Feasibility study of fly ash as a substitute for fine aggregates in concrete and its behavior by alternate wetting and drying Process

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Abstract. The lack of quality material in today's rocks has led to the search for other sources. The possibility of using ash fly, a byproduct of the commercial sector, as a substitute for good mixing has been investigated in this study. This article presents the results of a research experiment conducted to evaluate the strength of concrete with fly ash instead of natural sand for 45 alternating wet-dry cycles. Consider 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70% and 80% replacement of fine aggregate with fly ash and subject the concrete to 45 alternate wet-dry cycles. According to IS standards, various mechanical properties of strength tests such as compressive, tensile, bending, shear and impact strength are studied in this research work. Experimental results show that the strength of ordinary concrete with fly ash obtained from natural sand greatly increases in the dry-wet transition. For this reason, it is possible to use fly ash in wet and dry transitions by combining well and it can be used effectively in concrete.

Keywords: Fly ash, fine aggregate, alternating wet and dry cycles, and structural concrete.

1. Introduction

Currently, the annual consumption of cement concrete in India is about 400 tons. This will obviously lead to a balance of sand, aggregate and other materials required to produce cement concrete. This naturally leads to the annual depletion of all natural resources associated with the production of cement concrete. In addition, the production of large quantities of cement requires a lot of energy causing CO2 emissions and related problems. Therefore, scientists are working to find cementitious materials that can partially or completely replace cement. Accordingly, it is recommended to partially replace the cement with fly ash, blast furnace slag, silica powder, metakaolin and rice husk ash [1].

Therefore, part of the industrial waste is effectively used in the production of concrete. However, the lack of abundance of stone led to the search for other sources. Fly ash is often used as a cement substitute, concrete additive and in cement production. The partial replacement of cement with fly ash was sufficiently studied by early researchers. Fly ash can
easily be used as a partial replacement for filler sand. Increasing the fly ash content increases the strength at a given density due to the pozzolanic properties of the fly ash [2]. Since most of the stone is an external element, it must withstand physical and chemical stress.

The dry-wet cycle simulates the return of rain and heat to the natural atmosphere, which promotes certain chemical and physical changes in rocks. Stones are resistant to wind, sun, rain, etc. is very sensitive to some combinations of such attacks are cyclical, such as wet and dry cycles [3]. The alternating wetting and drying cycles in concrete can affect structures in splash areas, buttresses, water retention structures, etc.

2. Literature review

After reviewing data from several research papers, it was found that further data should be available for natural sand for the following reasons:

1. Depletion of natural sand and the need to further reduce costs. The growth of stone production has led to an increased demand for finding alternative materials for natural sand.
2. The results show that the addition of quarry dust partially replaces the sand in the concrete and causes a decrease in the strength for mechanical properties of concrete.
3. Using coal under ash instead of natural sand in concrete reduces the density of the concrete and delays the setting time of the concrete.
4. The data also show that, the study is silent on durability properties of concrete such as acid effect, sulfate effect, chloride effect, constant temperature rise, variable wetting and drying and shrinkage when fly ash is used instead.
5. Though the literature is rich in publications regarding the effect of fly ash as replacement of cement but is silent in respect of fly ash as an alternate material for replacement of natural sand in concrete.

3. Materials Used

a) OPC 43 quality cement [IS 8112-1989], specific gravity 3.15 [16].

b) Locally available sand meets Zone III with a specific gravity of 2.68 and the modulus of fineness 2.24 [15].

c) The coarse aggregate size used in the research experiment was 20 mm and its specific gravity was 2.80 [15].

d) Fly ash, the fly ash used in this experiment was supplied from Shaktinagar thermal power plant in Raichur, Karnataka, India and the specific gravity of class F fly ash is 2.20.

e) Use polycarboxylate ether based high efficiency water reducer to improve performance and the amount is 0.3% by weight of cement.

f) The ratio of the mixture used is 1:2.2:4.28, hydrated cement ratio = 0.45 for M30 class concrete [13].
4. Methodology

1. Weigh the concrete components as the mixed and dry mix.

2. Replace natural sand with 0%, 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80% fly ash (by weight) [5].

3. Dry all materials with fly ash until smooth.

4. The required amount of water and the required amount of superplasticizer (Glenium B233) were added to this dry mixture and thoroughly mixed in the mixing bowl.

5. Remove all specimens from the water after 28 days of curing. Leave it in the open for a day, then soak it in water for a day. This includes wet and dry changes. The samples were subjected to 45 alternating wet and dry cycles.

6. According to IS standards, various mechanical properties of strength tests such as compressive [4], tensile, bending, shear [6] and impact strength [17,18] are evaluated for wet-dry cycles.

![Specimen kept for wetting](image-url)
5. Results and Discussions

5.1 Workability test results

![Graph showing variation of slump values with different percentage replacement of natural sand by fly ash](image1)

The above observations indicate, decreases the settling value as the percentage replacement of natural sand with fly ash increases. The reduction in slump is primarily due to the more cohesive and stiffer mix associated with higher fly ash content. In order to obtain a workable mixture, suitable flow agents must therefore be used.

