PARTIAL SUBSTITUTION OF CELLULOSE WITH TISSUE WASTE PAPER IN FIBRECEMENT SHEETS

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ABSTRACT

Cellulose fibres contribute to the development of high quality, environmentally friendly building materials. While the properties of cement-based building materials reinforced with the natural cellulose fibres from plants and agricultural crops are abundantly described in the literature sources, the implementation of cellulosic fibres sourced from waste paper in cement mortars or composites has not been sufficiently investigated.

The work presented in this paper explores the waste paper material sourced from the tissue making industry. The waste from this industry is treated through the wet lap process to produce the C+ and H2 grades that were investigated. It is shown that inclusion of the waste paper fibres in the fibre cement autoclaved mix enhanced the mechanical properties and the density by 5%. A significant increase in mechanical properties was observed in natural cured products where the cellulose was completely replaced with waste paper fibres. Over 10% reduction in movement of sheets was noted with incorporation of waste paper fibres.

KEYWORDS:

Cellulose; H2 grade; C+ grade; sludge; waste paper.

INTRODUCTION

Lignocellulosic fibres are available mainly from wood, but several plants and agricultural crops as well as industrial residues can be considered as potential sources of raw materials (Khiari et al., 2011). Waste paper provides a potential source of raw materials because paper is produced and used globally, and this leads to the production of enormous quantities of waste paper (Danial et al., 2015). Waste paper sources originate from many paper kinds such as newspaper, office and printing papers, boxes and paper packaging. The quality of cellulosic fibres from recycled paper depends on the waste paper purity. The utilization of waste paper fibres as an alternative process/ reinforcing material in cement composites could resolve the cost issues and simultaneously improve the associated environmental concerns (Sangrutsamee et al., 2012)

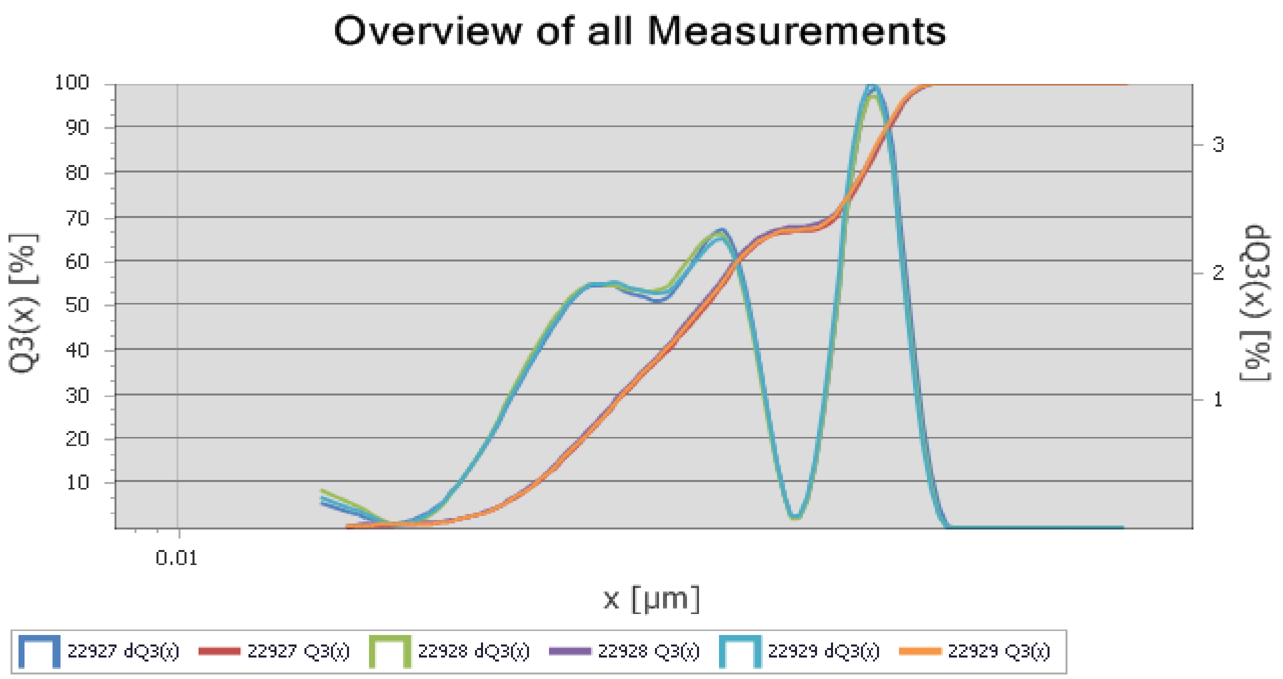
Natural lignocellulosic fibres provide significant improvement over the characteristics of cement-based materials, given their low cost in comparison to synthetic fibres, have no known health hazards, have adequate stiffness and strength, are easy to recycle and are eco-friendly. The physico-mechanical properties of fibre cement based composites depend on the fibre-matrix interactions. The interface controls the strength of composite materials, because stress is transferred from fibre to fibre through the matrix (Mohammadkazemi, 2015).

