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Influence of the surface treatment of tire rubber residues added in mortars

Influência do tipo de tratamento da superfície de resíduos de borracha de pneus adicionados em argamassas

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Abstract

In this work it was evaluated the influence tire rubber addition in mortars in order to replace part of the sand (12% by volume). It was also intended to verify if the tire rubber treatment with NaOH saturated aqueous solution causes interference on the mechanical properties of the mixture. Compressive strength, splitting tensile strength, water absorption, modulus of elasticity, and flow test were made in specimens of 5cmx10cm and the tests were carried out to 7, 28, 56, 90, and 180 days. The results show reduction on mechanical properties values after addition of tire rubber and decrease of the workability. It was also observed that the tire rubber treatment does not cause any alteration on the results compared to the rubber without treatment.

Keywords: tire rubber mortar, mechanical properties, and waste management.

Resumo

Neste trabalho foi avaliada a influência da adição de borracha de pneus em argamassas substituindo parte da areia (12% em volume). O trabalho também tem como objetivo verificar se o tratamento da superfície da borracha com solução aquosa saturada de NaOH, causa interferência nas propriedades mecânicas das misturas. Foram feitos ensaios de trabalhabilidade, resistência à compressão, resistência à tração e módulo de elasticidade em corpos-de-prova de 5x10(cm) para as idades de 7, 28, 56 e 90 dias. Os resultados mostram redução nos valores das propriedades mecânicas após a adição da borracha de pneu e perda da trabalhabilidade. Também foi observado que o tratamento da superfície da borracha de pneu não demonstra alteração nos resultados quando comparados com os resultados dos corpos-de-prova que não sofreram tratamento.

Palavras-chave: argamassa com borracha de pneu, propriedades mecânicas e resíduos.

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1. Introduction

The great amount of scrap tires has caused environmental problems because of its disposal. There are, in Brazil, 10 millions of tires out of use all over the country [1]. According to CONAMA (Conselho Nacional do Meio Ambiente), which is responsible for the environment of the country, it was established that after January 1st of 2005 for each tire produced in Brazil or imported, the companies that produces tires and those that imports tires must give appropriated destination to 5 tires out of use. And also for each 3 tires reformed or imported, of any kind, the companies that import tires must give appropriate destination to 4 tires out of use.
The addition of tire rubber in construction's elements is an alternative way to recycle this residue. Therefore researches have been done in order to evaluate the influence of tire rubber addition in cementitious materials. Many researchers observed that tire rubber added in cement composites causes decrease in its mechanical properties [2-11]. And it was also observed that the failure behavior is changed, since the tire rubber concrete supports more elastic strain than the reference concrete [12].
The shape of rubber aggregate also influences in the results of concrete. It was observed that specimens with tire rubber fibers presented better performance then the crumb ones [13]. In cement paste and concrete it was observed that the specimens with tire rubber have less water absorption by capillarity than the reference specimens [4, 14]. That may occur because the rubber does not absorb water [4].
The workability is also another property affected by the tire rubber addition. Slump tests made in concrete showed that the more the tire rubber added the less the workability [15].
The decrease in mechanical properties, which was observed by most of researches, is attributed to the lack of bond between aggregate and the cement paste [2-11]. So, in order to improve that bond, some authors suggest the treatment of the surface of the tire rubber aggregate [4, 16].
Some researches suggest washing the residue with water or treating it with CCl_4 solution, which results in compressive strength, respectively, 16% and 57% higher than the specimens without treatment [16]. The pre-processing of the rubber using the coating method with Methocel cellulose ether solution was also studied but it did not present any changes [17]. Studies made with cement paste showed that the treatment with NaOH improves the bond between residue and the cement paste. Since it is assumed that the NaOH hydrolyzes the acidic and/or carboxyl groups present on the tire rubber surface [4].
Because of the better performance of cement Portland paste with treated tire rubber, in this work, it was evaluated the influence of tire rubber addition in mortars and also the surface treatment of the residue with NaOH saturated aqueous solution. Tests at 7, 28, 56, 90, and 180 days were carried out. The evaluated properties were: compressive strength, tensile strength, modulus of elasticity, water absorption, and flow. In order to verify the adherence between the mortar and the residue some specimens were also analyzed by scanning electron microscopy (S. E. M).

