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Reduction of seismic response uncertainty by the introduction of dampers in civil engineering structures

B. Benahmed

Laboratoire de développement en mécanique et Matériaux, University of Djelfa, Algeria, Ecole Nationale Polytechnique, Algiers, Algeria Benahmed.tp@gmail.com

M. Hammoutene

Laboratoire de Génie Sismique et de Dynamique des Structures (LGSDS), Ecole Nationale Polytechnique, Algiers, Algeria hammoutene_m@yahoo.fr

Abstract

This work present the main results of a numerical investigation for the probabilistic description of the maximum response of systems under seismic excitations, taking into account random variations in the structural damping. These uncertainties resulting from numerous assumptions made in modeling the geometry, boundary conditions and behavior of the materials and others sources may have a significant effect on the reliability of many structures. Two types of damping are considered in this study, natural damping and the damping associated with new high-tech manufactured dampers, called manufactured damping here. The Monte Carlo technique of simulation is used to simulate the random values of damping. The results obtained are discussed in terms of distribution of the variations of the spectral response values. Conclusions and prospects are formulated in the light of the results obtained.

Keywords: Damping, Dampers, Uncertainty, Risk reduction, Monte Carlo method.

Introduction

It is necessary to consider a priori the effect of the uncertainty of the dynamic parameters on the structural response; this uncertainty can introduce a significant change in the structural response. It is caused mainly by the variation of material properties and the approximation in the estimation of parameters of mathematical models of structure. In this study, we will identify and examine the effect of the damping uncertainties on the dynamic response of structural systems using a Monte Carlo simulation.

Much research on the analytical modeling of the deterministic response was prepared by R. Hanson [1] and other researchers, more research is needed on the effect of damping uncertainties on this response, and the effect of the additional damping (dampers, insulators structures…) on the structural response values and the uncertainties in those values. What is lacking in the research is the recognition and quantification of the benefits that this new source of damping to give for seismic risk reduction.

The objective of this study is to investigate the influence of the introduction of dampers in civil engineering structures to increase reliability and reduce the seismic risk Associated to the inherent uncertainty damping. The uncertainty in spectral response is quantified by their statistical characteristic and a probability distribution for each frequency was made. In the end, a comparison was made between the results developed in this study where the damping is a mix between the natural damping and the additional damping (called here manufactured damping) and the results developed by benahmed [2] where the damping considered was only the natural damping. This comparison is made in terms of the coefficient of variation (Cov) of distribution around the average values of the response spectrum.

Full-scale measurements

The Selecting of an appropriate value of damping is a subject of controversy in design practice. The Evaluation of damping in complete structures was undertaken by several investigators. A sample of such studies can be found in Jeary and Ellis (1981) [3], Yokoo and Akiyama (1972) [4], Hudson (1977) [5], Hart and Vasudevan (1975) [6], Taoka et al (1975) [7], Raggett (1975) [8], Celebi and Safak (1992) [9] and Trifunac (1972) [10]. The information available from full-scale experiments has been assembled by Haviland (1976) [11], Jeary and Ellis [3], Yokoo and Akiyama (1972) [12], Davenport and Hill -Carroll (1986) [13], Jeary (1986) [14], Lagomarsino (1993) [15] and Tamura et al (1994) [16], among others. Haviland reported a range of data for different levels of response amplitudes, large classes of structural systems and building dimensions. This study showed that log normal and Gamma distributions provided the best fit in damping variability. The coefficient of variation (COV) based on the damping performance has changed in the range of 42-87 %. Davenport and Carroll [17] reviewed the database and noted that the COV ranged from 33 % to 78% and suggested a value of 40 % [18].

The natural damping and the manufactured damping

The accurate analytical modeling of damping in building design has always been a goal of structural engineers. Therefore, it is important that it be acknowledged that the damping is a random variable and that it must be realistically addressed in design in buildings. This type of damping will hereafter be referred to as "natural building damping" and, in this paper, it will be considered a random variable.

