**CHAPTER 4**

**RESULTS AND DISCUSSIONS**

**4.1. Introduction**

Series of tests were conducted on the SIFCON specimens made with 8%, 10% and 12% fibre volume fraction using manufacture sand as alternate to normal regular sand to study the performance of SIFCON before and after heating specimens to elevated temperature ranging from 100°C to 400°C for 1hr, 2hr and 3 hrs durations for the application in civil engineering field. The stress-strain relationships are also studied to assess the behaviour of SIFCON specimens under the compression of the SIFCON. In all the cases the mix proportion of the SIFCON is uniform.

**4.2 Experimental Results and Discussions**

The results of the experimental tests for determining the strength properties of SIFCON made with manufactured sand are discussed in the following sections.

**4.2.1 Compressive Strength of SIFCON**

The Compressive Strengths of the SIFCON were determined by crushing three cubes of size 150x150x150 mm size at the age of 7, 14 and 28 days of curing for each mix. The results of average of the three cube for 7-days, 28-days and 56-days compressive strength of SIFCON for different percentage of fibre fraction before heat are presented in the Table 4.1. The variation of the compressive strength with the age of curing is presented in Fig. 4.1. While, Fig. 4.2 represents the variation of compressive strength of all SIFCON mixes with amount of percentage fibre volume fraction.

Table 4.1 Values of Compressive strength of SIFCON for different fibre volume fractions before heat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.No.** | **Specimens** | **Compressive Strength (MPa)** | | |
| **7 days** | **28 days** | **56 days** |
| 1 | SIFCON8 | 29.30 | 35.71 | 43.70 |
| 2 | SIFCON10 | 35.19 | 42.54 | 47.11 |
| 3 | SIFCON12 | 43.85 | 46.15 | 53.63 |



Fig. 4.1 Variation of compressive strength of SIFCON for different fibre volume fractions with the age of curing



Fig. 4.2 Variation of compressive strength of SIFCON with fibre fraction

From the Table 4.1 and Figs. 4.1 & 4.2, it can be observed that increase in compressive strength of SIFCON mixes is observed at all ages as the percentage volume of fibre fraction increases. This indicated that various types of SIFCON mixes made with manufactured sand and addition of locally available binding wire contributes to higher compressive strength. Similar observation was made by earlier researchers using high tensile steel fibers and use of river sand.

The compressive strength of SIFCON with 12% of fibre fraction is very high when compared to SIFCON with 8% and 10% of fibre fraction respectively. This is due to the higher volume fraction of steel fibres in the specimen. Because the slurry strength, fibre volume, fibre alignment and fibre type greatly influence the strength of SIFCON specimens. The increase in 28 days Compressive Strength of SIFCON is 19.12% for 10% fibre fraction and 29.23% for 12% fibre fraction when compared to 8% fibre fraction. The increase in compressive strength of SIFCON mixes at lateral stage is more than the early stage.

The compressive strength of SIFCON12 is considerably higher than that of SIFCON8 and SIFCON10 mixes. A maximum increase of 49.65% is observed at 7 days age for SIFCON12 mix over SIFCON8 and SIFCON10 mixes. This result is expected because the addition of fibres enhances the load carrying capacity of the mix and the increase is also justified as per simple rule of mixtures.

From the above findings, it can be concluded that manufactured sand can be successfully used in the production of SIFCON with locally available binding wire as steel fibre to achieve high strengths.

**4.2.2 Split Tensile Strength of SIFCON**

The tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. The split tensile strengths of SIFCON concrete were determined by crushing 3 cylinders of 150mm and 300mm size at 7 days, 14 days and 28 days of curing. The results of split tensile strength of SIFCON with various percentage volume fibre fractions are represented in Table 4.2. The variation of split tensile strengths of SIFCON under study with curing period and percentage volume fibre fraction respectively in Figs. 4.3 and 4.4 below.

