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Prediction of the Stress-Strain Behavior of MSW Materials Using Hyperbolic Model and Evolutionary Polynomial Regression (EPR)

M. Keramati , H. Moradi Moghaddam , A. Ramesh

Faculty of Civil Engineering, Shahrood University of Technology, Semnan, Iran

ABSTRACT: In recent years, the rupture of landfill centers has resulted in the importance of studying the behavior of municipal solid waste (MSW). MSW as the main constituent element in landfills has a complicated performance. In this study, by using the results of large–scale direct shear experiments with dimensions of 300 mm*300 mm*150 mm, 2 models to predict the behavior of MSW with ages of fresh and 3 months were presented. The purpose of this investigation was prediction of MSW stress-strain behavior for kahrizak landfill as a sample of developing countries landfills under aging and by structural models. These models were Hyperbolic model and Evolutionary Polynomial Regression (EPR). In these collection of experiments, aging process up to 3 months was artificially applied to samples. Three normal stresses 20, 50 and 100 kpa along with three shear displacement rates of 0.8, 8 and 19 mm/min were used for samples with different ages. The results of these two models showed high accordance with experimental results by direct shear apparatus, in addition to predict MSW behavior under aging and degradation. Finally, this study stated the advantage of EPR model relative to Hyperbolic model in higher accuracy for all experiments.

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1- . Introduction

Recognizing the behavior of waste for the design and maintenance of landfills is of particular importance. Failure to recognize this behavior has resulted in environmental hazards, including the failure of landfill slopes in recent years in different parts of the world (Ano Liosia 2008 [--], Leuwigajah 2005 [--]). In this regard, many studies have been done on the mechanical behavior of municipal solid waste in recent years that can be mentioned (Shariatmadari 2009; Babu 2010; Zekkos 2012; Keramati 2016) [1-4]. A lot of researches has also been done on the effect of aging in the waste. In this regard, Machado 2002 and Karimpour-Fard (2011) stated the increasing of resistance with aging [5, 6].

The hyperbolic model was first proposed by Kondner in order to predict the stress-strain behavior of soils in 1963. It was supposed that this hyperbolic elastic model was also suitable for describing the stress-strain response of municipal solid waste. Thus, the stress-strain behavior of municipal solid waste was simulated using this model (for example, Singh & Fleming 2010; Assadi 2017) [7, 8].

In the years 1999 and 2000, Davidson introduced a new regression method called Rule-based Symbolic Regression (R-BSR) to construct polynomial models based on both numerical and symbolic regression methods [9]. Based on the idea presented by Davidson, the EPR method was introduced in 2004 by Giustolisi and developed in the following years [10]. Among the work done in this field, the shear strength of municipal solid waste can predict using the EPR method (Keramati 2014) [11].

The results of all researches carried out so far regarding the components of the waste material and the pattern of consumption in the landfill site are different. Therefore, local research is required to evaluate the mechanical behavior of waste.

2- Methodology

The samples studied in this study were collected from Kahrizak landfill site located in south of Tehran. The most part of the components of the waste material composition was organic material. The device used in this study was a large-scale shear machine with dimensions of 30*30*15 cm^3. In order to study the effect of aging in samples, it was decided that the tests should be done at two fresh and three-month ages. After transferring the samples to the Center of Geotechnical Studies located in Iran University of Science and Technology, part of the samples for preservation of freshness were kept in the refrigerator and other samples along the artificial process of increasing the age up to three months were kept in special barrels.

With regard to the differences in the components and the variable particle size, the sampling was done based on the fixed density energy in each layer. The waste samples with three stress levels of 20, 50 and 100 kPa and three shear

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

displacement rates of 0.8, 8 and 19 mm /min for fresh and three -month waste were investigated (Table 1).

Table 1. List of conducted experiments

NO	Age	Vertical Stress	Shear Displacement Rate
1	Fresh	20,50,100	0/8
			8
			19
2	Three-month	20,50,100	0/8
			8
			19

The relationship of hyperbolic model based on the results of the direct shear machine is as follows:

$$\tau = \frac{\varepsilon}{\dfrac{1}{KP_a\left(\dfrac{\sigma_n}{P_a}\right)^n} + \dfrac{\varepsilon_a \cdot R_f}{\sigma_n \cdot \tan\phi + C}} \quad (1)$$

K and n are non-parametric parameters, C and Ø are shear resistance parameters. $R_f=\tau_f/\tau_{ult}$ is reduction factor and P_a is atmospheric pressure equal to 3 kPa.

The EPR method is a computational intelligence technique that has recently been used in geotechnical engineering. The variables of this model are determined according to the initial conditions of the experiments including age, strain percentage, shear strain rate, vertical stress, fiber orientation and plastic percentage. The following equation is presented for the evaluation of stress-strain behavior of Kahrizak landfill waste in accordance with conducted experiments.

$$\begin{aligned} \tau = & -0.15023*(\sigma_n*O)^{0.5} + 0.13184*\sigma_n \\ & +1.89*10^{-5}*\sigma_n*R^3 - 2.0076*10^{-5}*\sigma_n{}^2 \\ & *T^{0.5}*P^2 + 1.0587*10^{-7}*\sigma_n{}^2*T^{0.5}*P^{0.5} \\ & +36.6036*(\sigma_n*\varepsilon_S)^{0.5}*P - 41.762*\sigma_n{}^{0.5} \\ & *\varepsilon_S + 0.0099018*(\varepsilon_S*\sigma_n*R)^2*O^{0.5} - 8.6585 \end{aligned} \quad (2)$$

In this case, the vertical stress is σ_n , R is the shear strain rate, t is the age of the sample (month), ε_s is the desired shear strain, O is fiber orientation and P is plastic percentage.

