Optimization of Egg Shell Powder and Lime for Waste Soil Improvement at Open Dumping Area Using Monte Carlo Simulations

Nur Irfah M. Pauzi, Mior A. Aimran, Mohammad S. Ismail and Mohd Shahril M. Radhi

Abstract The waste soil at open dumping area is prone to settlement problems. There are many soil stabilization methods available that can be used to improve soil strength. The addition of egg shell powder and lime for waste soil improvement is studied in this research. Soil stabilization method using the waste material as replacement to improve the strength has been explored widely. In this research, the egg shell powder and lime is added to the waste soil with the mixing portion of 2.5% lime and 2.5% egg shell powder, 5% lime and 5% egg shell powder and 7.5% lime and 7.5% egg shell powder. The compressive strength is conducted on the waste soil samples with different mixing ratio. The optimum value of the compressive strength is simulated using Monte Carlo simulation. In conclusion, there is potential for the waste soil to be improved in terms of strength using lime and egg shell powder. The compressive strength of waste soil is added with 2.5% lime and 2.5% ESP, 5% lime and 5% ESP, 7.5% lime and 7.5% ESP gave the results of 36.39, 70.66 and 337.13 kN/mm^2 respectively at curing of 28 days, which satisfies the soil improvement requirement. The Monte Carlo Simulation and optimization of the result using the mean value show that the compressive strength is increase when the data is simulated N = 16 to N = 20. It has proved that the accuracy of the result has increased by using Monte Carlo Simulation and optimization.

Keywords Soil improvement method · Open dumping area · Waste soil · Monte carlo simulations · Egg shell powder · Optimization value

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1 Introduction

Numerous kinds of stabilizers were used as soil additives to improve its engineering properties. A number of stabilizers, such as lime, cement and fly ash, depend on their chemical reactions with the soil elements in the presence of water [2, 7, 10]. The use of such geogrid and geofibre as having a physical effects can also be use as additive to improve the soil properties. Both chemical and physical stabilization can be used at the same time, for example by using lime or cement additives with geofibre or geotextile. This research is to find the alternatives of possibility of using the waste material such as egg shell powder and lime to treat the waste soil. Waste soil with the characteristics of having a combine waste and soil material are highly compressible and can absorb water. Waste soil has a weak strength and need to be treated if the dumping area is to be used for future construction [8].

2 Soil Stabilization Using Egg Shell Powder (ESP) and Lime

When lime and egg shell powder (ESP) are added to the soil, the first reaction that occurs is water absorption. Based on Eades and Grim [3], lime and ESP soil chemical reaction has two stages. The first stage is known as immediate or short-term treatment that occurs within a few hours or days after the lime treatment [1, 6]. There are 3 main chemical reactions that occurs in the first stage, namely cation exchange, flocculation-agglomeration and carbonation. The second stage is considered as a very long treatment that requires several months or years to complete. The main reaction is Pozzolanic reaction for this stage. The pozzolanic reaction is the chemical reaction that occurs in Portland cement containing pozzolans. The increase in soil strength and durability is associated with the long-term treatment, whereas the drying of wet soil and the increase in soil workability is attributed to the immediate treatment [4–7]. The egg shell powder and lime is added to the waste soil, as to study its potential to increase the strength of waste soil. The optimization will be done using Monte Carlo simulation method which is already applied for settlement modelling by Nur Irfah [9]. The possibility of Monte Carlo simulation to generate the maximize value of compressive strength is further enhance in this research.

3 Methodology

The dumping sites are identified for samples collection, the site was investigated to know the types of waste at the dumping sites and some samples will be collected at the sites. Sungai Ramal Dalam dumping area is selected as the dumping area.

The dumping area is not an active dumping site. The area is about 5 meters height of waste on top of the dumping area which consist of heterogeneous content such as concrete debris, paper, aluminum can, small twigs, plastic waste and others. A total of about 10 kg of soil samples were collected with different location at the open dumping area. The samples collected using the hand auger method as to get samples at a deeper depth. The samples are put into plastic bags and sealed for moisture content preservation. Figure 1 show the methodology of the research.

