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# Flexural Behaviour of Concrete Beams with M-Sand Subjected to Elevated Temperature

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**Abstract:**

The global consumption of manufactured sand as an alternative for natural sand is used extensively, due to the high demand and scarcity of natural sand. In this regard, to understand the flexural behaviour of concrete specimens with M-sand subjected to elevated temperature is studied experimentally. A total 95 specimens are casted and are subjected for various elevated temperature (100$^0$C -600$^0$C) for different duration of exposure time (1hr, 2hr and 3hr) and these specimens are tested for flexural strength by two point loading. The results so obtained are compared with the flexural strength of specimens at room temperature. Results show that the flexural strength gradually decreases as the exposure temperature and duration increases. Fire represents one of the most severe exposure conditions in structures. Hence provisions for appropriate fire resistance for structural members are major safety requirements for any building design. Manufactured sand offers viable alternative to natural sand but it has to satisfy the strength requirements when concrete is subjected to elevated temperature .On this aspect research on concrete with manufactured sand is scarce, so this project aims at studying the flexural behavior of concrete using M-sand as a replacement for natural sand subjected to elevated temperatures

**Keywords***:* M-Sand, elevated temperature, Flexural strength, Two point loading.

## Introduction:

Concrete is a widely used material in the world. More than ten billion tonnes of concrete are consumed annually. Based on global usage it is placed at second position after water. Conventional concrete, a versatile material is a mixture of cement, sand, aggregate and water. Aggregate content is a factor, which has direct and far-reaching effects on the quality of concrete. Unlike water and cement, which do not alter any particular characteristic except in the quantity in which they are used, the aggregate component is infinitely variable in terms of shape and grading. High quality aggregate, both coarse and fine for concrete, is of extreme importance. Aggregates occupy 65 to 80% of the total volume of concrete and affect the fresh and hardened properties of concrete. Out of the total composition of concrete, the fine aggregate consumes around 20 to 30% of the volume. The term sand as used in the building and construction industry is synonymous with fine aggregate, which is the material with a particle size less than 4.75mm. The particle size distribution of the sand determines its particular use such as roofing tile sand, plaster sand, concrete fine sand, concrete coarse sand, masonry sand, fill sand, grout sand, bedding sand, filter sand and so on. Sand is used all over the world in the construction industry and is an essential raw material for providing infrastructure and shelter. The primary use of sand is in the manufacture of concrete and concrete products such as ready mixed concrete, masonry products, poles, stumps, manholes, pipes, panels, beams, walls, roof tiles and a diverse range of other products. The river beds are the main sources for the natural sand. These natural resources are being depleted very fast, due to over exploitation and contamination by chemicals and waste from nearby industries. This causes scarcity of natural sand. The natural sand is transported from available places to the construction sites. Transporting river sand to the construction sites increases its sale price significantly.

## Drawbacks of Using Natural River Sand

Natural Sand is deficient in many aspects when used directly for concrete production, due to some of the listed factors:

From the environmental point of view:

- Extraction of the sand from river bed in excess quantity is hazardous to the environment
- It is a common sight that well foundations of the bridges are exposed considerably, due to excessive extraction of sand around the sub structure endangering the sub structure of the bridges.
- Excessive mining of the sand from river beds reduces the water head. This is due to the less percolation of rainwater in the ground.
- The absence of sand in river bed results in more water being evaporated due to direct sunlight.
- The sand shortfall in river beds will affect the water filtration.

The arguments are mostly in regard to protecting river beds against the erosion and the importance of having natural sand as a filter for ground water. For these reasons, periodic restrictions are being introduced by governmental authorities against the collection of river sand.

