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COMPARATIVE STUDY ON SELF-CURING CONCRETE

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ABSTRACT
A self-curing concrete is provided to absorb water from atmosphere to achieve better hydration of cement in concrete which solves the problem of lowered cement hydration because of improper curing and thus unsatisfactory properties of concrete. The present investigation involves the use of self-curing agent viz., polyethylene glycol (PEG) of molecular weight 6000 (PEG 6000) for dosages ranging between 0.5 to 2% by weight of cement added to mixing water. The experimental program was planned as the following. Total 120 cubes, 120 cylinders, 120 prisms were cast which involves different dosages (0%, 0.5%, 1% and 2%) of self-curing agent PEG-6000 for different type of mixes (Mix 30 and Mix 40), under different curing conditions (indoor, conventional) with different aggregates (normal coarse aggregate and recycled coarse aggregate). Comparative studies were carried out for self-curing of recycled coarse aggregate and self-curing of normal coarse aggregate. Comparative studies were carried out for water retentivity, compressive strength, split tensile strength, flexural strength for 7 days and 28 days for conventional cured and self-cured concrete. The properties of self-cured concrete are at least comparable and sometime better than those of concrete with traditional curing. The comparative studies for strength were carried out at different dosages for different coarse aggregate. The results indicate that self-curing concrete has shown greater strength compared to conventional curing concrete. The maximum strength for normal coarse aggregate concrete is at dosage of 2% SCA and for recycled coarse aggregate concrete is at dosage of 1% SCA and then decreases. For concrete using normal coarse aggregate in place of Recycled coarse aggregate the compressive strength was found to be 7.5% more at 28 days. The compressive strength of self-curing concrete is 3% more than that of the concrete with conventional curing 28 days. Similarly, the spilt tensile strength with normal coarse aggregate was found to be 7% more then with recycled coarse aggregate at same 28 days testing. Again, the split tensile strength was found to be 3.1% more than the concrete with conventional curing at 28 days testing. The flexural strength 5% is more for natural coarse aggregate concrete compared to recycled coarse aggregate concrete 28 days. The flexural strength 2% more for self-curing concrete compared to the conventional curing concrete for 28 days. The maximum weight loss in the concrete occurs at 0% of SCA and increases with increases in percentage of SCA.**Keywords**: Self Curing Agent, PEG 6000, Recycled Coarse Aggregate, OPC, Curing.

I.INTRODUCTION

1.1 General

Curing is the process of controlling the rate and extent of moisture transport from concrete during Cement hydration. It may be either after it has been placed in position (or during the manufacture of concrete products), thereby providing time for the hydration of the cement to occur. Since the hydration of cement does take time in days, and even weeks rather than hours curing must be undertaken for a reasonable period of time, if the concrete is to achieve its potential strength and durability. Curing may also encompass the control of temperature since this affects the rate at which cement hydrates. The curing period may depend on the properties required of the concrete, the purpose for which it is to be used, and the ambient conditions, i.e., the temperature and relative humidity of the surrounding atmosphere. Curing is designed primarily to keep the concrete moist, by preventing the loss of moisture from the concrete during the period in which it is gaining strength.

Conventional Curing Methods

Methods of curing concrete fall broadly into the following categories:

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Minimise moisture loss from the concrete, for example by covering it with a relatively impermeable membrane.

Prevent moisture loss by continuously wetting the exposed surface of the concrete.

Steam curing.

Ponding or spraying the surface with water.

Difficulties in conventional curing methods

i. For the vertical member it is not possible to keep the surface moist as in case of the flat surfaces.
ii. In the places where there is scarcity of water.
iii. In the places where manual curing is not possible.
iv. A human error may lead to the cracking in the member and also decreases its strength i.e., when curing water is not provided at the right time.

1.2 Self-curing

Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. However, good curing is not always practical in many cases. Several investigators explored the possibility of accomplishing self-curing concrete. Therefore, the need to develop self-curing agents attracted several researchers. 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. Concrete incorporating self-curing agents will represent a new trend in the concrete construction in the new millennium. Curing of concrete plays a major role in developing the concrete microstructure and pore structure, and hence improves its durability and performance. 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. The use of self-curing admixtures is very important from the point of view that water resources are getting valuable every day (i.e., each 1cu.m of concrete requires about 3cu.m of water for construction most of which is for curing).Excessive evaporation of water (internal or external) from fresh concrete should be avoided; otherwise, the degree of cement hydration would get lowered and thereby concrete may develop unsatisfactory properties. Curing operations should ensure that adequate amount of water is available for cement hydration to occur. This investigation discusses different aspects of achieving optimum cure of concrete without the need for applying external curing methods. The effect of curing, particularly new techniques such as "self-curing", on the properties of high-performance concrete is of primary importance to the modern concrete industry. [1]

