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Utilization of Waste Aggregate for Aggregate Construction for Improvement of Soil Bearing Capacity

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Abstract. Soil bearing capacity is one of the important elements when designing the foundation, bridges, and embankment. The soil bearing capacity needs to be improved due to the weak soil such as clayey silt or silty clay soil that was encountered at the construction site. There are many stabilizations method such as bio treatment of the subgrade, chemical stabilization method, chemical grouting or injection systems, aggregates, or reuse of the waste materials, geosynthetic reinforced embankment and vibro compaction. One of the most common chemical stabilization methods is by using additives to improve soil strength. There are a few wastes material that can be used for strengthening clay soil which is more economic and environmentally friendly. The objective of this research is to improve the soil engineering parameters and bearing capacity using Recycled Waste Aggregates (RWA). In this study, soil samples will be added with different percentage weight of RWA and undergo a few series of laboratory experiments to study its behavior which will be sieve analysis, specific gravity, compaction, and California Bearing Ratio (CBR). The optimization of the percentage of recycled concrete aggregates can be determined from the simulation method. For bearing capacity value, the increase of bearing capacity greatly increases as the percentage of RCA increased and the optimum percentage of RCA is 15%. It concluded that the increasing value of RCA will improve the strength and soil subgrade structures. Recycled Concrete Aggregates have a really great potential material to be used in engineering.

1 Introduction

Bearing capacity of soil is an important parameter for foundation design. The foundation of the building such as shallow foundation and deep foundation will lies on the bearing capacity of the soil. The higher bearing capacity, the higher the load of the structure it can carry. The

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exploration of using waste materials from recycled construction aggregates are the main objectives of this research. Construction material production and consumption are ongoing, and the resulting environmental contamination is becoming a major issue on a global scale. Recycled utilization is one of the innovative methods to deal with Construction Demolition Waste (CDW) in economic and environmental-friendly way. A lot of civil engineering source materials are made from processed CDW, including formed bricks and blocks, recycled aggregates for concrete, and substitute materials for pavement engineering [3]; [6].

The landfilling and accumulation of construction and demolition (C&D) waste, which is increasingly used as building materials in engineering applications, is one of the key points of view. They are currently used in applications like concrete aggregates, pipe beds, engineered fills, pavements, and ground improvement. Crushed bricks (CB), recycled waste aggregates (RWA), and reclaimed asphalt pavement are the few major components of C&D materials (RAP) [1]. In this research, the study will examine the potential for enhancing the soil's bearing capacity by employing Recycled Waste Aggregates (RWA). Utilizing RWA will help assure continuity in terms of sustainability growth of civilization by saving on materials, energy, and natural resources.

2 Literature Review

Previous practice to improve the soil strength, methods such as dewatering, compaction, preloading with and without vertical drains, grouting, deep mixing, deep densification, and soil reinforcement are applied. The well-established techniques include dewatering, compaction, preloading, and grouting are one of the engineering methods [7]. All these methods are proven to be reliable in terms of practicality and cost-effective. Other than this method, the adding of recycled waste materials would also help in the improvement of soil strength. The addition of flay ash, cement, and lime on the soil to increase the strength have been studied previously by [4]. The problem is these common methods is not environmentally friendly and did not have sustainability values. Thus, new innovative ways to improve the soil bearing capacity must be initiated and prior to limitations of earth's natural resources.

A lot of construction waste has been generated due to the urban economic construction's rapid development. Most of the demolition waste from ancient buildings is currently simply dumped in the suburbs without any treatment or stacking. This not only consumes a lot of space, pollutes the environment severely, and endangers human life but also incurs some cleaning and shipping charges [2];[16]. Thus, reusing and recycling C&D wastes in infrastructure projects reduce environmental contamination while also maintaining the earth's natural resources [5]. The reuse of construction waste is also reducing the emission of carbon to the environment by reducing the production of concrete.

By adding the recycled aggregates waste by 5%, 10% and 15% to the clay soil will improve the strength of the soil. The experimental work involves increasing the strength such as bearing capacity, direct shear test and compaction test are tested to the weak soil to be added with recycled aggregates waste. Furthermore, to explore the optimized value to be added to the clay soil is conducted using Monte Carlo simulations method. This optimized value will find the correct amount of recycled aggregates waste to be added to clay soil provided the experimental data is obtained. This research would help in reducing the construction waste and help in the improvement of the clay soil.

