Influence of Behavior Models on the Response of a Reinforced Concrete Frame: Multi-Fiber Approach

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***Abstract*—**The objective of this work is to study the influence of the nonlinear behavior models of the concrete (concrete_BAEL and concrete_UNI) as well as the confinement brought by the transverse reinforcement on the seismic response of reinforced concrete frame (RC/frame). These models as well as the confinement are integrated in the Cast3m finite element calculation code. The consideration of confinement (TAC, taking into account the confinement) provided by the transverse reinforcement and the non-consideration of confinement (without consideration of containment, WCC) in the presence and absence of a vertical load is studied. The application was made on a reinforced concrete frame (RC/frame) with 3 levels and 2 spans. The results show that on the one hand, the concrete_BAEL model slightly underestimates the resistance of the RC/frame in the plastic field, whereas the concrete_uni model presents the best results compared to the simplified model "concrete_BAEL", on the other hand, for the concrete-uni model, taking into account the confinement has no influence on the behavior of the RC/frame under imposed displacement up to a vertical load of 500 KN.

***Keywords*—**Reinforced concrete, nonlinear calculation, behavior laws, fiber model confinement, numerical simulation.

I. Introduction

THE particularity of civil engineering structures is that concrete is widely used in its nonlinear field. Since this material is fragile, nonlinearities are accompanied by micro-cracks and sometimes macro-cracks. The degradation of concrete under a static or dynamic loading is characterized by several phenomena mainly nonlinear (plasticity, cracking, reclosing of cracks).

Simulation tools are more and more efficient and allow a very fine description of the phenomena. Moreover, these tools are no longer limited to linear mechanics, but are developed to describe more complicated behaviors up to the ruin of structures. Three constitutive laws can be adopted to model the behavior of a structural element subjected to mechanical loadings: global models, intermediate models and local models.

Global behavior laws are relations between a generalized deformation and its associated stress, without passing through the local laws of materials. This modeling level is particularly well suited). It allows much faster time calculations than those corresponding to local behavior models.

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Local behavior laws are fully described by local variables (stresses and deformations) and are usually independent of the geometry of the structure. The results obtained by this approach are complete and give access to the spatial distribution of the material state, which also makes it possible to display the critical zones [3].

The semi-local behavior laws make it possible to use local behavior models of concrete and steel, within the framework of a simplified kinematics, associated with the finite elements of beam, plate or shell type. The important advantage of this approach lies in the implicit coupling of bending forces and normal effort. This approach is best suited for modeling beam and column systems [3].

Our study consists of evaluating the behavior of a RC/frame structure by means of a numerical simulation carried out with the code "CAST3M". This study proposes a frame in reinforced concrete under two types of loading, the first one is an imposed displacement, and the second one is an axial loading both applied on the columns of the frame.

A comparison between the behavior curves of the RC/frame set in this work is carried out to draw conclusions on the performance of the two concrete models and the influence of taking into account the confinement of transverse reinforcement on the overall response of the RC/frame structure.

II. Principle of the Fiber Model for the Timoshenko Element

The fiber model allows to calculate the constitutive law of the Timoshenko beam element i.e. the relation between axial deformation, curvature, shear deformation and the associated generalized stresses (N, M and T) from a geometric description of the section based on two-dimensional elements TRIS and QUAS and uniaxial constitutive laws for each material (concrete and steel) [1], [7] (Fig. 1).

The fiber model makes it possible to calculate the constitutive law of the Timoshenko beam element i.e. the relation between axial deformation, curvature [2], [4], shear deformation and the associated generalized stresses (N, M and T) [9]. This constitutive law is based on the two-dimensional elements TRIS and QUAS and the uniaxial laws for each material (concrete and steel) [6], [8], (Fig. 2).

A. Behavior Laws Used

Two concrete models that exist in the library of the Cast3m code are adopted in this study (Tables I and II) namely models Concrete_BAEL [6], Concrete_Uni and an Elasto-plastic model for steel (Table III).

