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BEHAVIOUR AND STRUCTURAL DESIGN OF CONCRETE STRUCTURES EXPOSED TO FIRE

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Abstract

A systematic study of the effects of realistic thermal exposures is needed and a lot more work is required in order to unravel the mystery of spalling. The study of the response of complete concrete structures presents another challenge, requiring large-scale fire tests. The goal is to develop a concrete model that reflects the true behaviour of concrete structures exposed to fire. This model should incorporate the fully coupled hygro-thermal-mechanical behaviour combined with a sophisticated structural analysis, including the effect of transient strain.Due to rapid growth in construction activity, the available sources of natural sand are getting exhausted & also, good quality sand may have to be transported from long distance, which adds to the cost of construction. In some cases, natural sand may not be of good quality. Therefore, it is necessary to replace natural sand in concrete by an alternate material partially, without compromising the quality of concrete. Quarry dust as sand is one such material which can be used to replace sand as fine aggregate. The present study is aimed at utilizing and structural design of concrete structures exposed to fire and different tests from theQuarry dust as fine aggregate replacing natural sand and also the compressive strength of the water cured specimens is measured on the 7,14,28 Days. Split Tensile strength, Flexural Strength, Here we have conducting a test on concrete by using fly ash and m sand. By using these materials we have find out strength on a concrete by adding partial replacement on cement with fly ash and complete replacement of sand with marble dust.

Key words:-Concrete Structures, Cement, Fly Ash, Sand, M dust, fire structure

1.0 Introduction

The advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. Presently large amounts of marble dust are generated in natural stone processing plants with an important impact on environment and humans. This project describes the feasibility of using the marble sludge dust in concrete production as partial replacement of cement. In INDIA, the marble and granite stone processing is one of the most thriving industry the effects if varying marble dust contents on the physical and mechanical properties of fresh and hardened concrete have been investigated. Slump and air content of fresh concrete and absorption and compressive strength of hardened concrete were also investigated. Test results show that this industrial bi product is capable of improving hardened concrete performance up to 10%, Enhancing fresh concrete behaviour and can be used in architectural concrete mixtures containing white cement. The compressive strength of concrete was measured for 7 and 28 days. In order to evaluate the effects of marble dust on mechanical behaviour, many different mortar mixes were tested.

The basics of fire physics and fire safety:

The fire triangle A fire can only start when the following three elements are present simultaneously: oxygen (21 % volume in air), combustible materials and a heat source. Together, they make up what is commonly called the fire triangle, which is also shown in The first two elements will only start the process of combustion when the inflammation temperature is reached. The combustion of carbon produces carbon dioxide (CO2) and, in case of a lack of oxygen, the well-known gas carbon monoxide (CO) which is very dangerous to man.

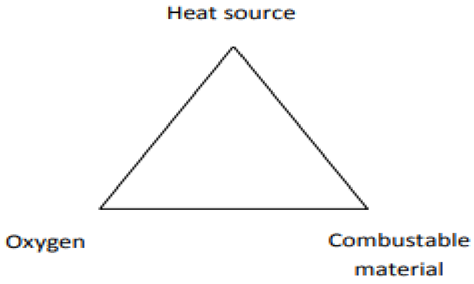


Figure: The fire triangle. Redrawn

The development of a fire and flashover This Section discusses the behaviour and the different stages of fires in rooms. The stages are ignition, growth, flashover, fully-developed fire and decay, as can be seen in Since their behaviour is completely different, a distinction is made between pre- and post-flashover fires. The information in this Section is based on Buchanan Generally it is found that, when structurally designing a building, the post flashover fire is of the essence. When designing for life safety in buildings, an understanding of the pre-flashover fire is essential.

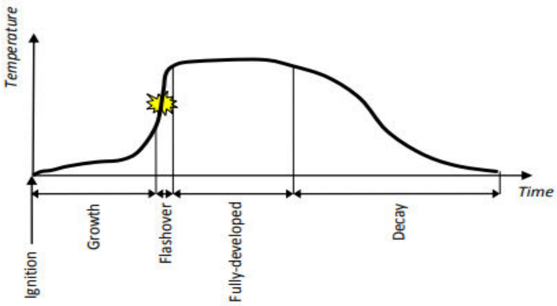


Figure: Temperature development stages of a fire

Pre-flashover when all three elements of the fire triangle are present, a fire originates. A small amount of material starts to burn and the first gasses and smoke appear. A plume of smoke develops, transporting the combustion products up to the ceiling. Initially, the combustion process consumes the oxygen from the air in the room, but soon air will flow in through openings like a door, a window or a ventilation opening.