The samples collected are bring to the lab for the geotechnical properties testing. The unconfined compressive strength of waste soil which has been treated and untreated are determined using the unconfined compression test machine. The results from the unconfined compression test will be simulated using Monte Carlo

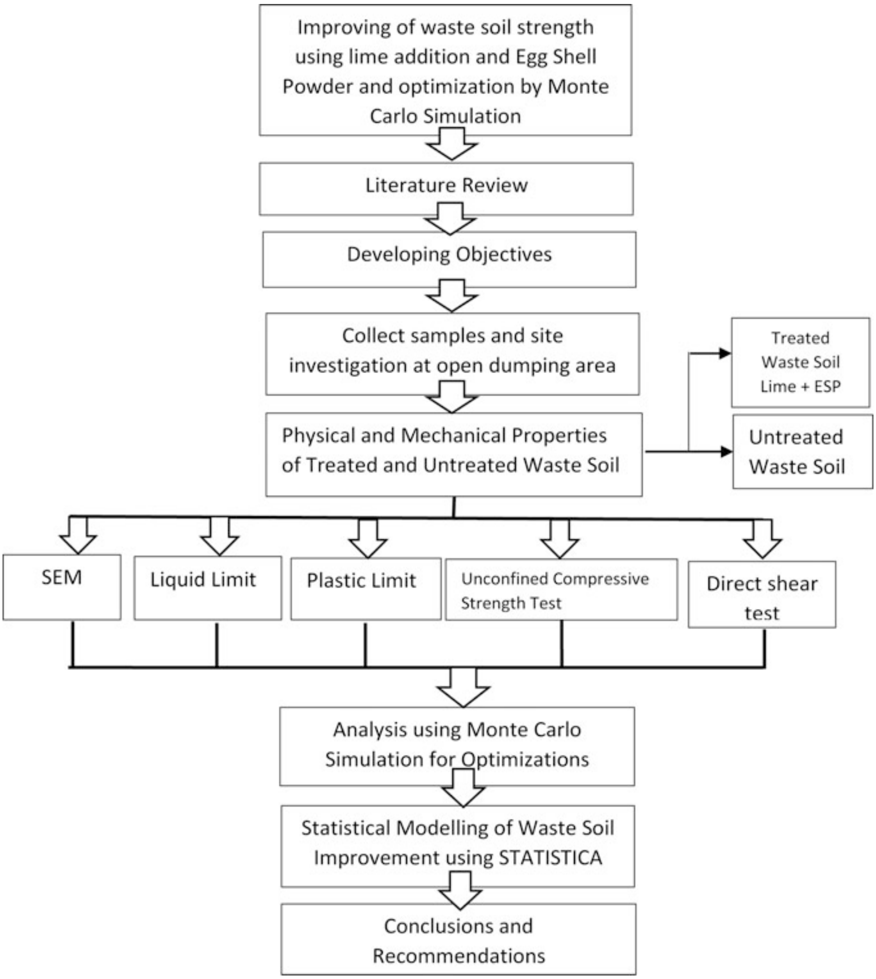

Fig. 1 The methodology of the research

simulation to find the optimization value for the unconfined compression strength of waste soil. The conclusions on the potential of the waste soil to be treated with egg shell powder and lime with the correct percentage of lime and egg shell powder to be added will be discussed in conclusion section.

