Investigation on Mechanical properties of self-curing concrete

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Abstract

Concrete curing involves maintaining an adequate moisture level in the preliminary stages of concrete development to achieve its respective properties. However, practical limitations often make proper curing difficult. Consequently, researchers have explored the self-curing agents as a solution. These agents aim to decrease water evaporation from the concrete and enhance its water retention ability compared to traditional concrete. Self-curing concrete absorbs moisture from the atmosphere, promoting improved cement hydration and addressing issues caused by inadequate or absent curing, which can lead to unsatisfactory concrete properties. The present investigation involves the use of self-curing agent viz., polyethylene glycol (PEG) of molecular weight 400 (PEG 400) for dosages ranging between 0% to 2% by weight of cement added to mixing water and GGBS added 0% to 40% by replacing cement. The experimental program was planned as the following. Total 225 cubes, 225 cylinders, 225 prisms were cast which involves different dosages (0%, 0.5%, 1%, 1.5% and 2%) of self-curing agent PEG-400 and addition of GGBS (0%, 10%, 20%, 30%, and 40%) for three grades of concrete mixes (Mix M20, M40 and Mix 60), under different curing conditions (conventional and self-curing). Comparative studies were carried out for conventional concrete, supplementary cementitious concrete, self-curing concrete and supplementary cementitious self-curing concrete. Comparative studies were carried out for compressive strength, split tensile strength, flexural strength after 28 days of concrete. Supplementary cementitious Self-curing concrete is better in all aspects compared to conventional cured concrete.

Keywords: Supplementary cementitious Self-curing concrete; Conventional concrete; Polyethylene glycol (PEG-400); Compressive strength; Flexural strength; Split tensile strength

Introduction

In the present world, concrete is one of the most widely used construction materials. This can be due not alone to the large choice of applications that it offers, however, besides, its behavior, strength, affordability, durability, and flexibility play vital roles. Therefore, constructing- building works have faith in concrete as a secure, strong, and simple object. It is utilized in all sorts of buildings (from residential to multi-story workplace blocks) and infrastructure. Concrete like other engineering materials needs to be designed for properties like strength, durability, workability. With advent of new generation admixtures, it is possible to achieve higher strength of concrete with high workability levels economically. Curing is the maintaining of a satisfactory moisture content and temperature in concrete during its early stages so that desired properties (of concrete) may develop. The concept of self-curing agents is to reduce the water evaporation from concrete, and hence

increase the water retention capacity of the concrete compared to conventional concrete. It was found that water soluble polymers can be used as self-curing agents in concrete. In the current concrete industry, self-curing of concrete has gained a lot of reputation among the available curing techniques. Apart from having the comfort of not using water, SC concrete offers many advantages over conventional concrete. It includes the quality, durability and strength of concrete while reducing the shrinkage. The included SC agents utilize the internal water inside the concrete for curing purposes. A proper composition of coarse aggregates and SC agents are required to achieve the optimum curing process.
Keeping in view of requirement of the need for study, the following aims and objectives have been set out.

- Develop mix proportions of self- curing concrete of M20, M40 and M60Grades of concrete.
- To study the Compressive strength properties of self- curing concrete and conventionalconcrete.
- To study the flexural strength properties of self- curing concrete and conventional concrete.
- To study the Split tensile strength of self- curing concrete and conventional concrete.
- To study the SEM and XRD of self-curing concrete and conventional concrete.

Literature Review

M.V.Jagannadha Kumar(2012) studied shrinkage-reducing polyethylene glycol (PEG 400) is used as an additive in concrete to provide greater hydration and, ultimately, strength. The effects of admixture (PEG 400) on compressive strength, split tensile strength, and rupture modulus were investigated for both M20 and M40 mixes, the effects of changing the PEG content in cement from 0% to 2%. PEG 400 was shown to have strength comparable to conventional curing, which could aid in self-curing. Additionally, it was discovered that for M20 grade concretes, 1% of PEG 400 byweight of cement was ideal, while for M40 grade concretes, 0.5% was ideal for achieving maximum strength without compromising workability. Mousa et al (2014) evaluated two different agents of self-curing concrete for their behavior in internal curing of presoaked lightweight aggregate (Leca) and a polyethylene-glycol (PEG) chemical agent. M. V. Jagannadha Kumar, K.Jagannadha Rao , B. Dean Kumar , V. Srinivasa Reddy.,(2018) discovered an ideal mix proportion of self-curing concrete for different grades M20, M40 and M60 by supplementing poly ethylene glycol (PEG-400)as internal curing agent. The ideal measurements of PEG (communicated in rate by weight of concrete) embraced for M20, M40 and M60 grades internal cured concrete are 1%, 0.5% and 0.5% separately. It is observed that there is a reduction in the weight loss and better pore structure of concrete, as the grade and the ages of self-curing concrete with PEG are increased. T. Vadivel et al. (2019) noted that water is an essential component, the quantity of which in concrete determines fresh and hardened properties. M30 grade of concrete is adopted using IS method of mix design. For the production of internal-curing concrete trial fractions of 1%, 2% and 3% of PEG-400 and silica fume of 15%, 18% and 20% by weight of cement was used and tested for different mechanical properties and found that 1% PEG at 20% silica fume is the optimal among all mixes. Podeti anil (2020) reports that influence of PEG and diaper polymer on the workability and compressive strength of the concrete was investigated. Expected result will probably solve two problems which are while use the disposable diapers polymer to reduce amount at dumping area and producing the eco-friendly concrete for construction. Workability Addition of Diaper Polymer in concrete mixture can have a considerable effect on concrete workability since it will absorb some amount of water content. Concrete mix with 1% diaper polymer resulted in maximum slump value due to the presence of additional water in the form of liquid gel.

