POLYMER EFFECT ON THE RHEOLOGICAL PROPERTIES OF THE PPC BLENDS

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ABSTRACT. A study was carried out on rheological properties of PCC (polymer concrete with cement) fresh blends containing polymers soluble in water and epoxy resins. The work refers to determine yield and plastic viscosity of fresh concrete according to the polymer weight. It was used methilcellulose as polymer and an epoxy resin, in different proportions. It was also carried out physico-mechanical tests on hard concrete. The study revealed that the addition of polymer matrix to produce PCC concrete, has a pronounced effect on the rheological property of freshly mixed. Influence of polymers on these properties is due to both the content of colloidal particles, and the amount of air present in the mixture due to stirring and mixing the paste.Changes that they produce polymer emulsions are found in terms of both flow and the viscosity value, and decreasing. This allows the scientifically and technologically, as they are controlled and adapted to specific requirements.Compressive strength of epoxy resin blends were found to be higher than those of mixtures containing methylcellulose.

Keywords: Metylcellulose, Rheological properties, Yield stress, Epoxi resins

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INTRODUCTION

PCC is obtained by mixing polymer dispersion redispersable powders, water soluble polymers or polymer liquid with fresh concrete mix (cement, water and aggregate). It can even be introduced monomers into cement under the assumption that adequate polymerization and film formation will take place in conjunction with the cement hydration process. Polymer dispersions are frequently used, which consist of small particles of polymer (0.05-5 m) spread in water [1].

Polymers soluble in water and epoxy resins are often used to obtain polymer concrete that is used to repair and renovate old and damaged buildings.

One of the advantages of concrete containing polymer emulsions is the improvement of workability fresh state.

Better workability of these systems is probably due to the colloidal particles (before their coalescence). Polymers improve the dispersion of cement particles in water is some tendency to delay clotting and minimize the formation of water-rich layers near the cement particles. They also provide better dispersion of cement particles non-hydrate mixture mass without significant drain water layer near the aggregate surface. Both effects are able to reduce the interface between cement and polymer, providing a structure more cohesive reducing the amount of cracks. Due to their nature, they can blend well with concrete, are therefore very suitable as a possible mix. Emulsions frequently used are of the type forming thin films with sub micrometer thickness generally placed between layers of crystals of $Ca(OH)_2$ and in the pores of the material in the form of bridges [2].

Solid polymer content in aqueous solution is about 50%, although commercial emulsion polymer having less than this value. Glass transition temperature (TG) or minimum temperature at which it forms thin films (MFFT) of these polymers is lower than room temperature (TR). On drying polymer particles come together to form a thin film. Repulsion forces between charged or polar particles dispersed in the liquid medium to keep them until it dries and particles approach each other. In this case, the thermodynamic system favours particle coalescence and the formation of a continuous film. This fundamental and important phenomenon also occurs in the concrete to set and dry. Polymer films are those two networks overlapped continue to make the system can be defined as a composite polymer - mineral (because of ettringit which mingles with polymer thin films as bridges)[3]. It is assumed that colloidal polymer particles are adsorbed on the cement particle surface forming a coating on mineral particles. Because of this coating, cement particle interaction with water is prevented, and the cement hydration reactions are lower in intensity.
The main effects of emulsions faction concrete properties are:

-In fresh state, workability is improved due to the effect of colloidal polymer particles induced (before their clotting);

- In its cured state is improved both the substrate adhesion of new polymer and old substrate, and resistance to water and chloride penetration, due to the formation of polymer films inside the concrete [4].

Materials and Methods

Rheological tests were performed on cement paste containing ordinary Portland cement according to DIN EN 196-1. Methylcellulose - MC (water soluble polymer) and epoxy resin (supplied by Sika) are added to fresh concrete mixtures. Polymer solubility in water is mainly determined by the viscosity of the solution. They are dissolved in water according to the dosage recommended by the manufacturer. It was found that at room temperature all polymer solutions form transparent film and without crack at this temperature. Rheological parameters measured are: yield stress (Pa) and plastic viscosity (Pa · s).

It was established as standard sample cement paste that has a water / cement ratio of 0.4 and contains no polymer.
Polymers have been added in the following proportions:

- Methylcellulose 0.2% by weight of cement
- 5% epoxy resin and 10% by weight of cement.

Were also conducted microstructural investigations on both composition containing polymer and the standard composition.

Determination of yield stress of mixtures was done at 30 minutes and at 120 minutes after water addition. Yield stress was determined using a rheometer. This device determines the time required to yield. Compressive strength was measured on cubes of side 50 mm.

