Potential and future: utilization of waste material on strength characteristics of marine clay

N Jamaludin¹, N Z Mohd Yunus¹*, S N Jusoh¹, F Pakir², A Ayub¹, N E Zainuddin¹, M A Hezmi¹ and Nordiana Mashros¹

¹School of Civil Engineering, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia
²Faculty of Civil and Environmental Engineering, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia

*Corresponding author e-mail: nzurairahetty@utm.my

Abstract. The utilization of waste materials has been a sustainable approach to soil improvement that took an interest in a number of researchers. Statistics show that out of the 76 percent of solid waste that is collected in Malaysia, only 5% is recycled while 95% of waste were dumped at landfills. This shows that there is a need to reutilize waste materials. This paper aims to discuss the different types of waste materials which are demolished tile material (DTM), demolished concrete material (DCM) and coal ash waste to improve the properties of marine clay. Experimental studies have been conducted by varying percentages of waste materials ranging from 5 – 15% with curing periods of 0, 7 and 28 days. Unconfined compressive strength test (UCS) was performed in order to determine the strength of these mixtures. The results obtained were that for both DCM and coal ash waste when mixed with marine clay would increase the strength of soil with increasing curing period. While for DTM, the strength of soil decreases with the immediate addition of additive but will later increase its strength gradually. Hence, the outcome obtained from this study is that both DCM and coal ash is suitable for the stabilization of marine clay soil while DTM is suitable for long term stabilization on marine clay.

1. Introduction
Waste materials are increasing at an alarming rate and it is causing negative effects on the environment. Based on previous research, the construction industry contributes almost 41% of the waste generation in Malaysia[1]. Fauziah and Agamuthu quoted that in 2009 construction and demolition waste is documented about 161.9 tons per year and approximately 299.69 tons per year in 2015. The numbers will keep increasing until 2023 which is expected to increase up to 368.31 tons per year[2]. Recently, in order to reduce this problem, many had implemented these waste materials in construction practices. Researchers have taken the initiative to reduce and minimize these waste by reusing them as stabilizing agents[3–7]. By practicing sustainability, we could easily combat this overwhelming increase in construction and demolition waste, thus saving the environment.

Marine clay is considered a problematic soil that is similar to other soft soils such as black cotton soil and peat. This is due to its high organic content and water content. It could be found abundantly along the coastal and offshore areas[1]. It has high compressibility, low strength, and could easily swell...
and shrink due to its ability to change in volume with the absorption of water. This is due to the presence of clay minerals such as smectite and vermiculite which would expand easily[2]. Hence, by referring to the characteristics stated, marine clay soil is not suitable for any construction activities to be performed on it. However, with the increment of development projects and the paucity of available land, there is more reason to construct structures on these deposits.

Granite tile is considered a construction and demolition waste. This waste is obtained due to inefficient handling and transportation of the materials as well as the inconsistency of the tile sizes. Based on a study done by Ahmad et al. (2014), tiles waste ranked 6th in the construction and demolition waste list[3]. Tam, Shen & Tam (2007) did a survey on material wastage and found out that high tile waste is generated by construction of private housing which is 12.21% and also private commercial which is 10.4%[4]. There are different types of tiles, and its properties are based on the type of product it is made from. Granite tile is said to be produced from natural stone, thus it is presumed that the characteristics and properties would replicate or similar to its parent rock. Granite is an igneous rock with a hardness scale of 7 with resistance to water and weathering.

Demolished concrete material (DCM) is waste available from construction sites due to the destruction of old buildings as well as waste concrete from new ones. It is a mixture of cement, aggregate, water, and the addition of other chemical admixtures[5]. As concrete is used abundantly in construction sites for building substructures and superstructures, its waste would also be available in large quantities. The main cause for this profusion of waste is due to the over assumption of the necessary amount of concrete needed for construction[6]. By referring to its size gradation, there are two types of concrete aggregate produced which are coarse recycled concrete aggregates and fine recycled concrete aggregate. Based on previous research, coarse recycled concrete aggregates is usually reused in road based material as a substitute for natural aggregate and also in new concrete[7] while the fine recycled concrete aggregate were discarded.

Coal ash waste consists of both fly ash and bottom ash. Fly ash is obtained from flue gases after the coal is burned[8], while bottom ash is accumulated from the bottom of the furnace[9]. For this research, we are using coal ash from Tanjung Bin power station. The Tanjung Bin power station notably produces 180 tonnes of bottom ash and 1,620 tonnes of fly ash daily while burning 18,000 tons of coal each day. Regarding these statistics, it raises the importance of reutilizing fly ash and bottom ash as a means of sustainable construction materials and simultaneously helping to reduce the abundance of these waste materials. Based on previous studies, fly ash is usually reused back in order to provide pozzolanic and cementitious reactions with the soil[10]. While bottom ash could contribute fine grained replacement for the soil, for example reusing it back as a road base material and aggregate replacement in concrete[9].

