Predictive Models for Determining Compressive Strength of Concrete with Marble Dust as a Partial Replacement of Cement with the Application of ANN

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Abstract. This paper proposes an experimental study of the influence of waste marble dust used as supplementary cementitious material on the mechanical properties and durability of concrete Mix25. Marble is a metamorphic form of limestone ($CaCO_3$). Waste marble dust has been elected as the replacement for cement for the reason of having high calcium oxide content present in marble dust. It uses marble dust as a partial replacement to accomplish sustainable concrete. That will be a sustainable move toward the environment by using waste dust segregated from the wastage of marble cutting. Second, the WMP has a specific gravity of 2.6 and the specific gravity of cement is 3.16, which helps to reduce the weight of concrete as much as we add up the marble dust. Based on previous studies, concrete mixes are prepared at the replacement percent of 10%, 20%, 30%, and 40%. The compressive strength of the concrete was evaluated with this partial replacement of cement with marble dust. Also, workability, fineness, consistency & the initial setting time test are performed. The analysis of the experimental result on concrete at 10%, 20%, 30%, 40% content of waste marble dust shows that it contributes to increase of the workability of concrete. On the contrary, it will reduce the strength of concrete as the quantity of marble dust increases.

Keywords: Artificial neural network (ANN), Waste marble dust, Sustainable concrete, Compressive strength, Regression model.

1 Introduction

Civil engineering is the area of professional engineering that deals with planning, constructing, and maintaining the built and naturally occurring environments, including all of the work that goes into making things like roads, dams, parks, bridges, and buildings. [1-4]. It is fragmented into several subdisciplines with environmental engineering, geotechnical engineering,

ICO-SEID 2022, November 23-24, Jakarta, Indonesia

DOI 10.4108/eai.23-11-2022.2341574

infrastructure and construction procedures, etc. This study deals with the forward-thinking construction method by concrete products like cement that different waste materials will replace. Concrete is an indispensable building material that is majorly and widely used in the infrastructure constructions such as buildings, bridges, highways, dams and many other complicated structures [5-7]. Cement manufacturing emits 7% approx of CO_2. of total greenhouse gases emitted to the ecological atmosphere. Waste marble dust was produced as a by-product through the cutting of marble. The waste is roughly 20% of the overall marble handled. The marble waste generated every year is in tonnes, discarded in the open space. This leads to severe environmental & dust pollution, which may lead to contamination below the groundwater reserve [9-13].

The ecological problems ascribed by waste marble dust enacts hazards to the environment's ecosystem, physical, chemical, and biological apparatuses. So, it becomes necessary to reuse the waste dust, which shall resolve most environmental concerns [14-16]. Artificial Neural Network (ANN) has evolved into a useful and efficient technique for handling complexity in all engineering disciplines today. It can quickly analyse relevant data and find solutions to issues. The reinforced cement concrete compressive strength prediction has excellent ramifications. Concrete would be able to overcome the ultimate bond strength because it would help to make an identical significant modification in a parameter, and because it is quick and compatible. In the future, ANN will assume the initiative in analysing and predicting the various characteristics of concrete without wasting time or money. We only have the raw information about how they have previously used that substance. In this paper, ANN was used to compute the prediction instance. Regression method [17–22] to estimate and forecast the dependent variable (concrete bond strength) in ANN and FL is being used in this research. The main objective of the work is to reduce the cost of making concrete by using leftover marble dust to investigate the effects of marble dust as a partial replacement for cement. The variations in compressive strength between concrete and marble dust ratios are compared in this study.

2 Methodology

All the materials were collected and mixed to form concrete samples. The samples were tested by a standard destructive test& non-destructive test. As per the specifications of IS 10262:2009 [23] & IS 12269 :2013 [24] design mix of M25 grade has been prepared using 43 grade Ordinary Portland Cement and cast into the required samples. Confirming to grade as per IS 383 – 1973 [25] the coarse aggregate of 20 mm size was collected with the specific gravity of 2.86. The specific gravity of fine aggregate and cement was 2.66 and 3.25 respectively. The percentage of marble dust replacement in the mix proportions are shown below in Table 1.

