Amirkabir Journal of Civil Engineering

Amirkabir J. Civil Eng., 50(5) (2018) 295-298
DOI: 10.22060/ceej.2017.12930.5293

Evaluating the Effect of Fiber Content on the Shear wave Velocity and Small-strain Shear Modulus of Municipal Solid Waste Using Bender Element (BE)

M. Keramati[1*], H. Torabi[2], P. Alidoust[2], N. Shariatmadari[2]

[1] Faculty of Civil Engineering, Shahrood University of Technology, Shahrood, Iran
[2] Department of Civil Engineering, Iran University of Science and Technology, Tehran, Iran

ABSTRACT: During the past years researchers have conducted a number of comprehensive in-situ and laboratory tests on municipal solid waste (MSW). Following these investigations, for the purpose of measuring shear wave velocity and small-strain shear modulus a set of bender element device mounted on cyclic triaxial test apparatus located in Iran University of science and technology was employed. Tests were conducted on medium-sized samples of fresh MSW in order to primarily evaluate the influence of fiber content (fiber contents of 0, 3 & 6 %), confining stress (75, 150 & 300 kPa confining stress) and unit weight (9 & 12 kN/m3) on shear wave velocity and small-strain shear modulus. The influence of fiber content on movement of shear wave velocity was observed using bender element tests. Although increasing the fiber content of MSW samples caused a higher shear wave velocity, the energy of received wave by bender element device had lower magnitude this could be attributed to lower capacity of plastic fibers to transmit the wave, however the increased shear wave velocity of samples with greater fiber content could be attributed to higher compaction effort. It is considerable that the effect of fiber content is more significant under higher confining stress.

Review History:

Received: 28 May 2017
Revised: 1 July 2017
Accepted: 9 November 2017
Available Online: 9 December 2017

Keywords:

Municipal Solid Waste
Small Strain Shear Modulus
Bender Element Test
Fiber Content

1- Introduction

During the past two decades the dynamic properties of MSW have been the subject of many investigations [1-4]. Small strain shear modulus is one of the key inputs in state-of-the-practice equivalent linear seismic analysis of landfills [5]. Furthermore the heterogeneous nature of municipal solid waste makes it imperative to investigate all the characteristics of these material for each landfill.

One of the most popular approaches in evaluation of small strain shear modulus, is the relationship between small strain shear modulus, shear wave velocity (V_s) and density of soil (ρ). This relationship is from elasticity theory:

$$G_{max}=\rho V_s^2 \quad (1)$$

Where V_s represents shear wave velocity and ρ represents mass density of material [6].

A large number of investigations has been done on shear wave velocity of MSW so far [3, 7, 8]. Many of these investigations has been done under in-situ conditions [8, 9]. This paper presents the results of bender element test on municipal solid waste. Successful employment of bender element test device on fresh municipal solid waste with fiber content has been unprecedented.

Corresponding author, E-mail: Keramati@shahroodut.ac.ir

2- Methodology

A series of bender element tests were performed on medium-sized cylindrical samples (100*100 mm) reconstituted from fresh MSW samples retrieved from Kahrizak landfill located on the outskirts of Tehran, Iran. The bender element device was mounted on cyclic triaxial apparatus for the purpose of consolidation and inducing the isotropic pressure condition before the soundings.

In this paper the influence of fresh waste composition, confining pressure and unit weight on shear wave velocity and small strain shear modulus has investigated. The effect of waste composition was investigated through compacting reconstituted fresh samples with three different fiber contents (0%, 3% and 6%, by weight). Samples were prepared following the same procedure used by Keramati et al. (2017) [10]. The effect of unit weight was studied for samples with 9 and 12 kN/m^3. Fresh MSW Samples were consolidated under isotropic condition. Confining pressures of 75, 150 and 300 kPa were induced to all the samples with different composition to investigate the influence of this factor. In Kahrizak landfill due to the poor leachate collection system and almost impermeable underlying soil, the moisture content is quite high. Thus Bender element tests were performed on saturated samples. Samples were saturated and consolidated prior to bender element test in accordance with ASTM D4767 [11]. Table 1 summarizes the tests performed in this research. It is notable that each test has been repeated at least in 4 frequencies to reach the best response.

Table 1. Summary of conducted tests

Unit weight (kN/m^3)	Confining pressure (mPa)	Fiber content (% by weight)
9	75	0
9	150	0
9	300	0
9	75	3
9	150	3
9	300	3
9	75	6
9	150	6
9	300	6
12	75	0
12	150	0
12	300	0

Measuring shear wave velocity using Bender element test has a very simple principle. The distance between two tips of bender element transducers (L_{tt}) divided by the arrival time of shear wave (t), equals the shear wave velocity. However, there are a number of factors that affects the results of bender element test: (a) aspect ratio effect, (b) geometry effect, (c) boundary effect and finally one of the most important factors is (d) the arrival time identification method. Currently, three different methods are being used for identification of arrival time: (1) time domain method (TD) (2) cross-correlation (CC) (3) frequency domain (FD). The use of time domain method is more widespread than other method. This can be attributed to the simplicity and accuracy of this method. Some researchers has stated that the frequency domain method is more accurate. On the other hand Chee-Meng (2011) compared these three methods and concluded that the visual picking of time domain method can be equally reliable [12].

$$V_s=L_{tt}/t \quad (2)$$

In addition to bender element tests a series of tests were conducted to evaluate the physical properties of fresh [1]MSW from Kahrizak landfill. Unlike the dynamic properties of Kahrizak MSW, physical characterization of this material has been evaluated by many researchers before [2, 13]. Therefore there are strong bases regarding these parameters. This paper has presented the result of physical characterization of MSW including waste composition, moisture and organic content. The methodology in Physical characterization of waste samples were derived from the process used by Zekkos (2005) and other researchers [6].

1 Municipal solid waste

3- Results and Discussion

3- 1- Physical characterization

Figure 1 demonstrates the result of waste composition analysis. As it is evident the main part of fresh MSW from Kahrizak landfill consists of organic material (paste), plastic and paper and cardboard.

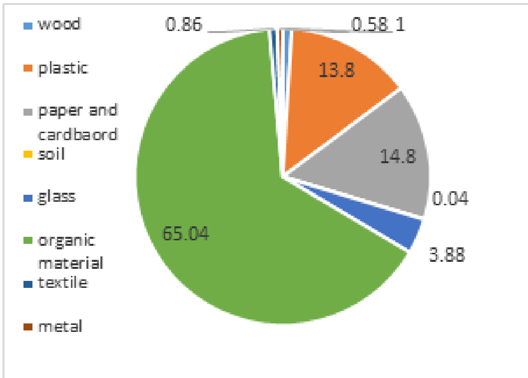

Figure 1. Kahrizak MSW waste composition

The results of this test were in agreement with the results previous research.

Moisture content and organic content test are 145 and 65 percent for fresh MSW, respectively. These results proofed to be valid by being in agreement with previous investigations on Kahrizak MSW [13-15].

From these results it can be infered that the behavior of MSW from Kahrizak landfill can be varying with time. With presence over 60 percent of organic material and 145 % moisture constant the decomposition of waste is quite fast. This change in characteristics of MSW affects the static and dynamic behavior of MSW which poses a challenge to landfill design.

3- 2- Effect of fiber content and confining stress

Based on the results of bender element test these two parameters are the most important parameters that control the dynamic behavior of MSW. Figure 2 and Figure 3 shows the increase in shear wave velocity and small-strain shear modulus for each waste composition with increasing confining stress. The increase in fiber content as it is evident in the Figure 2 resulted in higher shear wave velocity. In the process of sample preparation, samples with higher fiber content were harder to compact. Therefore higher compaction effort could be the key factor in the increase of shear wave velocity.

Since the samples were consolidated with 75, 150 and 300 kPa confining stress in each step the density of samples were increased caused a higher shear stiffness. This effect was presented in the other research study like Keramati et al. (2017), they were explained that with increasing the confining stress of MSW materials the shear modulus of MSW of Kahrizak landfill was increases [14].

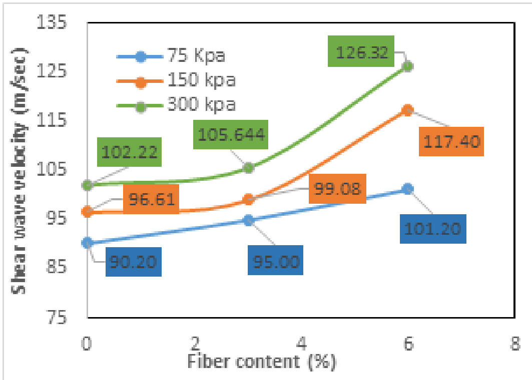

Figure 2. Effect of fiber content and confining stress on shear wave velocity

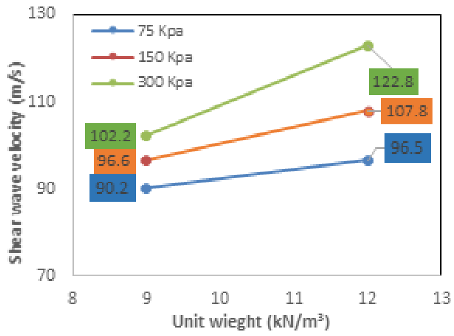

Figure 4. Effect of unit weight on shear wave velocity

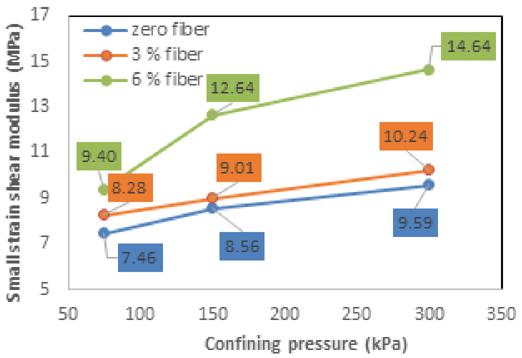

Figure 3. Effect of fiber content and confining stress on small-strain shear modulus

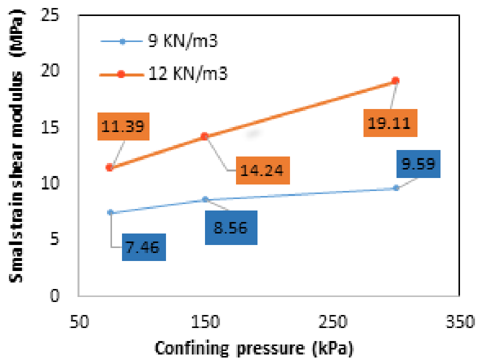

Figure 5. Effect of unit weight on small strain modulus

3- 3- Effect of unit weight

Based on Equation 1, the density of MSW samples directly affects the small-strain shear modulus or in other words shear stiffness. It is notable that with higher unit weight more waste constituents are in contact with each other, therefore the capacity for propagating energy wave is increased. Figures 4 and 5 demonstrate the effect of unit weight on shear wave velocity and small-strain shear modulus.

The strong effect of unit weight on small-strain is obvious with comparing the shear wave velocity and small-strain shear modulus of samples with 6 percent fiber content 9 kN/m^3 with samples with no fiber and 12 kN/m^3. Although both samples have close shear wave velocities, the sample with 12 kN/m^3 unit weight has considerably higher small-strain shear modulus.

4- Conclusions

- The increase in shear wave velocity becomes greater at higher confining stresses as well as higher fiber content. samples that has been consolidated under confining pressure of 75 kPa have shear wave velocity of 90, 95 and 102 m/s for respectively no fiber content, 3 percent and 6 percent fiber. Samples that has been consolidated under confining pressure of 150 kPa have shear wave velocity of 96, 99 and 117 m/s for respectively no fiber, 3 percent and 6 percent fiber. And finally samples that has been consolidated under 300 kPa have shear wave velocity of 102, 105 and 126 kPa respectively for no fiber, 3 percent and 6 percent fiber. This increase in shear wave velocity is an indication of higher shear stiffness in samples with higher fiber content, which could be attributed to higher compaction effort used to reach a certain unit weight.
- Unit weight is considerably more effective on small-strain shear modulus rather than shear wave velocity. For the sample with unit weight of 9 kN/m^3 under confining stresses of 75, 150 and 300 kPa the values of small-strain shear modulus are respectively 7.4, 8.5 and 9.5 MPa. For the sample with unit weight of 12 KN/m3 under confining stresses of 75, 150 and 300 kPa the values of small-strain shear modulus are respectively 11, 14 and 19 MPa.

References

[1] B. Ramaiah, G. Ramana, B. Bansal, Field and large scale laboratory studies on dynamic properties of emplaced municipal solid waste from two dump sites at Delhi, India, Soil Dynamics and Earthquake Engineering, 90 (2016) 340-357.

[2] M. Keramati, N. Shariatmadari, M. Karimpour-Fard, M.R.N. Shahrbabak, Dynamic behaviour of msw materials under cyclic triaxial testing: A Case Of Kahrizak Landfill, Tehran, Iran, IJST, Transactions of civil engineering, 40(C1) (2016) 13-25.

[3] D. Zekkos, N. Matasovic, R. El-Sherbiny, A. Athanasopoulos-Zekkos, I. Towhata, M. Maugeri, Dynamic properties of municipal solid waste, in: Geotechnical characterization, field measurement, and laboratory testing of municipal solid waste, (2010), pp. 112-134.

[4] B. Naveen, T. Sitharam, P. Sivapullaiah, Evaluating the dynamic characteristics of municipal solid waste for geotechnical purpose, Current Adv Civ Eng, 2(1) (2014).

[5] P. Yuan, E. Kavazanjian Jr, W. Chen, B. Seo, Compositional effects on the dynamic properties of municipal solid waste, Waste management, 31(12) (2011) 2380-2390.

[6] D.P. Zekkos, Evaluation of static and dynamic properties of municipal solid-waste, University of California, Berkeley, (2005).

[7] B. Ramaiah, G. Ramana, E. Kavazanjian Jr, N. Matasovic, B. Bansal, Empirical Model for Shear Wave Velocity of Municipal Solid Waste In Situ, Journal of Geotechnical and Geoenvironmental Engineering, (2015) 06015012.

[8] M. Khaleghi, In-situ CSWS test to determine the effect of aging on shear wave velacity of municipal solid waste (Case study: Kahrizak Landfill), Iran University of Science and Technology, (2011).

[9] J.J. Lee, Dynamic Characteristics of Municipal Solid Waste (MSW) in the Linear and Nonlinear Strain Ranges The University of Texas at Austin December (2007).

[10] M. Keramati, N. Shariatmadari, M. Karimpour-Fard, A. Saeedanezhad, P. Alidoust, Effects of aging on dynamic properties of MSW: A case study from Kahrizak Landfill, Tehran, Iran, Scientia Iranica, (2017).

[11] D 4767-04: Standard test method for consolidated undrained triaxial compression test for cohesive soils, in: ASTM Int., West Conshohocken, Pa, (2004).

[12] C. Chee-Ming, Bender element test in soil specimens: identifying the shear wave arrival time, Geotechnical and Geological Engineering, (2011) 1-8.

[13] N. Shariatmadari, M. Karimpour-Fard, M. Keramati, H.J. KOLARIJANI, A. Naebi, FIBER CONTENT IMPACT ON THE SHEAR STRENGTH OF MSW MATERIALS IN DIRECT SHEAR TESTS, in: Thirteenth International Waste Management and Landfill Symposium, 2011.

[14] M. Keramati, N. Shariatmadari, M. Sabbaghi, M.S. Abedin, Effect of confining stress and loading frequency on dynamic behavior of municipal solid waste in Kahrizak landfill, International Journal of Environmental Science and Technology, 15(6) (2018) 1257-1264.

[15] M. Keramati, Aging effect of Municipal Solid Waste on their dynamic Properties, Iran University of Technology, (2016).

Please cite this article using:

M. Keramati, H. Torabi, P. Alidoust, N. Shariatmadari, Evaluating the effect of fiber content on the shear wave velocity and small-strain shear modulus of municipal solid waste using bender element (BE), *Amirkabir J. Civil Eng.*, 50(5) (2018) 929-936.

DOI: 10.22060/ceej.2017.12930.5293