# Behaviour of concrete elements under the transversal forces and strengthening with the FRP

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## ABSTRACT

The behaviour of concrete elements, in this case the beams under the different loadings result with the capacity of section. In analyzing process results are followed with the deflections of beams and the cracks. In this paper we analyse the type, form and dimensions of cracks under the third point load method of applied loads in simple concrete beam. To improve the capacity we use the different types of FRP, including the GFRP and CFRP, comparing the deflections and cracks. The focused parameters are in using the different methods for transversal force , including the primary forms with steel stirrups and the new proposal for using the outside stirrups from FRP. The all analyses presented in this paper are based on the analytical model and experimental results.

The behaviour of beams under the mixed form with ordinary steel stirrups and proposal stirrups from FRP, successfully increase the energetic capacity of sections.

***Keywords:*** *Concrete; FRP; behaviour; cracks; deflections, strengthening.*

## 1 INTRODUCTION

The concrete beams during the serviceability are under the loads, in many cases under the flexure, axial, and shear forces. Most researches have been focused on flexural strengthening of Reinforced Concrete (RC) beams, while the research on shear strengthening of RC beams is very limited. In fact, it is very dangerous for structures to be brittle failure by shear force. This is due mainly to the structural failure mechanism by shear instantly occurred without warning. Beams mainly subjected to shear force are deep beam, with shear span to effective depth ratio (l/d) less than two. Behaviors of deep beam subjected to vertical static loading are significantly different from behaviors of slender beam, in both analytical method and design. From previous researches, most of the shear strengthening method involved the use of carbon fiber.

The technique of strengthening reinforced concrete beams with externally-bonded composite materials has been shown to be efficient. Results obtained from reports and manuals concerning the state-of-the-art of this technique indicate that the shear strengthening of reinforced concrete has some confusing and unexplained features. This is due to the fact that the composite material, glued to the concrete surface, has linear-elastic behavior, quite different to the non-linear behavior of the structural element. The shear strengthening of reinforced concrete beams in bridges and buildings may be applied due to several causes: design, faults, increased load, functional changes, environmental attacks, etc. The mechanisms by which shear is carried out in reinforced concrete beams are very complex, and still not well understood. In general, the contribution of the shear reinforcement is calculated according to the truss analogy (steel and CFC).

The tentative for improvement of the behavior in this case is based on the typically strengthening using the CFRP , such outside stirrups.

## METODOLOGY AND ANALYSING THE SHEAR FORCE IN CONCRETE BEAM

Shear strengthening of reinforced concrete beams use the diagonal cracking strength *c V* as an estimate of the concrete contribution, and, in general, adopt the classical truss model for calculating shear reinforcements (steel and CFC) to shear capacity. The concrete contribution to shear resistance is far more varied because it is the sum of several internal mechanisms of resistance: shear carried in the compression zone (uncracked zone), aggregate interlock (shear friction between cracks), and dowel action. The literature furnishes several formulas for calculating the concrete contribution, and the most important codes have selected significantly different approaches for the *c V* portion.

This study seeks to investigate a suitable upper-bound solution and evaluate this model by comparison with experimental data

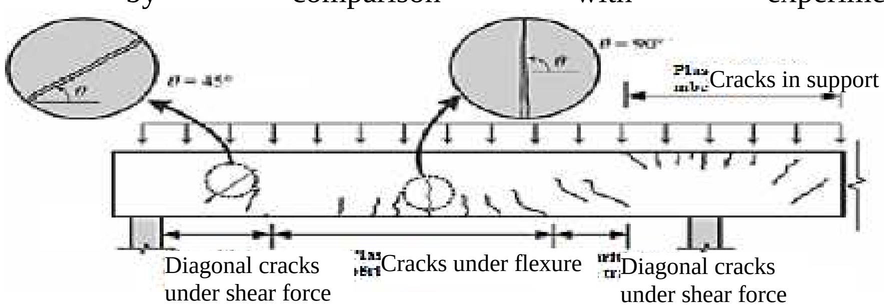


fig.1).

Fig.1. Different types of cracks under the loads

The different codes and different methods are used from the authors to analyses and to conclude the effects from shear force and also the calculations for strengthening of concrete beams. In this case we used the : Eurocode (2004 a,b); ACI; CA/CSA –S806-02; JSCE; and other manuals for design.

Different Codes , bring the different contributions of materials in capacity for shear force, presented in table 1.

