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Determination Of The Mechanical Properties Of Cement Fiber Roofing Sheets Treated With Calcium Hydroxide And Calcium Silicate Hydrate

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Abstract: This paper investigated mechanical properties of cement fibre roofing sheets manufactured using calcium hydroxide and calcium silicate hydrate as treatment and enhancing agents, respectively. Standard methods of production of cement fibre roofing sheets were detailed. The study has confirmed that stronger and more durable cement fibre roofing sheets could be produced.

I. INTRODUCTION

Cement fibre roofing sheets are manufactured employing completely indigenous technology, plant and machinery. The physical characteristics of cement fibre roofing sheets such as thermal insulation, fire resistance, water absorption and water permeability are favourable compared with Asbestos Cement and other conventional sheets. These sheets can be used for temporary and semi-permanent structures. Coir waste, wood wool or Sisal fibre can be profitably utilised in combination with cement as a binder for production of corrugated or plain roofing sheets.

The primary reason for the addition of fibers to cementitious matrixes is to delay and contain cracking. While it is generally believed that the inclusion of fibers enhances the pre-cracking behavior of cement composites by increasing its cracking strength, the effect of fiber addition becomes evident only after cracking. Fibers bridge the cracked parts of the matrix, thus delaying sudden global failure of the composite.

Therefore, in the post-cracking stage, the fiber behavior is governed by the interfacial bond stress response as being subjected to pullout loads. The bond between fiber and matrix is important—if fibers have a weak bond with the matrix, they can slip out at low loads and do not contribute to preventing the propagation of cracks. However, if the bond is too strong, then the fibers may rupture before they can contribute to the post-crack strength of the matrix material.

Fiber-reinforced composites (FRCs) resist tensile forces through a composite action, whereby part of the tensile force is resisted by the matrix, while the balance is taken by the fibers. The transmission of forces between the fiber and the matrix is achieved through a bond defined as the shearing stress at the interface between the fiber and the surrounding matrix. The fiber contribution to increasing the toughness (total energy absorbed with a unit mJ) of the composite is primarily dictated by the mechanisms of fiber pullout. Fiber pullout tests are often used to study the fiber-matrix bond behavior in fiber-reinforced cement composites.

Although calcium silicate hydrate (CSH) is critical to cement paste strength and durability, many ambiguities remain regarding its atomic structure. This knowledge is vital for optimizing CSH-based concretes with the aim of reducing the CO_2 associated with its production. Despite extensive study, CSH in cements has continued to escape detailed and direct atomic structure analysis for two main reasons: difficulty in separating it from other phases and its broad diffraction signal.

The manufacture of every ton of Portland clinker emits approximately 0.8 tons of CO_2 into the atmosphere, comprising 5%–7% of the total human-made CO_2 emission.

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CSH is the main binding phase in a Portland cement matrix; therefore, there is strong motivation to optimize the strength and durability of CSH so that less cement is used.

Despite the vast amount of literature available on cementitious materials, many questions and ambiguities on the understanding of the atomic scale structure of this cement remain. Colloidal models proposed by Jennings (Jennings, 2008; Allen, 2007) elegantly explain several bulk properties of CSH found in hydrated cement pastes. The basis of these models is the existence of a <5 nm diameter building block in CSH. Although neutron scattering (Allen, 2007), electron microscopy, and computer simulation have suggested the existence of such nanograins, they have yet to be demonstrated beyond reasonable doubt. An improved understanding of the atomic arrangement in cement paste can provide a basis for intelligently designing concrete with enhanced properties because one can manipulate the layered CSH structure and create a true hybrid CSH with such detailed structural information. For example, organic polymeric additives have shown to strongly interact with the surface of hydrated CSH, yet controlling the exact pathways or mechanism of the interaction between the organic molecules and CSH is limited to date mainly due to the limitation on the knowledge of the precise structure of CSH.

