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U-Shaped Concrete Drain Containing Rice Husk Ash as Partial Cement Replacement by Using Non-Autoclaved Aerated Technique

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Abstract: Concrete is the most widely used material in the world which increases the demand for cement as the main material. Hence, a huge amount of cement is manufactured to fulfill the demand and contribute to serious carbon emissions. However, the materials used for the concrete have been extensively modified to increase the durability and aesthetic value. Rice husk ash (RHA) is one of the alternative materials for cement replacement due to the pozzolanic behaviour which consists of 85%-90% silica. The objectives of this research are to determine the optimum percentage of RHA as partial cement replacement in concrete, to compare the compressive strength of the RHA concrete with the standard concrete cube, to compare the compressive strength of RHA non-autoclaved aerated concrete (NAAC) drain with standard drain and to determine the durability performance of RHA NAAC drain in normal environment. There are five cube specimens were cast to identify the optimum percentage and one RHA NAAC drain was cast to conduct a rebound hammer test according to BS 1881-202. After the experiment, the optimum percentage RHA is identified in 10% with 11.9 MPa compressive strength. Besides that, the compressive strength of RHA NAAC drain is 12.67 MPa compressive strength. The purpose of this research is to apply RHA to reduce the usage of cement as well as reduce carbon emissions. Furthermore, using NAAC technique in the drain can reduce the cost of the project in the progress of installation and delivery.

Keywords: Aerated Concrete, Rice Husk Ash, Non-Autoclaved Aerated Concrete

1. Introduction

Concrete is the most common material that used in the construction industry for a long time. Concrete consists of cement, sand, aggregate, and mixed with water. When the cement is mixed with water, the hydration is occurred and produce a gel to bind the sand and aggregate. The aggregate determines the hardness of concrete and it has the strong compressive strength that can afford the load of the building. The concrete will completely harden after 28 days of curing. Aerated concrete is deffenrent from normal concrete, it lightweight, precast, and have air void inside the concrete. The

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aerated concrete consists of aluminium powder as the foaming agent, the chemical reaction occurs when the cement is mixed with the aluminium powder and generated the hydrogen gas become foam in the concrete (Jiang *et al.*, 2021). After the aerated concrete become harden, the foam will become air void in the concrete and make the concrete light in weight (Ramakrishnan *et al.*, 2021). Besiedes that, aerated concrete can be autoclaved aerated concrete and non-autoclaved aerated concrete (NAAC) based on the method and technique of manufacture. The difference between these two concretes is the curing method. The autoclaved is the method of curing by putting the concrete under high temperature (174.5℃-213℃) and high pressure (0.8MPa-2MPa) (Jiang *et al.*, 2021). On the contrary, non-autoclaved is using the traditional method to cure the concrete. Furthermore, aerated concrete is a lightweight concrete that is famously used in the construction industry. The characteristic of aerated concrete is the concrete with a lot of air void inside to replace the concrete as well as reduce the weight of concrete. However, the pore hole in the concrete will affect the density and compressive strength of concrete. In the previous researchs found that the integration of RHA in aerated concrete can increase the compressive strength of aerated concrete to overcome the weakness of aerated concrete (Begum *et al.*, 2014). The hydration shown in Equation 1, when the cement is mixed with water it will generate C-S-H gel and calcium hydroxide. The function of C-S-H gel is to bind all the aggregates in the concrete and the calcium hydroxide is a cement solidified waste in the hydration process. However, the pozzolanic reaction shown in Equation 2, when the silica is mixed with calcium hydroxide, the silica will finely grind the calcium hydroxide and produce more C-S-H gel to bind the aggregate and reduce the cement solidified waste in the hydration process.

Hydration:

$$\text{Cement} + \text{H2O} \rightarrow \text{C-S-H Gel} + \text{Ca(OH)2} \quad (1)$$

Pozzolanic reaction:

$$\text{Ca(OH)2} + \text{SiO2} \rightarrow \text{C-S-H Gel} \quad (2)$$

The hydration could happen when the cement is mixed with water. During the hydration process, it will produce C-S-H gel and calcium hydroxide and the calcium hydroxide is the waste in hydrated cement. The solution for the calcium hydroxide is a pozzolanic reaction by adding silica and it will become C-S-H Gel. Partial replacement of cement by silica dioxide can reduce the calcium hydroxide and the usage of cement. Silica can be found in ashes from industrial waste in developing countries. Despite silica can get from the other ashes, but RHA is richest in silica and contain about 85%-90% silica suitable used for pozzolanic (Nagrale *et al.*, 2012). Previous study on RHA as cement replacement in the concrete will produce a hydraulic binder and it will improve the durability properties as well as increase the strength of concrete (Kasaniya *et al.*, 2021).

