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Behavior of Self Compacting Concrete Partial Replacement of Coarse Aggregate with Pumice Lightweight Aggregate

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Abstract: ***Concrete with low density is termed lightweight concrete. The unit weight of such concretes is about two-thirds of normal concrete. Most structural lightweight concretes weigh between 1600 and 1760 kg/m3. Design strengths between 20 to 35 MPa are common. The lightweight nature of these concretes is usually obtained either by using lightweight cellular aggregates. LWC can be produced by using lightweight materials like Lightweight Expanded Clay Aggregate, Pumice stone, expanded shale, Perlite etc. Structural lightweight aggregate can be produced naturally or from environmental waste. use of these aggregates can reduce the density of concrete, the self-weight of the structure and it helps to construct larger precast unit. Lightweight concrete (LWC) is an exceptional solution in terms of decreasing the dead weight of the structure, while self-compacting concrete (SCC) eases the pouring and eliminates construction difficulties. Investigations are also reported the literature on the performance of micro silica in SCC wall panels. The Self-Compacting Concrete made by partially varying coarse aggregate with the lightweight pumice aggregate is described in the paper. This paper presents the fresh and hardened properties of low strength grade and standard grade, self-compacting concrete partially incorporating pumice as coarse aggregate with different replacements.***

Index Terms: Pumice light weight aggregate, super plasticizers, VMA, SCC, micro silica etc.

I. INTRODUCTION

Concrete is one of the most commonly used construction materials in modern constructions and infrastructure needs. It is used as a construction material because it can be moulded into any structural form and shape. The density of normal concrete ranges from 2200 to 2600 Kg/m^3, Self-weight occupies a very large load coming on the structures critically in cases such as weak soils and tall structures. Lightweight concrete plays a major role in reducing the density of the concrete. It is used worldwide in many construction projects where soil is weak and heavy constructions are to be done, Lightweight concrete density varies from 300 to 1800Kg/m^3. LWC can be produced by using lightweight materials like Lightweight Expanded Clay Aggregate, Pumice stone, expanded shale, Perlite etc.

Structural lightweight aggregate can be produced naturally or from environmental by products, use of these aggregates can reduce the density of concrete, the self-weight of the structure and it helps to construct larger precast unit.

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The main aim of the present experimental study is to investigate the properties of pumice lightweight aggregate concrete (PLAC) under normal curing conditions and vacuum curing.

II. EXPERIMENTAL STUDY

A. Materials

This section gives the details of the characteristics of the different materials used in this experimental investigation.

B. Cement

Cement is used as a binding material. In this experimental investigation, Ordinary Portland Cement of Grade 53 is used. The cement is found to be conforming to various specifications of IS 12269-1987. The physical properties of cement are tested, and the results are tabulated in Table I as per IS 4031-1998.

Table I: Physical Properties of Cement

Test	Result
Specific gravity	3.10
Standard consistency	34%
Initial setting time	45 min
Final setting time	580 min
Bulk density	1440 kg/ m^3
Fineness of cement	2.37 %

C. Aggregates

Aggregates are sluggish granular materials such as fine aggregate, gravel, or crushed stone that are mixed along with water and Portland cement to make concrete. They are essential ingredients in making concrete.

D. Coarse aggregate

In present experimental work coarse aggregate passing through 12mm IS sieve and retaining on 10mm IS sieve is used. Certain care is taken while choosing coarse aggregate and it is seen that it is free from impurities. Characteristic Tests are conducted to find out the properties of the coarse aggregate and are tabulated in Table II.

E. Coarse aggregate (pumice)

Pumice Lightweight aggregate (PLA) is used as the lightweight aggregate which of size 8 to 12mm. PUMICE is free from impurities. Characteristic tests are also performed on PUMICE and the results are presented in Table II.

