INFLUENCE OF TEMPERATURE ON STRENTH OF CONCRETE

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CERTIFICATE

This is to certify that the project work entitled "**Influence of temperature on strength of concrete** " being submitted by **Rahul Kumar** to the School of Civil Engineering, Galgotias University, Greater Noida, for the award of the degree of Master of Technology is a bonafied work carried out by him under my supervision and guidance. The thesis work in my opinion has reached the requisite standard, fulfilling the requirements for the said degree.

The results contained in this report have not been submitted, in part or full, to any other university or institute for the award of any degree or diploma.

Guide

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ABSTRACT

Fire represents one of the most severe environmental conditions to which structures may be subjected and, hence, the provision of appropriate fire safety measures for structural members is an important aspect of design.

In the present study, the influence of temperature level and time on the mechanical behavior of concrete has been investigated. The concrete mixes of M-35 and M-45 grade are produced. These mixes are used to prepare 48 cubes (100x100x100 mm) . These cubes are cured for 28 days. After standard curing period, specimens are dried at room temperature and then the specimens are kept in laboratory for one day before exposing to 300,500 and 800º C for 1 and 3 hours. Then the mechanical properties are determined, which includes: Compressive strength, Loss in Mass, Rebound number and Ultrasonic Pulse Velocity. It is concluded that compressive and split tensile strength of the specimen are reduced after high temperature exposure. Also the width of crack increases with the rise in temperature.

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List of Abbreviation

IS	Indian Standard Code
BIS	Bureau of Indian Standard
NSC	Normal Strength Concrete
HSC	High Strength Concrete
Wt.	Weight of Sample
R. No.	Rebound Number
UPVT	Ultrasonic Pulse Velocity Test
MPa	Mega Pascal (N/mm^2)
ASTM	American Society for Tools & Machines
N_t	Rebound Number at elevated temperature
N	Rebound Number at room temperature
C_{ut}	Compressive strength at elevated temperature
C_u	Compressive strength at room temperature
T_t	Split tensile strength at elevated temperature
T	Split tensile strength at room temperature
E_t	Modulus of elasticity at elevated temperature
E	Modulus of elasticity at room temperature
V_t	Ultrasonic pulse velocity at elevated temperature
V	Ultrasonic pulse velocity at elevated temperature

Chapter 1

INTRODUCTION

In present scenario we people are surviving under many kinds of natural (Earthquakes, Floods, Fire etc.) and man-made threats (blasts etc.), both kinds of threats include “FIRE”. As a structural engineer we are supposed to make our structures perform better against fire. In the case of unexpected fire, constructing concrete factors inclusive of columns, slab and walls could be subjected to excessive temperatures. so that you can check the performance of excessive-upward push strengthened concrete individuals it's far essential to understand the modifications in the concrete residences due to hot temperature exposure. since the high-energy concrete produced may comprise various binder substances further to cement, it is also becoming necessary to research the affect of the binder cloth kind at the concrete houses beneath increased temperature exposure

Chapter 2

LITERATURE REVIEW

Concrete is the most versatile building material which shows remarkable resistance to fire damage and such damage can be repaired depending upon the intensity and duration of exposure to fire. In order to study the influence of elevated temperature on concrete, the following literature has been reviewed.

2.1 GENERAL

hearth-precipitated collapse of the world Trade Centre in new york, USA with heavy casualties has high-lightened the significance of the overall performance of creation materials at improved temperatures. Engineering properties along with power and stiffness and the thermal properties along with conductivity and growth of these substances ought to be understood by the designers while deciding on the opportunity substances. there's no question that excessive thermal conductivity and growth of steel further to losses in strength and stiffness have contributed to the collapse of the towers in front of tens of millions of visitors inside a especially quick period after the terrorist assault. the apparent question, now being asked with the aid of many, is that what might have been the performance of those towers if concrete become used rather than metallic? Is it reasonable to assume better performance with decreased range of casualties with out collapse? it's far no question that the proprietors of the high-rise homes, the builders and architects of excessive-rise buildings want to find solutions to those questions. searching for the solutions for those questions, it is essential to understand the consequences of hot temperature exposure at the properties of concrete used within the creation of excessive upward thrust buildings. The trend of utilising high-energy concrete decreased the thickness of the columns in addition to extended the manageable constructing heights. Thermal conductivity is an essential belongings of concrete because it controls the propagation of heat in a concrete detail. the cover to steel reinforcement acts as the barrier and allows to govern the warmth conduction through the metal reinforcement. based totally at the research stated via

Malhotra and Marshall

The thermal conductivity of concrete is decreased with the lack of moisture during heating. The combination type utilized in a concrete combination has full-size affect on conductivity. Concrete with lower cement paste content material as inside the case of high- strength concrete may be expected to have a lower thermal conductivity than for lean concrete combos. Binder material type impacts the thermal conductivity in thus far as water launch happens at high temperature from the paste containing cement supplementary material which includes blast-furnace slag.

