Modeling The Characteristics Of Concrete With Different Aggregates*

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Abstract

Here, in the present work combined effect of flaky aggregates and steel slag as partial replacement of coarse aggregate over the behavior of concrete prepared using marble powder as replacement of sand has been investigated. Two types of concrete mixes have been prepared by varying the ration of sand and marble powder which is 1:1 and 1:0.5. Using laboratory results a model has been developed to determine the compressive strength and slump values based on Percentage replacement of coarse aggregate, w/c ration, proportion of sand, marble powder, flaky aggregate and steel slag. The outputs produced by the model have been compared with the target outputs, which are the compressive strengths obtained experimentally.

Keywords— Cement, Concrete, Aggregates, Characteristics, Modeling.

I INTRODUCTION

The dimensions of aggregates and material used in place of coarse and fine aggregates are crucial characteristic, and these influences the basic characteristics of concrete such as strength and workability. Along with the shape of the aggregates, the texture of the coarse aggregate are also associated. Several researchers disagree with round aggregates due to bonding between aggregates and cement. The adhesion or bonding between cement paste and the aggregate has been subjected to several complex factors besides the physical and mechanical properties; this fact has been revealed by several researches and experiment. With the increase in smoothness of surface there is a decrease in contact area, hence a greatly refined and smooth particle will have low bonding in terms of area in comparison with a rough particle of the same quantity. 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]. (Qing-feng Liu, et. al. 2018) [6] This study investigates the impact of aggregate morphology on ionic migration in concrete-based structures. Using advanced numerical models and a multi-component ionic transport theory, the research explores how various factors, including aggregate shape, external electric fields, concrete heterogeneity, and interfacial transition zones, influence the transport mechanism. This thorough analysis uncovers previously unexplored insights into the interplay between aggregate shape and ionic migration, contributing valuable knowledge for enhancing the durability of concrete infrastructure. (Patrícia S. Lovato et. al. 2012) [7] This study addresses the use of recycled aggregates in concrete production, motivated by the need to preserve natural resources. Response surface methodology (RSM) is employed to assess mechanical and durability properties, considering different aggregate levels and water-cement ratios. The results highlight the influence of recycled aggregates on water absorption, carbonation depth, and mechanical properties. Notably, substituting up to 50% of conventional aggregates with recycled materials proves feasible from technical, economic, and environmental standpoints. (Huan Zhang, et. al. 2019) [8] Concrete composite mechanical properties are deeply influenced by ingredient composition and meso-structure, particularly aggregate characteristics. Creating accurate meso-scale models for predictive performance and structural optimization is crucial. This novel approach efficiently achieves high-volume fraction models with randomly distributed aggregates, maintaining statistical realism. Simulation results aligning with experimental data confirm the models' accuracy, validating their utility for performance prediction.

Aggregate is significantly vital matter in concrete that most of the properties and workability of concrete are directly altered with the properties of aggregates. Formerly in the early stages of cement and concrete improvement, aggregates were considered inert when considered chemically and detained collectively by cement. However, recent facts confirm that aggregates reveals chemical bond at the edge of aggregate and paste.

II OBJECTIVES

The major objective of this study is to assess the different properties of cement concrete produced by replacing normal aggregate by steel slag and flaky aggregates in terms of slump value and load-bearing capacities. Results of this study will presents the effects of aggregate type on the concrete produced by fusion of sand with marble powder on workability and compressive strength of concrete. Following parameters have been determined –

a) Compressive strength after 3, 14 and 28 days
b) Workabilit

Objectives of the this study are summarized as following -

a) To study the suitability of waste alternate materials in the construction industry.
b) To assess the effects of replacing aggregates with alternate materials over different properties.

III. MODELING OF EXPERIMENTAL DATA

Concrete mixes of target strength 20MPa were casted and Ordinary Portland cement of grade 43 has been used for this study. Sand has been mixed with marble powder in two different ratios 1:1 and 1:0.5. Mixes were 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. 114 types of concrete mixes have been prepared by varying proportions of sand, marble powder, flaky aggregates, steel slag, normal aggregates and water to cement ratio. Laboratory experiments for determining compressive strength and workability of concrete had been conducted. To obtain the combined effect of proportions of flaky aggregates, steel aggregates and marble powder artificial neural network has been used in the present research, in which Multi Layer Feed Forward Network is used. Neural Network Input Variables used for parametric study are tabulated in Table-5.2.