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Fig.1. Pumice Lightweight aggregate

Table II: Physical Properties of Coarse Aggregate

Property	Coarse aggregate	Pumice
Fineness modulus	6.41	5.84 5.84
Specific gravity	2.43	1.04 1.05410
Bulk density	1420 kg/ m^3	410 kg/ m^3 kg/ mm
Water absorption	0.6 %	30 %

F. Fine aggregate

Fine aggregate used in this experimental work is locally available river sand, care is taken to see that the sand is free from impurities, waste stones and to remain clean. Sand used is confirming to the requirements of IS: 383-1970. Characteristic tests are conducted on fine aggregate and the properties of fine aggregate are tabulated in Table III.

Table III: Physical Properties Of Fine Aggregate

Test	Result
Fineness modulus	2.83
Specific gravity	2.59
Bulk density	1570 kg/ m3
Water absorption	1%

G. Chemical Admixture

In the present study, CONPLAST SP 430 is used. It is used to improve the workability of the concrete and also especially formulated to give high water reductions up to 25% without loss of workability and reduce permeability to give excellent concrete.

H. Water

Water is the most important ingredient of concrete which helps to bind the cement content and aggregates. Clean potable water is used for concrete mixes.

I. Mix Design

In the present study, the mix design of the Pumice Lightweight aggregate concrete (PLAC) was done using the rational mix design method. The Pumice lightweight aggregate is replaced in place of coarse aggregate in concrete by replacing 10%,20%,30%&40% of Normal Weight Aggregate in volume fractions. The chemical admixture i.e. SP 430 is used in order to improve workability.

J. Casting of specimen

The fresh concrete was casted using different percentages i.e.10%,20%,30% & 40%. For each mixture, cube cylinder and prism specimens of size 150x150x150mm, 150x300mm and 100x100x500mm were cast individually. The composition of LWC mixtures is represented in Table IV.

Figure 3: Casting of cube specimens

K. Curing of specimens

All the casted concrete specimens were cured by placing the specimens in the curing tank containing water for a period of 28 days. The LECA was also cured using vacuum curing method by placing it in a vacuum chamber for 24 hours and then it is used in the casting of LWC.

Figure 4: Curing of cube specimens

III. III. EXPERIMENTAL METHODOLOGY

A. Compressive Strength

Cubes of size 150x150x150mm were cast and allowed for curing in curing chamber for 28 days and 56 days. and tested in Automatic compression testing machine of 2000KN-capacity.

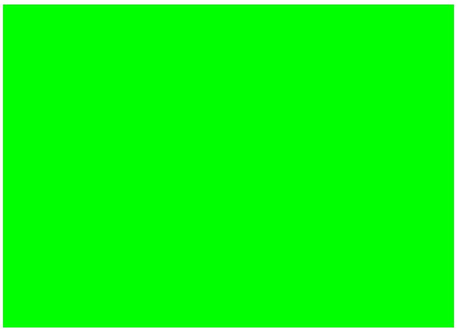

Figure 5: Compressive strength test and Split tensile test of PUMICE lightweight aggregate concrete cube and cylindrical specimen respectively with Automatic compression testing machine of 2000kN capacity

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Table IV: Quantities Of Materials For Casting Pumice Replacing Pumice Light Weight Aggregate Concrete With Different Percentages Of Replacements.

Grade of concrete	Percentages	Cement kg/m^3	FA kg/m^3	CA kg/m^3	Pumice kg/m^3	Fly Ash kg/m^3	S. P	Water kg/m^3
M20	10%	258	900	614.54	29.76	309	1	240
	20%	258	900	546.26	59.34	309	1	240
	30%	258	900	477.98	89.02	309	1	240
	40%	258	900	409.7	118.69	309	1	240
M30	10%	300	900	629.86	30.41	300	1.5	180
	20%	300	900	559.87	60.82	300	1.5	180
	30%	300	900	489.88	91.23	300	1.5	180
	40%	300	900	419.9	121.65	300	1.5	180
M40	10%	450	884	629.86	30.41	350	1.5	240
	20%	450	884	559.87	60.82	350	1.5	240
	30%	450	884	489.88	91.23	350	1.5	240
	40%	450	884	419.9	121.65	350	1.5	240

B. Flexural strength

Prisms of size 100x100x500mm were casted and allowed for curing in curing tank for a period of 28 days and tested in flexural testing machine.