Figure 1 – Tire rubber residue after sieved

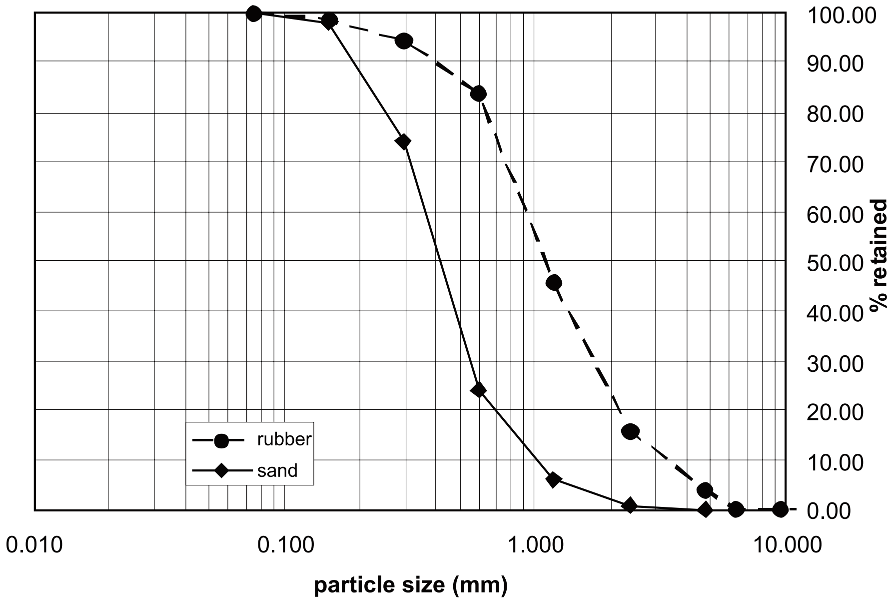
Table 1 – Mix proportions to reference and rubberized specimens

Materials	Consuption (Reference) kg/m³	Consuption (Rubber) kg/m³
Cement	510.60	510.60
Sand	1531.81	1378.63
Water	255.30	255.30
Rubber	-	81.05

2. Materials and experimental program

It has been used in the mixes the Brazilian Cement Portland CPV ARI PLUS, which is early high strength cement.
River sand and tire rubber from tire retreading were used as aggregate. The specific gravity of the cement, sand and tire rubber respectively are 3.05g/cm³, 2.65g/cm³ and 1.09g/cm³. The mix proportion used to prepare the specimens with and without rubber is showed in the Table 1.
The rubber used in this work, which is showed in Figure 1, was sieved and used the part that passed in the sieve opening of 0.8mm. The grading curve of the aggregates can be seen in Figure 2.
The mix proportion by mass used in reference specimens was 1:3:0.5 (cement: sand: water). 12% (vol.) of sand was substituted by tire rubber. The specimens were cast manually and kept in moist room until the test date. It was prepared three types of mixes: reference, with treated rubber and with untreated rubber.
The surface treatment was made through the immersion of the rubber in sodium hydroxide saturated aqueous solution (NaOH) and stirring the mix for 30 minutes. The mix, after filtered was rinsed and dried at room temperature.
It was studied properties in fresh and hardened state. In fresh state it was evaluated the workability by the flow test, according to the Brazilians standards [18].
In order to evaluate the properties in hardened state it was made compressive strength test, tensile strength test [19, 20], and wa-

Figure 2 – Gradation curve of the aggregate sieve analysis



ter absorption [21], all of them with 50mx100mm specimens and three specimens for test. The modulus of elasticity it was made according to the Brazilian standard for concrete specimens. The specimens' dimensions used to this test were the same of the concrete specimens (10cm x 20cm) [22]. The adherence between the residue and the cement paste was made by the scanning electron microscopy analysis at 28 days.

3 Results and discussions

3.1 Flow test

The evaluation of the workability, determined by the flow test can be seen on Figure 3.

It can be seen from Figure 3 that the reference mortar presents higher consistency, which indicates that the tire rubber mixes has less workability than the reference one. This behavior is also observed by other researchers.

The comparison between the treated rubbers to those without treatment is also made. As can be seen on Figure 3, it can not be said that the tire rubber treatment influences in that property, since the results are very close to each other.

3.2 Compressive strength

The results of the compressive strength tests, presented in the Figure 4, show the strength of the mixes for 7, 28, 56, 90, and 180 days.

