INFLUENCE OF AGGREGATE PROPERTIES ON CHARACTERISTICS OF CONCRETE

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The characteristics of ingredients used for performing construction will affect the performance of prepared concrete. Aggregates are major constituents of concrete and it has been observed by researchers that characteristics of material used as aggregate significantly influence the strength and workability of concrete.

Here, in the present work effect of flaky aggregates and steel slag as partial replacement of coarse aggregate on the characteristics of concrete composed by replacing cement by sand has been investigated. Two types of mixes have been prepared by varying the ratio of sand and marble powder which is 1:1 and 1:0.5, coarse aggregates are partially replaced by flaky aggregate and steel slag in 10%, 15%, 20%, 25% and 30% by weight. It has been observed that increase in proportion of flaky aggregate reduces the strength and workability of concrete and increase in steel slag increases the strength of concrete but reduces the workability. Mixing both the materials simultaneously increases the early strength of concrete and then lowers the percentage increase of strength, however, produces the concrete with low workability.

Keywords:*Cement, Concrete, Aggregates, Steel slag, Marble powder*

1. Introduction

Researchers are working worldwide to enhance the characteristics of concrete by mixing admixtures and various waste alternate materials (WAMs). Previously WAMs comprises of readily available materials like diatomaceous earth or volcanic ash, but, presently majority concrete mixtures consist of alternate materials which are mainly by-product or waste materials obtained from different industrial processes.

Aggregates are important ingredients of concrete and characteristics of concrete are directly affected by the properties of aggregates (Jain and Chouhan, 2011) [1]. Formerly in the early stages of cement and concrete improvement, aggregates were considered inert. However, recent facts confirm that aggregates reveals chemical bond at the edge of aggregate and paste.

Shape and properties of material used in place of coarse and fine aggregates influences the basic characteristics of concrete such as strength and workability (Ponnada, 2014) [2]. Flakiness index and elongation index are important physical properties of mineral aggregates which affect the quality of concrete mixes (Vyawahare and Modani, 2009) [3]. Flaky aggregates influence the aggregate gradation by reducing interlocking characteristic (Siswosoebrotho et al., 2005) [4]. Cubical particles were desirable for increased aggregate internal friction and improved rutting resistance (Chen et al., 2005) [5]. Muhit et al. (2013) [6] observed that aggregate shape and properties influences the characteristics of concrete significantly. Reliability, slump or shear flow, resistance against shear, tensile and other behaviors of concrete are related to the shape of the aggregates (Polat et al. 2013)[7].

Concrete made by replacing sand attained better performance as compared to made by replacing cement (Aliabdo, 2014)[8].Experimental results reveals that by replacing 10% of sand with marble powder produces concrete with optimum strength and workability (Aruntaş et al. 2010) [9].

The major objective of this study is to assess the properties of concrete produced by replacing aggregates by steel slag and flaky aggregates in terms of slump value and load-bearing capacities. Following parameters have been determined –

(a) 28 days compressive strength
(b) Workability by slump cone method]

2.Experimental Investigation

For conducting laboratory investigation concrete mixes of compressive strength 20 MPa have been prepared using flakyaggregate or steel slag partially with blended cement. Ordinary Portland cement grade 43 has been used for this study. Fine aggregate used was river sand with fineness modulus 2.25, w/c ratio for each concrete mix is taken as from 0.45 to 0.55. Sand has been mixed with marble powder in two different ratios 1:1 and 1:0.5.

Mix has been produced by replacing coarse aggregate with flaky aggregate and steel slag in different proportions such as 5%, 10%, 15%, 20%, 25% and 30%% for each variation of sand and marble powder. Mix design has been performed to develop compressive strength of 20 MPa and following is the proportion of ingredients shown in Table 1 and Figure 1.

