Original university :
University of Sciences and Technology Mohamed BOUDIAF Oran - ALGERIA

Host university :
"Politehnica" University of Timisoara - ROMANIA

Article presented as part of the scholarship "Eugen Ionescu" funded by the University Agency of the Francophonie

Title :

NUMERICAL MODELING OF REINFORCED CONCRETE COLUMNS STRENGTHENED WITH COMPOSITE MATERIALS

C. OUCIF[1], M.B. BENMANSOUR[1], V. STOIAN[2], C.A. DAESCU[2]

[1] Civil Engineering Department, University of Sciences and Technology Mohamed BOUDIAF BP 1505 El M'Naouer, 31000 Oran - ALGERIA.

[2] Civil Constructions and Installation Department, Politehnica University of Timisoara 2nd T. Lalescu St., 300223 Timisoara - ROMANIA.

Presented by :

Mr. C. OUCIF

SUMMARY

- Abstract.
- Geometry of the column.
- Materials properties.
- Experimental tests.
- Numerical modeling using ATENA software 2D.
- Results.
- Conclusion.

1. ABSTRACT

NUMERICAL MODELS

BEHAVIOR UNDER CYCLIC LOADING

Experimental RC columns strengthened with composite materials

//

Modeled RC columns strengthened with composite materials

STRENGTHENING MATERIALS USED

- Glass Fiber Reinforced Polymers (GFRP)
- BARS METALLIC (BM)

2. GEOMETRY OF THE COLUMN

Square cross section

Area of the column	• 25x25 cm^2
Height of the column	• 150 cm
Diameters of the steel bars	• 8, 10, 12 and 16 mm

2. GEOMETRY OF THE COLUMN

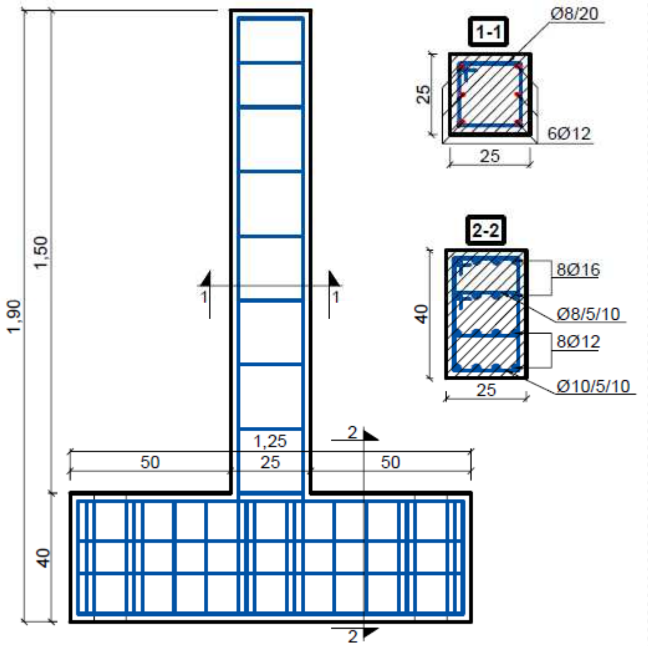


Figure 2.1 : Plan of reinforcement elements [1].

Figure 2.2 : Bars deformed [1].

Bars deformed before test

3. MATERIALS PROPERTIES

CONCRETE C16/20

Compressive strength [MPa]	• $f_{ck,cube}$ = 27,5 MPa
Elastic modulus [MPa]	• Ec = 34500 MPa
Tensile strength [MPa]	• Ft = 2,187 MPa

3. MATERIALS PROPERTIES

Steel bars Ø8, Ø10, Ø12 , Ø16

Tensile strength [MPa]	• ft = 560 MPa
Elastic modulus [MPa]	• Es = 200000 MPa
Density [Kg/m³]	• P = 7850 Kg/m³

3. MATERIALS PROPERTIES

Glass Fiber Reinforced Polymers (GFRP)

Tensile strength [MPa]	• ft = 2250 MPa
Elastic modulus [MPa]	• E = 70000 MPa
Density [Kg/m^3]	• P = 2530 Kg/m^3
Thickness [mm]	• Ø = 0.17 mm

4. EXPERIMENTAL TESTS

13 attempts was performed under cyclic loading [1]