## LITERATURE REVIEW

**Patagundi and Patil (2002) [13]** They have conducted experiments to investigate the properties of concrete when cement was partially replaced by fly ash and natural sand by crusher stone powder simultaneously. The compressive strength and flexural strength were studied. The behaviour of concrete when subjected to heat cycles was also studied. The replacement of sand was from 0- 40% at increments of 10%. Using OPC the design mix 1: 1.2: 2.4 was prepared with water cement ratio 0.30. To facilitate the flow of concrete a super plasticizer was used. In temperature resistance test, the concrete cube specimen were subjected to heat cycles say 8 hours of heating at 60°C followed by 16 hours of cooling at 25°C. Two heat cycles say 15 day cycle and 30 day cycle were adopted. From test results it was observed that 28 day compressive strength was maximum at 30% sand replacement and this was due to the fact that crusher powder fills up the maximum voids to get dense concrete and fly ash liberates strength during later periods. Similarly flexural strength was also maximum at 30% replacement itself. Due to heat cycle there will be some loss in compressive strength as well as flexural strength. The maximum resistance to heat was developed at 30% sand replacement. From the above test results it was concluded that quarry dust and fly ash may be used as replacement materials in concrete. **Sahu et al (2003) [15]** In this paper they have investigated the suitability of using crushed stone dust waste as fine aggregate for concrete. Two design mixes were chosen for natural sand to achieve M20 and M30 grades concrete using OPC with percentage of replacement 0, 20 and 40. The equivalent mixes replaced natural sand by stone dust partially and fully. A super plasticizer was added with dosages 0.5, 1, 2 and 3 % by weight of cement. Tests were conducted on workability, compressive strength, modulus of rupture and split tensile strength. From the test results he observed that the addition of stone dust decreases workability, the workability can be increased by adding super plasticizer and there will be a significant increase in compressive strength, tensile strength and modulus of rupture. He concluded that 40% sand replaced by stone dust in concrete reduce the cost and save a large quantity of natural sand and so, stone dust can be used effectively to replace natural sand in concrete

## OBJECTIVE OF THE PRESENT STUDY

The objective of the present investigation is to study the effect of elevated temperatures on the concrete by complete replacement of natural sand with M-sand. Concrete mix was prepared by replacing natural sand with M-sand completely to cast beams of size 500 x 100 x 100 mm. Beams were subjected to varying elevated temperatures for different duration of exposure.

The present investigation is carried out with the following objective;

1. To study the influence of M-Sand on the flexural strength of concrete subjected to different sustained elevated temperature.
2. Also to study the variation of flexural strength of concrete specimen with M-Sand subjected to elevated temperature for different duration of exposure.

## EXPERIMENTAL PROGRAM

### Methodology

The main objective of the research program was to understand the mechanical properties, especially flexural strength of concrete obtained using M-sand as replacement for natural sand. In order to achieve the objectives of present study, an experimental program was planned to investigate the effect of M-sand on flexural strength of concrete. The experimental program consists of testing of aggregates, mix design casting, curing and testing of controlled and replaced fine aggregate concrete specimens at the age of 28 days.

The experimental program included the following:
To determine the properties of materials used for making concrete.
Design mix (M30).
Casting of beam specimens.
Curing of specimens.
Specimens kept at elevated temperature
To determine the flexural strength.

### Mix Design

The concrete mix design is done by systematic analysis and knowledge to choose and proportion the ingredient used in a concrete mix produce economical concrete which will have the desired properties both when fresh and when hardened. The variables which can be controlled are water cement ratio, maximum aggregate size, aggregate grading, and use of admixtures. Interactions between the effects of variables complicate mix design and successive adjustments following trial mixes are usually necessary. Experiences built up by ready mix concrete producers should enable them to produce suitable mix design more quicker.

The mix design is carried out as per IS 10262-2009 for $M_{30}$ grade of concrete

#### Design stipulations for proportioning:

| | |
|---|---|
| Grade designation | - M30 |
| Type of cement | - OPC 53 Grade confirming to IS 8112 |
| Maximum nominal size of aggregates | - 20mm |
| Minimum cement content | - 300kg/m$^3$ |
| Maximum water content | - 0.55 |
| Workability | - 100mm(slump) |
| Exposure condition | - Mild |
| Degree of super vision | - Good |
| Type of aggregates | - Crushed angular aggregates |

### Test Data of Material

Cement used - OPC 53 Grade confirming to IS 8112
Specific gravity of cement - 3.1
Specific gravity of
Coarse aggregate - 2.634
Fine aggregate - 2.54
Water absorption:
Coarse aggregate - .81 (%)
Fine aggregate -1.63(%)

