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EFFECTS OF LOCAL SOIL CONDITIONS ON EARTHQUAKE DAMAGES

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A b s t r a c t

In projecting of structure systems it is necessary to take the interaction between structure-foundation-ground triplets. While designing engineering structures, structure foundation should operate in accordance with the ground as much as possible and should fulfill the design criteria in geotechnical and structural means. Structure-ground interaction should be a non-negligible element of structure design. The local geological soil conditions change the characteristics of surface seismic response. The structural damages after earthquakes have been influenced significantly by local soil conditions. In this study the effects of local soil conditions on earthquake damages have been evaluated. The aim of study was also to evaluate the interaction between soil conditions and structures. In a frame of a common model where ground environment, foundation type and superstructure are taken into consideration together, mutual interaction of ground and structure during earthquake should be taken into account while making the calculations. The other goal of this study is evaluate the impact of local soil conditions on structural design.

Introduction

The seismic risk of stock of buildings is of growing interest for academia as well as for the decision makers due to the increasing urbanization and concentration of populations in earthquake prone and vulnerable areas. Turkey, especially since 1999, is known as one of the most earthquake prone regions in the world. This is somewhat true considering that the most of the country is under earthquake threat.

Damage due to earthquakes generally decreases as a function of distance from the epicentre. However, destructive earthquakes have demonstrated that damage is often more severe over unconsolidated deposits than on rocks. The earthquake engineering community has accepted commonly that soft soils can play a large role in ground motion and must be included in seismic zoning. Since river valleys are often the site of recent alluvial and glacial deposits and also prime locations for the development of urban areas, local amplification is a major concern in earthquake-prone regions. In post-disaster reconstruction, information on soft soil response to large earthquakes becomes of prime importance. San Francisco and Mexico City earthquakes well-known examples for soil problems and many researchers have extensively cited to exhibit the role of soil [8]. In both earthquakes, soft soils have increased the ground shaking and played a major role on damages. The presence of soils, geological sediments and weathered rock can amplify the level of ground shaking experienced during an earthquake. There is not enough data to derive a correlation between topography and amplification. In San Francisco earthquakes (1906 and 1989), in areas with unconsolidated sediments the intensity level increased by 2 units. The seismic waves were amplified in the soft clay basin underneath Mexico City some two hundred kilometres from the epicentre in 1985 during the Guerrero Michoacan earthquake. Some destructive earthquakes such as Northridge (1994), Kobe (1995), Armenia (1999), Colombia (1999) and Turkey (1999) have clearly shown that near-surface geological and topographical conditions play a major role in the level of ground shaking and soft-soil amplification. In the framework of seismic risk study of cities, seismic zoning in urban areas is validated methodology [7],[2]. Horizontal shaking is also the primary cause of damage during most earthquakes since buildings and other structures are considerably more vulnerable to horizontal motion. Silva (1997) states how the horizontal shaking associated with earthquakes can be modelled with vertically propagating shear waves [9]. The one-dimensional wave equation for a vertically propagating shear wave in an elastic medium is where represents the densities of the medium, the vertically directed shear stress, the particle displacement, and the depth and time of observation respectively [5].

Site effects are associated with the phenomenon of the seismic waves travelling into soft soil layers. It is explained firstly by the lower velocity and density between unconsolidated sedimentary layers and the underlying rock. For conservation of energy, this requires larger amplitudes of the seismic waves in the sediments. The shape and frequency content of such waves depends on the geometry and physical properties of the structure. The degree of complexity of predicting a seismic response increases with the complexity of the structure.

In this study the effects of local soil conditions on earthquake damages have been evaluated. The aim of study was also to evaluate the interaction between soil conditions and structures. The other goal of this study is evaluate the impact of local soil conditions on structural design.

Effects of Local Soil Conditions on Structural Design

Earthquake damages will increase according to vulnerability of urban and rural building stocks. The size of earthquakes and the negative structural features will be caused an increase in damage amount. Knowing the properties of buildings that have been negatively influenced to the seismic behavior of buildings under earthquakes will be put forward to ensure more serious approaches to reduce the level of damage risk after earthquakes [3]. Another important issue is also the interaction between ground and structure. Local soil conditions affect directly to building design.

