International Journal of Interdisciplinary Innovative Research & Development (IJIIRD)
ISSN: 2456-236X
Vol. 10 Issue 01 | 2025

Behavior of Concrete Using Marble Waste as A Coarse Aggregate

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DOI: 10.5281/zenodo.16166094

ABSTRACT

India has currently taken a major initiative on developing the infrastructure such as express highways, bridges, power projects, international airports, metro rail etc., to meet the requirements of globalization. In the construction of buildings and other structures, concrete plays an important and rightful role and a large quantum of concrete is being utilized. Concrete is a reliable material, which is extensively used throughout in building the infrastructure of a nation. India produces more than approximately 170 million cubic meters of concrete annually. Investment in construction sector is enormous. Rising cost of construction materials coupled with the paucity of aggregates is creating problems for the construction industry. On the other hand, disposal and/or utilization of industrial waste is a global issue. One ingenious solution could be to use the waste material in the production of concrete, if suitable, thereby decreasing the cost of concrete. In India, millions of tons of waste from marble industry is being created after cutting, polishing, processing and grinding of marble. It can be utilized as both coarse & fine aggregate. Using waste generated by the marble quarries to produce aggregates for producing structural concrete has therefore been studied as a useful alternative from the perspective of environmental protection and sustainability of natural resources.

The aim of this paper is to study the performance of concrete prepared by using marble waste as coarse aggregates, at elevated temperatures. Since concrete is better known for its compressive strength, its quality was checked at high temperatures by using non-destructive tests like the Thermo gravimetric analysis, UV Pulse velocity test & visual inspection The main goal of this study is to demonstrate the possibility of using marble wastes as a substitute rather than natural aggregates in concrete production. The paper presents the study methodology, the characterization of waste marble aggregates and various practical formulations of concrete.

***Keywords:** Marble, NDT, BCS*

1.INTRODUCTION

The industries produce a lot of waste of marble in the form of powder/slurry and pieces of irregular size of stones. The waste generated during the quarrying operations is mainly in the form of rock fragments. The volume of refuse generated can reach 50% of the volume of all marble blocks processed, making up millions of tons of waste produced every year. The marble industry is one of the sectors that most produces waste from raw materials.

1.1 Marble waste generation

“The end material that is non-usable in any form, obtained after all the ‘primary’ and ‘secondary’ application is called as waste.” According to above definition, the waste should be only non-usable after even secondary application but in case of marble quarry waste, even the reduction in primary usage causes heavy reduction in financial returns since the large size blocks / tiles fetching returns manifold as compared to smaller blocks / tiles or any secondary product. The marble waste generation varies widely from 30% by weight (in mechanized mines using wire saw cutting methods for extraction of marble blocks) to 65% by weight (at mines where mining is resorted to and the rocks are fractured). Waste produce during quarrying by mechanized processes can be estimated at 30% to 40% of the production Mining Waste 50% Finished goods 30% Polishing Waste 5% Processing Waste 15%.

1.1.1 Classification of Marble Waste

A. Quarry waste :-

This waste includes blocks of various sizes and shapes, undesirable trimming and shaping of mined out blocks before dispatch to processing units. There are two types of Quarry Waste as follows:

a) Direct Waste
b) Indirect Waste

B. Processing waste: -

This waste produced in processing of marble is of direct type, i.e. produced, as a byproduct of the operation, thus only having any depleted secondary use. Various types of waste generated during processing of marble are:

a) Dressing waste
b) Cutting waste
c) Polishing waste
d) Transportation Waste
e) Handling waste

1.2 Problems generated due to marble waste

(a) Conservation of Natural Resources: The valuable national wealth is getting wasted mainly due to lack of management and technology. This waste, if used, can change perhaps the entire scenario of the industry.
(b) Air pollution: This is the most hazardous impact of the marble industry. Slurry is produced at almost every operation and it is a great problem. When it gets dry, it causes air pollution and related problems.
(c) Water pollution: Like any other industry, the marble industry needs water in its different operations for cutting, cooling and flushing. In these operations water gets contaminated by marble slurry.
(d) Visual impacts: Abandoned mines, dumping sites, slurry waste sites, deposition of dried slurry over almost every structure in surrounding areas gives a very bad, dirty look and aesthetic problem.