Concrete in a fire:

Fires are caused by accident, energy sources or natural means, but the majority of fires in buildings are caused by human error. Once a fire starts and the contents and/or materials in a building are burning, then the fire spreads via radiation, convection or conduction with flames reaching temperatures of between 600°C and 1200°C. Harm is caused by a combination of the effects of smoke and gases, which are emitted from burning materials, and the effects of flames and high air temperatures.

Figure: Concrete against fire

Changes of concrete in fire:

It is this slow rate of heat transfer (conductivity) that enables concrete to act as an effective fire shield not only between adjacent spaces, but also to protect itself from fire damage. The rate of increase of temperature through the cross section of a concrete element is relatively slow and so internal zones do not reach the same high temperatures as a surface exposed to flames. A standard ISO 834/BS 476 fire test on 160 mm wide x 300 mm deep concrete beams has shown that, after one hour of exposure on three sides, while a temperature of 600°C is reached at 16 mm from the surface, this value halves to just 300°C at 42 mm from the surface – a temperature gradient of 300 degrees in about an inch of concrete! Even after a prolonged period, the internal temperature of concrete remains relatively low; this enables it to retain structural capacity and fire shielding properties as a separating element.

2.0 Literature review

A. A Study has been conducted by BabooRaiet.al(2011) have done their research on Influence of Marble powder/granules in Concrete mix. They found that using marble powder and granules as constituents of fines in mortar or concrete by partially reducing quantities of cement as well as other conventional fines in terms of the relative workability & compressive as well as flexural strengths. Partial replacement of cement and usual fine aggregates by varying percentage of marble powder and marble granules reveals that increased waste marble powder or waste marble granule ratio result in increased workability and compressive strengths of the mortar and concrete.

B. A Study has been conducted by Vaidevi C (2013) have done their research on Study on the marble dust as partially replacement of cement in concrete. They found that the marble dust from marble processing is a waste utilized. The use of this waste was proposed in different percentages both as an addition to and instead of cement, for the production of concrete mixtures. In this study, the use of marble dust collected during the shaping process of marble blocks has been investigated in the concrete mixtures as cementitious material.

C.A Study has been conducted by V. M. Sounthararajanet.al(2013)have done their research on Effect of the Lime Content in Marble Powder for Producing High Strength Concrete. They found that the waste marble powder up to 10% by weight of cement was investigated for hardened concrete properties. Furthermore, the effect of different percentage replacement of marble dust on the compressive strength, splitting tensile strength and flexural strength was evaluated.

D. A Study has been conducted by ManjuPawar et.al (2014) have done their research on Periodic Research, The Significance of Partial Replacement of Cement WithWasteMarble Powder. They found that the effect of using marble powder as constituents of fines in mortar or concrete by partially reducing quantities of cement has been studied in terms of the relative compressive, tensile as well as flexural strengths.

3.0 Materials and methods

Concrete subjected to heat will undergo changes in its microstructural, thermal, hydral and mechanical behaviour. Strength loss occurs mainly due to the formation of internal cracks and degradation and disintegration of the cement paste. The cohesion between the cement paste and the aggregates is also affected. Understanding the different processes will help understanding how concrete is likely to behave under fire, but also how to optimize the composition of the material for better fire performance. The information in this Section has been based on the works of to effects of pore pressure and pore size (see further) within the concrete, the boiling temperature may range from 100 to 140°C. This evaporation of water may cause a build-up of pressure within the concrete. Eventually, the chemically bound water will also evaporate, at temperatures between 100 and 800°C. Starting from 300°C the cement past will begin to shrink, while the aggregates expand. Long-term heating at this temperature will significantly reduce the tensile strength. At a temperature of approximately 400°C up to 600°C, the calcium hydroxide ($Ca(OH)_2$) breaks down in to calcium oxide (CaO) and water (H_2O), causing even more water vapour and a significant physical strength reduction. The aggregate is also affected by the fire. For example, quartz-based aggregates experiences a volume expansion, due to a mineral transformation (α-quartz in to β-quartz), at about 575°C. Limestone aggregates will start to decompose at approximately 800°C. Generally speaking, the thermal response of any aggregate may be very straightforward and easy to be found.

