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COMPARATIVE STUDY ON EXTERNALSELF CURING CONCRETE AND CONVENTIONAL CURING CONCRETE USING DIFFERENT BINDING MATERIALS (OPC AND PPC)

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ABSTRACT

Abstract- Concrete is the most widely used construction material due to its good compressive strength and durability. The imagination of a world without concrete is impossible as the concrete is a soul of infrastructures. Conventional concrete which is the mixture of cement, fine aggregate, coarse aggregate and water, needs curing to achieve strength. So it is required to cure for a minimum period of 28 days for good hydration and to achieve target strength. Lack of proper curing can badly affect the strength properties and durability of concrete. The strength and durability of concrete depends on the curing of concrete. The ACI-308 Code states that “self-curing refers to the hydration process of cement with water.” The extent to which this reaction is completed influences the strength and durability of the concrete. Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. Self-curing concrete is one type of modern concrete which cure itself by retaining its moisture content in it. The need for adequate curing of concrete cannot be overemphasized as it has a strong influence on the properties of hardened concrete. This study is investigating whether the use of self-curing concrete is economical for concrete compared to normal curing concrete in remote areas or other regions where there is scarcity of water without compromising the strength properties of concrete while using different binding materials (OPC and PPC). In the present study, comparison of compressive strength, tensile strength and flexural strength of concrete and concrete water absorption for normal and external self

curing concrete have been made; concure WB concrete curing compound has been used for external self curing concrete. Experimental results indicate that conventional curing concrete for OPC and PPC mixes has better mechanical properties and percentage concrete water absorption as compared to external self curing concrete for both binding materials.

KEY WORDS: Normal Curing concrete (NCC), External Self-Curing concrete (SCC), Self-curing agents, Concrete strength characteristics and concure WB.

1. INTRODUCTION

Construction industry is growing day by day even in remote areas and desert regions. Even India and other countries are facing lot of problems in supplying drinking water to their citizens. Hence construction industries are under pressure in finding out alternative curing methods of curing concrete (Chikmagalur 2010)**.** Curing of concrete is maintaining of satisfactory moisture content in concrete during its early stages in order to develop the desired properties of concrete (Sujay Raghavendra N 2010).Concrete is basically composed of two components which are paste and aggregate controlled by workability of fresh concrete, durability and strength requirements based on concrete curing process (Jayeshkumar R. Pitroda 2014).

1.1 Curing

As per IS: 456 -2000“Curing is the process of preventing the loss of moisture from the concrete.”Curing is the maintenance of a satisfactory moisture content and temperature in concrete for a period of time immediately following placing and finishing so that the desired properties may develop. The need for adequate curing of concrete cannot be overemphasized because curing has a strong influence on the properties of hardened concrete, proper curing will increase durability, strength, water tightness, abrasion resistance, volume stability, and resistance to freezing and thawing effect.

In conventional concrete, curing is done after various stages like mixing, placing and finishing. Self-Curing is a technique which is used to provide proper moisture contents in concrete for better hydration for a long time, and then it 1 be used to provide additional moisture inconcretefor moreeffective hydration of cementand reducedself-desiccation. Self-Curing agent works to reduce self-desiccation contents present in the concrete and improves performance, strength and durability requirements. Self-curing is a technique used by construction industry that use lot of water in the name of curing to provide or promote indoor and outdoor construction activities in areas where there is scarcity of water. Self-curing concrete is the one which can meet the present and future requirements of concrete curing. In case of columns and beams the application is done after the removal of formwork. On the horizontal surface, the curing compound is applied upon the complete disappearance of all bleeding water (R. Sundharam 2016).

1.2 Objectives

The objectives are to determine and compare the concrete strength properties while using different binding materials.

1. To study compressive, tensile and flexural strength of normal and external self curing concrete for OPC mix.
2. To study compressive, tensile and flexural strength of normal and external self curing concrete for PPC mix.
3. To compare the strength characteristics for normal and external self curing concrete between OPC and PPC mixes.
4. To determine percentage of concrete water absorption for both OPC and PPC mixes.

2. LITERATURE REVIEW

2.1 Strength characteristics between conventional and self-curing concrete

Chikmagalur (2010) studied on external self-curing of concrete. The study investigated the performance of self-curing of concrete using Concure WB(specific gravity 0.98) curing agent compared to conventional curing concrete. This investigation was carried out on 53 grades OPC to study the strength behaviour of concrete. On fresh concrete workability related tests such as slump test and hardened concrete strength tests were conducted in accordance with BIS specifications. The grade of concrete chosen for investigation was M25 of w/c 0.55. The result of the investigation clearly indicated that self-curing concrete is economically in places where there is shortage of water without compromising the performance characteristics of concrete including durability. It was observed that the variation between concrete cured conventionally and with external self-curing compound was about 3.32% for compression strength and 20.94% for split tensile strength. Hence self-curing concrete is more economical because it eliminates the curing charges and efficiently adapted in the regions where scarcity of water is a big problem. Spray application reduces labor costs and eliminates the need for alternative curing systems. Self-curing concrete is the best solution to the problems faced in the desert region and faced due to lack of proper curing.

Krishna Rao et al.(2010) studied on the influence of curing on the strength of a standard grade concrete mix. The parameters of the study included the curing period (1, 3, 7, 14 and 28 day), curing method was conventional wet curing, membrane forming curing with concure WB (ASTM C309-90) and accelerated curing. The types of cement used were ordinary Portland cement (43 grade OPC), Portland pozzolana cement (43 grade PPC) and ordinary Portland cement (43 grade OPC) +10% Silica fume (SF) replacement for cement. Test results indicated a drop in strength at all ages for concretes with PPC and the one in which 10% OPC was replaced by Silica fume(SF) in comparison with the concrete with OPC. Curing by membrane forming curing compound yielded nearly the same results as that of conventional wet curing for concrete with OPC and there was a marginal decrement in concrete strength with PPC. Predicted 28-day strength of concrete from the accelerated curing test was found to be on a conservative side compared to control concrete.

