Adhesion between Polymers and Concrete

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EVALUATION METHOD FOR ADHESION TEST RESULTS OF BONDED WET CONCRETE TO EPOXIES

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Abstract

The use of epoxies is today current in repair and bonding works of concrete structures. The reason of this is the good adhesion they present in bonding hardened concrete-hardened concrete, hardened concrete-fresh concrete and hardened concrete-metallic materials. However, the adhesion decreases when the substrate concrete is wet. The incorporation of a filler in the epoxy makes possible a good adhesion even when the concrete is wet. We did tension tests to study the influence of the type, the granulometry and the quantity of the filler on the behaviour of the bonds. Also the influence of the thickness of the joint is studied. The presentation of the results is made in accordance with a square optimisation method where is taken into consideration the adhesion in tension and the failure mode.

1. Introduction

Polymers can be used in repair and bonding works of concrete structures. Epoxies have a lot of advantages when compared with other polymers. Some of the good properties of the epoxies are [1, 2]:
- good adhesion to concrete (hardened or fresh);
- good adhesion to metallic materials like steel;
- low curing shrinkage;
- no by-products generated during cure;
- ability to cure from very low to high temperatures;
- ability to cure under moist conditions or under water;
- good chemical resistance;
- ability to be formulating with low to high viscosity.

However, they have some bad properties like thermal behaviour and adhesion when the substrate is wet. The decrease of adhesion strength when epoxies are placed on a wet surface is a problem [3, 4]. It's true that is possible to formulate epoxies to bond under wet conditions, but is recommended that the applicator work closely with the manufacturer, because these materials are relatively new and experience is limited [2].

In our study we used normal epoxies with fillers. We tested their adhesion to wet concrete. The influence of the type, the granularity and the quantity of the fillers are studied. Also the influence of joint thickness is studied.

2. Materials and methods

We made tension tests in accordance with [5]. The concrete used had set 90 days and the compression tests performed show that it could be classified as a C25/30 [6].

To minimise, or annul, the effect of a punctual heterogeneity on the epoxy joint, we worked with prisms 14X9X30 cm³ (Fig. 1). The application of the epoxies was made on concrete surfaces of 420 cm² brushed and wets.

![Diagram of a prism](image)

**Fig. 1 - Prismatic specimen after bonding the two prisms of concrete.**

With another prism 14X9X30 cm³, we got the final prism 14X18X30 cm³. The thickness of the joints was obtained by the aid of four metallic plates with the dimensions 10 X 50 X 30 cm.
mm³, positioned at the corners of the prisms.

The specimens for the tension tests were drilled in the prism, 28 days after bonding. They were cylinders with 8 cm of diameter and 16 cm of height (Fig. 2). We bond metallic pieces in the cylinders in order to have the possibility to attach at the tension machine.

Fig. 2 - Cylindric specimen concrete-epoxy-concrete

We used two epoxies, epoxy A (with a hardener based on polyamine aliphatic) and epoxy X (with a hardener based on a mixture of cyclics amines and benzbic alcohol).

The failures modes may be classified in four types [7, 8] (Fig. 3). We studied how adhesion change with the type, granularity and quantity of the filler incorporated in the epoxy. Four different granulometries of a calcaceous filler and a siliceous filler were used (Table 1).
Fig. 3 - Types of failures modes: (a) Type I: cohesive failure in concrete, (b) Type II: mixed failure concrete-epoxy, (c) Type III: cohesive failure in epoxy, (d) Type IV: adhesive failure

Table 1: Specific surfaces of the fillers

<table>
<thead>
<tr>
<th>Type of filler</th>
<th>Reference</th>
<th>Specific surface (cm(^2)/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcareous</td>
<td>Ultrafine</td>
<td>53000</td>
</tr>
<tr>
<td></td>
<td>Fine</td>
<td>44000</td>
</tr>
<tr>
<td></td>
<td>1/2</td>
<td>35000</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>5000</td>
</tr>
<tr>
<td>Siliceous</td>
<td>Ultrafine</td>
<td>22150</td>
</tr>
<tr>
<td></td>
<td>Fine</td>
<td>16175</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>13619</td>
</tr>
<tr>
<td></td>
<td>5078</td>
<td></td>
</tr>
</tbody>
</table>

