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# IMPACT OF HIGH TEMPERATURE ON PROPERTIES OF MARBLE WASTE CONCRETE WITH POST- HEATED WATER CURING

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**3.1,Abstract:** This chapter explains the methodology followed during the course of the project in order to identify the effect of high temperature on mechanical properties of marble fine concrete. The chapter also describes the methods used in the assessment of mechanical properties fire damaged concrete. Use of waste and by-products in concrete will lead to green environment and such concrete can be called as Green concrete. Increase in demand and decrease in natural resource of cement for the production of concrete has resulted in the need of identifying a new source of cement and natural aggregates. The possibility of utilization of marble waste ash as replacement to aggregate in concrete is taken into consideration. This is the waste of marble after cutting manufacturing from it. This wastage of marble is used as course aggregate. The waste marble is obtained near marble factory and mines. Marble waste produced from the marble industries as a result of production more production equal more waste and more waste creates environmental contamination.

**Keywords:** Marble waste, High Temperature, pulse velocity, Post heated Curing, Fire damage, Compressive

## I. INTORODUCTION

**1.1General:** widely used as a major constituent in infrastructure development. Not only the buildings constructed in wood suffering from fire damage but also the buildings constructed in reinforced concrete are the examples of fire damage despite its good fire resisting properties. This is because of a change in its mechanical Concrete with its reliable properties like easy availability of constituent materials, mould ability i.e. capacity to acquire any desired shape when it is in the fresh state, durability, and better thermal resistance, it is properties due to the change in its physical and chemical composition Fire may occur at any time during the entire life span of the structure and it may occur during construction stage also. Most of the fire-damaged structures does not lose its strength completely and that only 9% RCC structures lose their entire strength hence, they can be demolished but, rest of 91% can be repairable. Hence, demolishing the entire structure may not prove to be an economical decision. Thus it is practiced to repair or retrofit the fire damaged structures by using different retrofitting techniques available in the construction field. Before retrofitting it is necessary for the engineer to evaluate the residual strength of fire damaged concrete members. Residual strength of fire damaged concrete may be evaluated by using destructive, partially destructive as well as non-destructive tests. Correlation established between destructive and non-destructive test may be used for calculating the residual strength of concrete. An economically suitable solution to this problem should include utilization of this material for the new products especially in construction applications. Which in tone minimizers the heavy burden on the nations landfills saves natural resources energy and reduces environmental pollution?

**1.2 Fire and Fire Classification:** NFPA defines the fire as "oxidation process that happens very fast so that light, heat, and sound are released". Fuel heat and air are the three components of fire and the presence of all the three is necessary. The fourth component i.e. unrestrained chain reaction is added to explain the fire and this chain reaction provides the heat required to maintain the fire. Fire class is a term used to denote the type of fire, in relation to the combustible material which is being ignited.

**Table 1.1 Fire Classifications**

| **Class** | **Material** |
|---|---|
| Class-A | Solid combustible materials of organic nature such as wood, paper rubber, plastics, etc. |
| Class-B | Flammable liquids- Oil based products, tar, solvent, paints, etc. |
| Class-C | Flammable gases under pressure including liquefied gases |
| Class-D | Combustible metals, such as magnesium, sodium, potassium, etc. |

### 1.3 Major Fire Incidences in the Decade

a) b)

**Figure 1.1 Major fire disasters Table 1.2 Major fire disaster**

| | **a)** | **b)** |
|---|---|---|
| **Date** | 15th November 2010 | 14th June 2017 |
| **Location** | Shanghai, China. | Grenfell Tower, London, England. |
| **Cause** | Scaffolding erected for the renovation caught fire due to the sparks of welding work. | Freezer in the refrigerator caught fire due to an electrical fault. Cladding and insulation gave rise for the rapid spread offire. |
| **Decision after damage assessment** | Renovation | Demolition |
| **Source** | Photo: Peijin Chen | Photo: Jeremy Selwyn |

**1.4 The Response of Concrete to Fire:** Reinforced concrete structure deteriorates when exposed to elevated temperature. Loss in properties such as a reduction in bond strength, compressive strength, elastic modulus, tensile strength and ductility of steel, spelling and cracking. Although the concrete structure damaged during fire holds a certain load carrying capacity. Consequently, it is good to repair the structure by using retrofitting techniques rather than demolishing and rebuilding. The rebuilding of the whole structure proves to be an uneconomical option.

Investigation of the structural integrity is necessary for planning the detailed repair strategy and it reveals the performance of the structural members. In the past few years, the applicability of different techniques has been increased in the field of fire damage assessment for determining the changes in the mechanical, physical and micro structural properties of the concrete after exposure to high temperature. The techniques include various methods such as a Schmidt Rebound Hammer, Ultrasonic Pulse Velocity (UPV), micro-crack density analysis, image analysis, Differential Thermal Analysis (DTA), Thermal Gravimetric Analysis (TGA), calorimetric, petrographic analysis, and others (Chew 1993). Methods used in the fire damage assessment of concrete can be broadly classified into laboratory tests and in situ tests. Non-destructive test (NDT) such as Schmidt hammer and UPV are the examples of situ test and they are applied on the surface of the concrete. Situ tests are advantageous because extensive damage investigation is possible in a relatively short time. Application of in situ tests is easy but the information produced from these tests is very limited for understanding the exact damage in the inside layers of concrete. For discovering the exact depth of damage along the cross section a core drilling test is preferred. Information such as depth of fire damage, color change in the concrete, concrete residual compressive strength can be obtained from the concrete core. Exposure of concrete to elevated temperature during fire leads to thermal expansion of the constituents of concrete, moisture evaporation, and development of pore pressure. Two major effects of fire on structural concrete can be observed:

Loss in strength of the matrix by the degradation of the hydrate structure, cracking.

The severity of the spelling of the outermost concrete, physical effects and color change in concrete which depend on the change in temperature.

Heating above 300°C, changes the color of the concrete to pink (300-600°C) and then to whitish grey between the temperature range 600 to 900°C. Free moisture present in the concrete evaporates between the temperature range of 100°C and 200°C; this evaporation builds the vapour pressure and encourages the spilling. At 250°C temperature, concrete dehydrates. At 300°C, 15-40% strength reduces because of dehydration of calcium hydroxide and at 550°C, 55-70% strength reduces due to aggregate deterioration. Siliceous aggregate Quartz shows volumetric expansion and thereby damage to theconcrete with temperature. At 800-900°C $CaCO_3$ present in limestone aggregate concrete turns into CaO and further expands with temperature.


**Figure 1.2 Surface of the concrete surface after exposure to elevated temperature**

Spelling is often mentioned as an important consequence in the post-fire evaluation of structural concrete exposed to fire. Spelling is the breaking-off of layers of the concrete surface in response to applied heat. It may cause the loss of sections of concrete elements or create fire damage depth on exposed surfaces while reducing the protective ability of the reinforcement. Concrete spilling is attributed to the loss in tensile strength of concrete at high temperatures and could be grouped into the following categories: aggregate spilling, corner spilling, surface spilling and explosive spilling. All forms of concrete spilling may cause fire resistance failure through the loss of load-bearing capacity or loss of integrity.

Marble chips concrete: Use of waste and by-products in concrete will lead to green environment and such concrete can be called as “Green Concrete”. Increase in demand and decrease in natural resourceof cement for the production of concrete has resulted in the need of identifying a new source of cement and natural aggregates. The possibility of utilization of marble waste ash as replacement to aggregate inconcrete is taken into consideration.

This is the waste of marble after cutting manufacturing from it. This wastage of marble is used as course aggregate. The ash available at the marble manufacturing factory and mining. The waste marble is obtained near marble factory and mines. Marble waste produced from the marble industries as a result of production more production equal more waste and more waste creates environmental contamination.

A high volume of marble production has generated a considerable amount of waste material. Almost 70% of the minerals get wasted in the mining, processing and polishing stages which have a serious impact on the environment.
An economically suitable solution to this problem should include utilisation of this material for the new products especially in construction applications. Which in tone minimizers the heavy burden on the nations landfills saves natural resources energy and reduces environmental pollution?

**1.6 Assessment of Fire Damage:** In many cases structure needs a repair after the fire and, demolition of the entire structure as a result of fire is rare. Demolition leads to serious financial consequences to the owner. In case of structural repair which is referred to as retrofitting, needs a proper repair strategy. Absolute investigation of the effect of elevated temperature on the properties of steel and concrete, permanent change in their material characterization is required for evaluating future structural performance. Tests such as Schmidt hammer, Pull-off test, UPV are used to give an apparent reduction in strength. While, thermo gravimetric, color, crushing strength, and thermo-luminescence tests are used for the analysis of the temperature history of the member.

**Schmidt hammer test (Rebound Hammer):** It is a strength indication based on the impact hardness of the concrete. This method is a quick method and most commonly used. Presence of air pockets and other irregularities may affect the results of Schmidt hammer. For all test angles, hammer requires a correction chart due to the gravity effect. Moisture condition of the concrete, smoothness of the surface, and movement of the small test specimen may affect the rebound hammer reading.

**Color test:** Heating brings color change in the concrete. This color change analysis may be used to indicate the maximum temperature attained and fire duration (Ingham 2008). Following table 1.3 gives a general idea about the change in color with respect to temperature change.