The replacement of the sand by tire rubber causes a decrease in compressive strength values as it can be seen in Figure 4. It was also noticed that the specimens added by treated tire rubber does not show a better performance then those added by regular tire rubber. Comparing the strength loss between the reference and rubberized mixes it shows that the strength of the specimens made without treated rubber is about 40% less than the reference and for the treated rubber is about 47% less than the reference for all the analyzed ages.

3.3 Splitting tensile strength

Figure 5 presents the results from the tensile strength tests of the specimens with and without rubber.

As in the compressive strength results, it was also observed that rubberized specimens have less strength than the reference specimens. The comparison between rubberized specimens and references shows that mixes with untreated rubber has 40% less strength than the reference and mixes with treated rubber has 37% less strength than the reference at 28 days.

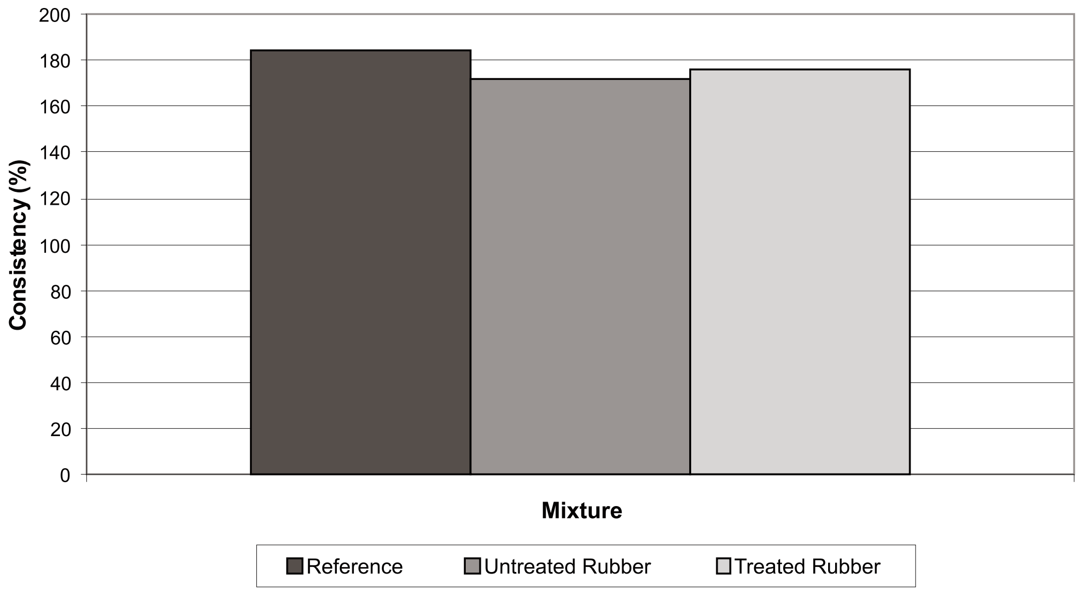
The comparison between specimens made with untreated rubber and specimens with treated rubber shows that, the specimens made with untreated has 8.5% less strength than the treated ones for all the ages studied. Although, it has been seen that there are some differences between the results, they are very close to each other.

3.4 Modulus of elasticity

To evaluate this property it was used the Brazilian standard for concrete specimens. The specimens' dimensions used to this test were the same of the concrete specimens (10cm x 20cm). In Figure 6 are shown the results of the modulus of elasticity test.

As in compressive and tensile strength test, the modulus of elasticity test shows a better performance of the reference mix when compared to the rubberized mixes. At 7 days the modulus of elasticity of rubberized specimens is 44% less then the modulus of elasticity of the reference specimens at 28 days. It was also ob-

Figure 3 – Flow test of the mortars



served in this property that the treatment does not show difference between the results.

3.5 Water absorption

Water absorption test was made up to the age of 90 days and its results can be seen in Figure 7.

