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EFFECTS OF POLYMER MODIFIED MORTARS ON MECHANICAL PROPERTIES OF FERROCEMENT

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ABSTRACT

The study of ferrocement mechanical properties when using styrene butadiene rubber latex modified mortars is presented in this work. The polymer modified mortars were prepared using aqueous polymer dispersons at various polymer-cement ratios (50 to 200 kg per cubic meter of mortar), and welded wire meshes.

Natural sand with fineness modulus = 2.13 was used as aggregate, and the consistance of fresh mortar were fixed in 220mm at flow table apparatus.

The hardened mortar characteristics were evaluated by compression and deformation tests. In uniaxial compression test speciments to determine the modulus of elasticity were used cylindrical samples with 50mm diameter per 100mm lenght, and were used one hundred eight speciments in a total with nine in each group, in same conditions of the flexion test.

The ferrocement speciments used in flexion test had a thickness of 15mm, width of 210mm and lenght of 1000mm, and with steel ratio of 170kg per cubic meter of mortar. Forty eight speciments, gathered in three groups with different ratios aggregate-cement were used for flexion tests. In each group four series were performed, with polymer-cement ratios of 0, 10, 20 and 30 percent, with four speciments each.

In all tests, specimen deflections were measured at every loading stage. Also the cracking load, craching behavior (spacing, width and type) and failure load were observed.

From the results of the tests, it is concluded that the polymer-cement ratio has influence on cracking behavior, cracking load and hardened mortar compression strenght. These characteristics can change at different relations depending of cement content per cubic meter of mortar that were used in a specific polymer-cement ratio.

1. INTRODUCTION

The ferrocement can be considered as a particular type of reinforced concrete, showing very special characteristics related to structural performance and durability. The small thickness and the armature finely distributed in the interior of the cement mortar, give to the ferrocement structural elements, when submited to significative loads, a differente behaviour from that observed in the case of reinforced concrete, considerably the craking load, the width and the fissures spacing.

The influences exercised by the reinforced armature, upon the ferrocement structural behaviour has been object of investigation by many researchers around the world. Different types, arrangements, and volumes of armature, have been used looking for the improvement of the mechanical properties of the ferrocement. Although, with relation to the matrix constituted by cement mortar involving the armatures, there are few researchs.

It can be considered that the difficulty related to the improvement of the cement matrix properties comes from the impossibility to introduce the use of new materials and technical procedures without promoting significative alterations in the way of producing the ferrocement.

In order to guarantee the versatility of the buildings using ferrocement, i.e., in the presence of elementary technics usage and intensive utilization of workmanship (in undeveloped countries) or through highly mechanized and rationalized processes (in developed countries), it is necessary that the introduction of new materials and execution methods don't imply in big aditional costs and adapt to the production way adopted in those countries.

The utilization of polymer modified mortars doesn't imply in significative changes to any process used in the ferrocement production. This condition comes to favor the application of polymers to the fresh mortar because it is constituted in a simple task that can be easily introduced in the routine of ferrocement production processes.

The characteristics of the hardened mortar when the relation polymer-cement is altered, were analised by tests using specimens submited to compression and deformation.

The realization of tests with ferrocement plates submitted to flexure using matrixes with different latex content had as a result the best understanding of their flexural behaviour, allowing to observe the polymer influence upon the development of cracking through the results obtained with relation to the first cracking load, ultimate load and width of craks.

2. MATERIALS

2.1. CEMENT AND FINE AGGREGATE

The mortars used in this work were constituted by ordinary portland cement and natural sand with maximum size of aggregate = 1,2mm and fineness modulus = 2,13.

The specific gravity was 2,65 kg/dm^3 and its bulk density was 1,60 kg/dm^3.

2.2. POLYMER DISPERSION

The polymer used in the cement mortars analised in this work is constituted by a polymer particles dispersion in water, produced from the styrene butadiene rubber latex - SBR, which properties can be seen in table 1.

Specific gravity (25°) Kg/l	pH	Surface Tension (dynas/cm)	Total Solids (%)
1,01	10,5	32	48

Table 1 - Properties of Polymer Dispersion - SBR

2.3. REINFORCEMENT

The armature used in the ferrocement plates was constituted by only one mesh formed by welded steel wires, with 2mm diameter, spaced 25x50mm. The flow tension obtained for the wires was 60KN/cm² aproximately.

3. PROCEDURES ADOPTED IN THE TESTS

3.1. SPECIMENS PREPARATION

The amount of latex - SBR - added to the cement mortars, varied from 10, 20 and 30% in relation to the cement mass.

