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EXPERIMENTAL STUDIES ON PERFORMANCE OF SELF COMPACTING CONCRETE (M30) DESIGNED BY PACKING DENSITY CONCEPT WITH POLYSTYRENE AS PLASTIC AGGREGATE

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ABSTRACT

The usage of plastic has become in evitable in present world. The consumption of plastic in packaging, automotive and industrial applications has been increased extensively. Out of various types of plastics used, polystyrene a light weight classified plastic type which has high heat retaining tendency is been used for the present study. The use of Self Compacting Concrete (SCC) which is capable of flowing in form work and congested reinforcement without any mechanical vibrator fills the concrete voids with its high paste content is highly durable and economical. It is believed that this kind of property is attained by achieving high packing density among the constituents of concrete with satisfactory workable properties and such mix design is been followed. A comparative experimental studies on the arrived M30 grade SCC is carried out with replacement of coarse aggregate with polystyrene plastic wastes varying from 0% to 50% to determine optimum replacement. Fresh properties of SCC reveal the enhancement of workability satisfying permissible limits. An optimum replacement upto 30% coarse aggregate with plastics aggregates is suggested without any significant variation in compressive strength. Durability properties such as water absorption, sulphate resistance are improved under plastic replaced concrete at all levels.

KEYWORDS: Self Compacting Concrete, Packing density, Plastic aggregate, M30 grade concrete, Mechanical properties, Durability.

INTRODUCTION

GENERAL

Self-compacting concrete (SCC) is a concrete, which flows and compacts only under gravity. It fills the mould completely without any defects. Usually self-compacting concretes have compressive strengths in the range of 60-100 N/mm^2. However, lower grades can also be obtained and used depending on the requirement. SCC was originally developed at the University of Tokyo in Japan with the help of leading concrete contractors during 1980's to be mainly used for highly congested reinforced structures in seismic regions. As durability of concrete structures was an important issue in Japan, an adequate compaction by skilled labours was required to obtain durable concrete structures. This requirement led to the development of SCC. The development of SCC was first reported in 1989.

SCC is a new kind of High Performance Concrete (HPC) which has an excellent deformability and segregation resistance. By name it can be defined as a concrete, which can flow through and fill the gaps of reinforcement and corners of the moulds without any need for external vibration. SCC compacts itself due to its self weight and de-aerates almost completely while flowing in the formwork. SCC can also be used in situations where it is difficult or impossible to use mechanical compaction for fresh concrete, such as underwater concreting, cast in-situ pile foundations, machine bases and columns or walls with congested reinforcement. The high flowability of SCC makes it possible to fill the formwork without vibration. Since its inception, it has been widely used in large construction works or projects in Japan. Recently, this concrete has gained wide use for different applications and structural configurations across the world.

High strength concrete can be produced with normal concrete. But these concrete cannot flow freely by them, to pack every corner of moulds and all gaps of reinforcement. High strength concrete based elements require thorough compaction and vibration in the construction process. SCC has more favourable characteristics such as high fluidity, Segregation resistance and distinctive self-compacting ability without any need for external or internal vibration during the placing process. It can be compacted into every corner of formwork purely by means of its own weight without any segregation. Hence, it reduces the risk of honey combing of concrete.

Development of SCC is a very desirable achievement in the construction industry for overcoming the problems associated with cast-in place concrete. It is not affected by the skill of workers, shape and amount of reinforcing bar arrangement of a structure. Due to its high fluidity and resisting power to segregation, it can be pumped over longer distances. It extends the possibility of use of various by products in its manufacturing.
The use of SCC not only shortens the construction period but also ensures quality and durability of concrete. It replaces manual compaction of fresh concrete with a modern semi-automatic placing technology. Some of the advantages of Self Compacting Concrete are as follows:

1. Safe working environment.
2. Speed of placement, resulting in increased production efficiency.
3. Ease of placement, requiring fewer workers for a particular pour.
4. Better assurances of adequate uniform consolidation.
5. Reduced wear and tear on forms from vibrator.
6. Reduced wear on mixers due to reduced shearing action.
7. Improved surface quality and fewer bug holes, requiring fewer patching.
8. Improved durability.
9. Increased bond strength.
10. Reduced energy consumption from vibration equipment.

