

EXPERIMENTAL STUDY ON SHEAR STRENGTH BEHAVIOR OF SUPER PLASTICIZED FIBER REINFORCED CONCRETE BEAMS WITH HIGH REACTIVE METAKAOLIN

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Abstract

Experimental investigation is carried out to study the behavior of Metakaolin reinforced concrete in comparison to fly ash reinforced concrete with and without steel fibers on compressive strength and under shear strength. The weakness in tension of conventional concrete is overcome by incorporating steel fibers into the matrix while the Metakaolin and Fly ash can increase many properties of concrete and also reduces the cementing consumption. 12 beams of length 1500mm, breadth 150mm and depth 200mm having 4-12mm diameter bars as tension reinforcement and 2L, 8mm diameter bars spaced at 130mm c/c as stirrups were casted and cured for 28 days and tested under two point loading applied at 1/3 span points.

Keywords: Cement, Fly Ash, Metakaolin, Super Plasticizer, Steel Fibres, Shear Strength.

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I. INTRODUCTION

Concrete is one of the most extensively used construction materials in the world, with two billion tons placed worldwide each year. In reviewing technology advances through the centuries it is evident that material developments place a key role. Considerable efforts are still being made in every part of the world to develop new construction materials. In the construction industry concrete technology is heading towards entirely a new era by the use of supplementary cementitious materials such as Fly ash, Metakaolin, Rise husk ash and silica fume in concrete.

While conventional concrete has poor strength, low resistant to tensile cracking, so that its capacity to absorb energy is limited. The weakness in tension is conventionally overcome by strengthening their matrix with steel and more recently by reinforcing with fibrous materials. Concrete when mixed with fibres, give fibrous concrete. The mechanical property of fibrous concrete is superior to that of ordinary concrete. Fly ash and Metakaolin will be evaluated for use as supplementary cementitious material in cement based system, the performance of Fly ash and Metakaolin mixtures will be compared to controlled mixtures and mixtures incorporating Metakaolin as partial replacement for cement.

The manifold benefits of usage of Metakaolin, Fly ash and Steel Fibres in concrete are now well recognised. To improve the usage of Fly ash and Steel Fibres in structural concrete studies on aspects such as Compressive strength of Metakaolin Fly ash fiber reinforced concrete are to be undertaken which will spread its usage.

Hence an experimental investigation is carried out to understand the behaviour of conventional concrete and replacement of cement by supplementary cementitious materials such as Metakaolin and Fly ash in various combinations with and without steel fibres. A comparative study is made on shear strength.

The following are the specimens considered for the present study:

1. Two reinforced concrete beams of mix M-25. (C.C)
2. Two beams of consisting of M-25 with 50kg/m³ of steel fiber concrete (CFB)
3. Two beams of M-25 with cement replaced have been replaced by 10% of fly ash (CF)
4. Two beams of M-25 with cement replaced have been replaced by 10% of fly ash along with 50kg/m³ of steel fiber concrete(CFF)
5. Two beams of M-25 with cement replaced have been replaced by 10% of Metakaolin (CMK).
6. Two beams of M-25 with cement replaced have been replaced by 10% of Metakaolin along with 50kg/m³ of steel fiber concrete(CMKF)

II. METHODOLOGY

2.1. General

The properties of various materials used throughout the experimental work are explained. Also the details of method of casting and testing of beams are explained.