Table 2 shows the characteristics of many ordinary mortars and the polymer modified mortar.

Cement-sand (by weight)	Polymer-cement Ratio (%)	Water-cement Ratio (%)
1:3 (average cement content = 530 kg/m³)	0	50
	10	33
	20	23
	30	16
1:2,5 (average cement content = 600 kg/m³)	0	42
	10	28
	20	20
	30	13
1:2,0 (average cement content = 695 kg/m³)	0	38
	10	26
	20	16
	30	7

Table 2 - Mix proportions of Polymer Modified Mortars

These mixtures were evaluated in their fresh stage relatively to the consistence and the workability. The conditions required for the mix proportions confection, the handling of the materials and the desired characteristics to production process usually adopted for the ferrocement plates were studied with polymer modified cement mortar.

The consistence of cement mortar with or without polymer was fixed in 220mm in the "flow table", value considered convenient for the throwing and compaction of the fresh mortar in the molds normally used in ferrocement pieces, taking into account the armature disposition and the criteria usually adopted for its vibration.

The establishment of the water-cement ratio adequated for each mixture containing different latex-SBR percentage was proceeded by tries, having an acentuated decrease of the water cement ratio with the increase of latex content in the mortar.

The specimens size used for the determination of the compressive strenght and the modulus of elasticity was 50mm's diameter by 100mm's hight. These specimens were moldered according to the Brazilian Standards NBR 7215.

The specimens submitted to the flexural test with 15mm x 210mm x 1000mm were reinforced by a layer of welded wire mesh equidistant placed from the plate's surfaces. The armature coating was obtained by using small polipropilene discs inserted in the mesh's wire, adequately positioned in order to avoid that the mesh's ondulations would alter its positioning in the interior of the matrix.

The mortar mixture was proceed in a mixer normally used for concrete, in time enough to make its homogenization possible. The mortar compaction, in the interior of the molds made of metal plates, was done using a vibrating table normally utilized for reinforced concrete pieces, by a total vibration time of aproximately 5 minutes.

The moist cure of the polymer modified mortars, as in the case of cylindrical specimens (used for determination of the compression strenght and strain modulus), as in that case of plates tested to flexion, was promoted until the second day. The first ones were maintained in a moist chamber during this time, and the plates were kept humid by placing a foam blanket soaked in water on the molds. After the second day, the cylindrical specimens and the plates were dismounted and kept in ambient, with a dry cure for a period of 26 days, under a temperature between 20 and 24°C and 70% of relative humidity (70% H.R.). After that they were sent for tests, always executing then after 28 days of molding.

3.2. COMPRESSIVE STRENGHT DETERMINATION

The test for the mortar compressive strenght determination was executed following the standards NBR 7215 prescriptions.

The axial compressive test results for the age of 28 days are indicated in figure 1, and are based on 9 specimens average.

3.3. MODULUS OF ELASTICITY

The average value of the compressive longitudinal modulus of elasticity was obtained though the tension x elasticity diagrams verification corresponding to the loading prescribed in the NBR 8522 standards obtaining the tangent modulus in the origin.

The results obtained for the mortars with 28 days old are in figure 2.

The measurement of the shortenings in the mortar specimens with 5 cm diameter and 10 cm height, was done by the test equipment itself which consists of a hydraulic press linked to a X-Y register, making possible the direct acquisition of the load vs. displacement diagram.

3.4. FLEXURAL TESTS ON FERROCEMENT PLATES

All the specimens contained in their interior reinforcement as that already mentioned in item 2.3.

The loading was applied on the specimens until the cracking was reached. In the load application stages the pieces deformations were folowed. The load responsable for the first visible cracking appearance, and the plates ultimate load can be seen in figures 3 and 4.

During the loading stages, from the first cracking load, the sistematic cracking avaliation was done through the maximum width and average crack width measurement.

The specimens were maintained freely supported, being measured the transversal displacements and the specific deformations corresponding to the several loading stages, and observed the crack width through a crack scale Mitutoyo.

The total specimens number was 48 units, distributed in three series of 16 specimens, presenting cement average content of 530, 600 and 695 kg/m³ in mortar.

In each series showing a determined cement content, it was varied the polymer-cement ratio according to the percentage of 10%, 20% and 30%, having a specimens serie that didn't received polymer, to be used as comparation. In each series, 4 specimens were tested.

The mixture, moulding, compacting and unmoulding conditions of the specimens were the same for all series.

The cure method referred in item 3.1 was different in the case of plates without polymer, which were maintained in moist cure during 28 days.