Table 4.2 Values of Split Tensile strength of SIFCON for different fibre volume fractions before heat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.No.** | **Specimens** | **Split Tensile Strength (MPa)** | | |
| **7 days** | **28 days** | **56 days** |
| 1 | SIFCON8 | 7.29 | 7.86 | 8.93 |
| 2 | SIFCON10 | 8.76 | 8.95 | 10.27 |
| 3 | SIFCON12 | 9.21 | 9.85 | 11.40 |

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Fig. 4.3 Variation of Split Tensile Strength of SIFCON for different percentage fibre fraction with the age of curing



Fig. 4.4 Variation of Split tensile strength of SIFCON with fibre fraction

From the Table 4.2 and Figs. 4.3 & 4.4, the average values of split tensile strength of SIFCON increases as the % of fibre volume fractions increases. The values of split tensile strengths of SIFCON at the age of 28 days are 7.86, 8.95, 9.85 MPa for 8%, 10% and 12% volume fibre fraction respectively. It can be seen from the results that there is a good amount of enhancement in the tensile strength of the SIFCON specimens with the addition of locally available steel fibre and use of manufactured sand. These results are justified as that of SIFCON made with regular sand and use of high tensile steel fibre. Thus, it can be observed that addition of fibres has significantly increased the split tensile strength. The increase in tensile strength of SIFCON is observed to be very less at early age when compared to lateral stages for 10% fibre fraction. Whereas SIFCON8 and SIFCON12 mixes shown maximum difference in strength at both stages. This showed that the SIFCON concrete are not only increased the compressive strength of concrete but also increased the values of split tensile strength.

Figs. 4.3 and 4.4 reveals that the split tensile strength of SIFCON made with locally available steel binding wire and manufactured sand exhibited similar trend with age as that of Compressive Strength of SIFCON. The improvement in the split tensile strength at later ages is mainly due to the pozzolanic reaction and micro filler effect of Steel Fibre in addition to its pozzolanic properties.

From above Table and Figures it is observed that increase in tensile strength for SIFCON is in the range of 20.16% to 26.33% for 7 days, while in the case of 28days the tensile strength is in the range of 13.86% to 25.31% and the tensile strength for 56 days is in the ranges of 15% to 27.65%.

**4.3.3 Flexural Strength of SIFCON**

The flexural strength test was conducted on prism SIFCON specimens made with 8%, 10% and 12% fibre fraction by loading them at middle third points at the age of 7, 28 and 56 days. The values of flexural strength obtained from the test for all percentage fibre fractions were presented in Table 4.3 and curves Figs. 4.5 & 4.6.

Table 4.3 Values of Flexural Strength of SIFCON before heat

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **S.No.** | **Specimens** | **Flexural Strength (MPa)** | | |
| **7 days** | **28 days** | **56 days** |
| 1 | SIFCON8 | 21.71 | 23.95 | 25.22 |
| 2 | SIFCON10 | 26.91 | 27.46 | 29.16 |
| 3 | SIFCON12 | 31.75 | 35.67 | 37.44 |

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Fig. 4.5 Variation of Flexural strength for various percentage fibre fractions with the age of curing

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Fig. 4.6 Variation of flexural strength with age of curing

Figs. 4.5 and 4.6 show the values of flexural strength of SIFCON at the age of 7, 28 and 56 days of curing. The results show an increase of flexural strength by adding the locally available binding steel wire from 8% to 12% volume fibre fraction. Using steel binding wire and manufactured sand, the flexural strength achieved are 23.95 MPa, 27.46 MPa and 35.67 MPa at 28 days for various fibre fractions respectively. The results indicate that the increase in lateral flexural strength is observed to be maximum when compared to early strength. The values of flexural strength of SIFCON are about 3 to 4 times the values of strengths of normal concrete mixes as observed from the other researchers.

An increase in flexural strength of about 14.65 percent is shown by SIFCON specimens with 10 percent fibre volume and about 48.93 percent with 12 percent fibre volume fraction over 8% volume fibre fraction. It may also be of interest that the ultimate flexural strengths obtained from the tests are in the range of 21 to 36 MPa.

The results indicate that the 14.65% increase in flexural strength is marginal at all the ages for 10% fibre fraction when compared to SIFCON with other fibre fractions.