The objective of the present study was to investigate the feasibility of partial or complete substitution of cellulose fibres in fibre cement composites with waste paper from the tissue making industry. The scope explored the substitution in both fibre cement autoclaved and natural cured composites. Three grades of waste paper fibres were used – H2, C+ and sludge. The resulting properties of fibre cement composites were compared with those of the reference cement composite reinforced with cellulosic fibres originating from wood pulp.

MATERIALS AND METHODS

Materials

The materials used in these trials were cement, sand, condensed silica fume, polyvinyl alcohol (PVA) cellulose, waste paper and water. The sand was milled with steel balls and water until the desirable fineness was achieved, see Figure 1.



Q3(x) [%]	x [µm]	CV [%]	M22927	M22928	M22929
10	1	1.5	1	1	1
50	8.7	2.8	9	8.4	8.7
90	91.1	1.6	93	90.6	89.7

x [µm]	Q3(x) [%]	CV [%]	M22927	M22928	M22929
38	67.9	0.6	67.4	68.4	67.8
75	83.5	0.7	82.7	83.7	84
90	89.6	0.6	88.9	89.8	90.1
212	100	0	100	100	100

Figure 1: Particle size distribution curve for milled silica

The cement used was 32.5N, containing calcium carbonate with no grinding agents. For natural cured fibre cement composite, condensed silica fume was utilized and its properties are presented in Table 1. Cellulose fibres used were received at a kappa number range of 24 – 32 and fibre lengths greater than 3mm. These fibres were refined to a freeness of 400 – 440 CSF. The PVA fibres added were 6mm long with a tenacity of 13 cN/dtex and Young’s modulus of 320 cN/dtex. The two grades of waste paper, H2 and C+, had the properties demonstrated in Table 2 and the image in Figure 2. The third waste paper material was a sludge collected at the end of the tissue making process and used as is, untreated.

Table 1: Condensed silica fume properties

Customer Specifications					
SPEC	% SiO_2	% Moisture	% LOI	% > 45 micron	%MgO
Min	85.0				
Max		0.8%	4.0%	5.0%	1.0%
Chemical Results Per Lot					
Lot Number	% SiO_2	% Moisture	% LOI	% > 45 micron	%MgO
RC 9281	90.3	0.79	3.2	0.71	1.4

Table 2: Properties of waste paper fibres

Parameters	Wetlap C+ grade	Wetlap H2 grade
Dryness (%)	45 ±2	45 ±2
Brightness with UV part: (%)	66 ± 5	75 ± 4.5
Freeness (CSF)	350 ±100	380 ±100
Ash content (%)	3.5 ±1	3 ±1
Dirt particle: 50µm to 5mm (Spots/m^2)	<30000	<18000
Total yield (%)	66	68
Pulp dimensions: LxWxH (mm)	1000 x 1000 x 1100	1000 x 1000 x 1100