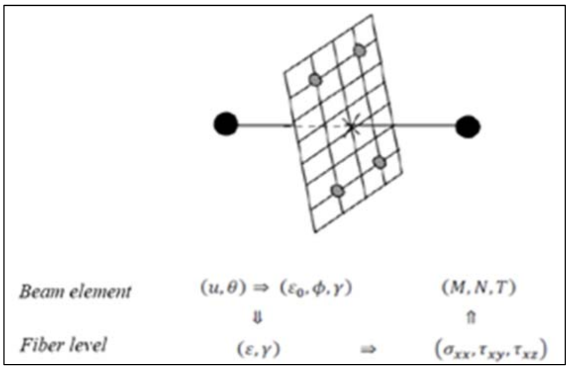


Fig. 1 Principle of the fiber model

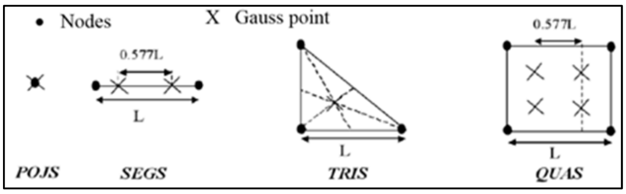


Fig. 2 Two-dimensional elements used for the description of sections

TABLE I
BEHAVIOR LAW CONCRETE _BAEL [5]

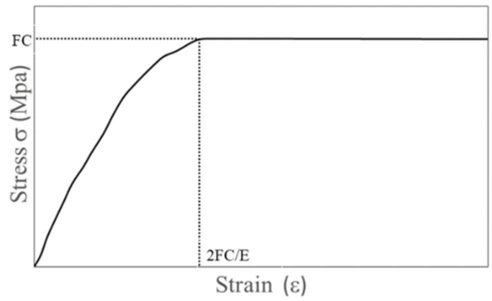
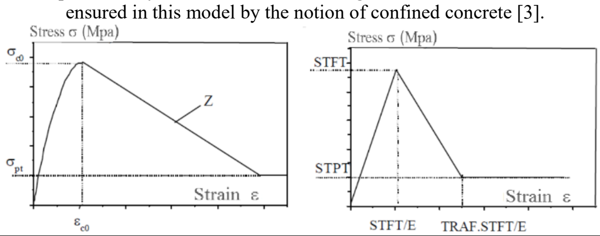
Model Concrete_BAEL :
It is defined by a simplified behavior law in compression [5]. The stress is a parabolic function of the deformation up to (zero slope at the peak)


TABLE II
BEHAVIOR LAW OF CONCRETE_UNI

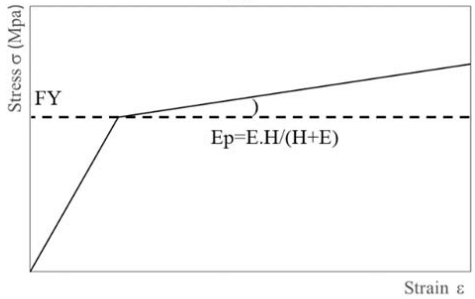
Model Concrete_Uni:
It takes the model of Hognestad [5]. This law allows to reproduce the softening after cracking. The unilateral behavior of the concrete (reclosing of the cracks) as well as the softening after reaching the compressive strength is well reproduced by this model. The modeling of transverse reinforcement is ensured in this model by the notion of confined concrete [3].


III. BEHAVIOR LAWS USED

A. Presentation of the Studied Model

In the study a simulation of a reinforced concrete frame of 2 spans (7.00 m total length) and 3 levels (9.00 m total height) has been carried out, the frame structure shown in Figs. 3 and 4 is mentioning the columns' and beams' cross sections and the reinforcement arrangement.

TABLE III
BEHAVIORAL LAW STEEL-PERFECT

Steel model
An elasto-plastic model with kinematic hardening (Steel-Perfect) available in the software is chosen for the modeling of reinforcement [3].


A triangular horizontal load representative of an earthquake is applied at the top of the frame; the latter is controlled in imposed displacement of the order of 0.5 m.