The first problem we have when we add a filler to an epoxy, is the maxim incorporable quantity. For the epoxies A and X those quantities are presented in Table 2. As we showed in a previous paper [7] the maxim incorporable quantity decrease with the finesse of the filler. The type of epoxy also influences this quantity.
Table 2: Maxim incorporable quantities

<table>
<thead>
<tr>
<th>Type of epoxy</th>
<th>Type of filler</th>
<th>Reference</th>
<th>Incorporable quantity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Calcareous</td>
<td>Ultrafine</td>
<td>54</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>Fine</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1/2</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>61</td>
</tr>
<tr>
<td></td>
<td>Siliceous</td>
<td>Ultrafine</td>
<td>43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fine</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>57</td>
</tr>
<tr>
<td>X</td>
<td>Calcareous</td>
<td>Ultrafine</td>
<td>59</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fine</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Siliceous</td>
<td>Ultrafine</td>
<td>51</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fine</td>
<td>54</td>
</tr>
</tbody>
</table>

3. Results and discussion

We performed two series of tests. For the first series all the specimens had a joint with 0,6 mm of thickness. Figures 4 to 7 present graphics with the results. In the graphics we can see the adhesion in tension and the % of cohesive failures in concrete.

The second series was performed only with epoxy A. The thickness of the joints changed between 0,1 and 2 mm.

In the right side of the graphics we mark the tensile resistance of the various classes of concrete considered in [6]. Note that our tests were made with a C25/30. But is true that as weak is the concrete more % of cohesive failures in concrete we will find for the same adhesive. It may be expected that when the adhesion in tension is higher than the tensile resistance of the concrete, failure occur in the concrete.
Fig. 4 - Variation of adhesion in tension and type of failure with the granulometry of siliceous filler (Epoxy A).

Fig. 5 - Variation of adhesion in tension and type of failure with the granulometry of calcareous filler (Epoxy A).
Fig. 6 - Variation of adhesion in tension and type of failure with the granulometric of siliceous filler (Epoxy X).

Fig. 7 - Variation of adhesion in tension and type of failure with the granulometric of calcareous filler (Epoxy X).
Fig. 8 - Variation of adhesion in tension and type of failure with the thickness of joint (Epoxy A).

Fig. 9 - Variation of adhesion in tension and type of failure with the thickness of joint (Epoxy A).
Looking at the results we can see that the quantity, the nature and the granulometric of filler are very important in the adhesion between wet concrete and epoxy. For Epoxy A the best result is obtained with calcareous filler and in small quantities (between 5 and 20 %). The Epoxy X presents a better behaviour with much more 100 % of cohesive failures in concrete.

Related with thickness of the joint we found a large quantity of cohesive failures in concrete. This can be interpreted that this parameter does not affect very much the adhesion between wet concrete and epoxies.

4. Conclusions

We studied the adhesion between wet concrete and epoxies. We found advantages in the way of present the results showing in the same graphic the adhesion in tension and the % of cohesive failures in concrete.

To have good adhesion between wet concrete and epoxies is very important the presence of a filler siliceous or calcareous. The quantity and the granulometric of the filler influence the adhesion. Thickness of the joint seems to be less important for adhesion. With a thickness of approximately 1 mm we found good adhesion with the two types of fillers used. But other thicknesses gave also good results.

5. Acknowledgement

The author wish to acknowledge “Laboratoire Central des Ponts et Chaussées, Paris” where the experimental work was done.

6. References

2. American Concrete Institute, ‘Use of epoxy compounds with concrete’, reported by Committee 503, (ACI, Michigan, 1990).
3. Fédération Internationale de la Précontrainte, ‘Repair and strengthening of


