EFFECT OF VARIOUS TEMPERATURES ON THE STRENGTH OF CONCRETE WITH PARTIAL REPLACEMENT OF CEMENT BY RICE HUSK ASH AND PARTIAL REPLACEMENT OF COARSE AGGREGATE BY BLAST FURNACE SLAG

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Abstract — This experimental study is to find the strength of concrete under different temperature by using partial replacement of cement with Rice Husk Ash and partial replacement of coarse aggregate with Blast Furnace Slag. Concrete does not burn, it cannot be 'set on fire' like other materials in a building and it does not emit any toxic fumes when affected by fires. It will also not produce smoke or drip molten particles, unlike some plastics and metals, so it does not add to the fire load. For this reason concrete is said to have a high degree of fire resistance and in the majority of applications, concrete can be described as virtually 'Fire Proof '.This excellent performance is due in the main to concrete's constitute materials. (I.e. Cement and Aggregate) which when chemically combined with concrete, form a material that is essentially inert and importantly for fire safety design has a relatively poor thermal conductivity. 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 concrete element is relatively slow and so internal zones do not reach the same high temperature as surface exposed to flames. When concrete is exposed to the high temperatures of a fire, a number of physical and chemical changes can take place.

Keywords-Rice Husk Ash, Blast Furnace Slag, Steel Fibers, Various Temperatures, Mix Proportion, Partial Replacement.

I. INTRODUCTION

Any engineering advancement is for betterment of human life. Shelter is considered as one of the basic needs for human beings. The buildings constructed should give protection from heat, cold, rain, and also from disasters like fire, floods and earthquakes. Fire is considered as one of the disastrous event which causes loss or damage to human life and property. When there is an accidental fire in a structure, the duration of fire will be less but the intensity of heat produced will be more, this heat causes damage to the structures. In addition to accidental fire there are some special structures which are subjected to high temperatures, like take-off areas of jet aircraft, rocket launching pads, nuclear reactors, chimneys, metallurgical or chemical industries, glass, cement industry, coke ovens, storage tanks for hot crude oil and hot water, where the localized areas of concrete are subjected to high temperatures, The material used for construction should be capable of resisting high temperatures and it should also give minimum time for the inmates to escape.

With the increased incidents of major fires and fire accidents in buildings; assessment, repair and rehabilitation of fire damaged structures has become a topical interest. This specialized field involves expertise in many areas like concrete technology, material science and testing, structural engineering, repair materials and techniques etc. Research and development efforts are being carried out in these related disciplines. Any structure can undergo fire accident, but because of this the structure cannot be denied neither abandoned. To make a structure functionally viable after the damage due to fire has become a challenge for the civil engineering community. The problem is where to start and how to proceed. It is vitally important that we create buildings and structures that protect both people and property as effectively as possible. One of the advantages of concrete over other building materials is its inherent fire-resistive properties. However, concrete structures must still be designed for fire effects. Structural components must still be able to withstand dead & imposed loads without collapse even though the rise in temperature causes a decrease in the strength & modulus of elasticity for concrete & steel reinforcement.

Fire resistance is measured in terms of structural stability, structural integrity and insulation. Stability refers to the ability to remain standing without collapse. Integrity refers to the ability to remain intact and not move and buckle to create openings through which flames can escape. Insulation relates to the ability to either contain the fire within the building and not to ignite any material outside, or to insulate what is inside the building from being ignited by a fire outside

II. STRUCTURAL FIRE PROTECTION MEASURES MUST FULFILL THREE AIMS

1) Personal protection to preserve life and health
2) Protection of property to preserve goods and other belongings both in residential or commercial units that have caught fire, and in Neighboring properties. To this must be added substantial preservation of the building structures;
3) Environmental protection to minimize the adverse effects on the environment through smoke and toxic gases as well as from Contaminated water used for extinguishing fires.

III. LITERATURE REVIEW

Alaa A. Bashandy (2013)

In this investigation, the effects of elevated temperatures of 200, 300, 500℃ for 2 and 4 hours on the main mechanical properties of economical type of reactive powder concrete (RPC) are studied. The main variables in this study are cement content and steel fibers content in reactive powder concrete samples as well as elevated temperature and heating time. Compressive strength and tensile strength of RPC are obtained after exposure to elevated temperatures. It is found that, RPC can be used at elevated temperature up to 300°C for heating times up to 4 hours taking into consideration the loss of strength. Also, using steel fibers enhance the residual strength of high cement content RPC samples.

