A Study on the Strength Aspects of Concrete with Metakaolin, GGBFS and Rice Husk Ash as Partial Replacement of OPC

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Abstract: The impact of the OPC on the environment is important as its production generates a large amount of CO₂. In order to reduce the use of pure raw materials as resources, the use of industrial waste or secondary materials in construction sites for the production of cement and concrete has been encouraged. The volume of wastes generated worldwide has increased over the years due to the population, social and economic performance and social development. One of the most attractive options for waste management is to minimize waste and reuse the possibility of recycling. The cost of cement used in concrete works is increasing and unsatisfactory, but the demand for this material and other housing needs is rising, so it is important to find alternatives that can be used alone or in a partial replacement. In this research work several auxiliary cementitious ingredients such as metakaoline, GGBFS and Rice Husk Ash (RHA) were used to improve the strength properties of the conservative concrete. Metakaolin and GGBFS was used at a fixed percentage of 10 percent as fractional substitution of the OPC-43 grade cement, while the RHA was used at different percent ranging from 0 to 25 percent at an increment of 5 percent in each case as fractional substitution of the OPC-43 grade cement. Numerous examinations were executed so as to envisage the effect of these materials over the strength and engineering properties of the concrete. The test results conclude that the usage of the metakaolin, GGBFS and the RHA in combined form increased the strength and engineering properties of the conventional concrete up to a great extent. From the obtained test results it can be further concluded that the particle size of the supplementary cementitious materials plays a significant role in enhancing the internal micro-structure of the concrete and which further leads to the higher strength of the concrete. Also the main reason behind the advanced strength was the presence of the metakaolin and GGBFS in the concrete, whose chemical properties densifies the concrete and made the concrete more stable and promotes higher strength. Future work can also be done on the usage of several other supplementary cementitious materials at different other percentages so as to improve concrete properties.

Keywords: Rice Husk Ash, Ultra-Sonic Pulse Velocity, Conventional Concrete, Metakaolin, Rebound Hammer
1. Introduction

1.1 General
Concrete is a superior kind of constructional material that is mainly composed of natural sand and natural aggregate that is mainly bonded with the help of a binder with the accumulation of water into it. Concrete are mainly of different types depending upon the type of binder, depending upon the manufacturing process, depending upon the type of material utilized in it. In this research work special type of concrete was taken into consideration in which three different kinds of materials were used as binding material for the production of the concrete [1–3].

1.2 GGBFS
GGBFS is a special type cementitious material that can be used or utilized to improve numerous engineering properties of the conventional or normal concrete made up of cement, river sand and natural hard aggregate. GGBFS is mainly derived after the processing of the iron ore from the iron processing industry and is mainly composed of calcium oxide in a broader perspective. The numerous properties of the GGBFS is stated below. In the recent times the usage of GGBFS in numerous constructional activities has been increased [4–6]. It has been used both replacement of cement as well as sand for improving the strength properties of the concrete. In several countries GGBFS has partially replaced cement as the core cementitious materials, see table 1 and 2.

| Features                  | Value                  |
|---------------------------|------------------------|
| Moisture Content (%)      | 0.51                   |
| Specific gravity          | 2.56                   |
| Colour                    | White                  |
| Size                      | 10 micron - 100 micron |
| Shape                     | Spherical glassy       |
| Category                  | Grade-II as it is derived from lignite Iron |

**Table 1 Properties of GGBFS**

**Table 2 Chemical Composition of GGBFS**

| Component (%)                  | Wt. Percentage |
|--------------------------------|----------------|
| CaO                            | 41.70          |
| SiO$_2$                        | 33.70          |
| Al$_2$O$_3$                    | 14.40          |
| MgO                            | 8.60           |
| FeO                            | 0.37           |

1.3 Metakaolin
Metakaolin is generally a special type of the cementitious clay that is generally derived as a waste from the kaolin processing industry. It is generally either in the form of white powder or white clay that can be used in concrete as either replacement of the OPC-43 or natural fine aggregate [7,8]. When the mineral kaolin is burned at very high temperature of about 700 degree Celsius, metakaolin produced. Due to numerous effective properties of the metakaolin, the usage of this metakaolin has been increased drastically and as per the several previous research works the metakaolin usage in
concrete as replacement of both cement as well as the replacement of the natural fine aggregate has increased the mechanical properties of the concrete, see table 3 and 4.

