Comprehensive Study of High Strength Concrete with and without Natural Organic Fibres

Rustam Sahu[1] & Abhishek Tiwari[2],

[1]*M.Tech. Scholar, Dept. of Civil Engineering, SISTec-R, Bhopal, India*
[2]*Asst. Professor, Dept. of Civil Engineering, SISTec-R, Bhopal, India*

Abstract - *Use of fibers is not new to the construction industry. But the way they are being used and its ever-growing varieties have always made it a burning topic for the researchers. The principal reason to incorporate fibers into a cement matrix is to increase the compressive strength and to improve the soundness characteristics of the resultant composite. Previous studies related to the use of natural organic fibres in concrete have shown strength variation with respect to the various types of fibres and fibres content.*

In the present investigation, an attempt has been made to design a high strength Fibre Reinforced Concrete by proportioning the mix with natural organic fibers obtained from pulverized horse manure/dung. Later study was carried out on this designed concrete mix by considering different parameters such as fiber content, proportioning of fine aggregates, time (days) and types of tests (Destructive and Non Destructive test).

Results of the study have shown that the performance of designed concrete mix with different mix proportions and different percentage of fibers as additive and replacement of fine aggregates are far more efficient and superior to the conventional mix. This research summarized the use of horse manure/dung, a natural organic fiber by some percentage in the concrete mix to get favorable workability, compressive and flexural strength.

***Index Terms*— High Strength Concrete, Natural Organic Fibre Reinforced Concrete, Horse Manure/dung**

1. INTRODUCTION

Extensive steps have been taken out universally to employ local natural waste as accompanying cementing material to improve the properties of cement as well as use of these material leads to the suitable disposal of natural waste consequence to less impact on surroundings in order to reduce the loss due to improper disposal of the waste. Usually a high strength concrete is prepared by evaluating artificial fiber or polymer which results in increment of cost. By habituation of natural fibres or fibres from waste in concrete mix, an effort was made to amend the physical properties of concrete. High strength concrete is typically recognized as concrete with a 28 days compressive strength greater than 35 MPa as per IS code. By finding optimum mix design with regards to the amount of water-cement ratio, fiber and aggregates, the high strength concrete was prepared by using waste in beneficial manner. Natural organic fiber from waste (horse manure) is used as admixture in concrete. The physical composition of horse dung consists of straw, straw pellets, straw flax, flax, wood pellets, saw dust. The chemical composition of the excreta is 24.63% crude fiber, 32.84% dry matter, 81.83% volatile organic matter, 18.17% ash and 2.95% ether extract. The regular fiber length of the manure is 10-15 mm. The fiber has a diameter of 0.1-0.3 mm. About 5.56 Megatons of manure is produced annually in India. There is a need of investigating the behavior of horse manure for different grades of concrete as a fibrous reinforced material for concrete and analyzing properties of fresh as well as hardened concrete.

The earliest employment of fiber as reinforcement in concrete has been dated in 1870's. Since then, researchers globally have been interested in improving the compressive and tensile properties of concrete by adding wood, iron and other wastage. One of the important factor is the use of natural fibers intend to produce a sustainable green concrete by using natural fibers such as palm, banana leaves and industrial hemp fibers resulted in reducing the coarse aggregate quantity without affecting the flexural performance of concrete (Elie Awwad, Mounir Mabsout, Bilal Hamad and Helmi Khatib, 2010) Previously experiment suggested that addition of Arenga Pinnata fibre increased the toughness characteristic of concrete, the positive effects of the fibre become less significant after 28 days, but still sufficient to give the concrete better toughness properties compared to the plain concrete (H. Abdul Razak and T. Ferdiansyah, 2004). Latterly the observation made by evaluating Cellulosic fibers produced by the Kraft pulping process from slash pine trees (Pinuselliottii) showed High modulus of rupture, high fracture energy (toughness), excellent dimensional stability, and low water absorption (J.H. Morton, T. Cooke and S.A.S. Akers, 2009). It was reported that acid attack generally degraded the strengths, while alkali attack had only a limited effect. This was tested by implicating Pyrolyzed banana leaves, coconut coir, and coconut sheaths to concrete mix for development of strong cementitious matrix composites (M.A. Arsene, A. Okwo, K.Bilba, A.B.O. Soboyeio and W.O. Soboyejo, 2003) Later on it was concluded that application of hemp fiber reinforced concrete under the optimum conditions improves the compressive strength by 4%, flexural strength by 9%, flexural toughness by 144%, and flexural toughness index by 214% (Zhijian Li Lijing Wang and Xungai Wang, 2006)

2. EXPERIMENTAL BACKGROUND AND ANALYSIS

In order to analyze the strength of concrete, the concrete is formed as plain and fibre reinforced concrete molded as cube of side 150 mm and beam of size (700x150x150) mm. The load is applied on the cube block under universal testing machine for compressive strength and 3 point loading on beam for flexural strength, which causes crack or fracture developed on the surface of cube. For this there is maintained proportion of fibre is used to attain various data. Using this maintained proportion of fiber, the behavior of fresh concrete is also determined.

