International Journal of Scientific & Engineering Research, Volume 4, Issue 8, August 2013
ISSN 2229-5518

Studies on Suitability of Fly Ash Based Cement Mortar Dry- Mix with Quarry- Dust as Fine Aggregate

Shefeena.N, Dr. Nazeer M, Muhammed Siddik A

Abstract— Demand for producing durable and environmental friendly construction material is in an alarming state. Exploration of river sand results in environmental issues such as deepening of ground water table. The replacement and reduction in consumption of this material is highly required to achieve sustainable construction. Supplementary cementitious materials proved to be effective to meet most of the requirements of the durable concrete / mortars. Usage of quarry dust and pozzolanic materials from industrial waste such as flyash are receving more attention these days as their uses generally improves the properties of concrete/ mortar. This study aims to find the effect on strength and sulphate durability of masonry mortars while using quarry dust as fine aggregate and replacement of part of cement with flyash. Ordinary Portland cement (OPC) is partially replaced with fly ash at the dosage of 0,20,30,40 and 50 per cent by weight of cement. The binder to quarry dust ratio of 1:3, 1:4 and 1:6 and the water to binder ratio was selected as 0.65,0.75 and 0.85 based on the workability requirements. Mortar cubes cured on normal water and in sulphate rich water are tested for compressive strength, at different ages of 3,7,28,56 and 90 days. To study the volume change due to the exposure to sulphate, the change in length of mortar prisms were observed. Test results indicate that the early age strength of mortar is less and strength gain was observed at higher ages. Durability aspect also shows good response with the usage of flyash. The 20 percent fly ash replacement shows a better response in respect strength and durability.

Index Terms—Durability, Fly ash, Mortar, Pozzolanic material, Quarry dust, Strength, Sulphate attack,

1. Introduction

The river sand deposits are the most common fine aggregate used in the preparation of cement mortar. Nowadays, the natural river sand has become very rare and costly. Unscrupulous and uncontrolled quarrying of sand has results in lowering of water table, soil erosion and under-mining of bridge foundation. Furthermore, a ban based on environmental reasons on dredging operations has created a crisis for construction industry in certain parts of India. Hundreds of stone crushing plants in our country generate several thousand tonnes of quarry dust every day. If it is possible to use this in making mortar/concrete by replacement of river sand, then it will not only save the cost of construction but at the same time will solve the problem of its disposal. Approximately 100 million tonnes of fly ash are produced in India annually from the combustion of coal, and this is increasing rapidly due to the growth in the demand for energy. It is predicted that the amount of fly as produced in India will double in the next ten to fifteen years. Unused fly ash in large quantities leads to environmental issues and its storage/disposal will be expensive.

A large volume of literature is available in the area of use of supplementary cementitious materials in mortar/concrete as partial replacement to cement **(Ghrici, et al., 2007;Chindaprasirt et al., 2005 (a,b); Curcio and DeAngelis, 1998;). Misra (1984),** investigated the effect of shape and size of fine aggregate on the strength of cement –sand mortars and the possibility of replacing sand by crushed stone dust. The water requirement and the compressive strength was found higher for crushed stone dust as compared to that for conservative sand samples for same grading and mix proportions.

2.EXPERIMENTAL DETAILS

2.1 Materials

Ordinary Portland Cement (OPC) confirming to **IS 12269** (53 Grade) having specific gravity 3.12 and standard consistency 31.25% was used for the experimental work. Fly Ash from Tuticorin Thermal Power Plant and conforms to ASTM Class F. The density and specific gravity of fly ash was around 1.108g/cc and 2.083 respectively.

Quarry dust having specific gravity 2.82 and fineness modulus 1.80 was used as fine aggregate. The maximum particle size of fine aggregate was limited to 2.36mm. water from the main supply was used for mixing mortar, curing and the preparation of sulphate exposure medium.