Table 1: Percentage of marble dust replacement in the concrete sample

Mix Proportions	Percentage of marble dust replacement in the sample	
	Cement (%)	Marble Dust (%)
CM*	100	0
C90MD10	90	10
C80MD20	80	20
C70MD30	70	30

C60MD40	60	40

*CM represents Control Mix, whereas C90MD10 indicates 90% of cement and 10% of marble dust in the specimens.

IS:7320–1974 Reaffirmed1999 [26] was referred to determine the workability of the concrete mixes by performing slump test. The rheological properties of cement and marble dust paste is performed using
standard consistency test of cement by vicat apparatus IS 4031 – Part IV [27].
Destructive and non-destructive tests were performed on M25 grade concrete for this experimental study. For the test, five types of concrete mixes were prepared as given in Table no.1. Concrete cubes of 150*150*150mm were used to cast the concrete cubes for the determination of compressive test strength. All the specimen was casted and appropriately compacted by the help of a vibrating table. It was demoulded and cured as per requirement and testing condition and divided into three testing phases 7, 14, and 28days, respectively. Mix design of M25 grade concrete with cement and marble dust as per IS10262:2019 [23] and mix proportion is represented in Table 2.

Table 2: Mix proportion of Concrete

Mix proportions	Mix ID	Coarse aggregate	Fine aggregate	Marble Dust	Cement	Water
		(Divided by weight of cement [a])				
CM	M0	2.886	1.51	0.0	1	0.45
C90MD10	M1	2.886	1.51	0.1	0.9	0.45
C80MD20	M2	2.886	1.51	0.2	0.8	0.45
C70MD30	M3	2.886	1.51	0.3	0.7	0.45
C60MD40	M4	2.886	1.51	0.4	0.6	0.45

[a] Cement = 416.43 kg/m^3

Concrete moulds were prepared accordingly for the compressive strength test. Non-destructive and destructive both test was performed respectively on the casted and cured samples as per IS: 516-1959 [28]. ANN is used to validate the experimental data by implementing the regression technique, a mathematical integrated process, used to tackle the complex data and interpret it before the time bond. ANN predict the reliable equation and also gives the prediction rate that how much the equation has the probability of achieving the desired output with the help of certain instance of a particular constituent. In this study, the purpose is to interpret the data of marble dust-based concrete. The purpose of this interpretation is to validate and to expand the output based on several instances. and to interpret the compressive strength of concrete by the help of generated equation.

3 Results and Discussion

3.1 Fresh properties:

3.1.1 Fineness test

The fineness of the fresh cement paste of the control mix was observed to increase with marble dust content, as shown in **Figure 1.** The fineness of the fresh cement paste was observed to increase with 40% marble content and 60% cement. This is due to the reasons that the marble dust particles are comparatively smaller than cement particles.

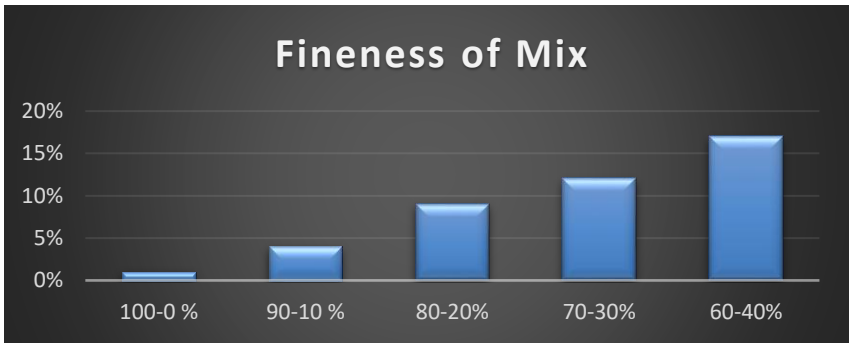

Fig. 1. Fineness of fresh cement and marble dust paste

3.1.2 Consistency Test

The consistency of the fresh cement and marble dust paste was observed to increase with marble dust content in the content, as shown in **Figure 2**. This again may be due to the reason that dust particles are comparatively smaller smooth as compared to cement particles.

