EFFECT OF LOCALLY AVAILABLE FLY ASH AS PARTIAL REPLACEMENT OF CEMENT ON CONCRETE STRENGTH

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ABSTRACT

Cement industry is the most energy intensive of all manufacturing industries of recent time. So various solutions are currently under investigation with the aim of reducing the environmental impacts of cement production; and one of them is replacing cement with fly ash. Fly ash is a naturally-occurring by-product from the coal combustion process which is used as a partial replacement of cement. Because fly ash use displaces cement use, it also reduces the need for cement production – a major energy user and source of greenhouse gas emissions. Fly ash being less expensive, increased percentage of fly ash replacement results in cost reduction of concrete. Due to its pozzolanic effects, fly ash also enhances the compressive strength and durability of concrete. In Bangladesh, Portland Composite Cement (PCC), which contains certain percentages of fly ash and other supplementary cementing materials, is becoming popular nowadays, but its exact composition is not mentioned by the production companies. This paper investigates the effect of locally available fly ash as partial replacement of cement and tries to determine an optimum percentage of fly ash for maximum strength; making the concrete economical in the process. It was found that 10% fly ash replacement provided maximum compressive strength.

Keywords: Fly ash; compressive strength; Portland Composite Cement; Ordinary Portland Cement

INTRODUCTION

Fly ash, consisting of spherical and glassy particles, is a residue produced from combustion of coal. Presently in Bangladesh, it is estimated that 1.3 million cubic feet of fly ash is produced per annum from thermal power plants, and is estimated to reach an alarming crescendo of 9.5 million cubic feet by 2018 (Tamim et al., 2013). Dumping of this huge amount of fly ash is a big concern. Experts estimate that cement production contributes to about 7% of carbon dioxide emissions from human sources. If all the fly ash generated each year were used in producing concrete, the reduction of carbon dioxide released because of decreased cement production would be equivalent to eliminating 25% of the world's vehicles. ("Fly Ash & amp; The Environment | Headwaters Resources," n.d.) Fly ash replacement also helps in reducing the cost of concrete as fly as is cheaper than cement. Several investigations have already been carried out by researchers all over the world to study the effect of fly ash replacement on compressive strength of concrete (Berryman et al., 2005; Pitroda et al., 2012; Thomas, 2007; Kumar, et al., 2014). (ASTM C618 - 03 Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete)However, very few researches are found regarding locally produced fly ash of Bangladesh. Farooque et al. (2010) investigated the pozzolanic activity of fly ash collected from Meghna Cement Factory. Sultana et al. (2014) studied the influence of rice husk ash (collected from a rice mill of Joypurhat) and fly ash (locally produced in thermal power plant of Boropukuria) on properties of clay samples collected from Naogaon. Islam et al., (2015) also used fly ash from Boropukuria power plant as a replacement of clay and made fly ash bricks. Muhit e al. (2013) studied fly Rainbow Holdings Limited, Dhaka as partial replacement of cement and found 10% replacement as optimum in terms of strength. In this study, fly ash collected from Boropukuria thermal plant was used as a partial replacement of cement and its effect on concrete compressive strength was observed.

EXPERIMENTAL PROGRAM

The experimental program was planned to study the effect of locally produced fly ash as partial replacement of cement on the compressive strength characteristics of hardened concrete at different curing ages. The details of the program including different materials used test conducted are summarized below.

Materials

a. Cement: ASTM (C-150 Type-I Portland Cement was used as binding material.
b. Fly ash: Fly ash collected from Boropukuria thermal power plant was used as a supplementary cementing material. The fly ash was of class F according to ASTM (C618 – 03) as already analysed and classified by previous researchers (Khan et al.,2013; Tamim et al., 2013).
c. Aggregate: 20 mm downgrade and 10 mm downgrade stone chips in the ratio of 60:40 were used as coarse aggregate and Sylhet sand was used as fine aggregate for preparing the test specimens.

Mix Design

Two different grade concrete mixes, M25 and M40, were produced having water cement ratio of 0.50 and 0.40 respectively using 10%, 20 %, 30% and 50% fly ash replacement. Percent replacement of fly ash was done by weight of cement. Table 1 shows the mix designs used for preparing the concrete specimens.