Results and Discussions

Figure 1 shows the apparent viscosity of cement pastes studied and it can be seen that an amount of 5% resin material produces increased viscosity leads to the idea that the amount of polymer is not sufficient to improve the workability of the material. In case of methylcellulose addition the viscosity of material decreases, observing is also a large amount of training air inside the cement paste, a phenomenon that can be observed in microscopic investigations conducted. These studies showed that the flow behavior of cement paste is influenced by the same factors that contribute to any other suspension flow: the degree of saturation of the solution and the degree to which the particles are coagulated. Cement pastes show a modest pseudoplastic flow at small a / c ratio and a newtonian flow at large a / c ratio. Coagulates cement paste unless he is added to a polymer or additive to reduce the amount of water needed, to disperse the particles. Only factor influencing the flow behaviour is hydration, leading to a considerable increase in yield, until the paste begins to lose fluid properties (by the end of the latent period). A quantity of 10% resin produces a significant decrease in viscosity of the material and thus putting is easier. As time goes by hydration reactions take place as the solid fraction increases. Increase in volume of solid fractions leads to a considerable increase in viscosity and development of plastic or pseudoplastic behaviour until curing mixture.

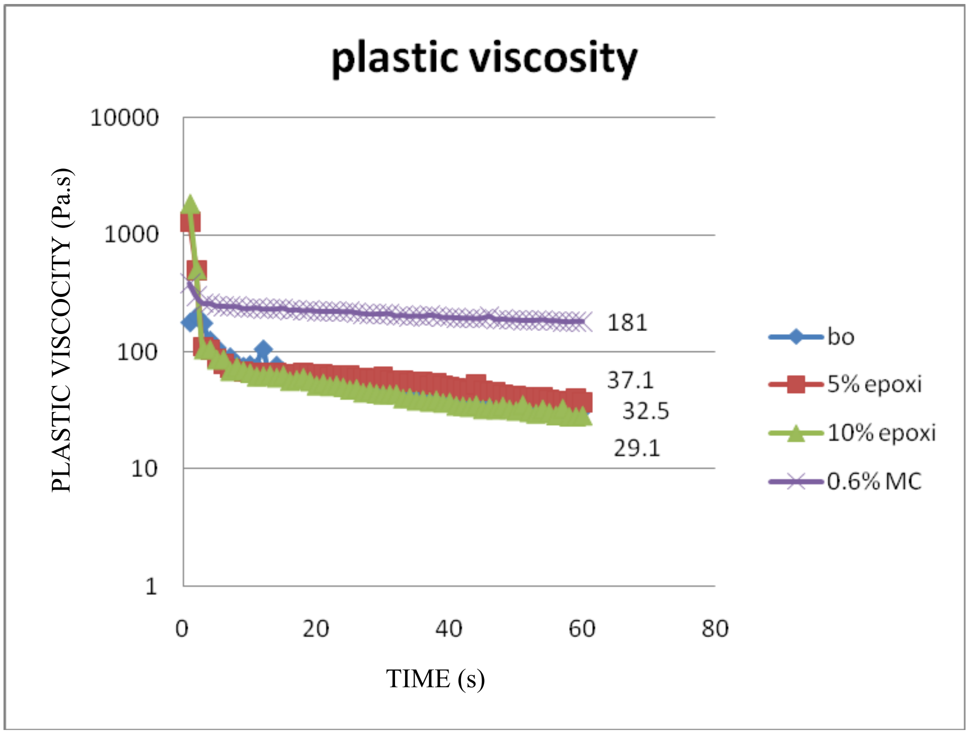

Figure 1 Plastic viscosity of the mixtures studied

Figure 2 shows the yield of normal concrete paste, it predicts a relatively high yield strength, the material can be put in the form with difficulty.