1.3 Practical Utilization of Marble Waste

(a) As a filler material for roads and embankments: As marble dust is an inert material it can be mixed with certain types of soils for the preparation / raising of embankments etc. which will result in the saving of valuable soil. Central Road Research Institute (CRRI), New Delhi has carried out preliminary research on the utilization ofmarble dust in road sector. Unconfined Compressive Strength (UCS) have been performed to determine the strength of the mixes with soils and it has been observed that, there is a 20% increase in UCS with 30% marble dust

(b) Manufacture of Portland cement: Cement grade limestone is the main raw material along with clay and other corrective materials for the manufacture of Portland cement. Analysis of marble waste shows that it satisfies the chemical composition requirements of cement grade limestone to a great extent. As a part replacement of limestone, either marble waste and or a combination of along with limestone and or lime can be used.

(c) For manufacturing of concrete: In concrete mixes there is a 15% increase in compressive strength when sand is mixed with 35% marble dust. There is an improvement in the density of the concrete as well.

(d) For manufacture of bricks: Marble slurry is chemically dolomitic in nature and consists of very fine particles. It may be used as a fine aggregate in manufacturing bricks by using cement or lime as a binder. Central Brick Research Institute (CRRI), Roorkee has conducted research on this aspect. The results are very encouraging and the physical properties of the bricks produced by this process exceed those of normal bricks.

(e) Manufacture of Ceramic Tiles: A possibility of utilizing marble slurry as a raw material for production of Ceramic Wall tiles needs to be evaluated on a pilot plant level. A leading ceramic producer in the country has undertaken laboratory scale studies on this matter, which were reported to be highly successful.

2. METHODOLOGY:

Experimentation will involve the study of residual compressive strength in marble aggregate concrete & the general quality after exposure to elevated temperatures. Concrete cubes cooled after heating will be assessed for compressive strength, along with normal cubes of same lot. Minimum three different grades of concrete shall be tested.

2.2 CUBE CASTING PROCEDURE AS PER IS CODE:

2.2.1 Sampling of Materials:

Representative samples of the materials of concrete for use in the particular concrete construction work shall be obtained by careful sampling. Test samples of cement shall be made up of a small portion taken from each of a number of bags on the site. Test samples of aggregate shall be taken from larger lots by quartering.

2.2.2 Preparation of Materials:

All materials shall be brought to room temperature, preferably 27° ± 3°C before commencing the tests. The cement samples, on arrival at the laboratory, shall be thoroughly mixed dry either by hand or in a suitable mixer in such a manner as to ensure the greatest possible blending and uniformity in the material, care being taken to avoid the intrusion of foreign matter. The cement shall then be stored in a dry place, preferably in air-tight metal containers. Samples of aggregates for each batch of concrete shall be of the desired grading and shall be in an air-dried condition. In general, the aggregate shall be separated into fine and coarse fractions and recombined for each concrete batch in such a manner as to produce the desired grading. IS Sieve 480 shall be normally used for separating the fine and coarse fractions, but where special grading are being investigated, both fine and coarse fractions shall be further separated into different sizes.

2.2.2.1 Preparing marble aggregate:

Marble waste is collected from nearby marble industry and broken them into pieces for the required size of aggregates, sieve analysis is performed. Marble aggregate passing through IS sieve 16mm and retaining on IS sieve 12.5mm are to be taken as coarse aggregate.

Fig. 2.1: Marble waste

Fig.2.2: Marble aggregates

2.2.3 Proportioning:

The proportion of the materials, including water, in concrete mixes used for determining the suitability of the materials available, shall be similar in all respects to those to be employed in the work. Where the proportions of the ingredients of the concrete as used on the site are to be specified by volume, they shall be calculated from the proportions by weight used in the test cubes and the unit weights of the materials.

2.2.4 Weighing:

The quantities of cement, each size of aggregate, and water for each batch shall be determined by weight, to an accuracy of 0.1 % of the total weight of the batch.

2.2.5 Mixing Concrete:

The concrete shall be mixed by hand, or preferably, in a laboratory batch mixer, in such a manner as to avoid loss of water or other materials. Each batch of concrete shall be of such a size as to leave about 10 % excess after moulding the desired number of test specimens.