Akanksha A. Patil (2014) investigated the Comparative study on compressive strength of Self cured Self-compacting concrete (SCC) and normally cured self-compacting concrete (SCC). This investigation was done with concrete curing compound such as Materkure107i(density :1± 0.05, colour: white liquid) and membrane forming concrete curing compound Concure WB(specific gravity : 1 to 1.01 g/cc, colour: bulk liquid white). The materials used were 53 grade OPC, fine aggregate, coarse aggregate, silica fume, ordinary potable water and Superplasticisers GLENIUM B233 complies with IS: 9103– 1999. The study was investigating whether the use of self-curing compound is economical or not in remote areas without compromising the compressive strength of concrete. From the experimental results obtained, Self-curing with curing compound Concure WB gives about 10% less compressive strength than normal water curing, self-curing with curing compound materkure107i gives about 15% less compressive strength than normal water curing. In areas with shortage of water, sustainability of water can be achieved by using suitable chemical compounds for curing of concrete, compressive strength can also be achieved by using chemical compounds for curing and spray application reduces labor costs and eliminates the need for alternative curing systems.

Mohammed Shafeeque et al. (2016) studied on the strength comparison of self-curing concrete and Normal curing concrete. The aim of this investigation was to study the strength properties of concrete using water soluble Polyethylene Glycol as the self-curing agent. The function of self-curing agent is to reduce the water evaporation from the concrete and to increase the water retention capacity of concrete compared to the conventionally cured concrete. In this study, compressive strength and split tensile strength of concrete containing self-curing agent was investigated and compared with those of the conventionally cured concrete. The materials used are 53 grade OPC cement, fine aggregate, coarse, potable water, polyethylene glycol PEG (600) at 0.5%, 1%, 1.5%, and 2% by weight of cement. From experimental results obtained, it was found that self-curing concrete has maximum workability at 1% of PEG, as percentage of PEG600 increased slump and flow values increased for both M20 and M25 grade concrete. The optimum dosage of PEG600 for maximum strength (compressive and tensile) was found to be 1% for both M20 and M25 grade. Strength of self-curing concrete was equal to that of conventional curing concrete. Self-curing concrete is an alternative to conventional concrete in desert regions where scarcity of water is a major problem.

Radhakrishna and Rajasekhar (2015) have been studied an experimental investigation on self-cured concrete. The aim was to study the strength of conventional curing and self-cured concrete for compressive strength and tensile strength of similar mix design for 7 days and 28 days. The study was carried out on standard concrete cubes of dimensions 150mmx150mmx150mm in which the variation of internal moisture content was measured. The concrete cubes were exposed to environment in which chloride was present to find out the durability of self-curing concrete and compressive strength of cubes was determined. The materials used were sand, grade 53 Sri Chakra cement, coarse aggregates and Polyvinyl Alcohol (PVA) as self-curing agent. This study shows that water retention for concrete mixes incorporating self-curing agent is higher when compare to conventional concrete mixes. When compared to conventional concrete, self-curing concrete resulted in better hydration with time under drying condition. The results also showed that the cement content and the w/c ratio affect the performance of the self-curing agent. Compressive, tensile and flexural strength are higher when polyvinyl alcohol (0.48% by the weight of cement) is used as self -curing agent. The authors concluded that when polyvinyl alcohol percentage increases, it results in reduction of weight loss and the durability of self-curing concrete to sulphate salts and chloride induced corrosion and it is needed to be evaluated.

Amal Viswam and Arjun Murali (2018) studied on self-curing concrete to compare conventionally curing concrete and self-curing. In this study the compressive strength of self cured concrete and conventionally cured concrete was determined. Shrinkage reducing agents like Polyethylene-Glycol (PEG) and lightweight aggregates such as Leca and silica fume were used to achieve effective curing results**.** Based on test results of this research work, the following conclusion was, water retention for the concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes, as found by the weight loss with time. Self-curing concrete resulted in better hydration with time under drying condition compared to conventional concrete. Water transport through self-curing concrete was lower than air-cured conventional concrete. Slump value increases with increase in the quantity of PEG. Self-curing concrete is the answer to many problems faced due to lack of proper curing. It was found that compressive strength of self cured concrete was high than conventionally cured concrete.

Jayeshkumar (2014) studied on "self-curing concrete in construction industry". In this research paper, the individual effect of admixture Polyethylene Glycol (PEG600 & PEG1500) on compressive strength by varying the percentage of PEG600 and PEG1500 by weight of cement 0.5%, 1.0%, 1.5% and 2% were studied. The study shows that PEG600 and PEG1500 could help in gaining the strength of conventional curing. The different materials used in this investigation were 53 grade OPC, fine aggregate, coarse aggregate, Polyethylene Glycol and potable water. It was also found that 1% of both PEG600 and PEG1500 by weight of cement was optimum for M25 grade concrete for achieving maximum strength without compromising workability. Compressive strength of self-curing concrete is increased by applying self-curing admixtures. The test result indicates that the use of water soluble polymers in concrete has improved performance of concrete**.** The compressive strength of concrete mix increased by 37% by adding 1.0% of PEG600 and 33.9 by adding 1.0% of PEG1500 as compared to the conventional concrete. The optimum dosage of PEG600 for maximum compressive strength was found to be 1% by weight of cement for M25 grade of concrete. The optimum dosage of PEG1500 of maximum compressive strength was found to be 1% by weight of cement for M25 grade of concrete. Self-curing concrete is the best solution to the problem faced in the desert region and faced due to lack of proper curing.

2.2 Durability and strength characteristics for conventional and self-curing concrete

Akanksha Anantrao Patil(2014) studied on the comparative study on durability of self cured self-compacting concrete (SCC) and normally cured self-compacting concrete (SCC).This paper reports the results of a research study conducted to evaluate the effect of self-curing method on the durability of self compacting concrete (SCC). Cube specimens were prepared and cured by curing compound and normal water. The sorptivity and acid attack tests were conducted on the concrete specimens and compare the durability of normally cured SCC and SCC cured with self-curing materials. The materials used are Concure WB, Materkure107i, 53 grade OPC, fine aggregate, coarse aggregate, silica fume, potable water and Superplasticisers GLENIUM B233 complies with IS: 9103– 1999. From the results obtained, it was known that normal curing method seems to be the best method for curing giving maximum strength and durability. It has also shown that by using curing compounds, we can achieve 90% of strength and durability achieved by normal curing method. Also it has been observed that curing compounds does not have any adverse effect on the durability of concrete. Self-curing concrete with curing compound Concure WB gives about 10% less compressive strength than normal water curing. Self-curing concrete with curing compound Materkure107i gives about 15% less compressive strength than normal water curing. Durability of concrete is not affected much by using chemical compounds for curing performance of both the curing compounds and it was almost the same for self - compacting concrete.

