wjert, 2018, Vol. 4, Issue 4, 319-332. *Original Article* ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org SJIF Impact Factor: 5.218

EXPERIMENTAL STUDY ON THE STRENGTH AND DURABILITY OF FLY ASH COARSE AGGREGATE WITH ADDITION OF SODIUM SILICATE

Roshan Peter*

PG Scholar, Department of civil engineering, S.R.M Institute of Science and Technology, Kattankulathur, Chennai – 603203, Tamil Nadu, India.

Article Received on 17/04/2018 **Article Revised on 08/05/2018** **Article Accepted on 29/05/2018**

***Corresponding Author**
Roshan Peter
PG Scholar, Department of civil engineering, S.R.M Institute of Science and Technology, Kattankulathur, Chennai – 603203, Tamil Nadu, India.

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 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 durability 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 compactness and water permeability of the structure. Various durability test conducted on concrete includes Rapid chloride penetration test, water permeability and Sorptivity. The test finding shows marginal increase in strength and significant improvements in the durability of light weight concrete structures.

KEYWORDS: Fly ash aggregate, Sodium silicate, Mechanical property, Durability.

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.

PRELIMINARY TEST ON MATERIALS

MATERIAL USED

1. Cement- Ordinary Portland Cement 53 grade
2. Fine aggregate
3. Normal Coarse aggregate-10-12 mm
4. Fly ash coarse aggregate 10-12mm
5. Sodium silicate
6. Water.

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 with an imperative blow on environmental and living organism. The use of fly ash in concrete can reduce the consumption of natural resources and also diminishes the effect of pollutant in environment. Thus, Fly ash is used to create fly ash aggregate by burning the aggregate under 1100°C and cooling it down slowly. This aggregate is light in weight by 40% -50% when compared with normal aggregate. 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%

Fig 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 and chloride attack.[5] The chemical formula of Sodium Silicate is Na_2SiO_3. The Density of Sodium Silicate is 2.61g/cm^3.

Water

Water is the main ingredient in the formation of concrete, because it helps in mixing the concrete elements like the cement, sand and coarse aggregate. The workability of concrete also depends upon the water cement ratio used in the concrete grade of mix. The chemical reactions in the concrete will not start unless water is mixed with them, as the formation of C-H-S bond formation depends mainly upon the usage of water.

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

The mechanical properties are tested by conducting their compression strength, split tensile strength and flexural strength of concrete.

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 a 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)

Fig 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%).

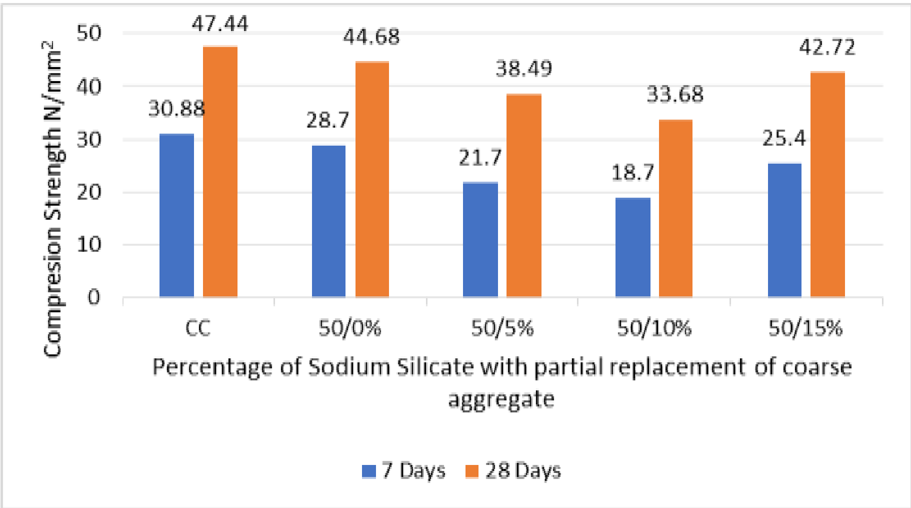

Fig 3: Compression strength for partial replacement of coarse aggregate with various percentage addition of sodium silicate.

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%).

