

Utilization of Sisal Fiber and Eggshell Waste as Sustainable Additives in Self-Compacting Concrete

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ABSTRACT

This study looks into using sisal fiber and powdered eggshell as eco-friendly additives to improve self-compacting concrete (SCC). Sisal fiber, from the agave sisalana plant, is strong and environmentally friendly. Powdered eggshell, a waste product high in calcium carbonate, can help make concrete production more efficient. The research involves changing the amounts of sisal fiber and powdered eggshell in SCC mixes to see how they affect properties like compressive strength, flexural strength, and impact resistance. Various tests, such as slump, compressive strength, tensile strength, and acid attack evaluations, are done to understand the fresh and hardened properties of the modified concrete. The study shows that using natural fibers and waste materials can improve concrete's mechanical properties and lower its environmental impact. This method offers a way to use renewable resources and waste in construction, supporting the circular economy and sustainable development goals.

Keywords —Construction, Concrete, Self-Compacting Concrete (SCC), Sisal Fiber, Eggshell Waste.

I. INTRODUCTION

Modern concrete is used to build homes, structures, and residences as it has its unique features, which include strength, adaptability, and ease of development. Cement development and mass production, however, have caused ecological problems such energy use, reduced raw material availability, water shortages, global warming, and landfill issues. For years, academics have been searching for more grant-friendly, cleaner materials. Compared to ordinary concrete, fiber-reinforced concrete has much-increased tensile strength, deformations, compressive strength, and durability. It can also endure dynamic impacts and load variations without breaking down. Throughout the concrete hardening process, ordinary concrete initially contains a lot of micro-cracks in its structure that form from loading, which lowers the tensile strength. Whenever microfibers are added to concrete, the fibers are distributed equally and randomly throughout the composition, significantly lowering shrinkage and micro-crack formation during the hardening process and enhancing the material's overall strength. Though cracks have

formed, the fibers resist further crack formation and maintain the concrete matrix.

Usually, fiber reinforcement in concrete is made of steel fiber, basalt, polypropylene, and cellulose. Carbon- or glass-fiber-reinforced concrete is also widely used. While steel, basalt, and artificial fibers have good tensile strength, materials often have to be produced and processed in isolation, which can be expensive in regard to energy. As a result, suitable characteristics are always brought to the construction process. Because concrete releases a lot of greenhouse gases, it has an effect on the environment as well. The observation that substantial amounts of non-renewable materials are required for building is not an exaggeration. Thus, the actual difficulty of modern designs is in discovering natural substitutes for the steel and artificial fibers that are now utilized for fiber reinforcement.

Concrete must be placed using traditional methods that require vibrations from the machinery and are labor-intensive, noisy, and sometimes dangerous. Self-compacting concrete, or SCC, evolved in order to go down this path. However, because of the comparatively high cement content

as well as the exceptionally high temperatures that result from it, issues have been raised regarding the self-compacting method because of the expanding demands of sustainable development. The heat of hydration raises the chance of fast solidification and consequent carbon releases. In addition, as already mentioned, a significant problem is the amount of waste produced while building and demolition. Environmental activists and environmentalists reusing this waste could help with waste management in an efficient way. The fragile nature of concrete is another problem. Applying fiber will assist in resolving this issue because there are rich raw materials. Conventional building materials are used more often, so it is expected that this research will be carried out and the use of recycled materials will become more popular.

Some of the harmful effects that conventional concrete materials have on the environment can be reduced by producing concrete building materials from plant fibers. Concrete's strength can be enhanced with plant fibers, which is consistent with current views of ecological and sustainable growth. The cellular concrete's pores are shielded by the support structure that the cement and fiber mix to form. Fibers are included in aerated concrete to protect certain air bubbles and lower the rate of degradation. In addition, the slurry's compaction and dissolution rate are dropped, the aeration guarantee's general stability is enhanced, crack formation and propagation are inhibited, and the concrete's porosity and toughness are raised.

Concrete manufacturing has evolved over time as a result of the global demand for affordable, safe, secure, and sustainable concrete housing. In order to produce a concrete product that is both affordable and long lasting, research was carried out. Assessing the study that has been done on concrete thus far has helped to clarify the significance of concrete and concrete research. The efficiency of concrete is increased by adding different admixtures to it. Admixtures improve concrete performance only if added in the specified amounts.

