POLYMER CONCRETE, CORRELATIONS BETWEEN PROPERTIES

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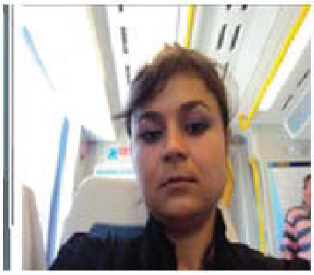
Key words: polymer concrete, density, porosity, epoxy resin.



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Abstract: *Has been adopted new method for determining the fluidity concrete with polymers. In the research were used three types of polmeri: epoxy resin - a rate of 10% polyurethane - at a rate of 10% methylcellulose - a rate of 0.6%. The experimental results showed that the same water / cement material behaves differently depending on the polymer used. Moreover, epoxy resin gives significant improvements in workability and strength. It was found that the polymer influence positively the mechanical properties and concrete workability. Were performed mycroscopical investigations on reinforced concrete structures.*

1. INTRODUCTION

Development of concrete technology presented the most spectacular progress in the last decade, probably pushed by new architectural and engineering requirements.

Sustainability structures is an area in which we invested a large amount of research work.

The new European standards EN 206 [1] make reference to sustainability in accordance with the use and exposure of concrete.

Is necessary new approach to sustainability, which requires the design, implementation and application of concrete and thus the properties of these materials require a deeper study.

In terms of material properties, the following issues must be optimized:
- The water content;
- Application (exterior / interior);
- Resistance to frost thaw cycles;
- Elimination of contraction
- Permeability;
- Cement content;
- Elimination of cracks
- Delay of reinforcement corrosion;
- Commissioning easy thing;
- Chemical resistance

The use of additives contribute greatly to solving the above problems and polymeric additives shall be entered in this context. For this we need to understand the relationship between the structure of polymeric materials and their effect on behavior of cement [2].

These investigations allow adaptation cement composition and structure of the polymer according to the market.

The cement composition is an essential factor for the best performance of polymer additives to obtain high performance concrete properties. Unfortunately, in the last years, concrete has been the subject of a major compositional changes due to technological and environmental protection requirements and created a major conflict between the desired and actual performance.

Despite these problems, concrete technology is continuously growing and using new types of advanced materials lead to obtaining high performance concrete.

In this context it is trying to obtain mixtures allowing an easy commissioning work, to provide to hardened concrete higher density and introduction of polymer admixtures to influence the strength between components.

In this field it is a new way to study the compositions by rheological tests we provide information on the flow properties of materials.

Rheology is the science of flow and deformation of materials under the action of external forces and focuses on the interactions between shear stress and strain in time [3]. Rheology of fresh cement paste, mortar or concrete can be influenced by a large number of parameters.

There are a variety of tools to describe the rheological parameters of cement-based materials. Literature can be found few studies that characterize the flow, choosing of constituents and obtaining high performance concrete [4,5].

Solids and liquids suspension may behave differently when subjected to different degrees of deformation. Fresh cement pastes can be classified into Non-Newtonian fluids group, in which are needed two points of measurement to characterize rheological parameters according to Bingham's model [6].

This paper presents the study of fluidity, strength, density and permeability of three different concrete compositions.

2. RAW MATERIALS AND THEIR CHARACTERISTICS

For preparation of polymer concrete were used:
- Epoxy resin, which combined with hardener and cement concrete forming polymer binder [7];
- Cement CEM I 42,5 R [8];
- Aggregate granite, crushed in two varieties [9]: 0-4 mm (Sort I) and 4-8 mm (Sort II).

2.1. *POLIMERS*

Have been used epoxy resin and hardener from SikaFlor81 composition, polyurethane and methylcellulose. Technical data for these materials are shown in Table 1.

The polymers are designed to improve both the workability and strength of polymer concrete mixtures. Epoxy resins have double role in strengthening concrete compositions:
- Through their polymerization the structure is influenced by achieving them flexible connection points between components;
- Forms a thin layer on the surface of the cement particles, loaded them with electric charge and produces a repulsion effect between them.

By participating directly in structure formation affect their mechanical strength.

