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RECYCLING OF SILT IN CONSTRUCTION PRODUCTS

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Abstract
Silt is the final product obtained in the recycling plants as filter cake, silt product is regarded as the waste from the plants and generally disposed as land fill, which can cause environmental hazards. The aim of this project was to find means on how to recycle/reuse silt product as a construction product. Block specimens were made, mixed with glass powder at different percentage by weight. The glass content in the mixture ranges from 0%-15% at 5% intervals. Two curing procedures were investigated. Firstly, cured at ambient temperature and secondly cured at 9500C. Six specimens of each percentage by weight were made. Compressive was conducted on the specimens, and the test data obtained was used to determine the compressive strength of the specimens.

Keywords: Block specimen, cured, compressive strength, ambient temperature

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1. Introduction

Composite materials have been widely used in the industry. Composites are preferably used because they consist combination of materials that requires lower cost, and also produce new material with improved properties**.** Silt has been one of the major cases in the construction sector. It is regarded for its particle size, soil profile, as well as its mechanical properties namely compressive stress. It can also be used to cover gaps in structures due to its smaller particle size i.e., increase compressive strength.

Mixing the silt with another material will improve the structural properties of the composite, in this research glass powder will be added. The aim of this project is to increase the mechanical compressive stress. The percentage composition of glass powder (by weight) will be mixed with the silt; these are 0% - 15% in 5 % intervals. For an example, take the production of 100 grams of a 10% sample. 10% of the sample i.e. 10 grams will be glass powder, and 90% i.e. 90 grams, will be silt. The success of a test depends on the repeatability of the results; therefore, six specimens will be made for each percentage sample.

In this project, the materials used will be silt sample from Welwyn Garden city UK and the waste glass powder is from Canada. Production of the samples will involve mixing the materials at room temperature. The mixture will then be poured into moulds of specified geometries, and allowed to cure in room temperature

To determine the strength, compressive strength test will be used to test the samples. This will involve simply applying load directly on the samples and recording the peak loads. The samples will be tested using BSENISO 7500 compression machine. The peak load will be determined, and the compressive strength can then be calculated. The results can then be compared to previous studies for verification and comparison.

2. Methodology

This chapter will describe the process involved in the preparation, production, curing and testing of the samples, the method implemented in this project is a standard for the purpose of obtaining repeatable results. These processes were demonstrated in reports previously done by students, materials such as; mould, materials were provided by the supervisor in the lab, production techniques is up to standard to give the best possible samples with the least possible defects. Production procedure is something that might change, but the main aim of the specimen was kept in the picture

2.1 Mould Used/Preparation

The mould used in this project was the same as the mould used in previous year projects. The mould is made of elastic material, which is essentially a rubber. The advantage of this is that it is tough, will hold its shape during curing, and has a slippery surface allowing the cured mould to be removed comfortably. The mould is a rectangular shaped with a top opening through which the mould can be poured, and also essential for curing of the specimen by allowing good ventilation with in the mould.



Figure 1: Mould Assembly

Before using the mould, it was essential to prepare them, preparing the moulds includes cleaning them. Cleaning the moulds is very important because the same moulds were used by other students, this means they have different residue of materials left in them, therefore cleaning these residues will ensure no contamination in the specimens made. The moulds were cleaned by scraping and washing off the old dry residues left over from previously used, and wiped clean and using paper towel, for this project the moulds doesn't need to be lubricated as the mould was designed in such a way the specimens can easily be removed, it has advantage of not to worry about the effect of the lubricants effect on the specimens

2.2 Sample Production

During The casting process, a mould cast only one specimen at a time, therefore all category of the same percentage by weight of glass powder was repeated six times, six specimens make up a sample, therefore four samples are made, with each sample containing six specimens. The samples made, ranged from 0% glass powder to 15%, in 5% intervals.

