International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Experimental Investigation of Self Curing Concrete with a Partial Replacement of Cement by Steel Slag

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ABSTRACT:

Today concrete is most widely used construction material due to its good compressive strength and durability. Depending upon the nature of work the cement, fine aggregate, coarse aggregate and water are mixed in specific proportions to produce plain concrete. Plain concrete needs congenial atmosphere by providing moisture for a minimum period of 28 days with water binder ratio of 0.50 for good hydration and to attain desired strength. The curing will badly affect the strength and durability of concrete. Self Curing Concrete is one the special concretes in mitigating insufficient curing due to human negligence paucity of water in arid areas, inaccessibility of structures in difficult terrains and in areas where the presence of fluorides in water will badly affect the characteristics of concrete. The present study involves the use of shrinkage reducing admixture polyethylene glycol (PEG-600) in concrete which helps in self curing and helps in better hydration and hence strength. In the present study, the affect of the admixture (PEG – 600) on compressive strength by varying the percentage of PEG by weight of water from 0%, 0.25%, 0.5, 1%, 1.5%, 2% were and it is also study by varying the percentage of STEEL SLAG by weight of cement from 0%, 5%, 10%, 15%, 20%, 25% were studied M20 mix. It was found that PEG - 600 could help in self curing by giving strength on par with conventional curing. It was found that 1.5%of PEG -600 for weight of water was optimum moisture content for M20 grade concrete with and without steel slag for achieving maximum strength without compromising workability. It is also found that by replacing up to 20% of cement with steel slag shows increase in strength of concrete and shows slight reduction in strength for 25% replacement. Based on the study carried out on mechanical properties of self-curing concrete mix with steel slag as a partial replacement of cement at various percentage replacements of cement and the optimum dosage of PEG 600 of maximum compressive strength is to find for M20 grades of concrete with steel slag and without steel slag and also finding the Strength properties of self-curing concrete and compare with conventional concrete.

Keywords: Cement, Fine aggregate, Coarse aggregate, Polyethylene Glycol (PEG-600) and Steel Slag

Introduction :

Concrete is a composite material composed of fine aggregate, coarse aggregate in which cement is used as the binder, also water is a key ingredient which produces paste when mixed with cement. Curing of concrete is very important. Curing is the process of maintaining of satisfactory moisture content and temperature in concrete during its early stages so that desired properties (of concrete) may developed. Curing is essential in the production of concrete that will have the desired properties. The strength and durability of concrete will be fully developed only if it is cured. No action to this end is required, however, when ambient conditions of moisture, humidity and temperature are sufficiently favorable to curing. Proper curing is necessary to achieve desired strength and performance of concrete. In conventional concrete curing is done by after various stages like mixing, placing and finishing. Self-Curing is a technique which is used to retain proper moisture contents in concrete for better hydration for a long time. Self-Curing agent works to reduce self desiccation contents present in the concrete. So some of shrinkage reducing agents are used to avoid and the concrete cures itself. Steel slag is an industrial by product from the steel manufacturing industry. This can be used as cement in concrete. Steel slag is the residue of steel making industry; the emission amount is about 12 to 20 percent of rough steel production. However, steel slag has not been used efficiently and thoroughly for long, which causes its great accumulation, waste of land, and serious air and water pollution. Steel slag has certain amount of important minerals of cement clinker, such as C2S and C3S.So it can be used as cement and concrete admixtures. India's steel output ranks No2 in the world, but the comprehensive utilization rate of steel slag and slag is only 10 percent at present. With Iron and steel production amounting to 8 million tons in 2009, is an important iron and steel base of India. If the steel slag occupies 15 percent of steel production (quality percentage) then the emission amount is 1.2 million tons. So, if cement can be replaced by steel slag and not only can the activity of slag be fully simulated but also the durability of concrete can be improved.