3 Methodology of Research

The methodology of research starts from problem statement, objectives, and literature review. The scope of works consists of experimental work, data analysis and modelling and strength improvement method and finally conclusion and recommendations. The details of the methodology of research is shown in Figure 1. The explanations of each step are as follows:

1. Experimental work: Particle size distribution (PSD) method, liquid limit and plastic limit method, compaction test and California Bearing Ratio (CBR) test. These experiments are to determine the soil properties and index test as to characterize the weak soil. The experiment will be conducted on the weak soil without adding the recycled waste aggregates and with addition of 5%, 10% and 15% of the recycled waste aggregates to the weak soil.
2. Data Analysis and Modelling: The mixing ratio will be optimize using the Monte Carlo Simulation method. The optimization from the data collected by experimental work such as CBR test, compaction test and others to simulate using Monte Carlo Simulation methods. The number of iterations will be used to simulate the data from N= 50 until N= 10 000 data. This will increase the accuracy of the recycled waste to be added to the weak soil.
3. Strength Improvement Method: The compaction and CBR test will be used to test the soil strength. The percentage of strength improvement will be determined from this test. Conclusion and recommendation for the weak soil improvement will be explain in this part.

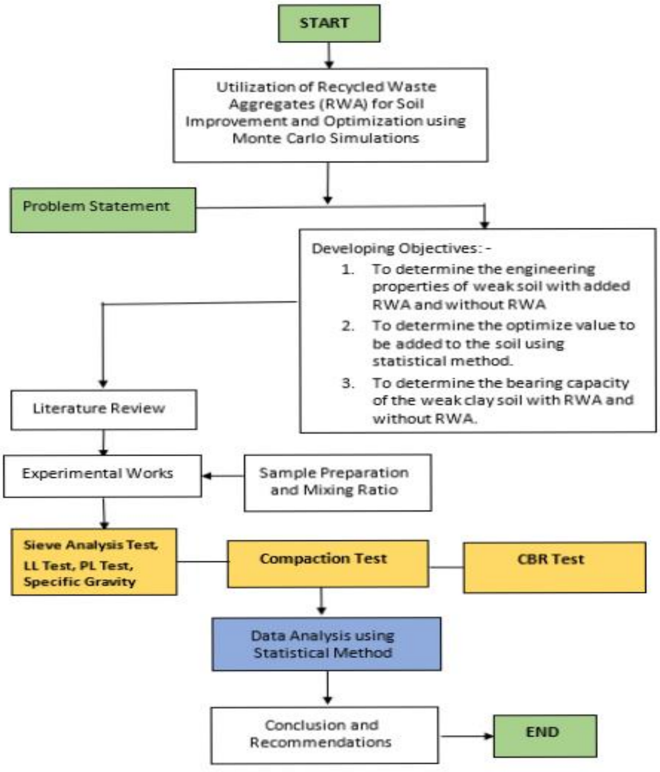

Fig. 1. Methodology of the research

4 Results and Discussions

4.1 Particle Size Distributions Test

The particle size distribution test is used to determine the grading of the samples and to separate the fine soil with the course soil. The sieve analysis of both soil sample and Recycled Concrete Aggregates (RCA) has been obtained by sieve analysis method. According to Unified soil classification, the gravel size limit is greater than 4.75mm and sand is 4.75mm to 0.075mm. And so, from the graph shown in Figure 2, the percentage passing for sieve 4.75 for soil sample is 72.8% which may conclude that the soil sample consist of 72.8% of sand and 27.2% gravel. Meanwhile, for Recycled Concrete Aggregates, it is 10.42% passing the 4.75mm sieve, which may conclude the RCA consist of 10.42% sand and 89.58% gravel. Fig. 2 shows the grain size distribution of the clay soil and RCA soil.