In developing countries, there have many places that were urbanized and cause the forest and wetland area are decreased. It increases the impervious surface area so that rainfall infiltration capacity is reduced, and it means the rainwater difficult flow inside the land. This leads to flash floods in urban and the flood will spill out the sediment in the drain on the road and cause the infectious diseases (Margaret, 2017). So, the drain and good drainage system is very for the rainwater flow into the land to prevent flood occur in urban area. The drainage system is essential in infra work to avoid floods in residential areas (Ngamalieu-Nengoue *et al.*, 2019). However, the construction of drainage needs a high cost and required many labours due to the weight of the drain itself (Kourtis & Tsihrintzis, 2021). This is because the use of machinery is required to make the process easier. In an overall construction project, the labor cost is occupied up to 30%-50% of the total budget cost (Alaloul *et al.*, 2021). The machinery uses to make the process of drain installation easier, but it also required skilled labour to operate the machinery. When skilled labour is required, it will increase the total cost of the project due to skilled labour requiring higher cost than general labour. However, the lightweight prefabricated concrete drain enables labour to carry the drain without machine. Therefore, machine and skilled labours are not required and reduce the project cost. Aerated concrete is one of the lightweight concretes that have many air voids fill in the concrete. The air voids will replace part of concrete as well as reduce the self weight of concrete. Furthermore, the transport can deliver more concrete drains to the site, and it will indirectly reduce the transportation cost. Hence, the delivery cost and installation cost can be reduced. Besides that, the demand for construction materials keeps increasing due to the growth of the construction industry. Klufallah *et al.* (2014) stated that the construction sector was emissions up to 24% of carbon dioxide. It was contributed to the global warming of the world. Every year, the production of cement in Malaysia is about 20 million tonnes and the process to manufacture the cement releases approximately 20 million tonnes of carbon dioxide (Bakhtyar *et al.*, 2017; Monteiro *et al.*, 2017). According to Monteiro *et al.* (2017), every year estimated about 30 billion tonnes of concrete are consumed and it still incrasing because the demand for concrete is increasing year by year. Cement the raw material of concrete produced by heating the limestone and clay to 1450℃. Due to producing cement need a high temperature to heat the limestone and clay, every 1 tonne of cement is produced it causes 1 tonne of carbon dioxide released to the environment (Monteiro *et al.*, 2017). Therefore, many studies and research were conducted to replace and reduce part of cement and pozzolanic material is good to replace the cement. The pozzolanic materials such as RHA, wood ash, coal ash, and palm oil fuel ash are suitable use to replace the cement in concrete and replace the pozzolanic material without affect the performance of concrete (Adnan *et al.*, 2021; Bhat, 2021; Alnahhal *et al.*, 2021). The situation of high usage in cement can be solved by using pozzolanic material such as RHA as cement replacement. Material of cement replacement such as RHA can actively react to the pozzolanic reaction in the concrete. The active pozzolanic reaction can help the concrete increase the compressive strength and durability in long term (Lung *et al.*, 2011). Due to the long-term exposure of drain to outside environemnt, the RHA is a suitable pozzolanic material use in cement replacement to increase the strength and durability of drain.

The objectives of this research are to identify the optimum percentage of RHA as cement replacement in concrete, to compare the compressive strength of the RHA concrete with the standard concrete cube, to compare the compressive strength of RHA NAAC drain with standard drain, and to determine the feasibility of RHA NAAC drain in normal environment. By conducting this research, it will encourage the partial cement replacement in concrete to reduce the use of cement as well as decrease the carbon emission, increase the awareness of society regarding industrial waste and the importance of RHA as partial cement replacement, the creation of NAAC drain can help the developer save the labour and machinery cost during the installation and tranportation, and this research can contribute in academically which can be continued by other researchers do the improvement of lightweight concrete.

2. Literature Review

This section introduces the rice husk and RHA and the functions used in the construction industry. Besides that, this chapter also discusses the previous research by using the pozzolanic material as cement replacement.

2.1 Rice husk and RHA

Rice husk also known as rice hull, is the coating on a seed or grain of rice. It is formed from hard materials, including silica and lignin to protect the seed during growing. Rice husk is a by-product of rice milling. Every year have 720 million tonnes of rice will produce in the world during rice milling (Chen *et al.*, 2021). In the process of rice milling, about 78% of the weight is rice and bran, the rest 22% is rice husk (Nagrale *et al.*, 2012). These rice husks can generate about 17%-20% of RHA after combustion (Zou & Yang, 2019). According to Rego *et al.* (2015), rice husk will be used as fuel to generate energy for thermoelectric plants and boilers in the rice processing industry. After combustion of the rice husk will become residue and it is an industrial waste without commercial value.

RHA also can be white RHA and black RHA based on the combustion is complete or incomplete. White RHA can be obtained when controlled combustion of the rice husk in the atmosphere. It contains more than 95% of silica in a hydrated amorphous form with high porosity and reactivity (Zou & Yang, 2019). The controlled combustion of rice husk in nitrogen will obtain black RHA containing different amounts of carbon and silica.

2.2 RHA in construction

(a) Cement replacement

In the construction industry, RHA become a popular material as cement replacement in the production of concrete. This is because RHA contains 85-90% silica that can high active the pozzolanic reaction in the hydration process and its low cost (Nagrale *et al.*, 2012). The pozzolanic reaction can increase the compressive strength of concrete (Srinivasreddy *et al.*, 2013). Besides that, RHA can solve the calcium hydroxide which is a waste in the hydration process. When the RHA contains high silica reacts with calcium hydroxide, it will become C-S-H gel to bind the aggregate.

Based on the experiment conducted by Minh & Tram (2016) by using rice hush ash as a partial cement replacement in the production of concrete brick. The experiment prepares two types of RHA which are primary RHA and RHA heat-treated at 500℃. Three concrete brick specimens were cast by using RHA and treated RHA, respectively. The percentage of RHA is 10% based on the cement weight was applied in the experiment. The compressive strength test after 7 days curing for primary RHA and heat-treated RHA is 3.60 MPa and 3.65 MPa respectively. Both RHA concrete bricks show the compressive strength is approximate to the standard concrete brick (3.75MPa). It proofs that the RHA is suitable to use for cement replacement, and it does not give a significant effect on the compressive strength of concrete brick.

(b) Soil Stabilization

The admixture of RHA and lime can reduce the plasticity, increase the compressive strength of strength. RHA can not be used alone as a soil stabilizer because lack of cementitious properties (Behak, 2017). The soil stabilization using RHA can be explained by the pozzolanic reaction. When the RHA is mixed with lime and water, it will produce the gel that covers and bind the soil gains to cause the strength of the soil to increase. The application of RHA is a substitute to minimize the cost of the construction of roads (Sarapu, n.d.).