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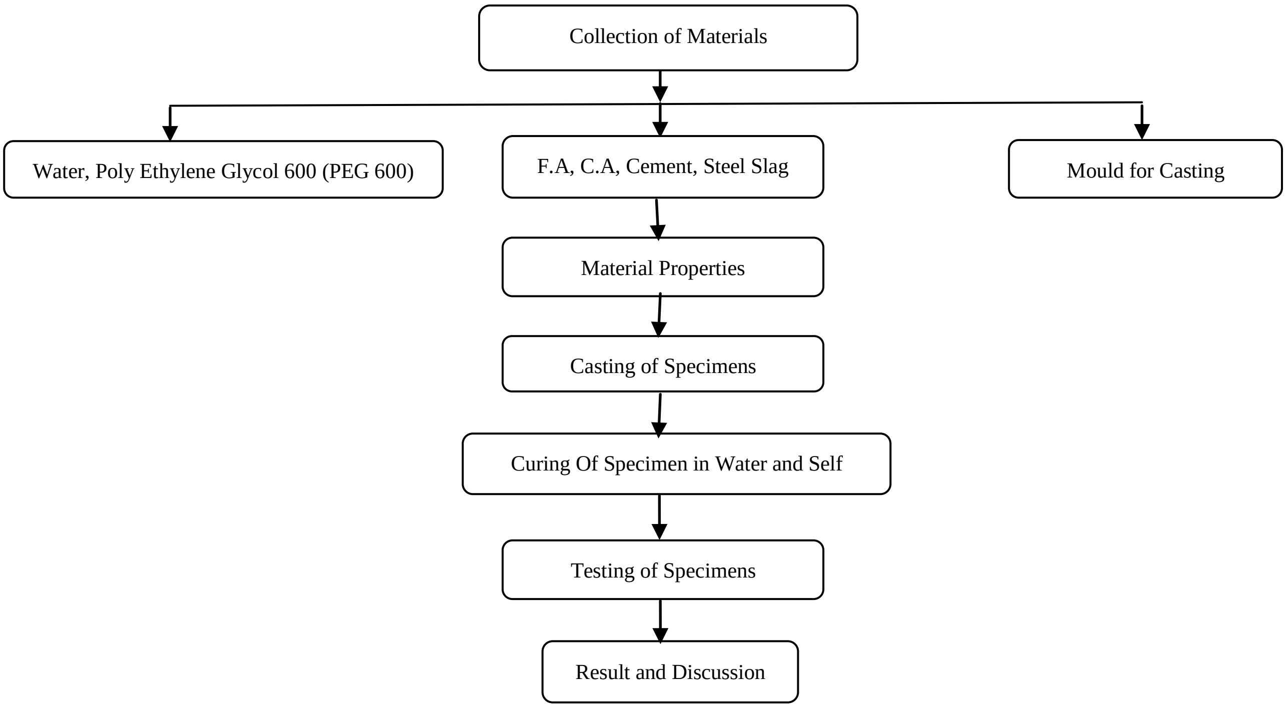
Nomenclature

- PEG 600- Polyethylene glycol 600
- SS - Steel slag
- SSC -Steel slag concrete
- SCC - Self curing concrete

Methodology :



Cement:

Lot of factors impact on the strength of concrete, but strength of cement is the most important and direct factor. The experiment uses the quality guaranteed local factor. The use of 43 grade PPC (Portland Pozzolana Cement) is preferred as it was seen from the past records of cements available in market. Among the chemical constituents of cement the most important are C_3A, C_2S and C_3S.

Chemical Composition of Cement in our Project

- Cement type - PPC (Portland Pozzolana Cement)
- Specific gravity - 3.14
- Fineness modulus - 2%
- Initial setting - 25 minutes
- Final setting - 590 minutes
- Grade of cement - 43 grades
- Name of the company - Sankar
- Quantity - 4 bags each 50 kg (200 kg)
- Collected from - Angalamman Agency Veerapandipirivu, Coimbatore

Fine Aggregate

Sand is the naturally occurring granular material composed of finely divided rocks and mineral particles. The composition of sand is highly variable, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non - tropical coastal settings in silica (silicon dioxide or Sio2),usually in the form of quartz. Locally available natural sand with size less than 4.75 mm is used as fine aggregate. In our project

Nature of sand - Normal river sand

Specific Gravity - 2.61
Fineness Modulus - 3.35
Quantity - 215kg
Collected from - Coimbatore

