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RESEARCH ARTICLE

# Comparative Analysis of Self Curing Concrete with Geopolymer Concrete

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**ABSTRACT**

Concrete is a majorly used construction material which gives both good strength and durability to the structures constructed. Good strength of the concrete is achieved by the process of curing. Curing requires large amount of water. If the curing is not sufficient, water evaporates and hydration stops in the concrete. It causes cracking and low compressive strength of concrete. To reduce this effect self-curing concrete is used. It reduces the crack and shrinkage that occur in the concrete. In our project cement is partially replaced by GGBS. The GGBS is added at 20% of weight of cement. The polyethylene glycol is used as a curing agent. It is added in the concrete at 0.5%, 1%, 1.5% by weight of cement. To enhance the property of curing glass fiber is also added. The fiber is added at a rate of 1.75% of the volume of the concrete. The mixing design is done through the IS methods. The grade of concrete is M40. The following results of the conducted tests like split tensile test, compressive strength test, flexural strength test were computed in the laboratory at an interval of 7, 14, 28 days of internal curing.

**Keywords:** Self curing concrete, Ground granulated blast furnace slag, Glass fiber, Curing agent, Tensile test.

## 1.1. INTRODUCTION

Concrete forms a fundamental part of any modern day structural construction. It forms the basic engineering material used in building the structures; used almost in all the civil engineering structures. It is widely recognized for its importance in the sections of economic feasibility, durability and its easy manufacturing. Like any other engineering materials, concrete also needs to be designed depending on the requirement of its specific properties like strength, durability, workability, etc. As the advancement of the knowledge in admixtures happened overtime, the manufacture of higher grades of concrete has become possible. It is basically an amalgamation of the ‘aggregate’ and cement, which when hydrated with water, forms a solid rock like material on curing [1]. In curing, sufficient amount of moisture and temperature is maintained during the early stages of concrete formation in order to achieve desired properties. Also, the term aggregate used here defines the mixture of inert substances such as broken rocks, natural gravel, sand, Ground Granulated Blast Furnace Slag (GGBS), glass fiber and such materials which can form a base material for the binder, namely cement, to be bound with. Majorly, curing is done with the help of external agents, but in this context a major stress is given on self-curing, also called as Internal Curing (IC) [2]. Self-curing refers to a process in which additional internal water, apart from the external agents that is not a part of the mixing water, is made available for the hydration of the cement. Curing done in sufficient amount has a significant impact on the properties of an hardened concrete which includes increase in its durability, strength, water compactness, abrasion resistance, volume stability, and resistance to freezing and thawing effects [3]. In this context curing is assisted through the curing agents like polyethylene- glycol. The basic nature of a curing agent is to withhold water when in contact with water which is possible because of its water malleable nature. One such curing agent, namely polyethylene glycol is tested by adding it into the concrete mixtures in different proportions [4] [5]. The strength of a concrete in terms of its

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resistance to the compression and tensile forces mainly depend on the admixtures and reinforcements used in composition. Here admixtures are majorly classified into chemical and mineral types. A proper selection of these admixtures will have a significant impact on the mechanical and corrosive properties of the concrete [6]. In this context, the usage of GGBS is done in the form of a mineral admixture with improves the mechanical strength in the form of improved compressibility strength. Reinforcement is also necessitated as the concrete, though resistant to compressibility, tends to deform under tensile forces and by including proper reinforcements like “glass fiber” concrete can be given necessary tensile strength [7-9].

### 1.1. Objective

- To make the concrete with partial replacement of cement by GGBS.
- To evaluate the strength and compare it to the geopolymer concrete.
- To make the concrete by adding the self-curing agent, and evaluate the strength by adding various percentage of self-curing agent.

