International Conference on Ground Improvement and Ground Control (ICGI 2012),
30 Oct. – 2 Nov. 2012, University of Wollongong, Australia
B. Indraratna, C. Rujikiatkamjorn and J S Vinod (editors)

SEISMIC BEHAVIOUR OF GEOSYNTHETIC REINFORCED MUNICIPAL SOLID WASTE LANDFILLS

L.GOVINDARAJU[1], E.V. CHANDEESHA[2] , K.V.S.B. RAJU[3] and B.P. NAVEEN[4]

[1] Associate Professor, Department of Civil Engineering, University Visvesvaraya College of Engineering, Bangalore University, Jnanabharathi Campus, Bangalore – 560 056, INDIA,*
Email: lgr_civil@yahoo.com
[2] Lecturer, Department of Civil Engineering, East West College of Engineering, Bangalore. INDIA
Email: chandishaev@gmail.com
[3] Assistant Professor, Department of Civil Engineering, University Visvesvaraya College of Engineering, Bangalore University, Jnanabharathi Campus, Bangalore – 560 056, INDIA,
Emil:kvsbraju.2007@gmail.com
[4]Research Scholar, Department of Civil Engineering, Indian Institute of Science, Bangalore – 560 012, INDIA,
Emil:bpnaveen@civil.iisc.ernet.in

Municipal Solid Waste (MSW) is extremely heterogeneous and its properties involve significant uncertainties. MSW landfills are an integral part of waste management and disastrous consequences happen if seismic vulnerability of these landfills is ignored. Therefore, seismic response analysis of municipal solid waste (MSW) landfills is receiving considerable attention these days. This paper presents dynamic response analysis of MSW landfills constructed on different sub soils. One dimensional dynamic response analysis of these landfills has been carried out using the computer code SHAKE2000. Since the seismic response of any structure depends on amplitude of ground motion, the effect of this parameter on the behaviour of MSW landfills are studied. The landfill profiles adopted for this study consists of different components to a height of 30m incorporated with geosynthetic layers as bottom and cover liners. The influence of geosynthetic reinforcements on the performance of these landfills due to dynamic loading is also explored. The results of the study indicate that the amplification of ground motion parameters decreased consistently with the usage of reinforcements. Rock and stiff sub soil strata showed significant reduction in peak ground acceleration and spectral acceleration values at the top of landfill with inclusion of reinforcements where as this reduction is not observed in soft sub soil conditions.

Keywords: Geosynthetics, Landfills, Municipal solid waste, Seismic response

1. Introduction

A landfill is a physical facility which has been specifically designed, constructed and operated for the disposal of waste materials. Earlier the conventional landfill method of disposal accepted as the safe method, later the experiences and studies indicate that the conventional methods of landfill are no longer safe. This is because the landfill results the formation of leachate because of the rainwater coming from the top or fluctuation of ground water at the bottom. The formation of leachate results the groundwater pollution and development of poisonous gases, which can be explosive in nature and cause harm to the health of the people living around. Hence, to avoid these effects, engineered landfills are designed with impervious layers at the bottom and providing a way for the gases to escape from the top of the fill. Today landfills are highly engineered in order to protect the environment and prevent the pollutants from entering the soil and possibly polluting the ground water. Municipal solid waste (MSW) means combined household, commercial and institutional waste material generated in a given area. MSW is extremely heterogeneous and its properties involve significant uncertainties.

For the past few years, increased attention has been placed on the vulnerability of landfills to earthquake-induced deformations. In addition to the overall stability of the landfill waste, the cover and bottom liner systems that protect the surrounding soil and the ground water from potential contamination have to be designed to sustain a seismic event. It is just because, landfills will be affected by seismic activity. The increased tensions in the landfill liner material may lead to tearing due to excessive stretching (Thusyanthan et al., 2007). Also, the top of the landfill may develop cracks thereby causing the gas collection systems to move relative to the cover (Matasovic and Kavazanjian, 2006). As mentioned by Hoe and Leshchinsky (1997) the seismic performance of landfills has been reported for the 1989 Loma Prieta Earthquake by Orr and Finch (1990); Buranek and Prasad (1991); Johnson et al. (1991); Shrarma and Goyal (1991) and the 1994 Northridge Earthquake by Augello et al.(1995) and Matasovic et al. (1995). Minor cracks and displacements related to the movement of cover soil were observed in some of the landfills. Also, major damage was reported for a landfill in which geomembrane was torn.