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Table 1

Proportion of all the ingredients in M-20 mix

Water	Cement	Sand	Course aggregate
0.5	1	1.62	3.4

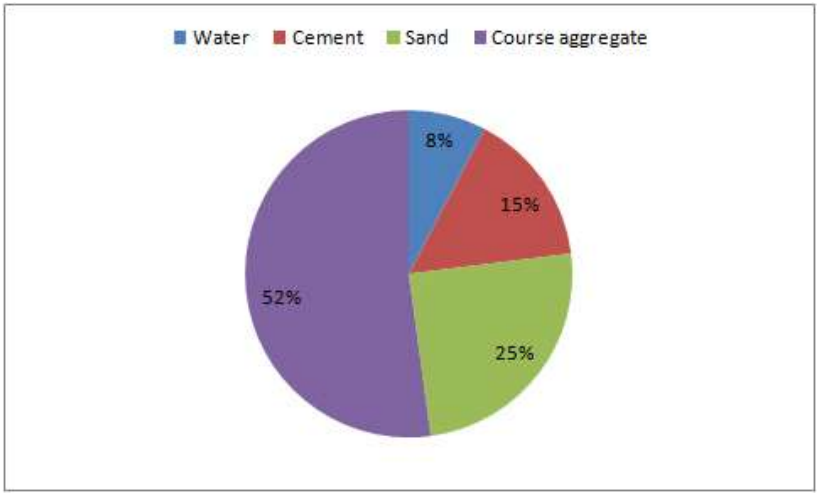

Fig. 1 – Percentage of each ingredient in prepared mix

114 concrete mixes have been prepared by varying proportions of sand, marble powder, flaky aggregates, steel slag, normal aggregates and water to cement ratio. For each sand to marble powder ratio (1:1 and 1:0.5), coarse aggregate has been partially replaced by flaky aggregate, steel slag and their composite mixture. For each replacement of aggregates three different water cement ratios 0.45, 0.5 and 0.55 have been considered. Table 2 presents the compositions of prepared concrete mixtures, this is also presented in Figure 2 and 3.

Laboratory experiments for determining compressive strength and workability of concrete had been conducted. For determining these parameters, compression test after 28 days of curing and slump cone test had been performed on the prepared concrete mixes. Results of these experiments have been shown in Table 3.

Table 2

Weight of ingredients (Kg) in prepared Concrete mixes and results of compressive strength and slump cone tests

S. No.	Concrete Mix	% Replacement of coarse aggregates	w/c ratio	Compressive strength (MPa)	Slump value (mm)
Sand/ Marble Powder (1:1)					
Replacement of Coarse aggregates by flaky aggregates					
1	Cx1	0%	0.55	19.2	97
2	Cx2	0%	0.5	19. 4	95
3	Cx3	0%	0.45	19.9	94
4	Cx4	5%	0.55	18.6	93
5	Cx5	5%	0.5	18.9	91
6	Cx6	5%	0.45	19.4	88
7	Cx7	10%	0.55	18.4	89
8	Cx8	10%	0.5	18.7	87
9	Cx9	10%	0.45	19.3	84

10	Cx10	15%	0.55	18.1	86
11	Cx11	15%	0.5	18.7	83
12	Cx12	15%	0.45	19.1	82
13	Cx13	20%	0.55	17.9	82
14	Cx14	20%	0.5	18.3	80
15	Cx15	20%	0.45	18.6	77
16	Cx16	25%	0.55	17.6	79
17	Cx17	25%	0.5	18.2	77
18	Cx18	25%	0.45	18.5	74
19	Cx19	30%	0.55	17.1	76
20	Cx20	30%	0.5	17.8	73
21	Cx21	30%	0.45	18	72
Replacement of Coarse aggregates by Steel slag					
22	Cx22	5%	0.55	19.6	92
23	Cx23	5%	0.5	19. 8	90
24	Cx24	5%	0.45	20.3	89
25	Cx25	10%	0.55	19.8	91
26	Cx26	10%	0.5	20.1	88
27	Cx27	10%	0.45	20.7	84
28	Cx28	15%	0.55	19.9	86
29	Cx29	15%	0.5	20.4	83
30	Cx30	15%	0.45	20.8	81
31	Cx31	20%	0.55	20.1	82
32	Cx32	20%	0.5	20.7	77
33	Cx33	20%	0.45	21.1	74
34	Cx34	25%	0.55	20.3	80
35	Cx35	25%	0.5	20.8	76
36	Cx36	25%	0.45	21.3	74
37	Cx37	30%	0.55	20.7	79
38	Cx38	30%	0.5	21.2	75
39	Cx39	30%	0.45	21.5	72
Replacement of Coarse aggregates by flaky aggregates and Steel slag both in same proportion					
40	Cx40	5%	0.55	19.2	91
41	Cx41	5%	0.5	19. 4	88
42	Cx42	5%	0.45	19.7	87
43	Cx43	10%	0.55	19.3	89
44	Cx44	10%	0.5	19.6	87
45	Cx45	10%	0.45	19.8	84
46	Cx46	15%	0.55	19.5	85
47	Cx47	15%	0.5	19.9	82
48	Cx48	15%	0.45	20.2	80
49	Cx49	20%	0.55	19.9	81

