International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 6 Issue 5, July-August 2022 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Assessment of Potential of Marble Slurry as a Mineral Admixture in Concrete

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ABSTRACT

Marble is a metamorphic rock composed of recrystallized carbonate minerals, most commonly calcite or dolomite. Marble is typically not foliated, although there are exceptions. In geology, the term marble refers to metamorphosed limestone, but its use in stonemasonry more broadly encompasses unmetamorphosed limestone. Marble is commonly used for sculpture and as a building material.

Quite a few industrial by-products have found their use as a partial replacement of cement. Also, they have been found to positively influence the properties of concrete. Fly ash (FA), silica fume (SF) and blast furnace slag (BFS) are the by-products of a coal-based thermal power plant, Ferro-silicone industry, and steel industry, respectively.

Cement industry all around the world is facing the pressure of continuously rising demand as there is a need to develop an enormous amount of infrastructure, such as power plants, roads, and ports, finding an alternative material, which can partially replace the cement clinker, are one of the best ways to meet this challenge. The experimental program, design compositions of the experimental samples and the methodology adopted to conduct the experimental trials. In first section material used in making of the cement mortar and the concrete mixes, and then their physical & chemical composition are determined. Concrete mix proportions, their design compositions and mixing procedures are mentioned in the second section. In the third section the experimental setup, tests adopted, reference codes used for testing have been discussed in detail.

KEYWORDS: *Marble Slurry, Compressive Strength, Tensile Strength, Concrete Mix, Physical & Chemical Composition, Partial Replacement*

How to cite this paper: Manisha Parte | Prof. Nitesh Kushwaha | Prof. Afzal Khan "Assessment of Potential of Marble Slurry as a Mineral Admixture in Concrete" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-6 | Issue-5, August 2022, pp.965-978, URL: www.ijtsrd.com/papers/ijtsrd50601.pdf

IJTSRD50601

1. RESULTS AND DISCUSSION

This chapter deals with results and discussion of experimental program conducted in the previous chapter.

Characterization of marble slurry

Table 1.1: Physical and chemical properties of cement and marble dust

Chemical composition	OPC (%)	Marble dust (%)	Physical Properties	OPC (%)	Marble dust (%)
SiO2	20.27	3.86			
Al2O3	5.32	4.62			
Fe2O3	3.56	0.78	**Specific gravity**	3.15	2.67
CaO	60.41	28.63			
MgO	2.46	16.9			
SO3	3.17	-	**Fineness (m^2/kg)**	313	250
LOI	3.55	43.3			

Preliminary data analysis

Test results of coarse aggregates (size – 10mm)

Table 1.2: Aggregate impact value .

SI. NO.	Initial weight (gm)	Final weight (gm)	AIV (%)	Avg. AIV (%)
1.	343.5	75.3	21.92	21.23
2.	344.2	70.7	20.54	

Table 1.3: Specified limits of percent aggregates impact value for different types of road construction by Indian road congress (IRC)

SI. NO	Pavement type	Maximum aggregate impact value
1.	Wearing course	30
a)	Bituminous surface dressing	
b)	Penetration macadam	
c)	Bituminous carpet concrete	
d)	Cement concrete	
2.	Bitumen bound macadam base course	35
3.	WBM base course with bitumen surfacing	40
4.	Cement concrete base course	45

(Source - IS: 383-1970)

The aggregate impact value is found to be 21.23 % which is found to be in the permissible range for the pavement. This test is done to perform the toughness of the aggregates.

Aggregate plays an important role in pavement construction. Aggregates influence, to a great extent, the load transfer capability of pavements. Hence it is essential that they should be thoroughly tested before using for construction

Table 1.4: Aggregate crushing value

SI. NO.	Initial weight (gm)	Final weight (gm)	ACV (%)	Avg. ACV (%)
1.	345.2	80.2	23.23	23.67
2.	346.7	83.6	24.11	

Table 1.5: Aggregate Crushing Values for Roads and Pavement Construction

SI. No.	Types of roads and pavements	Aggregates crushing value
1.	**Flexible pavement**	
a)	Soiling	50
b)	Water bound macadam	40
c)	Bituminous macadam	40
d)	Bituminous surfacing dressing or thin premix carpet	30
e)	Dense mix carpet	30
2.	**Rigid pavements**	
a)	Other than wearing course	45
b)	Surface wearing course	30

(Source - IS: 383-1970)

The aggregate crushing value is found to be 23.67%, which is suitable for the designing of pavements.

Table 1.6: Specific gravity (G)

SI. No.	Wt. of empty bowl in air (gm) (I)	Submergd wt of bowl (gm) (II)	Wt of specimen &bowl in air (gm) (III)	Submergewt of bowl & specimen (gm) (IV)	Wt of aggregate in air (gm) (III – I)	Wt of Aggregate in water (gm) (IV – II)	Specific Gravity (G)
1.	204	120	727	447	523	327	2.668

The Specific gravity of the coarse aggregates lies in the range of 2.4 – 3. This test results the specific gravity as 2.67, which is in the desirable range to give appropriate results of compressive strength test.

Test results of fine aggregate (% finer than 4.75mm)

Table 1.7: Fineness modulus

SI. No.	Sieve size	Weight retained (gm)	Cumulative % wt retained
1	4.75mm	038	03.8%
2	2.36mm	065	10.3%
3	1.18mm	156	25.9%
4	600µ	490	74.9%
5	300µ	197	94.6%
6	150µ	052	99.8%
7	75µ	002	100%
			FM = 309.3/100 = 3.09

Table 1.8: Standards of fineness modulus & nature of sand

SI. No.	Fineness Modulus	Nature of Sand
1	2.2 – 2.6	Fine sand
2	2.6 – 2.9	Medium sand
3	2.9 – 3.2	Coarse sand

(Source: IS: 383: 1970)

The sieve analysis of fine aggregates gives the fineness modulus of 3.09, which lies in the range of 2.9 to 3.2, that represents the coarse sand.

Table 1.1.2.2 Grading of fine aggregate

Table 1.9: Standards of grading zone of fine aggregates

	Percentage passing for different zones			
IS Sieve designation	Zone I	Zone II	Zone III	Zone IV
10mm	100	100	100	100
4.75mm	90-100	90-100	90-100	95-100
2.36mm	60-95	75-100	85-100	95-100
1.18mm	30-70	55-90	75-100	90-100
600µm	15-34	35-59	60-79	80-100
300µm	5-20	8-30	12-40	15-50
150µm	0-10	0-10	0-10	0-15

(Source: IS: 383: 1970)

Percentage passing through 600µ is 25.1% (15-34%), therefore the fine aggregates lies in grading zone I, which conforms to IS 383: 1970.

