ESTIMATION OF DUCTILITY DEMANDS OF RC FRAMES USING TIME HISTORY ANALYSIS

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Summary: *This paper presents an estimation of ductility demands of RC frames by using non-linear time-history analysis. RC frames with different number of storeys, are designed according to the provisions of EN 1992 and EN 1998 for two ductility classes and two intensities of seismic actions. Seismic response was assessed on three earthquake records according to the procedure given in EN 1998. Ductility demand is estimated at global and local level. These values were compared according to the ductility class, number of storeys and seismic intensity. The aim of this paper is to point out the influence of, not only the design ductility class, but also of the design seismic action and number of storeys to estimate the ductility demands.*

Keywords: *ductility demand, non-linear time-history analysis, displacement, curvature EN 1998, ductility class*

1. INTRODUCTION

Performance-based design (PBD) method is used in recent years in the seismic design and evaluation of structures. This approach enables engineers to design structures with predictable performance against earthquakes. One of important components of performance based seismic evaluation is the estimation of seismic demands. Determination of seismic demand requires accurate modeling and analysis. EN 1998 [1], [2] provides four different analytical procedures to estimate demands in a building. The

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nonlinear time-history analysis is the most accurate procedure for estimating seismic demands. The term ductility is often used for evaluation of seismic performance of structures, which indicates the amount of seismic energy that can dissipate through the plastic deformation. Ductility can be observed on a global, storey and local level. In this paper ductility demands are determined at a global level, through ductility demand of roof displacement, and local level, as ductility demand of a section curvature. RC frames, with different number of storeys (4, 6, 8 and 10) designed for two ductility classes (DCM and DCH) and two intensities of seismic actions (0.2g and0.3g), were analyzed and estimated using nonlinear time-history analysis. Estimated ductility demands are compared according to the ductility class, number of storeys and seismic intensity. The aim of this paper is to point out the influence of, not only the design ductility class, but also of the design seismic action and number of storeys to estimate the ductility demands.

2. SEISMIC ACTION FOR NONLINEAR DYNAMIC ANALYSIS ACCORDING TO EN 1998

The reference analysis method for displacement based seismic assessment and retrofitting of buildings is nonlinear method of analysis. For a nonlinear dynamic analysis, time-histories of ground motion are needed. Eurocode 8 requires a minimum of 3 different accelerograms, wherein the most unfavourable value of the response quantity among analyses should be used in relevant verifications. If the response is obtained from 7 or more nonlinear time-history analyses with different ground motions, the average of the response quantities from all of these analyses should be used. Eurocode 8 accepts artificial, historic or simulated records. The set of selected accelerograms need to satisfy the rule that the mean of the zero period spectral response acceleration values calculated from the individual time histories should not be smaller than the value of $a_g S$ for the observed location. Also, in the range of periods between 0.2 T_1 and 2 T_1 value of the mean elastic spectrum with 5% damping, calculated from all time histories of acceleration may not be less than 90% of the corresponding value of the elastic response spectrum with 5% damping. Recorded accelerograms may be used provided that the samples used are adequately qualified with regard to the seismogenetic features of the sources and to the soil conditions appropriate to the site, and their values are scaled to the value of $a_g S$ for the zone under consideration.

3. NUMERICAL EXAPLES

In this paper 16 RC frame structures were analysed, with different number of storeys (4, 6, 8 and 10), designed according to EN 1992 [3] and EN 1998 [1] for two ductility classes (DCM and DCH) and two cases of seismic action ($a_g = 0.2g$ and $a_g = 0.3g$). RC frames are described in [4].
Two sets (for $a_g = 0.2g$ and $a_g = 0.3g$) with three earthquake records were selected from nonlinear dynamic analysis, according to the selection procedure given in Eurocode 8.

The records are selected from the PEER database [5] and scaled according to EN 1998-1. The elastic response spectra of acceleration of the earthquakes in damping of 5% are shown, as well as the mean value of the spectrum response set records, together with the elastic spectrum and its 10% less values, for acceleration 0.2*g* (Figure 1) and 0.3*g* (Figure 2). In the selection of earthquake records, the size of magnitude and maximum acceleration as well as average shear wave velocity $V_{s,30}$, and peak ground velocity to acceleration *v/a(g),* were taken into consideration. The details of these records for both sets are given in Table 1.

