Studying the behavior of the concrete mixture with wheat straw as part of the cement

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Abstract. This paper is an experimental study that was made on the effects of using Wheat Straw Ash (WSA) as a partial replacement of cement in the concrete mixture. The control specimens with ordinary portland cement (OPC) were made and in other specimens, cement was replaced with 10%, 15%, and 20% of WSA by weight of the cement. Wheat straw locally available was burned to ash in a controlled manner in the oven, which was used in this study. The destructive tests included the compressive strength, modulus of rupture, and splitting tensile strength were carried out on the concrete mixture using WSA at a different percentage of cement replacement and were and compared with control specimens. The tests result gained show that the compressive strength decreases when surrogating cement with WSA. While the modulus of rupture increase with 10 % WSA also, the splitting tensile strength increase with 15 % WSA.

1. Introduction
Concrete is an artificial material used extensively and globally for a long time. The concrete is a composite of fine and coarse aggregate, cement, and water [1]. It is the imperative structure development material, and significant in different undertakings of framework around the world. It is capable as the second material all over-utilized by humankind. The utilization of normal resources i.e. normal aggregates like coarse and fine, cement as binding materials for the making of concrete has a reason for a lot of decreasing in the natural resources [2]. From an ecological perspective, the formation of concrete is regularly responsible for the liberation of greenhouse gases. It is stated that the yearly manufacture of concrete is around 1.6 billion tons universal, which discharges 7% of the overall carbon dioxide into the air [3]. Keeping in view these concerns of environment, cost of construction materials, shortage of raw materials, and higher demand of energy, the practice of utilizing alternate solid waste material is becoming a common worry of the globe [4].

Many researchers have conducted experiential studies that concentrated on finding the potential for substitutions to be used as cement substituting materials, that are of less rate which comprise industrial and agricultural wastes, whose probable benefits can be appreciated through recycling, reutilizing, and renewing operations. Hence, scientists have been exploring the efficient and workable use of waste materials that are pozzolanic in nature as a cement replacement [5]. It is proposed by scientists that the
consuming of supplementary cementitious materials in the concrete benefits to reduce the undesirable environmental effects connected to the manufacturing process of cement or concrete [6]. With the employment of these wastes as supplementary and replacement materials, there is large energy-saving and reduction in the consuming of cement which assists in the reduction of the release of carbon dioxide in the environment [7]. Moreover, there could be a considerable improvement in the strength and durability properties with the usage of added cementing materials in concrete. Hence, wide-range research has been carried out on several supplementary materials, like rice husk ash, metakaolin ash, sewage sludge ash, palm shale oil, etc [8].

A major agricultural by-product obtained from cereal production is wheat straw waste, which increases environmental pollution because the farmers burn it in open fields. However, when wheat straw waste is properly burnt under a controlled situation results in a material that has cement properties and that can be used in concrete as supplementary cementing material [9]. The resulting ash has a higher percentage of silica present, also higher fineness compared to the cement, thus the WSA is considered as the possible source of supplementary cementing material [10]. The advantage of utilizing WSA in concrete as cementitious material was revealed when WSA increased compressive strength up to 25% of mortar at a replacement level of 20% [11]. As one of the important properties of concrete is durability, therefore researchers are also investigating the durability aspects of concrete while using WSA as a replacement material. It was found that when cement was replaced by WSA, the resulting concrete performed better when exposed to sodium and magnesium sulfate solutions in terms of compressive strength as compared with conventional concrete.

The improved durability is due to the pozzolanic and filler actions of WSA in the concrete. The replacement of cement by WSA in the concrete resulted in higher resistance to freeze-thaw and the alkali-silica reaction was reported by Al-Akhras [12]. Additionally, Researchers utilized WSA as filler material in concrete due to the fineness of particles. The fine aggregates replacement by WSA in concrete enhanced compressive strength, improved resistance to sulfate, thermal cycling, abrasion, and water penetration due to its denser structure as WSA performed as filler material [13].