II. MIX FORMULATION WITH CONCRETE M30 GRADE

Section-1

Mix design for M30 grade concrete:

Refer: IS 456 (2000)

Grade of concrete = M30

Type of Cement = PPC 43 grade from IS Code (1489-1)

Admixture = Sisal fiber

Maximum aggregate size Nominal = 20mm

Minimum concrete content = 320 kg/m³

Exposure Condition = Severe (reinforcement of concrete) Method of concrete placing = Pumping

Specific gravity of cement = 2.88

Specific gravity of fine aggregate (Zone-II) = 2.65

Specific gravity of coarse aggregate = 2.74

Specific gravity of Admixture = 1.145

Step 1:

Target mean strength

$$F_m = F_{ck} + 1.65 \times 5 F_m = 30 + 1.65 \times 5$$

$$F_m = 38.25 \text{ N/mm}^2$$

Step 2:

Water cement (W/C) Ratio

$$W/C = 0.43$$

< 0.45, Hence ok

Step 3:

As per IS code Maximum Water content = 10262

Size of Coarse aggregate = 20mm

Slump value = 50mm

Weight of water (W_w) = 186 kg/m³

For slump = 75mm

$$W_w = 186 + 186 \times 3/100 = 191.58 \text{ kg.m}^3$$

After using super plasticizer, the water content can be reduced up to 20% and above.

$$W_w = 191.58 - 191.58 \times 20/100 = 153.264 \text{ kg.m}^3$$

Step 4:

$$W/C = W_w / W_c$$

$$W/C = 153.264 / 0.43 = 356.427 \text{ kg.m}^3$$

$$= 356.427 > 320 \text{ kg.m}^3, \text{ Hence ok}$$

Step 5:

Preparation of Coarse and fine aggregate

Volume of coarse aggregate corresponding to aggregate Size 20mm

Volume of Fine aggregate (Zone-II) As per IS code: 383 for water cement ratio.

For W/C ratio = 0.43, Aggregate Proportion = 0.634

Step 6:

Total volume of Concrete = 1 m³

- a) Volume of concrete mass = $1 - 1/100 = 0.99 \text{ m}^3$
- b) Volume Cement = $W/C / SC \times 100 \text{ m}^3 = 356.427 / 2.88 \times 100 = 0.1237 \text{ m}^3$
- c) Volume of Water = $W_w / 1000 = 153.264 / 1000 = 0.15326 \text{ m}^3$
- d) Volume of Admixture = Weight of admixture. / Sadm x 1000 = 1% of W/C / Sadm x 1000 = $1/1000 \times 356.427 / 1.145 \times 1000 = 0.00311128 \text{ m}^3$
- e) Volume of Total Aggregate = (a) – (b + c + d) = $0.99 - (0.1237 + 0.15326 + 0.00311128) = 0.709 \text{ m}^3$
- f) Weight of Coarse aggregate = Aggregate proportion x e x SCA x 1000 = $0.634 \times 0.709 \times 2.74 \times 1000 = 1231.64 \text{ kg}$
- g) Weight of Fine aggregate = (1 - Aggregate proportion) x e x SFA x 1000 = $(1 - 0.634) \times 0.709 \times 2.74 \times 1000 = 687.65 \text{ kg/m}^3$

III. RESULTS AND DISCUSSION

The experimental results were analyzed and presented in graphs and tables. Specimens were prepared using 0.0%, 1.0%, and 2.0% of silica fume as an admixture, along with varying percentages of powdered eggshell. The study includes detailed results on slump flow, compressive strength, and tensile strength of these specimens. Additionally, an acid attack test was conducted to evaluate their durability.

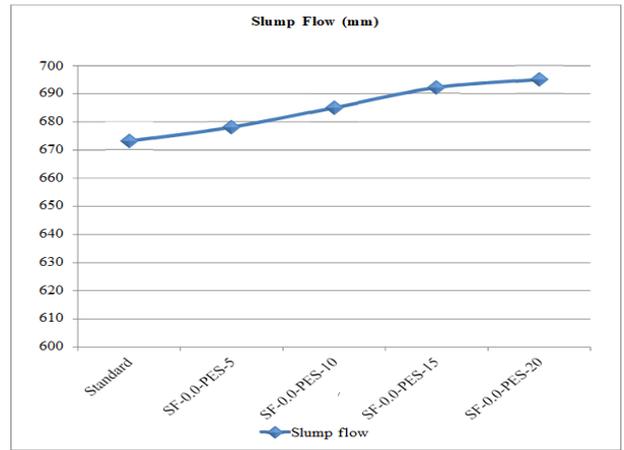


Figure 1: Slump flow value of concrete using 0.0% SF admixture with varying % of PES

