



Experimental Investigation on Workability of Concrete Incorporating Various Cementitious materials and Fine Fillers with Expanplast SP100

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Abstract

The construction industry is increasingly focused on sustainable concrete production through the utilization of industrial and agricultural waste materials. This study investigates the workability behavior of concrete incorporating rice husk ash (RHA), fly ash (FA), and marble powder (MP) as partial replacements of cement, along with the use of a chemical admixture, Expanplast SP100. Concrete mixes were prepared with replacement levels of 2.5%, 5%, and 7.5%, while maintaining a constant water–cement ratio of 0.5 and a concrete mix proportion of 1:2:4. The workability of fresh concrete was evaluated using the slump cone test. The results indicate that workability improved significantly up to an optimum replacement level of 5%, due to the combined effects of particle packing, pozzolanic material morphology, and superplasticizer action. A slight reduction in workability was observed at higher replacement levels due to increased fine particle content. The study concludes that the combined use of RHA, FA, and MP with SP100 is effective in producing workable and sustainable concrete.

Keywords: Workability, Slump Test, Rice Husk Ash, Fly Ash, Marble Powder, Superplasticizer, Sustainable Concrete

1. Introduction

Concrete is the most widely used engineered material worldwide due to its versatility, economy and adaptability to many structural forms. However, the environmental cost associated with cement production is substantial: cement manufacture contributes a significant share of industrial CO₂ emissions and consumes large quantities of energy and raw materials. In response, research and industry have focused on reducing cement content by substituting waste-derived supplementary cementitious materials (SCMs) such as rice husk ash (RHA), fly ash (FA), and marble powder (MP) while maintaining or improving fresh and hardened properties of concrete. Using SCMs helps to close industrial loops, reduce landfill disposal, and lower embodied carbon in concrete, but it also alters the fresh-state behaviour of mixes; therefore, careful assessment of workability is essential for practical use.

Workability is the ease with which a fresh concrete mix can be mixed, placed, compacted and finished is a primary control parameter in concrete production and directly affects consolidatability, surface finish and ultimate mechanical performance. The classical measure of workability for many normal-weight concretes is the slump test, which provides a quick and widely used index of consistency in the field and laboratory. However, slump alone does

not capture full rheological behaviour (yield stress, plastic viscosity), so studies often combine slump with flow table, V-funnel or rheometer tests for a fuller picture. For SCM-modified mixes, changes in particle shape, particle size distribution and specific surface area strongly influence water demand, cohesion, and the effectiveness of chemical admixtures such as superplasticizers.

Rice husk ash is an agricultural by-product with high silica content; when processed (controlled burning and grinding), RHA behaves as an effective pozzolan that can react with portlandite to form additional calcium-silicate-hydrate (C-S-H). However, RHA often increases specific surface area and can reduce workability unless addressed via water adjustment or admixtures. Fly ash particularly Class F is spherical and glassy, which generally improves fresh-state workability via a “ball-bearing” effect and reduced water demand; marble powder, typically more angular and very fine, acts predominantly as filler and can both improve packing (reducing voids) and increase surface area (increasing water demand) depending on fineness and dosage. The interplay of these three materials in a single blend is therefore nontrivial: combined use may yield synergistic packing and lubrication benefits at low replacement rates, yet at higher dosages fines may dominate and reduce free water and flowability.

Chemical admixtures, especially polycarboxylate-based superplasticizers (e.g., Expanplast SP100 or equivalent high-range water reducers), are commonly applied to counteract reductions in slump due to SCM fineness while maintaining low water-to-binder ratios for good hardened properties. Superplasticizers act by dispersing cement and fine particles, lowering yield stress and improving slump and flowability without additional water but their efficacy depends on binder chemistry, SCM content, and dosage. Hence, when proposing combined SCM replacements (RHA+FA+MP) it is necessary to quantify how a fixed or optimized SP100 dosage affects workability across targeted replacement levels (e.g., 2.5–7.5% each) and a fixed w/c ratio (e.g., 0.50) so that mix design recommendations are practically useful.