2.3 Water Volume Investigation

Silt as received filter cake contain moisture contents, making it almost impossible to measure the exact amount of the mixing materials, without getting rid of the water content in the silt. Therefore silt was put into a beaker, the amount of silt was measured, and different measuring techniques can be used, for this Project the weight of the beaker was measured first, so as to know the resultant weight of the beaker with the silt and without the silt. The weight of the silt was calculated to be 80g.

The silt was then put into the oven at the temperature 105^0c for about 2hrs 30 minutes, so as to get rid of the moisture content in the silt i.e. fully dried up. The sample was then measured again which showed a huge difference in the weight before and after heating, the simple calculation is shown below;
Weight of silt before heating = 80g
Weight of silt after heating = 55g
Volume of water = 25g
In percentage;
Pure silt = 69%
Water content = 31%

Therefore, instead of going through a long process of heating the sample before mixing the desired amount, the silt as received form can be mixed straight away with the glass powder and at the same time knowing the exact measurement, let's assume 100g of pure silt is to be mixed with glass powder, using silt as received form, 145.45g is to be used (only 69% silt).

2.4 Measuring Materials

Before starting to use any material in the lab, it is necessary to read and understand the material safety data sheets, all appropriate protective and precautionary measures were fully insured. The weights of the materials had to be measured. The samples range from 0% glass powder to 15% glass powder, at 5% interval. The rest of the sample mixture is silt and water, but water evaporates as the sample dries up, for a mould of this size 80g of the mixture was sufficient to fill up the mould, therefore approximately about 400g of the mixture would make six block samples, the weight of the silt decreases as the weight of the glass powder being added increases. At 15% glass powder, only 234.6 grams of silt is used.

Table 1 below illustrates the amount of each material being used to the percentage of glass powder, as well as the water mass used in the mixture. Using the table readings, and using separate containers the materials are measured, measuring technique to be used must be carefully calibrated accordingly before adding any materials in the container, after the desired measurements are obtained, the composite is set to be mixed.

Table 1: Composite Materials by weight

Glass Percentage	Composite (g)	Glass Powder (g)	Silt (g)	Water (g)
0	400	0	276	124
5	394.6	13.2	262.2	119.2
10	386.2	24.9	248.4	112.9
15	376.4	35.2	234.6	106.6

2.5 Mixing the Materials

This is a very crucial process, time must be dedicated in mixing the materials because this is the stage that will determine the internal structure of the sample, silt as received form has some solid particles that can cause void in the sample. The silt and the glass powder were mixed together in a beaker, and then water was added slowly, care had to be taken not to add too much water as silt already consist of 31% water, too much water will increase the drying up time rate, the mixture was squeezed by hand making sure all the tiny solid particles in the mixture loosen up, so as to minimize the voids with in the samples, figure 2 shows the pictorial view of the process, the squeezing process took about one hour as the mixture is very viscous and contain a lot of solid particles, after all the two are mixed in together, the mixture can be poured into the mould.



Figure 2 mixing the materials

The mixing was carried out in the lab environment at room temperature, this allowed one to carry out the process with in the comfort of the environment, vents were also opened for fresh air flow.

2.6 Pouring the Mixture into the Mould

Pouring the mixture into the mould could be a very tricky process, because the mixture is very viscous air bubbles could form at the base of the mould as the mixture is being poured, it may appear to be well placed from the top, but air bubbles actually are formed from the bottom, it is important to apply some form of pressure from the top surface or place it under vibratory motion, so as to compress the mixture further down to cover the voids caused by the air bubbles, the mould should also be placed on a flat surface in order to avoid the mixture from slanting towards one side of the mould, furthermore spatula was used to flatten the top surface to obtain a perfectly smooth flat surface, as it will appear to show some irregularities on the top surface of the sample due to high viscosity of the mixture.



Figure 3 Flattening the samples with spatula

2.7 Sample Curing and Removal

The samples are left to be cured at room temperature for at least twenty-four hours, this allowed the sample to shrink in size as the water evaporates from the samples into the ambient atmosphere i.e the mass occupied by the water disappears as the sample dries up. Removing the samples from the mould proved to be quite easy, because the mould was made of elastic rubber and perfectly sealed from all angles, that eliminates the problem of the mixture seeping through within the gaps and making it difficult to be removed from the mould, it was also easy to remove the sample from the mould because the size of the sample shrinked in size as it dries up, the walls of the mould are freed from contact with the samples, after the samples were removed, the mould was set to be used once again.

