A Study on the Seismic Characteristics of the Ground and Structure In Damascus-SYRIA Including Soil-Structure Interaction

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1. Purpose

This paper aims at studying the seismic behavior of soil and structure (High buildings) numerically in Damascus – Syria, specifically in Dummar – a district in the northern west of Damascus, and determining the seismic characteristics of both of them in order to enable the proper design for earthquake resistant structures.

2. Method (Figure 3-2)

2.1 Ground seismic response analysis

The dynamic response of the model ground during an earthquake was estimated using the SHAKE program (one-dimensional seismic response analysis used with multiple-reflection theory), by considering the non-linearity of soil properties from **G - γ, h - γ** curves generated from experimental results. The initial values for the numerical model are estimated as follows:

(1) The shear velocity (Vs) of the model ground is determined by the following equations (where Vs value depends on the soil type):

$Vs= 100N^{1/3}$ ($1 \le N \le 25$) /C ≠0/ (cohesion soil). $Vs= 80N^{1/3}$ ($1 \le N \le 50$) /C =0/ (cohesionless soil).

The boring data of the ground in that site was collected at eighteen points (ρ = 1.71 ~ 1.95 tf/m^3 and Vs = 172.4 ~ 259.6 m/sec in the surface layer, ρ = 1.95 ~ 2.18 tf/m^3 and Vs = 207.7 ~ 275.8 m/sec in the bottom layer).

(2) The initial shear modulus is: $G = \rho Vs^2 / g$ Where, **G**: shear modulus (tf/m^2), ρ: density of the ground (tf/m^3), **Vs**: shear wave velocity (m/sec), **g**: gravity acceleration (9.81 m/sec^2)

This research concentrates mainly on the effect of Kobe earthquake (Hanshin earthquake) on the soil and structures of the area mentioned above in Damascus – Syria. The model ground of all points is subjected to Kobe earthquake motion with different amplifications (100% = 818 gal, 50%, 25%, 12.5% and 2.5%), and a pre-recorded earthquake data of Zushi city (in the point K3, N-S direction (18 gal)).

2.2 Structure seismic response analysis

The dynamic response of the structure (one and two dimensional analyses) was analyzed using TDAP III (Time domain Dynamic Analysis Program III) that uses Newmark β method of non-delta form. The ground was modeled using two-dimensional finite elements (Plane strain elements) and the converged values of the soil properties used. The structure was modeled as a set of elastic beams elements. The dynamic behavior of the structure, the dynamic forces (shear forces, compression forces…etc) acting on the structure were evaluated. The structure was modeled as a set of elastic beam elements in two ways:

(1) One-Dimensional model (Spring – Mass model).
(2) Two-Dimensional model F.E.M (Finite Element Method). (Figure 3-3).

3. Results

3.1 Ground seismic response analysis

(1) In the case of a horizontal motion, the resonant frequency of the ground model was 0.7 Hz for Kobe 100%, 1.4 Hz for Kobe 50% and 1.9 Hz for Kobe 25%. The resonant frequency decreased with the increase of earthquake amplification. The ground model displayed strong nonlinear properties. By examining the resonant frequencies for vertical motions, the resonant frequency was 6.2 Hz for Kobe 50% and 6.7 Hz for Kobe 25%.

The resonant frequency did not decrease notably with increasing base acceleration. The model of ground did not display strong nonlinear properties. (Figure 3-4 and 3-5).

(2) The influence of acceleration on surface for horizontal motion is larger by some 2 times than that for vertical motion.

3.2 Structure seismic response analysis

(1) The Structure & Soil model displayed strong nonlinear properties when Kobe 100%-H was examined, which affected the results of the linear analysis (the results were not compatible with those of Kobe 50% & 25%). (Fig 3-7). (2) The ground characteristics did not change linearly when changing the earthquake motion despite conducting a linear analysis. (Figure 3-6). (3) The maximum shear force computed by Syrian Arab code method was much smaller than that computed by TDAP. (Figure 3-8). The general formula must be rephrased.

4. Conclusions

(1) The analysis results displayed a good agreement when moderate and weak motions were applied. On the contrary, when strong motions were applied strong nonlinear properties were displayed.