4 Results and Discussions

The result and discussions of the optimization of the ESP and lime using Monte Carlo Simulations. The ESP and lime samples are tested with unconfined compression test to obtain the compressive strength of the waste soil. The curing which was done on 14, 21 and 28 days. The optimization of the result is done using Statistica Method. The optimization value is based on the laboratory data of unconfined compression test. However the laboratory data is limited to only three numbers of testing. As for the Monte Carlo simulation, the number of simulations of data are run for N = 16 for 14, 21 and 28 days of curing. The mean value from the simulation run by Statistica software gave the mean compressive strength of 50.08 kN/mm^2 for normal soil, 84.60 kN/mm^2 for 2.5% lime and 2.5% ESP, 135.23 kN/mm^2 for 5% lime and 5% ESP and 184.75 kN/mm^2 for 7.5% lime and 7.5% ESP. The details of the results are shown in Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12 and 13. As the curing time is increase to 28 days, the compressive strength has increase to 337.13 kN/mm^2.

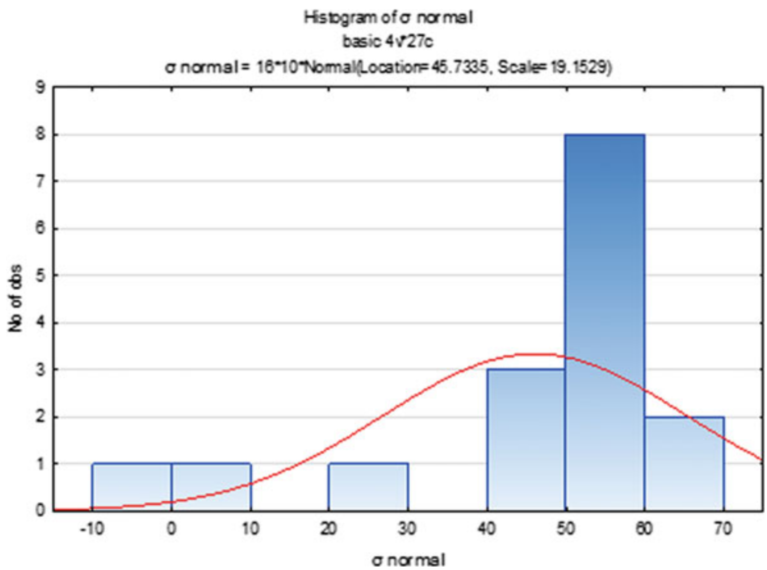

Fig. 2 Simulation data of the control sample for 2.5% Lime for 14 days of curing

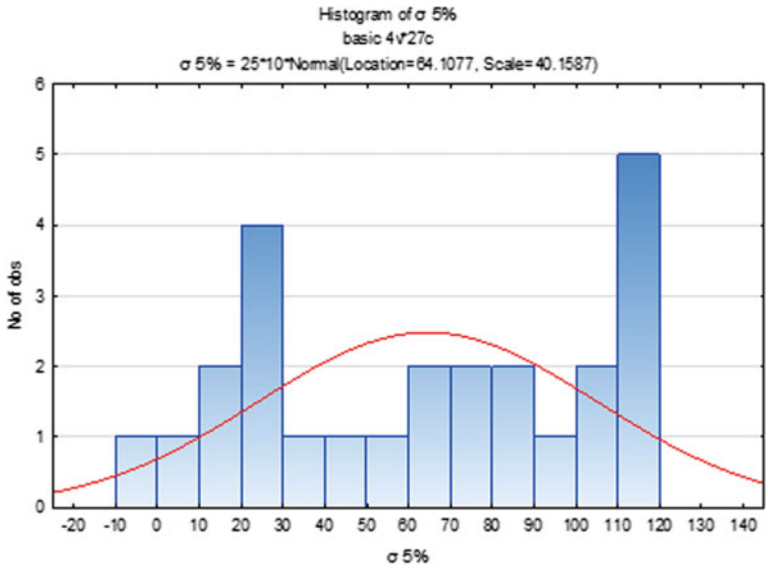

Fig. 3 Simulation data of the 2.5% ESP and for 14 days of curing

