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Multi Degree of Freedom Effects on Ductility Reduction Factor for Near Fault Ground Motions

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ABSTRACT: Study on single degree of freedom (SDOF) structures provided information on seismic demand for elastic and inelastic systems. But this information needs to be modified to become of direct use for design of real structures, which are mostly multi-degree of freedom (MDOF) systems, governed by several modes. According to the near fault ground motions have cause much damage in the vicinity of seismic sources, this paper evaluate the modification that must applied to strength reduction factors derived from simplified SDOF models in order to account for MDOF structures in near fault zones. This proposed by estimation the ratio of strength in MDOF systems that result by limiting maximum story ductility ratio to the strength corresponding to the same ground motion and same level of ductility in an equivalent SDOF system having a period equal to the fundamental period of the MDOF structures. Nonlinear dynamic time history analysis were carried out on four steel moment resisting frames with two distinct behavior of yield mechanism, undergoing five level of ductility ratio when subjected to 15 near fault ground motions with forward directivity effects. Modification factors spectra were computed as a function of period and number of stories and were compared to those of corresponding spectra for far fault ground motions. The required modification factor for inelastic MDOF systems, for near fault motions was shown to be dependent on target ductility ratio and the type of yield mechanism and to a lesser degree, period of vibration and number of stories. The result demonstrate that in the low level of ductility ratio, during the short period range, the modification factor given from near the fault ground motions is less than those from the far fault ground motions, and this is true during all period range as the level of ductility is increased. Finally, since the equivalent pulse of near fault ground motions have significant effect on structural response, modification factors were proposed as a function of the ratio of structural period to equivalent pulse period and ductility ratios.

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1- Introduction

In current seismic design of building code, structures are designed for the lateral forces, taken to be much smaller than those for a perfectly perfectly elastic property. The required strength of structures is to divide the elastic strength by a scalar parameter called reduction factor that accounts for some parameters which the ductility is the most important. The ductility factor is mostly proposed base of the SDOF analysis models [1-3]. But it needs to be modified by a new factor (modification factor) for usage of real structures that are multi degree of freedom (MDOF systems) [4-6].

2- Methodology

Since of the large amount of recent damage in near fault ground motions, the near fault records with forward directivity effect may be characterized by large long period pulse, are assumed. These motions are recorded on soil condition according to Bray & Rodriguez classification [6]. These motions have the moment magnitude (M_w) equal to or more than 6.5 for the radios of distance smaller than 20 km. and $6<M_w<6.5$ for the distance of smaller than 15 km to the fault center [8].

Simple moment resistance 2D frames with 3 bays and various type of first modal elastic period ($0.56<T<1.94$ S) are assumed to investigate their behavior in case of two failure mechanism: 1) beam hinge (BH) and 2) weak story (WS). All of the structures have the same distribution of mass, but the stiffness is specified so that above failure mechanism occurred in each models. More ever a bilinear hysteric force-displacement relationship and 5% damping were considered. In order to define ductility modification factor ductility demand of 1,2,4,6 and 8 are considered.

SDOF models have been defined for each of the MDOFs with the same mass period and damping.

Estimation of required strength reduction for SDOF & MDOF systems for which ductility demand equals are computed with:

$$V_{SDOF}\left(\mu=\mu_i\right)=\frac{V_{SDOF}\left(\mu=1\right)}{R_\mu} \quad (1)$$

$$V_{SDOF}\left(\mu=\mu_i\right)=\frac{V_{SDOF}\left(\mu=1\right)}{R_\mu \times R_M} \quad (2)$$

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$$R_M = \frac{V_{SDOF}\left(\mu = \mu_i\right)}{V_{MDOF}\left(\mu = \mu_i\right)} \tag{3}$$

3- Discussion and Results

The investigation of modification factor has been done by PERFORM 3D analytical computer program [9] and can be summarized as follows:

• The ratio of $1/R_M$ is dependence to the type of the failure mechanism and, it should be considered large value of $1/R_M$ and thus a smaller modification factor (R_M) in the case of WS mechanism.

• The strong dependence of the $1/R_M$ ratio to the ductility demand (μ_i) so it increases as the ductility demand (μ_i) increases.

• The modification factors (R_M) are smaller for the long period range.

