The effect of sludge water treatment plant residuals on the properties of compressed brick

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Abstract. The focus of this study is on the production of compressed bricks which contains sludge water treatment plant (SWTP) residuals obtained from SAJ. The main objective of this study is to utilise and incorporate discarded material (SWTP) in the form of residual solution to produce compressed bricks. This serves as one of the recycling efforts to conserve the environment. This study determined the optimum mix based on a mix ratio of 1:2:4 (cement: sand: soil) in the production of compressed bricks where 5 different mixes were investigated i.e. 0%, 5%, 10%, 20%, and 30% of water treatment plant residue solution. The production of the compressed bricks is in accordance with the Malaysian Standard MS 7.6: 1972 and British Standard BS 3921: 1985 - Compressive Strength & Water Absorption. After being moulded and air dried, the cured bricks were subjected to compression tests and water absorption tests. Based on the tests conducted, it was found that 20% of water treatment plant residue solution which is equivalent to 50% of soil content replacement with a mix composition of [10: cement] [20: sand] [20: soil] [20: water treatment plant residue solution] is the optimum mix. It was also observed that the bricks containing SWTP residuals were lighter in weight compared to the control specimens.

1. Introduction
In view of the wide usage of clay bricks especially in the construction industry today, numerous production techniques and processes have been investigated in order to reduce the cost of production without compromising the workability of bricks. Therefore, this research provides an alternative solution in improving the quality of compressed bricks and directly helps to reduce water treatment plant residue at SAJ residual disposal areas. The current production process of compressed bricks that is of interest is the production process of unburnt compressed bricks which are able to minimize the production cost [1].

With the accumulation of water treatment plant residue, a wide area is required to accommodate the safe storage and management of the residues. This in turn will increase the maintenance cost [6]. Apart from this, the disposal of polluted waste water treatment in accordance to SW 204 – Disposal category in First Schedule, "Peraturan-Peraturan Kualiti Alam Sekeliling
(Buangan Terjadual 2005)” [2] also increases the maintenance cost. Therefore, the main focus of this research is to overcome these issues and create improved construction material in civil engineering construction.

This research concentrates on the production of compressed bricks containing sludge water treatment plant residue in accordance to Malaysian Standard MS 7.6: 1972 and British Standard BS 3921: 1985 and takes into account the end users’/consumers’ requirements [7]. The main objective of this research was to investigate the optimum mix ratio of the water treatment plant residual solution in the production of compressed bricks that complies with the requirements of the Malaysian Standard MS 7.6: 1972 and British Standard BS 3921: 1985 in terms of its compressive strength and water absorption rate [7].

2. Materials and methods

2.1. Sampling of Material

The water treatment plant residuals were obtained from SAJ Holdings Sdn Bhd, Site 3, Loji Air Seri Gading, Lot 4704, Kawasan Perindustrian Sri Gading, Batu 6 Jalan Kluang, Batu Pahat, Johor Darul Takzim.

![Figure 1](image1.png)

**Figure 1.** The process of collecting water treatment plant residuals at one of the dried lagoons.

2.2. Preparation of materials

Mix ratios of 1:2:4 (1 Part : cement) : (2 Parts : sand) : (4 Parts : soil + WTP residual solution) were used for the evaluation of the compressive strength and water absorption rate of compressed bricks in accordance to the Malaysian Standard MS 7.6: 1972 and British Standard BS 3921: 1985 - Compressive Strength & Water Absorption [7]. Sludge water treatment plant residuals were crushed and sieved before use as shown in Figure 2.

![Figure 2](image2.png)

**Figure 2.** (a) WTP residuals before sieving, (b) WTP residuals after sieving (c) Laterite Soil.
2.3 Production of compressed bricks
The production of compressed bricks was done according to the Malaysian Standard MS 7.6: 1972 and British Standard BS 3921: 1985 - Compressive Strength & Water Absorption. A total of 5 mix ratios were prepared where 10 bricks were produced for each mix ratio. Each compressed brick measured 222 mm in length, 114 mm in width and 75mm in height as shown in Figure 3. The compressed bricks produced were of Class 1 Load Bearing brick. The mix ratios of the compressed bricks are shown in Table 1 [7].