3.4.1. LOADING AND FLEXURAL TEST INSTRUMENTATION SCHEME

Figure 5 shows the scheme used in the flexural test, where the plate's loading was introduced by a hydraulic jack linked to electric load cell, concentrated on the four point loading of the theorical span (specimens were tested under four point loading with span equal 900mm).

This inversion in the loading direction made possible a better observation, and the crack width following.

The plates transversal displacement were measured by mechanical deflectometers Mitutoyo, with sensibility of 1/100mm and scale of 50mm.

The deflectometers disposition is showed in figure 5.

In the displacement measurement it was also used an inductive deflectometer on the span center, which was linked to a X-Y register to obtain the load-displacement diagram, making possible the precise determination of the cracking load of the plates durant the test.

4. ANALYSIS OF THE RESULTS

4.1. COMPRESSIVE STRENGHT

The polymer modified mortars, with cement content of 600 and 695 kg/m³ showed a sensible decrease in the compressive strength, with the polymer-cement ratio increase, respectively of 23% and 16%, in relation to the common mortar.

This smaller compressive strength of polymer modified mortar, relatively to the common mortar has already been verified by others researchers (3).

Although, for the mortar with smaller cement content (530/m³), the polymer-cement relation increment aided the strength gain, as it can be observed by figure 1. Obviously, the compressive strength depend on several factors and the interation among them.

Considering that the studied mortars have the same components and were submited to the same cure criteria, the intervenient factors that can have influenced the results are those relative to the materials proportion, i.e., polymer-cement unload volume ratio, water-cement ratio, polymer-cement ratio, and so on.

4.2. MODULUS OF ELASTICITY

The modulus of elasticity is a measure of the mortar flexibility, and the increase of the latex in the matrix, brings the decrease of its value (4).

Figure 2 shows the values found for the polymer modified mortars. Polymer-cement ratios of 30% bring to the several mixtures a decrease of 38%, aproximately, in their modulus of elasticity, when compared to common mortar.

4.3. FLEXURAL BEHAVIOUR

The contribution by increasing the polymer-cement ratio upon the improvement of the ferrocement flexural strength has been described in many works (5,6) being the mortar's composition kept with a constant cement volume, varying the polymer-cement ratio and the characteristics of the reinforcement armatures.

In this work the armature is the same in all the specimens varying the cement content and the polymer-cement ratio.

The ferrocement specimens first cracking load increases with the plymer-cement ratio, as it can be seen in figure 3, independently of the cement content in the mortars, with exception of mortar with cement-sand ratio 1:3 and polymer-cement ratio of 10%.

The specimen's ultimate load decreases with the increase of the polymer-cement ratio, independently of the cement content. In figure 4 the obtained values are showed, where only the mortar with cement sand ratio 1:2 and polymer-cement ratio of 10% overcame the value obtained with common mortar without the SBR latex.

Figure 6 shows the relation between the average cracks width and the flexural load of the specimens.

For the matrices with bigger cement contents (600 kg/m³ and 695 kg/m³), the increase of the polymer-cement ratio contributes more efectively to the decrease of the average cracks width. However, for the case of mortar with smaller cement content (530 kg/m^3), the increase of the polymer-cement ratio didn't imply in an average crack width reduction.

The reason for this fact comes from the variation of the adherence between matrix and armature which depends on the cement content and the polymer-cement ratio, beyond others intervenient factors in the mortar compaction.

The ferrocement plates with polymer modified matrix tend to present a bigger ductility comparatively to common mortar, what favors the crack width limitation.

The plates with cement content of 600 kg/m^3 were those which had the best influence of the polymer-cement ratio increment, from the point of view of the crack width limitation.

5. CONCLUSIONS

a. The first cracking load is increased by the use of polymers in the mortar independently of cement content.

b. The ultimate load has reduction with the increase of the polymer-cement ratio, being this fact attenuated by the increment of the mortar cement content.

c. The use of polymers in the mortar is good for the limitation of the crack width in the ferrocement, although it must be considered the best cement-aggregate ratio to be used.

d. The compression strength sofers influences from the polymer-cement ratio and the cement content.

e. For a determined cement content the modulus of elasticity varies inversely with the increase of the mortar polymer-cement ratio.

f. The beneficts brought by polymers to the ferrocement mean real possibilities for improving not only the mechanical properties, as well as its durability in face of the cracking attenuation.

g. The use of latex in mortar consists on a simple procedure easily absorved within the used technics in the ferrocement constructions.