The functional requirements of a fresh SCC are different from those of a vibrated fresh Normal Concrete (NC). Filling of formwork with a liquid suspension requires workability performance like filling ability, passing ability and resistance against segregation.

MATERIALS

GENERAL

This chapter portrays the information regarding the materials such as cement, fine aggregate, coarse aggregate, admixture, plasticizer and water used for making Self Compacting Concrete (SCC) and also about the a simple and systematic mixture design procedure for SCC, the various workability tests conducted for SCC mix, the details about the size and number of specimens to be cast are presented elaborately.

MATERIAL INVESTIGATION

Cement

Cement is binding material which is used for making any type of concrete. Among the various types of cement available in the market, Ordinary Portland Cement of 53 grade confirming to IS 269-1976, whose compressive strength at the end of 28th day is 45N/mm2 when tested as per IS 4031-1988, from Penna Company is used in the project work.

Fineness of Cement:

Fineness of cement is that property of cement which indicates the particle size distribution and specific surface of cement. It has greater effects on hydration rate and thus the setting time, and the rate of strength gain. Finer the cement, faster is the strength developed. Fineness of cement is determined by sieve test by sieving it through a standard sieve 90 µm IS Sieve. The proportion of cement, whose grain size is larger than the specified mesh size, is thus determined. After sieving the residue left over the sieve should be less than 10%.

Consistency:

The normal consistency of cement paste is defined as consistency, which will permit the Vicat's plunger to penetrate to a point 5-7 mm from the bottom of the mould. This test is done to determine the quantity of water required to produce a cement paste of standard consistency for determining the setting times, compressive strength and soundness of cement. Consistency depends upon the composition of cement. The test was conducted as per the procedure given in IS 4031:1988.

Initial and Final setting time:
Initial setting time:
The stiffening of cement paste is called setting. The time elapsed between the moment water is added to the cement and the time when the paste starts losing its plasticity. The needle fails to pierce the block 5±0.5mm measured from the bottom of the mould shall be the initial setting time. Experiment is conducted using Vicat's apparatus as per the procedure given in IS 4031:1988. The initial setting time is noted when Vicat needle penetrates through a depth of 33 to 35 mm from the top.

Final setting time:
The time elapsed between the moment when water is added to the cement and the paste has completely lost its plasticity and attained sufficient firmness. The time at which the needle fails to make any impression on the surface is the final setting time. This is also determined by using Vicat's apparatus and as per procedure given in 4031:1988.

Specific Gravity of Cement:
The specific gravity is defined as the ratio of mass (or weight in air) of a unit volume of material to the mass of the same volume of water at the stated temperature. The experiment is conducted as per IS code. Kerosene is used instead of water in order not to react with cement.

Compressive Strength of Cement:
Strength tests on cement are conducted using cement-sand mortar in specific proportions with specified material under strictly controlled conditions at 27±2^{0}C. The test is conducted as per IS: 4031:1988. Specimens of size 70.8mm x 70.8mm x 70.8mm were casted using cement and sand in the ratio 1:3 and the quantity of water required for mixing was obtained from the relation (P/4+3)% of the combined weight of cement and sand. Where, P= standard consistency. After proper mixing mortar is placed in the mould and vibrated at 12000±400 rpm and then the specimen is kept under moist condition for 24hrs. After that, the specimen is marked and kept in water till the time of testing.

Physical properties of Cement (OPC 53 grade)

Sl.no	Property	Value
1	Standard Consistency	31%
2	Initial setting time	137 min
3	Final setting time	303 min
4	Specific gravity	3.11
5	Ultimate compressive strength at 28th day	45 N/sq.mm
6	Fineness (by sieving)	2.56%

Fine Aggregate
Good quality river sand free from silt and other impurities passing through 4.75 mm sieve is used in this study.

