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Use of Epoxy Resins with Incorporation of Fillers for Concrete Rehabilitation

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ABSTRACT

The use of polymeric materials in civil construction makes possible original bonding processes because they have good adhesion. Among the polymeric materials, the epoxies are the most advantageous in the application for concrete rehabilitation. In this paper the bond between fresh/hardener concrete was made using epoxy resins in aqueous solution, because in previous tests they obtained the best results. This study analyzes the incorporation of one filler in the epoxy resin, to understand until what quantity we can add without significant decrease of the adhesion. A conventional hardened concrete was used. Otherwise, two types of fresh concretes were used with the purpose to understand the influence of the strength class in adhesion. The evaluation of adhesion between fresh and hardened concrete was made using two shear tests - direct and slant. The results showed that the direct shear test is better than the slant because the mixed failure make easier the study of the adhesion. The incorporation of the filler is benefic and the optimal quantity of filler seems to be related with the concrete strength class.

KEYWORDS: rehabilitation, adhesion, epoxy, filler.

1 INTRODUCTION

The concrete is currently the most widely used construction material in the world. This is due to its ease application, ability to shape, high resistance to compression, durability and low cost. The concrete buildings that have been made, are, many of them deteriorated, needing work of rehabilitation. Even some new justify now, interventions in this direction, due in large part to the action of air pollution on the acceleration of the degradation. The appearance of polymeric materials in the construction industry has developed procedures for the original connection and can provide interesting works, since these materials present good performance in repair and bonding works, due to their high adhesion, which makes possible connection between hardened concrete-hardened concrete, fresh concrete-hardened concrete and hardened concrete-metallic materials by collage[1]. Among the polymers that can be used in bond and rehabilitation, the epoxies are those with more advantages in these applications. Rehabilitation may be external (reconstitution of carbonated concrete, increasing the strength capacity of concrete elements and fulfilling of voids of the concrete) or internal (fulfilling of cracks by injection). Also, when it concerns with bond of concrete elements or fresh concrete to hardened concrete the use of epoxy has been advised and their use has increased.

construction. Usually, it is determined by tensile, flexure or shear tests [2-4]. For this study two shear tests were selected: direct and slant. The shear test is considered more adequated to determine adherence of epoxy resins. When these materials present good results in the shear tests, the behavior will be also good in other tests.

2 EXPERIMENT

2.1 Materials

The concretes were made with Portland cement (CEM I 42.5 R), gravel with maximum size of 8 mm and density of about 2551 kg/m^3, sand with maximum size of 4 mm and density of about 2504 kg/m^3, fine sand with maximum size of 1 mm and density of about 2357 kg/m^3. The superplasticizer was a carboxylate. The epoxy was in an aqueous solution. The sieve analysis of the aggregates is shown in Fig. 1. The main characteristics of the epoxy resin are presented in Tab.1. Calcareous filler was incorporated in the epoxy resin.

