ISSN 2229-5518

STRENGTH CHARACTERISTICS OF CORRUGATED ROOFING ELEMENTS REINFORCED WITH GROUND GRANULATED FURNACE SLAG &POLYESTER FIBER

[2]Mr, Santhosh patil k.g

Mtech structural engineering,

Department of Civil Engineering

The Oxford College of Engineering, Bangalore, Karnataka, India;

Email id:**santhoshpatilkg@gmail.com**

[1]Mr,Arunkumar B.N., Assistant Professor, Department of Civil Engineering The Oxford College of Engineering, Bangalore,Karnataka,India;
Email id: arunsagar555@gmail.com,

ABSTRACT

In this paper artificial fiber namely polyester fibers are used as reinforcement in cement matrices for producing corrugated roofing sheets has been investigated and reported. Ground granulated blast furnace slag -based polyester fiber roofing sheets were cast manually and the strength of the corrugations of the above composite sheets in terms of splitting, due to direct and impact loads, were experimentally evaluated. It is found that the strength towards splitting of corrugations of the GGBS based polyester fiber corrugated roofing sheets due to direct and impact loads was improved as compared to the corrugated sheets without polyester fibers. Also it is observed that GGBS based polyester fiber reinforced sheets are comparable to the splitting of corrugations due to direct and impact loads of a commercial roofing sheet, as the fibers are the crack arresters and absorbs energy. The roofing tiles can be adapted particularly for hot climate due to its high insulation properties and therefore suitable to provide shelter for livestock by using the locally available waste materials for its production. Most of the corrugated roofing sheets have damaged due to tearing out at its corrugations by high wind loads and impact loads. The strength of these corrugations can be improved with fiber reinforcement. And also flexural, impact and water absorption testing on corrugated roofing elements.

Keywords: *Polyester fibers, Ground granulated blast furnaces slag, corrugated roofing sheet, bending strength,residual impact.*

1. INTRODUCTION:

Concrete is a very strong and versatile mould able construction material. It consists of cement, sand and aggregate (e.g., gravel or crushed rock) mixed with water. The cement and water from a paste or gel which coats the sand and aggregate. When the cement has chemically reacted with the water (hydrated), it hardens and binds the whole mix together. The initial hardening reaction usually occurs within a few hours. It takes some weeks for concrete to reach full hardness and strength can continue to harden and gain strength over many years. On its own, concrete has excellent resistance to compression, but is very poor in tension. To give it good load bearing capability when under tension, it has to be reinforced with steel bar, polymer strands or fibers. When the concrete has set, the tension is released and the reinforcement tries to pull back to its original length. Can be overcome by the inclusion of a small amount of short randomly distributed fibers (natural, glass, synthetic and steel) and can be practiced among others that remedy weaknesses of concrete, such as low growth resistance, high shrinkage cracking, low durability, etc. Fiber reinforced concrete (FRC) is a fiber reinforcing cementitious concrete composite,

ISSN 2229-5518

and by adding discrete short fibers randomly in concrete it exhibits many substantially improved engineering properties in compressive strength, tensile strength, flexural strength etc. The fibers are able to prevent surface cracking through bridging action leading to an increased impact resistance of the concrete.

The ordinary Portland cement is one of the main ingredients used for production of concrete. Production of cement involves emission of large amounts of carbon Di -oxide. Hence it is inevitable to search for material or partly replace it by some other material. Researchers all over the world are attempting to develop high strength concrete by using pozzolana and relevant admixtures in concrete up to certain proportions for better workability, durability and strength. Early consisted of natural, readily available materials like volcanic ash or diatomaceous earth.

2. MATERIALS AND METHODS:

2.1 MATERIALS:

Ordinary Portland cement (OPC - 43 grade); graded river sand conforming to IS: 383[44]; potable water and polyester fiber (0.25%, 0.5%, 0.75%, 1.0%,)by volume of mortar; and fiber length is 6mm were the various material used. Ground granulated blast furnaces slag was obtained from the nearest iron industry in Bellary , Karnataka, India. GGBS is obtained by quenching molten iron slag (a by-product of iron and steel-making) from a blast furnace in water or strum, to produce a glassy, granular product that is then dried and ground into a fine powder. The basic properties of the above materials are given in Tables: 1 to 5. And hence it is expected to possess both the 'pozzolanic and binding properties'.

