

Cyclic Experimental Response of Reinforced Concrete Frames: validation methodology

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Abstract

This article validates numerically the experimental behavior of a reinforced concrete frame subject to cyclical loads, resorting to a commercial program using finite element analysis. The experimental results were obtained in the National Laboratory of Civil Engineering (LNEC). In the numerical simulation several constitutive models were used, with different degrees of complexity, based on the concept of local plastification in critical zones (plastic hinges) of the elements that constitute the frame as well as on fiber models.

KEY WORDS: *cyclic behavior of concrete frames, time history analysis, fiber model.*

1. Introduction

Most of the buildings built in Portugal and in the remaining countries of southern Europe present a structural solution based upon the space repetition of reinforced concrete frames, filled out with brick panels. The damage and the collapse of structures of this type, induced by the lateral deformation of the floors associated to moderate to high magnitude earthquakes, was moderated, constitute at present two of the principal preoccupations of the designers.

The methodologies usually used for the seismic design based upon response spectra allow for the checking of the resistant capacity relatively to the ultimate limit states, and of the deformation relatively to the serviceability limit states. These verifications guarantee the strength necessary to avoid the collapse of the structure, and the sufficient stiffness (or rigidity) to avoid an excessive deformation of the structure; thus, with the consequent minimization of the damage and a better use and usefulness of the building after the seismic incident (when compared with the cases of these criteria not being satisfied).

In these methodologies, the response considers the ductility of the structure implying the reduction of the seismic forces induced by an earthquake through the use of ductility coefficients, to account for lower forces than those obtained in an elastic regime (Paulay and Priestley [6]). This methodology is based on the capacity of the structural elements to accommodate plastic deformations (material nonlinearities) without compromising the stability of the structure.

However, the new methodologies of analysis and structural design allow defining the criteria that governs the response of the structure for several levels of structural performance, and so allow identifying several levels of damage that may occur during an earthquake (Correia et al. [2], Deng et al. [3], Pedrosa et al. [7]). On the other hand these design philosophies started being implemented in design tools, namely by using the Finite Element Method (FEM), which implies the necessity of validating the analysis and design implicit codes in these programs.

In this context, the principal objective of this article consists on the validation of simplified models of non-linear material analysis, based on the definition of constitutive laws of different complexity associated to the plastification zones (fibers and hinges) of the structural elements, in order to characterize the level of damage of reinforced concrete plane frames subject to cyclical actions. To validate the above-mentioned models experimental information is used, available through tests carried out at LNEC (National Laboratory of Civil Engineering, Lisbon).

2. Experimental results

In Fig. 1 is represented an infilled reinforced concrete plane frame subject to cyclical actions, that underwent experimental tests at LNEC, that was used for studying comparatively the effect of the panel filling with brick blocks (Pires [8]).

The loading of such frame consisted in the application of a vertical constant load of 100 kN, on top of each column, and imposing a cyclic law of displacements at the beam (floor) level as represented in Fig. 2.

Fig. 3 shows the obtained experimental relation between the load and the horizontal displacements registered at the beam level. From this result, it is quite significant the incursion of the frame into the non-linear behavior range of material nonlinearities due to partial plastification of cross sections.