Table 3 Properties of Metakaolin

| Features          | Value |
|-------------------|-------|
| Moisture Content (%) | 0.41  |
| Specific gravity  | 2.83  |
| Colour            | White |

Table 4 Chemical composition of Metakaolin

| Chemical Compound       | Percentage |
|-------------------------|------------|
| Silica (SiO$_2$)        | 50.62      |
| Alumina (Al$_2$O$_3$)   | 45.71      |
| Iron oxide (Fe$_2$O$_3$)| 1.31       |
| Calcium oxide (CaO)     | 1.20       |
| Magnesium oxide (MgO)   | 0.31       |

1.4 RHA

Rice is generally an agricultural product that is produced in almost every part of the world and simultaneously the waste generated during its production is also generated in every part of the world with huge accumulation. This waste is generally composed of rice husk and rice straw. These both type of waste can be used for numerous other purposes with burning and without burning. In this research work the waste ash generated after the burning of the rice husk was used as auxiliary of the OPC-43. As per the previous research works the rice husk ash when used as partial substitution of the cement has positive impact over the mechanical properties of the concrete and it is found to be a cost effective supplementary cementitious material for replacement cement in the formulation of the concrete structures [9,10], see table 5 and 6.

Table 5 Properties of Rice Husk Ash

| Features           | Value |
|--------------------|-------|
| Fineness Passing 45 micron | 96%   |
| Specific gravity   | 2.06  |
| Pozzolanic activity| 84%   |
| Specific surface   | 27400 m$^2$/kg |

Table 6 Chemical composition of Rice Husk Ash

| Chemical Compound       | Percentage |
|-------------------------|------------|
| Silica (SiO$_2$)        | 87.20      |
| Alumina (Al$_2$O$_3$)   | 0.15       |
| Iron oxide (Fe$_2$O$_3$)| 0.16       |
| Calcium oxide (CaO)     | 0.55       |
| Magnesium oxide (MgO)   | 0.35       |
| Carbon                 | 5.91       |
| Loss of Ignition        | 5.44       |
1.5 Literature Review
Effect of high degree temperature on limestone, concrete and quartz’s mechanical properties. The specimens have been exposed to 25-650 degrees of heat for at least 2 hours. Compressive strength, flexible strength and elasticity modules have been examined. It has been analysed that the upsurge in temperature prejudiced the specific mechanical possessions of the specimen. As heat increases, compression strength, flexible strength and elasticity modules have diminished and the final train has increased. In this study basically the strength aspects of the concrete was improved using different percentages of the numerous supplementary cementitious materials and it was concluded at the last that the concrete mechanical properties completely depends upon the constituent materials of the concrete [11–13].
Rice Husk to prepare M20 grade sample. The authors have prepared total 45 cubes. The replacement of cement has been done by adding RHA in different percentages such as 2.5 %, 5%, 7.5% and 10 %. The compressive strength have been examined after 28 days for the four respective percentages are 19.71, 19.53, 19.08 and 18.91 N/mm². The parameters such as workability and compressive strength have been measured after 7, 14 and 28 days. From the test results it has been determined that with the increase in the fraction of replacement the concrete strength has been reduced. From the numerous test results it was found that the rice husk ash has extraordinary effect over the strength aspects of the normal concrete and it can be used both as replacement of the cement and replacement of the natural fine aggregate [14–16].
Sugarcane Bagasse Ash (SCBA) as a restricted auxiliary material with different percentage ranges from 5 % to 25 % with the increment of 5 %. The test has been analysed after, 7, 28 and 56 days. From the experiment consequences it has been analysed that SCBA has been perform better up to 5 % of its replacement. The presented work has also helps to reduce the CO₂ emission and hence contributed to the surroundings. In this research work sugarcane bagasse ash was used to enhance the strength properties of the conventional concrete. It was concluded at the last that the strength of the concrete was found maximum at 5 percent usage of the sugarcane bagasse ash [17,18].
Special learning on the use of constituents that can accomplish the opportunities of the manufacture productiveness in various fields. In this case, OPC was substituted with GGBFS with different percentage such as varies from 10 to 60 percent with the increment of 10 % M-25 mixture. Concrete mixes have been prepared, examined and compared to compression strength. 20% of PPC replacement by fly-ash has been improved slightly from 1.8% to 3.1% for twenty eight days and fifty six days. From the test results it has been examined that with 30 % of PPC replaced by GGBFS the strength is identical to the concrete strength measured after 56 days.

