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Utilization of industrial waste in construction material – A review

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Abstract: In the present age the waste generated from industriesis the huge concern for the environment, health, and cause for land filling. Recycling of such wastes and using them in construction materials appears to be viable solution not only to the pollution problem but also an economical option in construction. In view of utilization of industrial waste in construction material, the present paper reviews various waste materials at different levels in construction material. Compressive strength of concrete and mortar incorporating different waste materials is reviewed and recommendations are suggested at the outcome of the study. The reviewed approach for development of new construction material using industrial waste is useful to provide a potential sustainable source.

Keywords: Industrial waste, concrete, mortar, compressive strength

I. INTRODUCTION

Human activities on earth produce in considerable quantities of wastes more than 2,500 million tons per year, including industrial and agricultural wastes from rural and urban societies. This creates serious problems to the environment, health and also the land filling. Now a day the concrete is most used manmade material in the world. The Indian construction industry alone consumes approximately 400 million tons of concrete every year and the relative amount of mortar too. Therefore the demand of the concrete and the required raw materials are very high. This causes the hike in the costs of cement, fine and coarse aggregates. Quite often the shortage of these materials is also occurred. To avoid the problems like cost hike and cuts in supply of concrete and mortar, the alternate material or the partial replacements for the cement and aggregate should be developed by recycling of waste materials. This provides us the low cost, light-weight and eco-friendly construction products. Use of the waste materials also reduces the problem of land-filling, environmental and health concern. The present paper covers the review on the use of various waste materials like rice husk ash (RHA), quarry dust (QD), crumb rubber, sewage sludge ash (SSA) as mineral additive, paper mill sludge ash (PA), fly-ash, fly-ash based geo-polymer, ground granulated blast furnace slag (GGBF), pumice fine aggregate especially in mortar and concrete [1-12]**.**Rice husk ash contains silica with small amount of alkalis and other trace elements [13-14]. Controlled combustion influence the surface area of RHA, so that time, temperature, and environment to be considered to produce ash of maximum reactivity [15-18]. The mechanical properties of rubberized concrete with three different water cement ratio (0.41, 0.57 and 0.68), revealed slump values increase as the crumb rubber content increase from 0% to 30%[19].Researches were already accomplished investigating the use of SSA to produce bricks, aggregates for concrete, and filler for concretes and pavements, and the technical viability of using this residue was verified [20-24].A possible reuse of the paper mill sludge is blended with natural raw materials extracted from the ores in the production of cement, mortar, concrete, or bricks because the main constituent elements of paper mill sludge are Al, Mg, Si, and Ca, whose oxides are largely used in the concrete industries[25-28]. Adequate strength developments were found in mortars madeofthe mixed cement and 20-40% fly ash [29].RHA has been used in lime pozzolana mixes and could be a suitable partly replacement for portland cement [30-34].Geopolymer with fluidized bed combustion bottom ash (FBC-BA) experienced a decrease in compressive strength with the increase of the content of FBC-BA in the prepared specimens. Increasing the content of FBC-BA to about 50% caused the decrease of the compressive strength [35].Utilization of the widely spread industrial wastes in the civil construction practice may lead to a real possibility of significant decrease in the environment pollution by paper and lime production wastes and

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perceptibly economize the price of civil construction[36].The addition super plasticizer and air- entraining admixtures improved the strength and workability of pumice concrete [37- 38].The use of GGBF slag in the production of blended cements accounted for nearly 20 % of the total hydraulic cement produced in Europe [39].

II. LITERATURE SURVEY

Development of Mortar Using Other Materials as Partial Replacements

M. RameGowda et al. [1] developed and studied the strength of self compacting mortar(SCM) mixes using local materials like quarry dust and rice husk ash(RHA) as the partial replacement of cement and sand. The characterization of materials has been done and various tests conducted for cement werefineness, specific gravity, normal consistency, setting time,compressive strength for 3, 7, 21, and 28 daysas per EFNARC 2005 and IS 383: 1970[40- 41].

Muhammad HarunurRashidetal.[2] developed mortar incorporating RHA. The mortar mixes with ordinary Portland cement (OPC) and four other mixes using RHA with varying percentage by replacing OPC has been prepared. The compressive strength tests was carried out on these specimens according to ASTM C 109[42] for 7, 28, 90 days. The reported results were average of three samples. For determining the porosity of the mortar cylindrical specimen of 100 mm diameter and 200 mm height were casted. Samples were cured for 28 days and tested at 7, 28, 90 days. Results showed that the strengths of specimens at 28 days are slightly lower. The incorporation of RHA in mortar produced filler effect due to its fine particle size. The results suggested that RHA in this work were quite reactive and pozzolanic reaction starts at the age of 28 days onwards.