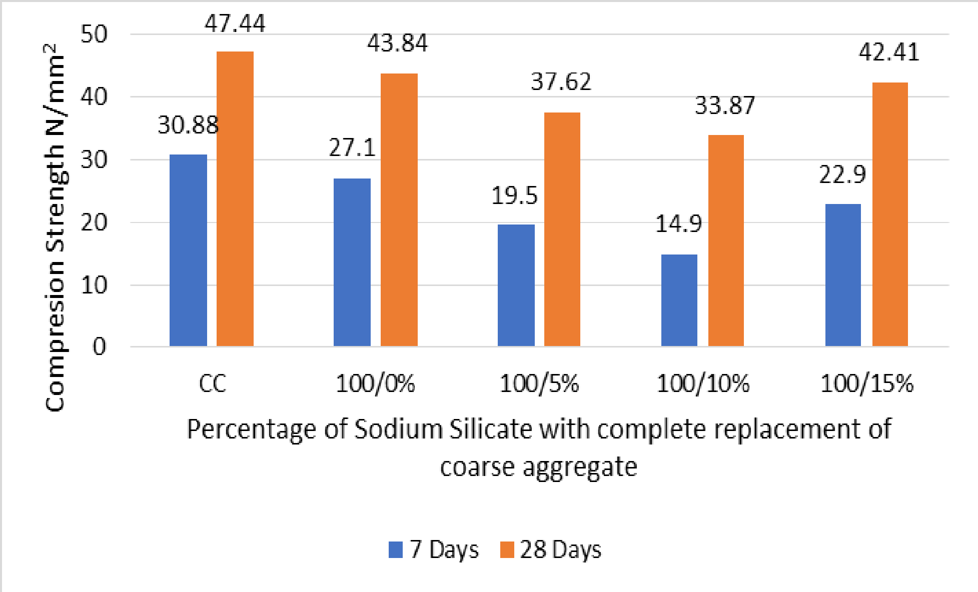

Fig 4: Compression strength for Complete replacement of coarse aggregate with various percentage addition of sodium silicate.

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:

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

Where,

P – Load (max) applied in kilo Newton

L – Length in mm

d – Diameter of specimen in mm.

Fig 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%).

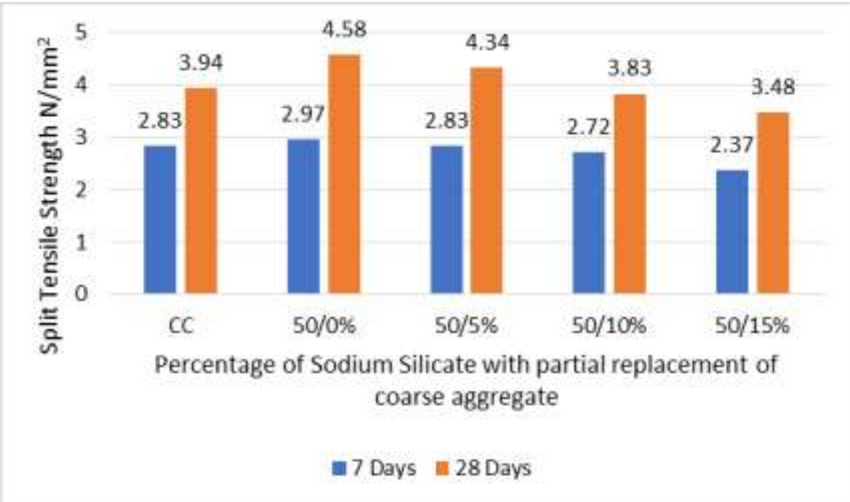

Fig 6: Split tensile strength for partial replacement of coarse aggregate with various percentage addition of sodium silicate.

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%).

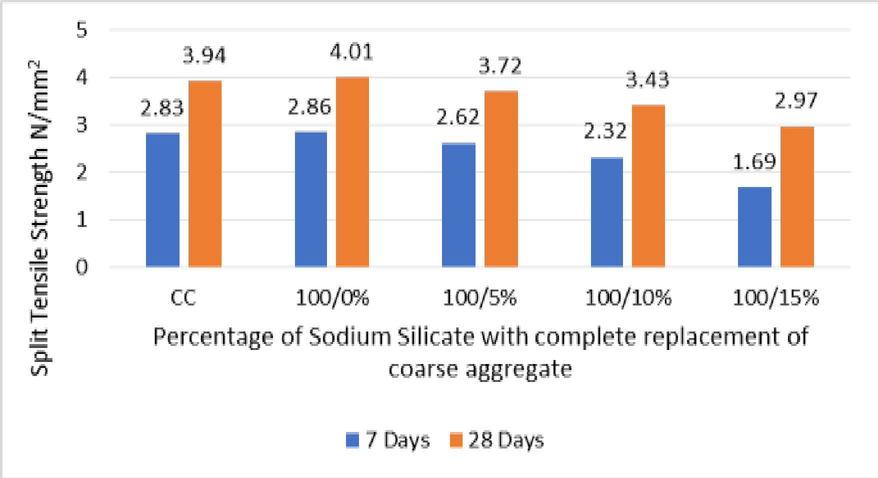

Fig 7: Split tensile strength for Complete replacement of coarse aggregate with various percentage addition of sodium silicate.