1.1.3.2 Initial and final setting time

Table 1.10: Initial setting time with or without RSA

SI. No.	Symbol of mix	Initial setting time
1.	OPC	155
2.	RSA 7%	160
3.	RSA 10%	170
4.	RSA 10.1%	170
5.	RSA 12%	200

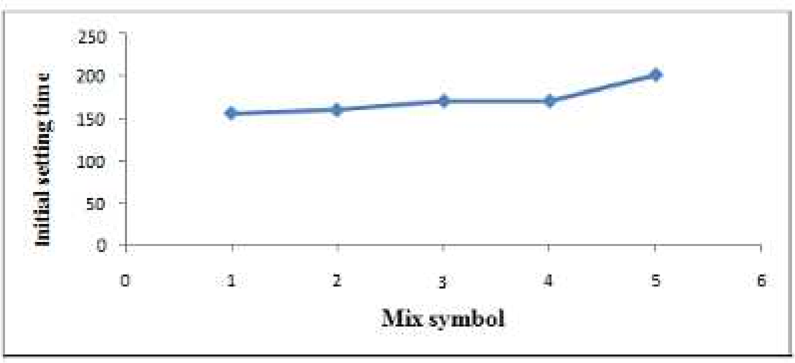


Figure 1.1: Initial setting time for different percentage of RSA in cement

Table 1.11: Standards of initial setting time (from earlier work done) (Source: Sharma et. al. 2013)

SI. No.	Symbol of mix	Initial setting time
1.	OPC	140
2.	RSA 5%	155
3.	RSA 10%	165
4.	RSA 15%	170

Table.1.12: Final setting time with or without RSA

SI. No.	Symbol of mix	Final setting time
1.	OPC	250
2.	RSA 7%	265
3.	RSA 10%	280
4.	RSA 10.1%	295
5.	RSA 12%	305

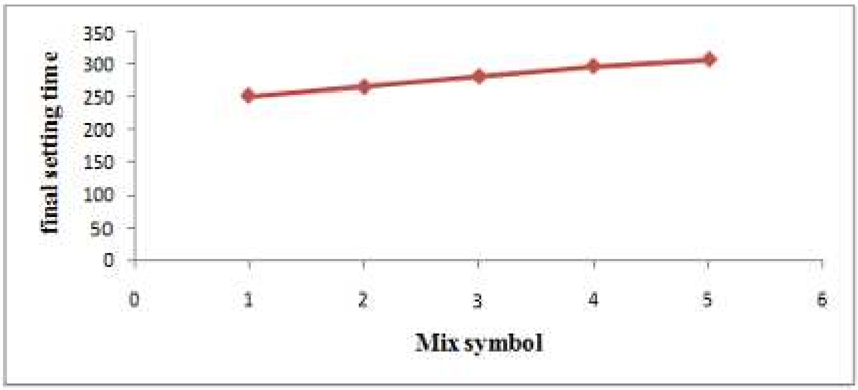


Figure 1.2: Final setting time for different percentage of RSA in cement

Table 1.13: Standards of initial setting time (from earlier work done)

SI. No.	Symbol of mix	Initial setting time
1.	OPC	240
2.	RSA 5%	255
3.	RSA 10%	270
4.	RSA 15%	285

(Source: Sharma et. al. 2013)

The deviation in the previous study is due to the temperature difference, which might have changed the chemical composition of the Rice Straw Ash. The other reason may be the change in water cement ratio and grade of the mix. The variation in size of coarse aggregates could also attribute to the change in the setting time.

Mortar compressive strength

An increase in compressive strength of mortar cubes is reported for 10% marble dust substitution of cement and for any further addition of marble dust compressive strength was found to decrease. The results are tabulated in Table 1-3. Increase observed could be due to micro filler effect of marble dust owing to which the strength starts decreasing after 10 % substitution as the amount of C3A and C2S required for hydration process reduces (Ergün 2011) . Micro structural analysis of broken samples was also conducted to ascertain whether any major changes in chemistry phases were observed.

However, the reason for increase in strength and confirmation was studied using strength activity test and XRD analysis of the samples.

Table 1.14: Drying shrinkage at 56 days and mortar cubes failure load

Mix	Drying shrinkage (mm)	Failure load (kN)
C0	1.31	60
C10	0.95	65
C15	0.83	65
C20	0.74	63
C25	0.67	60

Strength activity

The results for strength activity showed additional increase of strength in samples containing marble dust instead of silica sand. The strength ratio for samples at the end of 28 days is higher by almost 13 percent; indicating that a chemical reaction may be taking place. However, as very little amounts of silica and alumina were found to be present in marble dust, XRD was performed to determine the reason for the gain in strength. Table 1-4 shows the strength activity test results.

Table 1.15: Strength ratios

Days/CS	100% Cemen t	Δ	10% MD	Δ	10% Silica Sand	Δ
7 days	25 MPa	3.25	21 MPa	2.67	17 MPa	3.56
28 days	41 MPa	4.10	36 MPa	3.44	32 MPa	4.07
28-day Strength Ratio			0.88		0.78	

PROPERTIES OF FRESH CONCRETE

SLUMP AND DENSITY

The reductive power of the admixture improves the compactness of the concrete mix.