Table-5.1 Summary of Input Data

S. No.	Input Data		Range
1	% Replacement of coarse aggregates		0-30%
2	w/c ratio		0.45-0.55
3	Fine Aggregates	Sand	0.81-1.08
		Marble Powder	0.54-0.81
4	Coarse Aggregates	Flaky	0-1.02
		Steel Slag	0-1.02
		Normal	2.38-3.4

A total of 114 different experimental results are employed as a database. Total data set is divided into training set (70%), test set (15%) and validation set (15%). The predicted results are as follows:

Table 5.2- Comparison of experimental and predicted data

Sand/ Marble Powder (1:1)							
S. No.	Concrete Mix	Compressive strength	Predicted Compressive strength	Error %	Slump height in mm	Predicted Slump in mm	Error %
1	Cx1	19.2	19.09	0.57	97	97.42	-0.43
2	Cx2	19. 4	19.68	-1.44	95	93.44	1.64
3	Cx3	19.9	20.05	-0.77	94	93.4	0.63
4	Cx4	18.6	18.62	-0.08	93	92.1	0.96
5	Cx5	18.9	18.92	-0.11	91	88.82	2.39
6	Cx6	19.4	19.4	-0.02	88	87.87	0.14
7	Cx7	18.4	18.28	0.66	89	89.2	-0.22
8	Cx8	18.7	18.73	-0.18	87	86.01	1.14
9	Cx9	19.3	19.41	-0.59	84	84.5	-0.59
10	Cx10	18.1	18.07	0.18	86	85.91	0.11
11	Cx11	18.7	18.59	0.57	83	83.16	-0.19
12	Cx12	19.1	19.27	-0.89	82	81.62	0.46
13	Cx13	17.9	17.78	0.69	82	81.93	0.08
14	Cx14	18.3	18.32	-0.12	80	80.81	-1.02
15	Cx15	18.6	18.91	-1.66	77	77.85	-1.1
16	Cx16	17.6	17.54	0.36	79	78.94	0.08
17	Cx17	18.2	18.04	0.89	77	76.56	0.57
18	Cx18	18.5	18.46	0.2	74	73.81	0.26
19	Cx19	17.1	17.39	-1.69	76	76.52	-0.68
20	Cx20	17.8	17.8	-0.02	73	73.55	-0.75
21	Cx21	18	18.06	-0.31	72	72.18	-0.26
22	Cx22	19.6	19.57	0.16	92	94.06	-2.24
23	Cx23	19. 8	19.87	-0.36	90	90.17	-0.18
24	Cx24	20.3	20.23	0.36	89	89.4	-0.45
25	Cx25	19.8	19.93	-0.65	91	90.2	0.88
26	Cx26	20.1	20.21	-0.57	88	86.99	1.15
27	Cx27	20.7	20.58	0.58	84	84.1	-0.12
28	Cx28	19.9	20.02	-0.6	86	87.15	-1.34
29	Cx29	20.4	20.45	-0.23	83	82.39	0.73
30	Cx30	20.8	20.85	-0.26	81	78.48	3.11
31	Cx31	20.1	20.15	-0.23	82	82.6	-0.73
32	Cx32	20.7	20.64	0.31	77	77.73	-0.95
33	Cx33	21.1	21.05	0.26	74	74.11	-0.15
34	Cx34	20.3	20.39	-0.47	80	80.23	-0.28
35	Cx35	20.8	20.82	-0.09	76	75.86	0.18
36	Cx36	21.3	21.16	0.66	74	72.34	2.25
37	Cx37	20.7	20.68	0.12	79	78.86	0.18
38	Cx38	21.2	20.99	0.99	75	73.94	1.41