Bashandy A. et al(2017) studied on durability of recycled aggregate self-curing concrete. In this investigation, the durability of recycled aggregate self-curing concrete studied under the attack of sulfates and chlorides. The effect of sulfates on compressive, splitting tensile and flexure strengths at different ages (2, 4 and 6 months) was studied. The effect of chloride attack (as 8% concentrated sodium chloride solution) was studied on bond and flexural strengths at different ages (1 and 2 months), also the flexural behavior of the recycled aggregate self-curing reinforced concrete beams was studied individually under the effect of chloride attack after different exposure conditions. Ordinary Portland cement, drinkable clean water, fine aggregate, recycled coarse, steel rebars of 8 mm diameter with yield strength of 240 MPa and tensile strength of 350 Mpa, water reducing admixture and self-curing agent **(**Polyethylene Glycol PEG400) were used in this investigation. The test results indicated that recycled aggregates can be used in self-curing concrete with satisfied durability under chlorides and sulfate attacks. Dolomite crushed concrete followed by crushed red bricks can be used as coarse aggregates for self-curing concrete. The durability of self-curing concrete cast using dolomite aggregate was higher than both self-curing concretes with crushed concrete and crushed bricks as aggregates. The compressive, tensile splitting and flexure strength values increase under the effect of sulfates at 2 and 4 months, then starts to decrease at 6 months. It was observed that the stiffness decrease when the ductility ratio increases and the rate of decrease were faster when the loading rate was faster.

2.3 Effect of self-curing compounds on strength and durability of concrete

T.Suresh and Sreenivasa kumar (2015) studied on effect of self-curing compound on strength and durability of M25 Mix concrete. In this presented study, the effect of admixture (PEG-200) on compressive strength, split tensile strength for M25 mix was studied and it was compared with the properties of PEA (Poly ethylene alcohol).The materials used in this investigation were 53 grade OPC, fine aggregate conforming to zone III according to IS: 383-1970, coarse aggregate, Polyethylene Glycol-200 (PEG-200) and potable water. The optimum strength values for both self-curing agents were found among both agents PEG-200 and PEA. It was found that Poly Ethylene Glycol-200 was a good self-curing agent when compared with Poly ethylene alcohol because in the durability and normal compressive strength aspects it was giving good results when compared with both conventional concrete and Poly ethylene alcohol (PAE), also at the place of water scarcity areas these type of curing agents will give a better result. This study was shown about a clear cooperate picture about the strengths of PEG-200 and PEA and its stress strain behaviour also shown clearly. This study also gives a clear notation on durability.

Tapeshwar and Amjad Abass (2017) studied on the effect of self-curing compound on the properties of concrete. This study explored the suitability of internal curing for solving shrinkage problems and improves the performance of self- cured concrete. In this study, the effect of self-curing admixture (Poly ethylene glocol-4000) on the concrete was investigated. A comparison has been made between the concrete mixes with no curing, normal curing and concrete with self-curing admixture. The materials used are 43 grades OPC, river sand, crushed coarse aggregate, Polyethylene Glycols (PEG) as self-curing agent and potable water. They used self-curing admixture in different prepositions (0.5%, 1.0%, 1.5%, and 2.0% of PEG-4000 by weight of cement). The experimental results elaborate that the optimum dosage found was 1.0% of PEG-4000 where concrete has higher desired properties. It was seen that effect of internal curing agent and its combination with concrete influence the strength properties, self-curing agent (PEG) can be used as an alternative to general curing of concrete. It was clearly demonstrated that self-curing concrete can be used in the places where normal curing is not done properly like in arid areas, high rise buildings, areas were supervision is not possible regularly and highways where the surface is exposed to hot environmental conditions.

2.4 Scanning Electron Microscopy (SEM) for concrete

A.S.Adithya Saran (2017) studied on the experimental study on Sustainable High Performance Concrete and its microstructural behaviour (SEM). The major concrete constituents were replaced with alternative materials. Cement was partially replaced with Fly ash (30% and 35%) and Silica fume (7.5 % and 10%) and fine aggregate was entirely replaced with manufactured sand. Coarse aggregate was partially replaced with recycled aggregate by 30%, 40% and 50% .Seven concrete mixes were prepared and casted into cubes. The concrete cubes was tested for compressive strength after 28 days curing and a considerable value of compressive strength was observed in Mix 4 (7.5 % S.F+ 30% F.A+ 40% RCA).From SEM micrograph of Mix 4, The chemical reaction of silica fume and fly ash with Portlandite (Ca (OH) 2) leads to production of additional C-S-H gel which fairly improves the strength of Mix-4. The range of scale used in SEM analysis was 5 µm with the resolution of x5000. From the test results of compressive strength, it was observed that replacement of concrete ingredients fairly improves on the strength of concrete mixes. The strength of Mix-4 was not up to the expected level but, the mix is possibly suitable for normal concreting works. In SEM Observations, the existence of mineral elements and their reactions with the supplementary materials are studied which gives an initiative to understand the microstructure of the concrete mixes. Based on the comparison of the microstructure of concrete mixes, it is clear that the hydration process in the mixes with supplementary materials was different from conventional concrete mix. In Mix-4, the hydration process was quiet similar to the normal concrete mix but, the development of C-S-H gel in the mix was quiet lesser compared to the normal concrete mix (Mix-1).