5.2 Compressive strength test results

![Graph showing variation of compressive strength of concrete produced by replacing natural sand by fly ash and subjected to alternate wetting and drying](image2)
Based on the above observations, the compressive strength results obtained for different percentage replacements of natural sand with fly ash indicate that compressive strength improves at 10%, 20%, 30% and 40% replacement when alternately 45 wet and dry cycle. The percentage increase in compressive strength at 40% exchange level when concrete is subjected to 45 alternating wet and dry cycles is 14%. Above a replacement level of 40%, the compressive strength shows a decreasing trend. This may be due to the fact that at 40% rate, fly ash undergoes maximum pozzolanic reaction, which results in densification of the matrix and also effectively fills all the pores of the concrete. Fly ash particles with a replacement level above 40% remain unreactive and act as a filler without sufficiently affecting strength.

5.3 Tensile strength test results

![Tensile strength test results](image)

Figure 5: Variation of tensile strength of concrete produced by replacing natural sand by fly ash and when subjected to alternate wetting and drying
Based on the above findings, the splitting tensile strength results of sand-replaced fly ash concrete with 45 alternate wet and dry cycles clearly show an increase in tensile strength up to 40% replacement. After more than 40% replacement, the strength does not increase significantly. The percentage increase in tensile strength at the 40% replacement level when the concrete is subjected to 45 alternate wet and dry cycles is 14%. From the 40% exchange level, the tensile strength shows a downward trend. This may be due to the fact that at 40% rate, fly ash undergoes the maximum pozzolanic reaction, resulting in densification of the matrix, and also effectively fills all the pores of the concrete. Fly ash particles with a replacement level above 40% remain unreactive and act as a filler without sufficiently affecting strength.

5.4 Flexural strength test results

![Flexural strength test results](image)

**Figure 6:** Variation of flexural strength of concrete produced by replacing natural sand by fly ash and when subjected to alternate wetting and drying

**Fig. 7.** Flexural strength test (IS 516-1959)
Based on the above observations, the flexural strength results also show similar trends when material 45 is subjected to alternating wet and dry cycles. The percentage increase in flexural strength at the 40% replacement level when sand-replaced fly ash concrete is treated for 45 alternate wet and dry cycles is 12%. From the 40% replacement level, the flexural strength shows a decreasing trend. This is because at a rate of 40%, fly ash particles experience maximum pozzolanic reaction, which leads to densification of the matrix and in addition, it effectively fills all the pores of the concrete. Above 40% replacement rate, the fly ash particles only act as a filler without adding sufficient strength.

5.5 Shear strength test results

![Figure 8: Variation of shear strength of concrete produced by replacing natural sand by fly ash and when subjected to alternate wetting and drying](image)

Based on the above observations, the shear strength test results of sand-replaced fly ash concrete 45 in alternating wet and dry cycles clearly show that the shear strength increases up to the replacement level of 40%. The percentage increase in shear strength at the 40% replacement level when the concrete is subjected to 45 alternating wet and dry cycles is 19%. From the 40% replacement level, the shear strength shows a decreasing trend. This is because at 40% rate, the fly ash undergoes maximum pozzolanic reaction, forming a denser calcium silicate hydrate gel (C-S-H) and effectively filling all the pores of the concrete as well. Above 40% replacement rate, the fly ash particles only act as a filler without adding sufficient strength.
Fig. 9. Shear strength test arrangement & formula

Failure load \( F = P \frac{l_1}{l_1+l_2} \)
where, \( P \) = Failure load in KN
\( l_1 = 25\text{mm} \)
\( l_2 = 25\text{mm} \)

Shear strength is given by the relation
Shear strength = \( F/A \)
where, \( F \) = Failure load
\( A = \text{Area on which shear force is applied} = 150\text{mm} \times 60\text{mm} \).

Fig. 10. Shear strength test (IS 516-1959)
5.6 Impact strength test results

Figure 11: Variation of impact strength of concrete (for first crack) produced by replacing natural sand by fly ash and when subjected to alternate wetting and drying

Figure 12: Variation of impact strength of concrete (for final crack) produced by replacing natural sand by fly ash and when subjected to alternate wetting and drying

Similar observations were made in impact tests. The percentage increase in impact strength at a replacement level of 40% when sand-replaced fly ash concrete is subjected to 45 alternating wet and dry cycles is 62% leading to initial cracking and 58% to ultimate failure. This may be due to a better interfacial bond between the paste and aggregate, forming a denser CS-H gel with a 40% rate.

6. Conclusions

1. The compressive strength, split tensile strength, flexural strength, shear strength and impact strength are significantly improved in fly ash concrete with natural sand substitute at 40%
replacement level when subjected to 45 alternating wet and dry cycles compared to other replacement levels.

2. At a replacement level of 40%, the increase in compressive strength is 14% when subjected to 45 alternating wet and dry cycles.

3. At a replacement level of 40%, the increase in split tensile strength is 14%, flexural strength is 12%, shear strength is 19%, and impact strength is 58%.

4. The experimental results of this study suggest that Class F fly ash can be used as a partial replacement for natural sand in structural concrete, even when exposed to severe alternating wet and dry cycles.

References


13. IS 10262 -2009 :- Recommended Guide Lines for Concrete Mix Design.
17. IS: 516-1959: Method of Test for Strength of Concrete.
18. IS: 5816-1999: Splitting Tensile Strength of Concrete Method of Test.