39	Cx39	21.5	21.23	1.26	72	71.37	0.88
40	Cx40	19.2	19.18	0.12	91	92.18	-1.3
41	Cx41	19. 4	19.48	-0.41	88	88.72	-0.81
42	Cx42	19.7	19.86	-0.83	87	88.31	-1.51
43	Cx43	19.3	19.33	-0.16	89	89.13	-0.15
44	Cx44	19.6	19.68	-0.4	87	86.36	0.73
45	Cx45	19.8	20.13	-1.68	84	84.24	-0.29
46	Cx46	19.5	19.64	-0.73	85	85.44	-0.52
47	Cx47	19.9	20.06	-0.81	82	81.79	0.26
48	Cx48	20.2	20.44	-1.18	80	79.76	0.3
49	Cx49	19.9	19.89	0.06	81	81.09	-0.12
50	Cx50	20.3	20.32	-0.1	77	77.75	-0.98
51	Cx51	20.6	20.64	-0.18	74	74.57	-0.77
52	Cx52	20.1	20.11	-0.04	80	76.86	3.92
53	Cx53	20.4	20.57	-0.81	75	74.65	0.47
54	Cx54	20.7	20.81	-0.54	72	72.19	-0.27
55	Cx55	20.3	20.29	0.07	77	76.52	0.62
56	Cx56	20.8	20.73	0.35	73	73.15	-0.21
57	Cx57	21.1	20.9	0.94	69	71.41	-3.49

Sand/ Marble Powder (1:0.5)							
S. No.	**Concrete Mix**	**Compressive strength**	**Predicted Compressive strength**	**Error %**	**Slump height in mm**	**Predicted Slump in mm**	**Error %**
1	Cy1	19.1	19.08	0.11	99	97.4	1.61
2	Cy2	19. 3	19.47	-0.88	96	96.16	2.87
3	Cy3	19.8	19.91	-0.53	94	93.73	2.36
4	Cy4	18.4	18.57	-0.91	97	92.4	1.7
5	Cy5	18.6	18.82	-1.17	93	91.71	5.45
6	Cy6	19.1	19.25	-0.8	91	88.76	4.56
7	Cy7	18.1	18.27	-0.92	92	91.35	-0.38
8	Cy8	18.4	18.61	-1.15	89	89.02	3.24
9	Cy9	19.1	19.24	-0.73	87	87.22	2
10	Cy10	18.1	18.07	0.17	89	89.04	-2.35
11	Cy11	18.5	18.44	0.32	87	86.51	2.79
12	Cy12	19.8	19.07	3.68	84	83.9	3.56
13	Cy13	17.8	17.75	0.3	85	85.17	-1.39
14	Cy14	18.1	18.12	-0.09	82	82.07	3.45
15	Cy15	18.2	18.65	-2.5	79	79.67	2.84
16	Cy16	17.3	17.48	-1.06	83	82.47	-4.4
17	Cy17	18	17.79	1.19	79	79.76	3.9
18	Cy18	18.2	18.16	0.21	78	77.64	1.72
19	Cy19	17	17.33	-1.92	81	81.19	-4.09

20	Cy20	17.4	17.53	-0.76	79	78.66	2.89
21	Cy21	17.8	17.75	0.3	76	75.88	3.95
22	Cy22	19.2	19.3	-0.5	95	95.37	-25.49
23	Cy23	19. 4	19.49	-0.46	93	93.94	1.11
24	Cy24	20	19.91	0.45	90	90.47	2.72
25	Cy25	19.5	19.5	0.02	94	93.18	-3.53
26	Cy26	19.8	19.66	0.7	91	90.65	3.56
27	Cy27	20.1	20.13	-0.13	88	87.64	3.69
28	Cy28	19.4	19.49	-0.48	89	89.22	-1.39
29	Cy29	19.9	19.81	0.47	86	85.78	3.62
30	Cy30	20.2	20.28	-0.37	85	84.01	2.31
31	Cy31	19.9	19.58	1.63	88	85.82	-0.96
32	Cy32	20.3	20.05	1.25	85	83.86	4.7
33	Cy33	19.1	20.43	-6.98	83	82.37	3.09
34	Cy34	19.4	19.9	-2.55	83	82.79	0.25
35	Cy35	20.1	20.38	-1.39	80	81.21	2.16
36	Cy36	20.4	20.62	-1.06	78	79.48	0.65
37	Cy37	20.7	20.36	1.66	81	81.13	-4.02
38	Cy38	20.9	20.72	0.85	79	78.7	2.84
39	Cy39	21.5	20.8	3.24	76	76.02	3.78
40	Cy40	19	18.96	0.22	93	93.68	-23.27
41	Cy41	19.3	19.21	0.47	89	92.64	0.38
42	Cy42	19.5	19.61	-0.58	87	89.42	-0.48
43	Cy43	19.1	18.99	0.6	91	91.91	-5.64
44	Cy44	19.4	19.32	0.4	88	89.65	1.48
45	Cy45	19.7	19.81	-0.54	87	87.6	0.45
46	Cy46	19.3	19.27	0.15	88	88.73	-1.99
47	Cy47	19.4	19.59	-0.99	86	85.75	2.55
48	Cy48	19.8	19.98	-0.93	83	83.52	2.88
49	Cy49	19.6	19.59	0.06	86	85.51	-3.03
50	Cy50	20.1	19.84	1.29	83	83.19	3.27
51	Cy51	20.4	20.08	1.55	81	80.78	2.67
52	Cy52	19.8	19.87	-0.34	84	84.04	-3.76
53	Cy53	20.1	20.07	0.17	81	81.24	3.28
54	Cy54	20.3	20.16	0.71	79	78.64	2.91
55	Cy55	19.7	20.13	-2.19	81	81.72	-3.44
56	Cy56	20.1	20.26	-0.82	79	78.95	2.52
57	Cy57	20.4	20.23	0.86	76	76.28	3.44