2. Materials and testing program
For this particular research, the materials used were marine clay for soil, while the additives were waste materials such as demolished tile material (DTM), demolished concrete material (DCM) and coal ash.

2.1 Materials
Marine clay for this research was obtained from two different locations in Iskandar Puteri, Nusajaya Johor. Iskandar Puteri is developing and expanding rapidly, hence there is a need to stabilized soft soil in that area which would later solve the land shortage predicament. One of the marine clay soil was obtained at Gelang Patah whereas it is a dumping site near a seabed offshore at a coastal area. While the other was obtained at Iskandar Puteri which is a housing development site.

The first waste material, which is DTM, was acquired from a construction site at Taman Ponderosa, Johor Bahru. Next, DCM was collected at the Structural lab, School of Civil Engineering in Universiti Teknologi Malaysia. Lastly, coal ash which is a product from coal burning was obtained from Tanjung Bin, a powerplant situated in Johor Bahru. Coal ash consists of both bottom ash and fly ash.
2.2 Testing program
Preparation of materials and test were done in accordance with BS 1377:1990[11]. In order to determine the increment of strength for the mixtures of soil and additives, unconfined compression test (UCT) was done. The highest compressive force achieved indicates the unconfined compressive strength for the soil. A specimen of 38mm in diameter and 76mm in height cylinder sample was formed for this specific test. Before any sample preparation was done, standard proctor test was conducted to determine the maximum dry density (MDD) and optimum moisture content (OMC) which later would be used to determine the quantity of materials used.

In terms of preparation of materials, the DTM were crushed and sieved for passing 150 µm, which was chosen due to only particle size passing 2mm is permitted for this particular mould size. While for DCM, it was first grind by using a grinder to break it into small pieces. Later, the DCM was pulverized into a powder form by using the Los Angeles abrasion machine (LAA). Then, they were sieved by using sieve size 63 µm. Lastly, bottom ash was sieved passing 2 mm while for fly ash there isn’t a proper preparation as it already exists in powder form. These additives will later be added to marine clay soil with increments of 5%, 10% and 15% at curing periods of 0, 7 and 28 days.

3. Results and Discussions
The results procured were then summarized and discussed in this part of the paper. Unconfined compressive strength (UCT) results will be discussed according to the strength of the soil sample with increasing additive percentages, curing period and increment in strength. Table 1 shows a summary of the compressive strength for all of the soil mixtures with increasing curing period.

Table 1. Summary of the compressive strength for all of the soil mixtures with increasing curing period.

| Additives | Percentage of Additive (%) | Curing Period(days) | 0     | 7     | 28    |
|-----------|--------------------------|---------------------|-------|-------|-------|
| DTM       | 0                        |                     | 233.95| 233.95| 233.95|
|           | 5                        |                     | 210.55| 224.15| 240.05|
|           | 10                       |                     | 204.55| 203.9 | 240.4 |
|           | 15                       |                     | 192.25| 183.6 | 200.8 |
| DCM       | 0                        |                     | 88    | 88    | 88    |
|           | 5                        |                     | 153.6 | 163   | 188.3 |
|           | 10                       |                     | 173.4 | 210   | 320.6 |
|           | 15                       |                     | 217.7 | 249.4 | 352.2 |
| Fly Ash   | 0                        |                     | 88    | 88    | 88    |
|           | 5                        |                     | 92.3  | 96.8  | 98    |
|           | 10                       |                     | 97    | 117.3 | 124   |
|           | 15                       |                     | 119.1 | 139.7 | 184.4 |
| Bottom Ash| 0                        |                     | 88    | 88    | 88    |
|           | 5                        |                     | 103.1 | 80.1  | 76.4  |
|           | 10                       |                     | 96    | 76.95 | 69.2  |
|           | 15                       |                     | 68.2  | 66.85 | 57.4  |
3.1 Demolished tile material (DTM)

Figure 1. Graph of compressive strength of DCM mixed with marine clay soil.

Figure 1 shows a graph of compressive strength for DTM mixed with marine clay soil based on percentage of additives with increasing curing periods. From the graph, it could be perceived that the trend of the compressive strength is decreasing with increasing additives percentages. Moreover, it could also be deduced that with the increasing curing period the strength of soil sample would decrease. It could be observed that only sample 5% and 10% at 28 days sample is higher than the untreated sample. For 5% at 28 days, the increment of strength is only 2.61% while for 10% at 28 days had an increment of 14.18%. The rest of the samples are lower in terms of compressive strength when compared with the untreated soil. The highest compressive strength for this particular soil mixture is achieved at 10% DTM at 28 days while the lowest compressive strength is at 15% DTM at 7 days curing period. For most samples, with increasing percentages of DTM, the compressive strength would also decrease except for 5% DTM. From the graph, it was shown that with increasing curing period, the strength of soil increase gradually. Hence, it could be deduced that marine clay would work efficiently at 5% DTM as the strength of soil kept increasing up till 28 days. Addition of more than 5% will result in a gradual decrement of soil strength although most of the soil samples strength are lower than untreated soil. Thus, it could be concluded that DTM could provide long term strength gain as the highest strength is obtained at 28 days for 5% DTM.
3.2 Demolished concrete material (DCM)

![Graph of compressive strength of marine clay soil mixed with DCM.](image)

Figure 2. Graph of compressive strength of marine clay soil mixed with DCM.

