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Assessment of Mortar with Partial Replacement of Ceramic Waste Sand with Fine Aggregate

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Abstract- Now a day it is seen that there is a scarcity of the river sand but its demand is high as it is used in making mortar and concrete. To avoid this problem, some alternatives must be find out so that sand could be replaced. Ceramics waste can be one of the alternatives. By using the ceramics waste in mortars, its dumping problem could also be solved which is one of the leading problem. To make the environment green, there must be complete utilization of the waste like ceramics waste sand. This paper deals with the experimental study on the mechanical properties of mortar. In this study the strength and durability of the mortar is checked by the partial replacement of fine aggregate with ceramic waste sand. The replacement will be 50% and 100%. The fly ash is also replaced by cement 25%. The cement sand ratio is taken 1:3 and 1:4. The result shows that durability is improved by using the ceramics waste sand and there is also reduction of shrinkage and permeability.

Keywords: - Mortar, ceramic waste sand, fine aggregate, strength, durability etc.

I. INTRODUCTION

Mortar is a workable material consist of binder, fine aggregate and water used for binding construction blocks together, filling the gaps between them and for plastering. The river sand deposits are the most common fine aggregate used in the preparation of cement mortar [1].

Nowadays, the natural river sand has become very rare and costly. Uncontrolled quarrying of sand has results in lowering of water table, soil erosion and under-mining of bridge foundation.

Recovery and recycling is the best environmental solution to save raw materials and to reduce the amount of industrial waste materials produced, and consequently the contamination of environment [2, 3, 4, and 5]. Traditional ceramics, such as bricks, roof and floor tiles, other constructions materials, and technical ceramics, such as porcelain are usually highly heterogeneous due to the wide compositional range of the natural clays used as raw materials.

strength gain of fly ash mortar are affected by the characteristics of the fly ash(properties as chemical composition, particle size, reaction potential), the cement with which it is used, the temperature and other curing conditions, as well as the presence of other additives.

The durability of mortar contributes significantly to the overall durability of structure. Mortars used in masonry structures exposed to aggressive environments are designated to resist a range of possible physical and chemical degradation. The physical form of degradation may be caused by abrasion from wind action, salt crystallization and freeze-thaw action. The chemical form of degradation is usually caused by reaction with soluble salts.

1. Kaolin Processing Waste:

The kaolin industry, which processes primary kaolin, produces two types of waste materials. The first type derives from the first processing step (separation of sand from ore), which represents about 70% of the total waste produced, and is also known as china clay sand. The second type of waste is resulted from the second processing step, which consists of wet sieving to separate the finer fraction and purify the kaolin. These wastes are called ceramic industry waste [6, 7]. The waste from these industries are usually disposed into the land, but it should be treated before disposal as it contains chemicals which were incorporated during purification process of kaolin, otherwise it will contaminate the ground and surface water [8,9,10]. Disposal and treatment technologies require major long-term investments in capital equipment and have ongoing costs. So it will be effective if it included in the construction applications.

2. Objectives and Scope of the Work:

The main objectives of this work are to investigate the effect on workability, the effect on strength and durability of fly ash based cement mortar with C-sand as fine aggregate. The study limited to the workability, strength and durability of 1:3 and 1:4 proportions of mortar. The C-sand is replacing M-sand by 50% and 100%. The strength and durability are studied up to 90 days.

II. EXPERIMENTAL PROGRAMMES

1. Material Properties:

Ordinary Portland Cement (OPC) confirming to IS 12269 (53 Grade) was used for the experimental work. Fly Ash obtained confirms to ASTM Class F (Low-calcium dry fly ash). The specific gravity of fly ash was around 2.08. Locally available good quality M-sand was used. M-Sand (<2.36 mm) having fineness modulus 2.64 and specific gravity 2.92 was used as fine aggregate. It conforms to IS 383:1970 specification (Zone II).

Ceramic tailing sand which is the waste product obtained during the extraction and production of ceramic powder was collected from Kerala Ceramics Limited Kundara. The sand corresponds to zone II. Its fineness modulus is 2.9 which are less than M-sand, that it contains more fine particles. Sodium hydroxide pellets with 98% purity was brought from local market. 0.5% Sodium hydroxide by weight of tailing sand was used in four mixes to activate reacting components in ceramic tailing sand. Potable water is generally considered as being acceptable.

