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EFFECT OF CONTROLLED TEMPERATURE (27°C- 42°C) ON STRENGTH OF M20 GRADE OF CONCRETE

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ABSTRACT

Every year a large number of concrete construction projects are executed in different temperature conditions in India. The rapid development of the infrastructure facilities in Indian region has resulted in huge concrete construction programme executed in the last decade. Hot climate creates many effects on concrete like rapid evaporation of mixing water resulting in rapid slump loss of concrete, reducing the concrete strength as well as setting time of cement, also reduced durability and increasing thermal cracking and plastic shrinkage.

This paper presents an assessment of effect of increasing temperature on M20 grade concrete. Compressive strength and flexural strength being most important properties of structural concrete. Experimentation has been carried out to study the compressive strength and flexural strength properties of M20 grade concrete in desired temperature condition in chamber. The results have shown that workability of concrete decreases with increase in temperature. Temperature varying form 27^0C-42^0Cdoes not show much variation on compressive and flexural strengths.

Key words: Temperature effect, compressive strength, flexural strength, depth etc

INTRODUCTION

Concrete is the key material used in various types of construction from the flooring of a hut to a multi-storied high rise structure , from pathway to a runway , from an underground tunnel and deep sea platforms to high rise chimneys and TV towers. In these various situations it has to face various changes in environment such as temperature, humidity, presence of water etc. In India normally weather is hot for maximum period of years. During this period temperature can raise above the recommended temperature. This raised temperature affects adversely on the properties of concrete.

Experimental Investigation:-

The experimental work includes the casting, curing and testing of specimens under controlled temperature. A concrete mix M20 grade was designed. The locally available materials were used.

Materials Used For M20 Grade Concrete

Cement:-

Ultratech ordinary Portland cement of 53 grade was used. The specific gravity of cement is 3.15.

Coarse Aggregate-

Crushed stone aggregate of maximum size 20 mm was used and specific gravity was found to be 2.67 and fineness modulus was 7.84.

Fine Aggregate:-

The fine aggregate i.e. sand obtained from Local River & conforming to Zone I was used. Grading of sand was done strictly as per IS 383-1970. The specific gravity of sand was found to be 2.65 and fineness modulus was 3.34.

Water:-

Clean potable water was used for mixing.

Mix Design of M20 Grade Concrete

In this experimental work, M20 grade concrete has been considered and is designed by using the IS:10262-1982. The considerations and calculations involved in the mix design of concrete are presented in the following steps.

Design Stipulations

a) Characteristic compressive strength required in the field at 28 days= 20 MPa
b) Maximum size of aggregate = 20mm
c) Degree of workability = 0.90
d) Degree of quality control = Good
e) Type of exposure = Mild

Test Data for Materials

a) Specific gravity of cement = 3.15
b) Compressive strength of cement at 7 days = As per IS 269:1989
c) Specific gravity of coarse aggregates = 2.67
d) Specific gravity of fine aggregates = 2.65
e) Water absorption of Coarse aggregates = 0.406%
f) Water absorption of Fine aggregates = 1.1%
g) Free surface moisture of coarse aggregate = 1.78%
h) Free surface moisture of Fine aggregate = 4.43%
i) Fineness modulus of Coarse aggregate = 7.84
j) Fineness modulus of Fine aggregate = 3.34
k) Grading zone of fine aggregate = Zone I

Target Mean Strength of Concrete

The target mean compressive strength (F_{ck}) at 28 days is given by,

$$F_{ck}= f_{ck} + t\times S$$

Where,

f_{ck} = characteristic compressive strength at 28 days,
S= standard deviation, standard deviation is assumed as per IS 456:2000,
For M20 standard deviation is 4.0.
t= risk factor=1.65,

$$F_{ck}= 20+ 1.65\times 4$$

$$F_{ck}= 26.6 \text{ MPa}$$

Water/Cement Ratio

Water/ Cement ratio is selected form IS 456: 2000, for mild exposure, minimum cement content is 220 kg/m^3 and maximum free water cement ratio is 0.60. Therefore assume 0.50 as the water/ cement ratio for M20 grade concrete

Determination of Cement Content

Water-cement ratio=0.50
Water=191.61 liter
Cement=191.6/0.50=383.2 kg/m^3

Mass Of Fine Aggregate

$$V = \left[W + \frac{C}{S_c} + \frac{1}{P}\frac{f_a}{S_{fa}}\right]\frac{1}{1000}$$

$$\therefore (1-0.02) = \left[191.6 + \frac{383.2}{3.15} + \frac{1}{0.345}\frac{f_a}{2.65}\right]\frac{1}{1000}$$