The reduction of the response induced by an earthquake a building is a design constraint. To reduce this response, it is possible to introduce a manufactured damping system bracing building devices. This type of damping is hereinafter called (manufactured buildings damping. It is clear that the introduction of tele dampers reduce the structural seismic response, therefore, this point is not discussed here. Our point is to discuss the effect of the introduction of those dampers to reduce the variability and the uncertainties of structural seismic response due to the damping uncertainties. However, it is clear that the uncertainty in the damping introduced into the building is generally low for manufactured damping because the damping component or device is constructed in the manufacturing plant and requires typically test of quality control. Therefore, it is reasonable to consider the manufactured damping to be a random variable, but it is also reasonable to expect uncertainty in the values of damping to be typically in the range 3-6 % coefficient of variation [20].
This study aims to analyze the uncertainties inherent damping and their effects on the responses of structures. However, in a more general context, this study identifies the need to address and measure the reduction of uncertainty that can be achieved by mixing the uncertainty on the natural damping related to conventional building materials (eg concrete, steel, masonry) and new systems manufactured (e.g. dampers, insulators structures).
The motivation to date for the introduction of this type of damping has been to reduce the response based only on a deterministic perspective. However, it is clear that the uncertainty in the damping force introduced into the building is typically small in manufactured building damping because the damping component or device is constructed m the manufacturing plant and requires, typically, quality control testing. Therefore, it is reasonable to consider manufactured building damping to be a random variable, but it is also reasonable to expect the uncertainty in damping to typically be in the 3-6% coefficient of variation range [19].

Techniques of simulation

In this work, we use the Monte Carlo method to estimate the value S (ξ, T) of the response spectrum associated to a structure of a fundamental period T and uncertain damping factor ξ. We assume that the values ξ_i (i = 1 to n) of the random variable input ξ are independent and identically distributed, and in our case we choose to make them follow the Lognormal distribution. Under this assumption, the random values of the sample S (ξ_i, T) of size n (i. e. i = 1,2,...., n) of corresponding seismic structural responses are also independent and identically distributed and moreover, by virtue of the law of large numbers, the characteristics of the random sample approach even more statistical characteristics of the population as the sample size n increases.
To assess the convergence of this estimate, we use a limit state function [20]..

$$P = G(m_{S(\xi,T)}) \in \ (\mu_{S(\xi,T)} - \sigma(m_{S(\xi,T)})) - (\mu_{S(\xi,T)} + \sigma(m_{S(\xi,T)}))$$

where $G(m_{S(\xi,T)})$ is the estimation of the mean $\mu_{S(\xi,T)}$ of the population, obtained for a set of 1000 samples of size n and $\sigma(m_{S(\xi,T)})$ the standard deviation of these estimates. By virtue of the central limit theorem, the variable $m_{S(T)}$ follows the normal distribution with expectation $\mu_{S(T)}$ and variance $\sigma(m_{S(T)})/\sqrt{n}$. We see that when n is large the probability P approaches the value 0.68 while the variance $\sigma(m_{S(T)})/\sqrt{n}$ tends to zero.
Figure 1 above shows the convergence of the probability P as a function of the number n of samples. The stability of the simulation was obtained from n = 2000 which is the value that we used to simulate response spectra values in the present study.

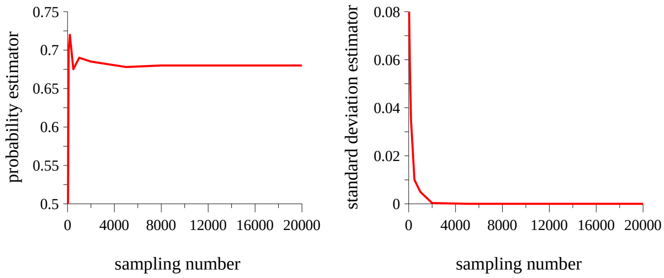

Fig.1. mean spectra ± 1 standard deviation of SD, PSV and PSA For: a) model 1,b) model 2. The spectrum of EL–Centro (18/05/1940).

Results and discussion

The figure 1 shows, for illustrative purposes, the spectral response values obtained for the responses in displacement, pseudo-velocity and pseudo-acceleration of an oscillator with uncertain dynamic parameters, representing the average values ± 1 standard deviation of spectral responses corresponding to take into account the uncertainties on the dynamic properties.
the results presented here are for a dynamic system with one degree of freedom with a mean coefficient of percentage of critical damping ratio ξ = 5%, the probability distribution of damping was taken into account by a log normal distribution with a variation coefficient of 40%.
Figure 2.b shows the results obtained when considering damping as a summation of two types of damping, "the natural damping and manufactured damping" The statistical characteristics of these two types from the literature [18,19]are shown in the table 1

TABLE.1. The statistical characteristics of natural and manufactured damping.