Specific Gravity:
Specific gravity is defined as the ratio of mass of material (in air) to the mass of the same volume of material in water at the stated temperature. The experiment was conducted using pycnometer as per IS 2386:1963. Specific gravity of aggregates is routinely used in the mix design of concrete.

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Bulk Density:
Bulk density is defined as the weight of a unit volume of material or simply weight per unit volume. It is expressed in kg/m^3. The experiment was conducted as per IS 2386:1963.

Fineness Modulus:
Fineness modulus is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the sum by 100. It is an index of coarseness or fineness of the material. Larger the fineness modulus, coarser is the material.

Physical properties of Fine aggregate

Description	Fine Aggregate
Specific gravity	2.7
Water absorption (%)	1.05
Bulk density(g/cm^3)	1.560
Fineness modulus	2.99
Zone	I

Coarse aggregate
Coarse aggregate is crushed granite stone obtained from locally available crushers, passing through 20 mm and retaining on 16 mm and passing through 12.5mm and retaining on 10 mm sieves are used for experimental work. The physical properties of coarse aggregate are tabulated as below.

Fineness Modulus:
Fineness modulus is an empirical figure obtained by adding the total percentage of the sample of an aggregate retained on each of a specified series of sieves, and dividing the sum by 100. It is an index of coarseness or fineness of the material. Larger the fineness modulus, coarser is the material.

Specific Gravity:
Specific gravity is defined as the ratio of mass of material (in air) to the mass of the same volume of material in water at the stated temperature. The experiment was conducted using pycnometer as per IS 2386:1963. Specific gravity of aggregates is routinely used in the mix design of concrete.

Bulk Density:
Bulk density is defined as the weight of a unit volume of material or simply weight per unit volume. It is expressed in kg/m3. The experiment was conducted as per IS 2386:1963.

Table 3.3 Physical properties of Coarse aggregate

Description	Coarse aggregate
Specific gravity	2.78
Water absorption (%)	0.6
Loose Bulk density(g/cm^3)	1.38
Rodded Bulk density (g/cm^3) dedensity(g/cm^3)	1.43
Impact value (%)	22.54

Fineness modulus	7.17

Plastic Aggregate

The polystyrene waste material collected from Lotus plastic Pvt.Ltd. Mettupalayam Puducherry. After the collection of the material it was cut into pieces by grinding machine of sizes 10 mm to 20 mm. The physical properties of plastic aggregates are given as below.

Physical Properties of Plastic Aggregate

Description	**Plastic Aggregate**
Specific gravity	1.08
Water absorption (%)	0.4
Loose Bulk density(g/cm^3)	0.583
Rodded Bulk density(g/cm^3)	0.616
Impact value (%)	4.4
Crushing value (%)	4.94
Fineness modulus	6.86

Manufacturing stages

1. Collection of waste
2. Thermal processing
3. Formation of lumps
4. Grinding material
5. Sieve the material to required size

MIX DESIGN

mix design for scc using a simple and systematic mixture design procedure for self-compacting concrete proposed by Prakash Nanthgopalan and Manu Santhanam, Department of Civil Engineering, IIT Madras, India using a packing density concept was followed. For the concrete constituents the following mix proportion was arrived for M30 grade.

S.No	**Materials**	**Quantity**
1	Cement	353.03kg/m^3
2	Flyash	155.6kg/m^3
3	Fine aggregate	627.92kg/m^3
4	Coarse aggregate-20mm	484.89kg/m^3

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5	Coarse aggregate-12.5mm	$479.66kg/m^3$
6	Water	$208.78lit/m^3$
7	Super Plasticizer	$1.017lit/m^3$

RESULTS AND DISCUSSIONS

GENERAL

The results of fresh properties of SCC such as Slump flow ,V-funnel, J-ring and Strength characteristics of specimens such as Compressive strength, Split tensile strength, Flexural strength, and durability properties such as water absorption and Sulphate resistance, are reported. The salient observations on the parameters are presented with necessary discussions on them.