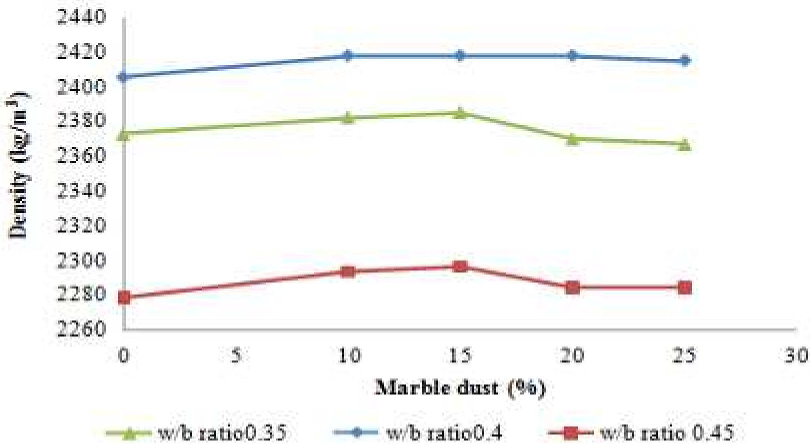


Figure 1-3: Marble dust percent vs density

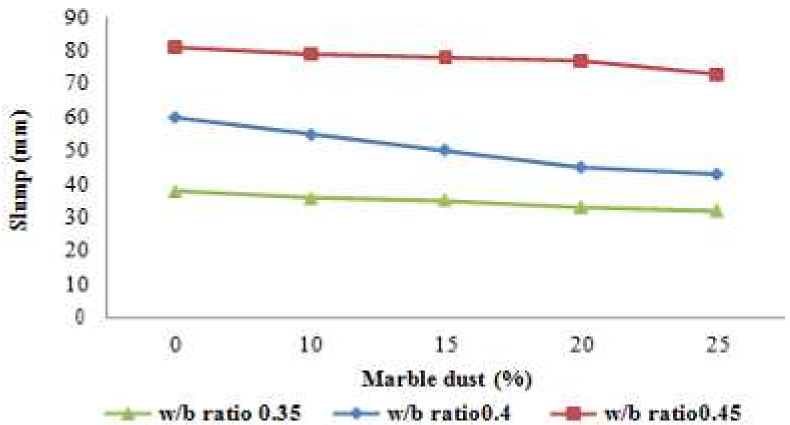


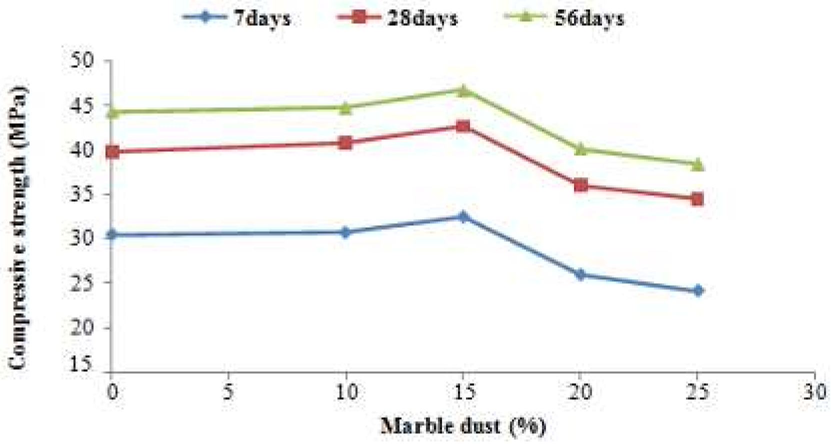
Figure 1.4: Marble dust percent vs slump

PROPERTIES OF HARDENED CONCRETE

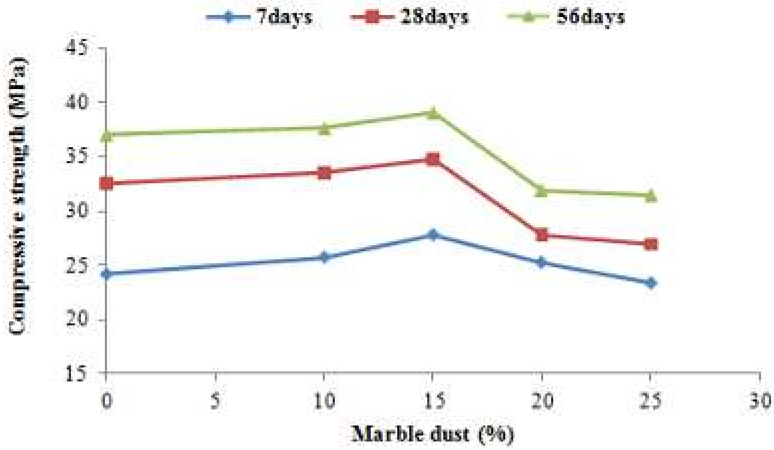
MECHANICAL PROPERTIES

Compressive strength

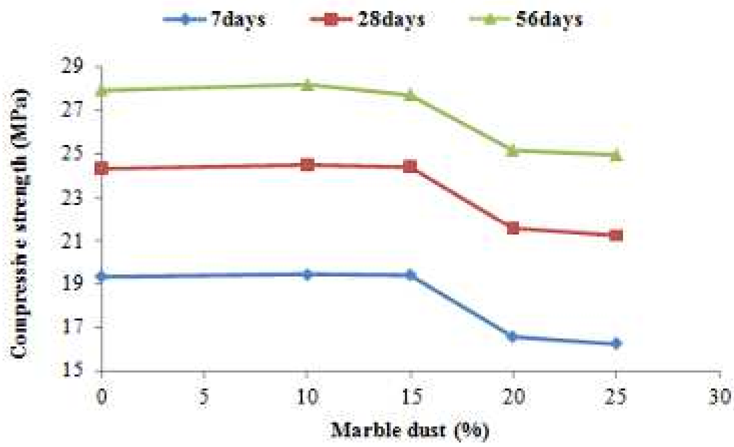
The compressive strength test results for cubes containing 0%, 10%, 15%, 20% and 25% marble dust used as partial replacement of cement by weight are presented in Figure 1-13 (a-c). 7.5% incompressivestreng that 10%and15%replacementlevelsisobservedforw/bratioof 0.35 where as 6% and 8% increase for w/b ratio 0.40 for same percentage replacement is found at 28days curing age. However, for w/b ratio of 0.45, there is a minimal increase in compressive strength at 28 days curing age for same percentage replacement levels of cement by marbledust.



(a) w/b 0.35



(b) w/b 0.40



(c) w/b 0.45

Figure 1.5: (a-c) Compressive strength test results of marble dust incorporated concrete

EFFECT OF VARYING DOSAGES OF SUPERPLASTICIZER

Table 1.16: Compressive strength trend at different dosages of plasticizer with use of marble dust

w/b ratio	0.35		0.4		0.45	
	CS at increasing Dosage (MPa)	CS at Constant dosage (MPa)	CS at Increasing Dosage (MPa)	CS at Constant dosage (MPa)	CS at Increasing Dosage (MPa)	CS at Constant dosage (MPa)
0% MD	39.77	38.54	32.54	31.37	24.32	23.54
10% MD	40.78	39.88	33.56	32.44	24.50	24.65
15% MD	42.67	41.35	34.78	33.65	24.40	23.08
20% MD	36.00	35.09	27.78	27.01	21.56	20.42
25% MD	34.52	33.12	26.95	25.74	21.23	20.03

*CS - Compressive Strength

Effect of particle size on compressive strength

Effect of particle size on compressive strength is shown in Figure 1-15.

