Evaluation of the Properties of Bentonite Concrete with and without Steel Fiber

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Abstract-Concrete is a major building material which is been used in construction industry throughout the world. It is an extremely versatile material and can be used for all type of structures. If bentonite is used for the partial replacement of cement, thus concrete becomes inexpensive and eco-friendly. This paper present the result of an experimental investigation carried out to evaluate the properties of concrete with bentonite and steel fiber bentonite in which ordinary portland cement was partially replaced with bentonite by weight for a mix of M30 grade concrete. Firstly, Workability, Compressive strength, split tensile strength and flexural strength of concrete were evaluated at different percentages of bentonite. Secondly, the same properties were examined in concrete adding different percentages of hooked end steel fiber by weight of concrete with constant amount of bentonite which in turn increases the strength of concrete.

Index Terms - Hooked end steel fibers, Steel fiber reinforced concrete, Bentonite, Flexural strength, Split tensile strength.

1 INTRODUCTION

Concrete is one of the most widely used construction material in the world. It can be cast in diverse shapes. Concrete is a composite material formed by the combination of cement, sand, coarse aggregate and water in a particular proportion. Ordinary Portland cement has been a binder for Civil Engineering tasks for a long time. In concrete the price of cement is higher than other raw materials as well as there are many other issues branching from its ever increasing use. Cement production consumes huge quantities of virgin materials, is energy-intensive, and leads to high emission of the greenhouse gas CO_2, which is the main reason behind Global warming. So there is a need of alter the cement by some natural materials which having pozzolanic properties. Bentonite is a natural pozzolan and basically it is an impure clay material [1].

This study is therefore to investigate the range of ordinary Portland cement - bentonite mix proportion that can be found useful for particular use in the construction industry. The strength and durability of concrete can be changed by making appropriate changes in its ingredients like cementitious material, aggregate and water and by adding some special ingredients [3]. Portland Pozzolana Cement concrete possesses a very low tensile strength, limited ductility and little resistance to cracking. Internal micro-cracks are inherently present in the concrete and its poor tensile strength is due to propagation of such micro-cracks, leading to brittle failure of concrete. This weakness and brittleness can be reduced by inclusion of steel Fiber in the concrete mix [5]. These Fiber help to transfer loads at internal micro cracks which called Fiber reinforced concrete.

Ali Memon et al. (2012) evaluated the feasibility of Bentonite as partial replacement of cement. The workability, density and water absorption decreased when bentonite % increased. In case of Strength activity Index, compressive strength and acid attack bentonite mixes showed higher strength than control mix. Low cost concrete can be produced by substituting bentonite as partial replacement of cement in concrete without compromising on strength parameters [4].

Abaza et al (2015) studied the load-deflection behavior of steel fiber reinforced rubberized concrete (SFRRC) up to the first-crack load. As a result SFRRC beams with 15% crumb rubber content were benefited by adding steel fiber at all volume fractions [2].

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2 Material Specifications

2.1 Odinary Portland Cement

OPC of 53 grade conforming to IS 4031:1968 was used. The properties of cement tested were Fineness 5 %, Normal consistency 29 %, Initial & Final setting time 45 minute & 330 minute and 28 days Compressive strength 49 MPa.

2.2 Fine aggregate

M sand passing through 4.75 mm IS sieve, conforming to grading zone-II of IS: 383-1970 was used. The physical properties were Fineness Modulus - 2.99, Specific Gravity - 2.7, Water absorption -1.4%.

2.3 Coarse aggregate

Crushed stone aggregate with nominal size 20 mm as per IS: 2386-1963 (part I, II and III) were used. The physical properties were Fineness Modulus - 6.31, Specific Gravity -2.82, Water absorption - 0.78%, Aggregate crushing value - 32.41%.

2.4 Bentonite

Natural sodium bentonite was used. Heat treatment was given to the bentonite at 100°C. The physical properties were Liquid limit -396 %, Fineness – 10 %, Specific gravity - 2.7, pH - 9.86, Sand content - 1.4 % Swelling Index - 12 times.

Fig. 1. Bentonite

2.5 Super plasticizer

Super plasticizer CONPLAST SP430 in the form of sulphonated naphthalene polymer confirms to IS: 9103-1999 and ASTM 494 was used to improve the workability of concrete.

2.6 Steel Fiber

Hooked end steel fibers conforming to ASTM-A820M standard has been used. Properties of steel fibers were Length - 50 mm, diameter – 0.8 mm, aspect ratio - 62, Tensile strength - 1100 MPa.