50	Cx50	20%	0.5	20.3	77
51	Cx51	20%	0.45	20.6	74
52	Cx52	25%	0.55	20.1	80
53	Cx53	25%	0.5	20.4	75
54	Cx54	25%	0.45	20.7	72
55	Cx55	30%	0.55	20.3	77
56	Cx56	30%	0.5	20.8	73
57	Cx57	30%	0.45	21.1	69
Sand/ Marble Powder (1:0.5)					
Replacement of Coarse aggregates by flaky aggregates					
58	Cy1	0%	0.55	19.1	99
59	Cy2	0%	0.5	19. 3	96
60	Cy3	0%	0.45	19.8	94
61	Cy4	5%	0.55	18.4	97
62	Cy5	5%	0.5	18.6	93
63	Cy6	5%	0.45	19.1	91
64	Cy7	10%	0.55	18.1	92
65	Cy8	10%	0.5	18.4	89
66	Cy9	10%	0.45	19.1	87
67	Cy10	15%	0.55	18.1	89
68	Cy11	15%	0.5	18.5	87
69	Cy12	15%	0.45	19.8	84
70	Cy13	20%	0.55	17.8	85
71	Cy14	20%	0.5	18.1	82
72	Cy15	20%	0.45	18.2	79
73	Cy16	25%	0.55	17.3	83
74	Cy17	25%	0.5	18	79
75	Cy18	25%	0.45	18.2	78
76	Cy19	30%	0.55	17	81
77	Cy20	30%	0.5	17.4	79
78	Cy21	30%	0.45	17.8	76
Replacement of Coarse aggregates by Steel slag					
79	Cy22	5%	0.55	19.2	95
80	Cy23	5%	0.5	19. 4	93
81	Cy24	5%	0.45	20	90
82	Cy25	10%	0.55	19.5	94
83	Cy26	10%	0.5	19.8	91
84	Cy27	10%	0.45	20.1	88
85	Cy28	15%	0.55	19.4	89
86	Cy29	15%	0.5	19.9	86
87	Cy30	15%	0.45	20.2	85
88	Cy31	20%	0.55	19.9	88
89	Cy32	20%	0.5	20.3	85
90	Cy33	20%	0.45	19.1	83

91	Cy34	25%	0.55	19.4	83
92	Cy35	25%	0.5	20.1	80
93	Cy36	25%	0.45	20.4	78
94	Cy37	30%	0.55	20.7	81
95	Cy38	30%	0.5	20.9	79
96	Cy39	30%	0.45	21.5	76
Replacement of Coarse aggregates by flaky aggregates and Steel slag both in same proportion					
97	Cy40	5%	0.55	19	93
98	Cy41	5%	0.5	19.3	89
99	Cy42	5%	0.45	19.5	87
100	Cy43	10%	0.55	19.1	91
101	Cy44	10%	0.5	19.4	88
102	Cy45	10%	0.45	19.7	87
103	Cy46	15%	0.55	19.3	88
104	Cy47	15%	0.5	19.4	86
105	Cy48	15%	0.45	19.8	83
106	Cy49	20%	0.55	19.6	86
107	Cy50	20%	0.5	20.1	83
108	Cy51	20%	0.45	20.4	81
109	Cy52	25%	0.55	19.8	84
110	Cy53	25%	0.5	20.1	81
111	Cy54	25%	0.45	20.3	79
112	Cy55	30%	0.55	19.7	81
113	Cy56	30%	0.5	20.1	79
114	Cy57	30%	0.45	20.4	76

