Dynamic Response of High-rise Building with Energy Dissipation Devices

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1. INTRODUCTION

In order to reduce the economic loss and repair cost of a building during an extreme earthquake to the minimum, energy dissipation devices such as Hysteretic Dampers (HD) or Viscous Dampers (VD) are usually considered in the design of high-rise buildings. The extent of economic loss and structural damage greatly depends on the interstory drift and acceleration response[1] that are correlated with the energy dissipation capacity of the building structure. An concept of performance based design for the high-rise buildings has been proposed by J.J.Connor and A.Wada[2]. On the basis of this concept, a design methodology of Damage Tolerant Structure (DTS) has been presented by the writers.

We state the philosophy of DTS as follows. A building structure could be divided into two independent parts, main frame structure and braces. Since the main structure subjects the vertical load and takes very important role in protecting the whole building from the dangerous of overturn collapse, we assume the main structure maintains elastic always by using high strength steel. The input energy of earthquake, however, is considered to be dissipated by the lateral load resisting members such as braces made from extra-low strength steel so that it has sufficient ductility to absorb the earthquake energy. DTS therefore could be able to work continuously through the damaged braces being replaced by new ones after the earthquake.

The purpose of this paper is to study the influence of HD on the seismic response of high-rise buildings such as energy dissipation capacity and response subduing capacity of interstory drift and acceleration, and to make the influence comparison of HD with VD.

2. ANALYSIS MODEL

We have developed a multi-spring and multi-dash pots model to make the dynamic response analysis for the DTS in which the shear and bending deformation could be separated independently. To connect the two adjoining masses, three springs standing for the elastic shear and bending stiffness of main structure and the stiffness of HD, as well as three dash pots standing for the natural and artificial damping effect in the shear and bending direction have been considered. Three kinds of artificial ground motions have been used in the response analysis.

3. RESULTS OF DYNAMIC RESPONSE

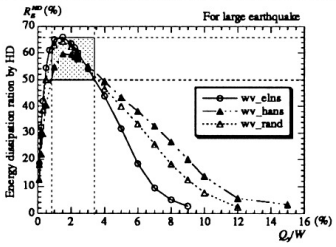
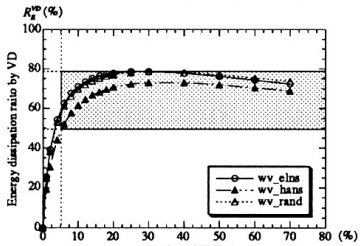
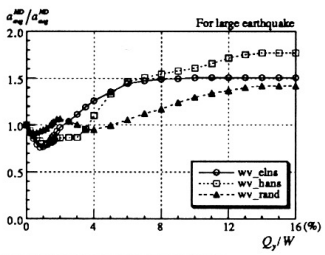
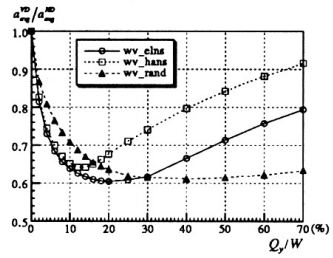
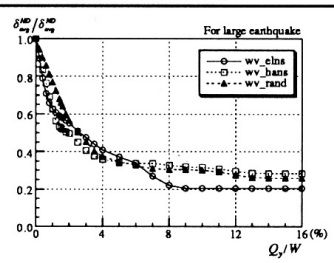
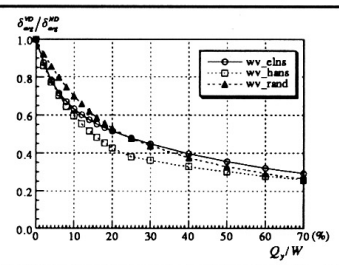
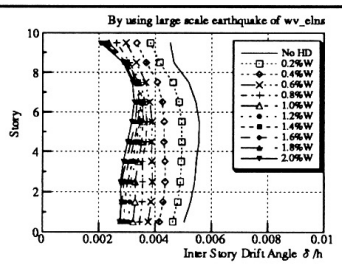
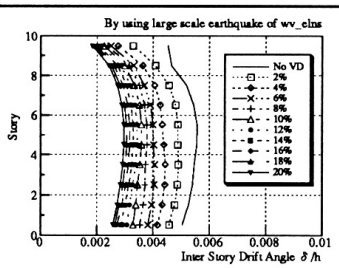
The obtained results of dynamic response about the energy dissipation capacity and interstory drift as well as acceleration are shown in Tab. 1.

The average energy dissipation ratio (ratio of the energy dissipated by HD or VD over the input energy of earthquake) over 50% appear at about (1~3)%W yield level of HD and over 5% VD coefficient. The energy dissipation ratio will decrease with the yield level of HD increase over 2%W. However, it is closed to constant if the VD coefficient is larger than 10%.

The acceleration response is appreciated by the ratio of $a_{avg}^{HD}/a_{avg}^{ND}$ or $a_{avg}^{VD}/a_{avg}^{ND}$ where a_{avg}^{HD} and a_{avg}^{VD} represent the average maximum acceleration with HD or VD respectively, a_{avg}^{ND} represents that without any dampers. The optimum yield level of HD and VD coefficient for the minimum acceleration ratio seems to be (1~3)%W and (10~20)% respectively.

Average maximum interstory drift ratio is represented by $\delta_{avg}^{HD}/\delta_{avg}^{ND}$ or $\delta_{avg}^{VD}/\delta_{avg}^{ND}$ where δ_{avg}^{HD} and δ_{avg}^{VD} represent the average maximum interstory drift with HD or VD respectively. δ_{avg}^{ND} represents that without any dampers. Interstory drift can be reduced largely by using HD or VD when the yield level of HD or the VD coefficient is in the small range.

Tab. 1 Comparison of Response Results Between Using Energy Dissipation Device HD and VD

	with energy dissipation device HD	with energy dissipation device VD
energy dissipation ratio		
average maximum acceleration		
average maximum interstory drift ratio		
maximum interstory drift ratio throughout the height		

4. CONCLUSIONS

1) HD can dissipate over 50% input energy of earthquake if the yield level of HD is used as (1~3)%W.
2) HD can reduce the interstory drift response more than 50% if the yield level of HD is over 2%W.
3) HD has some effects in reducing acceleration response if the yield level of HD is in (1~3)%W.
4) HD has the same important role as VD in reducing seismic response of high-rise buildings.

REFERENCES

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2) J. J. Connor and A. Wada, (1992), "Performance Based Design Methodology for Structures", Proc. of Inter. Workshop on Recent Developments in Base-Isolation Tech. for Buildings, Tokyo, Japan, pp57-70.