00249-LT

7th International Conference on Seismology & Earthquake Engineering
18-21- May 2015

EVALUATION OF SEISMIC RESPONSE OF COMPLICATED UTILITY TUNNELS BY SHAKE TABLE TESTING

Ali DERAKHSHANI
Assistant Professor, Shahed University, Tehran, Iran
adera@shahed.ac.ir

Ikuo TOWHATA
Professor, University of Tokyo, Tokyo, Japan
towhata@geot.t.u-tokyo.ac.jp

Keywords: Utility Tunnel, Shaking Table Test, Lifelines Geometry, Underground Concrete Wall

Preserving the serviceability of infrastructures is extremely important for recovery of metropolises after earthquakes. Embedded lifeline structures including different types of utilities, are the main part of modern cities infrastructure. In addition, it is essential to ensure the performance of the associated operational facilities.

Hashash et al. (2001) reported the response of underground structures during several major earthquakes. It is concluded that the underground facility might be damaged during earthquake, in case, seismic loading has not been considered in the design process.

Since tunnel is completely surrounded by soil, interaction between soil and structure is an effective issue in determining tunnel behavior during earthquake events. Hence, pipe deformation according to ground motion caused by seismic waves is more important than the inertia loading of the pipe (Colton et al., 1982).

Several tests were conducted on scaled lifeline models to investigate the response of utility tunnels with straight, elbow and T branch connections under input cyclic excitation. The buried pipes were instrumented to quantify their response to the imposed static and dynamic loads.

Container of the model ground was a box with overall dimensions of 2.00 m long, 2.00 m wide and 0.60 m high. Shock absorbers were placed on the walls of the box to reduce the wave reflection. Toyoura sand was used to make the model ground. Properties of Toyoura sand including specific gravity, minimum & maximum void ratios and mean particle size are presented in Table 1. Four layers of the soil were compacted uniformly to achieve the relative density of 70%.

Table 1. Properties of Toyoura sand

Gs (g/cm^3)	e_{min}	e_{max}	D_{50} (mm)
2.648	0.605	0.974	0.21

The tunnel models were made of several Polyethylene (PE) pipes with the length of 0.5 m. The outer diameter of tunnel is 0.042 m and the thickness is 0.0039 m. In addition, PE connections were used to join the pipes. Connection parts include three types: straight (with the angle of 180º), elbow (with the angle of 90º) and T branch. PE pipes were connected to the joint, so, perfect connections with the same quality were provided for variety of tests. The structure models were constructed with a geometrical scale of 1:30 using simulation rules for shaking table tests proposed by Iai (1989).

Figure 1 provides the plan views of the tests considered in P-Y curve study. P-Y curve slope (K = subgrade reaction modulus) versus soil shear strain amplitude (γ) is illustrated in Figure 2. In this figure, data is related to the input motions of 500 and 700 Gal for different tunnel models. As can be seen, stronger shaking leads to the increase of strain amplitude and decrease of subgrade reaction modulus. These are consistent with the development of soil nonlinearity.

Comparing the data of tunnels “C & D” with that of “H & G”, it can be concluded that T branch model has lower “γ” (and more or less higher “K”) in contrast to the model with straight joint.

In fact, in case of T branch model, higher joint mass and presence of an extra tunnel reduce the strains in contrast with the model that includes straight joint.

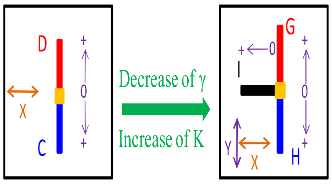

Figure 1. Plan views of the tests for P-Y calculations

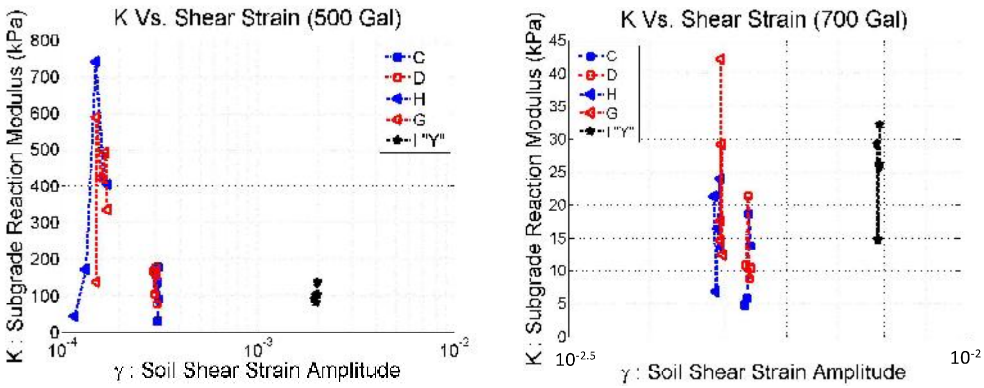

Figure 2. P-Y curve slope versus soil shear strain amplitude

It is inferred that two tunnels of T branch (with 180º angle in between) show lower "γ" and higher "K" in contrast to straight model. It is due to lower displacement (Y) of T branch model caused by its higher weight and also different geometry i.e. presence of an extra tunnel.

REFERENCES

Colton JD, Chang PHP and Lindberg HE (1982) Measurement of dynamic soil-pipe axial interaction for full-scale buried pipelines, *Soil Dynamics and Earthquake Engineering*, 1(4): 183

Hashash YMA, Hook JJ, Schmidt B and Yao JC (2001) Seismic design and analysis of underground structures, *Tunnelling and Underground Space Technology*, 16: 247-293

Iai S (1989) Similitude for shaking table tests on soil–structure-fluid model in 1g gravitational field, *Soils and Foundations*, 29(2): 52-68