Durability and Mechanical Characteristics of Sustainable Self Curing Concrete Utilizing Natural and Recycled Aggregates

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***Abstract*—High-performance concrete is defined as concrete that meets special combinations of performance and uniformity requirements that cannot always be achieved routinely using conventional constituents and normal mixing, placing, and curing practices. Also, it is very important to maintain the water cement ratio within the minimal range, for that we have to use the water reducing admixture i.e. superplasticizer, which plays an important role for the production of high-performance concrete. So, we herein the project has tested on different materials like rice husk ash, Ground granulated blast furnace slag, silica fume to obtain the desired needs. Also X-ray diffraction test was conducted on different pozzolanic material used to analyses their content ingredients. We used synthetic fiber (I.e. Recon fiber) in different percentage i.e. 0.0%, 0.5%, 1%, 2% to that of total weight of concrete and casting was done. Finally, we used different percentage of silica fume with the replacement of cement keeping constant fiber content and concrete was cast. In our study it was used two types of cement, Portland slag cement and ordinary Portland cement. We prepared mortar, cubes, cylinder and finally compressive test, splitting test, flexural test are conducted. Also to obtain such performances that cannot be obtained from conventional concrete and by the current method, a large number of trial mixes are required to select the desired combination of materials that meets special Performance.**

I. INTRODUCTION

1.1 Curing

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, if the 1concrete 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. Concrete curing methods are designed to maintain moisture and temperature, ensuring proper hydration and strength development, and include water curing, wet coverings, membrane curing, sheet curing, and heat-based techniques.

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.

II. PROBLEM STATEMENT

- Conventional concrete production heavily relies on natural aggregates and large volumes of freshwater for curing, leading to significant depletion of natural resources and environmental degradation.
- Moreover, traditional curing practices are often difficult to maintain effectively, especially in regions with water scarcity, resulting in inadequate hydration, reduced strength, and poor durability performance.

III. METHODOLOGY

The experimental programme was planned as the following-Total 120 cubes, 120 cylinders 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 (indoor, conventional). The compaction factor test was conducted for all mixes to know the fresh property of concrete. Compressive strength test was conducted for 7and 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. The flow chart for experimental programme.

Nomenclature for Specimen

- MIX A- normal coarse aggregate (A1- M35 Grades)
- MIX B- recycled coarse aggregate (B1- M35 Grades)
- O-Ordinary Portland cement (OPC)
- H-PEG 600(Higher Molecular Weight)
- I-Indoor Curing
- W-Wet/Conventional Curing
- Self-Curing Agent (S C A)

For example sample with name A1OW represents Mix A with PEG 6000 and dosage of 0% by weight of cement subjected to wet curing. Sample A1OI represents Mix A1 with PEG 6000
and dosage of 0% by weight of cement subjected to indoor curing. Sample A1H1 represents Mix A1 with PEG 6000 and dosage of 1% by weight of cement subjected to indoor curing.

The cement used in the investigation was 53- grade ordinary Portland cement conforming to IS
12269-1987. It was taken from a single lot and stored properly throughout the programme. The
physical properties of cement are shown in table 3.2.1

Table 3.2.1 Physical properties of cement

Specific gravity	3.14
Initial setting time	75 Min
Final setting time	215 Min

3.1 Fine Aggregate

The fine aggregate that falls in zone-II conforming to IS 383-1970 was used. The fine aggregate used was obtained from a nearby river course. The sand obtained from quarry was sieved through all the sieves (i.e. 2.36mm, 1.18mm, 600μ, 300μ and150μ). Sand retained on each sieve was filled in different bags and stacked separately for use. To obtain zone- II sand correctly, sand retained on each sieve is mixed in appropriate proportion. The physical properties of fine aggregate and proportion in which each size fraction is mixed is shown in table 3.2.2&3.2.3 respectively.

