Effect of Rapid Impact Compaction Energy on Unconfined Compressive Strength Properties of Fill Clay Soil

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ABSTRACT: In order to advantages the Rapid Impact Compaction (RIC) test method, a number of Unconfined Compression Tests (UCT) were performed on the RIC compaction samples. The UCT sample size is 6 cm in diameter and 12 cm in height, which was drilled out from the mould compaction that has been previously compacted with RIC Method. The compaction process is carried out in a standard modified mould (15 cm in diameter and 25 cm in height) by varying number of 5 - 35 blows for each compacted sample with frequency 30 - 40 blows per minute. All compaction processes are controlled by electro-mechanical new development system of repeated RIC method. The test results represented that at the same energy level with larger number of blow variation of RIC results produce higher unconfined compressive strength value in comparing to that of the energy level for larger masses with smaller number of blows. It is possible to make relative compaction relation which is the result of the achievement of UCS value using Rapid Impact Compaction method to UCS value of proctor method that fulfill a linear line equation. Based on these results, it could be created a simple relation of energy compaction in determining unconfined compressive strength value with appropriate process and lower RIC energy consumption.

Keywords: rapid impact compaction, unconfined compression test, clay soil.

1. INTRODUCTION

The selection of the compaction method is one of the important stage in the embankment construction. Several methods of dynamic compaction for a thick soil layer is known today among them are the Rapid Impact Compaction. This method is a dynamic soil compaction with Low Energy Dynamic Compaction concept. (Becker, 2011), (M M Mohammed, et al., 2013). The main equipment of Rapid Impact Compaction consists of masses of hammer which is dropped from a certain height.

In the laboratory the effect of compaction effort is generally tested using standard proctor and modified proctor with reference to compaction curve. Has been commonly known that if the energy of the compaction effort of per unit volume of soil is changed then the tendency of a curve of compaction will also change with increasing compaction effort and main parameters is the dry density and water content (Das, 2010).

In relation to the Rapid Impact Compaction method and the commonly used compaction standard that is standard proctor and modified proctor then to obtain optimal implementation in the use of compaction energy, it is necessary to conduct a research to extent the effect of Rapid Impact Compaction energy, especially on the compaction of fine gradation soil such as clay and silt.

2. LITERATURE REVIEW

2.1 Characteristics of Compaction

Proctor (1933) (Das, 2010), has observed that there is a definite relationship between moisture water content and the dry. In general, for a variety of soil types, there is a value of optimum moisture content to achieve maximum dry density. Dry density at optimum moisture content is defined as maximum dry density. Any increase in water content that exceeds the optimum water content tends to reduce dry density. In addition to the water content and the soil type, other important factors that affect the compaction is the energy per unit volume (Das, 2010). The compaction energy per unit volume used for the Proctor test is determined by the amount of blows of the layer; number of layers per mould and per unit volume of mould.

The general relationship between water content, density and compaction energy can be predicted from a compacted curve. In an effort compaction, increasing water content will be relatively easy to change the structure of the soil, and the achievement of dry density will be increased with a given compaction effort. There are two main parameter quantities obtained from the compaction curve where maximum dry density is reached, namely maximum dry density and optimum water content (Rajasekhar, et al., 2016).

Increasing the compaction effort will increase maximum density but will reduce the optimum water content. In general, the compaction curve shows that the ratio of air voids remains the same at maximum density, so at high moisture content, there is only a slight increase in the density obtained by increasing the compaction effort. The clay soil has a much higher optimum water content, consequently reducing the maximum dry density. The effect of increasing the compaction effort is also much greater in the case of clay soil (Rajasekhar et al., 2016).

2.2 Rapid Impact Compaction,RIC

Rapid Impact Compaction Equipment, RIC consists of three main components namely the foot hammer; rig where the hammer is attached, and hammer its self (Kristiansen & Davies, 2004) (M Mohammed et al., 2010). On the method of RIC, the hammer is dropped on a foot hammer which is placed above the surface of the soil with the frequency of the blows 30 - 60 /min as a characteristic of rapid impact compaction (Falkner, et al., 2010).

The parameters of the compaction energy of RIC methods is determined by the weight of the hammer, the weight and area of the geometry of the foot hammer, the frequency and the cumulative amount of the blows in one cycle of compaction at the fixed point. One important thing, in accordance with the results of previous research (Koohsari, et al., 2016) that in the impact method the effect of hammer weight is more significant than the falling height.

Similar to the magnitude of the compaction energy according to Falkner on the method of dynamic compaction, then the cumulative amount of blows energy per area of contact area of the foot hammer (kNm/m^2), determined by the impact area of the foot hammer (anvil) (m^2), weight of hammer, weight of hammer foot, velocity of blows, and number of blows (Falkner et al., 2010).

