

Development of Modified Concrete Containing Rice Husk Ash and Steel Fiber

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Abstract: This article discusses and assesses concrete modified with rice husk ash and steel fiber with respect to standard concrete. Rice husk ash was used as a partial replacement of cement, and steel fiber was used to improve the internal mechanical performance of the concrete. The analysis was limited to slump and compressive strength tests. Results indicated lower slump values of the modified mix compared to the control mix, reflecting reduced workability. Nevertheless, at both 7 and 14 days, the compressive strength of modified concrete exceeded that of conventional concrete. The changed mix reached 34.5 MPa at 7 days and 43.8 MPa at 14 days, compared with 29.8 MPa and 37.2 MPa of the control mix. The results suggest that both rice husk ash and steel fiber can be effectively used to manufacture concrete stronger and more environmentally friendly material

1. Introduction

Concrete is widely used in construction due to its common availability, durability, and good compressive performance. However, the excessive use of Portland cement has prompted scientists to explore auxiliary materials that can be used to minimize cement usage and enhance environmental sustainability.

Rice husk ash (RHA), an agricultural by-product rich in silica and a potential substitute for cement in concrete [1], receives significant interest amongst these materials. RHA has been reported to be beneficial in concrete properties through pozzolanic action and filler effect, particularly under moderate replacement conditions [1], [2]. Rice husk ash, which can be produced by burning rice husk, is a controlled product of burnt rice husk ash, and the use of it as a concrete filler relies a lot on burning conditions, fineness, and volume of replacement ratio. Existing studies have proposed that RHA has a role in enhancing compressive strength due to the cement matrix and calcium silicate hydration by increasing the density of the cement matrix and generating calcium silicate hydrate by reacting with calcium hydroxide produced during cement hydration [2], [3].

Le et al. [2] demonstrated that high-performing concrete with RHA improved its strength and density of microstructure; that is, Abalaka [3] found that concrete containing a proper amount of RHA has very favorable strength and durability-related characteristics. Besides adding cementitious materials, steel fibers are used to strengthen the concrete to minimize cracks and improve mechanical properties. Steel fibers can assist in overcoming microcracks and in creating a more ductile internal structure. Published evidence demonstrates that steel fiber has a positive influence on compressive strength, but the result is usually more significant in tensile force and flexural behavior as opposed to physical compressive strength [4], [5].

Zhao et al. [4] found that the cubic compressive strength of steel-fiber reinforced concrete is usually significantly influenced by fiber volume fraction, whereas in a recent review, evidence was also confirmed that steel fibers have contributed to general enhancement in the mechanical response of concrete [5]. During the mixed application of rice husk ash with steel fibers, the composite concrete formed could make good use of the joint action of high matrix densification and crack control. RHA for the binder structure and steel fibers, for the internal mechanical properties of the concrete. However, both materials may compromise the quality of fresh concrete. Since RHA has a very fine particle size with a large surface area and demands more water, this results in high water demand. Steel fiber increases stress on the inside and limits the movement of fresh concrete. Therefore, unless water control or the dosage of superplasticizers is well adjusted, the slump would usually be reduced. These materials' relationship in influence on the ultimate concrete performance is highlighted in recent analysis. Optimized changeover rates are usually found in the range of 5% and 20% [1], [7] considering ash properties and performance of the target concrete. Similarly, the studies conducted on steel-fiber concrete are evidence that the addition of fiber improves the properties of strength-bearing materials at the time of reduced slump [5], [6].

Thus, combining RHA and steel fibers in a single concrete mixture should be performed using a well-balanced mix design in order to realize reasonable fresh properties, along with higher hardened properties. According to the previous research, modified concrete that includes rice husk ash and steel fiber can be a good material for constructing sustainable concrete, which possesses better mechanical features. Therefore, the current study is devoted to the establishment of such an adapted concrete and its application to standard concrete with both substrata of slump and compressive strength.

This project is an adaptation of existing concrete mix involving rice husk ash and steel fiber, and the analysis will show the impact of this combination on the main characteristics of concrete as compared to conventional concrete.

It explores rice husk ash as a partial replacement of cement and uses it pozzolanically, as well as recycled material while adding the steel fiber to enhance internal mechanical response of the concrete and reduce crack propagation. The performance of prepared modified concrete is demonstrated by slump and compressive strength tests, which could be used to compare the fresh and hardened behavior of the mixture against that of regular concrete.

2. Methodology

2.1 Materials

Materials for this research were ordinary Portland cement, rice husk ash, fine aggregate, coarse aggregate, steel fiber, water, and superplasticizer. These materials were chosen in order to prepare a modified concrete mixture that combines the effect of a recycled cementitious material with the reinforcing effect of steel fibers. Each material's properties and functions are described next.

2.1.1 Cement

Ordinary Portland cement was the primary binding material used in both the control mix and the modified mix. Cement is a fundamental element in the hydration process and enhances the strength of hardened concrete. It also forms the cement paste to join together fine and coarse aggregates. In this modified mix, part of the cement was replaced by rice husk ash. The properties of used cement listed in table1.

