Studies on Utilization of Fly Ash and Rice Husk Ash in Concrete

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Abstract— **In the last decade, the use of supplementary cementing materials has become an integral part of high strength and high performance concrete mix design. These can be natural materials, by-products or industrial wastes, or the ones requiring less energy and time to produce. Some of the commonly used supplementary cementing materials are fly ash, rice husk ash silica fume and ground granulated blast furnace slag. The present paper reports the experimental investigation to study the strength characterization of the concrete made from the pozzolanic waste materials. For this purpose, the pozzolanic materials such as fly ash and rice husk ash were used as a cement replacing materials in conjunction with ordinary Portland cement. The equal amounts of these materials were used in eight trial mixes with varying amount of cement. The water cement ratio was also varied. The compressive strengths for 7 and 28 days' were evaluated whereas split tensile strengths corresponding to 7 and 28 days were evaluated. The study corroborates that the pozzolanic materials used in the present investigation along with the cement can render the sustainable concrete.**

Index Terms— **Concrete Strength, Pozzolanic materials, Fly ash, Rice husk ash (RHA).**

I. INTRODUCTION

The excessive global population growth brings high demand for buildings with higher levels of comfort and to low costs, but it also appears the need to produce sustainable architecture in order to reduce energy consumption while lowering environmental impact. Around this, a worldwide interest in optimizing energy resources is growing as well as has the primary responsibility to promote comfort, it is also the most expensive component, therefore this brings the need for alternatives comprehensive address bioclimatic, economic aspects, material substitution technologies and environmentally friendly . Against this background it explores the use of rice husk that besides of being an agro-industrial by-product of big generation and accumulation of large producing areas around the world it is emerging as an important alternative in the development of composite materials for possessing important features requirements for building such as thermal isolation, sound isolation ,low density force, porosity, in addition to its high potential as a source of SiO_2, which by their pozzolanic properties for strength and durability.

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Fly ash is a waste product from coal- fired power plants, and as such, is thought of as a by-product. Because of this, the carbon footprint is attributed to the power industry and not the concrete industry that uses this waste product.

II. BRIEF REVIEW OF THE LITERATURE

There have been several studies reporting the utilization of pozzolanic waste materials such as fly ash and rice husk ash. M. Kohubu [1] long back pointed out the utilization of fly ash in making the concrete. Thereafter, many researchers worked on the theme. Some of the significant works are reviewed briefly in this section. Oluokun [2] worked for fly ash-cement and fly ash concrete mix design. Malhotra [3] described the amount of CO2 being contributed by the Portland cement industry and discussed how these emissions can be reduced considerably by the increased use of large volumes of fly ash and other supplementary cementing materials in the concrete industry. Obla and Karthik [4] discussed the fresh and hardened properties of concrete made with an ultra-fine fly ash (UFFA) produced by air classification. Dhadse and Bhangia [5] presented a review of different ways of using fly ash and subsequently, the policies of Govt. of India regarding utilization and disposal of fly ash. Environmental and occupational health hazards associated with fly ash were also discussed. Aggarwal and Gupta [6] reported the development of high volume fly ash concrete for construction with reference to its predecessors like HSC and HPC. Different ways of using Fly ash in various sectors of civil engineering construction industry in India was presented by Alam and Akhtar [7]. Using rice husk ash for increased compressive and flexural strengths Zhang et al., Ismaila, Rodriguez [8] discussed the effects of fly ash as a partial replacement of cement on the strength of concrete. Meusel and Rose [9] By using rice husk ash – increased resistance to chemical attack. Presented by Chindarprasirt [10] RHA concrete is like fly ash/ slag concrete with regard to its strength development but with a higher pozzolanic activity it helps the pozzolanic reactions occur at early ages rather than later as is the case with other replacement cementing materials. Malhotra [11] RHA has been used in lime pozzolana mixes and could be a suitable partly replacement for Portland cement. Smith et. al., Zhang et.al. Nicole et al.,[12] The most essential asset of RHA that identifies pozzalanic activity is the amorphous phase substance. The production of rice husk ash can lead to the formation of approximately 85 % to 95 % by weight of amorphous silica. Della et al. [13] the reactivity of RHA associated to lime depends on a combination of two factors: namely the non-crystalline silica content and its specific surface. Dakroury et al. [14] Mehta reported that the finer particles of RHA speed up the reactions and form a smaller CH crystals. [15] Berry et.al. revealed that high volume of not completely reacted pozzolanic particles in the cement paste may fill up the voids and enhance density of the paste. [16] Habeeb et.al.