**4.2.4 Modulus of Elasticity**

The cylinders were tested to measure modulus of elasticity of SIFCON. Test was performed using 100 ton Universal Testing Machine (UTM) in the SM Laboratory, Department of Civil Engineering, Andhra University, Visakhapatnam. Three cylinders from each SIFCON mix were used for determining the modulus of elasticity.

A standard compressometer was used to measure strain as the cylinders were loaded to determine the Modulus of Elasticity. The deformation reading was taken at a known initial load as initial reading. Following this initial reading, deformations were measured at regular intervals till SIFCON specimens fail. These measurements are used to draw stress strain curves to determine the tangent modulus of elasticity within elastic limit.

The modulus of elasticity was determined using the expression given below

Modulus of elasticity (N/mm2) = 

Table 4.4 shows the values of stress-strain of SIFCON for 8%, 10% and 12% fibre fraction. Figs. 4.7a to 4.7d show the resulted stress strain curve for the three percentage (8%, 10% and 12%) fibre fractions of the SIFCON. From Fig. 4.7a it can be concluded that, SIFCON with 12% fibre fraction specimen exhibit greater ductility, fewer cracks and less spalling of concrete compared to the other two fibre fraction SIFCON i.e. 8% and 10%. It is also clear from Fig 4.7a that the SIFCON has a good ability to restrain the compressive deformation, and the addition of steel fibres may further restrain the matrix strain.

The results indicate that the SIFCON12 specimens are stiffer than the SIFCON8 and SIFCON10 specimens, but strains at ultimate load were reduced. Figs. 4.7a to 4.7d present the influence of fibre fraction on the stress-strain relationship of a SIFCON. These data show a significant increase in ultimate strain and a loss of stiffness with increasing fibre fraction. Fig.4.7a shows SIFCON specimens made with manufactured sand are stiffer and stronger than identical companion specimens.