Khoury , and Noumowe

They suggested the outcomes of high temperature publicity at the residences of concrete. several mechanisms had been diagnosed for the deterioration of concrete because of high temperatures. these consist of decomposition of the calcium hydroxide into lime and water, growth of lime on re-hydration, destruction of gel shape, phase transformation in a few varieties of mixture, and improvement of micro-cracks due to thermal incompatibility among cement paste matrix and aggregate segment. excessive energy concrete compared to medium power concrete is more brittle; contains much less water; and the solid debris are greater compact. for this reason, the consequences of excessive temperature on excessive electricity concrete will be exclusive to those with the medium electricity concrete.

Gabriel A. Khoury, Patrick J.E. Sullivan

preliminary studies of the effect of heating on the electricity of concrete display positive developments which may additionally fluctuate from the ones expected from cutting-edge expertise. basic creep research at consistent temperatures indicated a marked increase in creep above 550–600°C for cement paste and lightweight concrete. From this they recommended that the structural, even though now not always the refractory, usefulness of Portland cement-based concretes in trendy could be constrained to temperatures below 550–600°C. This indicates that it may be possible to design concretes inside the future which keep a larger proportion of their preliminary electricity after heating than is carried out at present.

Dattatreya, B. Balakrishna Bharath

The conduct of metal Reinforcement at various improved temperatures from 100° C to 1000°C became studied. The specimens for trying out have been TMT bar of 12mm diameter. 20 bars have been cut to 30 cm size. tremendous alternate in ductility became found at excessive temperatures & near remaining load. a chief trouble caused by excessive temperatures changed into spalling of concrete i.e. separation of concrete mass from concrete element which resulted inside the publicity of steel reinforcement directly to high temperatures. If the period and the intensity of hearth are better, the weight bearing decreased to the quantity of the applied load resulting in disintegrate of shape.

S. C. Chakrabarti, K. N. Sharma

The authors concluded that the concrete simply received a few strength among one hundred to 300°C within the presence of siliceous & carbonaceous aggregates. a few other researchers too have said this phenomenon, however they confronted complaint then help. As according to the authors, concrete failed to lose tons of its energy up to 500°C & in reality regained 90% of misplaced electricity as much as this temperature after about a 12 months. Concrete cubes heated past 800°C for four hours commenced crumbling after 2-3 days.

A. R. Mundhada

108 R.C.C beams (36 every for concrete grades M 30, M 25 & M 20) of size 100*100*450 have been forged. The beams had been reinforced with 2 no's 8Y bars at top & backside. half of the beams had carefully spaced stirrups while the last had in moderation spaced 5mm Ø stirrups. After the beams were cured for 28 days, they were heated at 30°C, 200°C, 350°C, 500°C, 650°C, and 800°C for twenty-four hours. non-unfavourable exams like Thermo gravimetric evaluation, Schmidt Hammer take a look at & UV Pulse speed take a look at have been completed. upto 350°C, concrete remained unaffected excellent wise and electricity smart. electricity misplaced turned into @10% or much less. At 500°C, satisfactory of concrete reduced, however remained fair & energy came down by using 20-25%. shape/members remained serviceable but factor of safety reduced. Affected member might require minor maintenance to become serviceable once more. At 650°C, power decrease became substantial and are available down with the aid of a third. At 800°C, concrete lost most of its electricity & affected component might require replacement.

K. Thamaraiselvan, V. Jeevanantham

This study mainly addressed three kinds of concretes viz. every day, high energy and fly ash concrete. these specimens had been tested in separate circumstance states. the primary representing air-cooled country. section two entails heating the specimen. The energy and stiffness degradation of concretes for numerous grades has been studied. weight loss turned into marginal at 200°C. For specimens uncovered to 200 to 400o C, the average reduction of compressive energy became 20% and 25% respectively. At 500°C surprising explosive spalling turned into determined in few excessive electricity concrete specimens. At higher temperatures, the discount became observed to be higher. approximately eight% weight reduction turned into found in high electricity concrete specimens at a 1000°C. The discount changed into determined to be more in excessive strength concrete specimens. At 600 and 800C the residual strength changed into determined to be round one fourth of its original capability.