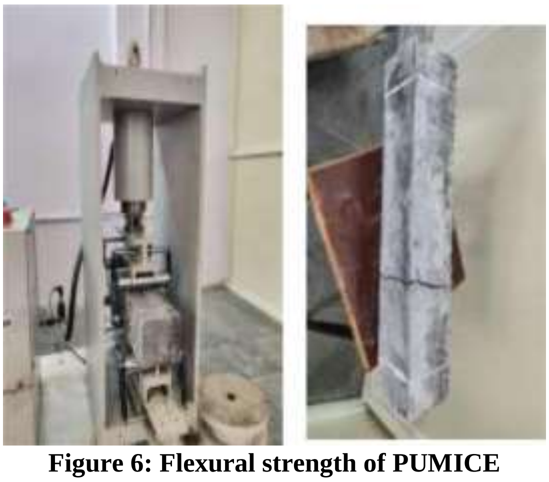

Figure 6: Flexural strength of PUMICE lightweight aggregate concrete prism along its failure

C. Split tensile strength

Cylinders of size 150x300mm were casted and allowed for curing in curing tank for 28 days and tested in the Automatic compression testing machine of 2000KN capacity.

Figure 7: Split tensile strength test using Automatic Compression Testing Machine

IV. EXPERIMENTAL RESULTS

Table II: Fresh and Hardened Properties of SCC And PASCC

Grade of concrete	Fresh Properties			Remarks	Designation
	Slump flowT50cm Test Sec	V-Funnel Test Sec	L-Box Test H2/H1		
20	4.05	6.89	0.88	RS	NSCC
	3.89	7.02	0.983	RS	10%
	3.96	7.05	0.9	RS	20%
	4.07	7.23	0.86	RS	30%
	4.12	7.48	0.79	RNS	40%
30	2.23	6.17	0.9	RNS	NSCC
	2.78	8.23	0.78	RNS	10%
	2.7	6.76	0.94	RS	20%
	3.2	7.58	0.915	RS	30%
	3.78	8.27	0.97	RS	40%
40	3.59	7.53	0.956	RS	NSCC
	3.56	7.12	0.92	RS	10%
	3.98	7.98	0.88	RS	20%
	3.03	8.01	1	RS	30%
	3.42	8.64	0.79	RNS	40%

RNS: Results Not Satisfactory in fresh state.

RS: Results are Satisfactory in fresh state

The first phase of investigations was carried out to develop different SCC mixes of different grades of low strength standard grade and High-grade concrete i.e., M20, M30, M40 using fly ash and chemical admixtures, and to study its fresh and hardened properties. For developing different SCC mixes of different grades of low strength standard grade and High-grade concrete i.e., M20, M30, M40, the mixes were designed based on Nan-Su method of SCC mix design using fly ash as the mineral admixture.

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Table III: Hardened Properties of SCC and PASCC at 7days & 28 days

S.No.	Grade of concrete	Designation	Cube Compressive Strength Mpa		Prism flexural strength Mpa		Cylinder split tensile strength Mpa	
			7 Days	28 Days	7 Days	28 Days	7 Days	28 Days
1		NSCC	18.3	27.2	3.67	5.10	4.3	6.25
2		10%	18.05	27.10	3.61	5.06	4.13	6.07
3	20	20%	17.90	26.50	3.50	4.95	4.01	5.90
4		30%	15.10	21.6	2.80	3.17	3.28	5.10
5		40%	14.7	20.6	2.20	2.98	3.12	4.85
6		NSCC	23.95	38.90	3.9	6.1	6.55	8.37
7		10%	23.35	37.85	3.85	5.98	6.40	8.11
8	30	20%	23.05	35.67	3.60	5.80	6.25	7.96
9		30%	21.25	30.18	3.10	5.20	5.92	7.41
10		40%	19.35	28.37	3.01	4.97	5.61	7.17
11		NSCC	27.55	50.8	4.65	7.1	7.45	9.65
12		10%	27.40	49.50	4.61	7.02	7.22	9.39
13	40	20%	26.97	46.13	4.25	6.91	7.03	9.12
14		30%	23.72	40.28	4.07	6.38	6.81	8.91
15		40%	23.16	38.63	4.72	3.89	6.34	8.73

