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The Study of Crushed Autoclaved Aerated Concrete as Sand Replacement in Concrete

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Abstract: Fine aggregate is one of the most important materials in the production of concrete for construction projects. AAC is an eco-friendly and green building materials that is very sustainable. Nowadays, the uses of AAC in Malaysia is in a great demand due to rapid urbanization of development that needs to implement the quality of AAC properties. Therefore, AAC is used as the fine aggregate partial replacement in the concrete mixture. The main objective of this study is to determine the physical properties of concrete such as workability, density and mechanical properties such as compressive strength. The AAC blocks was crush to produce AAC aggregate as the partial sand replacement in concrete. The properties of concrete will be tested. There were five concrete mixtures with crushed AAC as the replacement of sand were prepared and tested. The mixture of concrete was partially replaced by 0%, 10%, 20, 30% and 40% of CAAC replacement with concrete grade of 30. A total of 30 specimens of concrete cubes with the dimension of 100mm × 100mm × 100mm were tested for the compressive strength after 7 and 28 days of curing. The compressive strength of concrete mix with CAAC is higher at the age specimen of 28 days for it is the ideal design of concrete. The compressive strength replaced by 0%, 10%, 20, 30% and 40% of CAAC replacement with concrete grade of 30 for 28 days of the concrete is 31.2 MPa, 30.5 MPa, 30.1 MPa, 29.1 MPa and 25 MPa respectively. Meanwhile as for slump height are the 28 mm, 30 mm, 36 mm, 41 mm and 45 mm. The allowable addition of CAAC replacement in the concrete mix should not be greater than 20%. Besides, the workability of concrete is in medium workability range. The higher the percentage of CAAC replacement, the density and compressive strength of concrete is reduced.

Keywords: Autoclave aerated concrete (AAC), Sand replacement, Compressive strength

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1. Introduction

Sand, a key component in concrete mixing, is also being employed in greater quantities by the building industry. Negative impacts on the river and water quality might be caused by excessive sand mining. Sand, gravel, and other minerals can be mined at a pace that surpasses the rate at which natural processes produce them [1]. Local industries benefit greatly from sand mining, thus it cannot be prevented. Other waste products that may operate as partial sand replacement materials can be introduced to manage the amount of natural sand gathered.

Realization on the importance of managing the resources smartly for sustainable environment, has inspired local researchers [2-4] to investigate the potential existing waste materials as partial fine aggregate in concrete. Thus, the present research looks into the potential of the freely available autoclaved aerated concrete block to be transformed into environmentally friendly sand replacement material for the use in concrete production.

Over-mining is a common occurrence, putting the health of the river and the ecosystem at risk. The extent to which the influence is felt is largely controlled by the amount of sediment extracted in comparison to the amount of sediment supplied and transported [5]. Thus, this study is performed in order to create a sustainable building that can reduce sand usage in production of concrete by replacing sand with crushed autoclaved aerated concrete block. Hence, with increasing environmental awareness, many experiments have been done by researchers to create a sustainable building to reduce the usage of sand in concrete production.

Therefore, the aim of this study is to investigate the workability and density crushed autoclaved aerated concrete as partial sand replacement in concrete and to determine the compressive strength of crushed autoclaved aerated concrete as partial sand replacement in concrete.

1.2 Autoclaved Aerated Concrete

Autoclave aerated concrete blocks (also known as autoclaved lightweight concrete (ALC) are one of the most environmentally friendly and environmentally certified green construction materials available. It was the Swedish architect who perfected AAC in the mid-twentieth century. It has risen to become one of the most widely used construction materials in Europe, and its usage is fast expanding in a rising number of other nations across the world [6].

Increasing urbanisation in developing nations is creating a significant market demand for autoclaved aerated concrete (AAC) blocks in the building process, which is also resulting in a significant volume of autoclaved aerated concrete waste (AACW) being created [7]. Many academics have worked hard to find ways to use AAC waste in concrete manufacturing to its advantage. Researches regarding AAC blocks as fine aggregate can be seen in Table 1.

