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Quality Assessment of Concrete produced with Marble dust as Partial Replacement of Cement using Ultrasonic Pulse Velocity Test

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Abstract

Cement concrete is one of the most frequently used materials in the construction industry. Constant studies are being carried out to find some alternative material to save natural resources & instead make use of industrial byproducts/waste material which is otherwise polluting the environment. Marble dust which is an industrial waste obtained from sawing, shaping, cutting and polishing of different marbles, is a big environmental hazard. Around 6.8 million tonnes of marble dust is currently being dumped annually in Rajasthan, Gujarat & Madhya Pradesh in India. Although past studies have already investigated the use of this material as a substitute for fine aggregates, since its distribution of particle size is nearer to that of cement, it could be more appropriate for partial replacement of cement in concrete. Cement concrete cubes of size 150 mm were cast as control specimens for two different grades of concrete (M25 Grade & M30 Grade). Effect of marble dust on compressive strength of concrete with varying %age of marble dust as partial replacement of cement is investigated in this study. Marble dust is used as 0, 5, 10, 15 & 20 percent partial substitute of cement by weight in concrete mixes. The compressive strength of concrete mixes is studied at age of 28 days and maximum value of compressive strength is observed at 10% partial replacement of marble dust with cement for both grades of concrete. The quality of concrete so produced is also assessed by using Ultrasonic Pulse Velocity (USPV) method. The ultrasonic pulse velocity is 3850, 4100, 4350 & 3710 m/s for M25 grade concrete & 3870, 4120, 4360 & 3700 m/s for M30 grade concrete for 0%, 5% & 15 % partial replacement of marble dust with cement. As per IS :13311(Part 1):1992 these values of pulse velocities represents good quality of concrete and also justified the use of marble dust in concrete up to 15 percent for both grades of concrete (M25 & M30).

Keywords: Cement, Compressive Strength (CS), correlation, Marble dust (MD), Ultrasonic Pulse Velocity (UPSV), Fineness modulus (FM)

1. Introduction

Marble dust is one of the most generated waste products in this era as stone cutting process produces large amount of marble dust which is an environmental hazard when we leave this dust in the environment. Concrete is one of the most commonly used building materials consisting of cement, aggregates, water and admixtures. Marble dust and other mineral additives such as granulated blast furnace slag (GBFS), fly ash (FA) & silica fume have been used in mortar & concrete. Different studies were conducted to use such waste product to maintain or improve concrete durability and strength. From the outcomes, it is found that marble dust can be used in concrete manufacturing as one of the most appropriate admixtures. The UPV technique offers a fast and simple non-destructive solution for testing the segregation of fresh and hardened concrete.

