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Study On The Effect Of Superabsorbent Polymer On Strength Properties Of Concrete With And Without GGBS

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Abstract: Concrete is a construction material used widely due to its high compressive strength and durability.Good concrete is made out of specific proportions of cement, fine aggregate, coarse aggregate, and water. Despite its wide use, in recent days pozzolanic materials like Ground Granulated Blast Furnace Slag (GGBS), fly ash, rice husk ash are used as partial replacement in concrete to reduce the environmental effects caused during cement manufacturing and to effectively use industrial waste material as the replacement to cement. For maintaining the proper moisture conditions and to promote optimum cement hydration curing must be done immediately after placement. Enough water needs to be present in the concrete mix for the hydration of cement to take place. The Self-curing technique provides the additional moisture in concrete for more effective hydration of cement and also self-desiccation can be reduced. Self-curing agents minimize the evaporation of water from concrete thereby increases the water retention capacity. Internal curing materials such as lightweight aggregate, super absorbent polymer, shrinkage reducing admixtures, lightweight sand and wood powder improves the strength as well as durability of concrete, reduces permeability and shrinkage, and improve the rheology of concrete.

In this project, GGBS is used as a pozzolanic material in concrete and the cement is replaced by GGBS at 50% by weight of cement. For better hydration and strength development, Super Absorbent Polymer (SAP) is used as an internal curing agent. The effect of Super Absorbent Polymer (SAP) on compressive strength, split tensile strength and flexural strength were studied by varying the percentage of SAP by weight of cement from 0% to 0.4% in the order of 0.1% for M25 grade of concrete. From the test results, it was found that 0.3% of SAP was optimum for achieving maximum strength.

Keywords:Ground Granulated Blast Furnace Slag; Self-curing; Super Absorbent Polymer; compressive strength; split tensile strength; flexural strength

1. INTRODUCTION

Curing is achieved by maintaining definite moisture content and temperature both at depth and near the surface, for a certain period of time(Shetty Be, 2000) (Gelber and Jones, 2001). Hydration takes place continuously in properly cured concrete where an adequate amount of moisture is present (Gelber and Jones, 2001). During cement hydration, the rate and extent of moisture loss from concrete is controlled by the curing process(Kern, 1983). Rapid evaporation of water from fresh concrete will take place when it is exposed to the atmosphere. To prevent the evaporation of water, proper curing is required. Concrete will show signs of excessive shrinkage and inadequate strength and durability in the absence of proper curing(IRC 84,1983)(Shetty Be, 2000).To maintain the satisfactory hygro-thermal conditions for continuous and progressive hydration of cement, sufficient curing of concrete after placing is essential.It is necessary to fill the gel pores which is formed as a result of hydration of cement by supplementing the water(IRC 84, 1983)

Internal curing refers to curing from inside out, that is curing is performed inside the concrete itself, or in other words it can be referred to as concrete that cures itself by internally available water. Curing is done by adding internal water reservoirs at the time of casting which releases water at the time of hydration(ACI (308-213)R-13,2015). Self- curing agents commonly adopted are lightweight aggregates, cenospheres, Polyethylene glycol, Super Absorbent Polymers(Paul and Mathew, 2009).Internal curing reduces the shrinkage and cracking also increases the strength and durability performance. Water supply within the concrete will increase the reaction of cement materials is achieved through internal curing. Water - filled inclusions are used by internal curing for better dispersion of curing water throughout the depth of concrete. (Weiss and Montanari, 2017).

2. SUPER ABSORBENT POLYMER

Super absorbent polymers are cross- linked polymers that absorb a large amount of fluid relative to from surrounding and retain within the structure and expands to form an insoluble gel. Super absorbent Polymers may absorb water up to 5000 times its own weight. The incorporation of SAP as a self- curing agent act as an internal water reservoir and gradually releases water when concrete becomes dry(Jensen, 2013). When SAP is used as an internal curing agent hydration of cement is increased and self desiccation is reduced. Autogenous shrinkage and capillary porosity get reduced with the addition of SAP. The addition of SAP increases the Plastic viscosity and yield stress (Mechtcherine et al, 2012). Larger capillary porosity can be formed due to the addition of SAP. Reduction in pore size was observed with high absorption capacity SAP. An increase in porosity with the addition of SAP reduces the compressive strength of concrete(Almeida and Klemm, 2018).Extra water added due to the addition of internal curing materials reduces the shrinkage of concrete(Liu et al,2017)

3. LITERATURE REVIEW

Gowtham et al, 2016 carried out an experimental study on the effect of fly ash as partial replacement of cement in strength characteristics of self-cured fibre reinforced concrete. Super absorbent polymers (SAP) are used as a self curing agentand alkali resistance glass fibre is used concrete. Using 0.3% SAP by weight of cement and AR glass fibre at 0.03% of the volume of thefraction of concrete and the percentage of flyash as 0%, 10%, 20%, 30%, 40% and 50% by partial replacement of cement and concluded that the optimum percentage of fly ash for maximum strength was found to be 20% for M40 grade concrete.