	Mean of ξ	The coefficient of variation of ξ
Natural damping	5 %	40 %
manufactured damping	15 %	5 %

Note that the graphs obtained by the two cases have the same trend, but we see a large fluctuation author of the average value in the figure 2.a for the three graphs on the displacement, pseudo-velocity and pseudo-acceleration. We note that the response is characterized by large fluctuations in the spectra around the mean values, it varies quite consistently. It is can be observed from the results of the figure 2, especially for pseudo-velocity spectra, that even small uncertainties in the damping values can have a significant influence on the spectral amplitudes. It is remarkable from the Fig 2.b that those fluctuations are greater reduced comparing to the curves of Fig 2.a. this reduction is due of the introduction of the dampers effect in the response estimation.

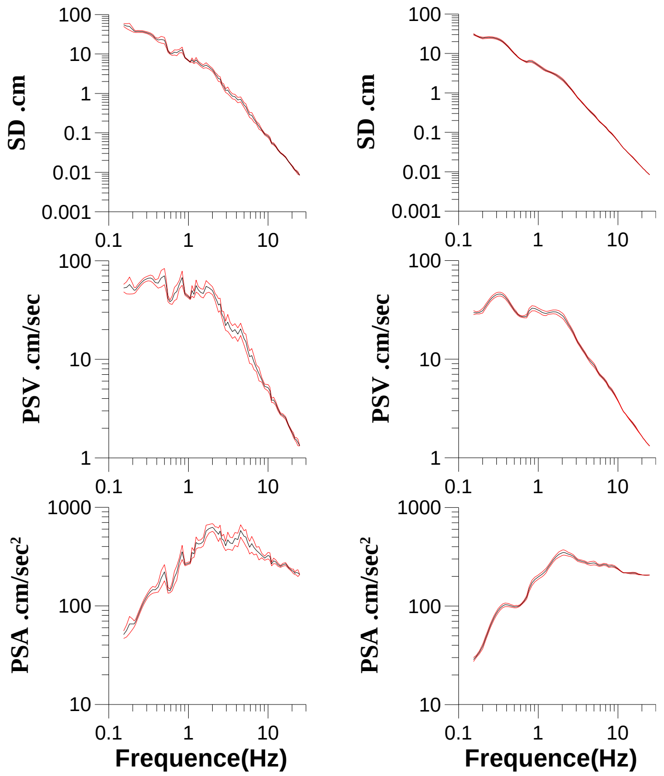

Fig.2. mean spectra ± 1 standard deviation of SD, PSV and PSA for: a) model 1, b) model 2.

The comparison between the results obtained for the two cases described above is made in the table 2. For different frequencies of the spectrum, the PSA statistics (mean and standard deviation and coefficient of variation) are obtained from statistical study, after that, we calculus the statistical parameters of the Cov of PSA values, the results found are presented in the table, for the two cases, the natural damping and that of the mix of the two damping types. It was found that the fluctuation of the dynamic response are reduced in terms of Cov of PSA about 66% (mean of distribution is reduced from 9.68 to 3.31%). This reduction of Cov of PSA involves reducing uncertainty in spectral responses, which means a reduction of seismic risk compared to the case where there is only the natural damping.

This gain in reducing variation in spectral response around average values that justified the use of shock absorbers that are used to increase the values of damping and secondly to reduce the uncertainty in the seismic response values.

TABLE.2. Values of coefficient of variation of PSA

	natural	Nat + manu
Mean of COV	9.68%	3.31%
Standard deviation of COV	5.14%	1.76%
range of COV	1.2- 19.66%	0.01% - 6.22%

Conclusion

This paper presented a look at damping in buildings through the glasses of a structural reliability educated structural dynamics researcher. It is clear that based on this limited view one must incorporate the uncertainty in the damping into the building analysis. Also, the addition of manufactured building damping can have a very positive impact on the uncertainty in response and associated structural safety.

The technique of Monte Carlo simulation was used to estimate the probability of the seismic response; however, to generate values for depreciation, it provides a simple and practical method for assessing the variability of the amplitudes spectral response induced by small uncertainties in the dynamic parameters. These uncertainties can have a significant impact on the spectral amplitudes.

Furthermore, the use of dampers in constructions may have a positive impact by reducing the uncertainty in the spectral response of the one part, and on the other hand serve to increase the damping values.