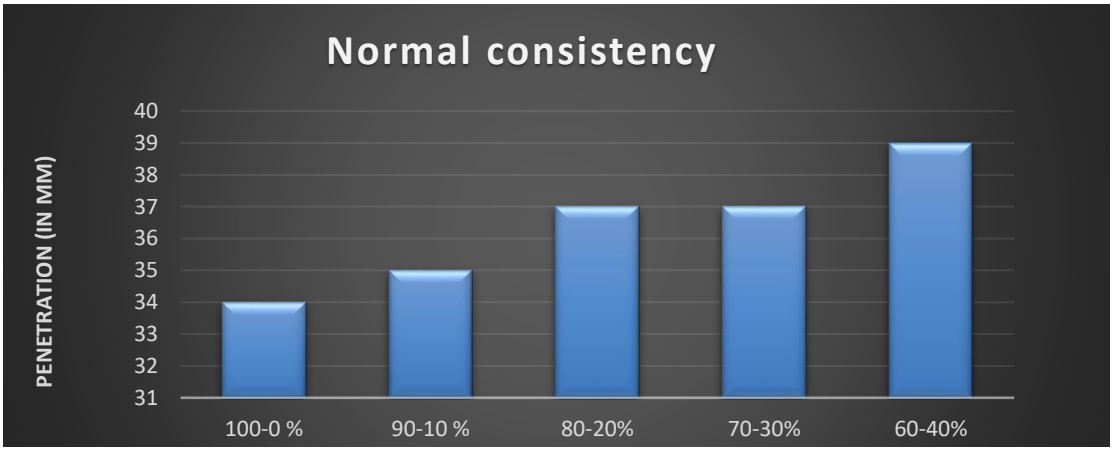

Fig. 2: Normal consistency of Cement paste

3.1.2 Slump test

The slump of the fresh concrete was observed to increase with marble dust content in the content, as shown in **Figure 3**. This again may be due to the reason that dust particles are comparatively smaller smooth as compared to cement particles. They fill in the voids and increases the workability of concrete.

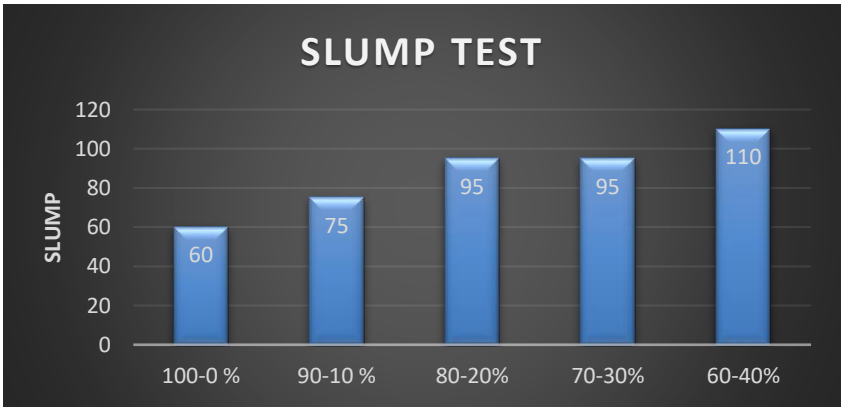

Fig. 3. Slump Test of Fresh Concrete

3.2 Hardened properties of Concrete

As per the test results, it is obtained that with the addition of Marble dust in the concrete, there is decrease in the compressive strength of the concrete as shown in Figure 4. It is because of the absence of siliceous and pozzolanic substance in the marble dust. However, it was observed that

increasing the replacement level of cement with MD did not affect the hydration process, leading to a significant decrease in the compressive strength of the concrete.