Chapter 3

MATERIALS AND METHOD

3.1 Mix Design

According to IS: 456:2000 and IS: 1343-1980 the design of concrete mix should be based on the following factors:

- ✓ Grade of designation
- ✓ Types of Cement
- ✓ Maximum nominal size of aggregates
- ✓ Grading of combined aggregates
- ✓ Water- Cement ratio
- ✓ Workability
- ✓ Durability
- ✓ Quality control.

3.1.1 Mix design calculation

1) Design stipulations:

   Compressive Strength = 35 Mpa

   Degree of workability =0.90

   Degree of quality control = Good

   Types of Exposure = Very sever

2) Test Data for materials

   Cement sp. gravity =3.15

   Sp. Gravity of coarse =2.8

   Sp gravity of fine sand=2.660

3) Target mean Strength = fs + K*S

   = 35+ 6.5*1.65

=45.725

4) Water cement Ratio- = from graph of SP-23-1982

The w/c ratio for 45.725 Mpa is 0.45 < 0.65

5) Selection of water content= from tables and graph of grading zone III of sand the water content is 186 kg + Adjustment

= 186 + 5.58 = 191.58 kg

6) Cement content = W/C ratio is 0.45

Cement = 425.3 Kg

7) Determination of coarse and sand content= Taking 2% of amount of air in the wet concrete.

V= (W +(C/SP.G) + (1/p)*(FA/Sp. G)) * (1/1000)

FA=556.06 kg

AND CA =1248.3 Kg

Table No.3.1 Final mix proportion for concrete

Water	Cement	Fine Aggregate	Coarse Aggregate
191.58	425.3 kg	556.06 kg	1248.3 kg
0.45	1	1.31	2.99

Mix design of M-45

(1)Target mean strength of concrete,

45+ [7*1.65] =56.55

(2) Selection of w/c ratio=0.35(assume)

= 180 kg/m3 [as per table no IS 10262]

As plasticizer is proposed we can reduced water content by 20%

Now water content =180*0.8=144kg/m3

(3) Calculation of cement content

Cement content = 144/0.35=411.4kg/m3

(4) Sand as percent of total aggregate by absolute volume=25%

(5) Fine aggregate=425kg/m3

(6) Coarse aggregate = 1502kg/m3

water	Cement	F.A.	C.A
0.35	412	425	1502

water	Cement	F.A.	C.A
0.35	1	1.03	3.64

3.2 EXPERIMENTAL SETUP AND TEST PROCEDURE

In this study, an ordinary Portland cement 43 grade with specific gravity 3.15 was used as a cementations material. With specific gravity of 2.8 coarse aggregate and specific gravity of 2.66 fine aggregate used in the test and super plasticizer was used to achieve the required work ability (slump value 100 mm + 20 mm) of the concrete mixes. Concrete mixes were prepared for two different grade m-35 and m-45 having w/c ratio 0.45 and 0.35 respectively.

The sequence of mixing procedure was as follows

1. The aggregates were placed in the mixer and dry mixed for two minutes.
2. Half of the water with addition of superplasticizer was added to mixture and the mixture is run for two minutes.
3. Afterwards, cement and the remainder of water + superplasticizer have been added to the mixer and the mixer become run for and additional two minutes. total blending time became six mins for all concrete mixtures

100mmx100 mm dice specimen had been prepared for compression energy take a look at. without delay after mixing and casting of concretes, the dice molds have been saved in humidity room for twenty-four hrs at 95 % relative humidity and 20°C temperature. Then the dice specimens had been eliminated from the molds and cured in water for 28 days. at the quit of the curing durations, all specimens have been dried at room temperature for twenty-four hr. specimens had been exposed to a few temperature situations(300,500 and 800C) in a furnaces after at some point the furnace turned into heated up to internal temperature degree so one can reach the prescribed temperature degrees. After that the heat became applied for an additional 1, 3 hr before the sample have been allowed to cool naturally to room temperature. The compressive strength, mass loss, rebound no. and ultrasonic pulse velocity tests have been carry out on all specimens for each temperature level and each concrete mixture.

3.3 TEST ON FRESH CONCRETE

3.3.1 Workability Test: workability defines because the belongings of concrete which determines the quantity of beneficial inner paintings essential to supply full compaction. every other definition which envelopes a much broader meaning is that, it is described because the "ease with which concrete may be compacted hundred in keeping with cent having regard to mode of compaction and region of deposition" Workability is carried out by conducting the slump test compaction factor test and cone penetration test on normal concrete .The slump in experiment were taken 100 to 120.

