STUDY ON MICROSTRUCTURE AND DURABILITY PROPERTIES OF CONCRETE WITH DIFFERENT MINERAL ADMIXTURES

Prakash S Bhure

M-tech student, department of civil engineering(computer aided structural engineering), REVA University, Bangalore.

---***---

ABSTRACT - Concrete is the most used material in the world next to water and food materials. It is the evidence for the civilization. But the production of concrete leading to environmental degradation and pollution since it involves emission of CO_2, which is the one of the reason for global warming. And the industries such as thermal power plants and steel manufacturing industries produces lots of fly ash and GGBS. The mineral admixtures such as fly ash and ground granulated blast furnace slag(GGBS) are currently using as supplementary cementitious materials (SCM) to reduce cost and environmental pollution associated with the production The main objective of present study is to investigate the effect of Fly ash and GGBS on chemical, mechanical, durable and micro structural properties.The concrete mixes were prepared by replacing 30% of cement with fly ash, GGBS and 1.2% super plasticizer (conplast SP430) and water to cement ratio 0.45 was maintained for mix design of M35 grade concrete. This study investigates the performance of concrete in terms of compressive strength at 3, 7, 28 days. durability proprties such as water absorption and sorptivity at age of 28 days. Advanced technique such as scanning electron microscope(SCM) and X-ray computed tomography(X-CT) were used to understand the effect of Fly ash and GGBS on morphology and porosity of concrete. From the present study it can be conclude that with the addition of super plastizer and mineral admixtures the compressive strength of GGBS mix was comparatively more than the compressive strength of fly ash mix. With respect to water absorption and sorptivity tests GGBS mix showed better results than the fly ash mix. From the SEM and X-CT images it is observed that concrete with GGBS improves the micro structural properties such as morphology and porosity of concrete.

Keywords: Fly ash, GGBS, compressive strength, water absorption, Sorptivity, SEM, X-CT.

1. INTRODUCTION:

Concrete is a standout amongst the most broadly utilized development material on the planet. The most expensive ingredient of ordinary concrete is undoubtedly cement, both economically and environmentally. It is also noticed that due to production of cement every year several million tonnes of CO2 is releasing to environment, in order to overcome all these adverse effect supplementary cementitious materials. supplementary cementitious materials (SCM) for example, Fly ash, Ground granulated blast furnace slag (GGBS) are utilized as incomplete substitution of cement. The global warming is caused by the emission of greenhouse gases, such as carbon dioxide (CO2), to the atmosphere by human activities. The cement industry is held responsible for some of the CO2 emissions, because the production of one ton of Portland cement emits approximately one ton of CO2 into the atmosphere. However, Portland cement is still the main binder in concrete construction prompting a search for more environmentally friendly materials. Several efforts are in progress to supplement the use of Portland cement in concrete in order to address the global warming issues. In the present investigation to find out the effect of these admixtures in Concrete cubes replaced with 10%, 20%, 30% and 40% for M35 mix. The compressive strength is determined after 7 days curing and the more strength is attained at 30% replacement . Finally replacement of Fly Ash and GGBS is fixed as 30% by weight of binder, super-plasticizer a chemical admixture is Fixed as 1.2% by weight of water.

2. MATERIALS:

Cement:

Ordinary Portland Cement (OPC) locally available in bangalore (the BIRLA SUPER CEMENT Brand Name) in 50kg bags was used for the experiment.