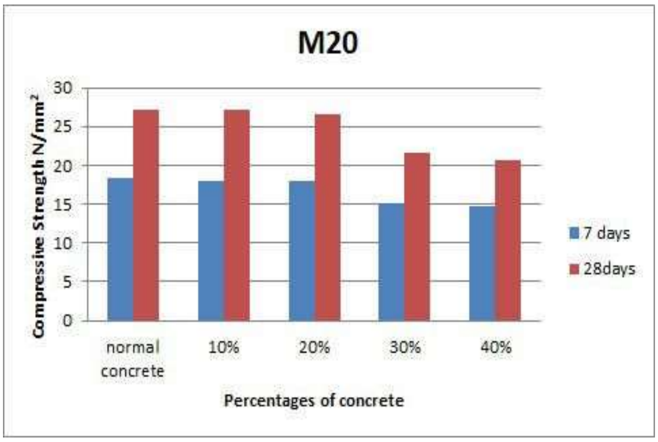
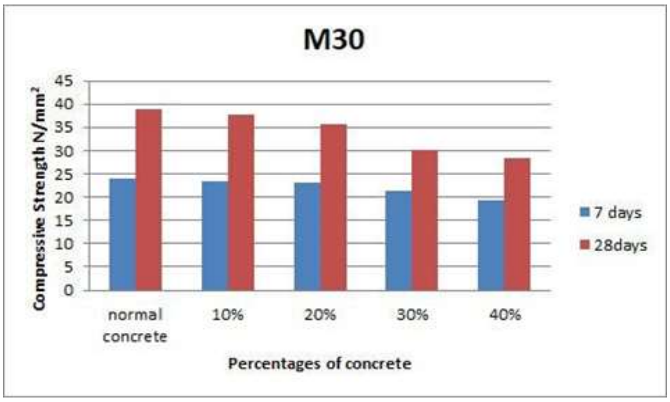


Figure 1: Variation of compressive strength for NASCC & PASCC M20 grade at the age of 7days & 28 days.



Variatio Figure 2. Variation of compressive strength for NASCC & PASCC M30 grade at the age of 7days & 28 days.

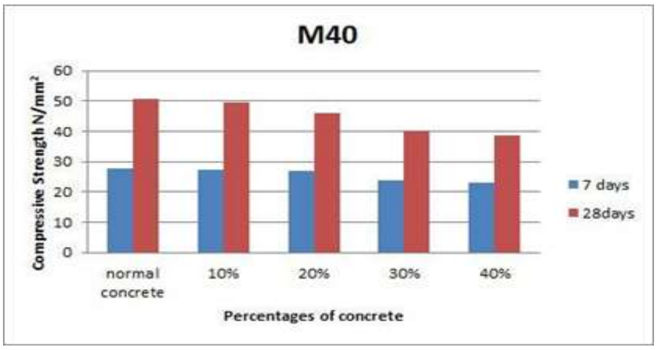


Figure 3: Variation of compressive strength for NASCC & PASCC M40 grade at the age of for NASCC & PASCC M40 grade at the age of 7days and 28days

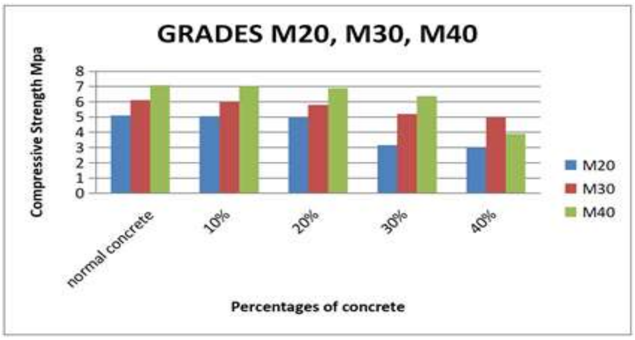


Figure 4: Variation of Compressive strength for NASCC &PASCC at different grades (M20, M30, M40) at the age of 28 days.

