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MECHANICAL PROPERTIES OF TWO EPOXY ADHESIVES WITH DIFFERENT CURING TIME

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Abstract. *Adhesive materials have been widely used in various areas of engineering, especially in the automobile industry, building structures in civil, aerospace and other industries, replacing other conventional methods used in joining metals and other classes of materials. Thus, there is a need to improve knowledge about the behavior of these adhesives, in particular, the mechanical and adhesion properties. This work aims to present a comparative study of some of the mechanical properties of two epoxy adhesive materials with differences between cure time. For this, a comparative study was developed that proved to be quite adequate, evidencing the differences and similarities in the behavior of the materials. In this methodology the performance of metallic plates bonded with these adhesives, as well as the mechanical properties of the adhesive itself, is analyzed. Two types of adhesives were studied, where metal plates were glued and tested in shear strength tests, as well as the adhesives were tested in a tensile test. The results showed that, even if these adhesives showed differences between curing times, method of use and application, these showed similar behavior up to approximately 3.0 kN of load application on shear strength in the adhesion test..*

Keywords: *Adhesive, Epoxy, Bonded joints, adhesive properties.*

1. INTRODUCTION

The growing need to develop new technologies in the area of materials is mainly due to the need to improve the cost / benefit ratio, as well as the great competition between the different materials in an increasingly demanding and competitive market. Adhesive materials are one example, in particular adhesives which will effectively replace other metal bonding processes such as welding, screws and rivets. By raising interest in knowing and improving the performance of other materials joining methodologies.

This work aims to present a study of the adhesion behavior of adhesive materials based on epoxy resin in metal. The use of adhesives on structural bonds has known over time a significant evolution. Glued joints are increasingly used in structures in the automotive and aerospace industries, these structures are fabricated by the union of metals through an adhesive, usually of polymer origin. These bonded joints have significant advantages, such as: strength-to-weight ratio, fatigue strength, better finish, higher impact absorption and vibrations, better stress distribution in the bonding region, cost-benefit ratio, good adhesion to metals and other substrates, possibility of rapid or slow curing over a wide temperature range. However, there are limitations such as: strength of the joint depends directly on the preparation of the application surface, limited resistance at high temperatures, are not removable, are susceptible to environmental degradation, durability under extreme long-term service conditions.

In this work a comparative study was performed between commercial adhesives based on epoxy resin, where the behavior in the adhesion of metals was analyzed. The metal-adhesive assembly was evaluated by the tensile test in the "Single lap joint" configuration. This configuration of bonded joint is the simplest and most studied in the literature, De Barros, 2016; Icahr-Aman *et al*. 2007; Da Silva *et al* ,2009; De Souza (2012), Sampaio, E.M. *et al*. , 2006, Trindade, M. P. *et al*. , 2015; Banea, M. D. *et al*., 2016. This test allows determination of the shear force of an adhesive when bonded to the metal.

The adhesives are widely used in metal-metal bonding, due to their high mechanical strength and easy application (Quaresimim M & Ricotta M., 2006). These are the ones that present themselves with a greater diversity of applications, being used in the mechanical industry to unite almost all the materials.

2. EXPERIMENTAL PROCEDURES

In this research, two commercial adhesives based on epoxy resin, a rapid curing adhesive (RE) and a slow curing adhesive with at least 24 hours of curing (SE) were studied. In this work, these adhesives will be denominated according to table 1. This table presents the main characteristics of the adhesives studied. These characteristics were obtained from suppliers.

Table 1- Main characteristics of the adhesives studied in this work.

Adhesive	Characteristics
Rapid curing epoxy (RE)	working time: 5 to 10 minutes
	Working temperature: 25 ° C
	Texture: Viscous liquid
	Volumetric mixing ratio: 1: 1
	Polymer base: Epoxy
	Staining after mixing: Orange
Slow curing epoxy (SE)	Working time: 20-30 minutes
	Working temperature: 25 ° C
	Texture: Viscous liquid
	Volumetric mixing ratio: 5: 1
	Polymer base: Epoxy
	Coloring after blending: White

The adhesive (RE) is of immediate use, without preparation before application. The slow cure adhesive (SE), however, consists of a diglycidyl ether of bisphenol A, in which aliphatic amine hardener was added to initiate the polymerization process. This catalyst was added in the proportion of 20%, as specified by the manufacturer. After the addition of the catalyst and its homogenization. In the rapid cure adhesive (RE), the initial cure takes up to 30 minutes and the total cure in 24 hours, in the slow healing adhesive (SE), the initial cure occurs in up to 24 hours and the total cure in up to one week .