Dayalan et al, 2015studied the workability, strength characteristics, and acid resistance of the concrete with 0, 0.12, 0.24 and 0.48% of super absorbent polymer by the weight of cement. SAP as a self-curing agent, exhibit higher strength and acid resistance compared to the conventionally cured concrete.

Aarthi et al,2014 studied the strength behavior of self-curing fly ash concrete using steel fibre. The effect of strength properties with varying dosages ofSAP from 0% to 0.5% by weight of cement and steel fibre by 1%, 1.5%, 2% is compared with the concrete containing fly ash. The optimum percentage of SAP was found to be 0.3% and steel fiber was found to be 1.5%.

Oner et al,2007investigated to find the optimum level of ground granulated blast-furnace slag (GGBS) on compressive strength of concrete. GGBS was partially added at percentage of 0%, 15%, 30%, 50%, 70% and cured for 7, 14, 28, 63, 119, 180, and 365 days before testing. The test results proved that the compressive strength of GGBS concrete increases as the percentage of GGBS increases and also the early strength of GGBS concrete was lower than conventional concrete. However, as the curing period is extended, the strength of GGBS concrete increases. After the optimum point, at around 50%, the addition of GGBS does not improve the compressive strength.

Yogendra et al, 2002 investigated GGBS as a partial replacement of OPC in Cement Concrete. Ordinary portland cement is partially replaced by ground granulated blast furnace slag in different proportions varying from 0% to 40. The strength of concrete is inversely proportional to the percentage of replacement of cement with ground granulated blast furnace slag. The optimum percentage of replacement of cement by GGBS is 20% without compromising the strength with 90 days curing.

4. RESEARCH SIGNIFICANCE

Internal curing is a process by which the concrete releases water required for hydration by adding internal curing materials to the concrete. The required water for hydration will be supplied or released by internal curing materials for more effective hydration and reduced self desiccation. Self-curing provides an internal water reservoir so that enough water is available for hydration of cement and reducing the autogenous shrinkage. The main objective of this paper is to investigate the influence of superabsorbent polymer on the Strengthcharacteristics of concrete (such as compressive, tensile, and flexural strength) with and without GGBS.

5. EXPERIMENTAL PROGRAM

The effect of a variation on strength properties was studied for M25 grade concrete with different dosage of SAP such as 0.1, 0.2, 0.3, and 0.4% by weight of cement and compared with the concrete with 50% replacement of cement by GGBS.

5.1. Materials used

5.1.1 Cement

Cement used for the study was 53 grade Ordinary Portland Cement confirming IS: 12269: 1987. The Physical properties of OPC are tested as per IS 4031-1988 and are shown in Table1.

Table 1. Physical properties of Cement

S.No	Physical Properties	Results
1	Specific gravity	3.15
2	Standard Consistency	33%
3	Initial setting time	180 minutes
4	Final setting time	350 minutes
5	Fineness	1%(retained)

5.1.2 Fine aggregate

The river sand conforming to the requirements of IS 383:1970 is used. The physical properties of the fine aggregateused in this experiment are tested as per IS 2386: 1963and are shown in Table 2.

Table 2.Physical properties of Fine Aggregate

S.No	Physical Properties	Results
1	Specific gravity	2.58
2	Water absorption	2%
3	Bulk density in loose state (kg/m$^{3)}$	1330.91
4	Bulk density in rodded state (kg/m$^{3)}$	1623.47
5	Particle size distribution(Grading Zone)	II

5.1.3 Coarse aggregate

The coarse aggregate conforming to IS: 383-1970 was used in this experiment. The maximum coarse aggregate size used in this study is 20 mm. The physical properties of the fine aggregate used in this experiment are tested as per IS 2386: 1963 and are shown in Table 3.

