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Probabilistic correlation of damage and seismic demand in R/C structures

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ABSTRACT: Within a probabilistic performance-based evaluation procedure, the influence of the geometrical and mechanical uncertainties on the definition of the demand parameters correlated to the damage states, is assessed. Numerical simulations are carried out on a r/c sample column, leading to the definition of fragility curves of the story drift ratio for different basic damage conditions.

1 INTRODUCTION

The deformation limits associated with the seismic performance of r/c columns represent a fundamental issue in the definition of the performance criteria of r/c structures of any shape and dimension.

The method used to assess the probabilistic correlation between the damage and seismic demand in r/c structures is based on the definition of the drift limits of the columns at different performance levels. The story drift ratio is therefore the referred Engineering Demand Parameter (EDP), which assumes different limit values at various damage levels. Considering the scattering characterizing the material and geometrical properties of the columns, the drift limits should be determined in a probabilistic manner.

The final purpose of the performance-based methodology is to assess a Consequence Parameter (i.e. the retrofitting cost) of a r/c structure for various damage levels, expressed by the stress or strain status of relevant point.

2 DAMAGE STATES

Current guidelines usually propose five performance levels for structures, namely: fully operational, operational, life safety, near collapse and collapse. With the aim of an economical assessment, some predefined performance levels are grouped together, basing it on the costs to be supported for the necessary works associated to structural damage.

Crushing of compressive unconfined concrete and 1 mm residual crack widths, may be used to define the functional performance limit state because damage up to this degree may be repaired at a relatively low cost and without major interruption to the normal functions of the building. The initial cracking of the concrete cover and the yielding of the longitudinal bars are included within this damage level.

The second level corresponds to a status in which the confined concrete reaches the ultimate compressive strain or the longitudinal reinforcement at the tension side reaches the ultimate tension strain. It depends primarily on the quantity of the reinforcement (fragile or ductile collapse). Hoop fracture and buckling of the longitudinal bar are included within this damage level. Important retrofitting work is necessary and involves an interruption of the building's occupancy. The last damage level consists of the collapse.

3 ANALYSIS

A r/c cantilever element having half the height of an interstory column is assumed, simulating one half of the expected fixed-ends deformed shape (Figure 1). A static non linear analysis is carried out increasing the lateral top displacement while checking the strain-stress state at specific points at control sections.

A refined sectional analysis programme (OpenSees, 2000) is used, based on a fibre-element model. The cross-section is divided into fine strips parallel to the axis (Figure 1), the confined concrete core, cover regions and bars are modelled separately by means of different constitutive stress–strain laws (the Kent-Park law for the concrete and the elastic-plastic law for the steel).

Structural uncertainties were considered by means of random extraction, assuming log-normal

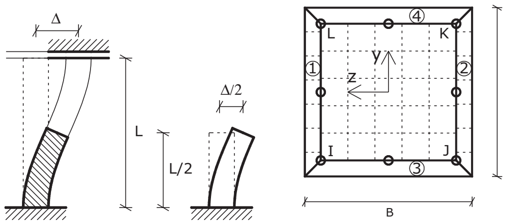

Figure 1. Column model and transverse section modelling.

Table 1. Mean and standard dev. of the assumed parameters.

	Parameter	Mean	st.dev.
fc	Concrete compressive strength (MPa)	33	4.52
e_{1c}	Concrete compressive strain (‰)	2	0.2
f_y	Reinforcing bar yield strength (MPa)	478.8	28.7
E_s,	Reinforcing bar Young modulus (MPa)	206000	6800
B	Section Depth (mm)	401.6	6.35
H	Section Hight (mm)	401.6	6.35
c	Cover (mm)	28.1	4.20
s	Distance hoop (mm)	100	5.90
e_a	Eccentricity axial load (mm)	10	6.10

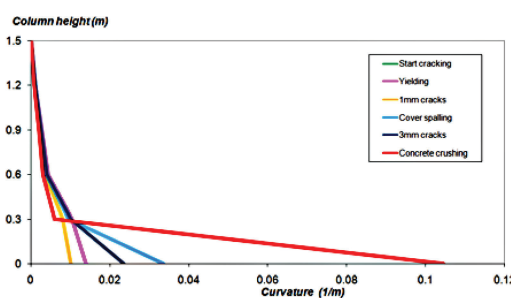

Figure 2. Section curvatures values along the column for various damage state (axial force ratio n = 0.4).

distributions of the relevant geometrical and mechanical parameters. Table 1 reports the statistical parameters used, assumed from the existing literature.

During the analysis, the stress/strain values at three control points on the section, representative of the status of the concrete core, concrete cover and tensile bar, are monitored. It is possible to establish the story drift ratios corresponding to the damage states by means of an automatic procedure. A characterization of the section curvature at various damage states is also computed, as shown in Figure 2.

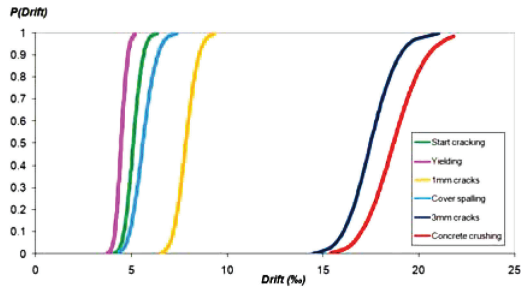

Figure 3. Fragility curves (n = 0,4).

Table 2. Storey drift ratios [%] at the damage states.

	$\nu = 0.2$		$\nu = 0.4$	
	Mean	st.dev.	Mean	st.dev.
Start cracking	0.37	0.02	0.45	0.03
Yielding	0.45	0.03	0.51	0.04
1 mm cracks	0.79	0.04	0.79	0.05
Cover spalling	0.81	0.05	0.56	0.06
3 mm cracks	1.76	0.10	1.75	0.11
Concrete crushing	2.11	0.13	1.87	0.13

Two hundred simulation runs are carried out at two axial force levels (expressed by the ultimate force ratio $\nu = 0.2$ and $\nu = 0.4$). Each model is defined by a random assumption of its geometric and mechanical parameters. A log-normal PDF is assumed for representing the distribution of the drift ratio corresponding to the damage states: carried out Kolmogorov-Smirnov tests confirm the assumption. The results are expressed in terms of fragility curves (Figure 3). Defining the CDF of the story drift ratio corresponding to the type of damage: the curves appear very steep for the light damage states. Table 2 reports the numerical values of the mean and standard deviation of the computed drift ratio PDF's.

4 CONCLUSIONS

Within a probabilistic performance-based procedure for the assessment of conventional and enhanced seismic-resistant structures, the uncertainty on the geometrical and mechanical characteristics play a double role. The first aspect (Mezzi, 2008) concerns the characterization of the member capacity influencing the global non linear response. The second one, described in the present paper, concerns the scattering in the definition of the demand parameters to be correlated to the damage states and consequence parameters. The first results show a low influence of the randomness of the structural parameters on the light damage states, whilst a drift range from 2 to $5^{0}/_{00}$, can be found for the most serious damage states, considering the fractiles 10% and 90%.

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REFERENCES

Mezzi, M. 2008. Uncertainty in structural capacity and influence on seismic demand and damage. *IALCCE08 First Int. Symp. on Life-Cycle Civil Engineering*. Varenna, Italy.

OpenSees (Open System for Earthquake Engineering Simulation) 2000. *Pacific Earthquake Engineering Research Center*. http://opensees.berkeley.edu