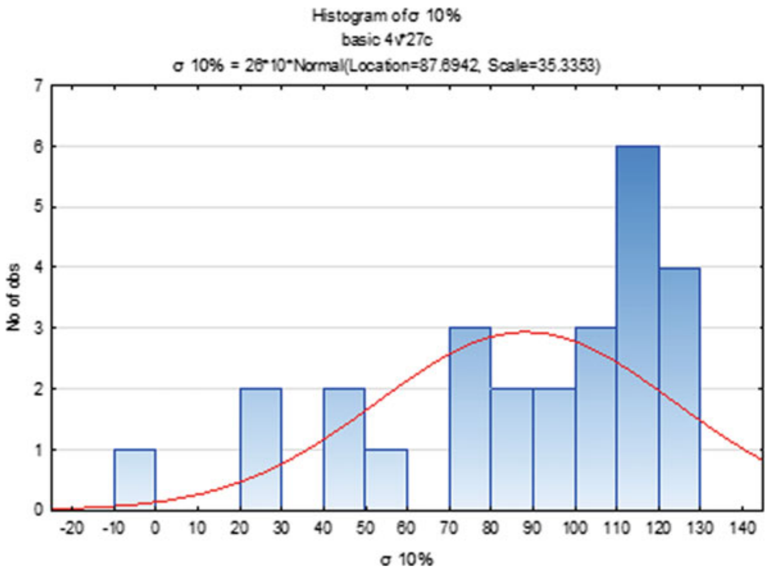

Fig. 4 Simulation data of the 5% ESP and 5% Lime for 14 days of curing

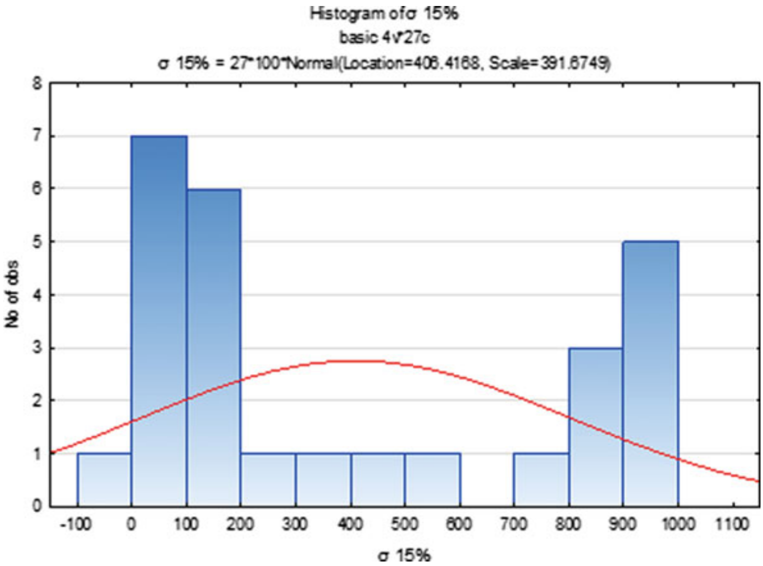

Fig. 5 Simulation data of the 7.5% ESP and 7.5% Lime for 14 days of curing

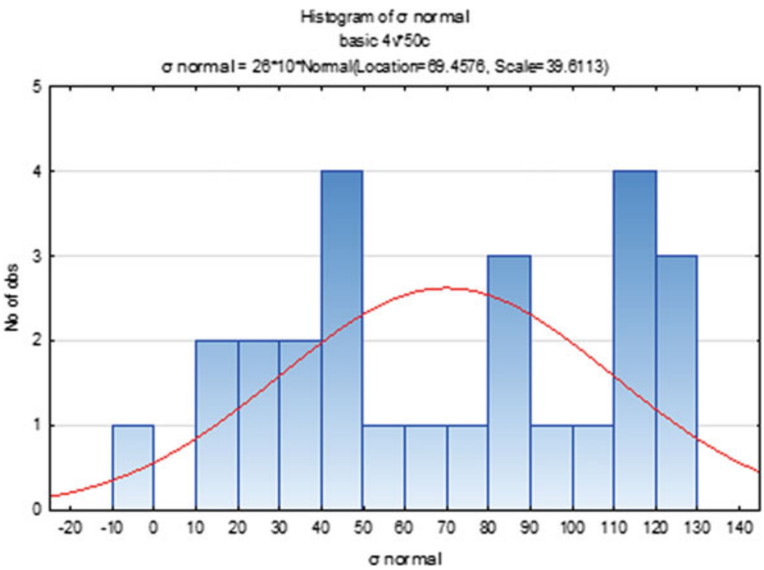

Fig. 6 Simulation data of the control sample for 21 days of curing

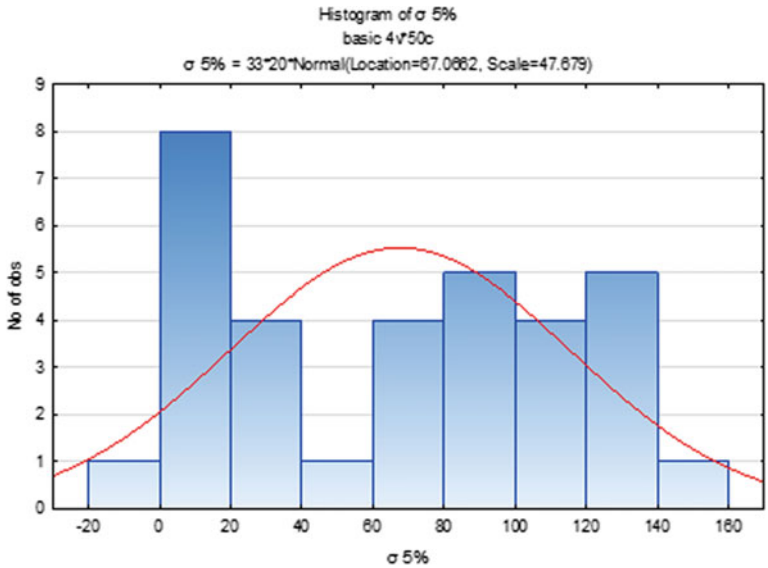

Fig. 7 Simulation data of the 2.5% ESP and 2.5% Lime for 21 days of curing

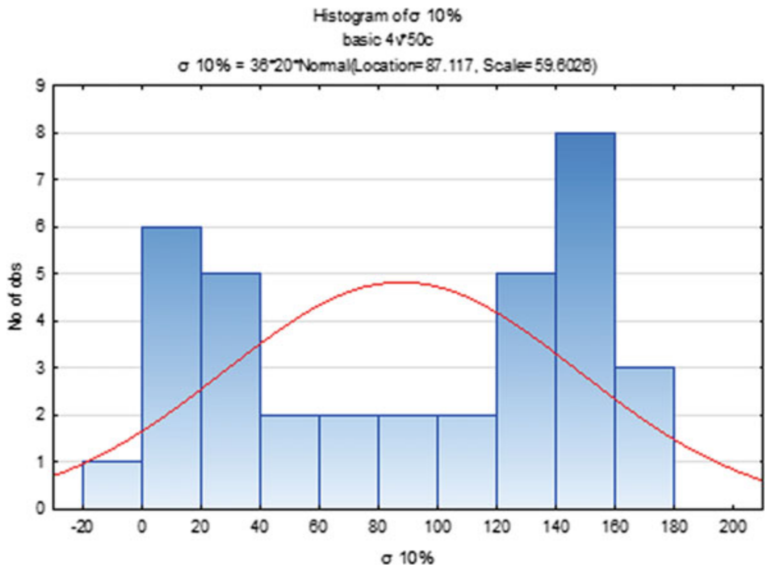

Fig. 8 Simulation data of the 5% ESP and 5% Lime for 21 days of curing

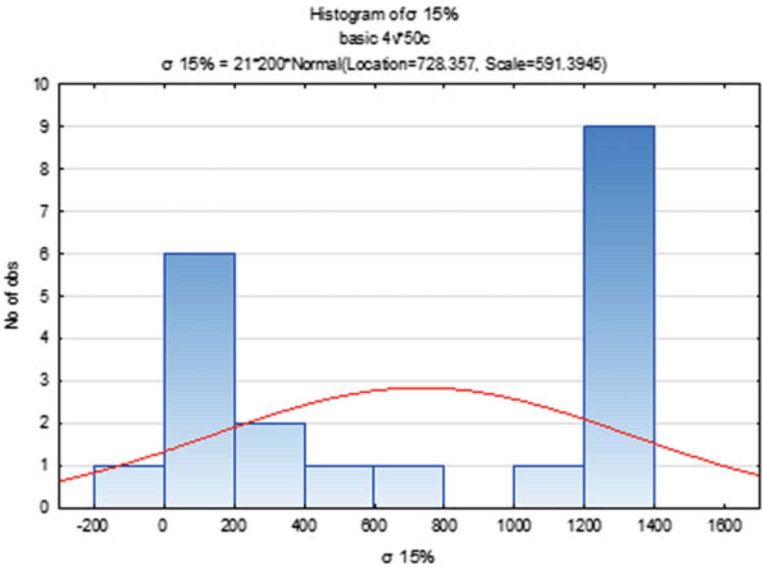

Fig. 9 Simulation data of the 7.5% ESP and 7.5% Lime for 21 days of curing