Table 3. Physical properties of Coarse Aggregate

S.No	Physical Properties	Results
1	Specific gravity	2.93
2	Bulk density in loose state (kg/m^3)	1696.70
3	Bulk density in rodded state (kg/m^3)	1843.70
4	Moisture content	0.7%

5.1.4 Ground granulated blast furnace slag

The GGBS is locally available and the tests were carried out as per IS: 1727-1967. The specific gravity of GGBS is 2.81 and the fineness modulus of 0.5%.

5.1.5. Super Absorbent Polymer

Super Absorbent Polymer used in this experiment is sodium polyacrylate. The physical properties of Super Absorbent Polymer are shown in Table 4

Table 4 Physical properties of SAP

Physical properties	Values obtained
Appearance	white fine granular
Particle size	85-50 mesh
pH value	6.0-7.0
Free absorbency in Distilled water g/g	350—500
(AUL) (0.3PSI)，g/g Absorbency Under Load	≥28
(AUL) (0.7PSI)，g/g Absorbency Under Load	≥20
Absorption Speed (by Vortex Method)	≤70
% of moisture	≤5

5.1.6 Water

Potable water available in the laboratory was used for preparing concrete in the entire experimental investigation.The quality of water used in concrete has a direct impact on the strength of the mortar and cement concrete. The water used for curing and mixing must be free from high quantities of alkalis, acids, oils, salt, sugar, organic materials, vegetable growth, etc that might be deleterious to bricks, concrete, or iron. Hence, portable water conforming to IS 456:2000 specifications was used throughout the experiment.

6. MIXING AND PROPORTIONING

All the dry constituents likecement, SAP, GGBS, and fine aggregates are mixed dry till it is thoroughly blended. Coarse aggregate was added and mixed till uniform distribution of mix is attained. Water is added until the concrete mix is homogeneous and desired consistency. The SAP was added at 0%, 0.1%, 0.2%, 0.3% and 0.4% by the weight of cement and cement is replaced by 50% GGBS are tested for freshand hardened properties of concrete specimens.M25 concrete was designed as per IS 10269:2009. The various mix combination is shown in Table 5.

Table 5. Various mix combination

Mix ID	Mix
D1	Controlled mix(CM)
D2	CM+0.1% SAP
D3	CM+0.2% SAP
D4	CM+0.3% SAP
D5	CM+0.4% SAP
D6	50%GGBS
D7	50%GGBS+0.1%SAP
D8	50%GGBS+0.2%SAP
D9	50%GGBS+0.3%SAP
D10	50%GGBS+0.4%SAP

7. EXPERIMENTAL WORK

7.1 Workability test

Workability is the most important property of concrete during its plastic stage. A workable concrete mix should not result in bleeding and segregation. The slump and compaction factor test are used to determine the workability of fresh concrete. The test is conducted as per IS 1199-1959. The test results of workability are shown in Table 6.

Table 6 Slump and Compaction Factor Value

Mix ID	Slump Test (mm)	Compaction Factor Test
D1	95	0.92
D2	95	0.91
D3	92	0.9
D4	91	0.86
D5	90	0.84
D6	100	0.92
D7	93	0.93
D8	94	0.94
D9	95	0.96
D10	99	0.97

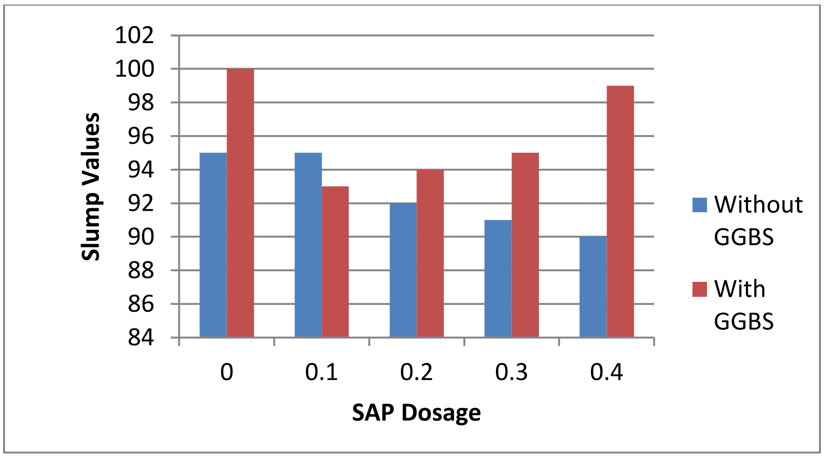

Fig 1. Comparison of Slump value

Increase in SAP dosage decreases the workability but the addition of GGBS increases the workability of concrete. The addition of 0.3% of SAP increases the workability of concrete with and without the addition of GGBS to the concrete.