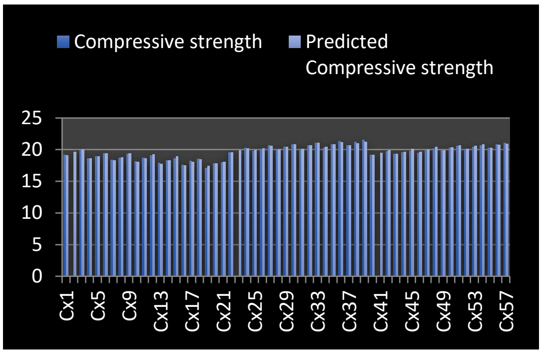

Fig. 5.19. Strength comparison (Sand/ Marble Powder (1:1))

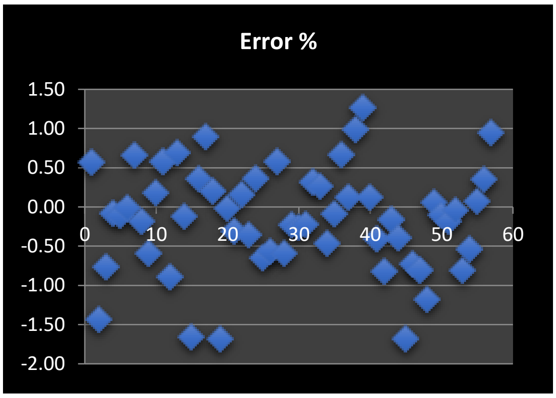

Fig. 5.20. Error between actual and predicted strength(Sand/ Marble Powder (1:1))

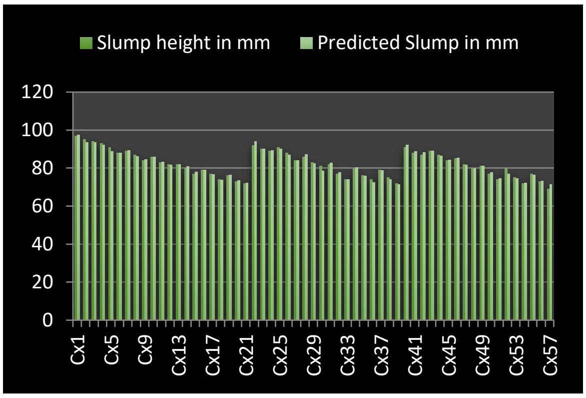

Fig. 5.21. Slump comparison (Sand/ Marble Powder (1:1))

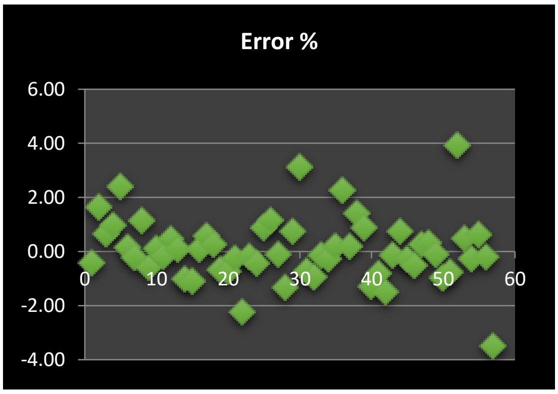

Fig. 5.22. Error between actual and predicted Slump (Sand/ Marble Powder (1:1))