Table 1.Contributions of materials and capacity of concrete beam section

| Design Standards | Contribute of Concrete [kN] | Contribute of Steel [kN] | Total Capacity [kN] | Experimental Value [kN] |
|---|---|---|---|---|
| Euro code | 6.079 | 5.495 | 5.495 | |
| ACI | 8.987 | 5.258 | 14.245 | |
| Concrete manual | 13.890 | 5.634 | 19.524 | |

The using techniques for improvement the capacity of shear forces, are different based on the using materials. The main methods are:

- Conventional methods using the conventional materials (steel; concrete, steel plate, etc),
- Actual methods using the new materials (FRP; Carbon plates; GFRP, etc)

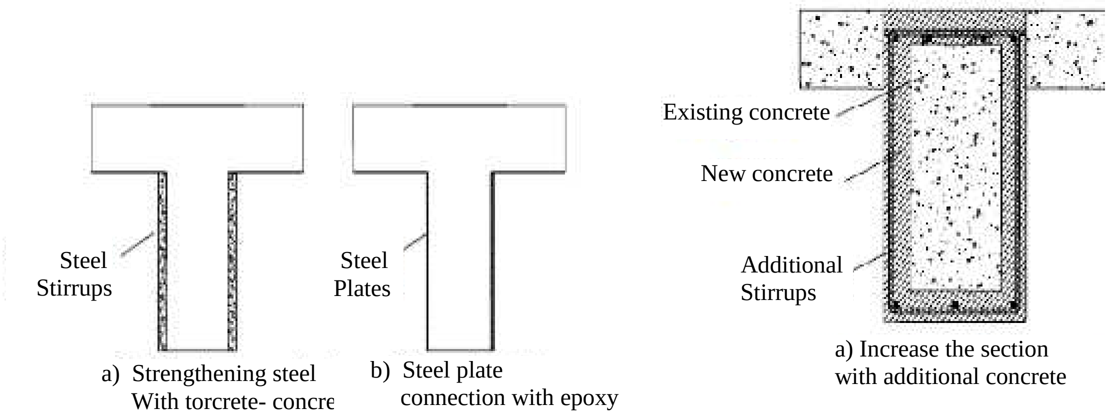


Fig.2.1. Conventional methods and materials

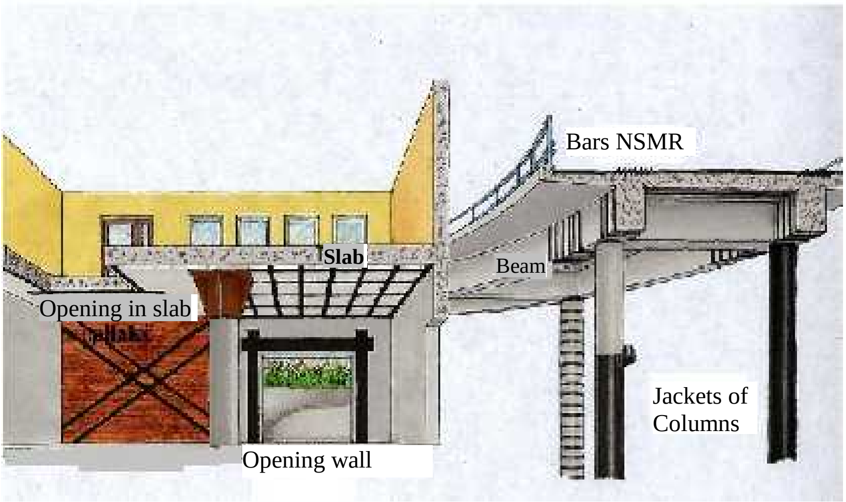


Fig.2.2. Actual methods and materials

The contribution of strengthening using the new material is presented in table 2.
Table 2-

| Design Standards | Contribute of Concrete [kN] | Contribute of Steel [kN] | Contribute of CFRP [kN] | Contribute of GFRP [kN] |
|---|---|---|---|---|
| Euro code | 6.079 | 5.495 | 16.662 | 12.071 |
| ACI | 8.987 | 5.258 | 15.945 | 11.551 |
| Concrete manual | 13.890 | 5.634 | 17.296 | 10.357 |

## EXPERIMENTAL PROGRAM

Nine orthogonal reinforced concrete beams with span of 1.20 *m* were tested , divided in three groups. All the specimens were designed to have the same nominal cross sectional dimensions: $b_w$ = 10 *cm* and $h$ = 15 *cm*. Cross-sectional details of the beams are shown in Figure [3], and figure [4]