$\therefore$ **Mass of fine aggregate , f_a = 609.57 kg/m^3**

Mass of Coarse Aggregate

$$\text{Mass of coarse aggregate}, C_a = \frac{1-P}{P} \times f_a \times \frac{S_{ca}}{S_{fa}}$$

$$\therefore C_a = \frac{1-0.345}{0.345} \times 609.57 \times \frac{2.67}{2.65}$$

$\therefore$ **Mass of coarse aggregate, C_a = 1166.03 kg/m^3**

Preparation of Specimen:-

The experimental work aims at casting and studying various properties like compressive strength of cubes at different depths and flexural strength of beams and slabs at different temperatures. In order to study effect of controlled temperature on M20 grade concrete, a total number of 18 specimens [6 cubes of size (150mm × 150 mm×150mm)], [4 cubes of size (150mm × 150 mm×125mm)], [4 cubes of size (150mm × 150 mm×75mm)], [2 beams of size 500mm×100mm×100mm] and [2 slab specimens of size 500mm×300mm×100mm] were cast.

Casting was done with water + cement+ fine aggregate and coarse aggregate. The experimental procedure is as follows:

1. Mix proportion chosen for experimental work was **"0.41:1:1.65:3.07".**
2. Before starting of experimental work we have taken a set of ready materials as per calculation on weighing machine. The accuracy of this equipment was 0.005 kg.
3. For that we have taken first coarse aggregate in two proportions in empty bucket
    a. 20 mm = 60% b.12 mm = 40%
4. After that sand was added which was of zone I. After addition of sand cement was added (O.P.C. 53 grade).
5. Then water was taken into measuring cylinder by weight (0.41%) as per requirement.
6. After that, required condition of temperature was created and controlled in the chamber by means of heater, bulbs (figure A) and **temperature controller DTC 303** (figure B) and foggers (figure C).
7. Then ready set was taken into chamber and poured on mixing pan for few minutes to bring the temperature of material up to the controlled temperature in chamber.
8. Material was then dry mixed in pan manually for few minutes then water was added into mixture and mixed properly.
9. After that the slump test on concrete was taken for which slump cone (figure D) was used.

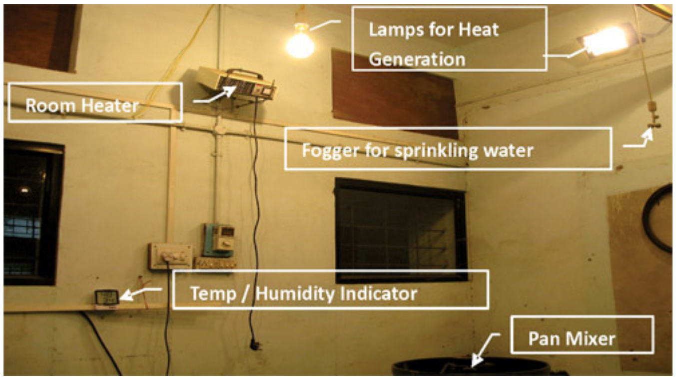


Fig. A: Room Controlled for Humidity and Temperature conditions

Fig. B Temperature Controller- DTC303

Fig. C Fogger

Fig. D Slump Cone

Test Results

Table 1 shows the results of compressive strength after 7 days curing for various depths of 150mm, 125mm and 75mm concrete specimens for the temperatures 27 °C, 30 °C, 33 °C, 36 °C, 39 °C and 42 °C. The variation of compressive strength is depicted in Fig.1.

Table 1 Compressive Strength at 7th Day

Size of Specimen \ Temperature	Compressive Strength N/mm^2					
	27 °C	30 °C	33 °C	36 °C	39 °C	42 °C
150 mm × 150 mm × 150 mm	23.840	16.786	16.350	19.402	15.478	21.364
150 mm × 150 mm × 125 mm	25.700	19.620	20.056	14.824	16.568	16.786
150 mm × 150 mm × 75 mm	42.570	35.543	38.368	36.624	37.278	31.174

Table 2 shows the result of compressive strength after 14 days curing for a depth of 150mm, concrete specimens for the temperatures 27 °C, 30 °C, 33 °C, 36 °C, 39 °C and 42 °C. The variation of compressive strength is depicted in Fig.2.

Table 2 Compressive Strength at 14th Day

Size of Specimen \ Temperature	Compressive Strength N/mm^2					
	27 °C	30 °C	33 °C	36 °C	39 °C	42 °C
150 mm × 150 mm × 150 mm	28.994	35.302	32.700	28.558	28.34	26.814

Table 3 shows the result of compressive strength after 28 days curing for a depth of 150mm, 125mm and 75mm, concrete specimens for the temperatures 27 °C, 30 °C, 33 °C, 36 °C, 39 °C and 42 °C. The variation of compressive strength is depicted in Fig.3.