3. MATERIAL and METHODS

3.1 Characteristics of Compaction

The local soil samples are used, the physical properties of soil samples are summarized in Table 1 and Figure 1.

Table 1 Physical Properties of The Materials

Properties	Values
Loose Wet density,(kN/m^3)	10.30
Water content (%)	38.36
Specific gravity	2.73
Liquid Limit, (%)	55.89
Plastic limit, (%)	47.48
Plasticity index (%)	8.41

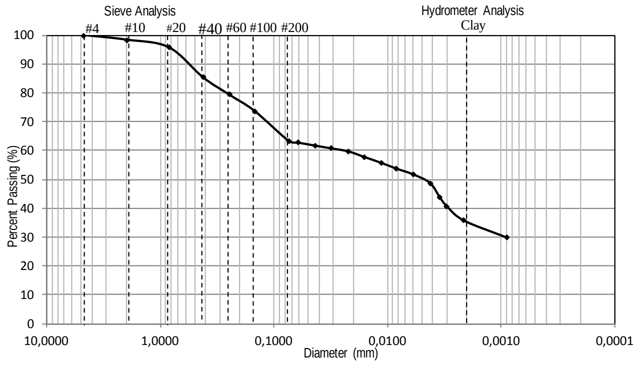

Figure 1 Grain size distribution

3.2 Apparatus of Testing

In this experimental test, the equipment of repeated load impact used air-pneumatic piston. The main components of the equipment consisted of air compressor, piston double-acting air pneumatic-pressure, valve solenoid, panel controller and mass of compactor as shown in Fig 2. Repeated load impact equipment has 150 kg vertical lift capacity of mass compactor and falling height can be set 10 cm to 30 cm, the time period of the impact compaction is being 2 - 3 seconds per blow. For testing stability, the apparatus was attached and positioned on a steel frame.

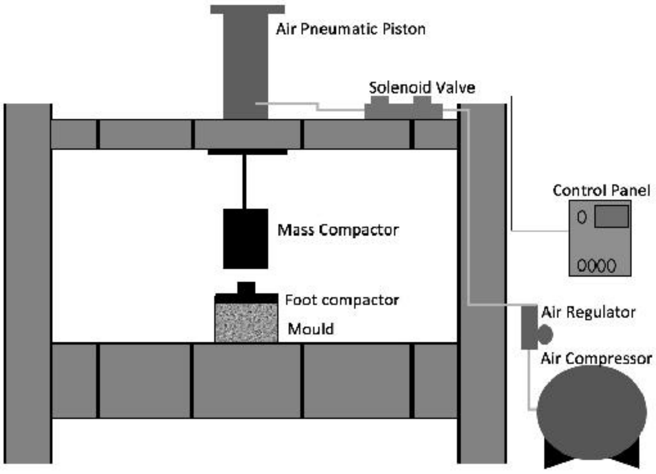

Figure 2 Schematic of model equipment of electro-mechanic system rapid impact compaction model

To produce energy required, the weight of the mass compactor was used by 45 kg and 70 kg of steel blocks which are attached at the ends of the piston rod. These compactor mass can be dropped at a height in accordance with the setting of the height on the control panel. For testing mould, the property of mould used were inner diameter of 15 cm, 25 cm in height, volume of the mould 0.0044 m^3. For the compacting process, the mould were equipped with a pedestal pad as foot compactor or anvil which has adjusted size to the diameter of the mould. The anvil was by steel plate which has 2 cm of thickness, the rod connection was 15 cm in height and diameter of 7.5 cm.

Figure 3 Compaction apparatus test: a. Cylindrical mould test; b. Anvil

3.3 Test carried out

The soil in the compaction mould was obtained from the remoulded sample, the required amount of soil was mixed with water and left under a plastic for air drying to obtain a water content in accordance with the standard proctor compaction of 15-35% and 0.046 kN of soil was filled in the compaction mould without compacting by controlling the loose density of 10.4 kN/m^3. The compaction process with rapid impact compaction was performed using various energy levels by applying the various impact blows.

In the compaction process, the mass of compactor was periodically dropped over the anvil with ranging of frequency 30 - 40 blows per minute and adjustable falling height were set in 15 cm, 20 cm and 25 cm for each sample tested, the impact process being carried out by varying blow ranging from 5 to 35 amount of the blows for each mould compaction at specified height.

The UCT sample size is 6 cm in diameter and 12 cm in height, which was drilled out from the mould compaction that has been previously compacted. In this research, all compaction process were controlled by a new developed electro-mechanic system of rapid impact compaction.