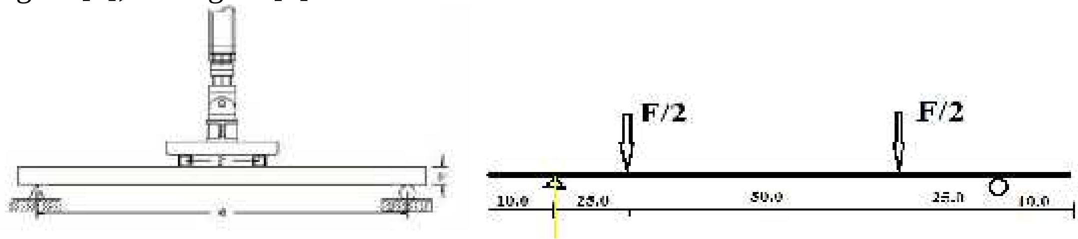


Fig.3. Applied force and statically system

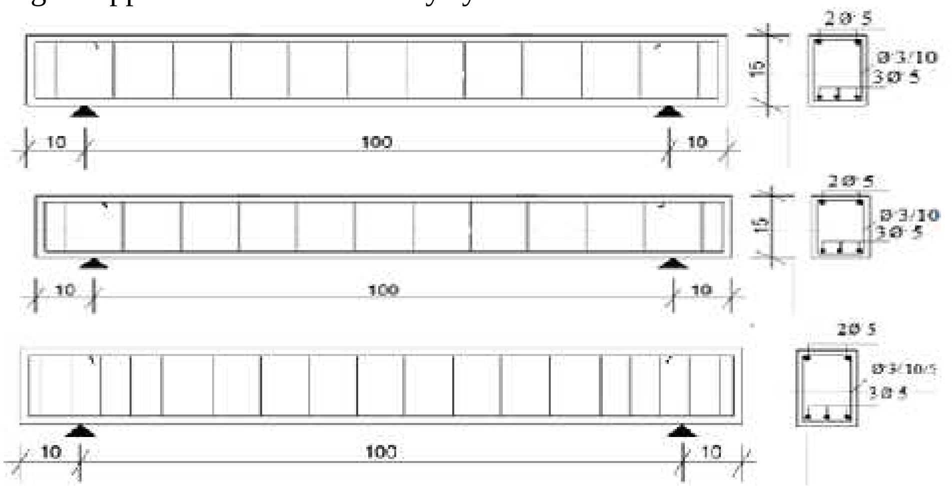


Fig 4-Three sets of concrete beams

The testing program was divided into three series with three beams tested as part of each series. The first series is : ***Set A/beam 1***: reference beam, reinforcement with steel stirrups Φ 3mm/100 mm; ***beam 2***, reinforcement with steel stirrups Φ 3mm/100 mm and CFRP stirrups /100 mm***; beam 3***, reinforcement with steel stirrups Φ 3mm/100 mm and CFRP stirrups /50 mm. ***Set B/beam 1***: reference beam, reinforcement with steel stirrups Φ 3mm/100 mm; ***beam 2***, reinforcement with steel stirrups Φ 3mm/100 mm and GFRP stirrups /100 mm; ***beam 3***, reinforcement with steel stirrups Φ 3mm/100 mm and GFRP stirrups /50 mm . ***Set C/beam 1***: reference beam, reinforcement with steel stirrups Φ 3mm/50 mm; ***beam 2***, reinforcement with steel stirrups Φ 3mm/50 mm and GFRP stirrups /100 mm; ***beam 3***, reinforcement with steel stirrups Φ 3mm/50 mm and GFRP stirrups /50 mm, presented in fig.5

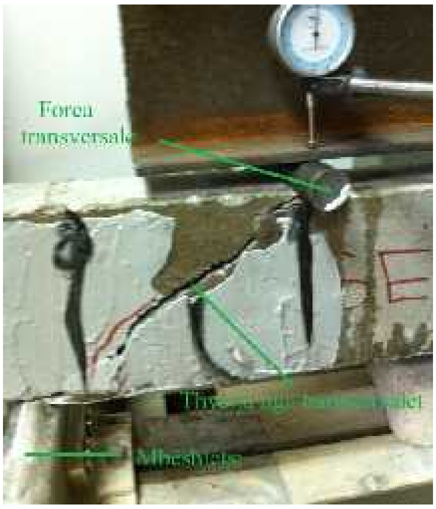

Fig.5.1-The cracks in Set A/beam 3 Fig.5.2-delaminate of the CFRP in Set A/beam 3

Fig.5.3- The cracks in Set B/beam 1    Fig.5.4. Cracks in set B/beam 3

Fig.5.5.Cracking under flexure force and shear force; Set C/beam 1

Fig.5.6 Cracks in Set C/beam 3

## EXPERIMENTAL RESULTS

### *Cracking*

The data collected by inspection was recorded and put it in table. During the test, the cracks developed were marked without interruption of the load process, or were the distance of stirrups are more .