Physical properties of cement:

Normal consistency = 28%
Intial setting time = 60 min
Final setting time = 310 hrs
Specific gravity = 3.11

Fine Aggregate:

The aggregate size is lesser than 4.75 mm is considered as fine total. The sand particles ought to be free from any earth or inorganic materials and observed to be hard and concrete. It was put away in open space free from tidy and water. It adjusts to IS 383-1970 goes under zone II.
Specific gravity = 2.54
Fineness modulus = 3.86
Water absorption = 1.12%

Coarse Aggregate:

The aggregate size greater than 4.75 mm, is considered as coarse total. It can be found from unique bed rocks. Coarse aggregate are accessible fit as a fiddle like adjusted, Irregular or incompletely adjusted Angular, Flaky. It ought to be free from any natural polluting influences and the earth substance was immaterial.
Specific gravity = 2.67
Fineness modulus = 8.4
Water absorption = 0.68%

Water:

Water is a vital element of concrete as it effectively partakes in the concoction response with cement. Since it frames the strength giving cement gel, the amount and nature of water is required to be investigated precisely. Blending water ought not contain undesirable natural substances or inorganic constituents in unreasonable extents. In this venture clean consumable water is utilized.

Admixture:

The Super plasticizer utilized as a part of cement is Conplast SP430. It depends on Sulphonated Napthalene Polymers and provided as a dark colored fluid immediately dispersible in water. Conplast SP430 has been uniquely detailed to surrender high water diminishments to 25% without loss of workability or to deliver top notch cement of lessened penetrability. The measurements of Super plasticizer was 0.5 to 1.5 liters for each 100kg of cement. The properties of super plasticizer are organized in table 1

Table- 1 Physical properties of super plasticizer:

Sl. No	Description	Test results
1	Type	Conplast SP430
2	Appearance	Brown liquid
3	Specific gravity	1.21
4	Dosage	0.5-1.5L/kg

Fly ash:

Fly ash for this study is collected from the Indian ready mix concrete plant. It is a by-product of the combustion of pulverized coal in thermal power plants. It is a fine grained, powdery and glassy particulate material that is collected from the exhaust gases by electrostatic precipitators or bag filters. When pulverised coal is burnt to generate heat, the residue contains 80 per cent fly ash and 20 per cent bottom ash. The size of particles is largely dependent on the type of dust collection equipment. Fly ash is a complex material consisting of heterogeneous combinations of amorphous (glassy) and crystalline phases. The majority of fly ash particles are glassy, solid, or hollow (cenospheres), and spherical in shape.