Figure 2: Treated waste paper

2.2 Methods

The mixing of all samples were carried out in two steps. In the first step, the refined cellulose fibres were mixed with water to obtain a consistency of 2% and stored in one chest. The waste paper was pulped with water, no refining required, and stored in a second chest. The mixture of 6% cellulose and 2% waste paper were added to the stirrer. For autoclaved samples, the second step consisted of cement, sand and water addition then mixing until a homogeneous distribution of fibres in the mixture was achieved. Flocculant was then added just before the mix box. The slurry was processed on the Hatschek machine to form 6mm ceiling board specimens. The standard sample was made with 8% cellulose, no waste paper. All the samples, cut into 250mm x 250mm, were shrink-wrapped with plastic for 24 hours, de-stacked at the end of this period before autoclaving for 14 hours.

On the other hand, natural cured specimens followed the same procedure as above but PVA fibres were added after cellulose then all the powders. The reference sample was prepared with 3% cellulose and on the other samples cellulose was replaced completely with waste paper. The samples, 250mm x 250mm, were shrink-wrapped with plastic and cured under atmospheric conditions. All the physico-mechanical parameters were measured on composite samples after 7 days and 28 days curing.

Tests which considered water absorption, density, modulus of rupture and linear expansion were carried out on the specimens.

RESULTS AND DISCUSSION

Autoclaved samples

The physical properties of fibre cement samples were determined after autoclaving. Samples were dried in the oven at 80°C for 24 hours then cooled in a desiccator before testing. The physical properties measured are graphically illustrated in Figure 3.

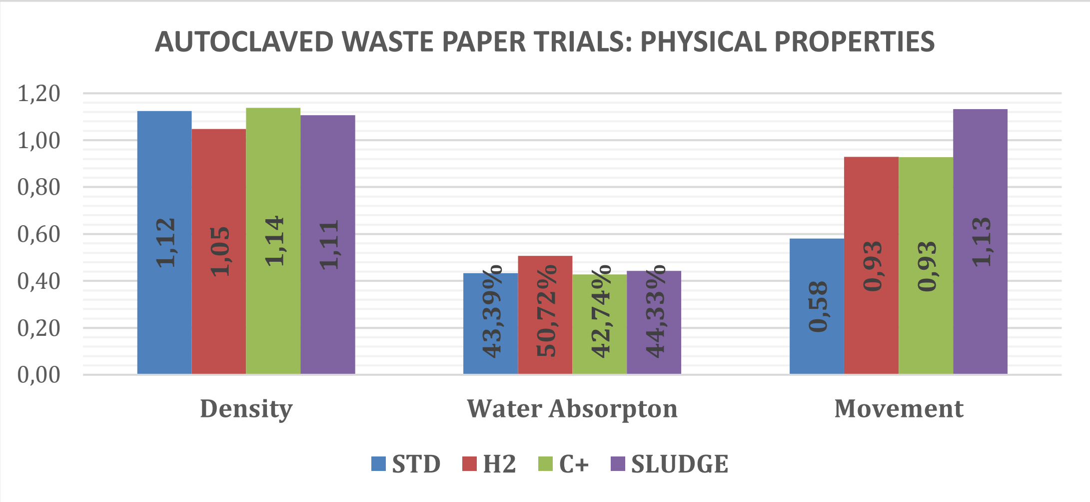


Figure 3: Physical properties of autoclaved samples

The density values were similar to the standard sample, with the exception of H2 sample that was low as a result of higher water absorption. The density is inversely proportional to the water absorption. The linear expansion is done to determine the movement in samples as the fibres swell. Addition of waste paper fibres resulted in higher linear expansion, with the sludge samples showing a 95% increase compared to the reference sample. The reduction is mainly attributed to the fact that recycled fibres are light in weight due to their porous structure and nature, leading to increases of water absorbability. Figure 4 presents the mechanical properties of all the autoclaved samples. The values plotted are an average of five samples tested. As can be seen, the modulus of rupture showed an increase as the waste paper fibres were introduced to the mix. The average increase was approximately 6% for the samples with waste paper fibres compared to the standard. The deflection of samples with waste paper fibres showed an increase of 3%, with the exception of C+ grade that had a reduction of 15%.