Table 1. Polymer characteristics

Technical data and chemistry	Epoxy resin	Hardener resin	methylcellulose	Polyurethane
Aspect	Liquid, white	Liquid, yellow	Powder, white	Liquid, yellow
Relative density (20ºC):	1,05 g/cm^3	1.3 g/cm^3	1.8 g/cm^3	1.6 g/cm^3
pH, 20ºC:	5	5	5	5
Viscosity (20ºC):	< 100 cps	<90 cps	-	<90 cps
Chloral content:	≤ 0,1 %	≤ 0,1 %	≤ 0,1 %	≤ 0,1 %
Alkali content	≤ 2 %	≤ 2 %	≤ 2 %	≤ 2 %

2.2 CEMENT

Type cement used was CEM I 42,5 R, at a rate of 18.41%, with a surface area equal to 380 m2/kg Blaine and specific density of 3.12 kg/m3 [3].

Table 2: Oxide composition of cement CEM I 42.5 R

Oxide type	Oxide composition, %
SiO_2	19.30
Al_2O_3	5.57
Fe_2O_3	3.46
CaO	63.56
MgO	0.86
Na_2O	0.13
K_2O	0.80
SO_3	2.91
Cl	0.013
TiO_2	-
L.O.I.	2.78

2.3. AGGREGATE

It was used crushed granite aggregate is two dimensional sorts:

-Sort 0-4 mm: at a rate of 29.73%;

- Sort 4-8 mm: at a rate of 44.25%.

In terms of physical properties granite are rock hard, compact, of origin metamorphic or volcanic with the following characteristics:

• Hardness: 6 to 7 on the Mohs scale;
• Density: 2.6 - 2.8 kg / cm ³;
• Compressive strength: 140-210 N / mm ²;
• Module breaking: 15 to 25 N / mm ²;
• Water absorption: 0.1-0.6%;
• relatively low porosity;
• Resistant to weather conditions.

In terms of chemical composition, granite are igneous rocks composed of quartz, feldspar and ferromagnesian minerals such as Kriol, chlorite, garnet etc.

A typical granite shall have the following chemical composition:

• Quartz (SiO_2): 70-75%;
• Aluminum oxide (Al_2O_3): 10-15%;
• Calcium Oxide (CaO): 0.5%;
• Magnesium oxide (MgO): 0.5%;
• Bauxite (Al_2O_3*nH_2O): 2-4%;
• Alkalies: 4-6%;
• titanium oxide (TiO_2): less than 0.5%;
• Loss on ignition (LOI): <0.5%.

3. WORKING PROCEDURES

3.1. OBTAINING OF POLYMER CONCRETE

In this study we have performed three polymer concrete compositions, which were obtained using resin epoxy (10%), methylcellulose (0.6%), polyurethane (10%), cement and aggregates.

Polymer concrete having different compositions were prepared by mixing the required amount of binder (cement and epoxy resin plus hardener) and two varieties of aggregate particle size. The hardened concrete have been studied by microstructure and it was determined the physical-mechanical properties.

Microscopic investigations were performed with a microscope FEG ESEM - EDS / EBSD: FEI brand, model and brand Novo 200 NanoSEM EDAX Pegasus model X4M, Resolution on the high-vacuum

<1.8 nm @ 1 kV (SE);
<1.0 nm @ 15 kV (SE);
<0.8 nm @ 30 kV (STEM).

3.2. OBTAINING OF CEMENT PASTES FOR RHEOLOGY

On this test the material was prepared in the laboratory with a mixer type HORBER. In the first stage, the cement - the amount required composition was mixed for three minutes in order to achieve a uniform scattering of large particles in the entire mass of cement. Afterwards, water was added at water / cement ratio calculated, followed by mixing of fresh mass for 2 minutes. Polymers was added and the mixing process continued for another two minutes.

3.3. SAMPLE PREPARATION

Tests were made at the same water / cement ratio of 0.4 ranging polymer type used to emphasize its influence on the material fluidity of fresh and hardened state on mechanical resistance.

