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A STUDY ON THE IMPLEMENTATION OF COMPOSITE MATERIALS ON CONCRETE SURFACES

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Abstract: Nowadays, one of the latest methods to strengthen and renovate concrete structures is the application of composite materials on concrete surfaces using special adhesives that have the matrix made out of epoxy resin. The use of composite technology and the ability to obtain the right adhesive are vital prerequisites and without them the whole system will be affected. This article presents several recommendations based on a laboratory experiment which explored the issue described above and it outlines the following: the ways (steps) to preparing the adhesive, the right time to release in the opera, the orientation (direction) of composites, and the importance of pre-cleaning the composite material and the area where it will be applied.

Key words: Structures, innovative materials, composite materials, concrete beam, consolidation, externally bonded reinforcement, wrapped.

1. INTRODUCTION

The sustainability of a building is its ability to maintain throughout its existence and the characteristics of its resistance based on how they were designed and executed, without requiring additional maintenance costs. Measures to ensure an adequate durability are chosen based on the environmental conditions and the importance of the building. During the years, concrete structures from all over the world have been severely damaged due to various aggressive environments, which resulted in the deep corrosion and destruction of the structural elements. Of all the tests one of the most promising method is the use of composite materials because those materials have the advantage of not corroding, even in hostile environments. For strengthening and renovation of concrete structures, the most utilized up to the present time is the use of externally bonded beams reinforced with FRP sheet or plate stuck with highly resistant adhesives, which have basic matrix made from a mixture of different epoxy resins. Polymer-based fibers, made of carbon fiber (CFRP) dominates these works, being used both for the issuing of CFRP independent bar and also for obtaining CFRP plates or sheets. The utility of carbon fibers characteristics determined researchers to use them in construction works.

2. THE EXPERIMENT

The experiment consisted in the assembly of a few reinforced concrete beams with externally bonded reinforcement CFRP sheet or plate and their laboratory testing of their bending exertion while inducing a concentrated force that was applied in the middle opening. In the experiment we tested 10 reinforced concrete beams with cross section 15 x 20 cm and 100 cm length.

The purpose of the experiment was tracking changes in bending and final tensile based on the application of CFRP materials, the appearance of elastic and plastic deformations with crack opening, and the influence of CFRP materials on damaged reinforced concrete.

During the experiment we observed that compliance with the application of materials technology is very important to obtain accurate results, because the behavior of beams during the experiment was influenced by the technology of the application of composite materials and adhesive preparation.

We present some conclusions and recommendations based on laboratory experiment which explores the issue described above and it outlines the following: the ways (steps) to preparing the adhesive, the right time to release in the opera, the orientation (direction) of composites, and the importance of pre-cleaning the composite material and the area where it will be applied.

2.1. The application of composite materials on concrete surfaces.

The manner of distribution of the CFRP materials, on the concrete elements, can be different depending on the type of application: tension by bending, uniformly distributed force, torque ... etc. Figures 1,2,3,4 show several ways of combining externally bonded reinforcement CFRP sheet or plate on concrete beams:

a) Coating the bottom beams with simple CFRP plates (Figure 1, a);

b) Coating the bottom beams with simple CFRP plates and L- wrapping (Figure 1,b);

Fig.1- Detail of applying CFRP materials on beams.

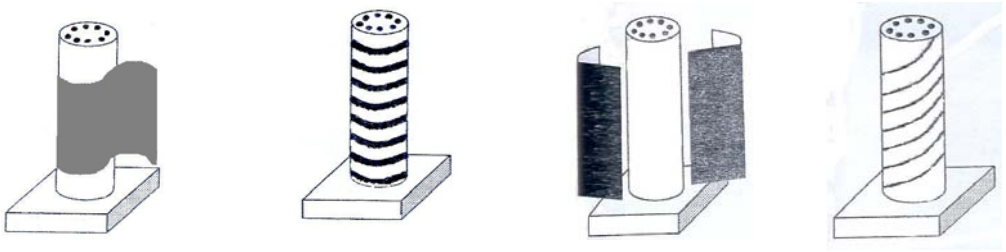
c) Coating the bottom beams with simple CFRP plates and U- wrapping (Figure 2, c);

d) Coating the bottom beams with simple CFRP plates and X- wrapping (Figure 2, d);

Fig.2- Detail on applying CFRP materials on beams.