2. Literature Review

Various tests were performed to check the strength of concrete for the ultrasonic pulse velocity transfer. **Lorenzi et al. (2011)** estimated a correlation between the ultrasonic experiments & the CS by focusing on it. The understanding of the relationship between CS and USPV becomes complicated once concrete is a heterogeneous material. In order to understand how certain parameters influence the UPV, this work studied various concrete types, with different characteristics, produced with portland cement and different aggregate types. The information was evaluated with the aim of establishing models to know how differences in tangible circumstances affect UPV outcomes. In general, the analysis indicates that UPV testing can determined the existence of defects in concrete systems, because the data obtained permitted the existence of heterogeneity in concrete blocks to be calculated. **Aliabdo et al. (2014)** were added marble dust by 0.0, 5.0, 7.5, 10.0 and 15.0% replacement ratios by weight of cement and sand to study Ultrasonic pulse velocity. The use of marble dust up to 15.0% by weight as a replacement for cement or as a replacement for sand has insignificant effect on the ultrasonic pulse velocity test values. **Kaur and Bansal (2015)** studied partial replacement of cement has been done at 0%,3%,5%,9%,12%,13% with MK(Metakaolin) and 0%,10%(constant) with MP (Marble Powder). Result showed that there was a gain of strength with the addition of MK and MP. There is decrease in strength after 9% replacement of MK and 10% replacements of MP but durability properties go on increase with increase in percentage of MK-MP. **Tank et al. (2015)** used "Ultrasonic Pulse Velocity Test" which is one of the well known methods that can be used to assess concrete homogeneity, its elastic modulus, the thickness of the material and the existence of honeycombs in concrete. An description of the use and drawback of Ultrasonic Pulse Velocity (UPV) was discussed in this article. In fact, an effort has been made to research the impact of recycled concrete aggregates on concrete substituted by normal aggregates on UPV outcomes. Around the same period, a variety of case studies have been reviewed, which could involve the impact of a concrete age on UPV and the influence of interference on the inner concrete path on UPV outcomes. **Rodrigues et al. (2015)** calculated CS as per method is specified in NP EN 12390-3, using a total of 11 cubes of size "150 * 150 * 150 mm^3" and finding satisfactory results in a 10% substitution with marble sludge. The USPV study was carried out in conjunction with NP EN 12504-4 using five 150 mm wet-cured cubes for a 28-day period. With the use of the Sluge Marble Extraction, the USPV droped as it has a significantly smaller hydraulicity than cement and thus does not add as much to the increase in compactness. Nevertheless, the decline is almost insignificant. **Ashish et al. (2016)** carried out study on USPV at the curing ages of 28 days of **concrete** mixtures with varying percentages of marble powder (MP) were like 0%, 10% (sand), 10% (cement), 15% (sand), 15% (cement), 20% {cement (10%) + sand (10%)} and 30% {cement (15%) + sand (15%)} as a partial replacement of cement and sand mix. The ultrasonic pulse velocity showed improved results up to 15% replacement of sand with MP. **Boukhelkhal et al. (2017)** focused on the impact of the use of MP as an external cementation medium on the mechanical properties of SCC. Ultrasonic pulse velocity (UPV) was calculated at age 7, 28 and 90 days. The application of MP to a cured condition decreases the UPV in concrete. It should be remembered, however, that an economical SCC may be generated when the cement is partially replaced by MP. The ultrasonic pulse transfer velocity that helped to study the consistency of cement concrete and denseness of concrete under the fiber reinforcement has shown the improved quality and the strength **(Ongpeng et al. 2017)**. **Singh et al. (2017)** studied experimentally on use of marble slurry (MS) as partial replacement of cement (10 to 25%) in concrete mix & did not found a very significant effect on the value of the USPV. Overall velocity values observed were in the good or excellent category range which shows that concrete quality is not affected by addition of MS. UPV value found to be higher for concrete containing 15% marble powder/dust by weight of cement. The average value was 3.75 (km/sec.) at 7, 14, 28 and 56 days of curing respectively **(Dixit et al. 2018). Uysal (2018)** Ten separate series were made, two of which were pigment-free, one of which was white SCC colour, including limestone powder, and the other was maroon SCC colour, including maroon powder. Experimental test results showed that the correlation between UPV and the compressive strength of the SCC series was very high. It was found that the R2 correlation coefficient was 95 percent. **Abdelouahab et al. (2019)** scientifically tested, a non-destructive approach was used to identify the uniformity of the concrete in terms of segregation. In view of the two main classes, dysfunctional and secure, the decline in the W / B ratio contributed to distinct rises in the segregated indices fu, f and Δ. The ultrasonic segregation index fu was observed to be less prone to the variance of the fine ratio than the segregation resistant index f. As predicted, the proportion of water was a significant factor in the segregation of the SCC. The influence of the F / B ratio has yielded similar performance. It is because the UPVs is calculated by the cement paste and the granular framework (the pulse velocity of the binder was greater than that of the aggregate), while the f value concerned the gravel mass only. Stable concretes (those with a sieve segregation index greater than 15 per cent) all showed resistance index f higher than 95 per cent and ultrasonic index fu higher than 99 per cent. This study demonstrated the possibility of characterizing a safe, quick, and easy-to-use, non-destructive process with reasonable precision and degree of separation. Author worked on more than 230 normal 150 mm cube samples and the samples used in the research were formed of concrete with a diverse water-cement ratio of 0.48 to 0.5. The experimental findings showed that while UPV and concrete compressive strength were connected, UPV and compressive strength are also linked to the water-cement ratio **(Zebari 2019).**