Coarse Aggregate

Coarse aggregate is one of the components of a composite concrete. The coarse aggregate serves as reinforcement to add strength to the overall composite material. Aggregates are also used as base material under foundations, roads, and railroads. In other words, aggregates are used as a stable foundation or road/rail base with predictable, uniform properties**.** The size of coarse aggregates varies from 80mm to 4.75mm. In our project

Size of Coarse aggregate - 20mm
Specific Gravity - 2.63
Fineness Modulus - 6.45
Quantity - 495kg
Collected from - Coimbatore

Polyethylene Glycol - 600

PEG is also known as polyethylene oxide (PEO) or polyoxy ethylene (POE), depending on its starting material and/or molecular weight PEG, PEO, or POE refers to an oligomer or polymer of ethylene oxide. The three names are structurally synonymous, but historically PEG has tended to refer to oligomers and polymers with a molecular mass below 20,000 g/mol. PEG is a crystalline, thermoplastic, water soluble polymers that is commercially available in a wide range of molecular weights depending on the number monomers. Polyethylene glycol 600 which is a shrinkage reducing agent is added along with the water that is to be mixed with to make concrete. Now PEG 600 forms hydrogen bond with water molecules and increases surface tension and does not allow water to evaporate outside thus reduces shrinkage and maintains moisture content inside and cures the concrete. Thus it becomes a self-curing agent. In our project chemical reaction of PEG

Type of admixture - PEG (polyethylene glycol) - 600
Molecular weight - 600
Melting point - 20˚c
Density (20˚c) - 1.120 g
Refractive index - 1.469
Quantity - 500ml (1 bottle)
Collected from - Hindustan Scientific Suppliers, 101, Karunanithi Road, Rathinapuri Coimbatore.

Steel Slag

Steel slag used in the test was produced by the steel plant industries, it has been stored for more than two years, and its apparent density is 2395 kg/m$_{3,}$ fineness modulus is 2.08.

Physical Properties of Steel Slag

Steel slag aggregate are highly angular in shape and have rough surface texture. They have bulk specific gravity and moderate water absorption.

Table 1 – Physical Properties of Steel Slag

Property	**Value**
Specific gravity	3.2-3.6
Unit weight kg/m^3	1600-1920
Absorption	Up to 3%

Chemical Properties of Steel Slag

The chemical composition of slag is usually expressed in terms oxides calculated from element analysis determined by x-ray fluorescence. Table lists the range of compounds present in steel slag from a typical base oxygen furnace. Virtually all steel slag fall within these chemical ranges but not all steel slag are suitable as aggregates of more importance is the mineralogical form of the slag, which is highly dependents on the rate of slag cooling in the steelmaking process. In our project

Type of slag - Steel slag
Specific Gravity - 3.84
Fineness Modulus - 3.12
Collected from - Agni Steels Private Limited Ingur (village) Perundurai (Taluk) Erode.

Water

Ordinary portable water is to be used. The mixing quality is required in accordance with the quality standards of range is pH >4 clean water. Portable water was used in the experimental work for both mixing and curing purposes. Portable tap water available in laboratory with pH value of 7.2. In our project

Type of water - Portable water
pH value - 7.2
Collected from - College Campus, Coimbatore

Properties of Material Used

Specific gravity of cement, g = 3.14
Initial setting time of cement = 25 minutes.
Final setting time of cement = 590 minutes.
The fineness modulus of the cement is 2%
Fineness modulus = 3.353 % (Which conforms zone III according to table of IS 383:1970)
Specific gravity of fine aggregate, g = 2.61
Fineness modulus of coarse aggregate = 6.45
Specific gravity of coarse aggregate, g = 2.63
Specific gravity of steel slag, g = 3.84
Fineness modulus of steel slag = 3.12

Properties of Concrete

There are two main categories in which the properties of concrete they are as follows

- Properties of fresh concrete
- Properties of hardened concrete

Properties of Fresh Concrete

Compaction Factor Test

Compacting factor of fresh concrete is done to determine the workability of fresh concrete by compacting factor test as per IS: 1199 – 1959. The apparatus used is Compacting factor apparatus

Table 2 - Compaction Factor Test.