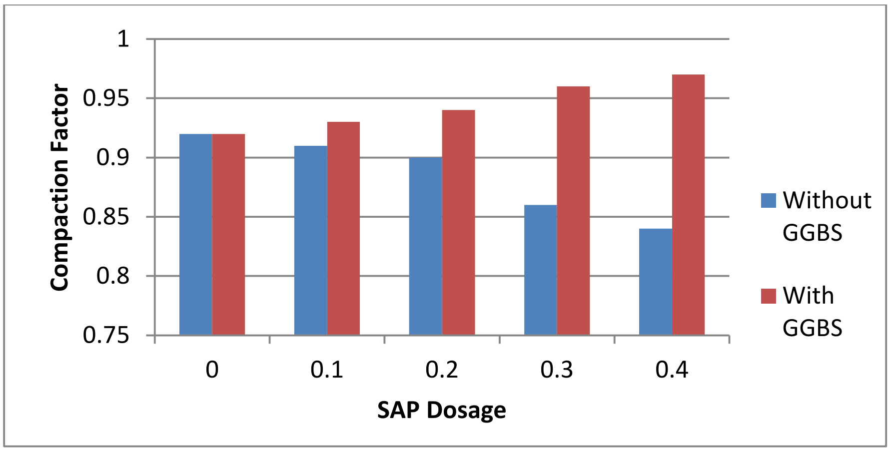

Fig 2.Comparison of Compaction factor Value

An increase in SAP dosage decreases the workability but addition of GGBS increases the workability of concrete. The addition of SAP with GGBS increases the workability of concrete Compared to the conventional mix

7.2 Hardened concrete

For ordinary concrete, fine aggregate and cement was weighted and mixed thoroughly before coarse aggregate to be added to mix and then the required amount of water was added and mixed continuously until the homogenous concrete is obtained.

When GGBS is replaced with cement, at first cement and granulated slag is mixedthoroughly and the process is continued same as an ordinary concrete mix. SAP is added to concrete by mixing it with the water and then added to concrete.SAP was added to concrete by varying the percentage from 0%to0.4% in an order of 0.1%.

For preparing the specimens for determining the compressive strength,splitten sileand flexural strength, permanent steel moulds were used. The fresh concrete was filled in mouldand compacted perfectly to get a clear finish and concrete free from the honeycomb. All the moulds were demoulded after 24 hours of casting and it is left for curingincuring tanks before testing,specimens with self-curing concrete cured at room temperature

7.2.1 Compressive strength test

The Compression test is the most common test conducted on the hardened properties of concrete. The compressive strength of concrete is determined as per IS 516-1956.The compression test was carried out on cube specimens of size 150mm x150mm x150mm. The cube strength was determined at the age of 7 days and 28 days. Figure 3 shows the compression test on a cube.Thetestresultsaretabulatedin Table 7

Figure 3 compression tests on cube

Table 7Strength test results

S.No	Mix	AverageCompressiveStrength (N/mm^2)		Average Split Tensile Strength (N/mm^2)	Average Flexural Strength (N/mm^2)
		7days	28days	28 days	28 days
1	ConventionalMix(CM)	19.257	27.686	2.222	5.768
2	CM+0.1%SAP	19.457	28.160	2.252	6.072
3	CM+0.2%SAP	19.620	28.814	2.256	6.194
4	CM+0.3%SAP	20.710	28.904	2.326	6.636
5	CM+0.4%SAP	18.748	26.015	2.291	6.3
6	50%GGBS	18.530	27.977	2.395	6.438
7	50%GGBS+0.1%SAP	17.478	28.579	2.422	6.488
8	50%GGBS+0.2%SAP	17.333	28.651	2.487	6.555
9	50%GGBS+0.3%SAP	16.786	28.749	2.534	6.609
10	50%GGBS+0.4%SAP	16.205	26.233	2.361	5.818

The test results of Compressive strength of cube at 7 days and 28 days are graphically represented in Fig 4 and Fig 5.