Table 4.4 Stress Strain Data of SIFCON (8%, 10% and 12%) fibre fraction

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **S.No.** | **Stress-Strain Data** | | | | | |
| **8%** | | **10%** | | **12%** | |
| **Stress (MPa)** | **Strain** | **Stress (MPa)** | **Strain** | **Stress (MPa)** | **strain** |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 6.79 | 3.33×10-4 | 6.79 | 3.33×10-4 | 7.09 | 3.33×10-4 |
| 3 | 11.88 | 6.66×10-4 | 12.45 | 6.66×10-4 | 13.05 | 6.66×10-4 |
| 4 | 16.41 | 1.00×10-3 | 16.38 | 1.00×10-3 | 17.01 | 1.00×10-3 |
| 5 | 20.37 | 1.33×10-3 | 19.77 | 1.33×10-3 | 20.41 | 1.33×10-3 |
| 6 | 23.77 | 1.66×10-3 | 22.60 | 1.66×10-3 | 24.24 | 1.66×10-3 |
| 7 | 26.59 | 2.00×10-3 | 26.55 | 2.00×10-3 | 27.93 | 2.00×10-3 |
| 8 | 28.86 | 2.33×10-3 | 27.68 | 2.33×10-3 | 28.20 | 2.33×10-3 |
| 9 | 29.70 | 2.66×10-3 | 29.38 | 2.66×10-3 | 31.76 | 2.66×10-3 |
| 10 | 33.39 | 3.00×10-3 | 30.51 | 3.00×10-3 | 32.16 | 3.00×10-3 |
| 11 | 35.08 | 3.33×10-3 | 31.07 | 3.33×10-3 | 33.29 | 3.33×10-3 |
| 12 | 36.21 | 3.66×10-3 | 32.20 | 3.66×10-3 | 34.42 | 3.66×10-3 |
| 13 | 38.48 | 4.00×10-3 | 33.33 | 4.00×10-3 | 35.55 | 4.00×10-3 |
| 14 | 39.61 | 4.33×10-3 | 33.90 | 4.33×10-3 | 36.68 | 4.33×10-3 |
| 15 | 40.71 | 4.66×10-3 | 34.46 | 4.66×10-3 | 37.82 | 4.66×10-3 |
| 16 | 41.30 | 5.00×10-3 | 35.03 | 5.00×10-3 | 38.38 | 5.00×10-3 |
| 17 | 41.87 | 5.33×10-3 | 35.59 | 5.33×10-3 | 39.51 | 5.33×10-3 |
| 18 | 43.01 | 5.66×10-3 | 36.16 | 5.66×10-3 | 40.08 | 5.66×10-3 |
| 19 | 43.01 | 6.00×10-3 | 36.72 | 6.00×10-3 | 41.21 | 6.00×10-3 |
| 20 | 43.57 | 6.33×10-3 | 37.29 | 6.33×10-3 | 42.78 | 6.33×10-3 |
| 21 | 44.14 | 6.66×10-3 | 37.85 | 6.66×10-3 | 43.34 | 6.66×10-3 |
| 22 | 44.70 | 7.00×10-3 | 38.42 | 7.00×10-3 | 43.48 | 7.00×10-3 |
| 23 | - | - | 38.98 | 7.33×10-3 | 44.04 | 7.33×10-3 |
| 24 | - | - | 39.55 | 7.66×10-3 | 44.61 | 7.66×10-3 |
| 25 | - | - | 40.11 | 8.00×10-3 | 44.74 | 8.00×10-3 |
| 26 | - | - | 40.68 | 8.33×10-3 | 45.30 | 8.33×10-3 |
| 27 | - | - | 41.24 | 8.66×10-3 | 45.87 | 8.66×10-3 |
| 28 | - | - | 41.81 | 9.00×10-3 | 46.44 | 9.00×10-3 |
| 29 | - | - | 42.37 | 9.33×10-3 | 46.44 | 9.33×10-3 |
| 30 | - | - | 42.94 | 9.66×10-3 | 46.54 | 9.66×10-3 |
| 31 | - | - | 43.50 | 0.01 | 47.14 | 0.01 |
| 32 | - | - | 44.07 | 0.01033 | 47.70 | 0.01033 |
| 33 | - | - | 44.63 | 0.01066 | 48.27 | 0.01066 |
| 34 | - | - | 45.20 | 0.011 | 48.83 | 0.011 |
| 35 | - | - | 45.76 | 0.01133 | 48.92 | 0.01133 |
| 36 | - | - | 46.33 | 0.01166 | 48.96 | 0.01166 |
| 37 | - | - | - | - | 49.23 | 0.012 |
| 38 | - | - | - | - | 49.50 | 0.01233 |
| 39 | - | - | - | - | 49.66 | 0.01266 |
| 40 | - | - | - | - | 49.98 | 0.013 |
| 41 | - | - | - | - | 50.12 | 0.01333 |
| 42 | - | - | - | - | 50.29 | 0.01366 |
| 43 | - | - | - | - | 50.36 | 0.014 |
| 44 | - | - | - | - | 50.92 | 0.01433 |
| 45 | - | - | - | - | 50.92 | 0.01466 |

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Fig.4.7aStress- Strain Curves for SIFCON at (8%, 10% and 12%) fibre fraction

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Fig. 4.7b Stress- strain curve for SIFCON at 8% fibre fraction

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Fig. 4.7c Stress-strain Curve for SIFCON at 10% fibre fraction

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4.7d Stress-strain curve for SIFCON at 12% fibre fraction

Table 4.5 Young’s Modulus of SIFCON for different fibre fraction

|  |  |  |
| --- | --- | --- |
| **S.No.** | **Percentage fibre fraction** | **Young’s Modulus (N/mm2)** |
| 1 | 8% | 20390 |
| 2 | 10% | 20391 |
| 3 | 12% | 21295 |

**4.2.5 Residual Strength of SIFCON for various Percentages Fibre Volume Fraction with Manufactured Sand:**

SIFCON specimens made with 8%, 10% and 12% volume fibre fraction using manufactured sand are studied after heating specimens to a elevated temperatures of 100°C, 200°C, 300°C, and 400°C in an electric furnace at an exposure temperatures of 1hour, 2hours and 3hours respectively. After casting, specimens were kept in saturated humid air at 20 ± 2 C for 24 h and then, the specimens were demoulded. At the age of 28 days, the specimens were removed from water and surface dried. A number of tests were conducted on SIFCON specimens after each exposure condition to determine weight loss, residual compressive strength, split tensile strength and flexural strength.