In this chapter, we had the opportunity to make a comparison between the two cases, the first of which is the natural damping the only type of damping that exists. The second, that both types of natural and manufactured damping and are presented.

The comparison shows a reduced fluctuation around the average value in terms of the distribution of PSA Cov about 66% (average of the distribution is reduced by 9.68 to 3.31%). This reduction in the fluctuation around the average value shows the advantage of the use of the seismic shock in calculation.

It is apparent that the addition of manufactured building damping has a significant benefit, not only, for the response values reduction but also the reduction of the random variability of this response around its mean values.

References

[1] R.O. Hanson, I. Aiken, D.K. Nims, PJ Richter and R.Bachman. Passive energy systems. Proc. Seminar on seismic Isolation. Passive Energy Dissipation. And Active Control, 1993.

[2] B. Benahmed, Mémoire of Magister, Effet of l'incertitude inhérente à l'amortissement sur la réponse des structures sous excitations sismiques, ENP, Alger., 2010.

[3] Jeary, A.P and B. R. Ellis vibrations tests of structures at varied amplitudes, in: Proc. ASCE/EMD. Specialty Conf. on Dynamics Response of Structures. ASCE. Atlanta. GA. 1981.

[4] Yokoo, Y. and H. Akiyama. Lateral vibration and damping due to wind and earthquake effects, in: Proc. Int. Conf on Planning and design of Tall buildings, Vol.11-17, ASCE. NY. 1972

[5] Hudson. D.E Dynamic Tests of Full-Scale Structures, J.Eng. Mech Div. ASCE 103(EM6), 1141-1157. 1977.

[6] Hart, G. C and R. Vasudevan. Earthquake design of buildings: J. Struc. Div. ASCE, 101 (ST1), 49-65. 1975.

[7] Taoka, G.T., M. Hogan, F. khan and R.H. Scanlan. Ambient response analysis of some tall structures, J. Struct. Eng. 101 (ST1), 49-65. 1975.

[8] Reggett, J.D. estimating damping of real structures, J. Struct. Div. ASCE 101(ST9) 1823-1835. 1975.

[9] Celebi, M.and E. Safak. Recorded seismic response of Transamerica building. Part I: data and preliminary analysis, J. Struct. Eng. ASCE. 1991.

[10] Trifunac, M. D. Comparisons between ambient and forced vibrations, Earthquake Eng. Struct. Dyn.1, 133-150. 1972.

[11] Haviland, R., A study of the uncertainties in the fundamental translational periods and damping values for real buildings'. Res. Rep. No. 5, Pub. No. R76-12, Dept of Civ. Engng, MIT. Cambridge, MA, 1976.

[12] Yokoo, Y. and H. Akiyama. Lateral vibration and damping due to wind and earthquake effects, in: Proc. Int. Conf. on Plannong and design of Tall Buildings, Vol. 11-17, ASCE, NY. 1972.

[13] Davenport, A. G., & Hill-Carroll, P. Damping in tall buildings: its variability and treatment in design. In Building motion in wind (pp. 42-57). ASCE. 1986.

[14] Jeary, A.P. Damping in tall buildings – a mechanism and a predictor, Earthquake Eng Struct. Dyn.14, 733-750. 1986.

[15] Lagomarsino, S. Forecast models for damping and vibrations periods of buildings. J. Wind Eng. Ind. Aerodyn. 50, 309-318. 1993.

[16] Tamura, Y., M. Yamada and H. Yokota. Estimation of structural damping of buildings, ASCE Struct. Cong. and IASS Int. Symp., Atlanta, USA, Vol.2, 1012-1017. 1994.

[17] Davenport and Carroll Davenport, A. G., & Hill-Carroll, P. Damping in tall buildings: its variability and treatment in design. In Building motion in wind (pp. 42-57). ASCE. 1986.

[18] Kareem, A., & Gurley, K. Damping in structures: its evaluation and treatment of uncertainty. Journal of Wind Engineering and Industrial Aerodynamics, 59(2), 131-157.1996.

[19] Gary C. Hart, random damping in buildings. Journal of Wind Engineering and Industrial Aerodynamics, Meeting on Structural Damping International Wind Engineering Forum and Additional Papers. Volume 59, Issues 2–3, March 1996, Pages 233–246.

[20] Melchers. E. R. structural reliability analysis and prediction, John Wiley and sons, 66-72.1999.