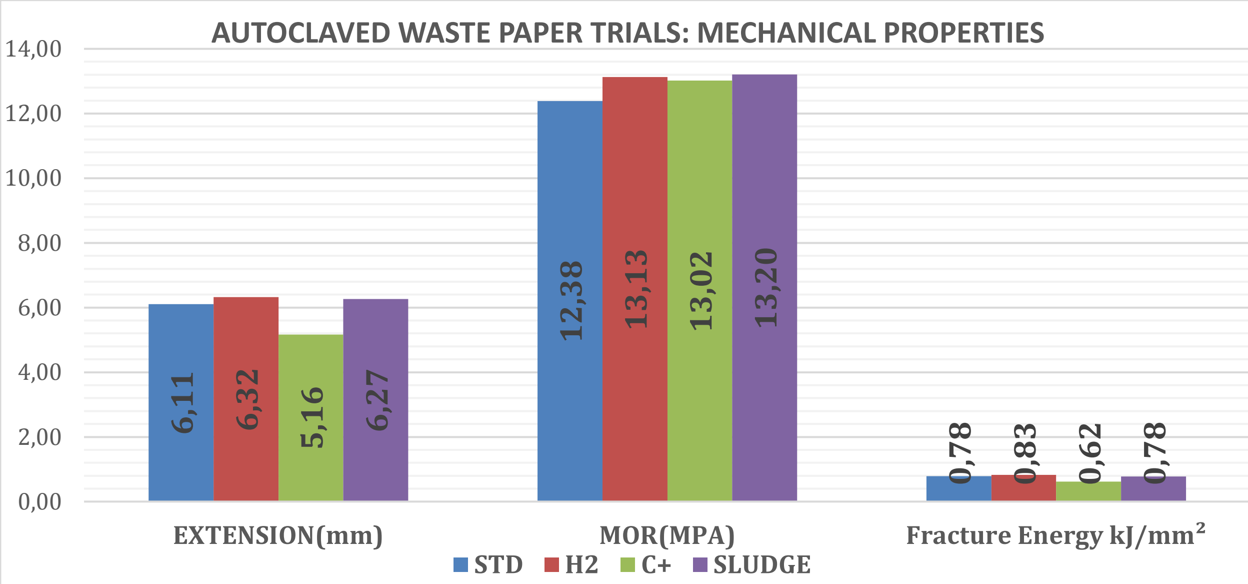


Figure 4: Mechanical properties of autoclaved samples

Natural Cured Samples

Tests were conducted at the end of 7 days and 28 days curing to determine the development of physical and mechanical properties with time. Figures 5 and 6 present the development of density and water absorption over 28 days curing. The H2, C+ and sludge samples showed an increase in density of 12%, 9% and 15% respectively compared to the standard. After 28 days there was a reduction in the increase, the sludge showing the least increase of 1.5% in comparison to the reference sample.