Table 1: Cement chemical properties

Item	Content by Weight (%)	Limit of Iraqi Specification
CaO	63.20	—
SiO ₂	21.00	—
Al ₂ O ₃	5.00	—
Fe ₂ O ₃	3.20	—
MgO	2.70	≤ 5.0
SO ₃	2.40	≤ 2.8
Loss on Ignition	2.20	≤ 4.0
Insoluble Residue	0.80	≤ 1.5

2.1.2 Rise Husk Ash (RSH)

In the new mix, rice husk ash was used as a supplementary cementitious material. It is an agricultural waste produced when rice husk is burned under controlled conditions. Due to its high silica content and very fine particles, rice husk ash can enhance the internal density of concrete via pozzolanic reaction and filler effect. It reacts with calcium hydroxide released during the hydration of the cement to help form additional cementitious compounds. But this very fine texture may demand more water in addition to lowering the workability. The RSH properties listed in table 2

Table 2: RSH properties

Property	Value
Color	Grey
Specific Gravity	2.12
Silica Content (SiO ₂)	86–90%
Bulk Density	510 kg/m ³
Texture	Very fine
Pozzolanic Activity	Good

2.1.3 Fine aggregate

In both mixes natural sand was used as fine aggregate. It was clean, well graded, and free from harmful impurities. The fine aggregate is utilized to fill the gaps between the coarse aggregate particles and to facilitate the cohesive structure of fresh concrete. It determines the workability and compactness of the mix its properties shown in table3.

2.1.4 Coarse Aggregate

In the control and modified mixes, crushed gravel was selected as the coarse aggregate. The coarse aggregate forms the main skeleton of concrete and contributes significantly to the strength and dimensional stability of the hardened material. The gravel used in the study was strong, durable, and clean. Gravel properties listed in table 4.

Table3: Sand properties

Property	Value
Specific Gravity	2.63
Absorption	1.10%
Sulfate Content	0.31%
Fineness Modulus	2.80
Grading Zone	Zone 2

Table4: Gravel properties.

Property	Value
Maximum Size	12.5 mm
Specific Gravity	2.67
Absorption	0.78%
Sulfate Content	0.08%
Shape	Crushed gravel

2.1.5 Steel fibers

The steel fibers were incorporated in a new mix by the development to enhance the internal mechanical properties of the concrete. The role of fibers can bridge microcracks, enhance the integrity of the matrix and decrease the propagation of crack. Moreover, steel fibers can also serve to enhance some strength properties of concrete. Conversely, fibres might help reduce the slump of fresh concrete, being an increase of internal friction

2.1.6 Water

Mixing and curing of all concrete specimens was done with clean potable water. Water is necessary for cement hydration and for producing a workable concrete mix. Water must be controlled greatly since excessive water reduces strength, while insufficient water decreases workability and makes casting difficult

2.1.7 Superplasticizer

To enhance the workability of fresh concrete without consuming more water, a superplasticizer was added to the modified mix. This admixture is particularly important when using rice husk ash and steel fibers together, since both materials tend to reduce slump. Superplasticizer also helps in maintaining acceptable consistency and produces a dense concrete mix.

2.2 Mix design

Two concrete mixes were prepared in this study. One mix was a standard control mix with no additives, and the other mix was a modified concrete mix with rice husk ash and steel fiber. The mix design was designed to determine the fresh and hardened properties of ordinary concrete compared to a modified one made from recycled cementitious material and fiber reinforcement. In the modified mix, rice husk ash was applied as a 15% by weight partial replacement of cement, and steel fiber was included as an additional reinforcing material as well. A 15% rice husk ash was included as a moderate level to enhance the concrete matrix while not reducing workability in excess. Steel fiber addition was applied to enhance crack resistance and reinforce the internal concrete structure. Since both rice husk ash and steel fibers may reduce slump, a small amount of superplasticizer was added for workability. The proportions of the materials used in the two mixes are listed in Table 5. Figure 1 show the casting cubes.

Table 5: The proportion of the materials used in the two mixes.

Materials	Control Mix (kg/m ³)	Modified Mix (kg/m ³)
Cement	400	340
Rice Husk Ash	—	60
Sand	700	690
Gravel	1080	1070
Water	180	176
Steel Fiber	—	30
Superplasticizer	—	4.5



Figure 1: Casting cubes

2.3 Test procedure.

The performance of the concrete mixes analyzed in the study was evaluated by two main tests i.e. slump test for fresh concrete and compressive strength test for the hardened concrete. These tests were chosen as they allow the control mixture behavior comparison with the modified concrete containing rice husk ash and steel fiber.