1.3 Definition of self-curing

The ACI-308 Code states that “internal curing refers to the process by which the hydration of cement occurs because of the availability of additional internal water that is not part of the mixing Water.” Conventionally, curing concrete means creating conditions such that water is not lost from the surface i.e., curing is taken to happen ‘from the outside to inside’. In 3 contrast, ‘internal curing’ is allowing for curing ‘from the inside to outside’ through the internal reservoirs (in the form of saturated lightweight fine aggregates, superabsorbent polymers, or saturated wood fibres) Created. ‘Internal curing’ is often also referred as self– curing."Self-curing concrete" means that no labour work is required to provide water for concrete or no external curing is required after placing which the properties of this concrete are at least comparable to and even better than those of concrete with traditional curing.Self-curing is an "internal curing system" where a water- soluble polymer is added to the concrete mix. This method overcomes the difficulty in ensuring that effective curing procedures are employed by the construction personnel as the internal curing composition is a component of the mix.

1.4 Potential materials for curing

The following materials can provide internal water reservoirs:

i. Lightweight Aggregate (natural and synthetic, expanded shale),
ii. Light Weight Sand (Water absorption =17 %)
iii. Light Weight Aggregate- 19mm Coarse (Water absorption = 20%)
iv. Super-absorbent Polymers (SAP) (60-300 mm size)
v. SRA (Shrinkage Reducing Admixture)
vi. Wood powder.

1.5 Chemicals to Achieve Self–curing

Some specific water-soluble chemicals added during the mixing can reduce water evaporation from and within the set concrete, making it 'self-curing.' The chemicals should have abilities to reduce evaporation from solution and to improve water retention in ordinary Portland cement matrix. [2]

1.6 Classification of Aggregates

For the purpose of this report, the following classifications are adopted.

1.6.1 Natural Aggregate

Construction aggregates produced from natural sources such as gravel and sand, and extractive products such as crushed rock, some of the examples are Crushed rock, Sand and gravel, Crushed River gravel.

1.6.2 Manufactured Aggregate

Aggregates manufactured from selected naturally occurring materials, by-products of industrial processes or a combination of these, some of the examples are Foamed Blast Furnace Slag (FBS), Fly Ash Aggregate, Manufactured Sand, Polystyrene Aggregate (PSA), Expanded Clays, Shale and Slates.

1.6.3 Recycled Aggregate

Aggregates derived from the processing of materials previously used in a product and/or in construction, some of the examples are Recycled Concrete Aggregate (RCA), Recycled Concrete and Masonry (RCM), Reclaimed Aggregate (RA), Reclaimed Asphalt Pavement (RAP), Reclaimed Asphalt Aggregate (RAA), Glass Cullet, Scrap Tyres, used Foundry Sand.

1.6.4 Reused By-product

Aggregates produced from by-products of industrial processes, some of the examples are Air cooled Blast Furnace Slag (BFS), Granulated Blast Furnace Slag (GBS), Electric Arc Furnace Slag (EAF), Steel Furnace Slag (BOS), Fly Ash (FA), Furnace Bottom Ash (FBA), Incinerator Bottom Ash (IBA), Coal Washer Reject (CWR), Organic Materials, Crusher fines, Mine tailings.

1.7 Sources of Recycled Aggregate

Traditionally, Portland concrete aggregate from the demolition construction are used for landfill. But now days, Portland concrete aggregate can be used as a new material for construction usage. According to recycling of Portland Cement Concrete, recycled aggregates are mainly produced from the crushing of Portland concrete pavements and structures building. The main reason for choosing the structural building as the source for recycled aggregate is because a huge amount of crushed demolition Portland cement concrete can be produced.

1.8 Applications of Recycled Aggregate

General, applications without any processing include:

Many types of general bulk fills

- Bank protection
- Base or fill for drainage structures
- Road construction

Noise barriers and embankments

Most of the unprocessed crushed concrete aggregate is sold as 37.5 mm or 50 mm fraction for pavement sub-bases.

