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Polypropylene reinforced cement sheets

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SYNOPSIS

The paper examines the effects of the addition of polypropylene mesh of different types and volumes upon the flexural load - deflection properties of a cement matrix at different ages developed at Universiti Teknologi Malaysia Laboratory. The products were chosen to highlight its potential use in low income housing and are intended to be used as an alternative to asbestos cement sheets. The major application of the composite will be as corrugated sheeting for roofing and cladding. The sheets consist of 1% to 10% by volume of polypropylene mesh in cement matrix. Comparative tests are also reported with the flexural behaviour of asbestos cement sheets. Both sheets underwent 4 - point loading and the results indicated that the new sheeting can satisfactorily sustain the loads showed by corrugated asbestos sheets.

INTRODUCTION

The interest in utilising the cheapest material for making low cost construction materials has been growing in recent years. Although the cost of cement is considered low, it cannot alone be used as a material for construction because it cracks easily and fails in a brittle mode. The inclusion of fibres to cement has solved the problem especially when the inclusion of asbestos fibres in it was discovered. The result was the large scale production for flat and corrugated asbestos cement sheet especially in the late nineteenth century. But, due to health hazards ascribed to asbestos fibres, there is a strong tendency to replace them with other fibres. There is also a strong indication that the supply of cheap asbestos fibres may be exhausted in the future (1). According to Baroonian et.al, relatively very few information has been published about the performance of asbestos cement under the recommended design loads (2). Therefore, an economic and safest material construction is sought to develop the non-asbestos cement based composites.

Polyolefins such as polypropylene fibres can be an economic and safest alternative to asbestos fibres. The fibres are cheap and can withstand attack by strong acids and alkalis as such make them more durable than other fibres. The fibres have been used for many years despite of their low modulus of elasticity. For instance, the successful use of polypropylene fibres in the manufacture of concrete piles to withstand impact loads (3).

Several investigations have already been carried out on various mechanical and physical performance using polypropylene fibres (4-9). These investigations have shown encouraging results.

The objective of this study deals with the reinforcement of corrugated sheets using two different grades of polypropylene woven mesh. Their benefit in increasing the flexural load deflection is experimentally evaluated under the variation of fibre types and sizes, different volume fraction of fibres (V_{RL}) and different ages of the specimen. The results are compared with typical commercially available corrugated asbestos cement sheet cut to required length.

TEST PROGRAMME AND METHOD

The asbestos cement corrugated sheet tested was a typical commercially available sheet of overall depth 57 mm, cross-sectional thickness 6-9 mm and pitch of corrugations of 45 mm.
Polypropylene reinforced cement (PRC) sheets were manufactured by hand in the laboratory. The matrix was cement paste with 0.45 water/cement ratio and constant for all the mixes. The properties and fibre structure of polypropylene woven mesh used in the investigation are given in Table 1.0 and Figure 1.0.

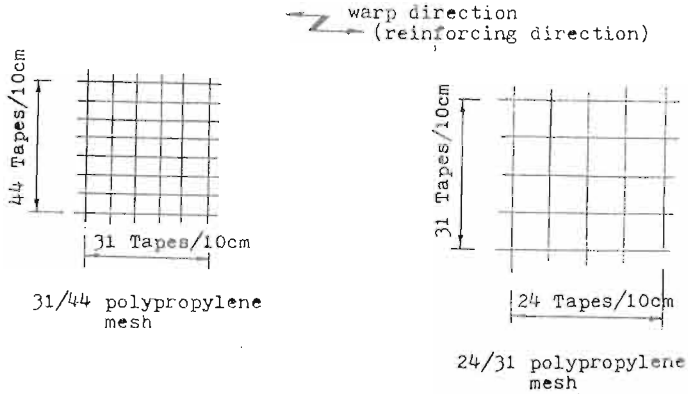

Figure 1.0 Types of polypropylene mesh used in the investigation

Table 1.0 Properties of polypropylene mesh

Mesh Type	Measured * Thickness (mm)		Measured * Width (mm)		Weft (transverse fibre spacing(mm)	Extension at break + (%)	Measured extension at break (%).
	Warp	Weft	Warp	Weft			
24/31	0.139	0.056	1.024	1.131	3.4	15-20	7.7
31/44	0.297	-.091	1.274	0.730	3.3	15-20	5.7

* Minimum of 30 samples.
\+ Specified by the manufacturer.