Sl. No	% of peg 400	% of steel slag	Partially compacted	Fully compacted	Compaction factor
1	0	0	18.65	20.6	0.905
2	0.25	5	18.8	20.65	0.910
3	0.5	10	18.95	20.6	0.919
4	1	15	19.15	20.7	0.925
5	1.5	20	19.20	20.6	0.932
6	2	25	19.25	20.4	0.943
The compaction factor of the given sample of concrete					0.922

Slump Cone Test

Weight of cement = 2 kg
Weight of fine aggregate = 3 kg
Weight of coarse aggregate = 6 kg
Height of slump cone = 300 mm
Given grade of concrete = M_{20}
Amount of water = 0.5 × 2 = 1000 ml
Mix design ratio = 1: 1.5: 3

Height of the slump, h_1 = 300mm
After removing the cone, h_2 = 270 mm
True slump value = h_1- h_2
= 300 - 270
= 30 mm
The slump value of the concrete is= 30mm
Hence it is True slump

Properties of Hardened Concrete

The property of concrete that is studied after curing the concrete is the properties of hardened concrete. This is also called as mechanical properties of concrete. There are certain tests done to study the Properties of hardened concrete they are as follows

- Compressive strength of concrete
- Splitting tensile strength of concrete
- Flexural strength of concrete

Compressive Strength of Concrete

The main aim is to determine the compressive strength of SCC specimens, cubical in shape (150mm ×150mm×150mm). Compression test is done at 7 and 28 days age of test specimens. Specimens that are taken from water are brought to dry state and is tested, whereas NC, SCC, SSC and SSSCC is tested at corresponding test date as such. In compression test machine in such a manner that the load is applied to opposite sides of the cubes and cast. The axis of the specimen is carefully aligned with the centre of thrust of the spherically seated plate. The spherically seated block is brought to bear on the specimen and the load is applied without shock and continuously at a rate approximately 140 $kg/cm^2/min$ until failure of the specimen. The maximum load applied to the specimen until failure is recorded. Then based on the load value the compression strength of the concrete specimen is calculated as follows.

Compressive strength = (Ultimate load) / (Contact area of the cube) = P / A in N / mm^2

Fig. 1 - Compression Test of Concrete

Mix Proportion and Experimental Results

Table 3 - By Volume (m^3) Batching.

Water	Cement	Fine Aggregate	Coarse Aggregate
0.191	0.266	0.363	0.846
0.71	1	1.36	3.18

Mix proportion for trial

Cement = 383.16 kg/m^3
Fine aggregate = 572.27 kg/m^3
Coarse aggregate = 1185 kg/m^3
Water = 191.58 lit/m^3
As per IS 10262:2009 for M_{20} we get 1:1.49:3.09 with water cement ratio 0.50

Table 4 - Mix Proportion of SCC without Steel Slag

Mix	Water (litre/m^3)	Cement (Kg/m^3)	F.A (Kg/m^3)	C.A (Kg/m^3)	% of Peg-600 (ml)	PEG-600 (litre/m^3)
NC	191.60	383.16	572.27	1185	0% (0)	0
SCC 1	191.12	383.16	572.27	1185	0.25% (6.25)	0.479
SCC 2	190.16	383.16	572.27	1185	0.5% (12.5)	0.955
SCC 3	188.25	383.16	572.27	1185	1% (18.75)	1.901
SCC 4	185.42	383.16	572.27	1185	1.5% (25)	2.823

SCC 5	181.71	383.16	572.27	1185	2% (31.25)	3.708

Table 5 - Mix Proportion of SCC With Steel Slag

Mix	Water (litre/m^3)	Cement (Kg/m^3)	F.A (Kg/m^3)	C.A (Kg/m^3)	% of Steel Slag (g)	Steel Slag (kg/m^3)
NC	191.60	383.16	572.27	1185	0 (0)	0
SSC1	191.60	364.00	572.27	1185	5 (250)	19.16
SSC2	191.60	327.59	572.27	1185	10 (500)	36.41
SSC3	191.60	278.45	572.27	1185	15 (750)	49.14
SSC4	191.60	222.76	572.27	1185	20 (1000)	55.69
SSC5	191.60	167.06	572.27	1185	25 (1250)	55.70