### Target strength for mix proportioning

$f'_{ck} = f_{ck}+1.65S$
where,
$f'_{ck}$ = Target average compressive strength at 28 days.
$f_{ck}$ = characteristic compressive strength at 28 days.
S= Standard deviation.
From Table 1 of IS:456- 2000 standard deviation , S=5N/ $mm^2$
Therefore target strength $f^1_{ck}$ = 30+1.65*5 = **38.25 N/mm²**

### Selection of water-cement ratio

From table 5 of IS-456-2000 for Mild exposure condition, maximum water-cement ratio= 0.55

Let us adopt an water-cement ratio of 0.53

0.53 < 0.55 Hence ok

### Selection of water content

From table 2 of IS-10262-2009 for 20mm nominal max size aggregate;
Maximum water content = 186litrs (for 25-50mm slump)
Estimation of water content for 100mm slump = 186+(6/100)*186
= 197.16litres
Based on trails with super plasticizers water content of 10 percent has been achieved. Hence the arrived water content = 197.16×.9 = 177.44litres

### Calcution of cement content

Water-Cement ratio= 0.53
Cement = (water/0.53) = (177.44/.53)= 334.79 Kg/$m^3$
Based on experience reduce the Cement from 334.79 Kg/$m^3$ to 330Kg/$m^3$

330Kg/m³ > 300Kg/m³ Hence OK
Therefore, Water content =W = .53×330=174.9liters

### Mix design calculation

a. Volume of Concrete = 1m³
b. Volume of Cement = ((mass of cement)/(sp.gravity ofcement))*(1/1000)
= (330/3.1)*(1/1000)
= 0.106
c. Volume of water = (175/1)*(1/1000) = .175m³
d. Volume of All in Aggregate = a-(b+c)
= 1-(0.106+0.175)
= 0.719
e. Mass of coarse aggregate = d×volume of CA×sp.gr of CA×1000
= 1167.23 Kg/m³
f. Mass of fine aggregate = d×volume of FA×sp.gr of FA×1000
=704.93 Kg/m³

### Mix proportion for control concrete

| | |
|---|---|
| Cement | 330Kg/m3 |
| Water | 174.9litrs/m³ |
| Fine aggregate | 704.93Kg/m³ |
| Coarse aggregate | 1167.23Kg/m³ |
| Super plasticizers | 1.35 litres/m³ |

### Experimental study

### Beam Specimens

Beams of dimension (100x100x500) mm are prepared for testing flexural strength of concrete. The regulations of IS:516-1959 are followed. Five number of specimens were prepared to test for each temperature and duration of exposure. So totally 95 beams are prepared for testing flexural strength. .

**Table 1 – Details of number of beam specimens for flexural strength**

| *Sl no* | *Duration* | *Temperature (º C)* | *No of beams* |
|---|---|---|---|
| 1 | - | Room Temperature | 5 |
| 2 | 1 hr | $100^0$ | 5 |
| 3 | | $200^0$ | 5 |
| 4 | | $300^0$ | 5 |
| 5 | | $400^0$ | 5 |
| 6 | | $500^0$ | 5 |
| 7 | | $600^0$ | 5 |
| 8 | 2 hrs | $100^0$ | 5 |
| 9 | | $200^0$ | 5 |
| 10 | | $300^0$ | 5 |
| 11 | | $400^0$ | 5 |
| 12 | | $500^0$ | 5 |
| 13 | | $600^0$ | 5 |
| 14 | 3 hrs | $100^0$ | 5 |
| 15 | | $200^0$ | 5 |
| 16 | | $300^0$ | 5 |
| 17 | | $400^0$ | 5 |
| 18 | | $500^0$ | 5 |
| 19 | | $600^0$ | 5 |
| | | ***Total number of beams =*** | ***95*** |

## Details of Electric Oven

The oven is installed below the ground with top sliding cover at ground level. Electric sensors are provided inside the oven to measure the temperature. The temperature is controlled through the control panel in which required magnitude of temperature can be set and for the required time. The dimension of the heating chamber is 2.1m×1.1m×1m. This chamber is heated through an electric coil, and can attain a maximum temperature of 1000ºC.

The specimens were placed equidistant from each other so that all the faces of the sample could be exposed to heat. After attaining the required temperature, the same is maintained constantly for a period of 1hr, 2hrs and 3 hrs.