Table 1: Summary of Previous Findings related to AAC as fine aggregates

Author	Title	Findings
(Yang *et al*., 2021)[8]	Potential Usage Of Porous Autoclaved Aerated Concrete Waste As Eco-Friendly Internal Curing Agent For Shrinkage Compensation	After a 28-day sealing curing period, the compressive strength of the AACW groups is nearly identical to that of the control group. Cement mortar's cracking time can be delayed and the internal relative humidity can be improved by using AACW internal curing instead of EPA. Internal curing improves the micro-hardness of the interfacial transition zone (ITZ) while also improving resistance to chloride penetration, as is the case with AACW.

(Lam, 2021)[9]	Recycling Of AAC Waste In The Manufacture Of Autoclaved Aerated Concrete In Vietnam	Autoclaved aerated concrete (AAC) may be made from recycled waste products instead of natural sand, minimising waste disposal pressure. At manufacturers, AAC waste bricks can be used to replace crushed sand at the maximum 25 percent ratio, although this is actually only 5 percent.
(Lam, 2020).[10]	Influence of Fly Ash and Recycled AAC Waste for Replacement of Natural Sand in Manufacture of Autoclaved Aerated Concrete	Recycled AAC waste products with a maximum content of 5% and fly ash with a content of up to 100% can be used to substitute natural sand in the construction of AAC bricks, according to research results. As far as economics and technology are concerned, fly ash is the better choice due to its ability to reduce density while increasing compressive strength and lowering grinding costs, both of which are essential for environmentally friendly, long-term building.
(Tewar *et al.*, 2017)[11]	Effect of Partial Replacement of Sand with Wastage of Manufactured AAC Block in Concrete	As water use rises, the fresh attributes of a material increase. The M25 grade of concrete can be replaced up to 35%.

2. Materials and Methods

Five concrete mixes containing various content of crushed autoclaved aerated concrete that are 0%, 10%, 20%, 30% and 40% were used in this experimental work. The concrete mix design used in this study is in Table 2. The replacement of CAAC is by density. In Table 2, water for sand, water for CAAC and water for CA was obtained by extracting results from water adsorption test that was previously conducted in the laboratory. The materials used in this study is the same hence, the results are reliable as confirmed by the laboratory assistant. Since water adsorption has such a substantial influence on a wide range of physical and chemical processes [12] it was necessary to prevent the concrete paste from dehydration which can impact the physical processes.

Table 2: Concrete mix design

Quantities	Cement (kg)	Water (kg)	Fine aggregate (kg)		Coarse aggregate of 10mm, (Kg)	Water (Sand) Kg	Water (CAAC) Kg	Water (CA) Kg
			Sand	CAAC				
Per m^3	400	215	860		895			
Per trial mix of $0.001m^3$	0.4	0.215	0.86		0.895			
1st testing of $0.007m^3$	2.8	1.505	6.02	0%	6.265	0.29	-	0.10
2nd testing of $0.007m^3$	2.8	1.505	5.418	10% = 0.319	6.265	0.26	0.18	0.10

3rd testing of $0.007m^3$	2.8	1.505	4.816	20% = 0.637	6.265	0.23	0.22	0.10
4th testing of $0.007m^3$	2.8	1.505	4.214	30% = 0.956	6.265	0.20	0.25	0.10
5th testing of $0.007m^3$	2.8	1.505	3.612	40% = 1.274	6.265	0.17	0.28	0.10

2.1 Materials

The materials used in this study is Ordinary Portland cement (OPC), sand (4.75mm±5mm), water, sieved crushed AAC (4.75mm±5mm) as sand replacement and coarse aggregate (10 mm). The CAAC used is listed in Table 3.

Table 3: List of CAAC Samples

Group	Percentage of CAAC replacement	Number of samples	Labelling of samples
A	0%	3	A1 A2 A3
B	10%	3	B1 B2 B3
C	20%	3	C1 C2 C3
D	30%	3	D1 D2 D3
E	40%	3	E1 E2 E3

2.2 Methods

To begin with, the AAC blocks were crushed using Jaw Crushing and Ball Mill Crusher and then sieve using 5mm sieve to get the desired size. Next, the prepared specimens were placed in water curing until the testing age which is 7 days and 28 days. The workability and density will be determined. Compressive strength test on blocks with size 100mm x 100mm x 100mm will be conducted at 7 and 28 days.

