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*Original Article*

# Experimental Analysis of RHA and Glass Fiber Impacts on Mortar using Construction and Demolition Waste as Fine Recycled Aggregate

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***Abstract*** *- The wastes from construction and demolition have grown significantly. The best approach to handle this waste is to recycle and reuse it as an aggregate. Although fine recycled aggregates do have some advantages, coarse recycled aggregates are still preferred. Therefore, replacing some sand with (Construction and Demolition waste) CDW is feasible. However, adding Rice Husk Ash (RHA) and glass fiber to preparation mortars has various effects. Replacing sand with fine recycled aggregate and some of the cement with Rice Husk Ash affects the mortar's properties differently. In order to identify the ideal percentage of both RHA and Glass Fiber that might be utilized in mortar preparation, it is necessary to understand the impacts of incorporating such RHA and Glass Fiber in CDW. Experimental studies support the findings. The mortar cubes with Glass Fiber 1%, 2%, 3%, 4%, and 5% of the weight of cement are tested. Varying replacement percentages of cement with RHA are 2%, 4%, 6%, 8%, and 10% only. The investigation's main objective is to establish the optimal percentage of RHA and glass fiber. Replacement for CDW is set at 35 percent in accordance with the literature. Reusing waste products and managing them effectively are efforts that will relieve pressure on river quarry sites and promote sustainable development. The mortar created from construction and demolition waste partially substituting river sand will perform better with the optimal percent of RHA and glass fiber. Efforts are made to improve the mortar performance by including recycled aggregates.*

***Keywords*** *- Construction and demolition waste, Fine aggregates, Glass fiber, Mortar, Rice husk ash.*

## 1. Introduction

Construction activity is at its prime value now, which results in the generation of massive amounts of heavy CDW, making transportation extremely challenging. Due to their primary composition, these wastes are advantageous as they are high in silica content and are effective when used as recycled aggregate. Humongous River quarrying of the sand used for construction negatively influences water resources, disrupts river flow, pollutes water, and causes landslides, etc. Thus, there is a greater immediate requirement for a workable sand replacement. Numerous researchers have investigated and advocated CDW as a suitable material for sand's partial substitution in aggregate production to address such emergent issues. According to *Osama Zaid et al.*, 7.4 million tons of RHA are produced annually and seriously threaten the environment by degrading the surrounding area and the land where it is dumped. *Silva R.V. et al.* concluded that it is still possible to obtain the required mechanical qualities of mortar by substituting CDW recycled aggregate for up to 30% of the sand. *Duan* also found that replacing CDW is only feasible up to 30% percent, while *H. Dilbas* experimental research findings also concluded that it was 30%. Whereas *Ledesma and Khalid* came to the conclusion that replacing natural sand with CDW aggregate at a proportion of 40 to 55 percent is possible for the production of masonry mortar. The majority of literature studies concluded that the ideal replacement rate of CDW fine aggregate is between 30 and 50%. Based on the above literature, 35% of recycled sand is used for this study to analyze the test results. A study conducted by Safiuddin et al. suggested that Rice Husk Ash (RHA) particles have a cellular structure with a relatively high surface area and include 90–95 percent amorphous silica. Due to its large surface area and high silica content, RHA has good pozzolanic activity. By using RHA, compressive, tensile, and flexural strengths of concrete are increased, reducing porosity as well.