Rajesh Kumar, Amiya K. Samanta and D. K. Singha Roy(2014)

At present in India, about 960 million metric tons of solid waste is being generated annually as by products during industrial, mining, municipal, agricultural and other processes. Advances in solid waste management resulted in alternative construction materials as a substitute to traditional materials like bricks, blocks, tiles, aggregates, ceramics, cement, lime, soil, timber and paint. To safeguard the environment, efforts are being made for recycling different wastes and to utilize them in value added applications. The cement industries have been making significant progress in reducing carbon dioxide (CO_2) emissions through improvements in process technology and enhancements in process efficiency, but further improvements are limited because CO_2 production is inherent to the basic process of calcinations of limestone. In the past two decades, various investigations have been conducted on industrial wastes like fly ash, blast furnace slag, Silica fume, rice husks and other industrial waste materials to act as cement replacements .This paper consist of a review extensively conducted on publications related to utilization of waste materials as cement replacement with an intention to develop a process so as to produce an eco-friendly concrete having similar or higher strength and thus simultaneously providing a remedy to environmental hazards resulting from waste material disposal.

K.G. Hiraskar and Chetan Patil (2013)

The Iron industries produce a huge quantity of blast furnace slag as by–product, which is a non–biodegradable waste material from that only a small percentage of it is used by cement industries to manufacture cement. In the present investigation Blast Furnace Slag from local industries has been utilised to find its suitability as a coarse aggregate in concrete making. Replacing all or some portion of natural aggregates with slag would lead to considerable environmental benefits. The results indicate that the unit weight of Blast Furnace Slag aggregate concrete is lower than that of the conventional concrete with stone chips. The experimental result show that replacing some percentage of natural aggregates by slag aggregates causes negligible degradation in strength. The compressive strength of Blast Furnace Slag aggregate concrete is found to be higher than that of conventional concrete at the age of 90 days. It has also reduced water absorption and porosity beyond 28 days in comparison to that of conventional concrete with stone chips used as coarse aggregate.

Osama M. Ghazi (2013)

This study presents the benefit gained from using steel fibre reinforcement on concrete mixture. The effect of fire on compressive strength is investigated. Two different tests, one of them is the non-destructive test which is the ultrasonic pulse velocity (UPV) test and the other is the destructive compression test, are carried out using (10cm) cubes. Forty-eight cubes (half of them are with steel fibre reinforcement of fibre/concrete ratio of (0.01) by volume and the remaining cubes are without fibre reinforcement) are heated to temperature levels of (100,200,300,400,500,600 and 700°C). Then after that specimens are air cooled and (UPV) test is done, the specimens are destructively tested. The results indicated that the addition of steel fibre increases the compressive strength at all tested heating levels with a maximum percentage increase of (56.9%) at a temperature level of (500°C), in spite of that they have the same behaviour but the residual compressive strength decreases with the addition of steel fibre for the tested heating levels lower than (400°C) and increases for the heating levels above this degree.

Rafat Siddique , Deepinder Kaur (2011)

Normal strength (NSC) and high-performance concretes (HPC) are being used extensively in the construction of structures that might be subjected to elevated temperatures. The behavior of concrete structures at elevated temperatures is of significant importance in predicting the safety of structures in response to certain accidents or particular service conditions. This paper deals with the mechanical properties of concrete made with ground granulated blast furnace slag (GGBFS) subjected to temperatures up to 350℃. For this purpose, normal concrete having compressive strength of 34 MPa was designed using GGBFS as partial replacement of cement. Cylindrical specimens (150·300 mm) were made and subjected to temperatures of 100, 200 and 350℃. Measurements were taken for mass loss, compressive strength, splitting tensile strength, and modulus of elasticity. This investigation developed some important data on the properties of Concrete exposed to elevated temperatures up to 350℃.

P. Jyotsna Devi, Dr. K. Srinivasa Rao (2014)

The present study aims at investigating the performance of steel fibre reinforced concrete at high temperatures. It also aims at comparing the flexural and split tensile strengths of normal (M30) and high strength concrete (M60) when mixed with 1% volume fractions of steel fibres. To study flexural strengths prisms of size 100x100x500mm were casted and to study splitting tensile strength cylinders of 150mm diameter and 300mm length were casted. The samples are cured for 7, 28 and 91 days. After specified period of curing, the specimens were air dried and then exposed to 100, 200, 300, 400 and 500oC (apart from 27oC), for duration of one hour and then allowed to cool. The prisms are tested in Universal Testing machine for flexure and cylinders are tested for split in compression testing machine. The use of fibres in high strength concrete is of good advantage than using in normal Strength concrete. By adding steel fibres fracture resistance of concrete can be increased.