## 2. LITERATURE REVIEW

[10] Studied for the variations in compressive strength of the self-compacted concrete having a medium strength using three different curing techniques. First batch was cured in a tank in which temperature can be controlled, whereas the second batch was cured using curing compounds externally. The third batches were cured by internal curing compounds. In the experiment, it was found that the 28 day compressive strength of cubes cured by applying curing compounds was 95% of the compressive strength of cubes which was cured in the laboratory. [11] analysed for some specific water-soluble chemicals such as polyvinyl alcohol. This compound was added while making a mixture of the concrete and due to this there was a significant reduction in the water being evaporated from ` and tensile strength of this concrete was tested at an interval of 7 and 28 days compared with a conventional concrete of a similar mix. The second type of chemical used was polyethylene- glycol (Ch.).

The usage of this self-curing agent (Ch.) showed an improvement of the physical properties in comparison with a conventionally produced concrete. [12] Studied for the compressive strength of self-curing concrete which was found to be increasing with the usage of self-curing admixtures. The admixtures used here were PEG600 and PEG1500, on addition of which increased the compressive strength of the concrete. This increased to 37% by 1.0% addition of PEG600, whereas it increased to 33.9% by 1.0% addition of PEG1500; when they were compared to the conventional concrete. It was found that when PEG600 was added by 1% of the weight of cement for M25 grade of concrete, the maximum compressive strength was found. In the same way, for PEG1500, the maximum compressive strength was found at addition of 1% of the weight of the cement in case of M25 grade of concrete.[13] was studied for the variation of the composition of the curing agents used while preparing a composition of self-curing concrete, In this paper self-curing concrete was analysed with different sets of mixtures which were used to analyse the properties of the curing agents and their effects on the concrete mixture after a varied time periods of curing the concrete. Here, the results included the importance of choosing an optimal curing time, Also, the curing agents used were Poly Ethylene Glycol (PEG) and Poly Acryla Mide (PAM). These agents were tested in different proportions and the results obtained here shows the improvement of the properties of its corrosion resistivity and better durability indices when compared to the conventional concrete structures. [14] studied for the significance of geopolymers over Ordinary Portland Cement (OPC) In this literature, Poly Ethylene Glycol (PEG) with molecular weight ranging between 400 to 20000 was tried and tested for the best suited agent. It was later inferred that with increase in the polymer molecular weight, its porosity also increased. In this, the effective results in terms of compressive strength and flexural strength was found with an addition of 5%, 7% and 10% PEG 400, in the total composition. In contrary to this, the lowest strength was determined in the geopolymer with PEG 20000. [15] studied for the properties of Self Compacting Concrete (SCC) by replacing cement with Supplementary Cementitious Materials (SCM) like silica fume and ultra-fine Ground Granulated Blast furnace Slag (GGBS) which are produced from steel and iron industries as a by-product. They were tested by taking varying ratios of their quantities. Inclusion of 10% silica fumes in the mixture produced the most suitable results in terms of both the mechanical and the durability studies against the combination of other ratios. Using a statistical approach of Design of Experiments (DOE) the best suited mixture of alccofin and silica was found out to form an SCC along with an addition of plasticizer.

[16] studied for the properties of Waste Steel Fiber (WSF) produced during tyre recycle instead of an Engineered Steel Fiber (ESF) so that it can be used in the production of a fiber-reinforced concrete. These studies substantially showed the waste steel fiber to have higher tensile strength and ductility than that of a regular engineered steel. The properties of WSFs and ESFs were compared and analysed. The stress-strain characteristics of both WSF and ESF differ significantly. WSF has more tensile strength and ductility when compared to EMF and also it can bear three folds more bend tests than EMF. [17] studied for the properties of concrete prepared by grounded and Recycled Aggregates (RA). The comparison studies of the Scattering-Filling Natural Aggregate (SFNA) concrete and RAC used in general was tested for its size, ratio, type and its moisture state. This was done majorly to determine its comparative mechanical properties and its durability. Though economically beneficial, in terms of high water requirement, high mortar ratio, low elasticity modulus it was found far inferior to the conventional reinforced aggregate concrete. In studies, it was found that the aggregate which was recycled has a high porosity and water absorption which forms its disadvantage. Thus, the process of SFCA was used to determine an efficient way to prepare the RAC.