Table 3 Compressive Strength at 28th Day

Size of Specimen	Compressive Strength N/mm^2					
	27 °C	30 °C	33 °C	36 °C	39 °C	42 °C
150 mm × 150 mm × 150 mm	34.880	38.368	40.112	38.804	35.970	37.482
150 mm × 150 mm × 125 mm	32.700	27.904	39.022	35.534	35.534	32.482
150 mm × 150 mm × 75 mm	73.030	60.604	54.921	64.310	61.694	64.310

Table 4 shows the result of flexural strength after 28 days curing for a beam, 500 mm× 100 mm × 100 mm, concrete specimens for the temperatures 27 °C, 30 °C, 33 °C, 36 °C, 39 °C and 42 °C. The variation of compressive strength is depicted in Fig.4.

Table 4 Flexural Strength at 28th Day of Beam

Temperature / Size of Specimen	Flexural Strength N/mm^2					
	27 °C	30 °C	33 °C	36 °C	39 °C	42 °C
500 mm × 100 mm × 100 mm	06.621	05.101	05.885	05.738	05.591	06.131

Table 5 shows the result of flexural strength after 28 days curing for a slab panel, 500 mm× 300 mm × 100 mm, for the temperatures 27 °C, 30 °C, 33 °C, 36 °C, 39 °C and 42 °C. The variation of compressive strength is depicted in Fig.5.

Table 5 Flexural Strength at 28th Day of Slab

Temperature / Size of Specimen	Flexural Strength N/mm^2					
	27 °C	30 °C	33 °C	36 °C	39 °C	42 °C
500 mm × 300 mm × 100 mm	13.332	10.165	11.333	12.999	11.666	13.666

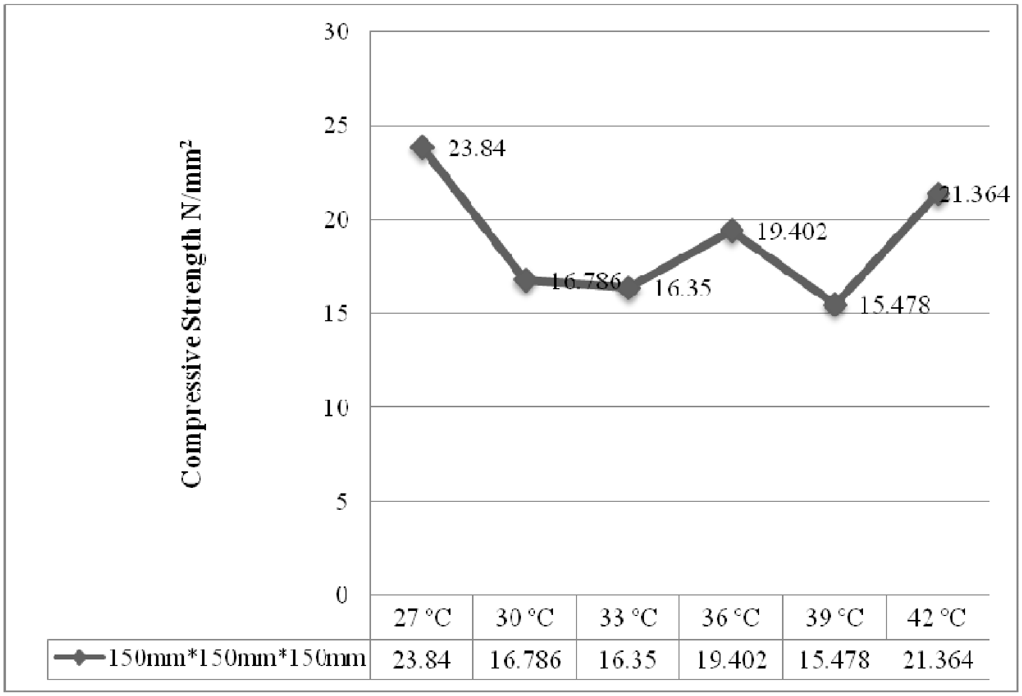


Fig. 1 Compressive Strength Vs Temperature after 7 Days of Cube Size 150 mm×150 mm ×150 mm