Although the reference mix absorbs more water than the rubberized mixes, the results are not very different between each other. The differences between reference specimens and untreated rubber specimens are about 6% for most of the tested ages. It was also observed that the treatment does not influence on that

Figure 4 – Compressive strength test results

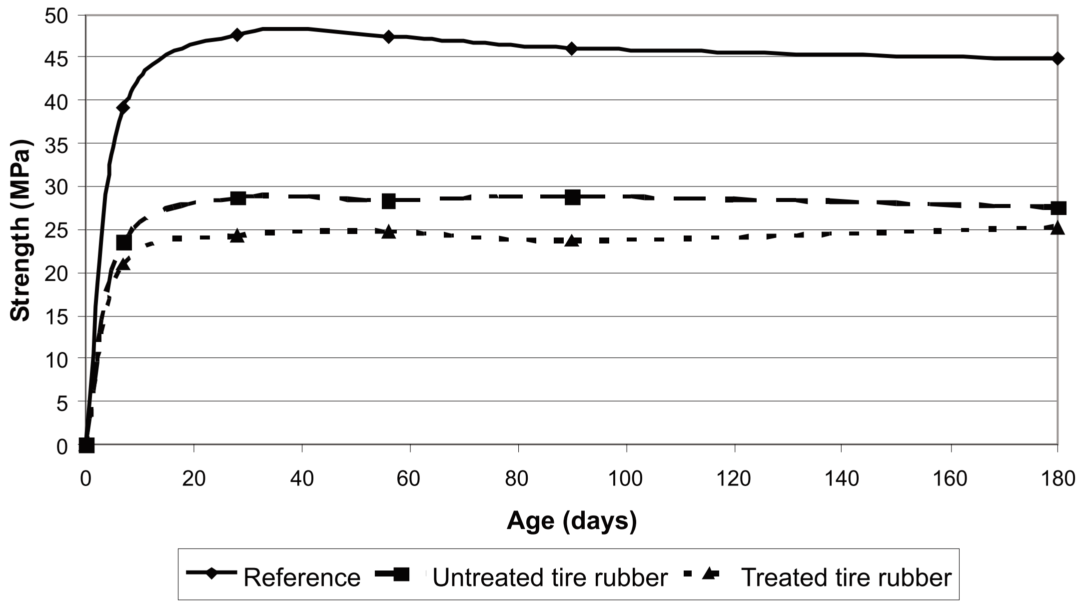
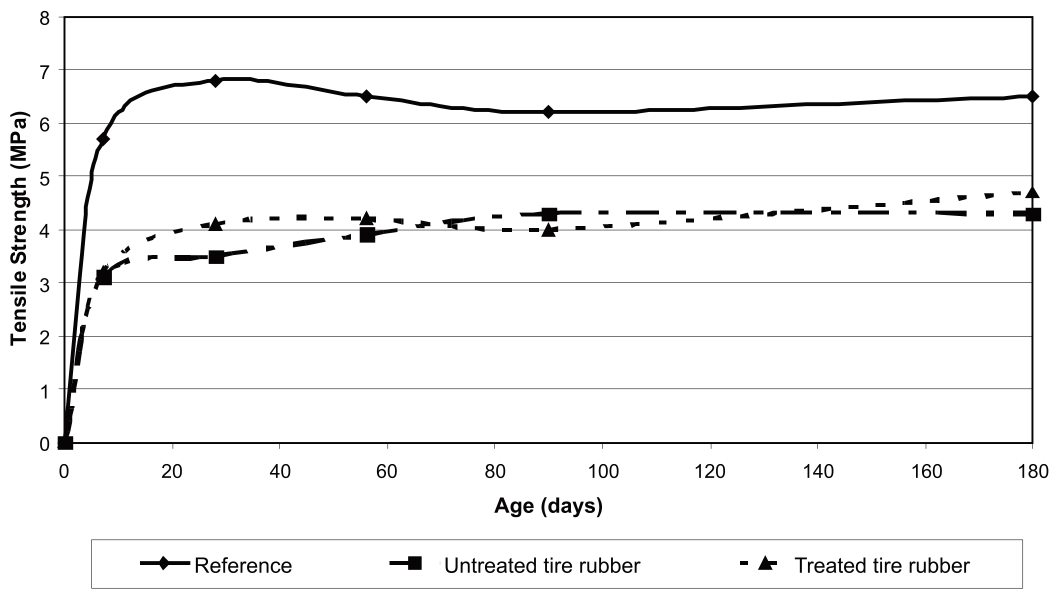


Figure 5 – Splitting Tensile strength test results



property, since the difference between specimens with and without treated rubber was just 1%.

3.6 Scanning Electron Microscopy

The scanning Electron Microscopy was used to analyze the adherence between the cement paste and the residue. Figures 8 and 9 present images from the scanning electron microscopy test of the studied mortars. Scanning Electron Microscopy shows that, in general, cement-residue interface exhibits discontinuities, possibly because of the voids in that interface, which justifies the lack of adherence between the rubber and the cement paste.