Investigated the effects of concrete incorporating 20 % RHA as partial replacement of cement at three different particle sizes. In their study the tensile strength of concrete increased systematically with increasing RHA replacement. [17] Pozzolanic materials are used to prevent or minimize cracking in concrete due to expansive gel formed by the alkali – silica reaction. Silica fume and RHA have been classified as highly active pozzolans. Hasparyk et al. studied the expansion of mortar bars made with different levels of cement replacement with rice husk ash, they reported that incorporation of high reactivity RHA as partial cement replacement between 12 % and 15 % may be sufficient to control deleterious expansion due to alkali – silica reaction in concrete, depending on the nature of the aggregate. [18] Saraswathy et al. investigated the corrosion performance of concrete made with 0,5,10,15,20,25 and 30 % RHA as partial replacement of cement. They have monitored the open circuit potential measurements with reference to saturated calomel electrode periodically with time as per ASTM C 876. From their study it can be observed that time of cracking were 42, 72 and 74 hours for concretes made with 0, 5 and 10 % RHA. However, no cracking was observed for concretes with 15, 20, 25 and 30 % RHA even after 144 hours of exposure. [19] Chindaprasirt et al. studied the effect of RHA and fly ash on corrosion resistance of Portland cement concrete and concluded that both fly ash and RHA are very effective in improving the corrosion resistance of mortar indicating better contribution of RHA to corrosion resistance in comparison to that of fly ash. [20] Studied the behavior of concrete made from both- fly ash and rice husk ash combined.

Based on the afore-mentioned review of literature, an effort is made in this investigation to study the combined effect of fly ash and rice husk ash as a cement replacing materials in conjunction with ordinary Portland cement for different water cement ratio on the compressive, split tensile and flexural strengths of the concrete. This work involved the experimental study to assess the effect of pozzolanic waste materials such as fly ash and rice husk ash when used as a cement replacing materials with ordinary Portland cement on the strengths of concrete.

III. EXPERIMENTAL PROGRAMME

The particulars of the materials used in the present investigation along with the methodology of investigation are described in this section.

A. Materials

The materials used in the study include cement, sand, aggregates, water, admixtures and cement replacing materials such as fly ash and rice husk ash (RHA). The cement used in the said investigation comprised of Ordinary Portland Cement (ACC: 53 Grade). While the sand brought from Tapi River (Gujarat) was used in the study, the coarse aggregates (Metal I and II) procured from the local quarry at Turbhe in Navi Mumbai were used. The fresh fly ash (Pozzocrete 60) (Source: Nasik Thermal Power Station) made available by Dirk India Private Limited, Borivali Mumbai was brought into use for the purpose of this study. The rice husk ash was procured from Paras suppliers' ltd. From wada – Mumbai. The potable water was added for obtaining concrete mix. The physical properties of the constituents of concrete obtained through various laboratory tests are summarized in Table 1.