Flexural cracks at the mid span started from the bottom face and propagated vertically through the height of the beams. As the applied load increased and the internal stress was redistributed, several other secondary flexural cracks were observed, starting from the main bending cracks. In analyzing cases the one of the important thing was the laminate or stick the plate with concrete, especially in positions were was starting the cracks.
Table 3 , will present the behavior under the applied force.

**Failure**

For the beam with no descending branch, the authors considered the ultimate load as equal to the maximum load.

The reference beams in the experimental program failed by diagonal tension, and the strengthened beams failed by diagonal tension with simultaneous CFRP stirrups.
Failure of the beams occurred after the steel stirrup yielded and started to present an inclined shear crack that grew in the direction of the beam flange. Bending or anchorage failure did not occur.

Table 3- behavior the beams under different strengthening

| Set/beam | Force (kN) | Displacement (mm) | Inspection of cracks |
|---|---|---|---|
| A/1 | 40 | 5.8 | Very large/45 $^0$ |
| A/2 | 55 | 5.9 | Large/45$^0$ |
| A/3 | 60 | 5.65 | Large/45$^0$ |
| | | | |
| B/1 | 45 | 5.55 | Small/45$^0$ |
| B/2 | 50 | 6.84 | Small/45$^0$ |
| B/3 | 60 | 7.1 | Small/45$^0$ |
| | | | |
| C/1 | 37.59 | 4.96 | Very small/45$^0$ |
| C/2 | 49.1 | 3.56 | Very small/45$^0$ |
| C/3 | 74.79 | 4.83 | Very small/45$^0$ |