2.8 Post Curing the Samples

The specimens were post cured in a furnace for a period of seventy-two hours. The furnace was controlled by a Eurotherm controller (series) programmed, the specimens were heated at 105 degrees Celsius for thirty minutes, then 950 degrees Celsius for 72 hours. The furnace controlled itself automatically without any intervention. However, it was monitored to make sure the temperature doesn't change over the period of time. The specimens were arranged on a brick, in case the blocks might melt as a result of the high temperature been applied to them, it will only have negative effect on the brick but not the furnace, care was taken to

make sure the specimens were evenly arranged and well-spaced. This was so as to have evenly distributed temperature across the specimens without any uneven temperature regions. The temperature in the furnace was very high, care had to be taken when monitoring the samples, the furnace was allowed to cool down before the specimens were removed from the furnace.

The LENTON THERMAL DESIGN furnace user manual was used to set the desired requirments, with the help of the supervisor.

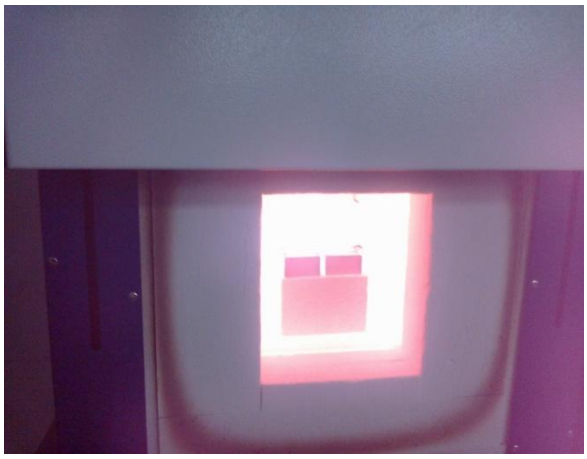


Figure 4 The specimens in the furnace



Figure 5 Furnace controller

2.9 Compressive Test

2.9.1 Test Preparation

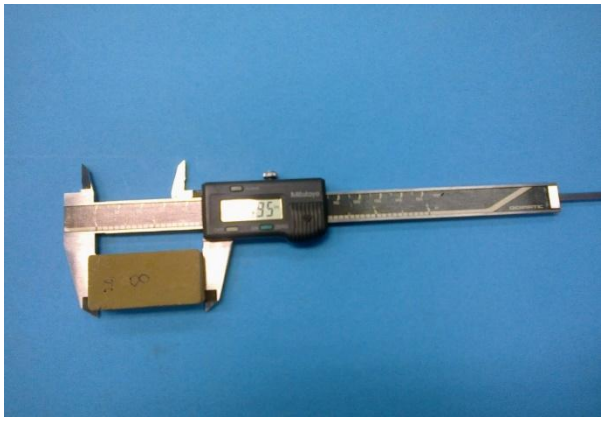
Some of the samples were not in good shape, as the moulds were over filled during the sample production, causing the specimen not to aligned accurately on the test base, these parts had to be filed down in order for the specimens to fit accurately in the testing machine to acquire better results, the samples were fixed into a filing machine, and all the necessary parts were removed as shown in the figure below. Eye protection goggles had to be used because of the dust generated by the filing machine.



Figure 6 The filing machine (Linisher)

2.9.2 Measuring the Samples

Tensile test applied only to a sample with known size and geometry, so as to be able to calculate further properties of the samples after the failure load is obtained, Vanier calliper was used to measure the dimensions of the samples, by taking the average of all the dimensions at three intervals i.e taking the measurement value of a typical geometry at beginning, middle and end on each side of the block.