2.2 Mix proportion

The mix design basically involves the determination of water – binder ratio for required consistency of mortar. This was determined by flow test by varying content of water on all mix compositions used in the investigation. The different mix proportions are 1:3, 1:4 and 1:6 (cement: quarry dust) with w/b of 0.65, 0.75, and 0.85 respectively. The cement content was replaced by fly ash by 0, 20, 30, 40 and 50% volume of cement.

2.3 Compressive Strength

Mortar cubes of 50mm size were cast and cured in water to determine the strength development. Specimens were tested at 3, 7, 28, 56, and 90days of casting. To study the influence of sulphate attack, the curing medium used was a sulphate solution prepared

ISSN 2229-5518

by dissolving 50g of $MgSO_4.7H_2O$ in one litre of water, which corresponds to a total sulphate ion concentration of 20000ppm.

2.4 Volume change

Cement mortar prism specimens (2.5cm x 2.5cm x 30cm) prepared for the determination of the change in length during exposure are cured in different exposure regimes as mentioned in strength determination.

3. RESULTS AND DISCUSSION

3.1 Compressive strength

The compressive strength determined on 50cm mortar cubes made of different binder material proportions and different cementitious materials-quarry dust proportions are presented in **Fig. 1.**

It is observed that for 1:3 mix with cement as the only binder, the compressive strength increases with age up to 56days. However, a strength reduction was observed beyond this age, probably due to the extended exposure to water (curing) results in the leaching of $Ca(OH)_2$ and weakening the micro-structure. The partial replacement of cement with fly ash in 1:3 mix causes reduction in compressive strength at early ages, however all 1:3 compositions show comparable compressive strength at 28days. Further, extended water curing results in increased strength for mixes containing higher proportion of fly ash (>40%). This indicates that the delayed strength development of such mixes is due to the microstructure modification by the pozzolanic reaction **[Fig. 1(a)].**

From **Fig. 1(b)** (for 1:4 mix), the compressive strength progressively decreases with the period of moist curing for mortar mix in which cement is the only binder. This is probably due to the leaching of $Ca(OH)_2$. But for mixes with higher fly ash content (>30%) there is an increase in compressive strength beyond the age of 28days because of pozzolanic reactivity and the resulting microstructure modification. The above mentioned improvement was more pronounced in case of leaner mixes (1:6 mix).

3.2 Compressive strength in sulphate environment

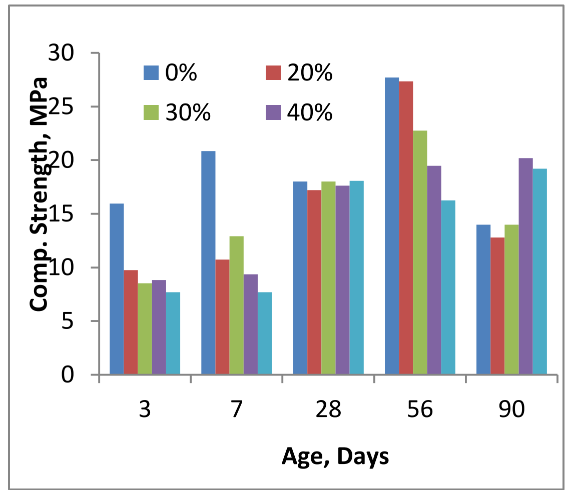
Mortar specimens exposed to sulphate environment are tested at designated ages and the compressive strengths of different mixes are plotted against the fly ash content in the mix and are presented in **Fig.2.**

Investigating the performance of 1:3 mix **[Fig.2(a)]** it is observed that the compressive strength of mortar increases with the duration of exposure irrespective of the fly ash content in the mix. However, the percentage increase in strength increases with the fly ash content in the mix. That is the highest percentage of increase (347%) was observed for 1:3 mix containing 50% fly ash.