Table I: Properties of materials Salient

Properties	**Value**
Cement	
Fineness (IS: 4031 Part II)	305 (Minimum225 cm^2/gm.)
Consistency	28 %
Specific Gravity	3
Setting Time	
Initial Setting Time	130 Min (Minimum 30 Min)
Final Setting Time	221 Min (Maximum 600 Min)
Compressive strength	
3 Days' curing	29 MPa
7 Days' curing	36 MPa
28 Days' curing	54 MPa
Aggregates	
Specific Gravity of Fine aggregate	2.72
Specific Gravity of Coarse aggregate - 20 mm	2.82
Specific Gravity of Coarse aggregate - 10 mm	2.7

B. Methodology

The methodology involved the combination of Ordinary Portland Cement (OPC) and mineral admixtures such as fly ash (FA) and rice husk ash (RHA). For this combination the various parameters such as water cement ratio, percentage of cement, fly ash, rice husk ash, fine and coarse aggregates were kept in varying proportion. On the backdrop of the literature, the percentage variation in cement replacing materials and cement was decided. The eight trial mixes were prepared. In each trial, 9 cubes, 3 beams and 3 cylinders were cast. Cement, sand, coarse aggregate and cement replacing materials were thoroughly mixed in dry state by machine so as to obtain uniform color. Then, the required water as per the designated water cement ratio was added to the dry mix in order to obtain uniform mixture. The compaction factor test and slump test were carried out on fresh concrete and the respective values were recorded for all the trial mixes. The moulds with standard dimensions i.e. 150×150×150 mm were filled with concrete in 3 layers by poking with tamping rod and vibrated by the table vibrator. The vibrator was used for 30 second and it was maintained constant for all specimens. Along similar lines, the cylinders of size 100 mm diameter and 300 mm length were also cast. The samples (cubes and cylinders) were air dried for a period of 24 hours and then, they were weighed to find out their weight prior curing. Thereafter, they were immersed in water. The cubes were allowed for 7 and 28 days' curing while the cylinders were also allowed for 7 and 28 days' curing. The samples were tested for their respective strengths.

IV. RESULTS AND DISCUSSION

The effect of cement replacing materials such as fly ash and rice husk ash when used in varying proportions in conjunction with OPC for different water cement ratio is studied on the engineering behavior of concrete made from the pozzolanic waste, in the context of the results obtained following different tests on fresh and hardened concrete and discussed in the subsequent sections.

A. Compressive Strength

The particulars of different trial mixes with varying proportions of cement and cement replacing materials and varying water cement ratio are given in Table II. The values of the compressive strengths for different curing periods are also indicated in Table II.With increase in cement contents and decrease in the contents of fly ash and RHA , the compressive strength of the concrete is found to increase for any curing period. Further, the compressive strength is found to increase with increase in curing period in respect of all the trial mixes.

The performance of the various mixes with respect to cement contents, water cement ratio, curing periods and that of cement replacing materials is discussed below. The graphical representation of the variation in the values of the compression strengths with respect to cement content is depicted in *Fig. 1.* It is observed that the compressive strength for all the mixes is found to increase with the increase in cement content. This is attributed to the increase in the availability of alkali (which is by-product of hydration of cement) for pozzolanic reaction. Further, the rate of gain in the strength is found to be high for higher cement contents.

TABLE II: DETAILS OF VARIOUS TRIAL MIXES AND COMPRESSIVE STRENGTH IN N/MM

Trial No	w/c ratio	Cement (%)	Fly Ash (%)	RHA (%)	Compressive Strength(N/mm^2) for different curing period	
					7 Days'	28 Days'
1	0.47	50	25.0	25.0	20.74	26.37
2	0.45	55	22.5	22.5	22.51	29.92
3	0.43	60	20.0	20.0	26.37	34.96
4	0.41	65	17.5	17.5	29.03	38.51
5	0.39	70	15.0	15.0	32.74	42.51
6	0.37	75	12.5	12.5	36.00	45.18
7	0.35	80	10.0	10.0	38.96	49.03
8	0.33	85	7.5	7.5	42.22	52.44