Khaled Mohammed Nassar , Prof. Samir Shihada(2011)

Fire has become one of the greatest threats to buildings. Concrete is a primary construction material and its properties of concrete to high temperatures have gained a great deal of attention. Concrete structures when subjected to fire presented in general good behaviour. The low thermal conductivity of the concrete associated to its great capacity of thermal insulation of the steel bars is the responsible for this good behaviour. However, there is a fundamental problem caused by high temperatures that is the separation of concrete masses from the body of the concrete element "spalling phenomenon ". Spalling of concrete leads to a decrease in the cross section area of the concrete column and thereby decrease the resistances to axial loads, as well as the reinforcement steel bars become exposed directly to high temperatures. With the increase of incidents caused by major fires in buildings; research and Developmental efforts are being carried out in this area and other related disciplines. This research is to investigate the behaviour of the reinforced concrete columns at high temperatures. Several samples of reinforced concrete columns with Polypropylene (PP) fibres were used. Three mixes of concrete are prepared using different contents of Polypropylene ;(0.0 kg/m³, 0.5 kg/m³ and 0.75 kg/m³). Reinforced concrete columns dimensions are (100 mm x100 mm x300 mm). The samples are heated for 2, 4 and 6 hours at 400 C°, 600 C° and 800°C and tested for compressive strength. Also, the behaviour of reinforcement steel bars at high temperatures is investigated. Reinforcement steel bars are embedded into the concrete samples with 2 cm and 3 cm concrete covers, after heating at 800°C for 6 hours. The reinforcement steel bars are then extracted and tested for yield stress and maximum elongation ratio. The analysis of results obtained from the experimental program showed that, the best amount of PP to be used is 0.75 kg/m³, where the residual compressive strength is 20% higher than of that when no PP fibres are used at 400 C for 6 hours. Moreover, a 3 cm of concrete cover is in useful improving fire resistance for concrete structures and providing a good protection for the reinforcement steel bars, where it is 5 % higher than the column samples with 2 cm concrete cover at 6 hours and 600 C°.

Rahul Subhash Patil (2014)

The present work is aimed to study the effect of elevated temperature ranging from 200oC to 600oC on the compressive strength on M20 grade concrete with percentage of polypropylene fibre (0.22%) & steel fibre (0.5%) by volume of concrete. Tests were conducted on 150mm side cube concrete specimens. The specimens were heated to different temperatures of 200oC, 400oC, and 600oC for 6 hour durations. After the heat treatment the specimens were cooled by wet and dry cooling condition and then they were tested for compressive. The results were analysed and presented with comparison of compressive strength of specimens with & without fibres for different cooling conditions. The concrete containing fibre exhibited better performance than without fibre for high temperature. Strength loss was more significant on specimens cooled in water.

Mr. Ran Vijay Singh and Prof. Prashant Awsarmal (2015)

The use of natural and chemical admixtures like Metakaolin, silica fume, fly ash, finely ground pumice, Palm Oil Fuel Ash, Rice Husk Ash as replacement of cement would be caused the decrease in the compressive strength, modulus of elasticity, tensile strength, ultrasonic pulse velocity and colour change of the concretes at elevated temperatures. The use of different w/c ratios and different types of aggregates would be exhibited reduction of mechanical properties of concrete at elevated temperatures particularly above 600^{0}C. Different curing methods irrespective of types of concretes made with different admixtures might be caused the reduction in the mechanical properties at elevated temperatures.