The electron microscope was apparently first used by Eitel (1941, 1942) and by Radczewski *et al*. (1939) to study the hydration process of concrete. Le Chattelier (1882) was among the first to apply the microscope to the study of cementitious materials. He used it to investigate the chemical and physical aspects of hydration and setting, rather than to study cracks. His efforts undoubtedly influenced later workers in their use of the microscope. Grudemo (1960) was another important pioneer in the use of high magnification, including the use of the electron microscope. Although most of these studies were not directly related to cracks, they led the way to later studies of cracks in which electron microscopy was a powerful tool. Tavasci (1941) successfully used the microscope to study the composition and structure of concrete, but not of cracks perse. His work, however, set the stage for the studies of cracks on the interior surfaces of cut specimens which were conducted in the 1960s.

3. MATERIALS USED AND THEIR PROPERTIES

3.1 The materials used for experimental program

1. Cement

Cement is defined as the bonding and binding material in concrete production having cohesive and adhesive properties which makes it capable to join uniformly the different construction materials and compacted assembly.

- **Ordinary Portland Cement (OPC)**

Ordinary Portland cement of 53 grades is used .It is one of the most widely used types of Portland cement. Ordinary Portland Cement (OPC) is the most commonly used cement in general concrete construction as per IS: 8112-1989.

Table1. Basic properties of ordinary Portland cement (OPC).

SI. No.	Particulars (tests)	Results obtained	References
	Type of cement	53 grade OPC	IS: 12269
1	Normal Consistency	32 %	IS: 269 -1976
2	Specific Gravity	3.15	IS: 269 -1976
3	Setting time (in min) (a) Initial setting time (b) Final setting time	 90 min. 270 min.	IS: 269 -1976. Should be not less than 30 minutes Should not be more than 600 minutes
4.	Fineness	3913.90 cm^2/g	Blain's air permeability test

- **Portland pozzolona cement (PPC)**

Portland pozzolona cement (PPC) is manufactured by inter grinding OPC clinker with 15-35% of pozzolonic materials. Pozzolans are essentially siliceous or aluminous materials, which in itself possess no cementitious properties which are in finely divided form and in the presence of moisture, react with calcium hydroxide liberated in the hydration process at ordinary temperature to form compounds possessing cementitious properties. The pozzolonic materials generally used are fly ash or calcined clay. PPC produce less heat of hydration and offers greater resistance to attach of aggressive environment gives long-term strength and enhances the durability of the structures as per IS: 1489-1991(part I**)**.

Table 2. Basic properties of Portland pozzolona cement (PPC).

SI.No	Particulars (tests)	Results obtained	References
	Type of cement	PPC	Is: 1489-1991
1	Normal Consistency	36%	Is: 1489-1991
2	Specific Gravity	2.85	Is: 1489-1991
3	Setting time (in min) (a) Initial setting time (b) Final setting time	 55 min. 170min.	 Should be not less than 30 minutes Should not be more than 600 minutes
4.	Fineness	3478.29 cm^2/g	Blain's air permeability test

2. **Fine aggregate**: Natural river sand conforming to Indian standard with fraction passing though 4.75mm sieve (called fine aggregates), having specific gravity of 2.58, fineness modulus of 2.84 was used for this study. Locally available sand conforming to zone II as per IS: 383: 1970 was used as fine aggregates for this present research work. The sand was tested as per IS: 2386:1963 (IS: 2386 Part I 1963).

Table 3. **Properties of fine aggregates.**

SI.No	Particulars	Results obtained	References
1.	Fineness modulus	2.84	IS: 2386 (Part III)-1963
2.	Specific	2.58	IS:

	gravity		2836(Part III)-1963, IS:383-1970 ,IS: 460-1962
3.	Grading zone	Zone-II	IS: 383-1963
4.	Water absorption	1%	---
5.	Moisture content	NIL	---

3. **Coarse aggregate**: The aggregates retained on 4.75 mm sieve (called coarse aggregates), which are generally crushed stones aggregates having 20mm was used in the experimental work. The crushed stones aggregates used were 20mm nominal maximum size and are tested as per Indian standards. The Coarse aggregates used in this study have the specific gravity of 2.70, fineness modulus of 7.76 and were tested as per IS: 383-1970.

Table 4. Properties of coarse aggregate.

SI.No	Particulars	Results obtained	References
1.	Fineness modulus	7.76	IS: 2386 (Part III)-1963
2.	Specific gravity	2.70	IS: 2836(Part III)-1963,IS: 383-1970, IS: 460-1962
3.	Water absorption	0.2%	---
4.	Moisture content	NIL	---

4. **Water:** Ordinary potable water is generally considered satisfactory for concrete mixing process. The PH value of water to be used should not be less than six. The portable water available in the laboratory taps conforming to the requirements of water for concreting and curing as per IS: 456-2000 was used in this project work for concrete production process.

5. **Super Plasticizer**: Super plasticizers are the water reducing admixtures as per IS: 9103. For obtaining concrete of good quality, water reducing admixtures (CONPLAST SP430) was used as a super plasticizer for the present investigation to reduce the frictional properties of concrete.

Table 5. Properties of CONPLAST SP430 (super plasticizer).

SI.No	Properties of super plasticizer(CONPLAST SP430)	
1.	Appearance	Brow liquid
2.	Specific gravity	Typically 1.20 at 30 ^{0}C
3.	Chloride content	Nil to BS 5075
4.	Air entrainment	Typically less than 2% additional air is entrained at normal dosage.
5.	Alkali content	Typically less than 72.0g.Na_2O equivalent/litre of admixture. A fact sheet on this subject is available

6. **Curing compound**: Concure WB (Fosroc Concure WB is a white, low viscosity wax emulsion which incorporates a special alkali reactive emulsion breaking system. This system ensures that the emulsion breaks down to form a non penetrating continuous film immediately upon contact with a cementitious concrete surface. This impervious film prevents excessive water evaporation which in turn permits more efficient cement hydration, thus reducing shrinkage and increasing strength and durability of concrete. Once formed, the membrane will remain on the concrete surface until eventually broken down and eroded by natural weathering. Where it is required to apply a further treatment to such concrete surface, it may be necessary to remove the membrane remaining after curing by wire brushing or other mechanical means.

Table 6. Properties of concure WB curing compound.