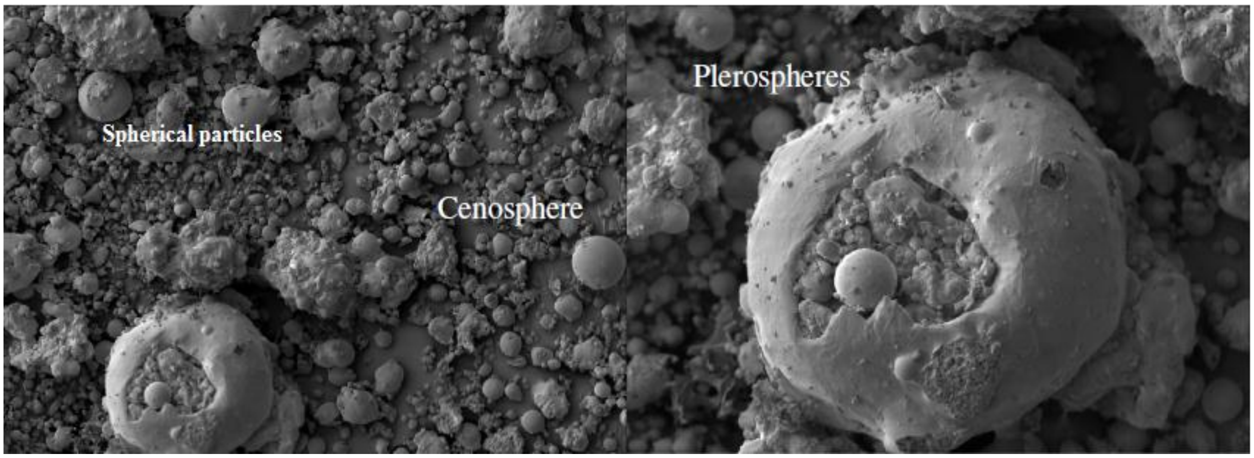

Figure- 1: Typical SEM images of fly ash

Ground Granulated Blast Furnace Slag

Ground granulated blast furnace slag (GGBS) is produced when iron oxide ore is reduced by coke to metallic iron at 1350 to 1550°C in a blast furnace. Slag is collected from the top of molten iron, at the bottom of the furnace. A large amount of water is sprayed at high pressure to quench the liquid slag to form granules, which are then ground to a fineness similar to Portland cement. If slow cooling is allowed, the material gets crystallized and develops no cementing properties. The use of slag in concrete does not have much effect on water demand and finer slags reduce bleeding in fresh concrete. Slag reduces the porosity and calcium hydroxide content in hardened concrete to certain extent.

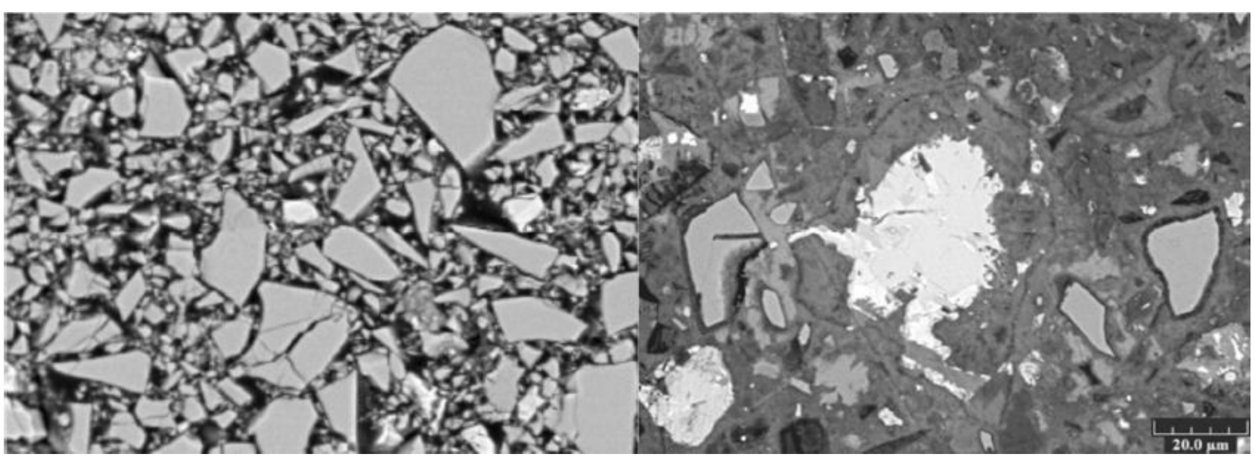

Figure 2 Backscattered images of microstructure of unhydrated slag (left) and hydrated slag (right) at 28 days

3. Concrete Mix Design:

The concrete mix for M35 grade concrete is prepared by using Ordinary Portland cement, fine aggregate sand and coarse aggregate (20 mm) as per mix design from IS:10262-2009 "Recommended Guidelines for Concrete Mix Design" shown below.

Cement : 350.488 kg/m^3
Fine aggregate : 803.962 kg/m^3
Coarse aggregate: 1066.90 kg/m^3
Water : 157.716 kg/m^3
Mix Proportion Ratio : C : F.A : C.A
1 : 2.29: 3.04
W/C : 0.45

Table- 2 Details of mixes for mechanical and durability properties

Mix designation	Mix constituents	Super-plasticizer dosage(% of binder)
F	Cement + Fly ash + Sand + Coarse aggregate	1.2
G	Cement + GGBS + Sand + Coarse aggregate	1.2

3.1CASTING AND CURING:

The Cube moulds are assembled on the concrete leveled flooring with a paper between the mould and the floor. The materials are mixed in the electronically operated mixer thoroughly to get the uniformity. The concrete is placed in the moulds in two layers and compacted with tamping rod. The moulds are de moulded after 24 hours of casting. After the required period of curing, the specimens are taken out of the curing tank, wiped off the moisture and the surface is made dry.