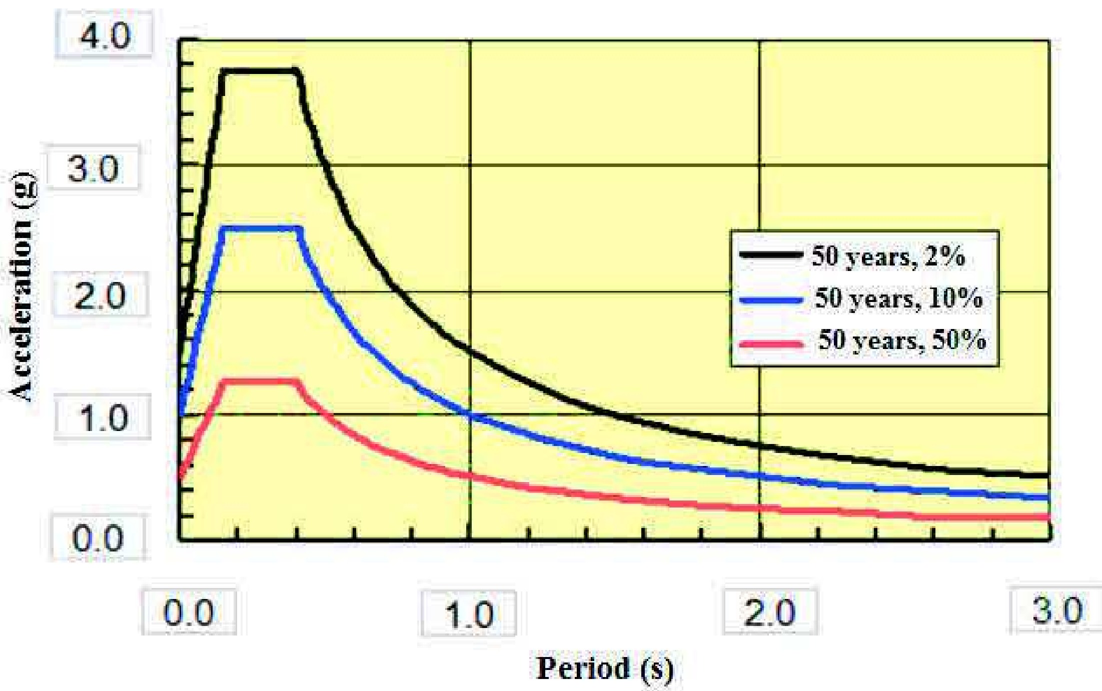
The local geological soil conditions change the characteristics of surface seismic response [1]. One on the important reason of the earthquake damages is local soil conditions. Study on the earthquakes was indicated that structural damages influenced by local soil conditions. Local soil conditions taking into account to create response spectra for earthquake resistant design in earthquake codes.

The demand spectra that were used for determining the performance of buildings systems have shown the maximum response to earthquake ground motion during an earthquake. In performance based design and assessment methods the earthquake demand has been calculated firstly. It was been necessary to determine the structural performance by comparison with these demand values to deformation capacity for the selected performance levels [4],[6] Building evaluations have been done separately for the spectrum which has been obtained from the seismic hazard analysis and for design spectra that has been given in TEC'07 [10].

According to Turkish Earthquake Code (TEC'07), the demand spectra that used for determining the seismic performance of an existing buildings which has been given in Section 2 in the Code is the design spectra (earthquakes which are probability of exceedance of 10% in 50-

year periods).It is noteworthy that, in probabilistic seismic hazard assessment, as a first stage, data from geological studies and records from the instrumental period were compiled to make a seismic source characterization for the study region.

Fig. 1: The earthquake spectrum curves for different exceedance probability



Modal capacity diagrams and response spectra has been obtained for a building. Peak displacement for this building has been calculated due to capacity diagram and response spectra. The displacement demand was calculated by using the equivalent displacement rule given in the TEC'07. Modal capacity diagram which coordinates given as "a (acceleration) – d (displacement) and response spectra which coordinates given as "S_a (spectral acceleration) – S_d (spectral displacement)" have been graphically for each studied building shown in Fig. 2.