Figure: Surface spalling after a fire in a car park

Cement

The cement used was ordinary Portland cement 53 (OPC 53).All properties of cement were determined by referring IS 12269 - 1987.

The specific gravity of cement is 3.15.

The initial and final setting times were found as 55 minutes and 258 minutes respectively. Standard consistency of cement was 30%.

Coarse Aggregate 20mm size aggregates- The coarse aggregates with size of 20mm were tested and the specific gravity value of 2.78 and fineness modulus of 7 was found out. Aggregates were available from local sources. 2.3 Fine Aggregate The sand which was locally available and passing through 4.75mm IS sieve is used. The specific gravity of fine aggregate was 2.60. 2.4

Water The water used for experiments was potable water.

Fly Ash Fly Ash is a by-product of the combustion of pulverized coal in electric power generation plants. When the pulverized coal is ignited in the combustion chamber, the carbon and volatile materials are burned off. However, some of the mineral impurities of clay, shale, feldspars, etc., are fused in suspension and carried out of the combustion chamber in the exhaust gases.

Advantages of Fly Ash in Concrete

Fly Ash is a pozzolan. A pozzolan is a siliceous or aluminosiliceous material that, in finely divided form and in the presence of moisture, chemically reacts with the calcium hydroxide released by the hydration of Portland Cement to form additional calcium silicate hydrate and other cementitious compounds. The hydration reactions are similar to the reactions occurring during the hydration of Portland cement.

The concrete structure and fire:

The different effects that occur in concrete structures when exposed to fire are briefly discussed here, based on the information in the fib Bulletin A general understanding of these effects is necessary to produce a good design. Naturally this is build upon how the material concrete behaves under high temperatures, which is described in Chapter Firstly, the material characteristics of the members are modified when the temperature rises. The strength as well as the stiffness of both the concrete and the steel is reduced. In fact, even the whole stress-strain diagram is modified.

4.0 structural fire design of concrete structures

As was put forth in the previous Chapter, the Euro code is the state-of-the-art in structural standards. If it has not yet replaced the old national standards in a Member State, it soon will. Thus, this Chapter studies how a concrete structure should be designed to withstand the effects of fire, according to the Eurocode. The first is general and applies to all types of materials, where as the second is for concrete structures. In addition, these Parts are designed to be used together with other Parts of the Eurocode. When information from another Part is used, this will be clearly stated in the text. The breakdown of the Eurocode in different Parts is definitely a necessity, considering how much it contains, but it does also diffuse all the information.

Fire resistance:

The concept of „fire resistance" has been for decades at the heart of research, design and assessment of concrete structures exposed to fire. It captures how an element should withstand a fire. As stated before fire resistance can be defined as the ability of an element (not a material) to fulfil its designed function for a period of time in the event of a fire. This designed function can be a load-bearing, separating or load-bearing and separating function An element with a load-bearing function is an element that requires mechanical resistance in the case of fire, as with beams and columns. An element with a separating function prevents the propagation from a fire from one room to another, as with non-load-bearing walls. This is crucial when compartmentation is needed. Some elements can have both load-bearing and separating functions, as with a floor. The Euro code then defines three performance criteria **load-bearing capacity (R)** = ability of a structure or a member to sustain specified actions during the relevant fire, according to defined criteria Behaviour and structural design of concrete structures exposed to fire

MIX DESIGN

In this investigation concrete combine style M50 was designed supported IS: 10262-1982 IS: 456-2000. This code presents a typically applicable methodology for choosing mixture proportion for top strength concrete and optimizing this mixture proportion on basis of trial batches. The tactic is restricted to high strength concrete production mistreatment standard materials and production techniques. Combine style area unit given below in table one. Combine proportioning for {the combine the combination the combo}as adopted within the study details area unit given below in tables the mix quantitative relation is 1:0.78:2.43 and w/c is zero.35 is adopted. Combine proportions cylinder specimens of size three hundred milli-meter height and a hundred and fifty milli-meter diameter for split strength studies were ready.

