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# MECHANICAL PROPERTIES AND DURABILITY CHARACTERISTICS OF MORTAR CONTAINING RICE HUSK ASH AND WASTE TILES

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## ABSTRACT

Increased in the cost of construction materials and raising environmental concerns urges for considerable efforts worldwide to utilize agricultural waste and industrial by product materials to alleviate the cost and improve the performance of construction materials. The rice processing industry generates a

## Introduction

The cement industry is one of the biggest producers of carbon dioxide ($CO_2$) making up to 8% of overall man-made emanation of greenhouse gases that cause global warming. The other components of the gases produced from cement enterprises are $N_2$, $O_2$, $SO_2$, water vapors and micro components of CO and NO (Fraaij & Kentgens, 2008).

The increase in the cost of construction materials and raising environmental concerns urges considerable efforts to utilize agricultural waste and industrial by-product materials to improve the performance of construction materials. Conventional building materials are beyond the reach of majority of the world population due to their poor affordability (Utkarsh & Rambharosh, 2017).

significant amount of rice husk as waste, while extensive amount of waste tiles are being generated around the world. These wastes are mostly sent to the landfill without considering recycling option. Various researchers considered these waste as cost-efficient and environmentally friendly pozzolanic material. Therefore considering the environmental impact of cement industries and the expensive rising cost of construction material the cheap and good accessibility of rice husk and waste tiles are the main motivations behind this research work. In this research, the rice husk are obtained from local mill and were burnt to ashes at a temperature of 600 to 700 °C in locally constructed furnace to produce the rice husk Ash (RHA). The waste tiles are obtained at construction sites and tiles sellers at a cheaper rate. Waste tiles are broken manually with hammer and sieved through a 4.75 mm sieve to match with the river sand. The strength and durability properties in terms of water absorption of mortar comprising RHA as supplementary cementing material and waste tiles as substitute for fine aggregate are investigated. Laboratory experiment are conducted to evaluate the characterization of RHA and waste tiles in terms of physical properties (consistency, setting time, particle size distribution, water absorption and specific gravity). Series of mortar were prepared with 10% constant RHA replacement to cement and 0%, 25%, 50%, 75% and 100%, replacement for fine aggregate with waste tiles. The water to cement ratio (w/c) of 0.48 was adopted. Compressive strength and water absorption of hardened mortar were determined. The mortar cubes of 50 mm$^3$ were casted and cured in water for 7, 14 and 28 days for Compressive strength. While the water absorption test and acid resistance attack were tested at 7, 28 and 56 days.

**Keywords:** Rice Husk Ash, Waste Tiles, Setting Time, Water Absorption, Acid Resistance Attack

Mortar is one of the most important components of a structure which is a product from mixture of sand (fine aggregate), a binder (lime, cement, etc.) and water. Improvement of some properties of mortar require additional constituents such as admixtures, which are composed of natural substances and industrial by product (Saklecha 2001).

Cement is the main element of mortar which act as a binding material. However, the exploration and production of cement causes numerous risks, such as cement dust, air contamination, solid waste pollution, noise pollution, ground vibrations and resource depletion due to crude material extraction (Bhagat, Saklecha & Kedar, 2017).

Sanjuán, Andrade, Mora & Zaragoza (2020) reported that cement used for mortar and concrete globally that raises the $CO_2$ emissions was reduced from 925 kg $CO_2$ per ton clinker to 850 kg $CO_2$ per ton clinker in 2015 when replaced with supplementary cementing materials.

Many researchers have not only been able to establish that the use of supplementary cementitious materials such as Blast Furnace Slag, Silica Fume, Metakaolin, Fly Ash and Rice Husk Ash etc. can improve the various properties of mortar but also contribute to the economy in construction costs (Amrutha, 2009).

Rice husk is an agricultural residue widely available in major rice producing countries such as Nigeria, and its Ash is a suitable construction material for sustainable built environment. Each ton of paddy rice can produce approximately 200 kg of rice husk, which on combustion produces about 40 kg of ash (Bui, 2001).

The Food and Agricultural Organization (FAO, 2016) put the global rice paddy forecast for 2016 at 745.5 million tons and can produced approximately149.1 million tons of rice husks.

Klaassen & Kentgens, (2008) reported that about 500 million tons of paddies are produced in the world annually and after incineration only 20% of rice husk is transformed to RHA. Similarly, the milling process of paddy grains produced 78 % of rice, broken rice and bran while the remaining 22 % of the weight of paddy are husk. This husk contains about 75 % organic volatile matter and the rest of 25% weight of this husk are converted into ash during the firing process and this ash is refer to as Rice Husk Ash (RHA).

In construction industry, many construction materials are used, most common ones are concrete, bricks, tiles, steel and wood. Waste tiles which are obtained from the construction sites and industries worldwide are disposed to landfill, which are not undergoing any recycle process and often daily becomes more dangerous to our environments. Conventionally, the fine aggregate used in mortar production are sharp sands and left over (dust) of crushed stone, granite, and limestone.

Waste tiles can be used widely in the production of concrete/mortar due to some of the favourable properties such as durability, hard and highly resistance to chemical and physical degradation (Jimenez, 2013). It has been also reported that ceramic waste in the form of fine aggregates in hot mix asphalt with 15% by weight, increased the rutting resistance of binder (Huang 2012). Most of the construction and demolition waste are not recycle but end up in landfills occupying valuable land not to mention the cost incurred in land filling (Naveen & Antil, 2016).

Nowadays almost all the researches were concentrated on how to utilize ash derived from uncontrolled combustion because controlled combustion influence the surface area of RHA, so that time, temperature and environment be considered to produce ash of maximum reactivity. However, from the review of literature, it was found that some works already done to find out the effect of RHA in cement mortar and they collect the RHA by percentage (FAO, 2016).

The replacement of sand with ceramic waste gave better results in terms of durability than normal mixture of cement and sand. Ceramic fine aggregates were used in high performance concrete replacing cement and coarse aggregates; increase the compressive strength at 20% replacement (Mandavi, Srivastava & Agarwal 2015).