The physical properties of concrete depend to a large extent on the degree of hydration of the cement and the resultant microstructure of hydrated cement. It is necessary to create conditions of temperature and humidity during a relatively short period immediately after placing and compaction of concrete, favorable to the setting and hardening of concrete. The process of creation of a favorable environment is termed as curing. The cube specimens are kept in water for 28 days of curing before conducting the tests. Different sizes of cubes are used for different tests are mentioned in Table 3.

Table- 3 Details of Tests and sizes of the specimens

Sl. No	Tests	Specimens	Sizes(mm)
1	Compressive strength	Cubes	150 × 150 × 150
2	Water absorption	Cubes	150 × 150 × 150
3	Sorptivity	Cylinder discs	100 × 50
4	Scanning electron microscope(SEM)	Micro cubes	5 × 5 × 5
5	X-ray Computed tomography(X-ct)	Micro cubes	5 × 5 × 5

4. Compressive Strength:

Compressive strength. Compressive strength was controlled by utilizing Compression Testing Machine (CTM) of 3000 KN limit. The compressive strength of concrete was tried utilizing 150x150x150 mm cube specimens. The test was done by setting specimen between the loading surfaces of a CTM and the load was connected until the specimen fails. Three test specimens were thrown and used to quantify the compressive strength for each test conditions and normal esteem was considered. cubes were tested at the age of 3, 7, and 28 days and the average strength of these cubes were reported for each age.

$$\text{compressive strength(MPa)} = \frac{\text{ultimate load}}{\text{area of cross section}}$$

Table- 4 compression strength of concrete cubes with mineral admixture

Materials	3Days (MPa)	7Days (MPa)	28Days (MPa)
Fly ash	17.77	22.44	40.14
GGBS	20.14	26.51	44.14

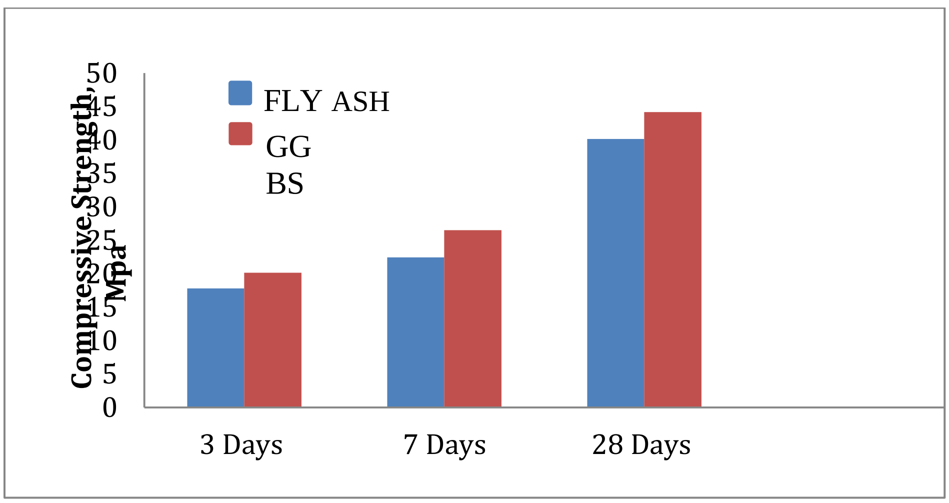

Chart 1: compressive strength of concrete cubes with mineral admixture.

5. Water Absorption Test:

Water absorption is characteristic of cubes which is due to presence of gel pores within the cubes. Water absorption test was conducted after 28 days water cured Concrete cubes with mineral and chemical admixtures. The test was conducted on 150X150X150 mm Concrete cubes and results are tabulated in table 5.