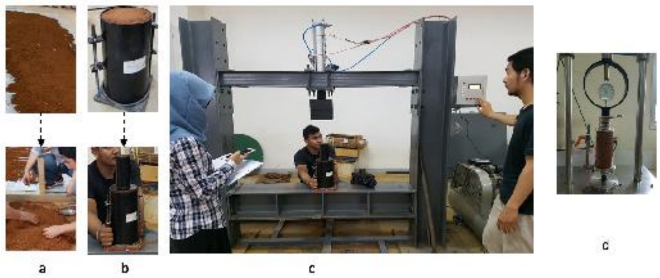

Figure 4 Program of testing: a. Sample preparation; b. Set up of anvil; c. Compaction proses; d. Measurement of UCS

4. RESULTS AND DISCUSSION

4.1 Energy of Proctor and Rapid Impact Compaction

The compaction energy of proctor methods are based on compaction efforts that carried out in a 101.6 mm diameter compaction mold with a height of 116.43 mm having a volume of 944 cm^3. In the standard proctor test the amount of compaction energy is 594 kJ/m^3 obtained from the compaction of 3 layers per mould using a pounder weighing 2.5 kg that dropped from a height of 30.05 cm with the amount of 25 blows for each layer, for modified proctor using a weight of 4.5 kg for a falling height of 45.7 cm, with 5 layers per mould using 25 blows per layer, the compaction energy size is 2,695 kJ/ m^3.

While for Rapid Impact Compaction method in this research use mould diameter 15 cm and height 25 cm with volume 4,417 cm^3. As for the weight scheme of hammer weight used is 70 kg, by varying the falling height respectively 15 cm, 20 cm and 25 cm for the number of 5, 15, 25 and 35 blows. All compaction processes are carried out using only 1 layer on each mould in the test, so from this

RIC compaction process the energy of compaction effort varies between 111 kJ /m^3 for the smallest and 1,365 kJ/m^3 for the highest energy or when compared to the standard energy of the proctor varies between 0.20 - 2.3 times.

Table 2 Energy Compaction Scheme Based on Compaction Type

Type of Compaction	Hammer Weight (kg)	Falling Height (m)	Blows Per Layer	Layer Per Mould	Volume Mould (m^3)	Compaction Energy (kJ/m^3)	Energy Ratio to Proctor
Standard Proctor	2.5	0.31	25	3	0.0009	594.29	1.00
Modified Proctor	4.54	0.46	25	5	0.0009	2695.13	4.54
RIC-01	70	0.15	5	1	0.0044	117.05	0.20
RIC-02	70	0.15	15	1	0.0044	351.15	0.59
RIC-03	70	0.15	25	1	0.0044	585.26	0.98
RIC-04	70	0.15	35	1	0.0044	819.36	1.38
RIC-05	70	0.20	5	1	0.0044	156.07	0.26
RIC-06	70	0.20	15	1	0.0044	468.20	0.79
RIC-07	70	0.20	25	1	0.0044	780.34	1.31
RIC-08	70	0.20	35	1	0.0044	1092.48	1.84
RIC-09	70	0.25	5	1	0.0044	195.09	0.33
RIC-10	70	0.25	15	1	0.0044	585.26	0.98
RIC-11	70	0.25	25	1	0.0044	975.43	1.64
RIC-12	70	0.25	35	1	0.0044	1365.60	2.30

4.2 Dry Density and Optimum Water Content at Different Energy Levels

Tables should be presented as indicated in Table 1. Their layout should be consistent throughout. Horizontal lines should be placed above and below label headings, below subheadings and at the end of the table. Vertical lines should be avoided.

First, to explain the relationship of dry density variables, optimum water content compaction and energy level of the compaction effort, it has been observed with the relationship of these three variables, in this case the relationship is expressed as a comparison to the energy of standard proctor method which is 594.29 kJ/m^3 to the changes in the moisture content of each compaction mould according to the amount of energy of Rapid Impact Compaction given as stated in the Table 3.

Table 3. Dry Density at Different Energy and Water Content Levels

Type of Compaction	Hammer Weight (kg)	Falling Height (m)	Blows	Cummulative Energy (kJ/m^3)	Energy Ratio to Proctor	Water Content (%)	Dry Density (kN/m^3)
RIC-01	70	0.15	5	117.051	0.20	15	10.52
						20	10.55
						25	10.66
						30	10.32
						35	9.31
RIC-02	70	0.15	15	315.153	0.59	15	11.05
						20	11.05
						25	11.33
						30	10.86
						35	9.80
RIC-03	70	9.15	25	585.256	0.98	15	11.30
						20	11.53
						25	11.74
						30	10.90
						35	10.00
RIC-04	70	0.15	35	819.358	1.38	15	11.60
						20	12.09
						25	12.16
						30	11.27
						35	10.20

Based on Table 3 it can be known and stated that the tendency of dry density relation is influenced by energy level of compaction effort and moisture content, at least this can be seen in Figure 4. The characteristics of the relation are illustrated by the prediction line of the optimum moisture content corresponding to the energy level of the compaction effort given. The results show that the addition of energy tends to reduce the value of the optimum water content.