Cement fibre roofing sheets can be treated with Calcium Silicate Hydrate for a number of reasons. To develop sustainable, green construction material, natural fibre reinforcement in a cement matrix is a feasible approach. Fibres from natural sources have the potential to be used as reinforcement in cement composite to overcome the inherent brittleness of the cementitious materials. Adequate research has been done to develop high-performance fibres like bamboo, sisal, coconut and coir reinforced cement composites.

The natural fibres in the cement matrix impart adequate toughness and ductility to the cement composite. However, the fibre-cement compatibility and hydration delaying activity of such fibres must be taken into consideration, which could be ensured by effective modifications either to the fibre surface or to the matrix composite. The fibre surface treatment is particularly important to reduce the hydration delaying activity and to improve the fibre strength as well as composite strength by improving the fibre matrix compatibility.

Hydration of cement is a complex sequence of interactions occurring between water and chemical phases of the cement (viz., tricalcium silicate ($3CaO·SiO_2$), dicalcium silicate ($2CaO·SiO$), tricalcium aluminate ($3CaO·Al_2O_3$) and tetra calcium aluminoferrite (($Ca_2(Al,Fe)_2O_5$)) (Neville, 2000; Gartner et al,2002; Mindess et al, 2003). Calcium hydroxide and calcium silicate hydrate are produced predominantly as hydrated cement products (Myers et al, 2013; Ridi et al, 2012). However, the cement hydration reaction equilibrium as well as nucleation and growth of the hydrated cement product may be disturbed by the presence of foreign substances. In natural fibre reinforced cement composite, the natural fibre leaches various organic soluble sugars in the cement medium, which form a protective layer around the cement grains (Jo et al, 2014). The protective layer of sugars prevents water from percolating to further hydrate the cement grain (Chakraborty., Kundu., Roy., Adhikari and Majumder, 2013; Bishop and Barron, 2006). Consequently, the nucleation and growth of the hydrated product is delayed. Therefore, an immediate practical plan is required to establish the convalescence of the antagonistic effect of the natural fibre.

Modifying the fibre may improve the fibre matrix compatibility as well as reduce the hydration delaying effect. Some special treatments such as silane grafting, hot-cold water extraction, and chemical soaking of the natural fibres are reported elsewhere to achieve targeted properties (Bilba and Arsene,2008; Eusebio., Soriano., Cabangon and Evans,2000; Alberto., Mougel and Zoulahan, 2000). Moreover, the alkali treatment is a unique scheme to remove soluble sugars from the fibre which remain dispersed in the interfibrillar region of the natural fibre (Bledzki and Gassan, 1999).

Due to the removal of the impurities from the interfibrillar region of the natural fibres, the fibrils become more capable of rearranging themselves along the direction of tensile deformation, which in turn leads to enhanced mechanical properties of the fibre (Bledzki and Gassan, 1999).

The cost of roofing sheets has been astronomically high in Nigeria for some years, now. This has adversely affected the level of housing provision in the country, especially among the low-income group. Some of the sheets produced from research investigations are heavy, not durable or difficult to install. This study is therefore necessary to bridge this gap.

The aim of this work is to produce sustainable cement: fibre roofing sheets impregnated with Calcium Hydroxide and Calcium Silicate Hydrate. The objectives included:

- ✓ Appraising existing similar roofing sheets used in building construction;
- ✓ Producing samples of roofing sheets, using the proposed matrix and
- ✓ Determining the mechanical properties of the proposed roofing sheets.

This study investigated only the following properties of the roofing sheets: water absorption; density; flexural strength and impact strength. Only natural coconut fibres were used in this study.

II. MATERIALS AND METHODS

From the load-extension data, the values of stress and strain were obtained. Four different thicknesses of fibres were tested under tensile strength test. Fibres fitted in the jaw of the tensile testing machine with gauge length (clear fibre length from one jaw to another) of 35 mm. For making corrugated sheets, weighed quantity of the fibre is soaked in water for sometime which is mixed with pressed quantity of cement thoroughly. The cement coated mixed stuff is uniformly spread on the drag mould and is pressed by hydraulic press.

The wedged mould assembly is then rolled out of the press and is cured for 3-4 hours in the curing yard. Water proofing paint is applied on top side of the sheets after demoulding.