2.3 Pozzolanic Materials

(a) RHA

Adnan *et al.* (2021) has studies on the experimental the performance of rice husk as partial cement replacement. The RHA percentage for the specimens use in the experiment are 0%, 10%, 20% and 30%. Two groups of specimens were cast, and each group consists of eight specimens for flexural test and compressive test, respectively. Every group have four specimens will test after 7 days curing and the rest will test after 28 days curing. The result for the flexural test after 7 days curing has showed 3.59 MPa for 0%, 3.90MPa for 10%, 4.37 MPa for 20% and 2.58MPa fpr 30%. After 28 days curing, the fexural test for 0%, 10%, 20% and 30% are showed 4.62 MPa, 5.29 MPa, 6.66 MPa and 4.55 MPa, respectively. It showed both sides have slowly increase of flexural strength from 0% to 10%. After that, it reached the highest flexural strength in 20% of RHA and have a slight drop in 30%.

In the compressive test after 7days curing, the 0% replacement specimen showed 28.13 MPa. After increase the percentage of replacement to 10%, the compressive strength drops to 26.42 MPa and the compressive strength rise back to 28.13 MPa when the replacement increases to 20%. Then, drop again to 17.08 MPa when replacement by 30% of RHA. After 28 days curing, all the specimens have a obvoiusly increases in the compressive strength 43.08 MPa for 0%, 39.73 MPa for 10%, 50.06 MPa for 20% and 26.65% for 30%. In the experiment showed that the 20% of RHA in cement replacement have same performance even greater than the standard concrete.

(b) Wood ash

The partial replacement of wood ash in cement have been studied by Hamid *et al.* (2021). There are two types of wood ash (WA) were prepared for the cement replacement. WA1 is collected from kitchen stoves that use forest wood made as fuel and WA2 is wood waste from industry. Both of the percentage replacement is designed in 0%, 10%, 15%, 20% and 25%. The compressive strength is conducted after 7 days and 28 days curing. After 7 days curing, the compressive test of WA1 showed 20.50 MPa for 0%, 21.46MPa for 10%, 21.28 MPa for 15%, 20.32 MPa for 20%, and 18.40 MPa for 25%. The WA2 also have the same situation with WA1, it showed a decrease from 20.50MPa (0%) to 16.40 MPa (10%). Then, the compressive strength still decreases from 14.30 MPa for 15% to 13.60 MPa for 20% and the compressive strength at 25% only have 9.15 MPa.

The compressive strength after 28 days in WA1 showed greater than after 7 days curing. The compressive strength of WA at 0% have increased from 20.50 MPa to 34.17 MP. In WA1 found that the compressive strength decreases to 24.71 MPa at 10%. As the WA1 increases to 15%, the compressive drop down to 24.35 MPa and continuously decreases to 23.17 MPa for 20% and 22 MPa for 25%. The compressive strength for WA2 in 10%, 15%, 20% and 25% also less than 0% with 19.91 MPa, 17.86 MPa, 16.53 MPa and 14.20 MPa, respectively. Two types of WA have the highest compressive strength at 20% but the performanced is decreased compare with the 0% WA in concrete.

(c) Coal ash

Bhat (2021) has studied on the cement replacement by using coal ash. Four specimens' size of 150mm x 150mm x 150mm was cast to conduct the tensile and compressive strength after 28 days curing, respectively. The tensile test after 28 days curing, it showed 2.79 MPa for 10%, 2.38 MPa for 15% and 1.76 MPa for 20%. The overall performance of coal ash is lower than standard conncrete with 3 MPa. For the performance in compressive strength, each of the percentage coal ash as partial cement replacement also get a lower performance compare with standard concrete.

(d) Bottom ash

In 2012, Wongkeo *et al.* are using bottom ash as partial cement replacement in aerated concrete. The experiment using 10%, 20%, 30% of bottom ash as partial cement replacement and 0.2% of aluminium powder based in the weight of concrete. In the experiment, three size of 50 mm x 50 mm x 50 mm of cube were cast to test the compressive strength. The experiment result showed that the standard aerated concrete has 9.5 MPa. As the bottom ash increase to 10% in aerated concrete, the compressive strength increases to 10.1 MPa. After that, the bottom ash adds to 20% it come with 10.9 MPa and 11.6 MPa for 30%. Based on BS EN 771: Part 4-aerated concrete block shall with a minimum compressive strength of 5N/mm2. The result of the experiment showed that all the cement replacement used in aerated concretes have approach compressive strength above 10Mpa, but the 30% of bottom ash is the highest result with 11.6 MPa.

2.4 Aerated Concrete

Shabbar *et al.* (2017) studied on the aerated concrete with diferrent aluminium powder content. The size of the specimens is 100mm x 100mm x 100mm and the aluminium powder content designed in 0%

as reference, 0.25%, 0.5%, 0.75% and 1%. In the experiment, the compressive strength of 0% content aluminium powder is 53MPa. By increasing the content of aluminium powder to 0.25% the compressive strength dropped to 32.3 MPa. Next, in 0.5% of aluminium powder, the compressive strength is 26 MPa and 23.4 MPa for 0.75% aluminium powder. The lowest compressive strength is 18.6 MPa for 1% aluminium powder. The 1% aluminium powder showed 35% of reduction in compressive strength compared to standard concrete.

3. Research Methodology

This section explains the method and process used which includes the flowchart, the preparation of experiments, the concrete drain test, and the result carried out by the experiment.

3.1 Research framework

The experiment process of experiment as shows in Appendix 1 and Appendix 2. The experiment started with materials preparation, followed by preparation standard cube mould for specimen, the specimen will pilot test based on the percentage of RHA. After 7 days curing, the cube specimen will test the compressive strength. Next, select the optimum percentage percentage RHA for casting u-shaped concrete drain and curing for 28 days. After 28 days of curing, the rebound hammer test was conducted on the RHA NAAC and standard drain. The final step in the process is collect data and data analyze.

3.2 Material Preparation

(a) Cement

The cement used in the experiment is Ordinary Portland Cement brought from workshop and store in storeroom to prevent from moisture surface and rainny weather.

(b) Sand

Sand is the fine agrgegate that used in the experiment to cast the concrete cube and drain. The size of sand is 1mm to 2mm and store well in the storeroom.

(c) Coarse Aggregate

The coarse aggregate brought from workshop and the size of coarse aggregate is 15mm to 20mm.