(2) The horizontal motion had more significant influence on the dynamic behavior of structure and soil than the vertical motion.

Keywords: Seismic Characteristics, Damascus-Syria, Soil-Structure Interaction, Seismic Response Analysis.
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(3) The two-dimensional analysis with equivalent linear method cannot evaluate precisely the dynamic behavior up t the failure of the structure because it does not consider the nonlinear material properties of the elements.

(4) The results from this study will be used in earthquake disaster mitigation of Damascus area (SYRIA).

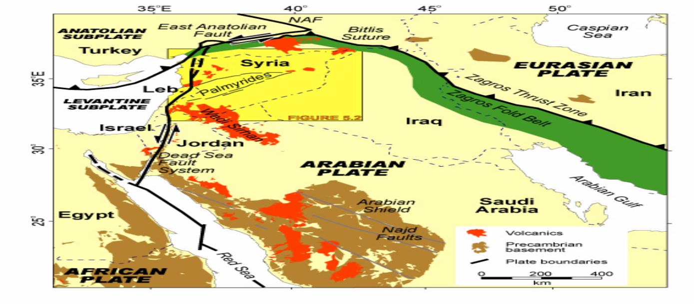

Figure 3-1 Tectonic Map of the region

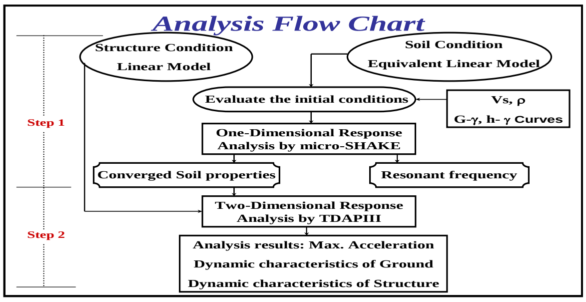