Fire design strategy:

In order to check if a member has an appropriate fire resistance, the following process must be followed, consisting of five steps: -

- A selection of the relevant design fire scenarios
- The determination of corresponding design fires
- The calculation of the temperature profiles within the structural members
- The calculation of the mechanical behaviour of the structure exposed to fire
- Verification of the fire resistance

Step 1: Consider the relevant design fire scenario The definition of a design fire scenario by Euro code 1 is a “specific fire scenario on which an analysis will be conducted”. For instance, where does the fire occur Is it a building fire, a tunnel fire, or a petrochemical fire Or how severe is the fire Perhaps it is a localised fire or a fully developed fire The particular fire scenario should be chosen based on a fire risk assessment, taking into account the likely ignition sources and any fire detection/suppression systems available. A suitable size, occupancy and ventilation condition of the compartment is identified, representing the “reasonable worst case scenario”. This will then dictate the choice of the design fire to be used in the subsequent analysis.

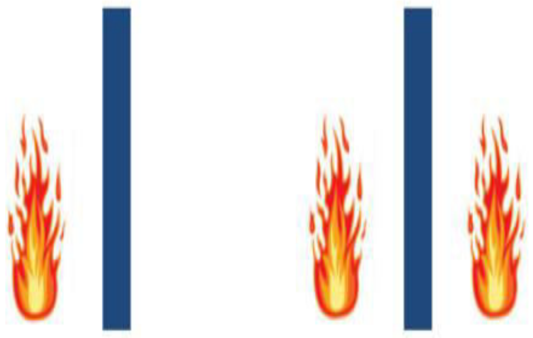


Figure: fire in one dimensional propagation

Step 2: Choose an appropriate design fire

A design fire is defined by the Euro code as a “specified fire development assumed for design purposes”, in other words, a model that represents the action of a fire There exist two types of models, a nominal and a natural fire model, given respectively in Section A nominal fire model consists of one simple relationship giving the temperature of the gases in the compartment as a function of time. They are easy to use and they are useful for the purpose of classification and comparison

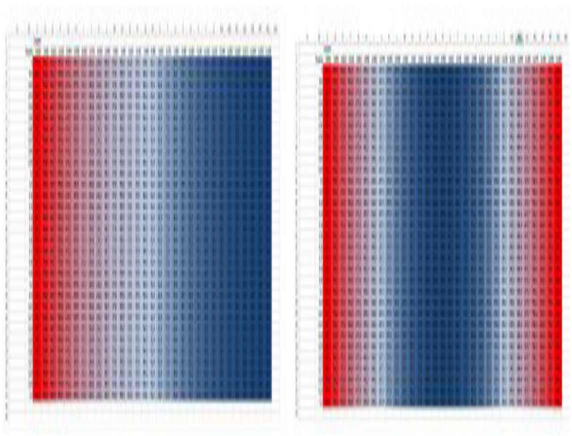


Figure: Temperature of the concrete slab with fire on left and on both sides

Step 3: Temperature analysis

After choosing a correct design fire, the net heat flux can be determined. In the temperature analysis, this net heat flux, together with the thermal material properties of the members and of any protective surfaces is used to determine the temperature profile inside the concrete members.

Assessment of the fire resistance: Verification of the load-bearing capacity The load-bearing function of a structure, a part of a structure or a member is verified in the strength domain, meaning that for the relevant duration of fire exposure t, the applied loads are less than the load capacity of the structure:

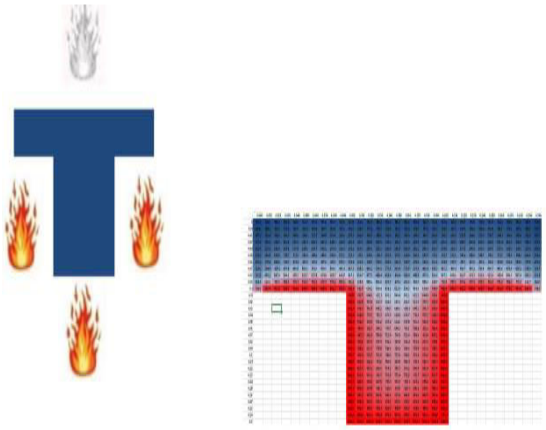


Figure: T-beam, fire on the bottom

Methodology of Experiment

It is necessary that the constituent material of concrete stay uniformly distributed inside the concrete mass throughout the varied stages of handling which full compaction is achieved, and ensuring that the characteristics of concrete that have an effect on full compaction like consistency, quality and compatibility area unit in conformity with relevant codes of apply. The tests were administrated in accordance with relevant IS Standards. The aggregates were taking a look acted for physical properties like relative density and particle distribution test. The recent concrete was subjected to the slump take a look at followed by casting of concrete in moulds for additional investigations

Flexural Strength

The take a look at was administrated on 100mm X100mm X500mm size prism. The take a look at was administrated on a universal testing machine of 400kN capability, adopting 2 purpose loading. The bearing surfaces of the supporting and loading rollers area unit cleaned, and any loose sand or different material far away from the surfaces of the specimen. The specimen was placed within the UTM which the load was applied to the topmost surface as forged within the mould, on 2 lines spaced 20cm apart.