1.9 The use of Recycled Aggregate in Concrete

The use of crushed aggregate from either demolition concrete or from hardened leftover concrete can be regarded as an alternative coarse aggregate, typically blended with natural coarse aggregate for use in new concrete. The use of 100% recycled coarse aggregate in concrete, unless carefully managed and controlled, is likely to have a negative influence on most concrete properties – compressive strength, modulus of elasticity, shrinkage and creep, particularly for higher strength concrete. Also, the use of fine recycled aggregate below 2 mm is uncommon in recycled aggregate concrete because of the high-water demand of the fine material smaller than 150 μm, which lowers the strength and increases the concrete shrinkage significantly. Many overseas guidelines or specifications limit the percentage replacement of natural aggregate by recycled aggregate. In general leftover concrete aggregate can be used at higher replacement rates than demolition concrete aggregate. With leftover concrete aggregate, information will generally be known about the parent concrete – strength range and aggregate source etc., whereas for demolition concrete very little information may be known about the parent concrete, and the resulting aggregate may be contaminated with chlorides or sulphates and contain small quantities of brick, masonry or timber which may adversely affect the recycled aggregate concrete. Often the sources of material from which a recycled aggregate came (and there could be more than one source), are unknown and the variability and strength of the recycled aggregate concrete could be adversely affected in comparison with a recycled aggregate 7 concrete where the recycled aggregate came from one source with a known history of use and known strength. It is therefore necessary to distinguish

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between the properties of recycled aggregate concrete made using demolition concrete aggregate and that using leftover concrete aggregate. Nevertheless, recycled aggregate concrete can be manufactured using recycled aggregate at 100% coarse aggregate replacement where the parent concretes, the processing of the recycled aggregate and the manufacture of the recycled aggregate concrete are all closely controlled. However, as target strengths increase, the recycled aggregate can limit the strength, requiring a reduction in recycled aggregate replacement.

1.10 Need of the study

Curing of concrete is maintaining satisfactory moisture content in concrete during its early stages in order to develop the desired properties. However, good curing is not always practical in many cases. Several investigators explored the possibility of accomplishing self-curing concrete. Therefore, the need to develop self-curing agents attracted several researchers. 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. A self-curing concrete is provided to absorb water from atmosphere to achieve better hydration of cement in concrete. It solves the problem that the degree of cement hydration is lowered due to no curing or improper curing, and thus unsatisfactory properties of concrete. It is now widely accepted that there is a significant potential for reclaiming and recycling demolished Debris for use in value added applications to maximize economic and environmental benefits. At present converts low value waste into secondary construction materials such as a variety of aggregate grades, road materials and aggregate fines (dust). Often these materials are used in as road construction, backfill for retaining walls, low-grade concrete production, drainage and brickwork and block work for low-cost housing. Due to issues relating to sustainability and limited natural resources, it is clear that the use of recycled and secondary aggregates (RSA).

1.11 Mechanism of self-curing

The mechanism of self-curing can be explained as follows: Continuous evaporation of moisture takes place from an exposed surface due to the difference in chemical potentials (free energy) between the vapour and liquid phases. The polymers added in the mix mainly form hydrogen bonds with water molecules and reduce the chemical potential of the molecules which in turn reduces the vapour pressure; This reduces the rate of evaporation from the surface.

1.12 Objectives

1. To prepare self-curing concrete with different percentages of self-curing agents when it added with natural coarse aggregate and recycled coarse aggregate
2. To obtain different strength characteristics of self-curing concrete by adding different percentages of self-curing agents and comparing it with conventional concrete.
3. To study the water retention ability of self-curing concrete when it compared with conventional concrete.

II. LITERATURE REVIEW

WEN-CHEN JAU (SELF CURING CONCRETE) (2008)

The objective of the research was to find out the effect of high performance self-curing agent on strength characteristics of self-compacted concrete in comparison with ordinary concrete (with different curing conditions). The self-curing agent used in this study was poly acrylic acid (PAA) and polyvalent alcohol. These two chemicals are most hydrophilic in nature. The dosage of self-curing agent was 1% and 2% by weight of cement. Compressive strength and water retentivity test were carried under different relative humidity conditions like 50%, 67.5% and 85%.

The following could be concluded from the results obtained in this study

- A self-curing concrete primarily comprising coarse aggregates, fine aggregates, Cement, and mixing water, and comprising a self-curing agent added during mixing, wherein the self-curing agent absorbs moisture from air and then releasing it into the concrete, thereby achieving self-curing without external curing method after placing.
- The self-curing concrete wherein a specific amount of the self-curing agent is added to the concrete such that a 10% higher compressive strength than that of concrete without curing.

