

Investigations on cement mortar using ceramic tailing sand as fine aggregate

Beemamol U.S., Nizad A., Nazeer M.

Department of Civil Engineering, TKM College of Engineering, Kollam – 5, INDIA

Abstract: - As part of industrialization construction industry is growing very fast. The widely used fine aggregate is river sand which is scarce and expensive nowadays. Ceramics industry is a growing industry and as the ceramic waste sand is piling up every day, there is a pressure on the ceramic industry to find a solution for its disposal. In this study of strength and durability of masonry mortar, the ceramic waste sand which is locally called ceramic tailing sand replacing fine aggregate by 50% and 100%. The fly ash (industrial waste) is also replacing cement by 25%. The binder to sand ratio of 1:3 and 1:4 and the water to binder ratio are selected based on suitable workability. Test result indicates that the use of ceramic waste sand did not significantly affect its strength properties and the durability is improved. The permeability and shrinkage are reduced by using ceramic waste sand. The 50% ceramic waste sand shows a better response in respect of strength and durability

Keywords: - mortar, ceramic tailing sand, fine aggregate, strength, durability

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 undermining 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 [2,3,4,5]. 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.

The strength at a given age and the rate of 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.

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.

II. 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.

III. EXPERIMENTAL PROGRAMMES

Material Properties

Ordinary Portland Cement (OPC) conforming 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 is 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.

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.

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

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.

IV. ANALYSIS OF TEST RESULTS

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.