Experimental Programe

The different materials used in this investigation are cement, fine aggregate, coarse aggregate, water, ground granulated blast furnace slag, polyethylene glycol 400 and super plasticizer. Cement used in the investigation was 53 grade ordinary Portland cement confirming IS: 12269: 1987. The fine aggregate used was obtained from a nearby river source. The fine aggregate conforming to zone II according to IS: 383-1970 was used. Crushed granite was used as coarse aggregate. The coarse aggregate according to IS: 383-1970 was used. Maximum coarse aggregate size used is 20 mm. Potable water was used in the experimental work for both mixing and curing purposes. Blast furnace slag is produced as byproduct during iron production. Iron ore, as well as scrap iron, is reduced to a molten state by burning coke fuel with fluxing agents of limestone or dolomite. The molten slag from the furnace is rapidly chilled by quenching in water to form glassy sand like material. GGBS is produced by grinding the granulated slag to less than 45µm size to obtain a fineness of 400-600 m2/kg. For the present study, GGBS is obtained from M/s. JSW steel works Ltd., Coimbatore, India. Polyethylene glycol is a condensation polymer of ethylene oxide and water with the general formula $H(OCH_2CH_2)nOH$, where n is the average number of repeating oxyethylene groups typically from 4 to about 180. The abbreviation (PEG) is termed in combination with a numeric suffix which indicates the average molecular weight. One common feature of PEG appears to be the water-soluble nature. The PEG-400 use in the investigation have Molecular Weight 400. Conspalt SP 430 used as a Super plasticizer.

Methodology

The experimental program was designed to investigate the strength of self-curing concrete by adding poly ethylene glycol PEG400 @0%, 0.5%, 1%, 1.5% and 2% by weight of cement to the concrete and Ground granulated blast furnace slag (GGBS) @0%, 10%, 20%, 30% and 40% replaced cement by weight. The experimental program was aimed to study the workability, compressive strength, split tensile strength, flexural strength. To study the above properties mixes M20, M40 and M60 were considered. The proportions of mixes were tabulated in Table 1 and Table 2.

Table 1. Mixing proportions of different concrete grades.

Grade of Concrete	Cement	Fine aggregate	Coarse aggregate	Water	GGBS	Polyethylen eglycol (PEG)	Super plasticizer
M20	320	720	1197	160	0%-40%	0% -2%	-
M40	394	669	1212	150	0%-40%	0% -2%	-
M60	534	614	1183	144	0%-40%	0% -2%	1%

Table 2. Mix Notations for M20, M40 and M60 type of Concrete

Mix Type	% Of Cement	% Of GGBS	% Of PEG
C0G0P	100	0	0
C10G0P	90	10	0
C20G0P	80	20	0
C30G0P	70	30	0
C40G0P	60	40	0
C0G0.5P	100	0	0.5
C10G0.5P	90	10	0.5
C20G0.5P	80	20	0.5
C30G0.5P	70	30	0.5
C40G0.5P	60	40	0.5
C0G1P	100	0	1
C10G1P	90	10	1
C20G1P	80	20	1
C30G1P	70	30	1
C40G1P	60	40	1
C0G1.5P	100	0	1.5
C10G1.5P	90	10	1.5
C20G1.5P	80	20	1.5
C30G1.5P	70	30	1.5
C40G1.5P	60	40	1.5
C0G2P	100	0	2
C10G2P	90	10	2
C20G2P	80	20	2
C30G2P	70	30	2
C40G2P	60	40	2

Experimental Setup

Compressive Strength

The specimens were evaluated as per IS 516:1969, using universal compression testing machine of 2000kN. Initially, the platens are cleaned and further the oil level is checked. The specimens are placed on the machine and load is applied at the mid. The smooth surfaces are kept over the bearing surfaces. The top plate should be in contact with specimen via rotating handle. Further, the oil pressure valve is closed and the machine is switched ON. The load at which maximum failure on specimen breaks and the average value is considered as mean strength. The maximum load applied on specimen was recorded. Figure 1 shows the experimental setup for compressive strength.

$fc = P/A$, where, P is load & A is contact area of cube

Figure 1. Testing the specimen for Compressive Strength.

Split Tensile Strength

Split tensile strength is evaluated as per IS 5816:1999. The initial load is applied without producing any shock and parallelly continue to increase at range from 1.2 N/(mm^2/min) to 2.4 N/(mm^2/min). The rate has to be maintained until failure. When the failure is approached the loading rate will start to decrease. The maximum load applied should be recorded. The appearance of failure features need to be recorded. In this test, a cylinder of 150 mm dia and 300 mm height is subjected to the load by compressing along the axial lines which are diametrically opposite and continue to apply until the specimen fails. This produces a transverse tensile stress along with vertical diameter. The splitting tensile strength is calculated by the formula. Figure 2 shows the experimental setup for split tensile strength.

$$ft = 2p/\pi ld$$

Where, p = maximum load applied in N.

l = length of the specimen in mm.

d = diameter of the specimen in mm.