**Table 1.3 Color changes to concrete caused by heating (Compiled from (Ingham 2008))**

| Heating Temperature | Color Changes |
|---|---|
| 250 - 350°C | Pink/ Red discoloration |
| 450 - 500°C | Red discoloration |
| 800 - 1200°C | Whitish Grey |

**Pull-off test:** Surface tensile strength of the concrete is measured from this test. This test is partially destructive in nature and involves adhesive, plate, and jack.

**Ultrasonic Pulse Velocity Test (UPV):** Non-destructive in nature. The pulse of vibration generated by the transmitter transducer travels a path of known length. Receiver transducer receives the signal and electronic timing circuits convert it into the transit time. Direct, semi-direct or indirect method can be used where the angle between the transducer and receiver are 180°, 90°, and 0° respectively. The indirect method gives poor quality results and hence the direct method is preferred because maximum pulse energy is received at the receiver. Dynamic Young's modulus of elasticity may be determined from the relationship given in IS 13311: 1992, between UPV readings, dynamic Poisson's ratio and the density of concrete.
Following factors influence the pulse velocity reading:

- **Mix design**
- Type of aggregates
- Moisture condition
- Surface condition

- Temperature of concrete
- Presence of reinforcement

**1.7 Objectives of study:** High temperature brings degradation in properties of concrete, and above- explained methods are used in the assessment of fire damaged concrete and these methods are employed on the basis of general survey (preliminary investigation).

- To study the behavior concrete at elevated temperature the result which is increasing durability and good performance under elevated temperature?
- To study the effect of post-fire water curing on compressive strength of fire damaged marble chips concrete at 3 days of post-fire water curing.
- To study the variation in compressive strength and other properties of marble chips concrete
- compare the properties of marble chips concrete before and after heating

**1.8 The layout of the report:** The dissertation is divided into five chapters. The content of each chapter is summarized below:

- **Chapter 2:** Focuses on the literature review in the assessment of fire damaged concrete by using various conventional as well as advanced methods and gives suitable background information for this research program.
- **Chapter 3:** Describes the materials, mix proportions, heating and cooling of the concrete specimens. This section also elaborates the main testing program and effect of ambient coolingand quenching on the marble chips concrete.
- **Chapter 4:** Presents the results of residual strength and residual UPV of heated. The established relationship between residual strength ratio and residual UPV ratio is also justified in this section.
- **Chapter 5:** Is allocated for the conclusion and direction for future work.

## II. LITERATURE REVIEW

**2.1 Opening Remarks:** Retrofitting of fire damaged structures is one of the most promising challenges for civil engineers and for understanding the exact level of damage, it is necessary to evaluate the residual compressive strength. There are few conventional methods like Ultrasonic Pulse Velocity method, compression strength on cores, split tensile test, rebound hammer test, and pull off test which is used widely in the retrofitting industry (Chew 1993; Chung 1985; Yang et al. 2009). But, there are few newly developed methods which are also destructive, partially destructive as well as non- destructive in nature can be used which has the capability of producing similar results as that of conventional methods.

**2.2** Literature Reviewed on marble chips concrete:

Natan Patel et al studied on Marble Waste Opportunities for Development of Low Cost Concrete The author studied Based on the Indian Standard (IS: 102624 1982), design mix for M30 grade of concrete was prepared by partially replacing fine aggregate with five different percentages by weight of marble powder (0 5%, 10 15% and 20%) There is a slight decrease in compressive strength value concrete mix when 20% marble powder is used as compared with that of 15 marble powder mix Compressive strength of the concrete has increased with increasing percentages of marble dust additions The author conclusion for this research rate of the marble waste 28 days strength is 38 N/mm2 at this strength of concrete rate is Rs 38

**2.3 Literature Reviewed effect of high temperature on concrete:**

**Hwang et al. (2018)** carried out the study to monitor continuously the integrity of concrete subjected to elevated temperatures. The concrete sample was tested before, during and after the heating for the pulse velocity. Cylindrical specimen with a diameter 10 cm and length 20 cm was used in the present experimentation. By using a heat transfer heating method the sample was heated in the electric heating furnace installed on the universal testing machine. The sample was exposed to an elevated temperature for 5 hours for 100, 200, 300, 400, 500, 600 and 700°C temperature at the rate of 1°C/min. The results indicated that higher residual strain in the concrete indicates higher heating temperature which leads to the decreased elastic modulus of concrete

**A. Husain et al. (2016)** had conducted study on the effects of temperature on the behaviour of concrete materials and structures. In this he had provided the temperature elevated or depress from the

ambient temperature. The main aim of this study was to effect of weather conditions on properties ofconcrete.This method used in current research particularly focuses on the study of elastic wave propagation through the medium of different acoustic independence and establishing the relationship between the parameters obtained from standard destructive tests and the impact-echo test. Material having high acoustic independence provides easy transfer of elastic wave. acoustic independence equal to zero or close to zero, in air. High temperature reduces this acoustic independence of concrete **(Katarzyna and Hager 2015)**. Pulse is triggered on the concrete surface which travels easily through the concrete medium but, it was encountered at the material having low acoustic independence i.e. inair. Receiver positioned on the surface of the test specimen that receives and stores the signal in thetime domain. It was observed that signals obtained from the test, are strongly reflecting the extent of damage to the concrete due to heat and hence, it is an effective non-destructive test for accessing thefire damaged concrete.

**S. O. Osuji et al. (2015)** studied the effects of elevated temperature on compressive strength of concrete: a case study of grade 40 concrete. This study presents the results of investigation of theeffects of elevated temperatures on the compressive strength of Grade 40 concrete. A total of thirtycube specimens were casted, cured in water at ambient temperature in the laboratory and subjected to various temperature regimes before testing. A concrete mix of 1:1:3 (cement: fine aggregates: coarse aggregates) with water content ratio of 0.44, fine aggregates lying in zone 2 of sieve tests as well as granite of maximum size 12.5mm was designed for these investigations using the Department of Environment Method. Specimens cured for 7 and 28 days were subjected to uniaxial compressive loading tests at room and elevated temperature of 24, 100, 150, 200, 250 and 300 degree Celsius at one hour duration. The result indicated 14.49%, 25%, 51%, 35.51% and 43.88% decrease in compressive strength at the earlier quoted temperatures respectively. At an elevated temperature of 300 degrees Celsius a peak decrease of 53.47% in compressive strength was observed.

**Nilmlyat P. S. (2013)** conducted study on performance of concrete at elevated temperatures: utilizing a blended ordinary portland cement (OPC)/ saw dust ash (SDA) as binder. This study aimed at investigating the effect of subjecting concrete, produced with cement being partially replaced with saw dust ash (SDA) to elevated temperatures..

**Anand N. (2011)** had conducted the effect of elevated temperature on concrete materials. In this study he found that the behaviour of Normal strength concrete, high strength concrete and self-compacting concrete were different when exposed to high temperature.

**Ingham (2009)** had studied the petrographic examination techniques to the assessment of fire- damaged concrete and masonry structures. He investigate this technique on masonry structure.

**Husem (2006)** studied the variation of compressive and flexural strengths of ordinary and high- performance micro-concrete at high temperatures. In the experiment, concrete specimens were exposed to high temperatures (200, 400, 600, 800 and 1000°C) and cooled differently (in air and water). Compressive and flexural strengths of these concrete samples were compared with each other and then compared with the samples which had not been heated. The results indicated that concrete strength decreases with increasing temperature, and the decrease in the strength of ordinary concrete is morethan that in high performance Concrete. The type of cooling also affects the residual compressive and flexural strength.

The effect of high temperature on high performance steel fiber reinforced concrete was carried out by **A. Lau. et al. (2006).** In this he provided the temperature of ranges between 105 $^0$C to 1200 $^0$C, the compressive strength , flexural strength, elastic modulus and porosity of concrete reinforced with 1% steel fiber (SFRC) and changes of color to the heated concrete have been investigated. He found that loss of concrete strength with increased maximum heating temperature and with increased initial saturation percentage before firing. For maximum temperature below 400 $^0$C, the loss of compressive strength was small, for all concrete heated above 400 $^0$C temperature started to suffer a greatercompressive strength loss than normal strength concrete. Strength of all mixes reaches minimum values at 1000 $^0$C to 1200 $^0$C. He concluded that the research study has identified a correlation that exists between the final permanent color of heated concrete and the maximum temperature reached.

**Noumowe A. et al. (2005)** had conducted study on mechanical properties and microstructure of high strength concrete containing polypropylene fiber exposed to temperatures up to 200 $^0$C. This investigation developed some important data on the mechanical properties and microstructure of high strength concrete incorporating polypropylene fiber exposed to elevated temperature up to 200

$^0$C. When polypropylene fiber high strength concrete is heated up to 170 $^0$C, fibers readily melt and volatilize, creating additional porosity and small channels in the concrete.

**Li et al. (2004)** had investigated mechanical properties of high strength concrete after fire. He had done the comparative study in between high strength concrete and normal strength concrete were used to investigate the compressive strength, split tensile and bending strength after fire. He had provided the temperature 200, 400, 600, 800 and 1000 $^0$C respectively. After the temperature inside the furnace reached 200, 400, 600, and 1000 $^0$C, the compressive strength of the specimens with a strength grade of C70 was retained at 82.3%, 63.2%, 58.1%, and 27.3%, respectively. After the temperature inside the furnace reached 200, 400, 800, and 1000 $^0$C, the splitting tensile strength was retained at 85.7%, 81.8%, 51.9%, and 16.4%, respectively, and the bending strength was retained 84.5%, 43.7%,
16.3%, and 7.4%, respectively.
To simulate the effect of fire fighting

**Nassif et al. (1999)** studied the effect of quenching on pulse velocity. It was noted that a 10% reduction in pulse velocity as a result of rapid cooling. The development of micro cracks and propagation of the existing one caused this reduction. These results are found to be discrepant with the findings of previous studies. Previous researchers Chung (1985) kept the concrete specimens for the longer time in the water which thereby increased the moisture condition and estimated the pulse velocity on the higher side. Rapid cooling was done by applying the water for 5 minutes which does not reflect the large change in the moisture content and underestimates the UPV. Hence, the results were discrepant.