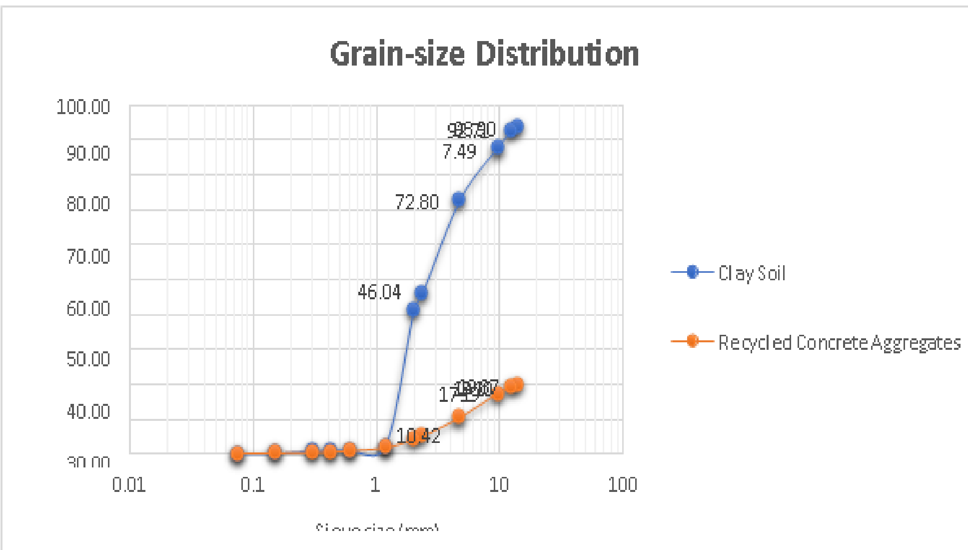

Fig. 2. Particle Size distribution of Clay Soil and RCA soil

4.2 Specific Gravity Test

The soil sample specimen without any added recycled aggregates (RCA) used in this experiment was discovered to have a specific gravity of 2.56, while (sample+ 5% RCA) is 2.63, (sample+ 10% RCA) is 2.62 and (sample + 15% RCA) is 2.50 The most prevalent minerals in soil, according to theory, have a specific gravity between 2.6 and 2.9. Clayey and silty soils have a specific gravity of 2.6 to 2.9, while sandy soil has a specific gravity of 2.65. While soils with hard materials may have a specific gravity of more than 3.0, organic matter- and porous- particle-containing soils may have a specific gravity of less than 2.0. As for this research, it can be concluded that the additional of RCA does not give significant impact towards the value of specific gravity of soil as the value obtained from the experiment process is in the range of soil materials which is 2.0 to 3.0.

Table 1. Specific gravity result

Parameters	Soil + 0% RCA	Soil + 5% RCA	Soil + 10% RCA	Soil + 15% RCA
Mass of density bottle, M1(g)	27.3	26.4	26.6	28.4
Mass of bottle + dry soil, M2 (g)	37.3	36.9	37.6	39.9
Mass of bottle + soil + water, M3(g)	83.4	82.3	82.6	84.8
Mass of bottle + water, M4 (g)	77.3	75.8	75.8	77.9
Specific Gravity, Gs	2.56	2.63	2.62	2.5

4.3 Compaction Test

There are four samples prepared for the compaction test. The first sample is empty clay soil without any additive. The second, third and fourth soil samples have been added with 5%, 10% and 15% RCA of the total sample volume respectively. The air voids content of a compacted soil layer from 4 different sample combinations has been determined by obtaining the value of maximum dry density of all four types of soil sample and optimum water content from compaction test. The highest compaction curve with the highest maximum dry density is the soil with 5% RCA. Fig. 3 shows the compaction curve of the different percentage of RCA.