2.2.5.1 Hand mixing

The concrete batch shall be mixed on a water-tight, non-absorbent platform with a shovel, trowel or similar suitable implement, using the following procedure:

a) The cement and fine aggregate shall be mixed dry until the mixture is thoroughly blended and is uniform in colour,

b) The coarse aggregate shall then be added and mixed with the cement and fine aggregate until the coarse aggregate is uniformly distributed throughout the batch, and

c) The water shall then be added and the entire batch mixed until the concrete appears to be homogeneous and has the desired consistency. If repeated mixing is necessary, because of the addition of water in increments while adjusting the consistency, the batch shall be discarded and a fresh batch made without interrupting the mixing to make trial consistency tests.

Fig. 2.3: Dry mixing

2.2.6 Workability:

Each batch of concrete shall be tested for consistency immediately after mixing, by one of the methods described in IS: 1199-1959. Provided that care is taken to ensure that no water or other material is lost, the concrete used for the consistency tests may be remixed with the remainder of batch before making the test specimens. The period of re-mixing shall be as short as possible yet sufficient to produce a homogeneous mass.

2.2.7 Size of test specimens:

Test specimens cubical in shape shall be 15 × 15 × 15 cm, if the largest nominal size of the aggregate does not exceed 2 cm.

2.2.8 Moulds:

2.2.8.1 Cube Moulds:

The mould shall be of 150 mm size conforming to IS: 10086-1982

A) In assembling the mould for use, the joints between the sections of mould shall be thinly coated with mould oil and a similar coating of mould oil shall be applied between the contact surfaces of the bottom of the mould and the base plate in order to ensure that no water escapes during the filling. The interior surfaces of the assembled mould shall be thinly coated with mould oil to prevent adhesion of the concrete

B) Tamping Bar: The tamping bar shall conform to 6.1(a) of IS: 10086-1982*.

Fig. 2.4: Cube moulds

2.2.9 Compacting:

The test specimens shall be made as soon as practicable after mixing, and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The concrete shall be filled into the mould in layers approximately 5 cm deep. In placing each scoopful of concrete, the scoop shall be moved around the top edge of the mould as the concrete slides from it, in order to ensure a symmetrical distribution of the concrete within the mould. Each layer shall be compacted either by hand or by vibration as described below. After the top layer has been compacted, the surface of the concrete shall be finished level with the top of the mould, using a trowel, and covered with a glass or metal plate to prevent evaporation.

2.2.9.1 Compacting by hand:

When compacting by hand, the standard tamping bar shall be used and the strokes of the bar shall be distributed in a uniform manner over the cross-section of the mould. The number of strokes per layer required to produce specified conditions will vary according to the type of concrete. For cubical specimens, in no case shall the concrete be subjected to less than 35 strokes per layer for 15 cm cubes or 25 strokes per layer for 10 cm cubes. Rod shall penetrate into the underlying layer and the bottom layer shall be rodded throughout its depth. Where voids are left by the tamping bar, the sides of the mould shall be tapped to close the voids.

2.2.9.2 Compacting by vibration:

When compacting by vibration, each layer shall be vibrated by means of an electric or pneumatic hammer or vibrator or by means of a suitable vibrating table until the specified condition is attained.

NOTE — Mode and quantum of vibration of the laboratory specimen shall be as nearly the same as those adopted in actual concreting operations.

Fig. 2.5: Casting of cubes

3. MISCELLANEOUS DETAILS:

3.1 Material used:

Cement used was Birla PPC (Grade 43) conforming to IS 1489(Part 1) -1991 (10). Fine aggregates consisted of natural river sand conforming to Zone II of IS383-1970 (11). The coarse aggregates consisted of crushed green and white marble passing through 20 mm sieve & retained on 12.5mm sieve. Potable water was used for mixing

& curing.

3.2 Test specimens:

The specimens for testing were individual concrete cubes of three different grades. Ninety cubes, thirty for each grade, were cast with similar cross-sectional details & materials. All the specimens were 150*150*150mm size. M: 20, M: 25 & M: 30 grade design mix concrete was used. Cement & aggregates from the same batch were used for all the specimens.

Mild steel cube moulds (ISI mark) were used for casting. Since only 33 such moulds were available in the laboratory, casting was done on three consecutive days, starting with M: 30 grade on day one. After 28 days of curing, the cubes were taken out of the curing tank & dried at room temperature for a day. Non-destructive testing of the unheated specimens commenced from 30th day onwards, starting with weighing.