**4.2.5.1 Weight Loss**

SIFCON specimens were removed from water and surface dried after curing period of 28 days. The cube specimens were weighed before heating in the Bogie Hearth furnace. After specified temperature exposure, the specimens are removed, cooled and weighed. The percentage weight loss is determined by dividing the difference in weight of specimen before and after heating with the weight of specimen before heating and expressed as percentage. Table 4.6 shows the reduction in weight or gain of SIFCON samples before and after exposure to the elevated temperature. The variation of weight reduction of SIFCON specimens made of different percentages of fibre fraction exposed to elevated temperature at the age of 28days was shown in Fig. 4.8 to 4.10.

Table 4.6 Weight of the Cube samples before and after the exposure to elevated temperature

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No. | Sample | Weight of the Cube Samples (Grams) | | | | | | | |
| 100°C | | 200°C | | 300°C | | 400°C | |
| Before | After | Before | After | Before | After | Before | After |
| 1 | SIFCON8 | 8999 | 8940 | 9035 | 8923 | 8936 | 8676 | 9057 | 8476 |
| 2 | SIFCON10 | 9024 | 8920 | 9051 | 8926 | 9076 | 8755 | 9376 | 8835 |
| 3 | SIFCON12 | 9408 | 9389 | 9325 | 9187 | 9382 | 9123 | 9432 | 8919 |

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Fig. 4.8 Variation of weight of the cube samples with 8% fibre fraction to the elevated temperature



Fig. 4.9 Variation of weight of the cube samples with 10% fibre fraction to the elevated temperature



Fig. 4.10 Variation of weight of the cube samples with 12% fibre fraction to the elevated temperature

When concrete is exposed to elevated temperature for a specified exposed condition, it leads to the loss of the moisture that is present in the concrete. This loss of moisture causes the concrete to lose some weight. From the study, it is observed that weight of cube specimens decreased with increase in temperature. Initially the loss in weight was minimum at the early temperatures, later the weight loss has increased with the increase in temperature.

The difference in loss of weight of all the SIFCON cube specimens was marginal. From the Table 4.6 and Figs. 4.8 to 4.10, it was observed that the weight reduction was only 1% to 6% that is practically negligible. However at 400°C, the loss of weight of SIFCON specimens is more than the SIFCON specimens at 100°C, 200°C and 300°C.

In all the SIFCON specimens weight loss observed in the temperature range of 300°C to 400°C were observed to be more than the weight loss in the temperature of 200°C and 100°C. The maximum percentage weight loss is observed to be more in SIFCON12 concrete mixes than SIFCON8 & SIFCON10 mixes when subjected to elevated temperatures. Further it can be seen that the strength loss in SIFCON8 is slightly less than that of SIFCON10 (by about 3 to 6 percent) under the exposed temperatures. SIFCON concrete mixes shown greater integrity than normal concrete mixes as observed in other researchers due to use of high volume fibre fraction.

**4.2.5.2 Residual Strength**

The SIFCON specimens made with 8%, 10% and 12% fibre fraction using manufactured sand exposed to elevated temperature for different exposure conditions were removed from the furnace and air cooled to the room temperature. The loss of compressive, split tensile, modulus of rupture strengths of SIFCON are determined by testing the cube, cylindrical and prism specimens exposed to elevated temperatures of 100°C, 200°C, 300°C and 400°C at 1hour, 2hours and 3 hours of exposure. The loss of strength is determined by subtracting strengths of specimens before and after exposure to heat and is expressed as percentage of pre-exposure strength.