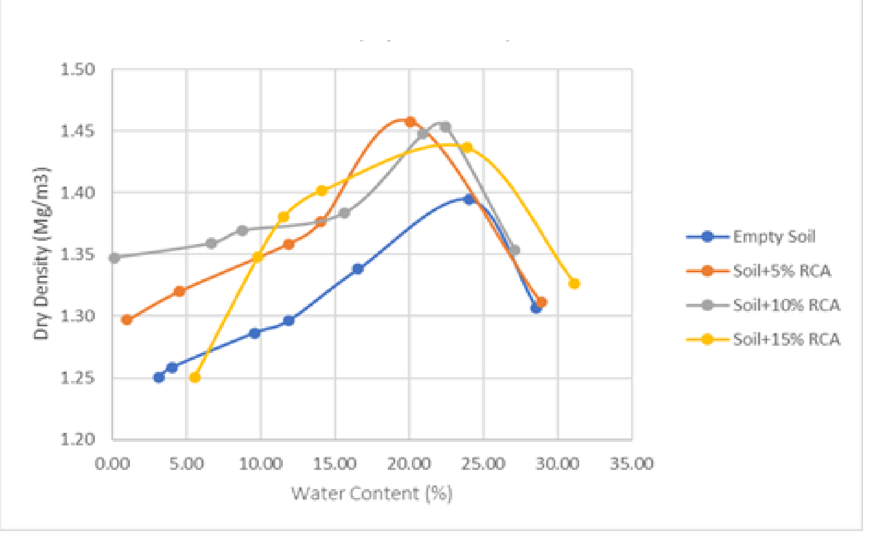

Fig. 3. Compaction curve with different percentage of RCA

4.4 Californian Bearing Ratio Test

The California Bearing Ratio (CBR) test is performed to determine the strength of soil subgrades and base course materials. The load required to cause a standard-sized plunger to penetrate a soil specimen at a particular pace is measured in this test. The CBR test was conducted using a CBR machine that showed the CBR% value of each sample after loads were imposed on the sample. The penetration speed was set at rate of 1.25mm/min. The CBR% value was shown on the CBR machine and each of the readings were recorded. Fig. 4 shows the equipment for CBR test. The test is following the standard by ASTM D1883.

Fig. 4. Equipment for CBR test and soil sample

Based on Fig.5, samples with 15% RCA show the highest value of CBR% with the average value of 47.88 kPa, followed by 10% RCA, 5% RCA and lastly soil sample with 0% RCA added. This indicates that by increasing the percentage of Recycled Concrete Aggregates (RCA) as additive material to soil sample will increase the value of CBR%.

As for the 5mm penetration, we may observe the value as illustrated from Fig. 6, the value of CBR% increases as the percentage of RCA increases. However, it drops after 10% RCA as 10% RCA of the soil weight was recorded as the highest CBR% value of 43.14. The results show that the addition of Recycled Concrete Aggregates (RCA) as additive to soil structure has been effectively increasing the subgrade clay soil and improve the engineering properties of the soil for construction purpose. The increment of CBR value for both 2.5mm and 5mm penetration are due to the filling voids between soil grains by RCA. However, the declining value of CBR% as the percentage of RCA is being increased shows that too much additive can weaken the clay soil strength parameters [11]. This agrees with the previous study that has been conducted by [12] that uses waste glass powder (WGP) as additive material to improve soil strength. The researcher has conducted the CBR test and illustrated that the optimum percentage of WGP is 15% then a reduction was seen. Furthermore, a study using fly ash as stabilization additive also shows that the optimum content of fly ash is at 10% and furthermore increment of the supplement to the mix decreases the CBR value [13]. Both studies have proof that each additive supplement has the optimum content before it decreases the CBR values and thus, tally with the results of this research.

In terms of the soil bearing capacity, the sample is being tested to withstand the highest load together with the displacement of the soil when the load is applied. From Fig. 7, the highest maximum average bearing capacity obtained from the CBR test is 1544.26kN/m^2 for the soil sample with 15% RCA, followed by 10% RCA, 5% RCA, while the soil sample without any additive record the lowest average bearing capacity value of 977.29kN/m^2 between three sample tested. The increments of bearing capacity value as the value of RCA increase have tally with the previous studies by [8] that the bearing capacity increase as the number of geogrids used increase. This indicates that a higher percentage of RCA will increase the value of bearing capacity and thus, increase the soil engineering properties. For this study, the optimum percentage of RCA is 15% which gives the bearing capacity value of 1544.26 kN/m^2 and that is massive different compared to empty soil sample without any additive that has bearing capacity value of 977.29kN/m^2 as illustrated in Fig. 7.