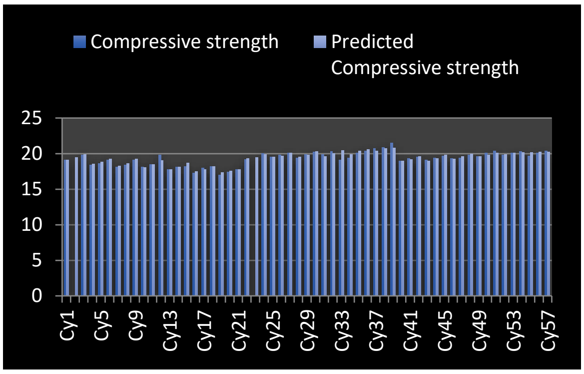

Fig. 5.23. Strength comparison (Sand/ Marble Powder (1:0.5))

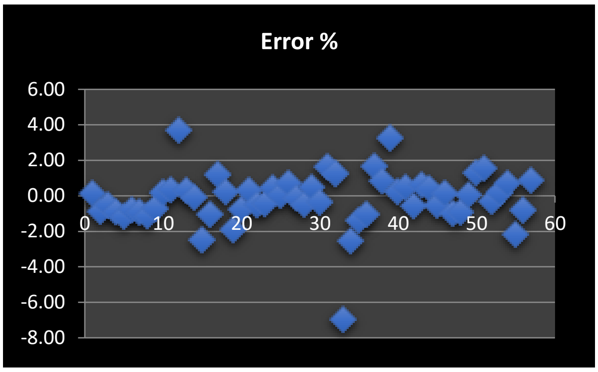

Fig. 5.24. Error between actual and predicted strength(Sand/ Marble Powder (1:0.5)

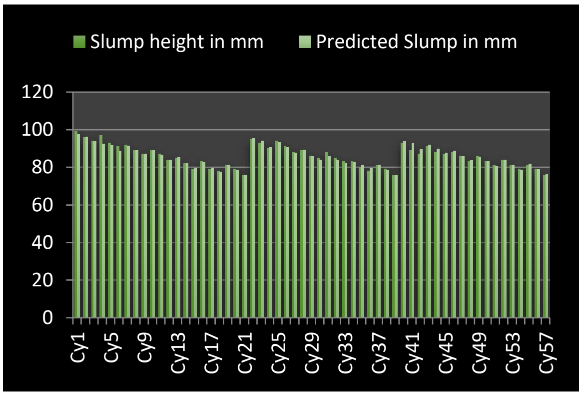

Fig. 5.25. Slump comparison (Sand/ Marble Powder (1:0.5))

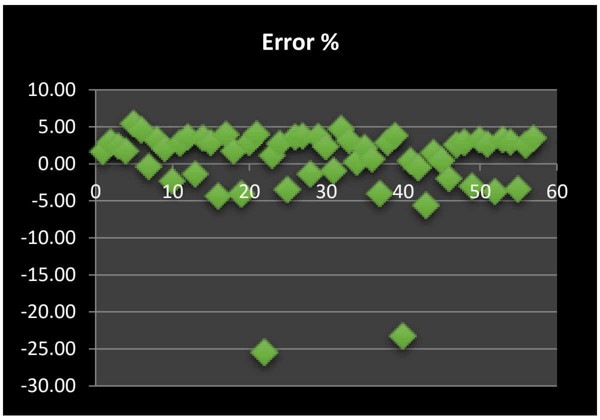

Fig. 5.26. Error between actual and predicted Slump (Sand/ Marble Powder (1:0.5))

V CONCLUSION

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. Results of performed experiments have been used to develop an ANN model. Following are the conclusions of the experimental works –

- Additional effect of marble powder over the variation of flaky aggregates and steel has been determined by sand with glass powder in different proportions, 1:1 and 1:0.5 for each variation of flaky aggregate.
- Using laboratory results an ANN model has been developed to determine the compressive strength and slump values based on Percentage replacement of coarse aggregate, w/c ration, proportion of sand, marble powder, flaky aggregate and steel slag.
- A total of 114 different experimental results are employed as a database. Total data set is divided into training set (70%), test set (15%) and validation set (15%)
- The outputs produced by the model have been compared with the target outputs, which are the compressive strengths obtained experimentally. It has been observed that MSE decreased after each run.

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