For flow tests were performed cemens pastes and for slump test and compressive strength the aggregate was dosed and mixed to obtain a fine distribution unit, then cement was aded and mixing continued until it was uniformly distributed aggregate mass.

In case of methylcellulose, which is a water-soluble polymer was mixed with water and then added to the mixture of cement and aggregate.

In the case of polyurethane and epoxy resins, which are liquid, first time water is added into the mixture of cement and aggregate then was added the polymer.

These masses were mixed until homogenize the material.

For compressive strength and porosity the samples was cast in moulds with the size of 50x50x50 mm.

Tests were performed according to European Standard EN 12390-3 / 2003 - Testing hardened concrete. Compressive strength of test specimens [10].

4. RESULTS AND DISCUTION

4.1 FLUIDITY

Fluidity was evaluated using two tests, the first test it was slump test is simple and widely used in construction sites work, and a new approach to study fluidity consists of rheological tests that have the ability to characterize two parameters: viscosity and yield stres of the material.

Figure 1 shows the apparent viscosity of the compositions studied. From this figure it can be seen that by adding epoxy resin viscosity of pastes with polymers in comparison with ordinary concrete is improved, it dragging itself and putting into work even easier. In case of ordinary concrete the viscosity requiring additional effort for filling of the molds.

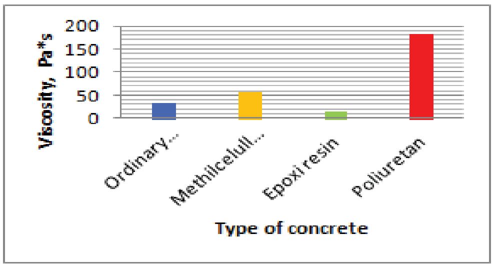

Fig. 1. Apparent viscosity of the compositions studied

Increased fluidity shows the ability of epoxy resin to reduce the amount of water so that you keep good workability of the mixture. On the other hand, polyurethane and methylcellulose do not have the ability to reduce the amount of water to maintain good workability. They show a higher viscosity than regular concrete, so registering a decrease of materials fluidity. It is found great difficulty in implementing it is not recommend their use at low water content because their rapid strengthening.

A high yield stress suggests that the material is very viscous, pouring it in shape is difficult, filled it requires intense vibration, even so, there is the possibility of incorrect filling it and there was the possibility of material segregation. Yield stress influence inversely compressive strength.

Figure 2 presents the values obtained in the yield stress and slump test to achieve a correlation between these parameters.

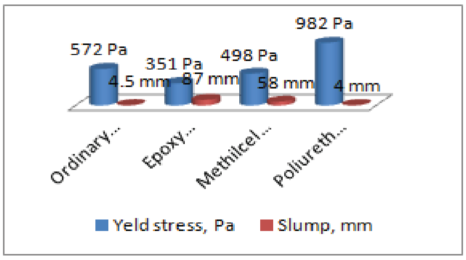

Fig. 2. Values of compaction and yield

It can be seen that the comparative proportions are kept the same for both tests, namely the lowest yield shows the highest value of compaction.

Therefore for ordinary concrete that has an a / c ratio equal to 0.4 Yield value is 572 Pa, which is also unsatisfactory for high-performance concrete because a high yield can lead to segregation material because it insufficient water quantity, the material becomes vigorous and might not be as complete cement hydration.

Determinations made on ordinary concrete highlight that an insufficient amount of water produces difficulties in cast and affect negative the resistance due to inadequate hydration of cement and the inability to fill correctly the mold. In such case material structure becomes more porous, mechanical strength are negatively influenced. The yield stress of composition which has a rate of 10% epoxy resin was lowest, this ratio improves workability due to the dispersion power of polymers on cement particles. Polymer action is to form a thin layer on the particle surface, it has the ability to charge negatively particles so these will be rejected. This rejection produces a better flow, a lower yield stress provides a longer period of wirkability.

Therefore some particles are charged negatively, others will have positive charge and thus will be crowded and will produce bulk forms of hydration that will grow in crowded floaters, without a uniform distribution in the concrete structure.

