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Sustainable Concrete Bricks Partially Comprised of Supplementary Cementitious Material and Alternative Fine Aggregate- A Review

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Abstract: The usage of cement and normal fine aggregates, sand is tended to give pollution to this world. Researchers finds that there are many materials or substances that can replace them. Most of the materials are waste materials and non-pollution materials. The potential of using this material of alternative fine aggregates and supplementary cementitious materials will produce more sustainable concrete bricks in the future. In this paper, an optimum percentage of partial fine aggregates and supplementary cementitious materials of the sustainable concrete bricks was observed. Then the mechanical properties such as compressive strength and water absorption of the sustainable concrete bricks will be compared. This will help other researchers and construction industry to produce more eco-friendly brick that can perform as conventional bricks.

Keywords: Sustainable Brick, Supplementary Cementitious, Alternative Fine Aggregate

1. Introduction

In general construction, bricks are common wall material options for housing and other applications such as drains, paving and canal lining, among other uses. Brick is one of the oldest of all building materials in the history of professional construction practices. Basically, bricks are most often used for wall construction, especially as an outer wall surface in this generation. The selection of materials used for brick making has tended to depend on both location and environment. Most communities have successfully managed to utilize clays or varying plasticity to provide the basic cementation capability (Kinuthia, 2015).

In this generation, green and sustainable building is highly demanding over the world. However, almost all the materials to create bricks are cement-based and it considers as environmentally un-friendly. While bricks that are from clay-based materials are consuming high energy and massive

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depletion of raw resources. This will lead to a serious environmental problem due to high greenhouse gas emissions. Studies shown that 12.8 million tons of waste is produced in 2015 in Malaysia (Burke et al.,2012).

1.1 Research Background

To overcome the environmental pollution to empower the green building conceptual in any construction. A lot of researchers have shown us positive result to develop a conventional brick. The usage of cement-based materials can be reduced by replace by others substance that have almost similarities function such as waste materials or supplementary cementitious materials (SCMs).

1.2 Problem Statement

A broad range of waste materials have been used for the manufacture of construction materials, including bricks, with enhanced physical, mechanical and thermal properties. In general, the production of low thermal conductivity insulation materials and the use of sustainable waste are to dominant elements that can contribute to the production of energy-efficient, eco-friendly building materials. In this regard, through integrating locally available waste materials. For instance, bricks were created in which glass powder, oil palm fibers, and palm oil fly ash were used as fillers and binding materials along with lime and crusher dust.

1.3 Objective of Study

In general, this research is to utilize the applications of alternative fine aggregates (AFAs) and supplementary cementitious materials (SCMs) to produce more sustainable concrete bricks. The objectives of this research are as follows:

1. To determine the optimum percentage of partial fine aggregates and supplementary cementitious materials of the sustainable concrete bricks.
2. To compare the mechanical properties such as compressive strength and water absorption of the sustainable concrete bricks.

1.4 Scope of Study

This study focused on gather the information related to the replacement composition of the AFAs and SCMs and the optimum percentage of these materials that affect the concrete brick mechanical properties. Expanded Polystyrene (EPS), Ground Granulated Blast Furnace Slag (GBFS), Quarry Dust, Copper Slag and Sheet Glass Powder are used for AFAs components. The Palm Oil Fuel Ash (POFA), Metakaolin, Bagasse, Rice Husk Ash (RHA) and Silica Fume are used for SCMs components. A detailed research is carried out on concrete mechanical properties consisting of compressive strength and absorption of water that assess the understanding of concrete characteristics and the behavior of waste materials.

2. Literature Review

The research work carried out on the effective and efficient utilization of different type of replacement for fine aggregate and cementitious supplementary in concrete brick manufacturing has been reviewed.

2.1 Alternative Fine Aggregates (AFAs)

Since the increase of urbanization and industrialization, it is also increasing the demand on concrete products for construction purpose. One of the mixtures to produce a good quality concrete is fine aggregates. Fine aggregates itself occupied 35.00 % in the total volume of concrete (Tiwari et al., 2016). Alternative Fine Aggregates (AFAs) is used as partial or fully replacement of normal fine aggregates which is river sand.