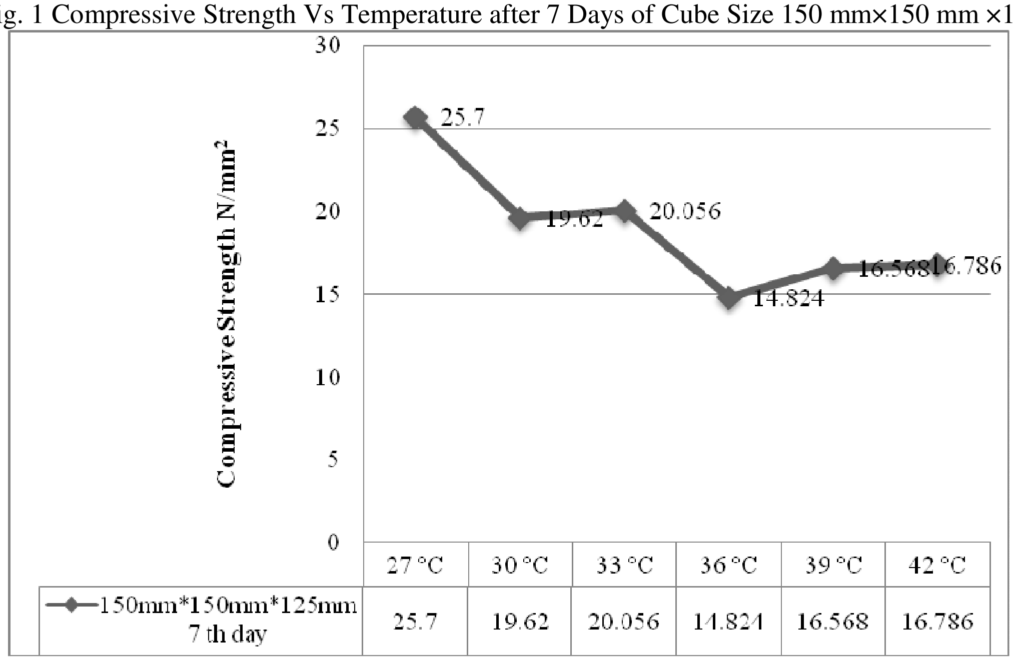


Fig.2 Compressive Strength Vs Temperature after 7 Days of Specimen Size 150 mm×150 mm×125 mm

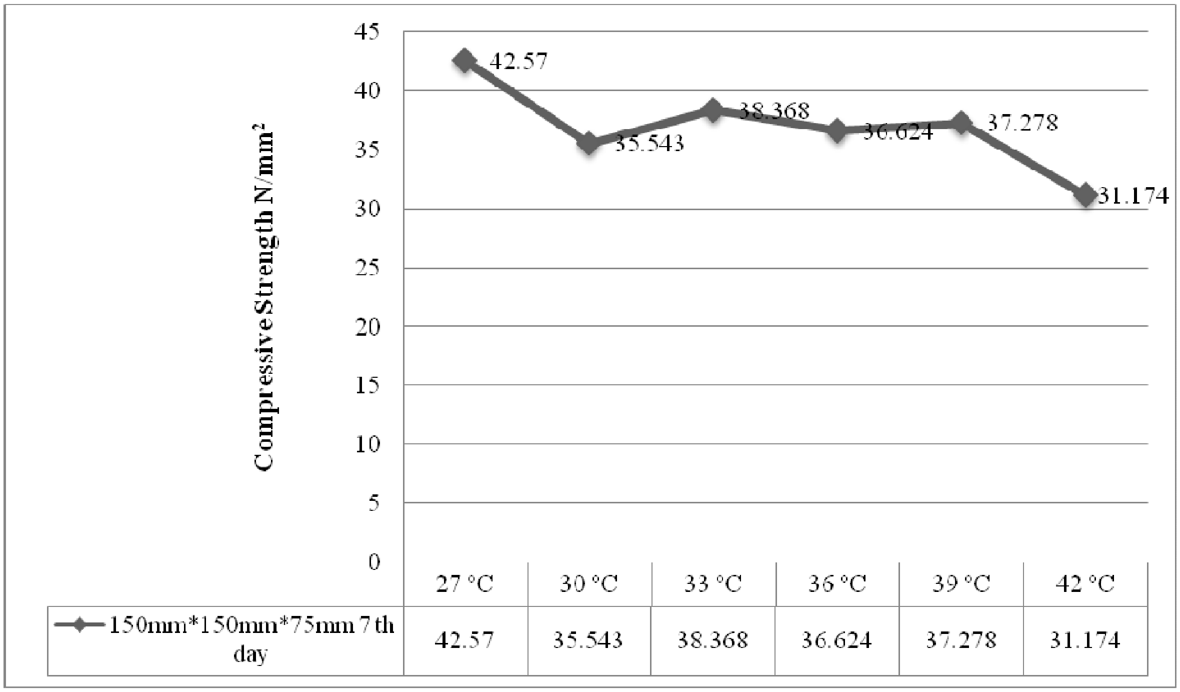


Fig.3 Compressive Strength Vs Temperature after 7 Days of Specimen Size 150 mm× 150 mm× 75 mm