RHA enhances the ability to withstand freezing and thawing as well as corrosion. Further, *Muhammad Harunur Rashid* examined the compressive strength of mortar samples at 7, 28, 90, and 350 days of age with the replacement of cement by RHA (0, 10, 15, 20, and 30%). According to test results, 15 to 20% of the use of RHA is found to be the ideal replacement. According to the study conducted by *Rambabu et al.*, a replacement level of 6% RHA in concrete performs and displays better strength than other replacements due to high pozzolanic activity. They also partially replaced cement with RHA at different percentages (0 percent, 5 percent, 6 percent, 7 percent, 8 percent, 9 percent, and 10 percent) by weight of cement. RHA reaches its peak strength at 6% replacement and also has a strong resistance to sulphuric acid attacks. According to *Osama Zaid et al.,* findings showed that RHA combined with steel fibers replaces around 10% of cement for comparable compressive strength. Concrete with higher than 15% RHA cement replacement performs poorly in terms of strength and durability. *Kedar S. Shinge* also came to the conclusion that compressive strength, RHA, is the best alternative material for replacing cement in mortar and can be utilized between 10 and 15%. In his research, *Rayed Alyousef* examined the addition of RHA and micro silica, which outperformed other minerals regarding the mechanical qualities of fiber-reinforced, recycled aggregate concrete (RAC). He further concludes that mixed micro silica and glass fibers in RAC result in stronger and more durable concrete than traditional Natural aggregate Concrete. *Chintan Khatri* carried out the experimental work to investigate the impacts of replacing cement with 5%, 10%, and 15% RHA by weight and the effects of adding 0.5%, 1%, and 1.5% Glass Fiber Composite, with w/c ratio of 0.50. He concluded that Glass Fiber, 12 mm in length, with an addition of 0.5 percent, results in 2.19 percent less strength than the control mix and 9.60 percent higher than that of other fibers. Concrete cubes' compressive strength decreased 7 and 28 days after replacement with 15% RHA and 3% plastic fibers. The compressive strength of concrete cubes increased at 7 and 28 days after replacing 5% and 10% RHA and 1% and 2% plastic fibers, respectively. Mortar has been successfully employed with up to 5% glass fiber by volume without balling. When *S. Azhagarsamy and K. Jaiganesan* tested concrete of the M25 grade, they discovered that 1% Glass Fiber, 10% RHA, and 10% silica fume by weight produced the highest compressive strength. *Rasha Salah Mahdi* demonstrated that the mortar mixed with 1% fiber content gave a greater compressive and flexural strength than the mortar mixed with 2% fiber content utilizing Glass Fiber content at 1, 1.5, and 2% by weight of cement. *J.D. Chaitanya Kumar* performed studies on concrete with Glass Fiber at concentrations of 0.5 percent, 1 percent, 2 percent, and 3 percent of cement, and an increase in compressive strength, flexural strength, and split tensile strength was found to be higher for 1% of Glass Fiber.

The manuscript provides an experimental examination of the substitution of sand in the mortar with CDW and Cement with Rice husk Ash. The experiment was carried out specifically for the field of mortar. Per the guidelines, the mix ratio for the mortar is from 1:3 to 1:6. Mortar cubes were cast using cement and sand in a ratio of 1:4 for exterior plastering on masonry and, more specifically, on concrete surfaces. The water-cement ratio was also kept constant at 0.50. This study will lead to better management of waste as recycled products and give a better analysis of such waste in the field of mortar production, which researchers minimally explore.

## 2. Materials

### *2.1. Cement*

Cement's principal role in mortar as a binder is to hold everything else together. This substance, which sets, hardens, and binds to other materials, is made of lime, alumina, and iron ore. Grade 43 ordinary Portland cement is used in this experiment. Compared to Pozzolana Portland cement (PPC), OPC cement lacks additives. When the OPC 43's specific gravity was measured in a lab, it was found that the cement had a specific gravity of 3.1.

### *2.2. River Sand*

River sand is most frequently used in concrete and masonry buildings. This experiment used easily accessible River sand from the local rivers of the study area, which is ideal for construction work since it has a smoother texture and requires less water because moisture is trapped between the particles. The sand used in this research had a specific gravity of 2.66 and was found to have 0.77 percent moisture after being dried in an oven for 24 hours.

### *2.3. CDW Waste*

Waste from construction and demolition sites was used as recycled aggregate in this experiment. These recycled waste aggregates replaced sand by 35%. It was gathered in a block shape and afterwards reduced by hammering and sieving to sand size. The specific gravity of the CDW recycled aggregate was found to be 2.59, which is quite similar to the value of natural river sand. After the materials were oven-dried, the recycled aggregate moisture level was found and estimated to be 3.25 percent, much greater than the moisture content of the natural river sand.

### *2.4. Rice Husk Ash*

Rice husks, which are generally regarded as agricultural waste, were used to make the RHA. The local rice husk from the nearby rice paddy was burned in an open field at an uncontrolled temperature to obtain the ash. The water used was the commonly used tap water, which is used for a range of building applications to keep the test result data as practical as possible. The 3 mm glass fiber admixture was also used in the investigation.

