porosity or presence of surface coatings.
**Agglomeration**: Depending on the preparation method, SEM also show whether the nanoparticles are well-dispersed or tend to agglomerate.
**Elemental Composition**: Energy-dispersive X-ray spectroscopy (EDS), often coupled with SEM, provide information about the elemental composition of the nanoparticles.

SEM analysis of silica nanoparticles in millet husk ash would therefore offer valuable insights into their physical characteristics, which are crucial for assessing their suitability in various applications like catalysis, drug delivery, or composite materials.

**TEM (Transmission Electron Microscopy)**
Transmission Electron Microscopy (TEM) results in silica nanoparticles derived from millet husk ash typically show the morphology, size, and distribution of the nanoparticles. Following are some possible findings:
**Morphology**: TEM reveal the shape of the silica nanoparticles. They might appear spherical, rod-shaped, or have other forms depending on the synthesis method and conditions.
**Size Distribution**: TEM provides information about the size distribution of the nanoparticles. This includes average particle size and the range of sizes present in the sample.
**Agglomeration**: It shows whether the nanoparticles are dispersed individually or agglomerated, which is crucial for understanding their potential applications and behaviour in various environments.
**Crystallinity**: TEM indicate the crystalline structure of the nanoparticles, showing whether they are amorphous or have distinct crystalline phases.
**Surface Characteristics**: It may provide insights into the surface features of the nanoparticles, such as roughness or the presence of surface coatings.

**XRD (X-ray Diffraction)**
The X-ray Diffraction (XRD) analysis of silica nanoparticles in millet husk ash typically involves several key steps and conclusions:
**Identification of Crystalline Phases**: XRD helps identify the crystalline phases present in the silica nanoparticles derived from millet husk ash. This includes determining if the silica is primarily in the form of quartz ($SiO_2$), cristobalite, tridymite, or other polymorphs.
**Crystal Structure Analysis**: XRD provides information about the crystal structure, such as lattice parameters, unit cell dimensions, and atomic arrangements within the silica nanoparticles.
**Particle Size and Morphology**: The analysing XRD peaks, one estimates the average crystallite size of the nanoparticles using techniques like the Scherrer equation. This gives insights into the size distribution and morphology of the nanoparticles.
**Amorphous Content**: XRD also detect any amorphous phases present in addition to crystalline phases, providing a comprehensive understanding of the structure of the silica nanoparticles.
**Conclusion**: Based on the XRD analysis of silica nanoparticles in millet husk ash, conclusions be drawn regarding the crystalline phases present, their relative abundance, the average particle size, and the overall structure of the nanoparticles. This information is crucial for further applications in areas such as catalysis, nanocomposite materials, or biomedical applications.

**FTIR (Fourier Transform Infrared Spectroscopy)-**
The Fourier Transform Infrared Spectroscopy (FTIR) analysis of Silica Nanoparticles in Millets Husk Ash would typically involve examining the absorption peaks and patterns in the infrared spectrum. Here's a general outline of what the results and conclusions might include:
**Identification of Functional Groups**: FTIR helps identify the functional groups present in the silica nanoparticles and the millets husk ash. For silica nanoparticles, characteristic peaks would appear around 1000-1200 cm^-1 (Si-O-Si stretching vibrations) and potentially others depending on surface modifications or impurities.
**Purity and Composition**: FTIR indicate the purity of the silica nanoparticles and their composition, especially if there are organic contaminants or residues from the husk ash.
**Surface Modifications**: If there are surface modifications on the nanoparticles, FTIR reveal changes in functional groups or bonding patterns.
**Comparison and Verification**: The FTIR spectra of the nanoparticles be compared with standard spectra or theoretical data to verify the composition and structure.

**Conclusion**: Based on the analysis
Confirm the presence of silica nanoparticles in the millets husk ash.
Assess the purity and identify any contaminants or additional components.
Discuss any surface modifications or treatments observed.

Draw conclusions on the suitability of the nanoparticles for specific applications based on their structural characteristics revealed by FTIR.