SI.No	Properties of curing compound (Concure WB)	
1.	Curing efficiency	Concure WB curing agent complies with the internationally recognized ASTM C309-90 standard
2.	Specific gravity Colour	1 to 1.01 g/cc Bulk liquid White
3.	Covers	3.5 to 5.0 m2/litre
4.	Shelf life	12 Months

4. METHODOLOGY

The methodology conducted for this research work was determined and discussed. This investigation was carried out to study the behavior of normal and external self-cured concrete within their ingredient materials. The followings are the methodologies adopted to achieve the objectives of this research project.

- To conduct comprehensive literature review related to subject of self curing and normal curing concrete.
- Selection of suitable ingredient materials required for concrete production including cement, aggregates, water and concrete curing compound to be applied on finished concrete surface.
- Determine the relative quantities of these materials in order to produce concrete mix design.
- Casting of concrete specimens and curing process by conventional curing and external self curing (by the application of curing compound on concrete surfaces) for both OPC and PPC mixes.
- Performing physical and mechanical laboratory tests on external self curing and normal curing concrete.
- To compare concrete strength behaviours for both conventional and external self curing between OPC and PPC mixes.
- Determine the percentage concrete water absorption between OPC and PPC mixes by conventional curing and external self curing.

5. EXPERMENTAL STUDY

5.1 Concrete mix design for both OPC and PPC mixes

In this study, the concrete mix was designed according to IS: 10262:2009. The mix proportioning of concrete was done by selecting M30 grade concrete and water cement ratio of 0.45 for both OPC and PPC based concrete mixes in order to study concrete strength when using different binding materials and curing methods . The mix proportions obtained was determined based on the field condition such as free surface moisture and water absorptions of aggregates as per IS:2386(part 3) and the final concrete mix proportion per cubic meter obtained for OPC and PPC mixes are determined in the **Tables7&8** below.

1. Concrete mix Design Stipulations

a) Characteristic compressive strength required at 28 days: 30N/mm^2 **(**M30Grade)

b) Type of cement used:

- OPC 53 Grade (confirming to IS: 12269)
- PPC (confirming to IS: 1489-1991)

c) Nominal maximum size of coarse aggregate:20 mm

d) Shape of coarse aggregates: Angular

e) Degree of workability required at site: 90-100 mm (slump)

f) Degree of quality control: Good

g) Type of exposure the structure will be subjected to (as defined in IS: 456) : Severe

2 Test data of material

The following materials are to be tested in the laboratory and results are to be ascertained for the concrete mix design for OPC and PPC mixes.

a) Specific Gravity of OPC Cement: 3.15

b) Specific Gravity of PPC Cement: 2.85

b) Chemical admixture: Super plasticizer confirming to IS: 9103. The quantity of superplasticizer used is 1.5% by mass of cement for OPC and 2.0% for PPC concrete mixes.

c) Specific gravity

- Specific gravity of Fine Aggregate : 2.58
- Specific gravity of Coarse Aggregate: 2.70

d) Water Absorption

- FineAggregate:1%

- Coarse Aggregate : 0.2%

  e) Free (surface) moisture

- Coarse Aggregate : Nil
- Fine Aggregate : Nil

  f) Fine aggregate falls into: Zone-II

Table7. Concrete mix proportion for OPC mix (per m^3).

W/C ratio	Water in litre	Cement in (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
0.45	177	393	663	1180
		1	1.69	3.0

Table 8. Concrete mix proportion for PPC mix (per m^3).

W/C ratio	Water in litre	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (kg)
0.45	177	393	648	1155
		1	1.65	2.94

6. SAMPLE PREPARATION

The concrete specimens were cast, cured and tested for mechanical properties of concrete such as compressive strength, split strength and flexural strength, then concrete water absorption. The test specimens were cured in clean fresh water for normal curing. For external self curing concrete, specimens were cured by the application curing compound (Concure WB from Fosroc India Ltd) after removed from the moulds for all binding materials OPC and PPC concrete mixes.

7. RESULTS AND DISCUSSION

7.1 Fresh properties results for OPC and PPC mixes

To determine the fresh properties of concrete, slump test was conducted in the laboratory for both OPC and PPC concrete mixes. Slump values for different binding materials such as OPC and PPC based concrete mixes were obtained. It was observed that the average slump test results are 90 mm for OPC and 95mm for PPC concrete mixes.

7.2 Hardened properties of concrete

The determination of hardened properties of concrete, tests was conducted on standard cubes, cylinders and beams specimens. From each type of curing condition, compressive strength test was conducted for 3, 7, 28 and 56 days, split tensile strength test and beams for flexural strength test were conducted for 28 days as per IS:516-1959. Three specimens namely cubes, cylinders and beams were tested to get the average results for concrete strength. Compression Testing Machine was used to conduct the test. The tests were carried out at the Concrete Laboratory of Civil Engineering Department, NITK Surathkal.

Table 9. Details of the concrete specimens for OPC and PPC mixes.

Specimen types	Tests to be carried out	Days of testing (d)	Total number of specimens
150mm×150mm×150mm cubes	compressive strength test	3d, 7d, 28d and 56d	48
150 ×300 mm cylinders	split tensile strength test	28d	12
100mm×100mm×500mm beams	flexural strength test	28d	12
150mm×150mm×150mm cubes	concrete water absorption test	After 28d	24

7.3 Compressive strength test results for concrete

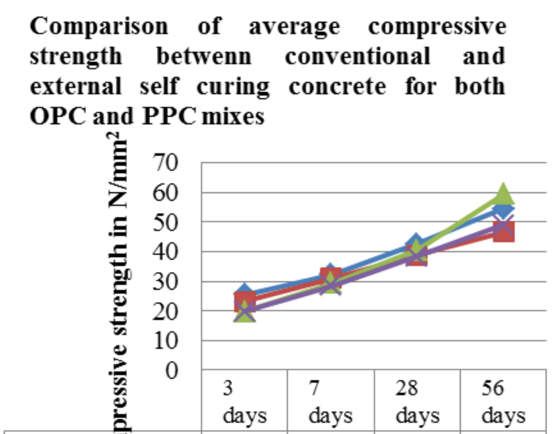
Compressive strength was conducted on 150x150mm cubes specimens for both OPC and PPC mixes and testing was carried out as per IS: 516-1959. A set of three cubes specimens were tested to get average results on compressive strength of concrete. The compressive strength was determined for 3, 7, 28 and 56 days for conventional and external self curing concrete. The results on compressive strength are presented in **Fig1.**

It was observed that the strength of concrete for conventional curing concrete was increased up to 28.31% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix for 3 days, and then the increase of concrete compressive strength for external self curing concrete is about 17.71% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix for 3 days.

