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THE USE OF RUBBER FOR IMPROVEMENT OF IMPACT RESISTANCE IN FERROCEMENT BOATS

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SUMMARY

An attempt was made to improve the impact resistance of ferrocement boats. It was found, that the resistance to fracture of such boats can be improved by the incorporation of 10% by weight of natural rubber into the portland cement in the form of low ammonia centrifuged latex. Lining these boats with rubber sheets, which vulcanise at room temperature in the sunlight, enhances their impermeability.

INTRODUCTION

Fernando (1975) has described the design and production of ferrocement floating craft such as pontoons, flat bottom barges, sand barges for canal development and fishing vessels. However, the impact resistance of these craft required improvement. This could be effected by using natural rubber-portland cement mixes in the construction of the ferrocement boats, as reported previously by Fernando *et al* (1977) on the construction of a rubberized ferrocement fender for a canal barge. This barge has given satisfactory performance to-date. In this paper we report further work on the improvement of impact strength of ferrocement used for boat building. Two distinct approaches taken to overcome this inherent weakness of ferrocement are described here *viz.* (*a*) improvement of its impact strength, and thereby the strength of the boat hull, from an overall stand point by incorporating rubber latex in the ferrocement mortar, and (*b*) improvement of the impact strength of the hull only, making it impermeable by lining the hull with a rubber sheet, which can be vulcanised after installation.

Incorporation of rubber latex in ferrocement

Nadarajah and Coomarasamy (1977) have shown that the setting and strength of portland cement are adversely affected by the sucrose and quebrachitol, respectively, present in natural rubber latex. Field latex contains large amounts of these two ingredients, once centrifuged latex less, and double centrifuged latex lesser still. The presence of these two ingredients in natural rubber latex restricts the maximum amount of rubber that can be incorporated into portland cement, without adversely affecting its physical properties and setting; the maximum amounts are: 3.5% for field latex, 10% for once centrifuged and 20% for double centrifuged latex. In this study 10% of once centrifuged latex was used, which is the maximum allowable in portland cement.

To prevent the latex from coagulating when mixed with portland cement, 4% of a soap (Nonidet T) was used (Nadarajah and Fernando, 1976). We reduced the Nonidet T to 2% when low ammonia, once centrifuged latex was used.

In investigating the flexural strength of Wirecon-latex mixes, Nadarajah and Fernando (1976) have shown that incorporation of field latex, to give 3.5% of rubber in the portland cement, and of double centrifuged latex, to give 15% rubber, did not give adverse results in ultimate stress. On the other hand impact strength was considerably enhanced, thus making the incorporation of rubber in Wirecon mixes a viable industrial proposition.

EXPERIMENTAL AND RESULTS

The ratio of cement to sand was 1:1.5. The water to cement ratio in the control was 0.35 and from 0.25 to 0.35 when rubber latex was also added, allowance being made for water in the latex. In mixing portland cement with ammoniated centrifuged latex, a soap (Nonidet T) was added at the rate of 2% of the latex to the required amount of water. The soap and water were well mixed with the required amount of latex before adding it to the well mixed sand-cement mixture.

Specimens for testing were made by hand tamping. They were removed after 24 h, cured in water and tested 14 and 28 days after preparation. The latex used was low ammonia once centrifuged latex containing 0.2% Ammonia, 0.0125% ZnO and 0.0125% TMTD (John *et al*, 1976). Tensile strength was determined on a briquette specimen; the area for testing being 0.25 cm². Compressive strength was measured on a 5 cm cube. Bending strength was done at the centre of a square prism the dimensions of which were 10 x 2.5 x 2.5 cm.

Physical properties

The physical properties of cement mortar/LA centrifuged latex mixes are given in Table 1.