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- Compressive strength of self-compacting concrete in this invention was improved significantly, or even higher than the compressive strength of standard moist curing.
- This indicates that self-curing concrete of this invention needs no long-lasting moist curing, which saves cost and guarantees a higher compressive strength and better quality.
- This was also found that the more is the relative humidity more will be the compressive strength for self-curing concrete.

ROLAND TAK YONG LIANG AND ROBERT KEITH SUN (2002)

The objective of the research was to produce self-curing concrete by using hydrophilic chemicals like polyethylene glycol and paraffin wax. Many experiments have done on ordinary concrete like compressive strength at different days of curing and also at different proportions of PEG and wax. The investigation was done using three internal curing compositions and is as follows: -

Curing material	Curing membrane	Internal curing Composition 1	Internal curing Composition 2	Internal curing Composition 3
Base material	Solvent borne Resin with dye	Water, wax Emulsion and High MW Polyethylene oxide	Water, paraffin Wax & Polyethylene glycol	Water based polyether's

EXPERIMENTAL ANALYSIS

3.1 General

The experimental programme was planned as the following. Total 120 cubes, 120 cylinders, 120 prisms were cast which involves different dosages (0%, 0.5%, 1% and 2%) of self-curing agent PEG-6000 for four different mixes (Mix A1, A2 and Mix B1, B2), under different curing conditions (controlled, conventional). The compaction factor test was conducted for all mixes to know the fresh property of concrete. Compressive strength test was conducted at 7 and 28 days of curing and to investigate the water retentivity capacity the cubes were weighed for every three days from the date of casting. The accuracy of the digital weighing machine used is 5 gm. Strength graph is plotted against percentage of self-curing agent; water retentivity graph is plotted for average weight loss verses number of days of curing. In this investigation the maximum dosage of self-curing agent is restricted to 2% and minimum dosage is of 0.5% is decided as per the literature available. [2]

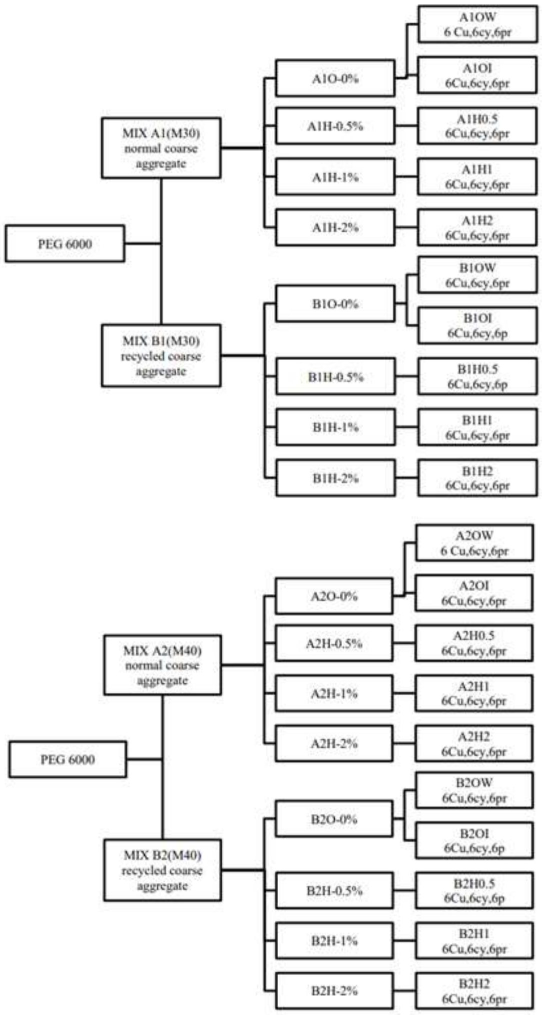

Fig: 1: Flow chart of experimental programme for concrete

3.5 Detailed Investigation on concrete

3.5.1 Mix design

In this study, mix design is done by three methods:

i) IS CODE

In order to obtain strength around 30Mpa and 40Mpa for Mix A1&B1 and Mix A2&B2respectively. Number of trails were conducted to obtain the desired strength and to maintain good workability (slump of about 100mm) and finally acquired four mix proportions as Mix A1 (M30), A2 (M40) and Mix B1 (M30), B2 (M40). To obtain good workability and desired strength the optimum water cement ratio used in

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Mix A is 0.40 and 27 super-plasticizer is used in the mix and in Mix B the optimum water cement ratio is 0.38 and no super-plasticizer is used in the mix.

