# Strength development in concrete using agricultural byproduct and use of soft computing models to predict strength parameter

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The potential of rice husk ash (RHA) as an alternate cementitious material was evaluated in this study. The physical, chemical and mineralogical characteristics of RHA were studied and analyzed. The Compressive strength, Split Tensile strength and Flexural strength of the RHA blended concrete was examined to peruse on the effect of RHA in concrete. The water to binder ratio of 0.4 and 0.45 was considered and concrete with five different dosage of RHA (OPC, 5%, 10%, 15%, 18% and 20%) were casted. Results of Compressive strength, Split Tensile strength and Flexural strength revealed that RHA provides a positive effect in the strength development at 28 days due to the excellent pozzoloanic effect of RHA in the blended concrete. The XRD test results and chemical analysis of RHA confirmed that RHA has potential to be used as alternate cementitious material. Through the analysis of strength results obtained in this study, it was established that RHA could be blended with cement without adversely affecting the strength properties of concrete. Also using a new statistical theory of the Support Vector Machine (SVM), strength parameters were predicted by developing a suitable model and as a result, the application of soft computing in concrete has been successfully presented in this research paper.

## 1. INTRODUCTION

The concrete, cement and clay bricks industry are coming under immense scrutiny from government and environmentalist alike due to the increasing awareness about the environmental and health hazards associated with these industries. Cement and concrete industry is one of the largest consumers of resources like aggregates, sand, clinker and fuel [1]. It is evident from the fact that as 7% of $CO_2$ emission is from cement industry, clinker production should be reduced and alternate mineral additives should be developed to cater to the growing need of cement as production of cement is costly, high energy consuming, and produces large amount of green house gases. As concrete is the one of the most extensively used building material, the incorporation of mineral additives could have improved technical and economic advantages [2-4].

The increasing consciousness about environment and energy conservation with reduced impact on economy was the motivation for the researchers to search for other alternatives for cement in concrete. Such potential was observed by researchers in some industrial and agricultural wastes such as byproducts of oil and coal combustion industry, slag, Rice husk ash, bagasse, fly ash, cement, coal, marble dust, brick industry, sewer sludge etc [5]. These wastes are produced in huge quantities (millions of tons) and are discarded every year. They cause environmental problems and leaching of toxic chemical like arsenic, beryllium, boron, cadmium, chromium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium when landfilled or dumped in lakes and oceans [6-7]. It is shown in studies that waste materials can be successfully used to replace cement and providing environmentally safe, stable and more durable and low cost construction material.

One of the main economy sectors in South Asian countries is agriculture given its suitable climatic condition, and India is one of the world's largest producers of white rice contributing about 20% of world's total rice production. After milling of paddy about 78% of weight is received as rice, broken rice and bran, but rest 22% of the weight is collected as husk [8]. About 20 million tonnes of RHA is produced annually in India. The rice husk is also not fit for animal feed due to its low nutritional properties. It's also an environmental menace as its siliceous composition is resistant to degradation. Thus incinerating of the husk is an effective method to reduce volume of the wastes alongwith energy production. On an average, each tonne of rice produces 200 kg of rice husks which on combustion leads to 40 kg of RHA [9]. Rice husk can be incinerated into desired mineral admixtures whose pozzoloanic activity depends upon many factors such as silica content, silica crystallization phase and size and surface area of ash particles. Also, it must have less residual carbon as excess carbon content have an adverse effect upon pozzoloanic activity of RHA [10]. When incinerated in controlled environment, the residue, the RHA contains 90-96 % silica in amorphous form [11]. The chemical composition of rice husk is also found to differ from sample to sample due to differences in the crop year, climate, geographical conditions and type of paddy.

