The paper was published in the proceedings of the 3rd International Symposium on Coupled Phenomena in Environmental Geotechnics and was edited by Takeshi Katsumi, Giancarlo Flores and Atsushi Takai. The conference was originally scheduled to be held in Kyoto University in October 2020, but due to the COVID-19 pandemic, it was held online from October 20th to October 21st 2021.

Effect of compaction ratio on shear strength behavior of municipal solid waste incinerator bottom ash in Vietnam

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ABSTRACT

In Vietnam, the larger amount of municipal solid waste (MSW) is generated but the main treatment method still is landfilling. Currently, the incinerator is applied for MSW treatment. Previous researches showed that MSW bottom ash (MSWIBA) can be used as construction material such as roadbed and foundation layers. The direct shear test results showed that the friction angle of MSWIBA was from 38° to 55°, which was suitable for construction materials. However, in Vietnam, there is limited research about the mechanical properties of MSWIBA. Thus, this paper focuses on the effect of compaction ratio on the shear strength of MSWIBA by using large direct shear with a diameter of 300 mmx300 mm. The results showed that the internal friction angle for MSWIBA was about 31° and 44° for compaction ratio of 90 percent and 95 percent, respectively. In addition, cohesion was also quite high for two cases.

Keywords: large direct shear test, compaction ratio, MSWIBA, cohesion

1 INTRODUCTION

Currently, MSW generation in Hanoi is about 6,400 tons/day. The MSW amount is treated mainly by landfilling in 8 municipal centers and waste treatment sites at district level. The largest landfilling site in Hanoi is Nam Son land1fill which can receive and process daily approximately 3,800 to 4,200 tons. Recently, incineration is also applied for MSW treatment in Vietnam. Incineration is the process of control and complete combustion of solid wastes. The temperature in incinerators varies between 980-2000 °C. One of the most attractive features of incineration is reduction in the volume of combustible solid waste by 80-90%. Unfortunately, in Vietnam, application of incineration for MSW treatment is still limited compare with other methods. Recently, several incinerators have been installed in North Vietnam such as Hanoi, Thai Binh city and Nam Dinh city and in the South such as Binh Duong city. Fig. 1 shows an incinerater plant in NamSon landfill in Hanoi.

a) b)

Fig. 1. Incinerator plant in Nam Son landfill. (a) waste for incinerator plant, (b) Incinerator plant

To investigate a potential of MSWIBA, a large number of studies have been conducted and successfully concluded that bottom ash can be effectively recycled and sufficient for use in lower strength applications as road pavement, embankment, fills or subbase materials due to the free drainage of water that prevents the accumulation of pore water pressures. Previous researches have indicated that the mechanical behavior of bottom ash is similar to initially dense sand materials (Arm (2000) and Becquart et al., (2009) and Nguyen et al., (2016) and Pecqueur et al., (2001).

However, there is limited available research on the effects of the large particles on the shear strength of MSWIBA. Therefore, in this research, a square of large-scale (300 mm x 300 x 140 mm) and a small-scale (60 mm in diameter) direct shear tests were carried out on MSWIBA samples to study the effect of specimen size on the shear strength of the samples. In addition, compaction ratio effect on shear strength of MSWIBA also was investigated for filling material of road embankment.

2 MATERIAL AND METHODS

2.1 Material

The MSWIBA samples were obtained from the Thanh Quang incinerator in Hanoi capital. Approximately 200 kg of the wet waste samples were collected and then dried in a room with an average temperature of 20^{o}C. The water content of MSWIBA is

https://doi.org/10.3208/jgssp.v09.cpeg115

25% and the specific gravity of the waste sample was 2.635.

The X-ray diffraction (XRD) analysis was conducted for MSWIBA sample according ASTM D5758 standard.

2.2. Method

After physical tests, compaction test and direct shear test were conducted according ASTM standard (shown in Table 1). Standard Proctor Compaction Test were conducted for small sample and Modified Proctor Compaction Test were conducted for large sample of MSWIBA. Small samples were prepared by compacting to the compaction ratio which is reached 90% and 95% of maximum dry density using Standard Proctor test. Compaction ratios of the large samples were 90% and 95% of the maximum dry unit weight Modified Proctor efforts.

For the direct shear test, small samples of 60 mm in diameter was conducted with normal vertical stress of 50 kPa, 100 kPa and 150 kPa. For the large direct shear test, specimens were prepared by a modified compaction test in the large direct shear box (300 mm x 300 mm x140 mm). The large direct shear test was performed on an WYKEHAM FARRANCE direct shear-testing machine with the maximum shear force of 100 kN. In this test, D/dmax= 300/40= 7.5 (where D is with of shear box in the large direct shear test and dmax is the maximum particle size of MSWIBA). For simulating the specimen overburdened at different depths, normal stresses were adopted of 100 kPa, 200kPa, and 300 kPa. Then, horizontal shear was applied at a speed of 1.2 mm/min. All tests are summarised in Table 1.

Table 1. Summary of test

Type of test	Name of test	Standard
Physical test	Moisture content determination	ASTM D2216
	Grain size analysis	ASTM D422
Mechanical tesst	Compaction	ASTM D698
	Direct shear test	ASTM D 3080
XRD	X-ray diffraction analysis	ASTM D5758

3 RESULT and discussions

3.1 Particle distribution and XRD result

Figure 2 shows the particle size distribution for small and large samples, determined according to ASTM D422. The maximum diameter of MSWIBA for the small and large direct shear test was 4.75 mm and 40 mm, respectively. The uniformity coefficient, C_u of the small sample and large sample were 8.16 and 3.24, respectively.

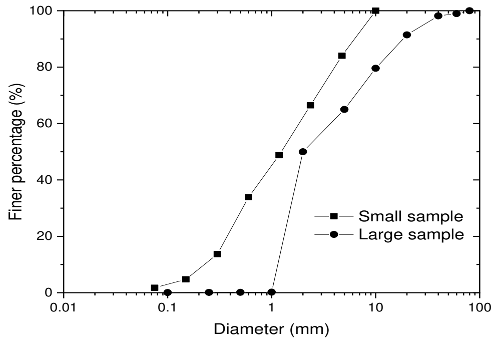

Fig. 2. Particle size distribution curves for small sample and large sample

The XRD test results of MSWIBA sample was plotted in Fig.3. The X-ray diffraction analysis results of MSWIBA sample showed that Quartz mineral (SiO_2) and calcium carbonate ($CaCO_3$) is dominant. This result is consistent with other research (Chimenos 2005).

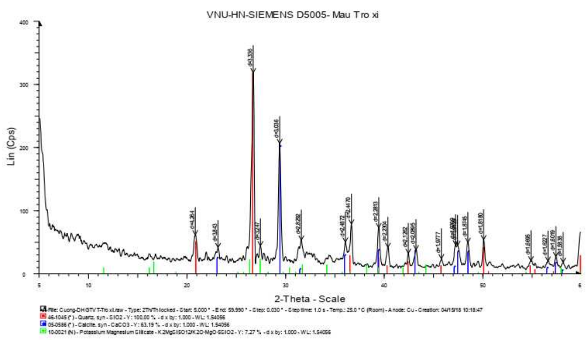

Fig. 3. XRD test results of MSWIBA

3.2 Compaction test result

Fig. 4 is compaction result for result for small sample and large sample. The maximum dry unit weight for small sample and large sample is 12.6 kN/m^3 and 15.0 kN/m^3, respectively. While those of optimum water content is 25.2% and 22.5%, respectively (Fig. 4). Large sample was observed a higher unit weight due to higher compaction. The maximum dry density of bottom is observed to be low, and optimum water content is quit high. This would be due to the irregular rough surface texture in MSWIBA.

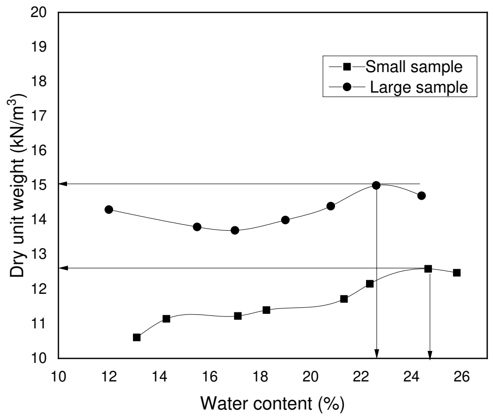

Fig. 4. Compaction result for small sample and large sample

3.3 Shear strength of MSWIA for small direct shear test and large direc shear test

The shear strength parameters for MSWIBA samples were obtained using the Mohr-Coulomb failure criterion:

$$\tau = c' + \sigma' tan\phi' \quad (1)$$

where τ is the shear stress, σ' is the effective normal stress, c' is the effective cohesion, and ϕ' is the effective angle of internal friction. Value s of c' and ϕ' can be obtained by drawn a best -fit straight line in Fig.5 and Fig.6.

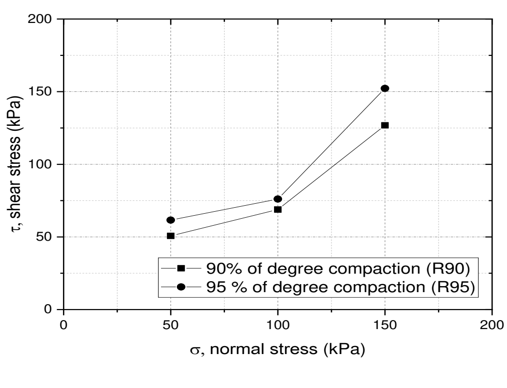

Fig. 5. Shear strength plot for R90 and R95 sample for small sample

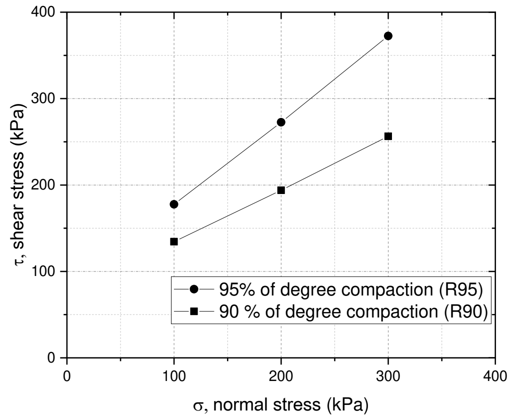

Fig. 6. Shear strength plot for R90 and R95 sample for large sample

4 DISCUSSION

4.1 Effect of compaction ratio on shear strength of MSWIBA

Table 2. Comparison shear strength for small sample and large sample

Type of direct shear tesr	Shear strength parameters	Compac tion ratio R90	Compacti on ratio R95
For small direct shear test (60 mm in diameter)	c' (kPa)	1.2	3.7
	ϕ' (degree)	40°	42°
For large direct shear test (300 mmx300mm)	c' (kPa)	73	79
	ϕ' (degree)	31°	44°

Table 2 shows the comparison of shear strength parameters for small direct shear tests and large direct shear tests for two cases R90 and R95. In the case of R90, the cohesion and angle of friction obtained are 6 kPa, 37° for the small sample, and 73 kPa, 31°for the large sample, respectively. While in the case of R95, the cohesion and angle of friction obtained are 3.7 kPa, 42° for the small sample, and 79 kPa, 44°for the large sample, respectively. It is clearly seen that the friction angle for R90 and R95 are quite similar, whereas the cohesion of the large sample is very high compare to small sample.

4.2 Comparison of shear strength parameters

Previous researches have reported the shear strength parameters and these parameters have been assessed from direct shear and triaxial shear tests. Table 3 shows that a high friction angles up to 59° and maybe it is attributed to the very angular glass particles present in MSWIBA (Luo et al., 2017).

Table 3. Comparison shear strength parameters with other research

Type of test	Cohesion, (kPa)	Friction angle (degree)	Reference	
CD triaxial test	-	53°-59°	(Becquart et al., 2009)	
	Range 14-34, mean 12	24°-50°, mean 42°	(Wiles and Shepherd, 1999)	
CD and CU triaxial test	1	55°-59° (CD) 53°-56° (CD)	(Becquart et al., 2009)	
Direct shear test (small sample)	0	38°-55°, mean 45°	(Lentz et al., 1994)	
	--	44°-53°	(Lin et al., 2012)	
	8	50°	(Muhunthan, Taha, Said, & Muhunthan, 2012)	
Direct shear test (This study)	1.2	40°	R90	For small direct shear test (60 mm in diameter)
	3.7	42°	R95	
	73	31°	R90	For large direct shear test (300mm x 300mm)
	79	44°	R95	

Note: CU-Consolidated Undrained, CD- Consolidated Drained

Wiles reported that cohesion values changed from 14 to 34 kPa (Wiles et al., 1999) due to increament of dry unit weight and confining pressures. For the case of a large direct shear test, high cohesion of MSWIBA is observed. It is related to high optimum water content (22.5%) compare to that of other research (Luo et al., 2017). The large samples showed higher strength parameters because of the particle size and the Modified compaction effort.

It is also reported that shear strength of MSWIBA similar to natural sand. In addition, MSWIBA is lighter than sand that may reduce the settlement of embankment when using MSWIBA for fill material.

4 CONCLUSIONS

Based on the experimental results, the following conclusion can be drawn as follows:

1) In this research, large direct the shear test was conducted and the results show that higher friction and the cohesion of MSWIBA samples were obtained.
2) It is recommended that MSWIBA can be used for filling embankment for both cases compaction ratio of R90 and R95.

ACKNOWLEDGEMENTS

The authors would like to thank Ministry of Education and Training, Vietnam for financially supporting this study (Code B-2019-GHA10).

REFERENCES

1) Alhassan, H.M., and Tanko, A. (2012): Characterization of solid waste incinerator bottom ash and the potential for its use. Int. J. Eng. Res. Appl., 2(4), 516–522.
2) Arm, M. (2000): Variation in mechanical properties of MSW incinerator bottom ash: Results from triaxial tests. Waste Management Series, 1, 567–578. https://doi.org/10.1016/S0713-2743(00)80067-7
3) Becquart, F., Bernard, F., Abriak, N. E., and Zentar, R. (2009): Monotonic aspects of the mechanical behaviour of bottom ash from municipal solid waste incineration and its potential use for road construction. Waste Management. https://doi.org/10.1016/j.wasman.2008.08.019
4) Chimenos J.M, Fernández A.I, Miralles L, Rosell J.R, Ezquerra A.N (2005): Change of Mechanical Properties during Short-Term Natural Weathering of MSWI Bottom Ash. Environ Sci Technol, 2005, 39(19):7725-30.
5) Lentz, D., Demars K.R., Long, R.P. and Garrick, N. W. (1994): Performance and analysis of incinerator bottom ash as structural fill. University of Connecticut, JHR 94-232, 1994.
6) Lin, C., Weng, M., and Chang, C. (2012): Effect of incinerator bottom-ash composition on the mechanical behavior of back fill material. Journal of Environmental Management, 113, 377–382. https://doi.org/10.1016/j.jenvman.2012.09.013
7) Muhunthan, B., Taha, R., Said, J., and Muhunthan, B. (2012): Geotechnical Engineering Properties of

Incinerator Ash Mixes Geotechnical Engineering Properties of Incinerator Ash Mixes. J. Air Waste Manage. Assoc., 54 (2004) 985–991. https://doi.org/10.1080/10473289.2004.10470959
8) Nguyen, C. L., Inui, T., and Katsumi, T. (2016): Scale effects on the shear strength of waste in coastal landfill sites. Japanese Geotechnical Society Special Publication, 2(52), 1824–1828. https://doi.org/10.3208/jgssp.VNM-04
9) Pecqueur, G., Crignon, C., and Quénée, B. (2001): Behaviour of cement-treated MSWI bottom ash. Waste Management, *21*(3), 229–233. https://doi.org/10.1016/S0956-053X(00)00094-5
9) Wiles .C., and Shepherd, P. (1999): *Beneficial Use and Recycling of Municipal Waste Combustion Residues a comprehensive resource document*.