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Experimental study on the mechanical properties of light weight Fly ash coarse aggregate with addition of Sodium Silicate

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Abstract

Concrete is a mixture of cement, aggregate and water. In order to conserve the natural resources, an artificial coarse aggregate created by the use of fly ash. In this study, the coarse aggregate is replaced with fly ash coarse aggregate. The mechanical strength of concrete was tested by performing compression test on cube, split tensile test on Cylinder, and flexural strength on beam. Sodium Silicate is added to increase the Strength and properties of concrete. Adding Sodium Silicate to concrete reduces the calcium hydroxide in the concrete, whereas there is an increase in the calcium silicate hydrate (C–S–H gel). This C–S–H gel partially fill the micro-pores, voids and cracks in the concrete thereby improving the density of concrete.

Keywords: - Fly ash aggregate, Sodium silicate, Mechanical property

INTRODUCTION

India produces 70% of its power requirement through thermal power plants [2]. Fly ash is also known as "pulverised fuel ash" is the by-product of coal combustion product that is composed of fine particles that are driven out of coal-fired boilers. In order to conserve the natural resources, fly ash is used to create artificial course aggregate. Artificial course aggregate is created by Granulation technique where the pellets are created. Later these aggregate is subjected to a temperature of 1100^{o}C to harden and achieve a better aggregate strength [4]. The Fly ash aggregate specific gravity is 40% lesser than normal aggregate. Thus there is a reduction in the overall weight of the structure. This decreases the construction cost spent on foundation. In this study the Fly ash coarse aggregate is replaced by (50% & 100%) normal coarse aggregate, and the corresponding strength is checked and compared with that of the conventional concrete. To increase the density and compactness of concrete, Sodium Silicate is added (0%, 5%, 10% & 15%) with respect to the weight of cement. Addition of Sodium Silicate decreases calcium hydroxide content, whereas there is an increase in the calcium silicate hydrate (C–S–H gel). This C–S–H gel partially fill the micro-pores, voids and cracks in the concrete thereby improving the density of concrete.

EXPERIMENTAL INVESTIGATION

The experimental investigation consists of testing cubes to determine compression, cylinder to determine the split tensile strength and beam to determine the flexural strength after 7 and 28 days of curing. Fly ash aggregate is used with complete and partial replacement to natural weight coarse aggregate along with the addition of Sodium Silicate.

MATERIALS

The materials used in the experimental work and their properties are summarized below.

CEMENT

The Cement used in this study is Ordinary Portland Cement. (53 grade) conforming to IS 12269:1987 [2]. The specific gravity of 53 grade of cement used in this study is 3.09.

FINE AGGREGATE

Fine aggregate used in concrete is graded to give minimum void ratio. Grading of Fine aggregate does not increase the water demand for the concrete and should be provided with minimum voids so that the fine cementitious particles fill the space. The specific gravity of fine aggregate used in this study is 2.68.

COARSE AGGREGATE

Coarse aggregate is a chemically stable material. Presence of coarse aggregate will reduce the drying shrinkage of concrete. The specific gravity of coarse aggregate used in this study is 2.86.

FLY ASH AGGREGATE

Fly ash is generated in thermal power plants produce an adverse effect on environment. The use of fly ash in concrete can reduce the consumption of natural resources while diminishes the effect of pollution on the environment. Fly ash contains silica (silicon dioxide, SiO_2) and lime (calcium oxide, (CaO). The material test on the Fly ash aggregate was conducted and compared with the normal coarse aggregate which is shown in Table 1.

Table 1. Fly ash aggregate test

Properties of Fly ash aggregate	Test Result	
	Fly ash aggregate	Normal Aggregate
Specific gravity	1.72	2.86
Water absorption capacity	13%	0.604%
Abrasion test	12%	3.28%
Crushing test (According to is code crushing value should not exceed 45%)	31.6%	26.43%

Figure 1. Fly ash aggregate

SODIUM SILICATE

Sodium silicate is a glassy gel material that reduces the permeability in the concrete. Sodium Silicate reacts with calcium hydroxide in cement to produces C-S-H gel, which induce density and strength to fly ash concrete [6]. This C-S-H gel blocks all micro pores and cracks in concrete to improve its resistance to water permeability [5]. The chemical formula of Sodium Silicate is Na_2SiO_3. The Density of Sodium Silicate is 2.61g/cm^3

WATER

The quality and quantity of water has more effect on the strength and workability of concrete in construction. Water is the main element responsible in mixing of concrete which contains the hydrated products that helps in the formation of C-S-H gel. The strength of cement concrete depends mainly depends on the binding action of hydrate gel.