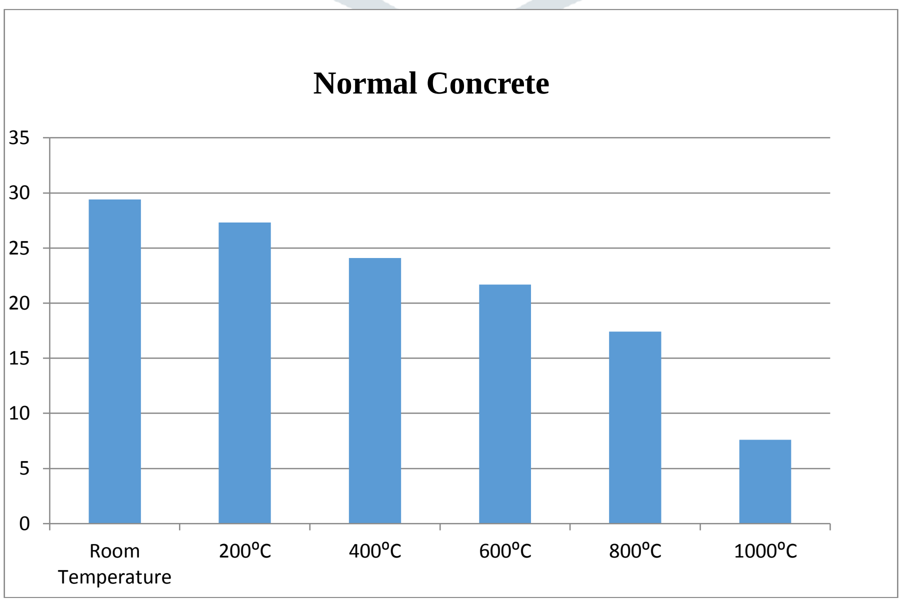
IV. MIX DESIGN FOR M25 BY INDIAN STANDARD AS PER IS 10262:2009

Cement	Water	Fine Aggregate	Coarse Aggregate
412	186	683	1022.38
1	0.45	1.65	2.47

V. TEST RESULT & DISCUSSION

COMPRESSIVE STRENGTH OF CONVENSIONAL CONCRETE (N/mm²)

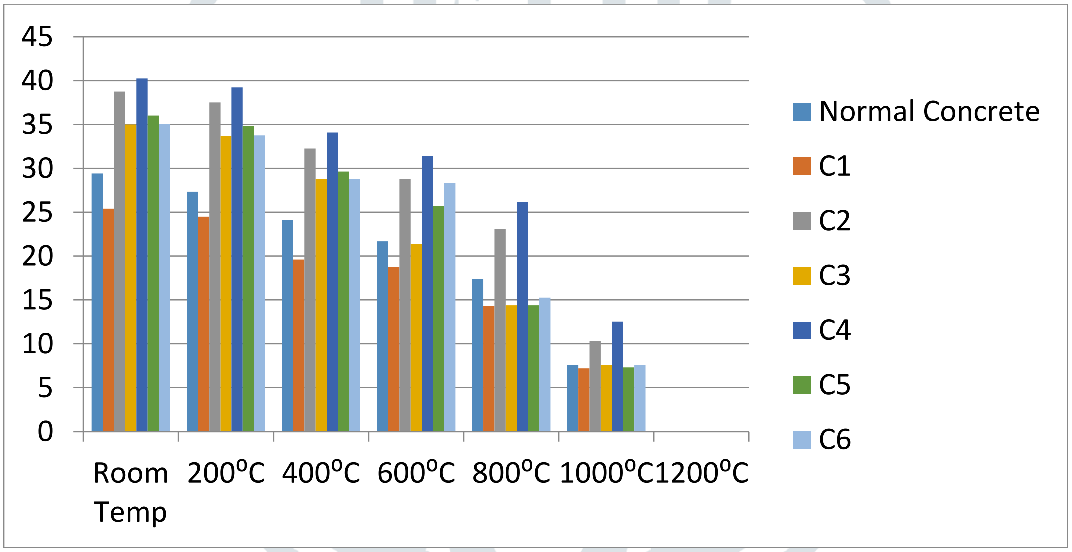
Temperature°C	Normal Concrete
Room Temp	29.41
200^{0}C	27.32
400^{0}C	24.1
600^{0}C	21.69
800^{0}C	17.41
1000^{0}C	7.6
1200^{0}C	0



- C1 - 5% RHA + 20% BFS+1% Steel fiber
- C2- 10% RHA + 20% BFS+1% Steel fiber
- C3 - 5% RHA + 40% BFS+1% Steel fiber
- C4- 10% RHA + 40% BFS+1% Steel fiber
- C5- 5% RHA + 60% BFS+1% Steel fiber
- C6-10% RHA + 60% BFS+1% Steel fiber

COMPRESSIVE STRENGTH IN N/mm² (28 DAYS) (CUBE SIZE 150×150×150)