Table 6 - Mix Proportion of SSC without Peg - 600

Mix	Water (litre/m^3)	Cement (Kg/m^3)	F.A (Kg/m^3)	C.A (Kg/m^3)	% of Peg-600 (ml)	PEG-600 (litre/m^3)	% of Steel Slag (g)	Steel Slag (kg/m^3)
NC	191.6	383.16	572.27	1185	0% (0)	0	0 (0)	0
SCC1	191.12	364.00	572.27	1185	0.25% (6.25)	0.479	5 (250)	19.16
SCC2	190.16	327.59	572.27	1185	0.5% (12.5)	0.955	10 (500)	36.41
SCC3	188.25	278.45	572.27	1185	1% (18.75)	1.901	15 (750)	49.14
SCC4	185.42	222.76	572.27	1185	1.5% (25)	2.823	20 (1000)	55.69
SCC5	181.71	167.06	572.27	1185	2% (31.25)	3.708	25(1250)	55.70

Table 7 - Compressive Strength of SCC without SS

Sl. No.	Property	Load (Kn)	Result (N/mm^2)	Avg. (N/mm^2)
1	Normal concrete 7days	310	13.7	13.2
		290	12.8	
		300	13.3	
2	Normal concrete 28 days	450	20	19.6
		410	18.2	
		420	20.8	
3	SCC PEG-0.25% 7 days	320	14.2	14.6
		340	15.1	
		330	14.6	
4	SCC PEG-0.25% 28 days	460	20.4	20.4
		480	21.3	
		440	19.5	
5	SCC PEG-0.5% 7 days	330	14.6	15.2
		360	16	
		340	15.1	
6	SCC PEG-0.5% 28 days	490	21.7	21.5
		500	22.2	
		470	20.8	
7	SCC PEG-1% 7 days	370	16.4	16.5
		390	17.3	
		360	16	
8	SCC PEG-1% 28 days	530	23.5	22.4
		500	22.2	
		490	21.7	
9	SCC PEG-1.5% 7 days	390	17.3	17.8
		420	18.6	
		400	17.7	
10	SCC PEG-1.5% 28 days	500	22.2	23.1
		540	24	
		520	23.1	
11	SCC PEG-2% 7 days	320	14.2	13.3
		300	13.3	
		310	13.7	
12	SCC PEG-2% 28 days	440	19.5	18.7
		400	17.7	
		430	19.1	

Table 8 - Compressive Strength of SSC without Peg-600

Sl. No.	Property	Load (Kn)	Result (N/mm^2)	Avg. (N/mm^2)
1	Normal concrete 7days	310	13.7	13.2
		290	12.8	
		300	13.3	
2	Normal concrete 28 days	450	20	19.6
		410	18.2	
		470	20.8	
3	SSC SS-5% 7 days	330	14.6	14.7
		350	15.5	
		320	14.2	
4	SSC SS-5% 28 days	460	20.4	20.5
		440	19.5	
		490	21.7	
5	SSC SS-10% 7 days	370	16.4	15.6
		350	16.5	
		340	15.1	
6	SSC SS-10%	480	21.3	21.8
		510	22.6	

	28 days	490	21.7	
7	SSC SS-15% 7 days	380 400 370	16.8 17.7 16.4	16.9
8	SSC SS-15% 28 days	500 530 510	22.2 23.5 22.6	22.7
9	SSC SS-20% 7 days	380 420 400	16.8 18.6 17.7	17.7
10	SSC SS-20% 28 days	540 530 510	24 23.5 22.6	23.3
11	SSC SS-25% 7 days	290 300 280	12.8 13.3 12.4	12.8
12	SSC SS-25% 28 days	440 420 460	19.5 18.6 20.4	19.5