WesamAmerAules[3]used the crumb rubber as partial replacement for sand in mortar. Various mixes were prepared with crumb rubber varying percentage and compared with reference mix proportion. The tests carried out on the mortar are compressive strength, fineness and setting time in accordance with ASTM C150-07 [43]. The strength of mixes with crumb rubber was lower than reference mix.Strengthwas reduced due to weak bond between crumb rubber aggregate and concrete.

Fontesetal.studied the potentiality of sewage sludge ash as mineral additive in cement mortar and high performanceconcrete[4]and concluded that SSA was a prospective material to be used as cement replacement in cement based material. Mortar mixtures containing 10-30% of SSA as cement replacement presented compressive strength as per NBR 12653 [44] at 7 days higher than that of the reference mixture and about the same strength at the age of 28 days.The high performance concrete produced axial compressive strength equivalent to that of the reference mixture at the age of 28 days. The partial replacement of portland cement by SSA promoted an increase in the total porosity and a reduction in the absorption values of the OPC reference mixtures.

Gabriele Fava et al.[5]stated that papermill sludge when combusted,converts into ash termed as paper ash (PA).All specimens were vibrated for 20 s on a vibrating table and then covered with a plastic sheet to minimize water evaporation. The dosage of super plasticizer was maintained equal to 1% by weight of the cement along with PA to reduce the water dosage. The mortar workability was similar for all the mortar mixtures and equal to 180 mm slump measured according to EN 12350- 2CEN 1999[45].

Valeria Corinaldesietal[6]explained the experimental results of use of paper mill sludge ash as supplementary cementitious material. The mortars containing 5% PA exhibited a compressive strength higher than that of conventional mortar at 28 days. The results presented encourage the researchers to undertake further study on the use of PA in concrete, which could lead to a reduction in the cost of concrete as well as a method for disposal of PA. The compressive strengths of mortars were measured after 1, 7, 28, and 60 days after casting.

Christy and Tensing[7]concluded that the incorporation of class F-fly ash in mixed cements feasible for making masonry mortars in brick joints. Adequate strength developments were found in mortar made of the mixed cement and fly ash as cement replacement for 1:3, 1:4.5, and 1:6 mortars Fly ash can be used in mortar to improve the long term bond strength. Partial replacement of portland cement with class F- fly ash significantly improves the masonry bond strength. The tests were conducted as per ASTM C 311, IS 1344:1968, IS 269: 1970, IS 3812: (part I) 1966[46- 49].

AlirezaNajiGivietal.[8]stated that 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, Silica Fume (SF), Ground Granulated Blast Furnace Slag (GGBFS) and Rice Husk Ash (RHA) etc.

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Vol. 3, Issue 1, January 2014

DjwantoroHardjito et al.[9]presented the results of study on effect of various parameters on mechanical properties of fly ash-based geo-polymer mortar with bottom ash as partial or full replacement for sand.Compressive strength of samples with 10% bottom ash (BA) was comparable to those with only sand. Further increase in bottom ash content decreased the compressive strength. However, the reverse tendency occurred after exposing the samples to 1000^{o}C for 24 hours.

BalwaikandRaut[10]studied the utilization of wastepaperpulp by partial replacement of cement in concrete.The cement has been replaced by waste paper sludge accordingly in the range of 5% to 20% by weight for M-20 and M-30 mix. The concrete specimens were tested in three series of test as compression test, splitting tensile test and flexural test. These tests were carried out to evaluate the mechanical properties for up to 28 days in accordance with IS 383: 1970, IS10262:1982, IS 456:2000, IS 1199:1959, IS 516:1959, IS 5816:1999 [50- 56].As a result, the compressive, splitting tensile and flexural strength increased up to 10% addition of waste paper pulp and further increased in waste paper pulp reduces the strengths gradually.

Degirmenci and Yilmaz explained the use of pumice fine aggregates [11] as an alternative for sand in the production of lightweight cement mortar. Pumice is natural material of volcanic origin produced during release of gases by solidification of lava. The purpose of this study is to evaluate the possibility of using granulated pumice as an alternative for fine aggregates in production of lightweight mortar. The compressive strength, flexural strength, freeze – thaw resistance, sulfate resistance water absorption test are determined for pumice/cementas per TS EN 197-1, TS EN 196-1, ASTM C 270-08a, ASTM 330[57- 60].

ACI Committee 233 reported about the use of ground granulated blast furnace slag as a cementitious constituent in concrete[12].The use of iron blast-furnace slag as a constituent of concrete, either as an aggregate or as a cementing material, or both, is well known. This report primarily addresses the use of GGBF slag as a separate cementitiousmaterial added along with portland cement in the production of concrete and the specimen were tested in accordance with C 94, C109, C162, C 186, C 227, C595, C 666, C989, C1012, C1073, A 23.5, A 363[61-72].