Kishore, Bhikshma, & Prakash (2011) reported that the strength of mortar depends on the quality of fine aggregates and the quality of fine aggregates equally depends on the sources of collection, size and gradation of the aggregates. The ceramic fine aggregates improve mortar quality with their proportion.

Durability is the ability of concrete/mortar to perform satisfactorily in the exposure condition to which it is subjected over an intended period of time with minimum maintenance. Circumstances such as penetration of water and aggressive chemicals, carbonation, chloride ingress, leaching, sulphate attack, alkali-silica reaction and freezing-thawing lead to severe deterioration of mortar. Most of the problems in construction are caused due to corrosion reinforcement through concrete by chloride and sulphate attack. Corrosion resistance from chloride attack was studied by replacing natural aggregates with ceramic aggregates. Results showed that ceramic aggregates have lower chloride diffusion rate than natural aggregates (Hunchate, 2013).

Rashid, Molla and Ahmed, (2010), reported that the mortar incorporating 20% replacement level of rice husk ash is more durable than OPC mortar. Chen, Chen and Yen (2017) studied the Mechanical Properties and Durability of Mortar with Rice Husk Ash Calcined at Low Temperature. They reported that the shrinkage in mortar was not influenced by the RHA up to the replacement of 20% and recorded a low shrinkage of 0.035%. Zahedi, Ramezanianpour, and Ramezanianpour (2015), showed that the chloride ion permeability in binary blended mortars containing nanosilica and RHA was reduced compared to RHA mixtures at the age of 90 days.

Madandoust, Ranjbar, Moghadam, and Mousavi (2011), carried out research on Mechanical properties and durability assessment of rice husk ash concrete. Their experiments showed that the higher the RHA content, the lower the chloride concentration across all the specimens as compared to control specimens. Their results also show that the rate of chloride penetration decreases with the depth.

According to Abalaka (2013), the RHA particles that were not used in pozzolanic reactions absorbed more water intake. He also reported that the marginal reductions in water absorption of RHA specimens were recorded at 180 days compared to 28 and 90 days.

This research focused on the replacement of cement and fine aggregates with Rice Husk Ash and waste tiles respectively. The idea of sustainability and green production persuades the consumption of various sorts of agricultural and industrial wastes to use as supplementary cementing materials, aggregates or even admixtures, leads to eco-friendly construction by reducing the cost of construction associated with disposing of waste materials (Samadi & Hussein, 2015).

## Materials and Methods

### Cement and Fine Aggregate

Ordinary Portland cement (OPC), CEM I with strength of 42.5 MPa, conforming with ASTM C150 (2012) was obtained from local Cement Manufacturing Company in Nigeria. The fine aggregate was locally as obtained river sand that passed through 600 μm sieve with bulk density of 1640 Kg/m. Sieve analysis was conducted on the fine aggregate, and the grading curve is shown in Figure 1. From the curve it was found that the coefficient of grading was 1.03, which was greater than 1. Therefore, the river sand was considered as well graded and conforms to ASTM C144 (2011) standard. Similar findings were reported by Kuranchie, Shukla, Habibi, Mohyeddin, and Puppala (2015). The grading limits of the river sand also fall into zone I classification of BS 812 - 103.1 (1985). The percentage retained on 4.75 mm sieve size was 4%, which was also within the recommended limits of 0 - 5% of BS 882 (1992) grading requirements for fine aggregate. The fineness modulus is 2.60 which is within recommended limit of 2.1 to 3.2 specified by ASTM C33 (2003).This indicate that the sand will not demand much water that will affect the workability, hence it is suitable for making good mortar. However, a Polycarboxylic ether based superplasticizer that complies with ASTM C494 (2013) was used to increase the workability of the mixtures to avoid increase of water.

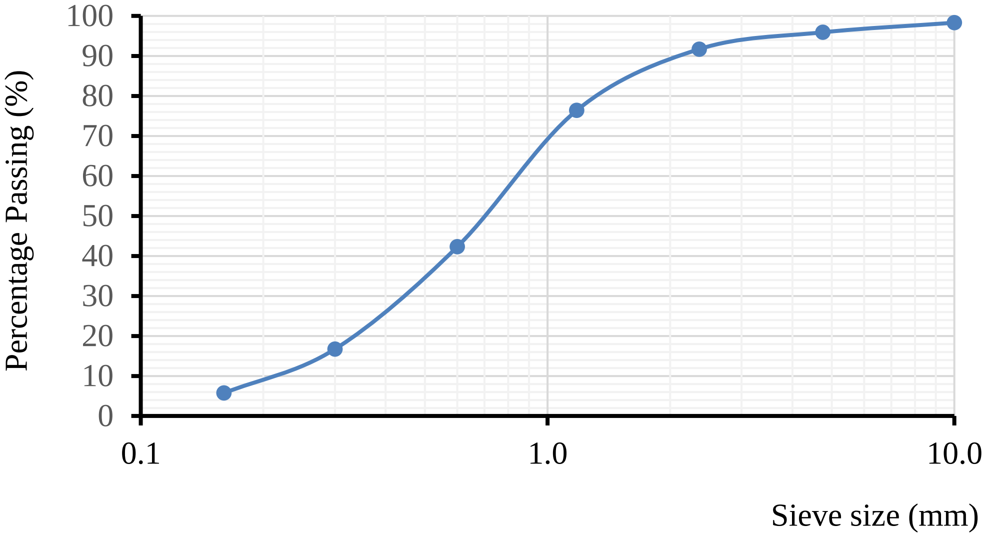

Figure 1: Graph of sieve analysis of sand

### Waste tiles

Waste tiles are waste from tile industries and during installations of tiles in buildings that are usually found at the end of polishing and finishing and normally discarded. This piece of tiles which are discarded as waste during installation and production were collected at negligible cost. They are broken with a crusher machine and sieved through 4.75 mm sieve to match with the river sand and used as an alternative material in production of the mortar. Physical test data of waste tiles showed that it had: specific gravity = 3.10, relative density = 1.36 g/cm$^3$, fineness modulus = 3.75 and water absorption rate = 15%. The particle size distribution indicated that waste tiles is coarse and fall to coarse grade quality of ASTM C144 (2011) (Figure 2). Table 1 shows the chemical composition of waste tiles.