Table 3.2.2 Physical Properties of fine aggregate

Fineness modulus	2.80
Bulk density	1.37gm/cc
Specific gravity	2.60

Table 3.2.3 Proportions of different size fractions of sand obtain zone-II sand Different size fractions of sand obtain zone-II sand

Sieve size (mm)	% Passing Recommended by IS:383	Adopted Grading.	Cumulativ e(%) weight Retained	%Weight Retained	Weight Retained in (gm)
10	100	100	-	-	-
4.75	90-100	100	-	-	-
2.36	75-100	85	15	15	150
1.18	55-90	70	30	15	150
600µ	35-59	45	55	25	250
300µ	8-30	10	90	35	350
150µ	0-10	0	100	10	100

3.2 Coarse Aggregate

The coarse aggregate used is from a local crushing unit having 20mm nominal size. 20mm well-graded aggregate according to IS-383 is used in this investigation. The coarse aggregate procured from quarry was sieved through all the sieves (i.e. 16mm, 12.5mm. 10mm and 4.75mm). The material retained on each sieve was filled in bags and stacked separately. To obtain 20mm well-graded aggregate, coarse aggregate retained on each sieve is mixed in appropriate proportions. The physical properties and proportions in each fraction are shown in table 3.2.4& 3.2.5 respectively. Table for physical properties of coarse aggregate.

Table 3.2.4 physical properties of coarse aggregate

Fineness modulus	7.4
Bulk density	1.60gm/cc
Specific gravity	2.7

TABLE 3.2.5 Proportions for CA to obtain 20mm well- graded aggregate.

Sieve size (mm)	% Passing Recommended by IS-383	Adopted Grading	Cumulative(%)Weight Retained	%Weight Retained	Weight Retained In(gm)
40	100	100	-	-	-
20	95-100	100	-	-	-
16	67-82	70	30	30	1500
12	42-66	45	55	25	1250
10	25-55	30	70	15	750
4.75	0-10	0	100	30	1500

Recycled coarse aggregate

The Recycled coarse aggregate used is from a lab crushing unit having 20mm nominal size. 20mm well-graded aggregate according to IS-383 is used in this investigation. The Recycled coarse aggregate procured from lab was sieved through all the sieves (i.e. 16mm, 12.5mm. 10mm and 4.75mm). The material retained on each sieve was filled in bags and stacked separately. To obtain 20mm well-graded aggregate, recycled coarse aggregate retained on each sieve is mixed in appropriate proportions. The physical properties and proportions in each fraction are shown in table 3.2.6 & 3.2.7 respectively.

Table 3.2.6 physical properties of recycled coarse aggregate

Fineness modulus	7.37
Bulk density	1325.93 kg/m3
Specific gravity	2.3

Table 3.2.7 Proportions for RCA to obtain 20mm well- graded aggregate

Sieve size (mm/µ)	Wt. retained (gm)	Wt passed	% Wt. Retained	cumulative % Wt. retained	100-cumulative % Wt. Retained
80mm	0	5000	0	0	500
40mm	0	5000	0	0	500
20mm	1598	3402	31.96	30	340.2
10mm	3310	92	66.2	98.16	9.2
4.75mm	92		1.84	100	0
2.36mm	0		0	100	0
1.18mm	0		0	100	0
600 µ	0		0	100	0
300 µ	0		0	100	0
150 µ	0		0	100	0
		5000		730.12	
Fineness Modulus of Coarse Aggregate					7.3012

M-35 Mix Designs as per IS-10262-2009

1.Stipulations for Mix Design Concrete

- Grade designation: M 35
- Type of cement: OPC 53 grade confirming to IS 8112
- Maximum nominal size of aggregate: 20 mm
- Minimum cement content: 340 kg/m^3
- Maximum water-cement ratio: 0.45
- Workability: 50-100 mm (slump)
- Exposure condition: Very Severe (for reinforced concrete)
- Method of concrete placing: Pumping
- Degree of supervision: Good
- Type of aggregate: Crushed angular aggregate
- Maximum cement content: 450 kg/m^3
- Chemical admixture type: Super Plasticizer

2.Test Data for Materials (to be determined in the laboratory)

- Specific gravity of cement: 3.12
- Specific gravity of Coarse aggregate: 2.74
- Specific gravity of Fine aggregate: 2.56

