Flexural Rigidity in Concrete Beam by using the Crimped Steel Fibers with Rapid Hardening Admixtures

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Abstract: With the increase in the fast track construction industries, the emerging techniques are used for improvement in the concrete strength and its properties. This paper focused on the test results for various mixes of concrete made by replacing OPC cement content with slag and fly ash in varying proportions the use of rapid hardening admixture along with the presence of crimped steel fibers. The flexural strength, crack depth measurement by using the ultrasonic pulse velocity and Elastic modulus of concrete were conducted with different proportions of fly ash (0-15%) and slag (0-25%) being replaced in cement and 0-50% of the fine aggregate is replaced with stone dust. The experimental test results show the volume reduction in flexural members, crack depth measurement by UPV and modulus of elasticity of concrete by scant modulus method was used for various mixes.

Keywords: Crack depth, Fly ash, Slag, Strength, Ultrasonic pulse velocity

I. INTRODUCTION

In the present days, civil engineering is not only confined to structural construction and architectural designs but engineers are putting great efforts in making green concrete innovation projects and sustainable buildings which have many economic, social and environmental benefits. In this paper, attempts have been made on making green concrete by replacing cement with byproducts of industrial waste [1-3]. As concrete is one of the most widely used material in the construction of buildings, globally a total of about 25 gigatonnes of cement is used annually for the development of the structures this increases the level of carbon dioxide which results in the greenhouse gases to reduce this the amount of cement used is partially replaced with fly ash (0-15%) and slag (0-25%) waste by-products and which replace cement in the best way and obtain a maximum strength [4-8]. The mechanical properties of the concrete as such as bending stress of fibre reinforced concrete which improves with an increase in the percentages of steel fibre. The steel fibres prevent the early deforming of the beams and increase the durability of the structure [9-12]. The NDT methods for measuring the strength of a structure are not accurate but can help in correlating the values which can help in estimating the strength of the structure and also useful for analyzing the concrete characteristics and its homogeneity. [13-16] The NDT test was adopted for testing the beams for determining the quality and cracking efficiency. Also, the quality assessments of the structural building construction are basically depended on the usage of material characteristics and also maintain the serviceability of the structures. Further, to monitor the velocity for various elements by using the UPV techniques to calculate the static and dynamic modulus of elasticity of concrete works as a good indicator in concrete deterioration [17-20].

II. MATERIAL USED

A. Cement:

The cement which gains the strength on hydration and holds the aggregate in position to form a structure. All type of mix proportions of concrete used for OPC-53 grade of cement for casting the concrete and testing at different age of curing. The necessity of initial lab test results for OPC as given in Table 1.

Table- I: Test values for cement (Physical properties)

| Name of the test     | Test values |
|----------------------|-------------|
| Specific-gravity     | 3.15        |
| Soundness test       | 3.3 mm      |
| Fineness (IS sieve 90 microns) | 3 %    |
| Standard consistency test | 34 % |
| Initial-setting time | 99 minutes  |
| Final-setting time   | 254 minutes |

B. Fine Aggregate:

The main aim of this research work to minimize the natural materials and replaced in stone dust/quarry dust up to 50% by weight of fine aggregate (river sand). The river sand is passing through IS sieve size of 1.18 mm sieve and stone dust of fine aggregate passing through the IS sieve size 2.36 mm and these materials used for casting the concrete and the test values are given in Table II.

Table- II: Test values for aggregates

| Name of the test     | Test values for river sand | Test values for stone dust |
|----------------------|----------------------------|----------------------------|
| Specific gravity     | 2.73                       | 2.65                       |
| Water absorption     | 1.2%                       | 1.4%                       |
| Rodded density(kg/m³)| 1751                       | 1763                       |
C. Coarse Aggregate:
The blue metal rough type of crushed stone used as a coarse aggregate and passing through IS sieve of 20 mm and retained on 12.5 mm. The attained lab test results are represented in Table III.

Table III: Test values for blue stone (course aggregate)

| Name of the test | Test values |
|------------------|-------------|
| Specific gravity | 2.78        |
| Water absorption (%) | 1.0        |
| Rodded density (kg/m³) | 1830       |

D. Fly ash:
It is rich in SiO₂, Fe₂O₃ with Al₂O₃ content up to 65% present in the chemical composition and this type of class ‘F’ fly ash is considered for binding materials in Portland cement following ASTM C618 [21] and image of class F type of fly ash as shown in Figure 1.

Fig. 1. Image of class F type of fly ash

E. Slag:
A total of 2.2 – 3.0 tons of copper slag is produced approximately while manufacturing of one ton of copper thus a huge amount of waste is partially reused in Portland cement to making the quality of concrete as well as better durability aspects in concrete and image of slag as shown in Figure 2.

Fig. 2. Image of slag

F. Steel fibres:
The main important role for the selection of steel fiber is depended on the aspect ratio and has to increase the bending stress in flexural rigidly. The dimension of the fiber having 30 mm length and 0.5 mm diameter (aspect ratio is 60) were used for various mixes up to 1.5% of Vf and image of the crimped type of steel fiber as shown in Figure 3.

Fig. 3. Image of crimped type steel fibers

G. Rapid hardening admixtures (RHD):
The detailed specification has given in IS code how to use the low water-cement ratio with help of chemical admixture for various mixes. The RHD (as shown in Figure 4) dosage limits were fixed in the range starting from 1500 ml to 3000 ml for 50 kg of Portland cement was noted based on the initial trial and error methods and exhibited the better improvement in fresh concrete.