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:

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

Where,

P – Load (max) applied in kilo Newton

L – Length in mm

b – Breadth of specimen mm

d – Depth of specimen mm

Fig 8: Flexural strengths on Beam.

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%).

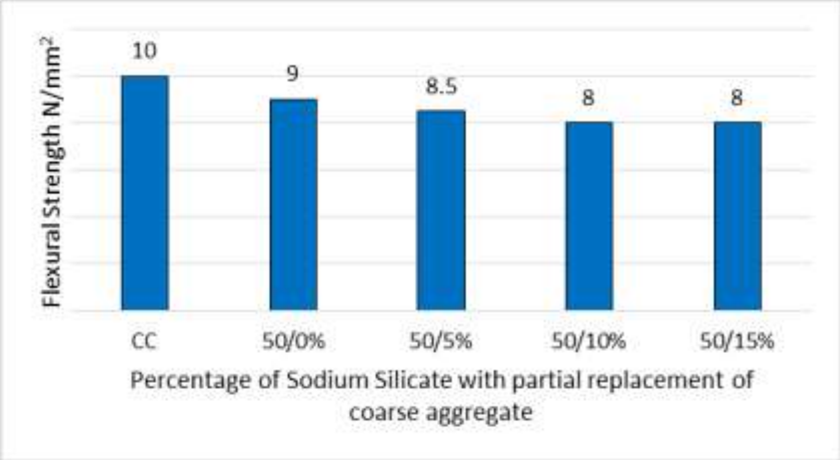

Fig 9: Flexural strengths for partial replacement of coarse aggregate with various percentage addition of sodium silicate.

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%).

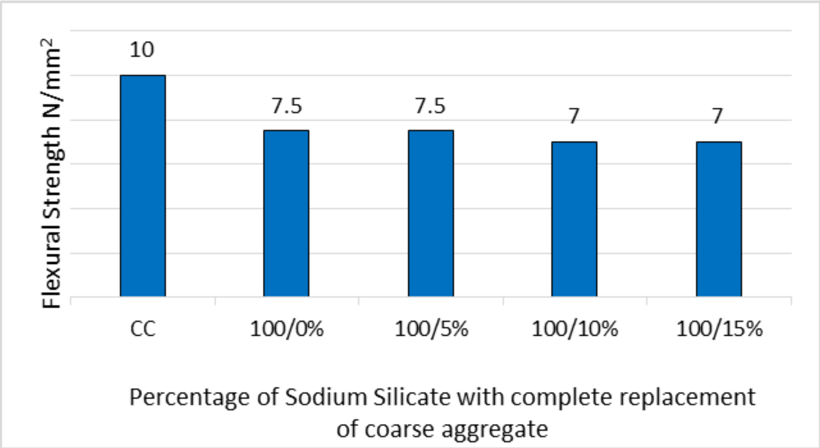

Fig 10: Flexural strengths for Complete replacement of coarse aggregate with various percentage addition of sodium silicate.

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.

Experimental Investigation on the Durability Behaviour of Concrete

Acid Attack Test

The cube specimen after 28 days of curing was placed in the acid container for another 28 days to check the resistance to the acid effect. The acid container contains Hydrochloric acid solution with a pH level of 2. Later the specimens were taken out of the acid container and dried at room temperature for 24 hours. Then the specimen is kept in the compressor machine and is tested for compressive strength to determine the effects of deterioration caused in the concrete.

