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Strength and ductility capacity of RC columns strengthened with CFRP materials

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Abstract

It is a usual practice that traditional methods with traditional materials (most frequently jacketing of elements) are used for repair and strengthening of structures. However, lately, particularly in the last two decades, there have occurred new construction materials intended for strengthening and design referred to as composites strengthened by polymer fibers (CFRP). These materials have special mechanical properties and special properties.

Within the frames of this paper, special emphasis will be put on RC buildings where, during construction, the built-in concrete has not achieved the designed concrete class and/or buildings that cannot satisfy the required strength, stiffness and deformation characteristics, particularly in earthquake conditions. In these cases, it is necessary to take measures for repair and strengthening of both individual structural elements and whole structures. In the paper part of the analytical, laboratory and quasi-static experimental investigations of designed models of RC columns will be presented. Particular attention will be paid to behaviour of these columns under cyclic loads, whereat a number of comparative analyses of a number of parameters obtained from the experimental investigations of the tested models will be carried out. It will be pointed out that the use of these innovative CFRP materials greatly contributes to the strengthening of RC columns and significantly increases the ductility capacity, which is of great importance in seismically active regions. Some recommendations and outcomes will be given as to the approach and technology of practical application of these materials.

Key words: Strength and ductility capacity, strengthening, innovative materials, CFRP, quasi-static test

1 Introduction

The need for repair and strengthening of RC buildings and their structural elements occurs when their elements do not possess sufficient strength, stiffness and/or ductility out of different reasons or due to slighter or more severe damages that are most frequently caused by earthquakes. Within the frames of this paper, special emphasis will be put on RC buildings where, during construction, the built-in concrete has not achieved the designed concrete class and/or buildings that cannot satisfy the required strength, stiffness and deformation characteristics particularly in earthquake conditions. In these cases, it is necessary to take measures for repair and strengthening of both individual structural elements and whole structures.

To present the possibilities and the benefits of use of these innovative construction materials in strengthening of structural elements of buildings and integral building structures, sample laboratory research for definition of the characteristics of these materials and experimental investigations of RC columns strengthened by CFRP by variation of concrete class, reinforcement percentage and different technologies of strengthening by CFRP (Fiber Reinforced Polymers) materials are carried out at the Institute of earthquake Engineering and Engineering Seismology – IZIIS, Skopje.

In this paper, some of the analytical, laboratory and quasi-static experimental investigations of designed models of RC columns are presented.

.Laboratory tests on materials built-in models for experimental research carried out at UKIM-IZIIS

To realize the experimental quasi-static tests, two models were designed and constructed, namely Model M1 and Model M2. The models were with identical proportions (supporting beam proportioned 50/50/116 cm and a column proportioned 30/30/200cm), constructed to the scale of 1:1.

For the purpose of easier incorporation of the FRP materials, it was decided to build the models in vertical position.

Fig. 1 shows photos taken during concreting of the foundation-beam and the columns of both models. In the first phase, concreting of the supports – foundations was done, while in the second phase, both columns were concreted.

During concreting of the models, three trial specimens - concrete cubes proportioned 15/15/15 were taken from the supports - beams and three trial cubes proportioned 15/15/15 were taken from the columns, in addition to the nine (9) cylinders proportioned 15/30 cm Fig. 2. To define compressive strength and concrete class, laboratory tests were performed at stock holding company-GIM-Skopje (for the cubes) and ZIM –Skopje (for the cylinders), while the tests for definition of the modulus of elasticity of the built-in concrete were done at ZIM – Skopje.

Figure 1. Photos taken during concreting of models **Figure 2. Photos of taken trial concrete specimens**

Using the trial concrete specimens – cylinders, three series of tests of compressive strength and tests for definition of the modulus of elasticity of the built-in concrete were carried out as follows:

- Series 0: concrete cylinders without FRP- plain concrete,
- Series 1: concrete cylinders wrapped with 1 (one) FRP layer,
- Series 2: concrete cylinders wrapped with 2 (two) FRP layers

Presented further are photos and results taken during laboratory tests for definition of compressive strength of concrete for the three series Fig. 3. It must be pointed out that the collapse of the models from the first and the second series was explosive, with big crushing of concrete wrapped with FRP. This was particularly pronounced in Series 2 where concrete was wrapped with two FRP layers.