RHA is considered as a highly active pozzoloan and when incorporated in cement, affect the rate of hydration [12, 13].It is also known to reduce porosity and $Ca(OH)_2$ in the interfacial transition zone between aggregate and cement phase [14-20]. In this study the effect of RHA in concrete was experimentally evaluated in terms of compressive strength, Flexural strength and split tensile strength. Also the mineralogical characteristics were determined using X-ray diffraction (XRD).

## 2. OBJECTIVE

The basic aim of this study is to investigate the effect of RHA obtained from rice paddy milling industry in Tamil Nadu, India on strength development of concrete (Compressive strength, flexural strength and split tensile strength) for 2 different water cement ratios (0.4 and 0.45). And through the analysis of the result, show that RHA blended concrete have better strength characteristics compared to conventional concrete and to develop a regression model using a new statistical learning theory, support vector machines (SVM) to predict the unknown strength parameters.

## 3. EXPERIMENTAL PROGRAM

### 3.1. Materials

#### 3.1.1. Cement

Ordinary Portland cement 43 grade conforming to IS 8112:2013 was used. The physical and chemical property of cement is in Table 1.

#### 3.1.2. Aggregates

Normal weight graded natural sand having a maximum particle size of 4.75 mm and specific gravity 2.6 was used as fine aggregate. Properties of sand are reported in Table 2. The coarse aggregate used was crushed gravel with maximum size of 12 mm and have specific gravity of 2.6

#### 3.1.3. Rice husk ash

Rice husk was obtained from a Rice mill in State of Tamil Nadu. The Rice husk ash was prepared by the open field burning of rice husk with average temperature lying around 600°C. The coarse aggregate and RHA particles were mixed

**Table 1. The chemical analysis and physical properties of the cement**

| | Particular | Value |
|---|---|---|
| | **Chemical properties** | |
| 1 | $SiO_2$ (%) | 20.30 |
| 2 | $Al_2O_3$ (%) | 5.0 |
| 3 | $Fe_2O_3$ (%) | 3.18 |
| 4. | CaO (%) | 64 |
| 5. | MgO (%) | 4.47 |
| 6. | $Na_2O$ (%) | 0.08 |
| 7. | $K_2O$ (%) | 0.47 |
| 8. | Loss on ignition (%) | 3.12 |
| | **Physical properties** | |
| 1. | Specific gravity | 3.1 |
| 2. | Mean size | 23 µm |

**Table 2. Grading and properties of fine aggregate**

| Sieve size(mm) | Percentage passing | Limits of specifications ASTM C33 / C33M-08 |
|---|---|---|
| 9.5 | 100 | 100 |
| 4.75 | 98 | 95-100 |
| 2.36 | 92 | 80-100 |
| 1.18 | 84 | 50-85 |
| 0.60 | 57 | 25-60 |
| 0.30 | 23 | 5-30 |
| 0.15 | 3 | 0-10 |
| **Property** | **Result** | |
| Specific gravity | 2.62 | |
| Water absorption (%) | 0.70 | |

together for 12 minutes to get finer and homogenized RHA particles as followed in [2]. Finer particles increase the efficiency of pozzolanic reaction and reduce the water content [21, 22]. Table 3 provides the physical and chemical properties of the rice husk ash.

### 3.2. Concrete mix proportion

Two water to binder ratio (0.4 and 0.45) and six different replacement percentages (OPC, 5%, 10%, 15%, 18% and 20% by weight of cement) were adopted. For each replacement percentage, three samples were casted for the experiments (3 specimens for 7 days and 3 specimens for 28 days) and average of the three results has been reported in this paper. The concrete mix was prepared to have a design compressive strength of 20 $N/mm^2$ at 28 days.

### 3.3. Casting of specimen

100 mm cubes for compressive strength test, 50 x 200 mm cylinders for splitting tensile test and beams 100 x 100 x 500 mm beams for flexural testing were cast accordingly. Compacting of concrete was done by vibration as per IS: 516-2000. After casting, all the test specimens were stored at laboratory conditions for 24h and then de-molded and placed into a water-curing tank with a temperature of $25^{o}C$-$30^{o}C$ until the time of testing.