(d) RHA

RHA is the important material use to replace the cement in concrete. The researcher bought the RHA from the online shopping plateform.

(e) Aluminium powder

The aluminium powder is the important material to cast the aerated concrete. The researcher bought the aluminium powder from online shopping platform. The mesh of aluminium powder is passing through 200 mesh. 1% from weight of cement is the weight of aluminium powder for mix design.

(f) Cube Mould

The Figure 1 below is shown the size of cube mould is 100mm x 100mm x 100mm.

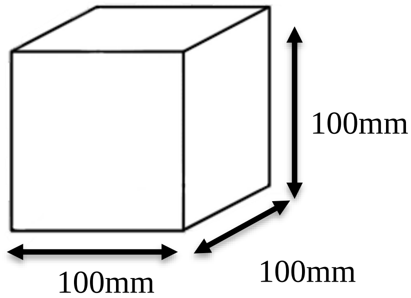

Figure 1: Size of Cube

(g) Drain Mould

This research required a standard u-shaped concrete drain design as a reference and comparison for optimum percentage of rice husk ash conrete mix into u-shaped concrete drain. The size of drain is based on CHOI FOOK SING ENTERPRISE SDN. BHD. as the reference to design. Figure 2 below shows the size of standard u-shaped concrete drain.

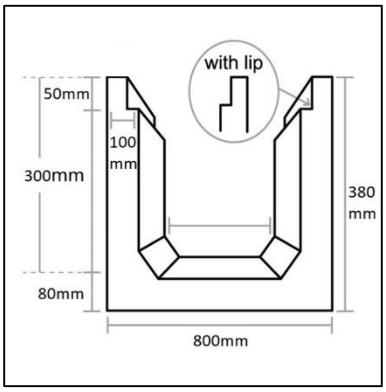

Figure 2: Size of Drain

3.3 Mix Design

The specimen of this research has 5 cubes were cast to identify the optimum percentage of RHA to replace in cement. Table 1 below shows the mix design for each cube specimen.

Table 1: Mix Design for Each Cube Specimen

RHA Replacement	RHA (g)	Aluminium powder (g)	Cement (g)	Sand (g)	Coarse Aggregate (g)	Water (liter)
0%	0	3	270	550	1090	0.16
10%	20	3	250	550	1090	0.16
15%	40	3	230	550	1090	0.16
20%	50	3	220	550	1090	0.16
25%	60	3	210	550	1090	0.16

3.4 Process of Casting Concrete Cube

Table 2: Process of Casting Concrete Cube

Figure	Discription
	The materials such as cement, sand, coarse aggregate, RHA, and aluminium powder use to cast concrete cube was measured by weight and dry mixed.
	All of the materials were mixed, and water was added according to the mix design. After mixing the materials, pour the concrete into mould.
	The concrete was puoured into the cube mould in 3 layers. Each of the layers were compacted by using steel rod with 30 strokes to make sure the concrete fill up the cube mould.
	After finishing casting, the concrete cubes were left for 24 hours at room temperature to harden.

3.5 Curing Process

A proper curing process will increase the compressive strength in concrete. In this experiment, the curing process will conduct after the u-shaped concrete drain and cube specimens are hardened. The cube specimens were removed from the mold after 24 hours left at room temperature and then put into water for 7 days curing.

Figure 3: Curing Process

3.6 Pilot Test

Before casting the u-shaped concrete drain, the pilot test will conduct to determine the optimum percentage of RHA as cement replacement. In the pilot test, 5 samples of RHA concrete cubes were cast for the pilot test. The concrete cubes were cast and cured for 7 days and used the compressor to test the compressive strength.

Figure 4: Pilot Test

3.7 Process of Casting Drain

Table 3: Process of Casting Drain

Figure	Description
	All the materials were measured by weight and pack in beg and brought to workshop for casting the drain.
	All the materials put in the mixing machine and mixed become concrete.
	Pour the concrete into drain mould in 5 layers. Each layer layers were compacted by using steel rod with 15 strokes to make sure the concrete fill up the cube mould.
	After casting, the concrete drains were left for 24 hours at room temperature for harden.

3.8 Rebound Hammer Test

Rebound hammer test is a mechanical test that measure the maximum compressive load of a structure. In the experiment, the rebound hammer test will conduct after pilot test all the concrete cube, the optimum percentage of RHA are selected and cast into u-shaped concrete drain then curing for 28 days. After 28 days curing, the concrete drain conducts a rebound hammer test and compare with standard u-shaped concrete drain. The rebound hammer test follows the BS 1881-202 to conduct the durability test. The equipement in the experiment will used is digital rebound hammer. The vertical face of the concrete selected to conduct the rebound hammer test. The middle of the vertical face and pick 9 points to collect the rebound hammer reading for the u-shaped concrete drain.

Figure 5: Rebound Hammer Test

3.9 Qualitative Approach

In the research, qualitative approach was applied to collect the opinion about the application of RHA NAAC drain in construction. The data will collect from contractor, project manager, and civil engineer through interview via Google Meet and phone call. Contractor, project manager, and civil engineer are selected to conduct the interview because they are the person who often face with the concrete and understand the characteristics of concrete in construction site.

4. Results and Data Analysis

This data describes the discussion of the finding from the test performed on concrete as well as interviews. This data also discribes the findings of test analysis made on the RHA aerated concrete cube. Data analysis includes the compressive strength test, weight of specimens, rebound hammer test on the U-shaped concrete drain and the feedback of RHA NAAC drain from the contractor and civil engineer.