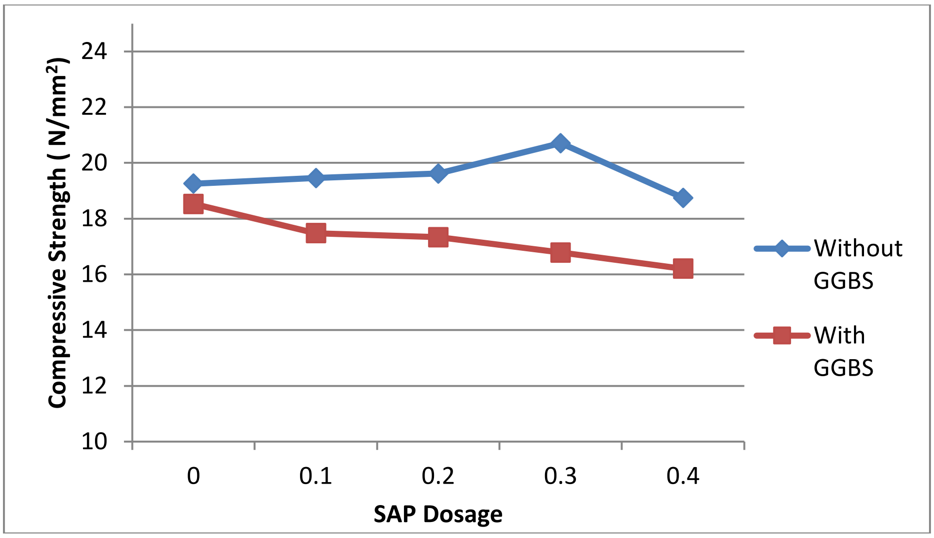

Fig 4. Compression strength at 7 days

Fig 4 shows that the compressive strength of self-curing concrete increases with an increase in SAP content for a mix without GGBS. Maximum compressive strength was attained at 0.3% addition of SAP. But the early age compressive strength of GGBS self-cured concrete was low compared to the mix without GGBS. The addition of GGBS as pozzolanic material reduces the compressive strength of concrete at early ages.

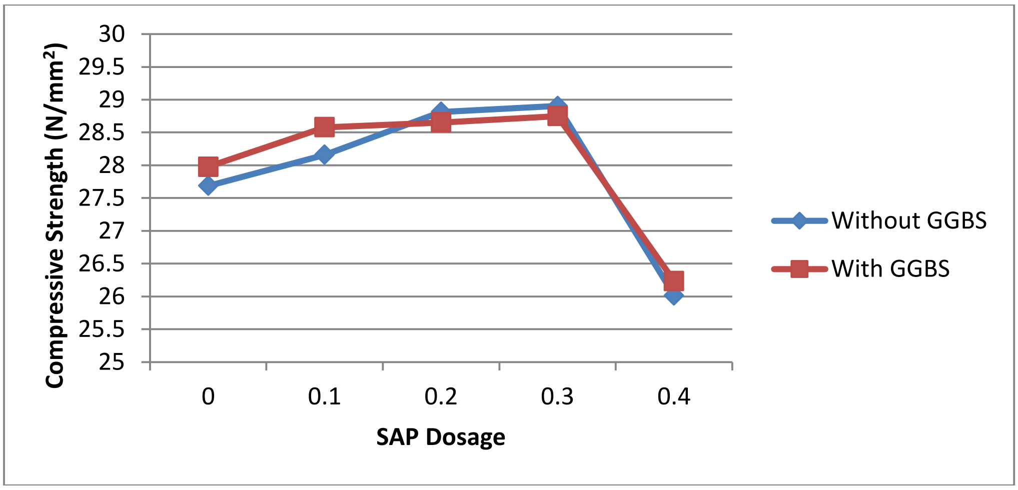

Fig 5. Compression strength at 28 days

From Fig 5, it is clear that compressive strength of concrete increases with the addition of SAP upto 0.3% by weight of binder. Replacing the cement by GGBS shows increases in strength at a later age upto 0.3 % by weight of binder but decreases at 0.4% of SAP addition in both cases with and without GGBS.

7.2.2 Split tensile strength test

Split tensile strength of concrete was carried out confirming to IS: 516-1959 is shown in figure 6. For Splitting tensile strength test, cylinders of 150mm diameter and 300mm height were cast and they were tested on after 28 days of curing.