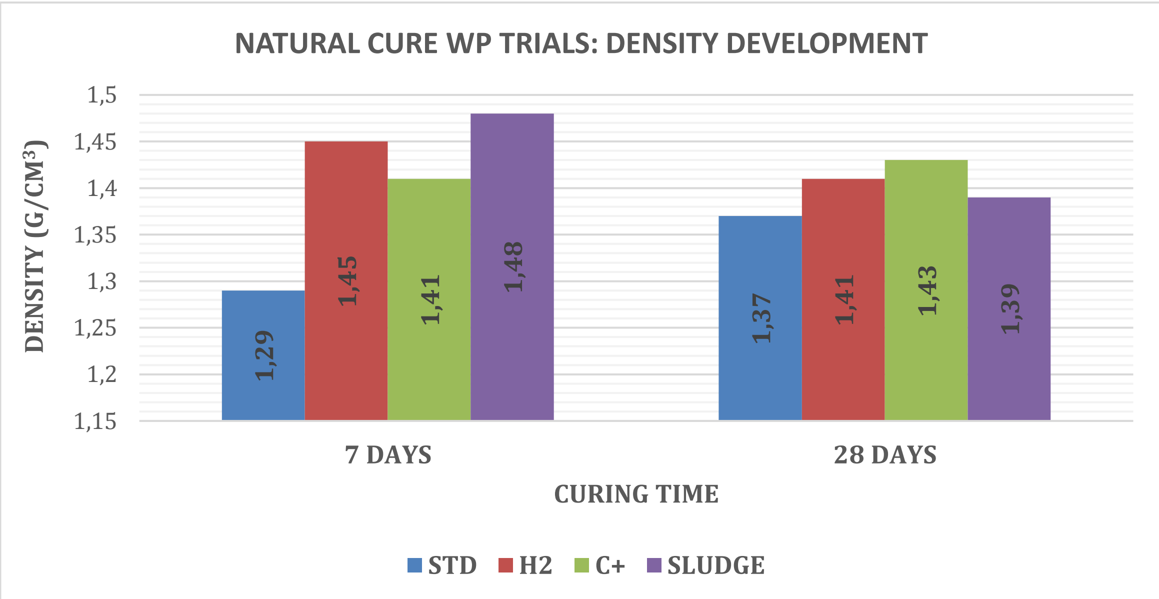


Figure 5: Density development of natural cured samples

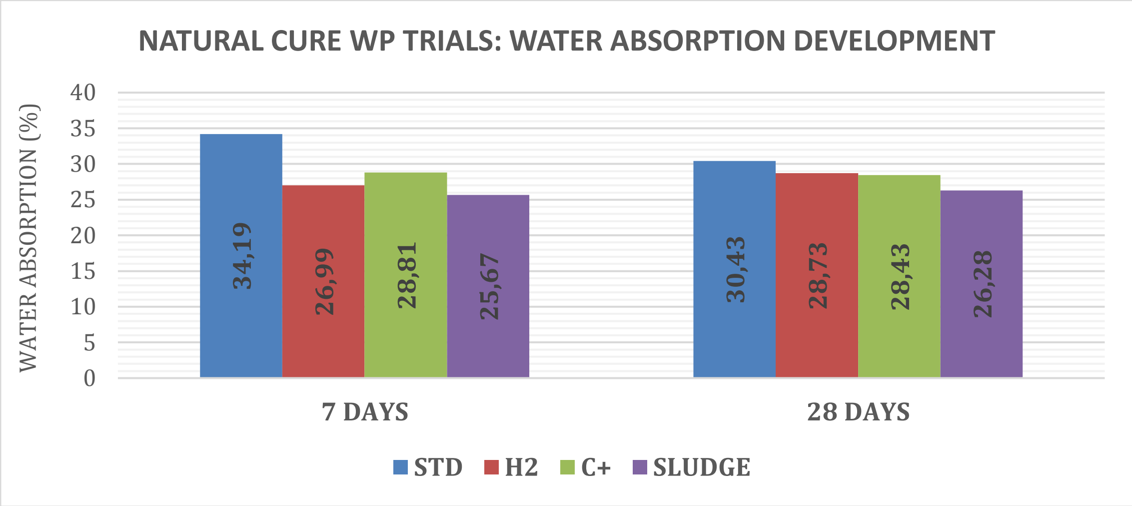


Figure 6: Water absorption development for natural cured samples

Figure 6 results indicated a reduction in water absorption of 21%, 16% and 25% for samples, cured for 7 days, with H2, C+ and sludge samples respectively. As the curing process continued, the reduction was not significantly high at the end of 28 days curing compared to the standard. The samples with H2 and sludge waste paper fibres showed an increase in water absorption from 7 days to 28 days.