Figure 7 Vanier Calliper measuring instrument

2.9.3 Testing

The specimen testing was carried out using BSENISO 7500 materials testing system. The system was equipped with all the necessary parts required to carry out the tensile test. The figure below illustrates how the specimen was fit into the system. The specimen was adjusted in such a way the load is applied directly at the centre of the specimen, a light weight flat plate was placed on top of the sample to distribute the applied load evenly against the specimen.

Once the specimen is in placed in the system, the engage button was hit, the load was applied from the top of the specimen at the rate of 2mm per second, and the system was controlled and monitored automatically using the computer program. The failure load was reached as the specimen failed simultaneously, the grid on the computer screen start to decrease where it is being monitored, as shown in figure 8, the engage button is then stopped once the failure load was reached. The result data is then stored. And the next specimen is ready to be tested.

The failure load is the required value from the test, as the value would be used to calculate the compressive stress applied to the specimens.



Figure 8 BSENISO 7500 during the tensile test

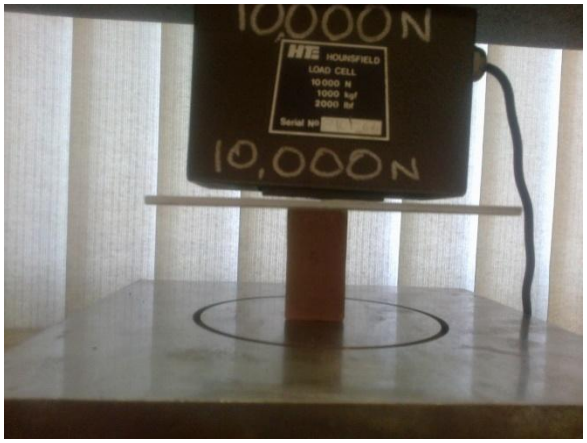


Figure 9 Specimen fitted in the BSENISO 7500

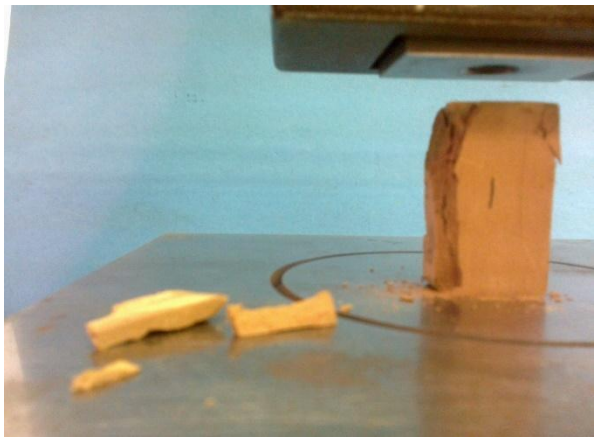


Figure 10 Specimen tested to failure

2.10 Data obtained

Figure 11 indicated the retrieved parameter from the test. The point of interest was the peak load shown at the peak of the plot, this is the load at which the specimen failed. And with failure load obtained the compressive strength of the blocks could be determined.

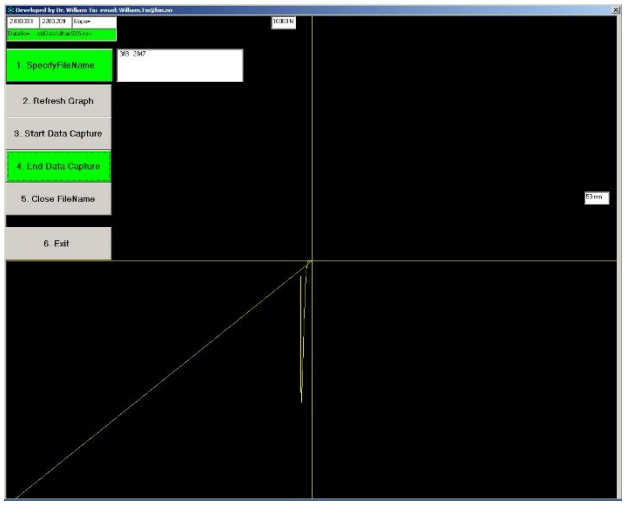


Figure 11 Computer Monitored Plot

3. Results and Discussion

This section will show the analysis of the results obtained from the tensile test and also discuss the results. Compressive strength of the specimens was calculated by using linear elastic failure mechanics with the assumptions. The results were compared with other related previous work done by others. The comparison will further validate the results