Table1: Chemical composition of Waste tiles

| **Chemical composition (%)** | **$SiO_2$** | **$Al_2O_3$** | **$Fe_2O_3$** | **CaO** | **$K_2O$** | **$TiO_2$** | **LOI** |
|---|---|---|---|---|---|---|---|
| **Waste tiles** | 72.5 | 15.8 | 3.68 | 2.03 | 2.80 | 0.46 | 0.2 |

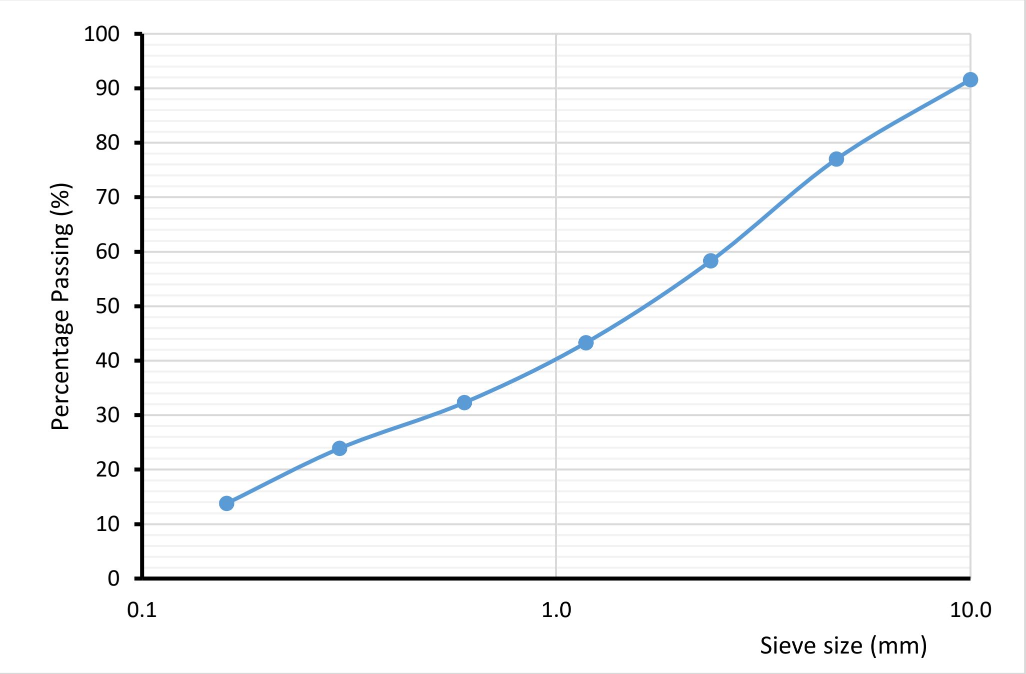

Figure 2: Sieve analysis curve of broken tiles

Figure 3: Waste tiles broken into pieces.

## Rice Husk Ash

The RHA used for this study was produced from rice husk sourced at local rice mill in North Eastern, Nigeria, using a local furnace located at Abubakar Tafawa Balewa University (ATBU), Bauchi, Nigeria. The rice husks were burned at a temperature of 600 °C to 700 °C within the duration of 6 to 7 hours. The local furnace requires 20 liters of kerosene for fueling the burning engine of the furnace. The resulting RHA was allowed to gradually cool to ambient temperature, collected and grinded with loss angles grinder machine and then sieved with sieve size of 150μm to achieved the level of fineness that could attained the extent of cement replacement with the low specific surface RHA produced. Figure 1 show the furnace in used.

Figure 4: Local furnace for the production of rice husk ash

**Mixture Proportion**

Table 2 shows the designed mix proportion. The fine aggregate (river sand) used for this study was natural and locally sourced. The cement in all mixtures was partially replaced with a fixed percentage of RHA (10% by cement weight). Series of mortar were prepared with 10% RHA and 0%, 25%, 50%, 75% and 100%, waste tiles replaced the fine aggregate are used. Constant water to cement ratio (w/c) of 0.48 was used. The design mortar slump floor of ≤ 340 mm diameter was adopted in accordance with BS EN 206 (2013). Polycarboxylic ether superplasticizer of 0.5% was used as admixture in all the mixtures. Designation of 0% was used for control mortar while WT25, WT50, WT75 and WT100 are used for 25%, 50%, 75% and 100%, respectively for waste tiles replacement of fine aggregate.

Table 2: Mixture proportion of five mortar mixes

| Description | **Mix Proportion** | | | | |
|---|---|---|---|---|---|
| | **0%** | **WT25** | **WT50** | **WT75** | **WT100** |
| OPC (kg/m$^3$) | 480 | 432 | 432 | 432 | 432 |
| 10% RHA (kg/m$^3$) | - | 48 | 48 | 48 | 48 |
| River sand (kg/m$^3$) | 1918 | 1438 | 959 | 480 | - |
| Waste tiles (kg/m$^3$) | - | 480 | 959 | 1438 | 1918 |
| Water (kg/m$^3$) | 230 | 230 | 230 | 230 | 230 |
| Superplastizer (%) | 0.5 | 0.75 | 1.0 | 1.25 | 1.5 |

## Experimental Program

### Consistency and Setting Time Test of OPC and RHA

OPC of 300 g was weighed and mixed with 28% water thoroughly to become a paste. The paste is then filled in Vicat mould placed on non-porous plate and the excess paste were cut and removed. The plunger on Vicat is then lowered to touch the surface of paste before it was being released and allowed to penetrate into the test paste as shown in Figure 5. The penetration of the plunger on to the paste was observed and the experiment was repeated at different water percentages of 30%, 32% and 33% respectively until the distance between the needle and the base-plate is 6 ± 2 mm in accordance with BS EN 196 - 3 (2016). The standard consistency value was used to calculate the quantity of water for initial and final setting time.