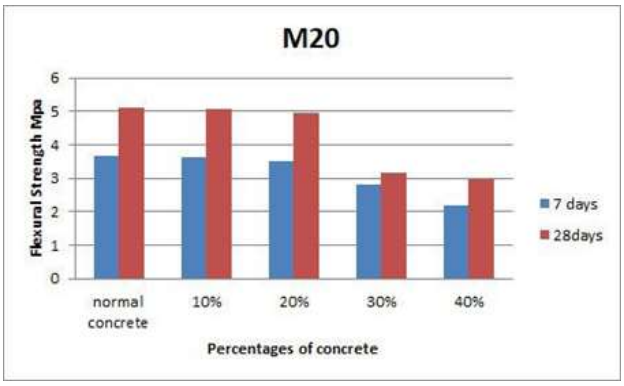


Figure 5: Variation of Flexural strength for NASCC & PASCC M20 grade at the age of 7days & 28 days.

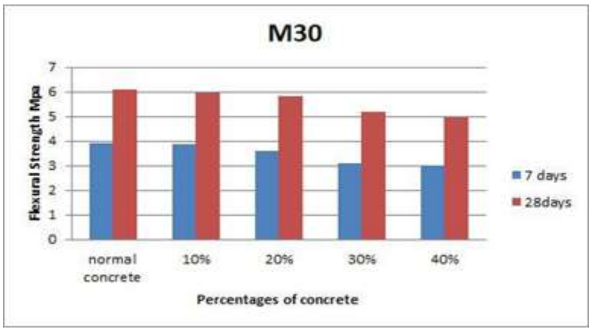


Figure 6: Variation of Flexural strength for NASCC & PASCC M30 grade at the age of 7days & 28 days.

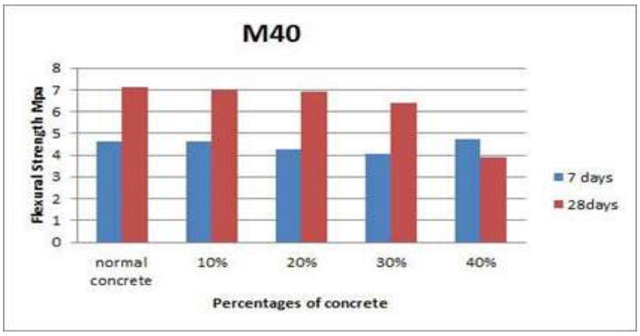


Figure 7: Variation of Flexural strength for NASCC & PASCC M40 grade at the age of 7days & 28 days.

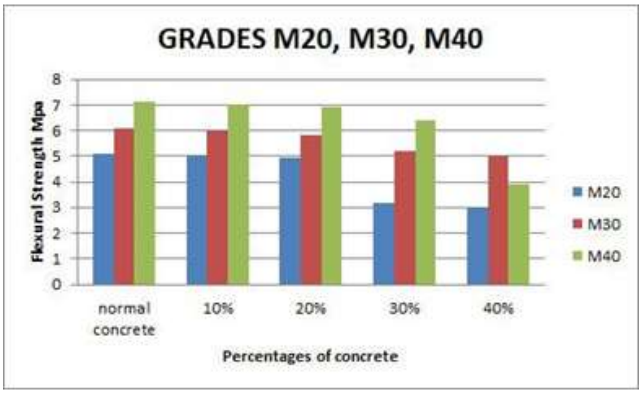


Figure 8: Variation of Flexural strength for NASCC&PASCC at different grades (M20, M30, M40) at the age of 28 days.