After exposure of the specimens to the required temperature and duration, the heating was stopped and was allowed to cool by opening the top slide cover. The specimens were taken out stacked for further testing.

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**Figure 1 Electric furnace**

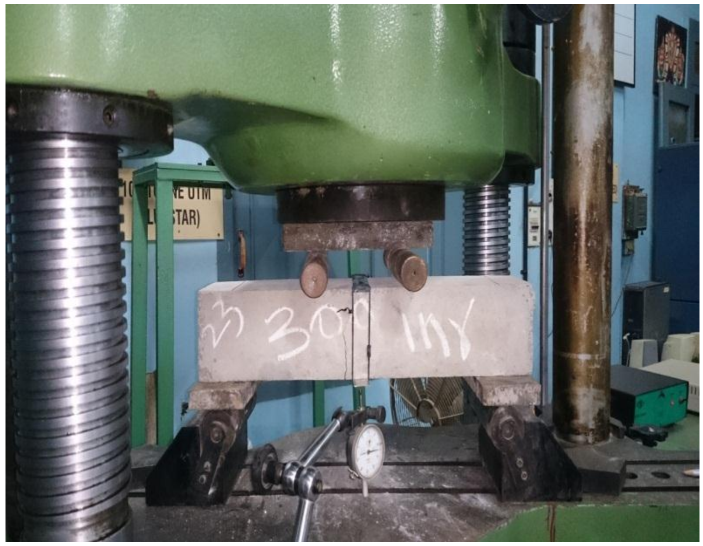

**Figure 2 Experimental setup for flexural strength test**

## Testing of specimens

### Flexural strength test

Tests were carried out to find the effect of elevated temperatures on the residual flexural strength. The flexural strength of beams exposed to elevated temperature is tested after 28 days of curing.

Concrete beams, 0.5m×0.1m×0.1m in size were tested for residual strength as per IS 516-1959. The beams were centrally placed in the testing machine of capacity 100 tones and load was applied gradually and uniformly without shock. At suitable load intervals deformation was noted using strain gauge. The load was applied until the specimen failed and maximum load carried by each specimen during the test was recorded. From the failure load, the residual strength of each specimen is calculated. Along with the flexural strength test, deformation in concrete beams was obtained by using Dial Gauge.

## Results and Discussions

**Table 2- Flexural strength of beams at room temperature**

| Temperature | Duration | Specimen number | Initial wt before fire (kg) | Final wt after fire (Kg) | Flexural strength | | |
|---|---|---|---|---|---|---|---|
| | | | | | Load (KN) | Flexural strength (MPa) | Average (MPa) |
| Room temperature | 0 | 1 | 12.540 | 12.540 | 26.10 | 10.440 | 10.250 |
| | | 2 | 12.330 | 12.330 | 24.10 | 9.640 | |
| | | 3 | 12.230 | 12.230 | 25.50 | 10.200 | |
| | | 4 | 12.460 | 12.460 | 26.25 | 10.500 | |
| | | 5 | 12.450 | 12.450 | 26.20 | 10.480 | |

**Table 3- Flexural strength of beams subjected to 100$^0$C**

| Duration | Specimen number | Initial wt before fire (kg) | Final wt after fire (Kg) | Loss of weight (kg) | Flexural strength | | |
|---|---|---|---|---|---|---|---|
| | | | | | Load (KN) | Flexural strength (MPa) | Average (MPa) |
| 1 hr | 1 | 12.375 | 12.370 | 0.005 | 26.0 | 10.400 | 10.534 |
| | 2 | 12.600 | 12.580 | 0.020 | 26.50 | 10.600 | |
| | 3 | 12.650 | 12.600 | 0.050 | 25.98 | 10.392 | |
| | 4 | 12.550 | 12.500 | 0.050 | 26.80 | 10.720 | |
| | 5 | 12.500 | 12.440 | 0.060 | 26.40 | 10.560 | |
| 2 hrs | 1 | 12.530 | 12.500 | 0.030 | 29.65 | 11.860 | 10.696 |
| | 2 | 12.450 | 12.390 | 0.060 | 25.75 | 10.300 | |
| | 3 | 12.450 | 12.380 | 0.070 | 26.10 | 10.440 | |
| | 4 | 12.560 | 12.490 | 0.070 | 26.30 | 10.520 | |
| | 5 | 12.520 | 12.450 | 0.070 | 25.90 | 10.360 | |
| 3 hrs | 1 | 12.170 | 12.110 | 0.060 | 24.05 | 9.620 | 9.640 |
| | 2 | 12.150 | 12.080 | 0.070 | 23.90 | 9.560 | |
| | 3 | 12.330 | 12.270 | 0.060 | 24.10 | 9.640 | |
| | 4 | 12.480 | 12.410 | 0.070 | 23.05 | 9.220 | |
| | 5 | 12.600 | 12.510 | 0.090 | 25.40 | 10.160 | |