2. Geometry of Landfill and Site Conditions

In the present study the landfill cross section adopted by Yegian and Kadakal (1998b). Fig.1 shows the cross section of the landfill considered for the seismic response study. However the height of the landfill chosen for the analysis is 30m. Fig.2 shows the landfill cross section in which geosynthetic reinforcements are converted in to equivalent soil layers. The detailed procedure of evaluating the equivalent soil layers can be obtained from Yegian and Kadakal (1998b).

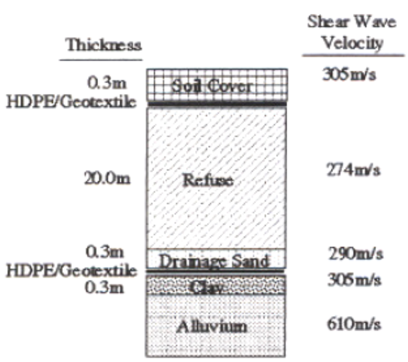

Figure 1. Cross section of landfill with geosynthetic reinforcement (Yegian and Kadakal,1998)

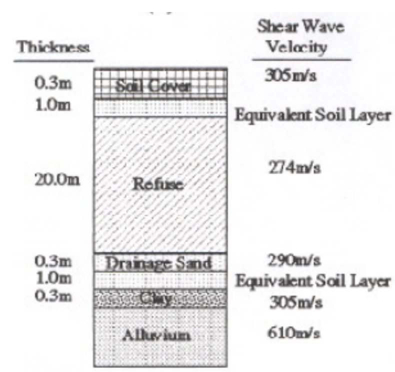

Figure 2. Representation of geosynthetic material with equivalent soil layers (Yegian and Kadakal, 1998)

In order to study the effect of various sub soil conditions on the seismic response of a landfill model landfills are selected considering various site conditions as per International Building Code 2006 classification. The depth of the subsoil layer chosen beneath the landfill is 30m.

Table 1 shows the average shear wave velocities and unit weights for a depth of 30m adopted for different sites. Fig.3 illustrates typical landfill cross section resting on sub soil (site class A).

Table 1: Average Shear Wave Velocity and Unit weights

Site Class	Shear wave velocity, V_s (m/s)	Unit weight, γ (kN/m^3)
Class A	1600	25
Class B	1000	22
Class C	500	19
Class D	200	18
Class E	100	16

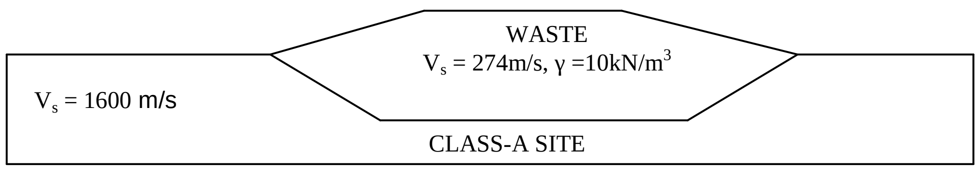

Figure 3. Geometry and properties of the landfill involving the subsoil

3. Seismic Response Analysis

Seismic response analysis of the selected landfills with and without geosynthetic reinforcements have been carried out using computer program SHAKE2000 (Schnabel et al.,1972) employing earthquake ground motions recorded during 2001 Bhuj earthquake in India. Fig.4 shows the time history of accelerations having peak acceleration of 0.104g. The peak acceleration was scaled in the range of 0.1g to 0.4g to study the effect of amplitude of ground motion on the seismic response of the landfills. For dynamic analysis, the required dynamic properties were selected for different materials. For sandy soils, rock and clay as per Seed & Idriss (1970), Schnabel (1973) and Vucetic and Dobry (1991) respectively. The dynamic properties of solid waste and geosynthetic liners were selected from Kavazanjian and Matasovic (1995) and Yegian & Kadakal (1998a & 1998b) respectively.

