Design Hints for Buried Pipes to Resist Effects of Blast

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ABSTRACT

Due to complexity in the formulation and solution of basic equations of motion for structures of complicated shapes subjected to transient pulse, response of underground structures due to blast loads could be effectively studied through modeling using Abaqus numerical code. Consequently, in the analysis and design of underground structures specifically pipes to resist the effect of blasts, geotechnical and material properties are required. These properties as revealed by several researchers, investigators and pipe manufacturers are used in this study. Using Unified Facilities Criteria (2008) for surface blast, internal explosion and empirical method for underground blast for commonly used explosives at various stand-off points, acceleration, seismic velocities, arrival time, etc for soils were determined. Correlation of blast and earthquake high-lighted and possible methods of burial of pipes also presented.

1. INTRODUCTION

Buried pipes are used for services like water supply, drainage, sewerage, oil and gas supply, etc. Due to huge investment in the construction of these structures, there is need to study their responses due to blast and natural earthquakes most especially where it is laid across the road or directly underneath multi-storied buildings. Blast can create sufficient tremors to damage sub-structures over a large area. This lead to loss of lives and property, in the industries, it causes disruption in production, collapse of buildings, etc (Olarewaju et al. 2010 & Olarewaju 2008).

2. METHODOLOGY

Response of underground pipes due to internal explosion, underground and open trench blasts was studied using finite element based numerical code, Abaqus. Using UFC (2008), blast energies in different sizes of pipes and ground movement parameters for surface blast were estimated while using empirical method for underground blast; ground movement parameters were estimated. Response of modeled steel and concrete pipes buried in loose sand, dense sand and undrained clay at different dept were examined. A total of 15 models were analyzed for the internal explosion while 150 models were analyzed for underground and open trench blasts respectively. Time integration technique of finite difference and finite element in Abaqus numerical code was used to solve Eq. 1 (Abaqus User’s Manual 2009, Ganesan 2000 & Kameswara 1998). Classes of blast applicable to buried pipes are underground, open trench, internal explosion and surface blasts (Olarewaju et al. 2010).

3. RESULTS AND DISCUSSION

The results are graphically presented below.
Under the impact of surface static pressure, for elastic linear response, for no slip condition using Abaqus program, at H/D = 1, the crown displacement at H/D=1 is 1.307 times that of crown displacement at H/D=2. The maximum horizontal spring-line response in terms of pressure, displacement, maximum principal strain and mises for H/D=1 is 1.2385 times that of maximum horizontal spring-line response for H/D=2 (Olarewaju et al. 2010). This agrees with the conclusions of Roanaki (1997) using SAP program.
In the case of internal explosion, as the thickness of steel and concrete pipes reduces, time history generated as a result of internal explosion increases in the same proportion while as the diameter of pipes increases, blast parameters (i.e. side-on overpressure, peak reflected pressure, etc) reduces. In addition, depth of burial of pipes showed no significant changes in the time history of energies generated due to internal explosion (Fig. 3), while stress components on the ground surface reduced as the embedded ratio of pipes increases (Olarewaju et al. 2010). Furthermore, pressure changes from negative to positive within the soil medium due to dilations and compressions caused by transient stress pulse of compression wave while velocity, displacement and stresses reduces as it approaches the ground surface. The reduction is more in loose sand due to arching effect. In order for earth arching to occur, the pipe must be: above the water table, cannot be laid in water saturated soil, buried in granular soil, or, the site must be backfilled with granular soil, the depth of earth covering above the pipe must be substantial, at least one-half of the minimum span of the pipe, and be flexible enough to yield under applied load. Consequently, for a period of 0.025s the velocity on the soil surface is higher than that produced by San Fernando earthquake of 1971 which got to the peak at 13s. In underground blast, the ratio of peak particle displacement for all soils to that of saturated clay is 0.135. In addition, ground movement parameters (Fig. 1) obtained for the stand-off distances of up to 100m indicates that the zone of influence of underground blast is relatively small compared to that of surface blast (Fig. 2). Consequently, energy impulse as it travels from internal explosion in buried pipes as well as underground and open trench blasts decreases by three dimensional dispersion of blast energy and due to energy dissipation (Olarewaju et al. 2010). Displacement in pipes due to underground blast is the same irrespective of the burial depth and material properties but higher compared to that obtained in trench blast. This is because, as the peak particle velocity travels within the soil medium, it transmits the load bodily to the buried pipes along the direction of travel. Unlike open trench blast, the wave energies only impeaches on the side of the open trench. Reduction in all the parameters in underground blast is noticeable at pipe embedded ratios of 3 and 4. Conversely, in open trench blast, virtually all the parameters–displacement, pressure, etc reduces at embedded ratios of 3 beyond which no significant changes occurred (Figs. 4, 5, 6, and 7).

4. CONCLUSIONS

This paper has highlighted the categories of blast applicable to buried pipes. Essential ground movement parameters for internal explosion, underground and open trench blasts were estimated for various stand-off distances. Time
histories for internal explosion were obtained while responses of buried pipes due to underground and open trench blasts were obtained at different embedded ratios. Numerical methods in ABAQUS code were used in solving dynamic equation of motion. Other software packages like ANSYS, FLAC 2000, etc could suitably be used to study linear and non-linear response of underground structures due to dynamic loads (Olarewaju et al. 2010).

5. EQUATIONS

The governing dynamic equation of motion is

\[ \begin{bmatrix} m \end{bmatrix} [\ddot{U}] + [c][\dot{U}] + [k][U] = [P]; \quad \text{for } U(t = 0) = U_o, \text{ and } \dot{U}(t = 0) = \dot{U}_o = v_o \]  

(1)

where m, c, and k are element mass, damping and stiffness matrices, t is the time, U and P are displacement and load vectors and dots indicate their time derivatives.

ACKNOWLEDGEMENTS

The project is funded by Ministry of Science, Technology and Innovation, MOSTI, Malaysia under e-Science Grant no. 03-01-10-SF0042.

REFERENCES


