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In-situ assessment of the dynamic properties of municipal solid waste at a landfill in texas

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ABSTRACT

An understanding of dynamic properties of Municipal Solid Waste (MSW) is essential for seismic response analysis of MSW landfills in areas of moderate to high seismicity. A field testing program aimed at characterizing the dynamic properties of MSW was executed at two locations in a Subtitle D landfill in Austin, Texas. Shear and primary wave velocities were measured using small-scale crosshole and downhole seismic tests. The combination of these seismic methods allowed an assessment of the effect of waste composition on dynamic properties, anisotropy, and Poisson's ratio of the MSW. In addition, steady-state dynamic testing was performed using two mobile vibroseis shakers to evaluate in-situ the nonlinear relationship between shear modulus and shearing strain. Horizontal steady-state shaking at increasing stress level generated shearing strains from 0.001% to 0.2% allowing evaluation of shear modulus reduction curves over a wide shearing strain range. The effect of confining stress on the dynamic properties of the MSW was also evaluated using the substantial weight of the vibroseis as reaction to apply surcharge vertical loads at the surface of the MSW.

1. Introduction

An understanding of the dynamic properties of Municipal Solid Waste (MSW) is essential for seismic response analysis of MSW landfills in areas of moderate to high seismicity. The required dynamic properties include small-strain shear wave velocity (V_s) (or the associated small-strain shear modulus, G_{max}), small-strain material damping (λ), and normalized shear modulus (G/G_{max}) reduction and material damping increase as a function of increasing shearing strain amplitude (γ). G_{max} and V_s are related by

$$G_{max} = \rho V_s^2 \tag{1}$$

where ρ is the total mass density of the MSW. The total mass density of MSW is an important input parameter in seismic analyses and Poisson's ratio (ν) is also needed in two-dimensional site response analyses.

Numerical investigation and laboratory testing have been performed by various researchers to assess the nonlinear dynamic properties of MSW. Numerical investigations involved the back calculation of the seismic response of instrumented landfills. Examples include the studies performed for the Operations Industries Inc. (OII) hazardous landfill in Monterey Park, California [1–3]. Back-calculation of properties using this approach implemented at the OII landfill has limitations. The ground motions recorded at the landfill and considered in the analysis were generally low with the highest peak horizontal acceleration recorded at the base of landfill being on the order of 0.1 g. In addition, significant differences were observed on the back-calculated normalized shear modulus reduction and damping curves recommended in the cited studies.

Large-scale laboratory testing of MSW has also been used to evaluate the dynamic properties of MSW [4–7]. Laboratory testing involves the reconstitution of MSW specimens because "undisturbed" sampling of MSW is not feasible. Apparatus and specimens need to be of relatively large size to accommodate the large size waste particles [6]. Recovery of waste samples is burdensome and poses health and safety risks. Furthermore, preparation and testing requires significant effort and specialized equipment.

Field measurements typically involve direct measurements of V_s at small strains primarily using surface wave methods [2,8–10]. Mass density of the MSW is often measured using an in-situ replacement method [2,11].

The results of an in-situ testing program performed on MSW in which V_s and primary wave velocity (V_p) were measured at small

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strains and the shear modulus reduction curve as a function of increasing shearing strains are presented. The directions of wave propagation and particle motion of V_s and V_p waves were varied allowing an in-situ assessment of waste anisotropy and Poisson's ratio.

2. Procedure

2.1. Test site, general test procedure, and test setup

Field tests were performed at two locations within the Austin Community Landfill (ACL) in Austin, Texas (USA), a Subtitle D landfill. Location #1 was at a cell with waste up to 3 years old and location #2 was at an older cell with waste age ranging from 2 to 8 years. At each location, small-scale crosshole and downhole seismic tests were performed at a range of externally applied static vertical loads. The term "Small-scale" is used to differentiate the crosshole and downhole seismic tests performed in this study from conventional crosshole and downhole seismic tests which are typically performed at greater depths and larger borehole spacings. Steady-state dynamic testing at larger shear strains was then implemented using the vibroseis and methodology proposed by Stokoe et al. [12,13]. Upon completion of all testing, pits were excavated at each test location to recover bulk samples of waste by the method proposed by Zekkos et al. [14] and to recover buried sensors. Unit weight of these MSW samples was evaluated by a method proposed in Zekkos et al. [11] that included pit volume assessment by gravel replacement. Bulk samples of the MSW from the pits were collected in 55-gallon drums for transport to the laboratory and for further testing and characterization. The results of waste characterization and unit weight measurements are presented in Table 1. The gross in-situ unit weight was 14.9 kN/m^3 and 15.6 kN/m^3 in locations #1 and #2, respectively. Waste composition was characterized using the collected bulk samples separately for each testing location. It should be noted that although the samples collected from the pit at each location contained significant amounts of waste material (i.e. 2.2–5.8 kN), these samples represent only a portion of the waste mass involved in the tests performed in the field. Thus, the waste compositions shown in Table 1 are only approximately representations of the waste tested.