2.2. MATERIALS USED

- a) **Cement:** Ordinary Portland cement of 53 Grade conforming to IS: 12269-1987 has been used. The specific gravity of cement is 3.1 and fineness is 5%.
- b) **Fine aggregate:** Locally available clean river sand passing IS: 480 sieve has been used. Sand conforms to Zone III as per the specifications of IS 383: 1970. The specific gravity of sand is 2.64 and fineness modulus is 2.71.
- c) **Coarse aggregate:** Crushed granite of 20mm maximum size and retained on IS 480 sieve has been used. Specific gravity of coarse aggregate is 2.7 and fineness modulus is 6.816.
- d) **Water:** Clean portable water is used for mixing and curing.
- e) **Reinforcement :** Untensioned high yield strength bars conforming to IS: 1786(Grade Fe 415) has been used.
- f) **Steel fibers:** Crimped end wire of length 36mm, diameter 45mm, Aspect ratio of 80 has been used.
- g) **Metakaolin :** The average particle size is 1.5mm. The specific gravity is 2.5. The bulk density is 300±30 gm/liter.
- h) **Fly ash:** The fineness is 380m³/kg, lime reactivity is 85.2%, and dry shrinkage is 0.048%.
- i) **Admixture:** Super plasticizer Conplast SP-430 a product from FOSROC chemicals conforming to IS: 9103 has been used.

Beams of length 1500mm, breadth 150mm and depth 200mm having 4-12mm diameter bars as tension reinforcement and 2L 8mm diameter bars spaced at 130mm c/c as stirrups were casted and cured for 28 days and tested under two point loading applied at 1/3 span points.

III. RESULTS OBTAINED BY THE INVESTIGATION

The test results of compressive strength of design mix M-25 on standard 150mm cubes at 7 and 28 days curing periods obtained are given below in the table 1 and are graphically represented in figures 1 and 2.

Table 1:

| Mix | MIX DESCRIPTION | Compressive Strength of Cube in N/mm ² | |
|------|---------------------------------------|---|---------|
| | | 7 days | 28 Days |
| CC | Control Concrete | 27.55 | 32.00 |
| CF | Fly Ash Concrete | 23.33 | 30.00 |
| CMK | Metakaolin Concrete | 28.51 | 40.88 |
| CFB | Control Concrete With Steel Fibers | 30.00 | 37.33 |
| CFF | Fly Ash Concrete With Steel Fibers | 27.77 | 35.11 |
| CMKF | Metakaolin Concrete With Steel Fibers | 33.33 | 43.50 |

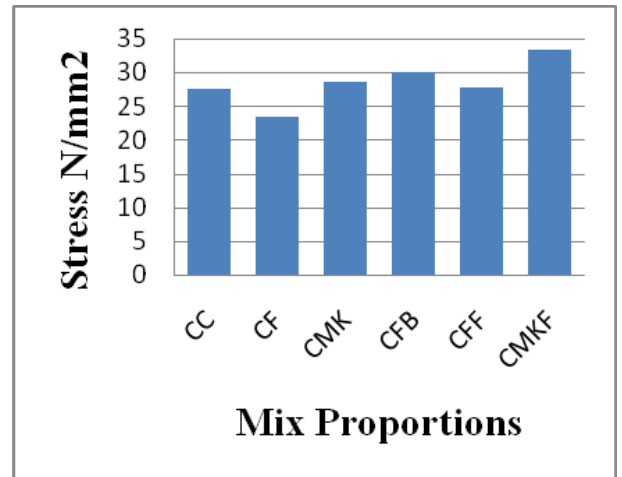


Figure 1- Variation Of Compressive Strength For 7 Days

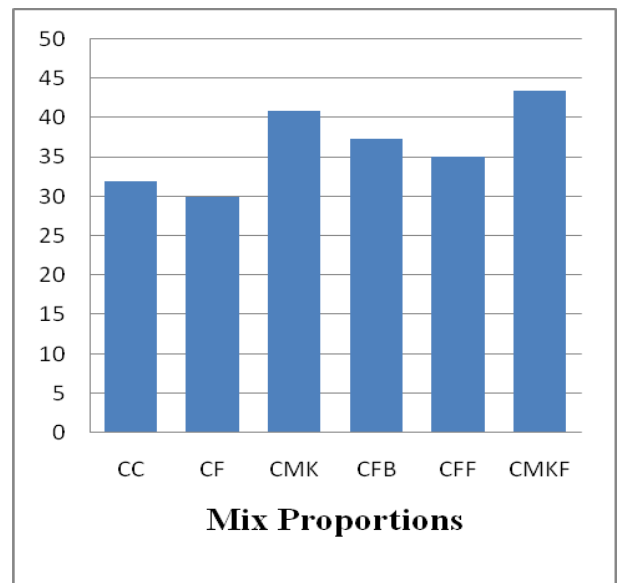


Figure 2- Variation of Compressive Strength for 28 Days

Results of shear tests indicating salient loads for control concrete, fly ash and metakaolin concrete beam specimen are shown in table 2.