### 3.4. Testing specimen

Tests carried on the hardened concrete were compressive strength test (Conforming to IS 516:2000), flexural strength test (conforming to IS 516:2000) and splitting tensile strength test (conforming to IS 5816:2000). Mechanical tests were performed at 7 days and 28 days on three specimens. A digital compression testing machine (conforming to IS 516:2000) was used for compressive strength and splitting tensile strength. For flexural strength test 3 point loading system was employed. The maximum load at failure was taken for strength comparison. To determine the mineralogical properties of RHA, X-ray diffraction test was performed.

**Table 3. The chemical analysis and physical properties of the RHA**

| | Particular | Value |
|---|---|---|
| | **Chemical properties** | |
| 1 | $SiO_2$ (%) | 94.97 |
| 2 | $Al_2O_3$ (%) | 0.35 |
| 3 | $Fe_2O_3$ (%) | 0.47 |
| 4. | CaO (%) | 1.28 |
| 5. | MgO (%) | 0.425 |
| 6. | $Na_2O$ (%) | 0.1 |
| 7. | $K_2O$ (%) | 1.425 |
| 8. | Loss on ignition (%) | 0.25 |
| | **Physical properties** | |
| 1. | Specific gravity | 2.1 |
| 2. | Mean size | 6 μm |

### 3.5. SVM implementation for strength parameters prediction

SVM algorithm developed by Vapnik [23] is derived upon statistical learning theory. In regression , the chief target is to develop a hyper plane that lies "close" to as many of the data points as possible [24, 25, 26]. Thus a hyper plane with small norm is chosen while working to simultaneously minimize the sum of the distances from the data points to the hyperplane. The main advantages of SVM being, it reduces training error and the solution to SVM is always unique and globally optimum unlike other machine learning tools [27, 28]. In SVM, first of all, each of the input variables (water to cement ratio and percentage replacement of wood ash) is normalized to their respective maximum value. To implement the SVM, the dataset has been divided into two subsets:

1. A training data set: This data set is required to construct the model. In this study, 6 out of a total of 12 data sets belonging to both water-cement ratios are considered for training.
2. A testing data set: This is required to estimate the model's performance. In this study the remaining 6 out of 12 are used as a testing data set.

The concept of the adopted data division has been taken from the study of Lee et al. (1996). The main aim of the study is to develop a regression model using a new statistical learning theory, support vector machines (SVM) to predict the unknown strength parameters.

## 4. RESULTS AND DISCUSSION

### 4.1. Physical and chemical analysis of rha and cement

The physical properties of cement and RHA are given in Table 1 and Table 3. The specific gravity and mean size of RHA was found to be less than that of cement. Chemical composition data for the cement and RHA is also presented in Table 1 and Table 3. This particular specimen of RHA contains 94.97 % of silica as related in Table 4. The loss on ignition data for RHA is 0.25 % which is way less than cement. The resulting RHA was blackish gray in color. The color change depicts the completion of combustion process as well as transformation of the silica in the ash where whitish color of the ash depicting completeness of combustion [15].

## 4.2. X–ray diffraction analysis

X-ray diffraction analysis (XRD) of the RHA was performed using XRD Diffractometer, Siemens D500 with K radiations. This analysis was performed to analyze the mineralogical phases (amorphous or crystalline) of the RHA.

Figure 1 presents the XRD pattern of the RHA sample. It shows humps showing it as amorphous as well as peaks of $SiO_2$ representing crystalline nature too. However the amount of amorphous silica is more as evident from Figure 1 The major peak of crystalline $SiO_2$ occurs at Bragg 2-Theta angle of 27.1. It is known that if amorphous silica is present in ash, then it has potential as alternate cementitious material due to its pozzoloanic activity [16-18].