Mix Design

Mix design is defined as the process of selecting suitable ingredients of concrete by determining their relative proportions with the object of producing concrete with minimum strength and durability as economically as possible. Mix design is done in accordance to **IS: 10262 – 2009**. The mix proportion used is M40 grade of concrete with a water-cement ratio of 0.45.

Mechanical Properties:

Terms used:

1. CC – conventional concrete
2. 50/0, 50/5,50/10, 50/15 – The percentage of Fly ash aggregate replaced (50%) and Sodium Silicate added.
3. 100/0, 100/5,100/10, 100/15 – The percentage of Fly ash aggregate replaced (100%) and Sodium Silicate added

Compression strength

Compression strengths is performed in a compression testing machine which has a maximum capacity of 2000 kN. The compression is calculated using the formula:

$$\text{Compressive Stress} = \frac{P}{A}$$

Where,

P= Load applied on the cube specimen (kN)

A= Cross section area of the cube (mm^2)

Figure 2. Compression strength on cube

The below graph shows the comparison of compression strength for conventional concrete against partial replacement of coarse aggregate with Fly ash with the percentage addition of Sodium Silicate (0%, 5%, 10%, and 15%).

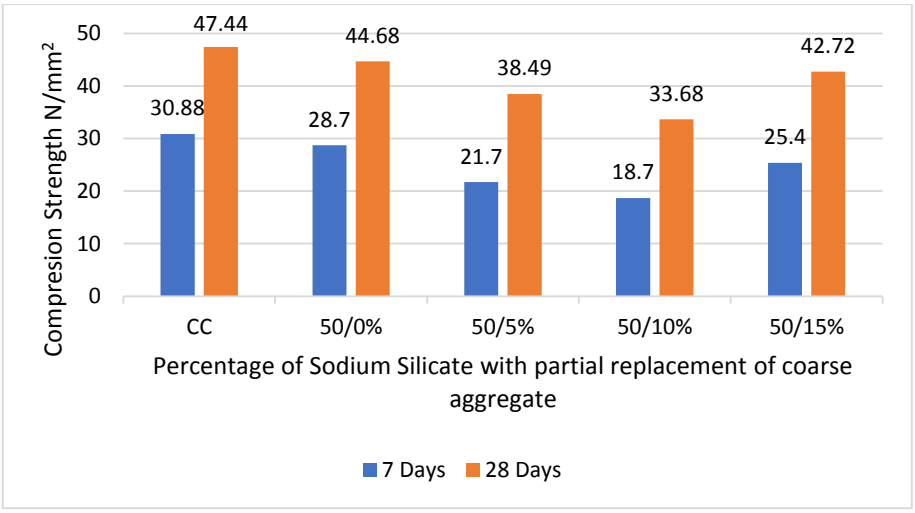

Figure 3. Compression strength for partial replacement of coarse aggregate with various percentage addition of sodium silicate

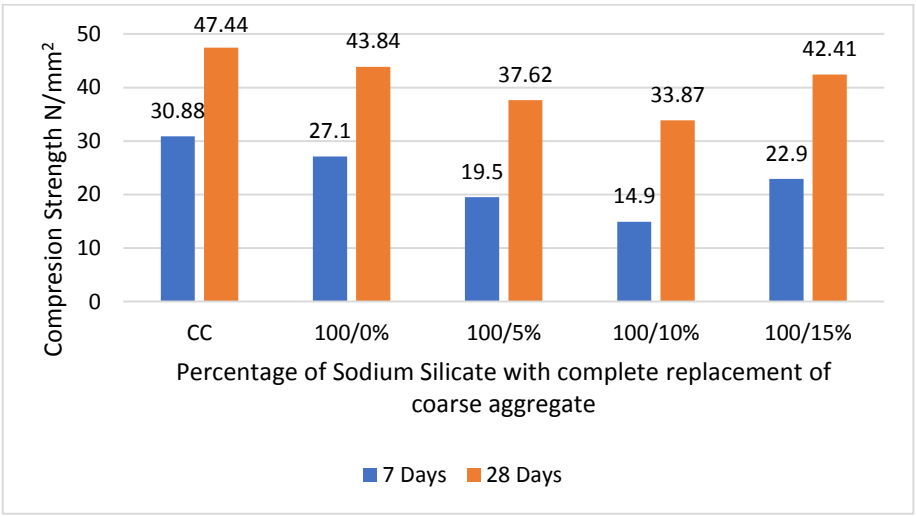

Figure 4. Compression strength for Complete replacement of coarse aggregate with various percentage addition of sodium silicate

The below graph shows the comparison of compression strength for conventional concrete against complete replacement of coarse aggregate with Fly ash with the percentage addition of Sodium Silicate (0%, 5%, 10%, and 15%).