3.3 Heating Specimen:

Heating of blocks up to 400°C is done in oven available in RCC laboratory. For heating at higher temperature i.e. up to 800°C, muffle furnace is used. Furnaces are usually heated to desired temperatures by conduction, convection, or blackbody radiation from electrical resistance heating elements.

4. TESTING AND EXPERIMENTATION

4.1 NON - DESTRUCTIVE TESTS:

4.1.1 Introduction:

Non-destructive test on concrete are said so because these test can be performed in situ as well as in laboratory without destructing the concrete member & results about strength and durability can be obtained. This test have been in use for about four decades & are considered as – powerful method for evaluating existing concrete structures with regard to their strength and durability and also for assessment and control of quality of hardened concrete without a significant damage to the structure. In certain cases, the investigation of crack depth, micro crack and progressive deterioration are also studied by these methods.

Non-destructive testing methods are simple to perform but the analysis and interpretation of test results are not so easy. In these methods, the specimens are not loaded to failure and as such the strength estimated may not be very accurate. These methods attempt to measure some other properties of concrete from which an estimate of its strength, durability and elastic parameters are obtained. Some such properties of concrete are hardness, resistance to penetration, rebound number, resonant frequency and ability to allow ultrasonic pulse velocity to propagate through it.

4.1.2 Methods of non-destructive testing:

4.1.2.1. Ultrasonic pulse velocity test:

Ultrasonic scanning is a recognized non-destructive evaluation test to qualitatively assess the homogeneity and integrity of concrete. When the pulse generated is transmitted into the concrete from the transducer using a liquid coupling material such as grease or cellulose paste, it undergoes multiple reflections at the boundaries of the different material phases within the concrete. A complex system of stress waves develops, which include both longitudinal and shear waves, and propagates through the concrete. The first waves to reach the receiving transducer are the longitudinal waves, which are converted into an electrical signal by a second transducer. Electronic timing circuits enable the transit time T of the pulse to be measured. IS 13311 Part-1 explains the procedure and the interpretation of the test results.

Fig. 3.1: Ultra-Sonic Pulse velocity test device

Fig. 3.2: Laboratory operation for UV test

4.1.2.2 Interpretation of results:

The ultrasonic pulse velocity of concrete is mainly related to its density and modulus of elasticity. This in turn, depends upon the materials and mix proportions in making concrete as well as the method of placing, compaction and curing of concrete. For example, if the concrete is not compacted as thoroughly as possible, or if there is segregation of concrete during placing or there are internal cracks or flaws, the pulse velocity will be lower, although the same materials and mix proportions are used. The quality of concrete in terms of uniformity, incidence or absence of internal flaws, cracks and segregation, etc. indicative of the level of workmanship employed; can thus be assessed using the guidelines given in below, which have been evolved for characterising the quality of concrete in structures in terms of the ultrasonic pulse velocity.

Table 4.1: Assessment of quality of concrete from UV Pulse Velocity

Quality of Concrete from UV Pulse Velocity	
Average UV Pulse Velocity	**Quality of Concrete**
>4.5 km/s	Very Good
3.5 to 4.5	Good
3.0 to 3.5	Fair
2.5 to 3	Doubtful
≤ 2.5	Very poor

4.1.2.3 Influence of test conditions:

1. Influence of surface conditions and moisture content of concrete: moothness of contact surface under test affects the measurement of ultrasonic pulse velocity. For most concrete surfaces, the finish is usually sufficiently smooth to ensure good acoustical contact by the use of a coupling medium and by pressing the transducer against the concrete surface. When the concrete surface is rough and uneven, it is necessary to smoothen the surface to make the pulse velocity measurement possible.

In general, pulse velocity through concrete increases with increased moisture content of concrete. This influence is more for low strength concrete than high strength concrete. The pulse velocity of saturated concrete may be up to 2 percent higher than that of similar dry concrete. In general, drying of concrete may result in somewhat lower pulse velocity.

2. Influence of path length, shape and size of the concrete member: As concrete is inherently heterogeneous, it is essential that path lengths be sufficiently long so as to avoid any error introduced due to its heterogeneity. In field work, this does not pose any difficulty as the pulse velocity measurements are carried out on thick structural concrete members. However, in the laboratory where generally small specimens are used, the path length can affect the pulse velocity readings. The shape and size of the concrete member do not influence the pulse velocity unless the least lateral dimension is less than a certain minimum value, for example the minimum lateral dimension of about 80 mm for 50 kHz natural frequency of the transducer.