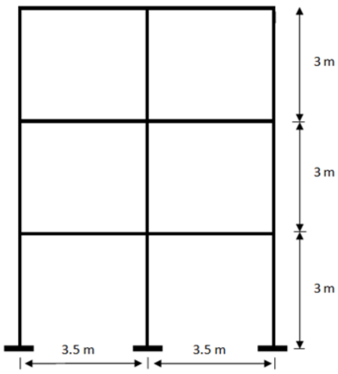


Fig. 3 Representation of the simulated frame

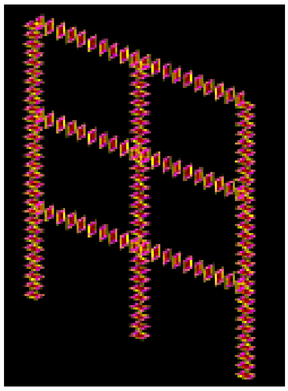


Fig. 4 Representation of the simulated frame with castem

To simplify the study, one adopted the same cross section of 30 x 40 cm^2 with a reinforcement section of 4 bars of Φ =

20 mm for the beams and columns (Fig. 5). To support confinement, a constant vertical load is added to the imposed displacement.

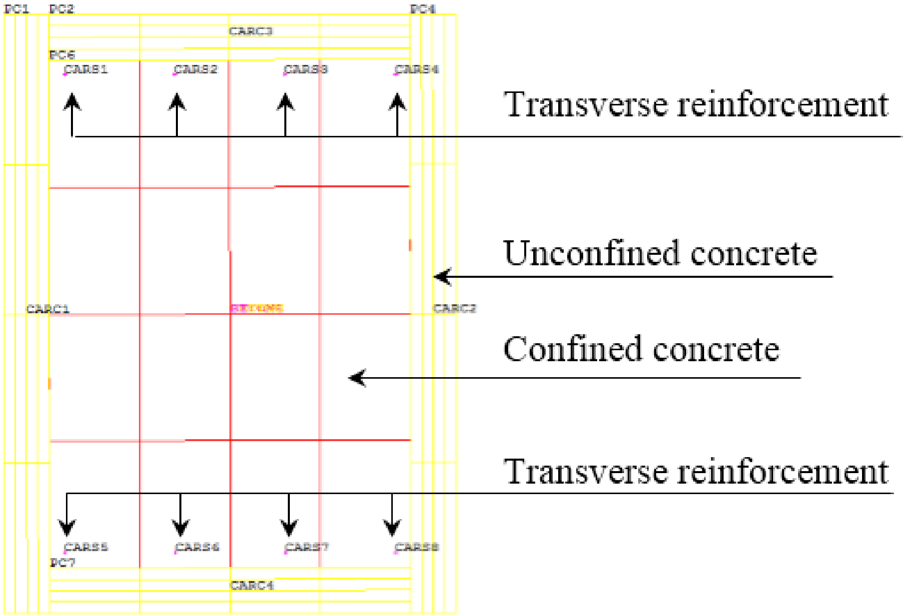


Fig. 5 The cross section of the frame elements

B. Frame Elements Mesh Convergence Study

In order to obtain the ideal mesh in the frame elements, we started with a mesh of 5 divisions per element and we increased the mesh up to 25 divisions per element. The results are shown in Fig. 6.

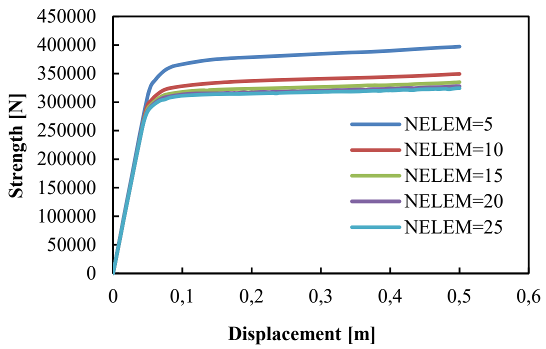


Fig. 6 Mesh convergence of frame elements (columns and beams)

Fig. 6 presents the superposition of the RC/frame behavior curves for the varying number of mesh elements, the curves are combined in the elastic domain up to a displacement of 0.05 m, that is to say that the mesh does not influence the response of the RC/frame in this area; on the other hand, in the plastic field, a variation is noticeable, in such way that the curves are getting closer and closer as the number of mesh elements increases. From the figure, one can observe that mesh stability is reached and 20 divisions per element mesh have been chosen as shown in Fig. 7.