Application of CFRP plates and sheets on concrete cylinders can be achieved in the field, the bottom, the top or on his full height.

a) Strengthening the cylinders using one or more layers of sheets (Figure3, a)
b) Strengthening the cylinders using plates of carbon fiber (Figure 3, b).
c) Strengthening of concrete cylinders using carbon fiber membranes (Figure 3, c)
d) Strengthening concrete cylinders with strands of carbon fiber (Figure 3, d).



a b c d

Fig.3 –Detail of strengthening concrete cylinders.

2.2 .CFRP sheets application.

Fig.4 –CFRP sheets and adhesive.

CFRP sheets (fig.4) can be used on concrete surface both hot and cold. Temperature is very important because it can influence the time of reinforcement. Thus we have:

- applying heat leading to a rapid reinforcement and a reduced time of execution;
- applying cold leading to a slow strengthening and a longer execution time.

Workers should be equipped with: goggles, rubber gloves and overalls to protect skin. The first thing recommended is to clean the surfaces on which the materials will be applied. This can be achieved through sandblasting, air or water pressure, or using a wire brush for smaller areas. The cleaning of the surface will continue until it becomes rough, thus eliminating a very thin layer of concrete, fig 5, fig 7.

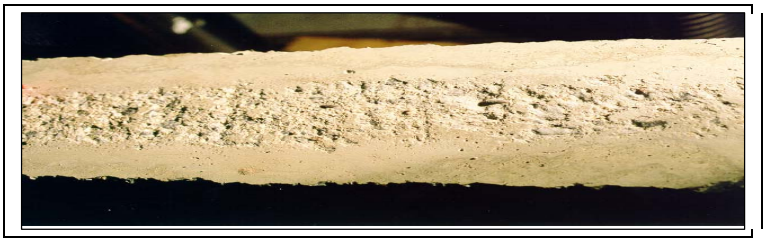


Fig.5 –Concrete surface after cleaning.

It is very important that the area where carbon sheets will be applied is clear from items that can attack and corrode concrete or even the sheets. The grease (residue) left sometimes by used equipment during the technological implementation is very dangerous and we recommend cleaning of the area, prior to the application of composite material, with a nitro solvent and also a thorough cleaning of the CFRP material Fig.6.

Before the application of the materials it is recommended a tensile test on concrete substrate with a special device. This helps choosing good and adequate glue, with a tensile strength greater than that of concrete to be consolidated. The next step is to apply a concrete surface primer that will help the subsequently applied adhesive to achieve a better grip.

Fig.6 –Nitro solvent and CFRP sheets.

Fig.7 –Concrete surface after brush cleaning.

Figure 8 represents a schematic way of the layers recommended to be applied on concrete surface before applying the composite material.

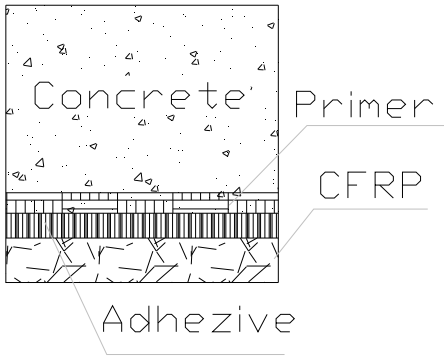


Fig.8 –The layers recommended being applied on concrete surface.

The resin is applied on the concrete surface using a brush and then the sheets are positioned in the direction required and pressed gently while rolling the resin. This process will continue until the resin comes out through the material fibers. The final part of the applied material can be seen in figure 9.

Fig.9 –The final aspect of CFRP sheets.

For overlapping layers, the application technology woven into all the fiber directions will be repeated from a distance of at least 10 cm. At the end of the operation, an easy or resistant coat could be applied over the last layer of polymer coating. This will protect the material or conceal any imperfections. Sometimes the final paint is part of the fire protection.

