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# Recycling of Waste Glass as Partial Replacement to Fine Aggregate and Rice Husk Ash as Partial Replacement of Cement in Concrete Production

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The Recycled Waste Glass (RWG) is a most suitable substitute to the natural sand to be utilized in the concrete manufacturing industry and Rice Husk Ash (RHA) is an agricultural by-product having enormous characteristics to utilize as cementitious material in concrete. This study was carried out to understand the effects of RHA as partial replacement to cement and RWG as a partial replacement to natural fine aggregate with 10%, 20% and 30% levels of substitutions in the concrete mixes respectively. The effects were investigated on the workability and compressive strength characteristics of fresh and hardened concrete. A total of 4 mixtures were prepared for M15 grade concrete with 1:2:4 concrete proportions and water to cement ratio of 0.55. Out of them one was controlled mixture and three were with 10%, 20% and 30% equal substitution levels of combined RHA and RWG. The acquired results showed that the slump values were like that of conventional concrete at combined incorporation of RHA and RWG at 10% replacement, but a decline was noticed at 20% and 30% replacement. The decline was due to the more surface area of RHA which absorbs more water. The compressive strength at 10%RHA and 10% RWG combined replacement in concrete mix was increased by 9.7% as compared to controlled mix after 28 days curing. The results were similar at 20%RHA and 20%RWG incorporation as compared to controlled concrete mix. It is concluded that RHA and RGW can be utilized at 10% equal replacement in the concrete and the cost of construction can be reduced. This research work will be helpful in developing a comprehensive scientific data base on combined utilization of RHA and RWG in the concrete mixes and the upcoming scientists, scholars and students will be benefitted.

**Keywords:** Glass waste, rice husk ash, cement replacement, compressive strength.

## 1. Introduction

The epicenter of consideration of researchers and scientists since last three decades is the recycling of industrial and agricultural waste materials in the construction industry. The reason is increasing requirements of huge quantities of concrete. According to an estimate about 30 billion tons of concrete is used around the globe (Jackson, 2021) and as

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a basic constituent of concrete, massive amounts of cement is needed, as per an estimate the production of cement reached to a volume of 4.4 billion tons in 2021 (Garside, 2022) and its production at large scale is causing environmental pollution by emitting 8% of global $CO_2$ (Amran el al., 2021). The manufacturing of cement is most carbon- intensive process because it needs huge quantities of fossil fuels to heat a mixture of lime and clay to reach to a temperature of more than 1400 $^{O}$C in a kiln (Radwan, 2012). The other main ingredient which is used as filler in the concrete is Fine Aggregate (FA). Besides the main natural resources of water and fossil fuels that are the essential commodities for development of economy and structure, the natural sand is also an indispensable resource on the earth (Seatao, 2021). The huge quantity of sand is utilized in the construction industry, according to an estimate around 40 – 50 billion tons of sand is consumed each year (Seatao, 2021). This abnormal extraction of natural aggregate resources will pose dangerous consequences on biodiversity, water transportation and landscapes in near future (Jad Bawa, 2021). The desert sand is very fine and dry and possesses high alkali, therefore very difficult to utilize in construction industry without a special treatment. Likewise, the sea sand is also very fine and round and contains chloride which is liable to cause corrosion to steel and iron, therefore, sustainable structures cannot be build (Anbazhagan, 2016).

Therefore, the speed of emissions of $CO_2$ and other dangerous gases can be slowed down and the depletion of natural resources can be stopped by utilizing some industrial by-products in construction industry (Channa, 2021). The Rice is one of the major crops produced in the world. After sugarcane and corn, the rice is the third most-produced crop of the world and a total quantity of 756 million tons of rice production was recorded globally in 2019 (World Economic Forum, 2022). Most of the rice, about 85% of the total produce globally is cultivated in 10 countries. There is a protecting cover surrounded the rice naturally that is known as hull or husk. This husk after incineration process at high temperatures of 700 $^{O}$C a reactive Rice Husk Ash (RHA) is produced, this RHA possesses pozzolanic properties and can be used as cementitious material in the concrete (Amran, el al. 2021). It has been proved from the previous research those different ashes obtained from industrial wastes can be utilized as construction materials (Mangi, et al. 2020) and (Jhatial, et al 2021). On the other hand, the waste glass powder has almost same properties as the natural fine aggregate possesses. The glass powder is supposed to be the best replacement to the natural sand (Keerio, et al. 2020). Therefore, the sustainability of the concrete industry can be achieved, and the environmental pollution can be minimized by utilizing these material materials. This research study could help the future researchers and scholars, those looking for utilizing renewable materials in the field of concrete technology.

