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A STUDY ON UTILIZATION OF FLY ASH IN CONCRETE FOR SUSTAINED CONSTRUCTION

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ABSTRACT

The term of sustainability gets more popularity among architectures, engineers and owners of newly designed buildings. Engineers try to produce new designs and make a link between long-life structures and more environmental friendly buildings. Using fly ash is an effective way to make concrete much more sustainable with less impact on environment, energy and reduces CO2 emissions as well. This was achieved by partial replacement of cement with high volume of fly ash. In this study five basic concrete mixes were considered, first mix was ordinary Portland cement with no replacements, other four mixes were cement replaced with fly ash by the following percentages 15%, 25%, 35%, and 50%. Compressive strength of concrete was investigated and found that mixes containing 15% of fly ash gave the best result (50 MPa) in 28 days. It is recommended to test these mixes before use in construction projects.

***KEYWORDS**: Portland Cement, Fly Ash, Sustainability, Compressive Strength, Durability*

1. INTRODUCTION

Fly ash, which is a waste material that produced by thermal power plants in large quantity, is used in concrete as a mineral admixture to improve the durability and compressive strength of concrete. Fly ash not only used in normal buildings but also used in various infrastructures such as long span bridges, high rise buildings, dams and tunnels to achieve durability in concrete and to avoid micro-cracks that come from too much heat of hydration due to use large quantity of cement [1]. Fly ash not only improves the engineering characteristics of concrete but also it has a

good impact on environment. Manufacturing each Kilogram (Kg) of Portland cement emits almost 1 Kg of CO_2 to the atmosphere [2]. Thus, construction materials contribute to 5-8% of all worldwide anthropogenic CO_2 emissions [3]. Obviously, raw materials are finite resources and one day will be finished in nature, so concrete structures are designed for life time of 50 years. With the help of being performing some concrete mixtures, some structures now designed for the life time of 100 years which means a great achievement in terms of sustainable development [4]. In addition, just in Turkey every year 15 million tons of fly ash is produced as industrial by-product material from the combustion of thermal power plants and only 1% of this amount is used in construction industry. Thus, to compensate the raw materials that minimized continually from nature, the rate of using fly ash should be increased [5]. The main aim of this paper is to investigate the compressive strength of concrete in which cement is replaced by fly ash with up to 50%. To achieve this goal a target of 28 day compressive strength of 30 MPa was prepared.

2. EXPERIMENTAL PROCEDURE

2.1 MATERIALS AND CONCRETE MIX DESIGN

Five different mixes were investigated for the concrete with natural aggregate. The first mix was a control mix and did not contain any fly ash while in other four mixes the cement was replaced by fly ash with 15%, 25%, 35% and 50% respectively. The cement used was Type 1 ordinary Portland cement. The fly ash used was complying with ASTM 618 with natural, round and smooth aggregate sieved to 19mm. Both coarse and fine aggregate were washed, dried, and been kept for 24 hours before use as shown in Figure 1.Different water/cement ratio has been employed for all the mixes which are shown in Table 1. All mixes were designed based on ACI 211 Report [6].The amount of materials is shown in Table 1.

FIGURE 1. Preparing the samples

TABLE 1. Quantities of used materials in Kg/m^3

Item	Cement	Fly ash	Sand	Aggregate	Water	w/c ratio
0 % fly ash	457.7	0	612.7	1143.5	200	0.437
15% fly ash	389	68.7	612.7	1143.5	180	0.393
25% fly ash	343.3	114.4	612.7	1143.5	180	0.393
35% fly ash	297.5	160.2	612.7	1143.5	200	0.437
50% fly ash	228.9	228.9	612.7	1143.5	200	0.437

2.2 MIXING AND CASTING PROCEDURE

All concrete mixes were prepared and mixed in a laboratory pan mixer. After drying fine and coarse aggregate they were blended for about 1 minute. Then cement and fly ash were added and blended for one more minute, and then water was added to the mix gradually to obtain a uniform batch. Cube samples were casted and compacted using a vibrating table until large bubbles were removed from cubes.