2.3. CFRP plates application.

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Fig.10 –CFRP plates.

In the beginning the applied technology is similar with previous forms of sheets. Before the application the CFRP plates must be also cleaned thoroughly with a solvent and a soft cloth. The CFRP plates are easy to handle and can even be cut on site using a diamond disc. First, on the cleaned concrete surface a layer consisting of a mixture of epoxy resin is applied and mixed at low speed. The adhesive layer is recommended to have 1mm thickness and to be made up very carefully. At the same time, the epoxy resin is applied on the polymer bands with a device that will control the thickness of the adhesive and ensure full contact between the two materials, figure 11.

Fig.11 –Applying the adhesive.

Fig.12 –Pressing the area with a metal cylinder.

Proper application of bands is made by hand from beginning to end of the section by simply pressing the area with a rubber or metal cylinder (2 kg),figure 12.At the end remove the excess epoxy resin.

2.4. Preparation of the epoxy resin.

Both the carbon sheets and plates have special adhesives, and they are delivered with the composite material and the method of preparation is provided in the datasheets. After preparation, the special adhesives are resistant to different temperatures and environments. For application, the experts recommended a temperature of +10°C and below +3°C when the work must be stopped.

In general the adhesive is composed of two parts, part A and part B. The two ingredients are mixed together, in a ratio recommended, for several minutes with a steady low speed (below 600rpm) until the mixture becomes smooth and presents a uniform color. It is recommended that during the mixing process any inclusion of air in the composition should be avoided. Because the adhesive loses flexibility after a maximum of 30 minutes, it should be prepared only in a small quantity, based on how much could be used within 20 to 25 minutes. Thereafter, the adhesive begins to strengthen and become unusable.

3. CONCLUSION.

The interface between CFRP plates and concrete surface plays a critical role in maintaining the mechanical performance and durability of concrete structures.

Complying with the application technology and achieving the adhesive seem very simple but they have some key points that if there are not respected rigorously will cause the whole system to fail. For example, the adhesive preparation and the time work allotment and the pre-cleaning of the composite material and the concrete surface.

Fig.13 –Recommended detach between plates and concrete.

If the technology is properly respected the two materials (concrete and composite) will detach with a disposal of a thin layer of concrete, as you can seen in figure 13.

During the laboratory experiment we found that the epoxy resin (adhesive) can fail even if its tensile strength is higher than the concrete tensile strength. Of the 10 beams that we tested, two of them failed prematurely because of carbon plate separation.

Fig.14 –Detach between plates and concrete.

This detachment occurred in the adhesive layer leaving the concrete intact, different from the other beams we tested (figure 14).Therefore, the results of this test were compromised and the two beams behaved as if they were not consolidated, similar to the etalon beam. After some analysis we discovered that the implementing technology was not strictly respected. Another important element is avoiding irregularities along the material, because these materials are very sensitive to sudden changes of section. This can severely damage the material by leading to its premature rupture.

The recommended temperature for applying adhesive is +10°C and it is not recommended below +3°C, because there is the risk of compromising the whole work.It is important that the execution must be carried out by specialized and qualified people.

The resistance to pulling of the concrete that will be consolidated with carbon material must be at least 4 N/ mm ^{2} and older than 28 days. The substrate must be in good condition, free of cement parts, ice, water or oil and to meet these requirements it is recommended that concrete surface will be well cleaned in advance.

Attention to these details it is necessary because failure to strictly apply the recommended technology can lead to incorrect behavior of the strengthened element.

Reinforcement of concrete elements, with composite materials using epoxy adhesives has proved to be an effective system to successfully accomplish the transfer of stresses from concrete to composite material. Sometimes accidents can happen even in laboratory because of concentration of effort or weak areas, but so far the results and the behavior of both materials was predicted.

In the present time, there are many research studies that analyze the relationship between concrete elements and composite materials, but few results are really reliable because they did not considered outside influence like the deformation of concrete after use or the influence of the environment (freeze-thaw, excessive heat or ultraviolet light).

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