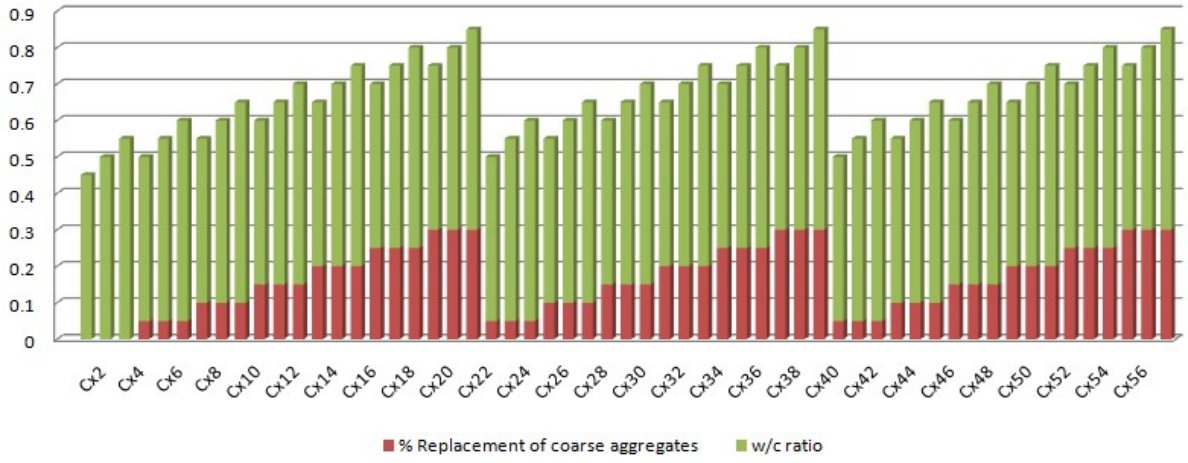

Fig. 2 – Replacement of coarse aggregate (%) and water cement ratio for concrete mixes with sand to marble powder ratio 1:1 and 1:0.5

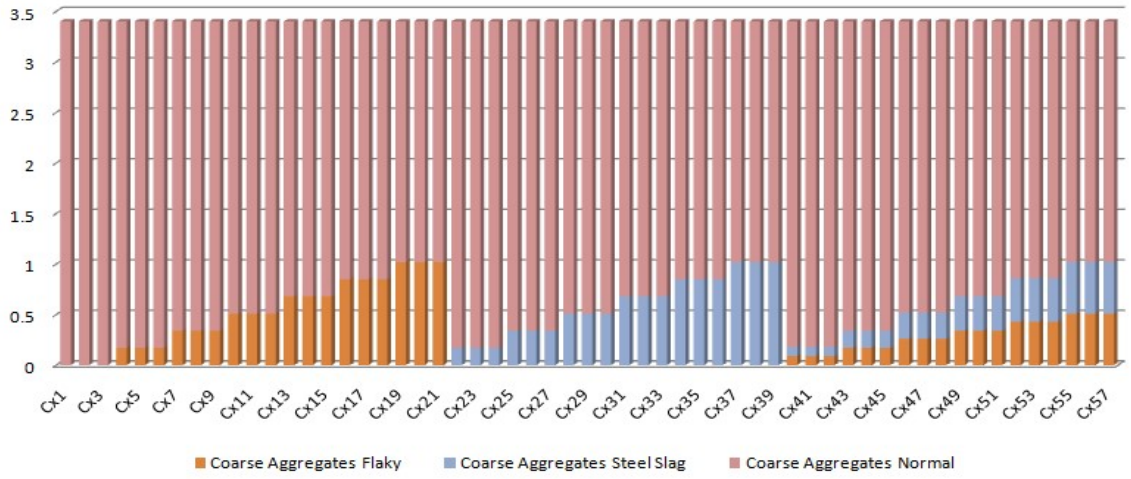

Fig. 3 – Weight of components in coarse aggregate for concrete mixes with sand to marble powder ratio 1:1 and 1:0.5

Table 3

Data with w/c 0.55 and variable flaky content with sand to marble powder ratio 1:1