### *2.5. Glass fiber*

The glass fiber incorporated is 3 mm in size, as shown in Figure 5.

**Fig. 1 Rice husk ash**

**Fig. 2 Rice husk**

**Fig. 4 RHA with CDW**

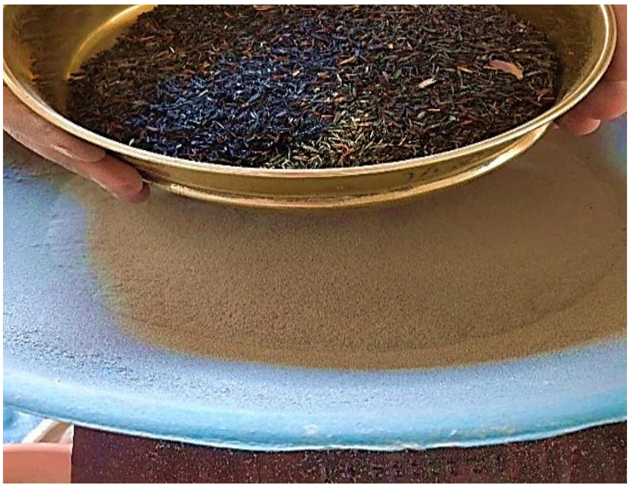

**Fig. 3 Sieving of RHA**

**Fig. 5 Glass fiber with CDW**

## 3. Methodology

### *3.1. SEM Test*

A Scanning Electron Microscope (SEM) test was used at JSM-6390LV to examine the microstructure morphology. The purpose of the experiment was to learn more about the microstructure of glass fiber and rice husk ash, as well as how it affects the material's functionality.

### *3.2. Compressive Strength*

The compressive strength of the mortar specimen's cast was assessed after 7, 14, and 28 days of curing. Sand, CDW recycled aggregate, RHA, Glass fiber, and cement were the main ingredients in the mixture used to make the specimen. 35 percent of the sand was replaced with recycled fine aggregate manufactured from CDW, and the cement was replaced with 2%, 4%, 6%, 8%, and 10% by RHA. In addition, glass fiber was added as an admixture in amounts ranging from 1 percent to 5 percent to the mixtures containing 35 percent CDW fine recycled aggregate. All combinations cast were kept at a constant water-to-cement ratio of 0.5. The cement: sand ratio of the mixture was 1:4, and a cube measuring 7.05 by 7.05 cm was cast. The CDW was gathered in block form, and after being crushed and milled into a fine powder, it was employed in the experiment as recycled aggregate in place of sand. Nine cubes were cast onto each combination, and the average compressive strength result of three cubes was taken for each curing period. The compressive strength testing machine (CTM) was used to conduct the test. Table 1 illustrates the mixture cast's composition.

### *3.3. Permeability Test*

Permeability measures how quickly a fluid moves through a porous material. Materials with a high permeability enable flow, while those with a low permeability prevent it. The permeability of mortar is one of the primary problems in relation to its properties. An I.S.: 3085-1965-compliant permeability apparatus was used to conduct the permeability test for this investigation. The specimens were examined at a water pressure of 2 kg per cubic centimeter after being cast in 15 by 15 cm cylindrical molds.

The tested mixture and composition are in accordance with Table No. I. The permeability coefficients of each mixture were determined and contrasted. The permeability test was carried out with the highest accuracy because it is the main criterion for the longevity of mortar. After 56 days of curing, samples were inspected.