If methylcellulose yield stress is higher due to very rapid reaction of the polymer with water. Slump test had an acceptable value due to the aggregate action that occurred in the polymerization reaction, on the other hand slump test was performed immediately after water addition. If this study yield stress was performed at 30 minutes after water addition during the reaction is in progress.

4.2 MECHANICAL PROPERTIES

Figure 3 shows the values of density, porosity and compression strength of concrete in the study. It can be seen that a high density implies a low porosity and these two properties lead to the improvement of the most important characteristics of materials, namely, mechanical resistance. The best results were obtained when mixtures of epoxy resin which leads to the conclusion that it is a polymer that can be used successfully in the preparation of high performance concrete.

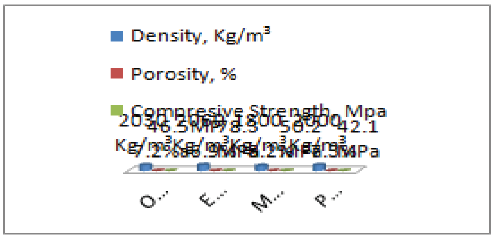

Fig. 3. The values of density, porosity and compression strength after 28 days hardened

The lowest values are presented by polyurethane wich tends to polymerize rapidly, absorbs much of the water quantity and leads to rapid installation of setting time. It acts as a hardening accelerator.

Concrete with methylcellulose shows good value although slump, tends to involve a lot of mixed air which makes the size of gaps to be much higher than for ordinary concrete. Methylcellulose has a tendency to foam, this explains the large volume of air. Also it can be seen that the porosity is high.

However concrete with methylcellulose shows a compressive strength greater than polyurethane, because it allows the cement hydration, hardening mixture is carried much slower than with polyurethane mixtures.

A proof of the existence of a link between fluidity and strength is provided by Figure 4, which shows a comparison between the yield of materials and their resistance to compression. It can be seen that a greater fluidity entails a lower viscosity of material and proper filling of forms therefore a much better their compaction and thus a stronger bond between the material components of the mixture. All above mentioned leads to improved resistance to compression.

From all diagrams we conclude that epoxy has the best effect on the concrete, and polyurethane shows the worst properties.

Polyurethane offers the highest value of yield stress. Also flow tests, slump and strength were unsatisfactory. Not advisable for use this polymer to obtain high performance concrete due, on the one hand, the difficulties of putting in work on the other side of this polymer capacity to achieve a not acceptable hardening. Is possible the use of this polymer at high water cement ratio for floors requiring fast setting and is not subjected to high loads.

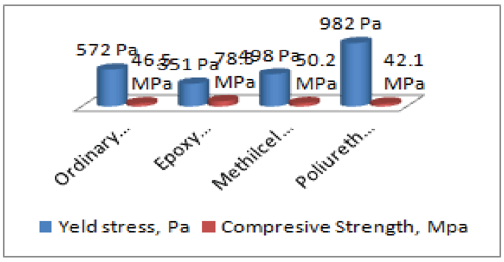

Fig. 4. Correlation between compressive strength and yield stress

4.3. MICROSCOPICAL ANALYSIS

Another test which illustrates the properties of concrete with polymers mentioned above is microscopic investigation.

