CRITICAL DISTANCE BETWEEN ADJACENT MID-RISE AND HIGH-RISE STRUCTURES CONSIDERING STRUCTURE-SOIL-STRUCTURE INTERACTION EFFECTS

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Adjacent structures affect seismic response of each other through connecting soil. Regarding population growth and urban structures density, the cross interaction of adjacent structures, well-known as structure-soil-structure interaction (SSSI), has received attentions in recent decades. Soil-structure interaction (SSI) studies showed that, as a general trend, possibility of unexpected damage is decreased by introducing base flexibility in seismic structural design. In these studies, it appeared that both dynamic properties such as dynamic damping and stiffness, called as dynamic impedance, as well as foundation input motion (FIM), of an isolated structure, change by the SSI effects. Moreover, the structure has influence on seismic motion of its surroundings, up to a distance of ten times the foundation length (Gueguen et al., 2002). Similarly, if a structure is constructed near the said structure, the nearby motion will change additionally. Thus the structures have influence on dynamic properties and input motion of each other. Gueguen et al. (2002) has shown that the effect of soil-structure interaction on nearby motion decreases as the distance increases. In contrast, finding critical distance between adjacent structures is not as simple as the case of the SSI because of the complexity of the SSSI. On the other hand, since adjacent structures have strong effects on each other, both favorable and unfavorable, study of the critical distance seems to be necessary.

Previously, SSI has been studied using direct and indirect methods. In indirect method, with the use of superposition concept, the problem is studied in two phases. I) Kinematic interaction, changing Free Field Motion (FFM) to FIM as a result of stiffness contrast between foundation elements and soil, and II) Inertial interaction, changing in dynamic properties, i.e. dynamic impedances, of structure caused by structure and foundation masses. Since kinematic interaction usually decreases horizontal component of FIM in SSI, in conservative approach, its effects are not considered in common designs and it has been less studied. However, kinematic interaction by creation of rotational components during earthquake can cause considerable effects on seismic response of structures and can be so destructive. Jahankhah et al. (2013) proposed simplified equations, for practical design, in which both horizontal and rotational FIMs are integrated in a single horizontal component called Net Horizontal FIM.

In this research, using the concepts introduced by Jahankhah et al. (2013) kinematic SSSI effects are studied. Critical and appropriate distances between mid-rise and high-rise adjacent structures are shown using envelope of FIM transfer functions (TF) of an assumed surface structure adjacent to a structure with deep foundation of four distances. At first, a series of adjacent surface rigid foundations (main) and structures with deep rigid foundation models, are constructed on homogeneous, isotropic and linear elastic half-space, through a 2D finite element numerical method using ABAQUS software. For kinematic study of SSSI, the main surface foundation is assumed massless and structure is assumed on the main foundation and its seismic responses using the first step results are calculated by MATLAB (Figure 1). Fixed parameters are as follows:

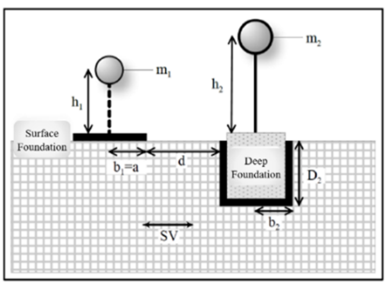


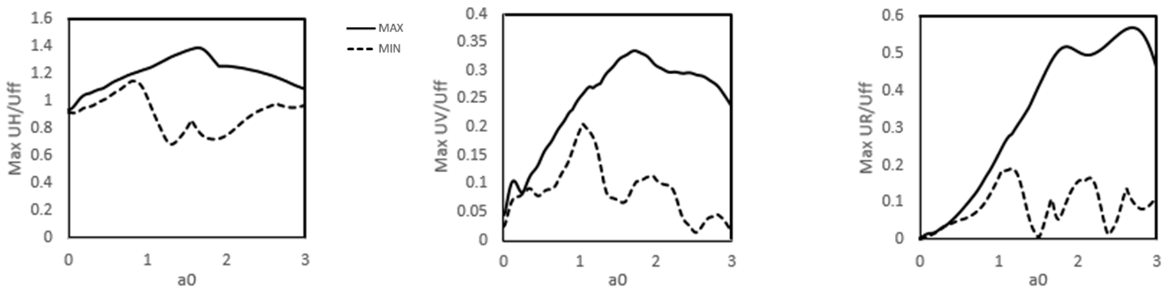
Figure 1. Numerical model.

1) a: half of the main foundation width,
2) d: is the distance between the foundations,
3) D: depth of the adjacent foundation,
4) b: half of foundation width,
5) $b_2/a=2$, width ratio of the adjacent foundation to main foundation,
6) $D/b_2=1$, embedment ratio of the adjacent foundation,
7) $\overline{m}=0.5$, mass ratio of the adjacent structure,
8) $a_{0fixed}=1$, fixed-base non-dimensional frequency of adjacent structure,
9) h: structure effective height,
10) $h_2/b_2=5$, height ratio of the adjacent structure,
11) Vs/a=5, ratio of shear wave velocity to main foundation width,
12) ν=0.33, Poisson's ratio,
13) E=10972.5 Kpa, soil Young modulus.

Models are subjected to a vertical incident SV-waves propagation in form of a sinusoidal pulse. The transfer functions of FFM to FIM are then obtained. For parametric study, the adjacent structure was located in four distance ratios. Also two slenderness ratios for the assumed main structure were considered. The other variable parameters are, distance ratio d/a= 2, 4, 6, 8, height ratio of the main assumed structure $h_1/b_1=1$, 4 and Vs/a = 10, 50. Main results are as follows:

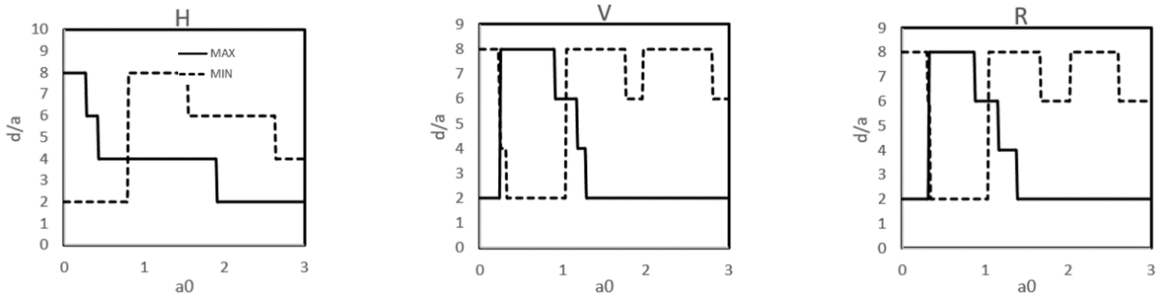
a: Up to 40% increase in horizontal component (Figure 2-a) and up to 30% and 55% (Figures 2-b and 2-c), creation of vertical and rotational components is seen at critical distances as a result of adjacent structure.

b: Regarding Figures 3-a, 3-b and 3-c, in unexpected way, critical distance is not related to Min. distance between adjacent structures in various frequency ranges. Therefore, there would be an optimal distance where the destructive effects of adjacency become minimized.



(a) (b) (c)

Figure 2. Max. & Min. of TF against Non-dimensional frequency.



(a) (b) (c)

Figure 3. Related distance ratio of TF's Max. & Min. – non-dimensional frequency.

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