iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 13 **Issue:** XII **Month of publication:** December 2025

DOI: https://doi.org/10.22214/ijraset.2025.76287

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 13 Issue XII Dec 2025- Available at www.ijraset.com

Study of Macro Mechanical Properties of High Strength Concrete (M70) by Partial Replacement of Cement with Fly Ash and Rice Husk Ash and Fine Aggregate with Steel Slag

K. Anudeep[1], T. Chandra Sekhara Reddy[2]
[1]M. Tech Student (Structural Engineering), Civil Engineering Department, G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India
[2]Professor, Civil Engineering Department, G. Pulla Reddy Engineering College, Kurnool, Andhra Pradesh, India

Abstract: High-strength concrete (HSC) is increasingly preferred in modern construction due to its superior mechanical performance and improved service life. In the present study, an experimental investigation was carried out on M70 grade high-strength concrete incorporating industrial and agricultural by-products as partial replacements for conventional materials. Cement was partially substituted with Fly Ash (10–30%) and, subsequently, the optimum FA level was maintained while Rice Husk Ash (RHA) was introduced at 5%, 7.5% and 10%. Further, using this optimized binary blend, natural fine aggregate was replaced with Steel Slag (SS) at 10%, 20%, 30% and 40% to examine its influence on overall strength characteristics. The mix design for M70 concrete was prepared as per IS 10262:2019 and tested for compressive, split tensile and flexural strengths at 7 and 28 days. The findings clearly indicate that the mechanical behaviour of high-strength concrete can be significantly improved when FA, RHA and SS are used in controlled proportions. Among all mixes, the blend containing 10% FA, 7.5% RHA and 30% SS exhibited the highest strength values, producing a 28-day compressive strength of 89.2 MPa, split tensile strength of 5.40 MPa and flexural strength of 6.70 MPa, outperforming the conventional mix. Based on the obtained results, the optimized ternary mix demonstrates superior macro-mechanical properties and presents a sustainable alternative to conventional high-strength concrete.

Keywords: High-Strength Concrete, Fly Ash, Rice Husk Ash, Steel Slag, Supplementary Cementitious materials

I. INTRODUCTION

High-strength concrete (HSC) has become an essential material in modern infrastructure due to its improved load-carrying capacity, enhanced durability, and reduced member size requirements. However, the production of such high-performance material typically demands large quantities of cement and high-quality natural aggregates, both of which raise environmental and economic concerns. The cement industry remains a major contributor to global CO_2 emissions, while continuous extraction of river sand is causing significant ecological degradation. These challenges have encouraged the use of sustainable alternatives through partial substitution of conventional materials without compromising performance.

In recent years, supplementary cementitious materials (SCMs) such as Fly Ash (FA) and Rice Husk Ash (RHA) have gained prominence due to their pozzolanic reactivity and micro-filling ability. Fly Ash improves long-term strength and workability, while RHA, being highly rich in amorphous silica, contributes to refined pore structure and dense hydration products. Parallel to cement replacement, steel industries generate substantial quantities of Steel Slag (SS), a granular by-product that has shown promise as a replacement for natural fine aggregates. Its angular particle shape, higher hardness, and improved interlocking potential make it a viable alternative to river sand in high-strength concrete mixes.

The present study focuses on developing M70 grade high-strength concrete by partially replacing cement with FA (10–30%) and optimizing RHA addition (5–10%) within the best-performing FA mix. Additionally, the optimum FA–RHA blend is combined with varying levels of Steel Slag (10–40%) as a fine aggregate replacement. The investigation evaluates the influence of these combined replacements on the macro-mechanical properties—compressive strength, split tensile strength, and flexural strength—at both early and later ages. Through this approach, the study aims to demonstrate how sustainable waste-derived materials can be integrated into high-strength concrete to achieve superior performance while minimizing the reliance on conventional raw materials.

II. REVIEW OF LITERATURE

Andres Salas Montoya et al. [1] had investigated that thermally and chemically treated RHA significantly improved mechanical performance, with compressive strength increasing by over 20% and flexural strength rising by nearly 46% compared to conventional mixes.

The enhanced modulus and refined pore structure indicated superior pozzolanic activity, making treated RHA a viable alternative to silica fume for high-performance concrete.

Asad A. Khedheyer Al-Alwan et al. [2] had investigated that adding 7–14% RHA increased compressive strength by approximately 11% and improved tensile and flexural strengths by up to 4.5%. The finer RHA particles enhanced matrix densification, lowering water absorption and improving chloride resistance, confirming its usefulness as a sustainable cement replacement.

Feifei Liu et al. [3] had investigated that RHA addition (up to 20%) enhanced the compressive strength of UHS-ECC to about 130 MPa and increased tensile strength to 8.5 MPa despite reduced ductility. Microstructural analysis confirmed increased C–S–H formation and denser ITZ, indicating that moderate RHA levels optimize both strength and durability.

Md.Montaseer Meraz et al. [4] had investigated that replacing cement with 10% FA and substituting silica fume with 10% RHA produced the highest mechanical improvements in HPFRC, increasing compressive, tensile and flexural strengths by 6–13%. Flexural toughness and durability also improved due to reduced pore volumes and a denser hydrated matrix, demonstrating strong eco-mechanical benefits of FA–RHA blends.

Mohammed NajeebAl-Hashem et al. [5] had compiled FA–RHA concrete data and developing ANN/GEP models, the authors found that moderate ternary blends (≈10–35% SCMs) can achieve compressive strengths equal to or greater than OPC mixes. Their review highlighted that FA’s spherical particles and RHA’s reactive silica significantly densify the ITZ, improving strength and durability, though early-age strength remains sensitive to RHA fineness and curing.