Concrete Mix	Cement	% Replacement of coarse aggregates	w/c ratio	Fine Aggregates		Coarse Aggregates			Compressive strength (MPa)	Slump value (mm)
				Sand	Marble Powder	Flaky	Steel Slag	Normal		
Cx1	1	0%	0.55	0.81	0.81	0	0	3.4	19.2	97
Cx4	1	0.05	0.55	0.81	0.81	0.17	0	3.23	18.6	93
Cx7	1	0.1	0.55	0.81	0.81	0.34	0	3.06	18.4	89
Cx10	1	0.15	0.55	0.81	0.81	0.51	0	2.89	18.1	86
Cx13	1	0.2	0.55	0.81	0.81	0.68	0	2.72	17.9	82
Cx16	1	0.25	0.55	0.81	0.81	0.85	0	2.55	17.6	79
Cx19	1	0.3	0.55	0.81	0.81	1.02	0	2.38	17.1	76

3. From the table 2 following inferences have been drawn –

Increase in proportion of flaky aggregates reduces the compressive strength and slump value of concrete. This can be revealed from table 3 and Figures 4 and 5. For this different data of w/c 0.55 and variable flaky content from table 3 have been considered.

Increase in percentage of Steel slag increases the compressive strength and decreases the workability of concrete. For this different data of w/c 0.55 and variable steel slag content from table 3 have been considered and shown in table 4 and Figures 6 and 7.

Replacing normal aggregate by both flaky aggregate and steel slag increases the compressive strength of concrete with the increase in their percentages, but obtained strength is lesser than strength obtained by using only steel slag. However, this combination reduces the slump

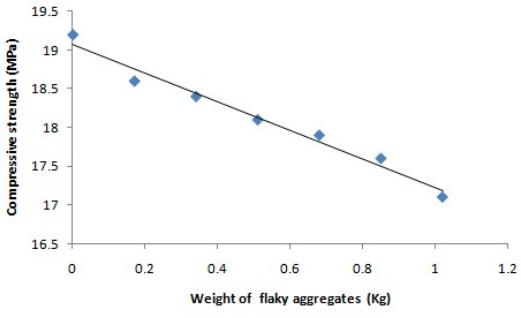

Figure 4 – Variation of compressive strength with content of flaky aggregate

value. For this different data of w/c 0.55 and variable steel slag content from table 3 have been considered. This data is presented in Table 5 and Figures 8 and 9.

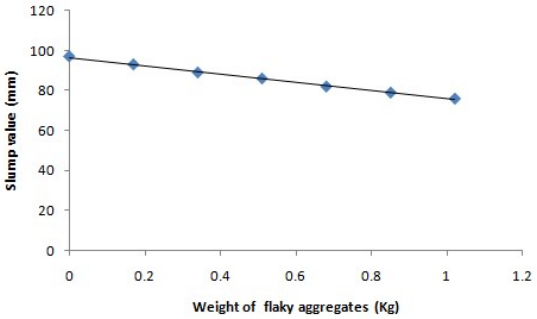

Fig. 5– Variation of slump value with content of flaky aggregate

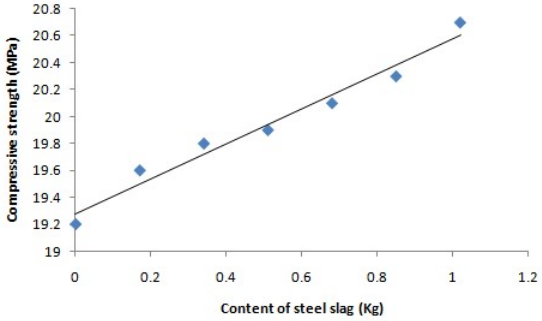

Fig. 6 – Variation of compressive strength with content of steel slag

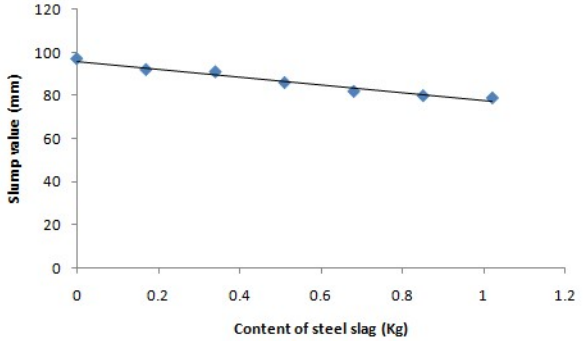

Fig. 7 – Variation of slump value with content of steel slag

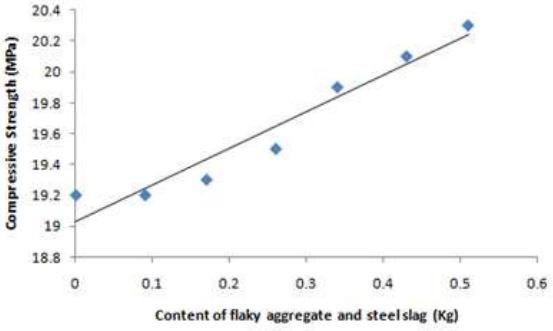

Fig. 8 – Variation of compressive strength with content of flaky aggregate and steel slag