The mechanical properties were plotted in Figure 7. The modulus of rupture determines the peak load the specimen can carry. The results show a significant increase in strength with complete substitution of cellulose with waste paper fibres. The maximum increase of 14% was observed in H2 samples at the end of 7 days curing compared to the standard. At the end of 28 days curing the increments were low as observed with the other parameters, but still better than the reference sample.

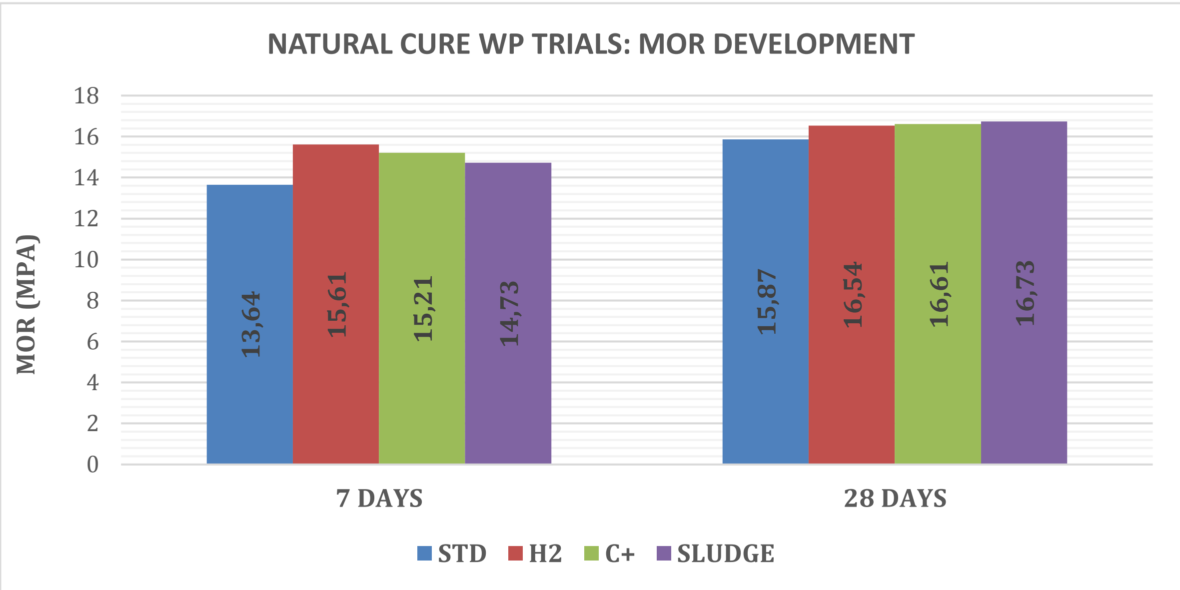


Figure 7: Strength development of samples over 28 days curing

The samples were subjected to wet-dry movement test and the results plotted in Figure 8 below. At the end of 7 days curing, the samples with waste paper fibres, H2 and C+, showed a reduction of 12% and 14% whereas the sludge samples resulted in an increase of 20%. The trend was different over 28 days curing, all the waste paper fibre samples showed a reduction in movement, including the sludge sample. Therefore, the C+ waste paper samples resulted in the least movement for both curing durations in comparison with the reference sample.