Muhammad Nasir Amin et al. [6] had investigated that a combined replacement of 20% FA and 10% RHA enhanced both early and 28-day compressive strengths, increasing from 25 MPa to over 30 MPa. The blended mix also showed higher workability and lower permeability due to the denser microstructure formed by synergistic pozzolanic reactions, confirming the mechanical advantage of FA–RHA combinations.

Parvin Montazeri et al. [7] had investigated that adding up to 20% RHA enhanced compressive strength by approximately 13% and significantly reduced chloride penetration and water absorption across all water–binder ratios studied. The densified pore structure led to major durability gains, and service-life modelling predicted over a threefold increase in lifespan, marking RHA (20%, W/B = 0.35) as the most mechanically efficient and environmentally superior blend.

Pham Vu Hong Son et al. [8] had investigated that replacing natural sand with processed steel slag (25–40%) in well-graded, low-cement mixes produced compressive strengths suitable for structural use. Durability indicators such as water absorption and freeze–thaw behaviour were improved in optimized blends, supported by SEM evidence of a denser binder matrix.

S. Azhagarsamy et al. [9] had investigated that using steel slag as fine aggregate significantly enhanced concrete strength, with 100% SSA achieving 51.01 MPa compressive strength and 5.76 MPa flexural strength at 90 days—an increase of nearly 30% over the control. Mid-range SSA replacements (40–70%) offered the best performance-workability balance, with 40% SSA also yielding the lowest water absorption.

Solomon Asrat Endale et al. [10] had investigated that RHA, containing up to 97% amorphous silica, improves packing density and stimulates strong pozzolanic activity. Optimal RHA dosages (10–20%) increased compressive strength by 10–30% and enhanced tensile and flexural strengths due to refined pore structure and increased C–S–H gel formation.

Yutong Zhao et al. [11] had investigated that controlled combustion of rice husk at 600–700°C followed by fine grinding greatly increases RHA reactivity by maximizing amorphous silica content. When used at 10–30% replacement, processed RHA improves strength, permeability, and corrosion resistance, while poorly burned or excessive RHA raises water demand and may reduce early strength.

III. MATERIALS AND THEIR PROPERTIES

A. Cement

Ordinary Portland Cement (OPC) of 53 grade from JSW was used as the primary binding material. The cement conformed to IS:12269 and was tested for specific gravity, standard consistency, setting times and 28-day compressive strength to ensure suitability for high-strength concrete. The obtained test results are presented in Table I.

B. Fine Aggregate

The fine aggregate used in the study was locally sourced river sand conforming to Zone II grading requirements as per IS: 383. Prior to use, the sand was sieved through a 4.75 mm sieve to eliminate oversized particles and washed to remove dust and impurities. Its physical characteristics are summarized in Table I.

C. Coarse Aggregate

Coarse aggregate of 20 mm nominal size was used throughout the work. The material was sieved to ensure proper size distribution and tested as per IS: 383 for specific gravity and mechanical properties. The physical properties of the coarse aggregate are given in Table I.

D. Fly Ash (FA)

Class F fly ash obtained from a Rayalaseema thermal power plant was used as a partial replacement for cement. Its pozzolanic nature and fine particle size contribute to improved workability and long-term strength. The relevant physical properties of FA are listed in Table I.

E. Rice Husk Ash (RHA)

RHA containing high amorphous silica content was used to enhance the pozzolanic reactivity of the binder. The ash was fine and lightweight, helping to refine pore structure and increase matrix density. The material properties of RHA are included in Table I.

F. Steel Slag (SS)

Processed steel slag was used as a partial substitute for natural fine aggregate. Its angular shape and higher density improved aggregate interlock and packing efficiency. The slag conformed to IS: 383-requirements for sand replacement, and its properties are presented in Table I.

G. Superplasticizer

Cera Hyperplast XR-W40, a polycarboxylate ether-based superplasticizer (PCE) was used to achieve the required workability at a low water–binder ratio. The admixture complied with IS: 9103 and ASTM C-494 specifications. Its use ensured better dispersion of binder particles and a denser concrete matrix.

H. Water

Potable water was used for both mixing and curing. Clean water is essential to initiate hydration reactions and ensure proper strength development. All curing was performed using the same quality of water to maintain consistency.

TABLE I
. PROPERTIES OF MATERIALS

Material	Properties
Cement	Specific gravity- 3.15 Normal consistency- 33% Initial setting time - 42 min Final setting time - 256 min Fineness-3% Compressive strength – 56 N/mm2
Fly Ash	Specific Gravity - 2.2
Rice Husk Ash	Specific Gravity - 2.18
Sand	Specific Gravity - 2.68 Fineness modulus - 2.86 Bulk density (Loose) - 1585 kN/m^3 Bulk density (Compacted) -1674 kN/m^3
Coarse Aggregate	Specific Gravity - 2.86

	Fineness modulus – 4.88
Steel Slag	Specific Gravity - 2.70 Fineness modulus – 4.59 Bulk density (Loose) - 1300 kN/m^3 Bulk density (Compacted) -1510 kN/m^3

IV. EXPERIMENTAL PROGRAM

The mix proportions for M70 high-strength concrete were designed as per IS 10262:2019 guidelines. The control mix consisted of OPC 53 grade cement, fine and coarse aggregates, potable water, and a PCE-based superplasticizer. Cement was partially replaced with Fly Ash (FA) at levels of 10%, 20%, and 30% to identify the optimum binder replacement. After determining 10% FA as the most effective proportion, Rice Husk Ash (RHA) was incorporated into this mix at 5%, 7.5%, and 10% replacement levels.

