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DEVELOPMENT OF NATURAL RUBBER LATEX PORTLAND CEMENT MIXES FOR ENGINEERING APPLICATIONS*

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SUMMARY

The deficiency in properties when Portland cement is used in mixes with natural rubber latex is due to non-rubber substances and especially sugars found in latex serum. These non-rubber substances could be reduced by centrifugation and further by dilution with water and recentrifugation.

A Rubber/Cement ratio of (1 : 1½) *cement sand mortar could be used up to* 0.03% *for field latex, up to* 0.10% *for centrifuged latex and up to* 0.20% *for double centrifuged latex without drastically impairing physical properties; on the other hand some improved properties are obtained. The latices could be prevulcanised with vulcanising chemicals without serious reduction in strength when compared with the unvulcanised latices.*

The incorporation of natural rubber latex in "Wirecon" boat building material has shown that appreciable improvement in impact strength is obtained by the incorporation of the rubber latex.

INTRODUCTION

Synthetic latices have been recommended for use in Portland cement mixes, as fluidity is obtained by their use, at a lower water content. The strength of cement is obtained by hydration of cement with water and normally 40 parts of water are added to 100 parts of cement. Of the 40 parts, about 25 parts chemically react with the cement and the balance 15 parts, which are necessary to obtain the fluidity of the mix are included within the gel pores, (Wagner, 1965). If a polymer latex is used, then a portion of the water that is required to obtain fluidity in the mix is replaced by polymer in emulsion form. This reduction in water content gives improvement in properties such as compression and tensile strengths, elastic moduli, hardness, permeability, adhesion and chemical resistance, (Wagner, 1973). Further concrete with the least water present will present the least volume change in drying and so be more impermeable and less susceptible to cracking as well (Larson, 1965).

Geist *et al.* (1953) have stated that the amount of the polymer (polyvinyl acetate) to cement ratio to give optimum physical properties is around 0.2. Wagner, (1965) has suggested that the amount of polymer to dry cement ratio/to give optimum properties is around 0.15 to 0.17. Further he states that water reacts chemically with cement to form cement gel and that the very finest strands of coalesced polymer appears to surround or to interweave the cement gel particles and cement grains (portions of cement remaining unhydrated) to construct the coarser network lying between sand particles. Recent work involving scanning electron microscope examination of the interfaces between the cement matrix and sand particles have indicated the early formation of a monolayer of polymer latex particles over the sand surface Wagner (1973). Geist et al (1953) have shown by photomicrographs that at a polyvinyl acetate: cement ratio as low as 1 : 5, the polymer becomes the continuous phase.

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Concentrated latex stabilised with casein at 5% on the rubber has been used in flooring mixtures and as an adhesive, (Stevens, 1948). Field latex stabilised with formaldehyde has been recommended for use in flooring mixtures and as an adhesive, but the tensile and compressive strengths of mortars and concrete made from it is low, (Nadarajah, *et al.* 1972, Nadarajah *et al.* 1975), and hence cannot be recommended for use in engineering applications.

Cherkinshu and Kalashni, (1960) have shown that the properties of Portland cement were changed considerably when mixed with latex, blending and crushing strength being lowered, elastic and deformation tendencies being raised and resistance to shock being sharply increased. Thevarasah and Selveratnam, (1969) have investigated the tensile strength, compressive strength and modulus of elasticity of natural rubber latex/Portland cement mixes, but were not able to obtain any improvement in any of the above properties as a result of adding natural rubber latex. Work was done by us to find the conditions under which natural rubber latex could be used with Portland cement to give improved physical properties.

EXPERIMENTAL

The ratio of cement to sand used was 1:1.5. The water to cement ratio in the control was 0.35 and from 0.25 and 0.35 where rubber latex was also added, allowance being made for water in the latex.

In mixing Portland cement with latex, the soap (Nonidet T) was added at a concentration of 4% of the latex to the required amount of water, the soap and water were then mixed well with the required amount of latex, before adding it to the well mixed sand-cement mixture. Nonidet T is a octyl phenyl ethylene oxide condensate with 40 ethylene oxide units (Non ionic stabiliser).