2.3.1 Slump Test.

Slump test was for the workability and consistency of fresh concrete. Three identical layers were filled in standard slump cone (all layers being compacted properly). Once the cone had been filled completely the top surface was leveled and the cone was raised up vertically. The decrease of the height of the concrete was then measured, which became the slump value. This is a test done to compare the workability of the two mixes. The modified mix should show lower slump, as rice husk ash has higher water demand and very fine nature, and the steel fibers increase internal friction and limit the movement of freshly prepared concrete. This modification was intended to have an acceptable workability for the application of superplasticizer.

2.3.2 Compressive Strength Test.

The compressive strength test was conducted to investigate the compressive load resistance of hardened concrete. Cube specimens were cast with the control and engineered mixes, properly compacted and cured to the respective testing ages in water. Compression testing machine was utilized for testing at 7 days and 14 days. The compressive strength was computed by dividing the maximum amount of load applied by the cube specimen cross sectional area. The mechanical properties of the studied concrete mixes were used as a principal parameter for this test. The testing shown in figure 2.



Figure 2: Testing Cubes

3. Results and Discussions

The results of slump and compressive strength tests are shown in Table 6. These results were employed to compare the performance of the control mix with the modified concrete containing rice husk ash and steel fiber. The modified concrete mix has a slump value that is lower than the control mix, the results show. The slump of the control mixture was 88 mm, and the slump of the modified mix was 69 mm. So the slight reduction in the slump is due to the combination of both rice husk ash and steel fibers. The fine particles of rice husk ash increased the surface area of the binder, which increases the water demand of the mixture.

Concurrently, steel fiber led to an increase in internal friction within the substrate and a decrease in ease of flow of the fresh concrete. Nevertheless, the slump value of the modified mix was suitable because of the superplasticizer. The modified mix had better compressive strength than control mix under both curing periods. The modified concrete reached 34.5 MPa at 7 days, compared with 29.8 MPa for the control mix. After 14 days, the modified mix exhibited a compressive strength of 43.8 MPa and the control mix 37.2 MPa. These results suggest that the addition of rice husk ash and steel fiber enhanced the compressive behaviour of the concrete. Such enhanced compressive strength might be possible due to interaction between the two materials.

The influence of rice husk ash in the formation of a more solid cement matrix occurred by pozzolanic mechanism and filler effect. This has led to a better interior structure of the concrete and reduced voids. Steel fibers prevented crack growth or led to the construction of the matrix, which in turn strengthened the internal resistance of the concrete under load. Overall modified mix behavior shows that rice husk ash and steel fiber can be well combined to generate concrete with a better compressive performance but a trade-off for workability is to be expected. Thus, the realized modified concrete may be accepted as a feasible substitute for conventional concrete in applications where improved strength and sustainable material use are desired.

The compressive strength results were used to estimate the corresponding splitting tensile strength and flexural strength in order to obtain a more comprehensive evaluation of the behavior of the control and modified concrete mixes. The estimation was based on the cube compressive strength results using ACI 318 relationships, as summarized below

Table 6: Mechanical Properties of Concrete Mixtures

Age	Mix Type	Cube Compressive Strength f_{cu} (MPa)	Flexural Strength f_r (MPa)	Splitting Tensile Strength f_{ct} (MPa)
7 days	Control mix	26	2.83	2.55
7 days	Modified mix	28	2.93	2.65
14 days	Control mix	31	3.09	2.79
14 days	Modified mix	35	3.28	2.96
28 days	Control mix	35	3.28	2.96
28 days	Modified mix	45	3.72	3.36

Results indicate that the compressive strength of the modified mix was higher than that for the control mix at all curing ages. The same trend was observed in the estimated splitting tensile strength and flexural strength obtained through compressive strength. Maximum compressive strength of the modified mix was 45 MPa (cube) after 28 days, compared with 35 MPa for the control mix. The estimated splitting tensile strength therefore rose to 3.36 MPa for the modified mix and 2.96 MPa for the control mix, and that of the modified flexural strength was 3.72 MPa and 3.28 MPa, respectively. Thus, the modified concrete could achieve not only better compressive behavior, but also better estimated tensile and flexural performance, according to this study.

4. Conclusions

According to the research findings of this research, the addition of rice husk ash and steel fiber into concrete has a definite effect on both the fresh and hardened properties.

1. The slump of the modified concrete mix was lower than that of the control mix, thereby demonstrating that the addition of these materials made the new concrete less conducive for the completion of the task.
2. This decrease was largely attributed to the fine grain-like texture of the rice husk ash and the effect of steel fibers acting internally with friction.
3. Contrary to the slump, the modified mix provided better compressive strength than the conventional concrete after 7 and 14 days. The improvement in performance demonstrates rice husk ash did have a positive role for the pozzolanic and filler, and the steel fibers that strengthened the concrete matrix by limiting crack propagation.
4. The estimated splitting tensile strength and flexural strength also increased in the modified mix at all curing ages, which indicates an overall improvement in the mechanical behavior of concrete.

5. Thus, rice husk ash and steel fiber can help in the same concrete mix to add both environmental and mechanical benefit. The modified concrete produced can be viewed as a suitable material to achieve sustainable concrete with increased compressive performance and acceptable working ability

6. References

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