For this article we study 02 attempts under cyclic loading BM - GW

Hydraulic pump

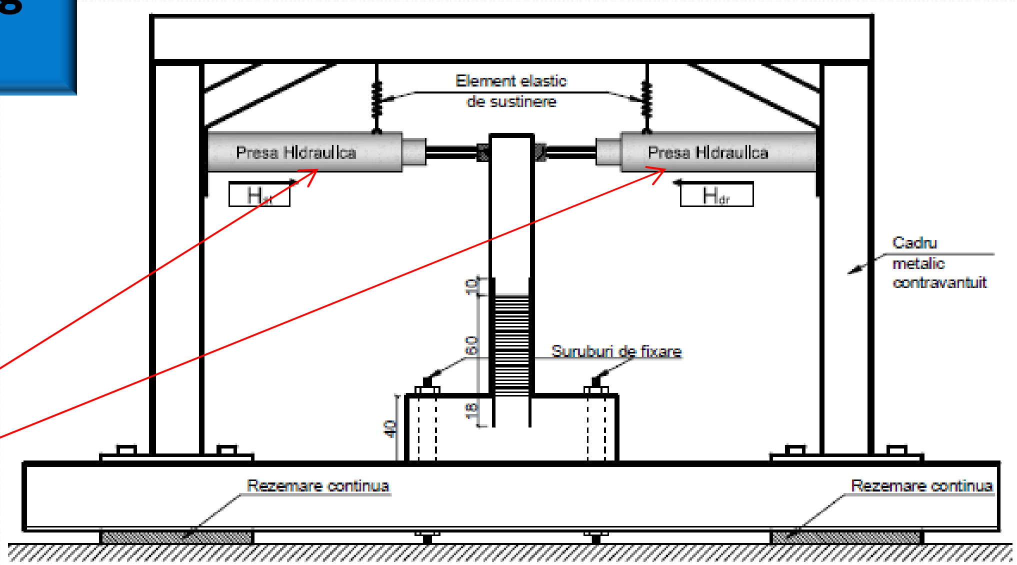


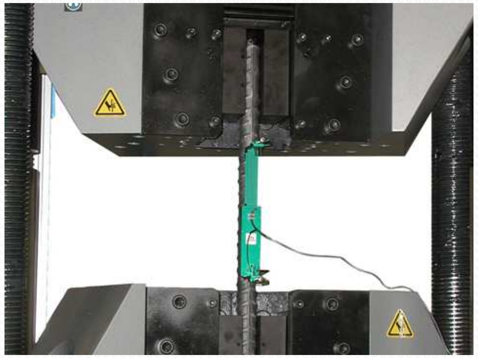
Figure 4.1 : Elements of the test bench [1].

4. EXPERIMENTAL TESTS

Determination of the limit of elastic behavior
25 kN – 24 mm

Figure 4.2 : Reference model C1C [1].

Compression test on concrete



Tensile test on steel bars

5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

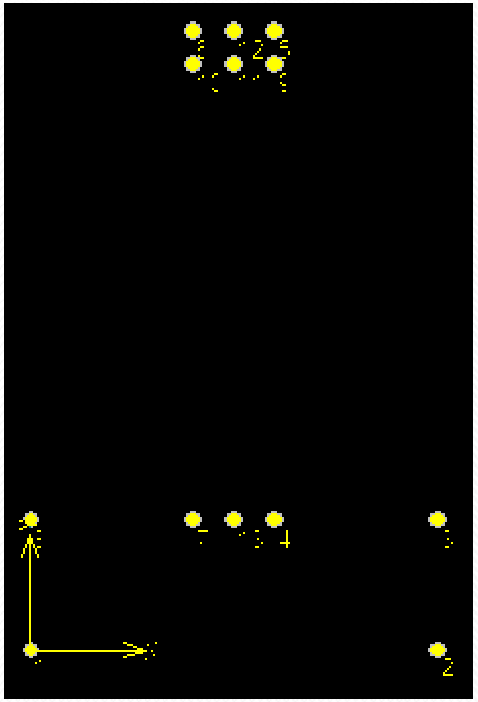
5.1. Definition of the materials

Material type in ATENA	Material
SBeta Material	• Concrete
Cycling Reinforcement	• Steel bars
Reinforcement	• GFRP

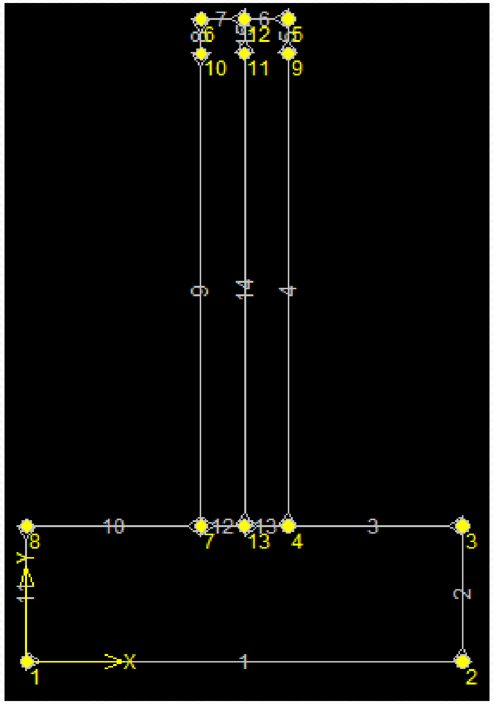
5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.2. Definition of the geometry