Testing configurations for each location are shown in Fig. 1. A 0.91-m diameter, 0.23-m thick, reinforced, prefabricated concrete foundation was placed on thin soil cover overlying the waste. Each configuration included two vertical arrays of three-component geophones embedded in the waste below the concrete foundation at four different depths up to a maximum depth of about 1 m. Sensors at greater depth will not be subjected to the same high level strain amplitudes as the shallower sensors. In addition, using the vibroseis for dead weight reaction as proposed by Stokoe et al. [12,13], the effect of confining stress was investigate in-situ and

Table 1
Waste composition at two testing locations at the Austin Community Landfill.

Total sample weight (kN)	Unit weight (kN/m^3)	Composition (% by weight)							
		< 20m m[a]	Paper	Hard plastic	Soft plastic	Wood	Metal	Gravel and glass	Others[b]
5.8	14.9	92.1	3	1.2	1.1	0.9	0.8	0.0	1.0
2.2	15.6	79.4	7.4	3.2	3.4	3.2	0.0	0.0	3.4

[a] Soil-like material with organic contents ~8%.
[b] Textile, rug, latex, rubber, food remnant, and sponge.

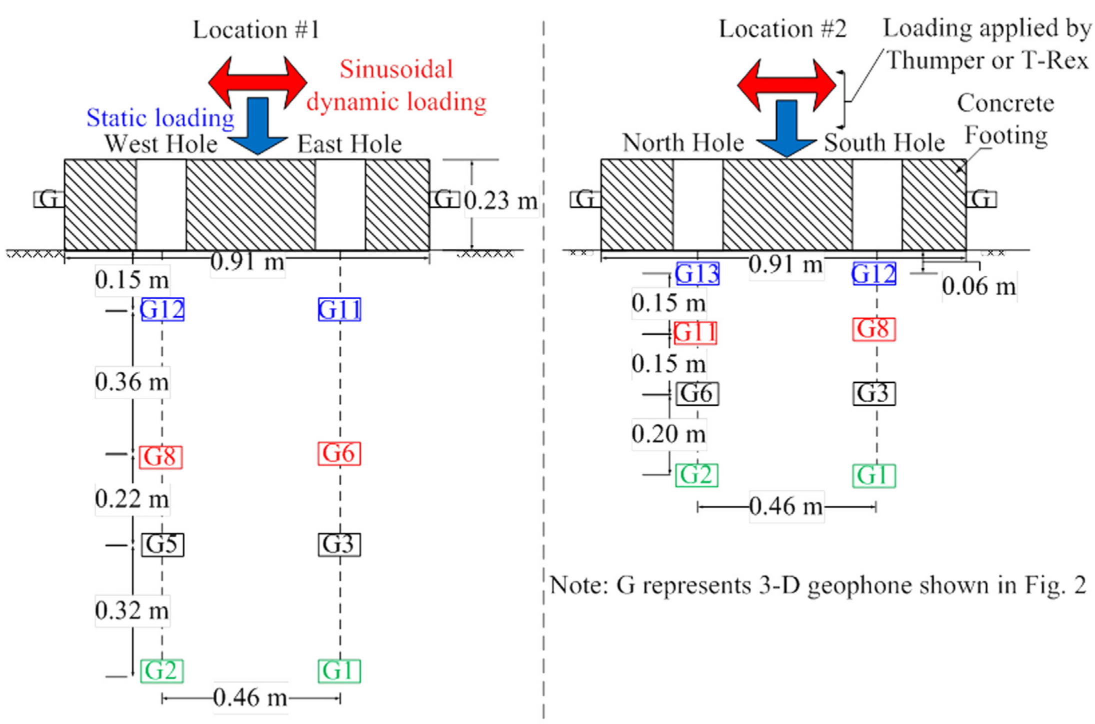

Fig. 1. Testing setup at each location.