1.6 Objectives
The foremost objective of the current study was to utilize several supplementary cementitious material such as RHA, GGBFS and the metakaolin for enhancing numerous engineering properties of the conventional concrete. To achieve this goal certain sub objectives has been formulated which as stated below:

- To study the effect of combined usage of the RHA, metakaolin and GGBFS over compressive strength.
- To study the effect of combined usage of the RHA, metakaolin and GGBFS over flexural strength.
- To study the effect of combined usage of the RHA, metakaolin and GGBFS over Rebound hammer and ultrasonic pulse velocity test.
- To compare the results of the modified concrete and the normal concrete.
1.7 Research Methodology

- First material such as Rice Husk Ash, metakaolin and GGBFS was collected from the various available sources and tested for their physical properties and the chemical composition.
- Then M35 grade of concrete was mainly prepared using IS-10262 with proportion of 1:2.04:2.86 in which 1 is for cement or material replacing cement, 2.04 is for fine aggregate or material replacing fine aggregate and 2.86 is for coarse aggregate or the material replacing the coarse aggregate.
- Then depending upon the type of concrete grade and proportion of materials several concrete specimen were prepared and then cured for a curing period for seven days and twenty eight days.
- Then after proper curing all the samples were tested for compressive strength test, flexural strength test, Rebound hammer and ultrasonic pulse velocity test.
- Then depending upon the test results several conclusion has been drawn. All the test results related to the research work are discussed further.

2. RESULTS AND DISCUSSION

2.1 General

Overall six different kinds of mix were prepared depending upon the percentage and the quantity of the materials. The six mixes mainly contain six different percentages of the RHA ranging from 0 percent to 25 percent at an increment of 5 percent in each case, see table 7.

| Mix | RHA (%) | MK (%) | GGBFS (%) |
|-----|---------|--------|-----------|
| A0  | 0       | 0      | 0         |
| A1  | 5       | 10     | 10        |
| A2  | 10      | 10     | 10        |
| A3  | 15      | 10     | 10        |
| A4  | 20      | 10     | 10        |
| A5  | 25      | 10     | 10        |

| Mix | 7 days | 28 days |
|-----|--------|---------|
| A0  | 26.10 N/mm² | 41.24 N/mm² |
| A1  | 26.60 N/mm² | 42.47 N/mm² |
| A2  | 27.46 N/mm² | 44.23 N/mm² |
| A3  | 27.77 N/mm² | 44.88 N/mm² |
| A4  | 24.49 N/mm² | 39.47 N/mm² |
2.3 Flexural Strength
The experiment consequences of the flexural strength examination displayed that the determined strength was found at 15 percent usage of the RHA, 10 percent usage of the GGBFS and 10 percent usage of the metakaolin. For performing this test several beams were casted and then tested with the usage of flexural strength test apparatus. The test results were shown below table 9 and figure 2.