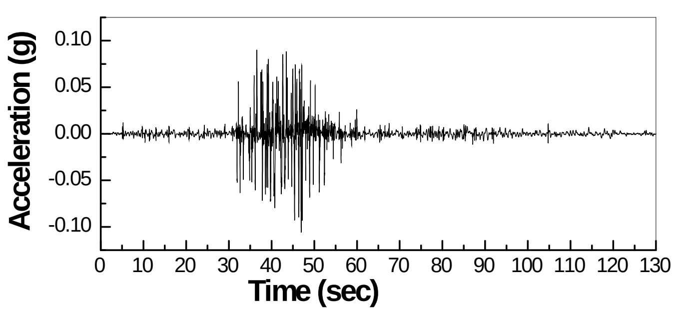

Figure 4. Strong motion record during 2001 Bhuj earthquake

4. Results and discussion

4.1 *Peak Ground Acceleration*

Fig.5 shows variation of peak ground acceleration (PGA) from the subsoil to top of landfill both for unreinforced (URF) and reinforced (RF) landfill profiles corresponding to 0.1g amplitude. It is observed that PGA has decreased from 0.25g to 0.197g by the inclusion of geosynthetic reinforcements. Table 2 shows comparison of PGA values for 0.1g to 0.4g at the top of landfills both for unreinforced for different sites. It can be noticed from Table 2 that as the input acceleration increases significant amplification of acceleration occur both in case of unreinforced and reinforced landfills for stiffer strata (site class A to C). However, such amplification of acceleration is reduced drastically in case of reinforced case compared to unreinforced landfills. Further, it is observed that for softer soils (site class D and E) the input motion gets attenuated significantly.

4.2 Spectral Acceleration

Fig. 6 shows spectral acceleration at the top of landfill at different period. At low amplitude (0.1g) there is no significant variation in spectral accelerations both for reinforced and unreinforced landfills for site class A. Table 3 illustrate the comparison of spectral accelerations for different cases. It is observed that the spectral acceleration values reduced with the usage of geosynthetic reinforcements in the landfill profiles when subsoil conditions were stiffer (class A to class C) beyond 0.1g amplitude. Further, softer soils (class D and class E) showed higher values when reinforcements were included in the profiles.

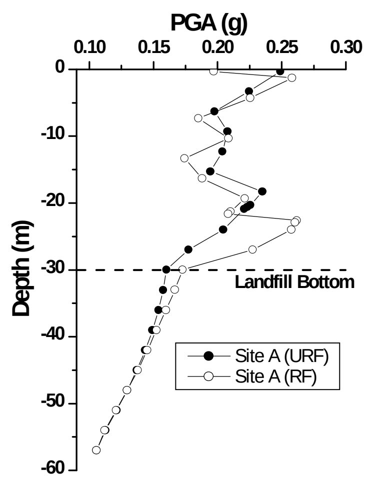

Figure 5. Variation of PGA for 0.1g input acceleration

4.3 Amplification Ratio

Fig. 7 illustrates the variation of amplification ratio (A) at the top of landfill for site class A. Significant reduction in amplification of ground motion parameters can be noticed when the landfills are reinforced with geosynthetics. Table 4 shows the comparison of amplification ratio for different cases. Usage of reinforcements in the landfill profiles reduces the amplification values considerably except for some minor variations in class D and E sites.

Table 2: Variation of Peak Ground Acceleration

Site	0.1g		0.2g		0.3g		0.4g	
	URF	RF	URF	RF	URF	RF	URF	RF
Class A	0.250	0.197	0.483	0.362	0.609	0.410	0.712	0.445
Class B	0.327	0.235	0.601	0.388	0.759	0.410	0.881	0.446
Class C	0.396	0.313	0.612	0.373	0.743	0.399	0.845	0.454
Class D	0.087	0.093	0.108	0.123	0.123	0.140	0.150	0.178
Class E	0.043	0.044	0.043	0.048	0.056	0.060	0.075	0.086