3.4 Test on Hardened concrete

3.4.1 Mass Test: the mass test is performed on cube size 100x100x100 the electronic balance is used to determine the mass of cube sample of 2 grade of concrete.

3.4.2 Rebound hammer Test: Schmidt's rebound hammer developed in 1948 is one of the commonly adopted equipments for measuring the surface hardness. Rebound hammer is performed because of it provide the quick inexpensive means of checking uniformity of concrete. The method is based on the principle that the rebound of an elastic mass depends on the hardness of the surface which it strikes. The test is fast and is unlikely to cause damage to the concrete

The rebound hammer is carried on the cube sample and rebound number is correlate with the compressive strength of concrete.

Fig.3.1 Rebound Hammer

3.4.3 Ultra sonic Pulse Velocity Test: Ultra sonic pulse velocity method which involved measurement of the time of travel of electronically generated mechanical pulses through the concrete. The fundamental principle of this method of testing is that the rate of an ultrasonic pulse through concrete is related to its density and elastic properties. a few care is essential whilst checking out, but an skilled operator may gain a considerable amount of information about a concrete member. The gain of this technique is that the pulse passes via the complete thickness of the concrete so that the extensive defects may be detected. The pulse can be generated either by the use of an elecroacoustic transducer, elecroacoustic transducers are preferred as they provide better control on the type and frequency of pulses generated

The unit which is used in work "PUNDIT' (Portable ultrasonic Non destructive Digital Indicating Tester) .the direct transmit ion type of method is used. The all the test value obtained from the test is verified from the codal provision.

Table No 3.2 Velocity criteria for concrete quality grading (As per IS : 13311 – Part I) in (m/sec)

Pulse Velocity	Concrete Quality control
4575	Excellent
3660 – 4575	Good
3050 – 3660	Questionable
2135 – 3050	Poor
2135	Very Poor

Fig. 3.2 USPV Test Equipment.

3.4.4 Compressive Strength Test: The comp strength of concrete is one of most important properties of concrete .in most structural applications concrete is employed primarily to resist compressive stresses.

Cube of 100x100x100mm size is used to determine the compressive strength of the normal concrete the mix design we taken for the M35 and M45. The test result came from the 28 days are given and it is shown in figure no. Specimens before failure and after failure are shown.

Fig. 3.3 Experimental setup for compression test

Fig. 3.4 Specimen: Before failure

Fig. 3.5(a) Specimen: After Failure at Room temperature.

Fig.3.6 : Specimen: After Failure at Elevated temperature.

Chapter 4

RESULT AND DISCUSSION

On the basis of experimental investigation, the results are discussed in the following paragraphs:

4.1 Colour of the concrete specimen:

The colour of the concrete specimens was changing with temperature and duration of heating. Upto 300ºC, the colour of the specimens was not change. However with the increase in temperature the specimen suffered noticeable change in colour. The natural grey colour changed into grey whitish. However the discoloration of concrete specimens may give the indication about the temperature and duration of fire. The change in color can be easily observed in following diagrams (Fig. 4.1 and 4.2)

Fig. 4.1 Specimen color before heating.

Fig. 4.2   Specimen color after heating on more than 300ºC

4.2 Crack Pattern and Mode of failure:

It was observed that due to increase in temperature of the concrete specimen the minute cracks start at the edge and propagate towards the faces. The width of crack increases with the increase in temperature. At higher temperatures the sign of crumbling was also observed. Following figures show the crack pattern.

Fig. 4.3 Specimen before heating (At room temperature)

Fig. 4.4 Specimen after heating (Temperature > 300ºC)