5.0 Results and tests

Table: Cube compressive strength for 7 days

S. No	Mix	% of marble powder	Load in kN	Compressive strength in Mpa
1	A	0	290	12.8
2	B	5	260.33	11.5
3	C	10	285.45	12.68
4	D	15	298.32	13.2
5	E	20	220	9.7
6	F	25	210.33	9.3

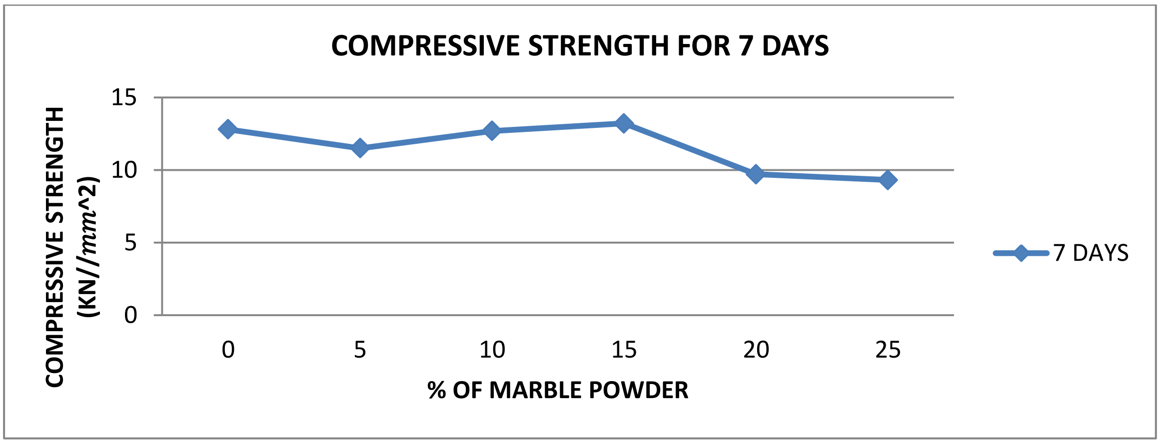
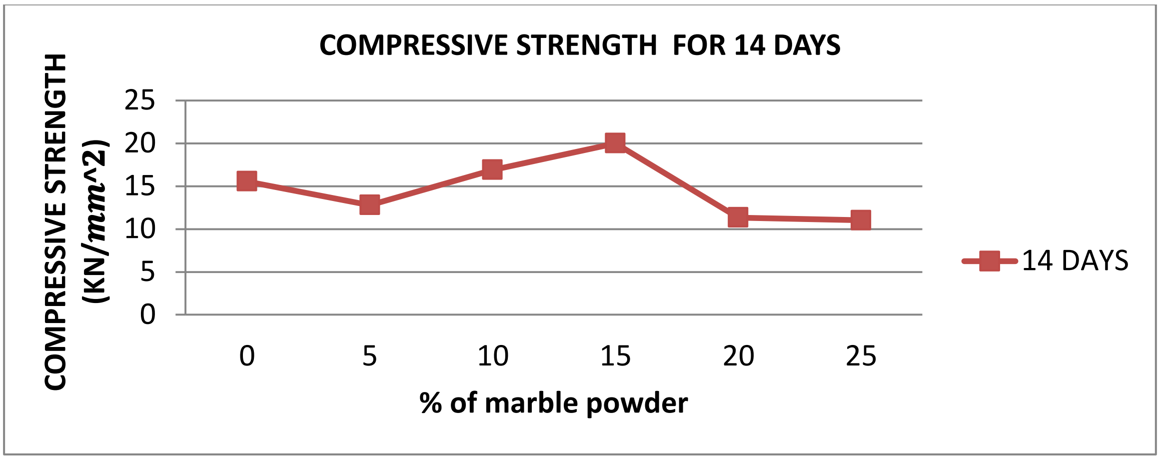


