INTERNATIONAL CAE CONFERENCE 2017

The PARC_CL 2.1: implementation, validation and application on RC columns

Francesca Vecchi ♥

♥ PhD Student, *Università degli studi di Parma* - DICATeA, 181/A Parco Area delle Scienze, 43124 Parma, Italia (francesca.vecchi1@studenti.unipr.it)

ABSTRACT

Collapse mechanisms of existing reinforced concrete (RC) members subjected to cyclic loading are often due to buckling phenomena of longitudinal bars. Indeed lacking of detailing in existing structures, like high value of stirrups spacing, is often associated to bar slenderness values that typically may cause second order effects. Furthermore damage induced by environmental actions, like corrosion, can cause breaking of stirrups or transversal area reduction of longitudinal bars which may increase the buckling effects on steel bars. In the poster the new PARC_CL 2.1 crack model (Physical Approach for Reinforced Concrete under Cyclic Loading condition) is presented. PARC_CL2.1 crack model is a fixed crack model assuming smeared reinforcement: it is implemented in UMAT.for user subroutine of Abaqus software. It is able to consider plastic deformations and hysteretic cycles. To take into account for the softening of steel in compression in case of bar slenderness values higher than 5, the Monti-Nuti model has been implemented in PARC_CL2.1 for the nonlinear finite element analysis of RC members subjected to cyclic loading.

1. PARC_CL 2.1 crack model

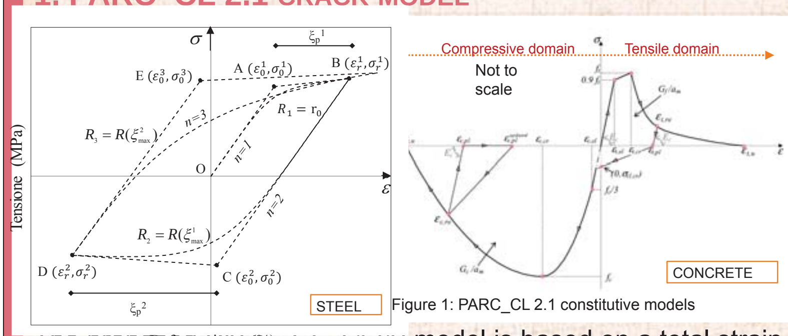

Figure 1: PARC_CL 2.1 constitutive models

The proposed PARC_CL 2.1 [1] model is based on a total strain fixed crack approach. The concrete and steel behaviours, as well as their interaction effects, are modelled with constitutive relationships for loading-unloading-reloading conditions, Figure 1. For the first time the Monti-Nuti model is employed in a smeared crack model to represent the hysteretic stress-strain behaviour of reinforcing steel because it takes into account the the buckling effect, depending on the **slenderness ratio (L/D)** i.e the ratio between the distance between the stirrups (L) and the longitudinal reinforcement diameter (D).

2. Importance of the study

During strong earthquakes longitudinal reinforcing steel in RC elements may undergo large tension and compression strain reversal. Because of insufficient tie spacing, specially in **old buildings**, this repeated loading into the inelastic range may lead to buckling of steel bars. Indeed **lacking of details** in existing structures, like high value of stirrups spacing, causes a bad confinement and consequently high lateral deformation after the spalling of the concrete. Furthermore, **damage** induced by **environmental actions**, like corrosion, can cause breaking of stirrups or transversal area reduction which may increase the buckling effects on steel bars. The lack of stirrups lead to high value of slenderness ratio, up to 20.

Monti-Nuti discovered that up to 5 the slenderness ratio doesn't influence the behaviour of the steel in compression (no buckling) but if the slenderness ratio is greater than 5 the buckling effect becomes more evident with the increase of the slenderness ratio.

3. Application of the model: NLFEA of RC column

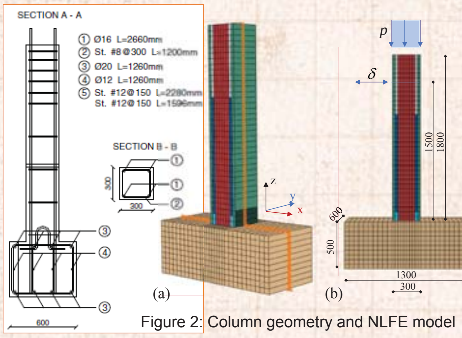

Figure 2: Column geometry and NLFE model

The RC column tested at the University of Bergamo [2], has been used to validate the proposed PARC_CL 2.1 crack model. The column had non-seismic resistant details typical of structures built in Italy in the 1960s and 1970s. The transverse reinforcement consisted in Ø8 mm stirrups, 300 mm spaced, that leads to a slenderness ratio equal to 11, and 4Ø16 mm longitudinal bars. The adopted materials and further details are described in [2]. The test, carried out in displacement control, was done applying to the specimens an axial load equal to 400 kN and then horizontal cyclic displacements of increasing amplitude up to failure at a height of 1.5 m from the column foundation connection. In order to measure the horizontal displacements, potentiometric transducers were placed on the column at the level of the load application. After all it is defined the drift (δ/*h*), as the ratio between the horizontal displacement at the load application point (δ) and the height (*h*) and the horizontal load-drift curve. The column is modelled with S8R multi-layer shell elements Figure 2 and the results of the analyses are presented in Figure 3 [3]. The PARC_CL 2.1 is able to reproduce quite well the force-drift cyclic curve and the cyclic behaviour of the steel reinforcement: furthermore is able to capture the buckling effect in function of the L/D ratio

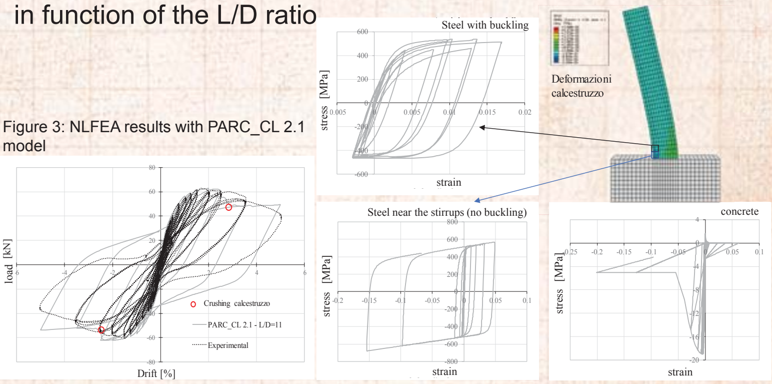

Figure 3: NLFEA results with PARC_CL 2.1 model

CONCLUSIONS

Multi-layered shell elements modeling with PARC_CL 2.1 crack model can well predict the global Force-Displacement cyclic behavior of RC elements. Moreover, shell elements and PARC_CL 2.0 crack model are very powerful for catching buckling of reinforcing steel bars and may be very useful tools also for the evaluation of local engineering parameters, like crack openings and stresses distribution.

REFERENCES

[1] Belletti B., Scolari M., Vecchi F. (2017), "PARC_CL 2.0 crack model for NLFEA of reinforced concrete structures under cyclic loadings". Computers and Structures, 191, 165–179.

[2] Meda, A., Mostosi, S., Rinaldi, Z., Riva, P. (2014), "Experimental evaluation of the corrosion influence on the cyclic behaviour of RC columns". Engineering Structures, 76(2014), 112-123.

[3] Belletti B., Vecchi F., Donninotti A. (2017), "Implementazione del fenomeno del buckling delle armature soggette a carichi ciclici nel modello fessurativo PARC_CL 2.1", ANIDIS 2017, Pistoia,Italy