Table- 5 Water absorption of concrete cubes with different mineral admixture

Material	Wet weight (A) (gm)	Wet weight (B) (gm)	(A) – (B) (gm)	Water absorption(%)
Fly ash	8216.33	7927.33	313.66	3.654
GGBS	8075.66	7806.66	269	3.428

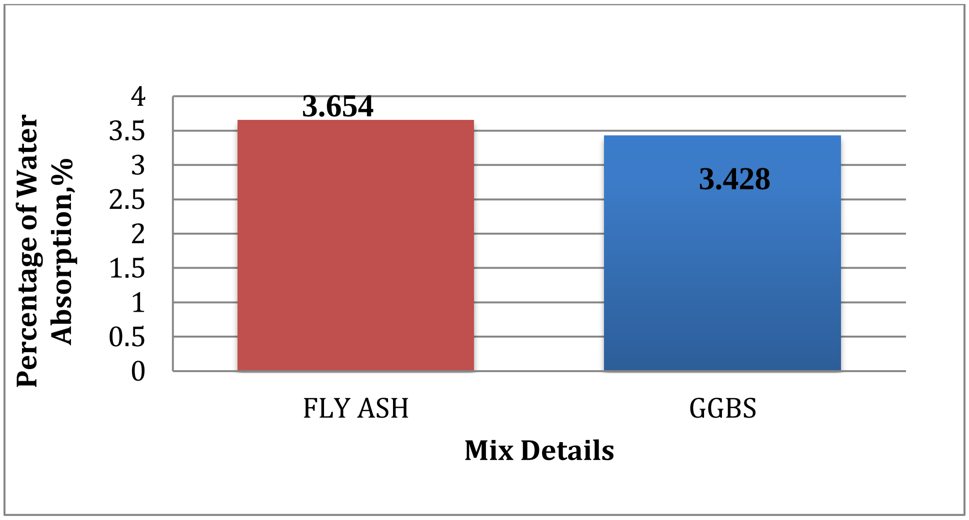

Chart- 2: Water absorption of concrete cubes with mineral admixture

6. Sorptivity Values:

The sorptivity can be determined by the measurement of the capillary absorption rate on reasonably homogeneous material. It is another parameter by which we can measure rate of water absorption by the specimen. The Sorptivity test was carried out after 28 days water curing on concrete composite cylinders of size 100x200 mm casted using both mineral admixture as Fly ash and GGBS. After 28days of curing those cylinders were removed from water and cut into specimens of size 100×50mm disc as shown in Fig 3. The results obtained are shown below in Table 6

Sorptivity is calculated by the formula given below

$$S= (Wx-Wy)/ (ADT^{1/2})$$

Where,
S = Sorptivity (mm)/ (min)$^{1/2}$;
Wx -Wy= Weight after 60 min-weight after 30 min (increase in weight for every 30 min (gm));
A = surface area of specimen through which water penetrates, mm^2 ;
D = density of water, gm/mm^3;
T = Elapsed time, min.

Table- 6: Sorptivity of concrete cubes with different mineral admixtures

Material	Sorptivity [mm/(min)$^{1/2}$]					
	30(min)	60(min)	90(min)	120(min)	150	180
Fly ash	0.1434	0.0301	0.0116	0.0141	0.0106	0.0097
GGBS	0.1316	0.0273	0.0156	0.01141	0.0104	.0095