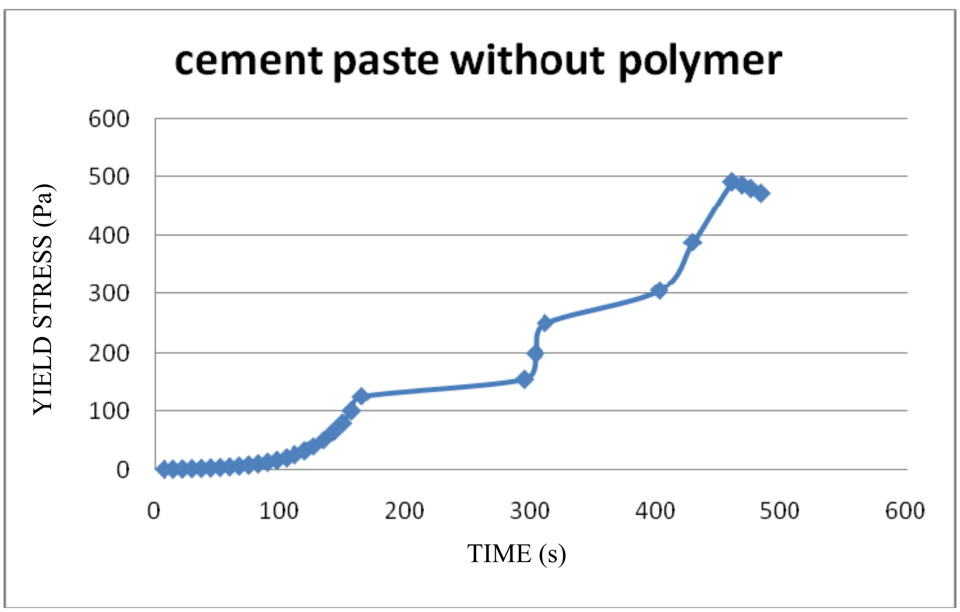

Figure 2 Yield stress of ordinary cement pastes

Performed detailed studies in this respect have shown that a good workability concrete is present a yield below 400 Pa. Therefore, with the addition of polymers to the improvement of concrete properties and also decrease yield. From these results we conclude that the proportion of water is not enough to have good workability and hydration reactions are in progress. What is meant by the addition of polymer is decreased viscosity and yield stress of the material thus obtaining a longer period of time, needed to put in material form. From previous results it is known that the polymer has the ability to delay the hardening of concrete due to the effect of dispersion of cement particles or polymers on its ability to form an interconnected matrix of ettringit and polymers, adding water penetration on particle surface.

In Figure 3 are flow limits for pastes containing polymers, thus determining that both methylcellulose and a proportion of 5% resin can provide a yield to allow for easily of working with concrete. It is also known as high yield as with the compositions and compositions containing methylcellulose may tend segregation. Even if it is vibrated does not become fluid and can be pumped easily.

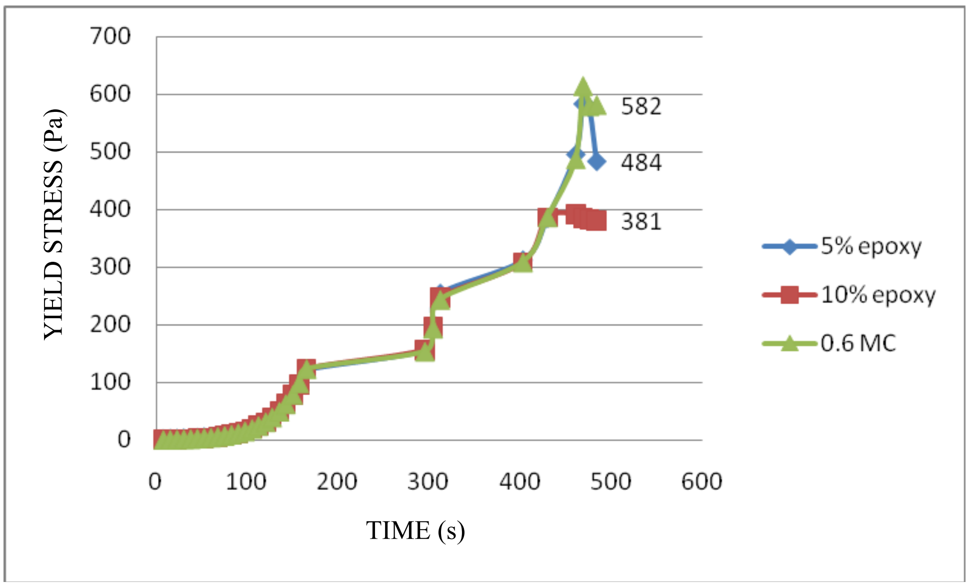

Figure 3 Yield of polymer cement pastes as 30 minutes from the addition of water

From the results we can see that by increasing content from 5% to 10% emulsion in fresh mixture occurs gradually decrease the flow of the reference mixture from 484 Pa (without polymer) to 381 Pa of the mixture containing 10% resin epoxy. You can also see that the 5% amount of resin and methylcellulose does not cause yield loss which leads to the conclusion that insufficient proportions of polymer and methylcellulose is not recommended for concrete mixtures.