2.2 METHODOLOGY:

Corrugated AC sheets of size 1.0m x 1.2m x 6mm (commercially available) was used as a mould to cast polyester fiber cementitious composite corrugated sheets of size 500 x 320 x 10 mm. 1:3 mix (Cement: Sand) was selected and adopted to cast the sheets using Ground granulated blast furnaces slag by partially replacing OPC. However, replacement of OPC by Ground granulated blast furnaces slag was restricted to a maximum. Therefore, Three replacement levels of Ground granulated blast furnaces slag (i.e., 30%,40% 50%) were adopted for the above investigation. Four fiber (polyester) contents in the range of 0.25% to 1% were considered for splitting studies on the corrugations of roofing sheets. Altogether 20 mix combination was considered (4 combination without Ground granulated blast furnaces slag and fibers and 4 combinations without Ground granulated blast furnaces slag but with polyester fibers and 12 combinations with Ground granulated blast furnaces slag and polyester fibers). For each mix combination, three sheets were cast. Water content required for each combination of the mix was obtained from the flow table test for 1:3 mix, with and without Ground granulated blast furnaces slag and with and without polyester fibers, at a constant flow value of 50. And also 3 cubes and 1 cylinder each is cast with the above combination for compression and split tensile testing. The salient stages in the casting of corrugated sheets are shown in fig-1.

3. TESTS:

Generally roofing sheets are expected to fulfill certain properties such as: (i) light in weight so as not to impose a heavy load on the building; (ii) good flexural strength - so as to offer a good load - (super imposed/total) carrying capacity; (iii) ductility - so as to sustain impact loading; (iv) water tightness - so as to prevent penetration/seepage of rain water into the building ; (v) fire resistant - so as to prevent/retard ignition and spreading of fire; (vi) good thermal properties - so as to provide a 'pleasant indoor climate' for a comfortable living.
In the present study, tests were conducted to determine the following characteristics of the corrugated polyester fiber reinforced sheets: (1.) compressive strength of mortar cubes (2.) split tensile strength of mortar cylinders (3.) flexural strength of corrugated sheets (4.) impact strength of corrugated sheets (5.) water absorption of corrugated sheets. The testing setups are shown in the following fig-2 with the above designations 1-4.

4. RESULTS AND DISCUSSIONS:

4.1 Compressive strength:

The behavior of cement mortar with Ground granulated blast furnaces slag as a blended material is reflected in the Table-6 which is a result of obtained experimental values.

The specimen with 30% replacement is showing a lower strength at 0% fibers. As the fiber content increases to 0.75% there is a gain in the strength. The achieved strength is not retained as the fiber content is increased, this might be due to the soft pockets of fiber that could be in the form of lumps.

The compressive strength of specimen with 50% Ground granulated blast furnaces slag is highest among the other replacement levels of 30% and 40%. The strength of this is around 18% lesser than the controlled mortar specimen. These reductions in strength is not very critical and hence cement mortar with 40% replacement of Ground granulated blast furnaces slag having 0.75% polyester fiber by volume can be very well used as a mortar mix for all works.

The mortar specimens with 40% and 50% replacement of Ground granulated blast furnaces slag have higher initial strength with no fibers but as the fiber content keeps increasing there is a drastic reduction in load taking capacity. This can be attributed to the lower rate of strength gain caused by addition of Ground granulated blast furnaces slag. These specimens are observed to lose around 35% of the strength with respect to the controlled mortar specimen.

4.2 Split Tensile Strength:

With the values reflected in the Table-6 the following analysis and discussions can be carried out. Cement mortar with 30% Ground granulated blast furnaces slag and having 0.75% as fiber has a good tensile strength by about 54% higher than the controlled cement mortar cylinders with no Ground granulated blast furnaces slag and fibers.

Cement mortar cylinders with 40% replacement of Ground granulated blast furnaces slag is showing better tensile strength than 30% replacements at 0.75% fiber addition by volume. Later on as the fiber % increases there is a reduction in strength till 0.5% additions, but it's also observed that beyond 1% there is an increase in tensile strength.