FRESH PROPERTIES

The effect of plastic aggregate on the slump flow, V-funnel and J-ring are studied. It shows an increasing trend in slump flow as replacement of plastic aggregate increases. This could be explained by hydrophobic nature of plastic aggregate and the lower internal friction resulting from the replacement of coarse aggregates by plastic aggregate. V-funnel increases as plastic aggregate percentage increases. However the results obtained satisfies the EFNARC criteria.

The results of the fresh properties are tabulated and its variation is shown into figure for M30 grade of concrete at various percentage replacements of plastic aggregate.

Workability Properties

Sl.No	Mix Id	Slump flow (mm)	V-funnel (sec)	J-ring Flow(mm)	J-ring Blockage(mm)
1	RSCC	617	7	605	5.5
2	P10SCC	630	7	615	6
3	P20SCC	635	8	610	6.5
4	P30SCC	651	9	611	7.5
5	P40SCC	655	12	622	8
6	P50SCC	661	15	625	8.5

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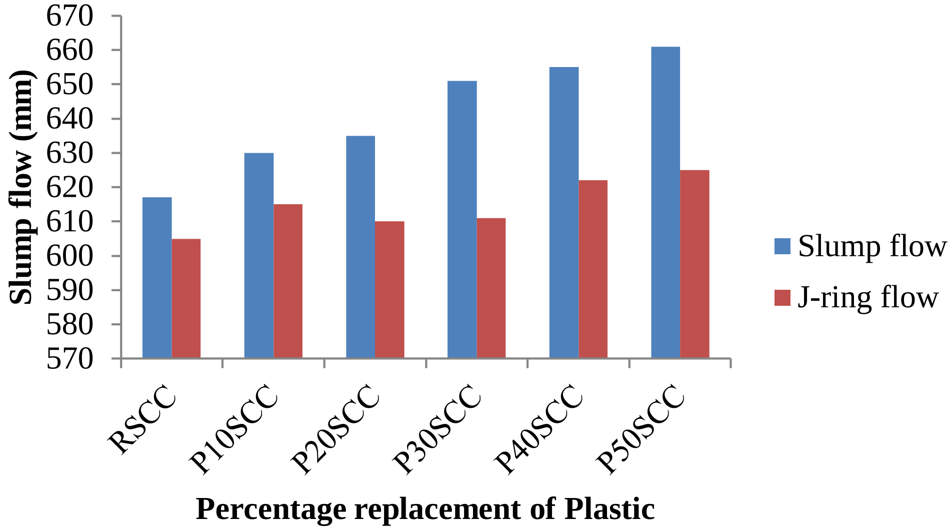
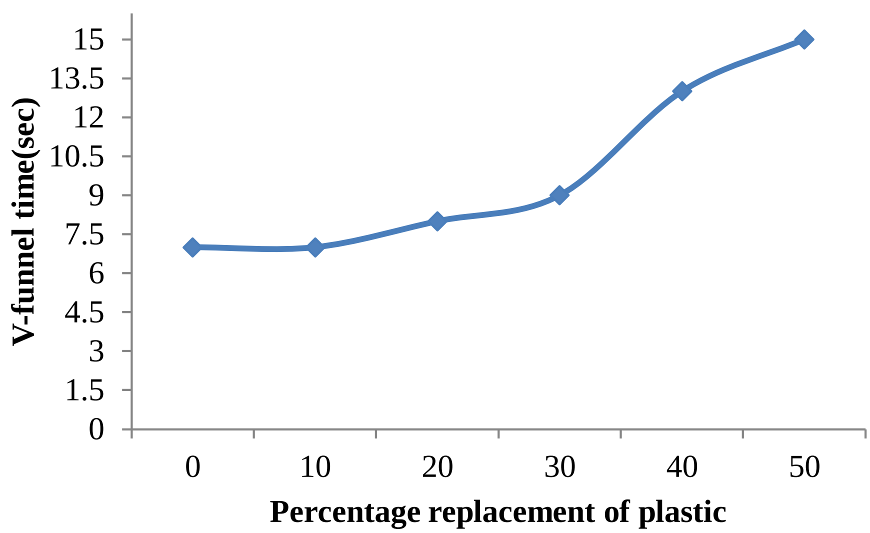