3- Results and Discussion

Initially, the required parameters for the hyperbolic model of fresh and three-month waste were evaluated. By using these parameters in Equation (1), a hyperbolic model can be obtained to predict stress-strain changes with given initial conditions.

The accuracy curves of this model are presented based on the model-evaluated data relative to the experimental data for both types of "modeling" and "validation" data. The highest accuracy is when the focus of data is around the y = x axis. For this model, the parameter R^2 (determination coefficient) was equal to 0.98 (Figures 3 and 4).

The data used in this model was derived from the results of a large-scale direct shear machine. In modeling with evolutionary techniques, about two-thirds of the total data was typically allocated to "modeling" and one third remaining to "validation" of model accuracy. The first and second sections are labeled "educational" and "experimental".

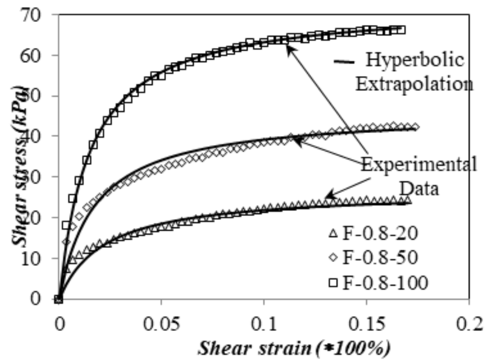

Figure 1. Hyperbolic model versus laboratory results of fresh samples with a shear displacement rate of 0.8 mm/min

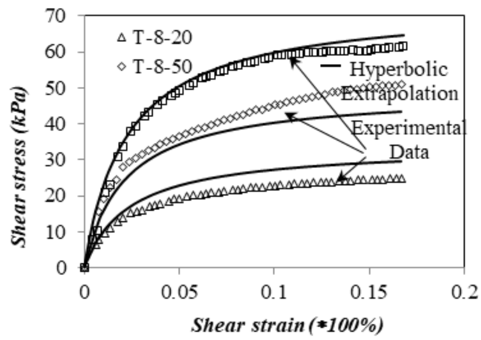

Figure 2. Hyperbolic Model versus laboratory results of three-month samples with a Shear displacement rate of 8 mm/min

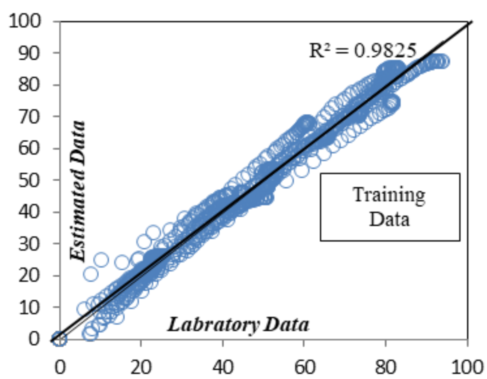

Figure 3. Model reliability through modeling data

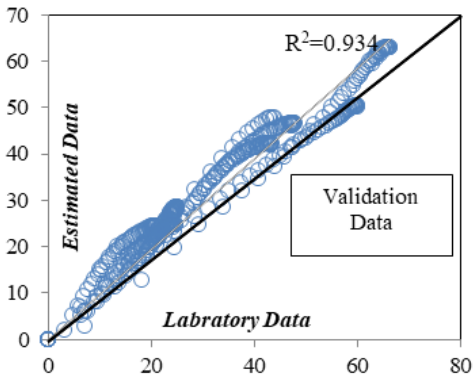

Figure 4. Model reliability through validation data

Selections of stress-strain curves predicted by EPR model are presented for the initial conditions of "training" and "validation" data (Figures 5 and 6).

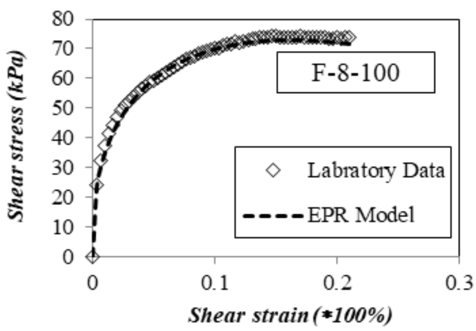

Figure 5. Prediction of EPR model for fresh sample, horizontal orientation of fibers, in situ plastic percentage , shear displacement rate of 8 mm / min and vertical stress of 100 kPa

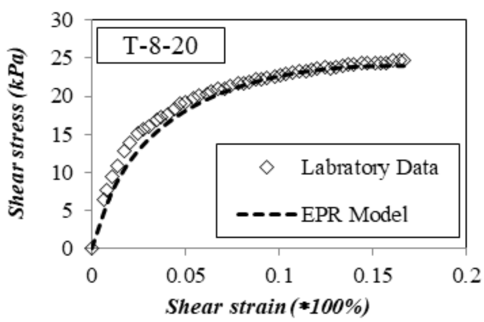

Figure 6. EPR prediction for a three -month sample, horizontal orientation of fibers, in situ plastic percentage, shear displacement rate of 8 mm / min and vertical stress of 20 KPa

As can be seen, EPR model can also be used to predict the stress-strain behavior of waste materials under different initial conditions. This model had high accuracy and was much more convenient and accurate than hyperbolic model.

The hyperbolic model was originally presented to evaluate the stress-strain behavior of soils using the results of a three axial device [12]. However, due to the considerable difference in the structure of waste with soil, this model predicts the results from experiments performed using direct shear machine with higher accuracy (Figure 7).

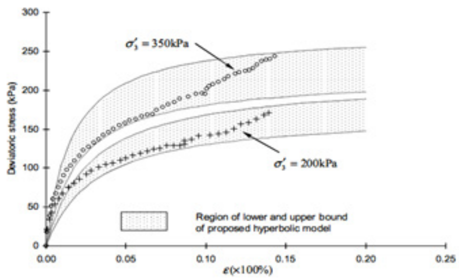

Figure 7. The results presented for hyperbolic model by Singh (2008) based on the results of conducted experiments by Caicedo and colleagues (2002)

4- Conclusions

The parameters of the proposed hyperbolic model were evaluated based on the results of conducted experiments to predict stress-strain behavior of the waste.

The results of this research showed that although the hyperbolic model was first introduced to evaluate the stress-strain behavior of soils using three-axial apparatus results, due to the difference in the structure and components of the waste relative to the soil as well as the effect of fiber reinforcement, this model predicts the results of experiments performed using a direct shear apparatus for municipal solid waste with higher accuracy. Also, the accordance of the hyperbolic function with tests carried out by a direct shear apparatus indicated that the model was in agreement with experimental results.

The model provided by Genetic Algorithm (EPR) method had also an acceptable accuracy. This model was more suitable than hyperbolic model and predicts stress-strain behavior of waste by entering the desired values for age, shear displacement rate, vertical stress, fiber orientation and plastic percentage. This model can be used to predict stress-strain behavior of the Kahrizak landfill without the need for related tests.

References

[1] N. Shariatmadari, S.L. Machado, A. Noorzad, M. Karimpour-Fard, Municipal solid waste effective stress analysis, Waste Management, 29(12) (2009) 2918-30.

[2] G.S. Babu, K.R. Reddy, S.K. Chouksey, Constitutive model for municipal solid waste incorporating mechanical creep and biodegradation-induced compression, Waste Management, 30(1) (2010)11-22.

[3] D, Zekkos, J.D. Bray, M.F. Riemer, Drained response of municipal solid waste in large-scale triaxial shear testing, Waste management, 32(10) (2012) 1873-85.

[4] M. Keramati, N. Shariatmadari, M. Karimpour-Fard, M.N. Shahrbabak, Dynamic behaviour of MSW materials under cyclic triaxial testing: a case of Kahrizak Landfill, Tehran, Iran, Iranian Journal of Science and Technology, Transactions of Civil Engineering, 40(2) (2016) 75-83.

[5] S.L. Machado, M.F. Carvalho, O.M. Vilar, Constitutive model for municipal solid waste, Journal of Geotechnical and Geoenvironmental Engineering, 128(11) (2002) 940-951.

[6] M. Karimpour-Fard, S.L. Machado, N. Shariatmadari, A. Noorzad, A laboratory study on the MSW mechanical behavior in triaxial apparatus, Waste management, 31(8) (2011) 1807-1819.

[7] M. Singh, I. Fleming, Application of a hyperbolic model to municipal solid waste, Geotechnique, 61(7) (2011) 533-547.

[8] M. Asadi, N. Shariatmadari, M. Karimpour-Fard, A. Noorzad, Validation of Hyperbolic Model by the Results of Triaxial and Direct Shear Tests of Municipal Solid Waste, Geotechnical and Geological Engineering, 35(5) (2017) 2003-2015.

[9] J.W. Davidson, D. Savic, G.A. Walters, Method for the identification of explicit polynomial formulae for the friction in turbulent pipe flow, Journal of Hydroinformatics, 1(2) (1999) 115-126.

[10] O. Giustolisi, D. Savic, A. Doglioni, Data reconstruction and forecasting by evolutionary polynomial regression, in: Hydroinformatics: (In 2 Volumes, with CD-ROM), World Scientific, 2004, pp. 1245-1252.

[11] M. Keramati, S.K. Reshad, S. Asgarpour, M.A. Tutunchian, Predicting shear strength of municipal waste material by evolutionary polynomial regression (EPR), Electronic Journal of Geotechnical Engineering, 19 (2014) 53-62.

[12] M.K. Singh, Characterization of stress-deformation behaviour of municipal solid waste, 2008.

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