	Normal Concrete	C1	C2	C3	C4	C5	C6
Room Temp	29.41	25.41	38.76	35.01	40.24	36.01	35.08
200^0C	27.32	24.51	37.52	33.67	39.22	34.86	33.76
400^0C	24.1	19.62	32.26	28.77	34.08	29.65	28.78
600^0C	21.69	18.75	28.78	21.36	31.38	25.72	28.34
800^0C	17.41	14.32	23.1	14.39	26.16	14.39	15.26
1000^0C	7.6	7.21	10.31	7.62	12.53	7.32	7.58
1200^0C	0	0	0	0	.0	0	0

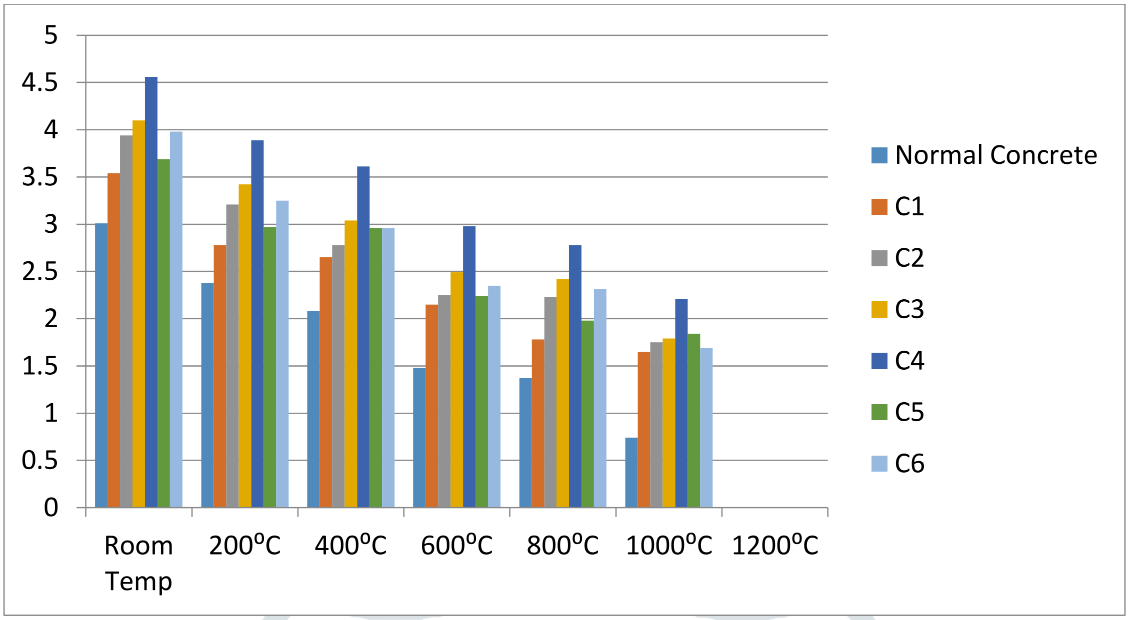


From above graph it is observed that,

1. As the temperature increases compressive strength of concrete gets reduced.
2. C4 (10%RHA+40% BFS+1% steel fiber) gives higher compressive strength as compare to other combinations
3. At elevated temperature normal concrete gives less compressive strength as compared to C2,C3,C4,C5,C6
4. At 1200°C blast furnace slag in concrete started to melt so it gives negligible compressive strength for all combination.

SPLIT TENSILE STRENGTH IN N/mm² (28 DAYS) (CYLINDER SIZE 150×300)

	Normal Concrete	C1	C2	C3	C4	C5	C6
Room Temp	3.01	3.54	3.94	4.1	4.56	3.69	3.98
200^0C	2.38	2.78	3.21	3.42	3.89	2.97	3.25
400^0C	2.08	2.65	2.78	3.04	3.61	2.96	2.96
600^0C	1.48	2.15	2.25	2.49	2.98	2.24	2.35
800^0C	1.37	1.78	2.23	2.42	2.78	1.98	2.31
1000^0C	0.74	1.65	1.75	1.79	2.21	1.84	1.69
1200^0C	0	0	0	0	0	0	0