Table 2:

| Beam no | Cube Compressive Strength (fck) N/mm ² | First crack load KN | Ultimate Load in KN |
|------------|---|---------------------|---------------------|
| B1 CC | 32.00 | 29.43 | 88.2 |
| B2 CFB | 37.33 | 34.33 | 122.5 |
| B3 CF | 30.00 | 24.52 | 73.5 |
| B4 CFF | 35.11 | 29.43 | 102.9 |
| B5 CMK | 40.88 | 3.24 | 93.1 |
| B6 CMKF | 43.5 | 44.145 | 137.7 |

Table 3: Strain Distribution under a Load for Beam B1 (CC):

| Load in KN | Depth of beam | 0 | 50 | 100 | 150 | 200 |
|------------|----------------------------|--------|--------|------|-------|-------|
| 0 | Strain in $\times 10^{-4}$ | 0 | 0 | 0 | 0 | 0 |
| 10 | | -17.58 | -14.2 | 0.28 | 14.29 | 17.42 |
| 20 | | -19.47 | -14.58 | 0.32 | 14.73 | 19.38 |
| 30 | | -21.38 | -15.45 | 0.33 | 15.53 | 21.25 |
| 40 | | -23.67 | -17.39 | 0.35 | 17.21 | 23.61 |
| 50 | | -25.65 | -18.63 | 0.34 | 18.51 | 25.86 |
| 60 | | -27.53 | -19.54 | 0.33 | 19.47 | 27.55 |
| 70 | | -29.58 | -22.66 | 0.32 | 22.63 | 29.51 |
| 80 | | -32.24 | -25.74 | 0.31 | 25.45 | 32.38 |
| 90 | | -34.79 | -27.59 | 0.3 | 27.23 | 34.73 |

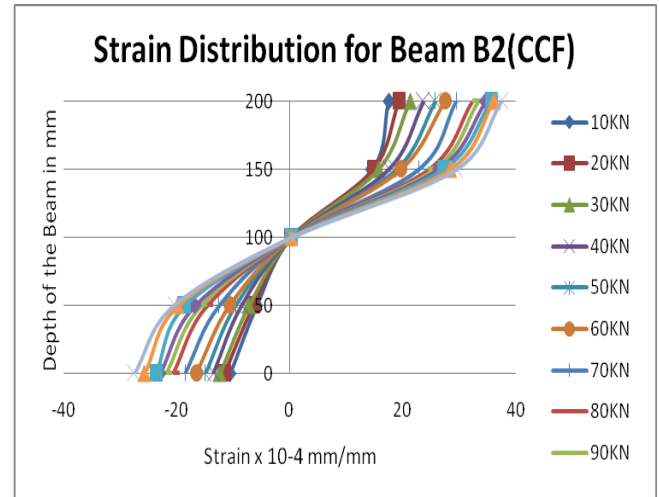


Table 5: Strain Distribution under a Load for Beam B3 (CF):

| Load in KN | Depth of beam | 0 | 50 | 100 | 150 | 200 |
|------------|----------------------------|--------|--------|--------|-------|-------|
| 0 | Strain in $\times 10^{-4}$ | 0 | 0 | 0 | 0 | 0 |
| 10 | | -20.25 | -17.25 | -0.07 | 17.44 | 20.35 |
| 20 | | -22.49 | -17.96 | -0.06 | 17.91 | 22.44 |
| 30 | | -24.71 | -18.57 | -0.025 | 18.83 | 24.12 |
| 40 | | -26.91 | -20.49 | -0.01 | 20.45 | 26.33 |
| 50 | | -28.48 | -21.21 | -0.065 | 21.82 | 28.7 |
| 60 | | -30.36 | -22.85 | -0.04 | 22.15 | 30.26 |
| 70 | | -31.56 | -23.84 | -0.015 | 23.36 | 31.76 |
| 80 | | -32.36 | -24.25 | -0.023 | 24.25 | 32.52 |