3.1 Tensile Test Results

The peak failure load was the only data obtained from the test and needed for the compressive strength calculations. The table below shows the raw data from the testing. Most of the results from the testing data are provided in the appendix A



Figure 12 Test Specimen Block

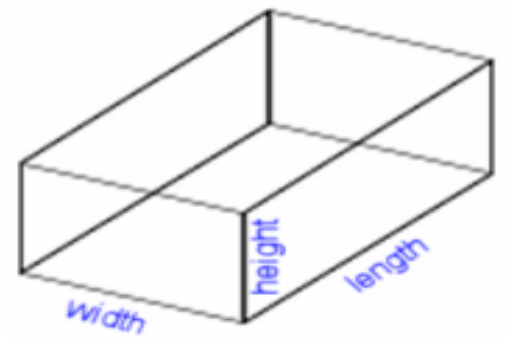


Figure 13 Showing the dimensions of the specimen

Table 2 Compressive Test results (Silt + Glass Blocks) cured at ambient temperature

Glass %	Specimen no	Width (mm)	Height (mm)	Length (mm)	Failure Load (N)
0%	1	25.3	15.8	46.1	3437.5
	2	25.4	15.6	45.5	3267.5
	3	25.2	16.2	46.4	3440.0
	4	24.7	15.5	45.2	3275.0
	5	24.8	15.8	45.6	3005.0
	6	25.2	15.5	44.2	3037.5
5%	7	24.3	15.5	44.3	2445.0
	8	26.3	15.8	47.1	2697.5
	9	23.7	14.5	42.7	1622.5
	10	23.9	14.8	43.7	2147.5
	11	26.1	15.6	46.5	2640.0
	12	24.6	15.7	44.9	2652.5
10%	13	25.3	15.7	44.9	2375.0
	14	25.3	16.2	45.5	2202.5
	15	25.5	15.9	45.4	2437.5
	16	25.6	16.2	46.1	2305.0
	17	25.5	15.9	46.1	2085.0
	18	25.1	15.7	45.3	2028.0
15%	19	26.0	15.9	46.6	1932.5
	20	25.7	16.2	46.6	2065.0
	21	24.7	15.3	43.8	1670.0
	22	24.8	15.4	45.1	1797.5
	23	24.6	16.2	45.9	2330.0
	24	26.0	16.3	47.4	1680.0

Compressive Strength

The strength of the specimens was calculated using the formula;

$\sigma = \frac{F_{Max}}{A}$

Where:

σ = Compressive Strength

F_{Max} = Peak Load

A = Surface Area

- A is calculated by the formula;

Area = Width × Height

Average = $\frac{Sum\ of\ the\ stress}{Number\ \ of\ specimens}$

The compressive strength of the bricks (silt + crushed glass) at different percentages by weight was then calculated, and since there are six samples of each percentage by weight, an average is calculated by adding each of the percentage categories and then dividing it by six. The results are given in the table below.

Table 3 Showing the calculated results cured at ambient temperature

Glass %	Specimen No	Area (m^2)	Compressive Strength (KPa)	Average Compressive Strength (MPa)
0%	1	0.0004	8599.34	**8.2**
	2	0.000396	8246.265	
	3	0.000408	8426.416	
	4	0.000383	8554.264	
	5	0.000392	7668.947	
	6	0.000391	7776.498	
5%				**6.2**
	7	0.000377	6491.438	
	8	0.000416	6491.553	
	9	0.000344	4721.373	
	10	0.000354	6071.186	
	11	0.000407	6483.938	
	12	0.000386	6867.847	
10%				**5.5**
	13	0.000397	5979.205	
	14	0.00041	5373.786	
	15	0.000405	6011.839	
	16	0.000415	5557.967	
	17	0.000405	5142.434	
	18	0.000394	5146.294	
15%				**4.8**
	19	0.000413	4674.649	
	20	0.000416	4959.889	
	21	0.000378	4419.042	
	22	0.000382	4706.483	
	23	0.000399	5846.633	
	24	0.000424	3964.134	