**Nassif et al. (1995)** used k-type thermocouples to study the distribution of temperature to the center of the specimen. For this purpose, three different concrete cores were used for testing. Reduction of pulse velocity due to the formation of a number of cracks and increase in their width was observed in the fired specimens and the effect was more considerable in the temperature range of 320°C to 378°C.

**G. T. G. Mohamedbhai et al. (1986)** also studied the effect of heating and cooling at a slow and quick rate. Four different duration of exposure were considered. Demoulded concrete cubes were cured for 7 days in water and then air-dried till the time of heating i.e. 84±1 days. It was observed that effect of heating and cooling rate negligibly affects the concrete between the temperature ranges of 600°C to 800°C but, the effect is considerable between the temperatures of 200°C to 400°C. As a large amount of moisture evaporates during the initial stage of exposure and loss moisture resulted in a lossin the strength of concrete.

**2.4 Significance of research:** Retrofitting techniques are mostly used for strengthening of the fire- damaged structures. If concrete is cured with water for some period after exposure to high temperature, it results into increase in strength of the mature concrete due to the regeneration of calcium-silicate- hydrate as a product of hydration reaction, which fills the micro cracks caused due to high-temperature exposure. Hence, this ability can be used as an effective retrofitting technique. To avoid the quality assessment of concrete by using destructive tests, a non-destructive method based on the correlation of Ultrasonic Pulse Velocity and the results of Compressive test can be developed.

**2.5 Project impact - Expected outcome:**

- Waste MARBLE will overcome the environmental impact.
- Capital involved in demolition and reconstruction can be saved by using the post-fire water curing method as a retrofitting technique.
- Non-destructive way of dealing with quality assessment of concrete can be developed. Hence, the uniformity of structure can be maintained by avoiding the application of destructive tests.
- Sample preparation for a destructive test such as core drilling can be avoided and therebyexpenditure involved in it.

**2.6 Closing Remarks:** From the literature, it can be seen that exposure of concrete to elevated temperature brings changes in physical, mechanical, and microstructural properties of concrete. Tests such as compression test, splitting tensile test, UPV test is commonly used in damage assessment. In recent years, we can find the application of new methods in the assessment of fire damage concrete. For mature concrete correlation between destructive and non-destructive test are available for evaluating the residual strength.

## III. METHODOLOGY

**3.2 Opening Remarks:** This chapter explains the methodology followed during the course of the project in order to identify the effect of high temperature on mechanical properties of marble fine concrete. The chapter also describes the methods used in the assessment of mechanical properties fire damaged concrete.

**3.3 Materials:** Materials used for casting concrete specimens consists of Ordinary Portland Cement (OPC) of grade 43 with 28 days compressive strength of 43 MPa, as a binding material provided by Ultratech Cement complying with IS 8112: 2013 (Ordinary Portland Cement 43 Grade - Specifications). Natural washed and uncrushed river sand was used as fine aggregate (FA), and as a coarse aggregate (CA) natural crushed basalt was used in saturated surface dry (SSD) condition.

In this study maximum nominal size of aggregates was restricted to 10 mm and it is smaller than the one-fourth of the minimum thickness of the specimen and satisfying the IS 456: 2000 (Plain and Reinforced Concrete - Code of Practice) requirement. The density of materials used in this experiment like fine aggregate and coarse aggregate in SSD condition was 2500 kg/m3 and 2600 kg/m3 respectively. Most of the civil engineering projects in India are constructed in concrete with 28 days design compressive strength of 30 MPa. Hence, concrete mix design was performed for M30 grade of concrete by considering the water/cement (W/C) ratio 0.45, Cement, fine aggregate and coarse aggregate were mixed in the assistance of distilled water.

**3.4 Material required for marble chips concrete:** Materials for Marble chips concrete are given below:

1. Cement
2. Fine aggregate (Natural sand)
3. Coarse aggregate
4. Water
5. marble chips

The ingredients of concrete i.e. cement, fine aggregate (Natural sand), coarse aggregate are tested before use in concrete.

**3.3.1 Cement:** The cement used in this experimental work is **"43 grades Ordinary Portland Cement".** Properties of cement are tested as per IS 12269 – 1987. Test results are presented in Table No.3.1.

**Table No. 3.1: Physical Properties of Cement**

| Sr. No. | Description of test | Requirement as per IS | Results |
|---|---|---|---|
| 01 | Fineness of cement (residue on IS sieve No.9) | 0- 10% | 9.5 % |
| 02 | Specific gravity | -- | 3.15 |
| 03 | Standard consistency of cement | -- | 35 % |
| 04 | Setting time of cement<br>a) Initial setting time<br>b) Final setting time | <br>30 minute<br>600 minute | <br>36 minute<br>428 minute |
| 05 | Soundness test of cement (with Le-chatelier'smould) | 10.0 mm | 5.0 mm |

**Photograph No. 3.1: Determination of Initial and Final setting time by Vicat apparatus**

**3.3.2 Aggregates:** Natural sand from Kopargaon (Godavari) river. Various tests such as specific gravity, water absorption, moisture content, sieve analysis etc. have been conducted on C.A. & F.A.The test results are shown in Table No. 3.2 to 3.4. Crushed black trap basalt rock of size 10mm down was used as coarse aggregate. The results of sieve analysis confirm the requirement of gradation as per I.S. 383-1970.

**Table No. 3.2: Physical properties of Natural sand**

| **Sr. No.** | **Property** | **Results** |
|---|---|---|
| 01. | Particle Shape, Size | Round, 4.75 mm down |
| 02. | Fineness Modulus | 2.583 |
| 03. | Silt Content | 3.1 % |
| 04. | Specific Gravity | 2.75 |
| 05. | Bulk Density | 1725 kg/$m^3$ |
| 06. | Surface Moisture | 0 |

The above physical properties of natural were determined in laboratory by conducting experiments onsamples of natural sand.


**Photograph No. 3.2: Sieve analysis Table No. 3.3: Sieve Analysis of Natural Sand.**

| Sr. No. | Sieve size | Weight Retained(kg) | CumulativeWt. Retained | % Cumulative Wt Retained | % Passing |
|---|---|---|---|---|---|
| 01. | 4.75 mm | 0.000 | 0.000 | 0.0 | 100.0 |
| 02. | 2.36 mm | 0.037 | 0.037 | 3.7 | 96.3 |
| 03. | 1.18 mm | 0.256 | 0.293 | 29.3 | 70.7 |
| 04. | 600µ | 0.241 | 0.534 | 53.4 | 46.6 |
| 05. | 300µ | 0.317 | 0.851 | 85.1 | 14.9 |
| 06. | 150µ | 0.117 | 0.968 | 96.8 | 3.2 |
| 07. | Pan | 0.032 | 1.000 | - | |
| Total | | 1.000 | | 268.3 | |

**Fineness Modulus = Total cumulative percentage retained/100**

**= 2.683 (**confirming to zone –II of I.S. 383-1970)

The fineness modulus obtained for natural sand is confirming to Zone-II. The physical properties of coarse aggregate are obtained by preliminary investigation which is given below:

**Table No. 3.4: Physical Properties of Course Aggregate**

| **Sr. No** | **Property** | **Results** |
|---|---|---|
| 01. | Particle Shape, Size | Angular, 10 mm down |
| 02. | Fineness Modulus | 6.01 |
| 03. | Specific Gravity | 2.78 |
| 04. | Water absorption | 2.635 % |
| 05. | Moisture content | 0 |
| 06. | Bulk Density | 1610 kg/m$^3$ |

**Table No. 3.5: Sieve Analysis of 10 mm Course Aggregates**

| **Sr. No.** | **Sieve size** | **Weight Retained(kg)** | **CumulativeWt. Retained** | **% Cumulative Wt Retained** | **% Passing** |
|---|---|---|---|---|---|
| 01. | 10 mm | 0.000 | 0.000 | 0.000 | 100.0 |
| 02. | 4.75 mm | 5.000 | 5.000 | 100.0 | 0.00 |
| 03. | 2.36 mm | - | 5.000 | 100.0 | - |
| 04. | 1.18 mm | - | 5.000 | 100.0 | - |
| 05. | 600µ | - | 5.000 | 100.0 | - |
| 06. | 300µ | - | 5.000 | 100.0 | - |
| 07. | 150µ | - | 5.000 | 100.0 | - |
| | Total | 5.000 | | 600.0 | |

**Fineness Modulus = Total cumulative percentage retained/100**

**= 6.03**

**3.3.3 Properties of MC:** This is the waste of Marble after cutting and drilling from it. This wastage of marble used as course aggregate. The waste marble extra is obtained near marble factory at Nashik .it can be again crushed to get approximate rounded shape

**Table No. 3.6: Physical properties of Marble chips**

| Sr.No | Physical properties | Values |
|---|---|---|
| 1. | Fineness Modulus | 2.40% |
| 2. | Water absorption | 0.4 % |
| 3. | Specific gravity | 2.40 |
| 4. | Impact value | 21.98 |
| 5. | Crushing value | 30.62 |
| 6. | Abrasion value | 9.98 |

**3.3.4 Determination of Optimum percentage of Marble chips:** From studied (Atul Krushna K.R 2017) we find out the optimum percentage for marble chips in concrete is 0% to 15%. In this investigation we adopted 15% replacement of fine aggregate by marble chips. 15% replacement of marble chips in concrete gives strength equal to the normal concrete.