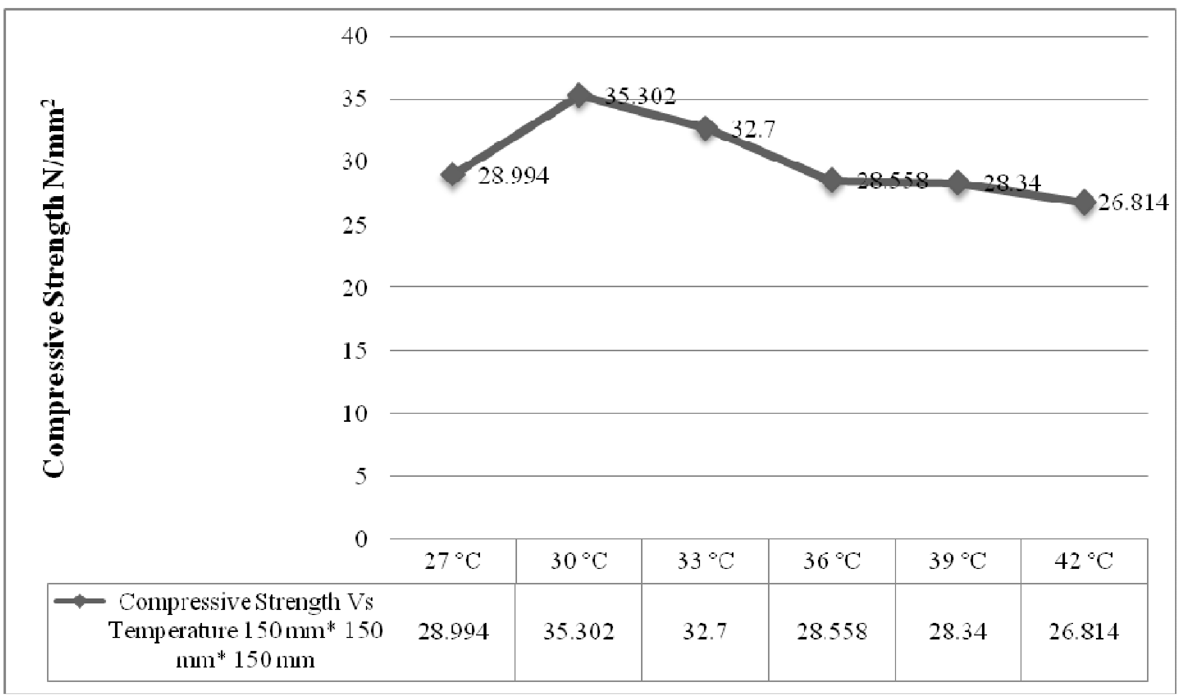
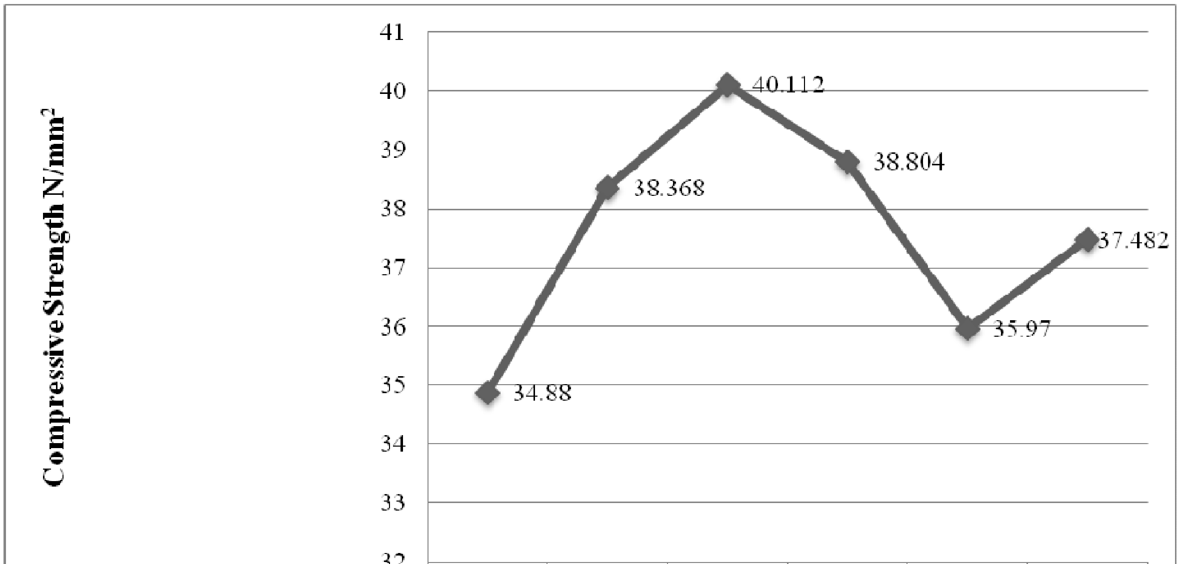