2.1 Material Used and Experimental Work:

2.1.1 Cement: Ordinary Portland Cement of 53 grade was used.

Table - 1: Properties of cement used in the study (Source- Specifications given as per the Ultratech cement manufacturing company)

Physical Property		IS:12269–1987 Specifications
Soundness	Le Chat Expansion (mm)	0.8
	Auto Clave Expansion (%)	0.062
Fineness (m^2/kg)		330
Standard Consistency (%)		30.5
Vicat initial setting time (minutes)		150
Vicat final setting time (minutes)		225
Compressive strength 3-days (MPa)		38
Compressive strength 7-days (MPa)		47.6
Compressive strength 28-days (MPa)		63.6
Specific gravity		3.15

2.1.2. Aggregates: The maximum nominal size of coarse aggregate is taken as 20 mm. Aggregate of size 10 to 12 mm is sought-after for structure having blocked-up reinforcement arrangement. Well graded cubical or rounded aggregates are desirable. The sample should be of uniform quality. Fine aggregates can be natural or manufactured. The grading must be uniform throughout the work. The Locally available natural sand with 4.75 mm maximum size was used as fine aggregates, having specific gravity, fineness modulus bulk density water absorption as given in the table 3.2. The coarse aggregate with 20mm maximum size having specific gravity, fineness modulus and bulk density as below (also shown in table 3.2) was used as coarse aggregates. Both fine aggregate and coarse aggregate validating to Indian Standard Specifications IS: 383-1970.

Table - 2: Properties of Aggregates used in the Study

Physical Properties of Coarse and Fine Aggregates Physical tests	Coarse Aggregates	Fine Aggregates
Specific gravity	2.66	2.66
Fineness modulus (mm)	6.86	2.68
Bulk density (kg/m^3)	1540	1780
Water Absorption (%)	0.81	0.80

2.2 Experimental Setup for Concrete.

Grade Designation for proposed concrete = M40
The mix design follows following four steps-

(i) Target mean strength [Clauses 3.2 (IS10262:2009)]
$F_t = F_{ck} + K.S$
Where F_t = Target mean strength of concrete at 28 days in N/mm^2
F_{ck} = Characteristics strength of concrete at 28 days in N/mm^2
K = Accepted proportion of low results usually 5% taken as 1.65
S = Standard deviation for M40 grade is 5

(ii) Selection of Cement content [Clauses 4.3 (IS10262:2009)]
Minimum Cement content = 320 kg/m^3
Maximum Cement content = 450 kg/m^3

(iii) Selection of Water content [Clauses 4.1 (IS10262:2009)]
Minimum Water content = 0.40
Maximum Water content = 0.45

(iv) Calculation of Fine and Coarse aggregate [Clauses 4.4 & Clauses 4.6 (IS10262:2009)]
For Fine aggregate,
$$V = \left[W + \left(\frac{C}{S_C}\right) + \left(\frac{1}{p}\right) * \left(\frac{Fa}{S_{Fa}}\right)\right] * \left[\frac{1}{1000}\right]$$
For Coarse aggregate,
$$V = \left[W + \left(\frac{C}{S_C}\right) + \left(\frac{1}{1-p}\right) * \left(\frac{Ca}{S_{Ca}}\right)\right] * \left[\frac{1}{1000}\right]$$
Where as
V = Absolute volume of fresh concrete which can be obtained by gross volume in cubic meter minus the total percentage volume of entrapped air.
W = Mass of water kg/m^3 of concrete.
C = Mass of cement kg/m^3 of concrete.
S_c = Specific gravity of cement.
p = Fraction of fine aggregate to total aggregate by absolute volume.

Fa and Ca = Total mass of fine aggregate and coarse aggregate kg/m³ of Concrete respectively.
S_{Fa} and S_{Ca} = Specific gravities of saturated surface dry fine aggregate and Coarse aggregate respectively.