3. Influence of temperature of concrete: Variations of the concrete temperature between 5 and 30°C do not significantly affect the pulse velocity measurements in concrete. At temperatures between 30 to 60°C there can e reduction in pulse velocity up to 5 percent. Below freezing temperature, the free water freezes within concrete, resulting in an increase in pulse velocity up to 7.5 percent.

5. Results & Discussion

Total three readings were taken for each cube. Average of the three is mentioned as its UV pulse velocity.

Table 5.5: UV Pulse velocity test for concrete grade M 30

Block No	Cube (150*150*150) mm		Concrete containing marble aggregate				Conventional Concrete		
	Temp	Time	UV pulse vel(km/s)	Category avg	Remark	Colour	Category avg	Remark	Colour
1	30	0	-	4.771	very good	normal	4.87	very good	normal
2	30	0	-						
3	30	0	-						
4	200	2	4.477	4.475	good	normal	4.63	very good	normal
5	200	2	4.57						
6	200	2	4.396						
7	350	1	4.084	4.152	good	Slightly brown patches	4.05	good	brownish patches
8	350	1	4.162						
9	350	1	4.209						
10	350	2	3.086	3.218	fair	brownish patches	3.98	good	brownish patches
11	350	2	3.137						
12	350	2	3.432						
13	500	1	3.056	3.057	fair	brownish patches	3.09	fair	slightly dark grey
14	500	1	3.042						
15	500	1	3.074						
16	500	2	2.488	2.539	doubtful	Blackish patches	2.99	fair	slightly dark grey
17	500	2	2.473						
18	500	2	2.657						

19	650	1	1.506	1.437	very poor	Lightly grey	2.00	poor	whitish grey
20	650	1	1.464						
21	650	1	1.343						
22	650	2	1.298	1.277	very poor	slightlygrey	1.74	poor	whitish grey
23	650	2	1.224						
24	650	2	1.309						
25	800	1	1.074	1.072	very poor	Whitish grey	1.40	very poor	whitish grey
26	800	1	0.916						
27	800	1	1.228						
28	800	2	0.857	0.902	very poor	Whitish grey	1.29	very poor	buff
29	800	2	0.92						
30	800	2	0.929						

Table 5.6: UV Pulse velocity test for concrete grade M 25

Block No	Cube (150*150*150)mm		Concrete containing marble Aggregate				Conventional Concrete		
	Temp	Time	UV pulse vel(km/s)	Category avg	Remark	Colour	Category avg	Remark	Colour
31	30	0	-	4.796	very good	normal	4.883	very good	normal
32	30	0	-						
33	30	0	-						
34	200	2	4.417	4.347	good	normal	4.576	very good	normal
35	200	2	4.31						
36	200	2	4.424						
37	350	1	4.193	4.103	good	slightly brown patches	4.042	very good	brownish patches
38	350	1	4.015						
39	350	1	4.1						
40	350	2	3.195	3.282	fair	brown-ish patches	4.006	very good	brownish patches
41	350	2	3.084						
42	350	2	3.567						
43	500	1	3.248	3.223	fair	brown-ish patches	3.212	fair	slightly dark grey
44	500	1	3.256						
45	500	1	3.165						
46	500	2	2.807	2.659	doubtful	blackish patches	3.042	fair	slightly dark grey
47	500	2	2.95						
48	500	2	2.22						
49	650	1	2.011	1.745	very poor	lightly grey	1.897	poor	whitish grey
50	650	1	1.662						
51	650	1	1.562						
52	650	2	1.552	1.497	very poor	slightly grey	1.838	poor	whitish grey
53	650	2	1.33						
54	650	2	1.608						
55	800	1	1.753	1.81	very poor	whitish grey	1.418	very poor	whitish grey
56	800	1	1.694						
57	800	1	1.985						
58	800	2	1.405	1.103	very poor	whitish grey	1.290	very poor	buff
59	800	2	1.02						
60	800	2	0.884						