3. Experimental Program

The purpose of the work is to examine the effect of MD in concrete as a substitute for cement. A total of 10 concrete mixes from CM1- CM10 are produced (5 each for mix M25 & M30) by replacing cement with MD varying from 0% to 20% by weight. In this study for each mix 6 cubes specimens of size 150 mm are cast as control specimens. After performing UPV test on control specimens, the compressive strength test were conducted.

3.1 Materials and Mix Proportions

3.1.1 Cement: Ordinary Portland Cement 43 grade is used in the research in accordance with IS 8112 -2013. The physical test on Ordinary Portland Cement is shown in **Table 1**.

Table-1. Ordinary Portland Cement physical test

Sr. no	Test	Results	IS Requirement as per 8112-2013
1	Consistency of cement	30 %	
2	Initial setting time	1.25hours	0.5 hours(Minimum)
3	Final setting time	190 mintues	10 hours(Maximum)
4	Fineness of cement	2.50%	10 percent (Maximum)
5	Cement's compressive strength 3days 7days 28days	26.60N / mm2 35.50N / mm2 46.50N / mm2	23.00N / mm2 33.00N / mm 2 43.00N / mm 2

3.1.2 Fine aggregates: Coarse sand

Table-2. Fine Aggregate Sieve Analysis

Sieve size in mm	Weight Retained in gm	Cumulative Weight Retained in gm	Cumulative percentage Weight Retained	Passing%
4.750	104.0	104.0	10.40	89.60
2.360	150.0	254.0	25.40	74.60
1.180	113.0	367.0	36.70	63.30
0.600	136.0	503.0	50.30	49.70
0.300	157.0	660.0	66.00	34.00
0.150	170.0	830.0	83.00	17.00
0.075	170.0	1000.0	100	
Sum	1000.0		∑ F = 371.80	

FM of coarse sand = {(∑F) /100}= 3.70

3.1.3 Coarse Aggregates

Table-3. Coarse Aggregates (20 mm) Sieve Analysis

IS Sieve size in mm	Weight Retained (gm)	Cumulative weight retained (gm)	Cumulative % Weight retained	Passing %
40	0.00	0.00	0.000	100.000
20	253.50	253.50	8.450	91.550
10	2470.6	2724.10	90.800	9.200
4.75	275.90	3000.00	100.000	0.000
Sum	3000.00		∑C=199.25	

FM of Aggregate (20 mm) = (∑C+ 500)/100 = 6.993

Table-4. Coarse Aggregates (10 mm) Sieve Analysis

Sieve size in mm	Weight Retained in gm	Cumulative weight Retained in gm	Cumulative % weight Retained	Passing%
20.0	0.00	0.00	0.000	100.000
10.0	500.40	776.00	25.860	74.140
4.75	2224.00	3000.00	100.000	0.000
Sum	3000.00		∑C = 135.870	

FM of Aggregate (10 mm) = {500+∑C}/100 = 6.259

3.1.4. Marble dust: Marble dust which is used in this study taken from the marble processing sector in Alwar, Rajasthan, India. **Table 5** presents the chemical structure of marble dust. XRD method is used to determine the marble dust mineralogical structure as shown in **Fig. 1**.

3.1.5. Mix Proportions:

Whereas CM1 is concrete mix of grade M25 with zero percent marble dust and CM6 is concrete mix of grade M30 with zero percent marble dust. Others (CM2-CM5, CM7-CM10) are mentioned in **Table 6** with different %age of marble dust replaced with cement in both grade of concrete.