**3.5 Mix Design Procedure of marble chips concrete:** Available methods of mix design are listed below and mostly they are based on empirical relations.

1. Trial and adjustment method of mix design.
2. British DoE mix design method (Improvement over Road Note No. 4 Method).
3. American Concrete Institute (ACI) mix design method.
4. Indian Standard (IS) method
5. Rapid method for mix design.

In this study concrete mix design was carried out according to the guidelines specified by the IS 10262-2009 (Concrete Mix Proportioning Guidelines), IS 383-2016 (Coarse & Fine Aggregate for Concrete- Specification), IS 456-2000 (Plain & Reinforced Concrete Code of Practice) and presented below in Table 3.7. This method aims at achieving the workability in fresh concrete and strength and durability in hardened concrete. Moderate environmental exposure condition was taken into account forthe mix design of concrete.

**Table 3.7 Mix Design of Concrete (M30) grade**

| Sr. No. | W/C | Mixture Proportion | | | | |
|---|---|---|---|---|---|---|
| | | M.C | Cement | FA | CA | Water |
| 1 | 0.45 | 0.25 | 1 | 1.02 | 1.93 | 0.45 |
| In $kg/m^3$ | 208 | 117 | 462.2 | 676.8 | 796.25 | 208 |

**3.6 Concrete Specimen:**

**3.5.1 Size and shape of the specimen:** A cylindrical and cube specimen of size 51 mm in diameter and 102 mm in length, 150mm x 150mm x 150mm size was adopted with reference to the previous literature. By considering the parameters like available dimensions of electric muffle furnace and the experimental test setup required specimen size was decided. The reason behind selecting the cylindrical and cube specimen was that uniform heating is possible; as the relatively larger surface area is available for exposure in the cylindrical specimen as compared with a cubical one. Also, it is possible to maintain the temperature difference in the cylindrical specimen within reasonable limits, i.e. minimum temperature gradient can be setup in the specimen. Three replicates were considered for representing each category.

**3.5.2 Specimen preparation:**

**Cylinder:** Concrete specimens (Size:51 mm X 102 mm) are cast in Polyvinyl Chloride (PVC) tubes. General applications of PVC tubes are found in the aggressive environment such as marine and saline environment for confining concrete (Abdulla 2017). To check the suitability of PVC tube for casting specimens, a trial are taken by applying three conditions,

1) Plain PVC tube.
2) PVC tube with surface oiling.
3) PVC tube with plastic paper inside and by closing one end of the tube completely with cardboard.

It is observed that a specimen obtained from a PVC tube by applying the second condition is good as compared to the other two conditions. Cutting the tube along the length for easy removal of a specimen. Later on, all the tubes were cut along the length before pouring concrete into them. Figure

3.2 shows the PVC cylindrical moulds. In the trial specimens escaping of the cement slurry from the vertical slit was observed. To avoid cement slurry to flow out from the vertical cut during compaction, the cut was sealed with adhesive tape as shown in figure 3.2.

**Figure 3.2 PVC cylindrical concrete moulds Cube:** Concrete cube specimen of size 150mm x 150mm x150mm receptively.

**3.6 Concrete mixing and moulding:** For mixing concrete, pan type concrete mixer and hand mixing were used. A measured amount of cement, sand, and coarse aggregate are shown in Figure 3.3 below. The concrete mixer was washed with clean water for avoiding the mixing of any foreign matter. Dry mixing of fine and coarse aggregate for 3 minutes was done before adding cement and Marble chips, thereafter cement, Marble chips and water were added at the same interval (Husem 2006) and a homogeneous mix of concrete was obtained. Concrete was poured in the mould in three layers by tamping each layer 25 times with a steel rod and allowed it to set for the next 24 hours at room temperature. Figure 3.4 shows the moulds filled with fresh concrete. After demoulding the diameter of the demoulded concrete specimens were checked with the help of venire caliper at 3 different sections along the length of the specimen, and a uniform diameter was recorded. No indication of flowing out of the cement slurry was observed from the vertical slit due to the presence of the adhesive tape. Subsequently, all de molded specimens after 24 hours were kept in water for 56 days curing at the 27°C temperature as shown in Figure 3.3. In this study total, 438 samples were cast for both the water-cement ratios.

Figure 3.2 measured cement, sand, and aggregate marble chips aggregate

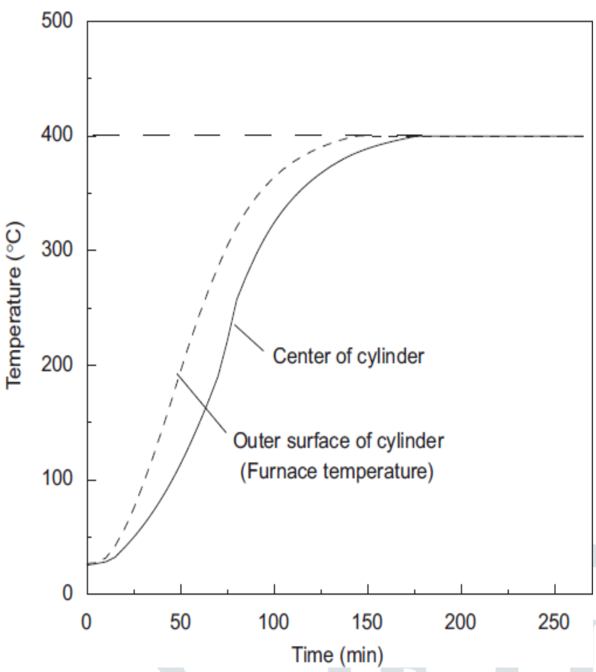
Figure 3.3 Homogeneous mix of concrete

**Figure 3.4 PVC moulds filled with concrete**

**3.7 Heating, cooling and post fire water-cooling regime:**

**3.7.1. Heating:** Heating of concrete brings mineralogical and strength changes in the concrete. From the literature, it was observed that up to 105°C temperature minor loss in strength which are smallerthan 10% of the overall strength by forming capillary porosity and minor micro cracking due to loss of physically bound water. Around 300°C temperature oxidation of iron compounds starts that results in pink/red discoloration of aggregate which causes significant loss in strength after 300°C temperature. α to β quartz transition phase was observed between the temperature 600-800°C and specifically at the temperature 573°C, this phenomenon is also called an inversion. Here α to β transition phase refers to an abrupt change in the volume of quartz crystals when they are heated from stable room temperature

i.e. from α crystal phase to the temperature above 573°C which brings β crystal phase in quartz. After heating to 600°C concrete does not remain structurally useful. Within 600-800°C temperature, if the calcareous aggregate is used, that imparts significant contraction in concrete by releasing carbon- dioxide which brings severe micro-cracking in the matrix of cement. Heating of the concrete up to 1200°C imparts whitish grey coloration caused due to dissociation and extreme thermal stress, caused due to the disintegration of calcareous constituents of aggregate and cement matrix (Ingham 2009). In addition to the above parameters, the shape of the specimen with the available surface area for uniform heating and relatively small size of the specimen, it was decided to heat the early age concrete up to the peak temperature 400°C, 600°C and 800°C to study the strength changes in concrete. After curing of the concrete specimens for 56 days they were kept in the electric muffle furnace with the electronic controller in the SSD condition. Before heating, a damp cloth was used to wipe off the surface water. According to the study carried out by (Nassif et al. 1999; Yang et al. 2009), it was stated that, once the furnace achieves the peak temperature, the temperature difference between the core and the outer fibers disappears. Further, this relationship was verified by the Lin et al. (2011) (as shown in Figure 3.4(a)) and found to be consistent with the previous relationship. In this experimentation Concrete specimens were kept in the electric muffle furnace for one hour once furnace achieves the peak temperature. One hour exposure time allows achieving uniform heating of the concrete throughout the section, Figure 3.5 (b) despites the heating of concrete specimen in electric muffle furnace.





a)b)

**Figure 3.5 (a) Time-temperature curve for the center of the specimen and outer surface of the specimen (Lin et al. 2011); (b) Heating of the specimens at elevated temperature in electric mufflefurnace.**

**3.7.2 Cooling:** Heated specimens were brought down to the normal room temperature with two different methods, one with air-cooling and another with quenching. After heating specimens were kept for air-cooling in the ambient environment and to simulate the effect of firefighting quenching was done. Air-cooled specimens took 1.5 to 2 hours to lower down the temperature whereas quenched specimens required 20 minutes. After cooling and before sending the samples for post-fire curing.