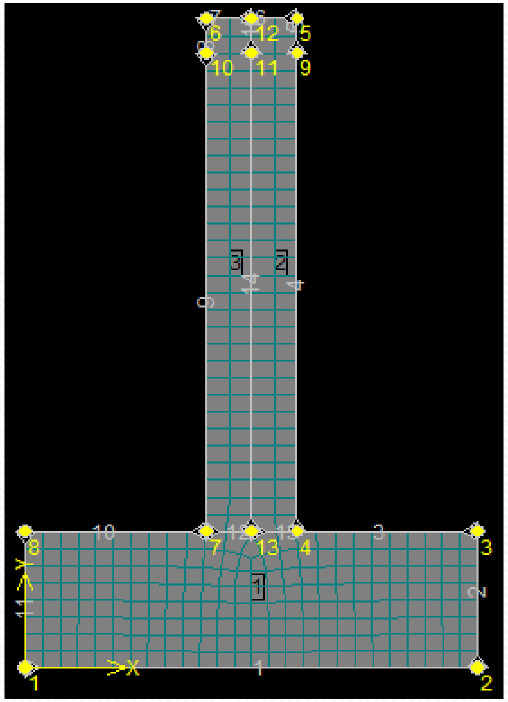
Joints



Lines



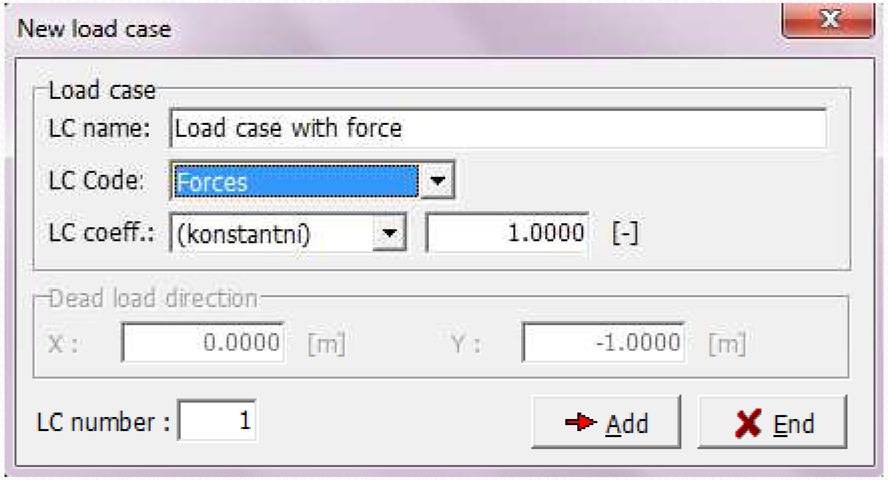
Macro-elements



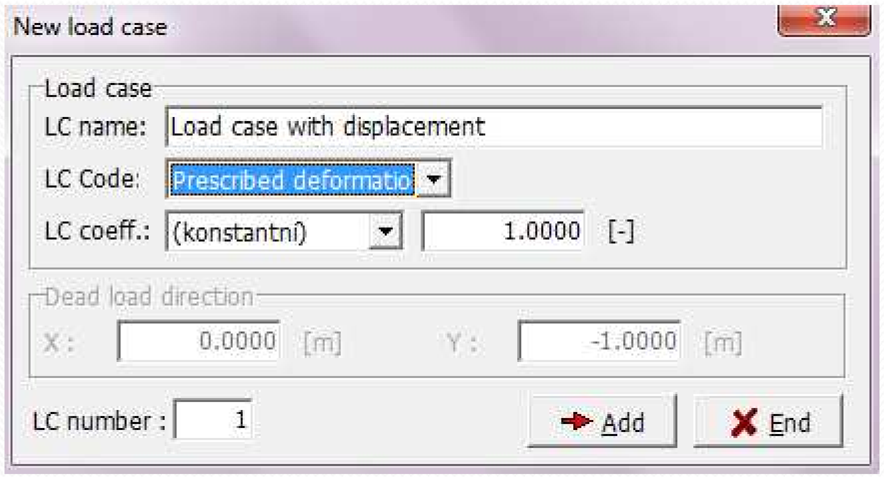
5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.3. Definition of loading and support