4.3. Loss in Mass

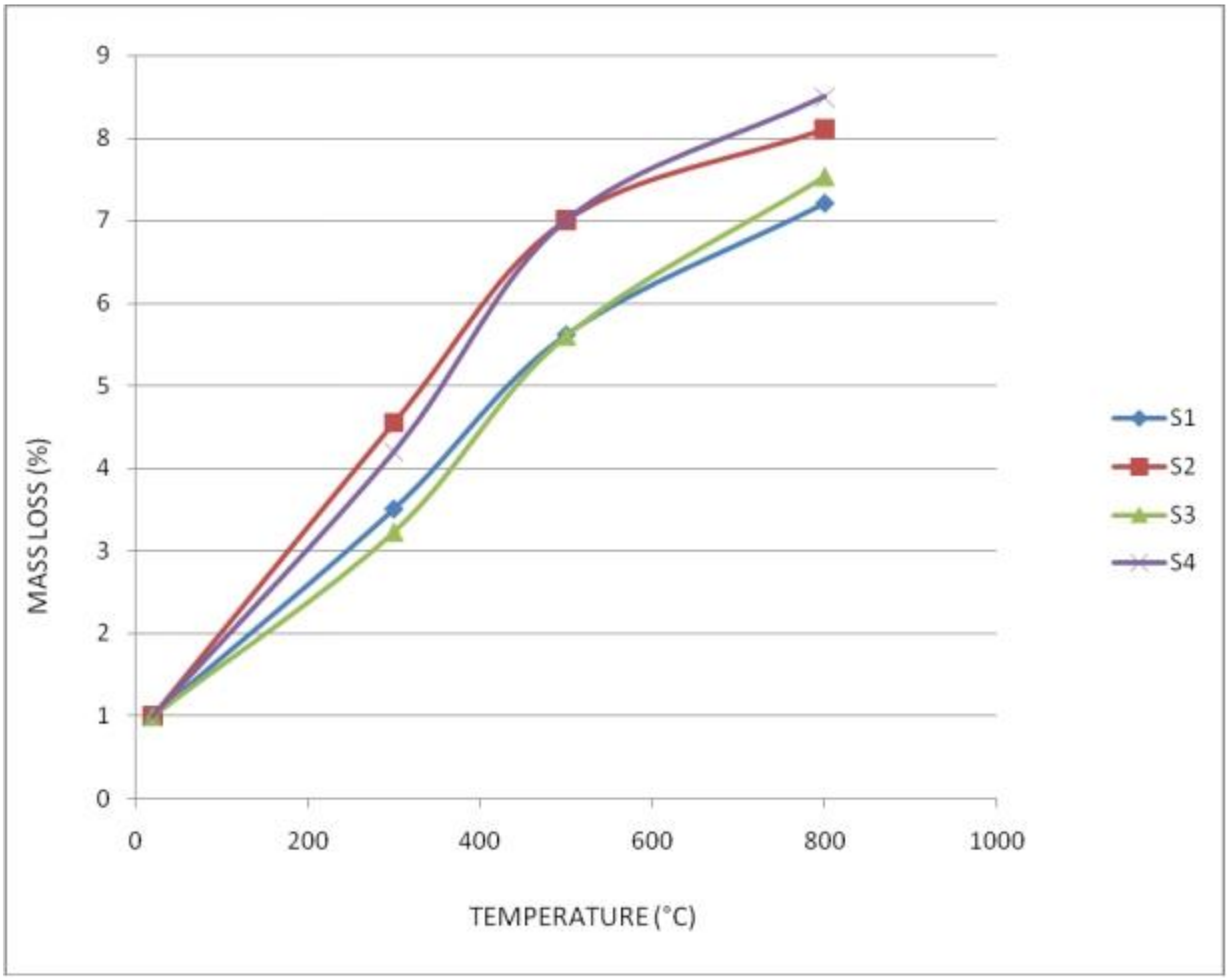
When hardened concrete is heated regularly, the loss of weight appears to take place within the following three degrees. within the first degree, referred to as drying stage, evaporation of water from big capillaries and voids will take place. On the dehydration level, which takes place among one hundred and 600oC, lack of non-evaporable water from gel pores and small capillary pores will take place. This degree is accompanied with good sized shrinkage of concrete. within the very last level, Decomposition stage, several changes will arise inside the concrete system. a few aggregate such as calcareous combination dissociates by way of releasing carbon dioxide at temperature over 800oC. on the temperature above 800oC, the combined water form hardened paste may be released. this will cause the hardened paste to lose its cementing property and for that reason appreciably lowering the hardened concrete property. This method will be followed with enormous shrinkage of cement paste as well as the loss in strength. figure 4.1 shows the weight loss in specimens for all concrete combos as the characteristic of the maximum temperature. With the increase of exposed temperature, the concrete showed expanded weight loss. however, the connection between the weight reduction and maximum temperature is non-linear. The mass loss are shown in Table (4.1)

TABLE-4.1 Loss in mass for concrete specimens (in % of mass)

		CUBE SPECIMEN AT TEMPRATURE			
GRADE	TIME	20°C	300°C	500°C	800°C
M-35	1 3	0 0	3.5 4.55	5.62 7	7.21 8
M-45	1 3	0 0	3.23 4.2	5.601 7	7.531 8.5

Table 4.2 : Notations used in graphs (For all successive graphs)