2.3 CONCRETE MECHANICAL PROPERTY (COMPRESSIVE STRENGH)

This study mainly focuses on compressive strength of concrete because it is the most important required factor by structural designers. Concrete samples were casted in cubes of 100mm, 100mm, 100mm dimensions and samples were cured for periods of 28, 60 and 90 days. It is reported by [7] that the fly ash has a negative effect on early ages strength of concrete. Therefore, later ages such as 60 and 90 days were chosen to examine the long term effect of fly ash on the strength. After curing the specimens were kept in a water tank for each period, three samples were tested per mix at each age i.e. 45 cubes were tested in total.

3. RESULTS AND DISCUSSION 3.1 WORKABILITY

Except for first concrete mixture which contains no fly ash other mixtures show a good workability in laboratory conditions. In other words, using fly ash leads to reduce w/c ratio up to a certain amount. Previous studies show that the shape particles of fly ash are spherical which help to mix particles easily and this fact could be felt during work. As shown in table 1 adding 15% of fly ash causes reducing water by 10% to produce the same level of slump as plain concrete. Reduce water from 200 Kg/m^3 to 180 Kg/m^3 for the same level of slump will produce more cohesive concrete and reduce segregation. The same situation will be true when cement replaced by 25%of fly ash. These results were consistent with other researcher's results which can be found in literature [9]. However, when the amount of cement are replaced by 35% &50% the amount of water added by 10% to obtain the same level of slump because the fineness of fly ash. Therefore, the results that obtained from experiments were satisfied with literature.

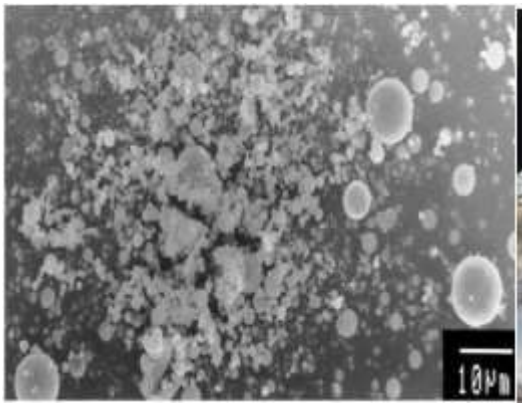

FIGURE 2.Fly ash particles [8]

FIGURE 3. Slump test

3.2 COMPRESSIVE STRENGTH AT 28 DAYS

The strength of concrete is the property most valued by structural designers and quality control engineers because if the compressive strength of concrete achieved the required strength at 28 days it means the cube sample results are accepted. But, in fact there are some other factors that effect on the properties of concrete in short and long term for example porosity, w/c ratio, curing, and types of aggregates. Porosity is an important factor that has fundamental inverse relationship with strength [10]. Since fly ash particles are finer than cement particles that would reduce the concrete porosity and improve permeability as well, this answer can be seen when cement replaced up to 15% of fly ash and then at 28 days a higher compressive strength can be obtained compared to normal Portland cement (average of 48.75 MPa vs. 44.87 MPa) respectively. Even, when using fly ash up to 25% almost an average of 42.33 MPa can be obtained. In addition, w/c ratio is another important aspect in determining the strength of concrete. Regarding to figure 2 that shows fly ash particles are spherical which leads to improve the workability of concrete paste. This can be taken as an evident that 15 &25% of replacing fly ash need less water as shown in table 1 and caused to increase the strength of concrete. As a result, it can be said that replacing cement by up to 25% of fly ash given a required strength at 28 days with less w/c ratio and more workable cement paste.

However, in commercial practice the dosage of fly ash is limited to 15%- 20% by mass of the total cementitious material [4] but in this study cement was replaced to fly ash up to 35% and 50%. The reason why limited to use fly ash up to 20% because it has a beneficial effect on the workability and cost of concrete but it may not be enough to sufficiently improve against sulfate attack and durability of concrete. This research shows that using fly ash by 35% and 50% has a negative impact on early strength and longer initial setting time due to the low reactivity of fly ash. An average of 26.55 MPa and 24.12 MPa were obtained for replacing fly ash for 35% and 50% respectively. Some research has been carried out to overcome this problem by activating fly ash. One method was to add an alkali activator such as 1 or 2% NaOH or KOH into concrete mix. Another way to get the same outcome was to use lime to mix with fly ash for a few days before incorporating the fly ash into the concrete mix [11]**.** Therefore, it is not recommended to use fly ash more than 25% at 28 days.