Imposed force



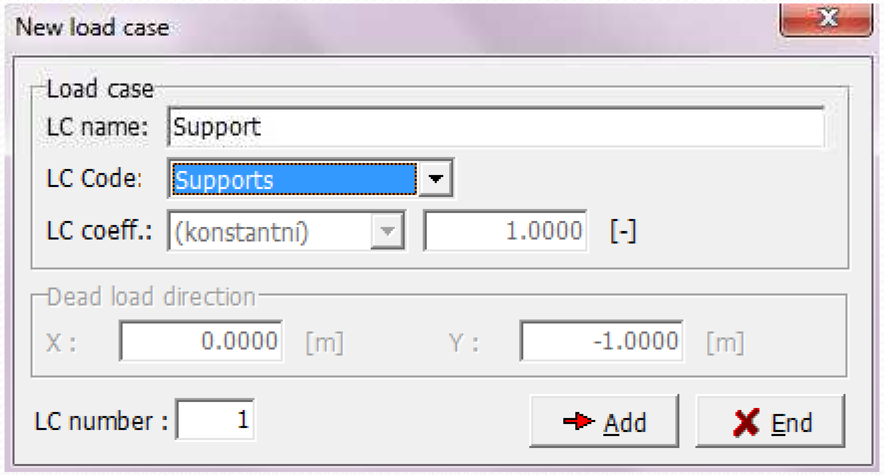
Imposed displacement



5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.3. Definition of loading and support

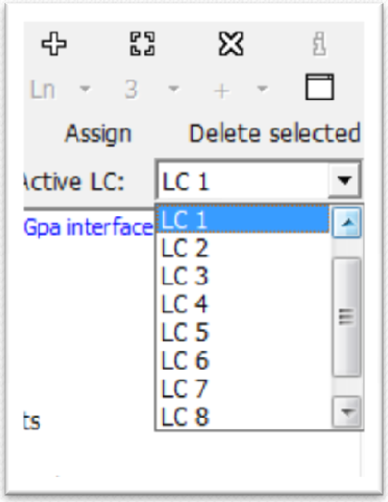
Support



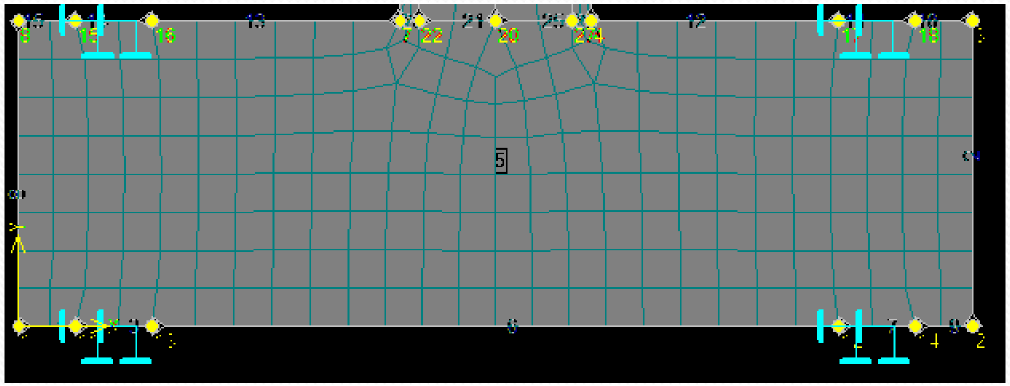
5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.4. Application of loading and support

Selection of the load case of support



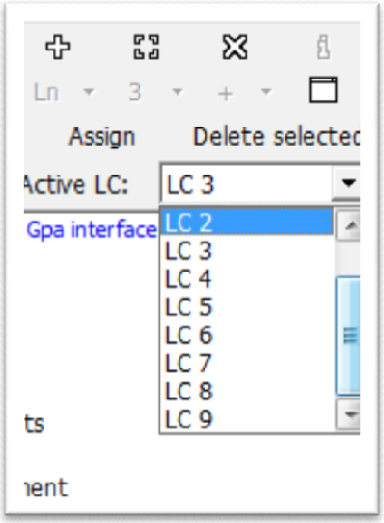
Application of the support



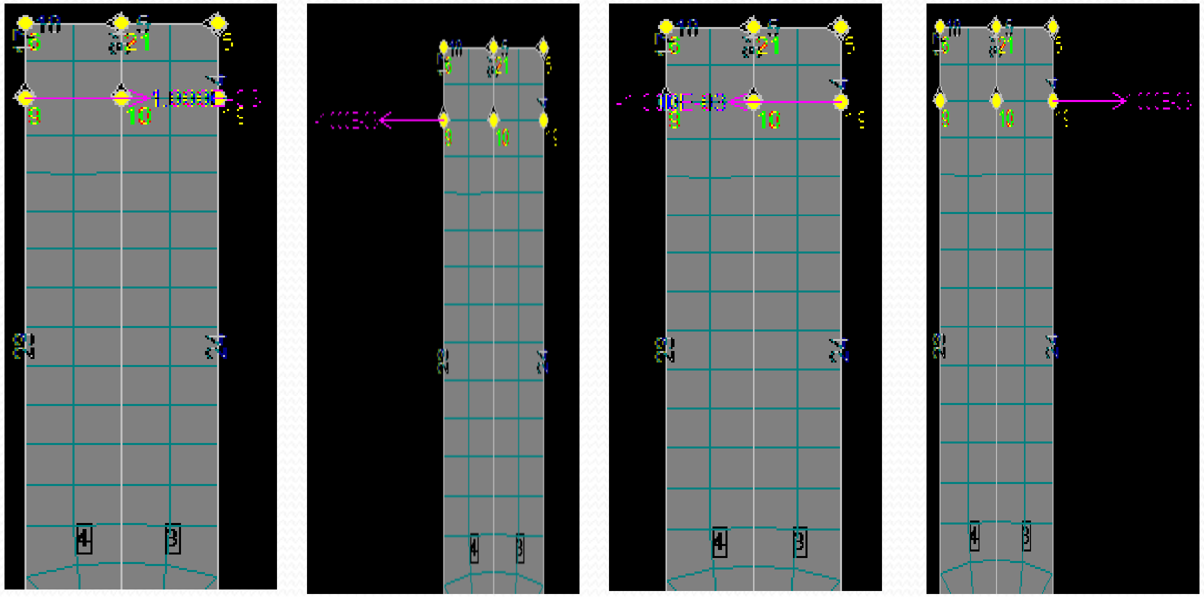
5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.4. Application of loading and support