2.3 Equations

Dry samples of specimen were weighed and Eq. 1 was used to determine the density.

$$Density = \frac{Volume}{Mass} \qquad Eq. 1$$

The formula for compressive strength, N/m^2 is express by Force, N per Area, m^2 is in Eq.2:

$$Compressive\ strength, \sigma = \frac{Force}{Volume} \qquad Eq. 2$$

3. Results and Discussion

The results from testing which was slump test to determine the concrete workability, compressive strength test of concrete and density of concrete block for each of specimen.

3.1 Results

3.1.1 Slump test

As shown in Figure 1, the slump value increases with the increase in percentage replacement of CAAC for for M35 grade of concrete as water requirement also increases with the percentage of replacement.

Table 4: Average of Slump result

Group	Percentage of CAAC replacement	Number of samples	Average Height of slump, (mm)
A	0%	3	28
B	10%	3	30
C	20%	3	36
D	30%	3	41
E	40%	3	45

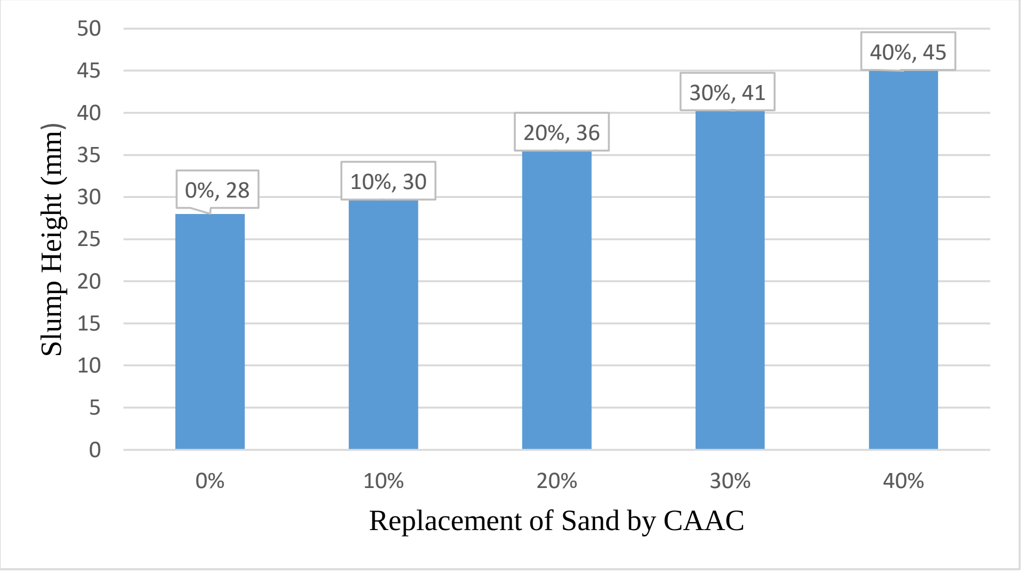

Figure 1: Average of Slump result with 0%, 10%, 20%, 30% and 40% CAAC replacement

3.1.2 Density

Density for all samples were shown in Table 5 and Figure 2. The highest density is in Group A with 10% CAAC replacement with the average of 2300 kg/m^3 meanwhile the lowest density which is 2173 kg/m^3 can be seen in Group B with 40% of CAAC replacement. It can be seen that the higher the percentage of CAAC replacement, the average density for each sample are in decreased. The decrease in density could be cause by the porosity in physical properties of CAAC.