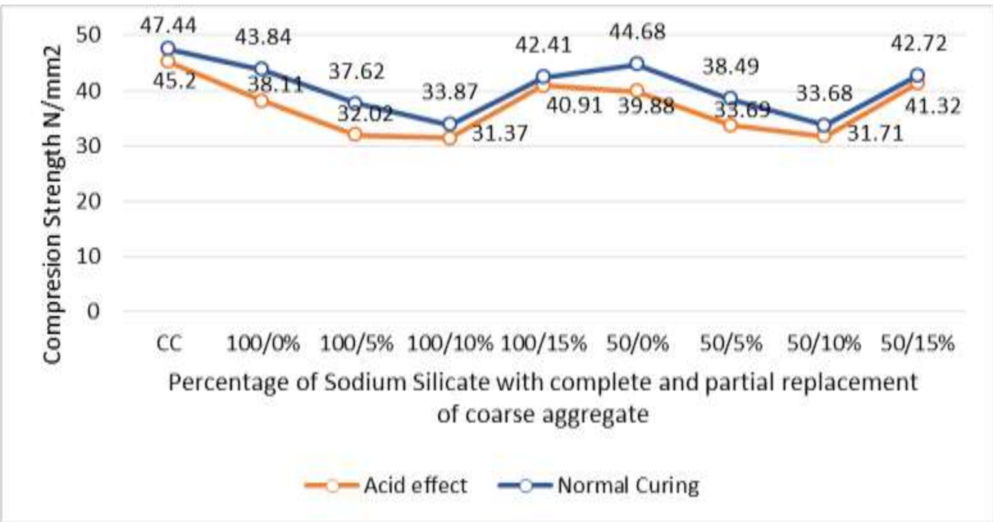

Fig 11: Acid test.

The acid test results show that for both partial and complete replacement of coarse aggregate when adding sodium silicate, the permeability of concrete reduces thus effects of acid in concrete reduces with increase in sodium silicate.

Rapid Chloride Permeability Test

The specimens used for RCPT are Cylinders of size 50mm x 100mm. This specimen is obtained from the centre portion of the cylinder which is cured for 28 days. This specimen is then kept in the RCPT apparatus and two different chemicals are poured on either size of the specimen. The chemicals used are NaOH and NaCl. The amount of current passed through the specimen is measured by coulomb. This test is used to identify the permeability of chloride ions in the concrete. This test is mainly necessary for structures which are constructed in places near sea shore. The rapid chloride penetration test was conducted as per ASTMC 1202-1997.

Fig 12: RCPT testing.

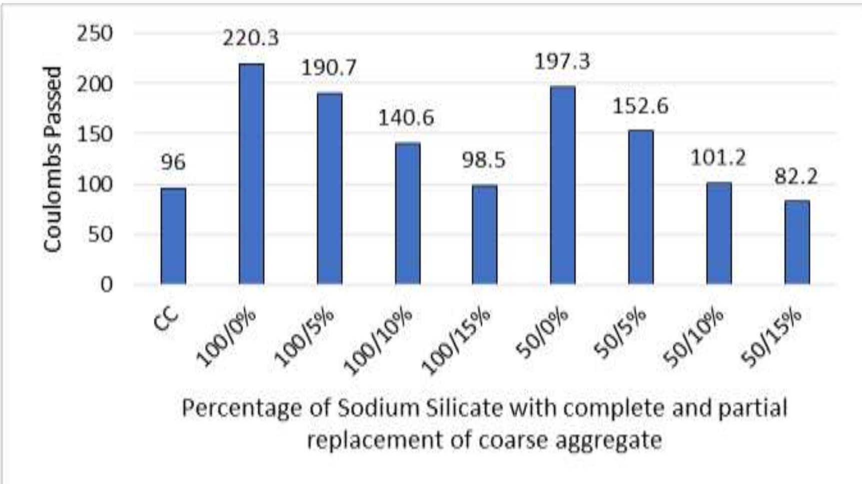

Fig 13: Rapid chloride penetration test.

The Rapid chloride penetration test results show that for both partial and complete replacement of coarse aggregate the coulombs passed reduces in concrete with increasing the addition of sodium silicate. Thus the permeability of concrete reduces with increase in the addition of sodium silicate.

Sorptivity Test

Sorptivity is defined as a measure of identifying the surface absorption of the concrete. The specimen size is 100 mm dia with 50 mm height. The specimen is placed such that the bottom surface touches the water. The increase in weight with respect to time is used to calculate the sorptivity value.

$$S = \frac{I}{t^{1/2}}$$

$$I = \frac{\delta w}{Ad}$$

Where,

S= sorptivity(mm)