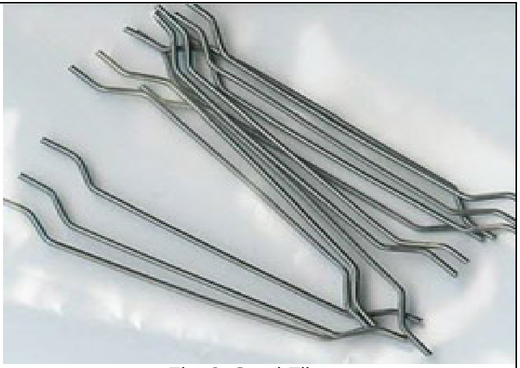

Fig. 2. Steel Fiber

2.7 Water

Water conforming to as per IS: 456- 2000 was used for mixing as well as curing of concrete specimens.

3 Concrete Mix Design

Based on trial mixes for different proportions of ingredients, the final design mix was prepared for M30 grade concrete as per IS 10262-2009. The mix proportion was 1:2.01:3.57 with w/c ratio 0.45.

Table 1. Concrete mix design

Sl No	*Items*	*kg per m³ of concrete*
1	Cement	360
2	Fine aggregate	723.28
3	Coarse aggregate	1286.26
4	Water	162

4 Casting of Specimens

The specimens were cast as per mix design. Bentonite was used in this investigation at 5 %, 10 %, 15 %, 20 %, and 25 % replacement of cement by weight. Hooked end steel fibers were also included at various percentages in the concrete containing 15 % replacement of cement by bentonite. The steel fiber content is varied as 0.5 %, 1% and 1.5 % of total weight of concrete (weight of cement, fine aggregate, coarse aggregate and water). The different specimens like cubes, cylinders and prisms as per the requirement of test were cast. Cubes of size 150 mm x 150 mm x 150 mm, cylinders with 150 mm diameter and 300 mm height and prisms of size 100 mm x 100 mm x 500 mm were prepared using the standard moulds. The samples are kept in a water tank for 28 days curing.

5 Specimen Designation

9 mixtures were prepared, which varied according to the following parameters: Bentonite content and fiber content. Specimen cast without addition of bentonite are designated as B0, where B represents bentonite content. Different mixes are listed in Table 2.

Table 2. Different mixes

Mix	*Bentonite content (%)*	*Steel fiber content (%)*
B0	0	0
B5	5	0
B10	10	0
B15	15	0
B20	20	0
B25	25	0
B15SF0.5	15	0.5
B15SF1	15	1
B15SF1.5	15	1.5

6 Testing of Specimens

The effect of different mixes on workability of fresh concrete was found out using slump cone test. The compressive strength, flexural strength and split tensile strength of different mixes were found out at 28 days as per the procedure laid down in IS: 516 - 1959. The concrete specimens were tested for compressive strength and split tensile strength in an automatic compression testing machine of capacity 5000 kN and flexural strength was tested in a flexure strength testing machine. Three specimens were used in computing the mean on each testing age of each mix and the final results are tabulated in comparison with reference mix.

7 Results and Discussion

7.1 Workability

The workability of concrete mixtures was measured by performing slump cone test. The variation in slump of different % replacement of bentonite and steel fiber on concrete is given in Table 3.

Table 3. Workability in terms of slump

Mix	*Slump value in mm*
B0	92
B5	88
B10	85
B15	80
B20	74
B25	69
B15SF0.5	78
B15SF1	75
B15SF1.5	71

The test results showed that the concrete matrix when replaced by different proportion of bentonite and steel fiber, the workability decreased with increasing quantity of bentonite and steel fiber. This is due to the extra fineness of bentonite in the concrete mix.

7.2 Compressive Strength

The variation in compressive strength of concrete mixes made with bentonite was determined after 7, 28, and 56 days of curing. The strength also determined in steel fiber reinforced concrete after 7 and 28 days curing. The results of different % replacement of bentonite and steel fiber on concrete are given in Figure 3 and 4.

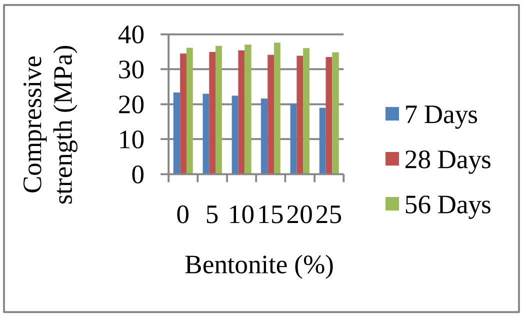

Fig. 3. Compressive strength of bentonite without steel fiber

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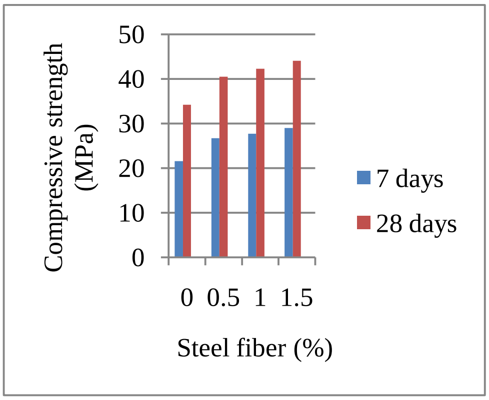

Fig. 4. Compressive strength of bentonite with steel fiber

For all mixes, the compressive strength was increased as the curing period increased from 7 to 56 days. At 7 days, the compressive strength of control mix was higher than the mixes with bentonite. At 28 days, the strength was slightly increased up to B10 and the strength was increased up to B15 at 56 days. This is due to the reason that strength gain in pozzolan containing concrete is generally slow at early age. The compressive strength of concrete mixes containing 15% bentonite and different percentage steel fiber were increased as increase in steel fiber percentage in both 7 and 28 days.