2. Materials

Ordinary Portland cement was used for this research work. Fine aggregate and coarse aggregate were used with maximum size (4.75 mm) and (19 mm) respectively. WSA was collected after burning wheat straws in the open air, introducing the incineration product into a furnace in a static air atmosphere for 2 hours [14] at 600°C temperature [15]. The resulting ash was passed from the #100 sieve. The controlled burning of wheat straw leads to the production of a high content of silica. Physical properties and chemical composition of cement and WSA show in table 1. The ratio of water to cement was fixed at (0.5) with different ratios of WSA as displayed in table 2.

| Compounds | Cement (%) | WSA (%) [15] |
|-----------|------------|--------------|
| Al₂O₃     | 2.24       | 1.53         |
| CaO       | 59.77      | 3.87         |
| MgO       | 3.06       | 1.87         |
| SiO₂      | 20.88      | 77.36        |
| K₂O       | 0.79       | 5.43         |
| TiO₂      | 0.21       | 0.97         |
| Fe₂O₃     | 4.68       | 1.27         |
| LOI       | 3.09       | 5.8          |
Table 2. Proportions of mix design For concrete mix.

| Concrete | Cement (Kg) | WSA (Kg) | Water (kg) | Sand (Kg) | Gravel (kg) |
|----------|-------------|----------|------------|-----------|-------------|
| 0% WSA   | 10.020      | -----    | 5.01       | 20.04     | 30.06       |
| 10% WSA  | 9.018       | 1.002    | 5.01       | 20.04     | 30.06       |
| 15% WSA  | 8.517       | 1.503    | 5.01       | 20.04     | 30.06       |
| 20% WSA  | 8.016       | 2.004    | 5.01       | 20.04     | 30.06       |

3. Results

The results of various types of tests are showed in the forthcoming subsections.

3.1. Compressive strength test

The compressive strength test of cube specimens (150×150×150) mm has been carried out according to BS1881-Part-116 [16] by three specimens for each ratio of WSA at 28-days. The average of three specimens results is shown in figure 1. The results of compressive strength test referred to a decrease in the strength when increase ratio of WSA and the ratio of (15 %) are closed to the control specimen.

![Figure 1. Compressive strength results.](image)

3.2. Modulus of rupture test

This test was worked according to ASTM C78/C78M[17], the modulus of rupture was determined by using prism specimens with dimensions (100×100×400) mm. It was simply supported subjected to two-point loads. The average of three specimens results is shown in figure 2. The results explain that the (10 %) of WSA increasing flexural strength by (3.47 %). When increase WSA above (10 %) the flexural strength will be decreased.
3.3. Splitting tensile test

It is the standard test for calculation the indirect tensile strength in the concrete, the test was managed by applying a uniform compression load in the diametrical direction along the length of the specimen up to the failure. The concrete specimen splits into two halves due to indirect tensile strength produced by the effect of Poisson's ratio. Splitting tensile strength according to ASTM C496/C496M [18] has been found by using cylinder specimens with dimensions (100×200) mm. as shown in figure 3. The results show that the (15 %) of WSA gives the high tensile strength by (12.84 %) corresponding to the control specimen.

4. Conclusions

The proposed paper summarizes the potential usage of agricultural waste (wheat straw) as a sustainable material in the production of green concrete. In the chemical analysis of the wheat straw
ash additive, it shows that 77.36% of the straw ash component is silica SiO2, which in turn interacts with the calcium hydroxide resulting from the hydration process, making the c-s-h gel. This reaction is one of the slow reactions, so the amount of heat released is less and the strength of the concrete is less from concrete that does not contain an ash additive, therefore, the sample that does not contain an ash additive gave more strength for this reason, while the sample containing 10% of the straw ash is lower than the sample that contains 15% of the straw ash, because you are the material for SiO2. The reaction products will close the capillary spaces that are large in size within the cement material, giving the results of greater resistance, but with the increase in straw ash to 20%, there was less resistance despite the increase in the amount of SiO2, due to the fact that the straw ash absorbed a large proportion of the mixing water, so that workability led to the presence of a percentage of unreacted cement, as the petal gave a resistance result of less than 15%. As for the difference in the results from the aforementioned research, the chemical and physical properties of wheat straw ash are affected by the geographical location, the chemistry of the soil, the change in the temperature and the fertilizers used. Therefore, the previous research does not give the same results for a difference in the properties of the straw ash material in addition to burning at different temperatures and for a different period. The reason for this difference in the results. On the other hand, the modulus of rupture for the concrete mix was improved with (10 %) content of WSA. While, the splitting tensile strength was perfected at (15 %) content of WSA.

5. REFERENCES
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