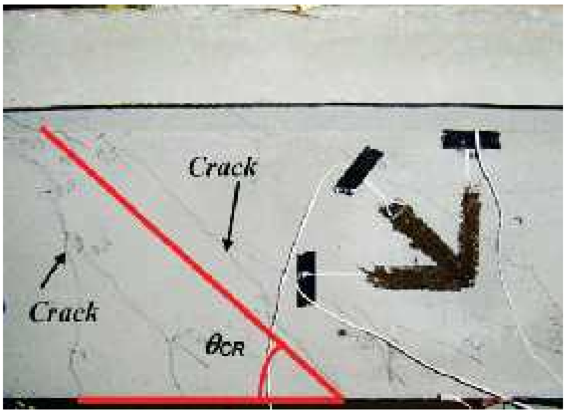

Fig.6 Crack and angles presented under microscope analyses

## Compare the test results

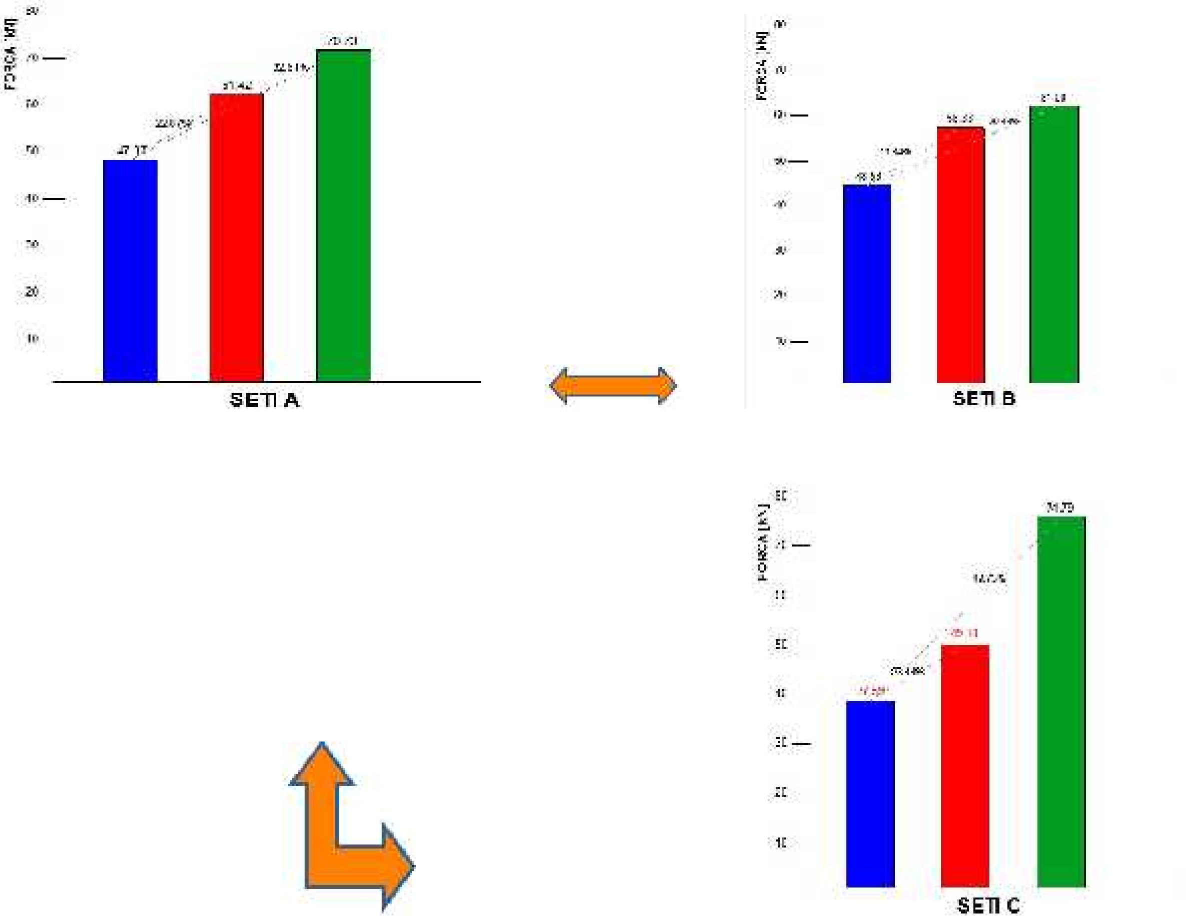


Fig.7 Comparing the output results in three study cases

## CONCLUSION

- The difference betwen the analytical and experimental results are the indicated of many factors , especially the span of the concrete element-beam (notes-small distance for Shear Force)
- The stirrups from CFRP and GFRP are analyse such ecuivalent thicknees , for the experimental study in this level is one of the hypotesis.
- One of the elements in this case study is rectangular cross sections of beams, and in practical analyses it will be the “T” section, because the strengthening and apply metodhs will cover also the real situation.
- The results in strengthening of element under the shear force are about 30 %, but in same element the improvement in flexure behavior it was arrived the better results.
- The dimensions of cracks in strengthening beams are decrease comparing the referent beams.

- The results confirm that the technique of strengthening with CFRP and GFRP increases shear capacity.
- All the beams showed good ductile behavior.

## REFERENCES


[1] Kabashi,N,and Krasniqi.C,(2007): Improving the Ductility of Usual and High Performance Concrete using the Confinement with Spiral Tiles, Steel Fibres and Polymer Fibres, ICPIC 2007;Chuncheon, Korea

[2] Hajrizi.B.(2012): Behaviour of concrete elements under the shear forces and strengthening with polyner materials, Master Thesis, Prishtina

[3] Kabashi,N,and Krasniqi.C,(2011): The Effect of Polypropylene Fibres on the Energy-Absorption of Reinforced Concrete Beams, Ready Mix Concrete, Istanbul

[4] A. Spagnolo Jr ae. S. Sánchez Filho bm. S. L. Velasco c: RC T beams strengthened to shear with carbon fiber composites; Ibracon Structures and Materials Journals,2013

[5] A.J.Clark; (fifth edition) Shear in Beams; Part I-Concrete Analyses and Design

[6] Patel Mitali R, Dr.R.K.Gajjar. Shear strengthening of different beams using FRP natural rivers; International Journal of Advanced Engineering Research and Studies E-ISSN2249–8974

[7] Sayan Sirimontree, Boonsap Witchayangkoon,Nathavudh Khaosri and Jaruek Teerawong: Shear Strength of Reinforced Concrete Beam Strengthened by Transverse External Post-tension; American J. of Engineering and Applied Sciences 4 (1): 108-115, 2011 ISSN 1941-7020© 2010 Science Publications

[8] Antonio Nanni.(2013); North American design guidelines for concrete reinforcement and strengthening using FRP: principles, applications and unresolved issues; Construction and Building Materials-Journal.

[9] Rob Irwin and Amar Rahman .(2002) FRP strengthening of concrete structures – design constraints and practical effects on construction detailing;