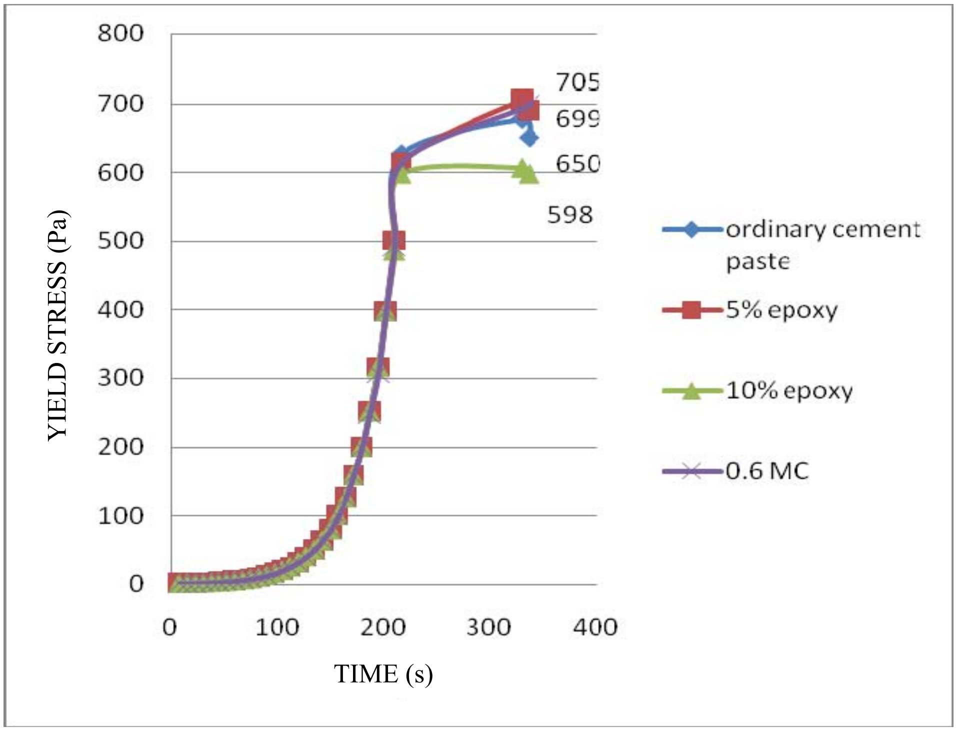

Figure 4 Yield at 120 minutes after water addition

Because in cement pastes the structure it is continuously changes, hydration reactions take place and the setting is installed it was determined yield stress at 120 minutes after water addition. During this assessment material structure is destroyed and the response is recorded as yield. Polymers affected the viscosity and yield stress decrease, so that the material can be uniformly compacted with effect on the development of higher mechanical strength.

In Figure 4 is shown the yield to 120 minutes of hydration observed its growth, leading to the conclusion that hidratre reactions take place, setting was installed and the material begins to harden. Also notice that the mixture containing 10% epoxy resin shows the lower limit of flow and mixing with methylcellulose require a greater force for structural damage. As with yield determined at 30 minutes after moisturizing blend with methylcellulose shows its highest value and therefore is inadequate compaction so performance is lower.

Yield determination of material involves the maximum effort required to fully destroy the material's structure. It also show the material time to return to the initial structure (before applying force), which means that the material is characterized by thixotropy.