The exact results and conclusions would depend on the specific spectra obtained and the objectives of the study. Each peak and pattern in the FTIR spectrum would correspond to specific molecular vibrations, providing valuable information about the structure and composition of the silica nanoparticles in millets husk ash.

**BET (Brunauer-Emmett-Teller)**
The Brunauer-Emmett-Teller (BET) analysis is typically used to determine the specific surface area of materials, including silica nanoparticles. In the context of millet husk ash, which contains silica nanoparticles, the BET analysis would provide information such as:

- **Specific Surface Area**: BET analysis would quantify the surface area per unit mass of the silica nanoparticles in millet husk ash. This is crucial because the effectiveness of silica nanoparticles in various applications often depends on their surface area.
- **Pore Size Distribution**: BET analysis also provides insights into the pore size distribution within the nanoparticles. This helps in understanding the accessibility of the surface and potential applications in adsorption or catalysis.

**Surface area analysis**
The analysis of surface area in silica nanoparticles derived from millet husk ash typically involves several steps and considerations:
**Measurement Techniques**: Surface area analysis is often conducted using methods like BET (Brunauer-Emmett-Teller) analysis, which measures the specific surface area by nitrogen adsorption.
**Results**: The specific surface area of silica nanoparticles from millet husk ash vary based on factors such as the preparation method, ash composition, and nanoparticle size. Higher surface areas indicate greater potential for applications like adsorption, catalysis, or reinforcement in composites.
The conclusion of such analyses often emphasizes the efficiency of millet husk ash as a sustainable source of silica nanoparticles with significant surface area. This lead to implications for environmental sustainability and industrial applications, highlighting the potential of agricultural waste as a valuable resource in nanotechnology.
**Particle Size and Morphology**: Present the particle size distribution, morphology (shape and surface characteristics), and crystalline structure of the silica nanoparticles obtained from millet husk ash. Discuss how different synthesis methods influence these properties.
**Properties**: Evaluate the physicochemical properties of the silica nanoparticles, such as surface area, pore size distribution, thermal stability, and chemical composition. Relate these properties to potential applications in various fields, such as biomedical, environmental remediation, and industrial sectors.
**Comparison with Other Nanoparticles**: Compare the properties of silica nanoparticles derived from millet husk ash with those obtained from other agricultural wastes or conventional silica sources. Highlight advantages such as cost-effectiveness, sustainability, and unique properties specific to millet husk ash.
**Applications and Future Perspectives:** The potential applications of these silica nanoparticles, such as drug delivery systems, catalysis, sensors, and reinforcement materials. Address challenges and propose future research directions to optimize synthesis methods, enhance nanoparticle properties, and expand application possibilities.

## VIII. RESULT AND ANALYSIS

We have 3 Case studies for Silica Nanoparticles and their use incorporated in the study. The application of Case study 1 is based on the Civil engineering work for concreate strengthening and as shown in Case 1 with add the result. The answer was extracted from the journals papers which we appended in references section.

### 8.1 Silica Nanoparticles in Rice Husk Ash (Silica Nano Particle) and Their Applications

In the present work, RHASNP have been used and studied as a partial substitution of coarse aggregate in recycled concrete. Rice husk was gathered and incinerated to ash, and then, was beneficiated to remove silica nanoparticles. Then (0, 5, 10, 15, and 20)wt% of these nanoparticles were introduced into recycled concrete for a workability and mechanical properties. It can also be seen that with 10% RHASNP substitution, the compressive and split tensile strengths of the RHA combined with SNPs concrete were better than that of the control specimens, indicating the feasibility of using agricultural waste for developing concrete with enhanced properties and consequently sustainability.

### 8.2 Research Methodology

We accumulate Many reports from different journals and e-books that are published in good quality magazines to study the different properties of recycled aggregates concrete. To this body of knowledge, is being added a Rice Husk Ash Silica Nano Particle (RHASNP), as partial replacement of coarse aggregate in recycled concrete. To this end, debris of crushed building beams, columns and lintels were procured from Patna, India. To get recycled aggregates (RA) the following procedures were done.