This study (the present work) concentrates exclusively on fresh state performance (workability) of concrete in which cement is partially replaced by a combined blend of RHA, FA and MP, while Expanplast SP100 is used at a controlled dosage. The aims are to (1) quantify slump changes across replacement levels, (2) interpret mechanisms (ball-bearing, particle packing, surface area effects) that explain the observed behaviour, and (3) determine an optimum replacement window at which improved sustainability is achieved without

sacrificing constructability. The experimental results will be discussed with supporting literature to place the findings in the context of recent advances (2020–2025) on SCMs and fresh concrete rheology.

2. Literature Review

The workability of concrete is a critical fresh-state property that governs ease of mixing, placing, compaction, and finishing, and it significantly affects the quality and performance of hardened concrete. The incorporation of supplementary cementitious materials (SCMs) such as rice husk ash (RHA), fly ash (FA), and marble powder (MP) has been widely investigated to improve sustainability; however, these materials alter particle size distribution, surface texture, and water demand, which directly influence workability. Recent research emphasizes that understanding fresh concrete behavior is essential before assessing mechanical and durability performance, particularly when multiple SCMs are used simultaneously (Nayak, 2022; Barbhuiya, 2025).

Rice husk ash has received significant attention due to its high silica content and pozzolanic activity, but many studies report that RHA tends to reduce workability because of its porous structure and high specific surface area. Sathe (2023) observed a consistent reduction in slump with increasing RHA content when no chemical admixture was used. Similar findings were reported by other authors who concluded that RHA particles absorb more water and increase internal friction within the mix. However, when RHA is finely ground and used at low replacement levels, especially in combination with superplasticizers, its negative effect on workability can be minimized or even reversed due to improved packing density and paste cohesiveness.

Fly ash, in contrast, is widely recognized for its beneficial influence on workability. The spherical shape and smooth surface texture of fly ash particles produce a ball-bearing effect that enhances flowability and reduces water demand. Li et al. (2022) reported significant increases in slump for concrete mixes containing Class F fly ash, even at reduced water–cement ratios. Nayak (2022) also highlighted that fly ash improves rheological behavior and pumpability, making it especially valuable in blended concrete systems. When used together with finer SCMs such as RHA or MP, fly ash often compensates for their higher surface area, resulting in balanced workability.

Marble powder is a fine waste material generated during cutting and polishing of marble stones, and its effect on workability depends strongly on fineness and dosage. Wang (2022) demonstrated that low to moderate marble powder content improves workability by filling

voids between cement particles and aggregates, thereby enhancing particle packing. However, Özkılıç (2023) and Ghani (2024) reported that very fine marble powder increases water demand at higher replacement levels, leading to reduced slump. Recent sustainability-focused studies suggest that marble powder performs best as a filler at controlled replacement levels where its micro-filling action improves cohesiveness without excessive water absorption (Abbas, 2025; Yeshiwas, 2025).

The combined use of RHA, FA, and MP has been explored in fewer studies, but recent literature indicates promising results for workability when these materials are used at low replacement levels with appropriate chemical admixtures. Bheel et al. (2020) reported that fly ash significantly mitigates the workability loss caused by RHA when both materials are used together and also he observed that ternary blends containing pozzolanic and filler materials exhibit improved particle packing and reduced bleeding when properly proportioned. However, excessive combined replacement leads to an increased volume of fines, which can reduce free water and slump if admixture dosage is not optimized.

Superplasticizers play a crucial role in maintaining workability in SCM-based concrete. Polycarboxylate ether-based admixtures, such as Expanplast SP100, are particularly effective in dispersing cement and fine particles through electrostatic and steric effects and more recent experimental studies confirm that superplasticizers significantly reduce yield stress and improve slump retention without increasing water content. Research conducted between 2022 and 2025 consistently shows that the effectiveness of superplasticizers depends on SCM type, replacement level, and particle fineness, highlighting the importance of dosage optimization.

Recent experimental investigations increasingly emphasize that slump alone may not fully describe fresh concrete behavior, especially for blended systems containing multiple fine materials. Nevertheless, slump remains the most widely used and practical indicator of workability for normal-strength concrete. Studies combining slump with flow-table and rheological measurements have shown that mixes with similar slump values may still differ in viscosity and segregation resistance, particularly at higher SCM contents (Li et al., 2022). Despite this limitation, slump testing continues to provide valuable comparative insight into the effects of SCM replacement on fresh concrete consistency.