Fig-3 Concrete Specimens during Sorptivity Test

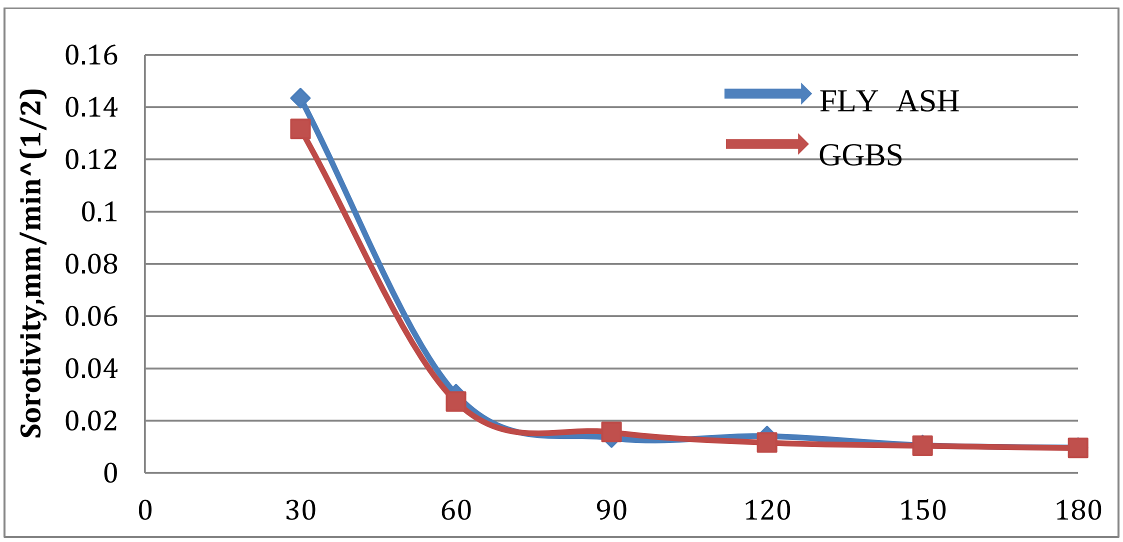

Chart- 3: Sorptivity of concrete cubes with different mineral admixtures

7. X-ray Computed Tomography Test (X-CT):

The technique used to analyze the concrete samples is a three dimensional imaging technique called X-ray Computed tomography. This method is a completely non-destructive means of visualizing the internal structure of any dense, solid object. X-ray micro tomography. The main differences lie with the x-ray emitting source, and the type of detector utilized in picking up these x-rays.

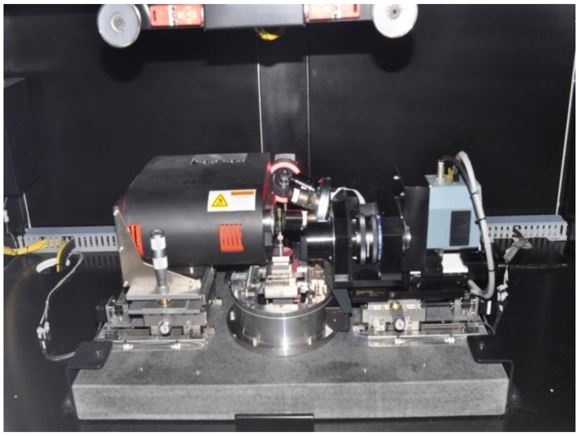

Fig-4: X-Ray Computed Tomography facility in CMTI ,bangalore lab

X-ray micro tomography presents an alternative approach in determining the porosity and pore size distribution of concrete specimens. A better image is obtained by using this new technique because it significantly enhances the picture of the pore structure in the millimeter to micron range.