**3.7.3 Post fire water-curing:** Post-fire curing of fire damaged concrete brings substantial strength recovery in the concrete due to rehydration process which regenerates calcium silicate hydrate gel and the level of recovery further depends on exposure temperature, concrete type, method and duration of post-fire curing. In the previous technical literature, it was observed that, increase in a number of days for post-fire curing results in substantial strength recovery. According to (Poon et al. 2001) curing with water for 28 days gives significant strength recovery and it was suggested that curing for more than 28 days may result in further regaining the additional strength. Furthermore, the rate of rehydration in mature concrete is rapid during the first 7 days of recurring and then slowing down thereafter. By taking into consideration the above facts, in the present study effect of post-fire curing of concrete was proposed to be done for the curing period of 0, 3 days of water curing. 0 days curing indicates testing ofthe concrete specimen immediately after cooling of the exposed concrete specimen to elevated temperature.

**3.8 Testing procedures:** Concrete is widely used construction material because of its easily available constituent materials, low thermal diffusivity, and the properties resistant to combustion. The property of lower thermal diffusivity setups a high-temperature gradient near the concrete surface exposed to fire. Therefore, it is of great interest to assess concrete exposed to fire in order to plan necessary strengthening action after the fire.

This test program was designed with three main objectives in mind:

1)To study the effect of post-fire water curing on compressive strength of fire damaged early age concrete at 3 days of water curing.

2)To develop a Non-destructive quality assessment approach for marble chips concrete fire damaged concrete, by establishing the correlation between Ultrasonic Pulse Velocity and the Compressive test results.

3)The properties of the specimens were measured by using Ultrasonic Pulse Velocity (UPV) Test and Compressive strength at the following important points of the heat cycle (Before andafter heating):

1) After post-fire curing to understand the effect of post-fire curing on marble chips ondamaged concrete.

Three specimens were tested for representing each exposure condition and all the specimens were tested in the saturated surface dry (SSD) condition. Primary investigation for evaluating the condition of fire damaged concrete was started with sound test and color observation, by using hammer and chiselbefore sending them for the post-fire curing.

**3.9 Ultrasonic pulse velocity test:** Ultrasonic Pulse Velocity is a type of non-destructive test used for assessing the quality of concrete and it is based on the vibration method. After the fire it is necessary to judge the strength of concrete. In spite of that sometimes it is also necessary to study the parameters like overall quality and uniformity, etc. The methods like the load-carrying capacity of the test, core test are the most reliable tests but they are cumbersome and furthermore, they create structural damage by disturbing the structural integrity. Use of the UPV test not only provides an estimate of relative strength but also helps in identifying the locations where the destructive tests are needed. The objectives ofusing UPV are listed as below:

1. To study the homogeneity of the concrete
2. Existence of voids cracks, and other discontinuities
3. Microstructural changes
4. Checking the quality of the concrete in connection to the standard requirement

The method consists of measuring the time of travel of an ultrasonic pulse passing through the concrete being tested according to IS 13311 (Part 1):1992 (Non - Destructive Testing of Concrete – Methods of Test). Comparatively higher velocity is obtained when concrete quality is good in terms of density, uniformity, homogeneity, etc. The UPV test setup consists of,

1. Electric pulse
2. generator Transducer
3. Amplifier
4. Electronic time device

The transducer produces an ultrasonic pulse, and pulse travels a given known path length (L), in the concrete specimen. Receiver transducer receives the pulse and converts into an electric signal and electronic time display unit displays the transit time (T). Pulse velocity (V) can be given by:

$$V=l/7$$

UPV gives best results when the transducers are kept at a right angle to the surface of concrete i.e. with cross probing or direct transmission. In some cases where opposite faces of the structural element may not be accessible in those cases surface probing is used. But, surface probing is not efficient than cross- probing. UPV test requires a smooth surface for ensuring the transmission of the pulse through the member under the test. In case of very rough surface couplets like grease, petroleum jelly, liquid soap are used on the surface and constant contact pressure is applied for ensuring good contact between the heads (transducer and receiver) and the concrete surface. Ultrasound transmission jelly was used in the present experimentation. It was observed that the test conditions like moisture conditions of concrete influences the test results (Chung 1985). In addition to this shape, length and size of specimen, temperature, presence of reinforcing bars affect the UPV reading.

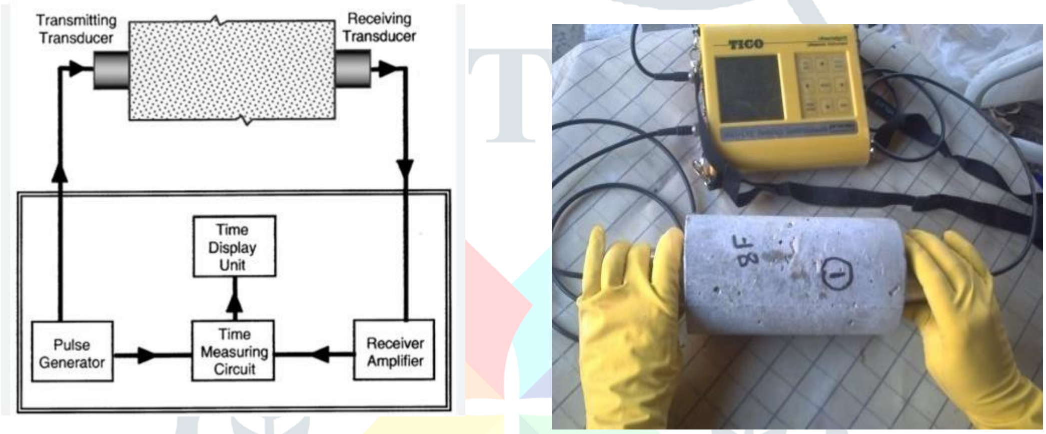



**Figure 3.6 Experimental details of the UPV test setup (direct method)**

In this experimentation, direct transmission was adopted and proper test conditions were adopted for avoiding the influence of test conditions. Calibration of the equipment was done with the help of standard aluminum rod of diameter equal to the diameter of the transducer. The transmitter generates a sinusoidal waveform and it passes through the cylinder. UPV of aluminum was measured about 6300 m/s, which resulted in the ν of aluminum equal to that obtained from the theory of elasticity (Juneja and Endait 2017). Each specimen was tested three times as shown in Figure 3.5 and their mean was used for calculating the velocity of the pulse through a given material. Three readings were taken in such a way that, in first two trials face "A" of the cylindrical specimen was kept on the side of the transmitter and for the last trial face "B" was kept on the side of the transmitter. After 3 days of curing the samples were tested for the UPV first and then subsequently tested for the compressive strength.

From the measured pulse velocity on the concrete specimen, the quality of concrete can be assessed from the criteria given in Table 3.3 from IS 13311 (Part 1):1992. The quality of concrete is governed by factors such as uniformity, presence or absence of internal cracks, and segregation. Furthertests are necessary to be carried out in case the quality of the concrete is doubtful.

**Table 3.8 Velocity criteria for concrete grading**

| **Sr. no.** | **Pulse Velocity(km/sec)** | **Concrete Quality** |
|---|---|---|
| 1 | Above 4.5 | Excellent |
| 2 | 3.5 to 4.5 | Good |
| 3 | 3.0 to 3.5 | Medium |
| 4 | Below 3.0 | Doubtful |

**3.10 Compressive strength:** After performing the UPV test on the concrete specimens, subsequently, compression test was performed on the same concrete samples. A compression test is a widely preferred method because of its reliable results but it's a form of destructive test. The compressive strength of the material is defined as the internal resistance offered to failure under the action of compressive forces. Compressive strength of the concrete represents the characteristics of concrete. Before placing the sample in the universal testing machine sample was checked for irregularities, bearing surfaces of the machine were wiped off to remove loose sand and other material. The uniaxial compressive test was performed on the Universal Testing Machine (UTM) of 1000 kN capacity with a minimum loading rate of 0.20 kN/s i.e. 0.1 MPa/s for evaluating the residual compressive strength of air-cooled and quenched concrete specimens. The experimental test setup of UTM is shown in figure

3.6. Before initiating the test it was ensured that the load is adjusted to indicate zero for avoiding the error in the readings. Test data was collected with the help of the data acquisition system and presented in the graphical form on the computer desktop. The test was conducted until the complete failure of the sample. Compressive strength of 28 days unheated concrete specimens were used to represent the relative recovery in the compressive strength, after post-fire curing of fire damaged concrete. Compressive strength of the specimen can be calculated by dividing the peak load with the specimen cross-sectional area. Average of three readings were taken as the representative of batch.