## 2. Materials & Methodology

### 2.1 Materials

This experimental study considered two industrial waste materials the Rice Husk (RH) and the Recycled Waste Glass (RWG). These both materials are available in abundance locally. These additional industrial waste materials are incorporated in concrete mixes to enhance the properties of fresh and hardened concrete (Shahid Ali Shaikh, 2021). The Rice Husk for this research work was collected from a locally established rice mill. Though Rice Husk is an agricultural by- product and it is available in abundance in the locality of the District Sukkur, Sindh, Pakistan. A huge amount of rice husk around 200 kg was gathered in an open area after that it was enkindled at about 600 $^{O}$C – 700 $^{O}$C temperatures for around 7 hours. All the safety measures were taken, and it was burned until the raw rice husk was turned into ash. After that it was grounded in the Loss Angles (LA) machine for up to 500 revolutions then it was passed through sieve 45 microns and the large particles were separated. The final product of very fine and grey in color RHA was incorporated in the concrete mixes at different percentages of substitutions. It has been observed through chemical composition of the RHA that it possesses a major amount of silica which help in pozzolanic reactivity (Mangi, et al. 2020), and the RHA acts as a binding material.

In case of Recycled Waste Glass (RWG), the used waste glass mainly bottled glass was purchased from a junkyard and after washing and cleaning it was grounded by hand at site with the help of Mortar as shown in Fig. 1. Then after the sieve analysis was performed as per the American Society of Testing Materials (ASTM) standards for fine aggregate_(ASTM C-33/C-33M-13, 2016). Then this sieved quantity of RWG was utilized at different levels of substitutions in the concrete mixes. The natural hill sand after performing sieve analysis and passed through 4.75mm sieve was used as fine aggregate (FA) along with the RWG in the concrete mixes.

Locally available the Ordinary Portland Cement (OPC) was utilized as a primary cementitious material with Type I general purpose cement as per the directions of the ASTM C150 standards_(ASTM C150/C150M-21, 2021). The OPC cement was purchased from local market and incorporated in the mixes along with RHA as partially substitute to cement.

A good quality crushed stone was utilized as a coarse aggregate (CA) and it was purchased from the local market of District Khairpur Mir's, Pakistan. The required quantity was sieved as per instructions described in the ASTM standards (ASTM C-33/C-33M-13, 2016). In addition, the portable water was served for preparing mixes and for curing purposes for this research study. The water to cement ratio of 0.55 was set to prepare all concrete specimens in the laboratory.

**Fig. 1 - Preparation of Recycled Waste Glass (RWG)**

**Fig. 2 - Preparation of Rice Husk Ash (RHA)**

## 2.2 Experimental Program

This research study was carried out on four concrete mixes incorporated with different proportions of RHA as a partial substitute to cementing material and RWG as a partial replacement to natural fine aggregate in concrete. The purpose was to investigate the effects of combined use of recycled waste materials on workability of the freshly mixed concrete. Out of four concrete mixes, initially the first concrete mixture was prepared as a controlled mixture with only OPC as binder material and natural hill sand as fine aggregate and no recycled material was added. After that the remaining three mixtures were prepared with combined partial replacement of RHA and RWG with 10%, 20% and 30% respectively. The concrete of strength 15 grade (M15) was prepared in the laboratory as per the ASTM standards (ASTM C192/C192M-14, 2015). Concrete cubes of specified sizes were prepared for this experimental research work as per the ASTM standards (ASTM C192/C192M-14, 2015) with 1:2:4 concrete proportions at (0.55) water to binder ratio. The details regarding the mix proportions are listed in Table 1 given below.

**Table 1 - Concrete mix proportions**

| Mix Code | Cement (OPC) (%) | Fine Aggregate (%) | Coarse Aggregate (%) | RHA (%) | RWG (%) |
|---|---|---|---|---|---|
| M0 | 100 | 100 | 100 | 0 | 0 |
| M1 | 90 | 90 | 100 | 10 | 10 |
| M2 | 80 | 80 | 100 | 20 | 20 |
| M3 | 70 | 70 | 100 | 30 | 30 |

**Table 2 - Physical properties of aggregates**

| S.No. | Properties | Coarse Aggregate | Fine Aggregate |
|---|---|---|---|
| 1 | Water Absorption | 2.1% | 1.5% |
| 2 | Specific Gravity | 2.61 | 2.63 |
| 3 | Fineness Modulus | 7.47 | 2.86 |
| 4 | Bulk Density ($kg/m^3$) | 1675 | 1925 |

## 3. Results and Discussion

### 3.1 Slump Test

The slump test for this research work was performed on all freshly mixed concrete mixtures to measure its flow ability. All the slump tests were conducted in the laboratory as per the specifications of ASTM standards (ASTM C143-78, 2017). The concrete mixtures were prepared with incorporation of different percentages of RHA as partially substitute to OPC and RWG as partial substitute to fine aggregate in the concrete. The slump values of different concrete mixes incorporated with 10%, 20% and 30% of RHA and RWG and controlled mix are detailed in Table.3 given below.