Figure 2. Testing of Spilt tensile strength on Specimen

Flexural Strength

Flexural strength is estimated in terms of modulus of rupture, Once the Prism is removed after curing, they are tested on load frame of having capacity of 20 kN as per IS 9399:1679. The load frame is fitted with the two rollers which is separate at a distance of 400 mm from the base. The load is applied using two rollers which are mounted at the third point of pan located 133 mm apart and placed centrally with respect to the rollers. The specimen axis is aligned carefully with loading frame axis. The load is gradually applied by increasing stress at rate of 7 $kg/cm^2/min$. i.e., applied load rate of 4000N/min. The load is distributed equally between the two roller points and keep on increasing until the specimen fails. The load gauge is used to measure load. Figure 3 shows the experimental setup for flexural strength. The modulus of rupture is

$$fb = pl/bd^2 \text{ for } a > 133mm$$

$$fb = 3pa/bd^2 \text{ for } 133mm > a > 100mm$$

Where, p = maximum load applied (N).

l = length of the span on which the specimen is supported (mm).

b = measured width of the specimen (mm).

a = the distance between the fracture line and the nearer support, measured on the centre line of the tension area of the specimen (mm).

d = measured depth of the specimen (mm).

Figure3. Testing for Flexural Strength

Results and Discussions

Compression Strength

The compressive strength for all the specimens of various replacement levels of GGBS and addition of PEG400 with cement has been tested at ages of 28 days of casting. From the above table and graph, it is noticed that compressive strength increases with increase of GGBS and PEG 400 up to 20% GGBS and 1.5% of PEG400 after that decreases with increasing dosage of GGBS and PEG 400 for M20 and M40 grade of concrete. Compressive strength increases with increase of GGBS and PEG 400 up to 10% GGBS and 1.0% of PEG400 after that decreases with increasing dosage of GGBS and PEG 400 for M60 grade of concrete. Maximum strength observed at C20G1.5P (29.12 MPa) for M20, (52.62 MPa) for M40 grade of concrete and at C10G1P got maximum strength 72.56 MPa for M60 Grade of concrete. With increasing grade of concrete its compressive strength increases. Figure 4 shows the comparison of

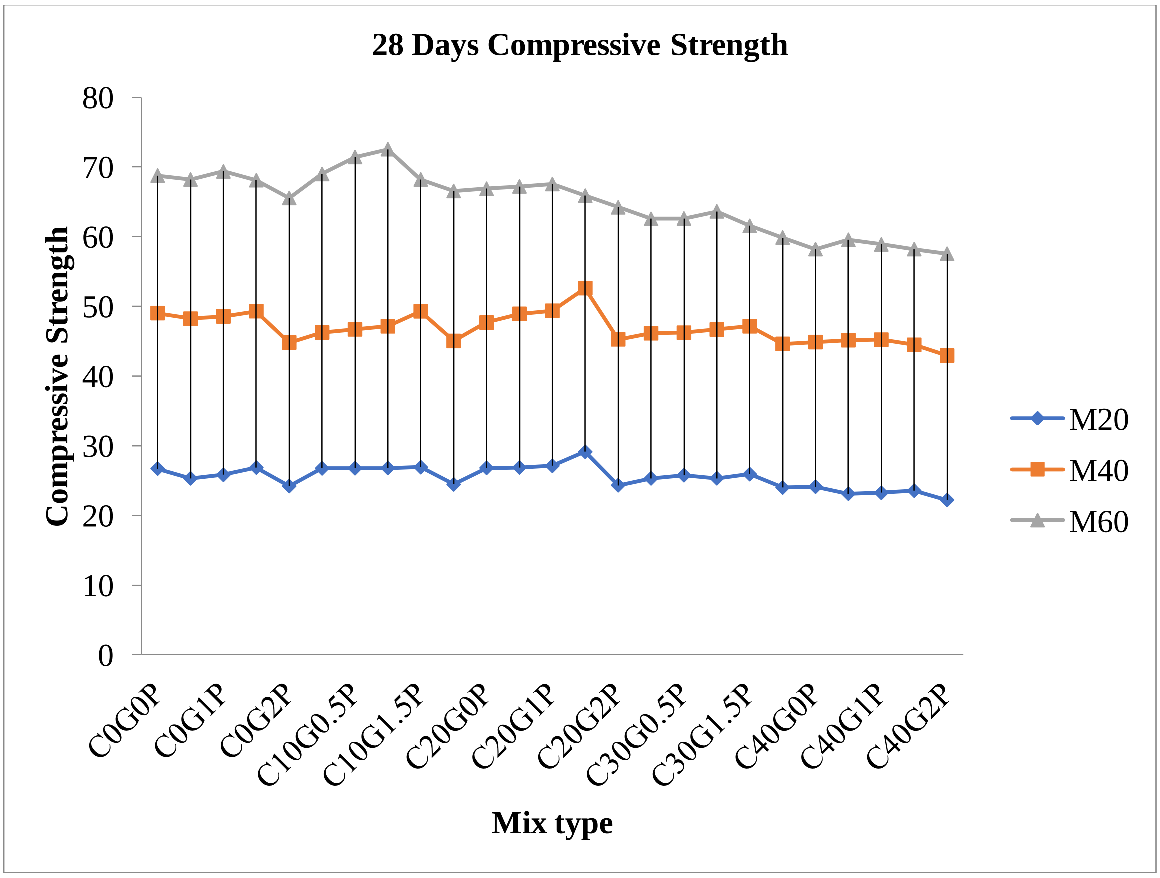


Figure 4. Comparison of 28 days Compressive strength for M20, M40 and M60 grade of concrete

Spilt Tensile Strength

The split tensile strength for all the specimens of various replacement levels of GGBS and addition of PEG400 with cement has been tested at ages of 28 days of casting. From the above table and graph, it is noticed that split tensile strength increases with increase of GGBS and PEG 400 up to 20% GGBS and 1.5% of PEG400 after that decreases with increasing dosage of GGBS and PEG 400 for M20 and M40 grade of concrete. Split tensile strength increases with increase of GGBS and PEG 400 up to 10% GGBS and 1.0% of PEG400 after that decreases with increasing dosage of GGBS and PEG 400 for M60 grade of concrete. Maximum strength observed at C20G1.5P (3.54 MPa) for M20, (5.32 MPa) for M40 grade of concrete and at C10G1P got maximum strength 6 MPa for M60 Grade of concrete. With increasing grade of concrete its split tensile strength increases. Figure 5 shows the split tensile strength of different concrete grades.