AFAs is not only to reduce the excessive use of natural sand that will leads to environmental problem but are also to increase the mechanical performance and durability of a concrete in a long-term condition. The most common substance in SCMs is granulated blast furnace slag, copper slag and crushed glass powder (Tiwari et al., 2016)

2.2.1 Expanded Polystyrene (EPS)

25.00 % and 50.00 % of EPS and several percentages of Palm Oil Fuel Ash (POFA) as a replacement for fine aggregates were studied (Suraya Hani Adnan et al., 2017). It was observed that replacement of fine aggregates by EPS led to decreases in strength with the result of 16.80 MPa and 12.20 MPA, respectively. It has the acceptable value strength. Water absorption for the 25.00 % is higher than 50.00 % of EPS.

2.2.2 Granulated Blast Furnace Slag (GBFS)

Studies from (Surul et al., 2019) observed the increases in GBFS content will increase the compressive strength of bricks. The replacement of GBFS was 0.00 %, 10.00 %, 20.00 %, 30.00 % and 40% produces 35.20 MPa, 42.10 MPa, 44.80 MPa, 47.30 MPa and 48.80 MPa respectively. The water absorption for 0%, 10%, 20.00 %, 30.00 % and 40.00 % produces 14.50 %, 10.80 %, 11.90 %, 12.20 % and 12.50 % respectively. It shown that more GBFS will increase the water absorption.

2.2.3 Quarry Dust

Effect of quarry dust as a sand replacement of brick gave us good outcome. Studies from (Mirasa et al., 2019) showed that the compressive strength and water absorption was above the minimum specified requirement. 0.00 %, 20.00 %, 50.00 % and 100.00 % were replace and the compressive strength were 11.80 MPa, 12.88 MPa, 10.60 MPa and 9.38 MPa, respectively.

2.2.4 Copper Slag

Copper smelting and refining process will produce copper slag. It is an industrial waste obtained from both processes. Many studies showed that concrete production with this material will increase the mechanical properties of concrete. The percentage replacement of copper slag in this study by (Sai Bhavagna & Lalitha, 2017) were 0.00 %, 5.00 %, 10.00 %, 15.00 %, 20.00 % and 25.00 %. It was found that the highest compressive strength was 15.00 % of replacement which is 35.26 N/mm^2.

2.2.5 Sheet Glass Powder

5.00 %, 10.00 %, 15.00 %, 20.00 % and 40.00 % of glass powder as a replacement of fine aggregates were studied (Nursyamsi & Liang, 2018). It was observed that there were slightly increases in term of compression strength. It shows that for 5.00 %, 10.00 % and 15.00 % of replacement will increases the compression strength while more than 15.00 % will reduce the compression strength.

2.3 Supplementary Cementitious Materials (SCMs)

Supplementary Cementitious Materials is used as partial replacement of Portland cement in concrete mixtures (Wu et al., 2014). In general, the use of SCMs is to minimum the environmental problems due to cement production. Cement production cost a huge amount of greenhouse gases (GHGs) emitted to the air (Shen et al., 2015)

SCMs is not only to reduce the GHGs emissions but are also used to improve the mechanical performance and durability of a concrete in a long-term condition. The most common sources in SCMs are silica fume, fly ash and others waste products (Juenger et al., 2019).

2.3.1 Bagasse

The percentage replacement of bagasse in this study by (Ali et al., 2016) was 0.00 %, 20.00 %, 25.00 % and 30.00 %. It was found that the specimen with 20.00 % has the highest compressive strength. It recorded that 15.33 MPa for 0.00 %, 16.23MPa for 20.00 %, 14.07 MPa for 25.00 % and 13.63 MPa for 30%. The percentage replacement over 20% will decreases the compressive strength. Water absorption test for 0.00 %,20.00 %,25.00 % and 30.00 % replacement gives the value of 6.04 %, 23.08 %, 23.49 % and 23.71 % respectively. This test was conducted for 28 days curing.