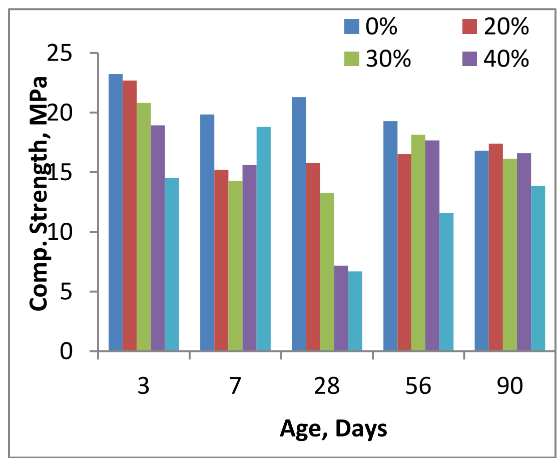
In case of 1:4 mix, the control mix shows strength deterioration. The same trend may be observed for 1:4 mix made with 20% fly ash replacement. However, in general 1:4 mix with higher fly ash content (>30%) shows strength gain with age on exposure to sulphate environment **[Fig.2(b)].**

The leaner mix 1:6 with cement as the only binder does not show any appreciable strength loss on exposure to sulphate environment. Also, most of the fly ash admixed leaner mortar mixes experiences strength deterioration during exposure to sulphate environment **[Fig.2(c)].**

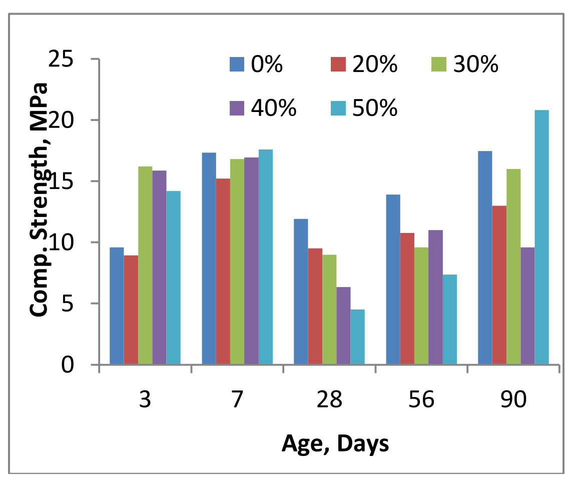
In general it indicate that the sulphate induced strength deterioration of cement mortar specimens increases with the decrease in cement content (that is leaner mixes are more prone to sulphate induced strength deterioration).