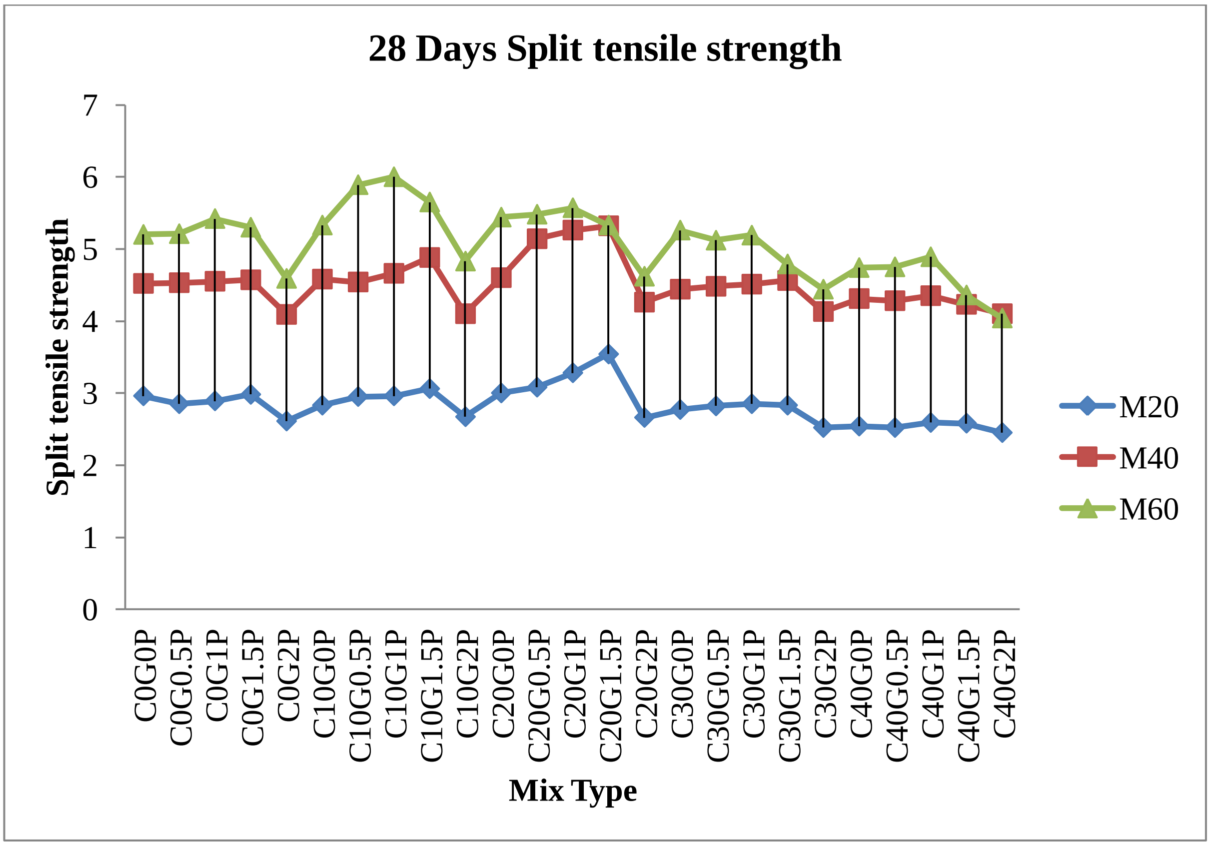


Figure 5. Comparison of 28 days Split Tensile strength for M20, M40 and M60 grade of concrete

Flexural Strength

At ages of 28 days after casting, the flexural strength of each specimen was evaluated to determine the different replacement levels of GGBS and the addition of PEG400 to cement. The evaluations were carried out. It can be seen from the table and graph up above that the flexural strength of M20 and M40 grade concrete rises with increasing percentages of GGBS and PEG 400 up to the point where there is 20% more GGBS and 1.5% more PEG400, and then it begins to decline with increasing percentages of both of those additives. For M60 grade of concrete, flexural strength rises with increasing dosages of GGBS and PEG 400 up to 10% GGBS and 1.0% of PEG400. After that point, flexural strength falls with increasing dosages of GGBS and PEG 400. Maximum strength was obtained at C20G1.5P (4.60 MPa) for the M20 grade of concrete, at C10G1P (8.83 MPa) for the M60 grade of concrete, and maximum strength was observed at C20G1.5P for the M20 grade of concrete (6.27 MPa). The flexural strength of concrete improves when the slope of the concrete is increased. Figure 6 shows the flexural strength of different concrete grades.