**Table 3 - Average slump values of different concrete mixtures**

| S. No. | Mix Code | Mix Type | Average Slump Value (mm) |
|---|---|---|---|
| 1 | M0 | Control Mix (CM) | 36 |
| 2 | M1 | 10%RHA &10%RWG | 25 |
| 3 | M2 | 20%RHA & 20%RWG | 20 |
| 4 | M3 | 30%RHA & 30%RWG | 15 |

The graphical presentation shown in Fig.3 indicates the behavior of workability of the freshly mixed concrete, partially incorporated with two recycled waste materials RHA and RWG having same levels of substitution that are 10%, 20% and 30% respectively as shown in Table 1. The optimum slump was determined by standard slump cone method, and it was observed 36 mm for the control mix and the minimum slump for the green mixture was measured at 15 mm at 30% RHA replacement to cement and 30% RWG replacement to fine aggregate. It was observed that with the increase in dosages of both recycled industrial waste materials in the fresh concrete mixes, the slump declines. This outcome resembles to (Bheel et al., 2019), where he observed that with increasing percentages of agriculture by-product RHA, the workability of the freshly mixed concrete will decline.

It can be understood from the outcome that, the workability of the green concrete mixes incorporated with different percentages of the RHA and RWG (10-30%) as a replacement to OPC and fine aggregate respectively gradually decreases with increase in percentages of both recycled materials.

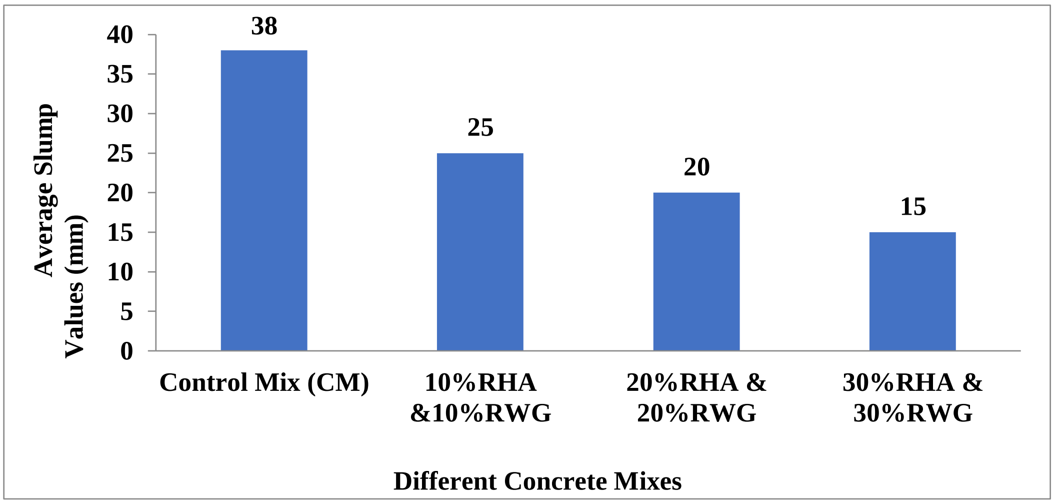


**Fig. 3 - Average slump values of different concrete mixes**

## 3.2 Compressive Strength

The compressive strength for this research study was evaluated in the laboratory by utilizing the CMT machine. This test was carried out as per the British standard (BS EN 12390-3, 2002).This compressive test was conducted on the concrete cubical specimens of size150mm x 150mm x 150mm at the curing age of 28 days. The concrete proportions for preparation of mixture are listed in Table 4 given below. The highest value of compressive strength was estimated 19.7MPa that was 9.4% higher than the controlled concrete mix. The lowest compressive strength was recorded 14.3MPa and that was 20.5% lower than the controlled mix.