(a) 1:3 Mix

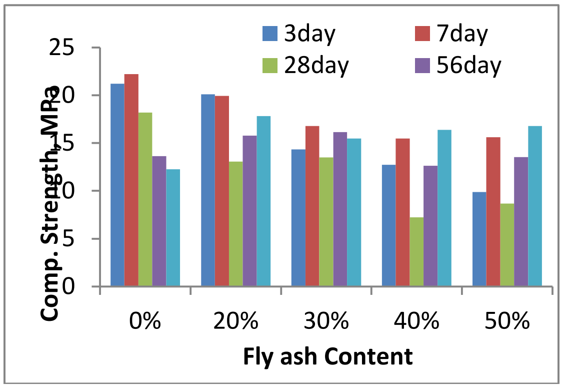


(b) 1:4 Mix

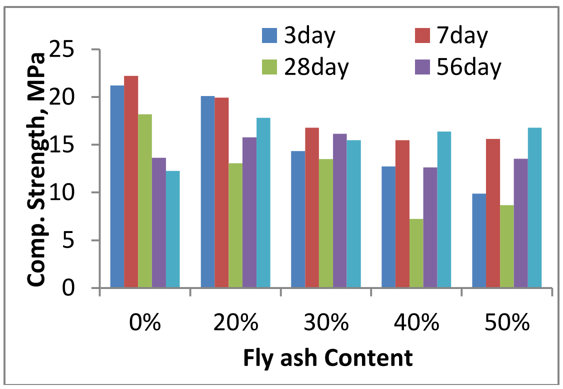


(c) 1:6 Mix

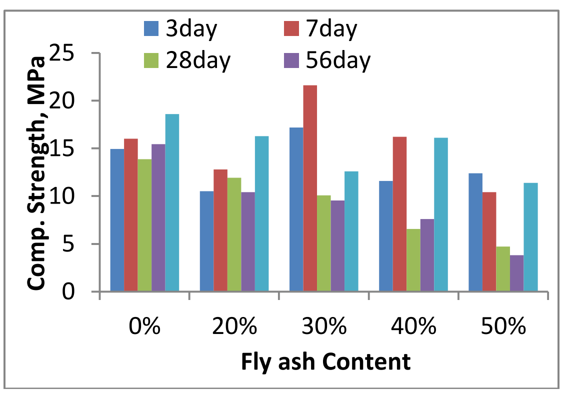
Fig. 1. Compressive strength of mortar cubes



(a) 1:3 Mix



(b) 1:4 Mix



(c) 1:6 Mix

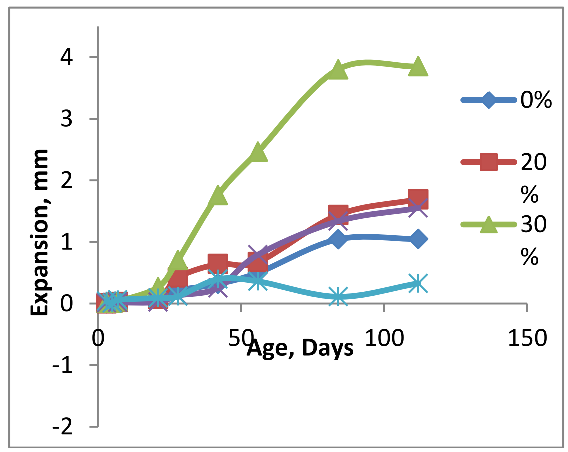
Fig. 2. Compressive strength of mortar cubes in sulphate environment

3.3 Volume change

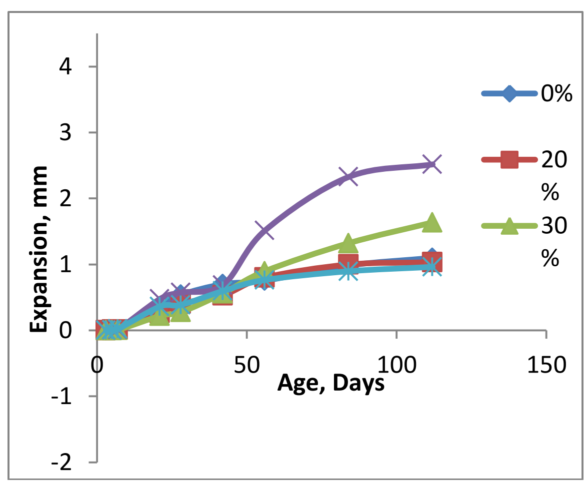
Cement mortar prism specimens (2.5cm x 2.5cm x 30cm) cured in water are taken out at intervals and the length change is determined. The expansion values thus observed for different mixes are plotted against the age of the specimen and presented in **Fig.3.** It is observed that all specimen experiences increase in length and the rate of increase declines with the age except for leaner mix (1:6 mix). For richer mixes (1:3 and 1:4) the least expansion was reported by the mix containing higher percentage of fly ash (50%).

The expansion calculated for the specimen exposed to sulphate environment is presented in **Fig.4.** Comparing with **Fig.3,** it may be observed that the expansion reduces due to the exposure to sulphate environment. However, certain mixes (1:4 mix with 30% fly ash and 1:6 mixes with 30% and 50% fly ash) undergo decrease in length during sulphate exposure.