3. Target Strength for Mix Proportioning

$f_{target} = f_{ck} + 1.65 \times S$

Explanation of terms:

'f_{target}' is the target average compressive strength at 28 days,

'f_{ck}' is the characteristic compressive strength at 28 days, and

's' is the standard deviation

As per the table I of IS: 10262-2009, standard deviation, s = 5.0 N/mm^2

Therefore, target strength = 35 + 1.65 x 5.0 = 43.25 N/mm^2

4.Selection of Water/Cement Ratio

From Table 5 of IS 456:2000,

Maximum water-cement ratio = 0.45

5.Selection of Water Content

From Table 2 of IS 456, maximum water content =186 litres (for 25 to 50 mm slump range) for 20 mm aggregate.

Estimated water content for 100 mm slump =186+(6/100) x 186 =197 liter.

(Note: If Super plasticizer is used, the water content can be reduced upto 20% and above.)

Based on trials with Super plasticizer water content reduction of 20% has been achieved, Hence the arrived water

content = 197-[197 x (20/100)] = 160 litres.

6.Calculation of Cement Content

Water-cement ratio =0.40

Cement content = 160/0.40 = 400 kg/m^3

From Table 5 of IS 456, minimum cement content for 'Very Severe 'exposure condition = 340 kg/m^3

400 kg/m^3 > 340 kg/m^3, hence, O.K.

7.The Proportion of the Volume of Coarse Aggregate and Fine Aggregate Content

From Table 3 of IS 10262, volume of coarse aggregate corresponding to 20 mm size aggregate and fine

Aggregate (Zone II) for a water-cement ratio of 0.50 = 0.62.

In the present case, the water-cement ratio is 0.45. Therefore, the volume of coarse aggregate is required to be

increased to reduce the fine aggregate content.

As the water-cement ratio is lower by 0.10, the proportion of the volume of coarse aggregate is increased by 0.02

(at the rate of -/+ 0.01 for every ± 0.05 change in the water-cement ratio). Therefore. the corrected proportion of the

volume of coarse aggregate for the water-cement ratio of 0.45 = 0.63.

NOTE– In case the coarse aggregate is not angular one. then also the volume of coarse aggregate may be required

10 be increased suitably, based on experience.

For pumpable concrete, these values should be reduced by 10 percent.

Therefore, volume of coarse aggregate = 0.63 x 0.9 = 0.567.

Volume of fine aggregate content =1 – 0.567 =0.433

8 Mix Calculations

a) Volume of concrete = 1m^3

b) Volume of cement = (Mass of cement/Specific Gravity of Cement) X (1/1000)

= (400/3.15) X (1/1000)

=0.126 m^3

c) Volume of water = (Mass of water/specific gravity of water) X (1/1000)

= (160/1) X (1/1000)

=0.160 m^3
d) Volume of superplasticizer = (Mass of superplasticizer / Specific gravity of admixture) X (1/1000)
= (4/1.145) X (1/1000)
= 0.006 m^3
e) Volume of all aggregate = (a-(b+c+d))
= 1 – (0.126 + 0.160+0.006)
= 0.708 m^3
f) Mass of coarse aggregate = Volume of all aggregate X volume of coarse aggregate X Specific gravity of coarse
aggregate X 1000
= 0.708 x 0.60 x 2.74 x 1000
= 1160 kg
g)Mass of fine aggregate = Volume of all aggregate X volume of fine aggregate X Specific gravity of fine aggregate
X 1000
= 0.708 x 0.40 x 2.56 x 1000
=814.73 kg

9.Concrete Mix Proportions

- Cement = 400 kg/m^3
- Water = 160 kg/m^3
- Super plasticizer = 4 kg/m^3
- Fine aggregates = 820 kg/m^3
- Coarse aggregate = 1160 kg/m^3
- W/c = 0.40