The plunger was replaced with initial setting time needle and the needle was being released at interval of every 5 minutes to observe the penetration until the needle reach a scale value between 3 - 6 mm scales (BS EN 196 - 3, 2016).

The needle is then replaced by the one with an annular attachment and the final setting time of cement was also determined. Similar procedure was applied for 10% RHA+OPC to perform the consistency and setting time.

Figure 5: Testing of consistency and initial setting time

**Specimens casting and curing**

For each mortar mixture, specimens of 50 mm cubes and 100 x 200 mm cylinders were prepared. The cubes were used to determine the compressive strength, water absorption and acid resistance test, while the cylinder was used for tensile strength. All the specimens were demoulded after 24 hours of casting and were cured under water for the period of 7, 14 and 28 days until testing date. After the 28 days of curing in water, water absorption and acid resistance attack test were performed.

**Compressive and splitting tensile strengths**

Compressive and splitting tensile strengths were determined using compression machine with a loading capacity of 3000 kN. The result of the compressive strength is presented in Figure 7 while tensile strength is plotted in Figure 8. The compressive strength and splitting tensile strength test were carried out at the curing ages of 7, 14 and 28 days curing. All the tests were conducted in accordance to ASTM C270 -14a (2014). Mortar cubes were prepared according to mix proportions shown in Table 2. The mortar cubes were allowed to dry from curing for 30 minutes before placing in the compression testing machine.

## Durability Tests

### Water absorption:

Three specimens of 50 mm cubes were used at the ages of 28 days of curing. The specimens were oven dried at 105° C for 72 hours. They were then allowed to cool in an air tight vessel for 24 hours. The specimens were weighed and immediately immersed in water tank for 30 minutes. The specimens were then weighed and water absorption was calculated as an increase in weight expressed in percentage of the mass of the dry specimen as shown in eqn. 1.

$$W=\frac{W_w-W_d}{W_d} \text{ x } 100\% \ldots\ldots\ldots\ldots\ldots\ldots \quad [\text{eqn. } 1]$$

Where:

$W$ = Percentage of water absorption
$W_W$ = Weight of specimen wet
$W_d$ = Weight of specimen dry

### Resistance to Acid attack

Mortar cubes of 50 mm were prepared with different batches of mix designed and cured in water for 28 days before immersing them in 5% $H_2SO_4$ solution. Prior to immersion, the cube specimens were dried under laboratory condition for 48 hours and weighed as referenced. The assessment of mortar specimens in acidic environment were made based on weight losses at 7, 28 and 56 days of immersion.

## Results and Discussion

### Consistency and Setting of Binder Material

Table 3 presents the result of the consistency and setting time test conducted on the binder combination (10% RHA+OPC) and the control (OPC) specimens. The result show that the water demand of the combined binders was higher than the control. This could be attributed to the specific surface area of RHA which is higher than the OPC and the ash is hygroscopic in nature, so demand more water. Similar findings was reported by Alam and Ahmad (2015) on possibilities of increasing setting time using rice husk ash (RHA) as binding material

The results of both initial and final Setting time of Binders revealed that 10% RHA binder combinations is lower than that of OPC. This behavior may be due to the low rate of hydration in the paste containing RHA.

Table 3: Result of consistency and setting time of binder

| Proportion of Cement | Consistency (%) | Initial Setting Time (minutes) | Final Setting Time (minutes) |
|---|---|---|---|
| **OPC** | 33 | 70 | 360 |
| **10% RHA** | 40 | 45 | 300 |

**Flow test**

The results of Figure 6 shows that flow rate of the waste tiles mortar mixtures were lower than that of control specimens (0%). As the percentage of waste fine aggregates increased workability decreased. This decreased in the flow rate can be attributed to the high angularity and flakiness, couple with high surface hardness of waste tiles lead to decreased workability by increasing the friction with the cement paste. Where, the higher the rough surface and the angularity, the higher the water required to produce workable of the mortar (Obaid, Nasr, Ali, Shubbar, & Hashim 2021). The addition of waste tiles to a mortar mixtures generally densifies the mortar by filling up the cavities and reducing the porosity. Moreover, the 10% RHA replacement to the cement also contributed in the stiffness of the matrix and resulted in lower flowability of the waste tiles mortar. The use of waste tiles as fine aggregate also resulted in higher water demand and to preserve a constant fowability, superplasticizers has been dosage to keep the water demand closer to that of control. It has been found that the higher the replacement level of waste tiles, the larger the water required to maintain the standard consistency of mortar, therefore reducing the workability. Similarly, Siddique, Shrivastava, and Chaudhary (2017) also reported on the reduction in workability of mortar with the addition of ceramic tiles. When considering that the ratios of superplasticizer content are different for all mixtures it can be concluded that the waste materials characteristics might have the greater role in affecting the workability of fresh mortar.