Following is the block diagram (Fig. 1) showing the methodology followed in manufacturing construction material incorporating industrial waste by various researchers during their study. Table1 summarizes the percentage waste materials used and various test conducted on construction material by various researchers during their research work.

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Vol. 3, Issue 1, January 2014

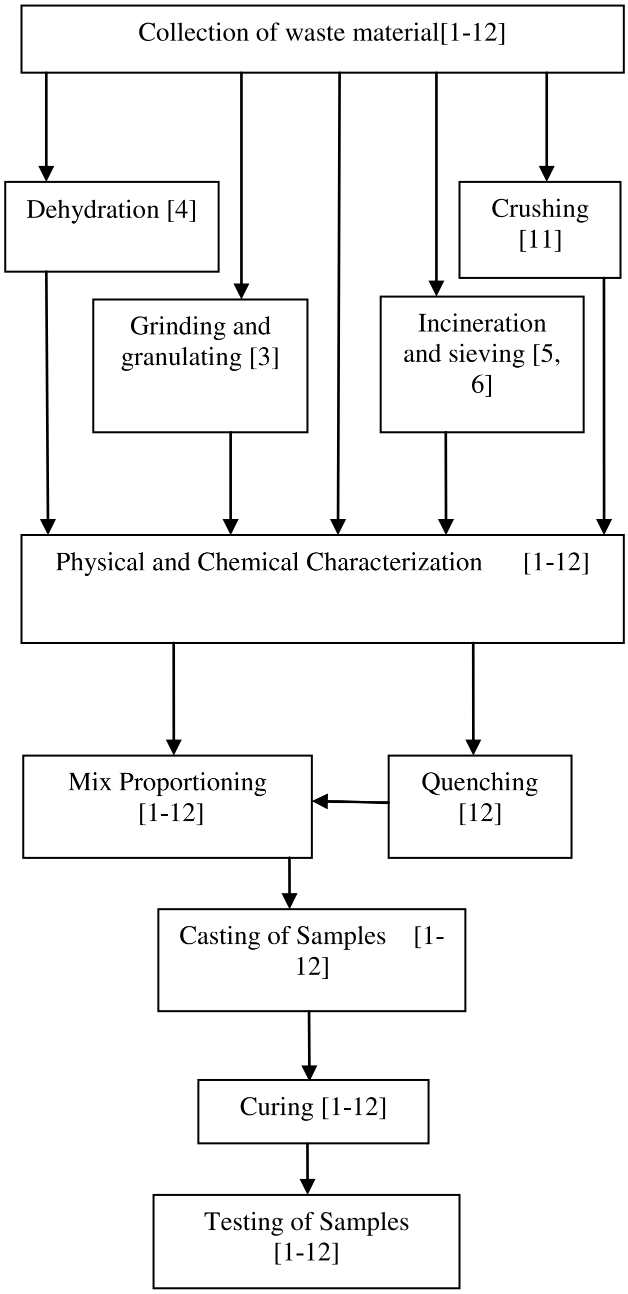

Fig.1. Methodology followed for manufacturing mortar and concrete

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Vol. 3, Issue 1, January 2014

Table 1:Design and development of construction material using industrial waste

Sr. No.	Waste material used for production mortar and concrete (% Used)	Size of moulds casted for test	Curing Days	Various Tests Conducted
1	Quarry Dust, (0 -40%) Rice Husk Ash (0 -20%)	150x150x150mm 50x50x50 mm	3, 7, 21, 28, 56, 90	Compressive strength, mini slump cone test, mini v-funnel test,
2	Rice Husk Ash (0 – 30%)	50x50x50 mm	3, 7, 28, 90	Compressive strength, porosity test
3	Crumb Rubber (0 – 30%)	50x50x50 mm 25x25x200mm 25x25x28.5mm	28	Compressive strength, flexural strength, length change , stress –strain curve
4	Sewage Sludge Ash (0 – 20%)	Cylinders of 50 mm dia. and 100 mm ht.	7, 28	Compressive strength
5	Paper Mill Sludge Ash (0.4 – 20%)	40x40x160mm	1, 7, 28, 60	Compressive strength
6	Paper Mill Sludge Ash (0.4 – 20%)	40x40x160mm	1, 7, 28, 60	Compressive strength, water to binder ratio
7	Class F-Fly ash (10 – 30%)	70.7x70.7x70.7mm	28	Compressive strength
8	Rice Husk Ash (0 – 20%)	150x150x150mm 50x50x50 mm	28, 90, 180	Compressive strength, setting time, water absorption, tensile and flexural strength
9	Fly Ash (0 – 100%)	50x50x50mm	7, 28	Compressive strength, effect of thermal exposure
10	Paper Pulp in concrete (5 – 20%)	150x150x150mm 100x100x500 mm	14, 28	Compressive strength, flexural strength, split tensile strength,
11	Pumice Fine Aggregate (0 – 100%)	40x40x160mm	2, 7, 28, 56	Compressive strength
12	Ground Granulated Blast Furnace Slag (0 – 65%)	150x150x150mm 70.7x70.7x70.7mm	3, 7, 28	Compressive strength