Table 5: The density of concrete blocks

Group	Percentage of AAC aggregate	Number of samples	Density of concrete, (kg/m^3)		Average of density, (kg/m^3)
A	0%	3	A1	2310	
			A2	2260	2277
			A3	2260	
B	10%	3	B1	2300	
			B2	2300	2300
			B3	2300	
C	20%	3	C1	2300	
			C2	2260	2277
			C3	2270	
D	30%	3	D1	2230	
			D2	2210	2227
			D3	2240	
E	40%	3	E1	2170	
			E2	2200	2173
			E3	2150	

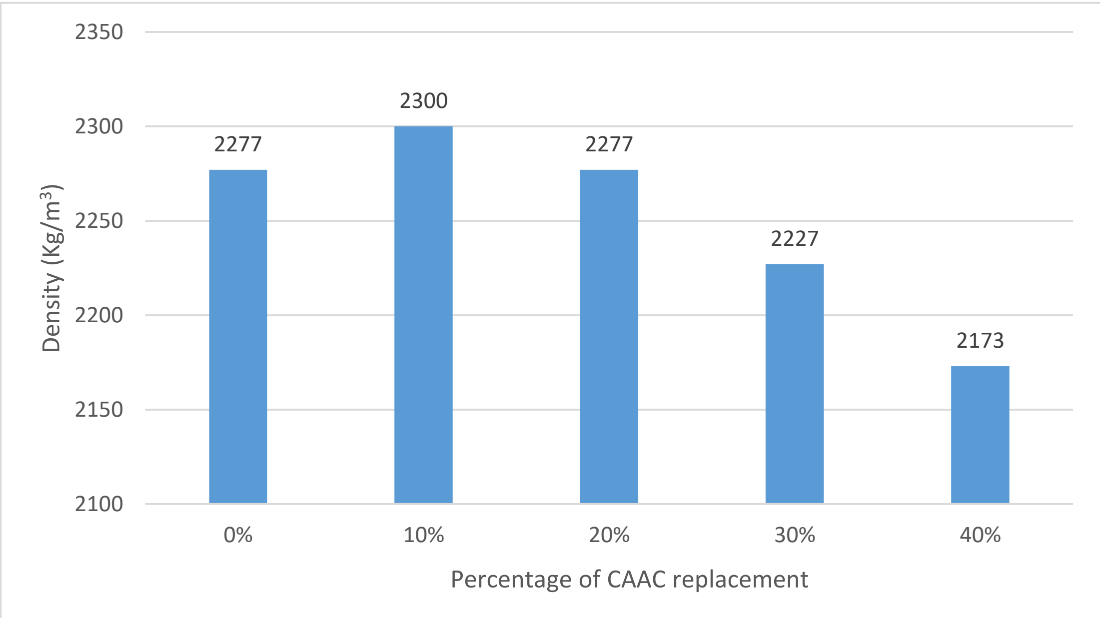

Figure 2: Density of Concrete blocks with 0%, 10%, 20%, 30% and 40% CAAC replacement

3.1.3 Compressive strength

Compressive strength test was conducted on five different concrete mixes that is containing CAAC replacement. The testing was carried out after 7 and 28 days. Both Table 6 and Table 7 are showing the collected data of compressive strength of concrete after 7 and 28 days respectively. Figure 3 and Figure 4 are displaying the average compressive strength of concrete after 7 days and 28 days of curing.

Table 6: Compressive strength of concrete after 7 days of curing

Group	Percentage of AAC aggregate	Number of samples	Compressive strength, (MPa)		Average of density, (kg/m^3)
A	0%	3	A1	21.9	21.5
			A2	20.8	
			A3	21.8	
B	10%	3	B1	21.9	21.3
			B2	20.4	
			B3	21.1	
C	20%	3	C1	20.3	20.0
			C2	19.7	
			C3	19.9	
D	30%	3	D1	19.0	19.2
			D2	19.4	
			D3	19.1	
E	40%	3	E1	16.9	17.1
			E2	17.2	
			E3	17.3	