Table 5.7: UV Pulse velocity test for concrete grade M 20

Block No	Cube (150*150*150) mm		Concrete containing marbles Aggregate				Conventional Concrete		
	Temp	Time	UV pulse vel(km/s)	Category avg	Remark	Colour	Category avg	Remark	Colour
61	30	0	-	4.771	very good	normal	4.871	very good	normal
62	30	0	-						
63	30	0	-						
64	200	2	4.605	4.471	good	normal	4.619	very good	normal
65	200	2	4.218						
66	200	2	4.591						
67	350	1	4.215	4.124	good	slightly brown patches	4.058	good	brownish patches
68	350	1	4.106						
69	350	1	4.052						
70	350	2	3.322	3.169	fair	brown-ish patch-es	4.000	good	brownish patches
71	350	2	3.156						
72	350	2	3.028						
73	500	1	3.056	3.103	fair	brown-ish patch-es	3.120	fair	slightly dark grey
74	500	1	3.157						
75	500	1	3.097						
76	500	2	2.6	2.686	doubtful	blackish patches	2.978	doubtful	slightly dark grey
77	500	2	2.876						
78	500	2	2.582						
79	650	1	1.763	1.773	very poor	lightly grey	1.951	poor	whitish grey
80	650	1	1.928						
81	650	1	1.628						
82	650	2	1.583	1.392	very poor	slightly grey	1.733	poor	whitish grey
83	650	2	1.326						
84	650	2	1.266						
85	800	1	1.102	1.179	very poor	whitish grey	1.396	very poor	whitish grey
86	800	1	1.082						
87	800	1	1.354						
88	800	2	1.007	0.981	very poor	whitish grey	1.315	very poor	buff
89	800	2	0.938						
90	800	2	1						