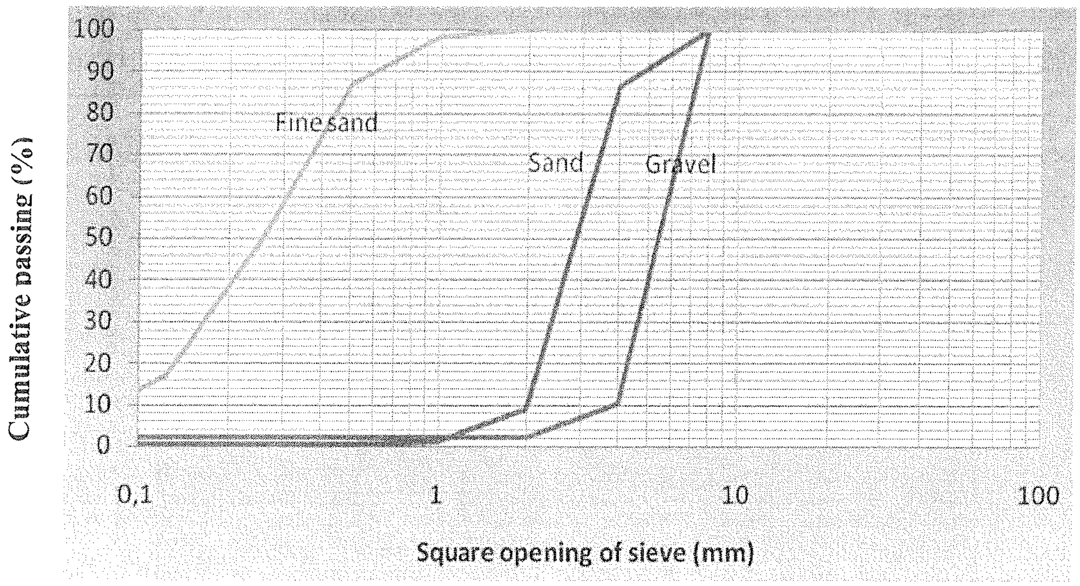

Figure 1. Sieve analysis of aggregates

Table 1. Characteristics of epoxy resin

Description	Component A	Modified epoxy resin
	Component B	Aqueous solution of a modified aliphatic amine
Density (A + B)	1.1 kg/dm^3	
Pot-life	60 min (at +20 ° C)	
Minimum temperature of application	+ 10 °C	
Proportions of mixture	Component A	47 p. w.
	Component B	53 p. w.

2.2 Description of Experimental Work and Testing

The study of the composition of the concretes was made using a spreadsheet, which is based on the method of Faury. For the study of the composition of the conventional concrete a cement content of 300 kg/m^3 and a water-cement ratio of 0.6, were assumed. For the study of the composition of the high strength concrete a cement content of 500 kg/m^3 and a water-cement ratio of 0.35, were assumed. According to the standard EN 12350-2 [5] the slump of the conventional concrete was about 9 cm and of the high strength concrete was about 17 cm. The tests performed were: compressive test, direct shear test and slant shear test.

The compressive tests were made with three cubes with 150 × 150 × 150 mm^3 in order to determine the strength class of the concretes. The average of the compressive strength of the conventional concrete was 24.3 MPa. So, according the standard EN 206-1 [6] this concrete belongs to strength class C16/20. The average of the compressive strength of the high-strength concrete was 65.0 MPa. This concrete belongs to the strength class C50/60.

For the direct shear tests, the specimens were obtained by bonding the 3 parallelepiped of concrete. The hardened concrete has dimensions of 8 × 10 × 10 cm^3 as illustrated in Fig. 2, since it was sawn (thus leaving to be a cube), while the fresh concrete is a cube with 10 cm of edge. The final specimen stayed with dimensions of 28 × 10 × 10 cm^3. The extremes are of hardened concrete (28 days), while the core is composed of fresh concrete. The tests were performed at 14 days in a hydraulic press at a speed of 15kN/min. The readings were taken by a digital system.

For the slant shear tests, the cylindrical specimens were sawn. The cutting section was defined by measurement of 5cm from the base and subsequent application of the cut with an angle of 45°, leaving the dimensions of 10cm in diameter of the base and two sides with different heights, one 15 cm and another 5cm. Then the sawed specimen stayed in the mold. The final specimen, illustrated in Fig. 3, is a result of fill the mold with fresh concrete. The dimensions are 10 cm in diameter at the base and 20cm in height. Due to surface contact in cylindrical specimens to be quite irregular, which could cause dispersion in experimental results, it was necessary to smooth by rectifying.