[18] studied for the possible usage and effect of the Recycled Concrete Aggregates (RCA) taken from the waste concrete used as an alternative to the crushed stone aggregates found in nature. The main focus of the work was to determine an appropriate mixture of the concrete made from Crushed Cement Aggregates (CCA) without significantly reducing the desirable properties of the formed concrete in terms of its compressive strength, flexural strength, tensile strength and modulus of elasticity. In this research, it was found that the replacement up to or more than 25% of CCA does much alteration to the strength properties of the concrete with splitting tensile strength being less affected when compared to the other properties.[19] was reviewed to find out about the water quality which is to be used in a concrete making process. In this research it was stressed on the usage of the water free from chemical and organic substance, which is to be used for curing and mixing; as this may cause significant effects in its initial stage of forming like in its setting time, workability, strength development and its long term durability. The final conclusion states that the ideal pH range of the water while mixing concrete lies between 7.2 and 7.6. Also, the total solids present in the mixture equal to the sum of organic and inorganic solids along with the suspended and dissolved solids should be accounted for.[20] studied about the mechanical properties of the concrete made from the self-curing agents like pre-soaked Light Weight Expanded Aggregate (LECA) and polyethylene-glycol. These observations showed improved mechanical properties of the concrete formed which is due to the continuity in the hydration process leading to a less porous constituent followed by a strong bond between the cement paste and the aggregate. The results shown by the usage of polyethylene-glycol was better than that of LECA. The optimum values of the polyethylene-glycol and LECA to be used in concrete was found to be 2% and 15% respectively. It was also inferred that the statistical modulus of elasticity is heavily inclined to the compressive strength which is related to all the self-curing concrete types at their different ages [21-24].

- In the above discussion, it was clear that with addition of the curing agent resulting in the either greater or lower curing time would invariably effect the properties of the formed mixture. Also, the choice of a water soluble polymer used as curing agent showed significant improvement in the corrosion protection and a significant reduction in the curing time of the concrete experimented with.
- The use of SCM will significantly reduce the demand of cement and other chemical admixtures containing aluminates and silicates in the formation of (SCC). Also, the GGBS generated as an industrial waste can be economically utilized into reducing the production of cement, which in turn cause the environmental pollution.
- These references of results substantiated more to the choice of Polyethylene Glycol-400 in further experimental observations. A varied approach is used in the experimentations here by the inclusion of carbon fibre which further

enhances the durability of the concrete formed.

## 3. MATERIALS AND PROPERTIES

### 3.1. Cement

An ordinary Portland cement or simply cement acts as a binder in the formation of the mixture of the mortar or concrete. When it is mixed with sand and water it forms mortar and it is mixed with gravel, and water it forms concrete. This concrete forms more stable of a structure. There are basically two types of cement classified, they are hydraulic and non-hydraulic. The commonly used among them is the hydraulic cement named as Portland cement which reacts when in contact with water and other ingredients, whereas the other type remains unreacted to water, but starts binding when in contact with the carbon dioxide present in air.

The general composition of cement includes a mixture of silicates and aluminates. The cement used here in investigation was of the grade of 43 and was an ordinarily used Portland cement. This cement confirms to the Indian standard as IS: 12269:1987. Also, the specific gravity of the cement used here is 3.15 (SG).

### 3.2. Fine aggregate

The fine aggregate used here is sand. Generally an aggregate mixture used is to give a base composition in a mixture so that it could be bound to the binding agents like the cement. In general it will be the composition of the sand and the grains of the materials derived from the disintegration or crushing of rocks. The fine aggregate used here had been passing through a sieve having an aperture of 4.75mm in diameter. It also has the specific gravity of 2.68. The fine aggregate used here confirms to the zone III of Indian Standard IS: 383-1970 was used.