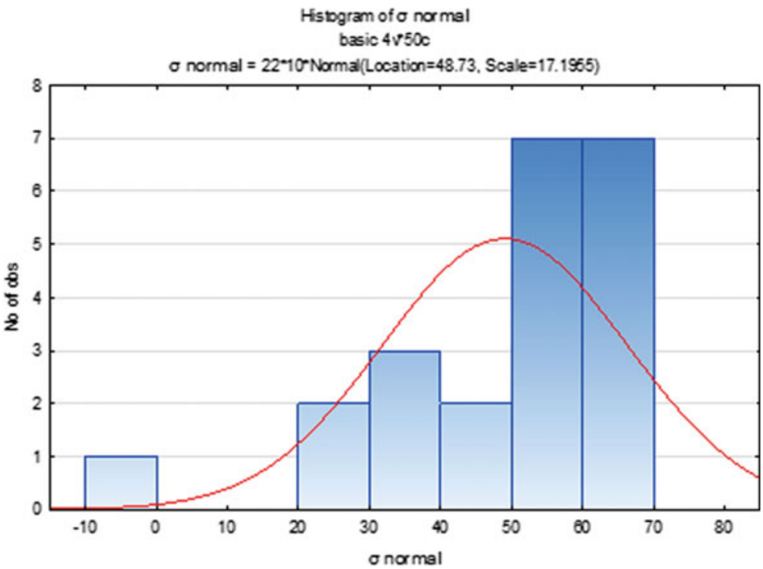

Fig. 10 Simulation data of the control sample for and for 28 days of curing

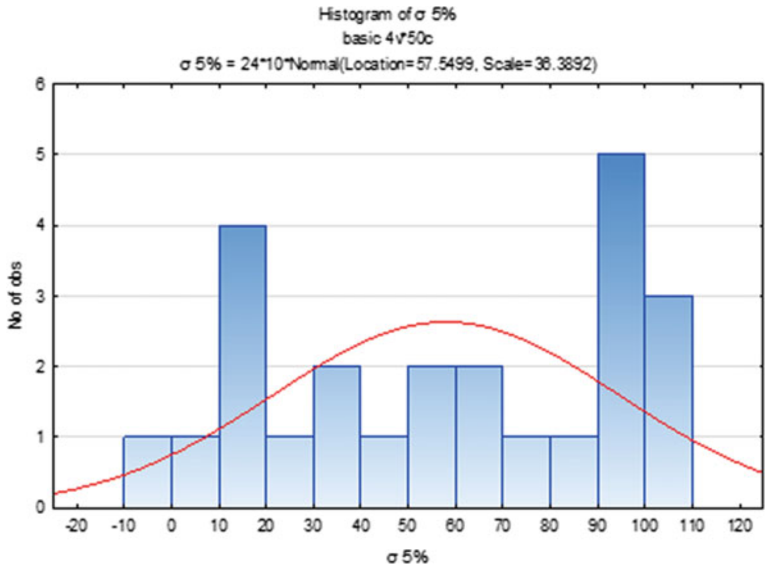

Fig. 11 Simulation data of the 2.5% ESP 2.5% Lime for 28 days of curing

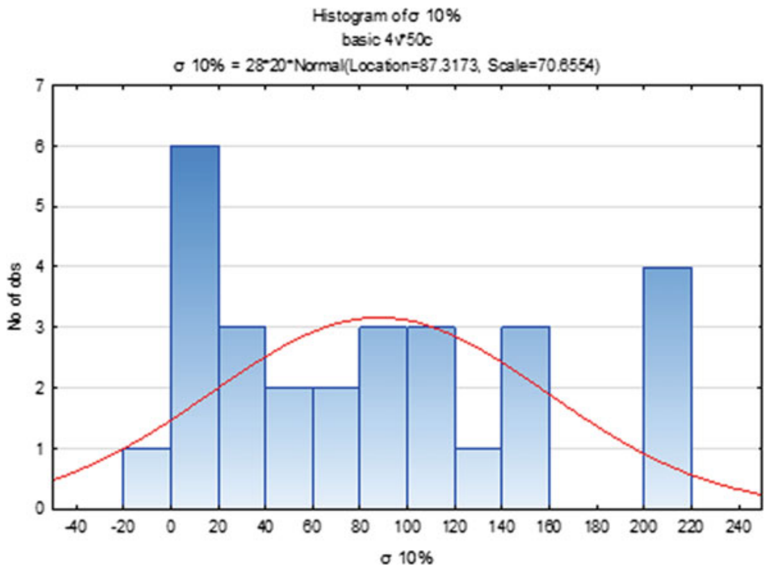

Fig. 12 Simulation data of the 5% ESP and 5% Lime for 28 days of curing

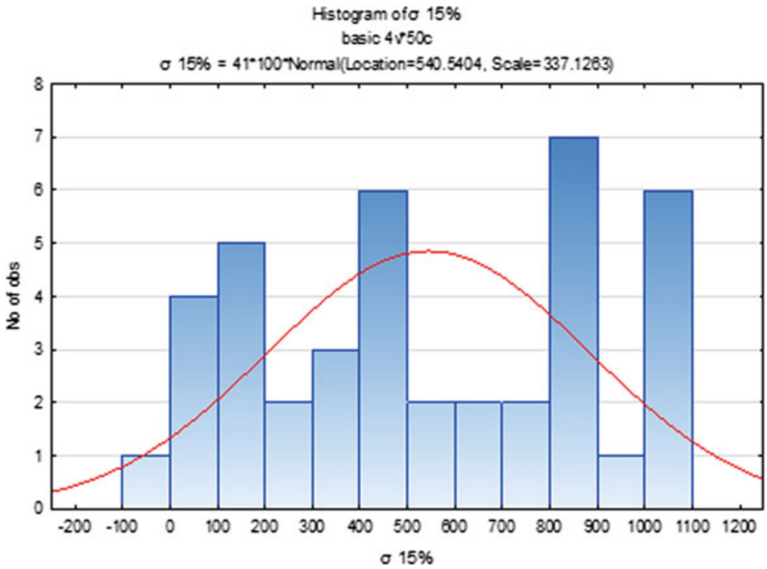

Fig. 13 Simulation data of the 7.5% ESP and 7.5% Lime for 28 days of curing

4.1 Unconfined Compression Test Results for 14 Days of Curing

The unconfined compressive strength in the Monte Carlo simulation show that the curve is not in normal distribution curve for 0% of ESP and lime. As the ESP and lime increases to 5, 10 and 15%, the compressive strength is also increases from 19 to 391 kN/mm^2. The experiment is further investigated with curing of 21 days. The results in Figs. 2, 3, 4 and 5 show that the graph has a bell shaped curve for 14 days of curing. The simulations for control samples has some mission data but as the lime and ESP is increases, the curve has become completed with more data of simulations. The unconfined compression strength data has been normalized with the use of Monte Carlo simulations and standard deviation value is obtained. The compressive strength obtained for 14 days of curing is 391 kN/mm^2.