A cement paste was spread on the base of the mould. A layer of matting was rolled and this process was continued until the thickness required was obtained. The cement paste was left to set for 2-3 hours in the form of a flat sheet. Later, the flat sheet was laid onto a corrugated zinc sheet supported by strips of woods as in Figure 2, and pressed into corrugations and covered with plastic sheet with water ponded on top for 24 hours before the sheet was cured.

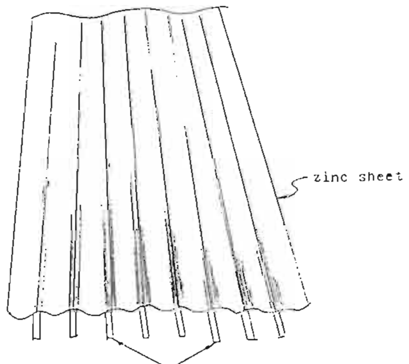

Figure 2.0 Zinc sheet supported by strips of woods.

All samples were 600 x 1000 x 10 mm size with a density of average 2246 kg/m ^{3}. All the sheets were loaded at the third points over a span of 900 mm. Deflections were measured at mid-span under each corrugation by displacement transducer linked to a data logger. Strain gauge readings were similarly monitored at various positions over the sheet.

There are two sets of specimen, one cured in ordinary water for 28 days, and the other exposed to natural weathering for 6 months (180 days) after initial curing in ordinary water for 28 days.

RESULTS AND DISCUSSIONS

The flexural load-deflection curves for PRC and asbestos cement at 28 days strength are shown in Figure 3. It is seen that the curves of PRC are slightly different from that of asbestos cement sheet. The asbestos cement sheet failed at a load of 1600 N at a deflection of 10 mm. Failure was sudden and the sheet broke into two sections as a crack propagated rapidly across the sheet. The ultimate stress was calculated as 29.6 N/mm ^{2}, whereas for PRC, generally all behave elastically until first crack. The load-carrying capacity, however drops immediately after cracking, then increases again with increase in deflection and then gradually decreases until fracture.

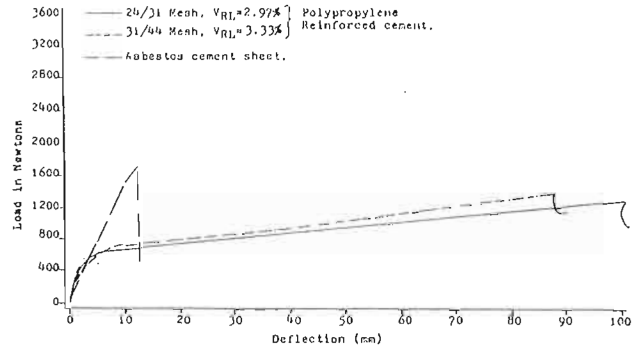

Figure 3.0 Load-deflection curves for corrugated sheets at 28 days strength.

The load deflection curves for PRC comprise two portions. The elastic portion and the inelastic portion. The elastic portion which is elastic before first crack, is the range where only cement carries the load. The fibres do not contribute to load capacity. The second portion, the inelastic range until fracture shows extensive cracking after reaching the ultimate loads indicating considerable ductility. In this region, the fibres carry all the loads.

Table 2.0 summarises important values on the flexural strength of PRC. As expected, the performance of 31/44 woven mesh is better than 24/31 woven mesh. This is probably deduced from their relative fibre structure and properties. The effect of V_{RL} of PRC can be seen clearly to show that as V_{RL} is increased, the better is the flexural strength. Similarly as seen in Figure 4, as V_{RL} increases, the slope after first cracking becomes steeper. This increase in slope is attributed to the viscoelastic property of the polypropylene fibres. Asbestos fibres do not show a similar behaviour because of the brittleness of the fibres themselves and the difference in the reinforcing mechanism.

Table 2.0 and Figure 5 show flexural strength of the sheets at two different ages and curing conditions. Some reduction in strength occurs after six months (180 days) exposure to natural weathering probably due to the embrittlement of the sheets within this period. But the reserve strength occurs is adequate enough for long term applications.

Table 2.0 Results of Flexural Strength

Fibre Type	V_{RL} (%)	Density Kg/m^3		Modulus of Elasticity N/mm^2		Stress at LOP N/mm^2		Ultimate Strength N/mm^2	
		28D	180D	28D	180D	28D	180D	28D	180D
31/44	3.33	2395	2099	17.5	22.5	9.3	6.8	19.4	
"	5.0	2309	2127	30.0	22.5	9.3	8.0	27.8	30.0
"	6.66	2285	2040	17.1	30.0	11.9	9.8	33.0	39.0
"	8.33	2310	2189	21.4	24.0	12.8	12.0	45.8	43.5
"	10.0	2260	2135	20.0	22.5	13.5	13.5	54.0	51.0
24/31	1.19	2423	2124	15.0	12.0	7.5	5.3	7.5	9.0
"	1.78	2510	2238	13.3	23.3	8.3	5.9	20.3	12.0
"	2.97	2396	2148	25.0	25.0	9.8	6.0	21.0	19.5
Asbestos.	-	2451	2453	21.5	19.8	29.6	25.9	29.6	25.9

Note: V_{RL} - volume fraction of reinforcement in the longitudinal direction.
28D - 28 Days strength.
180D - 180 Days strength.