**4.2.5.2.1 Residual Compressive Strength**

The compression test was carried out as per Indian standard specification. The compressive strengths of SIFCON under different exposed temperatures and percentage reduction in strength with increase in temperature determined from the study are presented in Table 4.7. The residual compressive strength of SIFCON with increase in Exposed temperature for different exposure durations are shown in Figs. 4.11a to 4.11c and variation of residual compressive strengths of all SIFCON mix specimens with elevated temperature for different exposure durations is shown in Fig.4.11d.

Table 4.7 Values of Residual Compressive Strength of SIFCON specimens for different exposure conditions subjected to elevated temperatures

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No. | Temperature  (°C) Exposure | | Compressive Strength (MPa) | | | Percentage Residual Compressive strength (%) | | |
| SIFCON8 | SIFCON10 | SIFCON12 | SIFCON8 | SIFCON10 | SIFCON12 |
| 1 | 27 |  | 35.70 | 42.54 | 46.15 | 100 | 100 | 100 |
| 2 | 100 | 1hr | 39.84 | 42.62 | 47.99 | 112 | 100 | 104 |
| 2hr | 43.33 | 47.78 | 49.33 | 121 | 112 | 107 |
| 3hr | 39.60 | 46.37 | 48.89 | 111 | 109 | 106 |
| 3 | 200 | 1hr | 41.07 | 43.85 | 48.70 | 115 | 103 | 105 |
| 2hr | 46.11 | 49.78 | 51.06 | 129 | 117 | 111 |
| 3hr | 36.67 | 45.67 | 47.06 | 103 | 107 | 102 |
| 4 | 300 | 1hr | 43.37 | 45.89 | 49.85 | 121 | 108 | 108 |
| 2hr | 41.30 | 42.89 | 45.55 | 116 | 101 | 99 |
| 3hr | 35.10 | 42.22 | 43.55 | 98 | 99 | 94 |
| 5 | 400 | 1hr | 42.37 | 43.03 | 45.48 | 119 | 101 | 98 |
| 2hr | 39.85 | 42.44 | 44.78 | 112 | 100 | 97 |
| 3hr | 33.67 | 40.00 | 41.33 | 94 | 94 | 89 |

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Fig. 4.11a Variation of compressive strength with elevated temperatures for 1 hr duration

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Fig. 4.11b Variation of compressive strength with elevated temperatures for 2 hr duration

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Fig. 4.11c Variation of compressive strength with elevated temperatures for 3 hr duration

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Fig. 4.11d Variation of Compressive strength with elevated temperatures

The curves shown in Fig.4.11d are the variation of residual compressive strength of SIFCON with elevated temperatures for different exposure conditions at the age of 28 days. Table 4.7 show the **v**alues of residual compressive strength of SIFCON exposed to elevated temperatures for different exposed durations. Increase in residual compressive strength of SIFCON specimens is observed up to elevated temperatures of 300°C for 1hour exposed condition. Whereas for 2 hours of exposed condition increase in compressive strength of SIFCON specimens are up to 200°C and up to 100°C for 3hours duration.

It is clear from the above Figs. that, the compressive strength of SIFCON decreases at elevated temperatures 200°C, 300°C and 400°C except at 100°C for all SIFCON specimens for 3hours of exposed condition where a considerable increase in the compressive strength is observed. The increase in the compressive strength may be due to the acceleration of the hydration of cement gel due to the increased rate of evaporation of free water. For temperatures higher than 100°C, the compressive Strength of SIFCON decreased. This decrease is attributed to the fact that chemically-bound water starts to disintegrate and evaporate at this stage.

The values of 28 days compressive strength of SIFCON for 8% of fibre volume fraction after 1 hour of exposure condition were 39.84 MPa, 41.07MPa, 43.37 MPa, 42.37MPa at 100°C,200°C, 300°C, 400°C respectively.

Similarly, the 28 days compressive strength of SIFCON for 10% of fibre volume fraction were 42.62MPa, 43.85MPa, 45.89MPa, 43.03MPa at 100°C, 200°C, 300°C, 400°C respectively. Whereas, for 12% of fibre fractions, the strengths were observed as 47.99MPa, 48.70MPa, 49.85MPa, 45.48MPa at 100°C, 200°C, 300°C and 400°C respectively.