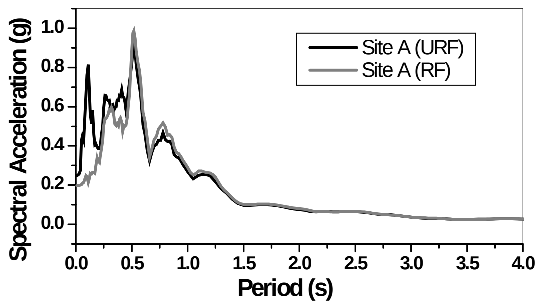

Figure 6. Variation of spectral acceleration for 0.1g amplitude

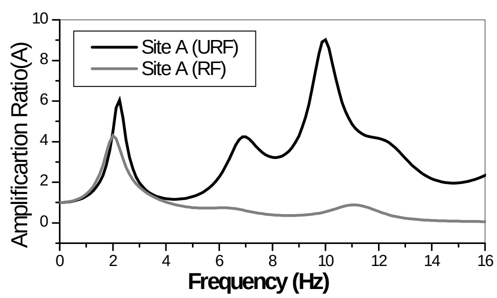

Figure 7. Variation of Amplification ratio for 0.1g amplitude

Table 3: Variation of spectral acceleration

Site	0.1g		0.2g		0.3g		0.4g	
	URF	RF	URF	RF	URF	RF	URF	RF
Class A	0.91	0.99	1.721	1.602	2.058	1.89	2.478	2.132
Class B	1.145	1.086	1.789	1.64	2.092	1.961	2.666	2.11
Class C	1.625	1.282	2.526	1.718	3.204	2.016	3.662	2.064
Class D	0.274	0.274	0.322	0.383	0.386	0.441	0.479	0.558
Class E	0.130	0.151	0.153	0.170	0.164	0.201	0.238	0.29

Table 4: Variation of Amplification ratio

Site	0.1g		0.2g		0.3g		0.4g	
	URF	RF	URF	RF	URF	RF	URF	RF
Class A	9.01	4.29	4.87	3.79	3.65	3.15	3.31	2.30
Class B	9.81	4.61	6.13	3.94	5.43	3.17	4.61	2.32
Class C	6.87	5.58	5.35	4.24	4.58	2.95	4.13	2.62
Class D	3.09	3.05	2.39	2.72	2.58	2.61	2.26	2.41
Class E	3.37	2.96	2.35	2.78	1.76	1.63	1.73	1.63

5. Concluding Remarks

Based on the results of the present study on both unreinforced and reinforced MSW landfills, it is observed that when input motions were applied at the base of the subsoil of reinforced profiles, (Class A to Class C) significant reductions in the peak ground acceleration and spectral acceleration values are observed even for low amplitudes such as 0.1g and 0.2g. This behavior can be attributed to the higher stiffness of the foundation soils which amplifies the input motion. These amplifications are considerably minimized with the usage of geosynthetic reinforcements even for smaller amplitudes. However, when landfills are resting on relatively soft soils (Class D and Class E) the incorporation of geosynthetics in to the landfill profile does not make any significant variations in peak ground acceleration, spectral acceleration and amplification values. This is due to the fact that the differences in the stiffnesses of subsoil and landfill structure are relatively small.

References

Augello Anthony J., Matasovic Neven, Bray Jonathan D., Kavazanjian Edward and Seed Raymond B (1995). *Evaluation of Solid Waste Landfill Performance During The Northridge Earthquake*, *ASCE, Geotechnical Special Publication,* No.54, Edited by Mishac K. Yegian and W.D. Liam Finn.

Bye Hoe I. Ling and Dov Leshchinsky (1997). *Seismic stability and permanent displacement of landfill cover system*", *J. Geotechnical and Geoenvironmental Engrg*, 123(2): 113-122.

Kavazanjian Jr., E and Matasovic, N (1995). *Seismic analysis of solid waste landfills, Geoenvironmental 2000, Geotechnical Special Publication,* and No.46. ASCE, New York, N.Y.

Matasovic, N.; Kavazanjian Jr., E. (2006). *Seismic Response of a Composite Landfill Cover. J. Geotechnical and Geoenvironmental Engrg,,* 132(4): 448-455.

M. K. Yegian, J. N. Harb, and U. Kadakal (1998a). *Dynamic response analysis procedure for landfills with geosynthetic liners. J. Geotechnical and Geoenvironmental Engrg,* 124(10), Paper No. 16464

M.K.Yegian U. Kadakal (1998b). *Seismic Response of Landfills with Geosynthetic Liners, J. Geotechnical and Geoenvironmental Engrg*, 154(25), Paper No. 18454.

Matasovic, N.; Kavazanjian Jr., E; Augell, A.J; Bray, J.D and Seed, R.B (1995). *Solid waste landfill damage caused by 17 January 1994 Northridge Earthquake, The Northridge, California, Earthquake of 17 january 1994*, M.C. Woods and W.R. Seiple, eds., California Dept. of Conservation, Div. of Mines and Geology.

Thusyanthan, N.I.; Madabhushi, S.P.G.; Singh, S. (2007). *Tension in Geomembranes on Landfill slopes Under Static and Earthquake Loading - Centrifuge Study, Geotextiles and Geomembranes,* 25: 78-95.