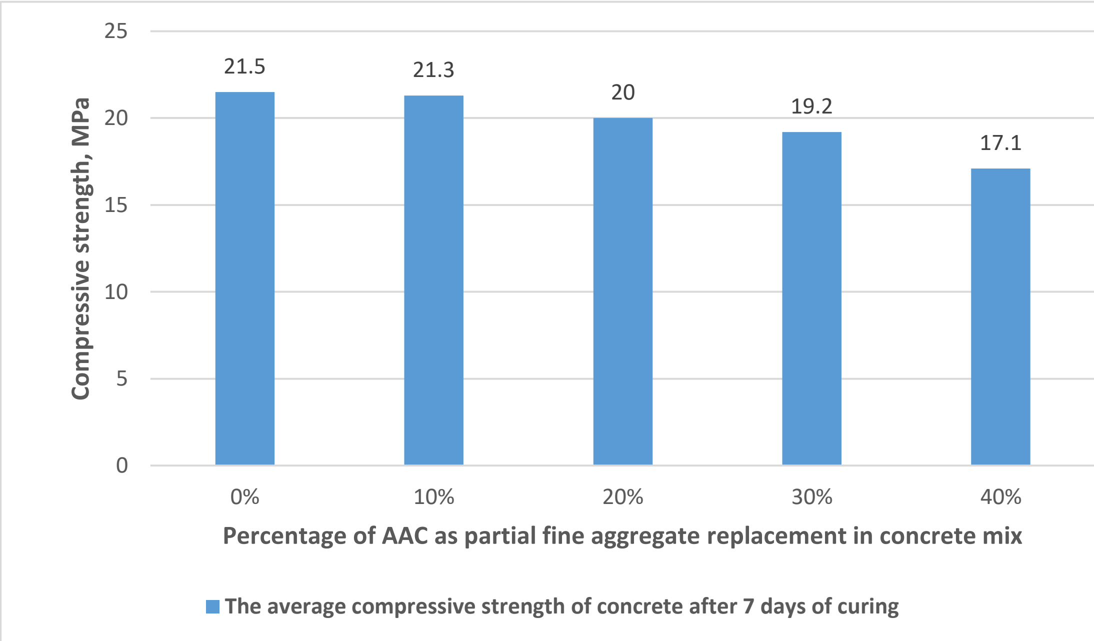

Figure 3: The average of compressive strength of concrete after 7 days of curing

Figure 3 and Figure 4 depicts the relationship between the compressive strength measured at a certain age of specimen and the age of the specimen. It shows that the longer the curing time has enhanced the compressive strength of all samples, regardless of whether or not additives were utilized. As demonstrated in Figure 4.2 and Figure 4.3, samples with 10% CAAC substitution exhibited the highest compressive strength of all the samples tested, with compressive strength values of 20.8 MPa and 30.5 MPa after 7 and 28 days of curing, respectively, after 7 and 28 days of curing. The compressive strength of the 20% CAAC replacement samples was 30.1 MPa, which was not significantly different from that of the control samples. However, substitution of CAAC at 30% and 40% failed to give the desired strength as the density of concrete decreased. For M30 grade concrete, the strength of 30 N/mm2 at 28 days is not obtained with replacement of 30% and 40%, which is 29.1 MPa and 25 MPa, respectively.

Table 7: Compressive strength of concrete after 28 days of curing

Group	Percentage of AAC aggregate	Number of samples	Compressive strength, (MPa)		Average of density, (kg/m^3)
A	0%	3	A1	23.2	30.5
			A2	31.5	
			A3	36.8	
B	10%	3	B1	24.6	31.2
			B2	30.6	
			B3	38.3	
C	20%	3	C1	31.4	30.1
			C2	29.4	
			C3	29.6	
D	30%	3	D1	26.6	29.1
			D2	30.6	
			D3	30.0	
E	40%	3	E1	25.3	25.0
			E2	25.5	
			E3	24.1	