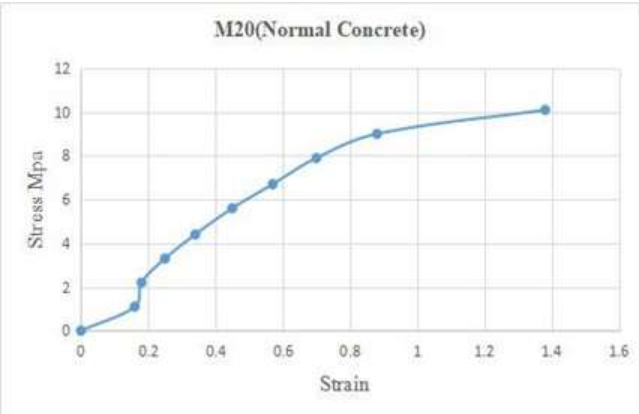


Figure 9: M20 Grade of Normal Concrete

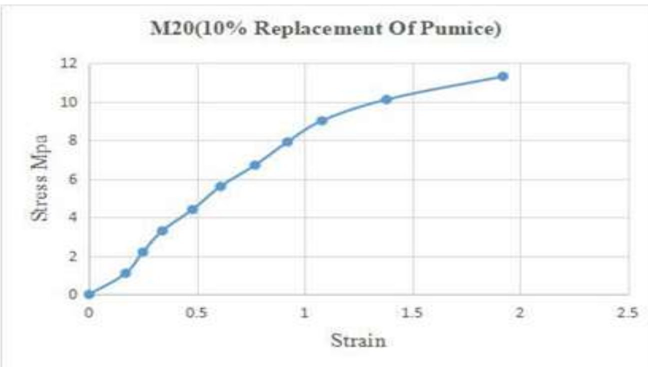


Figure 10: M20 Grade of Concrete for Replacement Of 10% of pumice

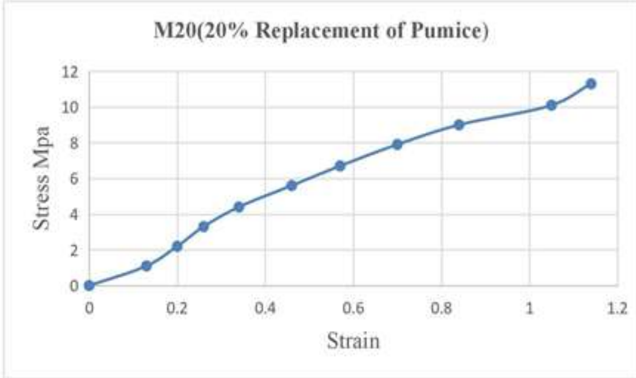


Figure 11: M20 Grade of Concrete for Replacement Of 20% Pumice

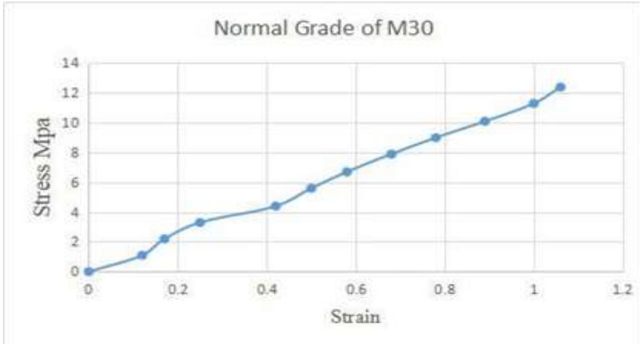


Figure 12: Normal self-compacting concrete For M30 Grade