## 4.3. Compressive strength

Table 5 presents the results of compressive strength of RHA blended cement concrete. Analysis of data shows that at 28 days, RHA concrete shows strength increased for 5%, 15% and 18% and reduced for 10% and 20% for both the water cement ratio. However the strength reduced was still in the acceptable limits. This observation is also reported by many researchers alike as Zhang and Malhotra (1996) who reported that compressive strength of concrete having variable replacement percentage of RHA was higher than that of control specimen at 7, 14, 28 and 90 days and Bhanumathidas and Mehta (2004) showed that the 90 days compressive strength of concrete with variable replacement percentage of RHA was higher than the corresponding concrete mixtures without RHA. However insignificant improvement in strength was observed for RHA blended concrete at lower ages (7 days). This can be attributed to the fact that pozzolanic reaction is slow at early ages (7 days) strength.

**Table 4. Properties of different types of pozzoloans as defined by ASTM C618**

| Properties | Class N type pozzoloan | Class F type pozzoloan | Class C type pozzoloan |
|---|---|---|---|
| Min. $SiO_2$ +$Al_2O_3$ + $Fe_2O$ (%) | 70.0 | 70.0 | 50.0 |
| Max. sulphur trioxide ($SO_3$)(%) | 4.0 | 5.0 | 5.0 |
| Max. $Na_2O$ + 0.658 $K_2O$ | 1.5 | 1.5 | 1.5 |
| Max. loss on ignition | 10.0 | 6.0 | 6.0 |

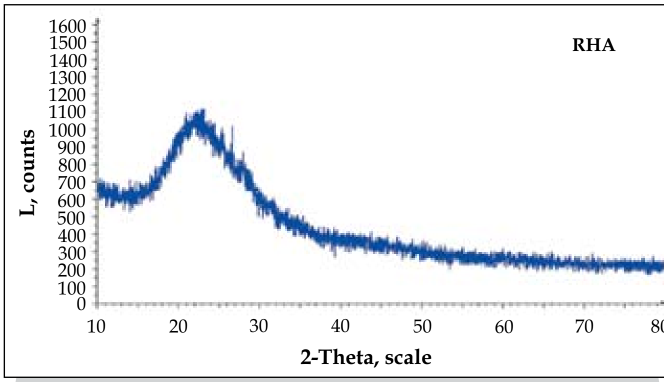


*Figure 1. XRD Analysis*

This can be attributed to the fine particle size and efficient packing of RHA particles which make the pozzoloanic reaction easy due to the presence of amorphous silica. It can be also attributed due to the secondary hydration due to the reaction of Ca $(OH)_2$ with the silicates/aluminates present in the matrix which is not prominent at early ages (7 days) . The increase in the strength observed from 7 days to 28 days also confirms this chain of thought.

## 4.4. Split tensile strength

The split tensile strengths of RHA blended concrete at 7 days and 28 days is presented in Table 5. Split tensile strength also showed the same trend of higher strength in RHA blended concrete having higher age (28 days) as compared to control

**Table 5. Test results**

| Water to binder ratio | Replacement percentage (%) | Compressive strength ($N/mm^2$) | | Split tensile strength ( $N/mm^2$) | | Flexural strength ( $N/mm^2$) | |
|---|---|---|---|---|---|---|---|
| | | 7 day | 28 day | 7 day | 28 day | 7 day | 28 day |
| 0.40 | 0 | 35.7 | 36.8 | 2.78 | 3.61 | 6.10 | 6.64 |
| | 5 | 37.3 | 37.1 | 2.52 | 3.72 | 5.97 | 6.69 |
| | 10 | 35.0 | 35.6 | 2.48 | 3.52 | 5.87 | 6.43 |
| | 15 | 36.6 | 38.8 | 2.46 | 3.60 | 5.70 | 6.52 |
| | 18 | 32.7 | 37.9 | 2.51 | 3.49 | 6.01 | 6.59 |
| | 20 | 30.0 | 31.7 | 2.37 | 3.10 | 6.00 | 6.11 |
| 0.45 | 0 | 33.0 | 34.1 | 2.20 | 3.50 | 5.10 | 5.90 |
| | 5 | 32.1 | 34.8 | 2.55 | 3.68 | 4.75 | 6.20 |
| | 10 | 31.7 | 33.7 | 2.14 | 3.47 | 4.98 | 6.18 |
| | 15 | 33.4 | 35.2 | 2.10 | 3.57 | 5.09 | 6.29 |
| | 18 | 30.8 | 36.3 | 1.90 | 3.39 | 5.00 | 6.21 |
| | 20 | 27.1 | 31.1 | 2.00 | 3.30 | 4.90 | 5.97 |