4.1 Optimum Percentage of RHA (Pilot test)

(a) Compressive Strength After 7 Days of Curing

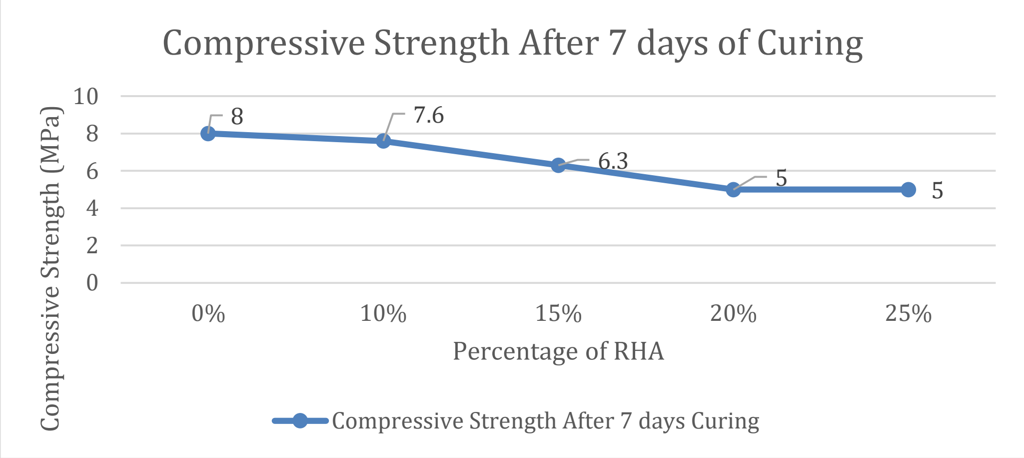

Figure 6: Compressive Strength after 7 Days of Curing

Based on the figure above, it shows the compressive strength of aerated concrete cube by applying different percentage of RHA as partial cement replacement after 7 days of curing. There are five specimens of RHA replacement in concrete mixture including 0% specimen as the reference in the experiment. The result shows the concrete cube replaced by 10% RHA has the highest compressive strength with 7.6 MPa. After the RHA was increased to 15%, the compressive strength of concrete cube decreased to 6.3 MPa. Next, the following cubes were replaced by 20% and 25% RHA had the same result compressive strength which were 5 MPa respectively.

(b) Compressive Strength After 28 Days of Curing (Prediction)

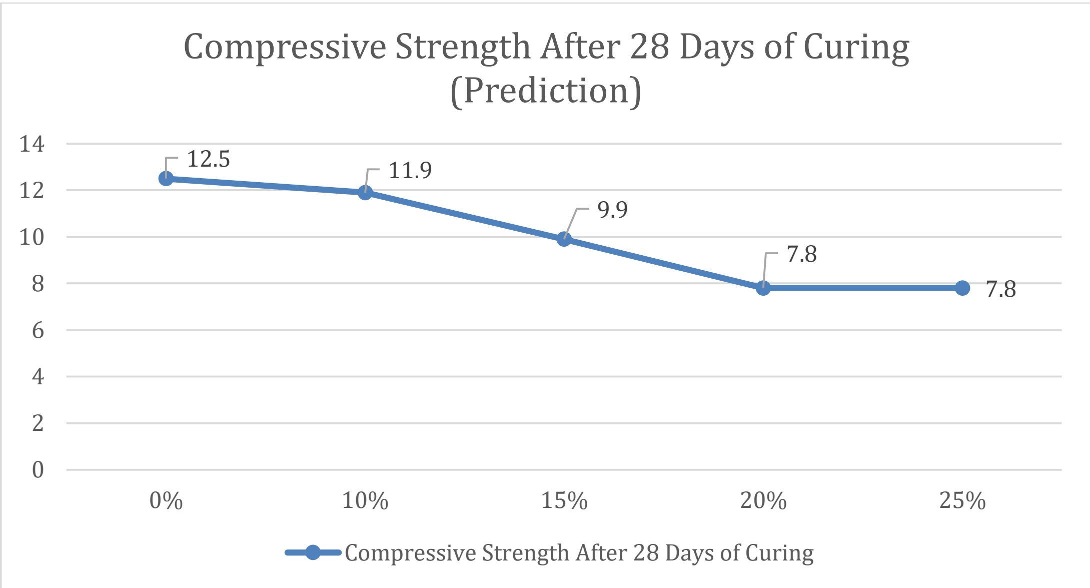

Figure 7: Compressive Strength After 28 Days of Curing (Prediction)

Based on the figure above, it shows the compressive strength of aerated concrete cube by applying different percentage of RHA as partial cement replacement after 28 days of curing. There are five specimens of RHA replacement in concrete mixture including 0% specimen as the reference in the experiment. The result shows the concrete cube replaced by 10% RHA has the highest compressive strength with 11.9 MPa. After that, when the RHA was increased to 15%, the compressive strength of concrete cube decreased to 9.9 MPa. Next, the following cube was replaced by 20% of RHA had the