It is well-known that the SIFCON consists of steel fibre dispersed in a continuous cement paste matrix and the transition zone between cement paste and the fibre is considered to be a critical zone and evidently affects concrete performance exposed to high temperature. The bond failure between fibre and cement paste, in addition to the effect of the vaporized water pressure during the heating process, the chemical changes occurring in this zone represented by the loss of free moisture are the cause for decrease in strength of SIFCON.

**4.2.5.2.2 Residual Split tensile strength:**

Table 4.8 and Figs. 4.12a to 4.12d shows the variation of tensile strength of SIFCON for various percentage fibre volume fractions with and without being subjected to elevated temperatures.

Table 4.8 Values of Residual Split Tensile Strength of SIFCON specimens for different exposure conditions subjected to elevated temperatures

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No. | Temperature  (°C) Exposure | | Split Tensile Strength (MPa) | | | Percentage Residual Split tensile strength (%) | | |
| SIFCON8 | SIFCON10 | SIFCON12 | SIFCON8 | SIFCON10 | SIFCON12 |
| 1 | 27 |  | 7.86 | 8.95 | 9.85 | 100 | 100 | 100 |
| 2 | 100 | 1hr | 8.57 | 9.25 | 11.56 | 109 | 103 | 117 |
| 2hr | 9.27 | 9.91 | 11.75 | 118 | 111 | 119 |
| 3hr | 8.58 | 9.32 | 11.03 | 109 | 104 | 112 |
| 3 | 200 | 1hr | 9.19 | 9.51 | 11.62 | 117 | 106 | 118 |
| 2hr | 9.06 | 9.43 | 11.40 | 115 | 105 | 116 |
| 3hr | 8.43 | 9.26 | 10.65 | 107 | 103 | 108 |
| 4 | 300 | 1hr | 8.99 | 9.70 | 11.89 | 114 | 108 | 121 |
| 2hr | 8.46 | 9.06 | 10.47 | 108 | 101 | 106 |
| 3hr | 8.32 | 8.93 | 10.26 | 106 | 100 | 104 |
| 5 | 400 | 1hr | 8.52 | 9.37 | 11.21 | 108 | 105 | 114 |
| 2hr | 8.18 | 8.63 | 9.91 | 104 | 111 | 101 |
| 3hr | 8.06 | 8.54 | 9.61 | 102 | 95 | 97 |



Fig. 4.12a Variation of Split tensile Strength with elevated temperatures for 1 hr duration



Fig. 4.12b Variation of Split tensile Strength with elevated temperatures for 2 hr duration



Fig. 4.12c Variation of Split tensile Strength with elevated temperatures for 3 hr duration



Fig. 4.12d Variation of Split tensile Strength with elevated temperature

From Table 4.8 and Figs. 4.12a to 4.12d, it is observed that the values of Split tensile strength are observed to be increased upto 300°C for 1hour exposure condition and further decrease in strength is observed as the elevated temperature increases. Whereas for 2 hours and 3 hours duration, the increase in strength is observed up to 100°C and further decrease in strength is observed as the elevated temperature increases. SIFCON is found to possess excellent ductility.

For 8% of fibre fraction, the values of 28 days residual tensile strength of concrete for 1 hour of exposure were 8.57MPa, 9.19MPa, 8.99MPa, 8.52MPa at 100°C, 200°C, 300°C, 400°C respectively. Whereas for 10% of fibre fraction, the strengths are 9.25MPa, 9.51MPa, 9.70MPa, 9.37MPa (1 hour) and for 12% of fibre fraction the strengths were 11.56MPa, 11.62MPa, 11.89MPa, 11.21MPa (1 hour) at 100°C, 200°C, 300°C, 400°C respectively.