S. NO.	DESIGNATION	DISCRIPTION
1	S1	M-35, 1hr
2	S2	M-35, 3hr
3	S3	M-45, 1hr
4	S4	M-45, 3hr



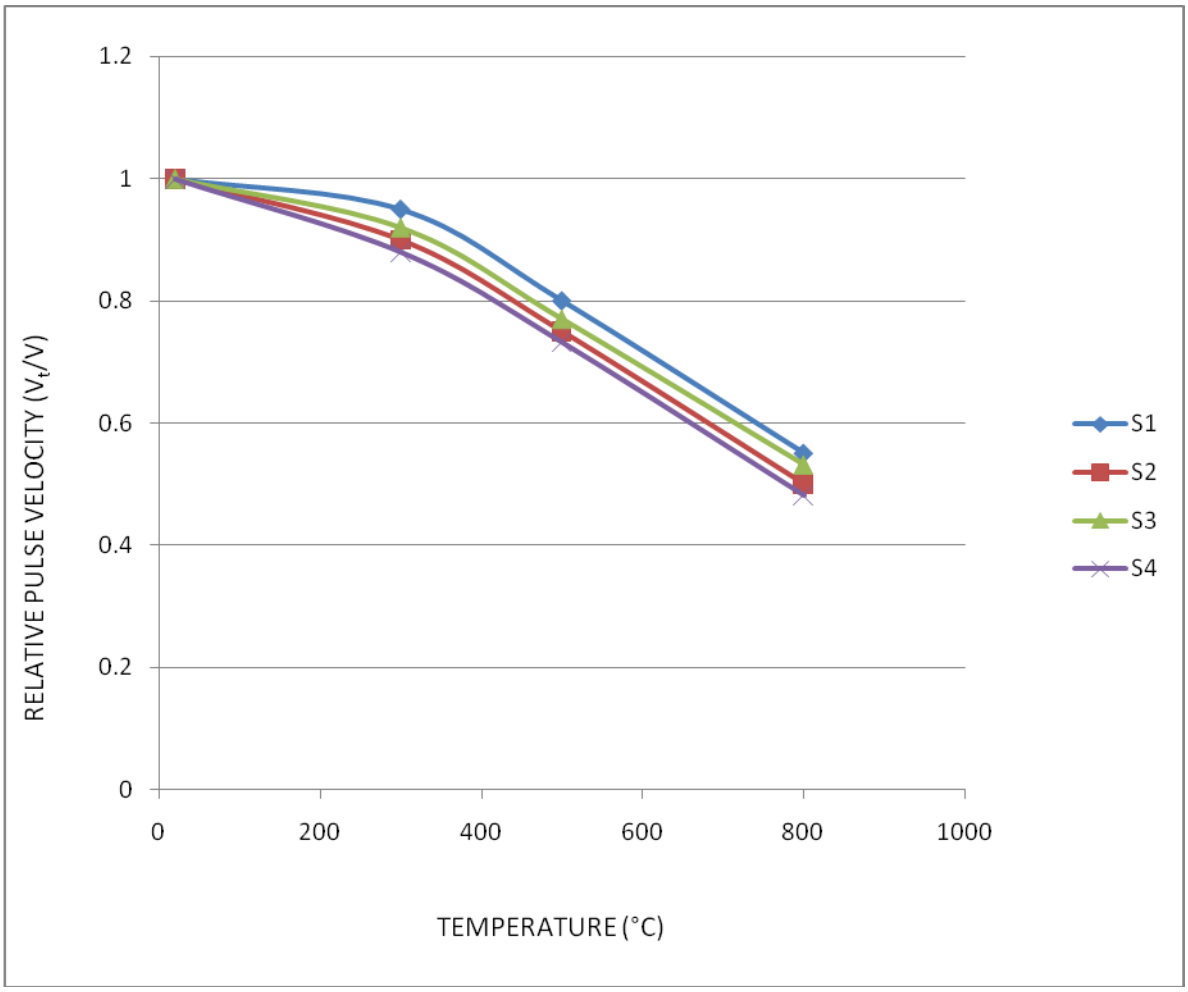
Graph 4.1 : Mass Loss v/s Temperature

4.4 Ultrasonic pulse velocity test

Figure (4.2) shows the ultra sonic pulse velocity for all concrete mixtures as a function of the exposed temperature. Similar to the strengths, pulse velocity was decreased with the increase in temperature the value are shown in Table (4.3)

Table 4.3 Ultrasonic Pulse velocity for concrete specimen (in km/sec.)

