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EFFECT OF FLY ASH ON WATER DEMAND AND STRENGTH OF A CONCRETE MIX

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ABSTRACT

The need to make concrete stronger, more workable and durable has led to increased research among scholars in the area of construction chemicals, especially cement dispersants or plasticizers. Fly ash seems to be the earliest, simplest and most common cement plasticizing compound; though not as active as the modern super plasticizers, but is still used in combination with them to achieve better results. This research studies the effect of fly ash on mixing water demand and 28-days strength of the hardened concrete at a constant consistency or slump. Five concrete mixes were studied containing 0%, 4%, 8%, 10% and 12% of class F fly ash, respectively, by weight of the cement content. The first mix containing 0% fly ash (control) was made with water-to-cement (w/c) ratio of 0.5, and it gave a slump of 30mm and a 28-days strength of 22.22N/mm^2. For the remaining mixes, approximately the same slump (or consistency) was maintained by increasing the quantity of fly ash while reducing the quantity of water needed. At 8% fly ash content, maximum strength of 34.67N/mm^2 and minimum water demand (effective w/c of 0.46) was obtained. Fly ash was then recommended to be used at 8%, by weight of the cement content, when used as a plasticizer alone, or in combination with other plasticizers, to achieve maximum results.

KEYWORDS: Admixture, concrete, consistency, fly ash, plasticizers, strength, water demand.

1.0 INTRODUCTION

Often concretes are purposely made to be stronger, more workable and durable, depending on the site conditions and level of exposure of the proposed structure to the environmental elements. The general way of achieving this is by altering the relative quantities of the constituent materials of concrete: cement, sand, gravel and water. A more pragmatic way of doing this is by inclusion of admixtures (plasticizers) in the concrete mix (Shetty, 2009).

From the perspective of mix proportions, at aggregate-cement ratio of 2 or less, change in cement content influences the workability of concrete remarkably. The workability of concrete indirectly affects the strength of concrete by enabling better compaction of the concrete mix to be achieved (Jacksn, 1981). Above aggregate-cement ratio of 2 the effect of the aggregate properties (size, grading, shape, surface texture, coarse-to-fine ratio, etc) play more prominent role on the workability of the fresh concrete mix than the properties of cement. For a particular water-to-cement ratio and workability the quantity of aggregate that goes into the concrete depends on the shape, surface texture and other physical properties of the aggregate.

For a fully compacted concrete the strength of the hardened concrete at a given water-cement ratio does not really depend on coarse-to-fine ratio; and this informed the theory of *optimum coarse aggregate content for producing highest workability for a given water-to-cement ratio*, proposed by Hughes (1960), to achieve maximum economy in concrete mix design as aggregates are cheaper than cement.

A more direct effect on the strength and workability of a concrete is observed when water-to-cement ratio of the concrete is changed. The higher the water-to-cement ratio the lower the strength and verse versa. Increasing the water-to-cement ratio increases the workability, but reduces greatly the durability of the hardened concrete. On the other hand reducing the water-to-cement ratio to increase strength greatly reduces the workability of the fresh concrete, hampering full compaction of the concrete.

Workability admixture or a water reducer plays this role better. While the water-to-cement ratio is reduced, as admixture is added, the strength of concrete increases and, at same time, ensuring good *compactibility* of the fresh concrete (Saeed *et al*, 2005; Shah *et al*, 2014 and Muhit *et al*, 2013). Though fly ash is not a proprietary water reducer, it is known to improve the strength and workability of concrete (Adinna *et al*, 2020; Feber, 1987). It's used mainly as a partial substitute for cement, but may have a secondary role of serving as a water reducer in concrete, as acknowledge by many literatures in concrete mix design (COREN, 2007; ACI, 1994; DOE, 1988 and IS, 1982). This research is aimed at determining the percentage reduction in water demand of a concrete mix and percentage improvement in strength for a given quantity of fly ash content in the concrete when constant consistency is maintained.

The result of this work will serve as a guide for optimal use of fly ash as a water reducing admixture in concrete especially when used in combination with other water reducers or plasticizers.