Fig 6. Split tensile test on cylinder

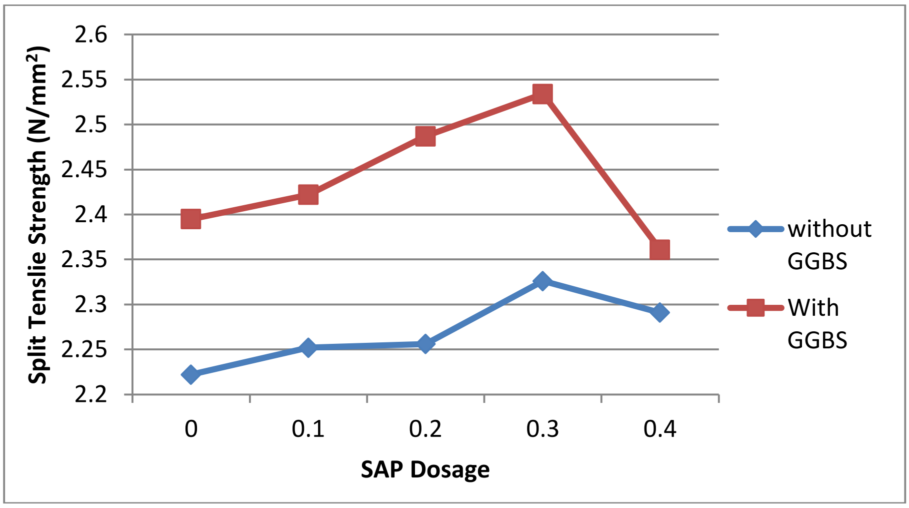

Fig 7. Split tensile strength at 28 days

From Fig 7, it is clear that the split tensile strength of the cylinder increases with addition of SAP up to 0.3 % dosage by weight of the binder. Split tensile strength of the cylinder increases for the concrete with 50% replacement of cement by GGBS when compared to concrete without GGBS.Split tensile strength of the concrete was also found to be decreased for 0.4% of SAP addition.

7.2.3 Flexural strength test

The Flexural strength of concrete test was carried out confirming to IS: 516-1959. Prism moulds of size 100mmx 100mmx 400mm were used for casting concrete. The arrangement of the test specimen is shown in figure 8.

Fig 8. Flexural strength test on prism

The test results of flexural strength of prism are graphically in Chart 6.

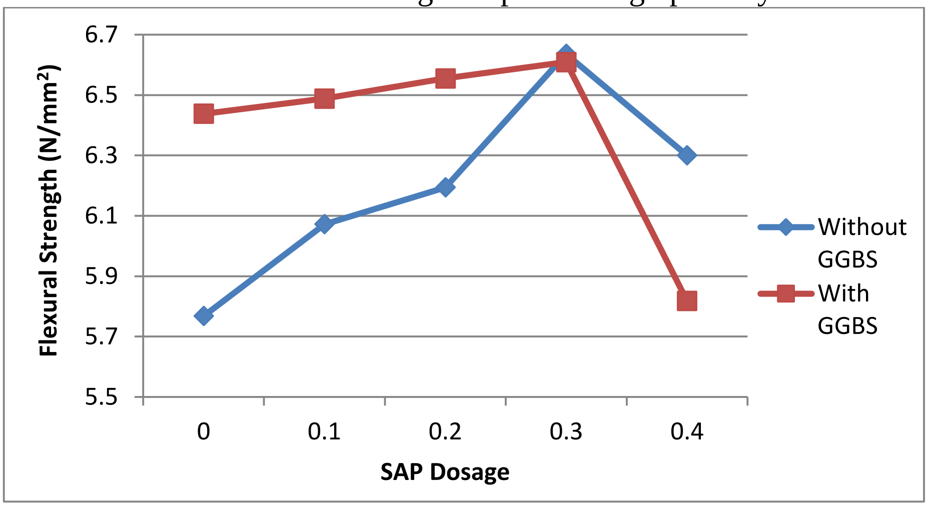

Fig 9. Flexural strength at 28 days

Flexural strength shows that there is an improvement in strength with the addition of SAP in both cases of self-cured conventional and self-cured GGBS concrete. Beyond 0.3 % of SAP, there is a decrease in strength. However higher strength is observed with 0.3% SAP addition by weight of binder content.

8. CONCLUSION

1. Workability of self-cured concrete decreases with an increase in SAP content. But with the addition of GGBS Workability of concrete is improved but lesser than the conventional mix.
2. Gradual increase in strength property of concrete with an increase in SAP Content upto 0.3% by weight of the binder but beyond that there is reduction in strength

3. Addition of SAP as a self-curing agent provides higher compressive strength, tensile strength and flexural strength than conventional concrete.
4. Increase in strength was found at later ages by replacing cement by GGBS by 50%
5. GGBS self-cured concrete shows good strength when compared to self-cured concrete without GGBS
6. The optimum dosage of SAP was found to be 0.3% by weight of the binder.

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