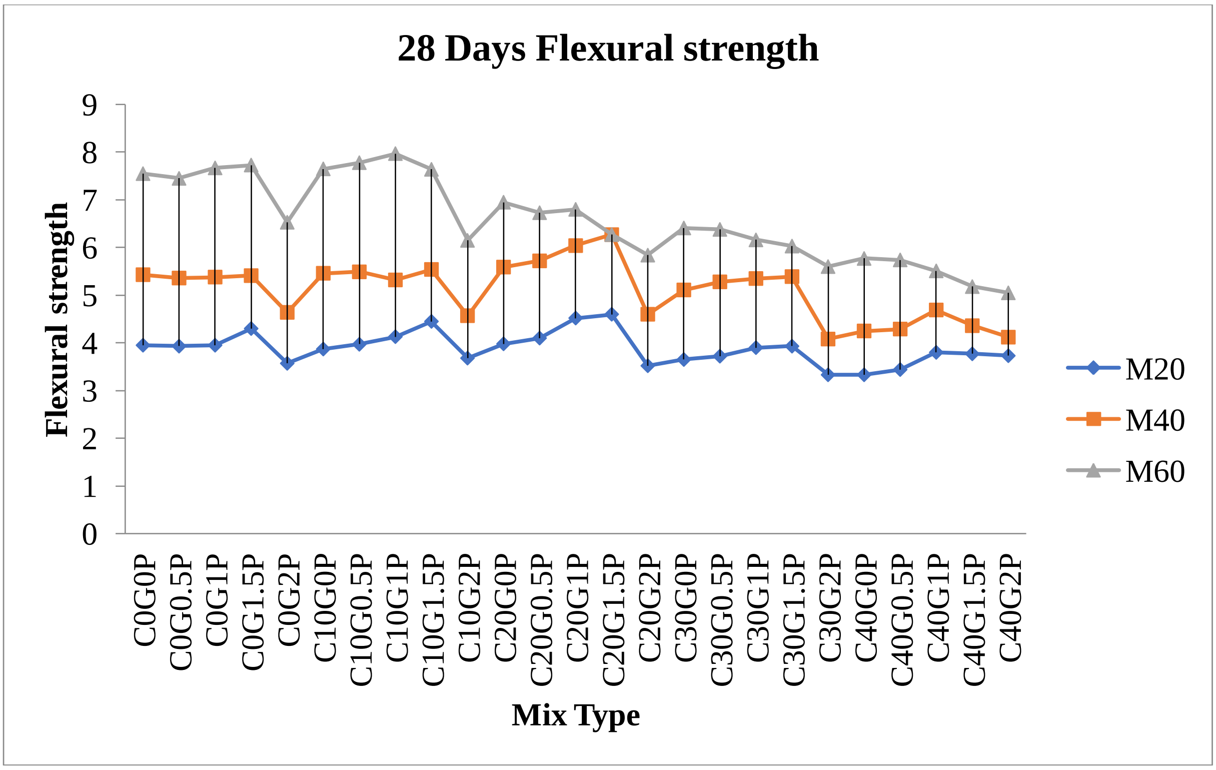
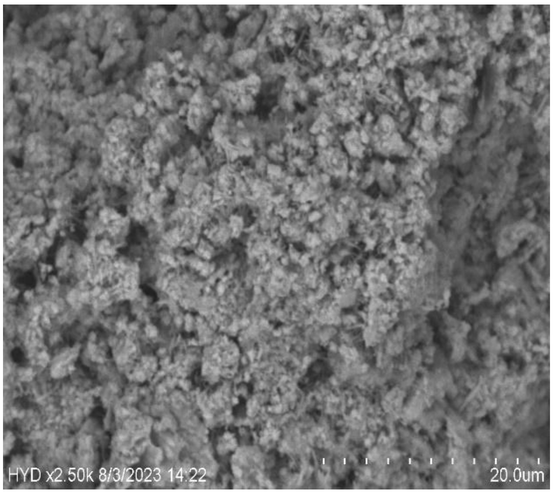


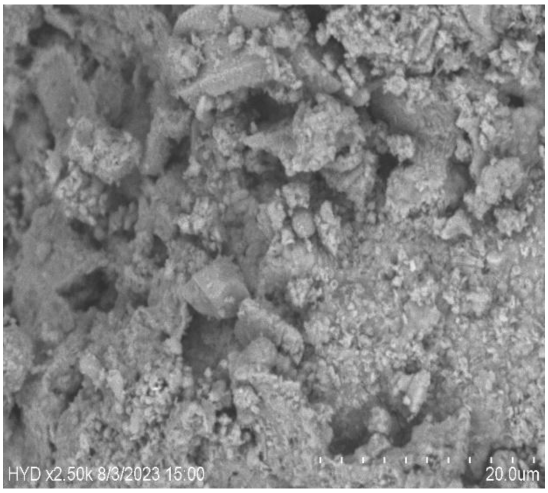
Figure 6. Comparison of 28 days Flexural strength for M20, M40 and M60 grade of concrete

SEM and XRD Analysis

Figure 7, 8, 9, 10, 11, and 12 shows the XRD and SEM analysis of different concrete grades. Form SEM and XRD images it is observed that, in self-curing concrete filling of micro-pores or pore size reduction due to presence GGBS and became denser also improve the strength and durability properties of self-curing concrete.