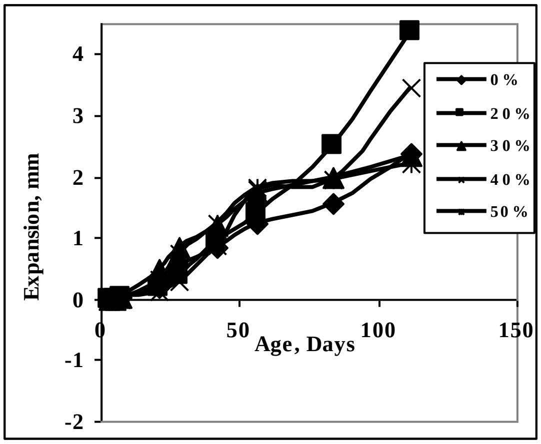
An attempt is made to estimate the sulphate induced length change of mortar prism by subtracting the change in length observed for specimens cured in water from the change in length of specimens which are exposed to sulphate environment. The variation of this with the age of specimen is presented in **Fig.5.** It is observed that most of the specimens show the trend of decrease in length (both control mix and mix with 50% fly ash in 1:3 and 1:4 mix are exceptions). From **Fig.5(c)** it may be concluded that leaner mix (1:6) shows better performance with respect to the deteriorating expansion due to sulphate attack.



(a) 1:3 Mix

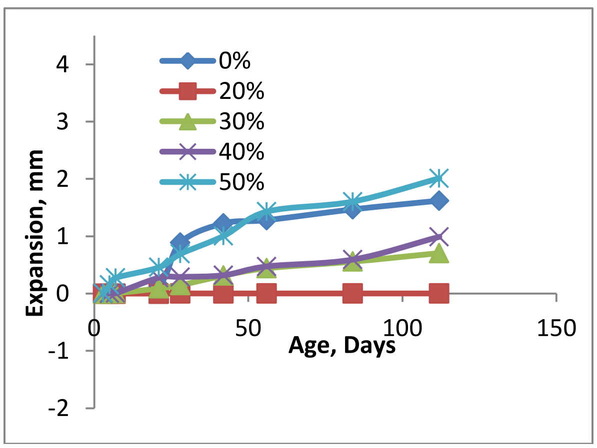


(b) 1:4 Mix

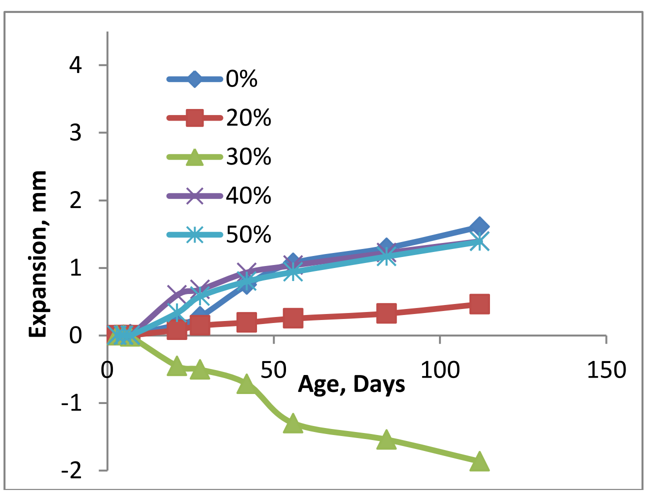


(c) 1:6 Mix

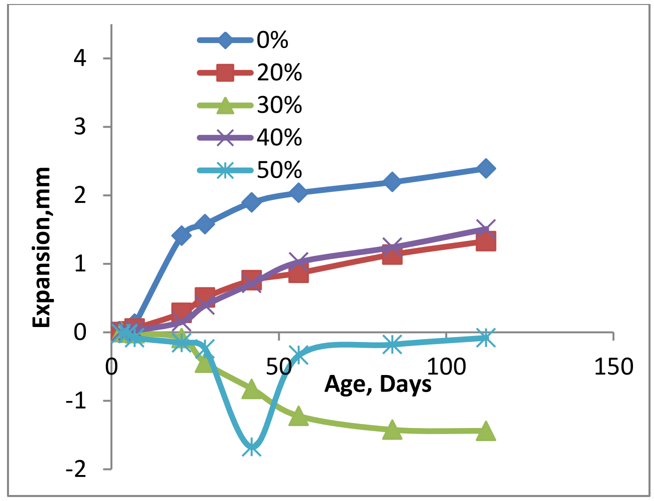
Fig.3. Expansion of mortar prisms under normal curing condition