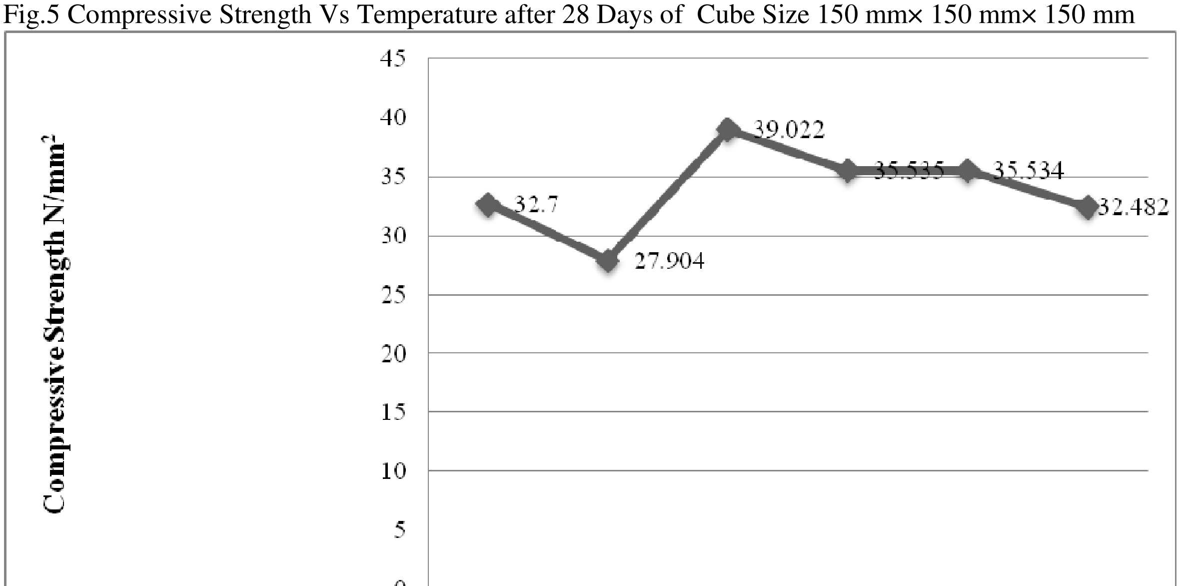