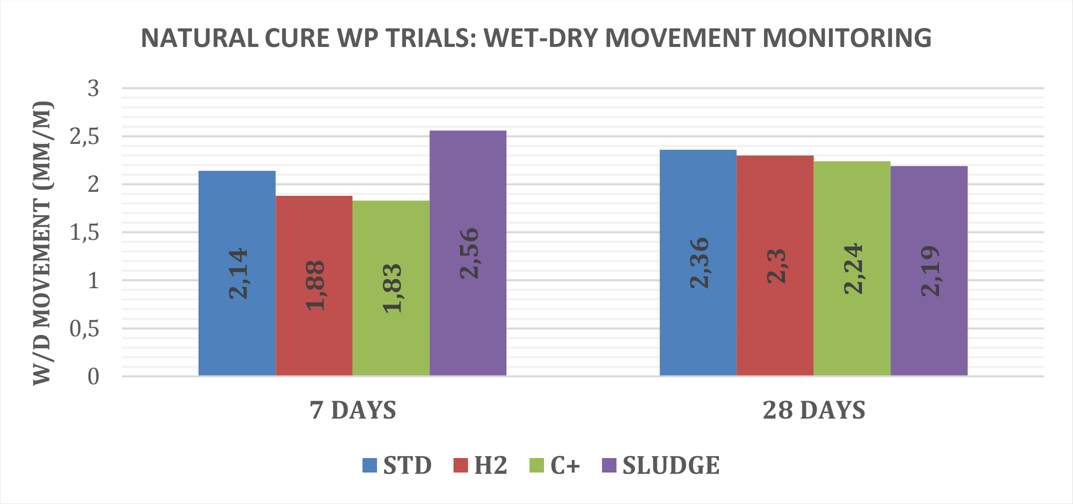


Figure 8: Movement monitoring in natural cured samples

CONCLUSIONS

From the results presented above, it could be concluded that recycled waste fibres have a positive effect on the physical and mechanical properties of naturally cured fibre cement composites. The performance of the sludge in natural cured fibre cement mix was on par with that of the waste paper grades after 28 days curing. The partial substitution of cellulose fibres with waste paper fibres and sludge in fibre cement autoclave mix showed enhancement of mechanical properties compared to the reference standard sample. On the physical properties, incorporation of H2 waste paper fibres and sludge demonstrated a negative impact, more significant on linear expansion, in comparison to the standard sample. Although the composites produced with incorporating C+ grade fibres followed the same trend in linear expansion performance, the improvement in other physical properties compared to the standard was observed. In spite of the good results found in these trials, durability tests need to be conducted to evaluate the behaviour of these building materials over time.

The study accomplished successfully its purpose of utilization of waste paper, from the tissue industry, either as partial (in autoclave technology) or complete substitution (in natural cure technology) of cellulose fibres in fibre cement composites. All the waste paper grades and the sludge can be substituted completely in natural cured technology mix with no detriment to both the physical and mechanical properties. But with autoclave technology, only C+ grade can be partially substituted in fibre cement mix to enhance the physical and mechanical properties.

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REFERENCES

Danial, W. H., Majid, Z.A., Muhid, M.N.M., Triwahyono, S., Bakar, M.B. and Ramli, Z. 2015. “The reuse of wastepaper for the extraction of cellulose nanocrystals”. Carbohydrate Polymer 118 165-169.

Khiari, R., Marrakchi, Z., Belgacem, M.N., Mauret, E. and Mhenni, F. 2011. “New lignocellusic fibres – reinforced composite materials: A step forward in the valorisation of the Poidonia oceanica ball”.Composites Science and Technology 71(16) 1867 – 1872.

Khorami, M. and Ganjian, E. 2011. “Comparing flexural behaviour of fibrecement composites reinforced bagasse: wheat and eucalyptus”. Construction and Building Materials 25(9) 3661 – 3667.

Mohammadkazemi, F., Doosthoseini, K., Ganjian, E. and Azin, M. 2015. "Manufacturing of bacterial nano-cellulose reinforced fibre-cement composites". Construction and Building Materials 101 958 – 964.

Sangrutsamee, V., Srichandr, P. and Poolthong, N. 2012. "Re-pulped waste paper based composite building materials with low thermal conductivity". Journal of Asian Architecture and Building Engineering 11(1) 147 – 151.

Yan, L., Kasal, B. and Huang, L. 2016. "A review of recent research on the use of cellulosic fibres, their fibre fabric reinforced cementitious geo-polymer and polymer composites in civil engineering". Composites Part B: Engineering 92 94 – 132.