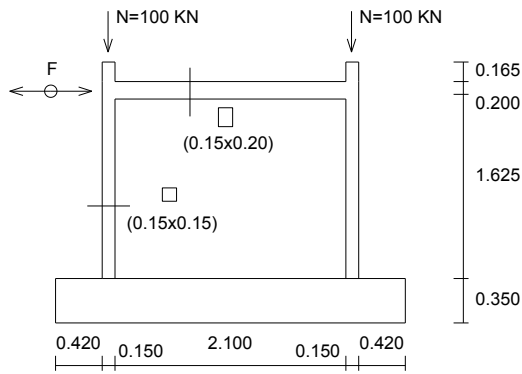


Fig. 1 Geometry of the tested frame

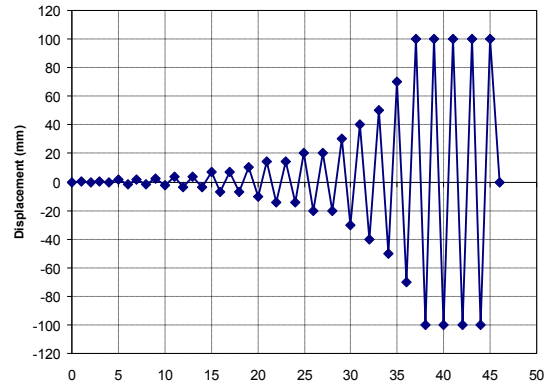


Fig. 2 Law of displacements applied to the frame

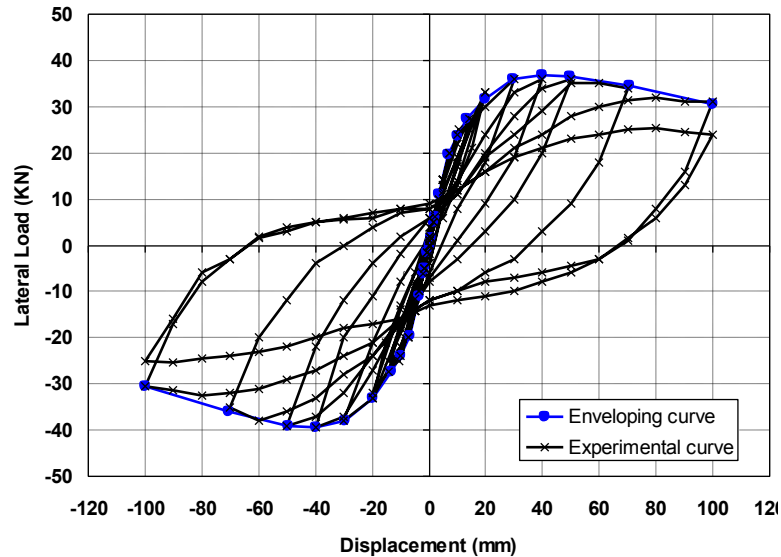


Fig. 3 Load-displacements experimental curve

3. Numerical modeling

In order to numerically validate the experimental results obtained, the structure was modeled with beam elements with different non-linear constitutive laws, using the structural engineering advanced software Midas [5]; in this manner, each of the material laws was assessed, to ascertain their accuracy for future potential use in non-linear structural dynamics of filled frames.

In this work four constitutive material models were used (Cesar, Oliveira and Barros [1]), with ascending complexity and potential accuracy:

- model of Clough (bi-linear);
- model of Takeda tri-linear;
- model of Takeda tetra-linear;
- model of fibers.

Figs. 4 and 5 summarily present two of the models used, the second of which led to very good matching of the experimental calibration results (Pires [8] , Gomes [4]) by the theoretical computational analysis. The model of fibers also led to very good accuracy for this calibration frame, nevertheless it requires much more CPU time. These facts permitted to decide that in future more complex modelling involving more elaborate frames with several floors and several bays, the model of Takeda tetra-linear will be the preferable choice.

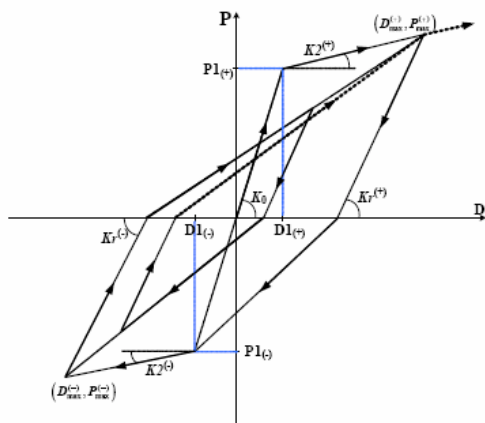


Fig. 4 Model of Clough (bi-linear and simple)

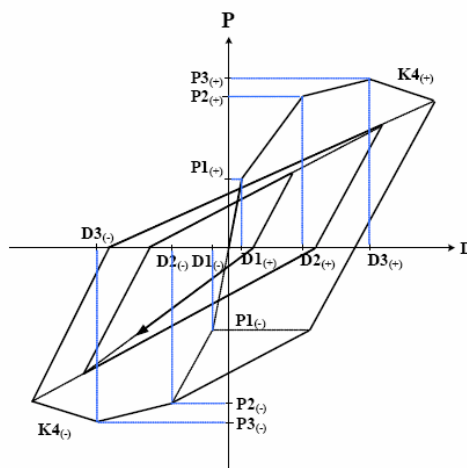


Fig. 5 Model of Takeda tetra-linear

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