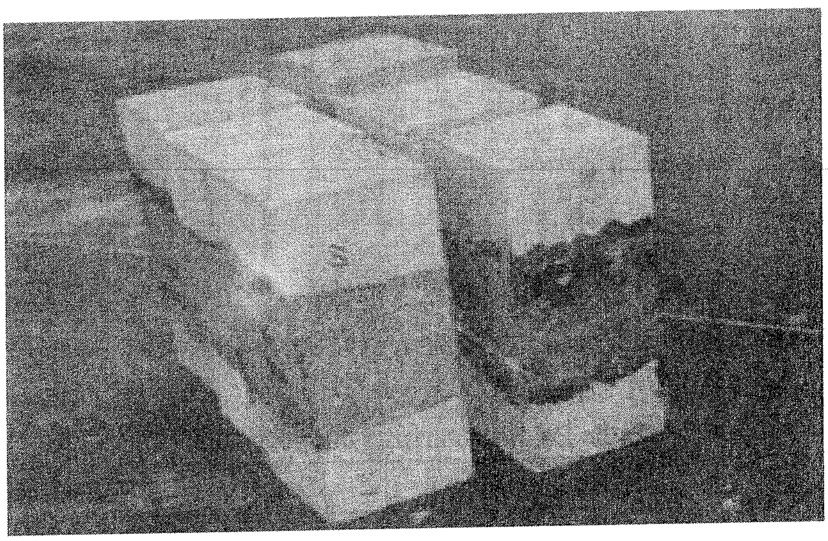

Figure 2. Cubic samples

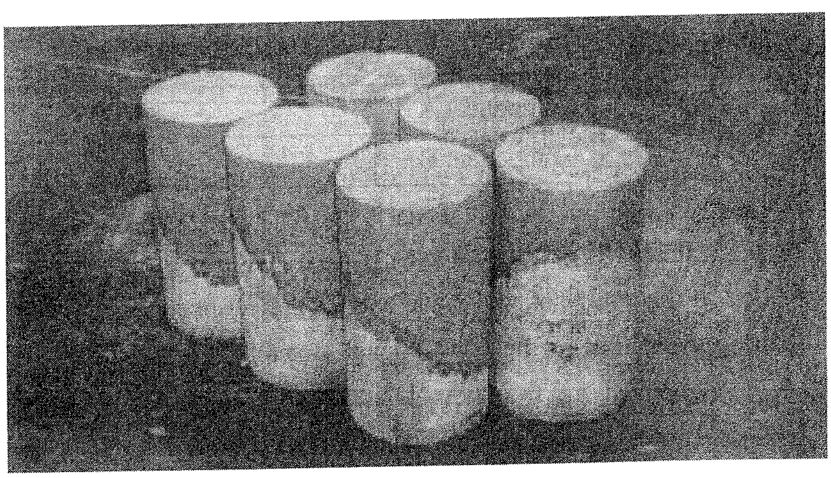

Figure 3. Cylindrical samples

3 RESULTS AND DISCUSSION

The test results of the direct and the slant shear tests are presented in Fig. 4 to Fig. 7. The comparison of the results of the two tests for each type of concrete is shown in Fig. 8 and Fig. 9.

The bonding between the surfaces hardened concrete - fresh concrete has been done through the use of epoxy resin in aqueous solution. Different quantities of filler were incorporated in the epoxy resin. The percentages of filler were by weight of the total quantity of epoxy mortar. In the direct shear tests the failures were all mixed adhesive – concrete. For the conventional concrete, it was found that with the incorporation of the filler the adherence increased reaching a maximum for the 23% of incorporation. For higher quantities of filler the adherence decreased. For the high strength concrete the maximum of adherence was found with 50% of filler incorporation. For the slant shear tests in both situations all failures occurred in the concrete. So, the test results only present the strength of the concrete.

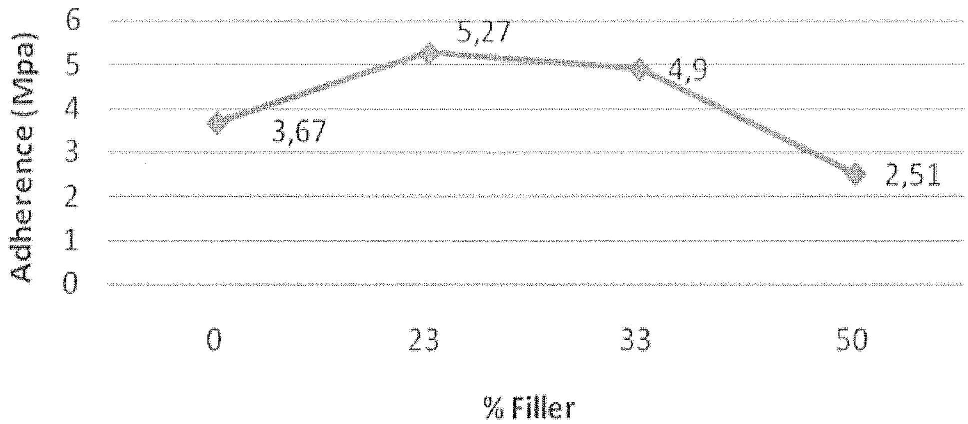

Figure 4. Influence of quantity of filler in adherence – direct shear test - conventional concrete