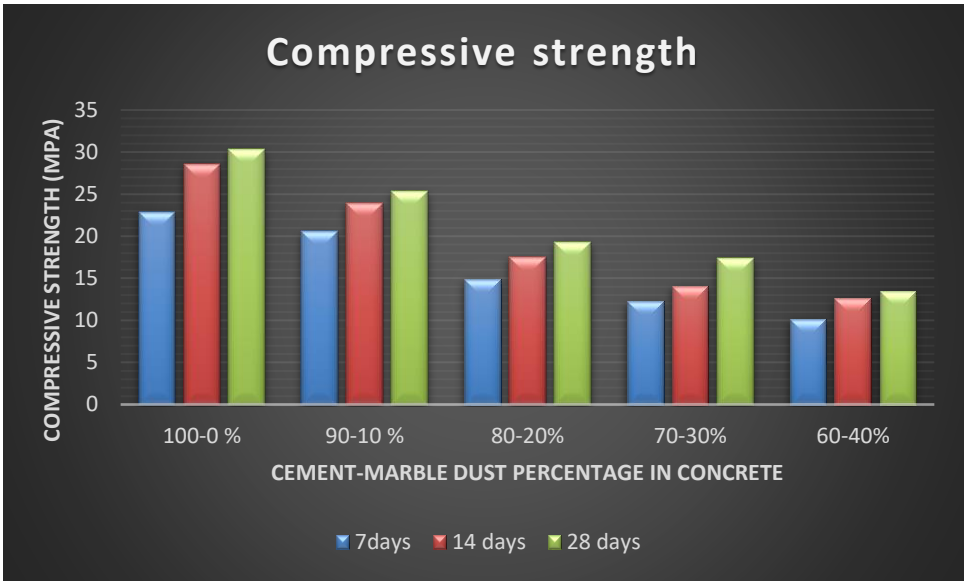

Fig.4. Compressive strength of all mix proportion at 7, 14 and 28 days

3.3 ANN Prediction result

After interpretation of the data collected through the references, a regression equation has generated and the prediction rate is also retrieved to check the probability of the generated equation for further achievement. The variables used as input are termed as independent variables & those used for evaluation are called dependent variables. In this ANN model, the dependent variable is 28 days of compressive strength. The independent variables are Cement, Marble dust, fine aggregate, coarse aggregate and water content.

Regression Equation:

28days = 37.00 + 0.1461 Cement + 0.0923 Marble Dust + 0.1086 F. A - 353 C.A (10mm) + 235.2 C. A (20mm) - 0.995 Water content

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
5.12770	69.85%	64.82%	61.02%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	6	2192.92	365.49	13.90	0.000
Cement	1	177.79	177.79	6.76	0.013
Marble Powder	1	55.42	55.42	2.11	0.155
F.A	1	512.55	512.55	19.49	0.000
C.A (10mm)	1	196.41	196.41	7.47	0.010
C.A (20mm)	1	196.37	196.37	7.47	0.010
Water content	1	181.38	181.38	6.90	0.013
Error	36	946.56	26.29		
Total	42	3139.48			

4 Conclusion

Different models have been developed in this study using ANN and linear regression models. Using input values, the developed model has been tested to predict the compressive strength of concrete for the regression equation. Compressive strength residual plots have been made for various input database instance sets in order to get the right regression. It could be used to determine whether the ordinary least squares theory is true. The least squares regression calculates an objective estimate of the coefficient with the lowest variance value.
These inferences can be made from the study's findings and analysis:

1) Marble dust increases the workability as much as we increase the replacement percentage. It has been noticed that the addition of the marble dust enhances the physical properties of concrete except for compressive strength. It may be due to the absence of siliceous and pozzolanic substance in the marble dust.
2) Marble dust could be used to increase the workability of concrete.
3) Without attempting any critical experimental complexity, ANN can help predict compressive strength in a very short period. So, this model will help in saving the wastage of time and material. Thus, the marble dust can be used as the partial replacement of cement to increase the workability of concrete

Acknowledgements

This research work was supported by Science and Engineering Research Board (SERB International Research Experience), a statutory body of the Department of Science and Technology, New Delhi, Government of India (Award Number: SIR/2022/000455). Great acknowledgement to Department of Civil & Environmental Engineering, Faculty of Engineering, Universiti Teknologi PETRONAS, Perak, Malaysia for the technical support. I would like to express my very great appreciation to Dr. Bashar S Mohammed, Chair, Civil and Environmental Engineering, Universiti, Teknologi PETRONAS, Malaysia for his valuable and constructive suggestions in this research work.

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