3.5.2 Test for Fresh Properties of Concrete

a) Slump Test

Slump test is the most commonly used method of measuring workability of concrete. It is not a suitable method for very wet or very dry concrete. It does not measure all factors contributing to workability. In this case study slump test is done according to IS 456-2000 Specifications.

b) Compacting Factor Test

It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as are normally used when concrete is to be compacted by vibration. Such dry concrete is insensitive to slump test. As shown in Fig 3.2

Fig 2: compaction factor apparatus

This test works on the principle of determining the degree of compaction achieved by a standard amount of work done by allowing the concrete to fall through a standard height. The degree of compaction, called the compacting factor is measured by the density ratio i.e., the ratio of the density actually achieved in the test to density of same concrete fully compacted.

3.5.3Test for Properties of concrete

a) Water Retentivity

Test Water Retentivity is the ability of the substance to retain water. To perform the water retentivity test, the cubes were weighed for every 3 days from the date of casting. Weight loss for the specimens in controlled curing, and weight gain for the conventional curing are noted and their behaviour is plotted in graph against number of days of curing. As shown in the plate 7 and 8.

3.6 Testing of Specimens

After the specimen prepared for testing on universal testing machine to find the Mechanical properties such as compressive strength on cubes, flexural strength on prisms, splitting tensile strength on cylinders.

3.6.1 Testing Procedure for Compressive Strength

The specimens were tested in accordance with IS 516:1969, the testing was done on universal compression testing machine of 2000kN velocity. The machine has the facility to control the rate of loading with a control valve. The machine has been calibrated to the required standards. The platens are cleaned, oil level is checked and kept ready in all respects for testing. As shown in the plate 4 and 11. It is placed on the machine such that the load is applied centrally the smooth surfaces of the specimen are placed as the bearing surfaces. The top plate is brought in contact with the specimen by rotating the handle. The oil pressure valve is closed and the machine is switched ON. A uniform rate of loading 140lg/sq.cm/min is maintained. The maximum load at failure at which the specimen breaks and the average value is taken as the mean strength. The compressive strength is taken as the load applied on the specimen divided by the area of the load bearing surface of the specimen (P/A).

Testing Procedure for Flexural Strength

Flexural strength is expressed in terms of modulus of rupture, which is the maximum stress at the extreme fibres in bending. It is calculated by flexure formula. After removal of the beam 29 specimen from the controlled curing, they are tested on the load frame of 20kN capacity in accordance with IS 9399:1679. The load frame is provided with two rollers at a distance of 400mm apart at the base. The load is applied through two similar rollers mounted at the third point of the supporting span spaced 133mm apart and centrally with the respect to the base rollers. As shown in plate 9. The axis of the specimen is carefully aligned with the axis of the loading frame. The load is applied gradually without shock increasing continuously such that the extreme fibre stresses increase at a rate of 7kg/ sq.cm/min. i.e., application of load it at the rate of 4000N/min. the load is divided equally between the two roller points and it increased until the specimen fails. The load is measured by a load gauge (proven ring) mounted on top of the loading rollers the modulus of rupture is calculated for the maximum load taken by the member.

IV.RESULTS AND DISCUSSIONS

As per Experimental programme results for different experiments were obtained. They are shown in table format or graph, which is to be presented in this chapter.

4.1. Studies on Concrete

4.1.1. Compaction Factor Test

The test results are shown in Table 4.1. The plot of the compaction factor and different dosage of PEG 6000 is shown in Figure 4.1. The following are the observations on Compaction factor test.

i) In case of specimens with PEG 6000 of Mix A it is clear that compaction factor for 0.5% dosage of self-curing agent is less when compared to other dosages 1% and 2%.

ii) In case of specimens with PEG 6000 of Mix B 1% dosage compaction factor is more compared to other dosages (0.5% and 2%).

iii) It is also clear that compaction factor is more for Mix B in 1% and 2% when compared to Mix A.

iv) It is also observed that in Mix A the compaction factor is increased with increase of % of PEG 6000. But in Mix B it is increased from 0.5% to 1% and then it is decreased.

4.2 Water Retentivity Test

4.2.1. Water Retentivity Test Results for Mix A1

Concrete with high molecular weight PEG subjected to controlled curing was studied by weighing the samples at regular intervals of 3 days, with digital weighing machine of accuracy 5gms up to 28 days. The results were recorded in Table 4.2. The analysis of results or average weight loss of individual specimen is shown in Table 4.3. The average weight loss is shown in Fig.4.2. The following are the observations on water retentivity of concrete.

i) It is clear that 0% dosage of self-curing agent is losing more weight when compared to other dosages (0.5%, 1% and 2% of self-curing agent).

ii) It is also observed that 2% dosage of self-curing agent shows lower weight loss when compared to other dosages (0%, .5% and 1% of self-curing agent).