![Figure 3. The production of compressed bricks using steel moulds.](image)

| Mix | Total Sample | Water (%) | Sand (%) | Cement (%) | Soil (%) | WTP Residual (%) |
|-----|--------------|-----------|----------|------------|----------|------------------|
| A   | 10           | 10        | 20       | 10         | 40       | 0                |
| B   | 10           | 10        | 20       | 10         | 35       | 5                |
| C   | 10           | 10        | 20       | 10         | 30       | 10               |
| D   | 10           | 10        | 20       | 10         | 20       | 20               |
| E   | 10           | 10        | 20       | 10         | 10       | 30               |

2.4 Brick testing
The compressive strength test and the absorption rate test were conducted in accordance to the Malaysian Standard MS 7.6: 1972 and British Standard BS 3921: 1985 - Compressive Strength & Water Absorption [7] as shown in Figure 4.
Figure 4. (a) Initial water absorption rate test (b) Absorption rate test, (c) Compressive strength test.

3. Results and discussion

3.1. X-Ray Fluorescence (XRF)
Table 2 shows that the concentration levels of Aluminium Oxide (Al2O3), Silicon Oxide (SiO2) and Calcium Oxide (CaO) were the highest among all the materials used. Based on the XRF data, cement contains the highest element of Calcium Oxide (CaO) at 59.4%. In general, CaO is an important element in the production of cement. It reacts actively in the presence of water and produces heat to assist in the setting of cement. The XRF data also shows that laterite soil contains 36.1% of Silicon Dioxide (SiO2). SiO2 is one of the elements in soil that influences the strength and stiffness of a soil mass. Meanwhile for the WTP residual solution, XRF revealed that it contains 51.76% Silicon Dioxide (SiO2) and 36.70% of Aluminium Oxide (Al2O3). Al2O3 is known as Alum which is used in the coagulation and flocculation stage in the water treatment plant process [8].

Table 2. Concentration of elements in materials from XRF data.

| Element | Cement (%) | Laterite Soil (%) | WTP Residual Solution (%) |
|---------|------------|-------------------|--------------------------|
| CaO     | 59.40      | 1.60              | 0.52                     |
| SiO2    | 15.00      | 36.10             | 51.76                    |
| SO3     | 3.56       | 0.85              | 0.38                     |
| Fe2O3   | 3.11       | 18.90             | 6.67                     |
| Al2O3   | 2.94       | 18.90             | 36.70                    |
| MgO     | 1.53       | 0.24              | 0.70                     |

3.2. Moisture Content
The Figure 5 shows the percentage of moisture content of the five (5) different mixtures. The moisture content of the mixture can be observed. Mixture A has the lowest moisture of 18.6% while the mixtures B, C and D contain a moisture content of 21.0%, 22.75% and 30.5% respectively. Mixture E contains the highest moisture content of 45.45%.
From Figure 5, it was observed that the moisture content of the mixture increases as the ratio of the WTP residual solution increases. The weight of water in the mixture increases as the ratio of WTP residual solution increases in the mixture [8].

3.3. Dimension test

The value of shrinkage in terms of volume for the five (5) different mixes of compressed brick for a curing period of 7 days and 28 days respectively is shown in Figure 6. It was observed that mixtures A, B and C did not exhibit any change in volume. Mixture D exhibited a volume shrinkage of 1.10 mm$^3$ and 1.30 mm$^3$ after a curing period of 7 days and 28 days respectively. On the other hand, mixture E shows a volume shrinkage of 1.20 mm$^3$ and 1.50 mm$^3$ after a curing period of 7 days and 28 days respectively.

The occurrence of volume shrinkage in compressed bricks is due to the dissipation of water during the drying process. Improper drying process and curing practices increase the rate of water dissipation in the compressed brick mixture. The abrupt change in water content will increase the porosity of the resulting compressed brick. The rate of shrinkage and porosity structure in a compressed brick can influence its physical features and the rate of initial water absorption [8].
3.4. Initial rate of absorption test
Figure 7 shows that the rate of initial water absorption increases from mixture A to mixture E. The test results show that mixture A had the lowest average percentage rate of initial water absorption with a value of 1.0% for a 60-second test period. This is followed by mixtures B, C and D with initial water absorption rates of 3.5%, 5.3% and 8.0% respectively. Mixture E had the highest average percentage rate of initial water absorption (9.1%) for the same test period.