(a) 1:3 Mix

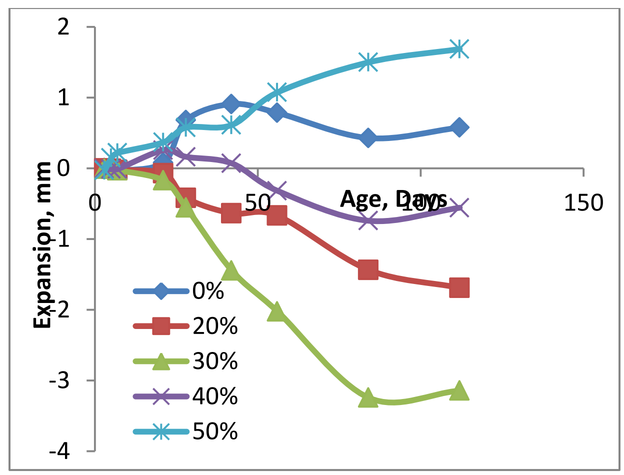


(b) 1:4 Mix

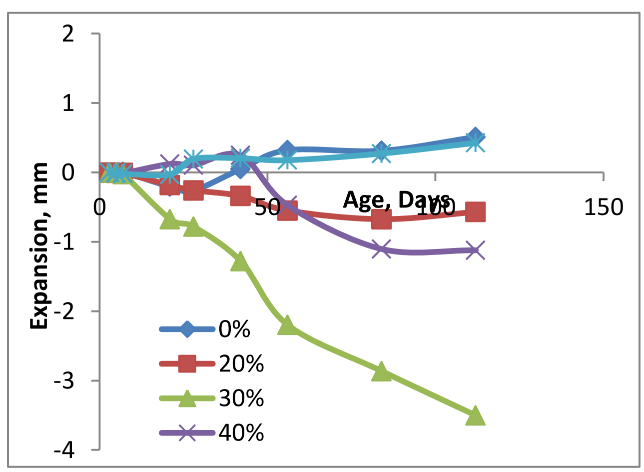


(c) 1:6 Mix

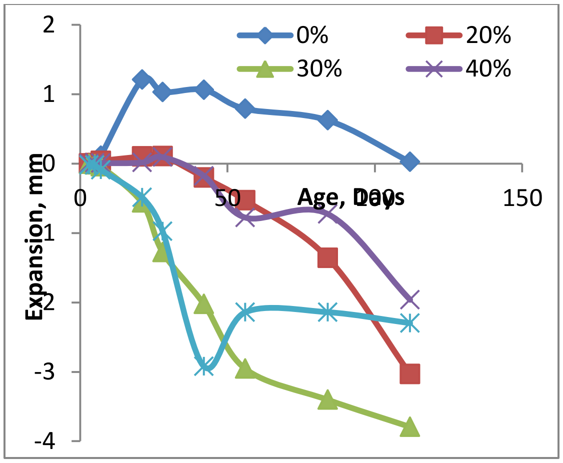
Fig.4. Expansion of mortar prisms under sulphate exposure



(a) 1:3 Mix



(b) 1:4 Mix



(c) 1:6 Mix

Fig.5. Sulphate induced length change of mortar prisms

4. CONCLUSIONS

In the present investigation, the strength and sulphate induced durability issues of a ready-to-use dry mortar mix was studied. The study revealed the mortar mix modified by replacing sand with quarry dust performs similar to that of the conventional mix, further a partial replacement of cement with the fly ash improve the later age strength and sulphate resistance of mortar.

5. REFERENCES

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