Table-5. Marble Dust chemical composition

Oxides compound	%age of compound
Calcium Oxide (CaO)	42.450
Aluminium Oxide (Al_2O_3)	0. 520
Silicon (SiO_2)	26. 350
Feric Oxide ($Fe_2 O_3$)	9.400
Mangnese Oxide (MgO)	1.520

Table-6. Concrete Mixes M25 & M30

Concrete Mixes	Cement (kilogram)	Marble dust as substitute of cement (Kg)	Fine aggregate (kg)	CA	Water in litres
CM1	415	0.00	610	1145	195
CM2	394.25	20.75	610	1145	195
CM3	373.5	41.5	610	1145	195
CM4	352.75	62.25	610	1145	195
CM5	332	83	610	1145	195
CM6	425	0	550	1140	187
CM7	403.75	21.25	550	1140	187
CM8	382.5	42.5	550	1140	187
CM9	361.25	63.75	550	1140	187
CM10	340	85	550	1140	187

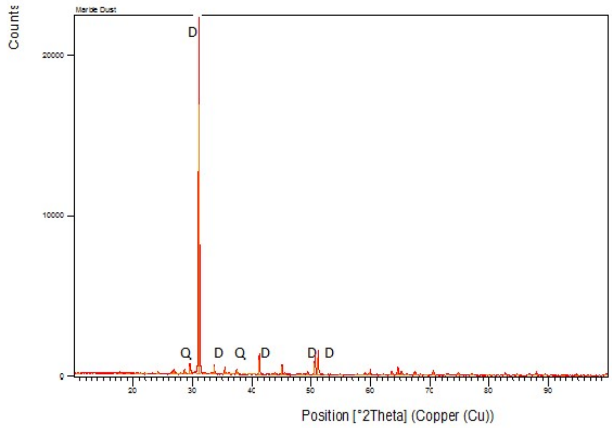

Fig. 1. X-Ray marble dust diffraction spectrum.

3.2 Ultrasonic Pulse Velocity Method

USPV experiment is performed as per IS 13311 (part-1): 1992 on 150 mm concrete cubes. The transducer route length separated by travel moment provides the average wave propagation velocity. In this test technique, the transducer that is kept in touch with one side face of the concrete specimen under test produces the ultrasonic pulse. After passage a known path length L in the concrete specimens, the vibration pulse is converted by the 2nd transducer in contact with the other concrete member surface into an electrical signal & an electronic timing circuit allows the pulse transit time (T in seconds) to be measured. The pulse speed (V) is specified by: V= L / T. The Direct Transmission Way is used to measure concrete pulse velocity. In terms of density homogeneity and concrete uniformity, this method has been use to check the quality of concrete. Concrete quality grades are outlined in **Table 7**. USPV Tests on concrete cube specimens are performed at 28 days using the apparatus shown in **Fig. 2**.

Table-7. Velocity Criterion for Concrete Quality Grading

Pulse velocity m/sec	**Concrete Quality Grading**
More than 4500	Excellent
In between 3500 – 4500	Good
In between 3000 – 3500	Medium
Less than 3000	Doubtful

Fig. 2. Ultrasonic Pulse Velocity Test Apparatus

Table-8. USPV & CS of M25 grades of concrete at age of 28 days

Mix	Pulse velocity in m/s	Quality of concrete as per IS 13311 (Part 1) : 1992	CS (N/mm^2)
CM1	3850	good	33.93
CM2	4100	good	37.81
CM3	4350	good	41.78
CM4	3710	good	31.54
CM5	2950	doubtful	20.45

Table-9. USPV & CS of M30 grades of concrete at age of 28 days

Mix	Pulse velocity in m/s	Quality of concrete as per IS 13311 (Part 1) : 1992	CS (N/mm^2)
CM6	3870	good	39.14
CM7	4120	good	42.52
CM8	4360	good	48.02
CM9	3700	good	37.24
CM10	2960	doubtful	26.62

4. Test Results and Discussions

Investigations are carried out to partially replace cement for two different concrete's grade M25 & M30 with marble dust by 0%, 5%, 10%, 15% and 20%. **Table 8 and Table 9** shows the USPV & CS of concrete cube specimens (CM1-CM5 in case of M25, CM6-CM10 in case of M30).