For 7 days, it was observed that the increase of concrete strength for conventional curing concrete is about 10.79% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then the increase of concrete compressive strength for external self curing concrete is about 8.82% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix.

For 28 days, it was observed that the strength of concrete for conventional curing concrete was increased up to 4.75% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then compressive strength of concrete for external self curing concrete was increased up to 1.25% for OPC concrete mix as compared to external self curing concrete for of PPC concrete mix.

For 56 days, the strength of concrete for conventional curing concrete was increased up to 8.99% for PPC concrete mix as compared to conventional curing concrete for OPC concrete mix, and then compressive strength of concrete for external self curing concrete was increased up to 4.75% for PPC concrete mix as compared to external self curing concrete for OPC concrete mix.



	3 days	7 days	28 days	56 days
Compressive strength by conventional curing for OPC mix (N/mm2)	25.47	32.34	42.52	54.36
Compressive strength by external self curing concrete for OPC mix (N/mm2)	23.19	30.95	38.85	46.66
Compressive strength by conventional curing for PPC mix (N/mm2)	19.85	29.19	40.59	59.25
Compressive strength by external self curing for PPC mix (N/mm2)	19.7	28.44	38.37	48.88

Fig 1. Comparison of Compressive strength.

7.4 Split tensile strength test results for concrete

Split tensile strength test was performed on **150mm** x **300mm cylinders** for both OPC and PPC concrete mixes for conventional and external self curing concrete. The three cylindrical specimens were taken to determine average result of split tensile strength for 28 days. The results on split tensile strength are presented in **Fig2.**

It was observed that the split tensile strength of concrete for conventional curing concrete was increased up to 3.44% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then the increase of concrete split tensile strength for external self curing concrete is about 5.84% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix for 28 days.

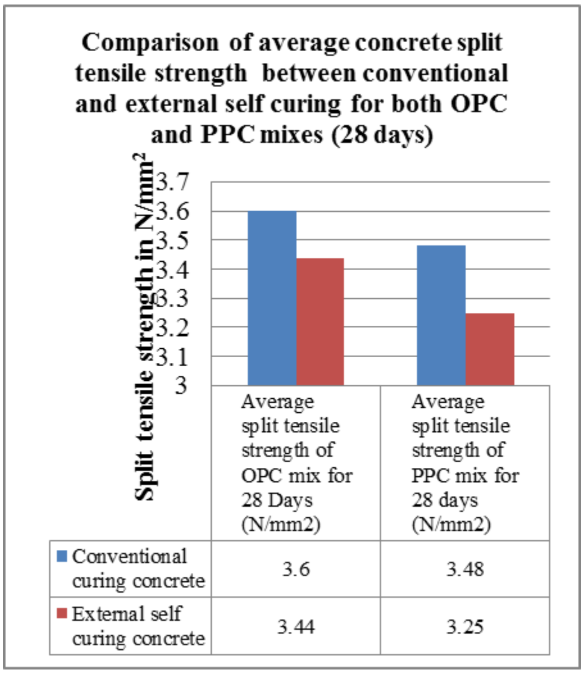


Fig 2. Comparison of split tensile strength.

7.5 Flexural strength test results for concrete

Flexural strength of concrete was carried out for both OPC and PPC concrete specimens as per IS: 516-1959 for conventional and external self curing concrete.

Testing to determine flexural strength of concrete was performed on three beam specimens of size 100 × 100 × 500 mm for 28 days. The average results on split tensile strength are presented in **Fig3.**

It was observed that the increase of concrete flexural strength for conventional curing concrete is about14.13% for OPC concrete mix as compared to conventional curing concrete for PPC concrete mix, and then the increase of concrete flexural strength for external self curing concrete is about 25.27% for OPC concrete mix as compared to external self curing concrete for PPC concrete mix for 28 days.