4.3 Bending strength:

From the above Table-8 and it was observed that irrespective of the Ground granulated blast furnaces slag content specimens having 0.75% fibers by volume are having higher bending strength than the other % fibers added, specimens with 50% Ground granulated blast furnaces slag is observed to have highest strength of 3.678N/MM^2 .

4.4 Impact strength of corrugations:

The results of the Impact strength test on corrugation of polyester fiber corrugated sheets in CM 1:3 are shown in the above Table: 8. Incorporation of polyester fibers in the cement mortar had generally contributed to comparable/marginal improvement in the impact strength and post cracking behavior i.e., "Ductility" measured in terms of "Irs" to that of plain cement mortar sheets, upto 1% of fiber content in the composite. Impact strength characteristics of corrugations of GGBS cement mortar composite corrugated sheets are not significantly improved due to the incorporation of GGBS, especially the ductility of the composite, as evident from the "Irs". However, in terms of actual energy absorbed there is substantial improvement up to 0.75% fiber content along with 30-50% GGBS. From the point of actual energy absorbed (i.e., at the initiation of crack and at failure) and ductility in terms of Irs[1], corrugated sheets with 0% GGBS and 0.75% fiber content, performed better to that of cement mortar corrugated sheets. And also at 50% GGBS replacement there was consistent ductility observed in case of 0.25 to 1% fiber addition, it is observed from the test, with the increase GGBS replacement along with fibers the ductility has reasonably increased.

4.5 Water Absorption:

It is observed that fiber reinforced corrugated sheets are having a water absorption of 5.1% for specimen with 30% GGBS replacement is the highest. This is much less than water absorption limit of 10% for fiber reinforced roofing sheet elements.

5. CONCLUSION:

Salient conclusions, based on the comprehensive experimental investigations carried out and on the range of various parameters considered in the present study, are summarized below:

Compressive strength:

In obtaining compressive loading, all the specimens irrespective of the percentage GGBS as replacement are observed to be similar.

The compressive strength of the cubes for all mix increases with age at curing and decreases as the GGBS content increases.

The specimens with .75% &1% fibers by volume are found to be reasonably sound in taking the compressive loading.

The specimens with 40% & 50% GGBS, having the highest compressive strength among all other replacements are seem to be efficient.

Split Tensile Strength:

1. In taking tensile strength, specimens are having much higher value than reference mix as long as fiber volume is up to 1%.
2. As the fiber volume is increased beyond 1%, there is reduction in split tensile strength of all specimens. This might be attributed to interruption of fibers during formation of CSH gel and hence the bonding will be weak resulting in lower strength.

Bending strength:

- But specimens with 40% & 50% GGBS replacement are better than other replacement levels
- Normal concrete has shown to be much superior in having bending strength than Ground granulated blast slag replaced specimens at 0.25%, 0.5% and 0.75% fibers by volume.
- Fiber reinforced corrugated sheets with 40% GGBS replacement is showing higher bending strength other replacement levels 0.75% fibers by volume.
- Other than 40% &50% GGBS, 0.75% &1% fibers by volume seem to be optimum for all replacement levels giving more than 90 MPa as strength.

Impact strength:

- In having residual impact strength, 40% GGBS 0.75% fiber mix is having higher value when compared to all specimens with GGBS replacement.
- 1% fibers by volume is observed to give same residual impact strength ratio as that of other replacement levels as well as reference mix.

Water Absorption:

The water absorption of tiles is within the standard value of 6%.

For a given mix, the water requirement decreases as the Ground granulated blast furnaces slag content increase.

In total from the test results it can be concluded that for having the alternate corrugated roofing elements with fiber reinforcement only 30% GGBS replaced specimen having 0.5% to 0.75% as fibers by volume can be adopted.