Table: Cube compressive strength for 14 days

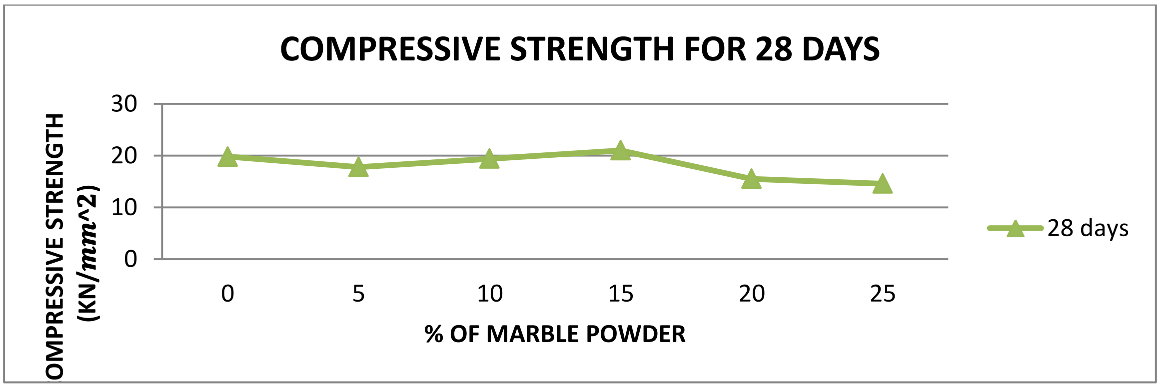
S No	**Mix**	**% of marble powder**	**Load in kN**	**Compressive strength in Mpa**
1	**A**	**0**	**350**	**15.55**

2	**B**	**5**	**290**	**12.8**
3	**C**	**10**	**381**	**16.9**
4	**D**	**15**	**450**	**20.0**
5	**E**	**20**	**255**	**11.33**
6	**F**	**25**	**248**	**11.02**



Cubes of compressive strength for 28 days

Sno	Mix	% of marble powder	Load in kN	Compressive strength in Mpa
1	A	0	445.52	19.80
2	B	5	400.01	17.8
3	C	10	440.00	19.39
4	D	15	460.05	21.0
5	E	20	350.62	15.5
6	F	25	328.0	14.57



Split tensile strength for 7 days

S.No	Mix	% of marble powder	Load in kN	Split tensile strength in Mpa
1	A	0	118.66	1.6
2	B	5	122.67	1.7
3	C	10	120	1.69
4	D	15	142	2.00
5	E	20	139.33	1.9
6	F	25	120	1.6

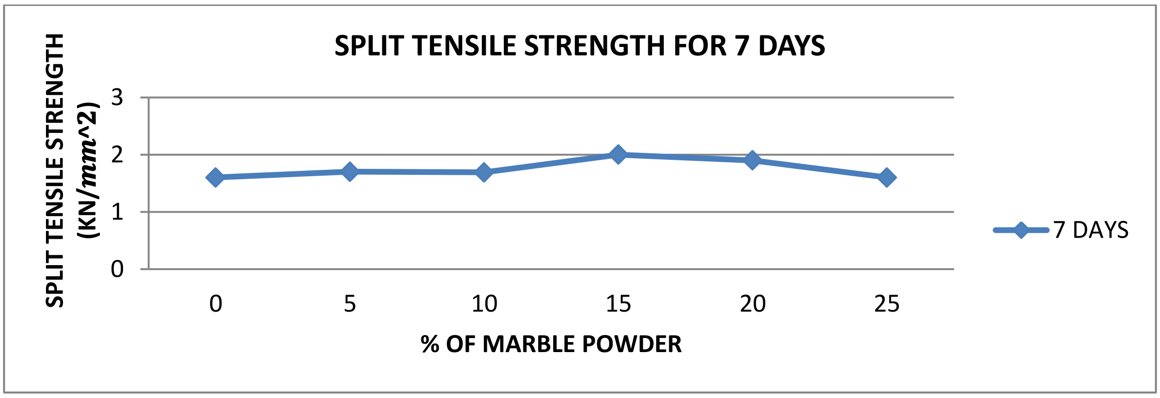


Table: Split tensile strength for 14 days

S. No	Mix	% Of Marble Powder	Load In Kn	Split Tensile Strength In Mpa
1	A	0	128.66	1.8
2	B	5	153.33	2.1
3	C	10	144.60	2.0
4	D	15	172	2.4
5	E	20	148	2.0
6	F	25	143.33	2.0