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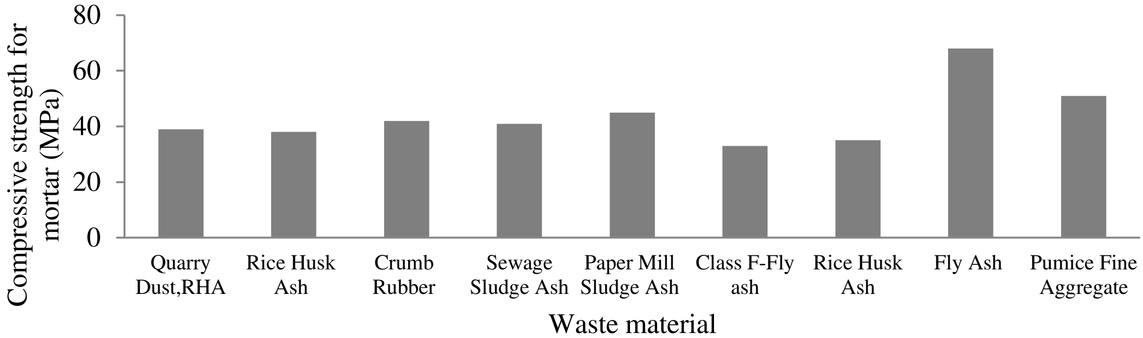

Fig. 2Compressive strength of construction material (mortar) made from different industrial waste

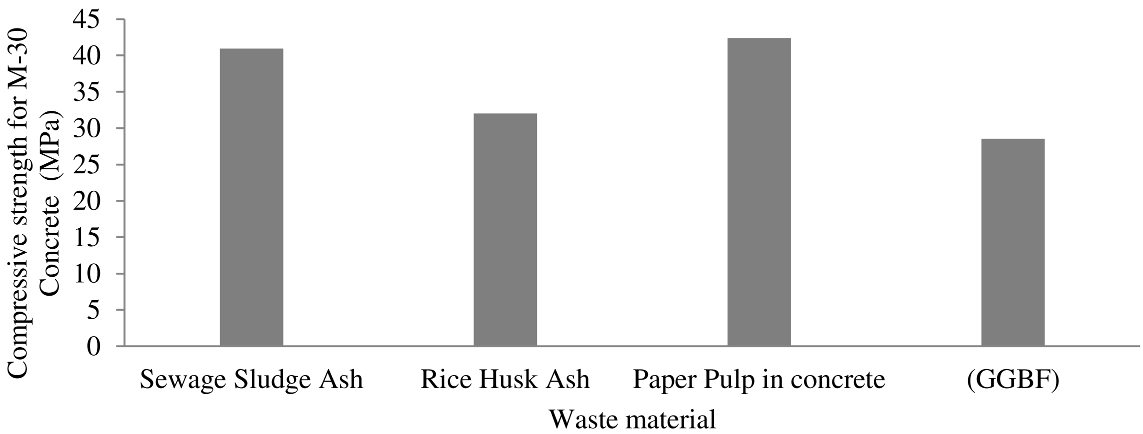

Fig. 3 Compressive strength of construction material (concrete) made from different industrial waste

III. DISCUSSION

From the above study, it is seen that researchers have used various industrial waste materials in different proportion for the replacement of fine aggregate and cement in mortar and concrete. Different tests have been conducted as per the standards on the concrete and mortar. The common parameter calculated by various researchers is compressive strength. Common minimum value recommended by IS 1727:1967 for compressive strength for mortar is 35 MPa. It is evident from the fig. 2 that the compressive strength for the mortar prepared by using the bottom fly ash as the partial replacement for cement is highest wherein all other values of compressive strength are almost greater than that of recommended value.It is observed from fig.3 that the compressive strength of concrete made from different industrial waste material is higher than the recommended characteristic compressive strength of M30 concrete. It has been observed that up to 10 % replacement of pozzolanic material or any type of aggregate is desirable when compared with conventional construction material.

IV. CONCLUSION

The various methodologies for the use of industrial waste products by partial replacements of cement and fine aggregates in concrete and mortar have been reviewed. Various physico-mechanical and chemical properties of the concrete and mortar incorporating different waste materials are studied in accordance with the reviewed literature and the standards. It is seen that waste materials like fly ash, rice husk ash, GGBF, were used extensively and sufficient research have been done on them.The study in turn is useful for various resource persons involved in using industrial or agricultural waste material to develop sustainable construction material.

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