### 3.3. Coarse aggregate

The coarse aggregate used are the remains of the crushed stones, which are generally used in making concrete. The size of the aggregate used here was about 20mm in diameter to the maximum while its specific gravity being 2.78. The coarse aggregate used here is according to the standard of IS: 383-1970.

### 3.4. Water

The water quality used in the construction is of a significant importance in engineering constructions. It should be sufficiently clean and restricted from any contamination with substrates of viscous liquids like oil, acids and alkali, organic compound or any such soluble which cause direct or indirect effect on the composition of the concrete formed. When the addition of water does not change the curing time of the concrete to a minimum extent of 30 minutes nor decreases the strength more than 20% it is considered suitable for concrete preparation. In order to manufacture cement in this experiment, the tap water was used which was available in the laboratory.

### 3.5. Glass fiber

In a graded fiber reinforced concrete, an optimum amount of the mixing of the short length and long length fibers is done. It has been researched that the the addition of short length fibers in a mixture helps in controlling the spread of any micro cracks which forms while any error of formation of concrete improving its ultimate strength. Also, longer fibers used in a given mixture helps in preventing the formation of macro cracks, preventing any deformation formed due to crack propagation. Therefore, an optimum mixture of both the short and long length fibers in a mixture helps in preventing any sort of crack formation on miniscule level or on a larger level. This will be significant in the performance of both the pre and post crack development of the concrete formed. In general, glass fiber is the most commonly used fibers as an reinforcement in concrete formation. The length of glass fiber used here is 25mm with a thickness of 0.5mm. The use of the glass fiber here makes improvements in the properties of the concrete such as its flexural index, its impact resistance and in its fatigue strength.

### 3.6. Polyethylene glycol-400

Self-curing agents play a prominent role in making an efficient self-curing concrete. In general curing agents are either water absorption based or water-soluble. In this way they retain water when continuous evaporation takes place due to the external climate. The curing agent used here is Polyethylene glycol or PEG-400 which in itself form with the combination of polymer ethylene oxide and water. The chemical formula of PEG-400 is written as H-(OCH2CH2)n-OH, here 'n' is the average of the number of oxyethylene groups which repeats themselves and ranges from 4 to 180. In the abbreviation (PEG)-400, the numeral '400' denotes its average molecular weight and also, PEG-400 is water-soluble.

### 3.7. GGBS

It is by product obtained from the steel industry and hence it is named "ground granulated blast furnace slag". The disposal cost of GGBS is very high and is not eco-friendly, but when used in a concrete business instead of cement, will prove to be a good commodity. This also contains salts of silicates and aluminates which forms a good substitute for the present day Portland cement. Table 1 shows the comparative constituents of Portland cement and GGBS.

Table 1.Comparative constituents of Portland cement and GGBS

| Constituents | Portland | GGBS |
|---|---|---|
| Calcium oxide | 65% | 40% |
| Silicon dioxide | 20% | 35% |
| Aluminium | 5% | 10% |
| Magnesium | 2% | 8% |

## 4. MIX DESIGN AND SPECIMEN PREPARATION

Self-curing concrete was casted for M40 grade of compressive strength. Generally, self-curing concrete mix design is based on achieving a density of 1435kg/m3.Mixing of GGBS, cement and aggregates per cubic meter was done. The curing agent was then added at 0.5%, 1% and 1.5% of the volume of the cement. The glass fiber is then added at a rate of 0.75% of the volume of the concrete. The specimens were cast and kept in steel moulds for 1 day. Then the specimens were remoulded and kept aside for the internal curing for the respective time periods of 7 days, 14 days and 28 days. Alongside, ordinary Portland cement concrete cubes of the same grade were casted for the purpose of comparison.

## 5. EXPERIMENTAL WORKS

### 5.1. Compressive strength test

Compressive strength of a specimen is defined as the maximum load it can withstand under compressive forces. In general, compressive strength testing equipment is used to test cement, brick or concrete through a point load until the specific block generates crack which will be noted in the form of a sudden change in the reading meter.