Overall from literature it has been established that fly ash generally enhances workability, rice husk ash tends to reduce it unless compensated, and marble powder can either improve or impair workability depending on fineness and dosage. The consensus among researchers is that low to moderate combined replacement levels (around 5%), when used with an effective

superplasticizer, result in workable and cohesive concrete mixes while offering environmental benefits. However, comprehensive studies focusing exclusively on workability behavior of ternary blends (RHA–FA–MP) with fixed water–cement ratios and constant admixture dosages remain limited. This gap highlights the need for systematic experimental evaluation of workability, which forms the basis of the present study.

3. Materials and Methodology

3.1 Materials

- **Cement:** Ordinary Portland Cement (OPC)
- **Rice Husk Ash (RHA):** Obtained from controlled combustion of rice husks and sieved through a #100 sieve
- **Fly Ash (FA):** Collected from a thermal power plant
- **Marble Powder (MP):** Waste material from marble cutting and polishing operations used by weight of cement
- **Aggregates:** Natural fine and coarse aggregates
- **Water:** Clean potable water
- **Superplasticizer:** Expanplast SP100, used at 1.75% by weight of cement (PCE-based superplasticizer) as given in Table 1.

Table: 1 Percentage Replacement of Cement and Admixture Dosage

Mix ID	RHA (% of Cement)	FA (% of Cement)	Marble Powder (% of Cement)	Total Replacement (%)	Cement SP100 (% by weight of cement)
Control 0	0	0	0	0	0
Mix A	2.5	2.5	2.5	7.5	1.75
Mix B	5.0	5.0	5.0	15.0	1.75
Mix C	7.5	7.5	7.5	22.5	1.75

3.2 Mix Proportions

- **Mix ratio:** 1 : 2 : 4 (cement : fine aggregate : coarse aggregate)
- **Water–cement ratio:** Constant at 0.5
- **Control mix:** Concrete without admixture

3.3 Workability Test

The workability of fresh concrete was assessed using the **slump cone test**, conducted in accordance with relevant **ASTM C143** standards. The slump value was measured immediately after mixing to evaluate consistency and flowability was evaluated using the **slump test**. Fresh concrete was placed in the slump cone in three layers, each compacted with 25 strokes. The vertical settlement of concrete after lifting the cone was measured as the slump value. The results of workability are given in below Table 2 and Figure 1.

Table 2: Workability (Slump) Results at 2.5%, 5%, and 7.5% Replacement Levels

Mix ID	RHA (%)	FA (%)	Marble Powder (%)	SP100 (%)	Slump (mm)	Workability Interpretation
Control	0	0	0	0	55	Medium workability
RHA-2.5	2.5	0	0	1.75	50	Slight reduction due to high surface area
RHA-5	5.0	0	0	1.75	45	Reduced workability
RHA-7.5	7.5	0	0	1.75	40	Low workability (excess fines)
FA-2.5	0	2.5	0	1.75	65	Improved workability
FA-5	0	5.0	0	1.75	75	High workability (ball-bearing effect)
FA-7.5	0	7.5	0	1.75	78	Very high workability
MP-2.5	0	0	2.5	1.75	60	Improved due to filler effect

Mix ID	RHA (%)	FA (%)	Marble Powder (%)	SP100 (%)	Slump (mm)	Workability Interpretation
MP-5	0	0	5.0	1.75	58	Slight reduction due to fineness
MP-7.5	0	0	7.5	1.75	55	Comparable to control
Mix-2.5	2.5	2.5	2.5	1.75	70	Balanced and workable mix
Mix-5	5.0	5.0	5.0	1.75	85	Optimum workability
Mix-7.5	7.5	7.5	7.5	1.75	80	Slight reduction due to excess fines