2.0 MATERIALS AND METHODS

(i) Materials

The materials used include granite rock aggregate of 18mm maximum size as coarse aggregate, river sand of 3mm maximum size as fine aggregate. These were all sourced locally from dealers. Cement used was a grade 42.5R, rapid hardening Portland limestone cement, by Nigerian standard. The fly ash used was *a class F* fly ash obtained from a thermal power plant at Oji-River, Enugu State, Nigeria. The fly ash was sieved with a 43µm B.S sieve size to remove larger sizes to enhance *pizzolanic* reactions.

Equipment used were concrete cube mold (150mm x 150mm x 150mm), a weighing balance, slump test apparatus, measuring scale, a curing tank and a universal testing machine.

(ii) Experimental Procedure

A nominal mix proportion of 1:2:4 (cement, fine aggregate, and coarse aggregate, respectively) was used with an initial water-to-cement ratio *(w/c)* of 0.5.

The materials were weighed out for five sets of concrete mixes, each set containing the same weights of cement, sand and gravel for a normal *grade 20* concrete, but with varying percentages of fly ash by weight of the cement content. The first mix was made with 0% percent fly ash and a water-to-cement ratio of 0.5, and to serve as control. Slump test was carried out on it, and two concrete cubes cast from the fresh concrete. The second set was just like the first, but made with 4% fly ash by weight of the cement content. The water, however, was added gradually while mixing until it reached the consistency of the first concrete that was mixed – this was proved by measuring the slump severally until it became approximately equal to that of the first mix. The quantity of water left of the quantity required for a 0.5

water-to-cement ratio that was weighed out was determined, and the water used calculated by simple subtraction. This was again recorded. Two concrete cubes were also cast from the second concrete mix. This procedure was applied to the third, fourth and fifth sets of concretes, but with 8%, 10% and 12% fly ash contents, respectively. The resulting ten concrete cubes were cured for 28 days in water and tested for compressive strength at 28 days with the use a universal testing machine. The compressive strengths of the hardened concrete, the effective water-to-cement ratio calculated from water used, percentage of water saved from the original 0.5 water-to-cement ratio, percentage increase in strength relative to the control cubes were all calculated and tabulated for analysis.

3.0 RESULTS AND DISCUSSION

The results of the compressive strength test, workability test, water savings, etc. are recorded in Table 1.0. Fig 1.0 and 2.0 explain this result further.

Table 1.0: Compressive Strength, *workability* and water savings results.

Fly ash content (%)	*Slump* (mm)	Effective water-to-cement ratio	Percentage water saved (%)	Average compressive strength (N/mm^2)	Percentage increase in strength (%)
0	30	0.5	0	22.22	0
4	31	0.48	3.12	23.67	4.76
8	32	0.46	6.77	34.67	35.9
10	30	0.49	2.18	24.22	8.26
12	31	0.48	2.38	22.89	2.91