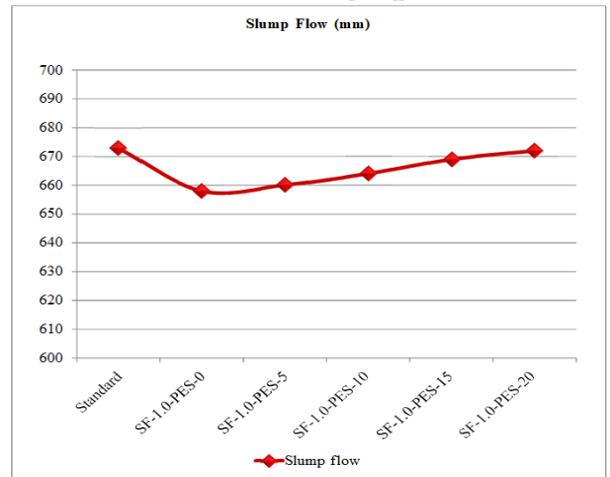


Figure 2: Slump flow value of concrete using 1.0% SF admixture with varying % of PES

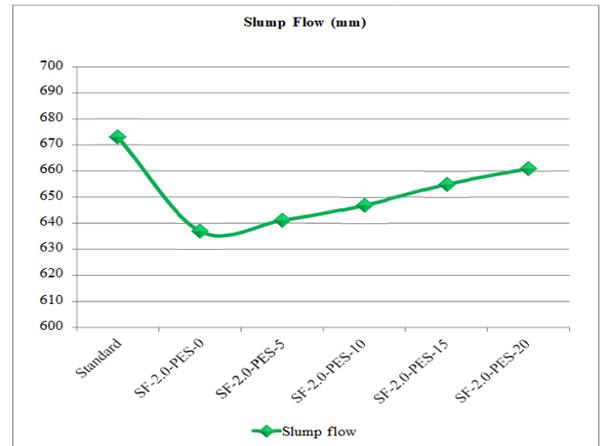


Figure 3: Slump flow value of concrete using 2.0% SF admixture with varying % of PES

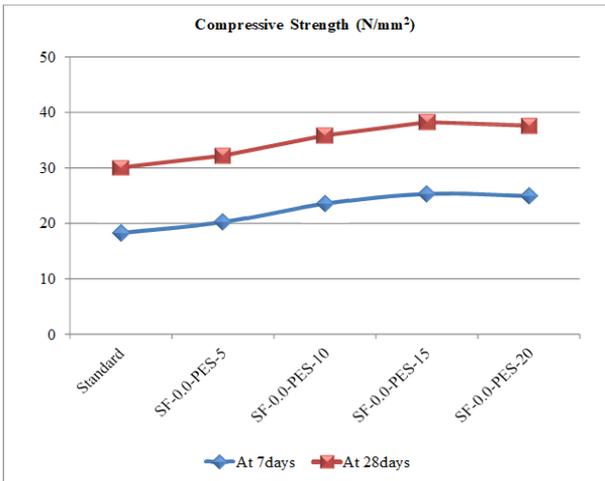


Figure 4: Compressive strength of concrete mix using 0.0% SF admixture with varying % of PES

Figure 6: Compressive strength of concrete mix using 2.0% SF admixture with varying % of PES

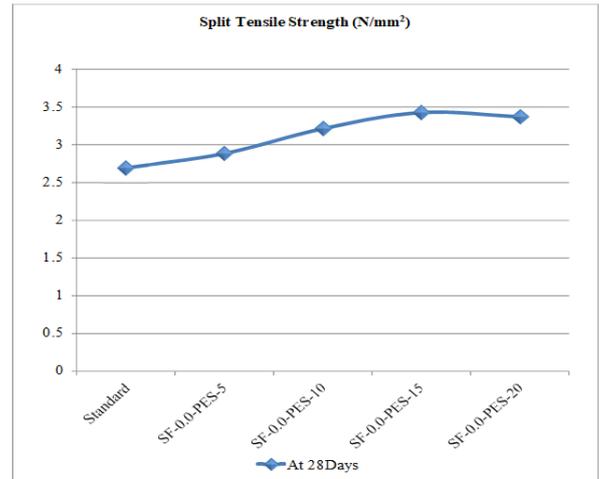


Figure 7: 28 days Split tensile strength of concrete mix using 0.0% SF admixture with varying % of PES

