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# Partial Replacement of Cement with Egg Shell Powder and Silica Fume

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**ABSTRACT:** The construction industry is exploring alternatives to traditional concrete, with egg shell powder and silica fume emerging as promising options. Experimental research shows that incorporating these materials can enhance concrete strength while reducing environmental impact and costs. By meticulously testing different proportions, it's evident that both additives contribute to stronger concrete. This research aims to promote eco-conscious innovation in concrete production, offering valuable insights for sustainable construction practices.

**KEYWORDS:** Concrete, Egg Shell Powder, Silica Fume, Cement, Workability, Compressive Strength, Split Tensile Strength

## I. INTRODUCTION

The interest of the construction of community in using waste or recycled materials in concrete is increasing because of emphasis placed on sustainable construction. The glass is an inert material which could be recycled and used many times without changing the chemical properties. Besides using waste glass as cullet in glass manufacturing waste glass powder and eggshell ash powder crushed in to specific size for uses as cement in various application. During the world, concrete is presence broadly used for the structure of greatest of the buildings, bridges etc. Presently, the complete construction industry is in exploration of an appropriate and operative the unused product that would greatly minimalize the use of cement and eventually decrease the creation cost. Such a substitute material are egg shell powder and silica fume. Greatest of eggshell waste is willing in landfills short of any pre-treatment since it is conventionally unusable and eventually makes thoughtful eco glitches.

Therefore, proper alternate is required to manage the wastes in eco-friendly way. The goal of this investigation work is to use the eggshell powder, silica fume as a limited additional of cement. Egg shell powder is replaced by 5%, 10% and 15% in addition with the silica fume by 2.5%, 5%, and 7.5% of weight of cement. Experimental research demonstrates the strength features such as split tensile strength, compressive strength, and flexural strength test of egg shell based concrete were investigated. It is found the strength of the concrete rises with the adding of eggshell powder and silica fume and finally the comparison is made for the egg shell and silica fume added strength of concrete.

## II. RELATED WORK

The objectives of a study investigating the partial replacement of cement with eggshell powder and silica fume in concrete production can be multifaceted, aiming to address various research questions and contribute to both academic knowledge and practical applications. Here are some potential objectives Assessment of Material Properties In-depth characterization of the material properties involves not only basic tests but also more detailed analyses to understand the nuanced behavior of cement, eggshell powder, and silica fume. This may include evaluating their morphological characteristics using scanning electron microscopy (SEM) and transmission electron microscopy (TEM) to observe particle morphology, surface features, and microstructure. Additionally, chemical analyses such as X-ray fluorescence (XRF) and X-ray photoelectron spectroscopy (XPS) can provide insights into the elemental composition and chemical bonding states of the materials. Understanding the inherent variability in material properties due to factors like particle size distribution, mineralogical composition, and processing methods is crucial for ensuring consistency and reliability in concrete production. Optimization of Mix Proportions Mix design optimization entails a systematic exploration of

the vast parameter space involving cement, eggshell powder, and silica fume proportions, as well as other factors like water-to-cement ratio, aggregate gradation, and admixture dosages.

Advanced optimization techniques such as genetic algorithms, particle swarm optimization, and machine learning algorithms can be employed to efficiently search for the optimal mix proportions while considering multiple performance criteria and constraints. Sensitivity analyses can help identify critical factors influencing concrete properties and guide decision-making in selecting the most robust and cost-effective mix designs for specific applications. Investigation of Fresh and Hardened Properties Beyond conventional mechanical tests, a comprehensive investigation of fresh and hardened properties may involve a range of experimental techniques and testing protocols tailored to the unique characteristics of concrete mixes containing eggshell powder and silica fume. For instance, rheological analyses using rotational rheometers or flow table tests can provide insights into the flow behavior and workability of fresh concrete mixes. Advanced mechanical testing methods such as nanoindentation, dynamic mechanical analysis (DMA), and acoustic emission monitoring can offer a deeper understanding of the microstructural changes and mechanical responses of concrete specimens under various loading conditions, including static, cyclic, and dynamic loading regimes.

The scope of a study investigating the partial replacement of cement with eggshell powder and silica fume in concrete production can encompass various aspects, including. Material Characterization In-depth material characterization involves not only the analysis of cement, eggshell powder, and silica fume but also the assessment of their compatibility and potential synergistic effects. This may include additional tests such as Fourier-transform infrared spectroscopy (FTIR) to identify chemical bonds and functional groups, thermal analysis (e.g., differential scanning calorimetry, thermogravimetric analysis) to study thermal behavior, and rheological analysis to understand the flow properties of concrete mixes. Mix Design Optimization The study can explore a wide range of parameters in mix design optimization, including different types of cement (Portland cement, blended cement), various sources and processing methods of eggshell powder, and different grades of silica fume.