Based on the outcome of the test results, it was observed that the mixture with a higher ratio of WTP residual solution exhibited a higher rate of initial water absorption in a test period of 60 seconds. The pattern of the obtained test results is consistent with the findings by Azizul[8] which stated that mixture E exhibited the highest rate of initial water absorption compared to other mixtures with a value of 11.20% in a 60-second test period. According to the research, mixture A had the lowest average rate of initial water absorption at 2.40%. Meanwhile, the average rate of initial water absorption for mixtures B, C and D were 4.9%, 7.9% and 8.6% respectively within the same test period. With the consistent pattern obtained from the test results, it can be concluded that as the ratio of WTP residual solution increases in a mixture, the rate of initial water absorption increases for a test duration of 60 seconds.

3.5. Rate of absorption test
Figure 8 shows the graphical presentation of the rate of water absorption in percentage for the five (5) mixtures. It was observed that the rate of water absorption increases from mixture A to mixture E. The value of rate of water absorption in percentage for mixture A, B, C, D and E are 13.22%, 14.65%, 15.51%, 17.61% and 27.81% respectively. The mixture A which is the control sample has the lowest rate of water absorption while mixture E has the highest rate of water absorption.

It was observed that as the WTP residual solution ratio increases in a mixture, the rate of water absorption also increases. Similar patterns were also observed from the analysis of the test results obtained from the moisture content test and the initial water absorption tests. The pattern of results obtained from the rate of water absorption test was found to be consistent with the research conducted by Azizul[8] which stated that mixture A exhibited the lowest rate of water absorption compared to other mixtures with a value of 12.88% while mixture E has the highest rate of water absorption with a value of 52.31%. The research also indicated that the average rate of water absorption for mixtures B, C and D was 19.26%, 27.87% and 32.46% respectively. With the consistent pattern of test results obtained, it can be concluded that as the ratio of WTP residual solution increases in a mixture, the rate of water absorption increases.
3.6. Compressive strength test

The compressive strength test results for the five (5) mixtures are shown in Figure 9. It was observed that the compressive strength decreases from mixture A to mixture E. Mixture A, the control sample, has the highest average compressive strength with a value of 20.5 N/mm² and 22.6 N/mm² after a curing period of 7 days and 28 days respectively. The average compressive strength of mixture B was 15.0 N/mm² and 16.7 N/mm² for a curing period of 7 days and 28 days respectively. Meanwhile, mixture C showed an average compressive strength of 8.5 N/mm² and 11.8 N/mm² after a curing period of 7 days and 28 days respectively. Mixture D has an average compressive strength of 7.0 N/mm² and 7.2 N/mm² while Mixture E has the lowest average compressive strength of 5.2 N/mm² and 5.5 N/mm² after a curing period of 7 days and 28 days respectively.

Based on the compressive strength test results obtained, it was observed that the compressive strength of a compressed brick decreases with the increase of WTP residual solution ratio in a mixture. The pattern of results obtained from the compressive strength test was found to be consistent with the research conducted by Azizul [8] which indicated that mixture A exhibited the highest average compressive strength compared to other mixtures with a value of 6.45 N/mm² and 8.25 N/mm² after a curing period of 7 days and 28 days respectively. His research also shows that Mixture B had an average compressive strength of 2.87 N/mm² and 3.61 N/mm² while Mixture C had an average compressive strength of 2.45 N/mm² and 3.54 N/mm² after a curing period of 7 days and 28 days respectively. The average compressive strength for Mixture D was at 1.30 N/mm²(7 days) and 1.71 N/mm²(28 days). The lowest average compressive strength was recorded for mixture E with value of...
0.94 N/mm² after a curing period of 7 days and 1.05 N/mm² after a curing period of 28 days. Therefore, it can be concluded that with the increase of WTP residual solution ratio in a mixture, the compressive strength of a compressed brick will decrease.

4. Conclusion
Through the observations and analysis of the test results obtained in this study, it can be concluded that the ratio of 20% of WTP Residual Solution in a compressed brick mixture is the optimum value. In this study, the compressed brick produced via mixture D which represents a mix ratio of 10% cement, 20% sand, 20% soil and 20% WTP Residual Solution was found to be the optimum mixture. The compressive strength test shows that mixture D with a ratio of 20% soil and 20% WTP Residual Solution produced a strong, light and durable compressed brick that can be utilised in the construction of non-load bearing and load bearing brick walls.

5. References
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