Furthermore, in simplifying the results for better visualization, the results were plotted, the plot will also provide an easier comparison. The plot started from 0% marker to 15%, this showed the full over view of the compressive strength of the specimens as the crushed glass percentage increases. The compressive strength of varying percentages of silt and crushed glass cured at ambient temperature is given in figure 14 below;

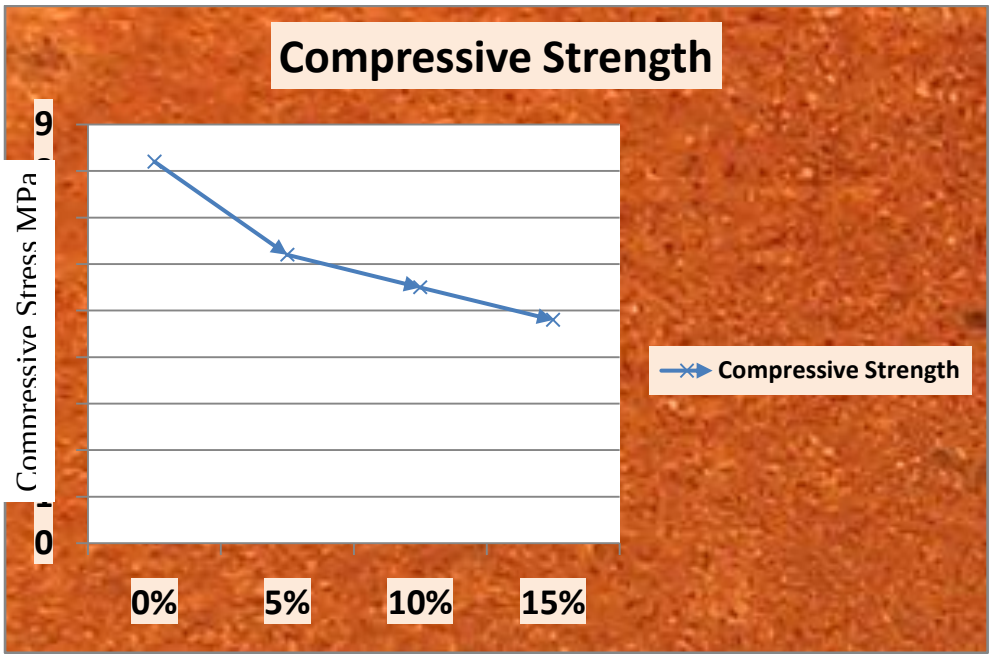


Figure 14 Plot of compressive strength of the blocks (Cured at Ambient Temperature)

From the figure above, it can be seen that the compressive strength of the specimens was highest at 0%. The compressive strength was 8.2 MPa, the compressive strength for different percentages showed significant variation, the compressive strength reduces as the crushed glass percentage increases. At the highest crushed glass content (15%), gave the lowest compressive strength, which was 4.8 MKPa. For 5% and 10% the compressive strengths were 6.2 Mpa and 5.5 MPa respectively. Therefore the result showed a linear decrease as the percentage of the crushed glass increases. It was concluded that waste glass and silt cannot be mixed together to produce quality bricks when cured at ambient temperature.