4.1 Effect of Marble Dust

Table 8 and **Table 9** show USPV of both concrete mixes (M25 & M30) with different proportion of MD as substitution of cement. The entire blend proportioning of the different concrete mix is performed according to the standard provided and the test is performed where we noted that with the substitute of cement with MD for 5 percent & 10 percent, there is an rise in strength at the age of 28 days.

The values of ultrasonic pulse velocity are increased by 6.49 percent & 12.98 percent for 28 days for concrete mix CM-2(5% MD) and CM-3(10% MD) respectively as compared with values of control mix CM-1(0% MD). CM2 and CM3 have greater ultrasonic pulse velocity than CM1.

It is also noted that there are decline in the values of USPV at 28 days for the concrete mix CM-4(15% MD) and CM-5(20% MD) made with partial substitution of cement with MD by 15 percent & 20 percent as compared with CM-1(0% MD).

For concrete grade M25, the values of ultrasonic pulse velocity were decreased by 3.63% & 23.37% at 28 days for concrete mix CM-4(15% MD) and CM-5(20% MD) respectively as compared with values of control mix CM-1(0% MD). It can be seen in **Fig. 3** that a linear increase of up to 10 percent MD material was noted in the variation in the ultrasonic pulse velocity for every concrete mix. For blend CM-3, a higher ultrasonic pulse velocity value was noted (10 percent MD). It begins to decrease with 15 & 20 percent substitution of cement with Marble Dust.

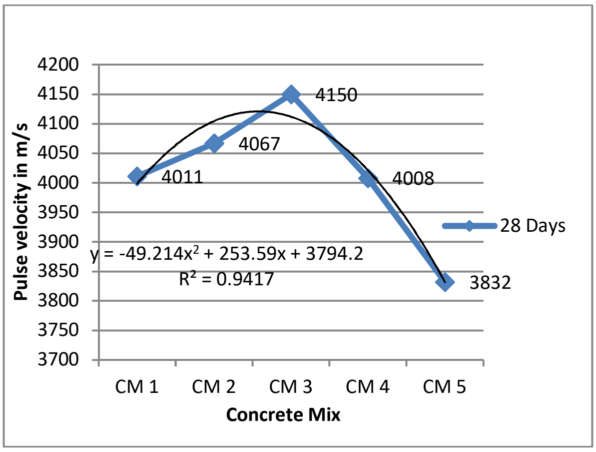

Fig. 3. Ultrasonic Pulse Velocity of Different Concrete Mix of M25 Grade

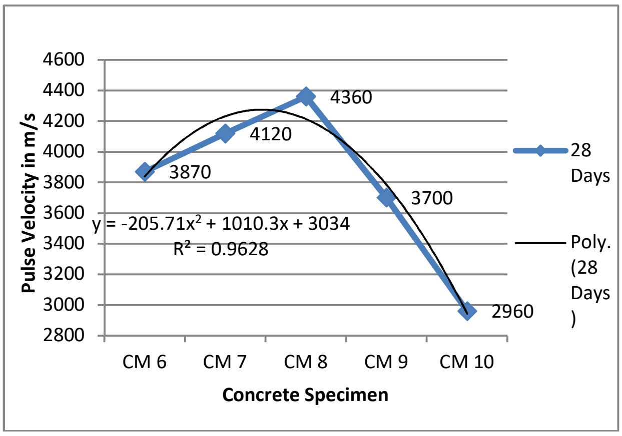

Fig. 4. Ultrasonic Pulse Velocity of Different Concrete Mix of M30 Grade

Similarly trend is observed for concrete grade M30, the values of ultrasonic pulse velocity are increased by 6.46 percent & 12.66 percent for 28 days for concrete mix CM-7(5% MD) and CM-8(10% MD) respectively as compared with values of control mix CM-6(0% MD). Likewise, CM7 and CM8 have greater ultrasonic pulse velocity than CM6. It is also noted that there is decline in the values of USPV at 28 days for the concrete mix CM-9(15% MD) and CM-10(20% MD) made with partial substitution of cement with MD by 15 percent & 20 percent as compared with CM-6(0% MD).