2.1. Lap Shear Joint

Single-shear joints (ASTM 1002 D, 2010) were tested in an Instron 5966 universal test machine, with a load cell with a capacity of 10 kN, in the adhesion laboratory of CEFET / RJ (Centro Federal University of Technology Education Celso Suckow da Fonseca, Rio de Janeiro, Brazil).

For preparation of the samples, the samples were made in 1/16 "(1.5875 mm) steel sheets, according to ASTM 1002 D (2010), (figure 1) and sanded with glass microspheres AG (53-105 microns) at a pressure of 9 bar in a BBV7570 / 8 blasting machine from the manufacturer Blastibrás. The bonding was also performed according to the measurements of the standard specimen by ASTM 1002 D (2010). Figures 1 and 2 show the cut steel plates and a sample of the bonded joint being tested, respectively.

The tensile test was performed according to ASTM D638 (2002). The specimens were made with the suggested V type dimensions of this standard ASTM D 638.
The molds for the preparation of the test choirs were made with silicone rubber and were filled with the two types of adhesives, making an average of six to ten specimens of each adhesive. In figure 3 is shown a mold, of silicone rubber.

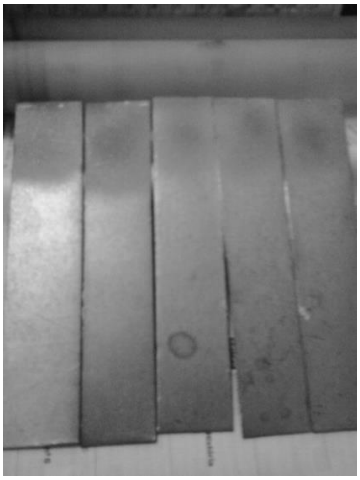

Figure 1: Specimens according to ASTM D 1002 (2010).

Figure2: Tensile Testing of single shear joints

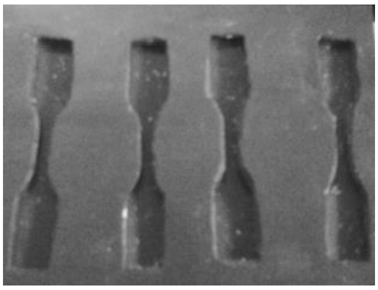

Figure 3: Silicone rubber mold for making test specimens - ASTM D 638 (2002).

3. EXPERIMENTAL RESULTS

The experimental results obtained in the adhesion tests, Lap-shear Joint, and the tensile tests are presented below.

3.1. Lap Shear Joint.

The results of the adhesion tests, lap-shear, will be presented in the force versus displacement diagram, since the samples had practically the same dimensions in the transversal session and the interest here is to make a comparison between the materials of the two materials studied.

In Figures 4 and 5 the results of the rapid cure (RE) and slow cure (SE) adhesives respectively.

Figure 4 shows the relationship between the load versus displacement of the rapid curing adhesive. It is verified that the rupture occurred around 3.87 ± 0.10 kN of applied force.

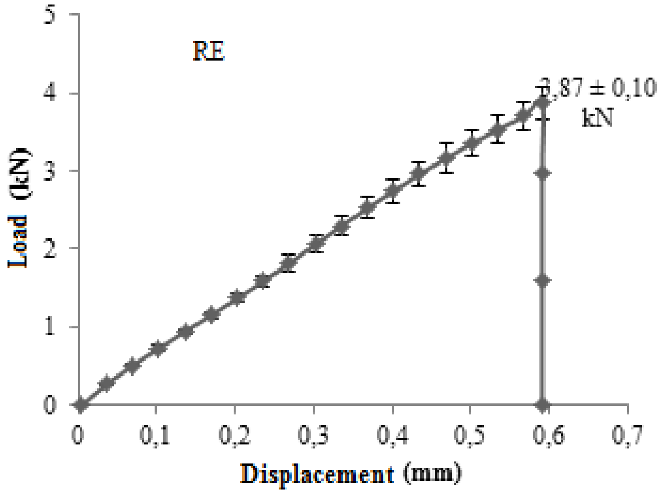

Figure 4: lap-shear test of rapid curing ((RE) epoxy resin.