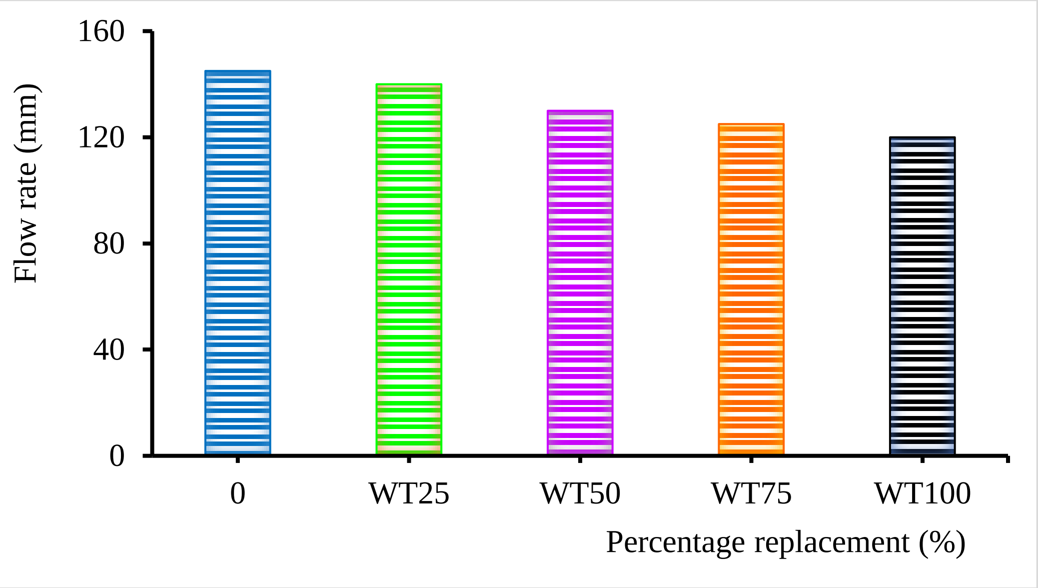

Figure 6: Comparison of flow diameter between mortar specimens

**Compressive Strength Test**

Compressive strength of mortar with different percentage of waste tiles as river sand replacement is shown in Figure 7. The control specimen (0 %) show higher compressive strength at 28 days in comparison with waste tiles specimens. However, 50 % waste tiles replacement showed higher compressive strength compared with normal mortar at 7 days. This may be due to the early pozzolanic reaction occurred between silicon oxide ($SiO_2$) and calcium hydroxide $Ca(OH)_2$ from hydration process. In addition, the amount of Aluminum oxide ($Al_2O_3$) in waste tiles also caused the gain of strength at early age. It can also be observed that the compressive strength of WT50 mortar is 16% lower compared to the control mix at 28 days. This reduction of compressive strength could be attributed to the poorer interfacial bond between the cement paste and the waste tiles aggregate. Similar observation was reported by Obaid et al. (2021),.

The results also indicate that the difference in compressive strength of all the specimens are not significantly wider. This may be due to the size distribution and physical characteristic of waste tiles aggregates that were almost similar to the river sand. It was also found that the compressive strength of the waste tiles mortar at later ages was relatively similar with the normal control mortar. Similar to the control specimens, waste tiles mortar also shows increment of compressive strength as the curing period progressed. But this increase of compressive strength of specimens with replacement is not too much compared with control specimens which may be due to the amount of active silicate in waste tiles. The results generally indicates that the waste tiles aggregates can be used to replace sand in mortar mix.

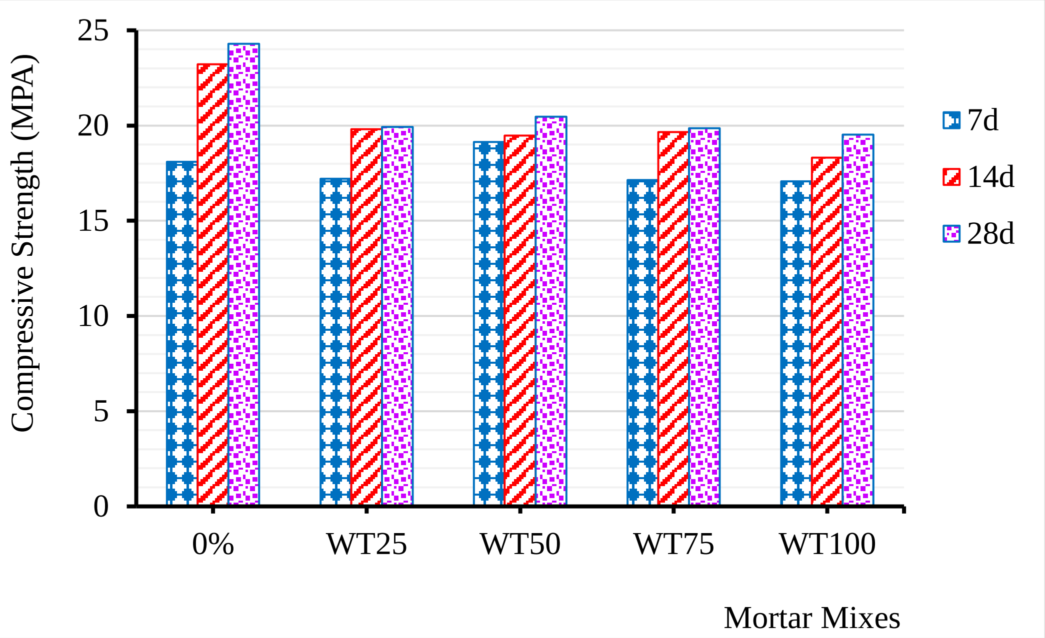

Figure 7. Compressive strength results of mortar mixtures

### Splitting tensile strength

Figure 8 shows splitting tensile strength results of mortar specimens. The results indicated that the splitting tensile strength increased sharply in mortar specimens containing waste tiles throughout the replacement compared to 0%. It is also observed that splitting tensile strength of waste tiles mortar was found to be increased with the increasing ages of curing. This might be due to the pozzolanic reaction that happened amongst the $SiO_2$ and $Ca(OH)_2$, which were released from the hydration process of the OPC and RHA. Despite, the pozzolanic activity of waste tiles, the splitting tensile strength values for the waste tiles mortar at the age of 28 days were slightly lesser than that of 0% mortar at 100% replacement. Unlike compressive strength, the splitting tensile strength of the waste tiles mortar were generally higher than those of the control specimens. The increase in tensile strength observed in waste tiles mortar could be due to the enhanced bonding between the aggregates and the cement paste engendered by the powdered particles of the waste tiles. It is also suspected that waste tiles improved the microstructure of the interfacial transition zone and increased the bond strength between the cement and the aggregates. However, comparing the results at 7 and 28 days, there was a significant improvement in the splitting tensile strength of mortar with waste tile mixtures. The splitting tensile strength of the specimens with 50 % waste tiles as river sand replacement was 15 % higher than control specimens. Similar observations was reported by Mohammad, Lim, Tahir, Alyousef, and Samadi (2019) that the tensile strength value of mortar containing 40% ceramic powder was 15% higher than that of OPC mortar at the same curing period.