Hence clean drinking water available in the college water supply system was used for casting as well as curing of the test specimens.

2. Mix Proportion and Methodology:

The design basically involves the determination of water –binder ratio for required consistency of mortar. This is determined by flow test by varying content of water on all mix compositions used in the investigation. The different mix proportions are 1:3 and 1:4 (cement: fine aggregate) with different w/b ratio. The cement was replaced by fly ash by 25% by weight of cement. In some mix 0.5% NaOH by weight of C- sand was added to find the reactivity of mineral admixtures in presence of alkalies. The various mixes and w/b ratio are shown below.

Machine mixing was done and compaction done using table vibrator. The measured quantities of materials are mixed in a planetary type, variable speed mortar mixer. Specimens were de-moulded after 24 hours of casting and were kept in a curing tank for water curing. In case of sulphate curing specimen were cured in sulphate solution. The specimens includes 50mm cubes for strength studies, 40×40×160mm bars for flexural strength study, 150mm diameter and 50mm thick disc for RCPT, 25×25×280mm prisms for the determination of length changes.

III. ANALYSIS OF TEST RESULTS

1. Compressive Strength Test:

Compressive strength study was carried out on 50mm cube specimen at the ages of 3, 7, 28, 56, 90 days. The compressive strength values of 1:3 mixes and 1:4 mixes are shown in figure 1 and figure 2 respectively.

When M-sand was completely replaced with C-sand, there is a small reduction in strength but when 50% replacement shows later age strength gain. Addition of NaOH with C-sand cause a reduction of strength compared with other mixes. This may be due to chemical reactions between components in C-sand with alkali.

2. Flexural Strength Test:

Flexural strength study was carried out on 40mm×40 mm × 160 mm bar specimen at the ages of 56, 90 days. The flexural strength values at 56th and 90th day for 1:3 and 1:4 mixes are shown in Fig 3 and Fig 4 respectively.The same trend of strength variation was observed both at 56th and 90th days. The presence of NaOH with M-sand improves the strength due to alkali activation but reduces strength with 100% C-sand. The 50% C- sand shows an improvement in strength. The reactive silica in fly ash in richer mix results in formation of secondary calcium silicate hydrate due to pozzolanic reaction which imparts the flexural strength of mixes. In 1:4 mixes calcium hydroxide is less, so no improvement in flexural strength compared with control mix.

3. Rapid Chloride Permeability Test:
This test was conducted to evaluate the electrical conductance of mortar specimens to provide a rapid indication of their resistance to chloride ion penetration. The total current passed through the specimen is tested at the age of 90 days. Fig 5 shows the variation of current passed for different mixes with time.

In 1:3 mixes, it is observed that the addition of fly ash increases the chloride penetration. The replacement with 100% C-sand reduces the chloride penetration and 50% of M-sand with 50% C-sand increases the penetration. The presence of C-sand improves the pore structure of the mix, thus reduces the chloride ion permeability.

The 1:4 mixes was weaker which shows more chloride ion permeability than 1:3 mixes. But the addition of C-sand reduces the pores and thus chloride ion permeability reduces. The presence of NaOH in the various mixes may lead to erroneous results in RCPT because NaOH solution was used in the cathode side of test set up. So the mixes contain NaOH cannot be taken for comparison.

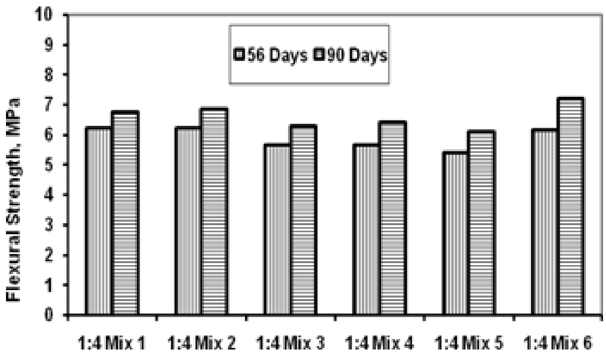

Fig 1. Comparison of flexural strength of 1:3 Mix.

