Reinforced concrete specimens retrofitted by carbon cloth submitted to localised loading

J.-L. Clément¹, K. Verók¹,² & C. Boulay¹
¹ Division BCC / Section CMM, Laboratoire Central des Ponts et Chaussées, France
² Department of Structural Engineering, Budapest University of Technology and Economics, Hungary

Abstract

One of the use of FRP to reinforced some RC elements consist to retrofit the top of bridge pile. These elements are subjected to localised pressures. Their RC design consist to calculate an axial stress which takes into account the retrofitting effect given by the reinforced steel bars. A previous study has shown that in the case of HPC concretes, the security coefficient is lower than in the case of ordinary concrete.

So we have choose to retrofitted concrete specimen, which are reinforced by steel bars or no, using FRP. The carbon cloth (TFC) is glued on the external surface of 20*20*60 cm³ specimen, after surface preparation. The load is applied on a 10*10 cm² surface, and increases until failure. The tests are performed using a 5000 kN test machine, with longitudinal et transversal displacement measurements. In the case of RC elements, some strain gauges are glued on transversal steel bars, and on FRP too in the case of retrofitted specimens.

We present first of all the experimental program, then the main results.

The results analyse enables us to conclude than is it possible to use this kind of technique in order to strength some cylindrical bridge piles : The rupture of the concrete elements concrete is relatively brutal. That of the elements retrofitted by composites is much more ductile.

This work belongs to the LCPC 's research operation “strengthening and repairing of reinforced or pre stressed structural elements using carbon fibre cloths”.
1 Introduction

This paper presents the results of an experimental study about the strengthening of RC members subjected to localised loading, using FRP carbon cloths. The aim of the studies is to compare the experimental behaviour of concrete prism, reinforced concrete prism, concrete prism strengthened by carbon FRP, and reinforced concrete prism strengthened using carbon FRP.

The main idea of this study was the no-ductile behaviour of RC members under these loading conditions, in particular when an HPC is used (Boulay & all, [1]). In our project, we want to use elastic-quasi brittle FRP material in order to retrofit the concrete. We present first of all the specimen geometry and the loading system, the main results and the result analysis.

2 Geometry of the specimen. Experimental program

2.1 Prism dimensions

The prism dimensions are the followings:
- height 60 cm
- transversal section 20 cm x 20 cm

The external load is applied on a 10 cm x 10 cm surface on the top of the prism. In the case of RC prisms, the steel reinforcement was designed with respect to the indications of the figure 1.

Figure 1: steel reinforcement of the RC prism
In that case, four strain gauges are glued on one transversal steel bars.

2.2 Experimental program

The experimental program consists in eight tests, according to the figure 2:
- two concrete samples
- two reinforced samples
- two concrete samples with carbon cloth
- two reinforced concrete samples with carbon cloth.

![Diagram of samples geometry with and without FRP reinforcement](image)

The chosen FRP is the carbon cloth TFC from Freyssinet. But the results we will present do not depend on the carbon FRP type, if the usual bond length is respected.

2.3 Loading system and measurements

The chosen prism is vertically placed under the load jack of a MFL press, which has a load capacity equal to 5000 kN. During the tests, some measurements are performed:
- the jack displacement, using the displacement indication given by the press controller,
- the relative vertical displacement of the load steel plate, using four LVDT (one for each face of the prism),
- the transversal displacement, using four horizontal LVDT which are placed in the same plane as the second transversal stirrup,
- the steel strain using four strain gauges glued on the second stirrup, in the case of RC tests (with or without FRP cloth)
- the FRP longitudinal and transversal strains using two strain gauges per face (one vertical and one horizontal) in the case of FRP use (figure 3).

![Figure 3: Strain gauges on FRP](image)

A view of the loading and of the measurements LVDT is shown figure 4.

![Figure 4: specimen under load and LVDT positions.](image)

The tests are conducted in two parts:
- loading until 100 kN under load imposed speed (100 kN/min).
- Loading until failure with imposed mean longitudinal displacement speed 80 µm/min then 300 µm/min when the mean value reaches 19000 µm).
3 Main results

3.1 Failure load

The names of the different concrete are given table 1, and the registered failure load table 2. These results are issued from Verok [2].

Table 1: 20x20x60 sample names

<table>
<thead>
<tr>
<th>Sample name</th>
<th>Without steel bars</th>
<th>With steel bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without FRP</td>
<td>NueSA1</td>
<td>NueAA1</td>
</tr>
<tr>
<td></td>
<td>NueSA2</td>
<td>NueAA2</td>
</tr>
<tr>
<td>With FRP</td>
<td>TFCSA1</td>
<td>TFCAA1</td>
</tr>
<tr>
<td></td>
<td>TFCSA2</td>
<td>TFCAA2</td>
</tr>
</tbody>
</table>

Table 2: failure loads

<table>
<thead>
<tr>
<th>Sample</th>
<th>First cracking load [kN]</th>
<th>Failure load [kN]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NueSA1</td>
<td>795</td>
<td>831</td>
</tr>
<tr>
<td>NueSA2</td>
<td>855</td>
<td>885</td>
</tr>
<tr>
<td>NueAA1</td>
<td>710</td>
<td>1115</td>
</tr>
<tr>
<td>NueAA2</td>
<td>722</td>
<td>1172</td>
</tr>
<tr>
<td>TFCSA1</td>
<td></td>
<td>1037*</td>
</tr>
<tr>
<td>TFCSA2</td>
<td></td>
<td>1028*</td>
</tr>
<tr>
<td>TFCAA1</td>
<td></td>
<td>1275*</td>
</tr>
<tr>
<td>TFCAA2</td>
<td></td>
<td>1273*</td>
</tr>
</tbody>
</table>

* maximal registered load

3.2 Global behaviour

For one of each kind of samples, the curves load versus longitudinal displacement are plotted on the figure 5.
NueSA samples: the failure is brutal and after test we obtain only a pyramidal piece of concrete.
NueAA samples: after failure, the load decreases and there is a lot of cracks, in both longitudinal and transversal directions. The plateau corresponds to the yield stress which is obtain for the stirrups.
TFCSA sample: the efficiency of the cloth is well shown by this global curve, with a more extend ultimate capacity and with a important ductility.
TFCAA sample: the ultimate load is greatest than the NueAA’s one, and the ductility is much higher.
For all cases of FRP strengthened samples, no failure was observed after 10 mm of steel plate displacement.
4 Conclusion

With these results, the use of FRP to retrofit the top of bridge pile subjected to localised loading will be efficient.
The retrofitting effect is present only when the load reaches values near the ultimate value of the no strengthened sample. Then, the FRP remains elastic and we do not observe local failure.
The ultimate load is greatest and the ductility better.
This study has to be done again with other industrial products.
We have now to develop some design model, which takes into account the retrofitting effect given by both the reinforced steel bars and the FRP.

Acknowledgements

This study was supported by the French DRAST (MENRT).
The carbon cloth is the TFC® product of Freyssinet International.

References