Following the identification of the optimum FA–RHA combination (FA10 + RHA7.5), fine aggregate was further replaced with Steel Slag (SS) at 10%, 20%, 30%, and 40% to study its influence on mechanical performance. A constant dosage of high-range water-reducing admixture (superplasticizer) was used in all mixes to maintain required workability at the low water–binder ratio needed for M70 concrete. All concrete mixtures developed for this study including the reference mix and the FA, RHA, and SS modified blends—are presented in Table II.

TABLE II

Mix proportions of all concrete mixes

Mix designation	Cement (kg/m^3)	FA (kg/m^3)	RHA (kg/m^3)	Water (lit/m^3)	Super plasticizer (lit/m^3)	Fine aggregate (kg/m^3)	Steel Slag (kg/m^3)	Coarse aggregate (kg/m^3)	w/c ratio
M1 (Reference Mix)	497	0	0	144	3.97	630	0	1325	0.29
M2 (FA10)	447.3	49.7	0	144	3.97	630	0	1325	0.29
M3 (FA20)	397.6	99.4	0	144	3.97	630	0	1325	0.29
M4 (FA30)	347.9	149.1	0	144	3.97	630	0	1325	0.29
M5 (FA10 + RHA5)	422.45	49.7	24.85	144	3.97	630	0	1325	0.29
M6 (FA10 + RHA7.5)	410.02	49.7	37.28	144	3.97	630	0	1325	0.29
M7 (FA10 + RHA10)	397.6	49.7	49.7	144	3.97	630	0	1325	0.29
M8 (SS10)	410.02	49.7	37.28	144	3.97	567	63	1325	0.29
M9 (SS20)	410.02	49.7	37.28	144	3.97	504	126	1325	0.29
M10 (SS30)	410.02	49.7	37.28	144	3.97	441	189	1325	0.29
M11 (SS40)	410.02	49.7	37.28	144	3.97	378	252	1325	0.29

A. Specimen Preparation and Curing

For each mix, a total of six cubes, two cylinders, and two beam specimens were prepared. The cubes measured 100 × 100 × 100 mm, the cylinders were cast with a diameter of 100 mm and a height of 200 mm, and the beams were sized 100 × 100 × 500 mm. All specimens were cured in potable water until their designated testing ages of 7 and 28 days.

B. Testing

The hardened concrete specimens were evaluated for compressive, split tensile, and flexural strengths at 7 and 28 days. Compressive and tensile tests were performed using a Compression Testing Machine (CTM), while flexural strength measurements were conducted on a Universal Testing Machine (UTM).

V. RESULTS AND DISCUSSION

This chapter presents the mechanical performance of M70 concrete incorporating Fly Ash (FA), Rice Husk Ash (RHA), and Steel Slag (SS) as partial replacements for cement and fine aggregate. The behaviour of concrete under compression, tension, and flexure is evaluated at 7 and 28 days. The influence of each replacement material is discussed separately.

A. Compressive Strength under Partial Replacement

1) Effect of Partial Replacement of Cement with Fly Ash (FA)

The results show that substituting cement with FA influences both early and later age strength. At 7 days, the reference mix recorded 56.7 MPa, while the 10% FA mix showed a slight reduction to 55.1 MPa, and further increases to 20% and 30% FA led to additional decreases (53.2 and 51.9 MPa). At 28 days, however, 10% FA exceeded the control with 82.4 MPa, indicating beneficial pozzolanic activity at moderate FA levels. Higher FA proportions reduced strength due to slower hydration and lower cementitious content. Based on this, 10% FA was chosen as the optimal base mix for further modification.

Table III
Compressive Strength of M70 Concrete with Varying Fly Ash Replacement Levels

Concrete Mixes	**7 Days(N/mm^2)**	**28 Days(N/mm^2)**
Reference Mix (RM)	56.7	80.3
FA10	55.1	82.4
FA20	53.2	81.1
FA30	51.9	78.2

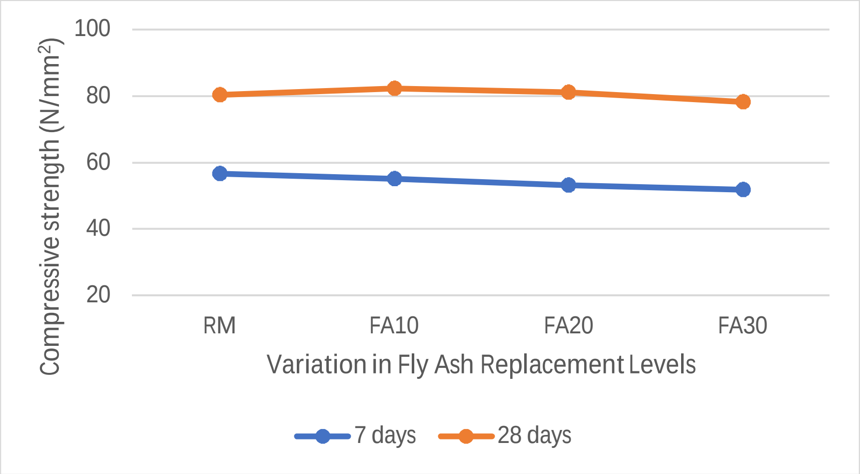


Fig I Compressive Strength Variation with Fly Ash Replacement Levels at 7 and 28 Days

2) *Effect of Partial Replacement of Cement with RHA (within FA10 base mix)*

Introducing RHA into the optimized FA10 matrix significantly improved strength. At 5% RHA, compressive strength increased to 60.6 MPa (7 days) and 85.1 MPa (28 days). Peak performance occurred at 7.5% RHA, yielding 64.5 MPa and 87.4 MPa at 7 and 28 days respectively. The ultrafine silica in RHA enhances secondary C–S–H formation and densifies the matrix. However, 10% RHA caused a noticeable reduction (58.4 MPa at 7 days and 77.8 MPa at 28 days), attributed to increased water demand and reduced effective binder. Thus, 7.5% RHA was identified as the optimum RHA level.

