Modern Solutions for Rehabilitation of Old Reinforced Concrete Structures

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Summary

The paper deals with the results and design recommendations obtained from an experimental programme and its application on a structural rehabilitation.
The experimental programme presents the strengthening effect of RC columns by coating with new RC jacketing. Methods of increasing bond between old and new concrete are analysed: no bonding agent; surface chemical bonding agent; mechanical fixed connectors; chemical fixed connectors.
The analysed strengthening solutions are applied on an existing four storeys RC framed structures built in 1940 and located in a seismic zone. The structure presents poor quality concrete, poor reinforcement detailing and weakness of reinforcement at present-day magnitude of seismic action.
As the owner requirement was to build two more storeys, some rehabilitation solutions were adopted: RC jacketing of foundations and columns; CFRP jacketing of beams and slabs.

Keywords: strengthening; reinforced concrete framed structures; reinforced concrete jacketing; chemical bonding agent; connectors; carbon fibre reinforcement polymer; seismic zones.

1. Experimental programme

The experimental programme focuses on quantifying the influence of different techniques for connecting between the two concrete layers: old concrete substrate and the added new concrete. The test selected for the study was the pull-off test.

The concrete class adopted was: C 20/25 and C 16/20 for the substrate; C 20/25 for the jacketing.

The connection between the substrate (RC prism) and the added concrete (RC jacketing) were: concrete-to-concrete bond; bonding agent as epoxy resin; chemically (Fig. 1) or mechanically anchored steel connectors.

The results of experimental tests are presented in Table 1 and Fig. 2.

Fig. 1: RC columns strengthened by RC jacketing

Table 1: Pull-off test results

No.	Concrete-to-concrete bond		Improved Bond		Efficiency
	Bond strength τ_{ai} [N/mm^2]	$\frac{f_c^{prism}}{f_c^{jacketing}}$	Bonding solution	Bond strength τ_{af} [N/mm^2]	$(\tau_{af} - \tau_{ai}) / \tau_{ai}$ x 100 [%]
1*	1.30	25.4/27.5	epoxy resin bonding agent	1.38	6 %
2*	1.42	25.4/27.5	mechanical anchored connectors	1.70	23 %
3*	1.38	25.4/27.5	chemical anchored connectors	2.18	54 %
4**	1.38	20.0/36.8	chemical anchored connectors	1.92	39 %

Notes: - substrate concrete (inner prism): * C 20/25; ** C16/20
- added concrete (jacketing): C 20/25.

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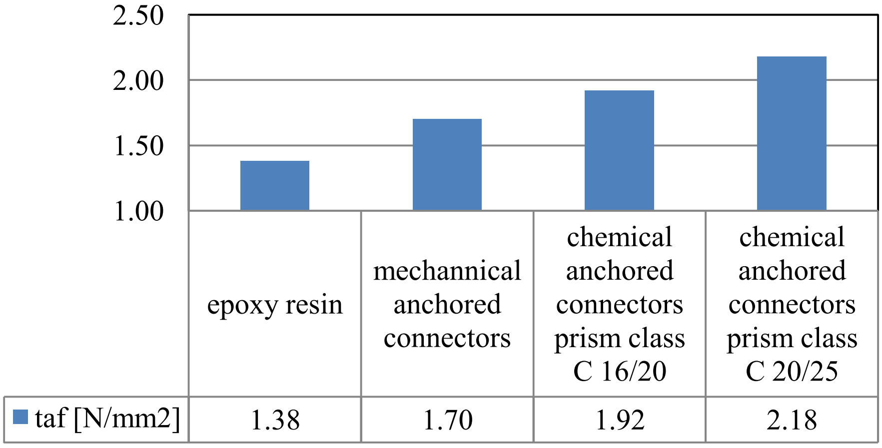

Fig. 2: Influence of bonding solution on bond strength

2. Strengthening example

The analysed strengthening solutions are applied on an existing four storeys building, GUBAN factory, erected in 1940 and located in a seismic zone – Timisoara, Romania. The structure consists of: vertical inner reinforced concrete frame and brick masonry resistance walls on outer perimeter; horizontal reinforced concrete floors with main and secondary beams. The owner requirement was to build two more storeys.

The factory has been assessed and rehabilitated. The main problems comprised local damage of some structural elements and weakness of reinforcement of columns and beams at present-day magnitude of seismic action. Local damages were observed and assessed at slabs, main girders, secondary beams and columns. The damage consisted of: concrete cover dislocated over a large surface; corrosion of many stirrups; deep corrosion of main reinforcement.

Weakness of reinforcement was deduced from the structural analysis. The initial analysis, done in 1940, was performed according to Romanian norms, under which aseismic design was inadequate, owing to weakness in the structural system. On the other hand, weakness of shear reinforcement was deduced; inclined cracks were noticed at some main girders.

The rehabilitation of the RC structure, performed in 2008, was adopted for both types of damages. The strengthening consisted in jacketing with reinforced concrete of columns and foundations. For columns the previous experimental studied solution was adopted by using chemical anchored connectors (Fig. 3). The strengthening solution adopted for beams and slabs was based on carbon fibre polymer composites (CFRP): longitudinal CFRP lamellas and transversal CFRP wrap for beams; CFRP wrap for slabs.

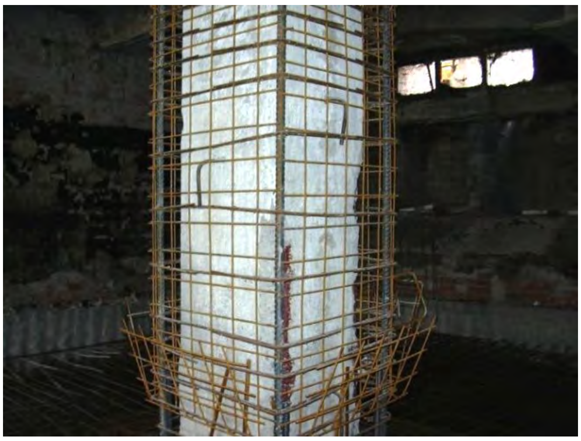

Fig. 3: RC strengthening of columns

3. Conclusions

Concerning the rehabilitation of RC concrete columns by RC jacketing the bond strength obtained on specimens without special techniques for connection – concrete-to-concrete bond – seems to be similar to the specimens with roughening technique: partially chipped and pre-wetted, partially chipped. The specimens with a bonding agent, with steel connectors and special connectors “conexpand” show an improved adherence of the RC jacket.

The analysed strengthening solutions were applied on an existing four storeys RC framed structures built in 1940 and located in a seismic zone. As the owner requirement was to build two more storeys, some rehabilitation solutions were adopted: RC jacketing of foundations and columns; CFRP jacketing of beams and slabs.