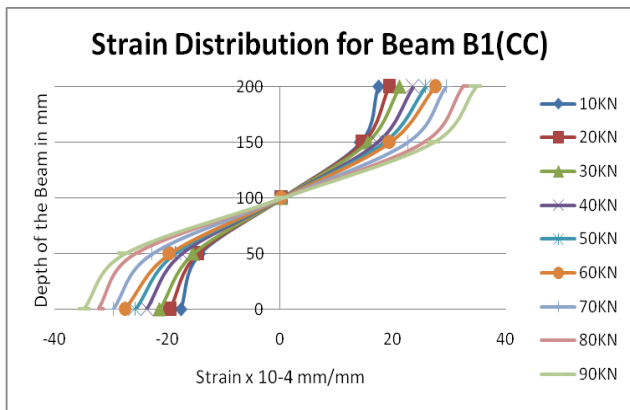


Table 4: Strain Distribution under a Load for Beam B2 (CCF):

| Load in KN | Depth of beam | 0 | 50 | 100 | 150 | 200 |
|------------|----------------------------|--------|--------|------|-------|-------|
| 0 | Strain in $\times 10^{-4}$ | 0 | 0 | 0 | 0 | 0 |
| 10 | | -10.53 | -5.85 | 0.3 | 14.59 | 17.52 |
| 20 | | -11.49 | -6.4 | 0.32 | 14.83 | 19.38 |
| 30 | | -12.35 | -7.23 | 0.33 | 15.73 | 21.35 |
| 40 | | -13.52 | -8.52 | 0.34 | 17.51 | 23.71 |
| 50 | | -14.92 | -9.53 | 0.35 | 18.81 | 25.76 |
| 60 | | -16.51 | -10.63 | 0.33 | 19.67 | 27.55 |
| 70 | | -18.49 | -12.52 | 0.32 | 22.83 | 29.51 |
| 80 | | -20.59 | -14.6 | 0.33 | 24.55 | 32.38 |
| 90 | | -21.89 | -15.72 | 0.31 | 25.55 | 33.43 |
| 100 | | -22.92 | -16.76 | 0.3 | 26.3 | 34.73 |
| 110 | | -23.67 | -18.53 | 0.29 | 27.2 | 35.68 |
| 120 | | -25.65 | -19.74 | 0.28 | 28.43 | 36.2 |
| 130 | | -27.53 | -20.46 | 0.27 | 29.53 | 37.53 |

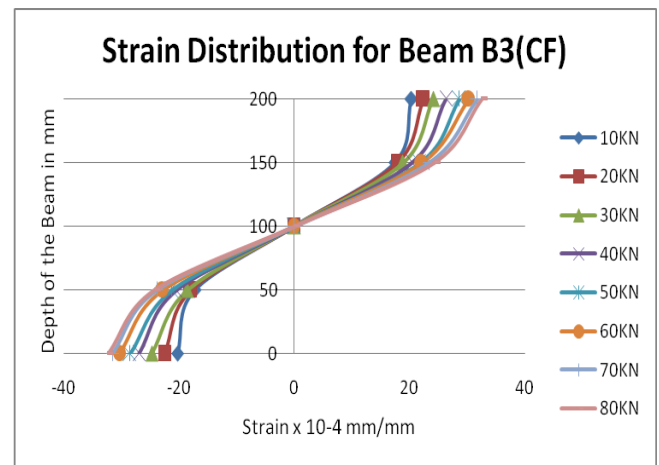


Table 6: Strain Distribution under a Load for Beam B4 (CFF):