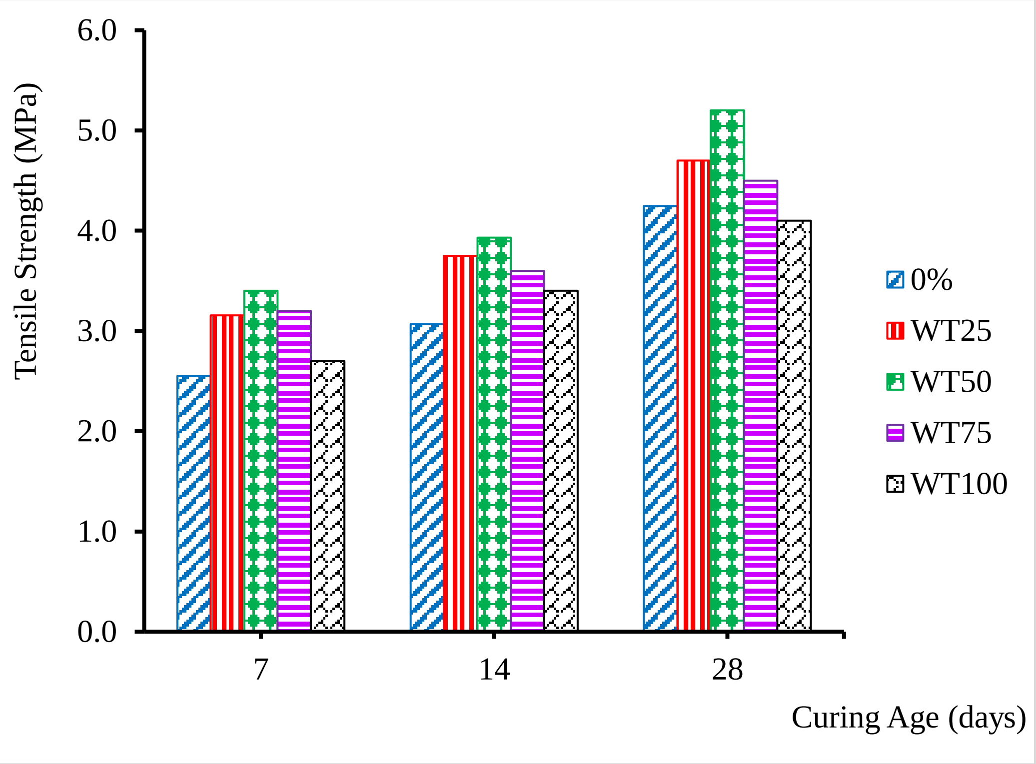

Figure 8: Splitting tensile strength of mortar specimens

## Durability Properties

The respective mortar of control and waste tiles were investigated with respect to their durability properties in terms of water absorption and resistance to acid attacks,.

## Water absorption

The results of water absorption test conducted after 28 days of curing are presented in Table 4. The data revealed that mortar permeability decreased slightly at WT25 and WT50 compared to the control specimen. This might be attributed to the continuous hydration of the cementitious materials in waste tiles which occupied both the macro and micro pores in the mix that reduced the water absorption of mortar during the curing age. In other words, the waste tiles content influenced the pore and grain refinements of the mortar (Yu, Zhang, & Mu, 2012). But as the replacement of river sand with waste tiles further increased, so also the water absorption increased with waste tiles mortar specimens. For example, the percentage increase of water absorbed by the WT75 and WT100 specimens were 2.5%, and 36.1%, respectively as compared to control specimen. This increased in water absorption is possibly due to the small particles size of waste tiles powder that has larger surface area thus, tends to absorb more water. In a related research, Correia, de Brito, and Pereira (2006) observed similar trend when ceramic waste was used as coarse aggregate. They reported that water absorption by immersion increases with the increase in proportion of ceramic aggregates in the concrete mix. In general, the water absorption of all the mortar specimens were low compared to the permissible limits of 10% recommended by Neville (2011).

Table 4: Water absorption of control specimen and waste tiles mortars

| Mortar Specimens | Average Water Absorption (%) |
|---|---|
| **0%** | 3.9 |
| **WT25** | 2.6 |
| **WT50** | 3.6 |
| **WT75** | 4.0 |
| **WT100** | 6.1 |

## Acid resistance test

The results of the weight loss of the respective concrete mixes due to sulphuric acid attack are presented in Figure 9. It is observed that all the specimens exhibited the same trend of decrease in mass throughout the period of 7, 28 and 56 days of immersion. This mass loss is brought about by the action of the acid which reacts with calcium hydroxide to damage the cement gel binder of mortar (Bakharev, Sanjayan, & Cheng, 2003) and forms white, soft and soluble gypsum on the surface. Throughout the period of exposure, the weight of mortar containing waste tiles decreased more than the control, which is contrary to the submission of Sharifi, Ranjbar, and Mohit (2020). They reported that mortar specimens containing ceramic waste powder is effective in decreasing the mass loss rate after exposure to sulphuric acid. The loss of mass of mortar specimens with waste tiles could be attributed to the direct attack on the aluminosilicate framework by breaking the bonds that are prone to breakage due to their weakness. This leads to less aluminate in the composition of the waste tiles mortar. The stronger silica bonds of river sand in the control specimens tend to resist the attack by acid more than the alumina bond of waste tiles mortar.