Heat Treated Samples

The results of the calculated compressive strength test on the specimens heated at 950 degrees Celsius is shown in the table below, the data obtained from the test is provided in the appendix. The same procedure used in table 3 was used to derive table 4:

Table 4 Calculated results cured at 950^0C

Glass %	Specimen No	Width	Area (m2)	Failure Load (N)	Compressive Strength (Kpa)	Average Compressive Strength (MPa)
0%	1		0.00036		17920.9	**17.53**
	2		0.00038		19301.0	
	3		0.00036		13440.6	
	4		0.00039		19440.9	
5%						**17.54**
	5		0.00038		15299.5	
	6		0.00039		16604.8	
	7		0.00041		18318.3	
	8		0.00041		19922.6	
10%						**19.38**
	9		0.0004		14796.9	
	10		0.00037		23232.6	
	11		0.00036		22059.1	
	12		0.00041		17439.3	
15%						**21.02**
	13		0.0004		24821.0	
	14		0.00038		18846.1	
	15		0.0004		16139.5	
	16		0.0004		24253.8	

It can be seen in this case, the results showed positive increase to the compressive strength of the specimens, in comparison to the compressive strength of the specimens cured at ambient temperature, whereby the strength reduces as the glass content increases. In this case the strength increases as the glass content increases, this is due to the chemical reaction triggered by the heating temperature. The strength of the bricks was dependent on the amount of glass and firing temperature. It is supposed as the result of the firing temperature, the glass phases became more vitrified and thereby formed a stronger bond with the silt particles i.e. forming a ceramic like structure, thereby increasing the strength of the specimens. The plot in figure 15 showed a better visual overview of the temperature effect:

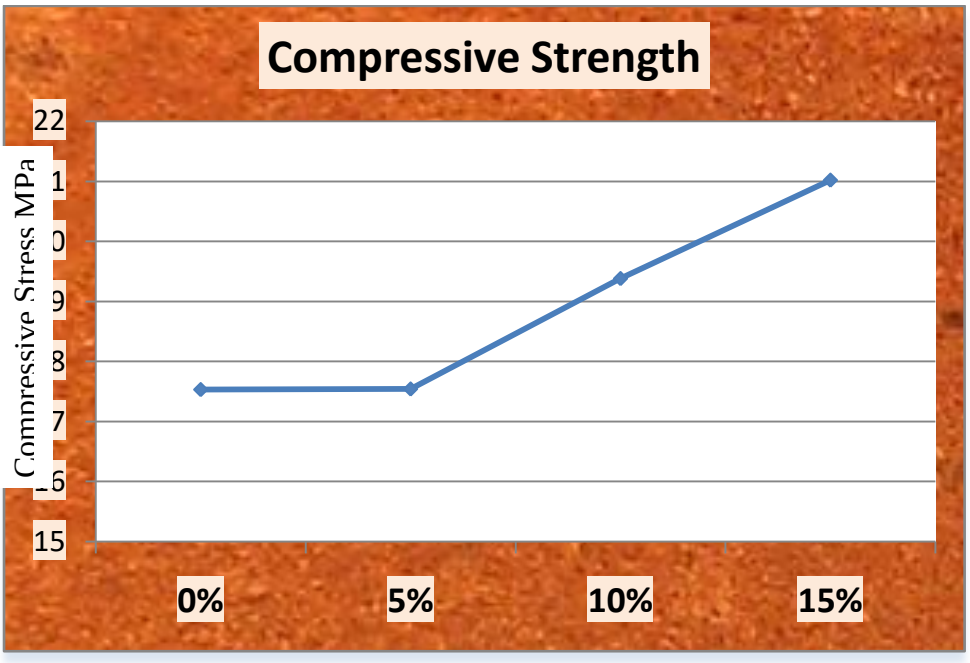


Figure 15 Compressive strength of the blocks (cured at 950^{0}C)

From the plot, the compressive strength was highest at 15% with a compressive strength of 21.02 MPa, as the amounts of crushed glass in the mixture varied from 0% to 15%, the specimens compressive strength changed, starting from 0% glass content with the lowest strength of 17.53 MPa, there was a slight increase between 0% and 5%, the compressive strength was 17.54 MPa. For 10% the strength increased directly to 19.38 MPa. The compressive strength of the specimens peaked at 15%, it is possible that at some point when the crushed glass content increases, the specimens will fragment. So in this case the optimal amount of crushed glass that could be mixed with silt to produce good block samples was 15% by weight. It is concluded that waste glass and silt can be blended together in different proportions to produce good quality bricks if cured at high temperature.