Figure 6 – Modulus of elasticity test results

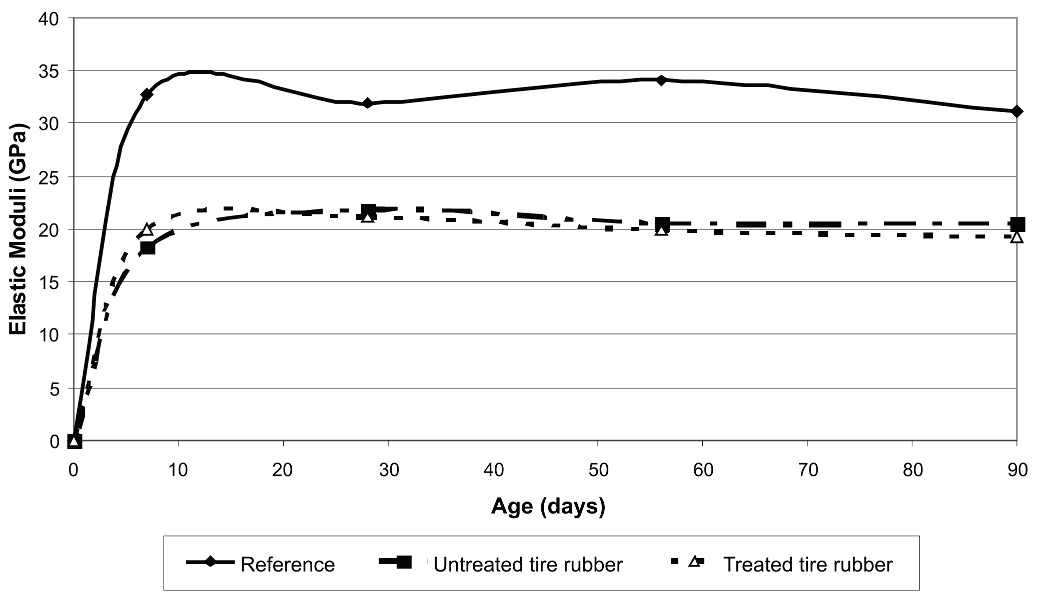
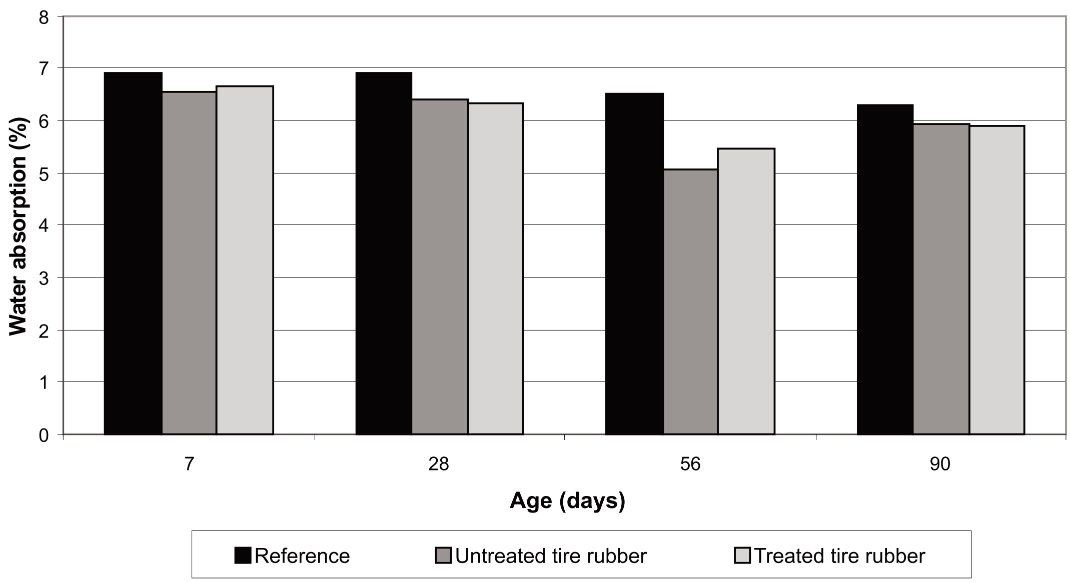


Figure 7 – Water absorption test results



It can also be seen in Figures 8 and 9 that the rubber distribution inside the specimen is not changed by its treatment and even after the treatment there is no adherence between the residue and the cement paste, i. e., the interface cement-rubber does not present good bond.