Table- 7: X-CT Values on percentage of Voids in the Concrete Mixes

Mixes	Percentage of Voids (%)	
	7days	28days
Fly ash	20.48	9.34
GGBS	26.85	3.66

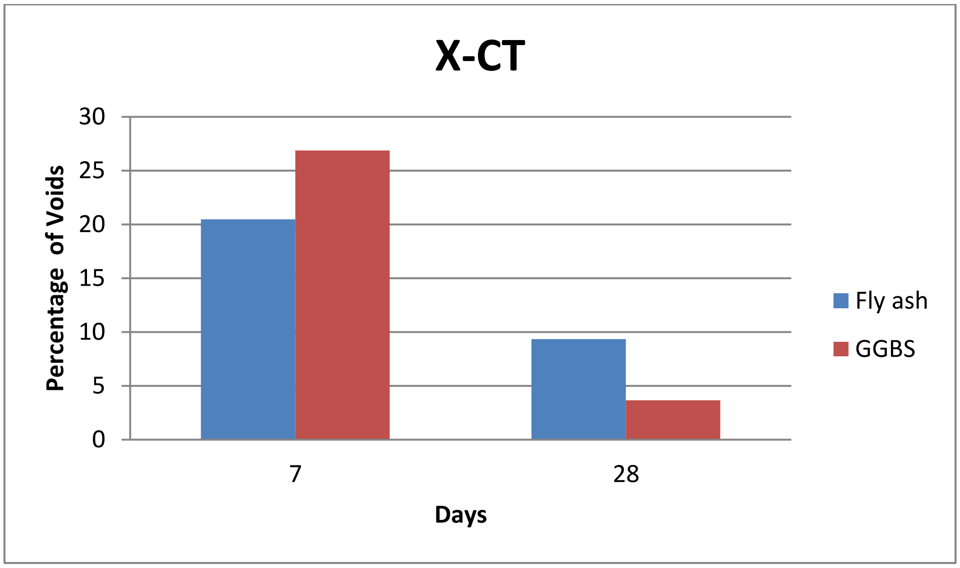

Chart- 4: X-CT Values on percentage of Voids in the Concrete Mixes

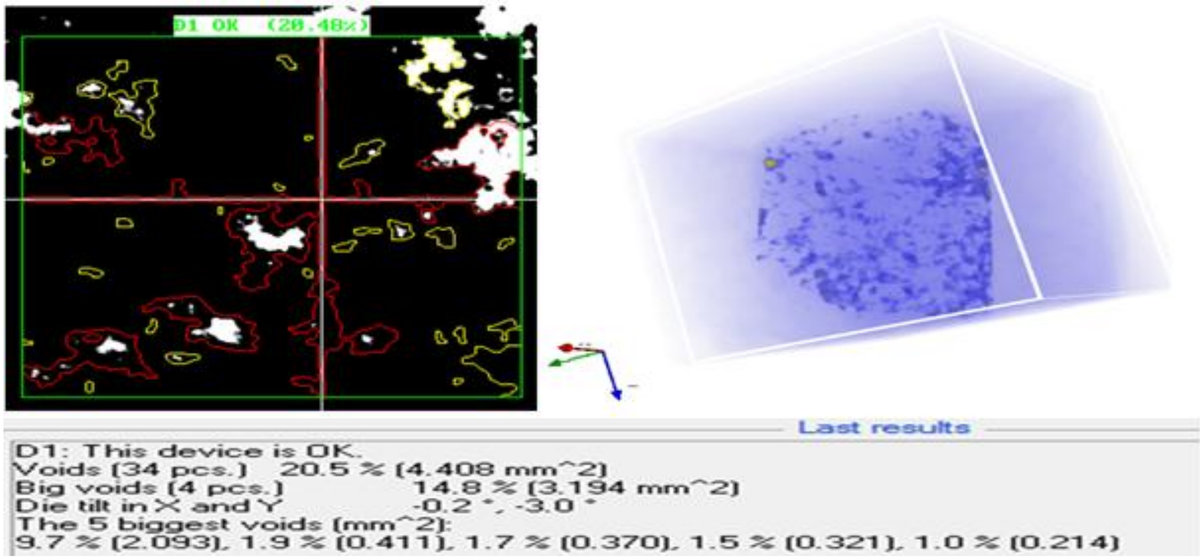

Fig-5: 2D and 3D view of F7 sample with colour-coded voids according to size distribution