2.3.2 Metakaolin

Metakaolin has been widely studied for its highly pozzolanic properties. The percentage replacement of metakaolin in this study by (Shah et al., 2019) was 0.00 %, 2.00 %, 4.00 %, 6.00 % and 8.00 %. It was found that the compressive strength increases up to 25.00 % with 8.00 % replacement of cement by Metakaolin

2.3.3 Palm Oil Fuel Ash (POFA)

POFA can be used as constituents in concrete due to the pozzolanic properties. Researchers such as (Munir et al., 2015) use POFA as a replacement of cement partially. The percentage replacement was 0.00 %, 10.00 %, 20.00 %, 30.00 %, 40.00 % and 50.00 %. Basically, the compressive strength is decreased by increasing the portion of POFA. This is due to the physical and chemical properties of POFA. The bottom of ash was used in this research while many other research use fly ash POFA.

2.3.4 Rice Husk Ash (RHA)

The percentage replacement of RHA in this study by (Noaman et al., 2018) was 0.00 %, 10.00 %, 15.00 %, 20.00 % and 25.00 %. Basically, the compressive strength was increased from control specimen. The maximum compressive strength was at 10.00 % replacement followed by 15.00 % replacement, and it was the optimal limit of replacement.

2.3.5 Silica Fume

The percentage replacement of Silica Fume in this study by (Cheah & Nurshafarina, 2019) was 0.00 %, 2.00 %, 4.00 %, 6.00 %, 8.00 %, 10.00 %, 12.00 %, 14.00 %, 16.00 %, 18.00 % and 20.00 %. The result show at 7 days curing age, the compressive strength increased up to 4.00 % replacement of silica fume with 11.4 MPa. However, it starts to decrease when more than 4.00 % replacement of silica fume. For 14 and 28 days, the compressive strength at 10.00 % and 12.00 % respectively has the highest strength.

3. Methodology

The task flow to accomplish the objectives of the research is demonstrated by the flow chart in a planned flow.

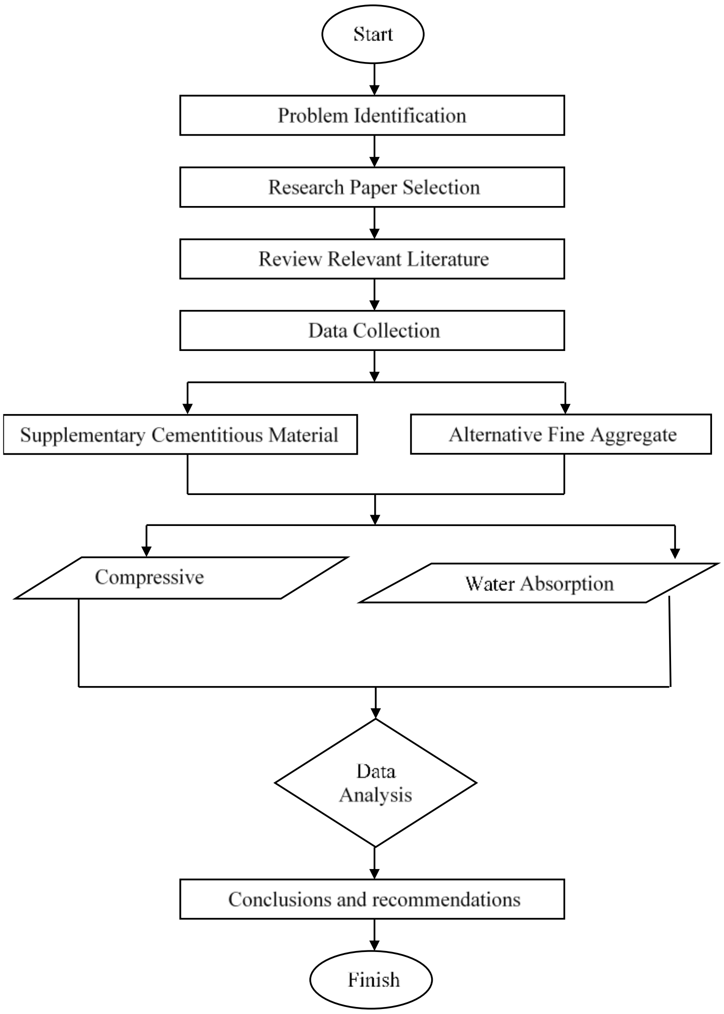

Figure 1: Research flowchart

3.1 Journals Obtained Method

This review mainly obtained from the related journals or articles. The journals are from the last 5 years back. Total journals use for this review is almost 40 papers. The sources are from Mendeley, Google Scholar, Science Direct and others related.