Table 9 Flexural Strength

| MIX | 7 days     | 28 days    |
|-----|------------|------------|
| A0  | 5.15 N/mm² | 5.91 N/mm² |
| A1  | 5.23 N/mm² | 5.99 N/mm² |
| A2  | 5.32 N/mm² | 6.10 N/mm² |
| A3  | 5.34 N/mm² | 6.14 N/mm² |
| A4  | 4.18 N/mm² | 4.92 N/mm² |
| A5  | 3.16 N/mm² | 3.91 N/mm² |
Figure 2 Flexural Strength

2.4 Rebound Hammer

The experiment consequences of the rebound hammer test showed that the maximum strength and minimum strength was observed at 15 percent and 25 percent usage of RHA correspondingly. The determined significance of compressive strength as per the rebound hammer test results was found at 15 percent fractional substitution of OPC with RHA, 10 percent usage of the metakaolin and 10 percent usage of the GGBFS. In this research work the rebound hammer test was mainly performed to check and verify the results of the compressive strength test results of the concrete, see table 10 and figure 3.

| MIX | Compressive strength | Quality of Concrete as per IS code |
|-----|----------------------|-----------------------------------|
| A0  | 43.69 N/mm²          | Very Good Hard Layer              |
| A1  | 44.30 N/mm²          | Very Good Hard Layer              |
| A2  | 46.08 N/mm²          | Very Good Hard Layer              |
| A3  | 46.86 N/mm²          | Very Good Hard Layer              |
| A4  | 41.76 N/mm²          | Very Good Hard Layer              |
| A5  | 39.46 N/mm²          | Good Layer                        |
The test consequences of the ultrasonic pulse velocity test showed that the maximum value of ultrasonic pulse velocity was found at 15 percent usage of the RHA, 10 percent usage of the metakaolin and 10 percent usage of the GGBFS. It was found that with further intensification in the proportion of the RHA the value of ultrasonic pulse velocity was decreasing and simultaneously the strength was decreasing, see table 11 and figure 4.

2.5 Ultrasonic Pulse Velocity Test

The test consequences of the ultrasonic pulse velocity test showed that the maximum value of ultrasonic pulse velocity was found at 15 percent usage of the RHA, 10 percent usage of the metakaolin and 10 percent usage of the GGBFS. It was found that with further intensification in the proportion of the RHA the value of ultrasonic pulse velocity was decreasing and simultaneously the strength was decreasing, see table 11 and figure 4.

Table 11 Ultrasonic Pulse Velocity Test

| MIX | Velocity | Quality of Concrete as per IS code |
|-----|----------|-----------------------------------|
| A0  | 4.53 Km/sec | Excellent                         |
| A1  | 4.61 Km/sec | Excellent                         |
| A2  | 4.73 Km/sec | Excellent                         |
| A3  | 4.86 Km/sec | Excellent                         |
| A4  | 3.93 Km/sec | Good                             |
| A5  | 3.51 Km/sec | Good                             |
3. Conclusions
In this research work three materials were used in combination were one another so as to enhance several mechanical aspects of the normal concrete. Primarily metakaolin was used at fixed percentage of 10 percent, GGBFS was used at fixed percentage of 10 percent and the rice husk ash was used at varying percentage from 0 percent to 25 percent at an increment of 5 percent in each corresponding case. Then depending upon the percentage of the materials and depending upon the M35 grade of concrete several concrete samples were prepared and then tested for numerous destructive test and numerous nondestructive test. The depending upon the test results various conclusions has been drawn which are discussed as under:

- The test results of all the tests were quite similar and it was found that the maximum strength was found at 15 percent usage of the RHA, 10 percent usage of the metakaolin and 10 percent usage of GGBFS. It was found that with the increase in the cemintitious material in the concrete the strength was inclining and when this cementitious content starts decreasing the strength also starts declining.
- This type of results were observed mainly due the change in the proportion of the RHA, as when the percentage of the RHA was used up to 15 percent, metakaolin was used up to 10 percent and GGBFS was used up to 10 percent the cementitious content of the concrete was fulfilled but beyond this percentage the cementitious content of the concrete starts decreasing at 25 percent usage of the RHA and simultaneously the strength also declines.
- The other parameter of resulting in the increase in strength was found to be the actual particle size of the RHA, metakaolin and GGBFS, as the particle size of these materials were found to be lower as compared to the particle size of the cement due to which the internal micro structure of the concrete densifies to a greater extent and resulting in the increase in the desired strength.

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