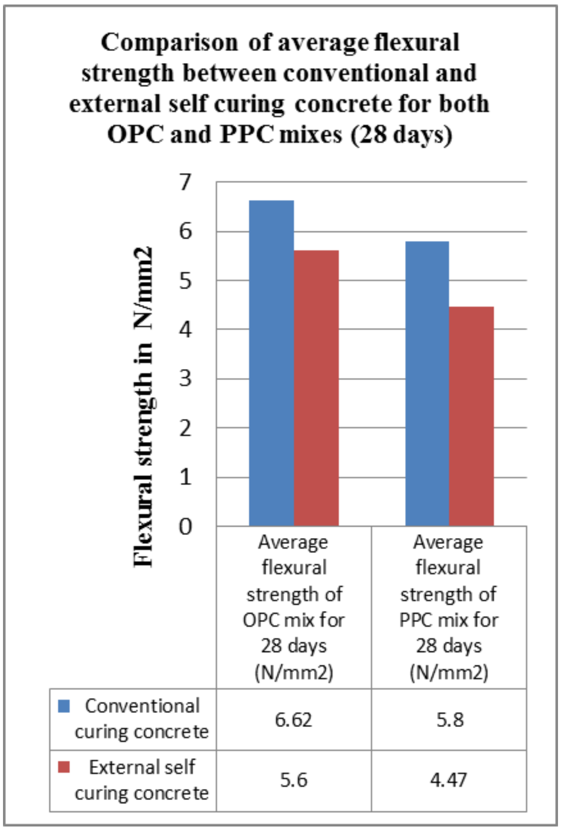


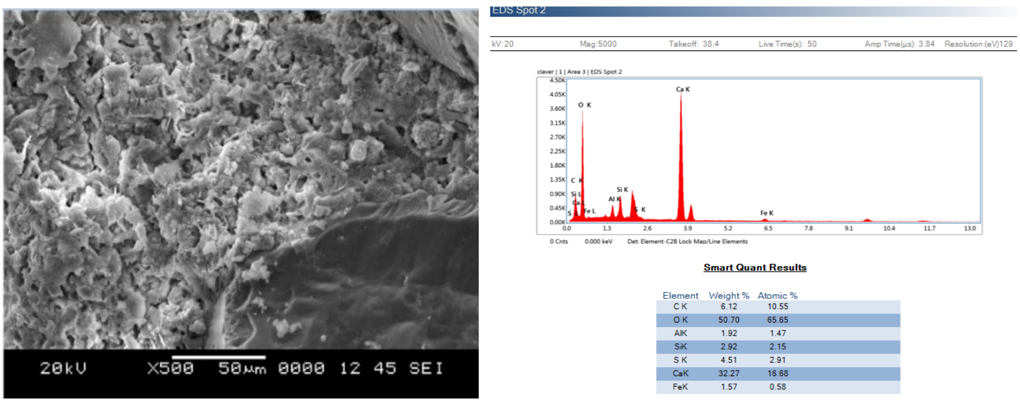
Fig 3. Comparison of flexural strength.

7.6 Scanning Electron Microscopy (SEM) for both OPC and PPC concrete mixes

The scanning electron microscope (SEM) is a powerful technique in the examination of materials. It is used widely in metallurgy, geology, biology, engineering and medicine, to name just a few. The user can obtain high magnification images, with a good depth of field and can also analyse individual crystals or other features. A high-resolution SEM image can show detail down to 25 Angstroms, or better. When used in conjunction with the closely-related technique of energy-dispersive X-ray microanalysis (EDX, EDS, EDAX), the composition of individual crystals or features can be determined.

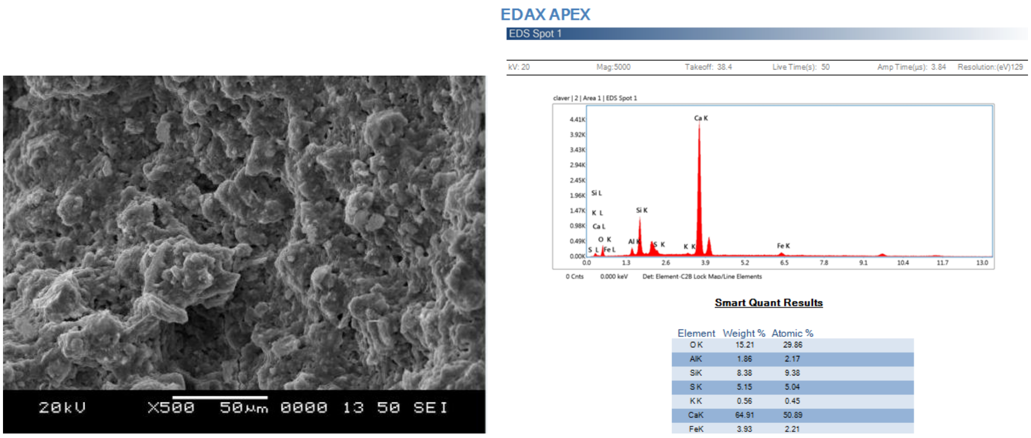
SEM is one of the most versatile instruments available for the examination and analysis of microstructural characteristics of solid objects. The primary reason for the SEM's usefulness is the high resolution that can be obtained when bulk objects are examined. The microscope has been a powerful tool in the study of cement and concrete since the early development of these materials.

In the present study, the microstructure of the concrete was analysed using Scanning Electron Microscope (SEM) which practically helps to visualize the microstructure of the hydrated cement paste. SEM was carried out for both OPC and PPC concrete mixes to obtain high magnification images and chemical compositions (EDS or Energy Dispersive Spectroscopy) of concrete from both concrete mixes. After Compressive testing for 56 days was finished, the cube samples are crushed and the hydrated cement was collected from the innermost core of the concrete cube sample for both OPC and PPC mixes. Scanning Electron Microscope (SEM) test was carried out in NITK Scanning Electron Microscope laboratory and the results are shown in the **fig 4, 5, 6 and 7** below.



Element	Weight %	Atomic %
C K	6.12	10.55
O K	50.70	65.65
AlK	1.92	1.47
SiK	2.92	2.15
S K	4.51	2.91
CaK	32.27	16.68
FeK	1.57	0.58

Fig 4. **SEM images and EDS spectra of conventional curing concrete for OPC mix.**



Element	Weight %	Atomic %
O K	15.21	29.86
AlK	1.86	2.17
SiK	8.38	9.38
S K	5.15	5.04
K K	0.56	0.45
CaK	64.91	50.89
FeK	3.93	2.21

Fig 5. **SEM images and EDS spectra of external self curing concrete for OPC mix.**

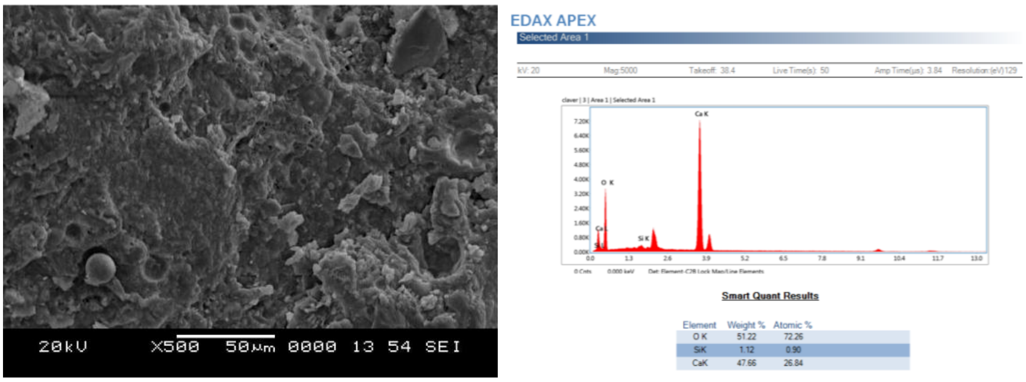


Fig 6. SEM images and EDS spectra of conventional curing concrete for PPC mix.