4.2 Unconfined Compression Test Results for 21 Days of Curing

The unconfined compressive strength in the Monte Carlo simulation show that the curve is not in normal distribution curve for control sample. As the ESP and lime increases to 5, 10 and 15%, the compressive strength is also increases from 39 to 591 kN/mm^2. The experiment is further investigated with curing of 28 days.

The results in the graph has the pattern of normalized data at Figs. 6, 7 and 8. It has reach maximum value at the 7.5% ESP and 7.5% lime addition as shown in Fig. 9. The optimized value for ESP and lime are found at 7.5% ESP and 7.5% lime for 21 days of curing. However, the data for controlled sample are higher in frequency as compared to 7.5% ESP and 7.5% lime. This is due to the unconfined compression data that has normalized value in controlled sample as compared to addition of lime and ESP.

4.3 Unconfined Compression Test Results for 28 Days of Curing

The unconfined compressive strength in the Monte Carlo simulation show that the curve is not in normal distribution curve for 0% of ESP and lime. As the ESP and lime increases to 5, 10 and 15%, the compressive strength are also increases from 17 to 337 kN/mm^2. Figures 10, 11, 12 and 13 show that the graph have a bell shaped curve data for 28 days of curing. The simulations for control samples have some missing data, but as the lime and ESP has increases, the curve has become completed with more data simulations. The unconfined compression data has been normalized with the use of Monte Carlo Simulation and standard deviation value is obtained. The data is has become optimized at 28 days and the strength has increases to the maximum value of unconfined compressive strength. The data is distributed at the center of the data which uses the central point with standard deviation. In this analysis, the optimum mixing is 7.5% egg shell powder and 7.5% lime to get the maximize value of unconfined compressive strength.

5 Validation of the Monte Carlo Simulation Data

The Monte Carlo Simulation data are validated based on the laboratory data of unconfined compression test. Based on the laboratory data, the optimum value is at 7.5% ESP and 7.5% lime for 21 days curing with unconfined compression value of 591.39 kN/mm^2. As compared to the Monte Carlo Simulations, the value obtain is 728.36 kN/mm^2 for 21 days of curing with mixing ratio of 7.5% ESP and 7.5% lime. The percentage of different between MCS data with laboratory data approximately 23%. Between the two data of simulation and laboratory data, the value from simulation is slightly higher than the laboratory data. The MCS data simulate more data with $N = 16$ while the laboratory data use $N = 3$. Thus, Monte Carlo Simulation data is more accurate than the laboratory data.

6 Conclusions

In conclusion, the egg shell powder and lime have potential to increase the compressive strength of the waste soil. Base on this investigation, the following conclusions were being drawn:

- The compressive strength of waste soil is added with 2.5% lime and 2.5% ESP, 5% lime and 5% ESP, 7.5% lime and 7.5% ESP gave the results of 36.39, 70.66 and 337.13 kN/mm^2 respectively at curing of 28 days, which satisfies the soil improvement requirement.
- The Monte Carlo Simulation and optimization of the result using the mean value show that the compressive strength is increase when the data is simulated into N = 16. It has proved that the accuracy of the result has increased by using Monte Carlo Simulation and optimization.

From the result obtained, egg shell powder and lime is recommended to be used for improving the strength of waste soil. The recommended percentage with the optimized value is 7.5% lime and 75% ESP to be added to waste soil for soil improvement. Further increase of lime and ESP will reduced the strength of the waste soil.

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