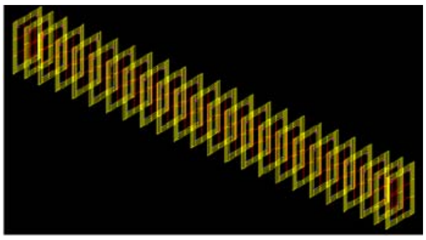


Fig. 7 Mesh of a gantry element.

IV. Results and Interpretation

A. Capacity Curves Comparison (Concrete _ Uni and Concrete _BAEL)

Fig. 8 shows the response of the RC/frame using the 2 concrete models. The BAEL concrete model underestimates the response of the RC/frame with a percentage of 4%, this is due to the fact that the tensile strength of the latter is not taken into account.

B. Capacity Curves Comparison (WCC and TAC)

The force-displacement results obtained using the Concrete-Uni model in the presence of transverse reinforcement (TAC) and without these WCC reinforcements are presented in Fig. 9. These results are obtained by simulating the studied frame without vertical load. These results show that the transverse reinforcement has no influence on the capacity curve in the absence of vertical load.

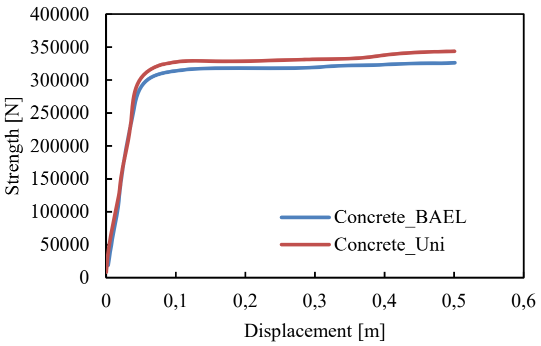


Fig. 8 Comparison of the capacity curve between the concrete model _BAEL and Concrete _ Uni

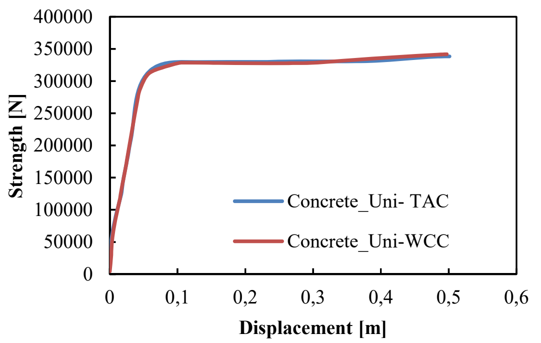


Fig. 9 Comparison of the capacity curves of the concrete-Uni model with and without containment

C.Comparison of Capacitance Curves between WCC and TAC Models with a Vertical Force of 100 kN and 500 kN

Fig. 10 shows:

- The TAC model has a higher ultimate load than the CCPC, which shows the contribution of taking into account the transverse reinforcement during modeling, on the post-elastic behavior of the RC frame structure.
- Degradation of the resistance undergone by the RC frame for a loading of 500 kN corresponds to a displacement of 0.237 m for the WAC model and 0.157 for the TAC model.
- TAC model presents a better response compared to the WCC model; this is explained by the consideration of transverse reinforcement, which significantly improves the response of the structure.
- Impairments of the capacity observed on WCC are due to load transfer in the concrete from one section to another.

V.Conclusions

The results presented in this work show that the simplified concrete-BAEL model underestimates the overall response of reinforced concrete structures. The consideration of transverse reinforcement in the modeling of reinforced concrete structures has no influence on the capacity curves in the absence of vertical load. In the presence of a large vertical load, the consideration of transverse reinforcement influences considerably the overall response of reinforced concrete structures.

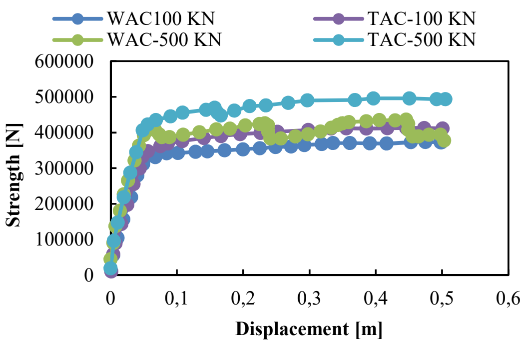


Fig. 10 Comparison of the capacity curve between the concrete-Uni model with and without confinement consideration in the presence of N = 100 kN and N = 500 kN

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