Fig. 4. Image of RHD

H. Curing methods:
The curing technique method was adopted to increase the high strength in concrete for various mixes. For each sample of specimens cured in normal potable water curing for 7, 14 and 28 days after reached the curing the same sample followed by five hours kept in hot air oven curing up to 105-110°C before testing on the concrete specimens.

III. EXPERIMENTAL PROGRAM
This research work consisting of Eight mixes as represented in Table IV for each mix proportion was calculated for M25 grade of concrete (1:1:2:0.45) in accordance with IS 10262-2019 [22].

Table IV: Mix proportion details

| Mix ID | Cement required kg/m³ | Fine Aggregate kg/m³ | Coarse Aggregate kg/m³ | Steel Fiber (%) | RHD used for 50 kg of cement |
|--------|------------------------|----------------------|------------------------|----------------|-----------------------------|
| C1     | 420                    | 60                   | 120                    | 300            | 300                        | 1200                  | 1.5                 | 18000               |
| C2     | 360                    | 90                   | 150                    | 300            | 300                        | 1200                  | 1.5                 | 24000               |
| C3     | 420                    | 60                   | 120                    | 300            | 300                        | 1200                  | 2                   | 18000               |
| C4     | 360                    | 90                   | 150                    | 300            | 300                        | 1200                  | 2                   | 24000               |
| C5     | 420                    | 60                   | 120                    | 300            | 300                        | 1200                  | 1.5                 | 30000               |
| C6     | 360                    | 90                   | 150                    | 300            | 300                        | 1200                  | 1.5                 | 36000               |
| C7     | 420                    | 60                   | 120                    | 300            | 300                        | 1200                  | 2                   | 30000               |
| C8     | 360                    | 90                   | 150                    | 300            | 300                        | 1200                  | 2                   | 36000               |

A. Flexural strength test:
The flexural rigidity in concrete is determined with varying percentage (0-2%) use of steel fibre to attain the maximum strength. The size of prism 500 x 100 x 100 mm for cast and tested by third-point loading arrangement was used to determine the bending stress and the dial gauge was read to 1 division on the dial gauge as 1.25 kN of the load. Figure 5 shows the experimental setup for carrying out three-point loading on the beams.
B. Ultrasonic Pulse Velocity:
The non-destructive test (NDT) is performed to calculate the velocity for various mixes by indirect method and test setup as shown in Figure 6. The beams are divided into 5 equal segments (5 x 100 = 500 mm) on the top surface beam axis to fix the transistor and receiver to record the velocity based on the path length.

C. Crack depth by using UPV:
Figure 7 shows the schematic line diagram to calculate the crack depth for various mixes and various steps are involved as given in the equation number (1). The RHD chemical admixtures owing to rapid hardening occurred privileged inside the microstructures of concrete, thus indicating the quality of assessment in terms of rate of pulse velocity. Indeed, the recorded values to substitute the equations and calculate the crack depth (mm) for different mixes. Also, manually to measure the crack depth by normal steel scale (mm) and compared all the test results.

D. Modulus of Elasticity of concrete:
The cylindrical size of concrete specimen height 150 mm by 300 mm for diameter was fitted with the compressor meter at the centre of the specimen in the test set up as shown in Figure 8. This experimental test to calculate the secant modulus of concrete by applying the external load gradually for every 5 kN interval up to 40% of the total failure load and corresponding dial gauge reading was observed. Finally, all values are converted into deflection (mm) for various mixes.
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C. Crack depth in prism by using UPV:

The maximum bending stress occurred owing to the addition of steel fiber along with chemical admixtures and also material characteristics. This technique is to record the velocity as per IS 13311-1992 part 1 [23] and calculated the crack depth (mm). Figure 11 shows the different test values for manually measured and also using the formula to calculate the crack depth. From the test results shows the higher percentage of slag with fly ash replaced in OPC has calculated depth up to 75 mm for manual and also 82 mm was noted by using the UPV than compared to conventional concrete.

D. Modulus of Elasticity:

The modulus of elasticity is found out for the cylinders. The cylinder is fitted to the compressor meter and placed in the compression testing machine, for every 5 kN load is applied and the strain is measured in terms of change in length by reading the dial gauge division multiplied with the least count. The graph shown below was plotted based on stress and strain values which were obtained the test values during the experimental work. The maximum load applied to the cylinder for determining the modulus of elasticity is taken about 40% of the failure load. The readings were taken up to 220 kN for each mix. The slope of the curve gives the value of elastic modulus of the concrete which was observed to be 23.07 GPa. Figure 12 shows the graph drawn from the stress and strain values obtained.

V. CONCLUSION

The following conclusions were drawn from the experimental limitations of the study.

- Increase in the volume of steel fibre to reach the maximum bending stress and attained the target mean stress was 3.5 N/mm² at 7-days of curing.
- No change occurred in the flexural strength in concrete beam having 0% of steel fiber reinforced concrete.
- Steel fibre contributes to limitation of initial cracks, bridging the gap and increases the bending stress and also pull-out resistance capacity.
- The elastic modulus of concrete represents good strength and reduction in the deterioration of concrete, as obtained 92.28% of elastic modulus for 7-days of curing.

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