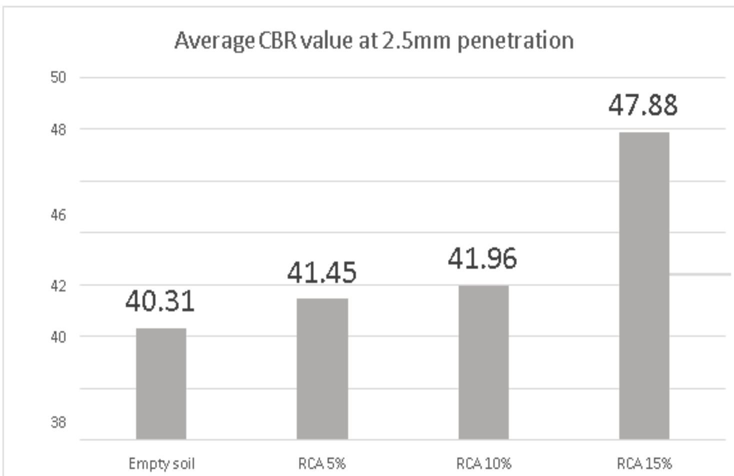

Fig. 5. Average CBR value at 2.5 mm

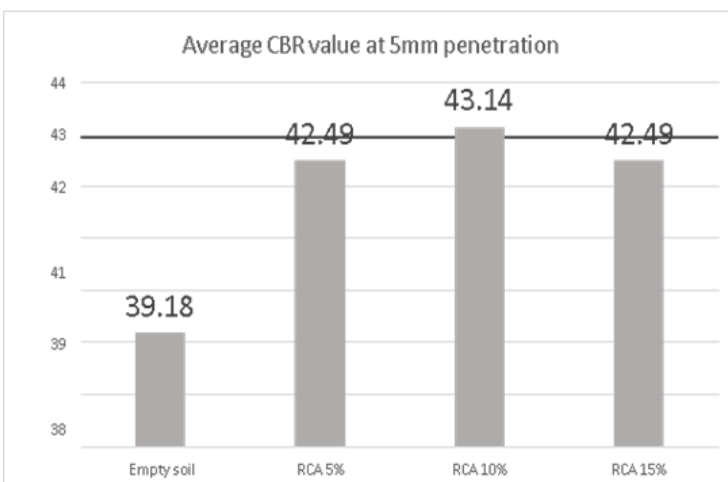

Fig. 6. Average CBR value at 5 mm

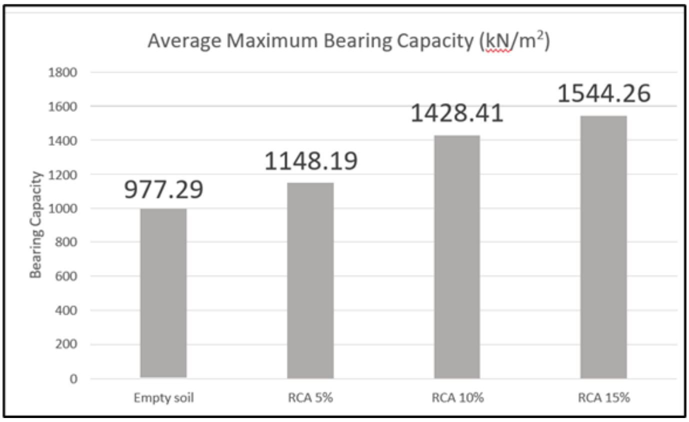

Fig. 7. Average Maximum Bearing Capacity of the soil and added with 5%, 10% and 15% RCA

5 Conclusions

Based on the result analysis and discussion of this study, it is concluded as follows:

1. For specific gravity test, by adding additional RCA into soil sample does not give significance impact towards specific gravity value of soil sample

2. For the compaction test, soil sample with addition of 15% RCA give the lowest value of Air Voids (Av) which mean it has better ability towards compaction compared to other sample combination. Furthermore, the optimum content of RCA that achieves maximum dry density values is 5% RCA which is slightly different with the previous studies. This might be due to human error during laboratory work. However, the results are not much different between the sample that has additive compared to empty soil.

3. The California Bearing Ratio (CBR) test demonstrates that the CBR value has increased along with the proportion of RCA. However, as the CBR% value decreases later, it is demonstrated that the best percentage RCA for 5mm penetration is 10%. In terms of bearing capacity, the bearing capacity increases significantly as the percentage of RCA increases. This means that if RCA increases in value, soil engineering qualities and soil subgrade structures will both improve.

4. For the California Bearing Ratio (CBR) test, it shows that the increasing percentage of RCA has increased the CBR value as well. However, for 5mm penetration, it is shown that the optimum value of percentage RCA is 10% as the CBR% value is decreased after. For bearing capacity value, the increase of bearing capacity greatly increases as the percentage of RCA increased and the optimum percentage of RCA is 15%. It concluded that the increasing value of RCA will improve the strength and soil subgrade structures.

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