Table-1: Mix designs used for preparing sample

Mix No	Characteristic Strength	Coarse Aggregate	Fine Aggregate	Cement	Water	W/C Ratio
	(MPa)	(kg)	(kg)	(kg)	(kg)	--
1	25	1250	618	380	190	0.5
2	40	1225	605	450	180	0.4

Compressive Strength Test of Cylindrical Concrete Specimens

Compressive strength test on concrete specimens was done according to the specifications of ASTM test method for Compressive Strength of Cylindrical Concrete Specimens (ASTM C39 / C39M - 16a). Compressive strength test was carried out on 4" X 8"cylindrical concrete specimens at 3, 7 and 28 days. Procedure for mixing and casting of fresh concrete cylinders and determination of compressive strength are shown in the self-explanatory figures below (Fig. 1).

Fig. 1(a): Weighing of fly ash

Fig. 1(b): Mixing and casting of cylinders

Fig. 1(c): Cylinders prepared for compressive strength test

Fig 1(d): Crushing of cylinder

Fig. 1: Compressive strength test of cylindrical concrete specimens

RESULTS AND DISCUSSIONS

Fig. 2 and Fig. 3 show the comparison of compressive strength for different percentages of fly ash replacement of M25 and M40 grades respectively.

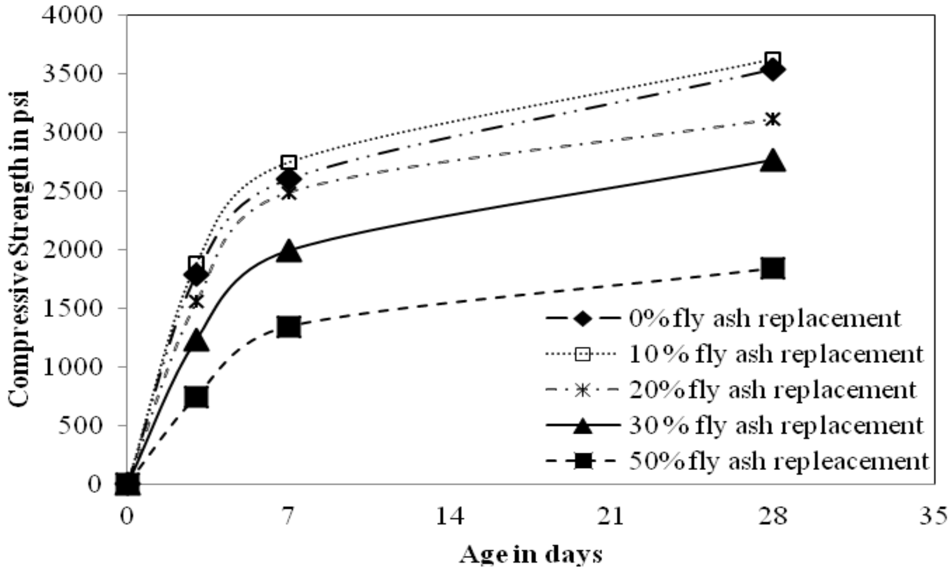

Fig. 2: Variation of compressive strength with age for different percentages of fly ash replacement of M25 grade concrete