7.3 Split Tensile Strength

Split tensile strength of concrete mixes made with bentonite and 15 % bentonite with steel fiber were determined. The variation in 28 days results of different % replacement of bentonite and steel fiber on concrete is given in Figure 5 and 6.

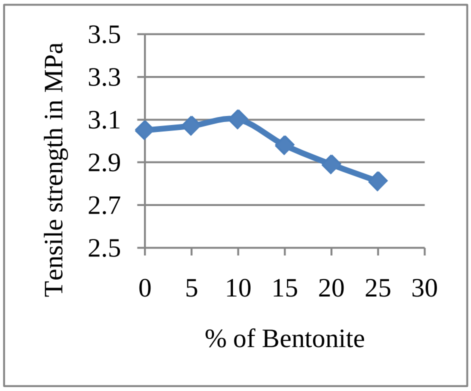

Fig. 5. Tensile strength without steel fiber

The split tensile strength was increased slightly up to the mix B10 compared to the control mix. After that the strength was decreased. Because of this reason the steel fiber was introduced at different percentages with 15 % bentonite concrete mix. As a result the tensile strength of B15 mix was increased at all percentages of steel fiber.

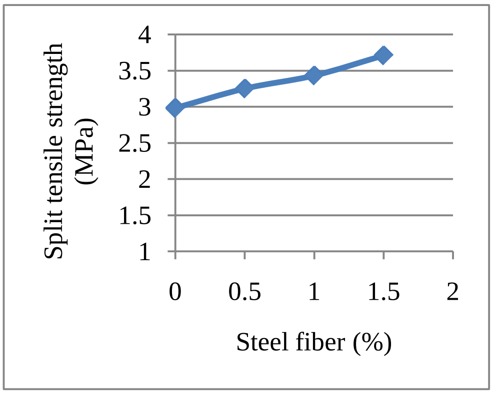

Fig. 6. Tensile strength with steel fiber

7.4 Flexural Strength

The variation in flexural strength on concrete is given in Figure. 7 and 8.

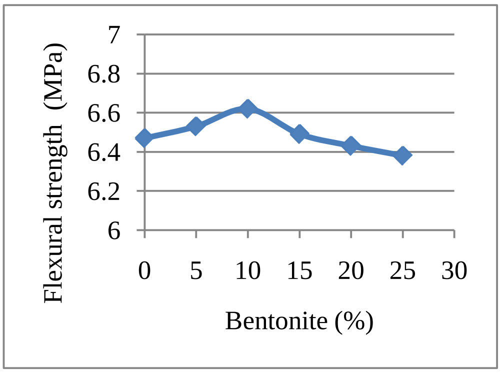

Fig. 7. Flexural strength without steel fiber

The maximum flexural strength is obtained for the mix B10 when compared with control concrete. In this case also the steel fiber was added at various percentages in B15 mix. The results showed that the steel fiber mix showed good results compared to B0 and B15 mixes.

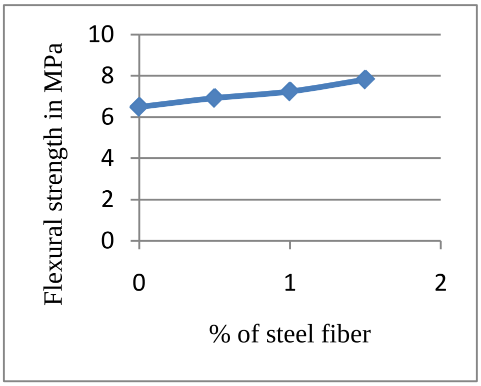

Fig. 8. Flexural strength with steel fiber

8 Conclusions

The fresh and hardened properties of bentonite mix concrete with and without the addition of fibers were investigated. The workability decreases with the increase of the replacement level of the cement with bentonite as well as the addition of steel fibers. The greatest increase in compressive strength was achieved for B15 mix at the age of 56 days. Split tensile strength and flexural strength were increased slightly up to B10 mix and then decreased. The addition of steel fiber in B15 mix showed good results in all mixes of steel fibers. Compressive strength, tensile strength and flexural strength were increased from 0.5% to 1.5% addition of fibers.

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