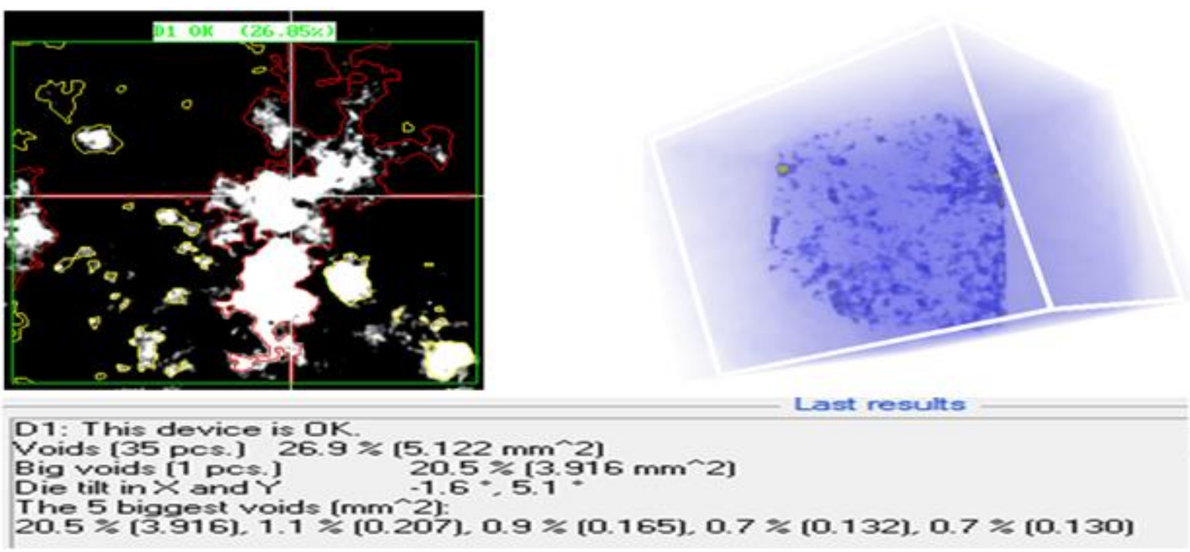

Fig-6: 2D and 3D view of G7 sample with colour-coded voids according to size distribution

8. CONCLUSION:

- The Optimum percentage of GGBS and fly ash was found to be 30%.
- The compressive strength for M35 grade at 30% of fly ash and GGBS as partial replace of cement was found to be 44.14 N/mm^2 and 40.14 N/mm^2 at 28 days of curing. GGBS mix was showing better results in compression strength than the fly ash mix with satisfying the designed compressive strength of concrete as per IS-10262(2009).
- The optimum value of water absorption for Fly ash and GGBS mix are 3.654% and 3.428% respectively as GGBS mix absorbs less water when compared with the fly ash mix.
- Capillarity value was high in the initial period and as time elapses the sorptivity value decreased gradually, and at 180min it was almost equivalent to zero.

- From the present studies it can be conclude that at 7 days more % of voids were observed in GGBS mix when compared to fly ash mix, it may be due to behaviour of fly ash particles which act as filler materials.It can also conclude that at 28 days more % of voids were observed in fly ash mix when compared to GGBS mix, it may be due to increase in the hydration process and increase in gel formation which may reduced the amount of voids in that mix.

9. REFERENCES:

1) Ahmad, M. A., Shahnawaz, M., Siddiqui, M. F., and Khan, Z. H. (2014). "A Statistical Review on the Current Scenario of Generation and Utilization of Fly-Ash in India." International Journal of Current Engineering and Technology, 4(4), 2434–2438.

2) ACI Mater J 1991; 88:159– 63. Aitcin P-Claude, Baalbaki M. In: Canadian experience in producing and testing HPC, ACI international workshop on high performance concrete. Bangkok, Thailand; 1994. p. 295–308.

3) Mehta, P. K., and Monteiro, P. J. . (2010). Concrete: Microstructure, properties and materials. Mc Graw Hill Publication.

4) Mehta, P. K. (1985). "Influence of fly ash characteristics on the strength of portland-fly ash mixtures." Cement and Concrete Research, 15(4), 669–674.

5) Brand R, Pulles T, Van Gijlswijk R, Fribourg-Blanc B, Courbet C. European pollutant emission register. Final report; 2004. <http://www.eper.cec.eu.int>. Brown, P., Hooton, R.D., and Clark, B. (2004). Microstructural changes in concretes with sulfate exposure. Cement and Concrete Composites, 26, 993-999.