4.2.2 Water Retentivity Test Results for Mix A2

Concrete with high molecular weight PEG subjected to controlled curing was studied by weighing the samples at regular intervals of 3 days, with digital weighing machine of accuracy 5 gm up to 28 days. The results were recorded in Table 4.4. The analysis of results or average weight loss of individual specimen is shown in Table 4.5. The average weight loss is shown in Fig.4.3. The following are the observations on water retentivity of concrete.

It is clear that 0% dosage of self-curing agent is losing more weight when compared to other dosages (0.5%, 1% and 2% of self-curing agent).

It is also observed that 2% dosage of self-curing agent shows lower weight loss when compared to other dosages (0%, .5% and 2% of self-curing agent).

Water Retentivity Test Results for Mix B1

Concrete with high molecular weight PEG subjected to controlled curing was studied by weighing the samples at regular intervals of 3 days, with digital weighing machine of accuracy 5 gm up to 28 days. The results were recorded in Table 4.6. The average weight loss is shown in Fig.5.6. The analysis of results or percentage weight loss of individual specimen are shown in Table 4.7. The following are the observation on water retentivity of concrete.

It is clear that conventional concrete with controlled curing is losing more weight when compared to other dosages 0.5%, 1% and 2% of self-curing agent.

It is also clear that 1 % dosage of S.C.A result is almost nearer when compared to the dosages of conventional concrete with controlled curing.

It is also observed that 2 % dosage of S.C.A shows less weight loss when compared to other dosages.

V.SUMMARY AND CONCLUSION

After having prefer the experimental programme and results obtained analysis was carried out and following are the list of conclusions arrived for self-curing agent polyethylene glycol (PEG6000) and comparison of different aggregates are obtained.

VI.Conclusions

a) Workability of concrete was found to increase by 9% when self-curing agents are added to the concrete.

b) The compressive strength at 7days and 28 days for Mix A1 and Mix A2 self-curing concrete was found to be optimum at 2% PEG6000 dosage; and in case of Mix B1 and MixB2 self curing concrete the optimum value was observed at 1%PEG6000 dosage.

c) The compressive strength at 28 days for M30 self curing concrete prepared by natural coarse aggregate is 38.61MPa for mix A1H2 is approximately equal when compared with conventional concrete A1OW.

d) The compressive strength for M40 self curing concrete prepared by natural coarse aggregate is 48.3MPa for mix A2H2 is approximately equal when compared with conventional concrete A2OW.

e) The compressive strength approximately 17.5% more for the concrete using normal coarse aggregate compared to the concrete using recycled coarse aggregate for 28 days in both the mixes(M30,M40)

f) The compressive Strength approximately 3% more for self curing concrete compared to the conventional curing concrete for 28 days in both the mixes(M30,M40)

g) The splitting tensile strength approximately 7% more for natural coarse aggregate concrete compared to recycled coarse aggregate concrete for 28 days in both mixes (M30, M40).

h) The splitting tensile strength approximately 3.1% more for selfcuring concrete compared to the conventional curing concrete for 28 days in both mixes(M30, M40)

i) The flexural strength approximately 5% is more for natural coarse aggregate concrete compared to recycled coarse aggregate concrete 28 days mixes (M30, M40).

j) The flexural strength approximately 2% more for selfcuring concrete compared to the conventional curing concrete for 28 days in both mixes (M30, M40).

k) The maximum weight loss in the concrete occurs at 0% for all the mixes(Mix A1,Mix A2,MixB1,MixB2) of self curing agent and increases with increases in percentage of self curing agent.

SCOPE FOR FUTURE STUDIES

a) The effect of self curing agent on the microstructure and pore size distribution of the self-curing concrete requires additional study.

b) Sorptivity and durability studies for sulphate salts and chloride induced corrosion on self-curing concrete need to investigate.

c) Mix design procedures for development of self-curing concrete and fibre reinforced self-curing concrete are to established.

d) Further in depth investigation is to done for choosing optimum dosage of self curing agent in strength and durability point of view.

e) Study on use of light weight aggregate and recycled aggregate is to be carried which possess more absorption capacities.

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