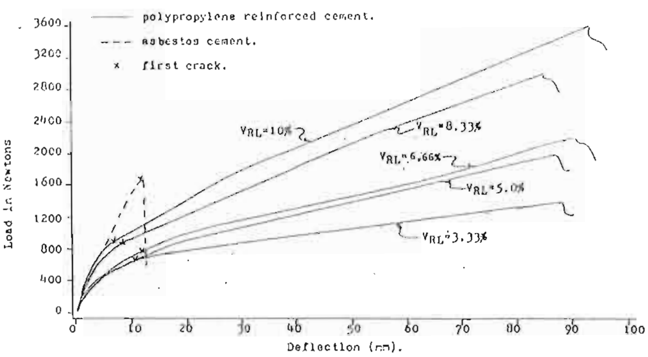

Figure 4.0 Load-deflection curves for various fibre contents for 31/44 woven mesh at 28 days strength and asbestos sheet

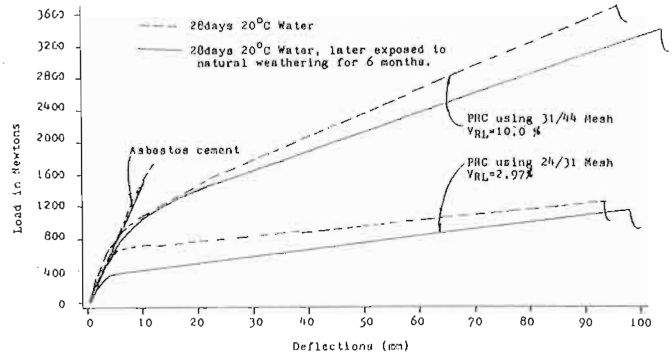

Figure 5.0 Load-deflection curves at different ages

ECONOMICS

Other than cost, which apply to the choice of materials for structural purposes, are the extent of mobility and compactability of the material and hence the ease with which it can be arranged to a required configuration and its behaviour under load.

Often, as in the case of cement, material cost consideration and the ease of application are sufficient to justify the usage of materials. Since PRC represents the whole range of cement, it is not possible to give any cost comparison which is meaningful. The properties of cement, however, permit simplification of moulds and reduction in costs of labour for placing, compaction and finishing, as well as increasing the quality of the end product and reducing the amount of wastage. The finished products of PRC are less likely to be damaged or fractured during handling or placing and when fixed to the building. These factors offer the total cost of a finished item to be minimised, and these savings are more than offset the extra material cost and therefore PRC can be an economical to use.

According to Naaman et. al (10) since the specific gravity of asbestos is three times that of polypropylene, for the same volume fraction of fibres in a given composite, the weight of asbestos fibres would be three times that of polypropylene. As fibre bought in a weight basis, polypropylene may have a substantial cost advantage.

CONCLUSION

The tests indicated that the addition of polypropylene fibre increases the first crack strength with increase in fibre content.

For 5 to 10% of volume fraction for 31/44 woven mesh showed comparable strength to asbestos cement sheet regardless of the types of curing (ages). The addition of 24/31 woven mesh did not increase the flexural strength as the inclusion of these fibres were minimised due to difficulty in casting.

Useful load is sustained after first crack, when deflection increases substantially. Its maximum value increases with increase in fibre content, and this value exceeds the first crack strength. The sheets showed extensive cracking after reaching their ultimate loads indicating considerable ductility. In fact, it is impossible to break the PRC sheets in the test rig as the maximum loads are well above the loads required to be sustained.

The results indicate that very little different in strength changes for both meshes at different ages. But only 31/44 woven mesh can satisfactorily sustain the loads showed in corrugated asbestos cement sheet. The composite retain most of its initial, good mechanical properties when exposed to natural weathering (especially in tropical country like Malaysia) over a period of six months (180 days).

Lastly, the great toughness of PRC is an important asset in its use as a roofing and cladding element and low cost sheeting.

ACKNOWLEDGEMENT

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