ESTIMATING MAXIMUM POUNDING FORCE BETWEEN TWO ADJACENT STRUCTURES

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Among different cases of structural damage, seismic pounding of the buildings with inadequate separation distance has been identified as the cause of severe damage in the past earthquakes. Such poundings can be expected in major cities which have valuable under-construction lands and contain many buildings with small distances in between. Pounding between structures could produce large acceleration demands on the floors which are directly involved in collisions (Cole et al., 2010). So, a rational estimation of the maximum pounding force would help us to control the extent of damages in different structures.

Pounding force beween two adjacent structures during an impact can be investigated using exact dynamic analysis. Previous studies have demonstrated that pounding force of these structures are strongly related to initial structural parameters such as mass, damping ratio, and gap distance between two structures along with site specifications including soil properties and ground motion characteristics. Additionally, correlation of two structural responses before and after the pounding phenomenon is another important factor for evaluating of pounding force. Thus, many dynamic analyses should be done to obtain a pounding force. Nevertheless, nonlinear dynamic methods are costly and time-consuming; also, considering great dependence of the pounding force of structures on the frequency content of earthquakes, these models must be developed in the presence of an appropriate number of selected records. To consider all these effects into one comprehensive method, adopting an approximate approach which could be initially capable of considering the fundamental parameters into the evaluation procedure, was of interest.

In this study, the expected extreme value (maximum) of pounding force with the aid of probabilistic methods is determined. To propose a reliably exact comprehensive relation considering the maximum pounding force, several systems with Bouc–Wen (BW) hysteresis model (including a variety of hysteretic patterns) were studied under input excitations with a spectral density as a representative for a range of records in a particular area. The pounding force between two SDOF systems is derived by the following formula (Jankowski, 2005):

$$\begin{cases} F(t)=0 & for \quad \delta(t)\le 0 \\ F(t)=k_h\,\delta^{\frac{3}{2}}(t)+c_h\,\dot{\delta}(t) & for \quad \delta(t)>0 \quad and \quad \dot{\delta}(t)>0 \\ F(t)=k_h\,\delta^{\frac{3}{2}}(t) & for \quad \delta(t)>0 \quad and \quad \dot{\delta}(t)\le 0 \end{cases}$$
$$\begin{cases} \delta(t)=x_1(t)-x_2(t)-d \\ \dot{\delta}(t)=\dot{x}_1(t)-\dot{x}_2(t) \end{cases} \qquad (1)$$

where k_h, c_h are the stiffness and damping parameter of contact model and x_1, x_2 are displacements of two adjacent systems and d is separation distance.

In order to determine the maximum pounding force, two adjacent SDOF system with BW model and different periods (T_1=1.2 sec, T_2=0.4, 0.6, 0.8 sec) are analyzed under 300 stationary and non-stationary records with Tajimi-Kanai spectral density and then, the average value of maximum pounding force of these records have been obtained. Also, the maximum of pounding force is investigated on the basis of statistical relations and a closed-form method is presented without any need to perform exact dynamic analysis.

Comparisons between expected extreme values of pounding forces obtained from the performed analyses by use of 300 stationary and non-stationary records and from the proposed algorithm are presented in Tables 1 and 2.

Table 1. Expected extreme value of pounding force under stationary records (Rahimi, 2014)

No.	T_1, T_2 (sec)	300 nonlinear dynamic analysis (exact method)	Frequency domain (proposed method)
1	1.2, 0.4	48873	49249
2	1.2, 0.6	44496	43563
3	1.2, 0.8	37979	36573

Table 2. Expected extreme value of pounding force under non-stationary records (Rahimi, 2014)

No.	T_1, T_2 (sec)	300 nonlinear dynamic analysis (exact method)	Frequency domain (proposed method)
1	1.2, 0.4	34888	36968
2	1.2, 0.6	31599	31767
3	1.2, 0.8	27639	27329

According to Tables 1 and 2, the proposed algorithm has the capability of estimating the expected extreme value of the pounding force of two adjacent systems under stationary and non-stationary excitation.

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