**Table 6. R values for training and testing**

| Output | Training performance | Testing performance |
|---|---|---|
| Compressive strength | 0.963 | 0.945 |
| Split tensile strength | 0.978 | 0.933 |
| Flexural strength | 0.985 | 0.977 |

specimen however the increased was less pronounced as compared to compressive strength.

### 4.5. Flexural strength

The flexural strength of RHA blended concrete at 7 days and 28 days is presented in Table 5. Flexural strength result presents a complicated result pattern. It can be observed from the analysis of data that strength increased with increasing dosage of RHA for water to binder ratio of 0.45 however strength reduced marginally for water to binder of 0.40 at 28 days. Only 10% showed increase in flexural strength for 0.40 when compared to reference sample but the increase was insignificant. This trend can be generally attributed to the increased packing efficiency of RHA particles as well as due to enhanced pozzoloanic reaction. Also, the amount of $Ca(OH)_2$ is reduced in the matrix due to secondary hydration which increases the flexural strength.

### 4.6. SVM prediction of strength parameter

The two input variables used for the development of SVM model to predict the compressive strength parameter of 28 days is water to cement ratio and Replacement percentage. The performance of SVM is graded in terms of coefficient of correlation (R). The value of (R) should be close to one for a good model [29]. The design parameters C and ε have been decided by trial and error approach values [30]. Table 6 shows the performance of SVM for prediction of different strength parameters.

**Table 7. Results of SVM prediction**

| Water to cement ratio | Replacement percentage | Compressive strength ($N/mm^2$) 28 days | Split tensile strength ($N/mm^2$) 28 days | Flexural strength ($N/mm^2$) 28 days |
|---|---|---|---|---|
| 0.4 | 8 | 36.758 | 3.6078 | 6.3626 |
| | 16 | 36.21 | 3.5038 | 6.4642 |
| | 19 | 37.858 | 3.4878 | 6.5826 |
| 0.45 | 8 | 34.058 | 3.5022 | 5.9074 |
| | 16 | 35.61 | 3.4415 | 6.2113 |
| | 19 | 36.253 | 3.3922 | 6.2174 |

Therefore, model has capability for predicting the strength parameter. Table 7 presents the data of strength parameters as predicted by SVM for replacement percentage which was not experimentally calculated.

## 5. CONCLUSIONS

1. The effect of RHA on the strength development of concrete (Compressive strength, flexural strength and split tensile strength) for 2 different water cement ratio was investigated and through the analysis of data it was verified that replacing cement by RHA in conventional concrete has positive effect on the strength parameters.

2. XRD data showed that that RHA contains amorphous silica making it fit as cement replacing material due to its high pozzoloanic activity.

3. The physical and chemical analysis showed that RHA has potential to act as alternate cementitious material due to presence of much finer particle and larger surface area per particle.

4. This article shows that replacing 20% of weight of cement by RHA still gives comparable and in some case higher strength when compared to conventional concrete.

5. Thus, use of RHA helps to transform rice husk from an environmental concern to a useful resource for the production of a highly effective alternative cementing material.

6. The statistical regression model of SVM was successfully used to predict the strength parameters.

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