Finally, the graph of the slow cure adhesive test is shown in figure 5, it can be seen that the rupture occurred around 2.51 ± 0.21 kN, as mentioned previously, this result is the average of the tests performed in five specimens. It is also observed that the standard deviation was slightly higher than the results of the other adhesives, which may be due to the greater fluidity of this adhesive, besides the fact that it is not ready for application, it is necessary to prepare the adhesive before the application. which may have caused some heterogeneity in the bonded joints. Comparatively, it can be seen that the slow cure adhesive showed the rupture in the test at a lower loading level followed by the rapid curing adhesive.

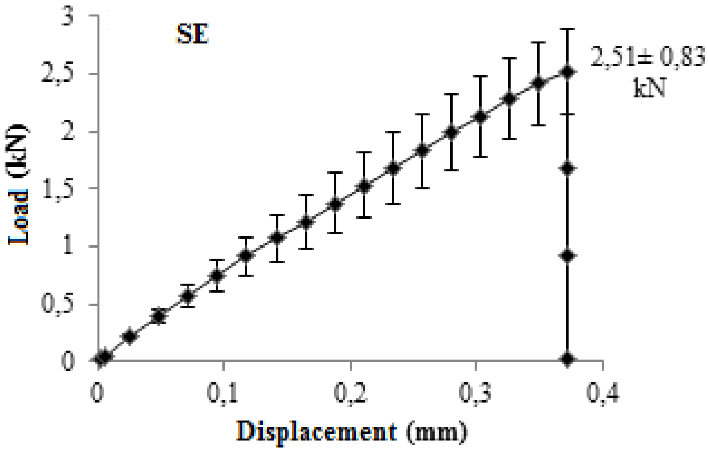

Figure 5: Lap-shear test of slow cure (SE) epoxy resin.

All the curves present the same inclination, the same behavior of the load in relation to the displacement, which is quite coherent since all the adhesives are based on the epoxy resin.

It can be seen also that the two adhesives exhibit a very similar behavior up to about 3000N. In addition, in terms of adhesion, it is verified that the (RE) has a higher resistance than (SE).

3.2. Tensile Testing of Adhesives

The adhesion tensile tests were also carried out in the adhesion test laboratory of the Celso Suckow Federal Center of Technological Education of Fonseca (CEFET / RJ), in an Instron 5966 universal test machine, with load cell with a capacity of 10 kN , starting from the guidelines proposed by ASTM 638D, the tests were carried out with a tensile speed of 1.0 mm / min with 5 specimens of each type of epoxy resin. Figure 6 shows the specimen attached to the claw to start the test.

Figure 6: Adhesion tensile test (ASTM 638D, 2002).

It should be noted that a very small standard deviation of the mean of the results obtained from the test specimens was observed, this indicates that they have similar behaviors in the lot to which they belong and indicate a good level of reliability of the results. The Elastic Modulus was calculated using the strain range between 0.0 and 0.2%, with a tangent to this region corresponding to the elastic region of the material. Figure 7 shows the the tensile test with the rapid curing epoxy adhesive and slow curing with the respective error bars. The graphic, of the tensile test with the rapid curing epoxy adhesive, shows that a standard deviation was higher than the other adhesive, from the mean of the test specimens, indicating a more heterogeneous behavior in the lot to which they belong. This may have occurred due to the nature of the adhesive having a very small pot life, which made it difficult to leak the adhesive into the molds for the preparation of the specimens.

