CAPACITY CURVES FOR REINFORCED CONCRETE BUILDINGS DESIGNED IN ACCORDANCE WITH PORTUGUESE REGULATION

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ABSTRACT
The aim of the present study is to assess the resisting capacity of reinforced concrete buildings designed after publication of RSA and REBAP and representative of Portuguese housing stock in order to obtain the corresponding capacity curves for further development of analyses based on specific performance levels. Some final remarks are presented and discussed.

Keywords: Reinforced concrete buildings, RSA, REBAP, pushover, capacity curves.

INTRODUCTION
In recent decades, more specifically in the last 50 years, has been observed a growing concern related to seismic risks in large urban areas. Thus, as a result directly related to this awareness, new methods of analysis and design have been created and developed allowing the structures to become more resistant and seismically safe. Currently the civil engineering structures are designed to be able to survive the worst actions expected to occur during its lifetime. As such, the structures must be designed and analyzed to be endowed with the capacity to withstand the demands faced, being subject to a complex process of design covering various aspects, not just the structural and seismic safety but also other complementary aspects related to occupant safety and comfort.

NUMERICAL MODELING
In a first phase of work were selected 3 buildings with a frame structure, variable number of floors (2, 4 and 8) and normal ductility ($\eta = 2.5$), which were considered representative of some typologies of the Portuguese housing stock. The design of the building structure was made in previous studies (LNEC, 1984) in accordance with Portuguese regulations (RSA, 1983). The structural solution adopted in buildings consisted of a flat slab supported by a mesh of beams and rectangular columns with variable section over the height. Numerical modeling was conducted to reproduce the expected behavior when subject to seismic actions and was based on geometric and material characteristics of each structural element. In modeling the behavior of the concrete was used a non-linear model with constant uniaxial confined. In the modeling of steel was used the elastoplastic behavior bilinear model with kinematic hardening in which the elastic range remains constant during the various stages of loading and kinematic hardening rule for yielding surface is taken as a linear function of the plastic extension increase. The nonlinear behavior of the frames was modeled using beam-column type elements with distributed plasticity (JPEE, 2014).
RESULTS AND CONCLUSION

The vibration modes were obtained by simplified linear models (Table 1). Capacity curves, representing the relationship between top displacement and base shear, were also obtained for the considered forces (proportional to modal shape) in both directions (Fig. 1a and Fig. 1b). In all analyzed buildings, was systematically observed that the maximum top displacement is higher in the transverse direction while the maximum base shear is higher in the longitudinal one. Moreover, as direct consequence of the application of modal profile of forces, when compared with uniform forces distribution, was identified the presence of higher forces at higher levels, which lead to the increased of shear forces on each floor for the same level of base shear, leading also to higher deformations. The facts presented are consistent with the detailing of the structural elements (LNEC,1984) and with the results of the dynamic characterization of the structures (JPEE, 2014).

<table>
<thead>
<tr>
<th>2 floors</th>
<th>4 floors</th>
<th>8 floors</th>
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<tbody>
<tr>
<td>2.47 (T)</td>
<td>2.62 (T)</td>
<td>1.47 (L)</td>
</tr>
<tr>
<td>2.58 (L)</td>
<td>2.69 (L)</td>
<td>1.54 (T)</td>
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</tbody>
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Fig. 1 - Capacity curves: a) Transverse and b) longitudinal

The conclusions obtained so far are still preliminary (JPEE, 2014): i) Good calibration of numerical models in agreement with results of previous dynamic linear analyzes, ii) higher resisting capacity and lower ductility in the longitudinal direction, iii) after the achievement of maximum load capacity softening effect is observed in both directions; iv) higher vulnerability in transverse direction and in certain areas of the structures, namely due to the occurrence of geometry and detailing changes in some structural elements cross sections. Further developments of the study will include complementary analysis performed over similar structures with variable floors, different levels of ductility, located in other seismic zones and based on other types of terrain. Complementary results will contribute to the definition of damage states thresholds, for the development of analyzes based on specific performance levels and to support seismic reinforcement needs.

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REFERENCES