Selection of the load case of loading



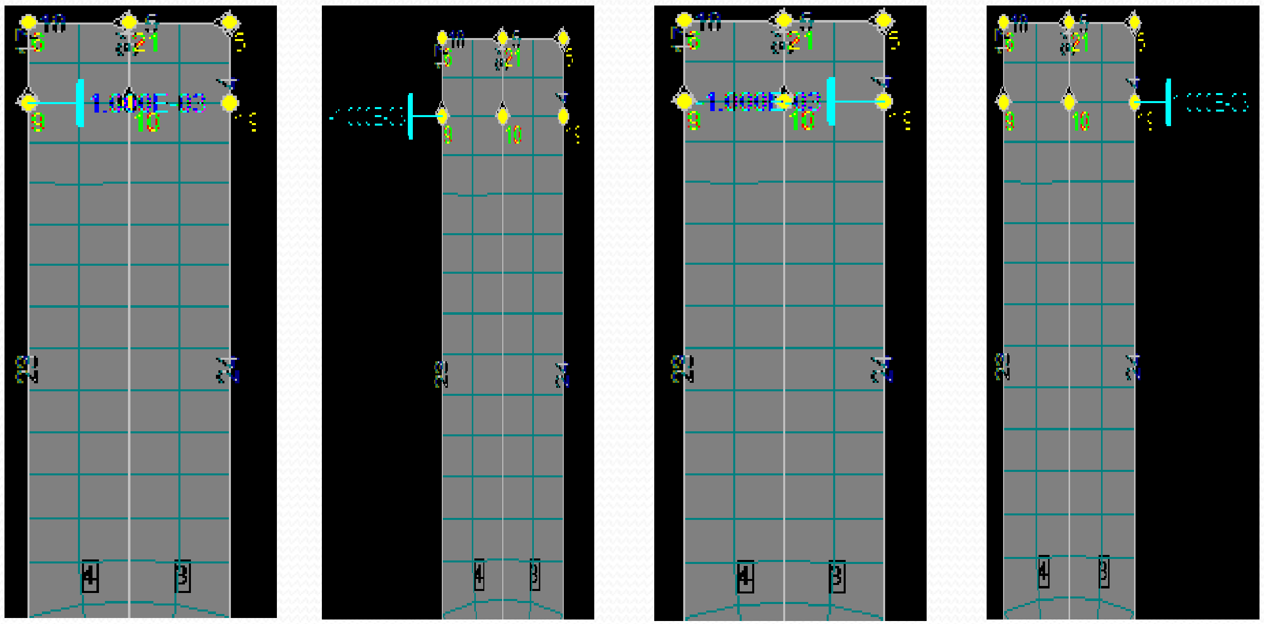
Application of the imposed forces (1 kN)



5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.4. Application of loading and support

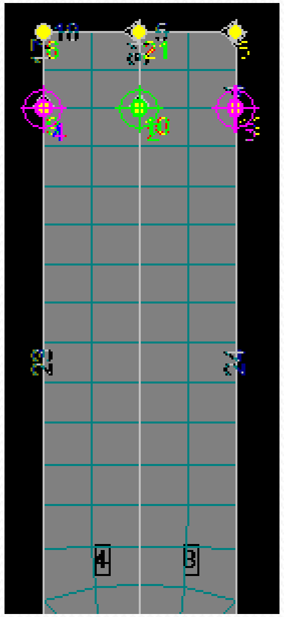
Application of the imposed displacement (1 mm)



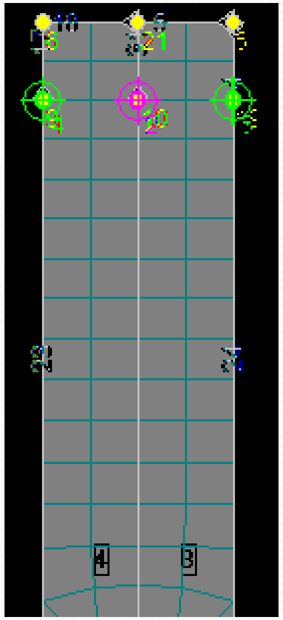
5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.5. Monitoring points