**4.2.5.2.3 Residual Flexural strength:**

The Table 4.9 shows the residual strengths of flexural strength of SIFCON concrete for various percentage fibre volume fractions at different exposure conditions. Variation of Residual flexural strength (%) of SIFCON at elevated temperatures 100oC, 200oC, 300oC and 400oC for all exposure conditions were shown in Fig 4.13a to 4.13d.

Table 4.9 Values of Residual Flexural Strength of SIFCON specimens for different exposure conditions subjected to elevated temperatures

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S.No. | Temperature  (°C) Exposure | | Flexural Strength (MPa) | | | Percentage Residual Flexural strength | | |
| SIFCON8 | SIFCON10 | SIFCON12 | SIFCON8 | SIFCON10 | SIFCON12 |
| **1** | 27 |  | 23.95 | 27.46 | 35.67 | 100 | 100 | 100 |
| **2** | 100 | 1hr | 24.27 | 30.44 | 37.17 | 101 | 110 | 104 |
| 2hr | 24.85 | 28.40 | 36.16 | 103 | 103 | 101 |
| 3hr | 22.89 | 24.32 | 33.40 | 96 | 89 | 94 |
| **3** | 200 | 1hr | 24.71 | 33.37 | 39.86 | 103 | 121 | 112 |
| 2hr | 25.20 | 28.00 | 31.60 | 105 | 102 | 89 |
| 3hr | 20.40 | 23.54 | 30.99 | 85 | 86 | 87 |
| **4** | 300 | 1hr | 24.53 | 32.90 | 38.24 | 105 | 120 | 107 |
| 2hr | 21.80 | 27.60 | 29.50 | 91 | 101 | 83 |
| 3hr | 18.83 | 22.75 | 29.03 | 79 | 83 | 81 |
| **5** | 400 | 1hr | 22.51 | 30.62 | 33.22 | 94 | 112 | 93 |
| 2hr | 19.36 | 22.00 | 24.40 | 81 | 80 | 68 |
| 3hr | 15.69 | 21.97 | 23.54 | 65 | 80 | 66 |



Fig. 4.13a Variation of Flexural Strength with elevated temperatures for 1 hr duration

 Fig. 4.13b Variation of Flexural Strength with elevated temperatures for 2 hr duration

 Fig. 4.13c Variation of Flexural Strength with elevated temperatures for 3 hr duration



Fig. 4.13d Variation of Flexural Strength with elevated temperatures

From Table 4.9 and Figs. 4.13a to 4.13d, it is observed that the values of residual flexural strength are observed to be increased upto 200°C for 1hour exposure condition and further decrease in strength is observed as the elevated temperature increases. Whereas for 2 hour duration the increase in strength is observed up to 100°C and for 3 hours duration the decrease in residual flexural strength is observed.

For 8% of fibre fraction, the values of 28 days residual flexural strength of concrete for 1 hour of exposure at 100°C, 200°C, 300°C, 400°C were 24.27MPa, 24.71MPa, 24.53MPa, 22.51MPa respectively. Whereas for 10% of fibre fraction, the strengths are 30.44MPa, 33.37MPa, 32.90MPa, 30.62MPa (1 hour) and for 12% of fibre fraction the strengths were 37.17MPa, 39.86MPa, 38.24MPa, 33.22MPa (1 hour)

For 1 hour exposure, the increase in residual flexural strength was observed to be 3% for 8% fibre fraction, 21% for 10% fibre fraction and 12% for 12% fibre fraction up to 200°C. Whereas for 2hours duration the range was 3% for 8% fibre fraction, 2% for 10% fibre fraction and 1% for 12% fibre fraction up to 100°C. However, decrease in strength was observed about 4% for 8% fibre fraction, 11% for 10% fibre fraction and 6% for 12% fibre fraction for 3hours exposure condition.

**4.3 Conclusions**

Experiments are performed to obtain the strength properties of SIFCON made with locally available manufactured sand for their use in ANN application. There is an increase in Compressive strength, tensile strength, modulus of Rupture and modulus of elasticity with the use of locally available materials. Residual strengths of SIFCON produced with locally available material shown better performance when compared to SFRC as mentioned by previous researchers [14, 30] for elevated temperature applications.