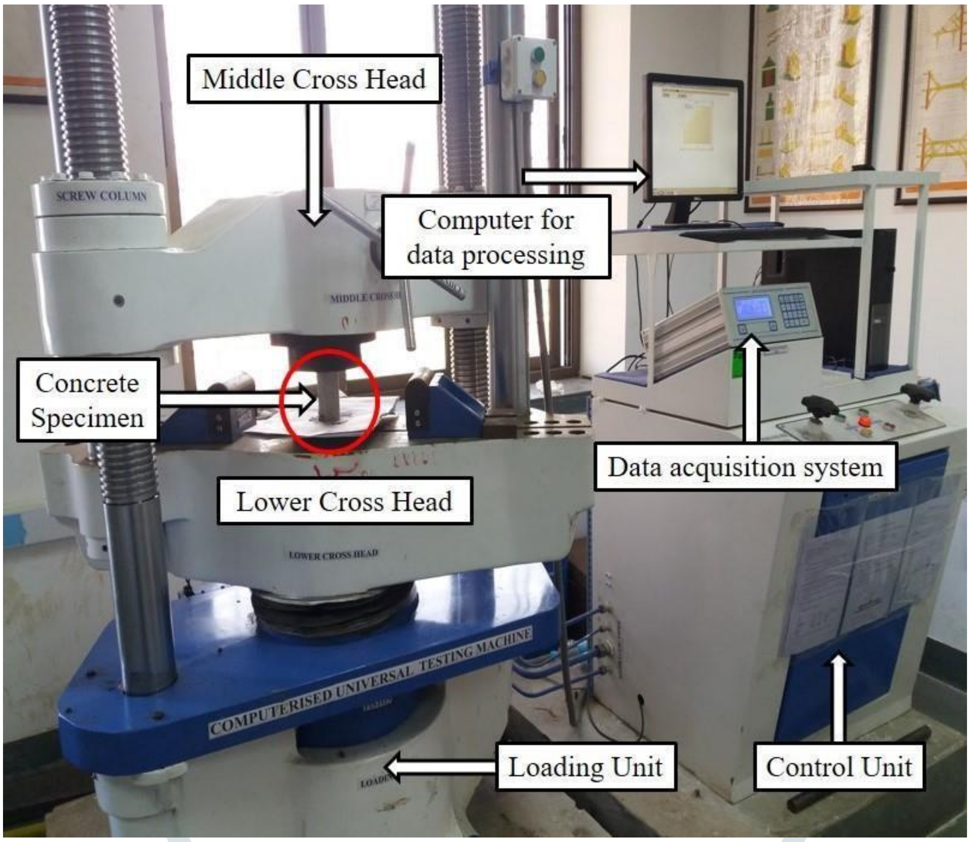



Figure 3.7 Experimental setup of Compression testing machine

**3.11 Correlation between Residual Compressive Strength and UPV:** To simulate the effect of high temperature on early age fire-damaged concrete, for predicting the residual strength of the fire damaged early age concrete, the correlation between residual strength ratio and residual UPV ratio was established. The residual UPV ratio is used quantitatively to evaluate the residual compressive strength ratio of concrete. The data obtained from the testing of the concrete specimens after sending for the post-fire curing of 0 days (i.e. immediately after cooling) were used to correlate the data. The normalization of the data was done with the help of control specimen and indicated in as a fraction of value obtained on the control specimen. Unheated concrete specimen cured for 28 days were used as a control specimen. Two separate equations were proposed to determine residual strength ratio in air- cooled specimens and quenched specimens. Non-linear Regression analysis is used to model the observation data. Non-linear regression is one of the types of regression analysis in statistics. The second-degree polynomial was obtained; a sample second degree polynomial is given below:

$$y = ax^2 + bx + c$$

Where, $y$ = Residual Strength Ratio

$x$ = Residual UPV Ratio

$a$, and $b$ are the coefficients of the equation

$c$ is the constants of the equation

**3.12 The calculation to determine the residual strength:** After substituting the value of residual UPV ratio ( ) in the above equation (3.1), the residual strength ratio ( ) can be obtained from the above established correlation. The residual strength ratio indicates the fraction of the original strength and its mathematical format is given below in equation (3.2) and (3.3). Pulse velocity acquired on the heatedconcrete specimen divided by the original value of pulse velocity gives the value of residual UPV ratio.

For calculating the residual UPV ratio the original value (control value) of UPV can be obtained from the adjacent area which has not been damaged due to fire. The value obtained from the above equation in the form of residual strength ratio multiplied with the original strength value of the concretegives out the residual strength of concrete.

x (residual UPA ratio)= Residual pulse velocity of heated concrete specimen / pulse velocity of unheated concrete specimen

y ( residual strength ratio)=Residual strength of heated concrete

**3.13 Problems Encountered in the Experimental Process:**

Following problems were encountered during the experimentation:

Specimens of the concrete with unique dimensions from the previous literature required the mould preparation. Manufacturing included cutting the PVC pipe in the required length along the longitudinal direction. Trial samples indicated that it is difficult to remove the concrete specimens from the PVC mould hence, the mould was provided with the longitudinal cut for easy removal of the concrete sample. The slit along the longitudinal direction was made so that only the bottom 5 mm circumference of the PVC mould is continuous and the whole upper portion is discontinuous due to the vertical incision. For avoiding the escape of cement slurry from the longitudinal cut, it was required to seal the cut with the adhesive tape.

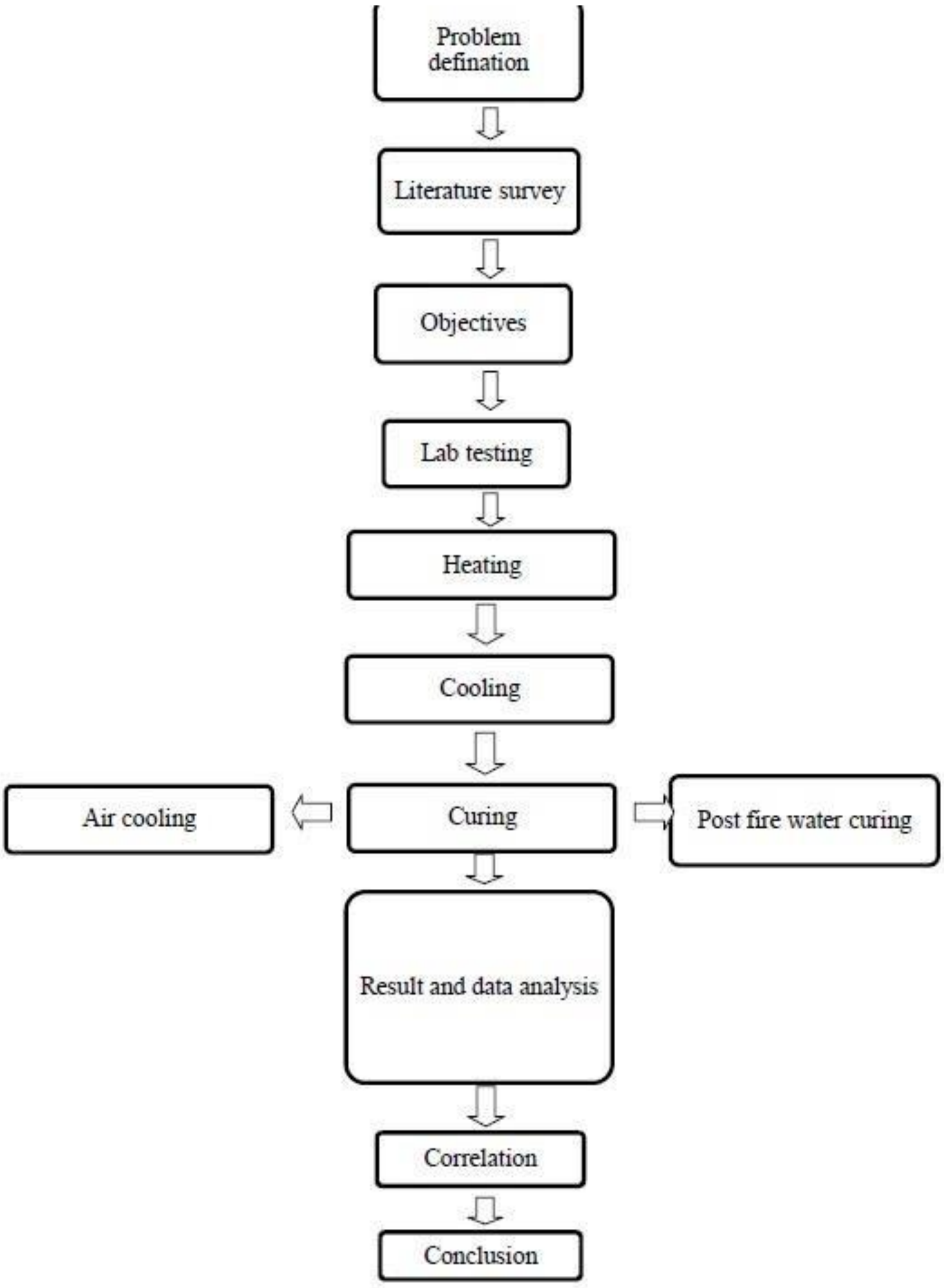
**3.14 Closing Remarks:**

In the present study concrete mix design with water-cement ratio of 0.45were adopted. The content alsoexplains the detailed process of mixing, casting, and curing of the concrete specimens. A cylindrical specimen of size 51 mm in diameter and 102 mm in length was adopted from the previous technical literature and also peak temperatures for heating the Marble chips concrete specimens were selected as 400°C, 600°C, and 800°C. After heating two cooling methods were adopted which are air-cooling and quenching? Methods used in investigating the properties of the heated concrete specimens and governing criteria for determining the quality of concrete was mentioned. Steps in calculating the residual compressive strength of fire damaged early age concrete was presented which is based on the correlation established between the residual strength ratio and residual UPV ratio.

**3.15 Schedule of casting:** Table No. 3.8 shows number of concrete specimens to be cast

**Table No. 3.9 Concrete Specimens to be cast**

| **Temperature Variation** | | **300 $^0$C** | | **400 $^0$C** | | **500 $^0$C** | |
|---|---|---|---|---|---|---|---|
| **No of Days** | **28** | **28** | | **28** | | **28** | |
| **Post fire Curing** | | | **3 days** | | **3 days** | | **3 days** |
| **No of Cubes** | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| **No of Cylinders** | 6 | 6 | 6 | 6 | 6 | 6 | 6 |
| **Total** | 12 | 12 | 12 | 12 | 12 | 12 | 12 |




**3.16 Methodology Flow chart:**

## IV. RESULT AND DISCUSSION

**4.1 General:** The result of the experimental investigation on sugar cane bagasse ash concrete where Sugar cane bagasse ash has been used as partial replacement of cement in concrete mix. On replacing cement with 15% percentage of Marble chips the compressive strength are studied after cubes exposed to different elevated temperatures for 1 hour and then gradually cooled in air and provided a 3 days post fire water curing.