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Comparison with Other Work

To further validate the project, it is important to compare and contrast the results to previous work or other related work. A previous study done by Kae – Long Lin, (2006) investigated the effect of heating temperature of waste glass as a partial substitute for clay in eco – brick, the compressive strength was determined using similar approach, only that the waste glass mixture ranges at 10% interval, but the results followed the same trend, the tables below displayed the results

Table 5 Waste Glass + Clay in Eco - Bricks

Percentage by Weight	0	10	20	30	40
Compressive Stress MPa	44.13	53.9	53.9	68.6	63.7

Table 6 Silt + Waste Glass in Compressed Earth Blocks

Percentage by Weight	0	5	10	15
Compressive Stress MPa	17.53	17.54	19.38	21.02

Figure 16 below shows the plot comparison of the results between this study and the previous study;

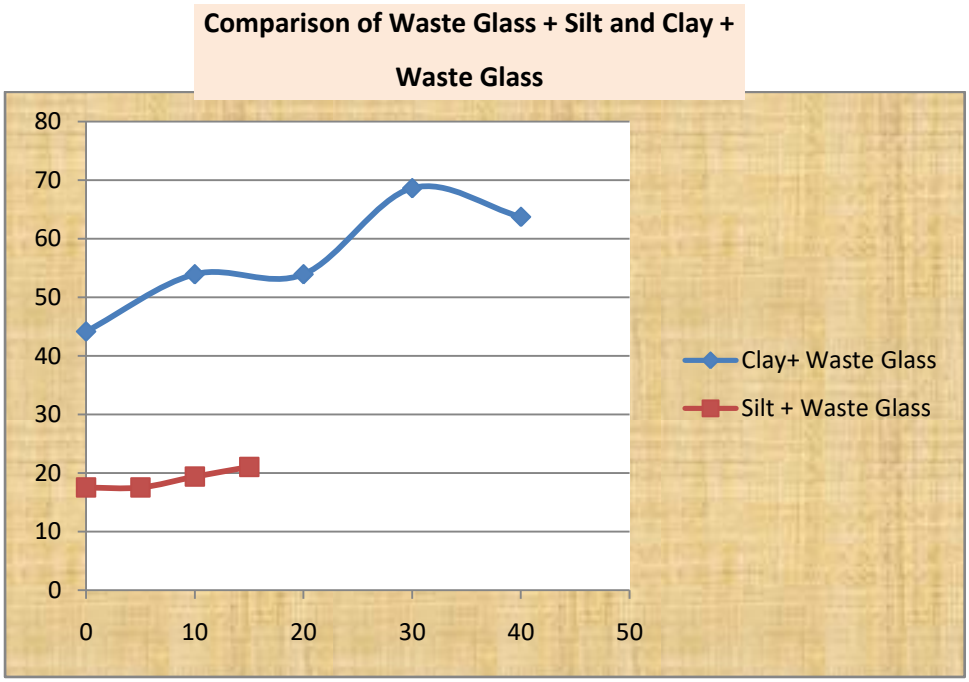


Figure 16 Comparison of the two studies

4. Conclusion

The conclusion of the report is drawn in this chapter. The section will highlight the investigation, this project intended to carry out; that is, can silt be recycled/reused in construction products? This chapter also discussed the results and future work that will further enhance the project is also recommended.

Due to the analysis of the results, it was concluded that silt can be recycled in construction products as compressed earth blocks. By mixing it with waste crushed glass powder, it was seen that the compressive strength of the blocks increases as the content of the glass powder increases (cured at 900 degrees Celsius). The results showed a similar trend when compared with other related studies, the comparison also further validate the results obtained.

After thorough investigation, this project intensively derived to conclusion that waste glass powder mixed with waste silt improves the compressive strength of compressed earth blocks, therefore silt can be recycled/reused.

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