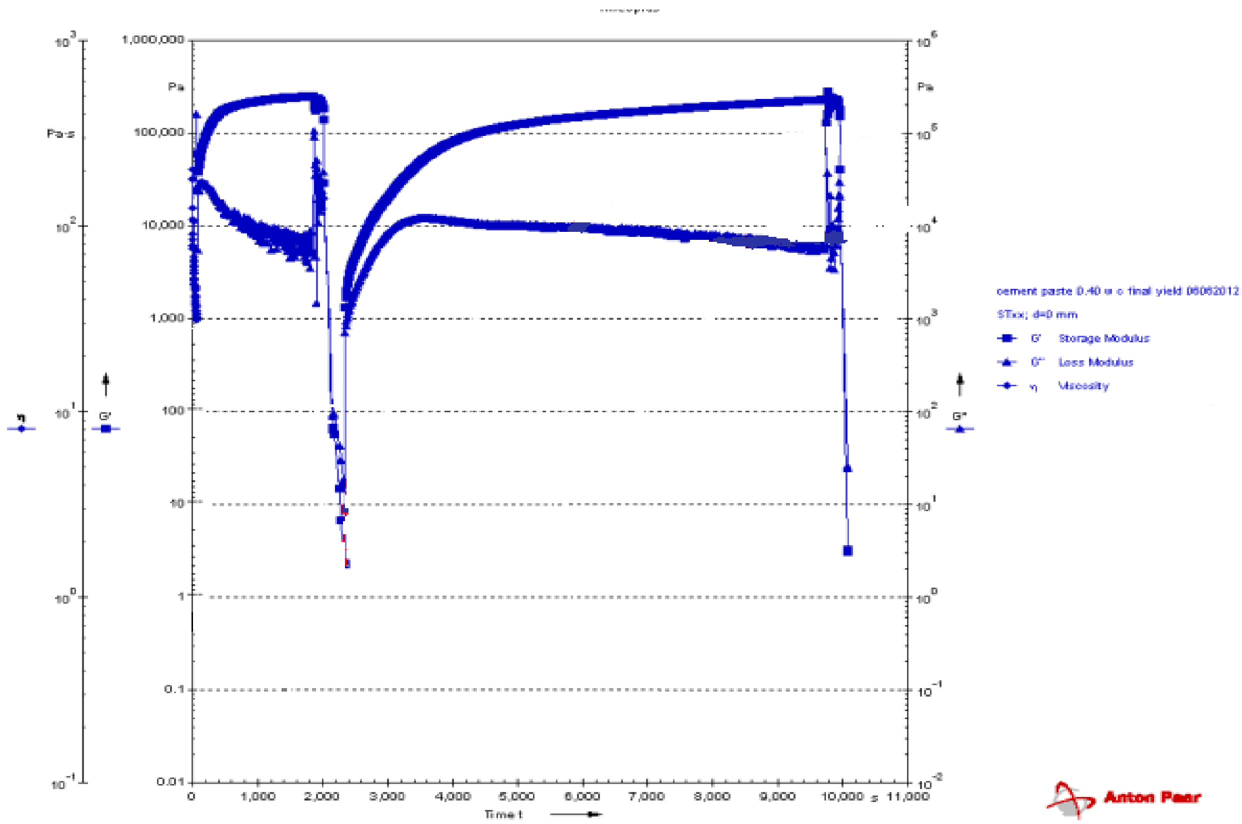

Figure 5 Thixotropic cement paste

In Figure 5 is shown the time evolution of the modulus of elasticity and viscosity of the composition module to the value of a / c ratio of 0.4. G' is the modulus of elasticity and shows the material's ability to store energy and G" is the material's ability to lose energy. It can be seen that after the destruction of the structure, the material's ability to return to its original shape.
Another way to determine the workability is the slump test. Table 1 shows the slump test values for w/c ratio 0.4.

Table 1 Slump test values

MIXTURE	SLUMP TEST VALUE FOR A/C = 0.4
0% polymer	4.5 mm
5% epoxy	8 mm
10% epoxy	67 mm
0.6% methylcellulose	58 mm

From these data we can see that the epoxy resin containing less than 5% and including not offer an improvement in workability. When using methylcellulose and a quantity 10% resin shows very high slump.
The data in Table 2 show that mixtures have in their composition methylcellulose shows lower values of mechanical resistance due to higher air content present in the structure.

Table 2 Compressive strength of polymer concrete compositions

	1 ZILE [MPA]	3 ZILE [MPA]	7 ZILE [MPA]	28 ZILE [MPA]
a/c = 0.4	17.32	41.8	26.6	42.0
	18.28	27.1	48.0	56.2
	19.28	34.1	49.4	50.9
	20.4	45.8	48.2	54.88
	17.86	43.2	44.2	52.08
	16.54	46.7	52.0	44.2
Epoxy 5% w/c = 0.4	16.18	31.7	40.92	50.0
	17.92	36	44.48	52.3
	18.51	35.2	39.88	56.0
	16.41	36.4	42.68	55.4
	17.63	27.4	42.36	56.4
	17.99	27.3	44.12	56.3
Epoxy 10 % w/c = 0.4	12.97	31.5	54.48	70.24
	13.22	28.8	49.9	68.2
	13.66	29.8	48.8	74.5
	12.99	28.2	57.7	66.2
	12.60	29.4	47.5	74.6
	12.96	29.4	56.8	75.2
0.6 methylcellulose w/c = 0.4	11.52	27.9	28.6	33.4
	10.65	28.5	32.2	48.9
	10.54	27.6	36.5	49.5
	10.90	26.3	36.2	50.2
	10.60	28.4	33.5	48.7
	9.99	26.6	36.4	51.4

The data obtained from the compressive strength of concrete mixtures can be seen that the compressive strength of concrete mixtures without polymer can reach 28 days from casting to a maximum value of 54.88 Mpa while for concrete compositions containing polymers depending on polymer type and amount added. For concrete mixtures containing epoxy resin shows an improvement in both compression strength, so the polymer concretes containing 5% strength can reach 56.4 MPa but the rheological tests found that concrete mixtures do not contain sufficient workability pour easily and is not recommended to use this polymer percentage. Optimal amount of epoxy resin concrete mixtures can be considered at the 10% because they found differences both in terms of material flow and the mechanical resistance. Material viscosity decreases and require a less force to work with the materials and yield of the mixture decreases. Compressive strength reaches the value of 75.2 MPa can thus be considered a high-strength concrete.

Regarding the results for samples containing methylcellulose compression compressive strength is lower even compared to those obtained us on a regular concrete. We conclude that the use of methylcellulose in mixtures leads to additional costs without improved property. Also its dissolution in water lead to large volumes of air entrainment due to foaming, and thus explain their lower resistance.

In the Figures 6a, b, are presented ordinary concrete microstructures. Structures do not show a high porosity, produced by hydration of cement particle surface and they can encapsulate particular aggregate causing so development of strength. Interface between aggregate and individual hydration products of cement is intended to be improved by additions of polymer.In the mixtures with methylcellulose as shows in the fig. 7 a, b, c, we can see a lot of air voids, most of them falling in the dimensional range 100-200 microns. However in the presence of MC, $Ca(OH)_2$ precipitates in the shape of stacks of layered crystals with undistorted morphology. Although, methylcellulose amount is insufficient to completely fill air voids in concrete.