Specimens for testing were made by hand tampering. The specimens were removed after 24 h, and for the control, immersed in water and tested after 7, 14 21 & 28 days. In cases where rubber latex was added, the samples were air cured for at least the first 3 days, water cured for 7 days and then air cured. Testing of specimens containing rubber was also done after 7, 14, 21 & 28 days curing.

The latices used in the tests were:

(1) High ammonia field latex (Ammonia 1.5% on latex, Rubber content 35%).
(2) High ammonia centrifuged latex (Ammonia 0.7%, Rubber content 60%).
(3) High ammonia double centrifuged latex (Ammonia 0.7%, Rubber content 60%).
(4) Prevulcanised ammonia preserved centrifuged latex (Rubber content 60%).

Tensile strength was determined on a briquette specimen with the area for testing being 2.5 cm square. Compressive strength was done on a cube of length 5 cm. Bending strength was done at the centre of a square prism of dimensions 10 x 2.5 x 2.5 cm.

The uniaxial flexural strength was determined by three point leading of prismatic wirecon reinforced cement mortar specimens, 50 cm long by 9 cm wide and about 1.2 cm thick, reinforced with six No. 20 gauge chicken mesh and a 5 cm by 5 cm welded mesh.

|
V P in g

<—25 mm—> Λ <—450 mm—> Λ <—25 mm—>
| Uniaxial flexural strength |

Impact strength was determined by a drop test, the test specimen being a square flat panel measuring 60 cm by 60 cm having two mutually 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 25 kg was dropped on it from various heights until the panel developed a leak. The leak was determined by means of a water hose. The impact strength was calculated by summing the total energy dissipated, *i.e.* 25 n h, where n is the number of drops to failure.

RESULTS AND DISCUSSION

Physical properties of cement mortar/latex mixes

The physical properties of cement mortar/latex mixes cured for 7 days are given in Table 1. It will be noted that the addition of rubber latex gives a significant lowering in bonding strength and compressive strength, but not of tensile strength. Further the use of ammoniated field latex and of centrifuged latex at rubber to cement ratio of above 0.05 and of above 0.15, respectively, adversely affects setting and also strength. The results of prevulcanised centrifuged latex which is obtained by centrifuging prevulcanised ammoniated field latex suggests that satisfactory physical properties can be obtained if the rubber to cement ratio is 0.10 and below. The physical properties of cement mortar/latex mixes cured for 28 days, given in Table 2 confirm the results given in Table 1. At least, 70% of the 28 days strength is attained in nearly all the samples in seven days.

The adverse effect of setting when field latex is used at a rubber/cement ratio of 0.05 and when centrifuged latex is used at ratios above 0.15 could be due to the non-rubber constituents in the serum phase. Rubber latex contains proteins, amino acids and carbohydrates mainly polyhydric alcohols, quebrachitol and myo-inositol and sucrose. Carbohydrates of the order of about 1% quebrachitol, 0.5% 1–inositol and 0.4% sucrose are present in field latex (Bealing, 1969). Though the actual amount present may vary, a total carbohydrate content of a minimum of 0.5% is to be expected in the field latex. It is known that carbohydrates containing the group HO – C – H act as retarders for the setting of cement (Lea, 1956). Quebrachitol, l-inositol and sucrose contain at least five such groups per molecule. It has been stated that a 1% solution of sugar and carbohydrate derivatives almost completely inhibits real setting and hardening, though there may be an immediate rapid stiffening giving the appearance of a quicks et (Lea, 1956). It is also reported that the addition of 0.05% sugar has little effect on the rate of hydration, but if the quantity is increased to 0.2%, hydration can be retarded to such an extent that final set may not take place for 72h or more (Orchard, 1973).

From Tables 1 and 2 it is noted, that with a rubber content of 7.0% of cement the setting is delayed and hence the carbohydrate content in the diluted latex mixed with cement and sand may have been of the order of over 0.2 percent. The concentration in the field latex would have been in the order of about 0.5 percent. Centrifuging results in the lowering of the sugar content by half. Hence it is noted that for once centrifuged latex, a rubber content of 10% of the cement gives a satisfactory strength, but not 15 percent; Rubber-Stichting (1955) states that the best strength values are obtained with 10% rubber on cement with once centrifuged latex. With double centrifuged latex, with the further halving of the sugar content the rubber to cement ratio can be raised to 0.175 with adequate strength properties (Table 1 & Table 2). The behaviour of using prevulcanised centrifuged latex which is satisfactory at a Rubber cement ratio of 0.10 and not 0.15 can also be explained by the presence of natural carbohydrates in the latex.