Control of displacement (D1)



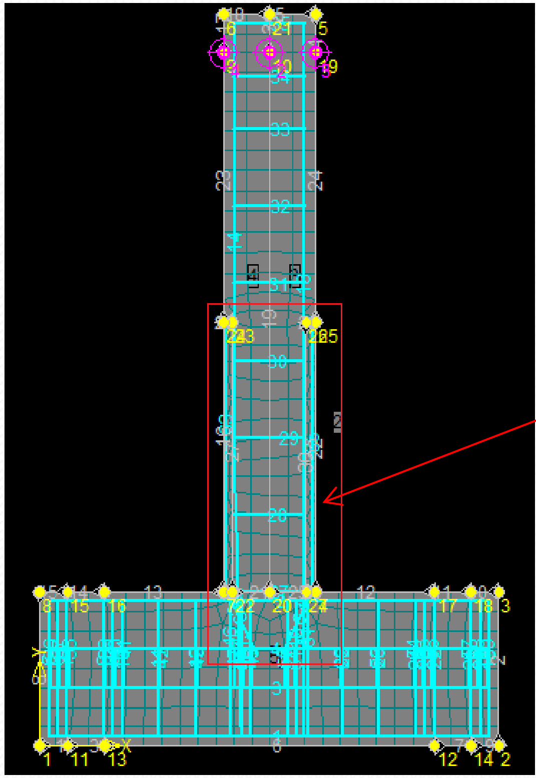
Control of force



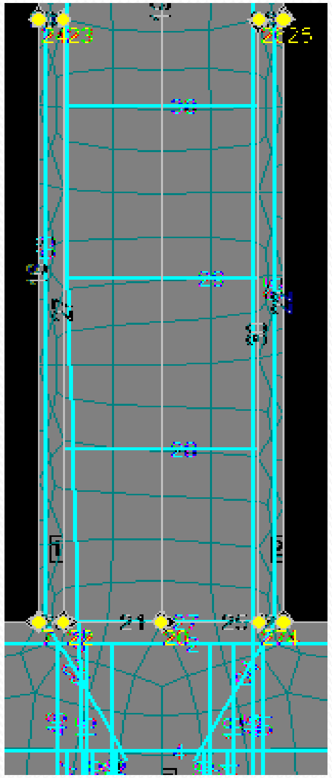
5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.6. Column strengthened with BM

Plan of the column C3C-BM-AF



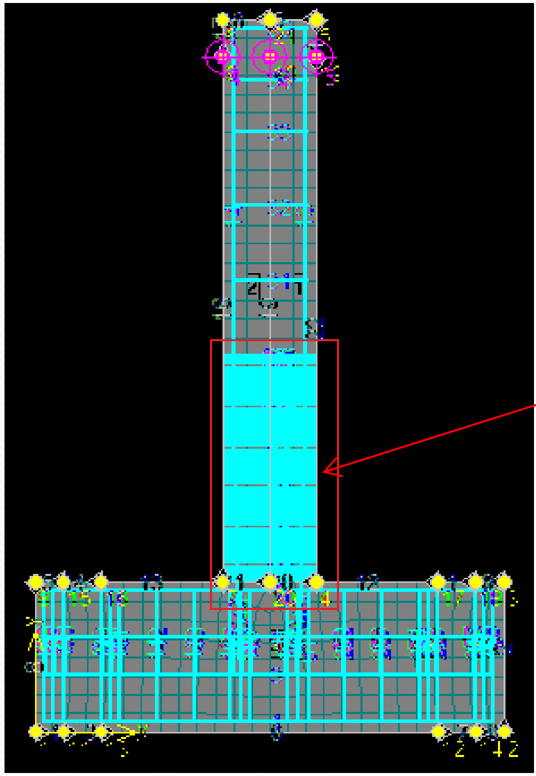
Detail of strengthening



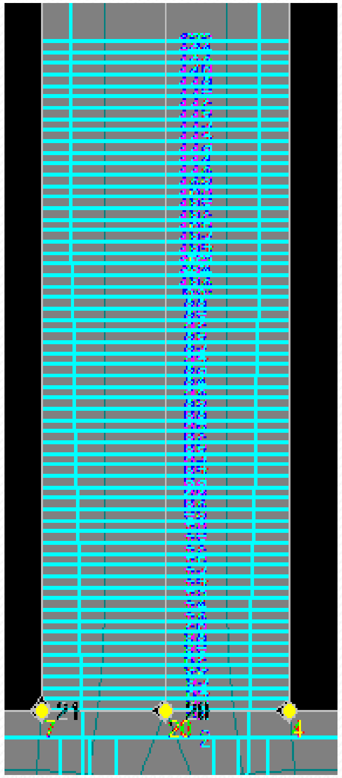
5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.7. Column strengthened with GFRP

Plan of the column C6C1-GW-BC



Detail of strengthening



5. NUMERICAL MODELING USING ATENA SOFTWARE 2D

5.8. Models used for materials

Concrete

- Non linear model for concrete.
- Strain softening in compression : softening law defined by means of the softening modulus.
- Strain softening in tension : Exponential crack opening law (Bazant 1983) [6].
- Rotated crack model for cracks.