FIGURE 4. Strength at 28 days

3.3 COMPRESSIVE STRENGTH AT 60 DAYS

It has been said that using fly ash as cement replacement has a negative impact on early strength of concrete so the 60 and 90 days period has been considered. It has been shown that replacing cement by 15% with fly ash had the highest compressive strength by an average of 51 MPa, then 25% of fly ash given an average of 50.55 MPa at the same period. The abovementioned results show a good performance of fly ash when replaced instead of Portland cement. In case of 35% - 50% of using fly ash an average of 33.3 & 29.70 MPa can be obtained for 60 days span. In conventional design method structures are designed based on 28 days concrete compressive strength. But if the time is not a big issue structures could be designed for long life service with better durability and more sustainability particularly during designing of infrastructures such as dams and other concrete mass structures.

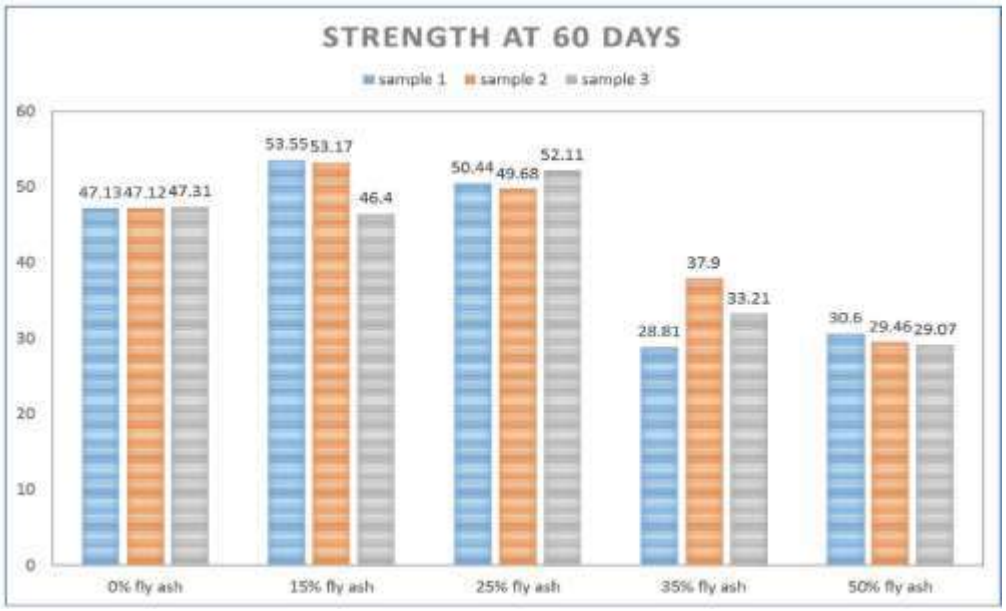

FIGURE 5.Strength at 60 days

3.4 COMPRESSIVE STRENGTH AT 90 DAYS

It can be seen from figure 6 that 0% of fly ash i.e. concrete with no replacement of fly ash had an average of 48.75 MPa whereas the average was 44.87 MPa at 28 days which can be seen as small improvements in term of strength. Meanwhile, at 90 days strength of concrete containing 50% of fly ash had an average of 33.3 MPa that means more 9 MPa higher than normal Portland cement at 28 days which was almost 24.12 MPa. Without considering time, fly ash can be used up to 50% and get the required strength at 90 days and solve slow early strength of concrete by using superplasticizer or alkali activators. As shown in table 1, 457.7 Kg of normal Portland cement was required for $1m^3$ of concrete, but if cement was replaced by fly ash up to 50% this amount will reduce to 228.9 Kg of Portland cement that leads to save 228.9 Kg of Portland cement and save 228.9 Kg of CO_2 emits into the atmosphere.

FIGURE 6.Strength at 90 days

4. CONCLUSION

This study shows that fly ash can be used up to 25% as cement replacement and obtain required compressive strength at 28 days. Without considering time fly ash can be used up to 50% at 90 days and apply this concept in dam constructions because it had less strength development which means less temperature produced due to the heat of hydration. Actually, fly ash is a waste material and could be useful for both economy and environment. In other words, The goal can be a achieved with using fly ash in concrete structures not only in terms of environment, but also improving the structural properties as well, such as compressive strength of concrete structures.

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