### III. METHODOLOGY

#### 3.1 Silica Fumes

The calculation of silica fume has presented to improve both and toughness of concrete and compressive strength Also, the presence of this admixture has been shown definite in snowballing the electrical resistivity and the durability of concrete bare to aggressive situations like chloride comprising environments. Pozzolanic materials are usually able to association with the hydrated calcium hydroxide starting the hydrated calcium silicate which is the principal responsible for the benefit of hydrated cement pastes. Also, a rise in the bulk density of concrete fallouts as the mixture voids are occupied with very small admixture elements. The addition of silica fume in concrete leads to decrease in porosity of the evolution zone between matrix and aggregate in the renewed concrete and delivers the microstructure desirable for a robust transition zone. Hence, silica fume is extra with egg shell powder in the cement to recover the strength and durability parameter of the conventional mortar cubes. Silica fume is replaced by 5%, 10% and 15% by the weight of cement .



Fig1 Silica Fume



Oxide content	Percentage (%)
SiO <sub>2</sub>	90.21
CaO	0.30
Fe <sub>2</sub> O <sub>3</sub>	0.15
Al <sub>2</sub> O <sub>3</sub>	0.12
MgO	0.73
SO <sub>3</sub>	0.01
Na <sub>2</sub> O	0.46
K <sub>2</sub> O	1.51

Chemical Composition of Silica Fume

S.NO	Physical properties	Value
1	Specific gravity	2.52
2	Bulk Relative Density (Kg/m <sup>3</sup> )	1691
3	Fineness modulus	3.9

Table1 Physical Properties of Silica Fume

S.NO	CHEMICAL PROPERTIES	VALUES
1	pH	7
2	Color	Grayish off white

Table2 Chemical Properties of Silica Fume

### 3.2 Egg Shell Powder

Contains of several mutually growing layers of  $\text{CaCO}_3$ , the inner most layer maxillary slayer grows on a outermost egg membrane and creates the base on which palisade layer constitutes the thickest part of the egg shell. The top layer is vertical layer covered by the organic cuticle. The eggshell prilimilarly contains calcium, magnesium carbonate and protein. In many other countries, it is accepted practice for eggshell to be dried and use as a sources of calcium in animal feed. The quality of lime in eggshell waste is influenced greatly by the extent of explore to sunlight, raw water and harsh weather conditions. It is the grained powder with suitable proportion which is sieved to the required size before use with concrete mortar.



Fig. 2 Egg Shell Powder

Components	White eggshell
Moisture	0.46
Protein	3.92
Ash	94.61
Fat	0.35
Calcium	34.12
Magnesium	0.29
Phosphorous	0.04
Potassium	0.03
Sodium	<1ppm
Copper	<22ppm
Iron	<1ppm

Table 3 Chemical Composition of Egg Shell Powder

S.NO	PHYSICAL PROPERTY	VALUES
1	Specific Gravity	0.85
2	Moisture Content	1.18
3	Bulk Density (g/m <sup>3</sup> )	0.8
4	Particle Density (g/m <sup>3</sup> )	1.012
5	Porosity (%)	22.4 BET
6	Surface Area (m <sup>2</sup> /g)	21.2

Table 4 Physical Property of Egg Shell Powder

### 3.3 Slump Cone Test

The slump cone test is a standard method used in construction to measure the consistency or workability of freshly mixed concrete. In this test, a truncated cone-shaped mold called a slump cone is filled with concrete in layers and then carefully lifted vertically. After removal, the concrete slumps or settles, and the difference in height between the



original and final positions is measured. This difference, known as the slump, provides an indication of the concrete's workability, with higher slumps indicating greater fluidity and lower slumps indicating a stiffer mix.

**3.4 Standard Consistency Test**

The standard consistency test is a procedure used to determine the water content required to produce a concrete or cement paste of standard consistency. In this test, a specified amount of water is gradually added to a sample of cement until a paste of standard consistency is obtained. The standard consistency is typically defined as the point at which a standard Vicat apparatus plunger penetrates a specified distance into the cement paste. This test helps ensure uniformity and predictability in cement hydration and concrete properties.

**3.5 Specific Gravity Test**

The specific gravity test is a method used to determine the density or relative density of a material compared to the density of water. In this test, the weight of a given volume of the material is measured and compared to the weight of an equal volume of water. The ratio of these weights provides the specific gravity of the material. This test is commonly used in construction and engineering to assess the quality and properties of materials such as aggregates, cement, and concrete.