Steel bars

- Perfect elastoplastic model.

GFRP

- Bilinear model.

6. RESULTS

6.1. C3C-BM-AF

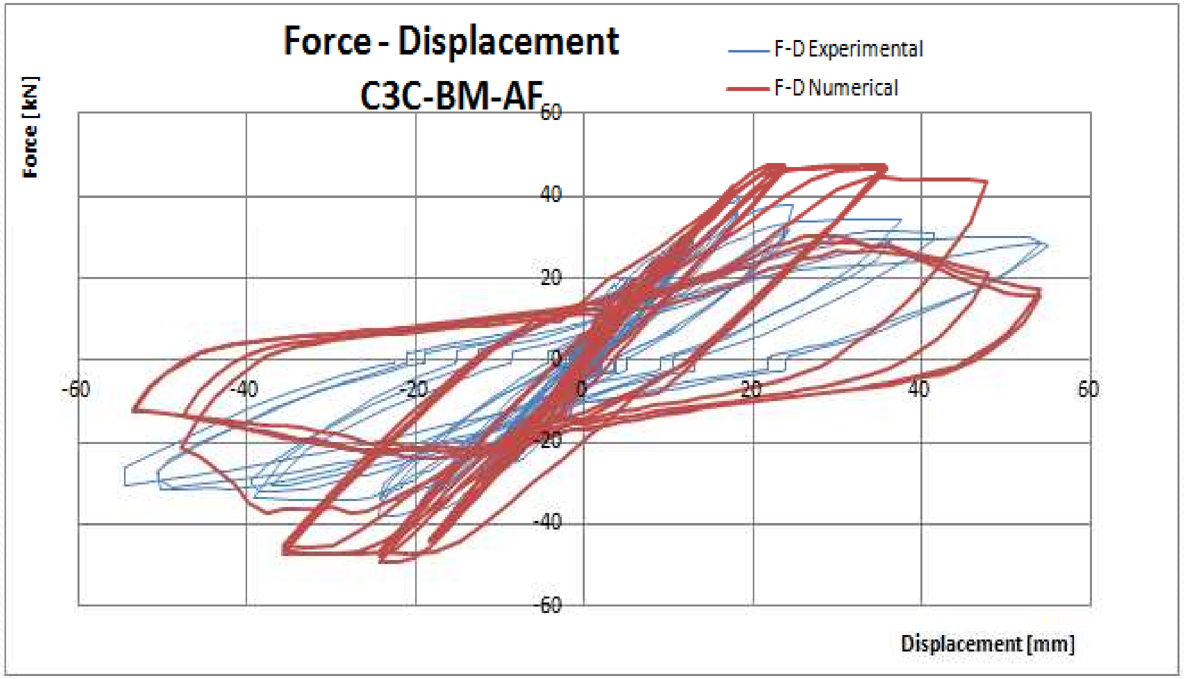


Figure 6.1 : Curve of comparison between the numerical and experimental test for the column C3C-BM-AF.

6. RESULTS

6.1. C3C-BM-AF

Maximum load

Experimental : 38.15 kN

Numerical : 49.24 kN

Maximum displacement

Experimental : 55.00 mm

Numerical : 54.04 mm

Figure 6.2 : Observed failure mechanism in experimental.

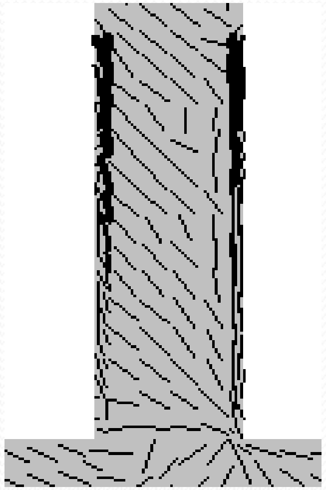


Figure 6.3 : Observed failure mechanism in numerical.