**Table 1. Composition of the mixture**

| Mix | % of CDW | % of RHA | % of Glass fiber | Composition |
|---|---|---|---|---|
| M1 | 35 | 0 | 0 | Cement: sand: CDW Recycled Aggregate (R.A.) |
| M2 | 35 | 2 | 0 | Cement: Sand: R.A.: RHA |
| M3 | 35 | 4 | 0 | Cement: Sand: R.A.: RHA |
| M4 | 35 | 6 | 0 | Cement: Sand: R.A.: RHA |
| M5 | 35 | 8 | 0 | Cement: Sand: R.A.: RHA |
| M6 | 35 | 10 | 0 | Cement: Sand: R.A.: RHA |
| M7 | 35 | 0 | 1 | Cement: Sand: R.A.: Glass fiber |
| M8 | 35 | 0 | 2 | Cement: Sand: R.A.: Glass fiber |
| M9 | 35 | 0 | 3 | Cement: Sand: R.A.: Glass fiber |
| M10 | 35 | 0 | 4 | Cement: Sand: R.A.: Glass fiber |
| M11 | 35 | 0 | 5 | Cement: Sand: R.A.: Glass fiber |
| M12 | 35 | 4 | 1 | Cement: Sand: R.A.: RHA: Glass fiber |

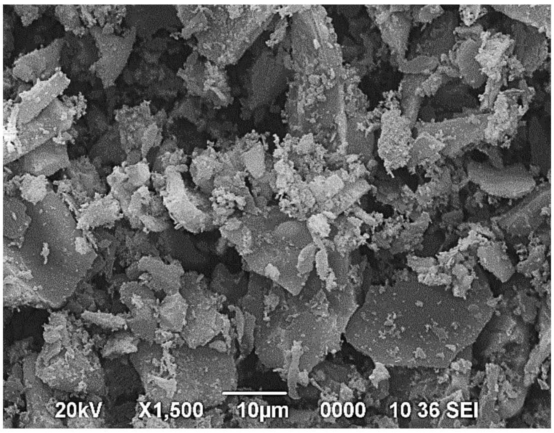

**Fig. 6 RHA**

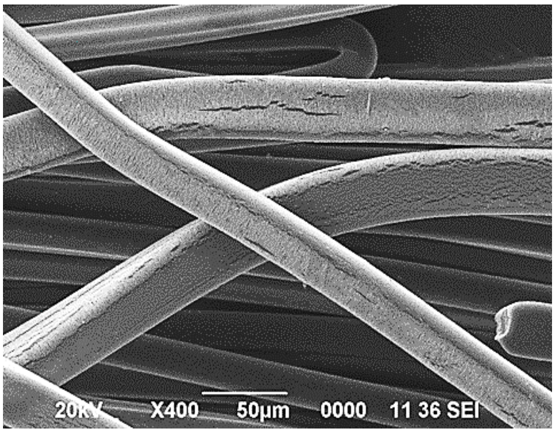

**Fig. 7 Glass fiber**

### *3.4. UPV Test*

At the construction site, the non-destructive ultrasonic pulse velocity test is performed to evaluate the quality of the mortar or concrete. This test essentially gauges how rapidly an electronic pulse travels through the structure from a transmitting transducer to a receiving transducer.

Pulse velocities of concrete or mortar are strength-related. Pulse velocity boosts mortar strength while reducing structural fractures. The Proceq UPV testing machine was used in a laboratory to conduct the test. The Formula for the calculation as per I.S.: 13311 (Part 1) – 1992 is:

$$Pulse\ Velocity = \frac{Path\ length}{Time\ of\ travel}$$

## 4. Results and Discussions

### *4.1. SEM Analysis*

In order to better grasp its microstructure, the SEM test was carried out on the powdered sample. The structure for RHA is depicted in Figure 6, where it is clear that the smaller particles are clustered next to the larger ones and that the form and size of the structure are irregular.

This irregular shape can produce better boding when compared to round-shaped particles. In contrast, the SEM pictures of glass fiber reveal its regular cylindrical shape as well as the existence of microcracks in the fiber's body, which are detrimental to the mortar's strength characteristics. The Figure 6 and Figure. 7 Images aid in better comprehension, as shown in.

### *4.2 Compressive Strength*

After 7 days, 14 days, and 28 days of curing, the compressive strength of the mortar mixtures mentioned in Table 1 was assessed.

Table 2 describes the compressive strength results for combinations including sand replaced with CDW recycled aggregate for 35% with RHA as partial replacement of cement for up to different percentages of 2%, 4%, 6%, 8%, and 10% by weight of cement.

The results are shown below in N/mm$^2$. Comparatively, Table 3 displays the compressive strength of combinations containing 1%, 2%, 3%, 4%, and 5% glass fiber by weight of cement as an admixture.