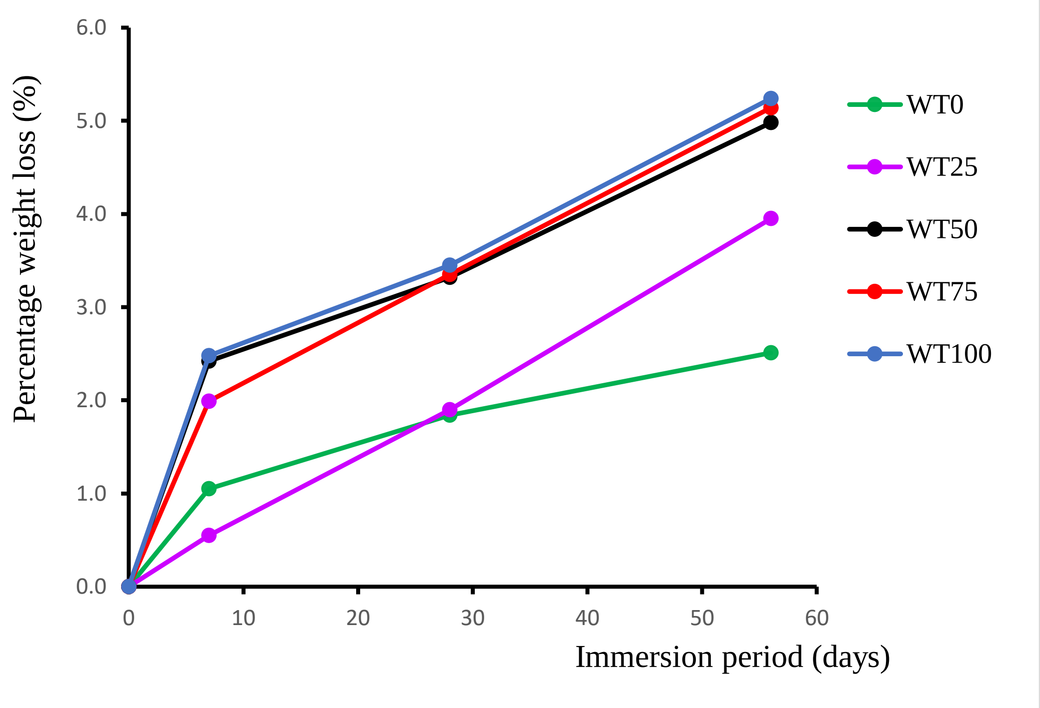

Fig. 9: Weight loss of various mortar specimens due to acid attack

## Conclusion

Based on this research work the following conclusions are highlighted:

1. Waste tiles has irregular, high specific surface area and porous in nature. The chemical composition revealed high silica, alumina and iron content.
2. Waste tiles material was found to be well graded and conform with recommended grading for fine aggregates that is suitable for mortar production.
3. The use of waste tiles and 10% RHA as partial replacement of sand and cement, respectively decreased the slump flow of the mortar workability. Slump flow of mortar was impaired while increasing the levels of replacement of river sand with waste tiles. This increased the amount of superplasticiser required in mortar on high levels of river sand replacement with waste tiles.
4. Compressive strength increases with the increased in the curing age. The results of waste tiles mortar are generally low compared to control. However, due to the early pozzolanic reaction between silicon oxide ($SiO_2$) and calcium hydroxide $Ca(OH)_2$ from hydration process the 7 days compressive strength at 50% is higher than control mortar.
5. The specimens containing waste tiles as fine aggregate replacement has the highest splitting tensile strength at all the curing periods except 100% replacement at 28 days.
6. Water absorption of the mortar increased with increase in percentage of the waste tiles at 75% and 100%. However, absorption rate was decreased at 25% and 50% replacements.
7. As the acid curing continued, the mass loss rate of mortar specimens increased. The negative effect on waste tiles specimens are influenced by the reaction between the acid and calcium in waste tiles material forming calcium carbonate.

## REFRENCE

Abalaka, A. E. (2013). Strength and Some Durability Properties of Concrete Containing Rice Husk Ash Produced in a Charcoal Incinerator at Low Specific Surface. *International Journal of Concrete Structures and Materials,* 7(4), 287-293. doi: 10.1007/s40069-013-0058-8

Alam, M., & Ahmad, S. I. (2015). *Possibilities of Increasing Setting Time Using Rice Husk Ash (RHA) Cement as Binding Material*. Paper presented at the 2nd International Conference on Advances in Civil Engineering, Chittagong, Bangladesh.

Amrutha H .A. (2009) *'Rice Husk Ash Concrete: the Effect of RHA Average Size on Mechanical Properties and Drying Shrinkage"*. Australian Journal of Basic and Applied Sciences. 3(3): 2009; pp-1616-1622.

ASTM C33. (2003). American Standard Testing of Materials - Specification for Concrete Aggregates. *American society of testing and materials Publication*, 11.

ASTM C144. (2011). American Standard Testing of Materials - Standard Specification for Aggregate for Masonry Mortar.pdf>. *American society of testing and materials Publication*. doi: 10.1520/

ASTM C150. (2012). American Standard Testing of Materials -Standard Specification for Portland Cement. *American society of testing and materials Publication*. doi: 10.1520/c0150_c0150m-12

ASTM C270 -14a. (2014). American Standard Testing of Materials - Standard test method for Mortar for Unit Masonry. *American society of testing and materials Publication*. doi: 10.1520/C0270-14A

ASTM C494. (2013). American Standard Testing of Materials - Standard Specification for Chemical Admixtures for Concrete. *American society of testing and materials Publication*, 10. doi: 10.1520/c0494_c0494m-13

Bakharev, T., Sanjayan, J. G., & Cheng, Y. B. (2003). Resistance of alkali-activated slag concrete to acid attack. *Cement and Concrete Research, 33*(10), 1607-1611. doi: 10.1016/s0008-8846(03)00125-x

Bhagat, N. A. Saklecha, P. P. Kedar, R. S. (2017) *"Strength Behavior of Concrete by Partial Replacement of Ceramic & Stone Waste with Coarse Aggregate and Copper Slag with Fine Aggregate"*, International Journal of Advance Research and Innovative Ideas in Education, ISSN (O)-2395-4396, 3(4), 869-883.

BS 812 - 103.1. (1985). Methods for determination of particle size distribution — Sieve tests. *BSI Standards Publication*.

BS 882. (1992). Specification for Aggregate from natural sources for concrete. *BSI Standards Publication, London.*, 14.

BS EN 196 - 3. (2016). Methods of testing cement: Determination of setting times and soundness. *BSI Standards Publication, London.*

BS EN 206. (2013). Concrete - Specification, performance, production and conformity. *BSI Standards Publication, London*.