6.REFERENCES:

1. G.Ramakrishna, T.Sundararajan and S.Kothandaraman, “Strength of corrugations of a roofing sheets Reinforced with sisal fibres” ARPN Journal of Engineering and Applied Sciences, Pondicheery, India, December 2011, Pg no: 24-32.
2. J.G.Keer and A.M.Thorne, “Performance of polypropylene reinforced cement corrugated sheeting” Composites, Volume 16, No.1, University of Surrey, UK, January 1985, Pg no:28-32.
3. M.B.Sayir, K.Hausler and M.Partl, “Impact behaviour of corrugated sheets of fibre- reinforced cement” Composites, Volume 23, No.6, Swiss Fedral Institute of Technology/ Swiss Fedral Laboratories for Materials Testing and Research, November 1992, Pg no: 441-452.
4. J.B.Studinka, “Asbestos substitutions in the fibre cement industry” The International Journal of Cement Composites and Light weight Concrete, Volume 11, No.2, May-1989, Pg no: 73-78.
5. Dr S Narayanan, Associate Member, Dr M S Mathews, Non-member, “Behaviour of Roofing Sheet Systems under Static Uplift Loads” IE (I) Journal-CV, Volume-84, November 2003, Pg no: 216-222.
6. C.M.R.Dias, M.A.Cincotto, H.Savastano Jr, V.M.John, “Long-term aging of fiber-cement corrugated sheets – The effect of carbonation, leaching and acid rain” Cement and Concrete Composites, Volume 30, Brazil, November 2007, Pg no: 255-265.

7. Silvio Delvasto, “Report about experiences with cement based corrugated sheets vaccum processing” International Inorganic-Bonded Fibre Composite Conference-2006, November 15-18, Sao Paulo, Brazil, Pg no: 218-228.
8. P.N.Opara, “Usability of rice husk in the production of roofing sheets” Journal of Agriculture and Social Research(JASR), Volume 6, No.1, 2006.
9. J.H. Morton, S.A.S. Akers, T.Cooke, “PERFORMANCE OF SLASH PINE FIBRES IN FIBRE CEMENT PRODUCTS” International Inorganic-Bonded Fibre Composite Conference-2006, November 15-18, Sao Paulo, Brazil, Pg no:168-177.
10. H.C. Uzoegbo, “Development of test methods for fibre reinforced roofing tiles” International Journal of Advanced Technology in Civil Engineering, South Africa, Pg no: 74-79.
11. Youjiang Wang, Stanley Backer, Victor.C Li, “An experimental study of synthetic fibre renforced cementitious composites” Journal of Material Science, Volume 22, Cambrige, USA, Pg no: 4281-4291.
12. Krunoslav Vidovic, Milan Ambrozic, Kristoffer Krnel, Tomaz Kosmac and Stephen Akers, “The fracture strength of fibre-cement corrugated sheets: A statistical approach using Weibull Analysis” International Inorganic-Bonded Fibre Composite Conference-2010, Switzerland, Pg no: 116-129.
13. KN Vishwanth and Raghu, “Effect of polyester fibres as filler material on compression and flexural strength of high strength flyash concrete” Preceedings of international conference on advances in architecture and civil engineering, Volume 1,ISBN:978-93-82338-01-7 Bangalore, Pg no:62-65.
14. “GOOGLE” Search engine.
15. IS 654-1992: Clay Roofing Tiles, Mangalore Pattern -- Specification
16. IS459:1992: Corrugated And Semi-Corrugated Asbestos Cement Sheets- Specification.
17. “Physico-Chemical characteristics Bending Strength”INSTITUT DE PROMOCIO CERAMICA, (www.ipc.org.es) pg no: 1-5.
18. G. Ramakrishna, T. Sundararajan, “Evaluation of durability of natural fibre reinforced cement mortar composite- a new approach” ARPN Journal of Engineering and Applied Sciences, Volume 5, No.6, June 2010, Pondicherry, India, pg no: 44-51.
19. IS: 383-1997: Specification for coarse and fine aggregates from Natural sources for Concrete, BIS, India.

TABLES:

Table-1: Physical properties of cement (OPC-43 grade).

Sl.no	Property	Value
1.	Standard consistency(%)	29%
2.	Initial setting time(min)	30min
3.	Soundness	1mm
4.	Specific gravity	2.6

Table-2: Physical properties of Ground granulated blast furnaces slag

Sl.no	Physical Properties	Values
1.	Physical State	Solid – Non Hazardous
2.	Appearance	Very fine powder
3.	Specific gravity	2.13
4.	Particle Size	25 microns – mean
5.	Odour	Odourless
6.	Fineness – median	8.3
7.	Density	2.9
8.	Finess m2/kg	450

Note: The properties were evaluated as per standard procedures prescribed in IS: 1727-1999[46] and IS: 4031(part8)-1988[47].