Table 9 - Compressive Strength of SCC with SS

Sl. No.	Property	Load (Kn)	Result (N/mm^2)	Avg. (N/mm^2)
1	Normal concrete 7days	310 290 300	13.7 12.8 13.3	13.2
2	Normal concrete 28 days	450 410 470	20 18.2 20.8	19.6
3	SCC PEG-0.25% SS-5% (7 days)	300 330 310	13.3 14.6 13.7	13.8
4	SCC PEG-0.25% SS-5% (28 days)	480 430 460	21.3 19.1 20.4	20.2
5	SCC PEG-0.5% SS-10% (7 days)	370 340 320	16.4 15.1 14.2	15.2
6	SCC PEG-0.5% SS-10% (28 days)	500 470 480	22.2 20.8 21.3	21.4
7	SCC PEG-1% SS-15% (7 days)	350 370 390	15.5 16.4 17.3	16.4
8	SCC PEG-1% SS-15% (28 days)	510 530 490	22.6 23.5 21.7	22.6
9	SCC PEG-1.5% SS-20% (7 days)	390 400 380	17.3 17.7 16.8	17.2
10	SCC PEG-1.5% SS-20% (28 days)	530 510 540	23.5 22.6 24	23.3
11	SCC PEG-2% SS-25% (7 days)	290 300 310	12.8 13.3 13.7	13.3
12	SCC PEG-2% SS-25% (28 days)	440 410 430	19.5 18.2 19.1	18.9

Table 9 - Mean Compressive Strength of SCC without Steel Slag

Mix	PEG- 600	7 days (N/mm^2)	28 days (N/mm^2)
NC	0%	13.2	19.6
SCC1	0.25%	14.6	20.4
SCC2	0.5%	15.2	21.5
SCC3	1%	16.5	22.4
SCC4	1.5%	17.8	23.1
SCC5	2%	13.3	18.7

Table 10 - Mean Compressive Strength of SSC without PEG - 600

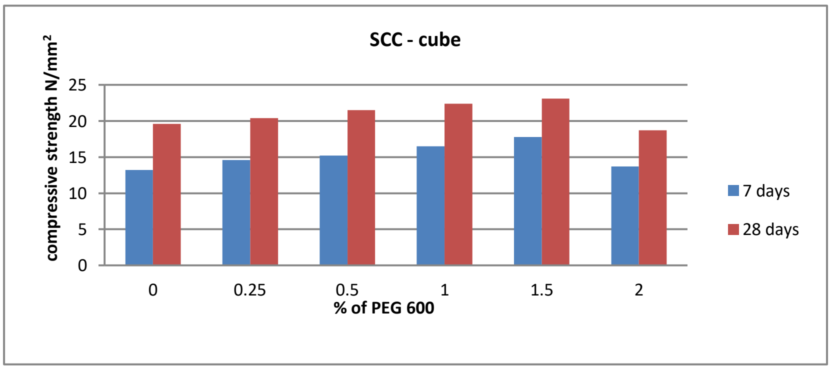
Mix	Steel Slag	7 days (N/mm^2)	28 days (N/mm^2)
NC	0%	13.2	19.6
SSC1	5%	14.7	20.5
SSC2	10%	15.6	21.8
SSC3	15%	16.9	22.7
SSC4	20%	17.7	23.3
SSC5	25%	12.8	19.5

Table 10 - Mean Compressive Strength of SCC with Steel Slag

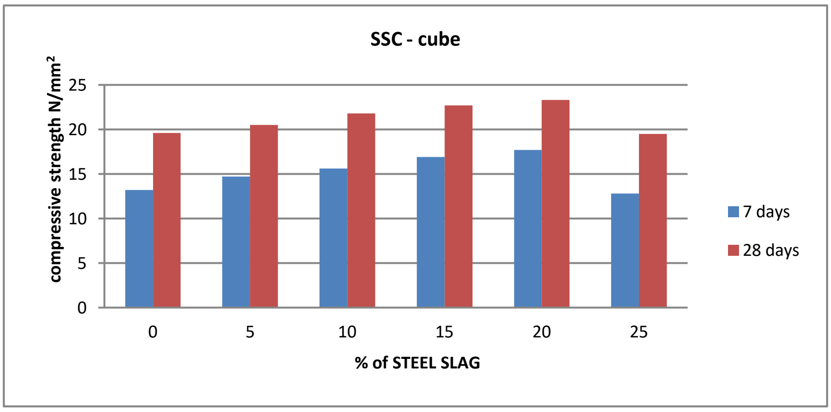
Mix	PEG- 600	Steel Slag	7 days (N/mm^2)	28 days (N/mm^2)
NC	0%	0%	13.2	19.6
SSC1	0.25%	5%	13.8	20.2
SSC2	0.5%	10%	15.2	21.4
SSC3	1%	15%	16.4	22.6
SSC4	1.5%	20%	17.2	23.3
SSC5	2%	25%	13.3	18.9