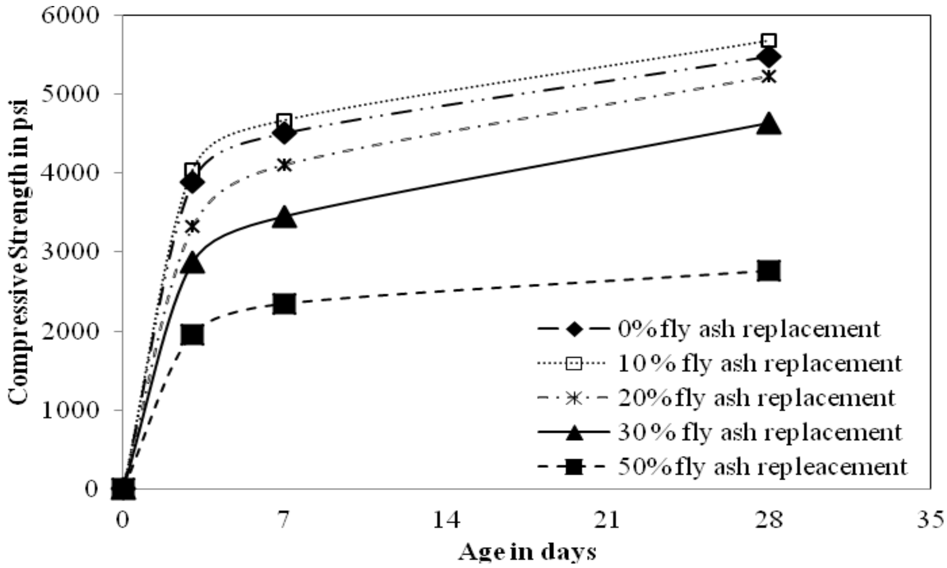

Fig. 3: Variation of compressive strength with age for different percentages of fly ash replacement of M40 grade concrete

From the graphs, it can be seen that for both M25 and M40 grade concretes, 10% fly ash replacement provided the highest compressive strength at all ages. The 2nd highest strength was achieved using OPC cement with no fly ash replacement. Compressive strength of M25 and M40 grade concretes with 10% fly ash replacement were 2.4% and 3.5% higher than that of OPC cement concretes respectively. After 10%, with increasing percentages of fly ash, compressive strength decreased and 50% fly ash replacement provided the lowest strength at all curing ages.

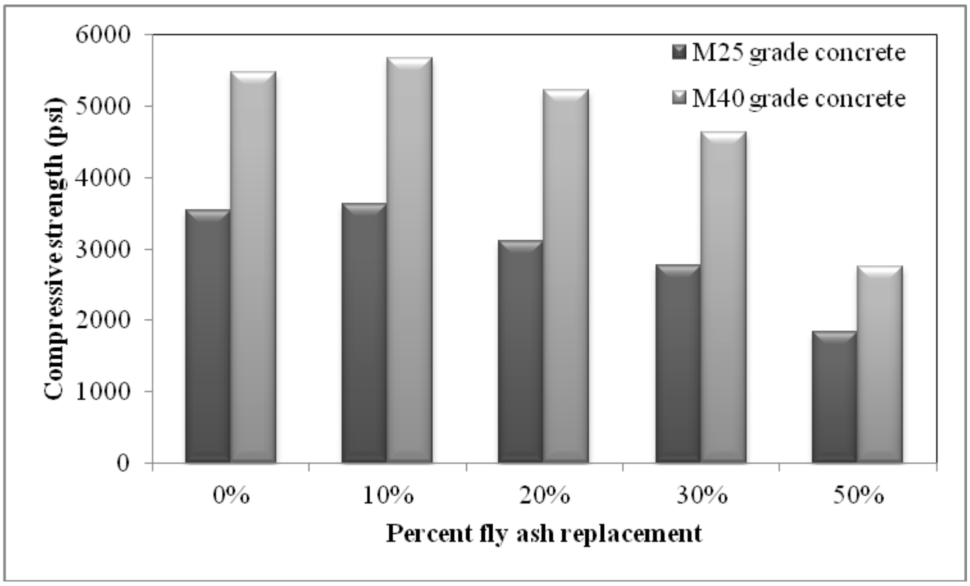

Fig. 4: Variations of 28 day compressive strength of M25 and M40 grade conretes for different percent replacement of fly ash

Fig. 4 presents a bar chart showing variations of 28 day compressive strength of both the concrete grades for different percent replacements of fly ash. Since 28 day strength is taken as concrete compressive strength so this strength was used for drawing the bar chart. This bar chart represents the comparison of the percent replacement of fly ash better.

CONCLUSIONS

Bangladesh has a vast resource of fly ash produced in Boropukuria thermal power plant and it has potential to be extended in the future. The proper use of local fly ash can solve the major problems of its disposal and reduce the consumption of energy and resources. This experimental exercise has helped to study the effect of replacing cement with fly ash at different percentages on concrete compressive strength, which is generally used in Bangladesh as a property for concrete quality control. The conclusion that can be drawn from this research is that, 10% fly ash replacement provided the maximum compressive strength of concrete for both grades. This strength is even higher than that of concrete made with Type I Ordinary Portland Cement. Since fly ash is less expensive than cement and its production generates less Carbon dioxide and also since it provides greater strength, 10% fly ash replacement could be considered as optimum.

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