7.8 MPa compressive strength. Last, the 25% of RHA shows the same result with 7.8 MPa compressive strength.

(c) Compressive Strength After 7 Days and 28 Days of Curing

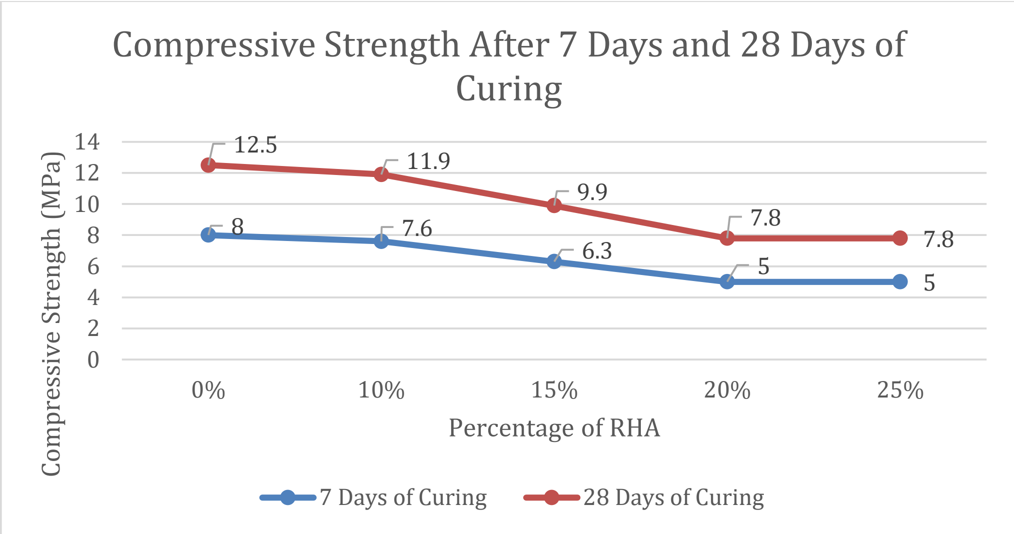

Figure 8: Compressive Strength After 7 Days and 28 Days of Curing

The Figure 8 shows the compressive strength of concrete cube after 7 days and 28 days of curing. The result shows in 10% of RHA has the highest compressive strength with 7.6 MPa in 7 days of curing and 11.9 MPa in 28 days of curing. After that, the compressive strength in 7 days and 28 days of curing is decreased in 15% of RHA with 6.3 MPa and 9.9 MPa respectively. Next, in the 20% of RHA, the compressive is dropped to 5.5 MPa in 7 days of curing and 7.8 MPa in 28 days of curing. Then, in 25% of RHA, the graph does not have any change and shows the compressive strength with 5 MPa in 7 days of curing and 7.8 MPa in 28 days of curing.

As a result, the graph clearly shows the 10% of RHA has the highest compressive strength in 7 days and 28 days of curing with 7.6 MPa and 11.9 MPa respectively.

4.2 Comparison of Compressive Strength for Each Percentage of RHA

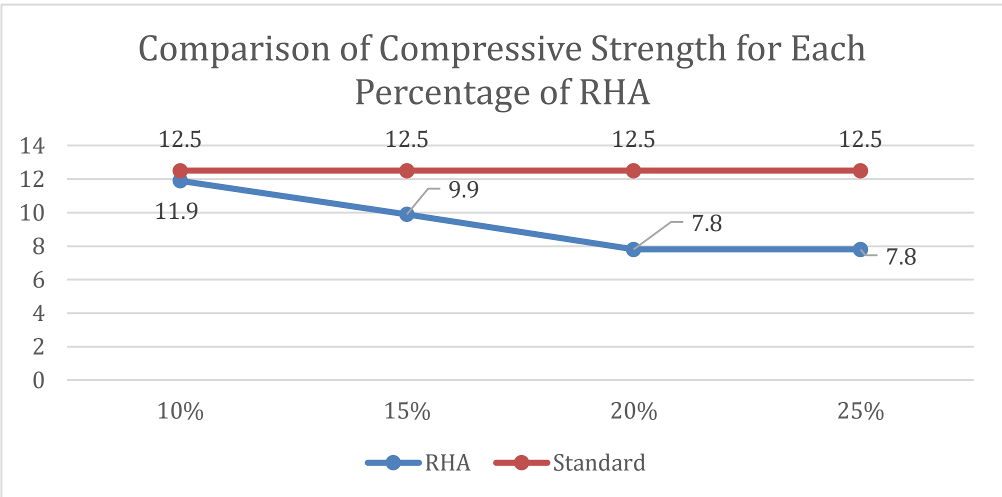

Figure 9: Comparison of Compressive Strength for Each Percentage of RHA

Based on the Figure 9 above, it shows the result of compressive strength of aerated concrete cube for each percentage RHA replacement in concrete with standard aerated concrete cube. As for reference, the red line represents for standard aerated concrete cube while the blue line represents to the RHA. Based on the graph, the compressive strength of standard aerated concrete cube is 12.5 MPa.

Based on the graph, the compressive strength in 10% of RHA is 11.9 MPa lower than standard cube with 0.6 MPa. Next, the compressive strength in 15% of RHA is 9.9 MPa and has lower about 2.6 MPa. For the 20% and 25% of RHA, both of the results are same with 7.8 MPa compressive strength and decrease 4.7 MPa compared to standard cube.

From the graph, it clearly shows the compressive strength of stadard concrete totally higher than RHA. It also shows the percentage of RHA affects the compressive strength of conrete. When the percentage of RHA is increased, the compressive strength will decrease. However, the 10% of RHA is the second-highest compressive strength in the graph with 11.9 MPa and it only 0.6 MPa differ from the standard cube.

4.3 Comparison of Compressive Strength of RHA NAAC Drain with Standard Drain

The table below shows the result of rebound hammer test. There have 2 RHA NAAC and 2 standard drains were used in the experiment test.

Table 4: Compressive strength between standard and RHA NAAC drain

Specimen Name	Specimen Strength (MPa)	Average Specimen Strength (MPa)
RHA NAAC drain 1	13.17	12.67
RHA NAAC drain 2	12.16	
Standard concrete drain 1	19.17	18.32
Standard concrete drain 2	17.46	