6. RESULTS

6.2. C6C1-GW-BC

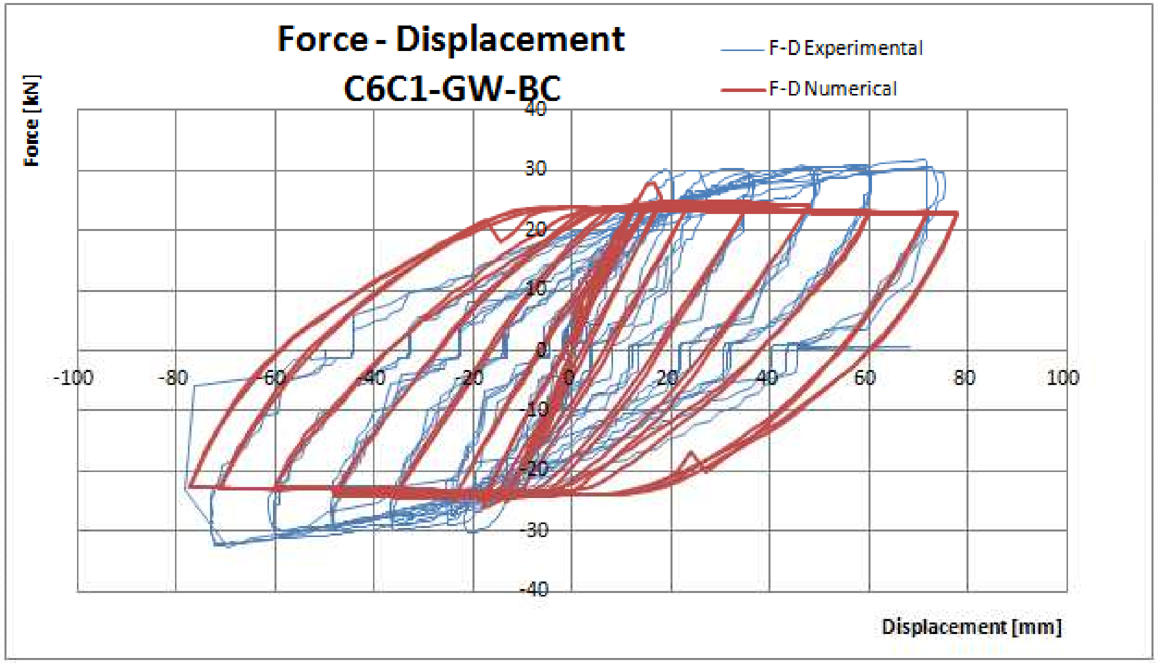


Figure 6.4 : Curve of comparison between the numerical and experimental test for the column C6C1-GW-BC.

6. RESULTS

6.2. C6C1-GW-BC

Maximum load

Experimental : 32.83 kN

Numerical : 28.01 kN

Maximum displacement

Experimental : 78.34 mm

Numerical : 77.82 mm

Figure 6.5 : Observed failure mechanism in experimental.

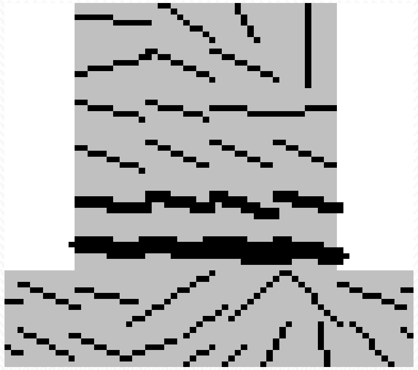


Figure 6.6 : Observed failure mechanism in numerical.

7. CONCLUSION

- Both numerical models for the columns strengthened with BM and GFRP show a behavior similar to the experimentally tested ones.

- **For C3C-BM-AF :** the numerical model is slightly more rigid compared to the experimental one. This can be partially due to the difference of the concrete constitutive model in the ATENA modeling and in the experimental test.

- **For C6C1-GW-BC :** The numerical behavior of the column is similar to the behavior of the experimental tested one.

This gives confidence to the design engineers and researchers in using finite element modeling for evaluating the cyclic behavior of RC columns strengthened with different types of composite materials.
To describe the real behavior of concrete elements strengthened with composite materials it is necessary to take into account all the parameters which can influence their behavior (thermal conditions, initial state of concrete, contact surfaces, boundary conditions . . .etc). This point is a subject for a future work.

Bibliography

[1] DĂESCU Alexandru Cosmin « REABILITAREA ELEMENTELOR DE CONSTRUCȚIE UTILIZÂND MATERIALE COMPOZITE POLIMERICE », PhD Thesis, Politehnica University of Timisoara, 212, 2011.

[2] C. Desprez, J. Mazars, P. Kotronis, P. Paultre « Damage model for FRP-confined concrete columns under cyclic loading », Engineering Structures, France, 519-531, 2013.

[3] Vladimír Červenka and Jan Červenka « User's Manual for ATENA 2D », Prague, 140, March 2010

[4] Vladimír Červenka, Libor Jendele, Jan Červenka « ATENA Theory », Prague, March 22, 248, 2010.

[5] FEMA 547 « Techniques for the Seismic Rehabilitation of Existing Buildings ». 2006.

[6] Stéphane Morel « Comportement courbe-R et effet d'échelle dans la rupture quasifragile. Cas des structures entaillées. », 25e rencontres de l'AUGC, Bordeaux, 8, 2007.

THANK YOU FOR YOUR ATTENTION