Table-3: Chemical characteristics of GGBS

Chemical Properties	**Values(%)**
Silicon dioxide (SiO_2)	90.7
Calcium oxide (CaO)	.4
Magnesium oxide (MgO)	0.8
(Al_2O_3)	.12
(Fe_2O_3)	.5
Others	.5

Result: specific gravity of fine aggregate is 2.60 and percentage of water absorption is 0.87%.

Table-4. Physical properties of polyester fibres.

Sl.no	Fibre type	Fibre	Cross-	Melting	Elongation(%)	Specific	Young's	Alkaline
1.	Polyester	6	Triangular	240°C	20-60	1.34	>5000	Very

Table-5. Physical Properties of fine aggregates.

Sl.no	Property	Value/description
1.	Specific gravity	2.6
2.	Water absorption	1.4%
3.	Bulk density	1.737gm/cc
4.	Fineness modulus	2.5

Table-6: Compression and split tensile strength of cubes and cylinders respectively.

Sl.no	**Fibre (%)**	**Charateristic strength (Mpa) at GGBS contents of**					
		30%		**40%**		**50%**	
		A	**B**	**A**	**B**	**A**	**B**
1.	0%	17.43	13.3	23.96	15.3	26.23	12.3
2.	0.25%	21.8	11.2	25.8	12	26.8	13.1
3.	0.5%	24.36	8	27.1	11.8	27.6	10.8
4.	0.75%	36.23	10.8	37	16.3	40	19.9
5.	1%	35.6	15.2	36.2	15.9	38.96	17.4

Note: 1. (A) - Compression strength of cubes; (B) - Split tensile strength of cylinders.
2. Mix of 0% fibre and 0% GGBS combination was taken as reference mix

Table-7: Bending strength of polyester corrugated sheets

Sl no.	Fibre content (%)	Flexural strength at GGBS contents of			
		0%	30%	40%	50%
1.	0%	2.964	2.591	3.162	3.246
2.	0.25%	3.078	2.656	3.218	3.303
3.	0.5%	3.190	2.740	3.275	3.443
4.	0.75%	3.556	2.993	3.471	3.678
5.	1%	3.500	2.937	3.415	3.661

Table-8: Energy absorbed by the corrugations of polyester fibre fly ash-cement mortar corrugated sheets (500×320×10mm size)

No.	Fibre content (%)	Energy absorbed(Joules) for GGBS contents of											
		0%			30%			40%			50%		
		A	B	C	A	B	C	A	B	C	A	B	C
1.	0%	4.22	8.44	2	4.22	8.44	2	4.22	8.44	2	12.66	16.88	1.33
2.	0.25%	4.22	8.44	2	4.22	8.44	2	4.22	8.44	2	12.66	16.88	1.33
3.	0.5%	4.22	8.44	2	4.22	8.44	2	12.66	16.88	1.33	12.66	16.88	1.33
4.	0.75%	8.44	12.66	1.5	8.44	12.66	1.5	12.66	16.88	1.33	16.88	21.1	1.25
5.	1%	8.44	12.66	1.5	8.44	12.66	1.5	16.88	21.1	1.25	12.66	16.88	1.33

Note: A= energy absorbed at initiation of first crack, B= energy absorbed upto ultimate failure, C= Residual impact strength ratio= indicates ratio (B/A)

Table-9: Water absorption in polyester fibre Ground granulated blast furnaces slag- cement mortar corrugated sheets after 24hour immersion in water.

No.	Fibre content (%)	Water absorption(%) at GGBS contents of			
		0%	30%	40%	50%
1.	0%	2.57	2.44	3.047	2.106
2.	0.25%	2.352	1.728	1.086	3.055
3.	0.5%	3.055	1.319	1.184	1.939
4.	0.75%	3.1	3.543	4.987	4.060
5.	1%	2.8	5.115	2.061	2.894