Fig.4 Compressive Strength Vs Temperature after 14 Days of Cube Size 150 mm× 150 mm× 150 mm



	27 °C	30 °C	33 °C	36 °C	39 °C	42 °C
150mm*150mm*150mm 28 th day	34.88	38.368	40.112	38.804	35.97	37.482

Fig.5 Compressive Strength Vs Temperature after 28 Days of Cube Size 150 mm× 150 mm× 150 mm



	27 °C	30 °C	33 °C	36 °C	39 °C	42 °C
150mm*150mm*125mm 28 th day	32.7	27.904	39.022	35.535	35.534	32.482

Fig.6 Compressive Strength Vs Temperature after 28 Days of Specimen Size 150 mm×150 mm× 125 mm

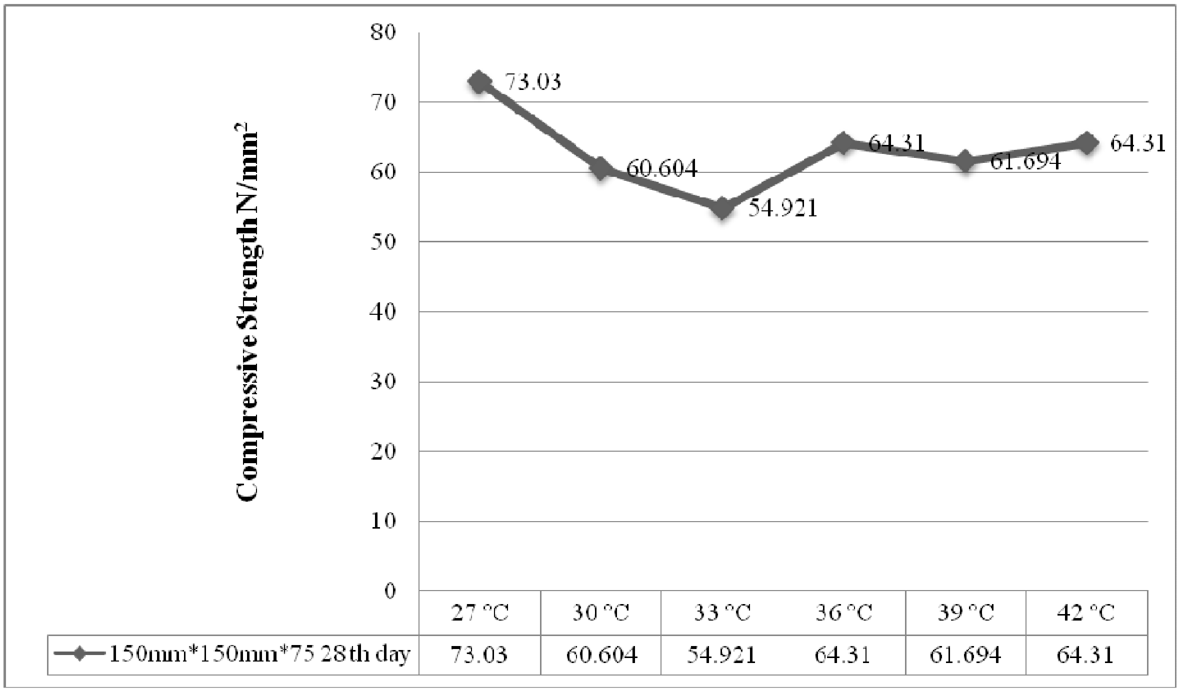


Fig.7 Compressive Strength Vs Temperature after 28 Days of Specimen Size 150 mm× 150 mm× 75 mm

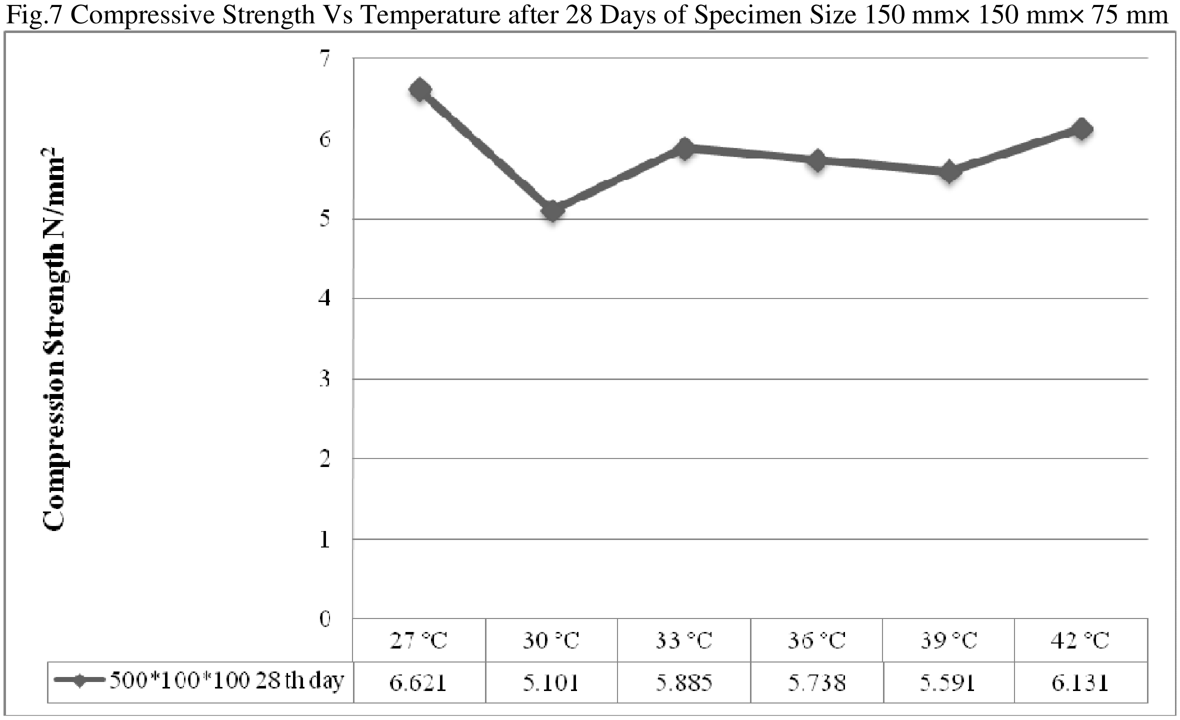


Fig.8 Flexural Strength Vs Temperature after 28 Days of Beam Specimen Size 500 mm×100 mm×100 mm