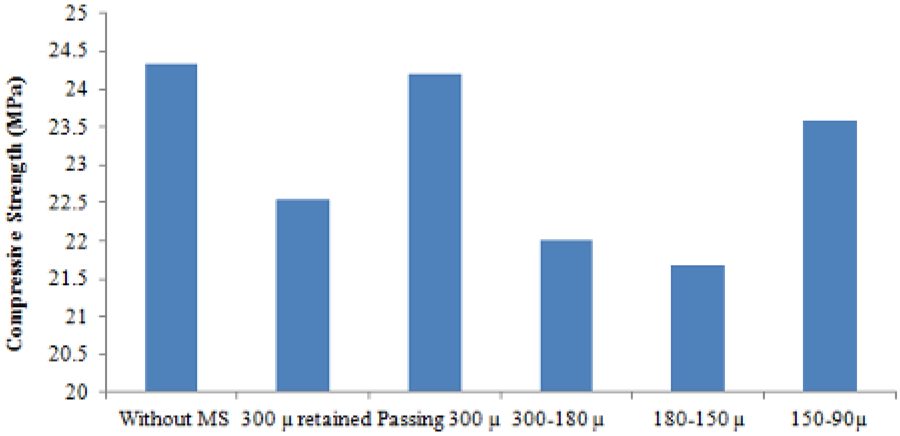


Figure 5.6: Effect of particle size on compressive strength

1.1.1.1.3 Long term effect

The strength value of reference concrete varied from 30 to 46 MPa depending upon the curing conditions. For the higher water-binder ratios of 0.35 and 0.4, the results show a progressive rise in strength until 15 percent marble dust replacement levels, across all curing times. The 15 percent replacement of marble dust resulted in a 3.9 and 7.4 percent increase in compressive strength at the end of 360 days for the water-binder ratios of 0.35 and 0.45For water-binder ratios of 0.35 and 0.40, severe strength losses are recorded throughout the testing ages for percentage replacements more than 15%. These strength decreases can be as high as 20%. Rai et al. (2011) reported similar findings, stating that a 5-10% rise in replacement levels was found up to 15%. For a w/b ratio of 0.45, as described in section 1.1.1.1, an increase in strength of up to 10% replacement level and up to 1% at the end of 90 days is observed. Any additional increase in replacement levels resulted in strength losses, which might be attributed to a lower binder content. All of the testing ages show a similar pattern. After examining the samples for up to a year after exposing them to unfavourable environmental conditions, no loss in strength is found.

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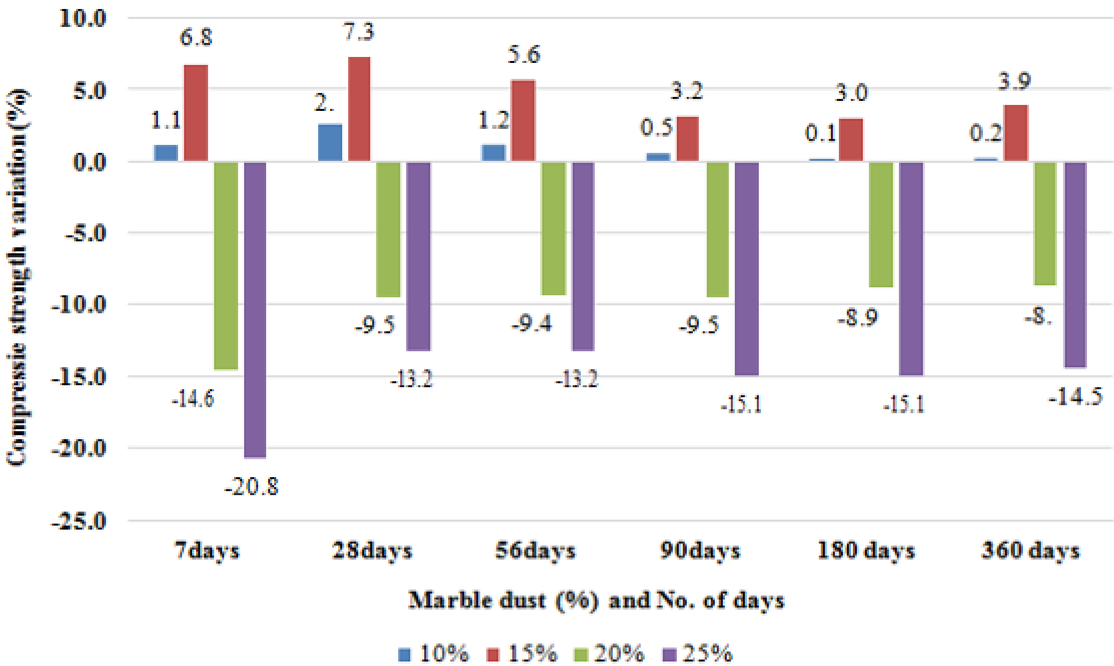
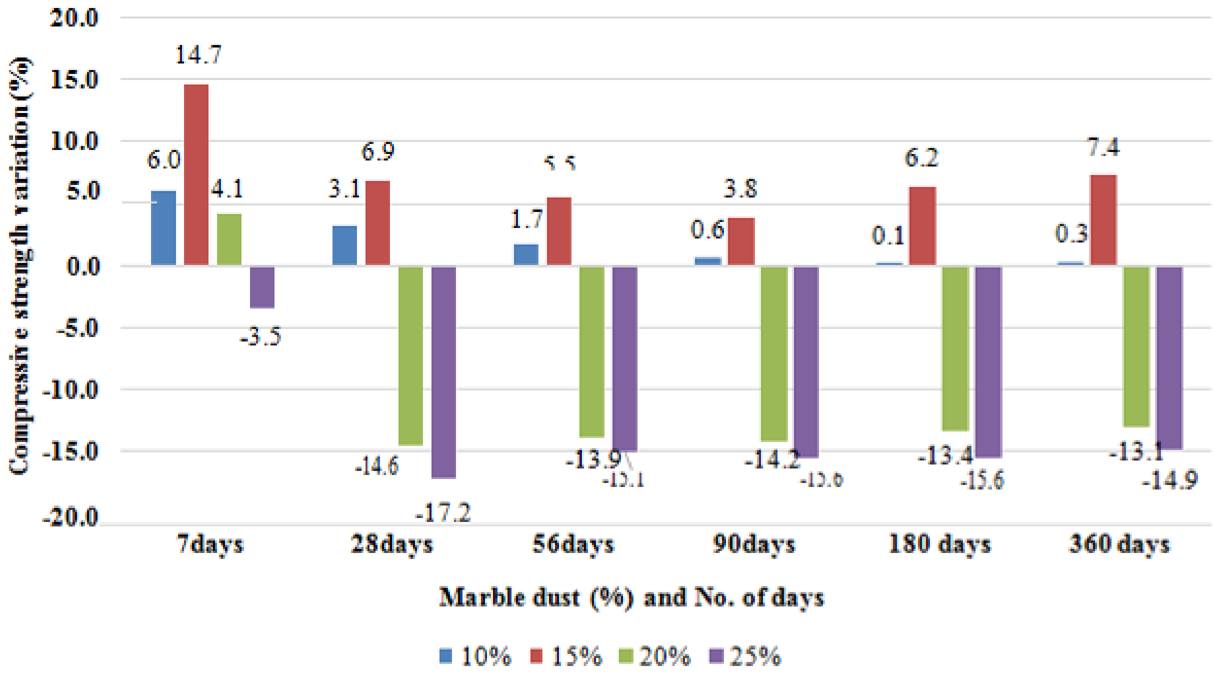
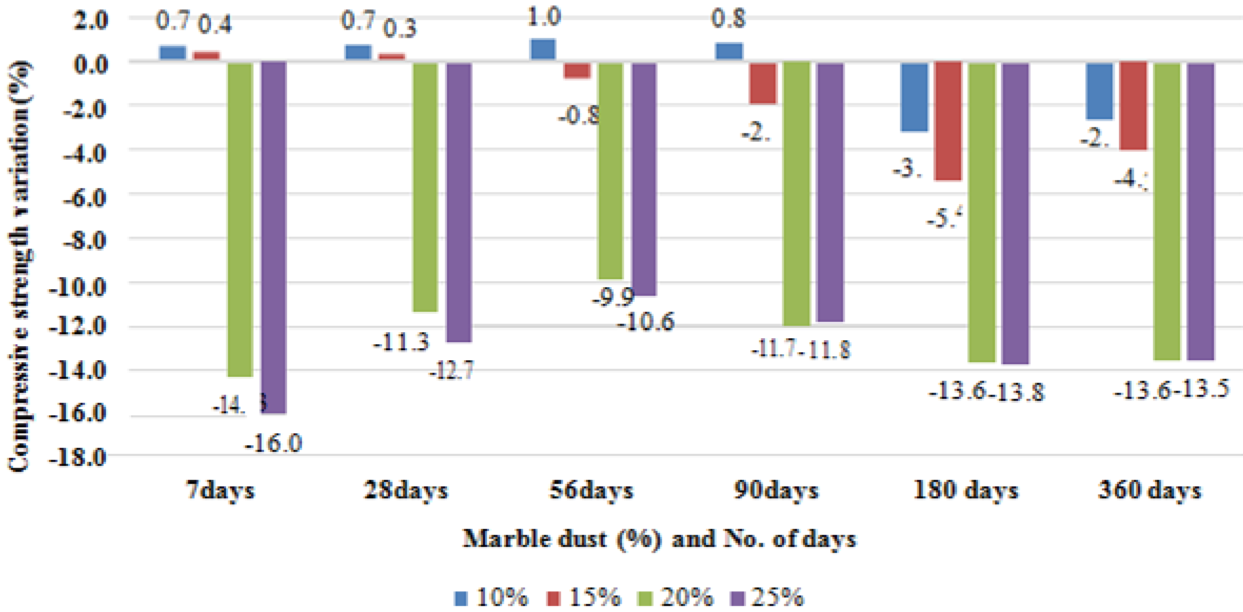