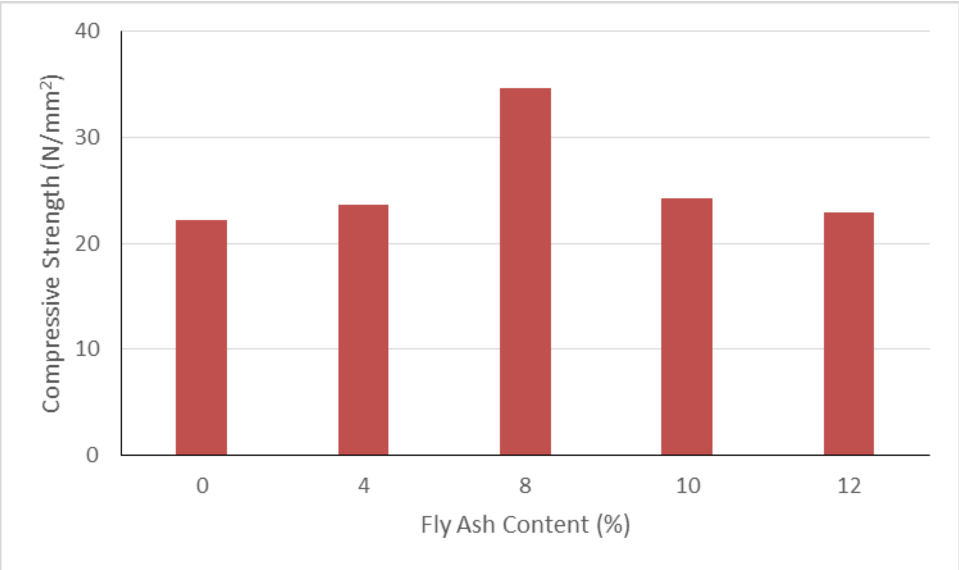

Fig. 1.0: Effect of fly ash on compressive strength of concrete at average constant consistency of 31mm *slump*.

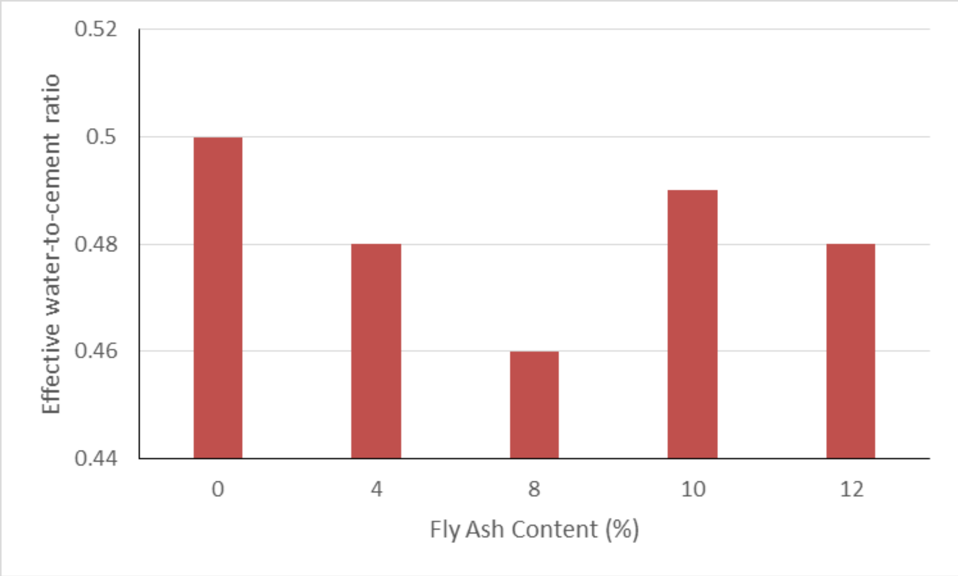

Fig. 2.0: Effect of fly ash on water-to-cement ratio of a concrete at average constant consistency of 31mm slump.

From the tabulated results in Table 1.0, it can be observed that at an average constant consistency of 31mm slump the water required or demanded by the concrete mix reduced with increase in fly ash content. At 8% fly ash content, a minimum value was reached where the effective water-to-cement ratio reduced to 0.46 from the original value of 0.5 at 0% fly ash content. Above 8% fly ash content, the water-to-cement ratio increase at the same rate as it previously reduced. see Fig2.

The compressive strength also increased with increase in fly ash content and reached its maximum value of 34.67N/mm^2 at 8% fly ash content. The compressive strength also increased in inverse proportion with the water-to-cement ratio, which is in agreement with *Abraham's law*. See Fig1.

5.0 CONCLUSION AND RECOMMENDATIONS

Though this research does not extend to other concrete grades and initial water-to-cement ratios, we can conclude that the results will be different as the cement content and initial water-to-cement ratio changes, as this also depends on the *pozzolanic* reaction of the fly ash, but the trends may be assumed to be similar.

Based on the results obtained in this experiment and the facts about *pizzolanic* effect of fly ash in concrete. Fly ash is therefore recommended as a water reducer in concrete. For a grade 20 concrete at initial water-to-cement ratio of 0.5 the 28-days strength can be improve by

35% as the water-to-cement *(w/c)* reduces to 0.46 at 8% fly ash content by weight of cement used. Fly ash is also used in combination with other water reducers that work in a different ways, 8% fly ash content by weight of cement can also be applied to achieve maximum result in 28-days strength in such cases.

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