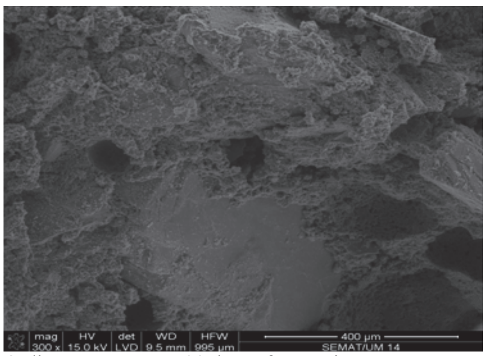

Fig. 5. Ordinary concrete at 28 days after casting

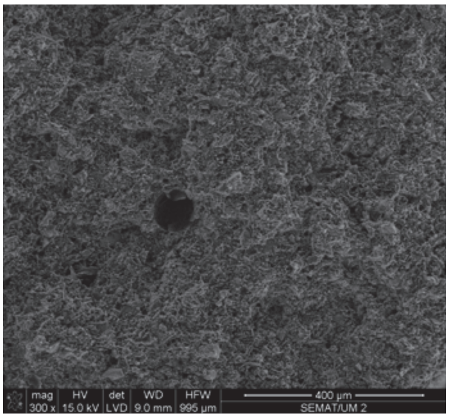

Fig. 6. Epoxy concrete at 28 days from casting

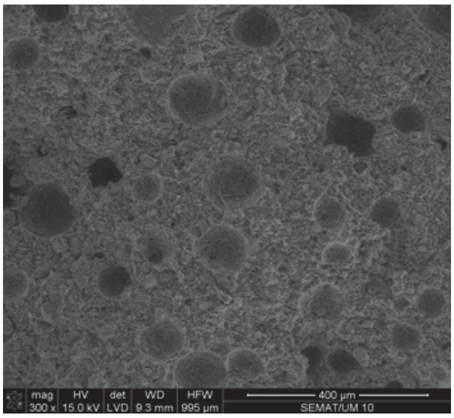

Fig. 7. Methylcellulose concrete at 28 days after casting

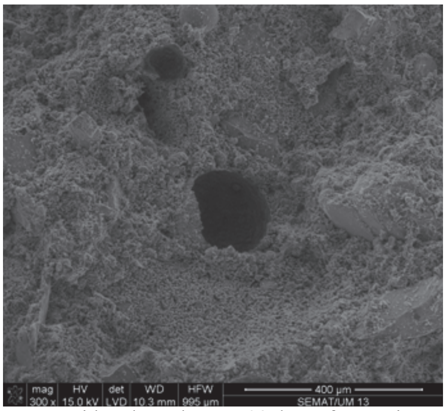

Fig. 8. Concrete with polyurethane at 28 days after casting

In Figure 5 is shown the structure of ordinary concrete. It can be seen how they developed products of hydration and how embedding of aggregate in the mix, do not notice any elastic formation just how new hydration products tend to cover both aggregate and cement particles unhydrated, they continue to grow and turn until the material hardening is complete. In Figure 6 is shown a concrete structure containing epoxy resin. This tends to form elastic bridges between the component materials which increases compression strength. The tendency of polymer at the time of addition is to achieve a thin layer on the surface of each particle slowing hydration reactions. When polymerization starts it shrinks and stretches between particles especially improving the flexural strength of the material. In Figure 7 is shown the structure of a composition containing methylcellulose. Because it tends to foam, air mixed trains, the material becomes more porous, so are many weaknesses in the structure. Methylcellulose is a tendency to polymerize inside these goals but the amount deposited is insufficient to fill them. In Figure 8 microstructure of mixtures containing polyurethane, where you can see a large number of air voids. Polyurethane tendency is to polymerize inside these goals.

5 CONCLUSIONS

Polymer concrete were obtained using different polymers: epoxy resin (10%), methylcellulose (0.6%), polyurethane (10%) and cement and aggregates. Composition containing 10% epoxy resin improves fluidity concrete, obtaining the best value for slump test. Mixtures containing methylcellulose shows a yield higher than that obtained for concrete with epoxy resin but is not satisfactory for put into work easier.

From investigations made on the compressive resistance of concrete containing polymers and making a comparison with standard samples it can be concluded that with the addition of polymers improves the compressive strength of mixtures containing epoxy resin implicitly and increase their workability.

Methylcellulose and polyurethanes are not recommended for use in obtaining concrete because they lead to a decrease in resistance to compression reinforced structures. The same conclusion can be drawn and the microscopic investigations of this mixture.

A high yield stess suggests that the material is very viscous, pouring it in shape is difficult, filled it requires intense vibration, even so might not be incorrect to fill it and there was the possibility of material segregation. Yield stress is inversely proportional to compressive strength.

The lowest values of properties posed polyurethane has a tendency to polymerize quickly because water absorbs some amount of work and leads to rapid onset of setting time. It acts as a hardening accelerator.

ACKNOWLEDGEMENT

"This work was partly financed by the European Social Fund through the POSDRU/CPP107/DMI1.5/S/77497 Program for PhD. Student

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