Results and Discussions

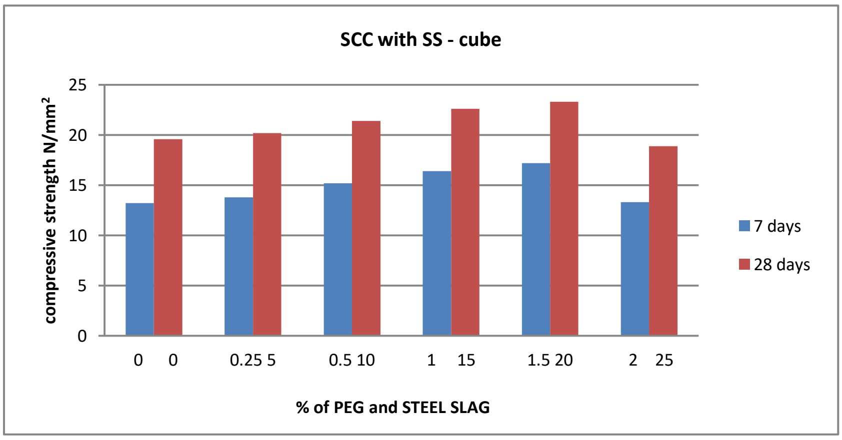
The compressive strength of controlled concrete at the age of 28 days is 19.5 N/mm^2. For varying dosage of PEG 600 say 0.25%, 0.5%, 1%, 1.5%, 2% of weight of water we get increase in strength of about 1.5% respectively when steel slag is not use. When steel slag is concrete strength related properties by replacing cement with steel slag by 5%, 10%, 15%, 20%, 25%.we get increase in strength of 20% respectively when compared to controlled concrete. It is represented graphically as follows.



Graph. 1 - Comparison of Compressive Strength of SCC without Steel Slag In N/mm^2



Graph. 2 - Comparison of Compressive Strength of SSC without PEG - 600 in N/mm^2



Graph. 6 - Comparison of Compressive Strength of SCC with Steel Slag in N/mm^2

Conclusion

Based on the experimental investigation carried out on mechanical properties of self-curing concrete mix with steel slag as a partial replacement of cement at various percentage replacements of cement. The following conclusions are made. The optimum dosage of PEG 600 of maximum strengths compressive was found to be 1.5% for M_{20} grades of concrete. Strength of self-curing concrete is on par with conventional concrete. Self-curing concrete is the answer to many problems faced due to lack of proper curing. Steel slag in cement manufacturing improves clinker production and reduces co_2 content in the steel slag excellent bonding capacity with Portland cement. Concrete with good strength can be produced using steel slag as a supplementary cementious material in concrete. The addition of steel slag results in a more cohesive concrete which results in a good concrete which is less prone to segregation. The compressive strength obtained at 1.5% of PEG 600 without steel slag is 23.1 N/mm^2 and with steel slag is 23.3 N/mm^2 of controlled concrete. The mechanical properties of concrete mixes up to 20% powdered steel slag as a replacement of cement shows better result. The mechanical properties of concrete mixes with 25% powdered steel slag as a partial replacement of cement, gradually reduces compared to that of control concrete. Experimental result show that the mechanical property of concrete attains peak value for cement replacement with 20% powdered steel slag. The cost of concrete gets reduced for the replacement of cement with steel slag. When compared with Normal concrete, Selfcuring concrete, Steelslag concrete, and steel slag self-curing concrete gives high strength

Scope of Future Study

There are many scopes for future study in this experimental study. In this paper we have studied only about the mechanical properties of SCC (self-curing concrete) and SSC (steel slag concrete). We can also study the following properties as follows:

- Splitting tensile strength
- Flexural strength
- Sulphate resistant properties
- Durability properties
- Fire resistant properties

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