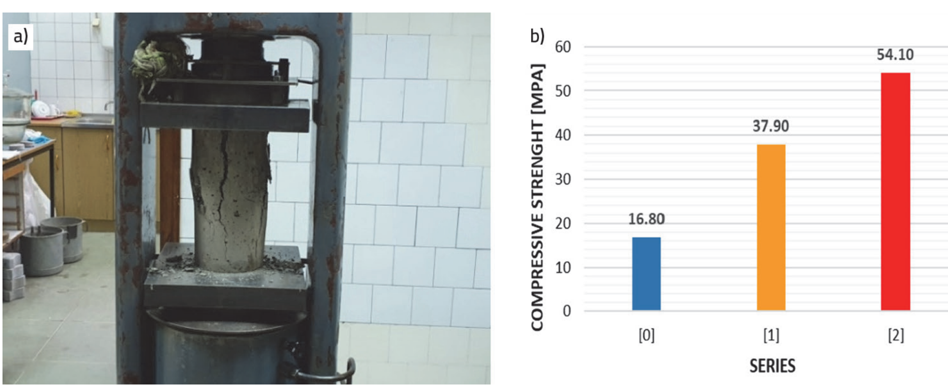

Figure 3. Testing and results: a) Testing of compressive strength for the first series: b) Diagram of compressive strength for each series

3 Experimental program

For the needs of own experimental investigations, two column elements were designed. The column models were designed as fixed cantilever girders with a constant length of both models of 200 cm (the column was treated only up to the inflection point, i.e., half of the total height) and cross-section of 30/30 cm. In both models, the varying parameters were the percentage of longitudinal and transverse reinforcement and the axial forces. The concrete class, i.e., the compressive strength of concrete and the type of the FRP was different for both models. The elements were designed to the geometrical scale of 1:1. Presented further are photos taken during construction of the models (Model M1 and Model M2), Fig. 4.

Figure 4. Construction of the models: a) Model M1 and Model M2; b) Construction of the column models for experimental tests; c) Photos taken during application of FRP

4 Results from experimental investigations it UKIM-IZIIS

Presented further are photos and results taken in the process of quasi-static tests on Model M1 and Model M2 with photos of characteristic damage Fig. 5, Fig. 6 and Fig. 7.

Figure 5. Shot during the quasi static testing of column Model M2

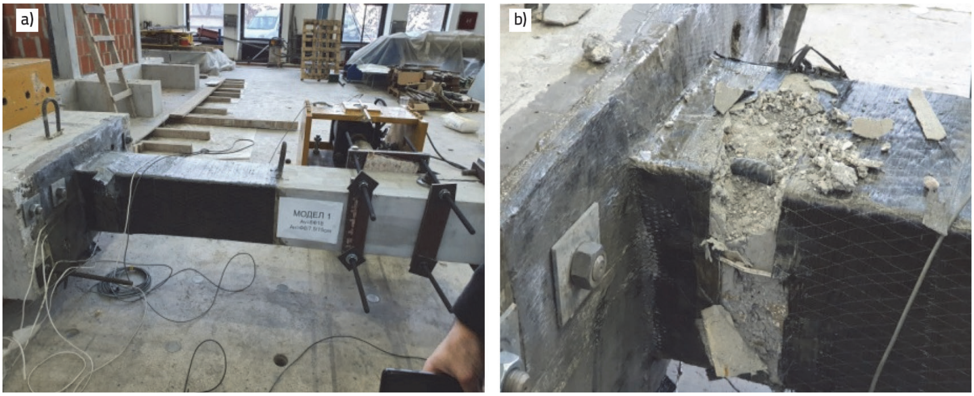

Figure 6. Quasi-static tests of Model M1: a) Shot during the quasi static testing of column Model M1; b) Damage from quasi static testing of column Model M1

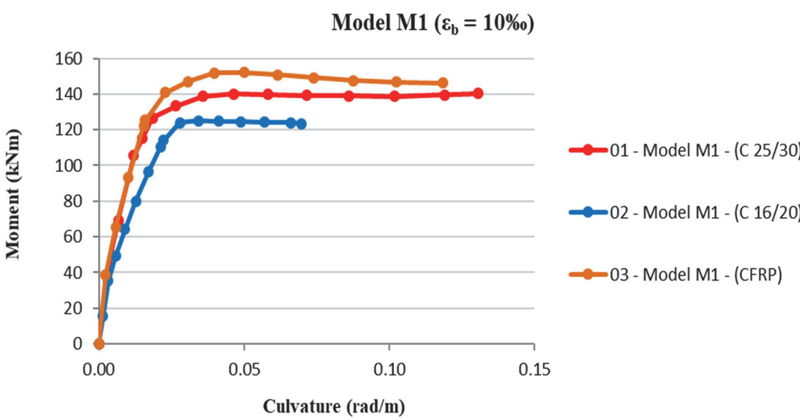

Figure 7. M-Φ Interaction Diagram for Model M1 – Comparison

5 Conclusions

In the paper part of the analytical, laboratory and quasi-static experimental investigations of designed models of RC columns strengthened with FRP were presented. Based on the experimental investigations the following conclusions can be outlined:

- In general it can be concluded that the compressive strength is higher with the number of FRP layers Fig. 3b).
- From the behaviour of the tested elements it can be concluded that in both Models, the failure was sudden and explosive, but with sufficient ductility capacity Fig. 7.
- These tests are good basis for further analytical and numerical investigations, which can provide additional conclusions.

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