The main reasons for the use of natural fibres are abundantly available and are comparatively cheap. Natural fibre composites are also claimed to offer environmental advantages such as reduced dependence on non-renewable energy/materials sources, lower pollutant emissions, lower greenhouse gas emissions, enhanced energy recovery and end of life biodegradability of components (Joshi, 2003; Majeed, 2011; Hamzah *et al*., 2010).

C. Mechanical properties of cement fiber roofing sheets impregnated with Calcium hydroxide and Calcium silicate Hydrate.

III. RESULTS

The following results were obtained from the study:

S/NO	GROUP A	GROUP B	GROUP C
1	22.52	26.50	32.25
2	21.85	25.10	30.10
3	20.50	27.25	29,25
4	21.65	26.45	30.40
5	20.65	25.30	28.75
Mean value	**21.43**	**26.12**	**30.15**

Table 1: Water absorption of roofing sheet samples (%)

S/NO	GROUP A	GROUP B	GROUP C
1	1250.00	1251.00	1251.15
2	1250.10	1250.95	1251.00
3	1250.05	1250.98	1251.22
4	1250.00	1251.05	1251.25
5	1250.02	1250.15	1251.20
Mean value	**1250.03**	**1250.83**	**1251.16**

Table 2: Density of roofing sheet samples (Kg/m^3)

S/NO	GROUP A	GROUP B	GROUP C
1	8.00	7.55	6.42
2	8.10	7.30	6.25
3	7.98	7.52	6.10
4	8.10	7.25	6.00
5	7.90	7.40	6.15
Mean value	**8.02**	**7.40**	**6.18**

Table 3: Flexural strength of roofing sheet samples (N/mm^2)

S/NO	GROUP A	GROUP B	GROUP C
1	70.25	65.50	63.55
2	71.00	64.90	62.97
3	70.20	65.20	63.22
4	69.85	65.00	64.00
5	70.20	65.15	63.00
Mean value	**70.30**	**65.15**	**63.35**

Table IV: Impact strength of roofing sheet samples ($J/s/m^2$)

S/NO	GROUP A	GROUP B	GROUP C
1	7.21	5.20	3.45
2	6.85	5.45	3.20
3	7.15	5.22	3.55
4	7.25	5.40	3.25
5	6.92	5.50	3.10
Mean value	**7.08**	**5.35**	**3.31**

Table 5: Compressive strength of roofing sheet samples (N/mm^2)

IV. RESULTS AND DISCUSSION

From the analytical characterizations, it is determined that fibre-cement compatibility is increased and hydration delaying effect is minimized by using alkali treated jute fibre as fibre reinforcement. Based on the experimental results and observations, the following can be stated:

In all cases, the compressive strength of the sheets decreased as the volume percentage of coconut fibres increased in the mix.

Compressive strength with the 3% coconut fibre volume (Group A) is between 6.92 and 7.21 N mm-2 with a mean value of 7.08 N mm^{-2} at 28 days and it satisfies the structural requirement of lightweight roofing sheets.

The 3% coir fibre volume sheets had the optimum set of mechanical properties in comparison with other cement fibre sheets.

Conventional roofing specimens were fully crushed when they reached their ultimate failure load but the specimens in case of 1% and 3% of coconut fibre by volume did not crush when they reached their ultimate failure load. Thus, cement fibre roofing sheets can enhance higher toughness.

V. CONCLUSION

Cement/ Coir fibre corrugated sheets require 30 percent less cement as compared to asbestos cement sheet. The sheets are light and can be carried over hilly and rough roads without any breakage.

The sheets are strong and possess good bending strength. A man can safely walk over them. The sheets possess good thermal insulation and are expected to provide greater comfort in tropics as compared to AC/CGI sheets. Their preparation needs neither heavy machinery nor high capital investment. The sheets are 50 percent cheaper than AC/CGI sheets. These can be laid on roof like AC/CGI sheets. The roofs made do not require any further finishing or waterproofing treatment and are fire-resistant.

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