## Table 1 - Flexural strength of beams subjected to 200$^0$C

| *Duration* | *Specimen number* | *Initial wt before fire (kg)* | *Final wt after fire (Kg)* | *Loss of weight (kg)* | *Flexural strength* | | |
|---|---|---|---|---|---|---|---|
| | | | | | *Load (KN)* | *Flexural strength (MPa)* | *Average (MPa)* |
| 1 hr | 1 | 12.530 | 12.470 | 0.060 | 24.70 | 9.880 | 9.312 |
| | 2 | 12.450 | 12.390 | 0.060 | 24.05 | 9.620 | |
| | 3 | 12.320 | 12.250 | 0.070 | 19.35 | 7.740 | |
| | 4 | 12.600 | 12.500 | 0.100 | 24.20 | 9.680 | |
| | 5 | 12.400 | 12.320 | 0.080 | 24.10 | 9.640 | |
| 2 hrs | 1 | 12.540 | 12.470 | 0.070 | 23.50 | 9.400 | 9.728 |
| | 2 | 11.960 | 11.930 | 0.030 | 25.30 | 10.120 | |
| | 3 | 12.590 | 12.550 | 0.040 | 24.80 | 9.920 | |
| | 4 | 12.210 | 12.160 | 0.050 | 24.10 | 9.640 | |
| | 5 | 12.450 | 12.400 | 0.050 | 23.90 | 9.560 | |
| 3 hrs | 1 | 12.400 | 12.120 | 0.280 | 22.10 | 8.840 | 8.926 |
| | 2 | 12.430 | 12.160 | 0.270 | 22.55 | 9.020 | |
| | 3 | 12.210 | 11.940 | 0.270 | 22.40 | 8.960 | |
| | 4 | 12.450 | 12.180 | 0.270 | 22.30 | 8.920 | |
| | 5 | 12.240 | 11.980 | 0.260 | 22.22 | 8.888 | |

## Table 2 - Flexural strength of beams subjected to 300$^0$C

| *Duration* | *Specimen number* | *Initial wt before fire (kg)* | *Final wt after fire (Kg)* | *Loss of weight (kg)* | *Flexural strength* | | |
|---|---|---|---|---|---|---|---|
| | | | | | *Load (KN)* | *Flexural strength (MPa)* | *Average (MPa)* |
| 1 hr | 1 | 12.320 | 12.220 | 0.100 | 24.65 | 9.86 | 9.840 |
| | 2 | 12.380 | 12.270 | 0.110 | 25.00 | 10..000 | |
| | 3 | 12.490 | 12.370 | 0.120 | 24.70 | 9.880 | |
| | 4 | 12.660 | 12.520 | 0.140 | 24.35 | 9.740 | |
| | 5 | 12.560 | 12.500 | 0.060 | 24.30 | 9.720 | |
| 2 hrs | 1 | 12.300 | 12.170 | 0.130 | 21.70 | 8.680 | 8.768 |
| | 2 | 12.320 | 12.080 | 0.240 | 22.00 | 8.800 | |
| | 3 | 12.330 | 12.180 | 0.150 | 21.80 | 8.720 | |
| | 4 | 12.480 | 12.300 | 0.180 | 22.20 | 8.880 | |
| | 5 | 12.520 | 12.320 | 0.200 | 21.90 | 8.760 | |
| 3 hrs | 1 | 12.430 | 11.940 | 0.490 | 22.80 | 9.120 | 9.140 |
| | 2 | 12.380 | 12.120 | 0.260 | 23.55 | 9.420 | |
| | 3 | 12.420 | 11.960 | 0.460 | 22.85 | 9.140 | |
| | 4 | 12.340 | 12.080 | 0.260 | 22.45 | 8.980 | |
| | 5 | 12.540 | 12.180 | 0.360 | 22.60 | 9.040 | |