**Dismantling and Segregation**: The collected debris was dismantled and segregated into smaller pieces using a hammer.
**Preliminary Testing**: The dismantled material was brought to the laboratory for preliminary testing.

**Grading of Aggregates**: The debris was classified using 19.5, 12.5, 9.5-, and 4.75-mm sieves to obtain the required grading of aggregates.

In order to analyze the hardened properties of concrete, 100 numbers of specimens - 4” x 4” x 4” cubes and 4” x 8” cylinders - were casted and tested in UTM, after curing of 7, 14 and 28 days. The characteristics of the specimens are presented in Table 1.

**Table 1:** Details of Specimens Tested

| **Specimens for Split Tensile Strength** | **Curing Ages** | **Plain Concrete** | **RCA + 5% RHASNP** | **RCA + 10% RHASNP** | **RCA + 15% RHASNP** | **RCA + 20% RHASNP** |
|---|---|---|---|---|---|---|
| Cylinders | 7 days | 3 | 3 | 3 | 3 | 3 |
| | 14 days | 3 | 3 | 3 | 3 | 3 |
| | 28 days | 3 | 3 | 3 | 3 | 3 |
| Total | | 9 | 9 | 9 | 9 | 9 |
| Cubes for Compressive Strength | 7 days | 3 | 3 | 3 | 3 | 3 |
| | 14 days | 3 | 3 | 3 | 3 | 3 |
| | 28 days | 3 | 3 | 3 | 3 | 3 |
| Total | | 9 | 9 | 9 | 9 | 9 |

**Materials**

***Rice Husk Ash-Silica Nano Particle (RHASNP)***

Rice husk is as a waste material after the process of rice grain separating. Rice husk, for the present study was collected from the vicinity of Patna city, was burned in open atmosphere to transform into ash and ash was processed to fabricate silica nanoparticles. The raw ash was sieved with a 30 sieve to eliminate unwanted material. The recovered silica nanoparticles from the sieved ash are

**Cement**

Ordinary Portland Cement (OPC) was used as the binding material. The locally available brand, Lucky Cement, was used. The preliminary properties of the cement were as follows: normal consistency 33%, initial setting time 30 minutes, and final setting time 120 minutes.

**Fine, Coarse, and Recycled Aggregates**

**Fine Aggregates**: Locally procured hill sand was used and conformed to Indian Standard Specifications IS: 383-1970. The physical properties and sieve analysis results are listed in Tables 2 (A) and 2(B).

**Table 2:** Sieve Analysis of Fine Aggregate

| **Sr. No** | **IS-Sieve (mm)** | **Mass Retained (gm)** | **Cumulative Mass Retained (gm)** | **Cumulative % Mass Retained** | **Cumulative % Mass Passing Through** |
|---|---|---|---|---|---|
| 1 | 4.74 | 1 | 1 | 0.1 | 99.9 |
| 2 | 2.36 | 22 | 23 | 2.3 | 97.7 |
| 3 | 1.18 | 77 | 100 | 10 | 90 |
| 4 | 600μ | 153 | 253 | 25.3 | 74.7 |
| 5 | 300μ | 264 | 517 | 51.7 | 48.3 |
| 6 | 150μ | 425 | 942 | 94.2 | 5.8 |
| 7 | Below 150μ | 58 | 1000 | 100 | 0 |
| Total | | | | | |
| FM | | 283.6/100=2.836 | | | |

**Table:** Physical Properties of Fine Aggregates

| **Characteristics** | **Value** |
|---|---|
| Specific gravity | 2.63 |
| Bulk density | 5% |
| Fineness modulus | 2.83 |

**Coarse Aggregates**: Locally available coarse aggregate with a maximum size of 20 mm was used. The aggregates were tested as per IS: 383-1970. The physical properties and sieve analysis results are listed in Tables 3(A) and 3(B).