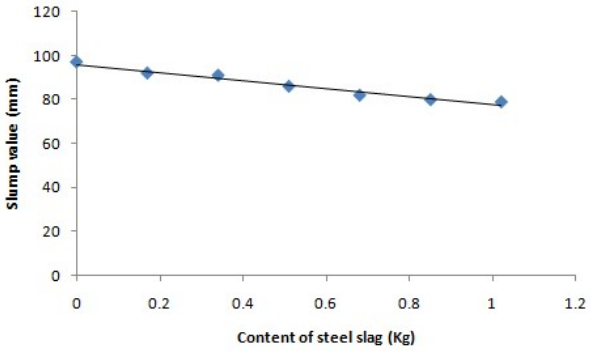

Fig. 9 – Variation of slump value with content of flaky aggregate and steel slag

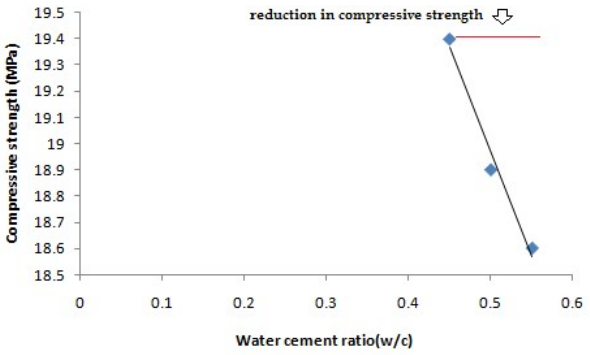

Fig. 10 – Variation of compressive strength with w/c

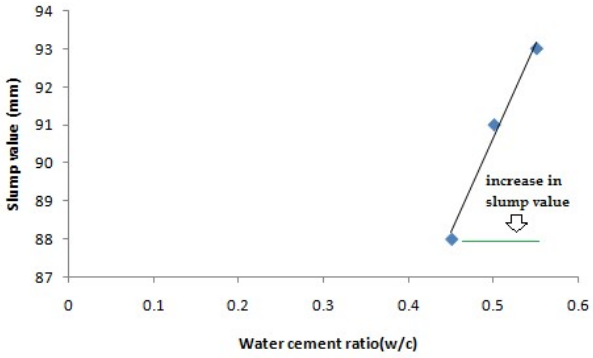

Fig. 11 – Variation of slump value with w/c

1. Increase in percentage of Marble powder reduces the strength and workability of concrete.
2. With the decrease in water cement ratio compressive strength for a fixed replacement of aggregate increases and workability reduces as shown in Figures 10 and 11

Above results are also presented in Figures 12, 13, 14 and 15.

Table 4

Data with w/c 0.55 and variable steel slag content with sand to marble powder ratio 1:1

Concrete Mix	cement	% Replacement of coarse aggregates	w/c ratio	Fine Aggregates		Coarse Aggregates			Compressive strength (MPa)	Slump value (mm)
				Sand	Marble Powder	Flaky	Steel Slag	Normal		
Cx1	1	0%	0.55	0.81	0.81	0	0	3.4	19.2	97
Cx22	1	5%	0.55	0.81	0.81	0	0.17	3.23	19.6	92
Cx25	1	10%	0.55	0.81	0.81	0	0.34	3.06	19.8	91
Cx28	1	15%	0.55	0.81	0.81	0	0.51	2.89	19.9	86
Cx31	1	20%	0.55	0.81	0.81	0	0.68	2.72	20.1	82
Cx34	1	25%	0.55	0.81	0.81	0	0.85	2.55	20.3	80
Cx37	1	30%	0.55	0.81	0.81	0	1.02	2.38	20.7	79

Table 5

Data with w/c 0.55 and variable steel slag and flaky content with sand to marble powder ratio 1:1