		CUBE AT TEMPRATURE			
GRADE	TIME	20°C	300°C	500°C	900°C
M-35	1	3.320	3.154	2.656	1.826
	3	3.309	2.988	2.49	1.66
M-45	1	4.12	3.790	3.172	2.187
	3	4.09	3.599	2.993	1.967



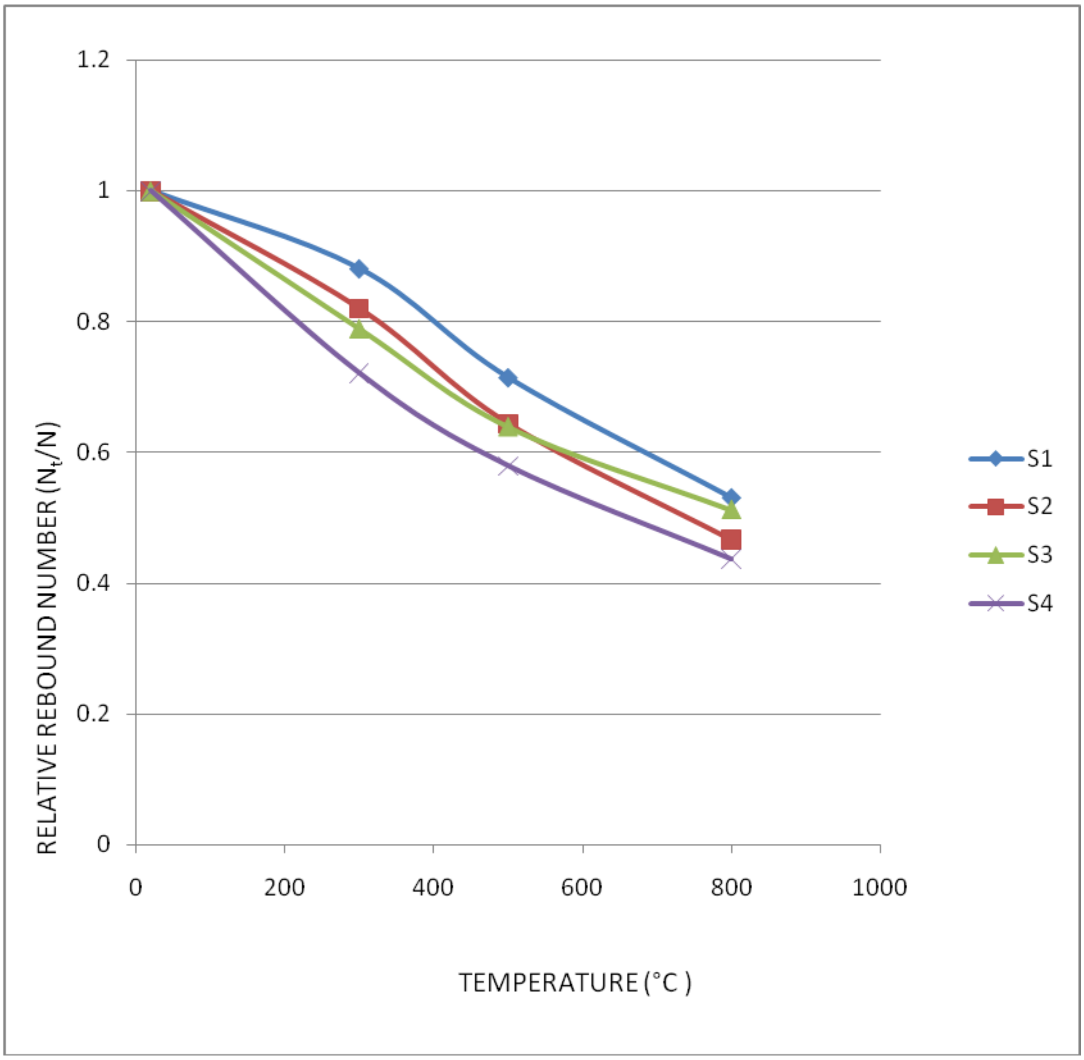
Graph 4.2: Relative Pulse velocity v/s Temperature

4.5 Rebound number

Figure (4.3) shows the residual rebound no for all concrete mixtures as a function of the exposed temperature. Similar to the strengths, rebound number was decreased with the increase in temperature the value are shown in Table (4.4)

Table 4.4 Rebound no. for concrete specimen

		CUBE AT TEMPRATURE			
GRADE	TIME	20°C	300°C	500°C	800°C
M-35	1	31.23	27.52	22.31	16.8
	3	31.221	25.61	20.13	14.58
M-45	1	33.431	48.86	21.38	17.13
	3	33.44	45.45	19.37	14.61