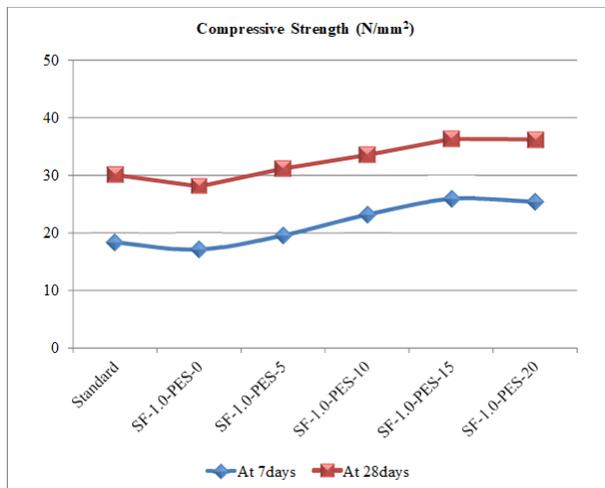


Figure 5: Compressive strength of concrete mix using 1.0% SF admixture with varying % of PES

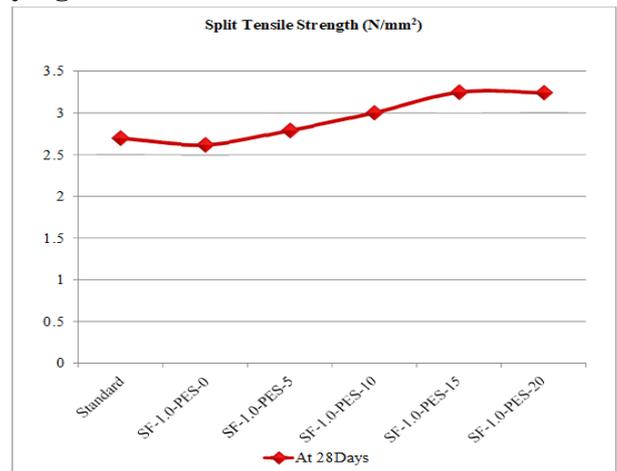


Figure 8: 28 days Split tensile strength of concrete mix using 1.0% SF admixture with varying % of PES

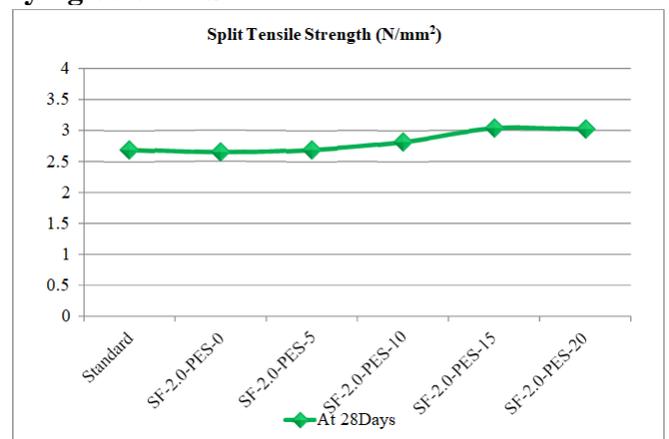
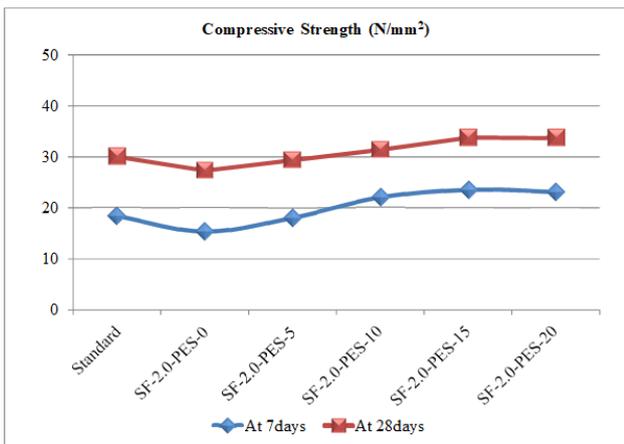