TABLE 1. PHYSICAL PROPERTIES OF CEMENT MORTAR/LATEX MIX (CURED 7 DAYS)

Type of Latex	Rubber Content on Cement %	Water Content % ratio	PROPERTIES					
			Tensile Strength		Compressive Strength		Bonding Strength	
			Newtons/mm^2	lb. in^2	Newtons/mm^2	lb. in^2	Newtons/mm^2	lb. in^2
Control	0	0.35	2.24	325	30.87	4476	6.15	893
Ammoniated field latex	3.5	0.35	1.54	224	9.88	1433	3.92	577
	5.0	0.35		260		2252		631
	7.0	0.35	Setting very poor					
Once centrifuged latex	5.0	0.35	1.30	189	9.71	1408	2.98	431
	10.0	0.30	2.11	306	13.73	1992	4.31	620
	15.0	0.30	1.00	145	9.05	1312	1.49	217
	20.0	0.28	0.12	18	0.57	83	0.28	41
Double centrifuged latex	10.0	0.30	2.24	325	12.07	1750	4.72	685
	15.0	0.30	2.24	265	11.83	1715	2.22	322
	17.5	0.30	2.93	425	10.52	1525	4.33	628
Prevulcanised centrifuged latex ..	10.0	0.35	1.96	286	12.07	1750	2.49	362
	15.0	0.35	0.36	53	1.89	275	1.78	258

TABLE 2. PHYSICAL PROPERTIES OF CEMENT MORTAR/LATEX MIX (CURED 28 DAYS)

Type of latex	Rubber Content on Cement %	Water/ Content % ratio	PROPERTIES					
			Tensile Strength Newtons/mm²	Tensile Strength lb/in²	Compressive Strength Newtons/mm.²	Compressive Strength lb/in²	Bonding Strength Newtons/mm²	Bonding Strength lb in²
Control	0	0.35	2.48	360	32.99	4784	7.01	1017
Ammoniated field latex	3.5	0.35	2.88	419	16.48	2391	5.44	820
	5.0	0.35		280		4071		951
	7.0	0.35	Setting very poor					
Once centrifuged latex	5.0	0.35	1.43	208	11.14	1616	4.98	722
	10.0	0.30	2.39	347	15.51	2250	4.55	660
	15.0	0.30	0.80	116	9.72	1410	0.86	125
	20.0	0.28	0.27	39	2.90	421	0.70	102
Doubled centrifuged latex	10.0	0.30	2.98	433	20.23	2933	5.74	833
.. ..	15.0	0.30	2.47	359	13.10	1900	4.67	677
	17.5	0.30	2.47	358	12.50	1813	4.47	648
Prevulcanised centrifuged latex ..	10.0	0.35	2.00	291	17.64	2558	2.42	351
	15.0	0.35	0.41	60	3.04	441	1.96	284

Quebrachitol was separated from latex serum by the method of Van Alphen (1951) and was added dissolved in water at the equivalent of 30 parts of rubber in field latex for 100 cement. It was found that the quebrachitol addition did not affect the setting of cement but the strength of the cement mortar was so poor that it crumbled when pressed between the fingers. These results indicate that the setting of the cement is adversely affected by the sucrose present in natural rubber latex and its strength by the quebrachitol present in it.

The results obtained for physical properties with natural rubber latex (Table 1 and 2) are generally much lower than the control. Browne *et al.* (1975) state that polymer emulsions entrap air on mixing and that concrete strength is very sensitive to void content, a 40% drop in cube strength occurs when the air content is increased from 2 to 8 percent. They also state that in general any increase in strength due to the lower water/cement ratio is offset by the loss in strength as a result of the increased void content. Their remedy is to use an antifoam agent and to keep the mixing time to a minimum which is being tested by us.