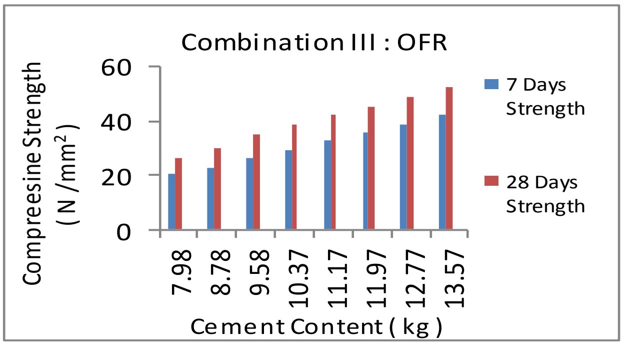


Fig.1 *(Variation in compressive strength with cement content)*

In respect of 7days' curing, the value of the strength is found to be 20.74 N/mm^2 for the first trial mix for cement content 7.98 kg and it goes on increasing to 42.22 N/mm^2. The increase in strength found to be 103% approximately. For 28 days' curing period, the difference goes on increasing with increase in cement contents. The compressive strength increases from 26.37 N/mm^2 for first trial mix to 52.44 N/mm^2 for the last trial mix. The difference between the strength in respect of first trial mix and last trial mix when cured for 7 days' is observed to be 103 % for the increase in cement content from 7.98 kg to 13.57 kg. For the 28 days' the corresponding difference between the strengths is observed to be 99 %. The value of compressive strength for 28 days' curing period is observed to be on higher side than that of 7 days' strength.

As evident from Table II, the contents of fly ash and RHA were decreased from first trial mix (No. 1) to the last one, i.e., No. 8. However, its proportion was kept same, i.e., out of total amount of cement replacing materials for any trial, 50% would be the contents of each of these cement replacing materials.

It is observed that out of total cement content if 50 % of cement is replaced by the fly ash and RHA for the first trial, the strength is found to increase for the curing periods considered in the study. The strength corresponding to 7 days' curing is observed to be 20.74 N/mm2 which is more than 27 % of the strength obtained corresponding to 28 days' curing. As the percentage of cement replacing materials goes on decreasing and percentage of cement in the mixes goes on increasing, the strength is observed to be on higher side in respect of all the trial mixes, considered in the present investigations, for all curing periods. It is observed from Table II, so far as the effect of curing period on compressive strength is concerned, that the compressive strength is found to increase with increase in cement content and curing period for all the trial mixes. This is attributed to increase in the availability of alkali (which is by-product of hydration of cement) for pozzolanic reaction. Further the rate of gain is found to be high for higher curing periods. Water cement ratio is varied from 0.33 to 0.47, the former one being used in the last trial mix whereas the last one, in the first trial mix. It is already mentioned in Table II. It is seen that with increase in water cement ratio, the compressive strength of concrete mix is found to decrease in respect of all the periods of curing considered in the present study. Further, the compressive strength of the concrete is obtained on higher side for the water cement ratio 0.33, as used in the last trial mix, in respect of all the curing periods.

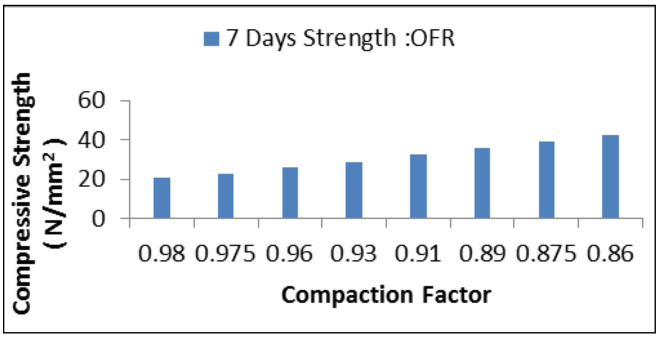
The values of the compressive strengths in respect of different trial mixes and various curing periods considered in the present investigation vis-à-vis compaction factor is shown in Table III.