2.2.1 Concrete Mix Design.

(i) From formula, $F_t = F_{ck} + K.S$
$F_t = 40 + 1.65 * 5 = 48.25$ N/mm²
(ii) Cement content C = 450 kg/m³
(iii) Selection of water content W (40%) = 450 * 0.40 = 180 kg/m³
(iv) Calculation of Fine and Coarse aggregate

From analyzed data:

Entrapped air = 2%
V = 100 - 0.02 = 0.98
V = Absolute volume of fresh concrete = 0.98
Cement content C = 450 kg/m³
Specific gravity of cement S_c = 3.15
Fraction of fine aggregate to total aggregate by absolute volume (p) = 0.38
Specific gravities of saturated surface dry fine aggregate S_{Fa} = 2.66
Specific gravities of saturated surface dry coarse aggregate S_{CA} = 2.66

For Fine aggregate,

$$V = \left[W + \left(\frac{C}{Sc}\right) + \left(\frac{1}{p}\right) * \left(\frac{Fa}{S_{Fa}}\right)\right] * \left[\frac{1}{1000}\right]$$

$$0.98 = \left[180 + \left(\frac{450}{3.15}\right) + \left(\frac{1}{0.38}\right) * \left(\frac{Fa}{2.66}\right)\right] * \left[\frac{1}{1000}\right]$$

Fa = 664.24 kg/m³

For Coarse aggregate,

$$V = \left[W + \left(\frac{C}{Sc}\right) + \left(\frac{1}{1-p}\right) * \left(\frac{Ca}{S_{Ca}}\right)\right] * \left[\frac{1}{1000}\right]$$

$$0.98 = \left[180 + \left(\frac{450}{3.15}\right) + \left(\frac{1}{1-0.38}\right) * \left(\frac{Ca}{2.66}\right)\right] * \left[\frac{1}{1000}\right]$$

Ca = 1083.76 kg/m³

Proposed Mix Design

Table - 3: Proposed Mix Design (kg/m³) of Concrete

S.No.	Materials	Proportions
1	Water (L.)	180
2	Cement (kg.)	450
3	Sand (kg.)	664.24
4	Aggregate (kg.)	1083.76
5	(C : S : A)	1 : 1.47 : 2.40

Table - 4: Proposed Design Parameters

Batch Designation		Fibers (%)	Grade of Concrete	Adopted Mix Proportion
Title	Description			
S1	Conventional	0	M 40	1:1.47:2.40
S2	Fiber Reinforced Concrete	2		
S3		4		
S4		6		
S5		8		
S6		10		
S7	Sand Replaced Concrete	2		
S8		4		
S9		6		
S10		8		
S11		10		

3. RESULT ANALYSIS

3.1 Results of tests performed on Fresh Concrete

3.1.1 Slump tests results

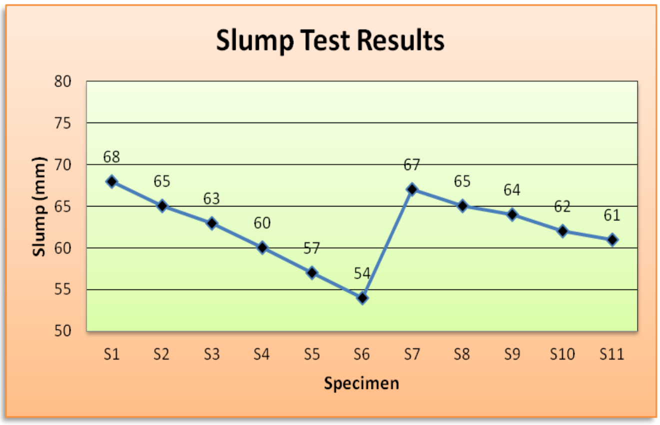

Chart- 1: Variation in Slump values for different mix.

3.1.2 Compaction Factor tests results

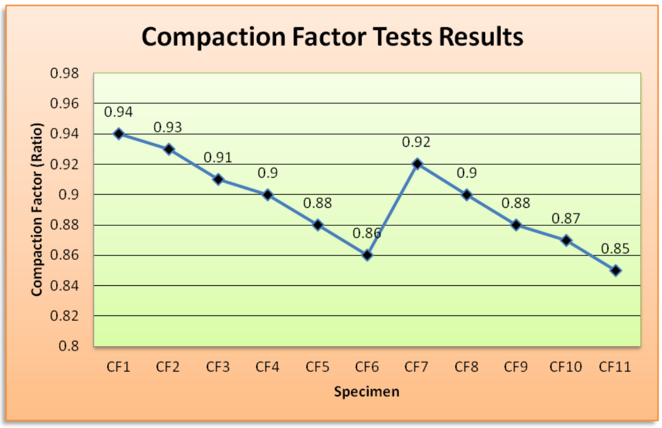

Chart- 2: Variation in Compaction Factor for different mix.

iv. The positive effects of the fibers become more significant after 28 days, but still it was capable of giving better early strength to the concrete as compared to the plain concrete.
v. The use of fiber resulted in better elasticity of hardened concrete than conventional concrete without affecting its performance.
vi. Replacement of fine aggregates also helped in achieving good compressive and flexural strength. Hence it is capable in reducing quantity of fine aggregates up to 10% without affecting the strength of the concrete.