Variation of Plastic aggregate on Slump flow

Slump flow appearance



Variation of plastic aggregate on V-funnel

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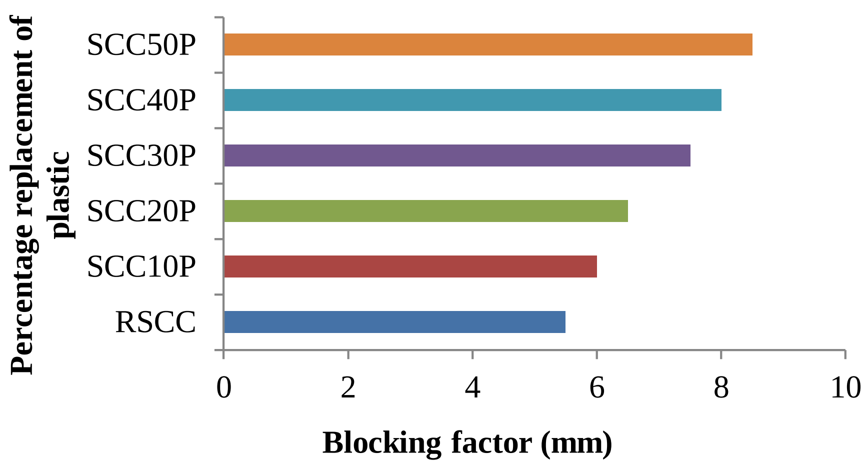
Appearance of V-funnel



Graph showing
Variation of plastic aggregate on J-ring blockage

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Appearance of J-ring flow

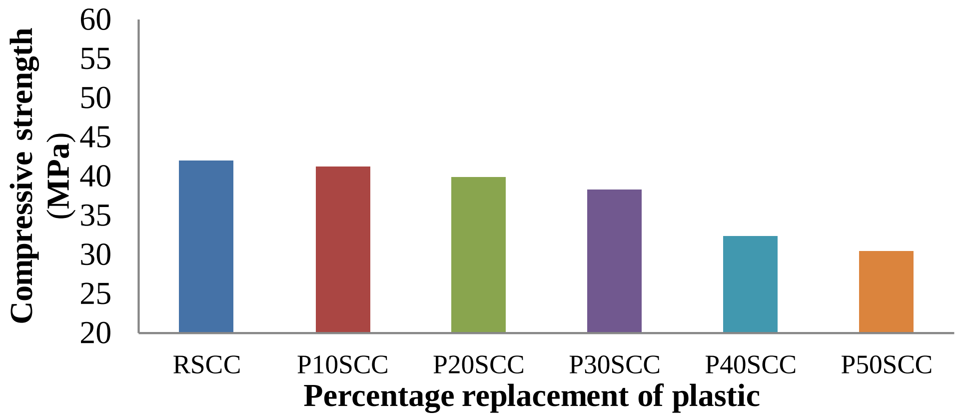
Density

Before subjecting the specimens for crushing test, they were weighed for density calculations. The average density of partially replaced concrete with plastic aggregate (50% of replacement of aggregate) was found to be 2361 kg/m^3. The values of the density of the concrete with the replacement level of aggregate are given in the Table 5.2