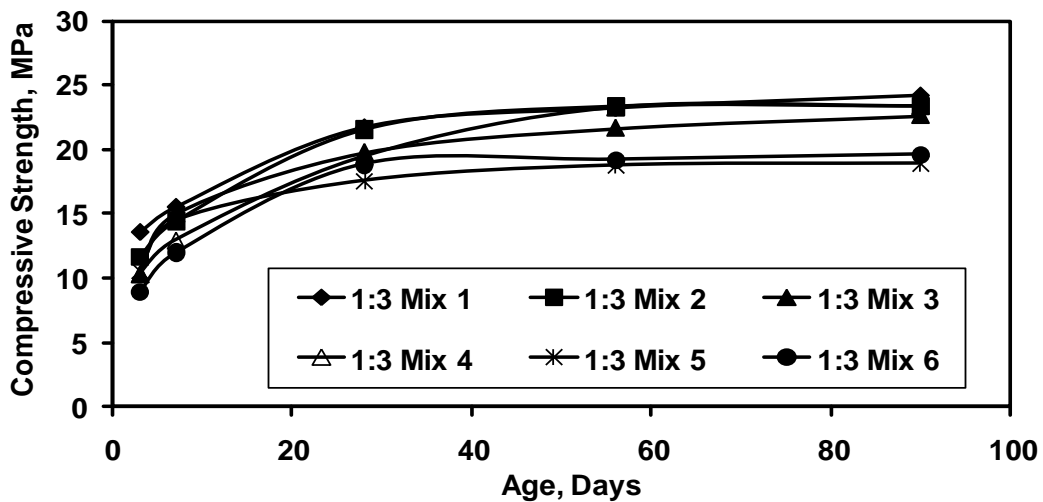


Fig 1 Compressive strength of 1:3 mixes

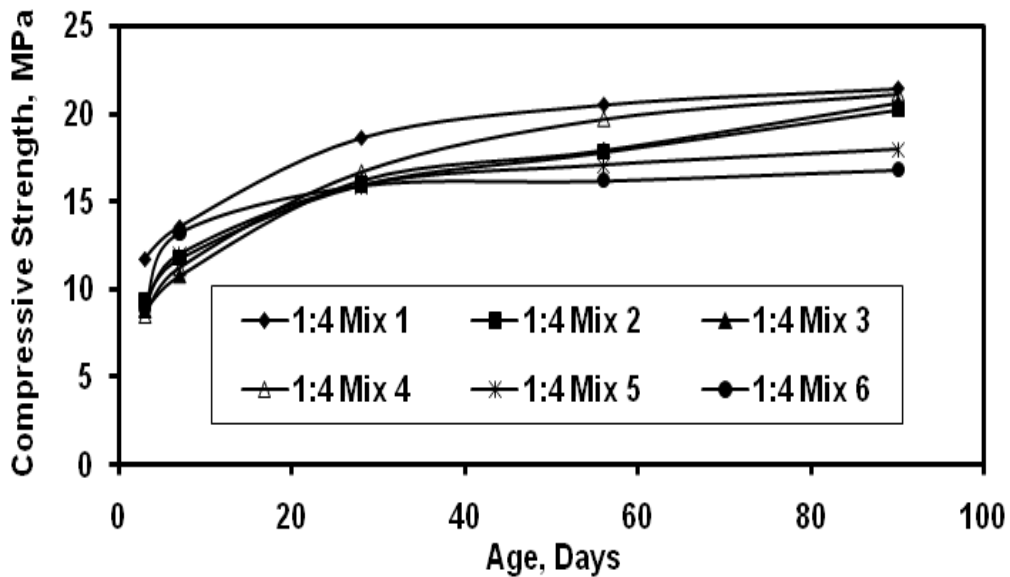


Fig 2 Compressive strength of 1:4 mixes

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.

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.