TABLE III. DETAILS OF VARIOUS TRIAL MIXES AND COMPRESSIVE STRENGTH AND COMPACTION FACTOR

Trial no	**Compressive Strength(N/mm^2) for different curing period**		**Compaction Factor**
	7 Days'	**28 Days'**	
1	20.74	26.37	0.98
2	22.51	29.92	0.98
3	26.37	34.96	0.96
4	29.03	38.51	0.93
5	32.74	42.51	0.91
6	36.00	45.18	0.89
7	38.96	49.03	0.88

8	42.22	52.44	0.86

For higher values of the compaction factor, the compressive strength is found to be less and with decrease in the compaction factor, the strength is found on the higher side. This holds good for all the curing period. The graphical representation of compressive strength and compaction factor is as shown in *Fig.2*.



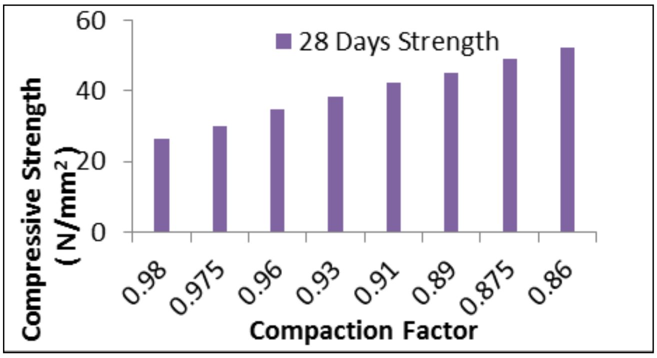


Fig . 2 (Variation in compressive strength with compaction factor)

B. *Split Tensile Strength*

The values of tensile strengths, as obtained from the split tensile test, for the various trial mixes in respect of all the curing periods, are shown in Table IV.

For first trial, for 50 % addition of fly ash and rice husk ash and at the same time 50 % addition of cement, 7 day's strength is observed less. But it is found to increase for 28 day's curing periods.

TABLE IV THE VALUES OF SPLIT TENSILE STRENGTHS FOR VARIOUS TRIAL MIXES

Trial no	w/c ratio	Cement (%)	Fly Ash (%)	GGBFS (%)	Strength (N/mm^2) for different curing periods	
					7 Days'	28 Days'
1	0.47	50	25.0	25.0	1.76	2.74
2	0.45	55	22.5	22.5	1.82	2.86
3	0.43	60	20.0	20.0	2.16	3.12
4	0.41	65	17.5	17.5	2.28	3.32
5	0.39	70	15.0	15.0	2.37	3.48
6	0.37	75	12.5	12.5	2.62	3.54
7	0.35	80	10.0	10.0	2.96	3.88
8	0.33	85	7.5	7.5	3.14	4.12

For first trial, for 50 % addition of fly ash and rice husk ash and at the same time 50 % addition of cement, 7 day's strength is observed less. But it is found to increase for 28 day's curing periods. For last trial, for 15 % addition of fly ash and rice husk ash and at the same time 85 % addition of cement, strength is observed on higher side for 28 day's curing periods.

V. CONCLUSIONS

The present experimental investigation was aimed at evaluating the suitability of the industrial waste and agro waste containing pozzolanic materials such as fly ash and rice husk ash as the cement replacing materials in the concrete as a sustainable construction materials. Some of the broad conclusions deduced from the present study are as follows.

- With increase in cement contents and decrease in the contents of fly ash and rice husk ash, the compressive strength of the concrete is found to increase for any curing period.
- The compressive strength for all the mixes is found to increase with the increase in cement content.
- The compressive strength of concrete mix is found to decrease with increase in water cement ratio in respect of all the periods of curing.
- With increase in compaction factor, the compressive strength of the concrete decreases.
- The gain in compressive strength up to 28 days' curing is considerable. However, the rate of gain in strength beyond 28 days' curing period is not that significant.
- The curing period hardly improves the split tensile strength of the concrete.

In view of the afore-mentioned some of the findings emerged from the present investigation, it can be concluded that the pozzolanic waste materials such as fly ash and rice husk ash when used as a cement replacing materials in conjunction with OPC can render the sustainable concrete.

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