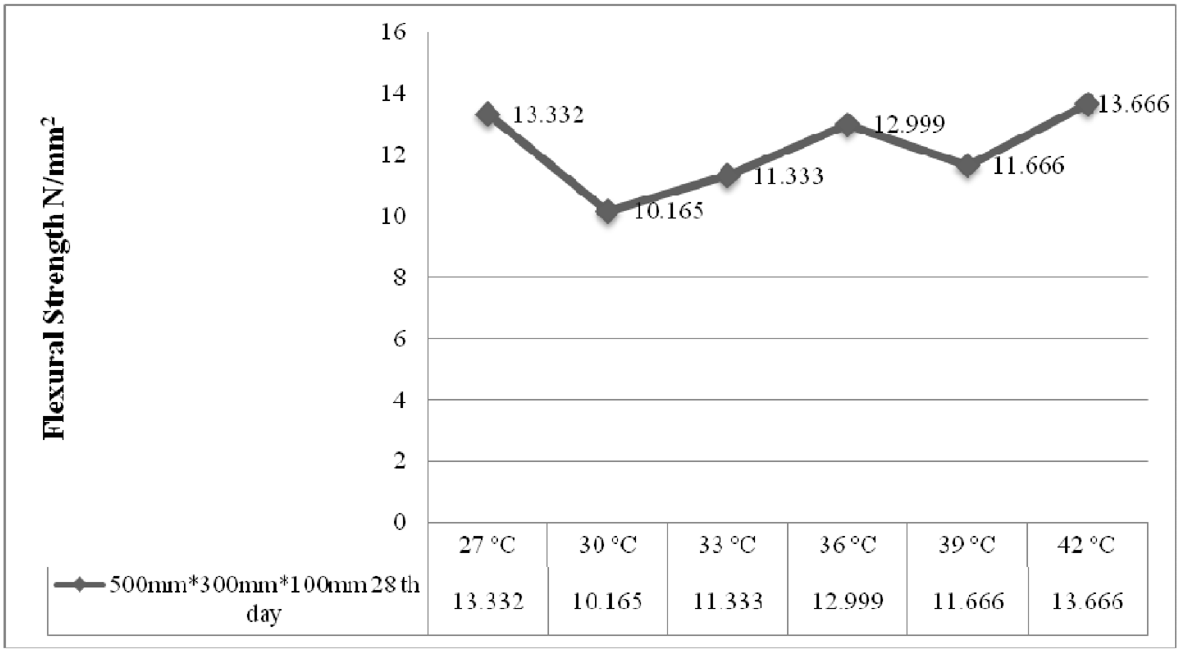


Fig.9 Flexural Strength Vs Temperature after 28 Days of Slab Specimen Size 500 mm× 300 mm× 100 mm

Discussion on Test Results

Effect of Temperature on 7 Days Compressive Strength

- As temperature increases compressive strength decreases, for all 150 mm, 125 mm, 75mm deep specimens.
- Rate of decrease in strength of 125 mm deep specimen is greater than that of 150 mm and 75 mm deep specimen.

Effect of Temperature on 14 Days Compressive Strength

- As temperature increases compressive strength of 150 mm deep specimen decreases.

Effect of Temperature on 28 Days Compressive Strength

- In case of 150 mm deep specimen compressive strength increases with increase in temperature up to 33 °C temperature. For temperature above 33 °C specimen shows less compressive strength than 33°C.
- In case of 125 mm deep specimen compressive strength increases with increase in temperature up to 33 °C, after which it decreases for higher temperature in uniform manner.
- For 75 mm deep specimen compressive strength results are opposite to results of 150 mm and 125 mm deep specimens . In this case compressive strength gets reduced up to 33°C temperature and for further increase in temperature it goes on increasing.

Effect of Temperature on 28 Days Flexural Strength

- Result of flexural strength does not show much variation for beam and slab specimens.
- Hence it is difficult to make any specific conclusion from obtained flexural strength results.

Effect of Change in Depth on Compressive Strength

- Results of 28 days compressive strength of 125 mm deep specimen are lesser than 150 mm and 75 mm deep specimen.
- Compressive strength of 75mm deep specimen is much higher than 150mm and 125 mm deep specimen.
- Compressive strength of 150 mm deep specimen is moderate and which shows very small variation with results obtained for 125 mm deep specimen.
- From obtained results it is difficult to conclude the effect of increasing temperature on varying depth of specimen.

CONCLUSION

- Workability (slump) of concrete decreases with increase in temperature. Slump was noted as 93 mm for 27 °C which get reduced up to 0 mm for 39 °C and 42°Ctempareture.
- Temperature (varying from 27 °C to 42°C) does not show much variation on flexural strength.
- 28 days compressive strength of 150 mm× 150 mm× 150 mm and 150 mm× 150 mm× 125 mm specimen increases up to 33 °C and reduced for further higher temperature while same was decrease up to 33 °C and increased for further temperature in case of 150 mm× 150 mm× 75 mm specimen.
- Effect of increase in temperature on flexural strength is small as compared to effect of temperature on compressive strength.
- From observed results it is not possible to make any specific conclusion about effect of temperature on specimen with varying depths.
- Proper curing decreases the effect of temperature (above 27 °C) during mixing of concrete, placing of concrete and 8 hours curing after placing of concrete.

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