Table IV
Compressive Strength of M70 Concrete with Different RHA Replacement Levels

Concrete Mixes	7 Days(N/mm^2)	28 Days(N/mm^2)
FA10	55.1	82.4
FA10 + RHA5	60.6	85.1
FA10 + RHA7.5	64.5	87.4
FA10 + 10% RHA10	58.4	77.8

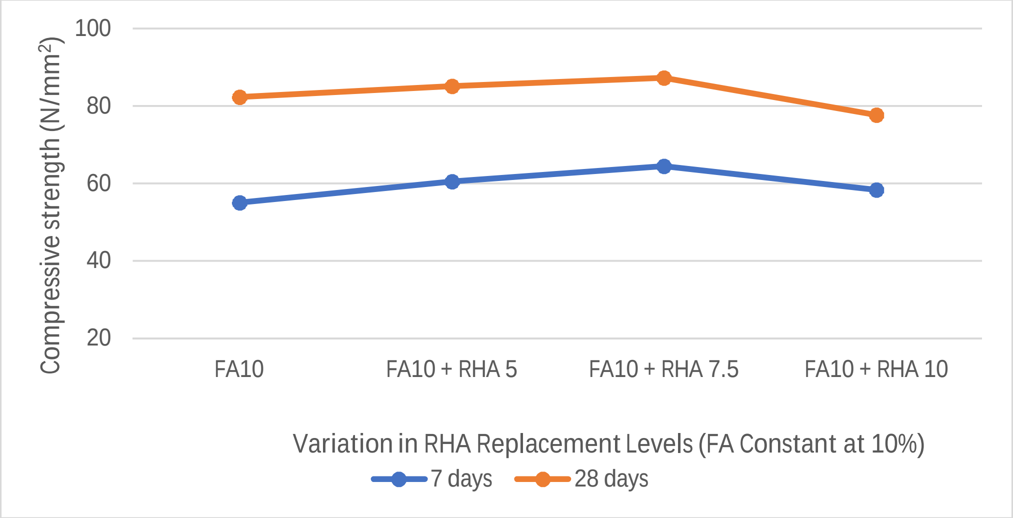


Fig II: Compressive Strength Variation with RHA Replacement Levels (FA Constant at 10%) at 7 and 28 Days

3) *Effect of Partial Replacement of Fine Aggregate with Steel Slag (SS)*

Steel slag replacement within the FA10+RHA7.5 binder system further improved compressive strength. SS addition from 10% to 30% consistently enhanced performance, with the 30% SS mix achieving 89.2 MPa at 28 days—the highest value observed, representing an 11.1% improvement over the reference mix. This increase is linked to SS's angularity and density, which improve packing and ITZ integrity. At 40% SS, strength dropped to 78.1 MPa, indicating that excessive slag disrupts matrix uniformity. Therefore, 30% SS is the ideal fine aggregate replacement for improved compressive performance.

Table V
Compressive Strength of M70 Concrete with Steel Slag as Fine Aggregate Replacement

Concrete Mixes	7 Days(N/mm^2)	28 Days(N/mm^2)
FA10 + RHA7.5	64.5	87.4
FA10+RHA7.5+SS10	64.7	88.1
FA10+RHA7.5+SS20	67.1	88.4
FA10+RHA7.5+SS30	62.8	89.2
FA10+RHA7.5+SS40	59.9	78.1

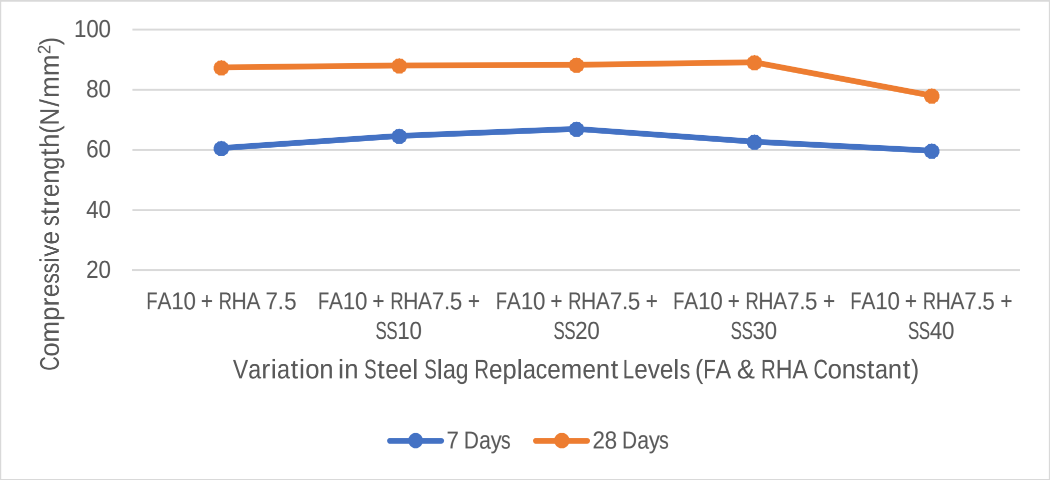


Fig III: Compressive Strength Variation with Steel Slag Replacement Levels (FA10 and RHA7.5 Constant) at 7 and 28 Days

B. Split Tensile Strength under Partial Replacement

1) Effect of Partial Replacement of Cement with Fly Ash (FA)

The split tensile strength values for FA-based mixes ranged between 4.98–5.11 MPa at 28 days. The 10% FA mix provided the highest tensile value (5.11 MPa), offering slight improvement compared to the control (5.06 MPa), while 20% and 30% FA showed marginal reductions. Lower tensile performance at higher FA levels is attributed to slower binding and reduced early-age matrix cohesion.