Concrete Mix	cement	% Replacement of coarse aggregates	w/c ratio	Fine Aggregates		Coarse Aggregates			Compressive strength (MPa)	Slump value (mm)
				Sand	Marble Powder	Flaky	Steel Slag	Normal		
Cx1	1	0%	0.55	0.81	0.81	0	0	97	19.2	97
Cx40	1	5%	0.55	0.81	0.81	0.09	0.09	3.22	19.2	91
Cx43	1	10%	0.55	0.81	0.81	0.17	0.17	3.06	19.3	89
Cx46	1	15%	0.55	0.81	0.81	0.26	0.26	2.88	19.5	85
Cx49	1	20%	0.55	0.81	0.81	0.34	0.34	2.72	19.9	81
Cx52	1	25%	0.55	0.81	0.81	0.43	0.43	2.54	20.1	80
Cx55	1	30%	0.55	0.81	0.81	0.51	0.51	2.38	20.3	77

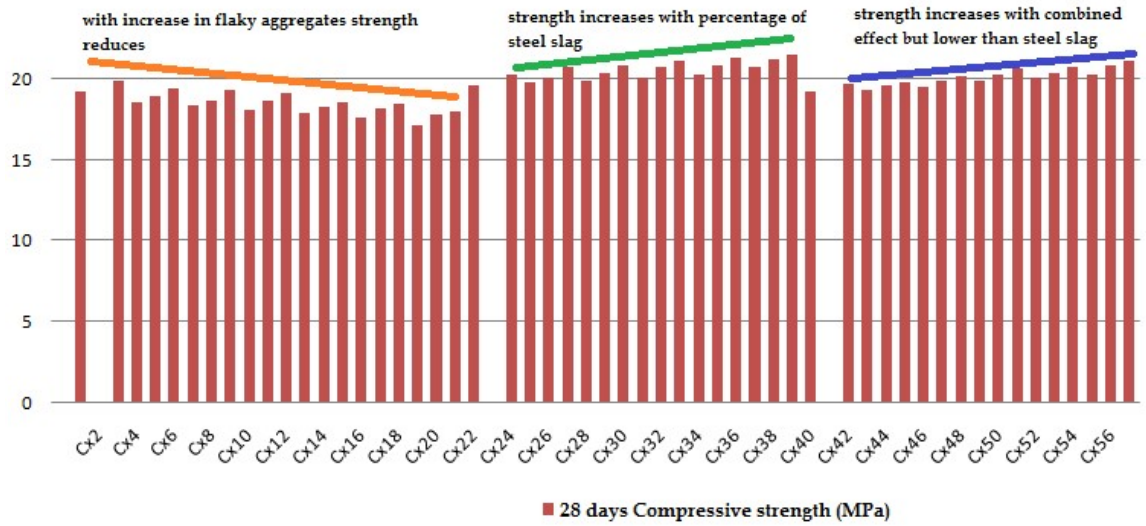

Fig. 12 – Compressive strength of concrete mixes with sand to marble powder ratio 1:1