(a) w/b 0.35



(b) w/b 0.40



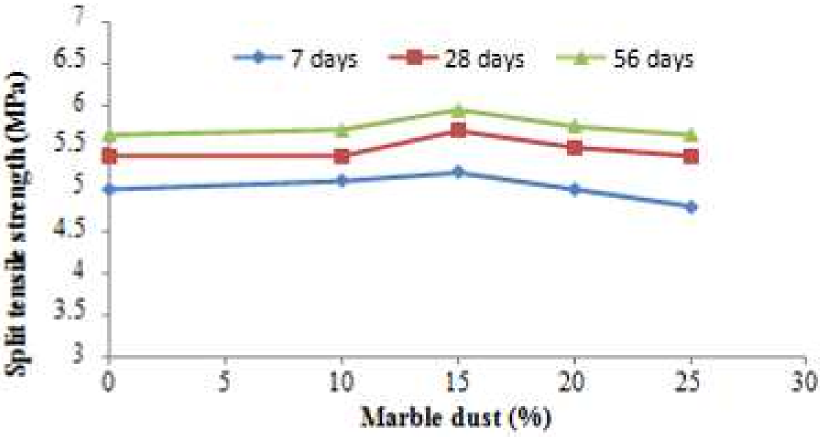
(c) w/b 0.45

Figure 1.8: (a-c) Percentage variation in Compressive strength

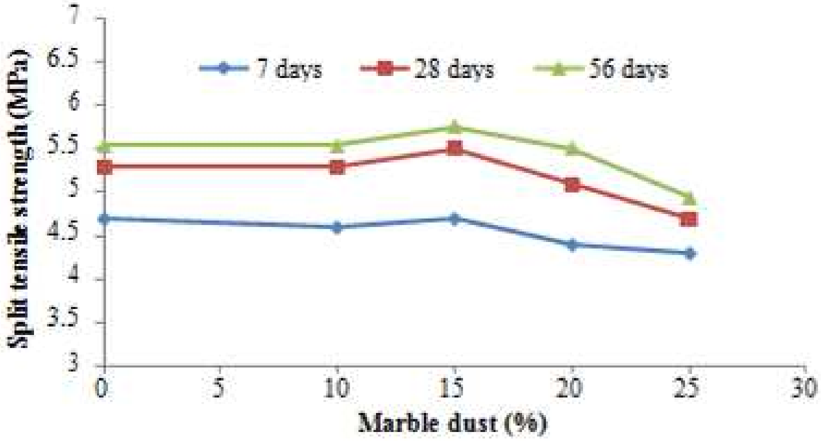
Split tensile strength

The test results of split tensile strength of concrete are shown in Figure 1-18 (a-c) . The maximum tensile strength is attained after 15% replacement, after which the strength begins to deteriorate. However, at 10% cement replacement by weight, maximum split tensile strength is observed for w/b ratio 0.45. Similar findings were also reported by Deshmukh et al. (2015) and Vaidevi (2013) .

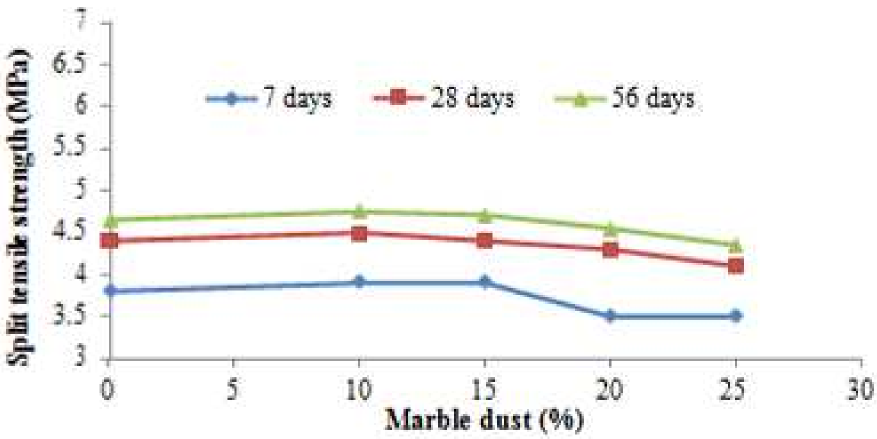
For example, at 10 percent and 15 percent replacement levels, w/b ratio 0.35 shows a 5.5 and 7.5 percent rise at 28 days curing age, respectively, but w/b ratio 0.45 shows a 4 percent increase at 10 percent replacement level.



a) w/b 0.35



(b) w/b 0.40



(c) w/b 0.45

Figure 1.9: (a-c) Split tensile strength test results of marble dust incorporated concrete

1.1.1.2.1 Long term effect

Equation (1.1) is the best fit equation considering concrete made with marble dust as partially replaced cement.