Table VI
Split-tensile Strength of M70 Concrete with Varying Fly Ash Replacement Levels

Concrete Mixes	**7days(N/mm^2)**	**28days(N/mm^2)**
RM	4.43	5.06
FA10	4.19	5.11
FA20	4.08	5.04
FA30	4.02	4.98

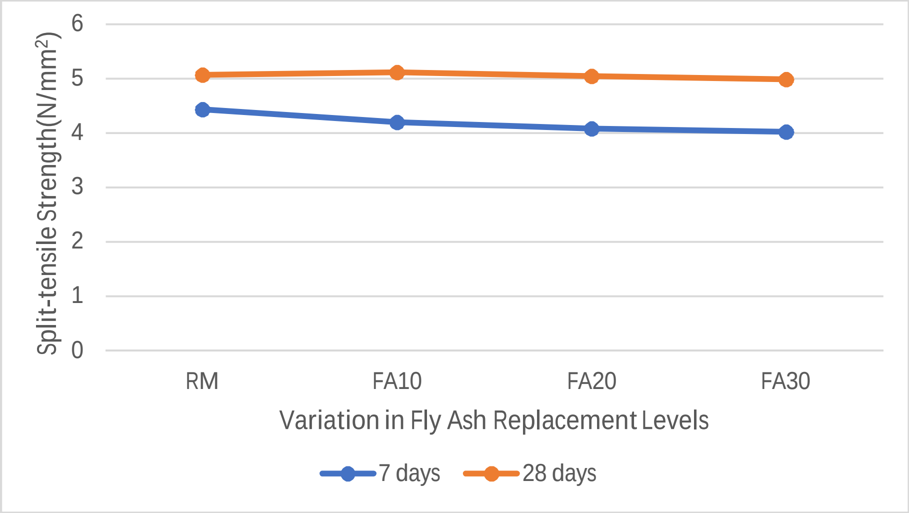


Fig IV: Split tensile Strength Variation with Fly Ash Replacement Levels at 7 and 28 Days

2) Effect of Partial Replacement of Cement with RHA (within FA10 base mix)

Adding RHA enhanced tensile strength due to matrix refinement. The 7.5% RHA mix recorded the highest value (5.27 MPa at 28 days), improving both over the control and over FA10. This is due to RHA's ultra fineness and high silica content, which strengthen the ITZ. Excess RHA (10%) resulted in strength drop to 4.90 MPa, indicating reduced cohesiveness. Thus, the optimal RHA level for tensile strength matches that of compressive strength: 7.5%.

Table VII
Split tensile Strength of M70 Concrete with Different RHA Replacement Levels

Concrete Mixes	**7days(N/mm^2)**	**28days(N/mm^2)**
FA10	4.19	5.11
FA10 + RHA5	4.51	5.19
FA10 + RHA7.5	4.6	5.27
FA10 + RHA10	4.3	4.9

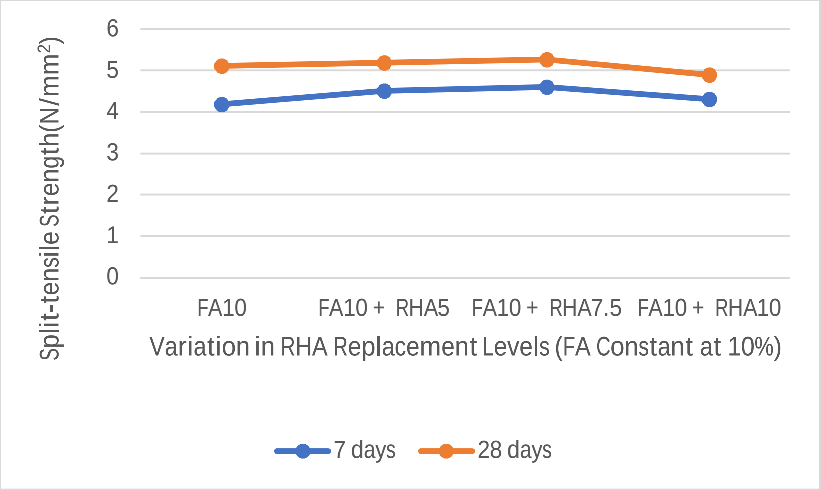


Fig V: Split tensile Strength Variation with RHA Replacement Levels (FA Constant at 10%) at 7 and 28 Days

3) Effect of Partial Replacement of Fine Aggregate with Steel Slag (SS)

When SS was introduced into the FA10+RHA7.5 mix, tensile strength continued to rise up to 30% SS, peaking at 5.40 MPa (6.7% higher than RM). Steel slag's angular texture improves interlock and tensile stress distribution. At 40% SS, tensile strength reduced to 4.85 MPa, reflecting poor packing and disrupted matrix continuity. Hence, 30% SS is confirmed as the ideal level for tensile performance.

Table VIII
Split tensile Strength of M70 Concrete with Steel Slag as Fine Aggregate Replacement

Concrete Mixes	7 days(N/mm^2)	28 days(N/mm^2)
FA10 + RHA7.5	4.6	5.27
FA10 + RHA7.5 + SS10	4.52	5.29
FA10 + RHA7.5 + SS20	4.61	5.34
FA10 + RHA7.5 + SS30	4.49	5.4
FA10 + RHA7.5 + SS40	4.35	4.85