**Table 4 - Compressive strength test of cubical specimens (150x150) mm$^3$**

| Mix Code | Cement (OPC) (%) | Fine Aggregate (%) | Coarse Aggregate (%) | RHA (%) | RGW (%) | Compressive Strength Test @ 28 Days |
|---|---|---|---|---|---|---|
| M1 | 100 | 100 | 100 | 0 | 0 | 3 |
| M2 | 90 | 90 | 100 | 10 | 10 | 3 |
| M3 | 80 | 80 | 100 | 20 | 20 | 3 |
| M4 | 70 | 70 | 100 | 30 | 30 | 3 |
| | | | Total | | | 12 |

**Table 5 - Average compressive strength test results of cubical specimens 28 days curing**

| Mix Code | Mix Type | Average Compressive Strength (MPa) | Compressive Strength Change (%) |
|---|---|---|---|
| M0 | Controlled Mix | 18.0 | - |
| M1 | 10% RHA + 10% RWG | 19.7 | 9.4 |
| M2 | 20% RHA + 20% RWG | 18.0 | 0 |
| M3 | 30% RHA + 30% RWG | 14.3 | -20.5 |

The graphical representation in Fig.4 shows that at incorporation of both partially replaced materials RHA and RWG at 10% level of substitution the compressive strength of the concrete mixture M1 increased at 9.4% as compared to controlled mix M0 after 28 days of curing time. At incorporation of RHA and RWG at 20% levels of substitution, the compressive strength of cubical specimen with mixture M2 observed almost similar to the conventional concrete mix M0 after specified curing age. Finally, at 30% replacement of RHA and 30% replacement of RWG in the concrete mix M3, the compressive strength of the concrete samples was noticed 14.3MPa that was a decline by 20.5% as compared to conventional concrete.

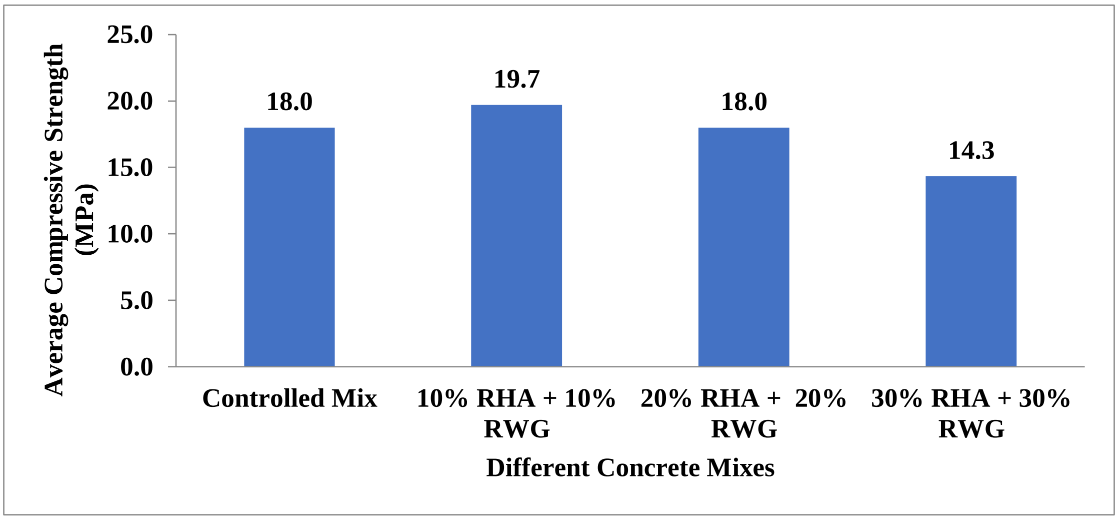


**Fig. 4 - Average compressive strength of cubical specimen at 28 days (MPa)**

It was observed from the experimental results that the optimum compressive strength of 19.7MPa with an increase of 9.4% was gained at 10% RHA as cementitious material and 10% RWG as fine aggregate replacement in the concrete mix. However, it can be perceived that the higher strengths could not be gained significantly with higher percentages of combined recycled waste materials.

## 4. Conclusion and Recommendations

In this research work the use of agricultural by-product in the form of RHA as a partial substitute to cement and the use of recycled glass waste as partial substitute to natural sand as fine aggregate in the concrete mixes were considered. The combined effects of RHA and RGW with 10%, 20% and 30% levels of substitutions have been analyzed after 28 days of curing and the conclusions are mentioned as under.

The incorporation of 10% RHA as a binding material and 10% RWG as a partial substitute to the fine aggregate, gives the comparable workability with reference to the conventional concrete. However, higher replacement percentages give the reduction in the slump values.

It was observed that the concrete contained 10%RHA and10%RWG deliver the optimum results. However, 20% to 30% the compressive strength reduces due to specific surface area of the particles of RHA and difference in the specific gravities of RHA and OPC.

It is obvious after completing all investigational study that the recycled waste glass can be utilized as a partial substitute to fine aggregate in the concrete manufacturing industry and the depletion of precious natural resources natural sand can be saved.

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