Fig. 2a. Modal Capacity – Response Spectra diagrams in the X direction

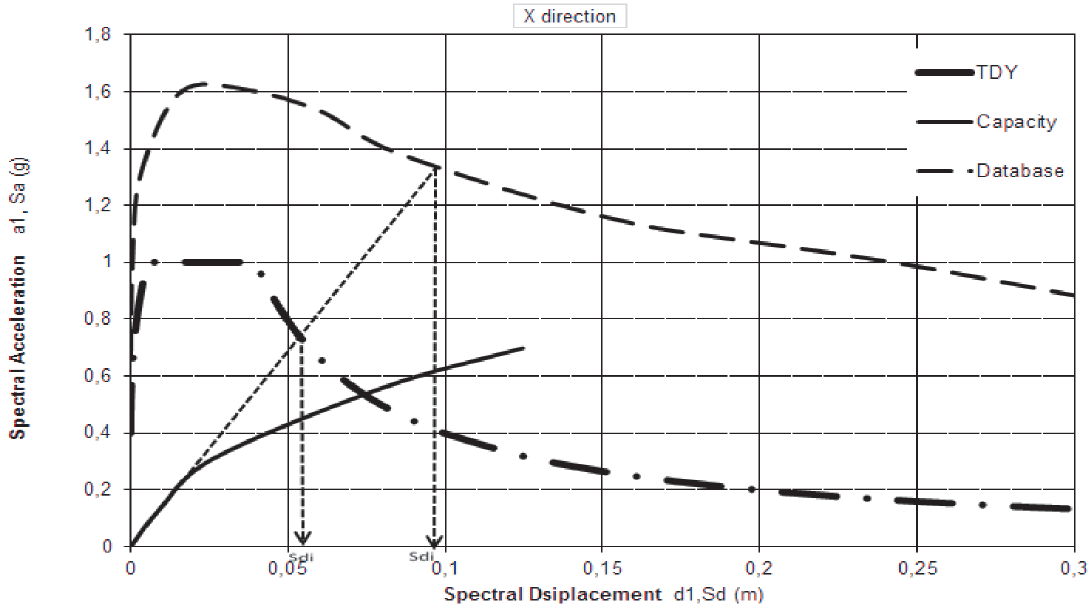
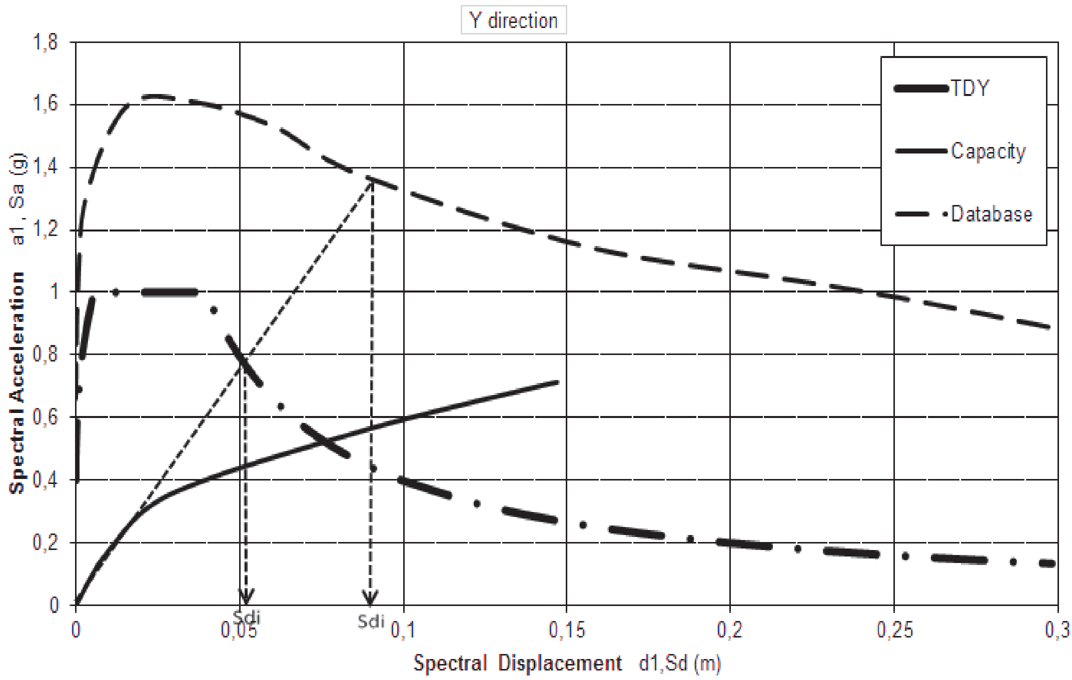


Fig. 2b. Modal Capacity – Response Spectra diagrams building in the Y direction



Building's peak displacements for TEC'07 and the response spectra obtained from this study were given in Table 1.