**Table 2. Compressive strength of mortar with RHA**

| Mixture | Compressive strength after 7 days of curing N/mm² | Compressive strength after 14 days of curing N/mm² | Compressive strength after 28 days of curing N/mm² |
|---|---|---|---|
| M1 | 12.74 | 14.69 | 16.49 |
| M7 | 10.8 | 11.47 | 12.61 |
| M8 | 9.33 | 9.52 | 10.73 |
| M9 | 8.38 | 9.46 | 6.84 |
| M10 | 6.84 | 6.79 | 8.6 |
| M11 | 6.3 | 6.64 | 8.51 |

**Table 3. Compressive strength of mortar with glass fiber**

| Mixture | Compressive strength after 7 days of curing N/mm² | Compressive strength after 14 days of curing N/mm² | Compressive strength after 28 days of curing N/mm² |
|---|---|---|---|
| M1 | 12.74 | 14.69 | 16.49 |
| M2 | 16.07 | 16.76 | 16.89 |
| M3 | 15.96 | 16.1 | 16.3 |
| M4 | 10.395 | 10.49 | 11.88 |
| M5 | 9.59 | 10.79 | 11.53 |
| M6 | 8.584 | 8.72 | 9.72 |

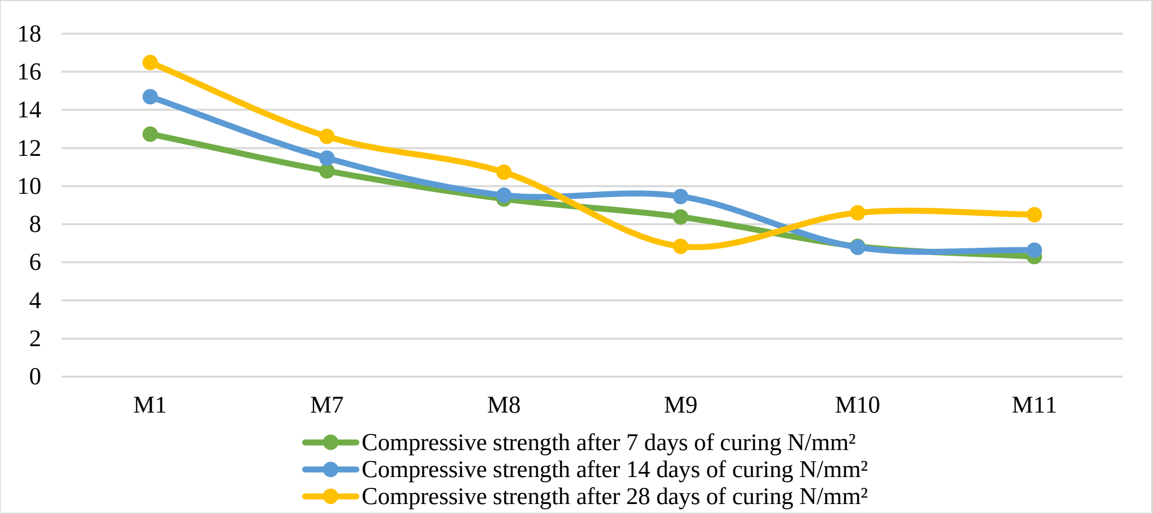

**Fig. 8 Compressive strength of mortar with RHA**

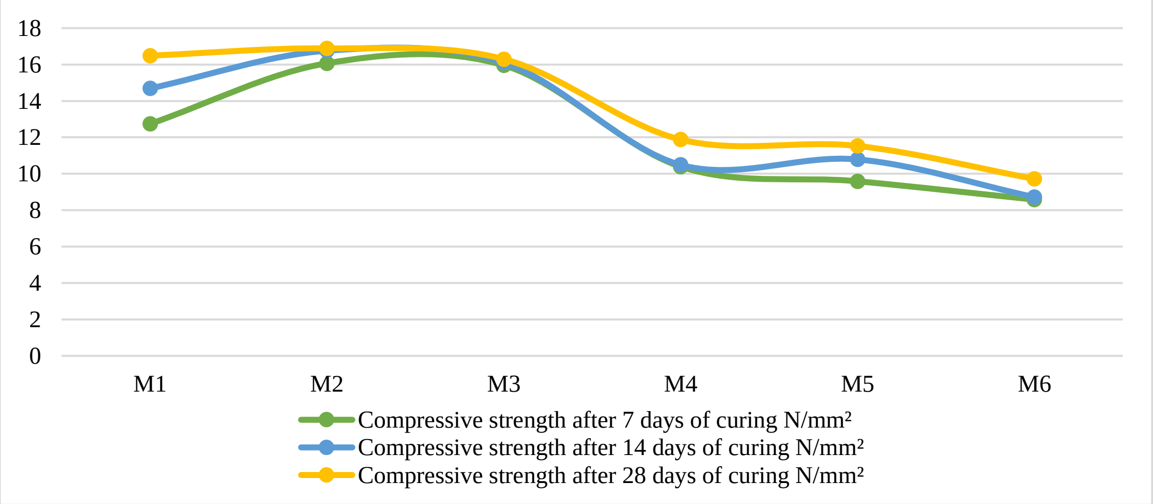

**Fig. 9 Compressive strength of mortar with glass fiber**

The obtained results unequivocally demonstrate that the compressive strength of mortar increases with 2% of replacement when RHA partially replaces cement. In comparison to the reference mortar without RHA, the outcome for 4 percent RHA is less than the reference mortar and that for 2 percent RHA, but it is still satisfactorily acceptable. The graph clearly illustrates a sharp drop in compressive strength at a replacement level of 6 percent. Therefore, it can be inferred that the 4 percent substitution of cement with RHA can be regarded as ideal based on the test findings. It may be because when fine RHA particles are used to fill mortar pores, the strength initially increases but then falls since RHA's binding ability is less effective than that of Portland cement. RHA results in increased water demand, according to *Fapohunda Christopher*, which can be one of the reasons for the decrease in strength with an increase in RHA.