The cube specimens were tested on a compression testing machine which was having the capacity of 3000 KN. The cubical mould size used here was of 150 mm ×150 mm× 150 mm in its dimension. Here, concrete is poured into the mould and tempered properly in order to avoid any voids. These are then cured in various groups of the interval and once the blocks of cement after curing are obtained they are tested for the compression tests under an continuous rate of loading.

### 5.2. Split tensile strength test

The "tensile strength" of a specimen is defined as the maximum load it can withstand under tensile forces. In general, split tensile strength test is conducted on a concrete cylinder to determine the tensile strength of the concrete. The cylindrical specimens were tested on a compression testing machine which had capacity of 3000KN. These specimens were laid horizontally on the surface so that the cylindrical surface was having maximum contact. In this way the force was applied horizontally along the axis outwards, thus forming a tensile stress under the pressing of the hydraulic arm. The load was applied gradually till the resistance of the specimen wears out due to the load and breaks down, no longer being able to sustain itself. Then the reading noted in the results section in the following table titled tensile strength of SCC.

### 5.3. Flexural strength test

In general flexural strength of a specimen is defined as its capacity to withstand bending without any major deformation. Flexural strength test or the bend strength test of a material is done to determine the maximum stress of the specimen before it yields. In this test a point load is applied to the centre of the specimen supported at two ends with a knife-edge support. The beam specimen of size 100 mm x 100 mm x 500 mm was casted to determine the flexural strength of the concrete with various percentages of polyethylene glycol-400. The load is applied here at a constant rate, increases the maximum stress until the crack generates from the centre and it gets break down. Then the reading noted. These readings are shown in the tables in the results section under the title flexural strength.

## 6. RESULTS AND DISCUSSION

The main aim of the experiments conducted was to determine and to compare the strength of the self-curing concrete with that of a geopolymer concrete, by adding different proportions of self-curing agent. The result of geopolymer concrete is given below.

### 6.1 Compressive strength

Table 2.Compressive strength of geopolymer concrete

| Period in days | Curing compressive strength(N/mm2 ) |
|---|---|
| 7 | 32 |
| 14 | 36.9 |
| 28 | 39.56 |

Table 2 shows the compressive strength of geopolymer concrete. With this a gradual trend can be seen which stagnates after a certain time period of curing. To study the compressive strengths of SCC with varying proportions of curing agent is given in Table 3.

Table 3.Compressive strength of SCC

| Curing in terms of days | Compressive strength ($N/mm^2$) | | |
|---|---|---|---|
| | 0.5% | 1% | 1.5% |
| 7 | 35 | 39 | 39.5 |
| 14 | 39 | 45 | 43 |
| 28 | 45 | 51 | 54 |

In the following Figure 1, a comparative graph of the compressive strength of the various compositions of specimens with a varied self-curing agent is shown. Here, the curing time given as 7 days, 14 days and 28 days respectively.

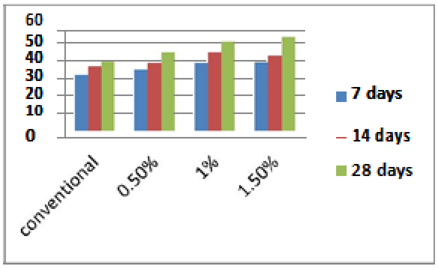


Figure 1.Comparison of compressive strengths of concrete

From the above results, a clear trend of the increase in the strength of the specimen can be observed with the increase in the percentage of the self-curing agent used in the composition.

### 6.2 Tensile strength

Table 4.Tensile strength of geopolymer concrete

| Curing period in days | Tensile strength ($N/mm^2$) |
|---|---|
| 7 | 3.546 |
| 14 | 4.253 |
| 28 | 5.78 |

In Table 4, a gradual increase in the tensile strength of the geopolymer concrete can be observed. With this, a gradual trend can be seen which stagnates after a certain time period of curing. To study the tensile strengths of SCC with varying proportions of the curing agent is given in Table 5.