ST= 0.0738 CS+2.7378 (1.1)

The concrete split tensile strength is ST, while the concrete compressive strength is CS in MPa. The equation was created using data from three water-binder ratios, testing ages of up to 360 days and marble dust replacement amounts of up to 25%.

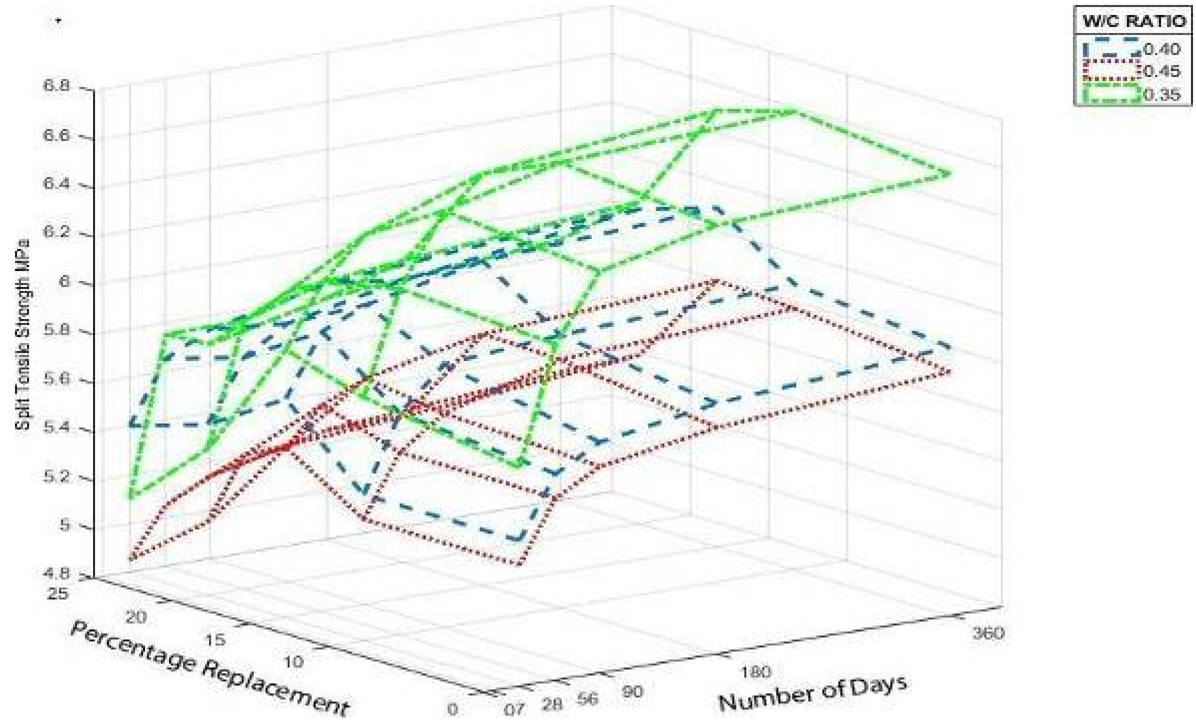
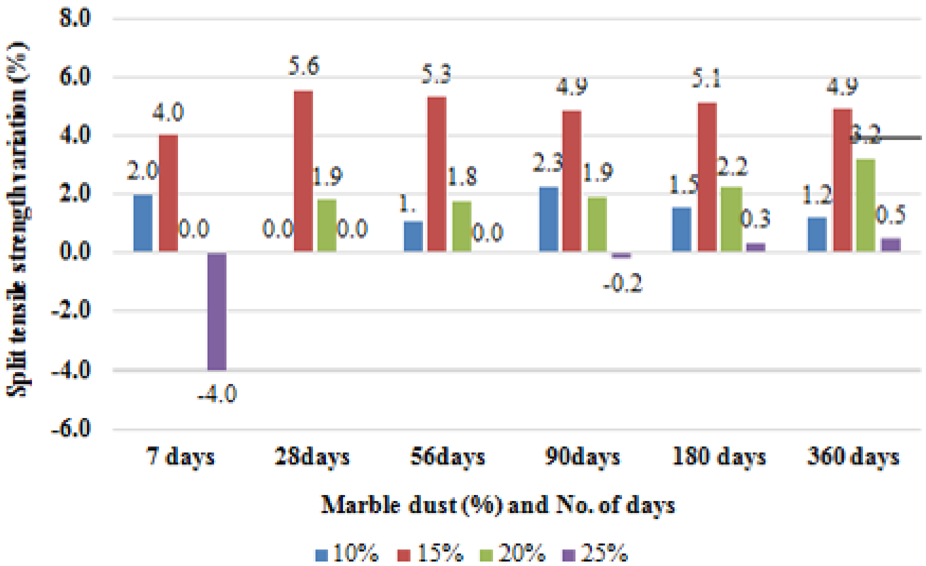
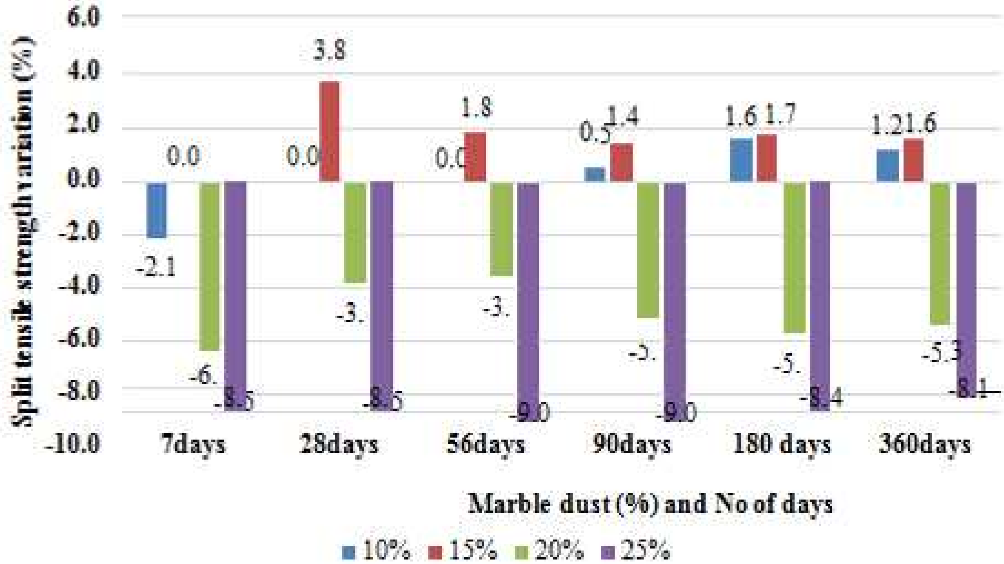