The graph in Figure 2 shows the compressive strength of marine clay soil mixed with DCM with increasing percentages of additives and curing periods. From the graph, it could be deduced that with increasing percentages of DCM, the strength of soil stabilized with DCM would increase significantly. A study done by Jain et al. stated that soil stabilized with demolished concrete material would have the same improvement as soil stabilized with cement or lime[3]. This is on account of the concrete having cement in the mixture. As cement could provide the necessary pozzolanic reaction which later produces cementation products. Xiao at al. mentioned that the drying of soil-cement mix and development of cementitious product is the reason as to why the increment of cement addition would increase the strength of soil[12]. Furthermore, it could identify that with increasing curing periods the strength of soil sample would also increase. A crystalline formation which would later harden with time is the cause of the increasing strength of soil[13,14,15]. All soil samples exhibit higher compressive strength when compared with the untreated soil sample. The highest compressive strength is obtained at 15% DCM at 28 days while the lowest compressive strength acquired at 5% 0 day. For the highest compressive strength which is at 15% DCM at 28 days which gives a result of 352 kPa, the increment of the soil sample is 300%. While the lowest compressive strength which is perceived at 5% 0 day with the result of 153.6 kPa gives an increment of 74.7%. This shows that DCM works well with marine clay soil at longer periods which in this case up to 28 days.
3.3 Bottom ash

![Figure 3. Graph of compressive strength for bottom ash soil mixture.](image)

Figure 3 shows a graph of compressive strength for bottom ash-soil mixtures. By observing the graph we could identify that with increasing percentages of additives, the strength of the soil sample would also decrease. Plus, with increasing curing periods, the strength would also decrease. Bottom ash particles might create voids in between soil particles due to the size of bottom ash itself. Thus, decreasing the strength of soil with increasing addition of bottom ash. From the graph, it could be perceived that most of the soil samples strength are less than the untreated soil except 5% and 10% bottom ash at 0 day. For 5% bottom ash at 0 day, the increment of strength is 17% while for 10% bottom ash at 0 day gains about 8.97%. Moreover, it could be identified that the highest compressive strength for marine clay stabilized with bottom ash was at 5% for 0 day which is 103.1 kPa while the lowest compressive strength was obtained from 15% at 28 days which is 57.4 kPa. Hence, it could be concluded that bottom ash is suitable for early strength gain and the optimum mix for is 5% bottom ash.

3.4 Fly ash

![Figure 4. Graph of compressive strength of marine clay soil mixed with fly ash.](image)
The graph in Figure 4 displays the compressive strength of marine clay soil when stabilized with fly ash. From the graph, it could be deduced that with increasing fly ash percentages, there would be a gain in compressive strength with increasing curing periods. All of the soil samples show increment higher than untreated soil sample. This is due to the finer particles of fly ash that would fill in the voids in the soil thus making it denser. This will in return increase the strength of the marine clay soil. The highest compressive strength is acquired at 15% fly ash for 28 days which is 184.4 kPa with an increment of 109.3%. Furthermore, the lowest compressive strength for marine clay stabilize with fly ash was obtained at 5% fly ash with a curing period of 0 day with an increment of 4.77%. When the soil is mixed with fly ash, chemical reactions that will occur such as cementation, pozzolanic reactions, cation exchange as well as carbonation which will results in particles to agglomerate in large sizes. Thus, the increase in strength of soil [16].

4. Conclusion
As a conclusion, waste materials could possibly be utilized as soil stabilizers for marine clay soil. For demolished tile material (DTM), the compressive strength decreased with increasing additives percentages. Plus, with increasing curing period the strength of soil sample would also decrease. Thus, it could be could be concluded that DTM could provide long term strength gain as the highest strength is obtained at 28 days for 5% DTM. While for demolished concrete material (DCM), the strength of soil increased with increasing additives percentages. Moreover, DCM works well at longer periods which in this case up to 28 days. In terms of coal ash materials, bottom ash is suitable for short term strength gain and the optimum mix for it is 5% bottom ash. Lastly, with increasing fly ash percentages the strength of fly ash would increase with increasing curing periods.

To summarize, waste materials would be able to be utilized as soil stabilizers for marine clay. Both DCM and fly ash are effective for long term stabilization while DTM and bottom ash are suitable for early strength gain.

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