4. Length Change:
There are three type of curing conditions used in the study. They are no moist curing, 3 day moist curing and 7 day moist curing. In no moist curing specimens are directly placed into the sulphate solution after demoulded. In 3 days and 7 days moist curing specimens were cured in water for 3 days and 7 days and then placed into the sulphate solution. A 20000 ppm sulphate solution was prepared by dissolving 52g $MgSO_4 \cdot 7H_2O$ in one litre of water. Eight specimens were used in each type curing.

The length change was measured using a length comparator. The readings were taken once in 2 days for initial 2 weeks, then once in 4 days and when age increases readings were taken once in a week.

Change in length= (Rx - Rl) ×0.002

Where Rx= dial gauge reading at any age * days.
Rl = dial gauge reading immediately after the final setting of paste specimen.

Addition of fly ash increases the shrinkage. The replacement of M-sand with C-sand decreases the shrinkage of mortar bars even with the addition of fly ash. Examining the trend of length change, the mix contains 50% C- sand and 50% M-sand shows small length change than any other mix even at the later age.

The addition of alkali with C-sand which contains acidic compounds caused the expansion may be due to acid-base reaction. The shrinkage of 1:4 mix with M-sand compared to 1:3 mix was less may be because 1:4 is leaner mix and so amount of fly ash that replaces cement is less than that in 1:3 mix. The reduction in shrinkage by using C-sand is because of its particle packing. The C-sand contains more fine particles than M-sand.

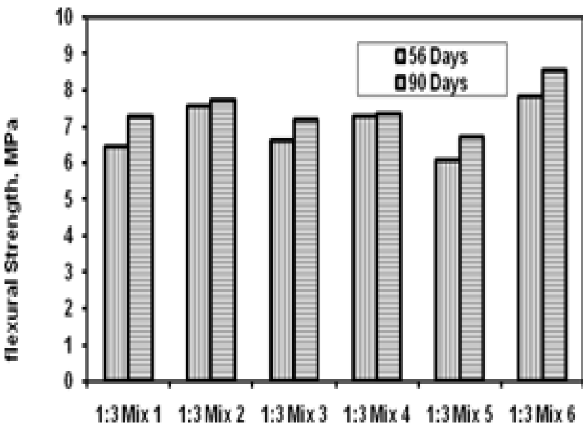

Fig 2. RCPT test on different mortar mix at 90 days.

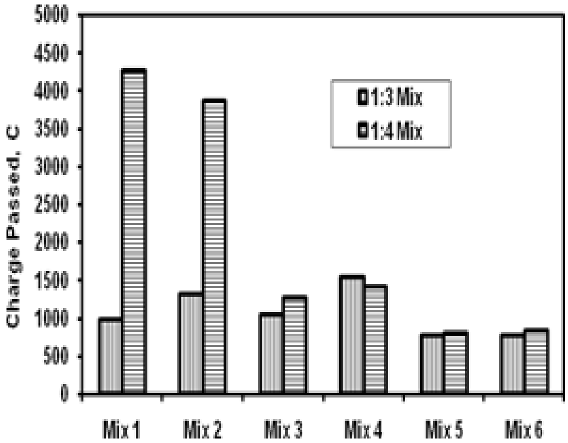

Fig. 2 Comparison of flexural strength of 1:4 Mix.

Table 1. Water–Binder Ratio for Various Mixes.

Mix Designation	Mix Composition	1:3	1:4
Mix 1	OPC+M-sand+ water	0.70	0.80
Mix 2	OPC+ fly ash+ M-sand+ water	0.70	0.80
Mix 3	OPC+ fly ash+ C-sand +water	0.76	0.92
Mix 4	OPC+ fly ash+ M-sand+ C-sand+ water	0.72	0.86
Mix 5	OPC+ fly ash+ C-sand+ NaOH+ water	0.76	0.92
Mix 6	OPC+ fly ash+ M-sand+ C-sand+ NaOH	0.72	0.86

IV. CONCLUSIONS

With the 50% replacement of ceramic waste sand, there is an increase of 2% for 1:3 mix. With the addition of NaOH, the flexural strength is increased by 16% for 1:3. Ceramic sand waste has the finer particles; improve the pore structure of mix.

The presence finer particles of C-sand improve the pore structure of mix by reducing pore connectivity thus reduces the (chloride ion) permeability.

The replacement of ceramic waste controls shrinkage. The replacement of ceramic waste controls permeability.

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