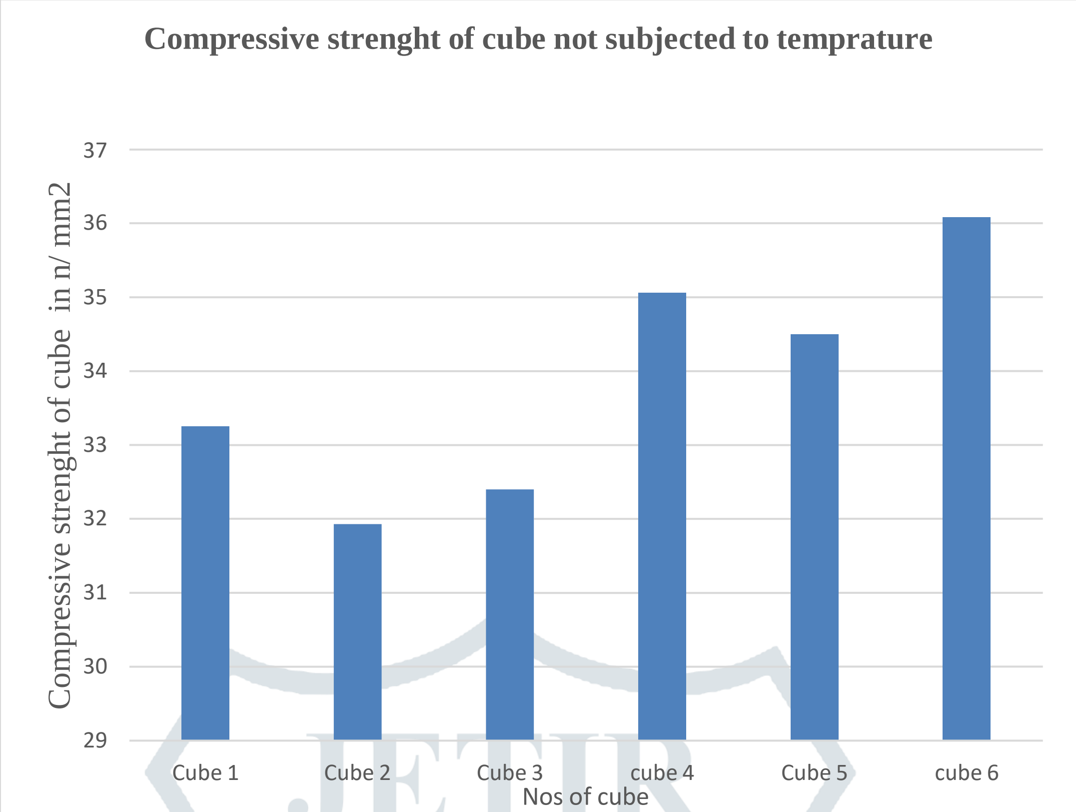
**4.2 Test on hard concrete**: Keeping in mind the gap in the research area, the To study the behavior of replacement of Marble chips in concrete at elevated temperature the result which are increasing durability and good performance under elevated temperature.

For this purpose different test on harden concrete were conducted at the age of 56 days like compressive strength on 150 x 150 x 150 mm size cube, splitting tensile strength on 51 mm X 102 mm cylinder,. As per codal provision total 60 number of specimen were tested and results are tabulated as below.

**4.2.1 Compressive strength Test:** The test was carried out as per IS 516: 1959 code. Compressive strength tests were performed on cube samples using compression testing machine. Three samples per batch were tested with the average strength values reported in Table No.4.1. The test was carried out for 28 days water curing at 27°C. The average strength for 28 days were calculated from breaking load obtained from compression testing machine for Marble chips with percentage of 15%

**Table No.4.1: Compressive Strength result for cube not heated**

| **M30** | | | | |
|---|---|---|---|---|
| **Concrete cube not subjected elevated temperature** | | | | |
| **Sr. No.** | **Cube No.** | **Average breaking load** | **Ultimate compressive strength after 28 days (N/mm²)** | **Average compressive strength (N/mm²)** |
| 1 | 01 | 80500 | 33.25 | 33.24 |
| 2 | 02 | 72000 | 31.93 | |
| 3 | 03 | 73300 | 32.40 | |
| 4 | 04 | 78900 | 35.06 | |
| 5 | 05 | 76500 | 34.5 | |
| 6 | 06 | 81200 | 36.08 | |




**Graph No. 4.1 Compressive Strength result for cube not heated**

**Table No.4.2: Compressive Strength result for cube subjected to elevated temperature**

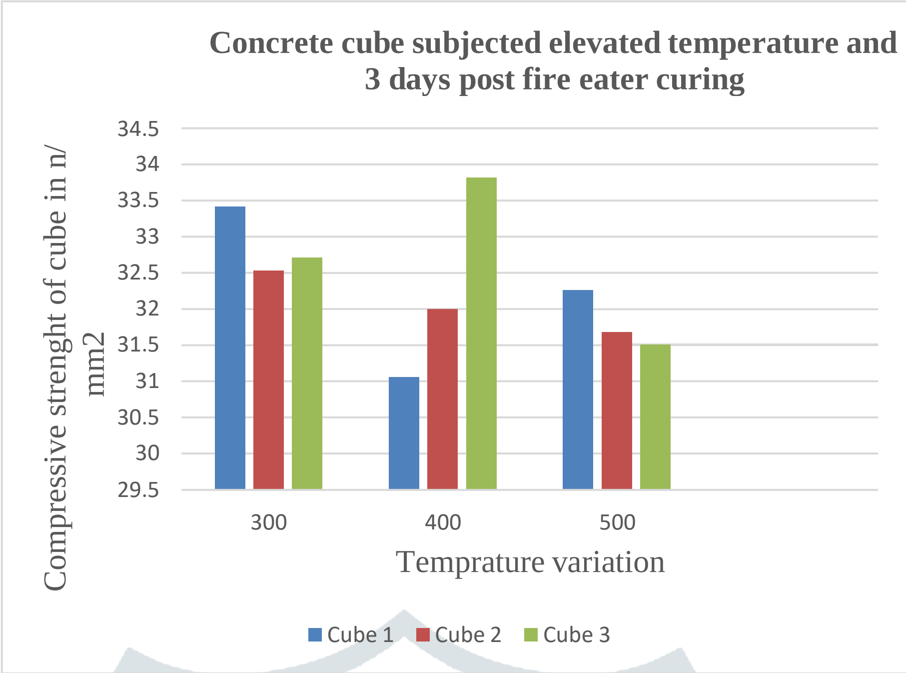
| | | | | |
|---|---|---|---|---|
| **M30** | | | | |
| **Concrete cube subjected elevated temperature** | | | | |
| **Temp.** | **Cube No.** | **Average breakingload** | **Ultimate compressive strength after 28 days (N/mm$^2$)** | **Average compressive strength (N/mm$^2$)** |
| 300 | 01 | 72600 | 33.1 | 33.24 |
| 300 | 02 | 71900 | 33.5 | |
| 300 | 03 | 70200 | 31.5 | |
| | | | | |
| 400 | 01 | 71000 | 34 | 32.86 |
| 400 | 02 | 67900 | 31.6 | |

**Graph No. 4.2 Compressive Strength result for cube subjected to elevated temperature**

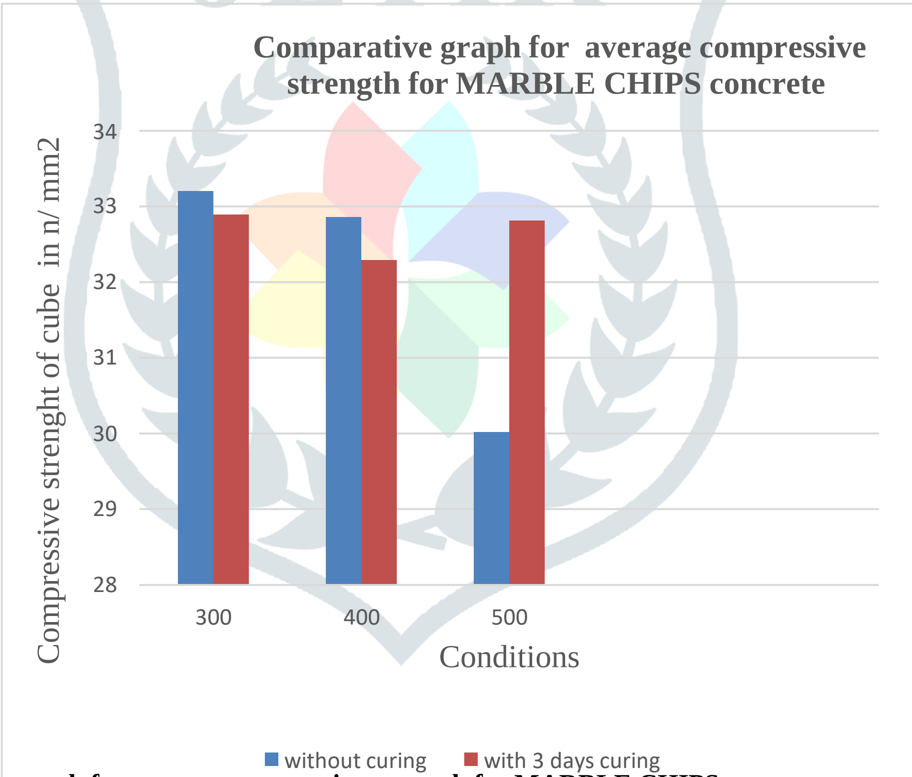
After the all heating process the half of cube send to the post fire water curing for 3 days the result forthose shown below:

**Table No.4.3: Compressive Strength result for cube subjected to elevated temperature with 3 days post fire water curing**

| M30 | | | | | |
|---|---|---|---|---|---|
| **Concrete cube subjected elevated temperature and 3 days post fire water curing** | | | | | |
| **Temp.** | **CubeNo.** | **Curing** | **Average breaking load In N** | **Ultimate compressive strength after 3 days post fire water curing (N/mm²)** | **Average compressive strength (N/mm²)** |
| 300 | 01 | 3 | 75200 | 33.42 | 32.89 |
| 300 | 02 | 3 | 73200 | 32.53 | |
| 300 | 03 | 3 | 73600 | 32.71 | |
| | | | | | |
| 400 | 01 | 3 | 69900 | 31.06 | 32.29 |
| 400 | 02 | 3 | 71800 | 32 | |
| 400 | 03 | 3 | 76100 | 33.82 | |
| | | | | | |
| 500 | 01 | 3 | 72600 | 32.26 | 31.81 |
| 500 | 02 | 3 | 71300 | 31.68 | |
| 500 | 03 | 3 | 70900 | 31.51 | |




**Graph No. 4.3 Compressive Strength result for cube subjected to elevated temperature and 3days post fire water curing**




**Graph No. 4.4 Comparative graph for average compressive strength for MARBLE CHIPS concrete**

**4.2.2 Ultrasonic pulse velocity test:** The test was carried out as per IS 13311 (Part 1):1992 code. Compressive strength tests were performed on cylinder samples using ultrasonic pulse velocity apparatus. Three samples per batch were tested with the average strength values reported in Table No.4.4. The test was carried out for 28 days water curing at 27°C. The average strength for 28 days were calculated from velocity measure obtained from apparatus for Marble chips with percentage of 15%.

**Table No.4.4: UPV result for cube not heated**

| **M30** | | | |
|---|---|---|---|
| **Concrete cube not subjected elevated temperature** | | | |
| **Sr. No.** | **Cube No.** | **Ultrasonic pulse velocity (m/s)** | **Average ultrasonic pulse velocity (m/s)** |
| 1 | 01 | 4630 | 4624 |
| 2 | 02 | 4523 | |
| 3 | 03 | 4958 | |
| 4 | 04 | 4739 | |
| 5 | 05 | 4663 | |
| 6 | 06 | 4231 | |

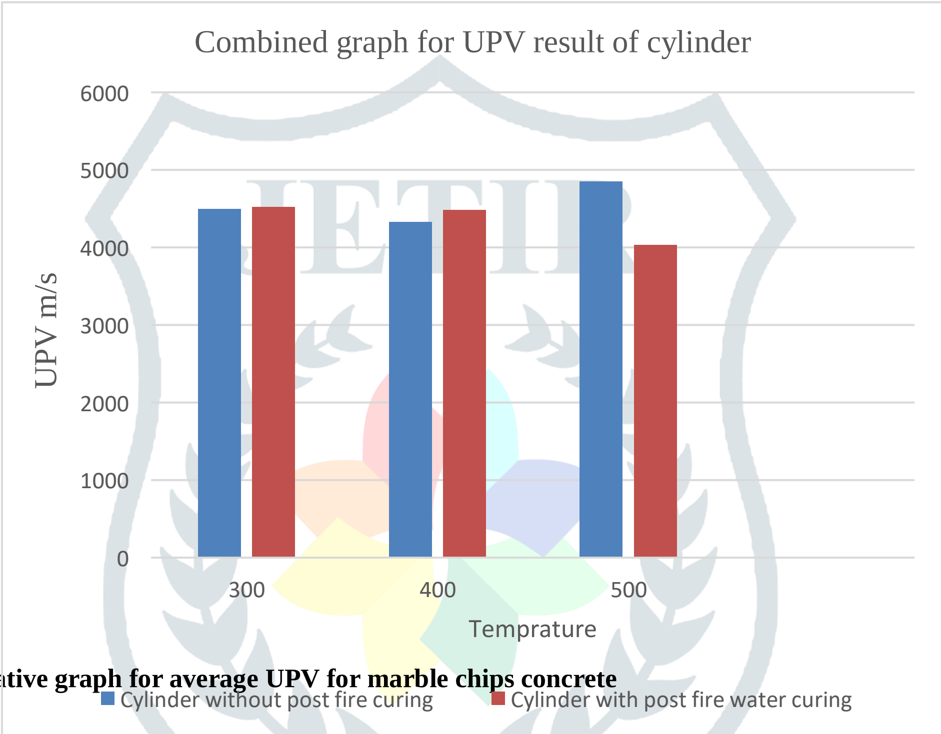
**Table No.4.5: UPV result for cube subjected to elevated temperature**

| **M30** | | | |
|---|---|---|---|
| **Concrete cube subjected elevated temperature** | | | |
| **Temp.** | **Cube No.** | **Ultrasonic pulse velocity (m/s)** | **Average ultrasonic pulse velocity (m/s)** |
| 300 | 01 | 4323 | 4497 |
| 300 | 02 | 4647 | |
| 300 | 03 | 4523 | |
| | | | |
| 400 | 01 | 4321 | 4327 |
| 400 | 02 | 4443 | |
| 400 | 03 | 4218 | |
| | | | |
| 500 | 01 | 3608 | 4847 |
| 500 | 02 | 3978 | |
| 500 | 03 | 4056 | |

**Table No. 4.6 UPV result for cube subjected to elevated temperature with 3 days post fire watercuring**

| **M30** | | | |
|---|---|---|---|
| **Concrete cube subjected elevated temperature and 3 days post fire water curing** | | | |
| **Temp.** | **Cube No.** | **Ultrasonic pulse velocity (m/s)** | **Average ultrasonic pulse velocity (m/s)** |
| 300 | 01 | 4434 | 4519 |
| 300 | 02 | 4711 | |

| | | | |
|---|---|---|---|
| 300 | 03 | 4412 | |
| | | | |
| 400 | 01 | 4551 | |
| 400 | 02 | 4569 | 4484.33 |
| 400 | 03 | 4333 | |
| | | | |
| 500 | 01 | 3881 | |
| 500 | 02 | 4090 | 4027.66 |
| 500 | 03 | 4112 | |




**Graph No. 4.5 Comparative graph for average UPV for marble chips concrete**

This shows that 15% Marble chips can be mixed in concrete for good results and economical profitable.

It had been observed that is no decrease of strength more than 10% for strength obtained for cubes exposed to $600^0$C and Room temperature. i.e. for M30 grade concrete- 15% marble concrete , at $300^0$C-34.24, $400^0$C-31.86, $500^0$C-30.67, There is increase in strength of heated concrete cube and cylinder due post fire water curing for 3 days as result shows there more strength increment in the $300^0$C-32.43, $400^0$C-31.81, $500^0$C-31.37 as compare to cube not subjected post fire water curing. Also for UPV result for cylinder shows improvement in the velocity for different temperature as $300^0$C-4452.33, $400^0$C- 4384.3, $500^0$C-3927.66. This increase in strength in marble chips concrete is due to presence of Silica in cane marble.

Due to the fine particles present in the marble waste, they react with the residual chemical and also fill the pores that formed while hydration of cement. It increases strength.

Due to filling of pores the concrete gains more strength than normal and results in opposing crack formation.


**Photograph No. 4.1: Compressive testing machine setup**


**Photograph No. 4.2: Cylinder in oven for $300^0$ C temperature.**

**4.3 Summary of results and discussion:** The summary of results contains discussion on obtained results from destructive and non-destructive testing of marble chips concrete with percentage of marblechips . The destructive testing contains tests like Compressive strength and non-destructive testing consist of compressive strength test by ultrasonic pulse velocity test apparatus. The main design criteria for marble chips concrete is the post fire water curing of concrete which is tested by various tests like compressive testing machine and ultrasonic pulse velocity test apparatus test. From the obtained results, conclusions may be drawn which is added in next chapter.

## V. CONCLUSIONS

1. The performance of concrete with 15% replacement of fine aggregate with marble chips has shownbetter to that of conventional concrete at higher temperature.
2. From the above study it can be concluded that waste marble chips can be used in concreteproduction as a course aggregates with fully replacement by natural aggregates.
3. Upon cost analysis results it is proved that marble concrete proves more economical at rate of around 8 -9 % than concrete made with conventional course aggregate.
4. There is no more strength different up $400^0$ C temperature means the marble concrete will be a perfect replacement for fine aggregates up to 15% in high temperature region.
5. Due to post fire water curing for 3 days there is increase of strength up to certain limit which create new opportunity to investigate properties for marble chips concrete for more days of water curing.
6. Post fire water curing increases the strength after fire damage and fill the cracks
7. which generated due to high temperature reaction which will going to fill after curing.
8. In the UPV result there is increase in strength of marble chips concrete. Marble chips concrete has performed better when it is compared with normal concrete

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