According to a literature review, the size of the glass fiber significantly impacts how well it performs in concrete or mortar; the glass fiber utilized in this investigation was 3 mm in size. With the addition of glass fiber as an admixture, the compressive strength results from the laboratory experiment are not entirely satisfactory. The findings unmistakably demonstrate that the strength of the mortar falls when glass fiber is added compared to reference mortar. Therefore, it has poor compressive strength when combined with building and demolition waste. The maximum compressive strength is found at a 1% inclusion of glass fiber. The water-cement ratio, held constant at 0.5, might be to blame for this drop in strength. The lack of workability could be the result of a decrease in compressive strength since the mixture while being made, was discovered to be drier than the other reference mortar with that amount of fixed water cement ratio.

### *4.3. Permeability*

Compressive strength results can persuade us that substituting RHA for cement is good when done partially, up to a percentage of 4 percent, which is then discovered to be most useful. As a result, only the permeability of the mixtures M1 and M3 were examined and compared in light of the results presented in Table 4. The results for the coefficient of permeability are shown below:

It is clear from the result that when RHA is added to cement mortar, the permeability of the mortar mixture decreases, which restricts the ease and flow of water. This is a result of the pores in mortar blocks being filled with the smaller RHA particles. On the other hand, the permeability with the addition of glass fiber as an admixture is shown in Table 5 and Figure 11; the findings precisely demonstrate that in comparison to the reference mortar M1, the permeability of the glass fiber incorporated mortar mixture is greater and also increases with increase in the percent of glass fiber. Glass fiber can therefore be used as an admixture to increase tensile strength, but not compressive strength or to improve permeability. Even though including glass fibers increases permeability from 2% to 4%, it increases only at a very slow and nearly stagnant rate.