As you can see from the results presented in Table 2 we conclude that a large volume of air voids leads to decrease the strength. From micro structural investigations it can be seen, fig. 8 a, b, c that epoxy resin formed inside the structure links between components can improve their mechanical strength. Bridges who are stretched between crystal layers act as additional links leading to a strengthening of the crystal structure. Because crystals of Ca (OH) 2 is the weak phase matrix binder and forms on their surface sites showing cleavage phenomenon, strengthening the polymer bridges can lead to an increased resistance of the matrix. This statement is also supported by the compressive strength obtained from materials containing epoxy resin. Polymer bridges tend to reinforce concrete structure but a quantity of 5% is insufficient polymer to improve resistance significantly. Their best results are obtained by 10% polymer blends because with increasing amount of polymer and polymer increases the amount of elastic bridges.

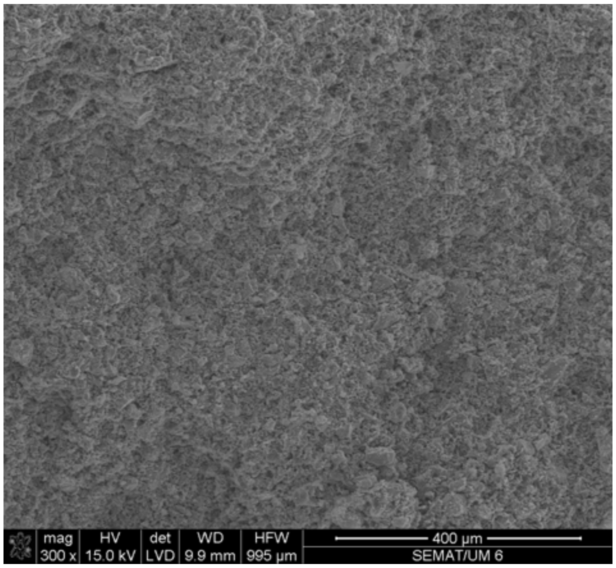

Figure 6 a

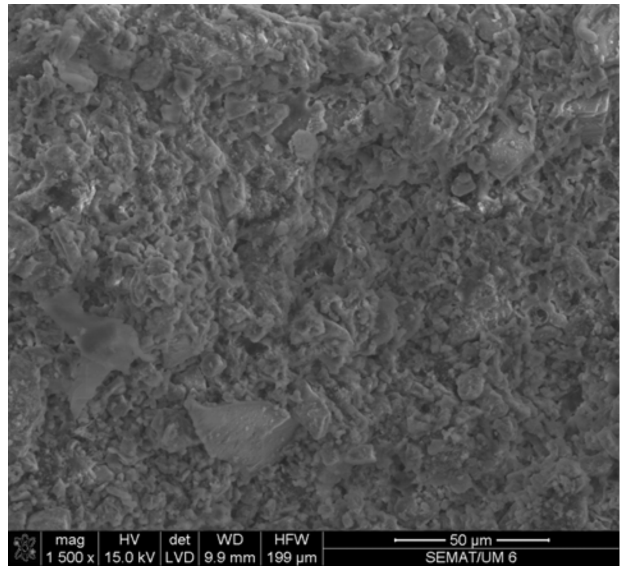

Figure 6 b

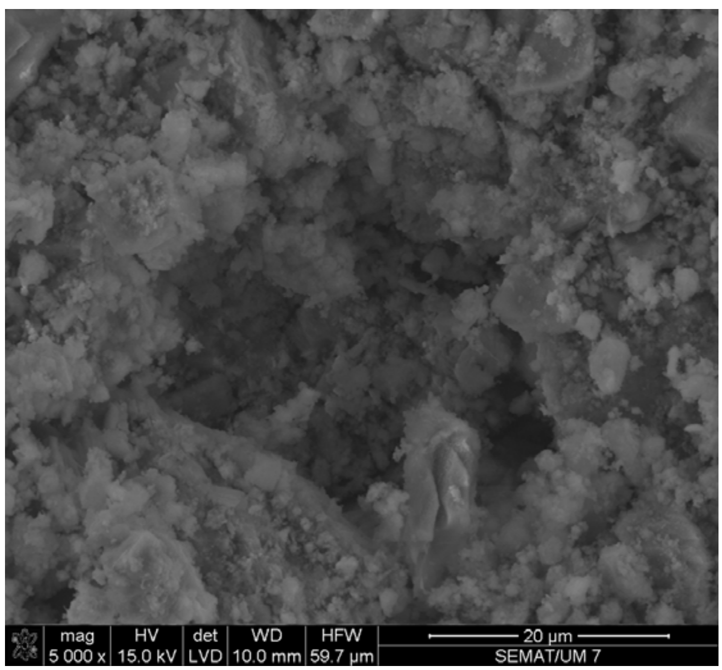

Figure 6 c

Figure 6. a, b, No polymer cement paste at different magnifications

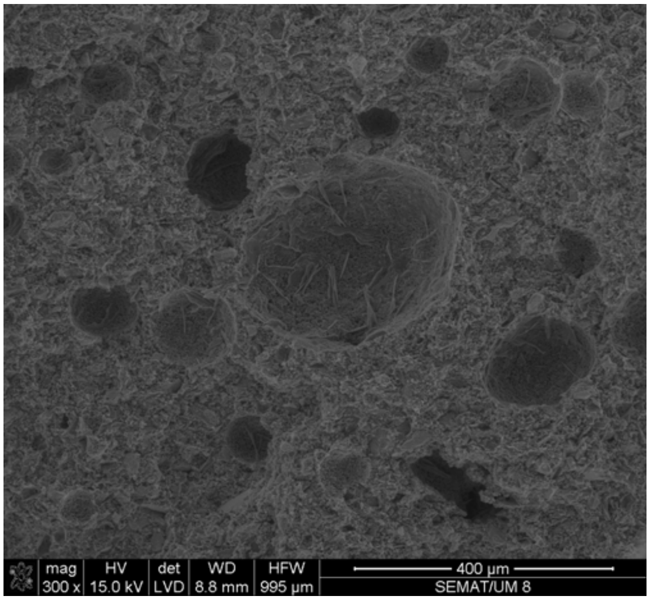

Figure 7 a

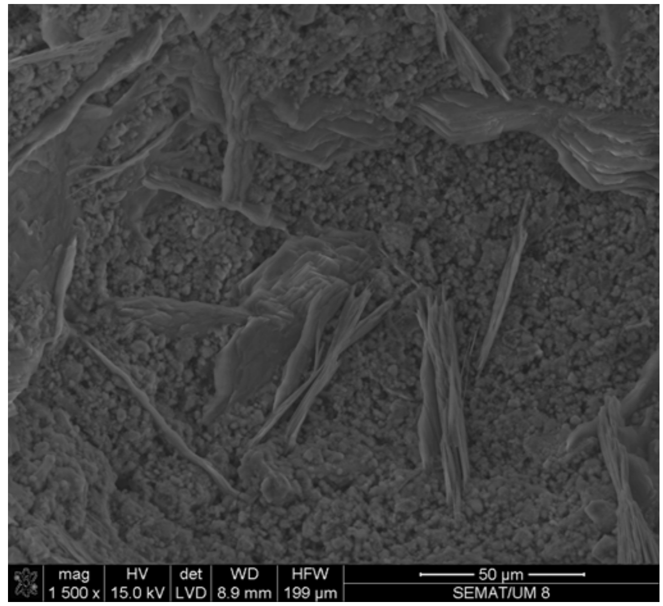

Figure 7 b

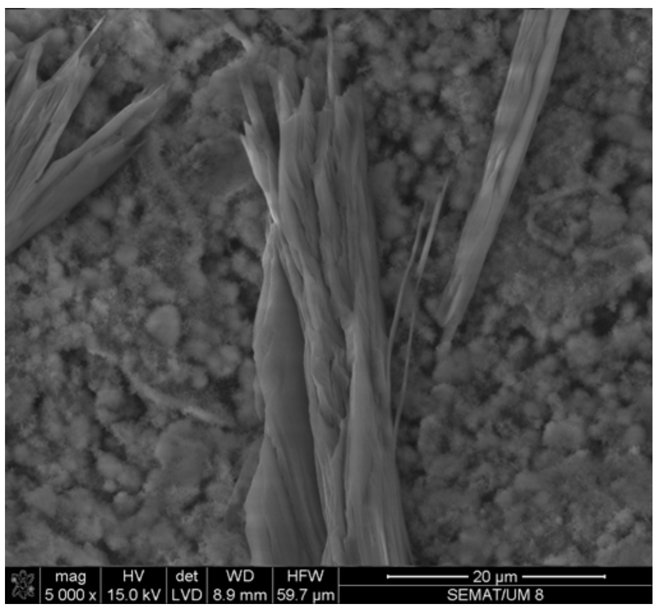

Figure 7 c

Figure 7 a, b, c the cement paste with methylcellulose at different magnifications