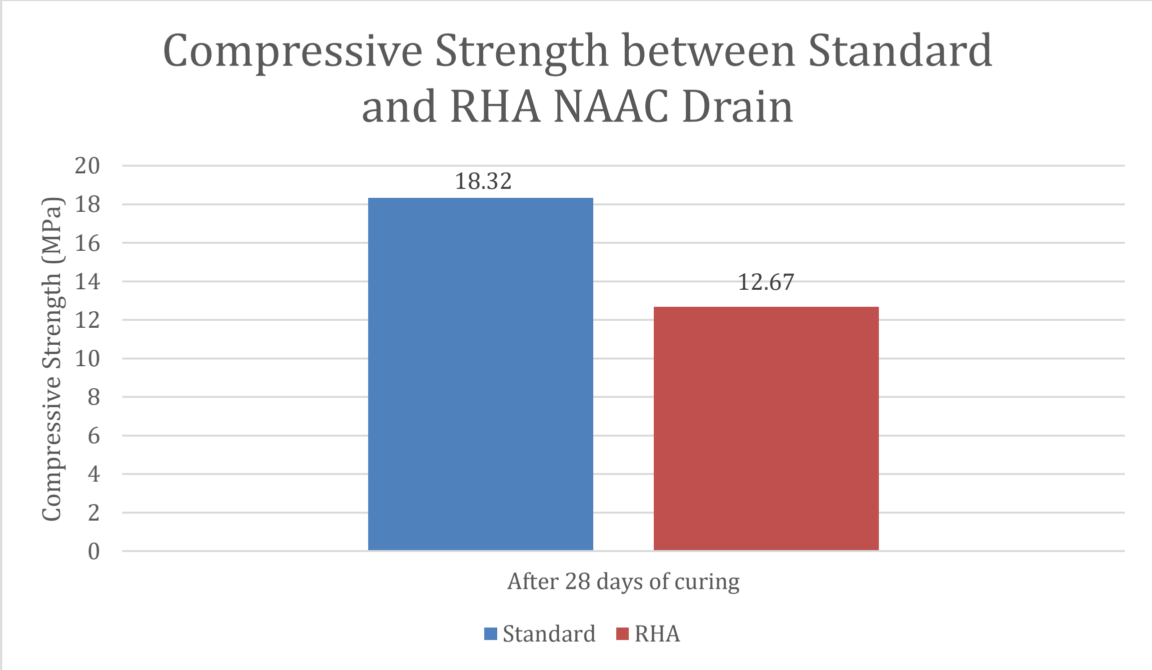

Figure 10: Compressive Strength between Standard and RHA NAAC Drain

Based on the Table 3 and Figure 10 above shows the result of rebound hammer test on the u-shaped concrete drain after 28 days curing. Based on the Table 3, the comparison of compressive strength between standard and RHA NAAC drain were sketched in Figure 5.

The figure shows the average compressive strength of standard and RHA NAAC drain is 18.32 MPa and 12.67 MPa. The compressive strength difference between standard drain and RHA NAAC drain is 5.65 MPa. The RHA NAAC drain has decrease nearly 31% of compressive strength compare with standard concrete drain. However, the reduction 31% of compressive strength is acceptable. The result of the experiment was close to the research studied by Shabbar *et al.* (2017) which had 35% compressive strength reduction.

4.4 Feasibility of RHA NAAC in Normal Environment

(a) Respondents Background

The respondent in this research consists of civil engineer, contractor and project manager. There are 3 respondents were found to conduct the interview to obtain their opinion about the RHA as partial cement replacement from the aspect environment, market, and the consideration of RHA NAAC drain. The table below shown the respondents' background in the research.

Table 5: Respondents' Background

Respondent	Company	Position	Working Experience
R1	Company A	Contractor	Above 5 years
R2	Company B	Civil Engineer	Above 5 years
R3	Company C	Project Manager	Above 5 years

(b) Comment on using RHA as partial cement replacement to the environment

Based on the interview, all the respondents agree that the effort of using RHA as partial cement replacement will reduce the impact of environment due to construction activities such as carbon emission. Besides that, using RHA as partial cement replacement can reduce the industries waste such as RHA and it will become environment friendly. In additonal to RHA, there are also wood ash, coal ash, and bottom ash can be partial cement replacement. The effort of using RHA as partial cement replacement also good to reduce the industry waste who using power plant.

"The construction field is huge, I don't know the other company got apply the cement replacement or not, but I think that is a good practice by using the cement replacement in the concrete can reduce the environment impact. But more studys need to conduct to confirm the strength of concrete when apply cement replacement" (R1)

"This is a good effort to design the cement replacement in concrete can reduce the environmental impact and reduce the waste of industrial power plant. However, I do not recommend use the cement replacement in concrete. Fisrt, if apply the cement replacement, the strength of concrete is a question mark. Because we never use cement replacement in concrete. Second, the RHA is silica fume and I don't know about the specific chemical reaction with the cement. The chemical reaction may harm the steel inside the structure." (R2)

"This is good research by using RHA as cement replacement to reduce environment impact due to construction activities such as the carbon emission from concrete." (R3)

(c) Consideration of RHA NAAC drain

The main consideration when normal concrete drain turns into RHA NAAC drain is the strength of the drain. All the respondents are more focus on the strnegth of concrete drian and the NAAC technique would reduce the strength of concrete.

"The NAAC technique is not suitable use to cast the concrete drain. This is because the NAAC technique will cause the air pore inside the concrete drain and affect the drain spoil easily. During the transportation of drain will happen some collision with other drain and cause the drain spoiled. Besides that, long-term exposure at the moisture surface can cause the mud penetrate the drain." (R1)

"It only suitable for the sub-structure only due to NAAC technique reduce the strength of concrete drian. For the current stage, the RHA NAAC drain is not suitable use in the construction, because in the construction still prefer use fully cement in the project. The RHA will bring a lot of problems to concrete such as the strength and the chemical reaction of RHA with cement. Besides that, in my opinion I think that the NAAC technique only suitable for block and never heard the NAAC on the other structure." (R2)

"My main consideration is the strength of the drain. Because in construction project, althought the structures are use fully cement is also will be spoiled when have a collision on the structures especially during unloaded the precast structures. The second consideration is about the weight. Currently, the precast structure is quite heavy if the NAAC can reduce the weight of concrete, it required less manpower to unload as well as save the labour cost." (R3)

5. Conclusion

This section concludes with the finding that has been collected and objectives of this research. A summary of observation, conclusion and recommendations based on the data analyzed in the previous chapter and opinion from the repondents who conduct the interview in this research. This chapter also lists the limitations and recommendation for this research.

5.1 Research Objectives

a) To identify the optimum percentage of RHA as cement replacement in concrete.

Based on the data collected from the experiment conducted, the optimum percentage of RHA as cement replacement was identified in 10%. This is because in the 10% RHA was reached the highest compressive strength with 11.9 MPa after 28 days of curing.

b) To compare the compressive strength of the rice hush ash concrete with the standard concrete cube.