Bui J.H. (2001), "New lightweight composite construction materials with low thermal conductivity Cement Concrete Composite", 23 (No.1); pp: 65-70.

Correia, J. R., de Brito, J., & Pereira, A. S. (2006). Effects on concrete durability of using recycled ceramic aggregates. *Materials and Structures, 39*(2), 169-177. doi: 10.1617/s11527-005-9014-7

Chen C. T, Chen P. H and Yen Y. L (2017), “Mechanical Properties and Durability of Mortar with Rice Husk Ash Calcined at Low Temperature”. 2nd International Conference on Bio-based Building Materials & 1st Conference on Ecological Valorization of Granular and Fibrous materials, Clermont-Ferrand, France

FAO (2016) “Food Agricultural Organization Bulletin, Online Conference 2016.

Fraaij Y. and Kentgens O. M, (2008) International Scholarly and Scientific Research & Innovation 4(7) 201 Open Science Index, Civil and Environmental Engineering Vol:4, No:7, 2008 waset.org/Publication/5235

Huang D. S. (2012) “Experimental Study on the Use of Marble Dust” *Research Applied Journal.* Vol. 4 PP 44-50.

Hunchate S. G (2013) “Influence of Water Absorption of the Ceramic Aggregate on Strength Properties of Ceramic Aggregate Concrete”, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 2, No. 11, Pp. 6329-6335.

Jimenez T. S. (2013) “Strength characteristics of concrete utilizing waste materials. International Journal of Engineering Research ISSN: 2319-6890) (online), 23475013(print) Volume No.4, Issue No.9, pp: 506-509.

Kishore, R., Bhikshma, V., & Prakash, P. J. (2011). Study on strength characteristics of high strength rice husk ash concrete. *The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction Procedia engineering*, *14*, 2666-2672.

Klaassen M. I & Kentgens A. (2008), “Waste materials and by-products in concrete”: Springer Press. International Journal Research in Science and Technology, Vol. 4, No. 4, Pp. 5632, /-5467.

Kuranchie, F. A., Shukla, S. K., Habibi, D., Mohyeddin, A., & Puppala, A. J. (2015). Utilisation of iron ore tailings as aggregates in concrete. *Cogent Engineering,* 2(1), 1083137. doi: 10.1080/23311916.2015.1083137

Madandoust, R., Ranjbar, M. M., Moghadam, H. A., & Mousavi, S. Y. (2011). Mechanical properties and durability assessment of rice husk ash concrete. *Biosystems Engineering,* *110*(2), 144-152. doi: https://doi.org/10.1016/j.biosystemseng.2011.07.009

Mandavi H. K, Srivastava V & Agarwal V. C (2015): Durability of Concrete with Ceramic Waste as fine Aggregate Replacement International Journal of Engineering and Technical Research (IJETR). ISSN: 2321-0869, Vol. 3, Issue 8, Pp. 196 - 199

Mohammad, H. H., Lim, N. H. A. S., Tahir, M. M., Alyousef, R., & Samadi, M. (2019). Performance evaluation of green mortar comprising ceramic waste as cement and fine aggregates replacement. *SN Applied Sciences,* *1*(6). doi: 10.1007/s42452-019-0566-5

Naveen P and Antil H, (2016) "Partial Replacement of Coarse aggregate by Crushed Tiles and Fine aggregate by Granite Powder to improve the Concrete Properties" International Journal on Emerging Technologies 6(1): 144-150(2015) ISSN No. (Print): 0975-8364 ISSN No. (Online): 2249-3255

Neville, 2011 Properties of Concrete: Pitman Publishing Limited, London

Obaid, M. K., Nasr, M. S., Ali, I. M., Shubbar, A. A., & Hashim , K. S. (2021). Performance of green mortar made from locally available waste tiles and silica fume. *Journal of Engineering Science and Technology, Vol. 16*(No. 1), 136 - 151.

Rashid, H, Molla, K. A and Ahmed, T. U (2010), "Durability of Mortar in Presence of Rice Husk Ash". World Academy of Science, Engineering and Technology, Vol, 43

Saklecha M. A, (2001) "Using rice husk ash as a cement replacement material in concrete". In the Proceedings of the first international Ecological Building Structure Conference. pp. 671- 684.

Samadi K. & Hussein, (2015) "The durability properties of ceramic industry waste as coarse aggregate in concrete". International Journal of Advance Research and Innovative Ideas in Education.

Sanjuán M. Á, Andrade C, Mora P & Zaragoza A (2020): Carbon Dioxide Uptake by Mortars and Concretes Made with Portuguese Cements, Journal of Applied Science. Vol. 10, 646; doi: 10.3390 PP 1-15

Sharifi, Y., Ranjbar, A., & Mohit, M. (2020). Acid Resistance of Cement Mortars Incorporating Ceramic Waste Powder as Cement Replacement. *ACI Materials Journal, 117*. doi: 10.14359/51720302

Siddique, S., Shrivastava, S., & Chaudhary, S. (2017). Lateral force microscopic examination of interfacial transition zone in ceramic concrete. *Construction and Building Materials, 155*, 688-725. doi: https://doi.org/10.1016/j.conbuildmat.2017.08.080

Yu, L., Zhang, J. X., & Mu, K. (2012). Relationships between Compressive Strength and Microstructure in Mortars with Iron Ore Tailings as Fine Aggregate. *Applied Mechanics and Materials, 188*, 211-218. doi: 10.4028/www.scientific.net/AMM.188.211

Utkarsh S. C & Rambharosh S. C, (2017) "Experimental Study on Partial Replacement Fine Aggregate By Broken Tiles in Concrete". International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, Vol. 6 Issue 10.

Zahedi, M., Ramezanianpour, A. A., & Ramezanianpour, A. M. (2015). Evaluation of the mechanical properties and durability of cement mortars containing nanosilica and rice husk ash under chloride ion penetration. *Construction and Building Materials, 78*, 354-361. doi: https://doi.org/10.1016/j.conbuildmat.2015.01.045