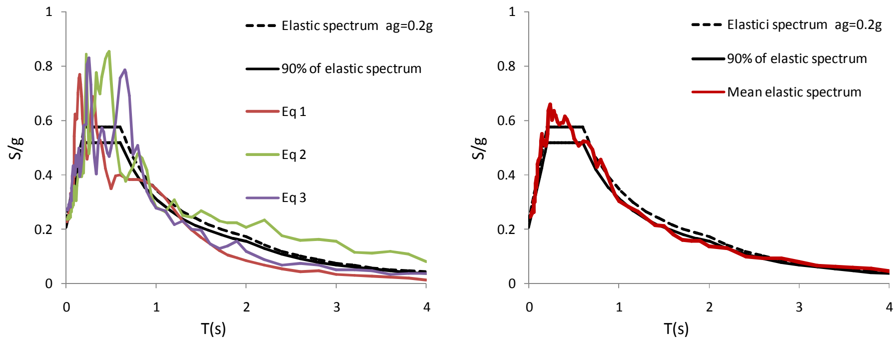

Figure 1. Response spectra of selected records, mean values of selected records, elastic spectrum and 90% of elastic spectrum for seismic action a_g=0.2g

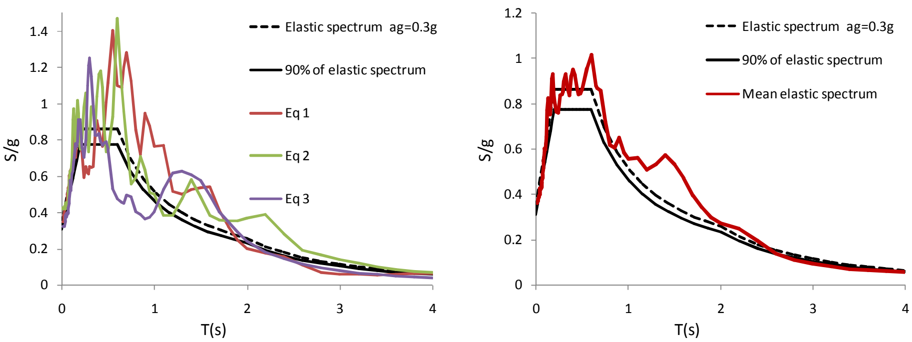

Figure 2. Response spectra of selected records, mean values of selected records, elastic spectrum and 90% of elastic spectrum for seismic action a_g=0.3g

At the global level, ductility displacement demands were estimated and shown in Figure 3. Ductility curvature demands at the local level were estimated for columns (Figure 4) and beams (Figure 5).

As can be seen in Figure 3, for frames designed for lower values of the seismic action, estimated ductility demands on global level were less than the ones designed for larger values of the seismic action. For frames designed for higher values of the seismic action, estimated ductility displacement demands were greater for DCH structures compared to DCM ones. For lower values of the design seismic action, estimated ductility displacement demands were greater for DCH structures, except for frame with number of storeys 4, because for this frame seismic response was in elastic range. It may be noted that number of storeys, in DCH frames with higher design seismic action, affects the values of demands. Values of estimated demands increases with the number of storeys.

Table 1 Ground motion details

$a_g = 0.2g$	Earthquake	*M*	*PGA(g)*	$V_{s,30}$[m/s]	*v/a(g)*[cm/s]
Eq. 1	Coyote Lake	5,74	0,228	278	126
Eq. 2	Chi Chi	7,62	0,237	272	110
Eq. 3	Imperial Valley	6,5	0,27	274,5	92

$a_g = 0.3g$	Earthquake	*M*	*PGA(g)*	$V_{s,30}$[m/s]	*v/a(g)*[cm/s]
Eq. 1	Chi Chi	7,62	0,349	549	117
Eq. 2	Northridge	6,69	0,42	267	144
Eq. 3	Loma Prieta	6,9	0,322	271	121

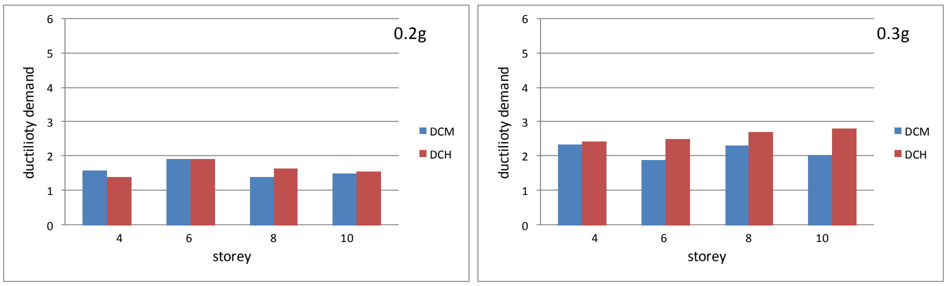

Figure 3. Ductility demand on global level

As can be seen in Figure 4, impact of ductility class was significant for frames with greater design seismic action, and for this seismic action the estimated ductility demand of section curvature of columns was mainly greater for the DCM frame than the DCH frame. For frames with number of storeys 6, this value for different ductility class was approximately the same. 10-storey frames had the lowest values of estimated ductility demands for both ductillity classes. Frames designed for seismic action 0.2*g* had very small values of estimated ductility demands, mainly in elastic range.