Table 5.Tensile strength of SCC

| Curing in days | Split tensile strength($N/mm^2$) | | |
|---|---|---|---|
| | 0.5% curing agent | 1% curing agent | 1.5% curing agent |
| 7 | 4.75 | 4.9 | 5.3 |
| 14 | 4.89 | 5.1 | 6.4 |
| 28 | 5.23 | 5.8 | 7.5 |

Comparative graph of the tensile strength of the various compositions of specimens with a varied self-curing agent is shown in Figure 2. Here, the curing time interval given as 7 days, 14 days and 28 days respectively.

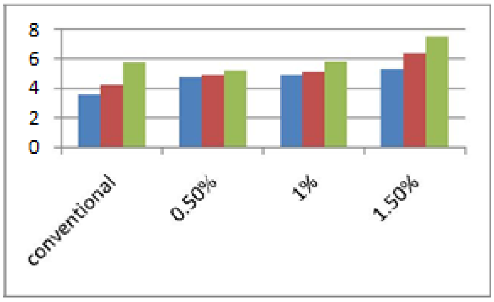


Figure 2.Comparison of tensile strength of concrete

From the above results, a clear trend of the increase in the strength of the specimen can be observed with the increase in the percentage of the self-curing agent used in the composition.

### 6.3. Flexural strength

Table 6.Flexural strength of geopolymer concrete

| Curing period in days | Flexural strength ($N/mm^2$) |
|---|---|
| 7 | 4.82 |
| 14 | 5.5 |
| 28 | 6.98 |

In Table 6, a gradual increase in the flexural strength of the geopolymer concrete can be observed. With this, a gradual trend can be seen which stagnates after a certain time period of curing. To study the tensile strengths of SCC with varying proportions of the curing agent, this is given in Table 7. In the following Figure 3, a comparative graph of the flexural strength of the various compositions of specimens with a varied self-curing agent is shown. Here, the curing time interval given as 7 days, 14 days and 28 days respectively.

Table 7.Flexural strength of SCC

| Curing in days | Flexural strength(N/mm$^2$) | | |
|---|---|---|---|
| | 0.5% curing agent | 1% curing agent | 1.5 % curing agent |
| 7 | 5.7 | 6.4 | 7.54 |
| 14 | 6.5 | 7.5 | 8.84 |
| 28 | 7.9 | 9.3 | 9.97 |

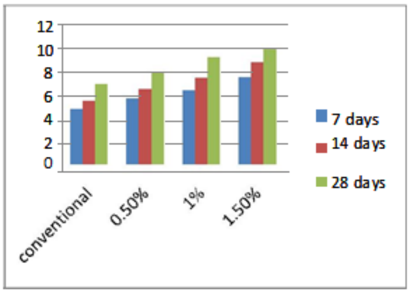


Figure 3.Comparison of flexural strength of concrete

From the above results, a clear trend of the increase in the flexural strength of the specimen can be observed with the increase in the percentage of the self-curing agent used in the composition.

## CONCLUSION

Water retention of the concrete formed due to the inclusion of a curing agent is higher than any geopolymer concrete mixtures prepared. As the percentage of the curing agent increases after a certain point, the strength of the specimen is also reduced. Hence, care should be taken in order to add the correct proportion of the curing agents. With an addition of the curing agent, curing time is reduced when compared to the geopolymer concrete. The strength of the concrete with the incorporation of GGBS has increased by a rate of 20% when it compared with conventional concrete. In terms of the compressibility strength, tensile strength and flexural strength, there has been a significant increase in the composition of an SCC concrete when compared to that of a regular concrete. As there is a substantial evidence of the improvement of the strength of the concrete, GGBS can be effectively used as a substitute to the cement used in the construction industry. This will effectively improve the economic feasibility of the construction material which will have a minimum environmental impact when compared with the regular construction methods involving cement as a binder.

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