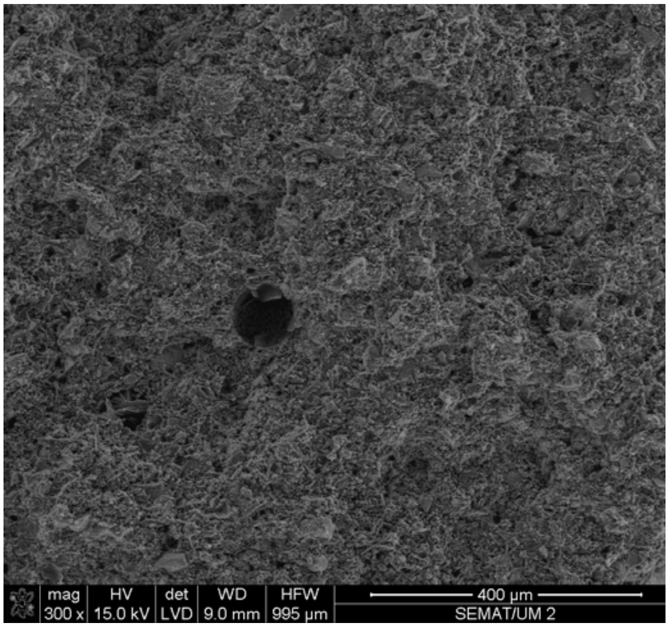

Figure 8 a

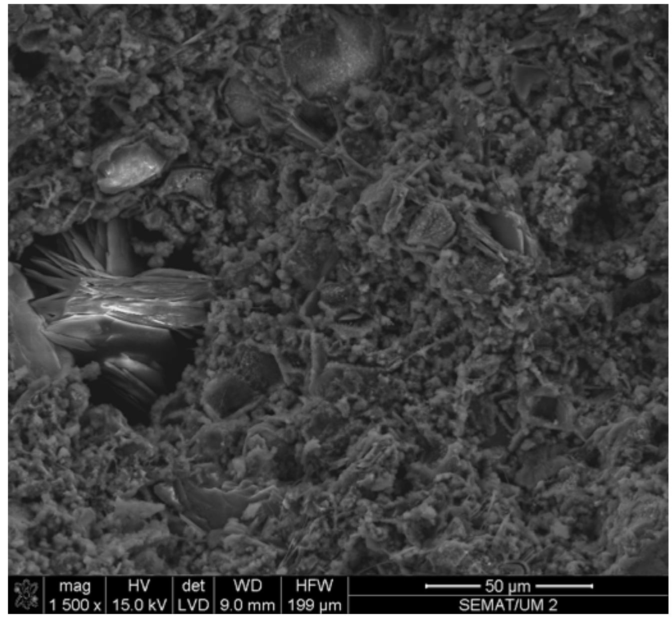

Figure 8 b

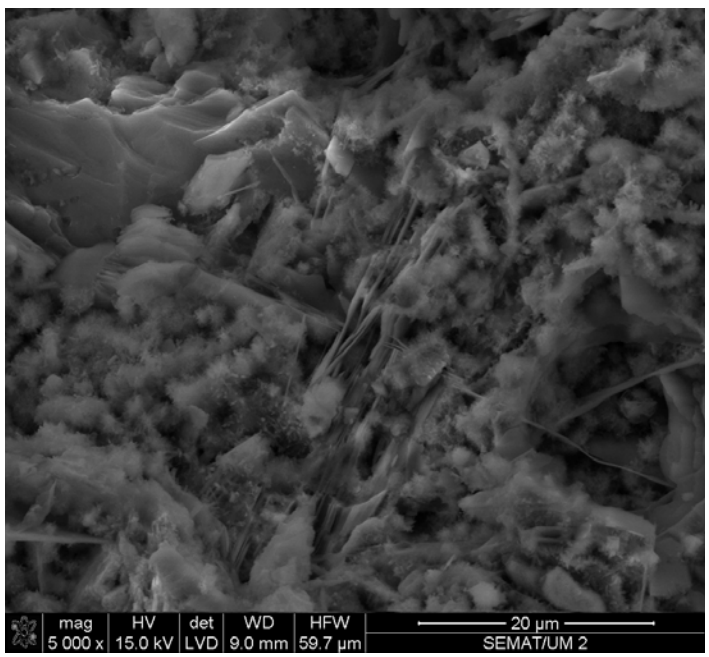

Figure 8 c

Figure 8 a, b, c, the cement paste epoxy resin at different magnifications

CONCLUSIONS

We conclude that the addition of polymer matrix to produce PCC concrete, has a pronounced effect on the rheological property of freshly mixed. Influence of polymers on these properties is due to both the content of colloidal particles, and the amount of air present in the mixture due to stirring and mixing the paste.

Changes that they produce polymer emulsions are found in terms of both flow and the viscosity value, and decreasing. This allows the scientifically and technologically, as they are controlled and adapted to specific requirements. Compressive strength of epoxy resin blends are higher than those of mixtures containing methylcellulose.

In methylcellulose mixtures, it can see a lot of air voids, and new hydration products are in the shape of crystalline layered stacks with undistorted morphology. The epoxy concrete structure forms bridges between particles, hence the effect over mechanical resistance.

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