Flexural strength of cement mortar/latex mixes

The results obtained for ultimate strength of wirecon/latex mixes are given in Table 3. It will be seen that the incorporation of rubber does not adversely affect ultimate stress.

TABLE 3. ULTIMATE FLEXURAL STRENGTH OF WIRECON/LATEX MIXES

Rubber content in cement	Water/Cement % ratio	Ultimate Stress	
		N / mm²	lb/in ²
0	0.35	6.68	969 7
3.5 (centrifuged latex)	0.35	3.62	525.6
3.5 (field latex)	0.35	5.46	732.2
15 (double centrifuged latex)	0.30	8.56	1249.0

Brown *et al* (1975) state that the main influence of a styrene butadiene emulsion on the tensile properties of a cement mortar is on the Young's modulus which is reduced from 80.6 to 11.3 KN/mm² with an increase in failure strain of from 0.0035 to 0.047 percent. They further state that this increase in flexibility makes concrete less brittle and improves its impact resistance. The results obtained by us also show that incorporation of rubber in cement mortar decreases the Young's modulus and increases failure strain. Hence experiments were carried out to confirm Brown *et al's* (1975) observation that impact resistance will be improved by incorporating rubber in cement mortar mixes.

Impact strength of cement mortar/latex mixes

The results for impact strength of cement mortar/latex mixes are given in Table 4. It will be seen that the incorporation of rubber considerably increases the impact strength.

TABLE 4

Rubber content in Cement	Water/cement % ratio	Height from which 25 Kg ball is dropped in cms	Number of drops to develop a leak	Impact strength in N/ mm²
0	35	30.5	One	56.8
10 (double centrifuged latex)	30	61	One	113.6

Potential uses of cement mortar / latex mixes

(a) *Repairs of old cement:* Wake (1970) has described the reasons why fresh portland cement does not bond to old cement. The NR latex portland cement mix is suitable for repairs of old cement.

(b) *Flooring*: The NR latex - portland cement mix is a good base for the attachment of floor tiles. The mix finds uses for industrial floors and for agricultural purposes including stabling. Their warmth in comparison with concrete is of great value where livestock is concerned. The use of rubber imparts resilience, impact resistance, toughness and durability to the floor. The rubber to cement ratio could vary from 0.035 to 0.30 and the water to cement ratio from 0.25 to 0.35. Fillers such as cork are added for lightness and resilience and for indoor applications granite chippings. For outdoor applications blends of cork and granite chippings may be used.

(c) *To protect sea defences against sea erosion:* Timber has been used in England to protect sea defences against sea erosion and it is claimed (Anon 1968) that the use of rubber latex/cement mix gives a saving of 50% in installation costs and a life potential of several times that of timber, because any signs of wear can be "made good" by an annual inspection and touching up without the need to replace them. Sri Lanka has a long coast line and this could be a major use of cement mortar/latex mixes in Sri Lanka.

(d) *In wirecon mixes*: Fernando (1975) has described the design and production with wirecon of the floating craft namely 5 ton pontoons 25 ton flat bottomed barges and 35 ton capacity sand barges required for the development of canals in Sri Lanka. A property of these craft which needs improvements is its impact resistance and it appears possible that the addition of natural rubber latex could improve this property and further investigations on this are in progress. It is known that among the important factors which give the efficiency of fibre reinforcement in concrete are the fibre matrix interfacial bond strength and the ductility of the concrete mix. Steel fibres have a far greater extensibility than concrete matrices. Hence bond failure occurs early in the composite and thereby hinders the efficient use of the fibre reinforcement. There is thus a need to increase both the ductility of the matrix and the fibre matrix interfacial bond strength without reducing the overall stiffness of the composite. A possible way of achieving this requirement could be the use of polymer admixtures in fibre reinforced concrete systems and Mangat & Swamy (1975) have shown that by using an acrylic polymer in a water emulsion form, the adhesion between cement and aggregate particles was improved and the failure surfaces of modified mixes showed the fracture of coarse aggregate particles, whereas the unmodified specimens showed a distinct failure of the aggregate - matrix interface. Natural rubber lowers stiffness and this has to be corrected. This can be done by using natural rubber latex and polyvinyl acetate blends or by using methyl methacrylate grafted natural rubber latex. Work using these two latex systems is being carried out.

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