The Compression strength results shows that for both partial and complete replacement of coarse aggregate there is a reduction in compressive strength, while adding sodium silicate by 5% and 10%. But by adding 15% of sodium silicate there is increase in the compressive strength.

Split tensile strength

The split tensile strength of cylinder is performed in a compressive testing machine. The Split tensile strength is calculated using the formula:

$$\text{Split tensile strength} = \frac{2P}{\pi dl}$$

Where,

P – Load (max) applied in kilo Newton

L – Length in mm

d – Diameter of specimen in mm

Figure 5. Split tensile strength on cylinder

The below graph shows the comparison of Split tensile strength for conventional concrete against partial replacement of coarse aggregate with Fly ash with the percentage addition of Sodium Silicate (0%, 5%, 10%, and 15%).

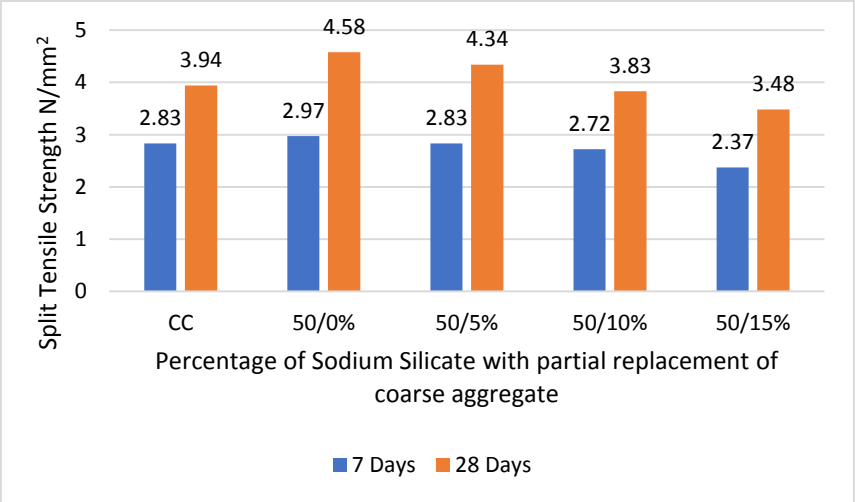

Figure 6. Split tensile strength for partial replacement of coarse aggregate with various percentage addition of sodium silicate

The below graph shows the comparison of Split tensile strength for conventional concrete against complete replacement of coarse aggregate with Fly ash with the percentage addition of Sodium Silicate (0%, 5%, 10%, and 15%).

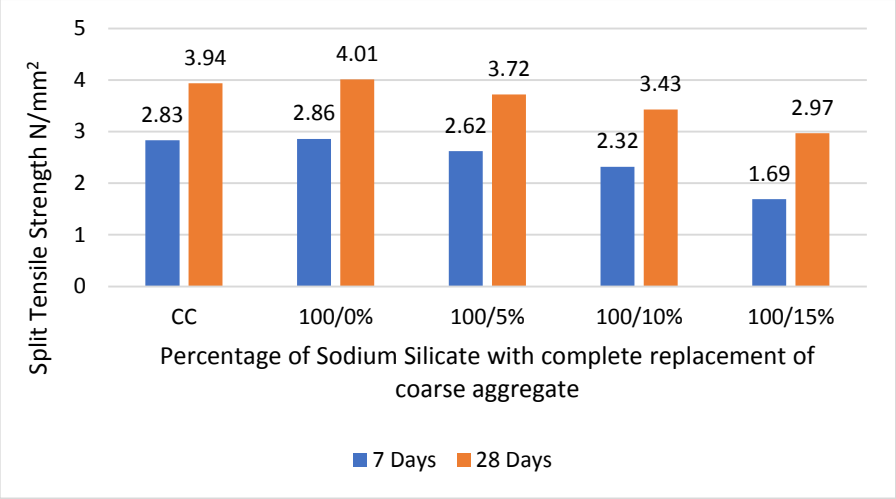

Figure 7. Split tensile strength for Complete replacement of coarse aggregate with various percentage addition of sodium silicate

Figure 8. Flexural strength on Beam

The Split tensile strength results show that with partial and complete replacement of coarse aggregate there is a gradual decrease in strength, while increase in addition of sodium silicate.