6. REFERENCES

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APPENDIX - FIGURES

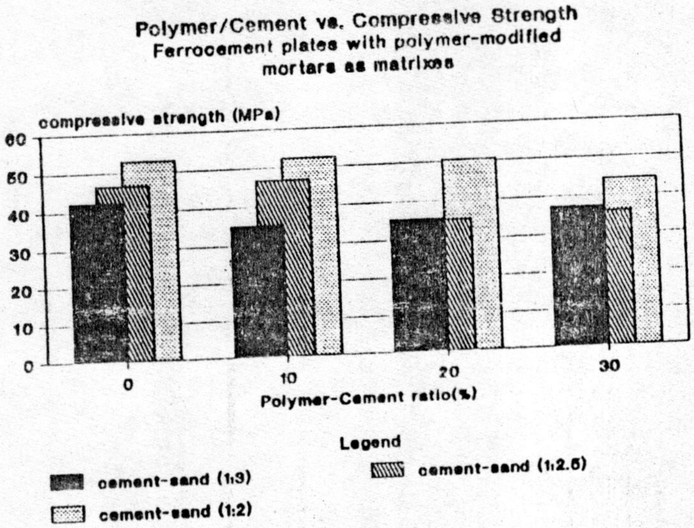

Figure 1

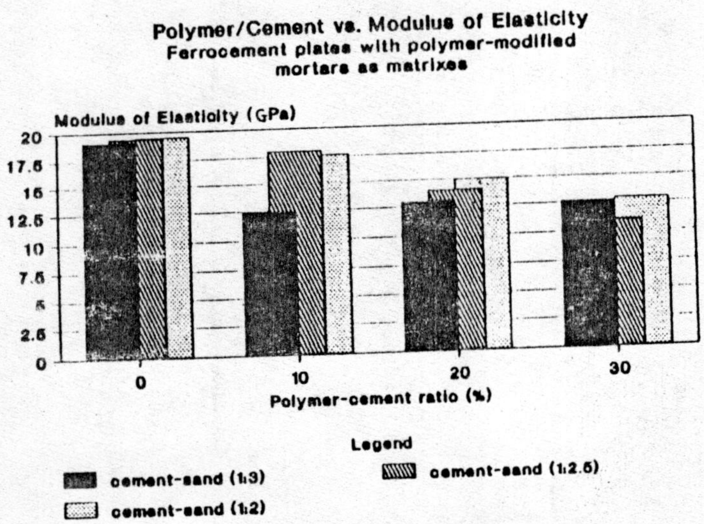

Figure 2

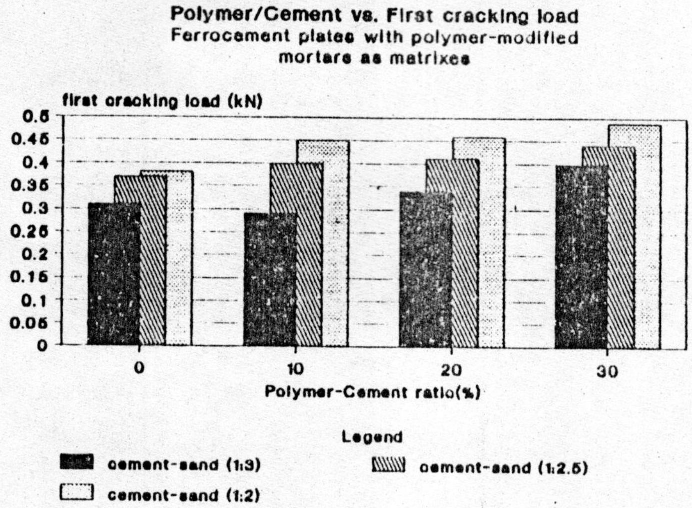

Figure 3

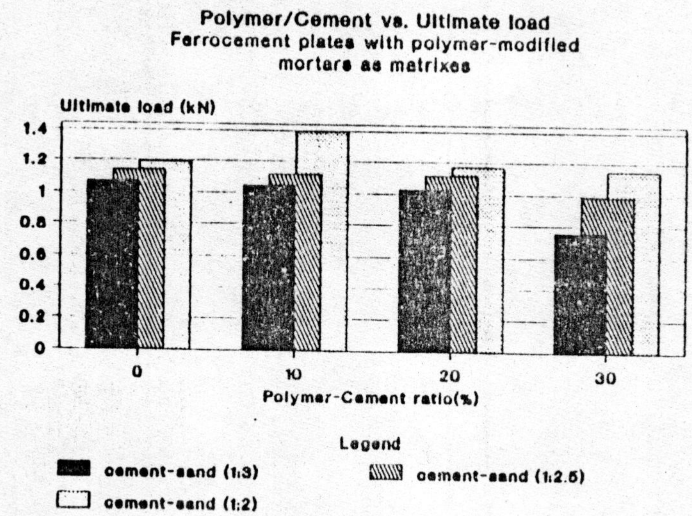

Figure 4

POSITION OF DEFLETOMETERS AND LOADING POINTS

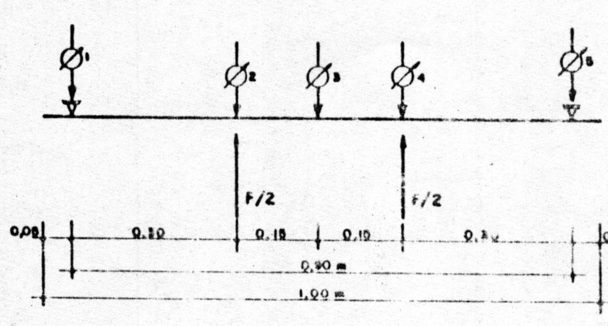

Figure 5

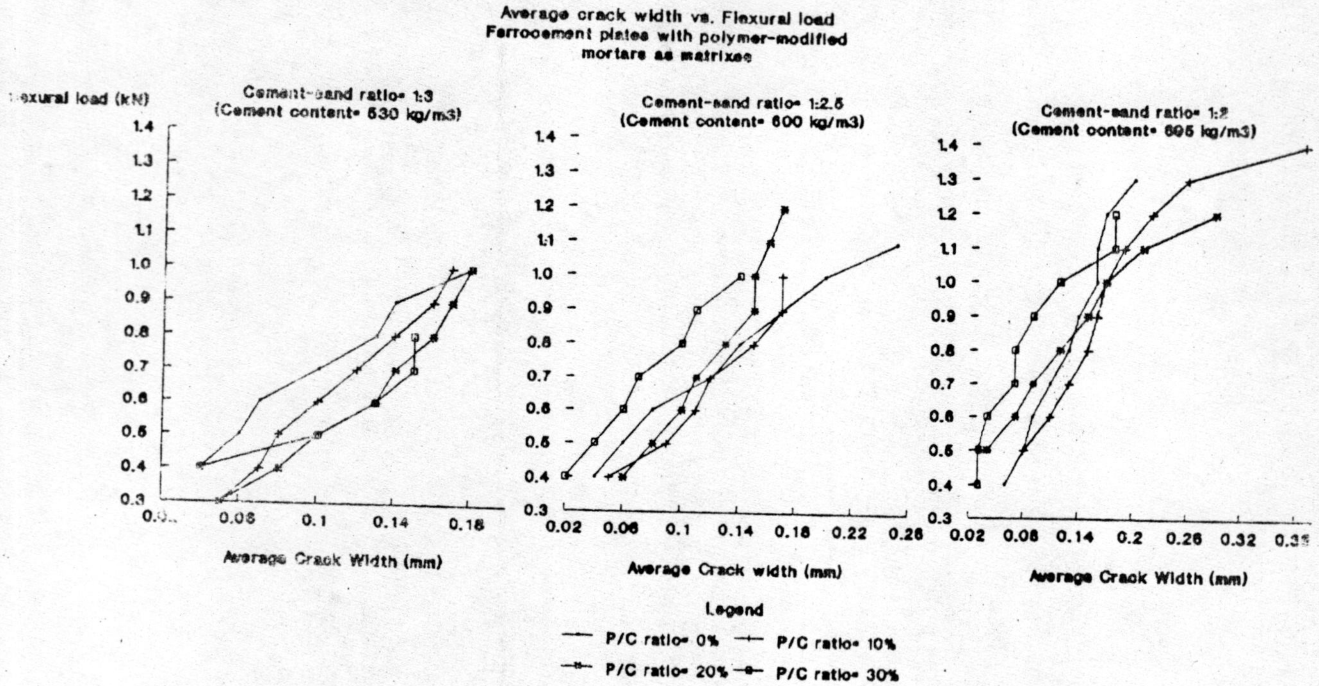
Average crack width vs. Flexural load
Ferrocement plates with polymer-modified
mortars as matrixes
Flexural load (kN)
Cement-sand ratio= 1:3
(Cement content= 530 kg/m3)
Cement-sand ratio= 1:2.5
(Cement content= 600 kg/m3)
Cement-sand ratio= 1:2
(Cement content= 695 kg/m3)
Average Crack Width (mm)
Average Crack width (mm)
Average Crack Width (mm)
Legend
P/C ratio= 0%
P/C ratio= 10%
P/C ratio= 20%
P/C ratio= 30%

Figure 6