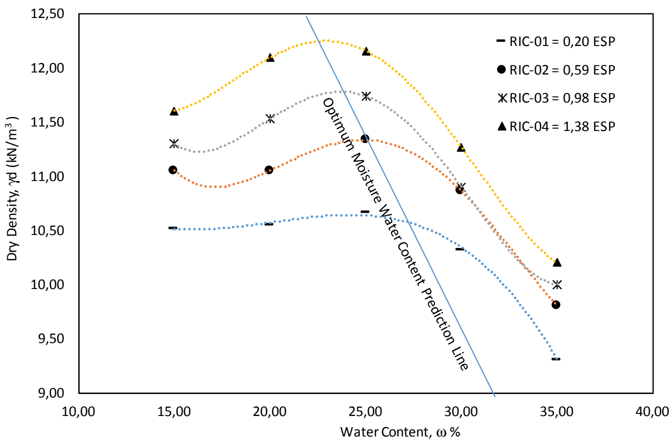

Figure 5 The density relations to optimum moisture content and energy levels

4.3 Unconfined Compressive Strength vs Optimum Compaction Energy

Unconfined compressive strength, UCS for optimum energy level were taken for moisture content of 25%. To obtain the optimum energy level then the observation of Rapid Impact Compaction compaction is done at different energy levels as shown in Figure 6.

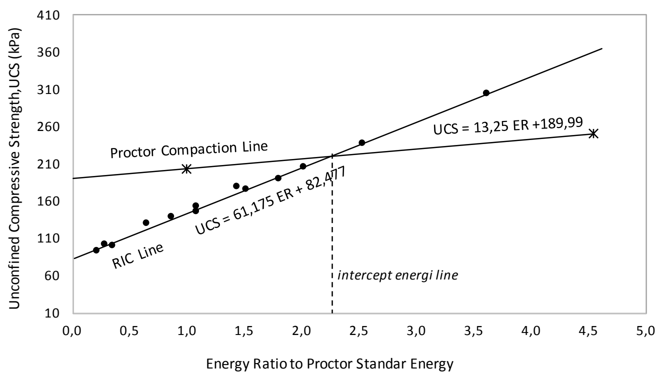

Figure 6 Linearization of UCS values from the relation of the proctor compaction energy line to the RIC energy line

The energy line compaction Rapid Impact Compaction which in this case according to Eq. (1), the other line is the energy line connecting the standard energy level of the proctor and the modified proctor which has previously been examined the relationship of its unconfined compressive strength value which has been linearly and satisfies the Eq. (2).

$$UCS_{RIC} = 61.175(ER) + 82.477 \quad \text{(kPa)} \qquad (1)$$
$$UCS_{Proctor} = 13.25(ER) + 189.99 \quad \text{(kPa)} \qquad (2)$$

From the Eq. (1) and Eq. (2) in as the Figure 6, there are three important parts are visible: first is for lower energy levels of RIC energy than the proctor energy in this case showing that the value of UCS obtained is also lower than the UCS of the proctor energy, then the next section is on the energy level zone greater than the standard energy of the proctor but still smaller than the proctor compaction energy line in this section shows the level of attainment of UCS values in general equal to the attainment of UCS at the proctor compaction energy line to a point of intersection, while the last part is the comparison of energy rapid impact compaction greater than the proctor energy line, where in general the results of achievement of its UCS value is also higher than the energy of compaction proctor.

Based on these three conditions, it is possible to obtain an optimum compaction energy level equivalent to the optimal UCS values corresponding to the intersection line energy proctor method to the Rapid Impact Compaction energy line and the proctor compaction energy line, i.e. a point where if applied greater energy ratio it will get greater compaction result from UCS of proctor method, and otherwise so the turning point of comparison is as reference of optimum energy where in this research got optimum point of energy ratio is equal to 2.25 .

5. CONCLUSION

Some conclusions that can be drawn from the results of this study are:

1. The tendency of the relationship of dry density is influenced by the energy levels of compaction effort and water content. The characteristics of relationship can be described with the line of prediction of the optimum moisture content corresponding with the energy level of a given compaction effort.

2. It is possible to make Relative Compaction relation which is the result of the achievement of UCS value using Rapid Impact Compaction method to UCS value of proctor method that satisfies a linear line equation.

3. By connecting the energy comparison line of Rapid Impact Compaction to the energy line of the proctor method, it can be determined the amount of optimum energy that is equal to the achievement of the UCS compaction value by the RIC method and the Proctor method.

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