Flexural strength

The Flexural strength of beam is performed in a compressive testing machine. The Flexural strength is calculated using the formula:

Flexural strength = $\frac{PL}{bd^2}$

Where,

P – Load (max) applied in kilo Newton

L – Length in mm

b – Breadth of specimen mm

d – Depth of specimen mm

The below graph shows the comparison of Flexural strength for conventional concrete against partial replacement of coarse aggregate with Fly ash with the percentage addition of Sodium Silicate (0%, 5%, 10%, and 15%).

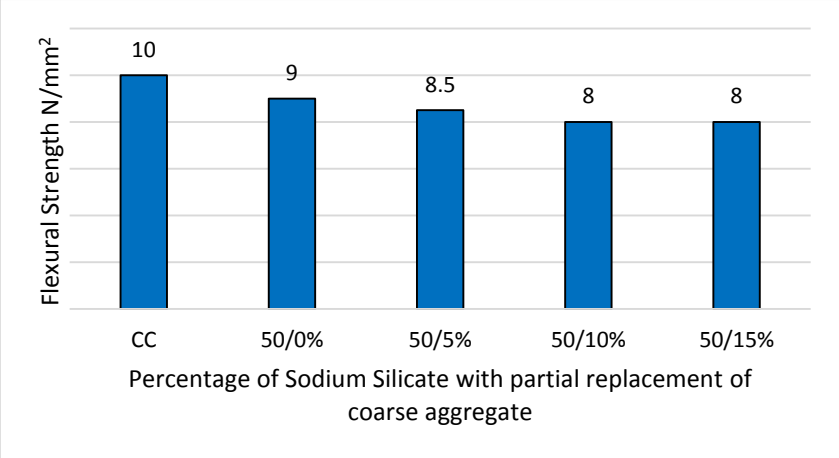

Figure 9. Flexural strength for partial replacement of coarse aggregate with various percentage addition of sodium silicate

The below graph shows the comparison of Flexural strength for conventional concrete against complete replacement of coarse aggregate with Fly ash with the percentage addition of Sodium Silicate (0%, 5%, 10%, and 15%).

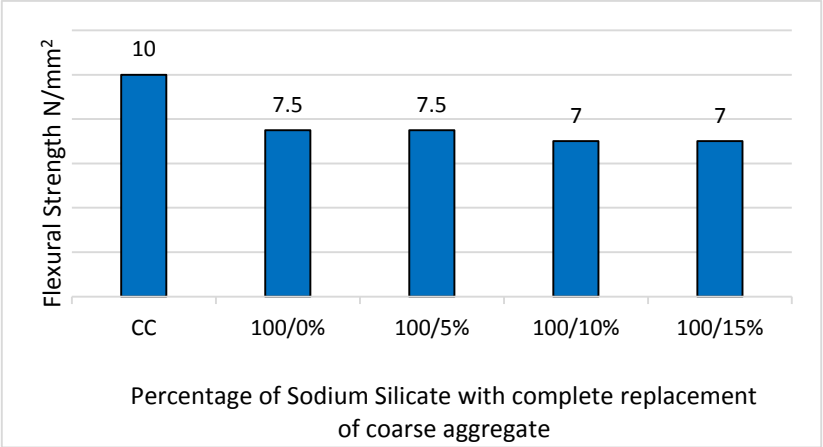

Figure 10. Flexural strength for Complete replacement of coarse aggregate with various percentage addition of sodium silicate

The Flexural strength results show that for both partial and complete replacement of coarse aggregate there is a gradual decrease in strength, while increasing the adding sodium silicate.

CONCLUSION

1. Since the specific gravity of Fly ash aggregate is 40% less than normal aggregate hence the Light-weight aggregates will reduce the dead load of the structure.
2. The properties of fly ash aggregates have been tested and compared with the natural aggregate. The study affirms that fly ash aggregates can be used to replace coarse aggregate in concrete.
3. Sodium silicate concrete improves the waterproofing performance of the structures by enhancing the compactness thereby reducing micro-pore, void and crack in the concrete structures.
4. Although the mechanical property of Fly ash concrete is slightly less than conventional concrete, the addition of sodium silicate (15%) has increased the strength and durability aspect of concrete. Complete replacement of fly ash aggregate shows an improved characteristic in concrete properties when compared with the conventional concrete.
5. The partial replacement of Fly ash aggregate has better mechanical strength when compared with the complete replacement of Fly ash aggregate.

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