# EVALUATION OF SEISMIC DESIGN APPROACH ON RC/MR BUILDING USING DIFFERENT PROBABILISTIC METHODS

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Direct displacement based design (DDBD), for its unique capabilities and simplicity is one of the most widely used displacement based design approaches. In this method, the inelastic multi degree of freedom system is substituted with an equivalent elastic single degree of freedom system (Powel, 2008). Substituted structure is characterized by secant stiffness at peak displacement and an equivalent viscous damping (DBD12, 2012). On the other hand, application of probabilistic principles in the seismic performance evaluation process, allows to determine the risk level accepted by different design codes (Cornell et al., 2002). Probabilistic seismic performance evaluation due to the randomness of different structural parameters has recently been seriously considered. In recent years, the probabilistic evaluation method proposed by Jalayer and Cornell (2003) is largely accepted and used as a criterion for estimating the reliability of structures.

In this study, probabilistic seismic performance of 8-story RC moment resistant building designed with DDBD and conventional force based design (FBD) approach is investigated and compared by studying (i) the mean annual frequency (MAF) (ii) seismic demand of limit states (iii) the confidence level of structures under the earthquakes with low to high hazard levels. Structural modeling is performed in OpenSees framework environment. Experimental model results were used to validate the analytical model implemented in OpenSees. It should be noted that in the estimation of the MAF of limit state exceedance, two different probabilistic methods are used “assessment by considering the only source of uncertainty” and “assessment by considering randomness and uncertainty as the sources of uncertainty”.

Table 1 shows the MAF of limit state exceedance for the two performance levels of the immediate occupancy (IO) and collapse prevention (CP). In responses estimation, all analysis are performed under 20 earthquake records proposed by FEMA P695. Based on the results, it can be said that considering aleatory and epistemic uncertainties, has increased MAF above 20 to 25 percent. Increasing this parameter increases the overall probability of failure and the vulnerability of the structure. In comparing MAF of exceedance of limit states for two mentioned seismic design approaches, it should be noted that by changing the design approach from DDBD to FBD, the MAF for IO and CP performance levels is considerably increased. Furthermore, the effect of seismic design approaches on the structural confidence level has been investigated and summarized in Figure 1. As seen, the structure designed with DDBD, unlike FBD approach up to the 4g spectral acceleration ($S_a$ ($T_1$, 5%)) is satisfied the 35% confidence level. Whereas for FBD approach, 0-100% confidence level, all is in the spectral acceleration range from 0 to 1 g. Confidence levels of structure can be obtained by having the maximum drift demands corresponding to the low to high hazard levels (see Figure 1). In this study, six hazard levels namely SLE25, SLE43, SLE72, DBE, MCE and OVE with return periods 25, 43, 72, 475, 2475 and 4975 years respectively were used to determine drift demands. As shown in Figure 2-a, the structure designed with DDBD approach at SLE25 hazard level corresponding to the CP performance level has a maximum demand value of 0.0019. The maximum demand value increases to 0.025 by moving from the SLE25 to OVE hazard level. On the other hand, maximum demand value has a steep upward slope with increasing seismic intensity and eventually maximum drift demand is resulted for OVE hazard level. In contrast, Figure 2-b shows that both structures designed with DDBD and FBD procedure, achieve 95-99% confidence level for hazard levels of SLE25 to DBE corresponding to IO and CP. However, earthquakes with the return periods from 25 to 72 years are not among the strong earthquakes and seem that the structure has an elastic behavior. But the conditions for both mentioned design approaches are quite different at MCE and OVE hazard levels. For DDBD approach at IO performance level corresponding to MCE and OVE hazard levels, structure achieves 61% and 8% confidence level respectively and the 99% confidence level is provided at CP. However, the confidence levels at both IO and CP performance levels for MCE and OVE hazard levels are reduced by changing the design approach from DDBD to FBD. So it can be said that reliability is reduced dramatically moving from DDBD to FBD.

*Table 1. Comparing MAF of exceeding limit state by different probabilistic methods.*

| | DDBD-The Only Source of Uncertainty | | | DDBD-Randomness and Uncertainty as the Sources of Uncertainty | |
|---|---|---|---|---|---|
| | IO | CP | | IO | CP |
| MAF | 3.61E-04 | 2.41E-05 | | 4.47E-04 | 3.01E-05 |

| | FBD-The Only Source of Uncertainty | | | FBD-Randomness and Uncertainty as the Sources of Uncertainty | |
|---|---|---|---|---|---|
| | IO | CP | | IO | CP |
| MAF | 6.35E-04 | 5.58E-04 | | 7.70E-04 | 6.89E-04 |

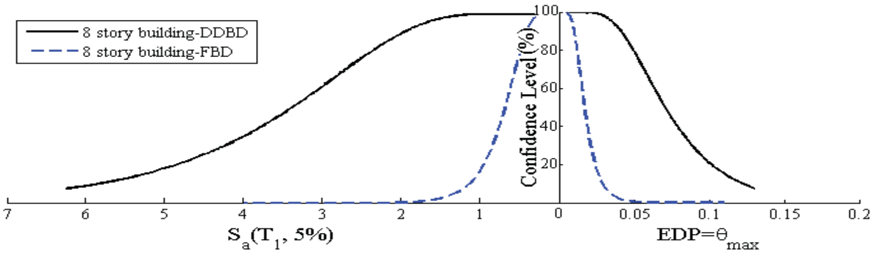


*Figure 1. Comparison of the confidence level of 8-story building designed with DDBD and FBD approaches.*

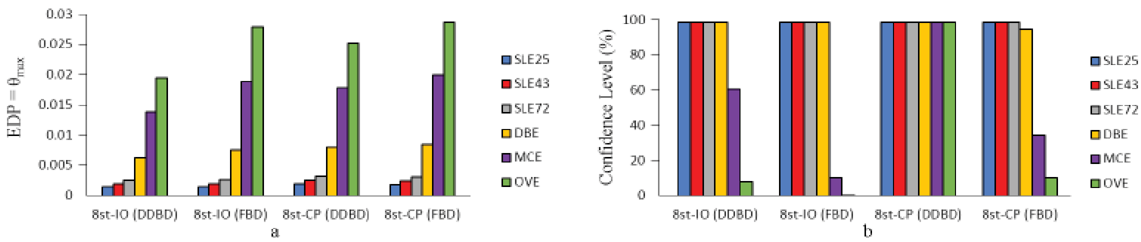


*Figure 2. Distribution of: a. drift demand, and b. confidence level at different hazard levels for the structure designed with two DDBD and FBD approaches.*

## REFERENCES

Cornell, C.A., Jalayer, F., Hamburger, R.O., and Foutch, D.A. (2002). probabilistic basis for 2000 SAC federal emergency management agency steel moment frame guidelines. *Journal of Structural Engineering, 128*(4), 526-533.

Jalayer, F. and Cornell, C.A. (2003). *A Technical Framework for Probability-Based Demand and Capacity Factor Design (DCFD) Seismic Formats.* RMS. Retrieved from PEER Berkeley, CA, PEER Report 2003/2008.

Powell, G.H. (2008). Displacement-based seismic design of structures. *Earthquake Spectra, 24*(2), 555-557.

Sullivan, T., Priestley, M., and Calvi, G.M. (2012). *A Model Code for the Displacement-Based Seismic Design of Structures. DBD12*.