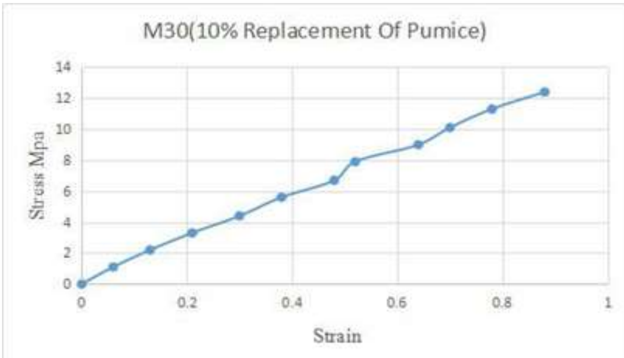


Figure 13: M30 Grade of Concrete for Replacement Of 10% Pumice

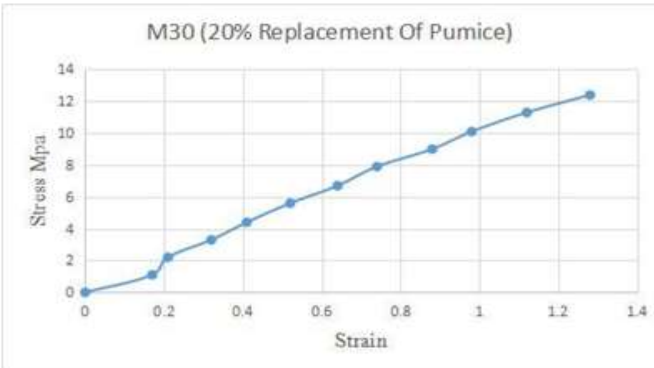


Figure 14: M30 Grade of Concrete for Replacement Of 20% Pumice

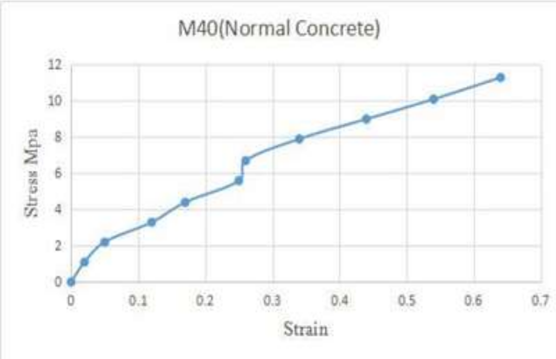


Figure 15: Normal self-compacting concrete For M40 Grade.

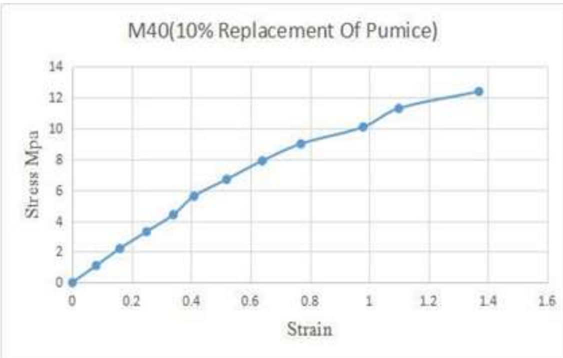


Figure 16: M40 Grade of Concrete for Replacement Of 10% Pumice.