• In design, the danger of using typical strength reduction factor (R_μ) values that obtained base on far fault ground motions for near fault motions will likely be greater and the modification factor (R_M) are increased for high ratio of ductility in near fault motions in comparison to far fault motions. In this case R_M should be assumed much greater than far faults motions.

Some of the above results are indicated at the following Figs. 1 and 2:

An approximate expression has been proposed to compute the ductility modification factor in forward directivity near fault ground motions. The R_M factor is influenced by the period of vibration and the ductility level. Thus these two parameters are taken into consideration in the proposed expression as follow:

$$R_M = a + b \times T \times \ln T + cT^{2.5} \tag{4}$$

Where a, b and c are constants that depends on the ductility demand levels.

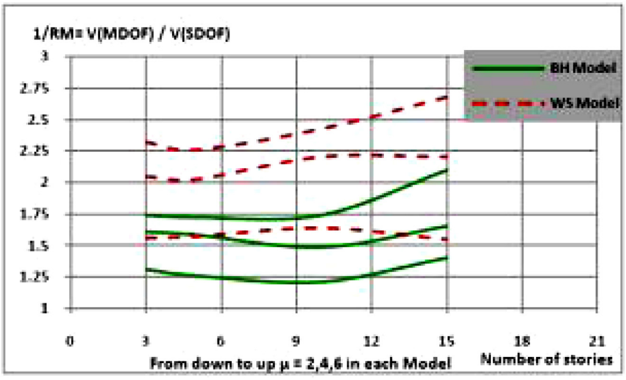

Fig. 1. Influence of failure mechanism on ductility modification factor

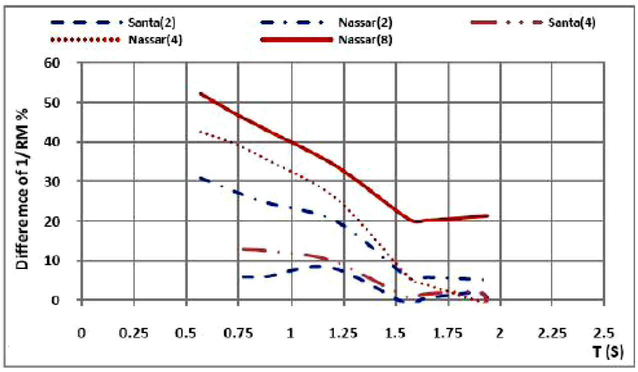

Fig. 2. Comparison of ductility modification factor ($1/R_M$) for near fault ground motion proposed in this study with those in previous investigation for far fault ground motions [2,6].

Table 1. Parameters in the fitting expressions of modification factor

μ	a	b	c
2	1.071	0.766	-0.225
4	0.752	0.331	-0.109
6	0.756	0.461	-0.167
8	0.656	0.353	-0.127

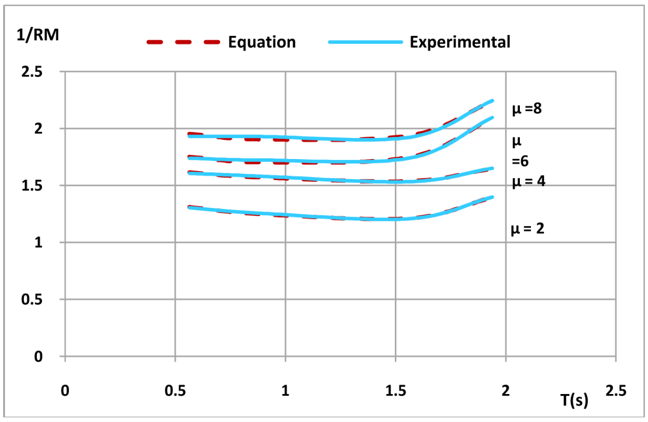

Fig. 3. Comparisons of fitting curves of this study with the previous investigations [2, 6].

4- Conclusions

The effect of multi degree of freedom in investigation of ductility reduction factor based of SDOF system behavior in the vicinity of near fault ground motions with forward directivity effect has been discussed. This effect will be considered by introducing a modification factor which has affected by the range of structure period, number of stories, and the type of failure mechanism. However the modification factor was compared in two types of ground motions (near & fault) and it showed that they are different.

Also a new expression of ductility modification factor involving the period vibration and the ductility demand level is proposed.

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