**Table 3 (A)** Sieve Analysis of Coarse Aggregate (20 mm)

| **Sr. No** | **IS-Sieve (mm)** | **Mass Retained (gm)** | **Cumulative Mass Retained (gm)** | **Cumulative % Mass Retained** | **Cumulative % Mass Passing Through** |
|---|---|---|---|---|---|
| 1 | 40 | 0 | 0 | 0 | 100 |
| 2 | 20 | 145 | 145 | 7.25 | 92.75 |
| 3 | 10 | 1829 | 1974 | 98.7 | 1.3 |
| 4 | 4.74 | 124 | 1998 | 99.9 | 0.1 |
| 5 | 2.36 | 0 | 1998 | 99.9 | 0.1 |
| 6 | 1.18 | 0 | 1998 | 99.9 | 0.1 |
| 7 | 600µ | 0 | 1998 | 99.9 | 0.1 |
| 8 | 300µ | 0 | 1998 | 99.9 | 0.1 |
| 9 | 150µ | 0 | 1998 | 99.9 | 0.1 |
| 10 | Below 150µ | 2 | 2000 | 100 | 0 |
| Total | | | | | |
| FM | | 805.35/100=8.0535 | | | |

**Table 3 (B)** Properties of Coarse Aggregates

| **Characteristics** | **Value** |
|---|---|
| Type | Crushed |
| Colour | Grey |
| Shape | Angular |
| Nominal Size | 20 mm |
| Specific Gravity | 2.62 |
| Total Water Absorption | 0.89% |
| Fineness Modulus | 8.05 |

**8.3 Rice Husk Ash-Silica Nano Particle (RHASNP)**

Rice Husk was collected from R.K. Enterprises, Hangout, (Mandi), Himachal Pradesh, India. The husk was washed with drinking water, sun-dried and finally incinerated in open air to obtain ash. The silica-nanoparticles were hereafter isolated from this ash. The physical properties of the Rice Husk Ash-Silica Nano Particle are given in Table 4.

**Table 4** Physical Properties of Rice Husk Ash-Silica Nano Particle

| **Characteristics** | **Value** |
|---|---|
| Appearance | Fine powder |
| Particle Size | Sieved through 90-micron sieve |
| Specific Gravity | 2.21 |
| | Light grey |

**Workability Tests**

***Slump Test***

The slump test measures the workability of concrete. The results for normal concrete and concrete with recycled aggregates and various percentages of RHASNP are shown in Table 5.

**Table 5** Slump Test Results

| Mix Control | Percentage | Slump Value |
|---|---|---|
| RHASNP | 0% | 100mm |
| | 5% | 75mm |
| | 10% | 65mm |
| | 15% | 35mm |
| | 20% | 30mm |

**Compaction Factor Test**

The compaction factor test results for all mixtures are shown in Table 6.

**Table 6** Compaction Factor Results

| Mix Control | Percentage | Compaction Factor |
|---|---|---|
| RHASNP | 0% | 0.93 |
| | 5% | 0.90 |
| | 10% | 0.87 |
| | 15% | 0.83 |
| | 20% | 0.82 |

**Hardened Concrete**

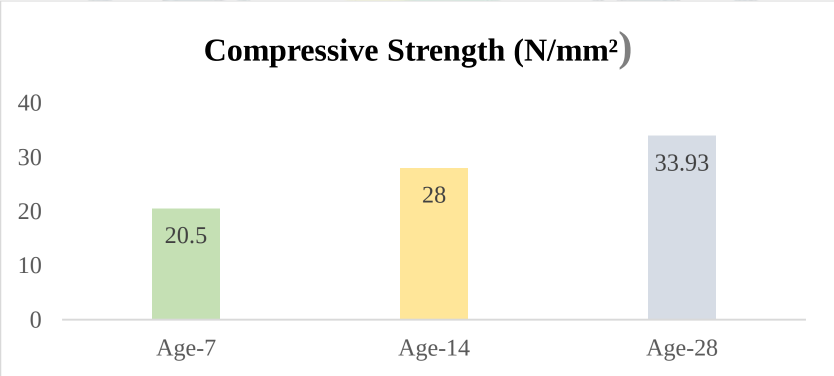
**Compressive Strength**

Compressive strength tests were conducted on cubic specimens. The compressive strength of M25 grade control concrete and concrete containing various percentages of RHASNP was tested at 7, 14, and 28 days. The results are shown in Table 7.