REFERENCES

1. Arun Kumar Jain, Ashok Kumar Jain and B.C. Punmia, “Reinforced Concrete Structures” Vol. 1, published by Laxmi Publications Pvt. Ltd, 1992.
2. Craig O. Thomas, Robert C. Thomas and Kenneth C. Hover, “Wastepaper Fibers in Cementitious Composites”, Journal of Environmental Engineering, Vol. 113, Issue 1 February 1987, pp 16-21.
3. Elie Awwad, Mounir Mabsout, Bilal Hamad and Helmi Khatib, “Preliminary Studies on the use of Natural Fibre in Sustainable Concrete”, Lebanese Science Journal, Vol. 12, No. 1, 2011, pp 109-117.
4. H. Abdul Razak and T. Ferdiansyah, “Toughness Characteristics of Arenga Pinnata Fibre Concrete”, Journal of Natural Fibers, Vol. 2, Issue 2, 2005, pp 89-103.
5. H. Mohamma Dhosseini and A.S.M. Abdul Awal, “Physical and Mechanical Properties of Concrete containing Fibres from Industrial Carpet Waste”, International Journal of Research in Engineering and Technology, Vol. 02, Issue 12, December 2013, pp 464-468.
6. IS: 516-1959, “Method of Test for Concrete” Bureau of Indian Standards, New Delhi 1959.
7. IS: 1199-1959, “Method of sampling and analysis of Concrete” Bureau of Indian Standards, New Delhi 1959.
8. IS: 383-1970, “Specification for coarse and fine aggregates from natural sources for concrete” Bureau of Indian Standards, New Delhi 1970.
9. IS: 12269-1987, “Specification for 53 grade ordinary Portland cement” Bureau of Indian Standards, New Delhi 1987.
10. IS: 9103-1999, “Specification for admixtures for concrete” Bureau of Indian Standards, New Delhi 1999.
11. IS: 10262-2009, “Recommended guidelines for concrete mix proportioning” Bureau of Indian Standards, New Delhi 2009.
12. Jayeshkumar Pitroda, L.B. Zala and F.S. Umrigar, “Innovative use of paper industry waste (hypo sludge) in design mix concrete”, International Journal of Advanced Engineering Technology, Vol. 4, Issue 1, Jan-March 2013, pp 31-35.
13. J.H. Morton, T. Cooke and S.A.S. Akers, “Performance of Slash Pine Fibers in Fiber Cement Products”, 10th International Inorganic Bonded Fiber composite conference, November 15-18, 2006 Sao Paulo, Brazil, pp 168-177.
14. L. Lawrence, J.R. Bicudo and E.Wheeler, “Horse Manure Characteristic Literature and Database Review”, Proceeding of the Ninth International Symposium Animal, Agricultural and Food processing Wastes IX. Raleigh, NC. ASAE, St. Joseph, MI., 2003, pp 277-284.
15. Pravin V Domke, “Improvement in Strength of Concrete by using Industrial and Agriculture Waste”, IOSR Journal of Engineering, Vol. 2 (4), April 2012, pp 755-759.
16. Ravindra K. Dhir, Trevor G. Jappy, “Exploiting Waste in Concrete”, Proceedings of International Seminar, University of Dundee, Scotland, UK in 1999.
17. Siddique Rafat, “Characteristics of Concrete Reinforced with San fibers”, Research gate, Article: January, 1996.
18. S.K. Duggal, “Building Materials”, fourth edition, published by New Age International (P) Limited, 2016.
19. Syed Mazharul Islam, Raja Rizwan Hussain, and Md. Abu Zakir Morshed, “Fiber Reinforced Concrete incorporating locally available Natural Fibers in Normal and High Strength Concrete and a performance analysis with Steel Fiber Reinforced Composite Concrete” Journal of Composite Materials, Vol. 46, 1, January 2012, pp 111-122.
20. Zhijian Li Lijing Wang and Xungai Wang, “Compressive and Flexural properties of Hemp Fibre Reinforced Concrete”, Journals of Fibers and Polymers, Vol. 5, Issue 3, September 2004, pp 187–197.