Figure 9: 28days Spit tensile strength of concrete mix using 2.0% SF admixture with varying % of PES

Figure 12: Acid Attack of concrete mix using 1.0% SF admixture with varying % of PES

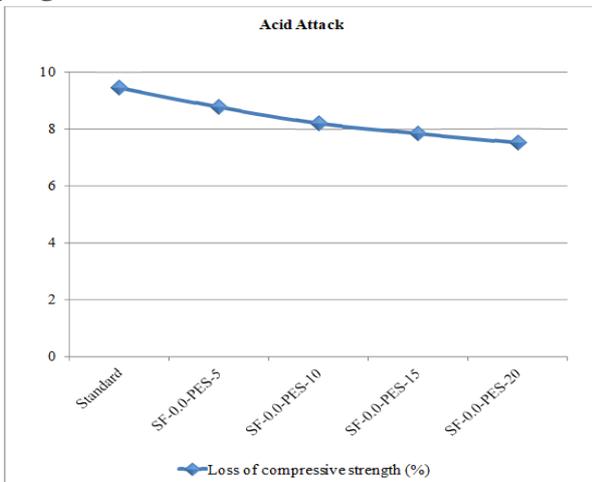


Figure 10: Acid Attack of concrete mix using 0.0% SF admixture with varying % of PES

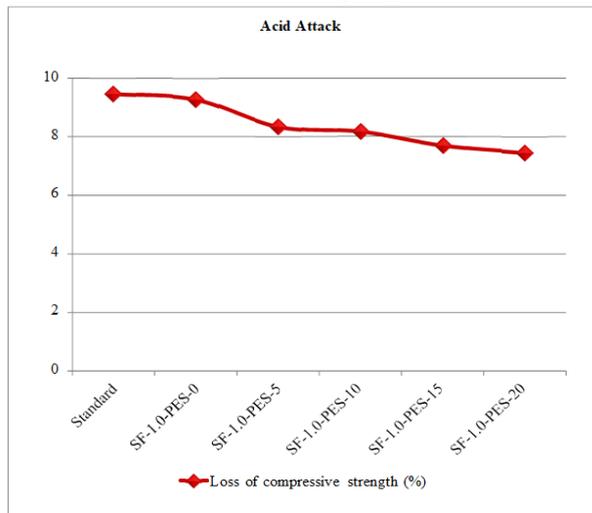
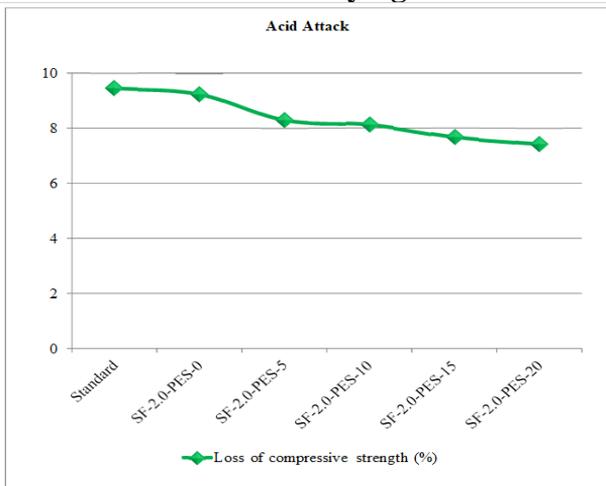


Figure 11: Acid Attack of concrete mix using 1.0% SF admixture with varying % of PES



IV. CONCLUSIONS

This study investigates the use of sisal fiber and powdered eggshell (PES) as eco-friendly additives in Self-Compacting Concrete (SCC). Results show that PES improves workability in mixes without sisal fiber (SF), but workability decreases with higher SF content. Both compressive and split tensile strengths increased with PES up to 15%, especially in mixes with 1.0% and 2.0% SF. Durability, assessed through acid attack tests, also improved with increasing PES, with the best performance at 2.0% SF and 20% PES. Overall, combining SF and PES enhances SCC's workability, strength, and durability while promoting sustainable and waste-utilizing construction practices.

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