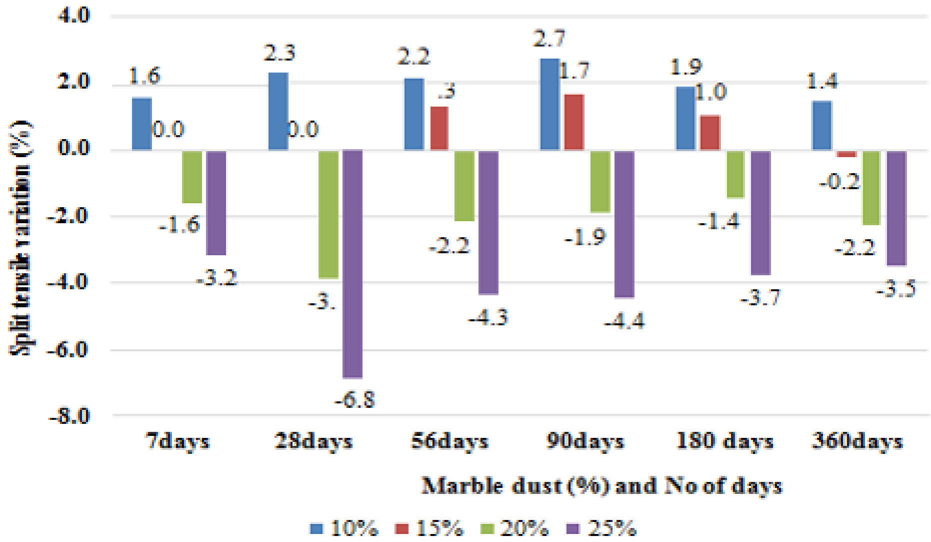
Figure 1.10: Split tensile strength in MPa vs. replacement percentage and No. of days



(a) w/b 0.35



(b) w/b 0.40



(c) w/b 0.45

Figure 1.11: (a-c) Percentage variations in Split Tensile Strength

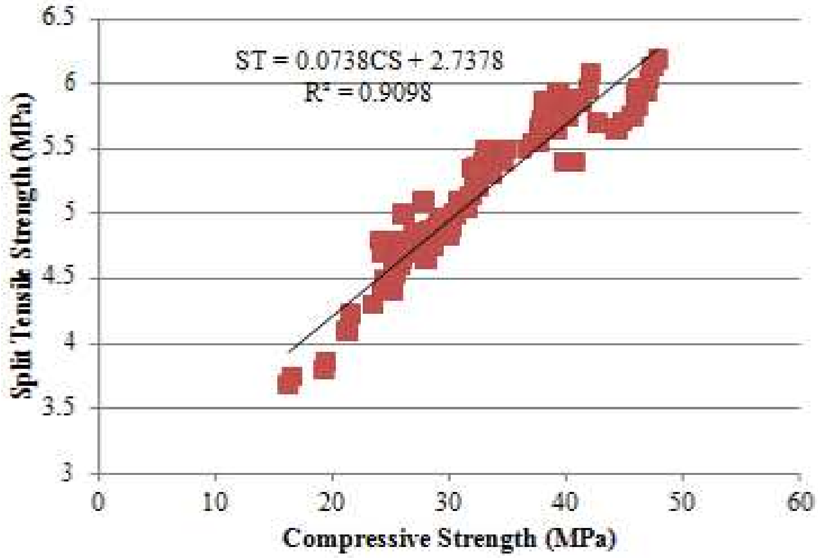
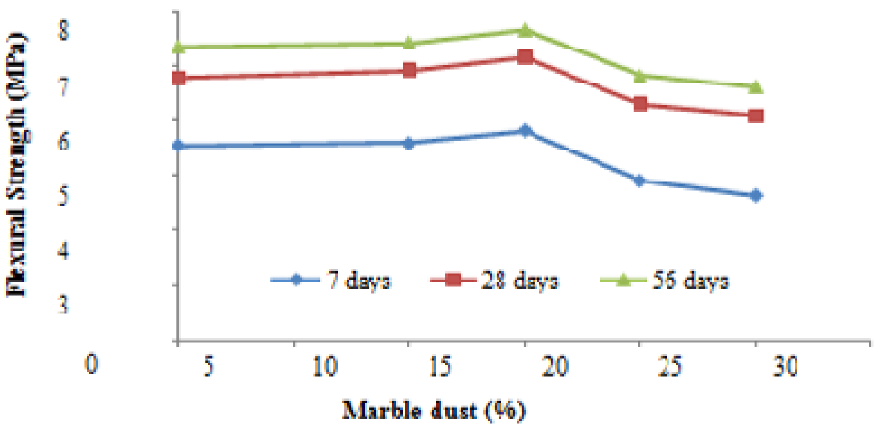


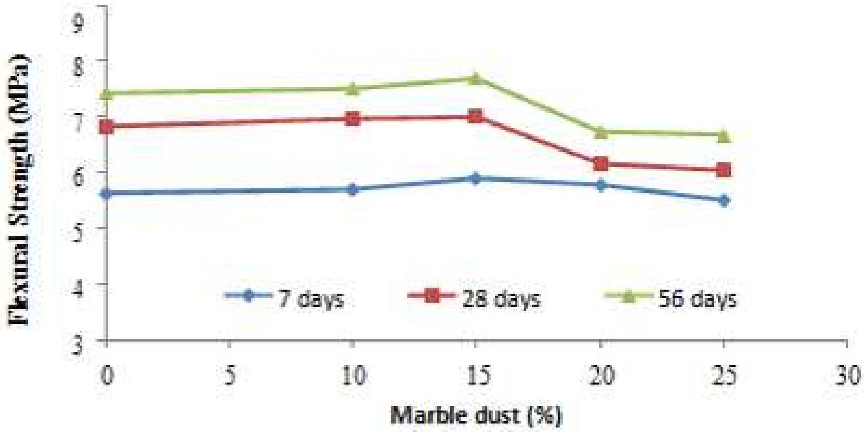
Figure 1.12: Relationship between Compressive and Split Tensile Strength