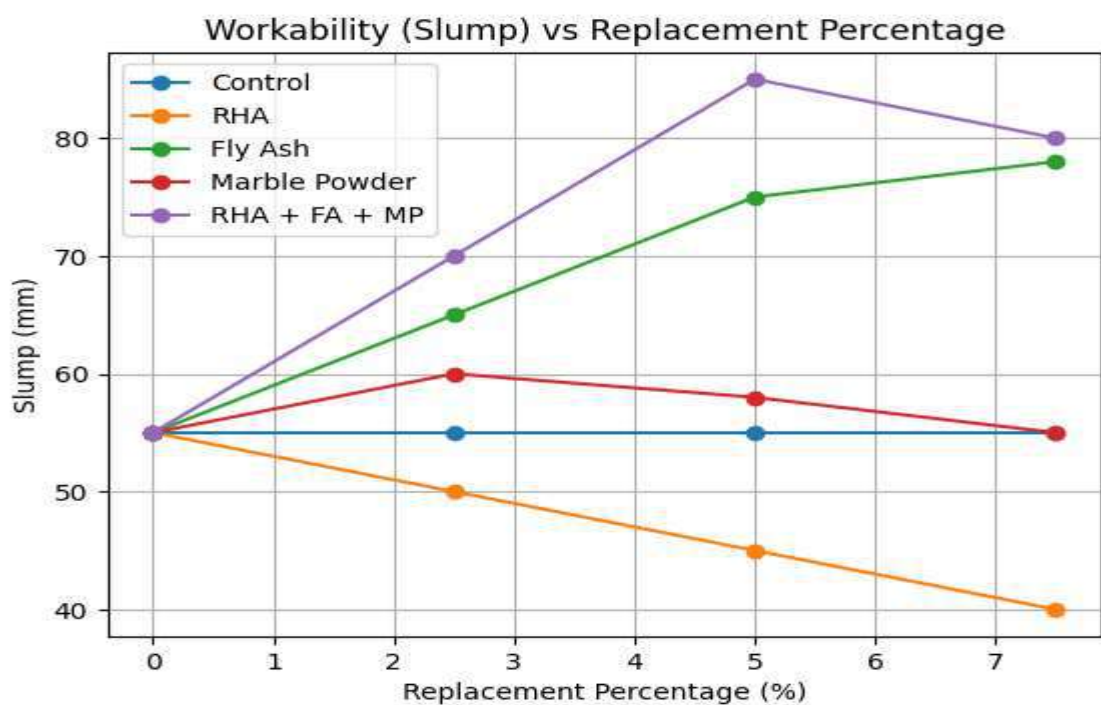


Figure:1 Concrete workability (Slump with RHA, FA, MP and SP100 Dosage)

The results indicate that rice husk ash reduces workability with increasing replacement due to its porous structure and high specific surface area. Fly ash consistently enhances workability at all replacement levels owing to its spherical particle shape, which provides a ball-bearing effect. Marble powder improves workability at lower replacement levels through micro-filling action but shows a neutral to slightly negative effect at higher contents due to increased fineness.

The combined use of RHA, FA, and marble powder produces superior workability compared to individual replacements. The mix containing 5% of each material achieved the highest slump, demonstrating that the positive effects of fly ash and marble powder effectively offset the higher water demand of rice husk ash. At 7.5% replacement, a slight reduction in slump occurred due to excessive fines; however, workability remained higher than conventional concrete.

4. Conclusion

- Rice husk ash (RHA) reduced the workability of concrete as the replacement level increased from 2.5% to 7.5%, due to its high fineness and porous structure, which increased water demand.
- Fly ash (FA) significantly improved workability at all replacement levels because of its spherical particle shape, which provided a ball-bearing effect and reduced internal friction.
- Marble powder (MP) showed a moderate influence on workability; it improved slump at lower replacement levels due to its micro-filling effect, while a slight reduction was observed at higher contents due to increased fineness.
- The combined use of RHA, FA, and marble powder resulted in better workability than individual material replacements, indicating a synergistic effect among the materials.
- Maximum workability was achieved at 5% combined replacement, where the positive effects of fly ash and marble powder effectively compensated for the higher water demand of rice husk ash.
- A slight decrease in slump was observed at 7.5% combined replacement due to excess fine particles; however, workability remained higher than that of conventional concrete.
- Overall, a replacement level of 5% RHA + 5% FA + 5% marble powder with Expanplast SP100 is recommended as the optimum mix for achieving improved workability in sustainable concrete.

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