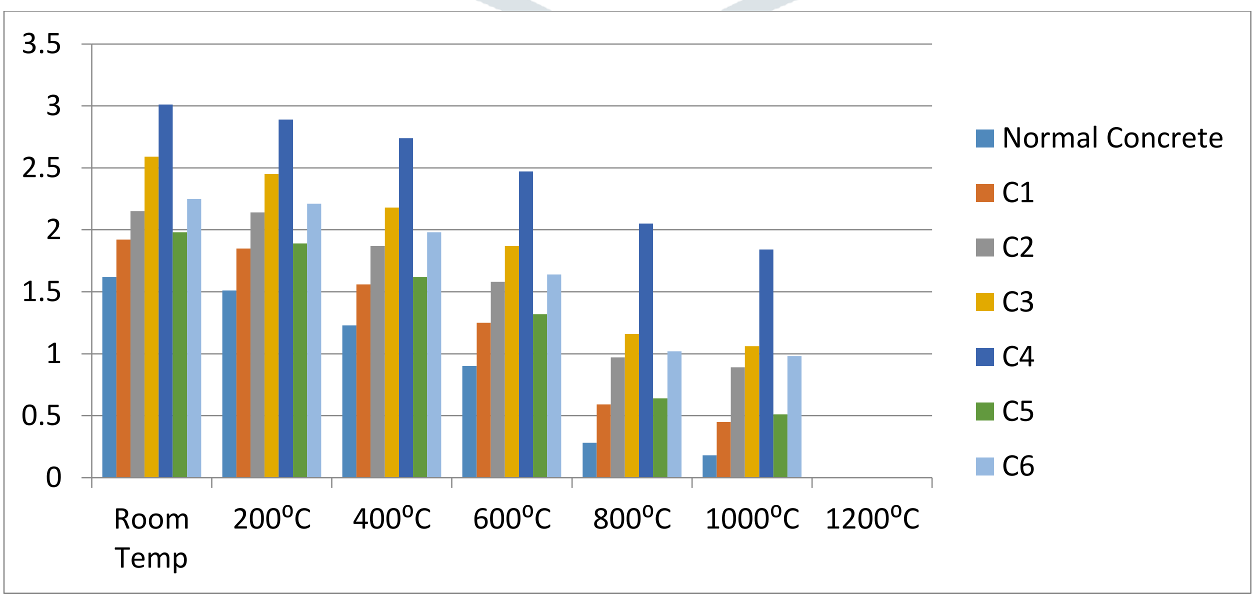


From above graph it is observed that,

1. As the temperature increases Split tensile strength of concrete gets reduced.
2. C4 (10%RHA+40% BFS+1% steel fiber) gives higher compressive strength as compare to other combinations
3. At elevated temperature normal concrete gives less compressive strength as compared to C2,C3,C4,C5,C6
4. At 1200°C blast furnace slag in concrete started to melt so it gives negligible compressive strength for all combination.

FLEXURAL STRENGTH IN N/mm² (28 DAYS) (BEAM SIZE 750×150×150)

	Normal Concrete	C1	C2	C3	C4	C5	C6
Room Temp	1.62	1.92	2.15	2.59	3.01	1.98	2.25
200°C	1.51	1.85	2.14	2.45	2.89	1.89	2.21
400°C	1.23	1.56	1.87	2.18	2.74	1.62	1.98
600°C	0.9	1.25	1.58	1.87	2.47	1.32	1.64
800°C	0.28	0.59	0.97	1.16	2.05	0.64	1.02
1000°C	0.18	0.45	0.89	1.06	1.84	0.51	0.98
1200°C	0	0	0	0	0	0	0



From above graph it is observed that,

1. As the temperature increases Flexural strength of concrete gets reduced.
2. C4 (10%RHA+40% BFS+1% steel fiber) gives higher Flexural strength as compare to other combinations
3. At elevated temperature normal concrete gives less Flexural strength as compared to C2,C3,C4,C5,C6
4. At 1200℃ blast furnace slag in concrete started to melt so it gives negligible Flexural strength for all combination.

V. CONCLUSION

Based on the limited study carried out in this particular study, The Following conclusions may be drawn out,

1. After elevated temperatures test and analysis it may be found that with the increasing temperature the strength of concrete gets reduced.
2. As temperature and exposure time increases the effect of fire on concrete increases.
3. Effect of fire can be observed on the surface of concrete in the form of deep cracks.
4. Between 400-600°C temperature Strength may loss.
5. Above 600^{0}C temperature concrete may not functioning at its full structural Capacity.
6. At 600°C temperature whitish colour and at 800°C temperature dark brown colour may appear on the surface of cubes.
7. At 1000°C temperature hair cracks may develop on specimen.

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