**Table 3 - Flexural strength of beams subjected to 400$^0$C**

| Duraton | Specimen number | Initial wt before fire (kg) | Final wt after fire (Kg) | Loss of weight (kg) | Flexural strength | | |
|---|---|---|---|---|---|---|---|
| | | | | | Load (KN) | Flexural strength (MPa) | Average (MPa) |
| 1 hr | 1 | 12.330 | 12.300 | 0.030 | 23.50 | 9.400 | 9.528 |
| | 2 | 12.600 | 12.310 | 0.290 | 24.00 | 9.600 | |
| | 3 | 12.310 | 12.000 | 0.310 | 23.60 | 9.440 | |
| | 4 | 12.240 | 11.950 | 0.290 | 24.10 | 9.640 | |
| | 5 | 12.480 | 12.400 | 0.080 | 23.90 | 9.560 | |
| 2 hrs | 1 | 12.450 | 12.030 | 0.420 | 22.60 | 9.040 | 9.196 |
| | 2 | 12.600 | 12.120 | 0.480 | 22.80 | 9.120 | |
| | 3 | 12.500 | 12.070 | 0.430 | 22.50 | 9.000 | |
| | 4 | 12.330 | 11.910 | 0.420 | 22.90 | 9.160 | |
| | 5 | 12.400 | 11.990 | 0.410 | 24.15 | 9.660 | |
| 3 hrs | 1 | 12.520 | 11.930 | 0.590 | 18.05 | 7.220 | 7.227 |
| | 2 | 12.140 | 11.530 | 0.610 | 18.10 | 7.240 | |
| | 3 | 12.500 | 11.900 | 0.600 | 17.89 | 7.156 | |
| | 4 | 12.460 | 11.840 | 0.620 | 18.30 | 7.320 | |
| | 5 | 12.230 | 11.640 | 0.590 | 18.00 | 7.200 | |

**Table 4 - Flexural strength of beams subjected to 500$^0$C**

| ***Duration*** | ***Specimen number*** | ***Initial wt before fire (kg)*** | ***Final wt after fire (Kg)*** | ***Loss of weight (kg)*** | ***Flexural strength*** | | |
|---|---|---|---|---|---|---|---|
| | | | | | ***Load (KN)*** | ***Flexural strength (MPa)*** | ***Average (MPa)*** |
| 1 hr | 1 | 12.520 | 12.130 | 0.390 | 20.10 | 8.040 | 7.956 |
| | 2 | 12.400 | 12.010 | 0.390 | 19.80 | 7.920 | |
| | 3 | 12.120 | 11.720 | 0.40 | 19.70 | 7.880 | |
| | 4 | 12.360 | 11.950 | 0.410 | 19.85 | 7.940 | |
| | 5 | 12.450 | 12.000 | 0.450 | 20.00 | 8.000 | |
| 2 hrs | 1 | 12.160 | 11.650 | 0.510 | 18.35 | 7.340 | 7.248 |
| | 2 | 12.200 | 11.630 | 0.570 | 17.90 | 7.160 | |
| | 3 | 12.340 | 11.870 | 0.470 | 18.20 | 7.280 | |
| | 4 | 12.550 | 12.000 | 0.550 | 18.15 | 7.260 | |
| | 5 | 12.420 | 11.920 | 0.500 | 18.00 | 7.20 | |
| 3 hrs | 1 | 12.630 | 12.020 | 0.610 | 17.60 | 7.040 | 7.012 |
| | 2 | 12.420 | 11.730 | 0.690 | 17.15 | 6.860 | |
| | 3 | 12.510 | 11.8250 | 0.685 | 17.80 | 7.120 | |
| | 4 | 12.550 | 11.850 | 0.70 | 17.40 | 6.960 | |
| | 5 | 12.33 | 11.68 | 0.650 | 17.70 | 7.080 | |