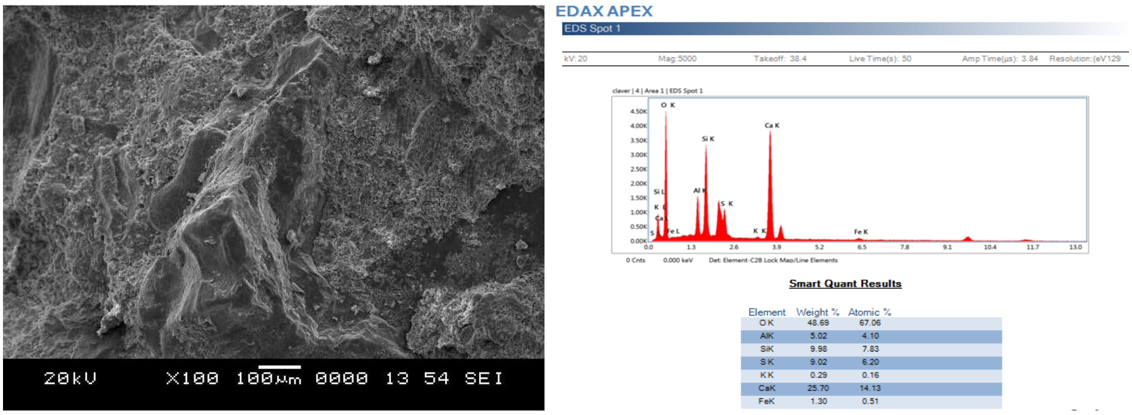


Fig 7. SEM images and EDS spectra of external self curing concrete for PPC mix.

7.7 Concrete water absorption test results

Concrete water absorption was carried out for both OPC and PPC concrete mixes as per ASTM C642 for conventional and external self curing concrete after 28 days.

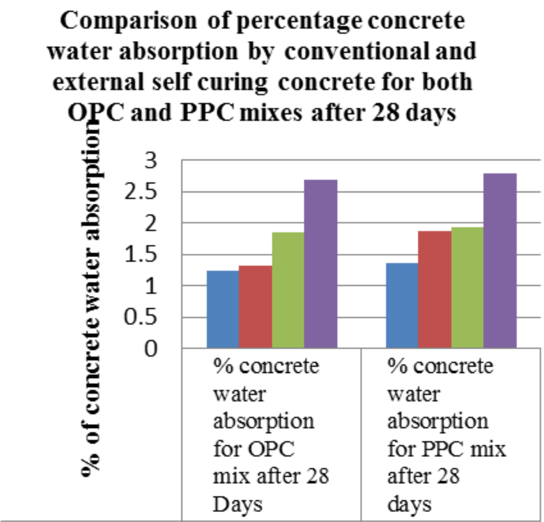
The average of three cube specimens of size 150 mm × 150 mm × 150 mm was taken to determine concrete water absorption. Percentage of concrete water absorption was determined by measuring the weight of three specimens and calculated with the following formula.

- Concrete water absorption after immersion,%= [(W2-W1)/W1]×100
- Concrete water absorption after immersion and boiling,%=[(W 3- W 1)/ W 1] ×100

Where: W1: Mass of oven-dried sample (in gm), W2: Mass of surface-dry sample in air after immersion (in gm), W3: Mass of surface-dry sample in air after immersion and boiling (in gm). The average results of concrete water absorption are shown in **Fig 8.**

The results shows that percentage of concrete water absorption after immersion, conventional curing concrete was increased up to 0.12% for PPC concrete mix as compared to conventional curing concrete for OPC concrete mix after 28 days, and then percentage of concrete water absorption after immersion and boiling was observed that conventional curing concrete was increased up to 0.56% for PPC concrete mix as compared to conventional curing concrete for OPC concrete mix.

I t was observed that percentage of concrete water absorption after immersion, external self curing concrete was increased up to 0.009% for PPC concrete mix as compared to external self curing concrete for OPC concrete mix after 28 days, and then percentage of concrete water absorption after immersion and boiling was observed that external self curing concrete was increased up to 0.29% for PPC concrete mix as compared to external self curing concrete for OPC concrete mix.



	% concrete water absorption for OPC mix after 28 Days	% concrete water absorption for PPC mix after 28 days
Conventional curing after immersion	1.24	1.36
Conventional curing after immersion and boliing	1.31	1.87
External self curing after immersion	1.85	1.94
External self curing after immersion and boiling	2.68	2.79

Fig 8. Comparison of percentage concrete water absorption.

8. CONCLUSIONS

On the basis of the results obtained from the present study, following conclusions can be drawn:

- The concrete strengths for both OPC and PPC mixes, it was observed that conventional curing for both binding materials has greater results as compared to external self curing concrete but also the strength external self curing is good as they are greater than target mean strength designed.
- The percentage of concrete water absorption after immersion and water absorption after immersion and boiling (OPC and PPC mixes), conventional and external self curing for PPC mix are greater than conventional and external self curing for OPC mix.
- External self-curing concrete is the answer to the many problems faced in construction industries due to lack of proper curing, lack of water in certain areas and it is an alternative to conventional curing concrete in desert regions where scarcity of water is a major problem.
- External self-curing concrete is more economical because it eliminates the curing charges and efficiently adapted in remote areas as well as in the area where there is water scarcity problem. Spray application reduces labor costs, eliminates the need for alternative curing systems and then curing compound increases water retention for self cured concrete. Concrete with curing compound gives smooth and fine finished surface than normal curing concrete.
- External self-curing concrete is the best solution to the problems faced in the desert region and faced due to lack of proper curing, the strength of external self curing concrete is increased by applying the curing compound on concrete surface. Curing compound seals the concrete surface effectively by forming monomolecular film on the surface immediately after placing .The results have been attained in strength with small amount of water, so this method can be implemented in construction field.

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