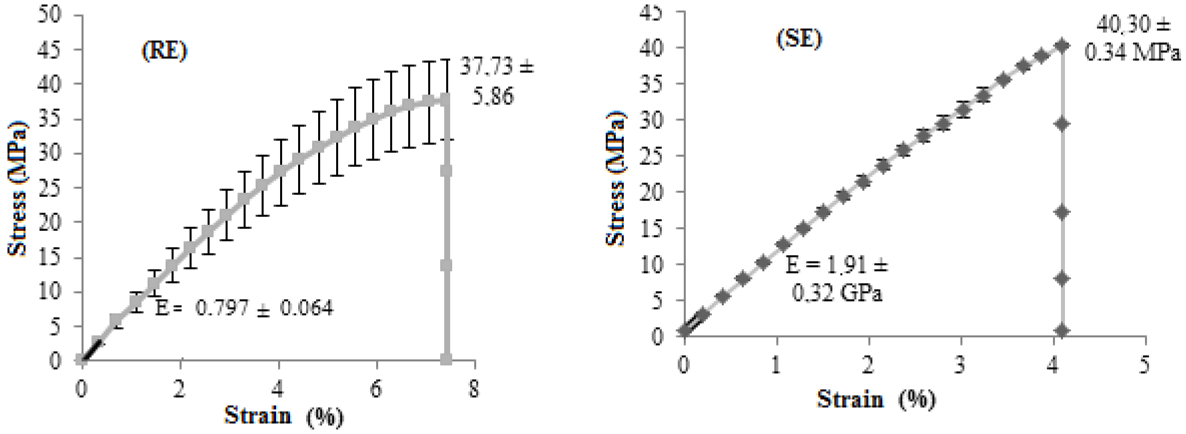

Figure7: Tensile test of the rapid curing and of the slow curing epoxy adhesive

Elastic Modulus was calculated using the deformation range between 0.0 and 0.2%, similarly to the others drawing a tangent in the initial linear region of the graph corresponding to the elastic region of the material.

The graphic of Figure 8 shows a comparison between the results of the tensile tests of the two adhesives and the difference in the mechanical behavior of these materials, it is observed that the slow cure epoxy resin (SE) possesses greater stiffness and tensile strength than the resin (RE), which in turn shows greater ductility.

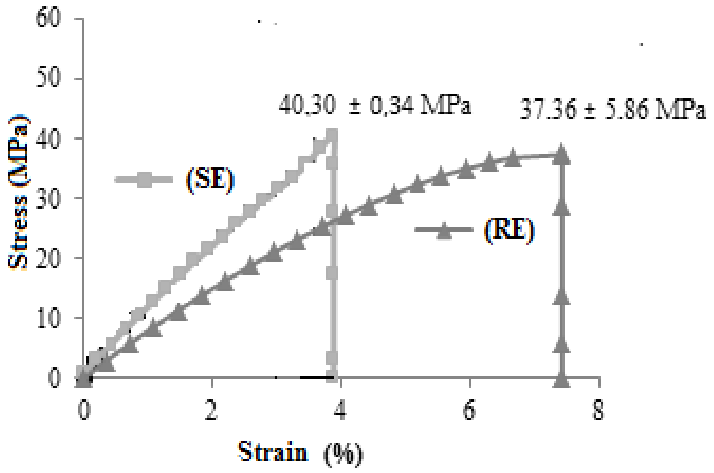

Figure 8: Comparison between rapid curing (RE) and of the slow curing (SE) epoxy adhesive (tensile test).

The next, Table 2, shows the results in the tensile tests of these two adhesives. The modulus of elasticity, the resistance limit and the elongation.

Table 2- obtained tensile tests Parameters

Adhesives	Elastic Modulus (GPa)	Tensile Strength (MPa)	Elongation (%)
Rapid curing epoxy (RE)	1.10 ± 0.08	37.73 ± 5.86	7.42 ± 0.72
Slow curing epoxy (SE)	1.44 ± 0.11	40.30 ± 0.34	4.10 ± 0.15

Table 3 shows a general summary with the results obtained in the tests performed in this work, lap-shear test and tensile test. Where can we do an analysisend of all the results obtained in the tests performed in these two adhesives and to compare the behavior in two different types of request to which the materials were submitted.
This makes it easier to reach the main conclusions.

Table 3- Experimental results of all the tests

Tests	Parameters	(RE)	(SE)
Adhesion tests	shear strength (MPa)	3.87 ± 0.10	2.51 ± 0.41
Tensile Tests	Elastic Modulus (GPa)	1.10 ± 0.08	1.44 ± 0.11
	Tensile strength (MPa)	37.73 ± 5.86	40.30 ± 0.34
	Elongation (%)	7.42 ± 0.72	4.10 ± 0.15

4. CONCLUSIONS

The methodology used in this study made it possible to compare the behavior of two adhesives, epoxy resin, in relation to their adhesion strength and tensile strength. It can be concluded that Rapid curing epoxy (RE) showed to have a higher adhesion resistance than Slow curing epoxy (SE), reaching a resistance limit of approximately 3.8 kN. RE also showed higher ductility and lower resistance limit in the tensile test of the adhesive. This fact allows us to verify that the fact that the adhesive has better mechanical properties in the Tensile tests does not mean that it will have better adhesion properties, since this property is influenced mainly by factors related to the adhesive / substrate interface, in addition to other influent factors to the capacity of adhesion.

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