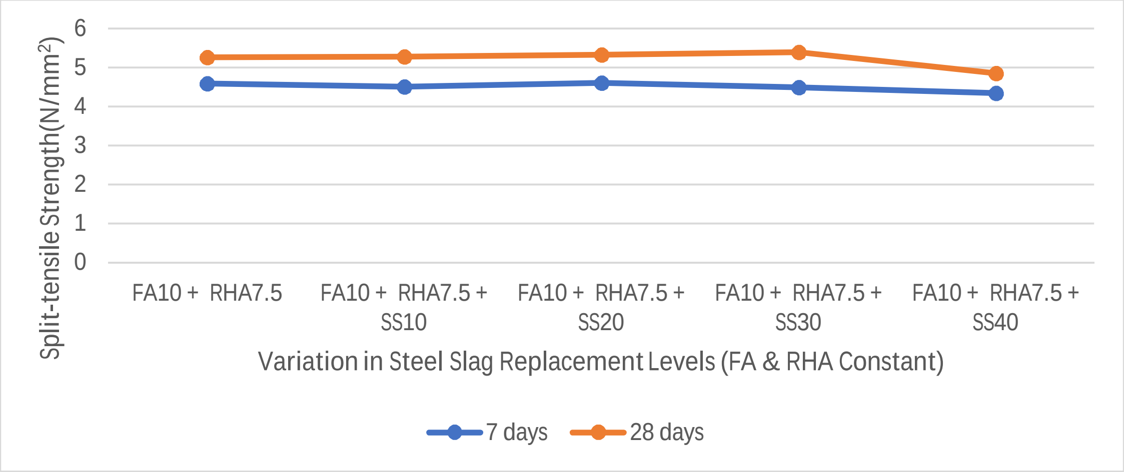


Fig VI: Split tensile Strength Variation with Steel Slag Replacement Levels (FA10 and RHA7.5 Constant) at 7 and 28 Days

C. Flexural Strength under Partial Replacement

1) Effect of Partial Replacement of Cement with Fly Ash (FA)

Flexural strength results also indicated an optimum at 10% FA. The reference mix achieved 6.30 MPa at 28 days, whereas FA10 slightly increased flexural strength to 6.37 MPa. Increased FA levels (20–30%) resulted in small reductions due to reduced early C–S–H formation and weaker initial matrix bonding.

Table IX
Flexural Strength of M70 Concrete with Varying Fly Ash Replacement Levels

Concrete Mixes	**7 days(N/mm^2)**	**28 days(N/mm^2)**
RM	5.29	6.3
FA10	5.21	6.37
FA20	5.07	6.25
FA30	5.02	6.15

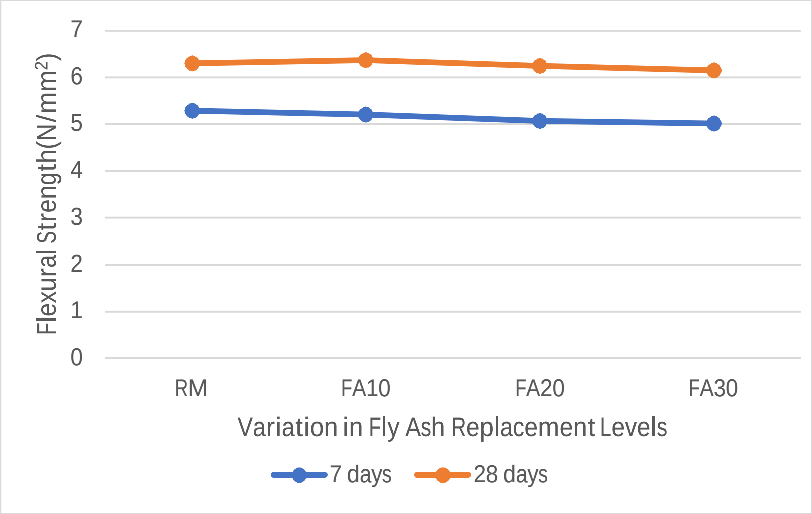


Fig VII: Flexural Strength Variation with Fly Ash Replacement Levels at 7 and 28 Days

2) Effect of Partial Replacement of Cement with RHA (within FA10 base mix)

Introducing RHA into the FA10 mix further boosted flexural performance. The 7.5% RHA mix obtained 6.58 MPa, representing a 4.4% rise compared to the control. The improvement is attributed to RHA-driven matrix densification and enhanced ITZ quality. However, 10% RHA produced a drop to 6.11 MPa, again indicating excessive replacement leads to poor cohesiveness.

Table X
Flexural Strength of M70 Concrete with Different RHA Replacement Levels

Concrete Mixes	**7 days(N/mm^2)**	**28 days(N/mm^2)**
FA10	5.21	6.37
FA10 + RHA5	5.44	6.47
FA10 + RHA7.5	5.66	6.58
FA10 + RHA10	5.37	6.11

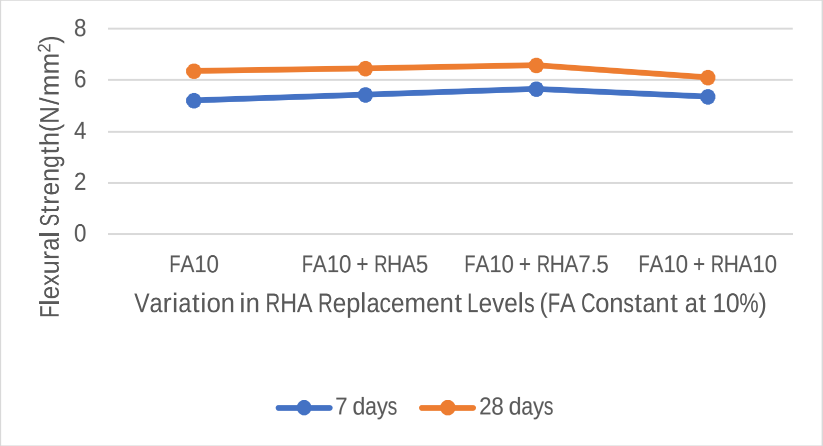


Fig VIII: Flexural Strength Variation with RHA Replacement Levels (FA Constant at 10%) at 7 and 28 Days

C.3 Effect of Partial Replacement of Fine Aggregate with Steel Slag (SS)

Flexural strength continued to rise with increasing slag content up to 30% SS. The FA10+RHA7.5+SS30 mix recorded the highest flexural strength at 6.70 MPa—a 6.3% improvement over the reference mix and marginally higher than the RHA-only blend. The enhanced bending capacity results from improved stiffness and aggregate interlock due to slag’s angular morphology. Beyond 30% SS, however, flexural strength reduced significantly (6.15 MPa at 40% SS).