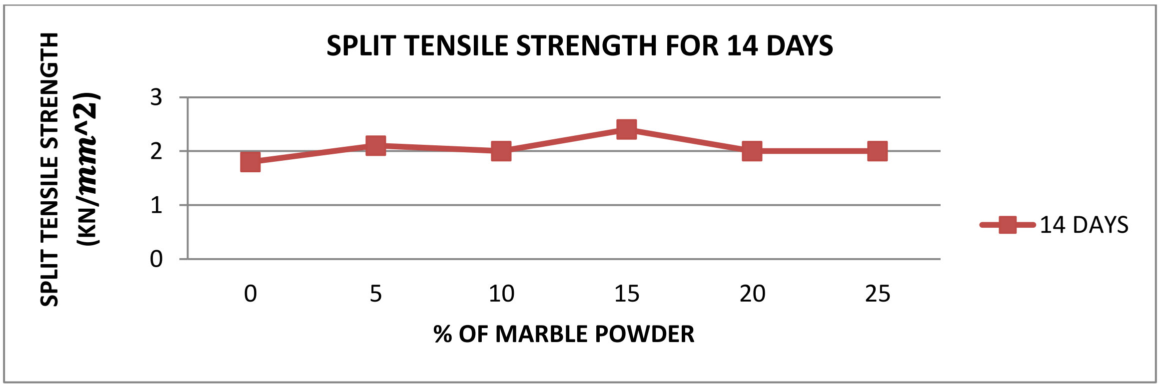
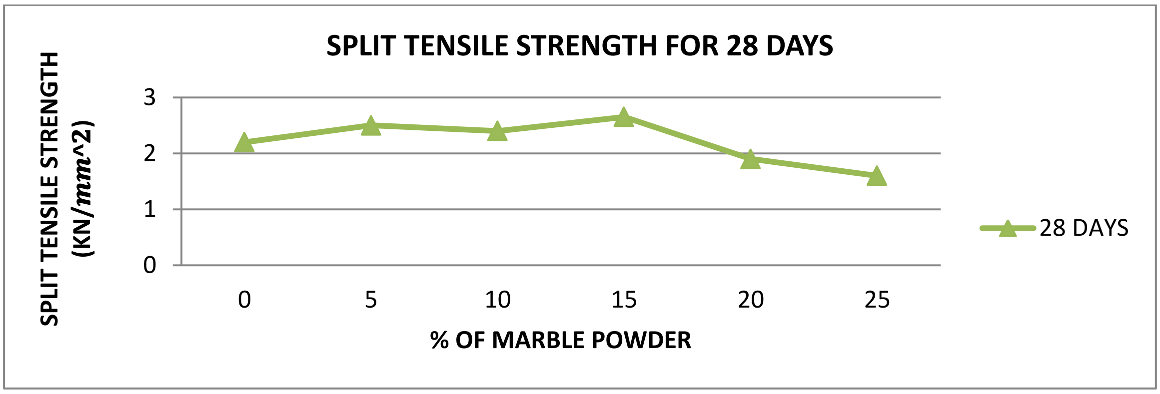


Table:Split tensile strength for 28 days

S. No	Mix	% Of Marble Powder	Load In Kn	Split Tensile Strength In Mpa
1	A	0	161.66	2.2
2	B	5	179.33	2.5
3	C	10	172.0	2.4
4	D	15	180.2	2.65
5	E	20	167.33	1.9
6	F	25	160.66	1.6



Conclusion:

To study the fire behaviour of newly developed concrete types. Besides a better understanding of the material, there is also the need for a proper structural analysis. More research is needed in investigating the different failure modes during, but also, after a fire. Furthermore, the effects of restrained thermal expansion should be incorporated in the design codes. The same applies to thermal transient stress, of which its effects on the structural behaviour still require further in-depth study. In order to understand the behaviour of concrete structures as a whole and to study the impact of small-scale phenomena at full sale, large-scale building tests are necessary, which are invasive and expensive. Another great source of information can be found in real fire incidents. However, better documentation is required for the latter finally; the goal is to develop a constitutive model that reflects the true behaviour of concrete structures when exposed to fire, both from a material as a structural point of view. This means that the better the previously discussed elements are understood, the better concrete models can approximate reality. These models can then be used together with finite-element analysis to fully investigate andpredict the behaviour of concrete structures and provide new design codes and methods. To realistically simulate structural concrete, a fully coupled model should be used, combining mechanical, thermal and hydral effects and their influence on each other, as well as a sophisticated structural analysis, including transient strain.

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