Table 1. Building's peak displacement for TEC'07 and the response spectra obtained from this study

Building Number	Direction	TEC'07		DATABASE	
		Sde1	*u*N1	Sde1	*u*N1
1	X	0,054	0,071	0,085	0,1169
	Y	0,051	0,065	0,082	0,1095

It has been revealed that there were significant changes in the demand displacement of buildings. As a result of this, damage estimates and determined building performance will more away from the real values for the buildings which unmet the demand displacement. Using specific spectra that obtained from site-specific investigation will be important for earthquake-resistant design of structures. Therefore, site-specific design spectra for the region should be developed, especially for local sites

Results

Knowing the reasons of earthquakes damages are very important in terms of minimizing the possible economic and life losses and taking necessary precautions for before, during and after the earthquakes. Recently modern disaster management was emphasized disaster preparedness but also importance of disaster prevention.

The obtained results are compared with the spectral responses proposed for seismic evaluation and retrofit of building structure in Turkish Earthquake Code, Section 7 and the amplitude and frequency range was different from each other. Peak displacement for this building has been calculated according to demand spectra and capacity diagrams. It has been seen that there were significant changes in the demand displacement of building. As a result of this, damage estimates and determined building performance will more away from the real values for the buildings which unmet the demand displacement. Using specific spectra that obtained from site-specific investigation will be important for earthquake-resistant design of structures.

In projecting of structure systems it is necessary to take the interaction between structure-foundation-ground triplet into consideration and take the effects of deformations caused on ground layers due to loads transmitted to the ground on inner forces and load distribution in foundation element and superstructure load bearing system into account. While designing engineering structures structure foundation should operate in accordance with the ground as much as possible and should fulfill the design criteria in geotechnical and structural means. Ground-structure interaction is generally reduced only to resolution of foundation element. Structure-ground interaction should be a non-negligible element of structure design. Adherence between the ground and the building must be enough. In a frame of a common model where ground environment, foundation type and superstructure are taken into consideration together, mutual interaction of ground and structure during earthquake should be taken into account while making the calculations.

References

[1] Borcherdt, R. D., 2004. *A theoretical model for site coefficients in building code provisions,* Procs. 13th World Conference on Earthquake Engineering. Vancouer, B.C., Canada, August 1-6.

[2] Büyüksaraç A, Bektaş Ö, Yılmaz H, Arısoy MÖ, (2013). *Preliminary Seismic Microzonation of Sivas city (Turkey) using Microtremor and Refraction Microtremor (ReMi) Measurements*. Journal of Seismology, 17(2), 425–435

[3] Işık, E., (2014).*The Effects of 23.10.2011 Van Earthquake on Near-Field and Damaged on Structures*. International Anatolia Academic Online Journal, Scientific Science, 2(2), 10-25

[4] Işık, E., Kutanis, M., Bal, İ., E., (2015). *Displacement of the Buildings According to Site-Specific Earthquake* Spectra. Periodica Polytechnica Civil Engineering 2015,

[5] Kramer, S.L. (1996). *Geotechnical Earthquake Engineering*, Prentice Hall, Inc., Upper Saddle River, New Jersey, 653 pp.

[6] Kutanis, M., Boru, O.,E., (2014), "*The need for upgrading the seismic performance objectives*", Earthquakes and Structures, 7(4), 401-414.

[7] Over, S., Büyüksaraç, A., Bektaş, O. and Filazi, A. (2011). *Assessment of potential seismic hazard and site effect in Antakya*

(Hatay Province), SE Turkey. Environmental Earth Sciences, 62, 313-326.

[8] Rosset, P., de la Puente, A., Chouinard, L., Mitchell, D., and Adams, J., (2002). *Site effect assessment at small scales in urban areas: A tool for preparedness and mitigation*, in Proceedings, "Improving Post-disaster Reconstruction Strategies in Developing Countries" Conference, May 23–25, 2002 , IF Research Group, Université de Montréal, Montreal, Quebec.

[9] Silva, W., (1997). *Characteristics of vertical strong ground motion for applications to engineering design*. In: Proceedings of the FHWA/NCEER Workshop on the National Representation of Seismic Ground Motion for New and Existing Highway Facilities, Technical Report NCEER-97- 0010, National Center for Earthquake Engineering Research, Sate University of New York at Buffalo, Buffalo, New York, pp. 205–252.

[10] Turkish Earthquake Code, (2007), Turkish earthquake code-specification for structures to be built in disaster areas, Turkey