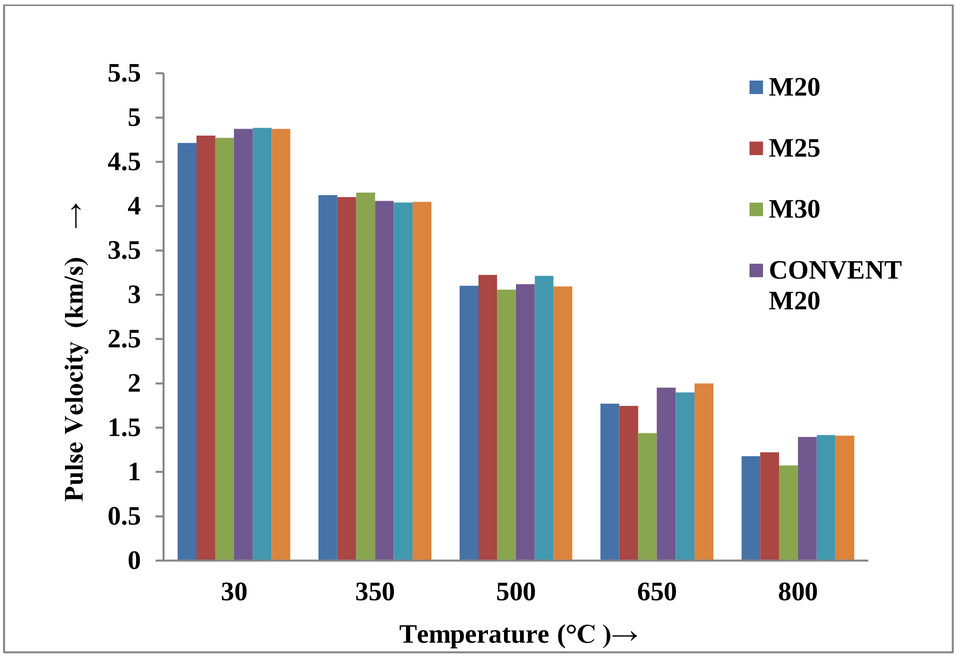

Fig. 5.1: UV Pulse velocity after one hour heating

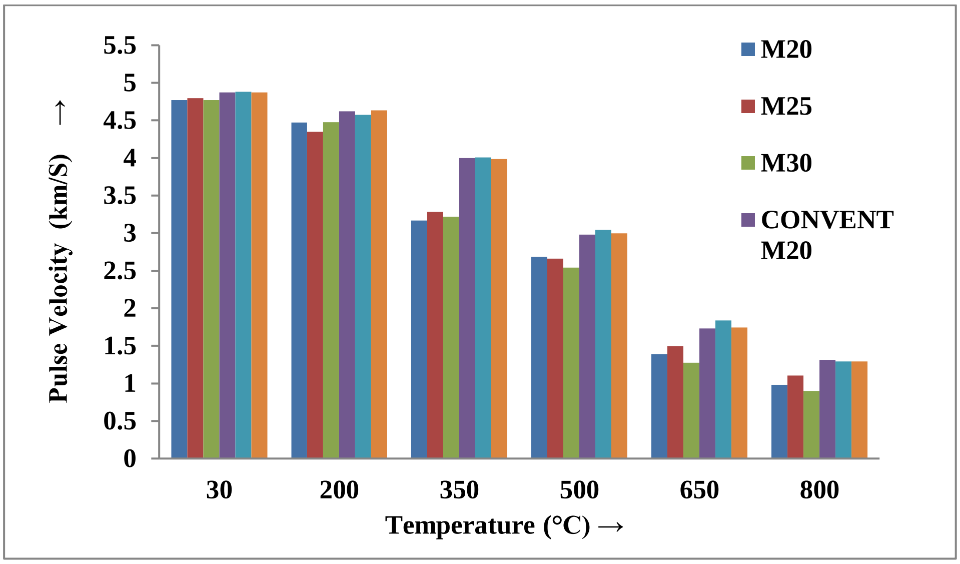

Fig.5.2: UV Pulse velocity after two hours heating

6. CONCLUSION

- A glance at these charts shows persistent fall in overall quality of concrete with rising temperatures.
- Up to 350°C, the concrete quality remains good in conventional concrete whereas in case of marble concrete, it remains good for 350°C at one hour heating only.
- For two hour heating, the concrete containing marble aggregates deteriorates & can at best be described as fair.
- At 500°C, the values of UV Pulse velocity indicate a fall in quality of concrete from good to fair in conventional concrete.
- While the fall from good to fair and from fair to good can be seen at 350°C (2 hrs. heating) and 500°C (1 and 2 hrs. heating).
- Beyond this, concrete quality becomes poor and very poor in conventional and marble concrete respectively.
- At 800°C, concrete quality became very poor & not at all acceptable.
- UV Pulse velocity test results were surprisingly devoid of any bias towards concrete grade. A higher exposure time, however, resulted in a slightly inferior response across all grades.

REFERENCES

[1]V. Ramesh Babu, B. Ramesh Babu , C. Sasidhar , N. Krishna Murthy, M. Vijaya Sekhar Reddy, N.Venkata Ramana (2014),"Influence Of Bethamcherla Marble Aggregate on fibre Reinforced Concrete" International Conference On Advances In Civil And Mechanical Engineering (ACME), Issue 9 Feb.

[2]Prof. Roshan Lal, Er. Kuldeep Kumar(2014), "An Investigation On Strength Characteristics Of Concrete Containing Recycled aggregates Of Marble And Granite Waste", Internatinal Journal Of Progress In Civil Engineering, Volume 1, Issue 1.

[3]A. R. Mundhada & final year Project batch, "Effect of Fire on Concrete"**,** Project Report (2014)', Prof. Ram Meghe Institute of technology and Research, Badnera, Amravati

[4]Diogo Silva, Filipe Gameiro and Jorge De Brito (2013), "Marble properties of structural concrete containing fine aggregates from waste generated by the marble quarrying industry" Journals Of Material In Civil Engineering, Volume 26, 23 May.

[5] Baboo Rai, Khan Naushad H , Abhishek Kr, Tabin Rushad S, Duggal S.K(2011), "Influence of Marble powder/granules in Concrete mix", International Journal Of Civil and Structural Engineering, Volume4, Issue 1, PP 827-834.

[6] NDT PAPERS: (International Journal of Earth Sciences and Engineering, ISSN 0974-5904, Volume 04, No 06 SPL, October 2011, PP. 677-680

[7] IS: 516 – 1959 (Reaffirmed 1999) Edition 1.2 (1991-07), Methods of Tests For Strength Of Concrete.

[8] IS: 13311 (PART 1): 1992 (Reaffirmed 1999) Non-Destructive Testing Of Concrete-Methods Of Test Part 1- Ultrasonic Pulselocity.

[9] Dietmar Hosser, Thomas Dorn, Ekkehard Richter(1994)," Evaluation of simplified calculation methods for structural fire design", Fire Safety journal, Volume 22, Issue 3, PP 249-304.

[10] IS: 1489 (Part 1):1991 Specification for Portland Pozzolona Cement- Part 1

[11] IS: 383-1970: Specification for Coarse and Fine Aggregate from Natural Resources