TABLE 1. Physical properties in lb/sq in. of cement mortar/latex mixes

Rubber content in cement	*Water/cement ratio*	*Tensile strength cured for*		*Compressive strength cured for*		*Bending strength cured for*	
		14 days	*28 days*	*14 days*	*28 days*	*14 days*	*28 days*
0	0.35	140	202	1613	1931	119	199
5	0.30	151	217	1712	1940	88	130
10	0.275	184	264	1524	2219	115	169

Impact strength

Impact strength was determined by a drop test, on a square flat panel measuring 60 cm having two parallel V grooves, 1 mm wide and 2 mm deep across the centre of the panel. The panel was supported along its four edges and a steel sphere weighing 19 kg was dropped on it from various heights until the panel developed a leak, which was determined by means of a water hose. The impact strength was calculated by summing the total energy dissipated, *i.e.*, 18.62 x n x h Joules, where n is the number of drops to failure and h is the height in metres. The results for impact strength of cement mortar/latex mixes are given in Table 2.

TABLE 2. Impact strength of latex-portland cement mortars

% Rubber in cement	*Water/cement % ratio*	*Total height(m) from which 19 kg ball was dropped*	*Impact strength in Joules*
0	35	2.6	49
10 (LA centrifuged latex)	25	8.6	163

Rubber lining of ferrocement boats

The formulation used for lining the ferrocement boat (Fernando & Nadarajah, 1978) was: Natural rubber, 100; ZnO, 5.0; HAF black, 30.0; Sulphur, 1.5; MBTS, 1.5; ZDC, 1.5 and DPG, 1.2 (parts by wt). This compound was sheeted on a cold mill and bonded to the ferrocement slab by means of a neoprene adhesive, commercially marketed in Sri Lanka as Stick-Quick. The rubber lining was cured in sunlight for about 20 h.

The physical characteristics of the rubber compound on being vulcanised in the sun for 6 h, are given in Table 3, and the impact strengths of a ferrocement slab with a vulcanized rubber lining is compared with that of an unlined slab in Table 4.

TABLE 3. Tensile strength and elongation at break of vulcanised rubber used in lining wirecon boats

Sample No.	*MOD 100% in kg/cm*	*MÖD 300% in kg/cm*	*Tensile Strength in kg/cm*	*%Elongation at break*
A	12.5	64.2	240	600
B	12.3	54.7	265	650
C	13.8	66.2	257	600
D	14.9	56.6	238	600
E	11.9	47.7	262	620

The adhesive bond strength between the ferrocement slab and the vulcanized rubber (calculated by means of pulling a sample of rubber 160 mm x 70 mm parallel to the surface bonded to the ferrocement hull slab) was 7 p.s.i. The frictional (skin and wave) resistance (along the surface of the craft when it moves at a velocity of 5 knots) against the bond strength was 1.25×10^{-3} p.s.i.

TABLE 4. Impact strength of ferrocement with vulcanised rubber

Specimen	*Weight*	*Thickness*	*Total height (m) from which 19 kg ball was dropped*	*Impact strength in Joules*
Control f/c slab	17.30	18	2.3	41.0
f/c slab with vulcanized rubber	23.40	30	32.9	613.0

The results can be summarized as follows:

(*a*) Improved impact strength of rubber latex-portland cement mortars:—

(i) Impact strength of cement/sand mortar alone (w/c = 35%) is 41 Joules, small cracks occurring at a height of fall of the steel ball at 20 cm.

(ii) Impact strength of c/s mortar with 10% LA centrifuged latex is 163 Joules, small cracks occurred at a height of fall of steel ball at 80 cm.

(iii) Impact strength c/s mortar with vulcanized rubber lining is 613 Joules, small cracks occurred at a height of fall of steel ball at 20 cm.

(*b*) The use of room temperature vulcanized and sunlight cured rubber, for lining ferrocement boats, resulted in high tensile strength of the hull.

(*c*) The adhesive bond strength (7 p.s.i.) is adequate to overcome the frictional resistance on the hull of the vessel (1.25×10^{-3} p.s.i.).

DISCUSSION

As shown in Table 1, there is no significant reduction in compressive strength when LA centrifuged latex is used at the rate of 5% rubber in portland cement and satisfactory results were obtained for tensile and compressive strengths. Satisfactory compressive, tensile and bonding strength results were obtained when 10% of rubber was mixed with portland cement (Table 1) and excellent impact strength properties were also obtained (Table 1). The results confirm that the reduction of the Nonidet T concentration in the latex from 4% to 2% has resulted in an improvement of properties (Nadarajah & Coomarasamy, 1977). The lining of ferrocement boats on the outside with vulcanised rubber has been shown to be promising.

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