| Load in KN | Depth of beam | 0 | 50 | 100 | 150 | 200 |
|------------|----------------------------|--------|--------|------|-------|-------|
| 0 | Strain in $\times 10^{-4}$ | 0 | 0 | 0 | 0 | 0 |
| 10 | | -17.5 | -13.4 | 0.07 | 13.2 | 17.43 |
| 20 | | -19.82 | -14.6 | 0.09 | 14.95 | 19.34 |
| 30 | | -22.53 | -15.86 | 0.14 | 15.44 | 22.2 |
| 40 | | -25.73 | -17.31 | 0.02 | 17.28 | 25.18 |
| 50 | | -28.4 | -18.43 | 0.01 | 18.8 | 28.77 |
| 60 | | -30.81 | -19.57 | 0.04 | 19.3 | 30.55 |
| 70 | | -32.58 | -22.76 | 0.05 | 22.47 | 32.53 |
| 80 | | -35.21 | -25.47 | 0.06 | 25.71 | 35.58 |
| 90 | | -36.43 | -26.32 | 0.07 | 26.23 | 36.88 |
| 100 | | -37.58 | -27.84 | 0.08 | 27.45 | 37.65 |
| 110 | | -38.23 | -28.56 | 0.09 | 28.65 | 38.83 |

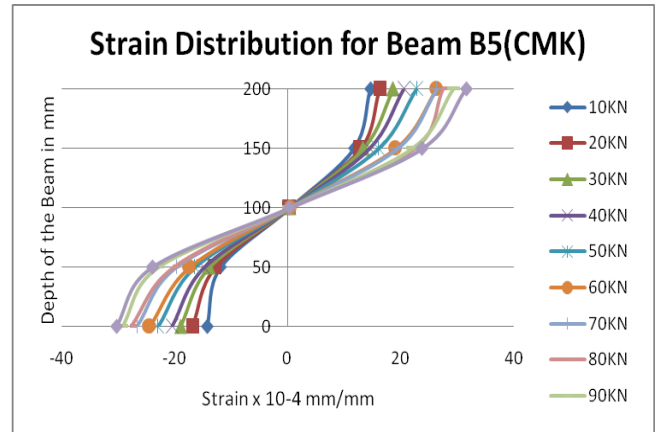


Table 8: Strain Distribution under a Load for Beam B6 (CMKF):

| Load in KN | Depth of beam | 0 | 50 | 100 | 150 | 200 |
|------------|----------------------------|---------|--------|------|-------|-------|
| 0 | Strain in $\times 10^{-4}$ | 0 | 0 | 0 | 0 | 0 |
| 10 | | -7.16 | -4.14 | 0.51 | 3.68 | 7.43 |
| 20 | | -8.16 | -4.36 | 0.53 | 4.74 | 8.64 |
| 30 | | -9.51 | -4.89 | 0.55 | 4.88 | 9.32 |
| 40 | | -10.335 | -6.7 | 0.56 | 5.78 | 10.33 |
| 50 | | -11.46 | -7.4 | 0.58 | 6.91 | 11.14 |
| 60 | | -12.68 | -8.52 | 0.6 | 8.22 | 12.17 |
| 70 | | -14.8 | -9.11 | 0.62 | 8.99 | 13.89 |
| 80 | | -14.59 | -9.62 | 0.61 | 9.36 | 14.19 |
| 90 | | -15.79 | -10.51 | 0.59 | 10.51 | 15.89 |
| 100 | | -16.89 | -11.3 | 0.57 | 11.4 | 16.39 |
| 110 | | -17.25 | -15.65 | 0.55 | 11.58 | 17.47 |
| 120 | | -18.48 | -17.77 | 0.54 | 12.23 | 18.59 |
| 130 | | -19.53 | -19.89 | 0.53 | 13.36 | 19.26 |
| 140 | | -20.32 | -23.13 | 0.51 | 14.27 | 20.82 |