For concrete grade M30, the values of ultrasonic pulse velocity are decreased by 4.39 percent & 23.51 percent for 28 days for concrete mix CM-9(15% MD) and CM-10(20% MD) respectively as compared with values of control mix CM-6(0% MD). CM-9(15% MD) and CM-10(20% MD) have lower ultrasonic pulse velocity than CM-6(0% MD) shown in **Fig. 4**.

4.2 Statistical Analysis

The analysis of the correlation was performed between CS and USP. A polynomial (trend line) relationship in the structure of $y = ax^2+bx+c$ seems best suited to R^2 values for the data.

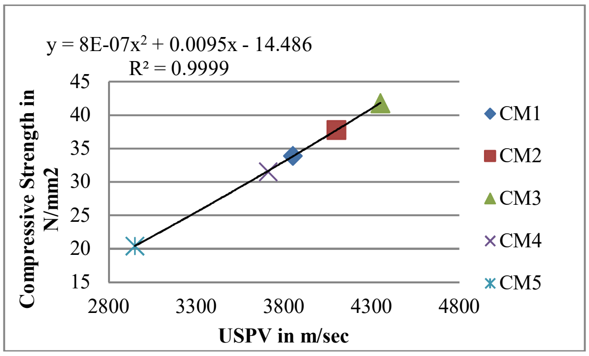

Fig. 5. Statistical Analysis between USPV & CS of Grade M25

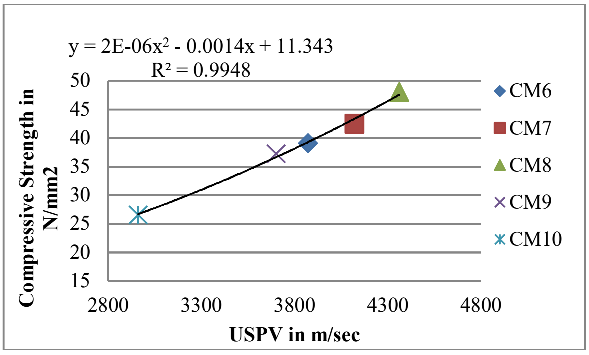

Fig. 6. Statistical Analysis between USPV & CS of Grade M30

Table-10. Regression Analysis of USPV & Compressive Strength

Grade	Equations	Correlation coefficient
M25	$y_{(for\ M25)} = 8\ E\text{-}07x^2 + 0.009x - 14.48$	$R^2 = 0.999$
M30	$y_{(for\ M30)} = 2\ E\text{-}06x^2 - 0.001x + 11.34$	$R^2 = 0.994$

The regression equations and value of correlation coefficient (R^2) between strength properties are given in **Table 10** and shown in **Fig. 5 and Fig. 6**. As evident from these results that value of correlation's coefficient is varies from 0.994 to 0.999. The high values of correlation's coefficient indicate that there is strong relationship between these properties of concrete. CS also has a very strong relation with USPV. It means that, partial substitute of marble dust with cement gives better affect to its strength properties in concrete. It makes the matrix dense due to its particle fineness. Due to this, the merit of concrete in term of its denseness and lack of imperfection improved.

5. Conclusions

From statistical analysis of experimental results we can drawn the important conclusions.

(1) Compressive strength has a very strong correlation with USPV where value of R^2 (0.999) is very close to 1 in case of grade M25.

(2) Compressive strength also has a very strong correlation with USPV where value of R^2 (0.994) is very close to 1 in case of grade M30.

(3) From the parabolic shape of trend line of data of ultrasonic pulse velocity which is best fitted to result values, shows that optimum value of substitute of marble dust with cement in concrete is very near to 10% in both grade of concrete (M25 & M30).