IV. RESULTS AND ANALYSIS

4.2 Comparison of Mix A1 and Mix B1
As per the figure 5.14 and 5.15 the following are the observations on strength of concrete for indoor curing with
different dosages of PEG 6000.
The compressive strength is more for Mix A1 at 7 and 28 days when compared to Mix B1.
The compressive strength is more for Mix A1 at 2% of SCA and it is very low at same 0.5% of SCA for Mix B1 at
7 days.
The compressive strength is nearly same for 0% and 0.5% of SCA for Mix B1 at 7 days.
The compressive strength is nearly same for Mix B1 at 28 days for 0% and 0.5% of SCA.
The compressive strength is more for 2% of SCA for Mix A1 at 28 days of age. The compressive strength is more
for 1% of SCA for Mix B1 at 28 days of age.
The split tensile strength is more for Mix A21at 7 and 28 days when compared to Mix B1.
The split tensile strength is more for Mix A1 at 2% of SCA and it is very low at same 0.5% of SCA for Mix B1 at
7 days.
The split tensile strength is nearly same for 0% and 0.5% of SCA for Mix B1 at 7 days.
The split tensile strength is nearly same for Mix B1 at 28 days for 0% and 0.5% of SCA.
The split tensile strength is more for 2% of SCA for Mix A1 at 28 days of age. The split tensile strength is more for
1% of SCA for Mix B1 at 28 days of age.
The flexural strength is more for Mix A1at 7 and 28 days when compared to Mix B1.
The flexural strength is more for Mix A1at 2% of SCA and it is very low at same
0.5% of SCA for Mix B1 at 7 days.
The flexural strength is nearly same for 0% and 0.5% of SCA for Mix B1 at 7 days.
The flexural strength is nearly same for Mix B1 at 28 days for 0% and 0.5% of SCA. The split tensile strength is
more for 2% of SCA for Mix A at 28 days of age.

V. CONCLUSION

After the analysis of the result of the experimental programme the following conclusions were arrived for self-curing agent polyethylene glycol (PEG6000) and comparison of different aggregates are obtained.
1.1 Conclusions

- Due to the use of PEG600 The workability of concrete with low w/c ratio has significant effect due to higher molecular weight polyethylene glycol (PEG600).
- Water retention of the concrete with low w/c ratio in conjunction has significant effect due to addition of higher molecular weight polyethylene glycol(PEG600).
- The compressive strength of concrete with lower w/c ratio and with lower dosage of polyethylene glycol (PEG600) is beneficial.

- The use of higher molecular weight polyethylene glycol (PEG600) with higher w/c ratio is not beneficial.

a) Conclusions from comparative studies of different coarse aggregate

- Effectiveness of self-curing concrete is affected by w/c ratio and percentage dosages of self-curing agent.
- Water retention of concrete mixes incorporating self-curing agent is higher compared to conventional concrete mixes.
- The compressive strength of concrete with low w/c ratio has significant effect due to change in curing regime.
- The mix which shows lower weight loss need not give higher compressive strength.
- Water retention of concrete with lower w/c ratio incorporating higher molecular weight polyethylene glycol (PEG 600) with lower dosage is more beneficial.

b) Due to the use of Normal coarse aggregate

- Workability of concrete has increased due to PEG 600 when compared to conventional concrete.
- Water retention of the concrete with low w/c ratio in conjunction has significant effect due to addition of higher molecular weight polyethylene glycol (PEG600).
- Compressive strength increases from 0.5% to 2% the increases in strength at 2% is maximum then of conventional concrete in both the grades (M35, M45).
- Split tensile strength increased from 0.5% to 2% at 2% is greater then of conventional concrete in both the grades.
- Flexural strength increased from 0.5% to 2%. The increases in strength at 2% is maximum of conventional concrete in both the grades.

c) Due to the use of Recycled coarse aggregate

- Workability of concrete has increased due to PEG 6000 when compared to conventional concrete.
- Compressive strength increases from 0.5% to 1% and then decreases at 2% the increases in strength at 1% is maximum then of conventional concrete in both the grades (M35, M45).
- split tensile strength increased from 0.5% to 1% and then decrease at 2% the increase in strength at 1% is maximum greater then of conventional concrete in both the grades.
- Flexural strength increased from 0.5% to 1%. The increases in strength at 1% is maximum of conventional concrete in both the grades.
- The strength is more for normal coarse aggregate compared to recycled coarse aggregate.

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