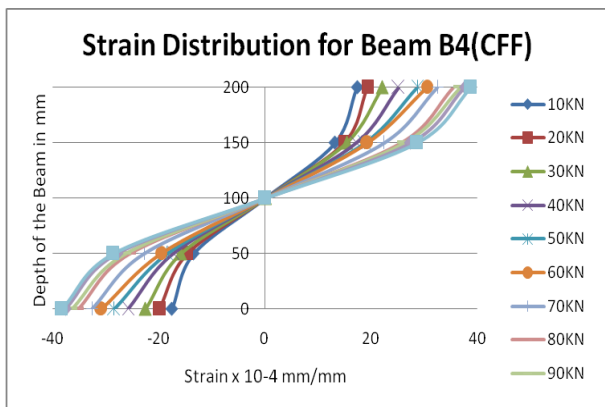
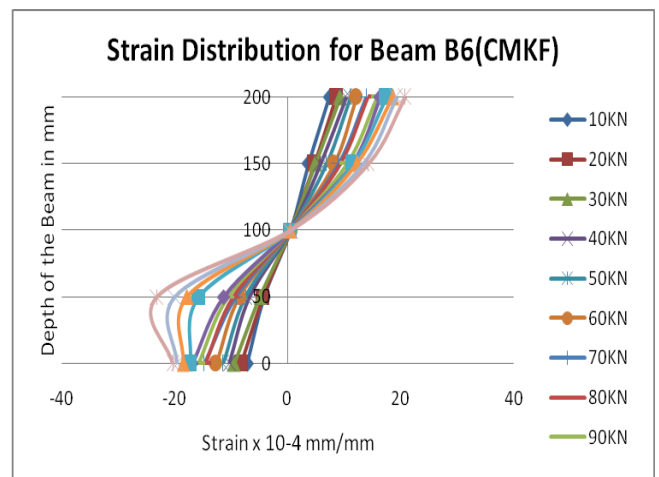


Table 7: Strain Distribution under a Load for Beam B5 (CMK):

| Load in KN | Depth of beam | 0 | 50 | 100 | 150 | 200 |
|------------|----------------------------|--------|--------|------|-------|-------|
| 0 | Strain in $\times 10^{-4}$ | 0 | 0 | 0 | 0 | 0 |
| 10 | | -14.27 | -11.87 | 0.35 | 11.79 | 14.68 |
| 20 | | -16.82 | -12.84 | 0.37 | 12.93 | 16.32 |
| 30 | | -18.96 | -13.9 | 0.38 | 13.42 | 18.65 |
| 40 | | -20.45 | -14.75 | 0.39 | 14.55 | 20.54 |
| 50 | | -22.96 | -16.41 | 0.4 | 16.1 | 22.87 |
| 60 | | -24.5 | -17.32 | 0.41 | 19.14 | 26.4 |
| 70 | | -26.64 | -19.7 | 0.4 | 19.41 | 26.4 |
| 80 | | -27.79 | -20.19 | 0.38 | 22.51 | 27.49 |
| 90 | | -29.29 | -22.99 | 0.36 | 22.1 | 29.33 |
| 100 | | -30.27 | -23.9 | 0.35 | 23.8 | 31.63 |



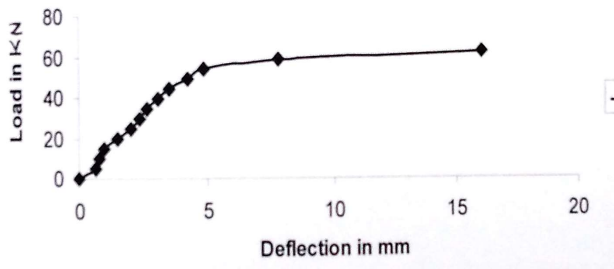


Figure 3: Load Deflection Behavior

Table 9: Theoretical and Experimental First Cracking Loads:

| Mix description | Theoretical cracking load KN | Experimental cracking load KN | ratio |
|--|------------------------------|-------------------------------|-------|
| Control Concrete | 14.95 | 29.43 | 1.968 |
| Control Concrete+ steel fibers | 15.69 | 34.33 | 2.188 |
| CC, Mix M25+10% of Fly Ash | 11.47 | 24.525 | 2.138 |
| CC, Mix M25+10% of Fly Ash+ steel fibers | 15.15 | 29.43 | 1.892 |
| CC, Mix M25+10% of Metakaolin | 16.81 | 39.24 | 2.333 |
| CC, Mix M25+10% of Metakaolin + steel fibers | 17.63 | 44.145 | 2.5 |

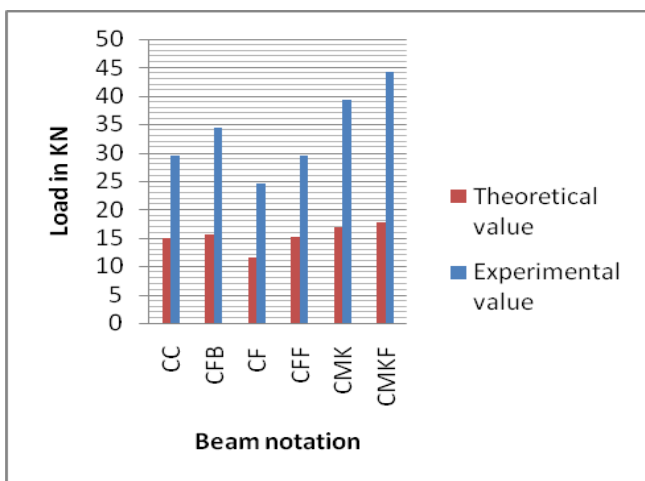


Figure 4- Theoretical and Experimental Cracking Loads of all Concrete Beams

Table 10: Test Results of Cracks Spacing and Number of Cracks:

| Mix description | Total no of cracks | Number of shear zone cracks | Max. crack spacing in mm | Average spacing in mm |
|--|--------------------|-----------------------------|--------------------------|-----------------------|
| Control Concrete | 10 | 4 | 125 | 85 |
| Control Concrete+ steel fibers | 9 | 7 | 110 | 80 |
| CC, Mix M25+10% of Fly Ash | 11 | 7 | 110 | 78 |
| CC, Mix M25+10% of Fly Ash+ steel fibers | 10 | 5 | 105 | 80 |
| CC, Mix M25+10% of Metakaolin | 10 | 7 | 100 | 75 |
| CC, Mix M25+10% of Metakaolin + steel fibers | 9 | 5 | 110 | 85 |

Table 11: Analysis Result of Theoretical And Ultimate Loads:

| Mix description | Theoretical load in KN | Experimental load in KN | Ratio |
|--|------------------------|-------------------------|-------|
| Control Concrete | 49.05 | 88.2 | 1.798 |
| Control Concrete+ steel fibers | 51.487 | 122.5 | 2.37 |
| CC, Mix M25+10% of Fly Ash | 48.63 | 73.5 | 1.511 |
| CC, Mix M25+10% of Fly Ash+ steel fibers | 49.2 | 102.9 | 2.09 |
| CC, Mix M25+10% of Metakaolin | 52.394 | 98.1 | 1.872 |
| CC, Mix M25+10% of Metakaolin + steel fibers | 42.63 | 137.2 | 2.55 |