**Table 5 - Flexural strength of beams subjected to 600$^0$C**

| *Duration* | *Specimen number* | *Initial wt before fire (kg)* | *Final wt after fire (Kg)* | *Loss of weight (kg)* | *Flexural strength* | | |
|---|---|---|---|---|---|---|---|
| | | | | | *Load (KN)* | *Flexural strength (MPa)* | *Average (MPa)* |
| 1 hr | 1 | 12.310 | 11.910 | 0.400 | 19.12 | 7.648 | 7.7072 |
| | 2 | 12.600 | 12.230 | 0.370 | 19.50 | 7.800 | |
| | 3 | 12.180 | 11.760 | 0.420 | 19.10 | 7.640 | |
| | 4 | 12.350 | 11.940 | 0.410 | 19.30 | 7.720 | |
| | 5 | 12.550 | 12.120 | 0.430 | 19.32 | 7.728 | |
| 2 hrs | 1 | 12.220 | 11.700 | 0.520 | 18.45 | 7.380 | 7.452 |
| | 2 | 12.000 | 11.510 | 0.490 | 18.65 | 7.460 | |
| | 3 | 12.310 | 11.710 | 0.600 | 18.80 | 7.520 | |
| | 4 | 12.400 | 11.850 | 0.550 | 18.55 | 7.420 | |
| | 5 | 12.500 | 12.220 | 0.280 | 18.70 | 7.480 | |
| 3 hrs | 1 | 12.160 | 11.410 | 0.750 | 16.10 | 6.440 | 6.469 |
| | 2 | 12.320 | 11.610 | 0.710 | 16.15 | 6.460 | |
| | 3 | 12.400 | 11.700 | 0.700 | 16.55 | 6.620 | |
| | 4 | 12.360 | 11.670 | 0.690 | 16.02 | 6.408 | |
| | 5 | 12.600 | 11.950 | 0.650 | 16.04 | 6.416 | |

**Table 9- Variation of Flexural strength for various temperature and duration of exposure**

| *Temperature* | *Flexural Strength for various duration of exposure (MPa)* | | |
|---|---|---|---|
| | *1 hr* | *2 hr* | *3 hr* |
| *100$^0$C* | 10.534 | 10.696 | 9.640 |
| *200$^0$C* | 9.312 | 9.728 | 8.926 |
| *300$^0$C* | 9.84 | 8.768 | 9.140 |
| *400$^0$C* | 9.528 | 9.196 | 7.227 |
| *500$^0$C* | 7.956 | 7.248 | 7.012 |
| *600$^0$C* | 7.707 | 7.452 | 6.469 |

### Variation of flexural strength at sustained elevated temperature for 1 hr duration

The results of flexural strength testing of specimens subjected to elevated temperature for 1hr duration is as shown in Table 9 and Fig 3 shows the variation of flexural strength of specimens.

From the fig 3, it is seen that for a temperature of 100$^0$C the flexural strength increased considerably. There after there is a decrease in flexural strength with increase in temperature as compared to strength at 100$^0$C . The increase in flexural strength at 100$^0$C is found to be 2.75% of the flexural strength at room temperature, whereas the decrease in flexural strength at 200$^0$C, 300$^0$C, 400$^0$C, 500$^0$C, and 600$^0$C is 9.17%, 4.02%, 7.06%, 22.39% and 24.82% respectively compared to that of room temperature.

### Variation of flexural strength at sustained elevated temperature for 2 hr duration

The results of flexural strength testing of specimens subjected to elevated temperature for 2hr duration is as shown in Table 9 and Fig 3 shows the variation of flexural strength of specimens.

From the fig 3, it is conspicuous that for a temperature of 100$^0$C the flexural strength increased considerably. There after there is a constant decrease in flexural strength with increase in temperature. The increase in flexural strength at 100$^0$C is found to be 4.33% of the flexural strength at room temperature, whereas the decrease in flexural strength at 200$^0$C, 300$^0$C, 400$^0$C, 500$^0$C, and 600$^0$C is 5.11%, 14.47%, 10.30%, 29.30% and 27.31% respectively compared to that of room temperature.

### Variation of flexural strength at sustained elevated temperature for 3 hrs duration

The results of flexural strength testing of specimens subjected to elevated temperature for 3hr duration is as shown in Table 9 and Fig 3 shows the variation of flexural strength of specimens.