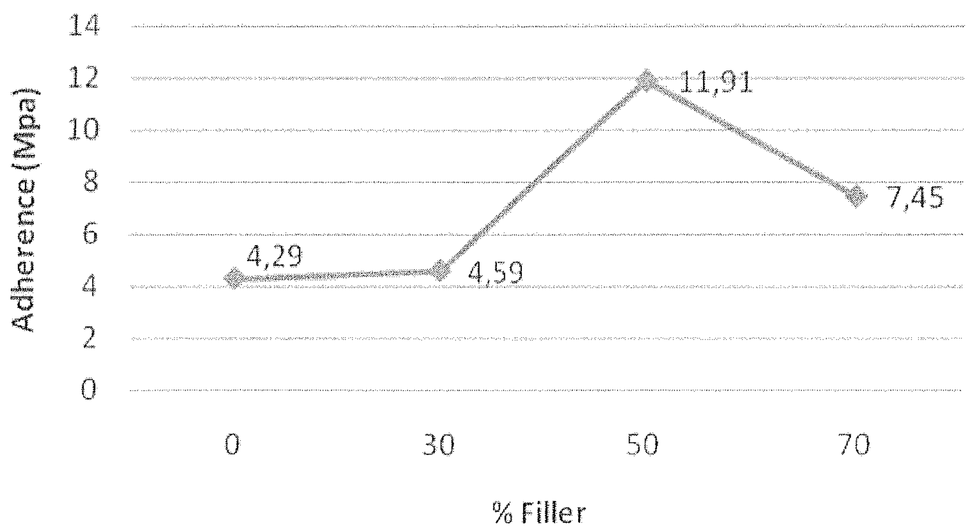

Figure 5. Influence of the quantity of filler in the adherence – direct shear test – high-strength concrete

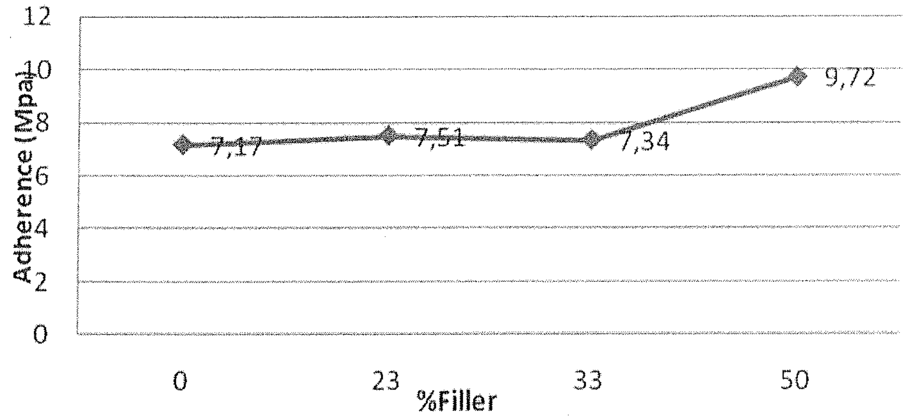

Figure 6. Influence of the quantity of filler in the adherence - slant shear test - conventional concrete

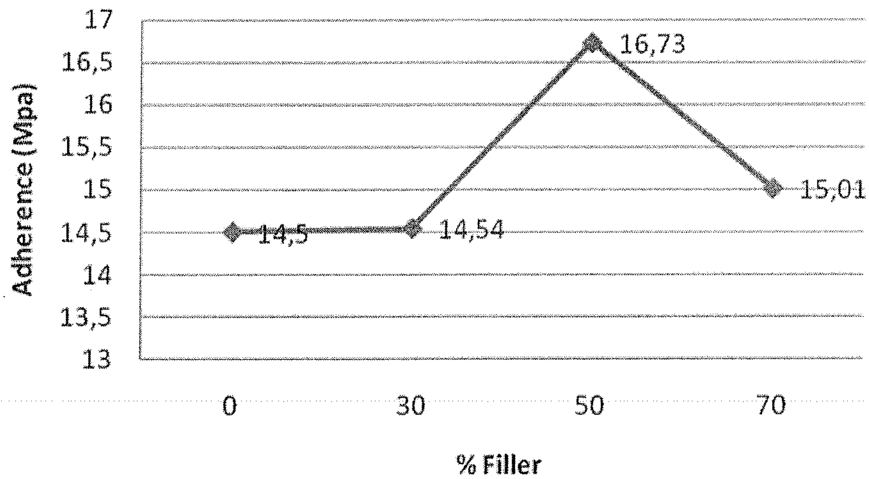

Figure 7. Influence of the quantity of filler in the adherence - slant shear test - high strength concrete