**Table 4. Permeability of Mortar Mixtures with RHA**

| Mix | % of CDW | % RHA | Coefficient of permeability in cm/min | K in cm/sec |
|---|---|---|---|---|
| M1 | 35 | 0 | 0.0117 | 1.95 x $10^{-4}$ |
| M3 | 35 | 4 | 0.0087 | 1.45 x $10^{-4}$ |

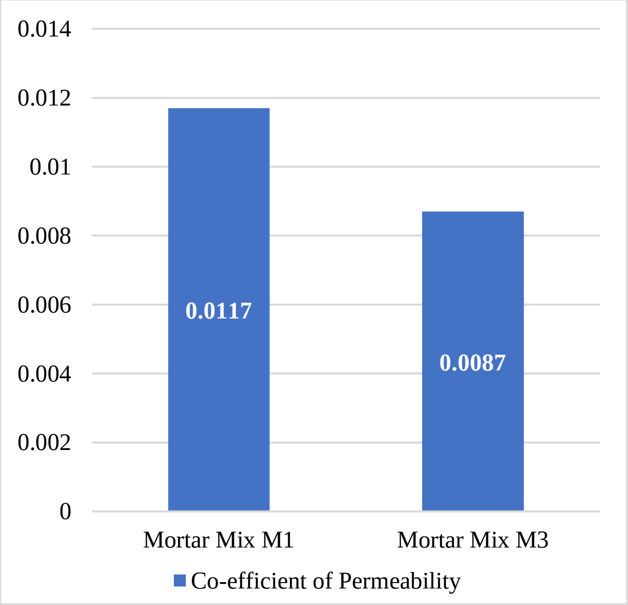

**Fig. 10 Coefficient of permeability, RHA**

**Table 5. Permeability of mortar mixtures with glass fiber**

| Mix | % Glass fiber | Coefficient of permeability in cm/min | K in cm/sec |
|---|---|---|---|
| M1 | 0 | 0.0117 | 1.95 x $10^{-4}$ |
| M7 | 1 | 0.0175 | 2.92 x $10^{-4}$ |
| M8 | 2 | 0.0212 | 3.53 x $10^{-4}$ |
| M9 | 3 | 0.0219 | 3.65 x $10^{-4}$ |
| M10 | 4 | 0.023 | 3.83 x $10^{-4}$ |
| M11 | 5 | 0.024 | 4 x $10^{-4}$ |

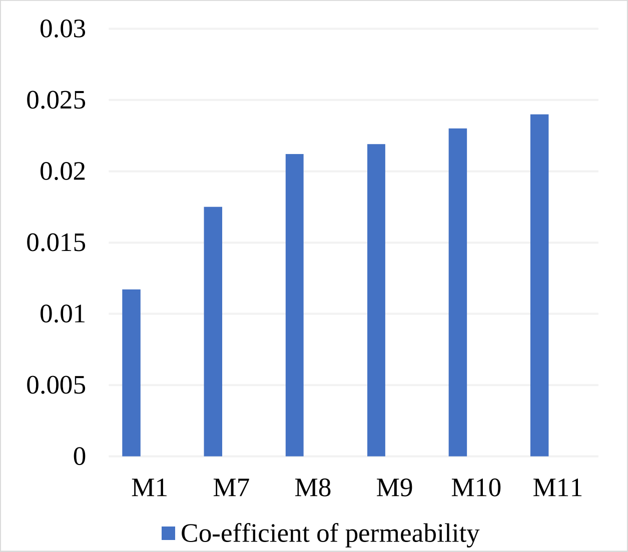

**Fig. 11 Coefficient of permeability, Glass fiber**

**Table 6. UPV results of mortar mixtures with RHA**

| Mix | Composition | % Of CDW | % RHA | Ultrasonic Pulse Velocity in Km/sec |
|---|---|---|---|---|
| M1 | Cement: sand: CDW | 35 | 0 | 3.65 |
| M3 | Cement: RHA: sand: CDW | 35 | 4 | 3.68 |

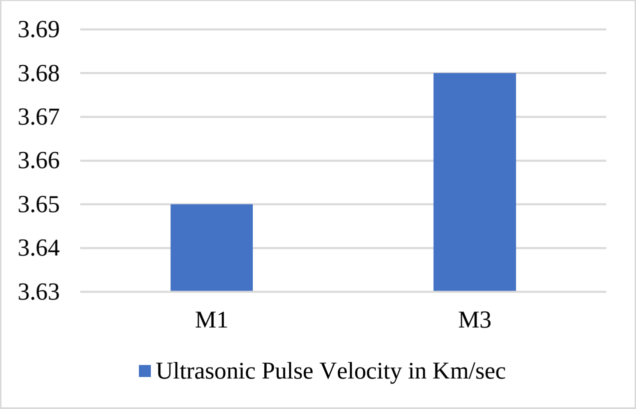

**Fig. 12 UPV results of mortar mixtures with RHA**

The decrease in compressive strength is due to low workability at a constant water-cement ratio, which results in weak bonding and lesser compressive strength. It is therefore recommended to increase the water-cement ratio further to gain better results in terms of compressive strength. Although the results are only for Glass fibers the results will vary according to different sizes of Glass fibers.