In the experiment, the RHA replacement in all the cubes shows the reduction of compressive strength. However, in 10% of RHA, the compressive strength is nearly close to the standard cube with 11.9 MPa and the standard cube is 12.5 MPa. It only decreases 0.6 MPa in the compressive strength.

c) To compare the compressive strength of RHA NAAC drain with standard drain.

Based on the data collected, it shows the standard drain had the compressive strength higher than the RHA NAAC drain. On average, the standard drain had the compressive strength of 18.32 MPa and RHA NAAC drain had the compressive strength of 12.67 MPa. It had shown a slight dropped 5.65 MPa from 18.32 MPa to 12.67 MPa. The result shows there have 31% dropped in compressive strength and it is acceptable to perform as drain.

d) To determine the feasibility of RHA NAAC drain in normal environment.

Currently, the RHA NAAC drain is not suitable apply in normal construction due to there have many factors will affect the performance of the drain. Therefore, more study needs to identify and figure out the other factors that will affect the durability of concrete drain such as identifying the chemical reaction of RHA will enhance the corrosion of steel bar.

5.3 Recommendations

The recommendation proposed is for a future research study that regards the apply NAAC technique in precast structure with partially cement replacement. This recommendation is proposed for improvement that cen be made for future research.

Recommendation of this research are as follows:

i. More tests need to be done to find out more about the properties of RHA and aluminium powder to determine the ideal mix design.
ii. In this study, compressive strength was tested on age of 7 days only. It is recommended that further studies test concrete for 7 days, 14 days, 28 days, and longer period to obtain more accurate result and understanding in long-term development.
iii. Use other types of tests on the precast structure to determine the durability of precast structure.

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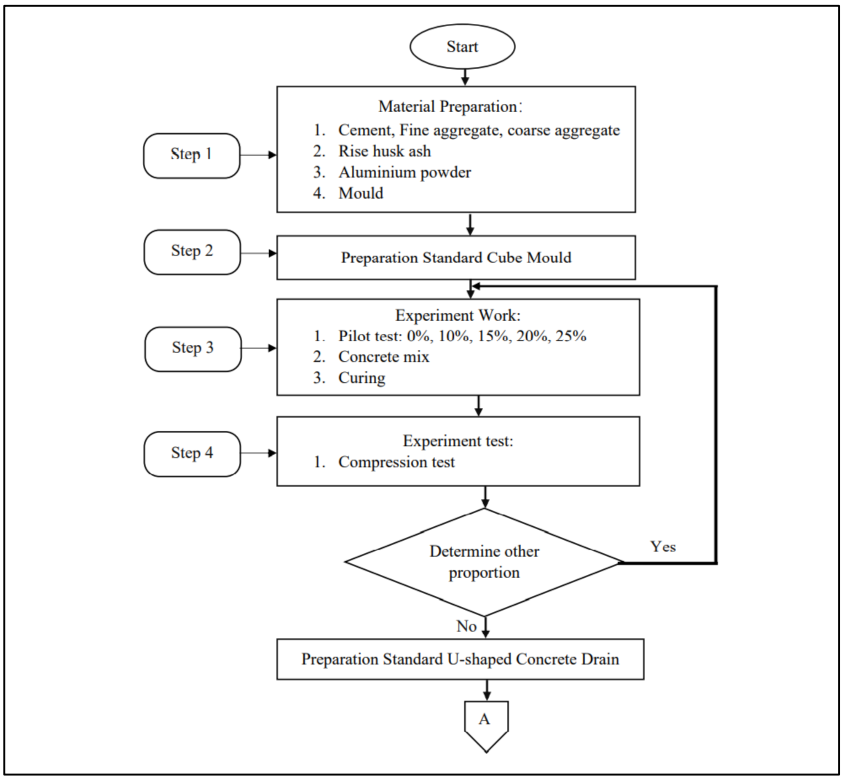
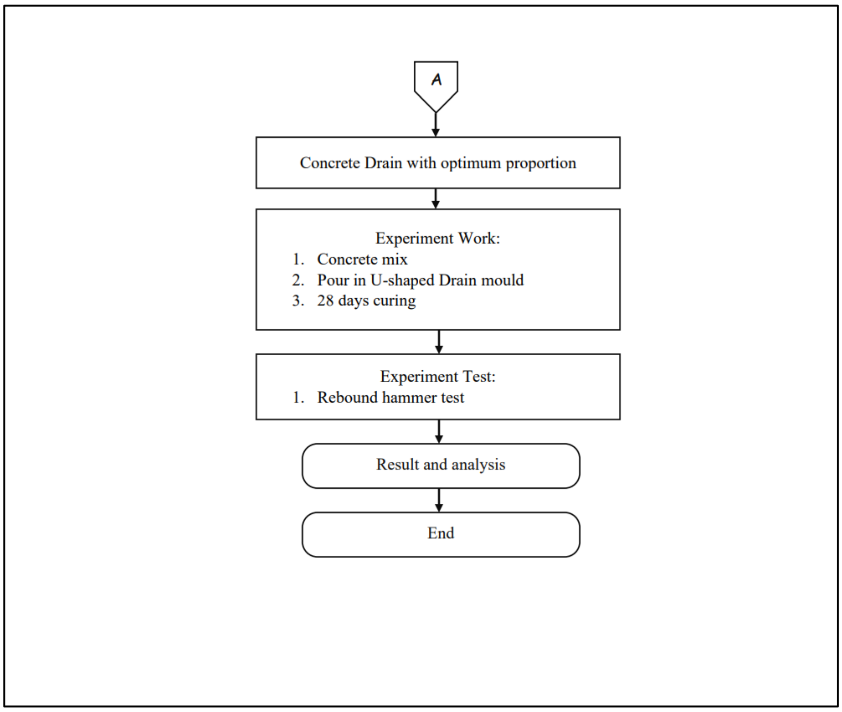
Appendix A



Appendix 1: Experiment Flow Chart



Appendix 2: Experiment Flow Chart