1.1.1.3 Flexural strength

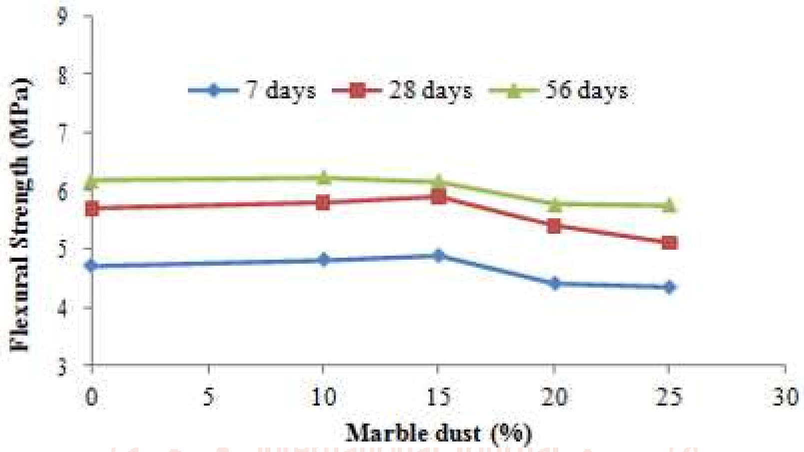
Figure 1-22 (a-c) illustrates the results of a flexural strength test for concrete in which 10 percent, 15 percent, 20 percent, and 25 percent by weight of cement is replaced with dried marble dust. There is a trend that is similar to compressive strength and split tensile strength.. Lower w/b ratios of 0.35 and 0.40 result in a 15 percent replacement gain in flexural strength, while w/b ratio 0.45 results in a very minor 10 percent replacement increase in strength. For 15% replacement, the flexural strength of w/b 0.45 is comparable to that of the control mix. There has been a documented increase in flexural strength when 10% cement is replaced with marble dust.9



(a) w/b 0.35



(b) w/b 0.40



(c) w/b 0.45

Figure 1.13: (a-c) Flexural strength test results of marble dust incorporated concrete

Experimental trails on reinforced concrete

Flexural strength

The failure loads of the beams are shown in Table 1-9. In comparison to the test mean result of 61.5 kN, the theoretical failure load for OPC concrete with a compressive strength of 25.33 MPa is 28.5 kN. In comparison to the test mean result of 66.5 kN, the predicted failure load for marble dust concrete with 15% cement replacement (S15) of compressive strength 30 MPa is 30 kN.. The increased concrete strength in the beams due to the presence of compression steel and confinement by shear reinforcement can be attributed to the substantial disparity between the computed and measured failure load. It could also be explained by higher compressive strength, which is related to the Limiting moment carrying capacity. (Mu lim) according to Annex G of IS 456 (2000) .

Deflections

Three dial gauges were placed below the beam at mid-span and one-third-sections to monitor deflections. The smallest dial gauge count was 0.01 mm. To avoid damage to the dial gauges, the deflections are only measured up to 60 kN and not up to failure loads.

Figure1-41 and Figure1-42 show the mean values of deflections at the one-third span and mid-span portions, respectively. Table 1-9 displays the results.

The behaviour of the sections and the values of deflections at a load of 60 kN at mid-span and one-third sections at 28 days are not significantly different for RS/15 and RC mix. When compared to the mid-span section, the range in values at the one-third span section is not as great. At one-third section, the RC beams have a mean deflection of 11.53 mm, whereas the RS/15 beams have a mean deflection of 11.88 mm. This is because more steel would be required to carry the load for concrete with higher strength, yet the same quantity of steel was provided for both sections.. The mean deflection at mid-span for RC beams is 13.99 mm, while for RS/15 beams it is 15.24 mm. Because the observed deflections are close together, it may be assumed that the marble dust concrete will also meet the serviceability requirements for deflections in structures.

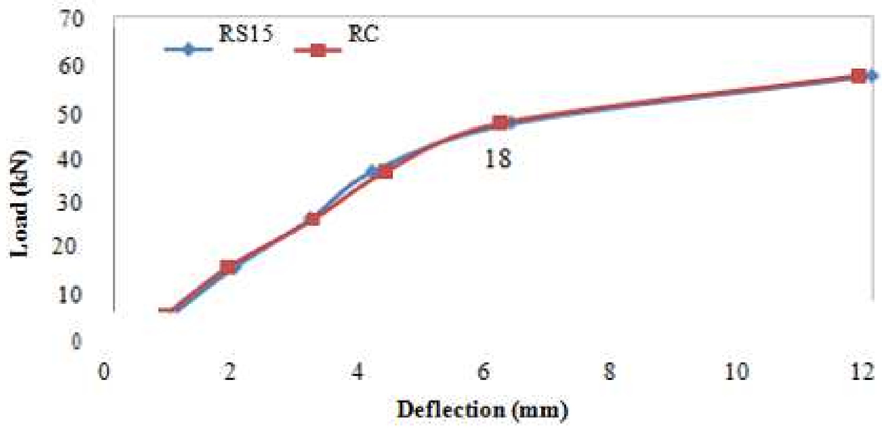


Figure 1.14: Mean values of beams at 1/3rd span at different loads

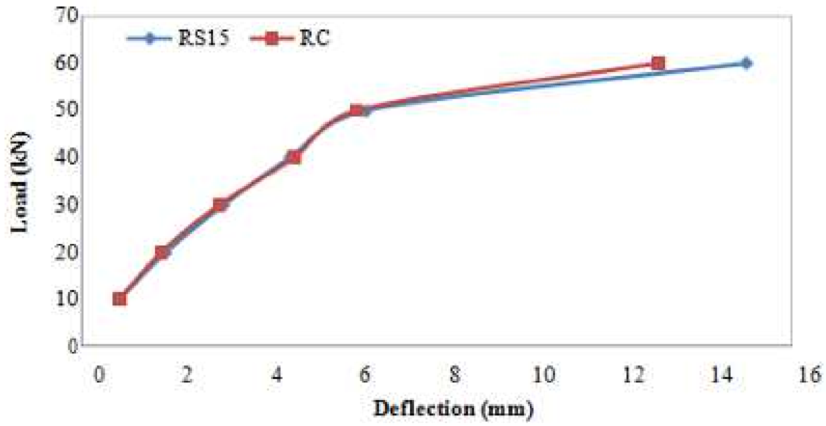


Figure 1.15: Mean values of beams at mid-section at different loads

Table 1.17: Failure loads of the beams and deflection at 60KN load at 1/3rd and mid span section

S. No.	Beam	Failure Load (kN)	Average	Deflection (mm)	Average		Average
1	RS/15 1	67.00		**1/3 section**	**Mid- span**		
2	RS/15 2	67.50	66.50	13.23	11.88	15.32	
3	RS/15 3	66.00		11.98		15.97	15.24
4	RS/15 4	65.50		12.44		15.11	
5	RC 1	62.00	61.50	9.87		14.56	
6	RC 2	61.50		12.32	11.53	14.32	13.99
7	RC 3	62.00		10.91		13.86	
8	RC 4	60.50		10.87		13.25	

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