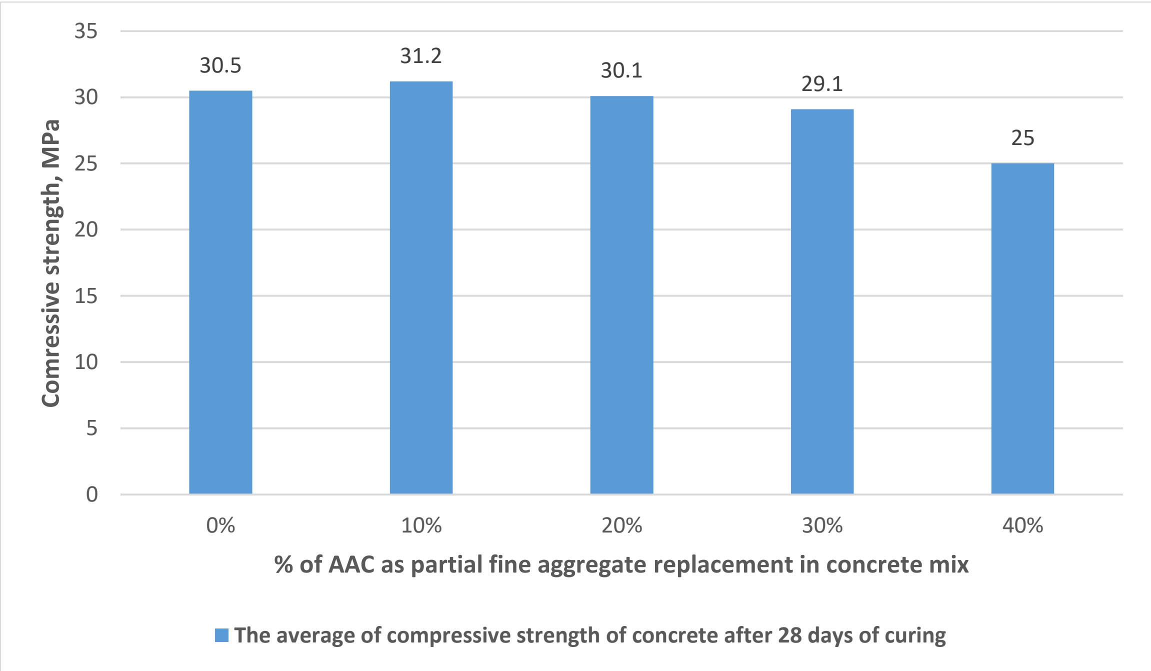

Figure 4: The average of compressive strength of concrete after 28 days of curing

3.2 Discussion

The workability of concrete is decreasing as the percentage of CAAC added in the mix proportion due to CAAC properties such as has many voids and higher porosity. The workability of concrete can be affected by water content, size and shape of aggregate, amount and cement and types of aggregates used. The higher use of CAAC as fine aggregate replacement leads in decrease of the compressive strength of concrete as the density also decrease. Therefore, the amount of this reduction depends on the amount of the CAAC used and its properties.

4.0 Conclusion

The objectives in this study are successfully achieved. The workability of concrete has been determined; it falls in the category medium workability and the height of slump increased as the percentage of CAAC replacement increased. The density of concrete is decreasing when the percentage of CAAC replacement is added, yet the concrete blocks are still categorized as the normal weight of concrete.

The compressive strength of concrete was determined, only 10 % and 20% of CAAC replacement gave the desired strength which is above or equal with the control concrete strength 30 MPa. Therefore, the potential of using recycled crushed autoclaved aerated concrete debris as a partial sand substitute in concrete is possible in low percentage. As a result, it is not suggested to utilise a large proportion of CAAC replacement since it will result in a reduction in concrete strength. As a result, it is advised that the percentage of CAAC used to replace natural sand in the manufacturing of concrete be used below 20%.

Few recommendations for future study, in the production of high strength concrete, admixtures such superplasticizers (SPs), also known as high range water reducers, are commonly employed to control the use of water. Next, further research should be conducted by on thermal conductivity, thermal insulation and sound insulation. It is recommended to use different size; use larger size of CAAC crumbs as fine aggregate replacement as the water absorption reduce when the surface area is increased. Lastly, conduct a study by using different percentage of CAAC for example 50%, 60%, 70%, 80%, 90% and 100%.

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