**3.6 Fineness Modulus Test**

The fineness modulus test is a standard method used to measure the average particle size of aggregate particles in a sample. It provides an indication of the fineness or coarseness of the aggregate, which is important for determining the workability and strength of concrete mixes. The fineness modulus is calculated by dividing the sum of the cumulative percentages by 100. This test helps ensure uniformity and consistency in concrete production by assessing the particle size distribution of aggregates.

**3.7 Compressive Test**

The compressive strength test on concrete measures the ability of concrete to withstand axial loads or forces pushing on it from opposite directions. It's one of the most important tests in concrete technology and construction engineering. In this test, cylindrical or cube-shaped specimens of concrete are cast and cured under specified conditions. After a curing period, typically 28 days, the specimens are subjected to a gradually increasing compressive force until failure occurs. The maximum load at failure is recorded, and the compressive strength of the concrete is calculated by dividing this load by the cross-sectional area of the specimen. This test helps assess the quality and suitability of concrete for structural applications, ensuring that it meets design requirements and safety standards.

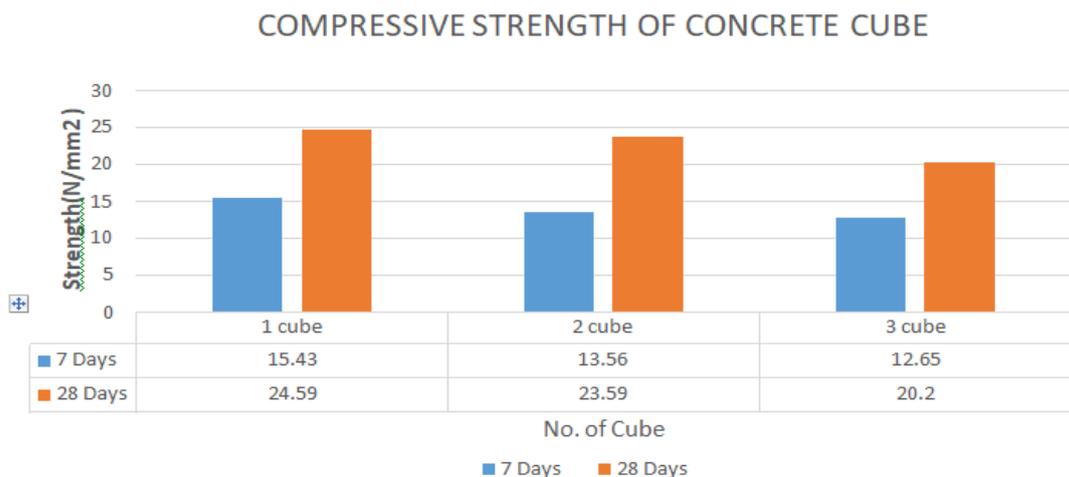


Table5 Compressive Strength of Concrete Cube

S.NO	% OF SF & ESP	COMPRESSIVE STRENGTH (N/mm <sup>2</sup> ).	
		7 DAYS	28 DAYS
1	0%	15.24	23.54
2	5%	15.43	24.59
3	10%	13.56	23.59
4	15%	12.65	20.20

Table6 Compressive Strength of Concrete Cube



Fig.4 Universal Testing Machine

### 3.8 Split Tensile Strength Test

The split tensile test on concrete measures its tensile strength indirectly by subjecting a cylindrical specimen to diametrical compression until failure. The tensile strength is calculated by dividing the maximum load at failure by the cross-sectional area of the specimen. This test provides valuable information about the ability of concrete to resist cracking and deformation under tensile forces, which is crucial for assessing its performance in structural applications.