Density of Concrete

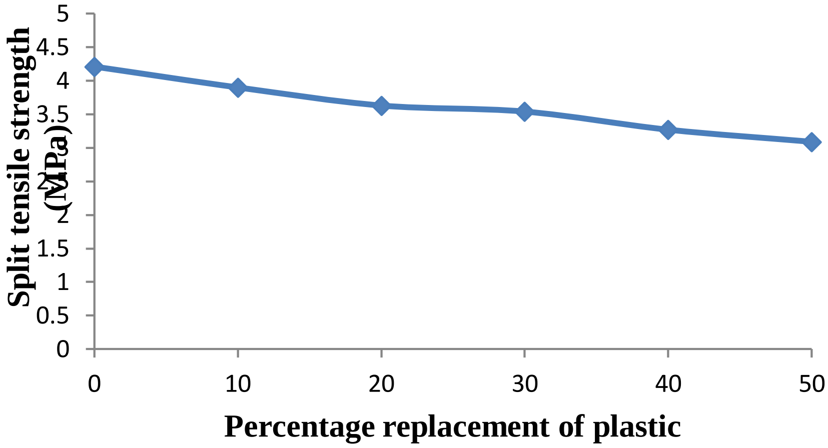
Sl.no	Mix Id	Cube size (mm)	Weight (kg)	Density (kg/m^3)
1	RSCC	150x150x150	8.31	2462
2	SCC10P	150x150x150	8.17	2421
3	SCC20P	150x150x150	7.98	2364
4	SCC30P	150x150x150	8.01	2371
5	SCC40P	150x150x150	8.05	2386
6	SCC50P	150x150x150	7.96	2361