Table XI
Flexural Strength of M70 Concrete with Steel Slag as Fine Aggregate Replacement

Concrete Mixes	**7 days(N/mm^2)**	**28 days(N/mm^2)**
FA10 + RHA7.5	5.66	6.58
FA10 + RHA7.5 + SS 10	5.68	6.61
FA10 + RHA7.5 + SS 20	5.74	6.64
FA10 + RHA7.5 + SS 30	5.51	6.7
FA10 + RHA7.5 + SS 40	5.4	6.15

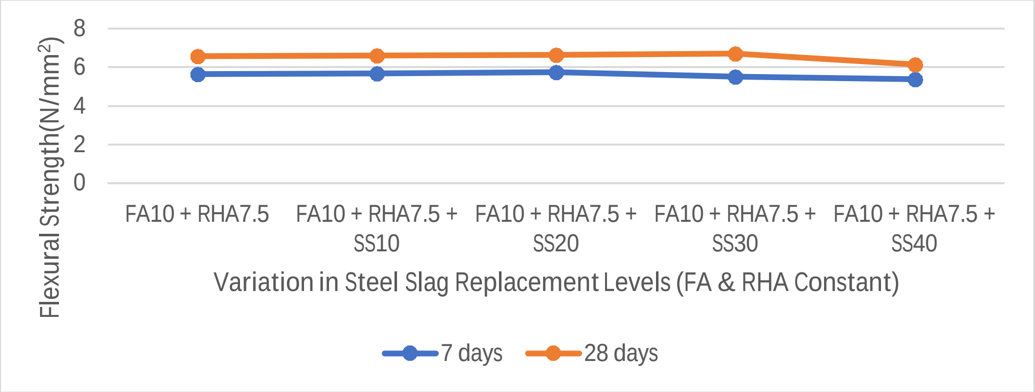


Fig IX: Flexural Strength Variation with Steel Slag Replacement Levels (FA10 and RHA7.5 Constant) at 7 and 28 Days

VI. CONCLUSIONS

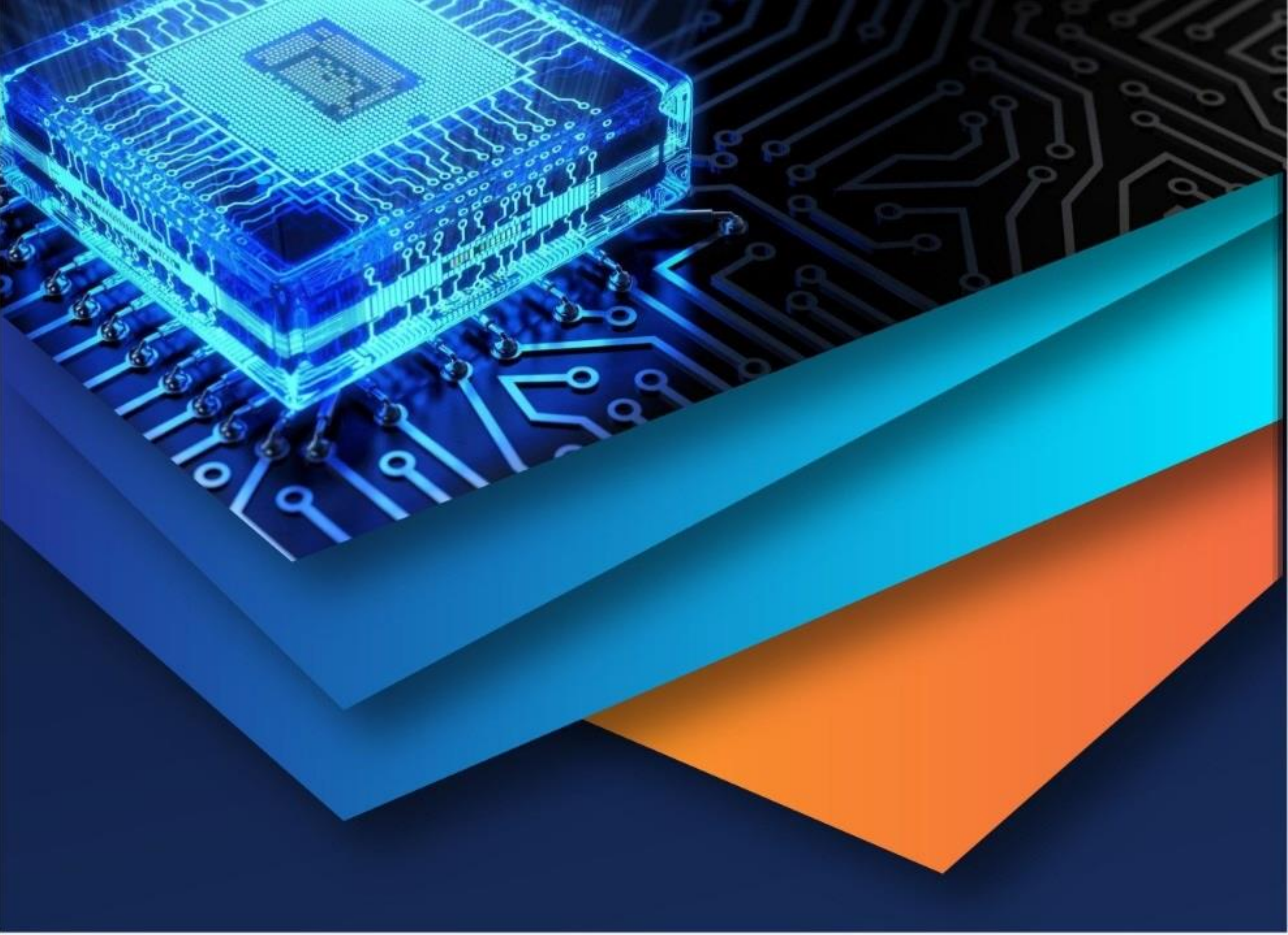
This study investigated the influence of Fly Ash (FA), Rice Husk Ash (RHA), and Steel Slag (SS) as partial replacement materials on the macro-mechanical properties of M70 high-strength concrete. Based on the experimental results and analysis, the following conclusions were drawn:

1) Partial substitution of cement with FA improved mechanical performance when used in controlled amounts. The 10% FA mix slightly exceeded the reference concrete in 28-day compressive strength and maintained comparable tensile and flexural values. Higher FA levels (20–30%) resulted in reduced strength due to slower pozzolanic reaction and lower cementitious content.
2) Incorporating RHA into the optimized FA10 mix significantly enhanced the concrete's mechanical properties. The 7.5% RHA replacement consistently delivered the highest compressive (87.4 MPa), split tensile (5.27 MPa), and flexural (6.58 MPa) strengths. Improvements were mainly attributed to RHA's fine particle size and high amorphous silica content, which refined pore structure and strengthened the interfacial transition zone. However, excessive RHA (10%) increased water demand and adversely affected strength.
3) Replacement of fine aggregate with steel slag further improved the mechanical performance of the FA10+RHA7.5 binder system. The 30% SS mix achieved the maximum compressive strength of 89.2 MPa, along with notable gains in split tensile (5.40 MPa) and flexural (6.70 MPa) capacities. The improved performance was attributed to slag's angularity, higher density, and enhanced packing characteristics. Beyond 30%, slag addition negatively affected the matrix continuity and reduced strength.
4) The combination of 10% Fly Ash + 7.5% Rice Husk Ash + 30% Steel Slag emerged as the best-performing blend across all mechanical tests. This ternary-aggregate system demonstrated a balanced and synergistic improvement in strength properties, outperforming both the reference mix and mixes containing only FA or RHA.
5) The results confirm that industrial and agricultural by-products can effectively replace traditional concrete ingredients without compromising structural performance. The use of FA, RHA, and SS contributes to reduced cement consumption, minimized natural sand usage, and improved waste utilization—supporting sustainable high-strength concrete production.

REFERENCES

[1] Andres Salas Montoya, Chul-Woo Chung and Ji-Hyun Kim. "High-Performance Concretes with Highly Reactive Rice Husk Ash and Silica Fume",2023.
[2] Asad A. Khedheyer Al-Alwan, Mustafa Al-Bazoonb, Faten I. Mussab, Hayder A. Alalwan, Mohanad Hatem Shadhar, Malik M. Mohammed, Mohammed Fakhri Mohammedf. "The impact of using rice husk ash as a replacement material in concrete: An experimental study", 2022.
[3] Feifei Liu, Baohong Jin, Qi He, Yun Zhou "Influence of rice husk ash on the mechanical properties of ultra-high strength engineered cementitious composites (UHS-ECC)".2024
[4] Md.Montaseer Meraz, Nusrat Jahan Mim, Md. Tanjid Mehedi, Ehsan Noroozinejad Farsangi, Sk. Abdul Kader Arafin, Rajesh Kumar Shrestha, Md. Shakhaoat "On the utilization of rice husk ash in high-performance fiber reinforced concrete (HPFRC) to reduce silica fume content", 2023
[5] Mohammed NajeebAl-Hashem, Muhammad Nasir Amin, Muhammad Raheel, Kaffayatullah Khan, Hassan Ali Alkadhim, Muhammad Imran, Shahid Ullah and Mudassir Iqbal "Predicting the Compressive Strength of Concrete Containing Fly Ash and Rice Husk Ash Using ANN and GEP Models", 2022.
[6] Muhammad Nasir Amin, Waqas Ahmad, Kaffayatullah Khan and Mohamed Mahmoud Sayed. "Mapping Research Knowledge on Rice Husk Ash Application in Concrete: A Scientometric Review" 2022.
[7] Parvin Montazeri, Omid Bamshad, Milad Aghililotf, Priyanka Singh**. "**Mechanical and durability-based life cycle assessment of rice husk ash containing concrete" 2025.

[8] Pham Vu Hong Son, Nguyen Van Nam, Nghia P. Tran, Long Le-Hoai, Tuan D. Ngo. “Steel slag aggregate low-cement concrete: Engineering performance, microstructure and sustainability” 2024.
[9] S. Azhagarsamy, N. Pannirselvam, J. Vanjinathan, R. Premkumar, Dasari Vijayakumar. “Optimizing mechanical and microstructural properties of concrete with steel slag aggregate using response surface methodology”, 2025.
[10] Solomon Asrat Endale, Woubishet Zewdu Taffese, Duy-Hai Vo and Mitiku Damtie Yehualaw. “Rice Husk Ash in Concrete”, 2022.
[11] Yutong Zhao, Yi Sun, Changming Bu, Xumei Cao, Qiutong Jiang, Yuhui O.Y, Dongxu Zhu, “Review on Application of Rice Husk Ash Based Concrete Composite and Preparation Conditions of Rice Husk Ash”, 2022.



10.22214/IJRASET

45.98

IMPACT FACTOR:
7.129

IMPACT FACTOR:
7.429

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY