Experimental analysis the compression and shear characteristics of municipal solid waste in hydraulic compactor machine for energy conversion

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Abstract: In last few years, municipal waste generation and regulating are common problems for all over world countries. Conversions of waste to energy technologies are creating many end-products like electricity, thermal energy, fertilizer and biogas etc. Due to this, compression of solid waste has become compulsory to save the space in garbage carrying truck, which is also known as hydraulic compactor machine. Hydraulic compactor machine is a garbage carrying compact truck after Compressing the garbage up to 50 to 60 percent more than the capacity of truck of municipal solid waste (MSW). Solid waste contains different component, high compressibility factor, and more water content. This study has been carried out with the municipal solid waste. The unpredictable compression mechanical characteristic varies with the simulation of solid waste compression process. The process shows the compression and shear characteristic analysis for compressing garbage. Experimental analysis of the mechanical properties of solid waste, an important test instrument for shear test and compression test was designed. Total fourteen tests on solid waste were conducted as per the designed test instrument and the model parameters by analyzing testing data. At last, the defined characteristic tests were simulated on tested model and designed model factors were justified. This paper gives us information for the mechanical behavior of garbage compression in hydraulic compactor for energy generation process.

Keywords: mechanical properties, municipal solid waste, hydraulic compactor machine, shear test, compression test.
1.0-Introduction

As per time variation, the life style of civilian is also changed with the devolvement of knowledge of atmosphere conservation. Compressed solid waste compactor with hermetically sealed have more loading and carrying capacity and due to it these compactors have been adopted by many municipal corporations in the interest of public and environment due to many advantages.[1] Solid waste contains various items like newspaper/study materials, green vegetables, shells, wooden scraps, green leaves, cotton residual, human body bones, plastics parts, rubber materials, metal component, construction waste, clay, porcelain and glass etc. along with more moisture content. Solid waste characteristics for a various compressive strain results to give an easy calculation method for model parameter of the solid waste and compared with the standard parameter of the garbage to analyze the waste compression vehicles. Yet, it is more problematic to apply the result due to the differentiation of the compression properties of the solid waste performing to calculate the mechanical characteristics of the solid waste in compression in many phases at various temperatures and strain.[2]

So, it has been observed the necessity of research on experimental analysis of compression and shear features of city solid garbage in hydraulic compactor machine for energy conversion to promote the latest design procedures of hydraulic compression waste compactor with another solid waste transforming instrument and machine.[3]

A standard operative model has been chosen for municipal solid waste with specific test equipment is being designed hereby to regulate operative test of solid waste. These obtained results of Duncan-Chang constitutive model were concluded by data conversion. Finally, waste this compression analysis was simulated with the Duncan-Chang constitutive model.

2.0-Methodology

The compression and shear characteristics of solid waste are studied with the use of high-ranking compression apparatus. MSW garbage is differentiated in three components, these are: usually biodegradable, non-biodegradable, and non-compressible municipal solid garbage in an environmental experimental lab. A various researcher pointed out the stress and strain properties of materials to get the optimal result.[4]

There are 3 mixed parts, 3 various initial densities, 4 various bio-degradable, 4 various pressures, and 8 various compression timings are chosen for compression testing. The compression testing results describes that: (1) The complete strain of biodegradable solid garbage is increasing along with vertical pressure and this relation in these two factor could be correlated as logarithmic model; (2) The complete strain of bio-degradable solid garbage is increasing along with initial density, and this relation can be show as a linear relation; (3) The density of bio-degradable solid garbage is increasing along with decreasing time, and this relation can be formulated as logarithmic model.

The Four categories of primary testing were carried out to compare the permeability and compression characteristics of solid waste specimen. Although other two series of primary testing were performed with a traditional small-scale
consolidometer, the two others were carried out in a high volume consolidate meter in analysis. In every consolidate meter, solid waste specimens were tested at two various precipitation essence, i.e., original water content and area field space. A scale effect between the two consolidate meter with various size was incorporated. These testing were done on specimen samples considering the pressure at 120, 240, and 360 kPa. Data obtained by this incremental load, is plotted on strain versus log-time graphs scale. [5] Acquiring these data by these compression testing has been utilized to calculate primary and secondary compression indices. This consolidate meter was acquired later for permeability testing. The samples were tested of solid waste for the different coefficient of compressibility and indices values within a respective defined range in spite of the shape and size of consolidate meter and various water contents of samples. The coefficient of permeability values has been found within a range of two magnitude order i.e. -10-6-10-4 m/s. [6] This experiment paper data has been well correlated with previous research data. The result regarding the scale effect in compression behavior effect is significant and no linearity relation between the obtained results was found on logarithmic model. 

The present paper has also studied the relationship between the primary and secondary compression indices of solid garbage. In the laboratory under standard temperature and pressure an experiment was organized for the validation of quantity of compression of solid waste under various changeable water content states. Many series of compression testing were organized with solid waste specimens under the water area content of 45% (with dry weight value) and three inflated water content of 65, 85 and 100% (with dry weight value). The specimens of solid waste were tested at various time intervals with increasing normal stresses of 46, 92, 184, 368, and 736 kPa. The improved compression ratios or indices were estimated on the basis of detailed measured of compression value versus stress data on scale. The maximum heat and force transfer occurs with a number of readjustment points available on surface. [7] The secondary compression effect for long lasting of solid waste was obtained by applying pressure for compression testing on solid waste sample under condition of normal stress of 368 kPa. [8]

The abrupt slope could not be found out on the vertical stress – strain graph for 45% water content specimen, possibly taking the limit of breakdown values of microorganisms and mini-organism of solid waste and displacement of these micro-particles. It has been shown in the present research paper; the improved primary compression indices of solid waste do not display any major correlation with increment in water moist content from 45 to 100% adopting change in value of starting components of solid waste in experimental testing lab with decreasing rate of solid waste components. There can be seen many techniques to understand the heat deformation behavior of any materials. [2] Computing the compression indices for the primary and secondary behavior was evaluated on the basis of value of means, standard deviation and coefficient of variation. In a nutshell, this experiment shows the compression characteristics of solid waste is mainly dependable on the solid waste composition generated by the people of city, water and moisture content, and biodegradability of waste and statistical results exhibit the variation related to the secondary compression.
index is magnificently a little more than the primary compression index that can be indicate to a valid distinction in the solid waste characteristics property and related to a limit of biodegradability of solid waste.[9]

2.1-Characteristics of solid waste under testing

Solid waste generated in the city form a complexity in mixture. Refuse-derived-fuel wastested related to biodegradability, grain size and shape, water/moisture content, applied pressure, and micro particle temperature. Nanoparticle coated materials may be replaced as a substitute for the stability.[7] Laboratory experiments were conducted on a single shove pelleting system duly fitted on universal testing machine. The samples of size 3.18 mm and 6.35 mm of grind were arranged and moist values were increased up to 10 %, 14 %, and 18 % wet bulb. At temperature ranges 55 °C and 95 °C, the applied pressure was set at 3kilo Newton, 4kilo Newton, and 5kilo Newton. The result obtained from this experiment was segregated and multiple compression and shear model was calculated as per applied load, compactor volume and design density.[10]

The experiment shows the grind density of compact RDF is improved with increase in grain sizes, whilst compact density of biodegradable pellets gets more as increment in pelleting pressure and temperatures. The pellets compaction density obtained from RDF is varied from 890–1030 kg/m3; the pellets compact density of the biodegradable obtained from RDF is varied ranges 1130–1295 kg/m3. As per Peleg and Moreyra model relaxation characteristics of the compressed material are analyzed on asymptotic modulus of the residual stress ranging 90 mega Pascal and 120 mega Pascal to all laboratory specification; yet, by this process the produced RDF has more strong pellets in comparison to biodegradable material.[11]

2.2 Duncan-Chang model and test devices (directly shear testing)

This is a very general procedures of finding the direct shear strength in mechanics for any material. The failure on the horizontal plane due to shear can be get due to horizontally shearing force applied to specimen under various upward loads. Cohesion force and internal friction angle can be evaluated as per Coulomb strength theory as described in the standard. As per Zhang’s recommendation, it is being using for slow shearing testing in direct shearing testing procedures, cohesion, inner atoms resistance slope angle was considered as per Duncan-Chang model parameters, when the shear strain is stressed up to 10 %. The relation with shearing stresses and normal stresses is drawn in Figure No1. The ordinate containing the intercept of the line is called cohesion and the internal friction angle is treated inclination of the line as shown below in Figure1
Fig. 1. Graphical presentation of shear testing

A high range test instrument is required for which test instrument is set to 500 mm as inner diameter. This direct shear device contains mainly two parts, one of them is shear surface, that is needed to control the friction force of the specimen and other is to control the weight of the samples. To get the accurate result of shear test of samples, the container has been designed in this way that produces a good result up to an international standard. It is basically divided into three main portions: above part, middle part and below part. The middle part of the sample is pressurized to get the shear stress of the specimen. The higher buckets and below containers are fixed rigidly, while the middle container is associated to Inline hydraulic compactor machine by the inline slide. Vertical hydraulic compactor is pressurized by a vertical shear and horizontal compactor is pressurized by the horizontal shear. The solid waste has a huge amount of moisture volume, and continuously discharging a huge volume of residual liquid at the time of compressor processing. For these few holes of 5.1-millimeter diameter was drilled on the bottom plane side of lower container for the continuous residual liquid flow to septic tank.

2.3. Specific compression test device

The figure 2a shows the line plotted as ordinate and as abscissa. The elastic modulus exponent contains the intercept and the slope in the graph. This process is utilized to find out the Duncan-Chang design specification and samples performed by triaxial load testing. As per primary Poisson’s ratio line is drawn on x-axis and on y-axis as shown in Fig. 2b.
A special compression test instrument is constituted on basic design of directly shearing test instrument. The above parts, middle parts and bottom parts are being conserved simultaneously along with vertical direction, and the horizontal compactor actuator is fixed. An extra bucket of 475 mm inner diameter, 505 mm height and 2 mm thick is fixed in bucket to organize the defined compression test. Strain gauges containing of 7 rows and 8 columns have been settled on exterior face of thin wall bucket in the direction of circumferential tangential to the surface. In this method of compression, each strain gauge has been utilized with Wi-Fi momentum strain test apparatus to observe their micro-strain value to get circumferential tangential stress.[12]

3.0 Testing data'sand Duncan-Chang constitutive system

3.1. Direct shear testing detail and Specific compression testing detail.

The primary shearing testing detail obtained from the experiment was calculated and common compression stresses and shear stresses points are drawn as shown in Figure 1. To get internal friction angle and the cohesion the linear line was drawn. The specific test data obtained from result was processed and elastic modulus coefficient and exponent have been got from linear processing as per shown in Figure 2(a).

3.2. The Duncan-Chang constitutive system specifications

As per Feng’s research theory, damage ratio of solid waste growth more increase in axial strain, so this is proposed to adopt 10-15% usually damage standard of solid waste and consider this damage ratio 0.50-0.60 with the effect of triangular axis test detail. Concluding Duncan-Chang constitutive systems specification of solid waste have been taken as the average, showed in below in Table No. 1

Table 1. Concluding Duncan-Chang constitutive system specification of solid waste

| Sl | Constitutive model parameters | Value | Obtaining method |
|----|-------------------------------|-------|------------------|
|    |                               |       |                  |
| number | Cohesion       | 10 kPa            | Directly shear testing |
|--------|---------------|-------------------|------------------------|
| 2      | Internal friction angle | 12°                | Directly shear test    |
| 3      | Damage proportion       | 0.55              | reference              |
| 4      | Modulus of elasticity  | 6                 | compression test       |
| 5      | Elastic modulus exponent | 1.15              | compression test       |
| 6      | Elastic modulus exponent | 0.39              | compression test       |
| 7      | Elastic modulus exponent | 0.0166            | compression test       |

### 4.0 Simulation of garbage compression process

#### 4.1 Model of specific compression test

On the basis of Duncan-Chang constitutive model of solid waste were obtained in this analysis, solid waste simulation of compression test was analyzed with ANSYS. yet all FEA software shows some slackness with Duncan-Chang constitutive model, so more technical development is to be acquired with the APDL language on ANSYS platform. The solid waste material characteristics of every micro-element are continuously variable in Duncan-Chang constitutive model. The mechanical property used in this analysis is to be calculated with the current stress state. Simulation of the specific compression test was analyzed on the basis of Duncan-Chang constitutive model. The ID and height of thin wall bucket are 475 mm and 505 mm respectively. Axisymmetric model has been adopted and a forced displacement load was applied on upper boundary portion of model. as the produced stress of solid waste is uniformly distributed everywhere in the specific model, the solid waste garbage can easily be treated as one system instead of finding the stress at each point of element, revising their elastic modulus, Poisson’s ratio and amending mechanical characteristics[13]. So, simulation of specific compression testing for this experimental analysis has become very easier to understand the theory of compression of solid waste.

#### 4.2. Analysis results

Experimental Analysis results due to element excessive distortion is shown in Fig. 3, in which element has reached the maximum deformation up to 185 mm. The average pressure curve with the forced displacement of the solid waste garbage is shown in Fig. 3. the average pressure curve with the forced displacement of 4 tests of the three batch is shown in Fig. 4.the resistance of the solid waste garbage was weak at the early compression stage, and after sometime the resistance has sharply increased. The elastic modulus of the solid waste variation with average load pressure is shown in Fig.4
4.3-Limitations of model

In this experiment some drawbacks and difficulties have been find out. One of them is geometric nonlinearity with respect to load and element surface contact nonlinearity is largely involved. The other drawback, it is not possible to calculate the principal stress of each micro element on applying the load at each step and estimate and update the elastic modulus and Poisson's ratios per Duncan-Chang model. Third is, the solid waste garbage has itself a large deformation within it, and this may carry out the element to twist the shape and size and even then, to negative volume, which resulted problematic way to the calculation. Generally, it is very difficult to simulate the complete hydraulic compactor machine waste for compression processing according to the Duncan-Chang model.

5. Conclusions

In this analysis, the hydraulic compactor was treated as the working objects and compression of solid waste of trucks is analyzed on the basis of model along with the mechanical properties of municipal solid waste were studied. Specific testing equipment containing the direct shear test with the special compression test was designed, manufactured and assembled to conduct test with municipal solid waste. During the experiment various detailed test data was obtained with application of load to waste to find the direct shear test and compression test. Then Duncan-Chang constitutive model parameters were utilized for simulation the defined compression test.

The accuracy of the result parameters of solid waste with Duncan-Chang constitutive model was confirmed, that provided a guideline for the simulation of the solid waste compression process of energy conversion from the solid waste as well as minimization of space by saving the fossil fuel with man power in the interest of nation and earth environmental also.

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