Fig. 13 – Slump value of concrete mixes with sand to marble powder ratio 1:1

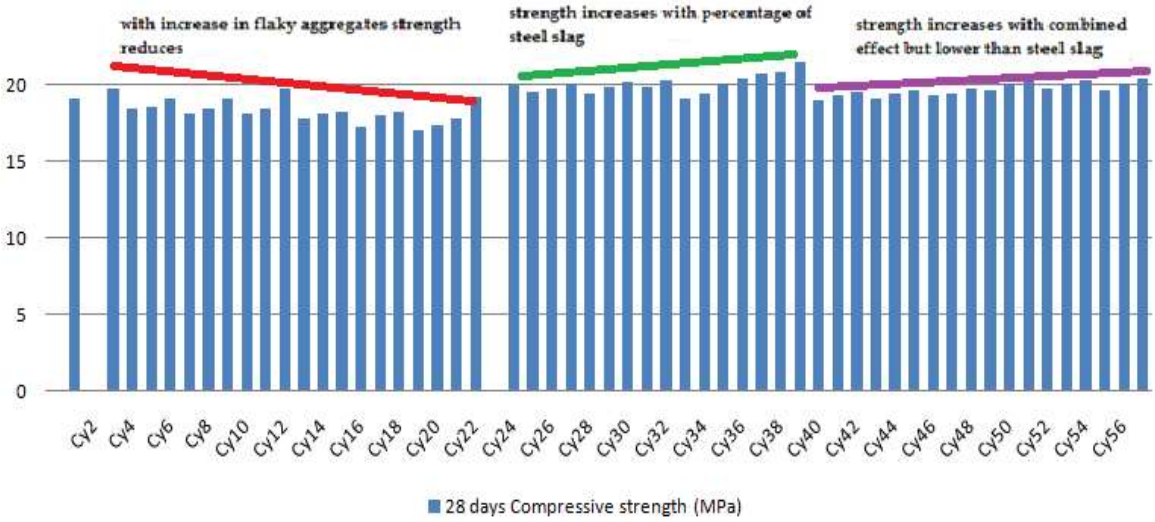

Fig. 14 – Compressive strength of concrete mixes with sand to marble powder ratio 1:0.5

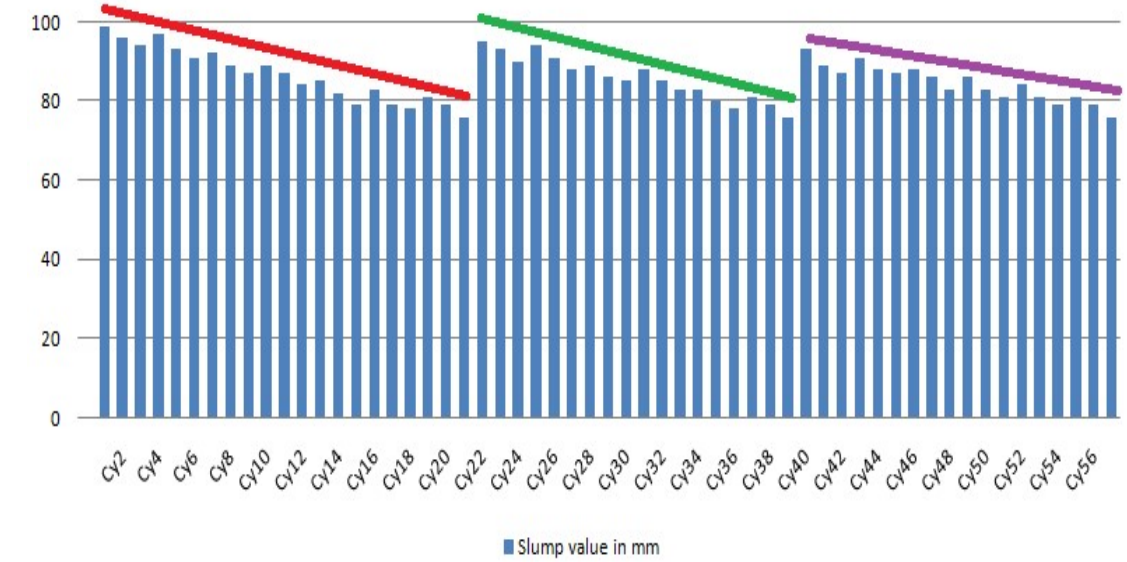

Fig. 15 – Slump value of concrete mixes with sand to marble powder ratio 1:0.5

4.Conclusions

An experimental study has been performed to evaluate the combined effect of using partially Flaky aggregates steel slag and marble powder over the compressive strength and workability of concrete. Following are the conclusions of the experimental works –

1. It has been observed from that concrete mixtures formed with 0 and 5% replacement of normal aggregate with flaky is almost equivalent with the values of 100% normal aggregate.
2. With the increase in percentage of flaky aggregate values of compressive strength and slump cone reduces.
3. With the increase in percentage of steel slag values of compressive strength increases and value of slump cone reduces.
4. When flaky aggregate and steel slags are used together moderate value of both compressive strength and slump values are obtained.
5. With decrease in water cement ratio values of compressive strength increases and slump value reduces.
6. Additional effect of marble powder over the variation of flaky aggregates and steel has been determined by using sand with marble powder in different proportions, 1:1 and 1:0.5. Increase in Proportion of Marble powder reduces the compressive strength for a flaky aggregate proportion.
7. Increase in percentage of marble powder reduces the slump value for a flaky aggregate proportion.

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