SPLIT TENSILE STRENGTH OF CONCRETE CYLINDER

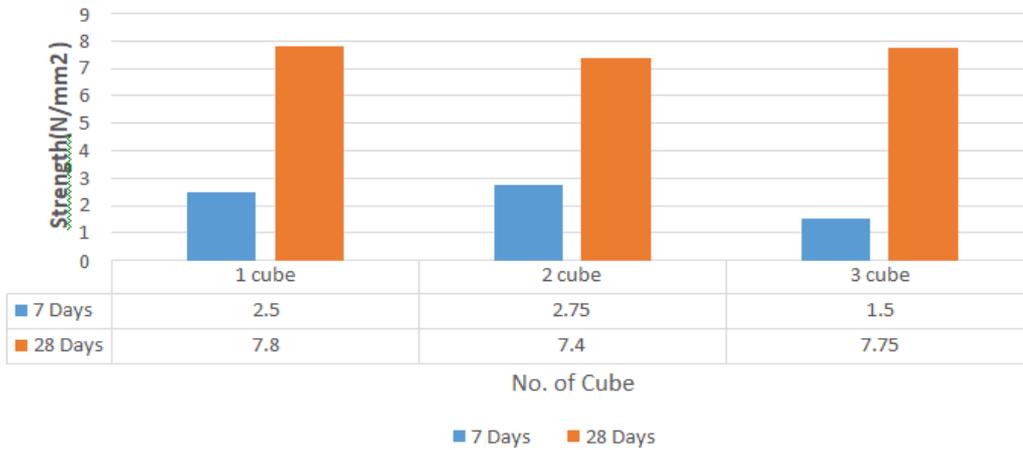


Table7 Split Tensile Strength of Concrete Cube

S.NO	% OF SF & ESP	SPLIT TENSIE STRENGTH (N/mm <sup>2</sup> ).		
		7 DAYS	14 DAYS	28 DAYS
1	0%	2.9	4	7.8
2	5%	2.5	3.6	7.4
3	10%	2.75	3.9	7.75
4	15%	1.5	3	6.5

Table 8 Split Tensile Strength of Concrete Cube



Fig.5 Split Tensile Strength Test Machine

#### IV. RESULT AND DISCUSSION

The utilization of eggshell powder (ESP) as a partial replacement for cement presents a multifaceted solution, addressing both the challenge of eggshell disposal and enhancing the mechanical properties of concrete. Our experiments have revealed compelling insights into the performance benefits associated with incorporating ESP into concrete formulations. Firstly, the incorporation of ESP addresses the issue of eggshell waste management by repurposing this abundant agricultural byproduct into a valuable construction material. By diverting eggshells from landfills and integrating them into concrete production, we not only reduce environmental burdens but also contribute to the circular economy by creating a secondary use for these discarded materials. Moreover, our findings demonstrate significant improvements in concrete strength parameters when ESP is used as a cement replacement.

The compressive strength of concrete can be enhanced by up to 7.15% compared to traditional concrete mixes, particularly when ESP replaces up to 10% of the cement content. This increase in compressive strength not only enhances the structural integrity of concrete elements but also extends their service life, thereby reducing maintenance requirements and lifecycle costs. Similarly, the flexural strength of concrete exhibits notable enhancements with the incorporation of ESP. By replacing 10% or 15% of cement with ESP, we observed respective increases of 11.62% and 6.97% in flexural strength compared to conventional concrete mixes. This improvement is particularly advantageous in applications where resistance to bending and cracking is critical, such as in beams, slabs, and other structural elements subjected to bending loads. Additionally, the split tensile strength of concrete experiences a notable boost with the incorporation of ESP, particularly at lower replacement levels.

Replacing up to 10% of cement with ESP can result in a split tensile strength increase of up to 3.5% compared to traditional concrete mixes. This enhancement further enhances the durability and performance of concrete, particularly in tension-dominated situations such as in pavements and bridges. Overall, our research underscores the viability and benefits of utilizing eggshell powder as a partial replacement for cement in concrete production. Beyond mitigating waste disposal challenges, this approach offers tangible performance improvements, including enhanced compressive, flexural, and split tensile strengths. As we continue to explore innovative materials and sustainable practices in construction, the integration of ESP represents a promising avenue for achieving both environmental and structural goal.

#### V. CONCLUSION

Through extensive investigation and experimentation our research team has made significant strides in enhancing the performance and sustainability of concrete in construction projects. One of our key findings involves the substitution of 40% of cement in m20 grade concrete, resulting in impressive strength achievements, notably attaining a strength of 20km/m<sup>3</sup>. This breakthrough not only demonstrates the feasibility of such replacements but also suggests a potential paradigm shift in the way we approach concrete mix designs for conventional buildings. Building upon the foundation laid by various researchers in the field, as well as our own experimental endeavors, we have identified silica fume and egg shell powder as promising candidates for partial cement replacement in concrete formulations. Not only do these materials enhance the workability of the concrete mix, but they also contribute to significant improvements in strength parameters such as compressive and split tensile strength.

This dual benefit not only ensures the structural integrity of the concrete but also opens avenues for optimizing material usage and reducing environmental impact. Furthermore, our investigation extends beyond the realm of conventional construction materials to explore the potential of waste materials in concrete production. By incorporating waste glass powder and egg shell ash into concrete mixes, we not only mitigate the challenges associated with waste disposal but also unlock economic advantages. This approach embodies the principles of circular economy and sustainable development, wherein waste materials are repurposed to create value-added products, thereby minimizing resource depletion and environmental pollution.

Not only does it offer a pathway to achieving higher performance standards, but it also aligns with the growing imperative to adopt eco-friendly practices in the built environment. Moving forward, further research and collaboration are essential to refine these methodologies, validate their scalability, and facilitate widespread adoption across the construction sector. By harnessing the potential of innovative materials and sustainable practices, we can pave the way towards a greener, more resilient future for construction.



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