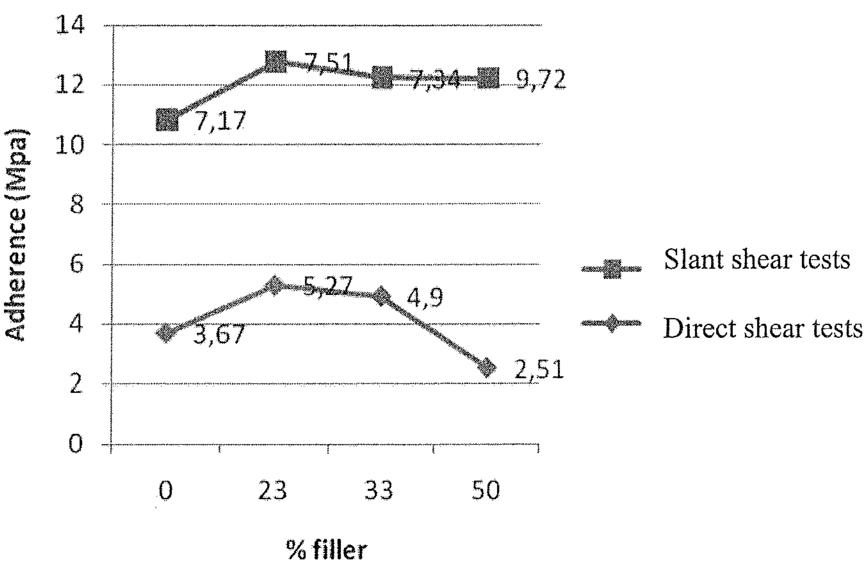

Figure 8. Influence of the quantity of filler in adherence - conventional concrete

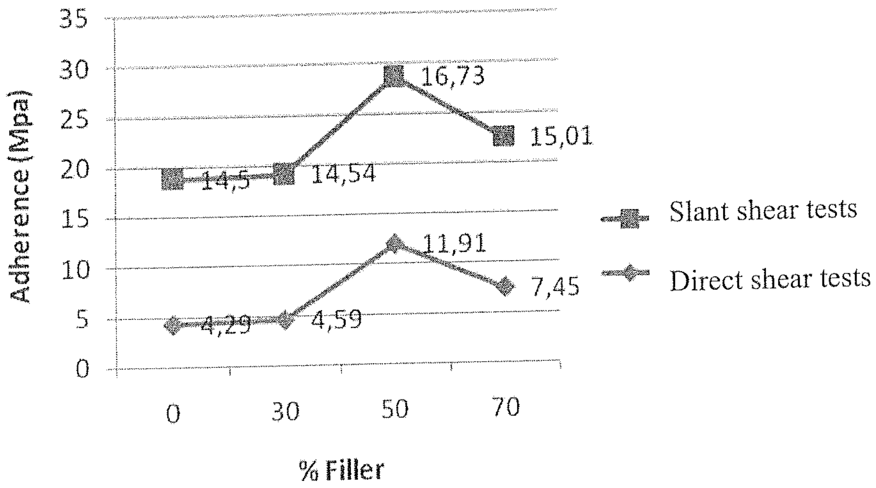

Figure 9. Influence of the quantity of filler in adherence - high-strength concrete

4 CONCLUSION

The main objective of this study was to evaluate the adhesion between hardened concrete and fresh concrete using two types of concrete and two shear tests: direct and slant. For the slant shear test, as all the failures occurred in the concrete little can be concluded regarding the phenomenon of adhesion. On the direct shear tests failures were mixed adhesive-concrete and it was possible to draw some conclusions. The incorporation of calcareous filler in epoxy resin influences the adhesive strength. There is an increase in the adherence until a maximum. After, with the incorporation of more filler the adherence decreased. The optimum values of filler incorporation were different for the two types of concretes. The completion of this work contributed to a better understanding on the feasibility of using epoxy resins in the rehabilitation of concrete. These products represent a clear added value in the field of rehabilitation.

REFERENCES

[1] AGUIAR J, VAN GEMERT. Advances in adhesion between polymers and concrete: Proceedings of 12th International Congress on Polymers in Concrete, Professor Yoshihiko Ohama Symposium, Chuncheon, Korea, 2007 [C].

[2] OZKUL M H, SAGLAM AR, PARLAK N. Wall insulating system with polymeric foams: Proceedings of 4th Asia Symposium on Polymers in Concrete, Chuncheon, Korea, 2003 [C].

[3] NSAMBU R, GOMES A. Flexural strength of reinforced concrete beams repaired with polymer-modified cementitious mortars: Proceedings of International Symposium on Polymers in Concrete, Guimarães, Portugal, 2006 [C].

[4] SLOPKOVÁ K. Sanations of reinforced concrete bridges with the polymer based materials: Proceedings of International Symposium Adhesion between Polymers and Concrete, Dresden, Germany, 1999 [C].

[5] European Committee for Standardization. EN 12350-2, Testing fresh concrete - Part 2: Slump test [S]. Brussels, Belgium, 1999.

[6] European Committee for Standardization. EN 206-1, Concrete - Part 1: Specification, performance, production and conformity [S]. Brussels, Belgium, 2000.