From fig 3, shown below, it is evident that there is a constant decrease in flexural strength with increasing temperature. Even for the temperature of 100$^0$C there is decrease in flexural strength compared to room temperature. The decrease in flexural strength at 100$^0$C, 200$^0$C, 300$^0$C, 400$^0$C, 500$^0$C, and 600$^0$C is 5.96%, 12.93%, 10.85%, 29.50%, 31.60% and 36.90% respectively compared to the flexural strength at room temperature.

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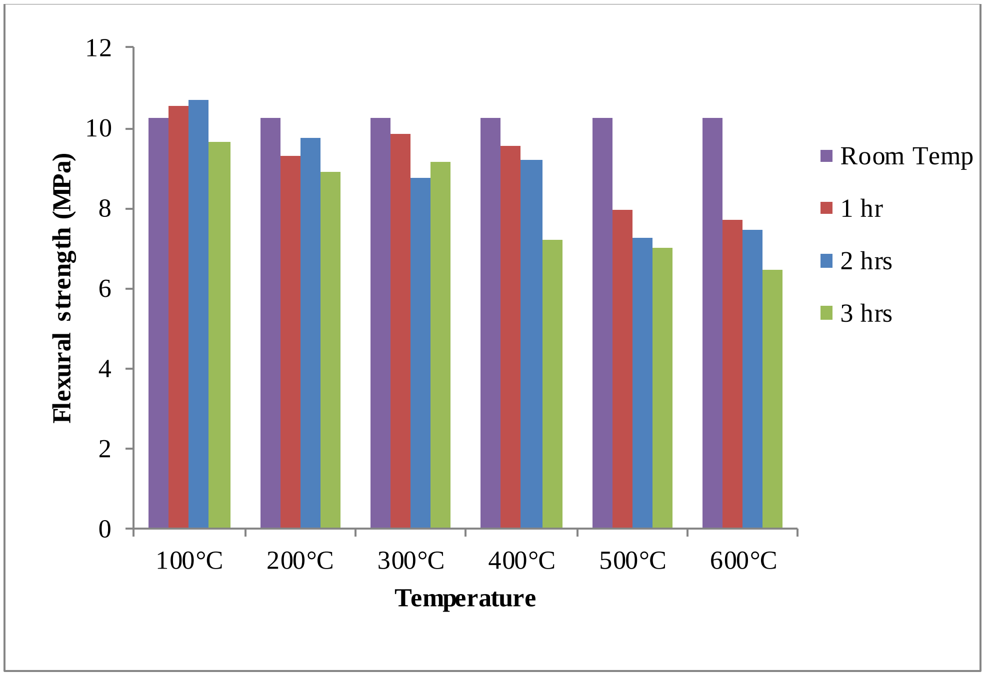


**Fig 3- Variation of flexural strength at different duration of exposure**

## CONCLUSIONS

From the present experimental investigation the following conclusion can be drawn.

1. Natural sand can be successfully replaced with M-Sand without affecting the basic properties of concrete and its flexural behavior under fire is also found satisfactory.
2. From the visual observation, it can be concluded that no cracks were developed in the concrete specimen subjected to sustained elevated temperature upto 400°C. The blackish color has been developed in the concrete specimens at 400$^0$C sustained temperature. Whereas the specimens that were subjected to 500°C to 600°C sustained temperature showed surface cracks and also the colour turned to milky white.
3. The flexural strength of concrete specimens found to be increasing till 100$^0$C thereafter as the temperature increases i.e. beyond 100$^0$C, the strength goes on decreasing for all the cases of duration of exposure
4. The concrete specimens show maximum flexural strength at 100$^0$C for a duration of 1hr, when compared to other temperatures. The flexural strength of the specimens goes on decreases as the temperature increases and also with the duration.
5. For all sustained temperature level, it shows slight variation in flexural strength of M-Sand when compared with beams flexural strength tested at room temperature.
6. The flexural strength of concrete goes on decreasing as the temperature increases mean

while there is a slight increase in flexural strength of concrete for 100$^0$C for 1hr and the remaining cases the strength decreases i.e. for 2hrs and 3hrs when a comparison is made between the sustained elevated temperatures and the room temperature.

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