### *4.4 UPV Test*

The mortar samples underwent an ultrasonic pulse velocity test after a 56-day curing period. The data show that using RHA instead of cement leads to higher ultrasonic pulse velocities, which means there are likely fewer microcracks in the structure overall than in a mortar combination used as a reference. Additionally, it is observed that when glass fiber is used as an admixture, the value of the ultrasonic pulse velocity first rises for the percentage of admixture incorporation before falling with an increase in incorporation. As a result, it can be said that it helps with pulse velocity to a certain amount. A structure with higher pulse velocity values is likely to be more continuous, have better compressive strength, and have fewer structural cracks. Table 6 and Table 7 include the Results. As a result showed in Figure 12 and 13, it is determined that the outcomes for replacement in terms of pulse velocity are favorable. The pulse velocity for M1 was found to be 3.65 km/sec, and for M3, it was 3.68 km/sec. Whereas, in Glass fiber the value varies from 3.73 km/sec to 2.95 km/sec.

## 5. Conclusion

In consideration of all the completed experiments and the outcomes, the following conclusions might be drawn:

- While considering the compressive strength factor, it is practicable to use RHA as a partial replacement for cement, with construction and demolition waste as a replacement for sand to some extent. Utilizing RHA in mortar production is beneficial for compressive strength up to a replacement of 4% by weight of cement. However, the compressive strength does not improve when glass fiber is added.

**Table 7. UPV results of mortar mixtures with glass fiber**

| Mix | % Of CDW | % Glass fiber | Ultrasonic Pulse Velocity in Km/sec |
|---|---|---|---|
| M1 | 35 | 0 | 3.65 |
| M7 | 35 | 1 | 3.73 |
| M8 | 35 | 2 | 3.56 |
| M9 | 35 | 3 | 3.16 |
| M10 | 35 | 4 | 3.08 |
| M11 | 35 | 5 | 2.95 |

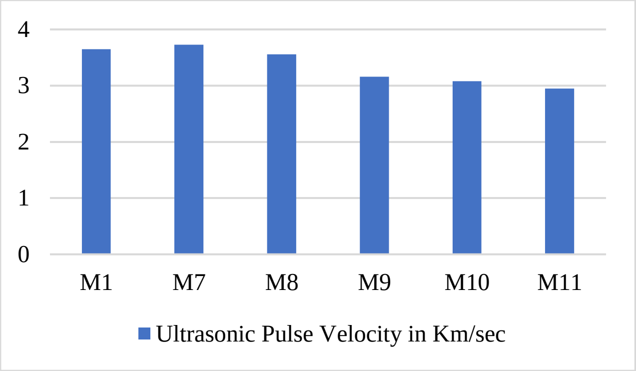

**Fig. 13 UPV results of mortar mixtures with Glass fiber**

- Although the permeability is not improved by the addition of glass fibers and results in an increase in the coefficient value of permeability, the permeability of mortar is decreased when 4 percent RHA replaces cement. As a result, the results for permeability in terms of glass fiber are not trustworthy.

- The UPV results were generally positive. The pulse velocity rises from 3.65 km/sec to 3.68 km/sec when building and demolition waste and RHA are utilized to partially replace sand and cement, respectively. An increase in pulse velocity indicates a stronger and more stable structure, a crucial characteristic of a structure. The pulse velocity findings for glass fiber support merely include a percentage of Glass fiber.

- The overall finding of the experiment is that construction and demolition waste can be suggested as a substitute for sand, with RHA as a partial replacement for cement in the production of mortar. For RHA and glass fiber, the recommended replacement percentages are 4% and 1%, respectively.

## Acknowledgements

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