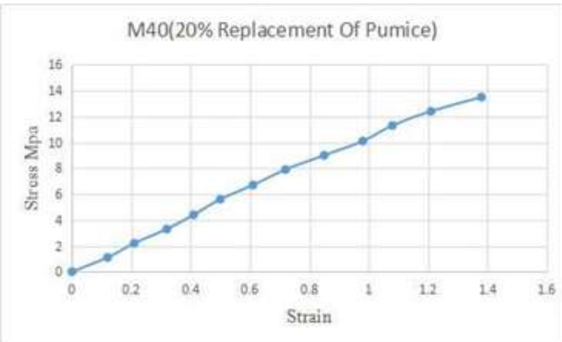


Figure 17: M40 Grade of Concrete for Replacement Of 20% Pumice

V. RESULTS

For M20, M30, and M40 and grade of concretes the fresh properties were satisfied. For M20, M30, and M40 Grade of Conventional self-compacting concrete the compressive strength for 7 days were 18.3, 23.95, and 27.55 N/mm^2 and 28 days were 27.2, 38.90 and 50.8 N/mm^2. For M20, M30, and M40 Grade of concrete the flexural strength for 7 days were 3.67,3.90 and 4.65 N/mm^2 and 28 days were 3.10,6.10 and 7.10 N/mm^2. For M20, M30, and M40 Grade of concrete the split tensile strength for 7 days were 4.3, 6.55, and 7.45 N/mm^2 and 28 days were 6.2, 38.90 and 50.8 N/mm^2. The densities of concrete are decreasing as the increasing in the percentage replacement of CA with PUMICE. The mechanical properties it was observed that for M20 grade of concrete the replacement of coarse aggregate by 0%, 10%, 20%, 30% and 40% with PUMICE the average compressive strength for 7 and 28 days in MPa were 18.05, 17.90, 15.10, 14.70 and 27.10 N/mm^2, 26.50, 21.60, 20.60 N/mm^2. It was observed that for M30 grade of concrete the replacement of CA with 10%, 20%, 30% and 40% with PUMICE the average compressive strength for 7 and 28 days in MPa were 23.35, 23.05, 21.25, and 19.35 N/mm^2 and 37.85, 35.67, 30.18 and 28.37 N/mm^2. It was observed that for M40 grade of concrete the replacement of CA with 10%, 20%, 30% and 40% with PUMICE the average compressive strength for 7 and 28 days in MPa were 27.40, 26.97, 23.72, 23.16 N/mm^2 and 49.50, 46.13, 40.28, 38.63 N/mm^2.

It was observed that for M20 grade of concrete the replacement of CA with 10%, 20%, 30% and 40% with PUMICE the average flexural strength for 7 and 28 days in MPa were 3.61, 3.50, 2.80, and 2.20 N/mm^2 and 5.06, 4.95, 3.17 and 2.98 N/mm^2 It was observed that for M30 grade of concrete the replacement of CA with 10%, 20%, 30% and 40% with PUMICE the average flexural strength for 7 and 28 days in MPa were 3.85, 3.60, 3.10, and 3.01 N/mm^2. and 5.98, 5.80, 5.20, and 4.97 N/mm^2. It was observed that for M40 grade of concrete the replacement of coarse aggregate with 10%, 20%, 30% and 40% with PUMICE the average flexural strength for 7 and 28 days in MPa were 4.61, 4.25, 4.07, and 4.72 N/mm^2. and 7.02, 6.91, 6.38, and 3.89 N/mm^2.

It was observed that for M20 grade of concrete the replacement of CA with 10%, 20%, 30% and 40% with PUMICE the average Split tensile strength for 7 and 28 days in MPa were 4.13, 4.01, 3.28, and 3.12 N/mm^2 and 6.07, 5.90, 5.10 and 4.85 N/mm^2 It was observed that for M30 grade of concrete the replacement of coarse aggregate with 10%, 20%, 30% and 40% with PUMICE the average Split tensile strength for 7 and 28 days in MPa were 6.55, 6.40, 6.25, and 5.92 N/mm^2. and 8.11, 7.96, 7.41, and 7.17 N/mm^2. It was observed that for M40 grade of concrete the replacement of CA with 10%, 20%, 30% and 40% with PUMICE the average Split tensile strength for 7 and 28 days in MPa were 7.22, 7.03, 6.81, and 6.34 N/mm^2. and 9.39, 9.12, 8.91, and 8.73 N/mm^2.

VI. CONCLUSIONS

The following conclusions are drawn from the Experimental Investigations:

1. The filling ability, passing ability, and segregation resistance of all SCC mix with PUMICE are in conformity with EFNARC guidelines.
2. The spherical shape of PUMICE has significantly improved rheological properties of the fresh concrete mix.
3. The increase in the percentage of pumice coarse aggregate showed a reduction on both compressive and flexural strengths of concrete.
4. The compressive strength and flexural strengths of pumice aggregate lightweight concrete (PASCC) are found to be optimum for 20% replacement of pumice aggregate.
5. Pumice aggregate absorbs additional water when compared to the normal coarse aggregate reducing workability. This problem has been overcome by a higher dosage of SP.

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6. Due to the less density pumice the aggregate was found to be segregating and floating on the surface of self-compacting concrete, which needs to be corrected with an appropriate dosage of superplasticizers and viscosity modifying admixture.
7. The compressive strength of lightweight SCC with pumice aggregate was found to increase when pumice is immersed in water for 24 hours before making concrete

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