**Table 7** Compressive Strength of Control Concrete (N/mm²)

| Age (days) | Compressive Strength (N/mm²) |
|---|---|
| 7 | 20.50 |
| 14 | 28.00 |
| 28 | 33.93 |

The results for concrete containing RHASNP at different percentages are graphically shown in Figure below.




**8.4 Split Tensile Strength**

Split tensile strength tests were conducted on cylindrical specimens. The results for M25 grade control concrete and concrete containing various percentages of RHASNP at 7, 14, and 28 days are shown in Tables 8 and 9.

**Table 8** Split Tensile Strength of Control Concrete (N/mm²)

| Age (days) | Split Tensile Strength (N/mm²) |
|---|---|
| 7 | 1.90 |
| 14 | 2.30 |
| 28 | 2.81 |

**Table 9** Split Tensile Strength of RHASNP Concrete (N/mm²)

| RHASNP (%) | 7 days | 14 days | 28 days |
|---|---|---|---|
| 5% | 2.00 | 2.40 | 2.90 |
| 10% | 2.10 | 2.50 | 3.00 |

| | | | |
|---|---|---|---|
| 15% | 1.80 | 2.20 | 2.70 |
| 20% | 1.60 | 2.00 | 2.50 |

It is observed from the experimental works that Rice Husk Ash-Silica Nano Particle (RHASNP) can be utilize successfully as partial replacement with coarse aggregate in Recycled Aggregate Concrete. Concrete mix workability reduces with the increase in RHASNP percentage as determined by the slump, and compaction factor tests. But, the compressive, split tensile strengths also reveal that the increase in percentage replacement of cement to RHASNP of up to 10% does not decreases strength of the concrete. Beyond 10%, the strength becomes lower though it is still acceptable in some application. This research provides an insight into utilizing plant waste-derived silica nanoparticles for sustainable construction purposes.

## XI. CONCLUSION AND FUTURE WORK

Silica nanoparticles recovered from wheat husk ash and its application on food grains for sustainable enhancement of agricultural production. Preliminary results are encouraging, but further research and oversight of potential environmental and health impacts will be needed to achieve the full potential of this technology.

Crystalline phases, relative crystallite abundance, average particle size and the general form of nanoparticles in silica having nanoparticles obtained from millet husk ash on XRD can be inferred from silica nanoparticles from millet husk ash. This data is vital for additional applications like catalysis, nanocomposite materials, or biomedical applications.

Based on the analysis

- Confirm the presence of silica nanoparticles in the millets husk ash.
- Assess the purity and identify any contaminants or additional components.
- Discuss any surface modifications or treatments observed.

Infer the efficacy of the nanoparticles towards different applications based on their structural features observed under FTIR. The precise findings and conclusions of such an analysis would vary based on the particular spectra extracted and the goals of the study. Each peak and band in the FTIR spectrum would be attributed to corresponding molecular vibrations, these could provide useful information regarding the structure and composition of the silica nanoparticles in the millets husk ash. The performance test results indicate that RHASNP can be efficiently used as a partial substitution of coarse aggregate in recycled concrete. The slump and compaction factor tests reveal that the workability of the concrete reduces with increasing RHASNP percentage. Nevertheless, they are relatively compared with the control concrete, for the compressive strength and split tensile strength, means that replacement of cement by up to 10% RHASNP does not reduce its strength values, or improve the strength of the concrete. Above 10%, the strength goes down, but is still usable for some applications. This study presents an opportunity to implement nanoparticles of silica from agro-waste in green construction sector.

**Applications and Future Perspectives:** The potential applications of these silica nanoparticles, such as drug delivery systems, catalysis, sensors, and reinforcement materials. Address challenges and propose future research directions to optimize synthesis methods, enhance nanoparticle properties, and expand application possibilities.

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