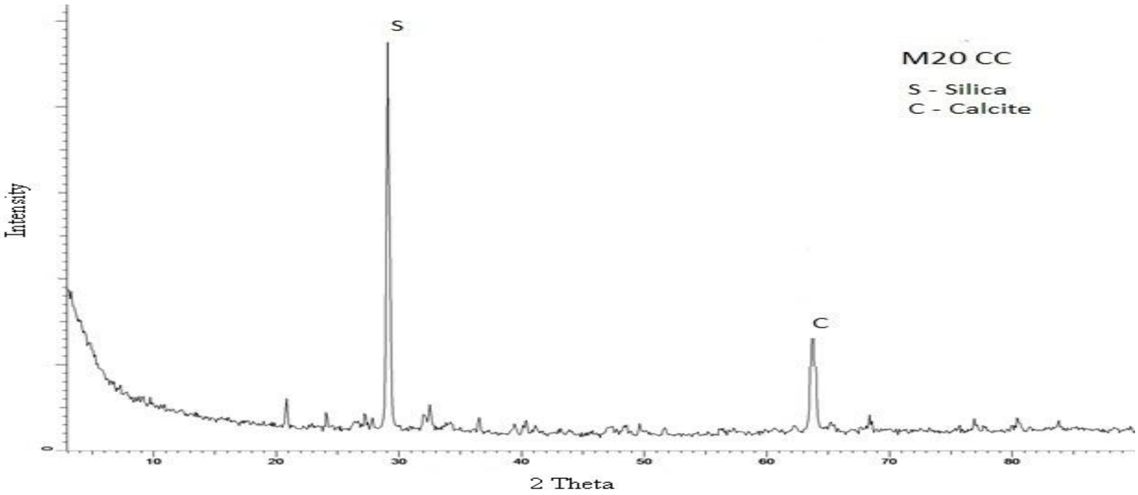


(a) conventional concrete

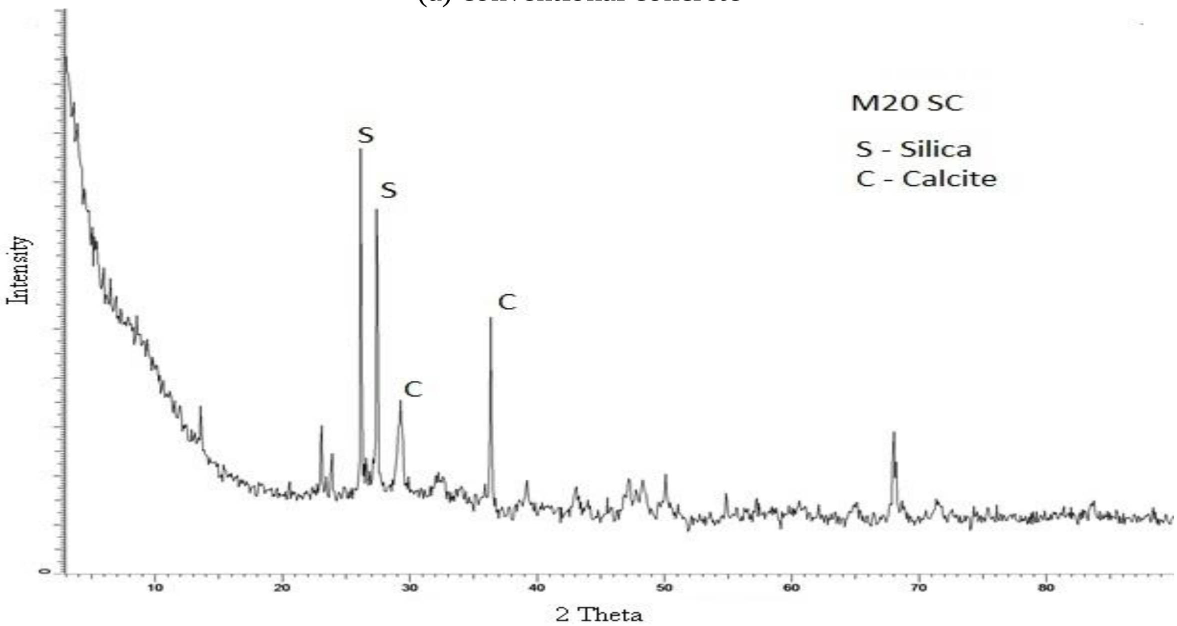


(b) self-curing concrete

Figure 7. SEM images of M20 Grade of concrete

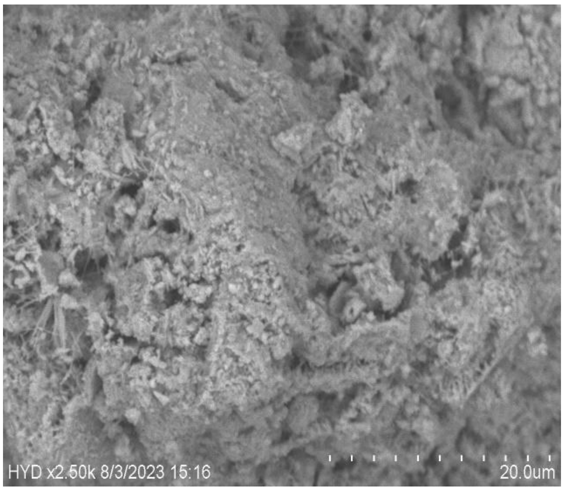


(a) conventional concrete

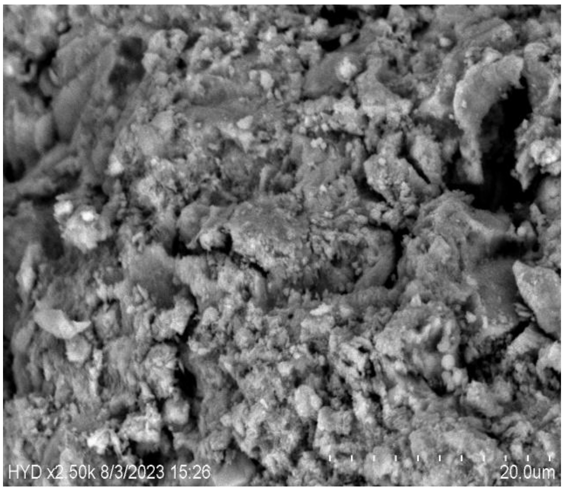


(b) self-curing concrete

Figure 8. XRD images of M20 Grade of concrete

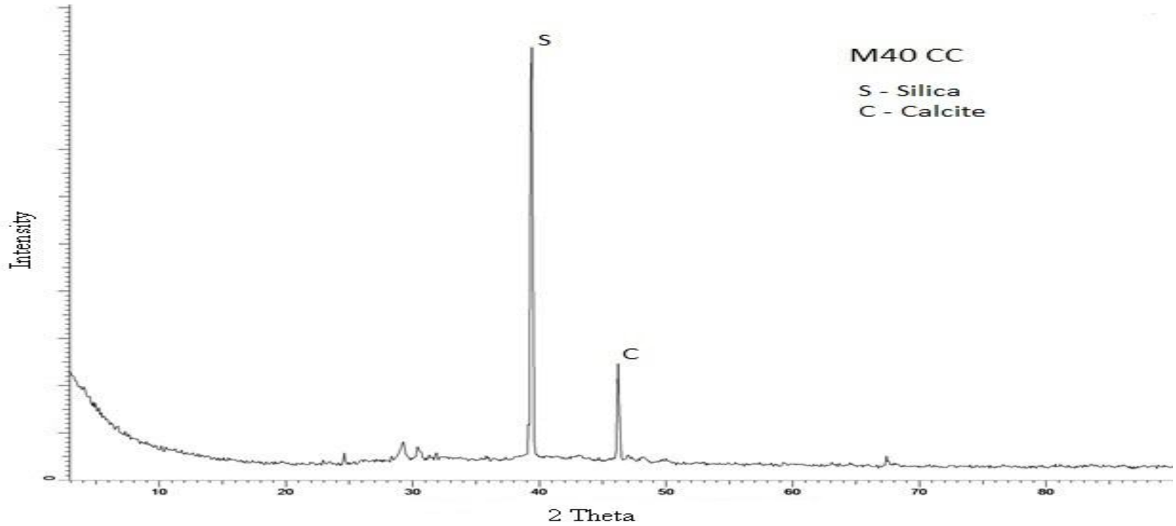


(a) conventional concrete

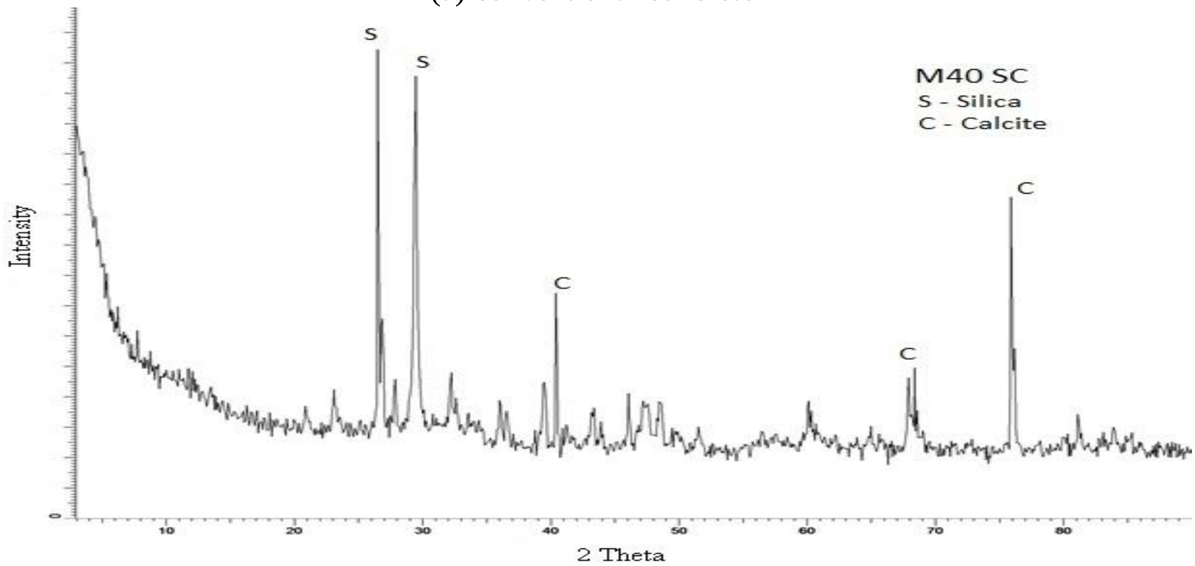


(b) self-curing concrete

Figure 9. SEM images of M40 Grade of concrete

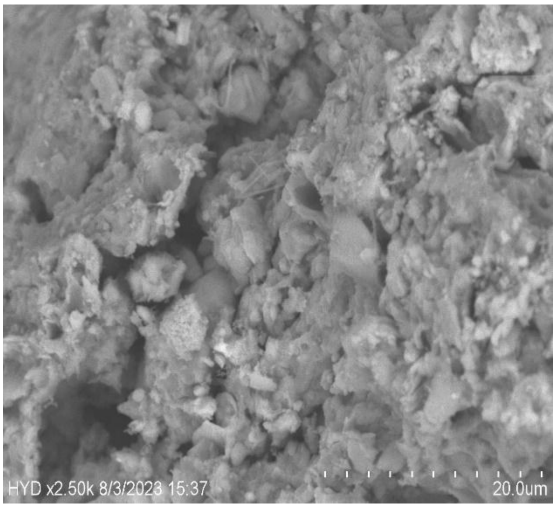


(a) conventional concrete

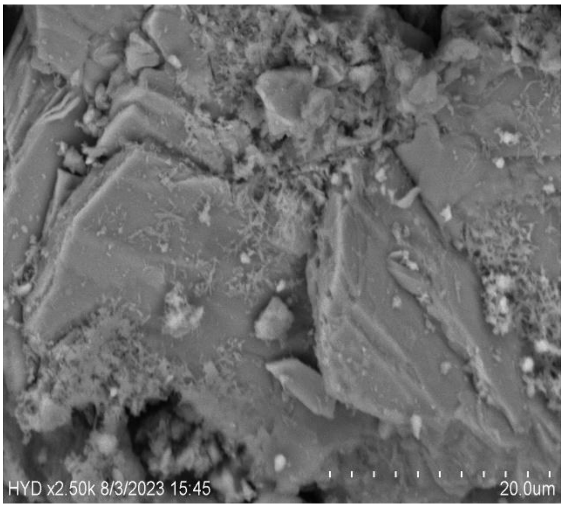


(b) self-curing concrete

Figure 10. XRD images of M40 Grade of concrete

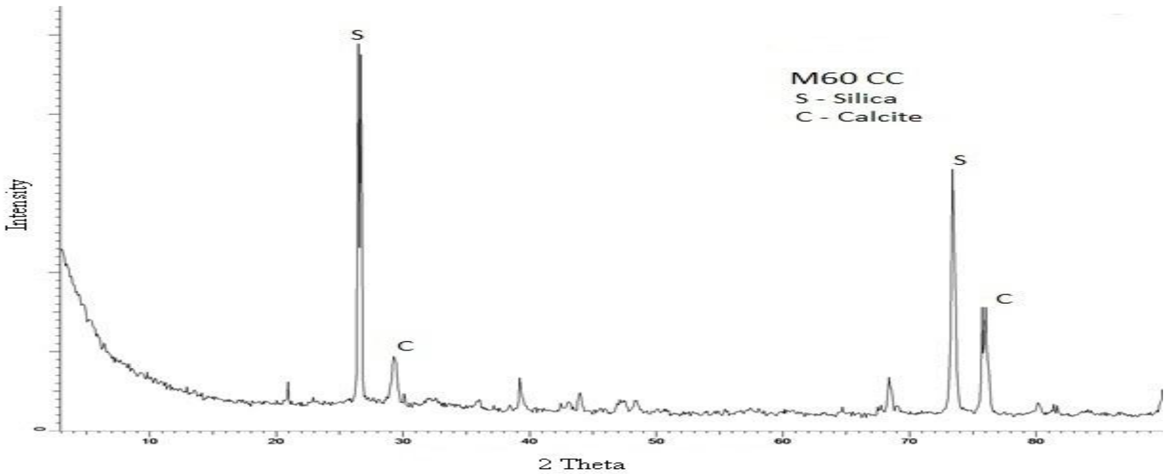


(a) conventional concrete

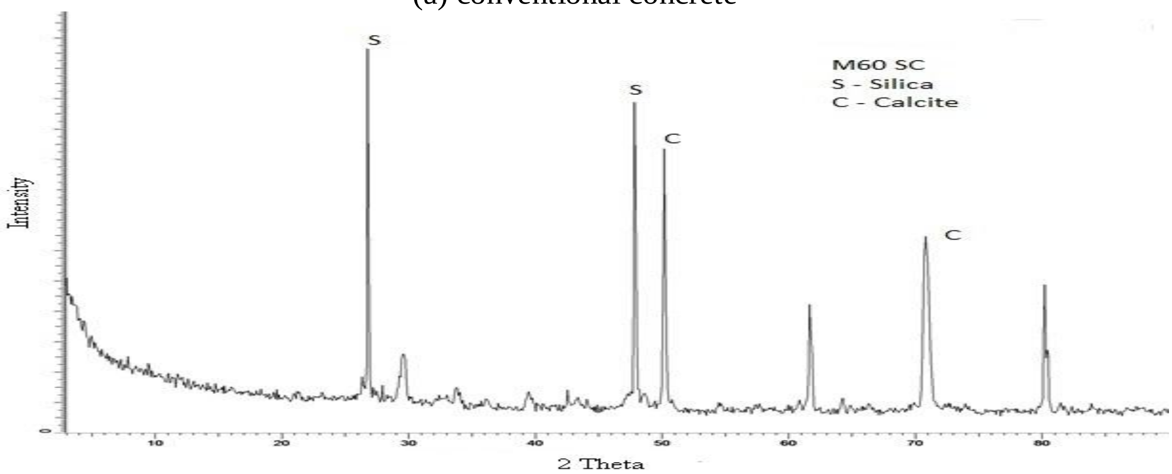


(b) self-curing concrete