STRENGTH CHARACTERISTICS



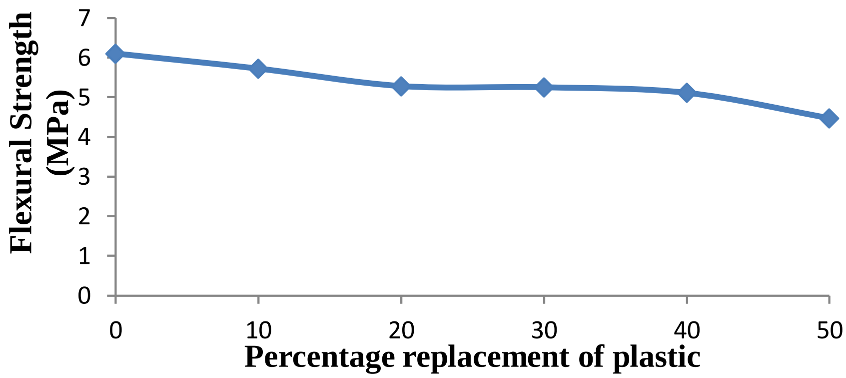
Compressive Strength at 28 days

Split Tensile Strength



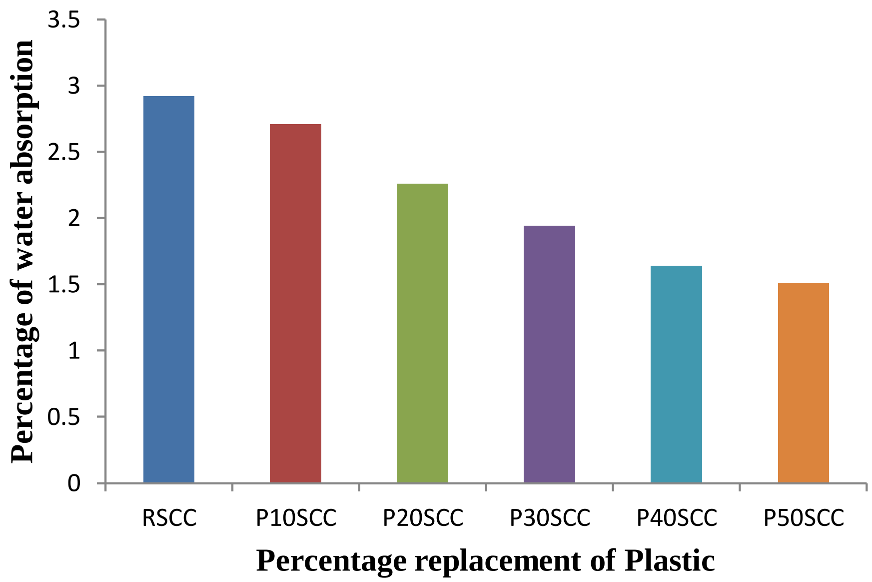
Split tensile Strength at 28 days

Flexural Strength



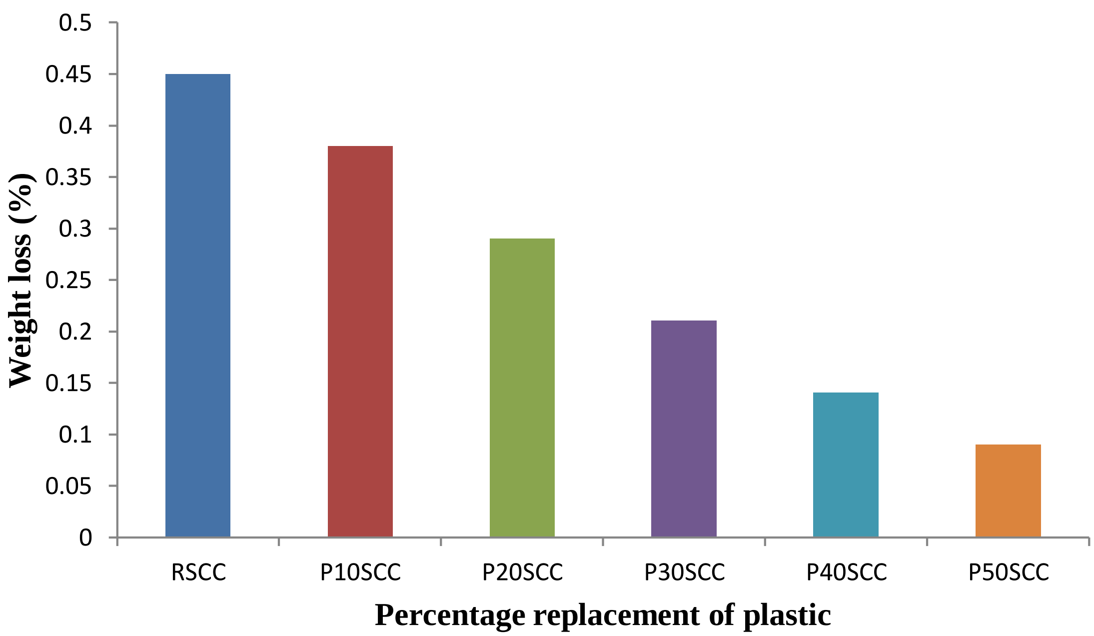
Flexible Strength at 28 days

DURABILITY CHARACTERISTICS



Water absorption

Sulphate resistance



Effect of Plastic aggregate on Sulphate resistance of concrete

CONCLUSIONS

The present experimental studies is to verify the dependency of usage of Polystyrene Plastic which is used in electronic goods for the partial replacement of coarse aggregate in M30 Self-Compacting concrete designed with packing density of the constituents used in the concrete. From the results, following conclusions are derived:

1. This type of plastic aggregate can be used successfully as a partial replacement of coarse aggregate in Self-Compacting Concrete especially in precast industry as precast elements.
2. The usage of plastic aggregate ensures the reduction in dead load. Hence it is economical.

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3. The workability and flowability of the SCC developed with replacement of plastic aggregate was improved significantly satisfying the EFNARC specifications.
4. The compression test show s that the average compressive strength at 28 days SCC containing upto 30% replacement doesn't reduce beyond 9% of Reference concrete.
5. Split tensile strength decreases as the percentage of replacement increases. The average reduction of about 27% at 50% plastic aggregate when compared to reference concrete.
6. Flexural strength of Self compacting concrete shows a decreasing trend at all replacement levels. The reduction of about 26 % at 50% replacement of plastic aggregate when compared to reference concrete.
7. Water absorption of concrete decreases as percentage of plastic aggregate increases. The reduction of about 48 % at 50 % replacement when compared to normal concrete.
8. Sulphate resistance of concrete are enhanced by using plastic aggregate. The percentage loss in weight of concrete after sulphate attack is minimum in concrete containing plastic than normal concrete.

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