t= passed time min

$\Delta w = w_2 - w_1$

w_1 = Dry weight

w_2 = weight of cylinder after 3 minutes

A= surface area of water

d= thickness of water

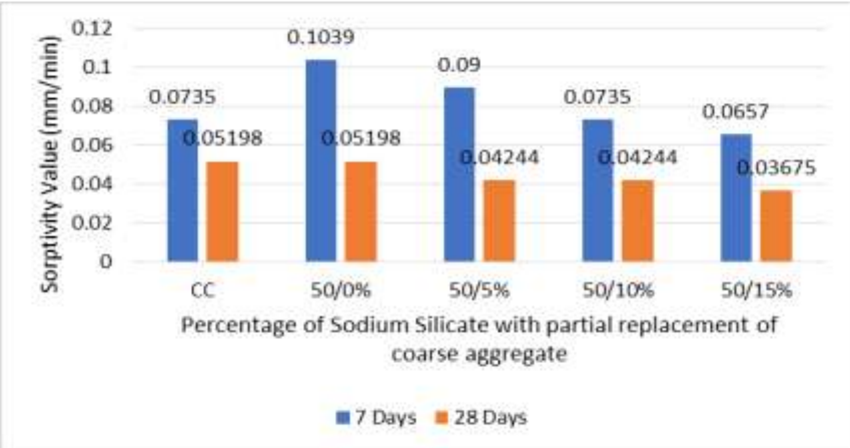

Fig 14: Sorptivity test for partial replacement of coarse aggregate with various percentage addition of sodium silicate.

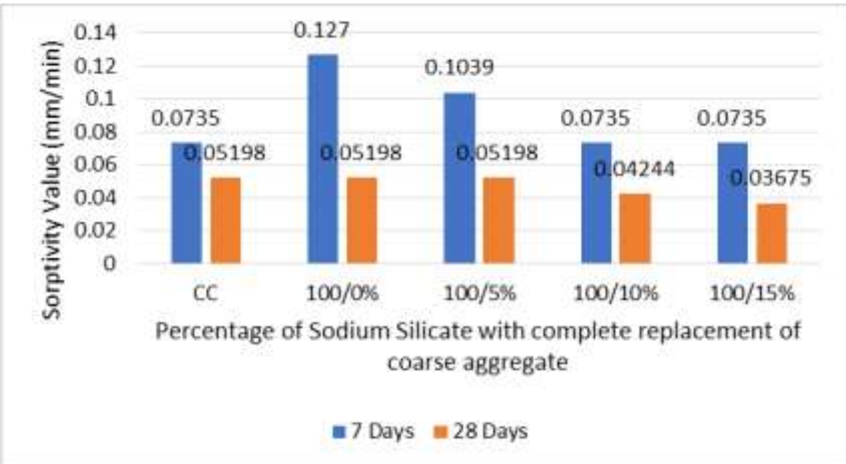

Fig 15: Sorptivity test for complete replacement of coarse aggregate with various percentage addition of sodium silicate.

The sorptivity test results show that for both partial and complete replacement of coarse aggregate the surface adsorption of concrete reduces with increase in the addition of sodium silicate. Thus the water permeability of concrete reduces with increase in the addition of sodium silicate.

CONCLUSION

1. As 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. To increase the durability of Fly ash aggregate concrete, Sodium silicate is added to the concrete. Sodium silicate will decrease the calcium hydroxide concentration, thereby increasing the C–S–H gel concentration.
4. Sodium silicate-based concrete improves the waterproofing performance of the structures by enhancing the compactness thereby reducing micro-pore, void and crack in the concrete structures.
5. Increasing the percentage of sodium silicate increases the durability of concrete.
6. 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.

REFERENCES

1. S.Azzaruddin, K.Tanuja and N.Vasu Deva Naidu - Effect and behaviour of light weight concrete using Fly ash aggregate. International research journal of engineering and technology, 2016; 3(9).
2. M. vijay sekhar reddy, M. C. Nataraja, K.Sindhu, V.Harani and K.Madhuralalasa – Performance of light weight concrete using fly ash pellets as coarse aggregate. International research publication house, 2016; 9(2).
3. Prafull Vijay – Use of fly ash aggregate in concrete and its application in structure. International journal of recent development in engineering and technology, 2015; 4(7).
4. J.Larosa Thompson, B.E. Scheetz, M.R.Silsbee and P.Grill - Sodium silicate application for cement and concrete. PQ Corporation Valley Forge PA 19482, 2010.

5. Sang soon park, Yun Yong Kim, Byung Jae Lee, and Seung-Jun Kwon – Evaluation of concrete durability performance with sodium silicate impregnants, 2014; 2014: Article ID 945297, 11 pages.
6. Zhongnan song and Xiao Xue – Experimental exploration of the waterproofing mechanism of inorganic sodium silicate-based concrete sealers. Construction and building materials, 2016; 104: 276-283.
7. Lihong Jiang, Xiao Xue a,b, and Jie Qin – The investigation of factors affecting the water impermeability of inorganic sodium silicate-based concrete sealers. Construction and building materials, 2015.
8. Erhan guneyisi, Mehmet gesoglu, Emad Booya and Kasim Merdas – Strength and permeability property of self – compacting concrete with cold bonded fly ash lightweight aggregate. construction and building materials, 2014; 74: 17-24.