Figure 3-2 Analysis Flow chart

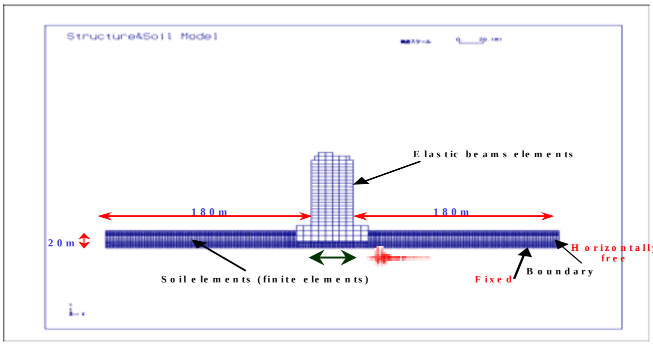

Figure 3-3 Soil-Structure interaction

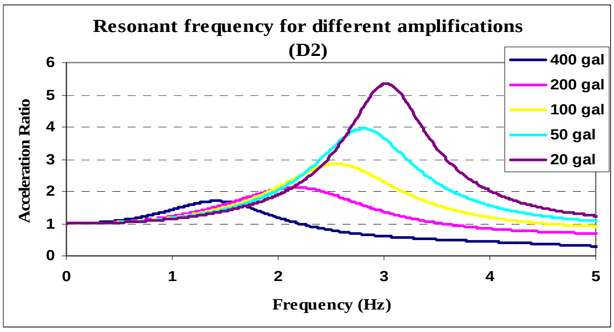

Figure 3-4 Resonant curves for Sin-sweep

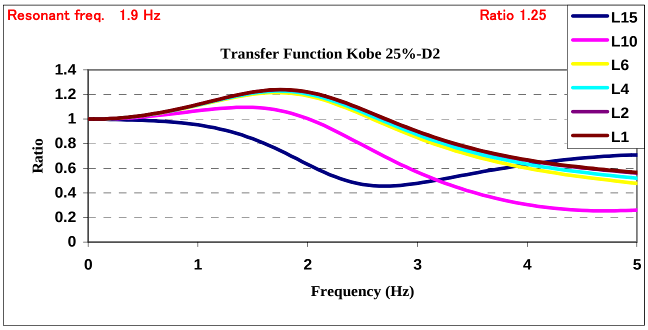

Figure 3-5 Resonant curves of the ground model

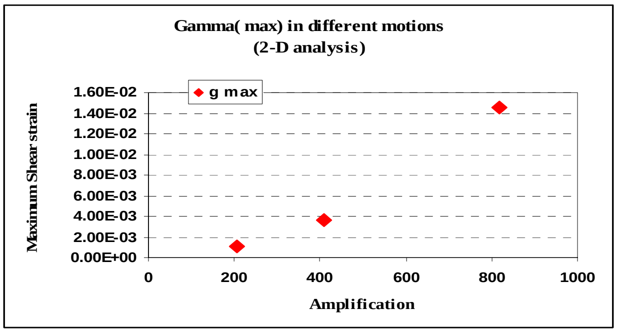

Figure 3-6 Max. Shear strain Vs amplification

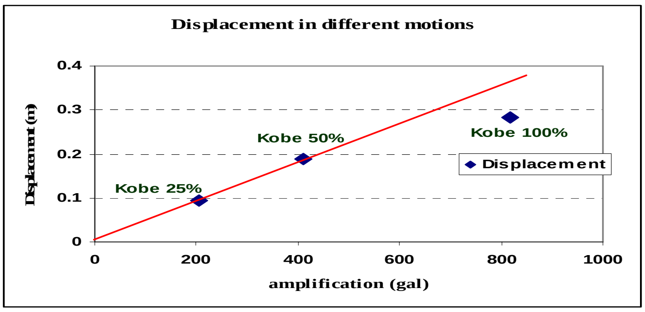

Figure 3-7 Relation b/w displacement & Amplification

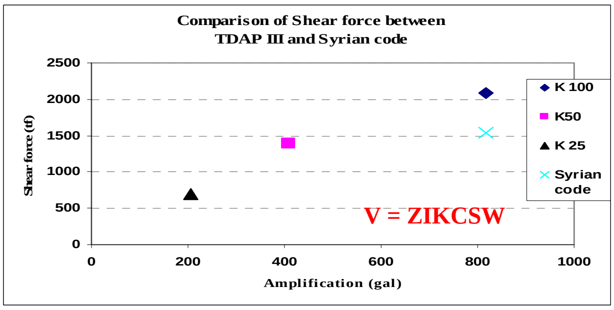

Figure 3-8Comparison b/w TDAP & Syrian code

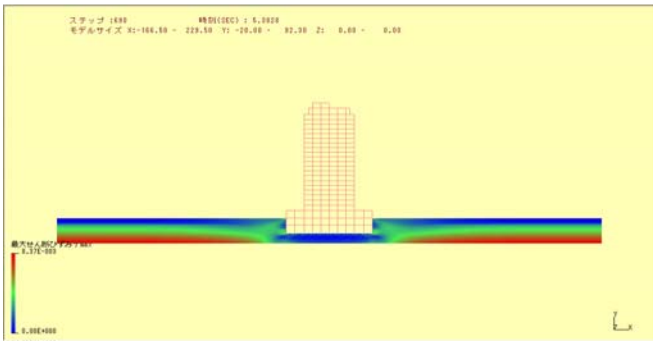

Figure 3-9Max. Shear Strain of soil/Kobe earthquake

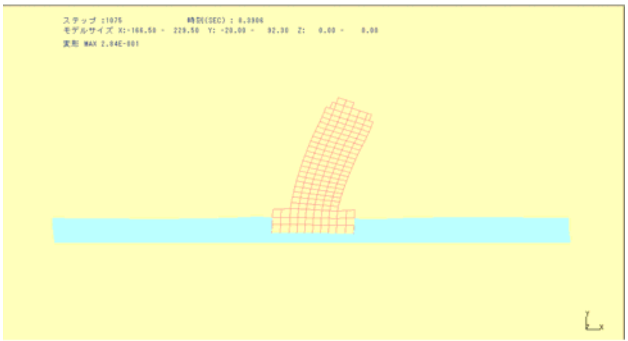

Figure 3-10 Displacement of the Structure/Kobe