(4) For mixtures tested (M25 & M30), the results of the UPV test show that good quality concrete can be developed with marble dust as a substitute for cement of up to 10%.

(5) The findings are the foundation for recommendations that the utilization of MD in concrete to replace cement, as a result saving the atmosphere from pollution arising from marble dust.

(6)

Disclosures

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References

1. Abdelouahab, G., Abdelhalim, B. and Laefer, D. F. Characterising the segregation of self‑consolidating concrete using ultrasonic pulse velocity. Journal of the South African Institution of Civil Engineering, 2019; 61(1), 26–37.

2. Aliabdo, A.A., Elmoaty, A.E.M.A. and Auda, E.M. Re-use of waste marble dust in the production of cement and concrete. Construction and Building Materials, 2014; 50, 28–41.

3. Dixit, S., Nigam, S. and Bharosh, R. Strength and Durability of Concrete Made with Marble Dust. International Journal of Advance Research, Ideas and Innovations in Technology, 2018; 4(2), 464-470.

4. IS 13311(Part 1): 1992 Non Destructive Testing of Concrete-Methods of Test.

5. IS: 383-1970 Specification for coarse and fine aggregates from natural sources for concrete. Bureau of Indian Standards, New Delhi.

6. IS: 456-2000 Code of practice for plain and reinforced concrete. Bureau of Indian Standards, NewDelhi.

7. IS: 4031 (Part 4)-1988 Determination of consistency of standard cement paste. Bureau of Indian Standards, NewDelhi.

8. IS: 10262: 2009 Concrete mix proportioning-Guidelines. Bureau of Indian Standards, NewDelhi.

9. IS-8112:1989 (Reaffirmed 2005) Specification for 43 grade Ordinary Portland cement. Bureau of Indian Standards, New Delhi.

10. IS: 516:1959 Method of test for strength of concrete. Bureau of Indian

Standards, New Delhi.

11. IS: 4031 (Part- 5): 1988 Methods of Physical tests for Hydraulic

cement. Bureau of Indian Standards, New Delhi.

12. Lorenzi, A., Filho, L. C. P. S., Lorenzi, L.S., Shimomukey, R. and Chies, J.A. Monitoring Concrete Structures through UPV Results and Image Analysis. The Journal of Nondestructive Testing, 2011; 16 (12), ID-11199.
13. Omar M.O., Elhameed G.D.A., Sherif M.A and Mohamadien H. A. Influence of limestone waste as partial replacement material for sand and marble powder in concrete. Housing and Building National Research Center Journal, 2012; 8 (3), 193–203.
14. Ongpeng, J. M. Ultrasonic pulse velocity test of reinforced concrete with induced corrosion. ASEAN Engineering Journal, 2017; 7(2), 9-17.
15. Pathan, V. G. and Pathan, M. G. Feasibility and Need of use of Waste Marble Powder in Concrete Production. IOSR Journal of Mechanical and Civil Engineering, International Conference on Advances in Engineering & Technology, 2014; 23-26.
16. Singh, G. and Madan, S. K. An Experimental investigation on utilizations of Marble Dust as partial replacement of Cement in Concrete. New Building Materials & Construction World, 2018; 23(11), 151-160.
17. Tank, Y. R., Joshi M. R. and Dhameliya, H. K. Strength Assessment of Recycled Aggregate Concrete by Ultrasonic Pulse Velocity Test. International Journal of Science, Engineering and Technology Research, 2015; 4(12), 4210-4214.
18. Uysal, M. The Use of Waste Maroon Marble Powder and Iron Oxide Pigment in the Production of Coloured Self-Compacting Concrete. Advances in Civil Engineering, 2018; 1-10.
19. Zibari Z. Using Ultrasonic Pulse Velocity Test to Assess the Effect of Water-Cement Ratio on the Compressive Strength of Concrete. Journal of Engineering , 2019; 25(7), 79–86.