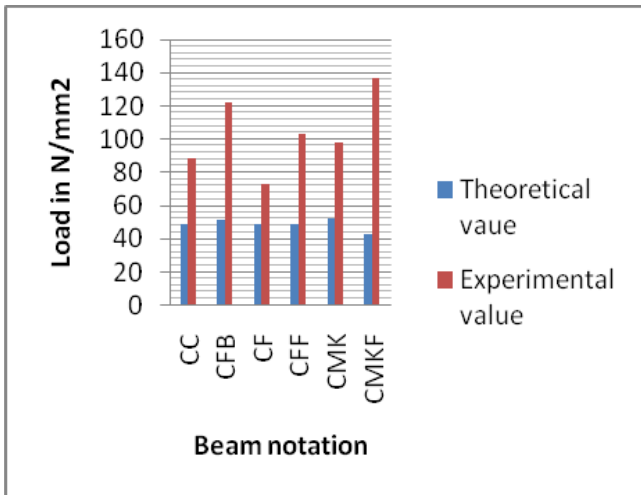


Figure 5- Theoretical And Experimental Ultimate Loads Of All Concrete Beams



Figure 6- Test Set Up

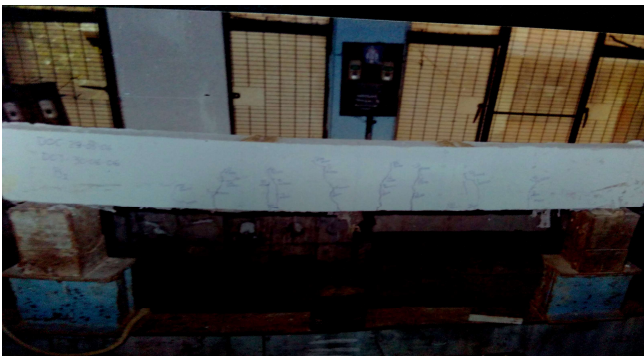


Figure 7- Crack Pattern in a Beam

IV. CONCLUSION

The experimental programme is done on the study of deformation of Metakaolin fly ash and modified steel fiber reinforced concrete beams under shear. a grade of concrete taken was M25. A total of 12 beams were casted under various mixers namely CC, CFB, CF, CFF CMK and CMKF were tested under two point loading. Based on the results of the experimental investigation carried out in the scope of work the following conclusions are made:

1. Metakaolin generally requires addition of super plasticizer so that concrete could attain its desirable workability. Since metakaolin is found to consume water either by absorption or reaction.

2. It is found that compressive strength of metakaolin concrete increase its strength around 22% when compared with normal concrete and fly ash concrete. Addition of steel fiber to metakaolin concrete there is a gain of 42% in strength as compared to normal and fly ash concrete.
3. As regards to shear behavior of beams it is found that metakaolin reinforced concrete beams have higher loads with lesser deflections than normal and fly ash concrete. At first crack metakaolin concrete beams deflected by an average of 20% less as compared to normal concrete beams and with steel fiber concrete beams deflected by 25% less than that of normal concrete beams with steel fibers.
4. It is noticed that ultimate tensile strength is larger inn metakaolin concrete and metakaolin steel fiber reinforced concrete. However normal concrete and fly ash concrete is found to be less.
5. When a comparison was carried out for metakaolin, fly ash and normal concrete beams with and without steel fibers it was found that both have some number of shear cracks and also cracking spacing was lesser in metakaolin concrete compared to flyash and normal concrete.
6. The experimental result of first crack load obtained for all mixes are more than the theoretically predicted value.
7. All the beams failed as per the expected mode of failure of under reinforced section.
8. Addition of metakaolin significantly improves the performance of concrete matrix; hence metakaolin concrete can be used for specialized applications.
9. The addition of fibers increases the compressive strength, shear strength and effective in controlling shear cracks and increases shear capacity.
10. The mode of failure of reinforced concrete in shear changes from shear failure to flexural failure by increasing the fiber contents up to 0.75%

V. SCOPE FOR FUTURE WORK

1. Comparison of flexural shear behavior of reinforced metakaolin concrete for other grades M30, M40, M50, of normal concrete with that of reinforced concrete with or without fibers.
2. To determine the flexural shear behavior of high strength reinforced metakaolin concrete.
3. Comparison of flexural behavior of reinforced metakaolin concrete with that of reinforced normal concrete and high strength concrete.
4. Crimped steel fibers with higher percentage 2%, 3%, 5% etc.

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