Upgrading Reinforced Concrete Structures by Adding New Concrete

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Summary

Placing reinforced concrete layers or jackets to strengthen concrete elements is a normal construction practice, but there are a number of crucial issues regarding the capacity of the new strengthened elements. In the absence of any guidance, engineering judgment is often used. A procedure for the structural design and detailing of reinforced concrete elements strengthened by the addition of new concrete layers of constant height is proposed. The strengthened element is considered as a composite one. Analytical expressions are derived, describing the shear stresses and resistances at the interface between old and new concrete, depending on whether the layer is added on the compressive or the tensile side of the element. Taking into account the slipping behavior at the interface, as well as existing experimental data for specific examined cases, a relation of the "composite" element to the relevant monolithic is obtained and reliable monolithic factors are determined.

Keywords: upgrading, retrofitting, reinforced concrete, layer, interface, monolithic factors.

1. Introduction

When addressing the technique of strengthening reinforced concrete (RC) structures by adding new concrete, two main issues should be considered: (a) whether the transfer of stresses on the contact surface between old and new concrete is achieved and (b) which is the resistance of the new retrofitted elements, taking into account that the interfaces of old-new concrete elements do not have a fully monolithic behaviour.

2. Verification of Sufficient Connection between the Contact Surfaces of a Retrofitted Element

The transfer mechanism of the forces at the interface between the old and the new element is verified as follows:

$$\bar{\tau}_{S(i\text{-}j)} \leq \bar{\tau}_{R(i\text{-}j)} \qquad (1)$$

where $\bar{\tau}_{S(i\text{-}j)}$ and $\bar{\tau}_{R(i\text{-}j)}$ = interface shear stress and resistance of a segment of length $l_{(i\text{-}j)}$, respectively.

The shear stress at the interface of a structural element strengthened by an additional RC layer of height h_n at the tensile or the compressive side of the element is obtained as follows:

$$\tau_{S,i} = V_{S,i} \Big/ b_n \cdot z_n \cdot \left(1 + \frac{A_{so}}{A_{sn}} \frac{d_o - x}{d_n - x} \frac{z_o}{z_n}\right) \qquad (2) \qquad \text{and} \qquad \tau_{S,i} = \frac{V_{S,i}}{b \cdot z} \frac{h_n}{x} \left(2 - \frac{h_n}{x}\right) \qquad (3)$$

where $\tau_{S,i}$ and $V_{S,i}$ = the shear stress and force at section i, z_o, d_o, A_{so} and z_n, d_n, A_{sn} = the lever arms of internal forces, the section heights and the reinforcement section areas of the existing and the new element, respectively, b_n = b= the width of the additional concrete layer and x = the height of the compressive zone.

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The shear resistance of the old-to new concrete interface can be activated through various mechanisms, such as adhesion, friction, clamping action, dowel action and welded connectors [1], [2]. Adhesion has a maximum value depending on the tensile strength of the weakest concrete (old or new) and is activated at slip of 0,01 to 0,02 mm. The friction mechanism presupposes the existence of compressive stress at the interface. However, in reinforced roughened interfaces, the presence of adequately anchored reinforcement cross passing the roughened interfaces of the old and new concrete can cause additional friction, called clamping action. Maximum shear resistance depending on the treatment of the interface is activated for interface slip approximately equal to 2 mm. Dowel action transferred by steel bars crossing the interface provides shear resistance, depending on the concrete strength and steel yield stress, with a maximum value corresponding to slip of approximately 2 mm. Sometimes, when it's practically convenient, steel connectors are welded on existing or new reinforcement.

A superposition of all the mechanisms cannot result as the total maximum shear resistance of any individual mechanism acting at the interface, since it can be noticed that the maximum shear resistance for each mechanism corresponds to different values of relative slip.

3. Capacity of strengthened elements

Interface slip may considerably affect the capacity of a strengthened element, resulting to lower resistance and stiffness in comparison with the monolithic [3]. In Fig. 1 the capacity curves for a strengthened element and the relevant monolithic, with exactly the same dimensions, strength of materials and quantity of reinforcement, are depicted. Correlating the mechanical characteristics of the strengthened element to those of the monolithic, relevant converting factors k_i, called monolithic, can be defined. Therefore, in order to apply an approximate design method, starting from well known design procedures of monolithic elements, the following three types of monolithic factors are necessary, k_{Fy}, $k_{\delta y}$ and $k_{\delta u}$, defined as follows (Fig. 1):

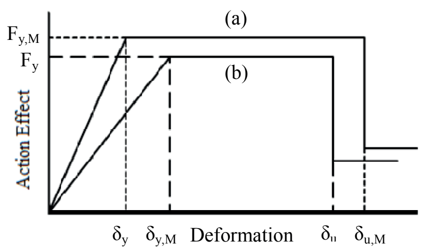

Fig. 1 Capacity curves (a) for monolithic elements and (b) for strengthened elements.

$$k_{Fy} = F_{y,M} / F_y \,,\; k_{\delta y} = \delta_{y,M} / \delta_y \,,\; k_{\delta u} = \delta_{u,M} / \delta_u \qquad (4)$$

From existing experimental data concerning RC jackets with four different interface treatments and connection means, following values of monolithic factors were extracted: k_{Fy} ranges from 0,80 to 0,94, $k_{\delta y}$ from 1,15 to 1,94 and $k_{\delta u}$ from 0,70 to 1,39. Obviously, interface treatment crucially affects the stiffness of the strengthened element, while its effect on strength is much lower.

4. Conclusions

In the present paper, in order to verify sufficient connection between the contact surfaces of concrete elements strengthened by new concrete layers, analytical formulas are presented, to express the interface shear stress. Moreover, an approximate method is proposed based on the use of monolithic converting factors, to define the mechanical characteristics of the strengthened element.

5. References

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