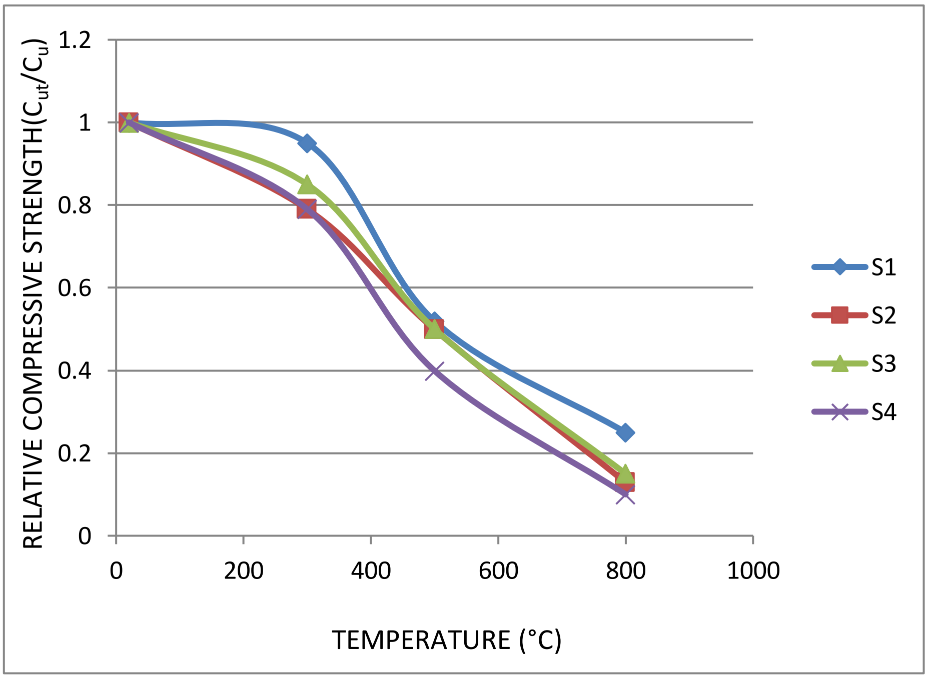
4.3 : Relative Rebound Number v/s Temperature

4.6 Compressive strength

The compressive strengths of heated and unheated specimens are shown in Table 4.5 and figure 4.4 shows the residual strength on the subject of the original strength for all concrete mixtures as a characteristic of the most exposed temperature. The compressive strength of the high-strength concrete dropped extensively because the most temperature expanded. The residual strength varied from 95 % to 79% of the corresponding initial strengths while the concrete heated to the temperature was 300oC followed by way of cooling at room temperature. as the temperature turned into extended to 500oC, the residual strength was ranged from 39% to 51% of the unfired energy. Over 600oC, the energy persevered to drop considerably and at 800oC , the residual electricity ranged from 10% to 25% of the unfired electricity . Reduction in compressive strength values of concrete with M-35 were low in comparison to that of specimens with M-45.

Table 4.5 : Compressive Strength of Concrete specimens (in N/mm^2)

		CUBES AT TEMPRATURE			
GRADE	TIME	20°C	300°C	500°C	800°C
M-35	1	43.56	41.38	22.65	10.89
	3	43.57	34.85	21.78	5.66
M-45	1	56.82	48.86	28.41	8.52
	3	56.83	45.45	22.73	5.68



Graph 4.4 Relative compressive strength v/s Temperature

CONCLUSION

On the basis of experimental investigations, following points may be concluded:

- ✓ Heating to a temperature upto 300ºC for one hour did no longer have extensive impact on the compressive and tensile strength of concrete. But losses of compressive and tensile strengths have been discovered at higher temperature level and exposure times.

- ✓ Reduction in compressive strength value of M-35 grade concrete is observed to be lower than that for M-45.

- ✓ Discoloration of concrete takes place at temperatures higher than 300ºC, temperature below 300ºC more or less no change in color was observed.

- ✓ For temperatures above 500ºC, Prominent crack patterns were observed in the concrete specimen. No such conspicuous cracks were observed when specimens were subjected to below temperatures 500ºC.

- ✓ Loss in mass increases with increase in temperature.

Chapter 6

SCOPE FOR FUTURE RESEARCH

- Data can be correlated with fire survey.
- Same work can be repeated for different grades of concrete.
- Work can be compared for Reinforced Cement concrete and Fiber Reinforced Concrete.
- Work can compared for different cement supplements such as: silica fumes, fly ash, GGBS (Ground granulated Blast Furnace Slag) etc.
- The data/results can be correlated with fire loads.

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