As can be seen in Figure 5, the estimated ductility of section curvature of beams were greater for seismic actions $a_g = 0.3g$ than $a_g = 0.2g$. The estimated ductility demand was mainly greater for the DCM frame than the DCH frame. Only for 6-storey frames with higher design seismic action and for 8-storey frames with lower design seismic action, this was not the case. For 0.2g frames, estimated ductility for both ductility classess was in range from 3 to 4. In comparison with estimated values for columns, ductility demands for beams were greater.

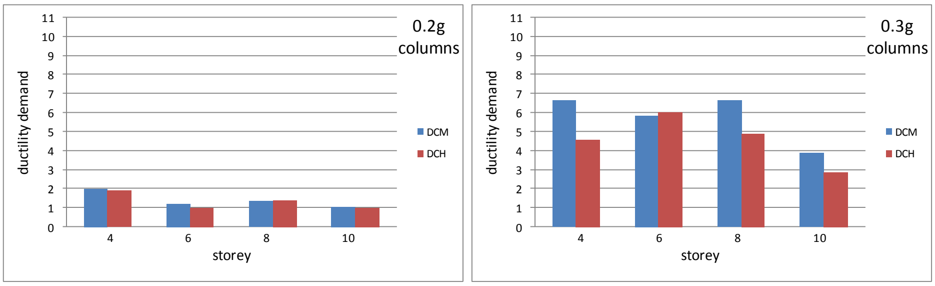

Figure 4. Ductility demand on local level for columns

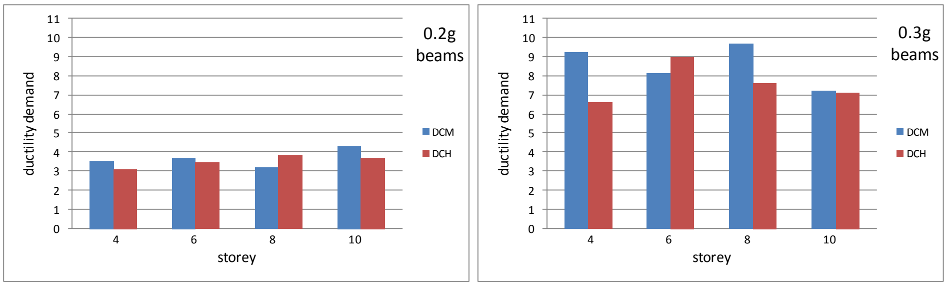

Figure 5. Ductility demand on local level for beams

4. CONCLUSION

The paper presents the estimated ductility demands on global and local level for 16 RC frame structures with different number of storeys, ductility class and intensity of seismic actions. Seismic reponses were obtained by nonlinear time-history analysis. Two sets (for $a_g = 0.2g$ and $a_g = 0.3g$) with three earthquake records were selected, according to the selection procedure given in Eurocode 8. Estimated ductility demands on global level are greater on the frame structures designed as DCH compared to DCM, which was to be expected. On local level, greater values, for estimated ductility demands, were mainly obtained for DCM frames. This can be explained by the more stringent requirements for detailing and dimensioning in DCH frames. For frames designed for lower values of the seismic action, estimated ductility demands were lower than the ones designed for larger values of the seismic action. Minor difference between DCH and DCM in the estimated ductility on global and local level was observed for 0.2g frames.

ACKNOWLEDGMENTS

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ПРОЦЕНА ЗАХТЕВАНЕ ДУКТИЛНОСТИ АБ ОКВИРА ПРИМЕНОМ ВРЕМЕНСКЕ АНАЛИЗЕ

Резиме: *У раду је приказана процена захтеване дуктилности АБ оквира помоћу нелинеарне анализе временског одговора. АБ оквири различите спратности су пројектовани према EN 1992 и EN 1998 за две класе дуктилности и два нивоа интензитета сеизмичког оптерећња.Сеизмички одговор је одређен на основу три записа земљотреса према процедури датој у EN 1998. Захтевана дуктилност је процењена на глобалном и локалном нивоу. Ове вредности су упоређене у зависности од класе дуктилности, броја спратова и сеизмичког интензитета. Циљ рада је да се укаже на утицај, не само пројектне класе дуктилности, него и пројектног сеизмичког оптерећења и спратности оквира на процену захтеване дуктилности.*

Кључне речи: *захтев дуктилности, нелинеарна временска анализа, померање, кривина, EN 1998, класа дуктилности*