Figure 11. SEM images of M60 Grade of concrete



(a) conventional concrete



(b) self-curing concrete

Figure 12. XRD images of M60 Grade of concrete

Conclusions

Based on this experimental study, the following conclusions are drawn

1. For M20, M40 and M60 grade self-curing concrete compressive strength 8.98%, 7.30% and 5.49% more than conventional concrete for 28 days.
2. For M20, M40 and M60 grade self-curing concrete flexural strength 16.45%, 15.46% and 12.48% more than conventional concrete for 28 days.
3. For M20, M40 and M60 grade self-curing concrete split tensile strength 24.21%, 17.69% and 15.38% more than conventional concrete for 28 days.
4. When the grade of concrete increases the percentage of increase in mechanical properties decreases.
5. The optimum quantity of PEG400 and Ground granulated blast furnace slag (GGBS) were observed at 1.5% and 20% for M20 and M40 grade of concrete and same are found at 1% and 10% for M60 grade of concrete.
6. The use of self-curing agent (polyethylene glycol 400) in concrete mixes improves the strength properties of concretes under air curing regime which may be attributed to a better water retention.
7. Self-curing concrete mixes have higher compressive, split-tensile, and flexural strength at all curing ages when compared to externally cured concrete mixes.
8. Internal curing is more effective at a later age on splitting tensile and flexural strength than on compressive strength.
9. SEM and XRD images it is observed that, in self-curing concrete filling of micro-pores or pore size reduction due to presence GGBS and became denser also improve the strength and durability properties of self-curing concrete.

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