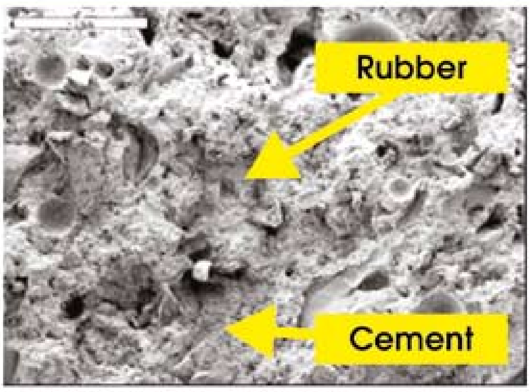
4. Conclusions

The results show that for all the tests, the treatment of the tire rubber surface with sodium hydroxide aqueous solution does not present significant change in mortar rubberized mixes.

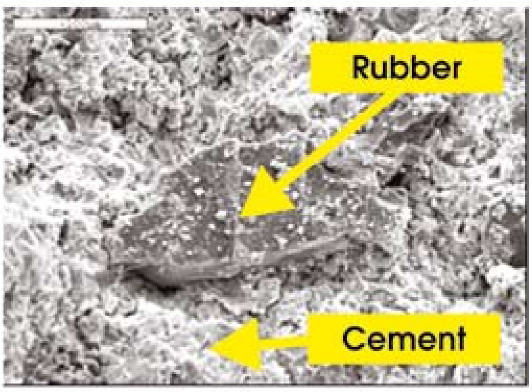
Although the flow test showed that the use of tire rubber decrease the mix workability, the difference between the specimens with and without tire rubber was not big. Water absorption indicates that although the use of the residue slightly decrease the water absorption compared to the reference mix, the results were very close. The less water absorption of the residue can be attributed to the less affinity of water to rubber than to sand.

The mechanical properties as compressive strength, splitting tensile strength and modulus of elasticity, the untreated tire rubber

Figure 8 – Scanning Electron Microscopy of untreated tire rubber mortar

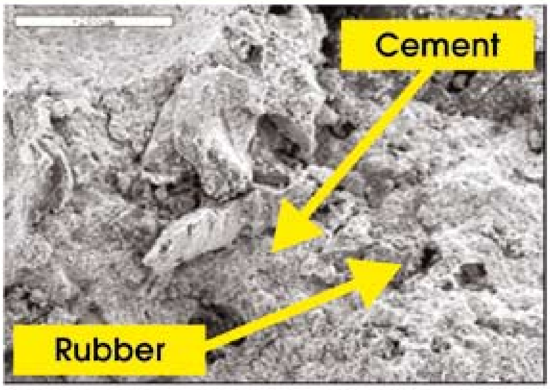


(a) Overview of cement paste and rubber residue

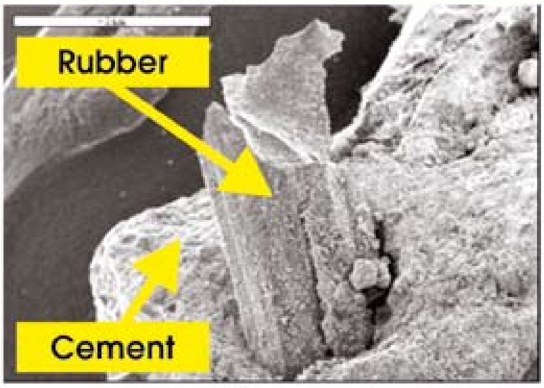


(b) Detail of the tire rubber in the cement matrix

Figure 9 – Scanning Electron Microscopy of treated tire rubber mortar



(a) Overview of cement paste and treated rubber residue



(b) Detail of the treated tire rubber in the cement matrix

specimens performed better than the treated ones. The lower results of modulus of elasticity indicate a higher capability to absorb strain after tire rubber addition.

The decrease of the mechanical strength of the specimens with the residue is attributed to the tire rubber capability to support fewer loads than the sand and also to the lack of adherence between the cement paste and the tire rubber. The use of tire rubber also increases the voids on the mixes and affects the mechanical properties.

Although researches with Cement Portland mixes presents better performance after the rubber treatment with NaOH aqueous solution, the use of treated rubber in mortars does not present any significant improvement of the studied properties.

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