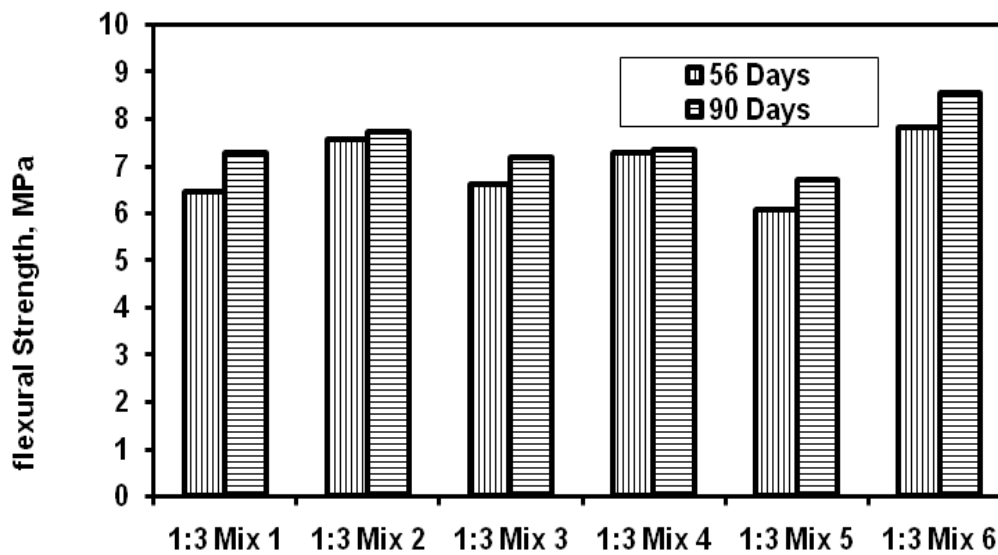


Fig 3 Comparison of flexural strength of 1:3 Mix

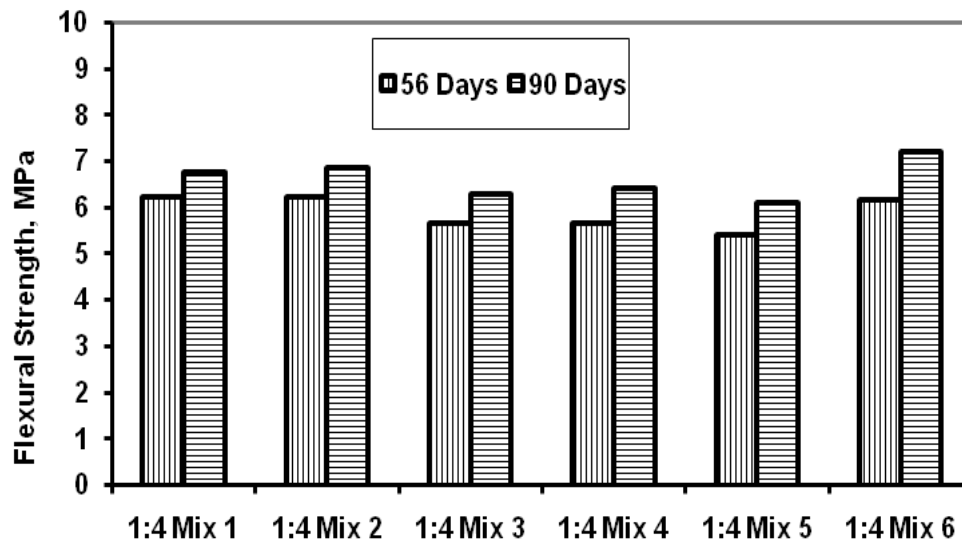


Fig 4 Comparison of flexural strength of 1:4 Mix

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.

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.

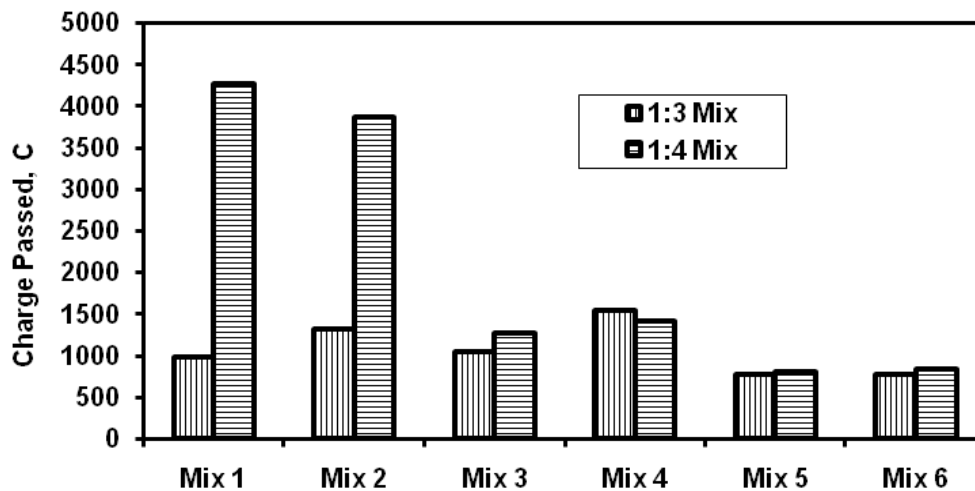


Fig 5 RCPT test on different mortar mix at 90 days

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.

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 MgSO₄.7H₂O 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.

$$\text{Change in length} = (R_x - R_l) \times 0.002$$

where R_x = dial gauge reading at any age * days.

R_l = 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.

V. CONCLUSIONS

1. The 50% replacement of M-sand with C-sand doesn't show any strength gain for 1:3 mix however, very nominal strength gain (4%) was observed for 1:4 mix at the age of 90 days.
2. The addition of NaOH with C-sand and M-sand reduces the compressive strength by 16% for 1:3 mix and 20% for 1:4 mix.
3. For flexural strength the 50% replacement with C-sand shows an increase of 2% than 100% C-sand for 1:3 mix at 90th day. The addition of NaOH with 50% C-sand shows 16% increase for 1:3 mix and 12% for 1:4 mix in flexural strength compared to mixes contain 50% C-sand without NaOH at 90th day.
4. The presence finer particles of C-sand improve the pore structure of mix by reducing pore connectivity thus reduces the (chloride ion) permeability.

5. The presence of NaOH in various mixes may lead to erroneous results in RCPT. This is probably due to the presence of NaOH solution on the anode side of the test specimen. This issue can be rectified by considering combination of other electrolytes.
6. The replacement with C-sand cause less shrinkage, a combination of C-sand and M-sand gives better result. The reduction in shrinkage may be because of particle packing in C-sand mortar specimen.
7. The use of NaOH causes expansion due to acid-base reaction.

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