3.2 Testing Involves

There are several tests involved in this review paper such as compressive strength testand water absorption test. The result for each test from researchers' observation was compared with the conventional concrete. The conventional concrete is different for each paper since the researcher use different type and class of concrete.

4. Discussion

Detailed analysis of the data that has been retrieved from previous study of the usage of alternative fine aggregate and cementitious material.

4.1 Optimum Percentage

Each paper determines the best and optimum percentage of partial fine aggregates and supplementary cementitious materials of the sustainable concrete bricks. Table 1 below shows the result from paper review.

Table 1: Review paper

Materials	Optimum Percentage	Remarks
Alternative Fine Aggregates (AFAs)		
Expanded Polystyrene (EPS)	Paper 1: 25% Paper 2: 25% Paper 3: 20%	All papers give almost the same optimum percentage amount of EPS.
Granulated Blast Furnace Slag (GBFS)	Paper 4: 40% Paper 5: 50%	Both papers show that more GBFS percentage will give good outcomes.
Quarry Dust	Paper 6: 20% Paper 7: 40%	It can be concluded that quarry dust can replace fully with sand. However, to get better performance, this optimum ratio is preferable.
Copper Slag	Paper 8: 15% Paper 9: 40% Paper 10: 40%	Paper 1 type of concrete is M20. While paper 2 and paper 3 used type of M25 concrete.
Sheet Glass Powder	Paper 11: 15% Paper 12: 30%	Paper 1 added the proportion mix foaming agent.
Supplementary Cementitious Materials (SCMs)		
Bagasse	Paper 13: 20% Paper 14: 25%	Both papers give almost the same optimum amount.
Metakaolin	Paper 15: 8% Paper 16: 20% Paper 17: 10%	All paper was determined in the same age, 28 days of curing. Paper 1 used M20 type of concrete. Paper 2 metakaolin powder was imported from Nigeria. Paper 3 mixes with some percentage of fly ash.
Palm Oil Fuel Ash (POFA)	Paper 18: 50% Paper 19: 50%	Both of paper gives the same optimum percentage of POFA. It can be concluded that 50% is the best amount.
Rice Husk Ash (RHA)	Paper 20: 10-15% Paper 21: 10%	Both of paper gives the same optimum percentage of RHA to produce high strength.
Silica Fume	Paper 22: 12% Paper 23: 12%	Both of paper gives the same optimum percentage of Silica Fume. It can be concluded that 12% is the best amount.

4.2 Mechanical Properties

Each paper determines the value of mechanical properties such as compressive strength and water absorption. Table 2 below shows the result from paper review.

Table 2: Compression Strength

Materials	**Percentage**													
	0	**5**	**10**	**15**	**20**	**25**	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65 >**
Alternative Fine Aggregate (AFA)														
	Compressive Strength (MPa)													
Expanded Polystyrene (EPS)	13.2	-	-	-	-	16.8	-	-	-	-	12.2	-	-	-
	27.4	-	-	-	-	-	20.5	-	-	-	13.5	-	-	-
	25.7	-	-	-	7.4	-	-	-	-	-	-	-	-	-
Granulated Blast Furnace Slag (GBFS)	35.2	-	42.1	-	44.8	-	47.3	-	48.8	-	-	-	-	-
	50	-	-	-	-	-	-	-	-	-	52	-	-	53
Quarry Dust	11.8	-	-	-	12.8	-	-	-	-	-	10.6	-	-	9.38
	28.4	-	-	-	29.6	30.8	32.8	-	-	-	-	-	-	-
Copper Slag	31.8	33.1	33.2	36.2	33.2	30.2	-	-	-	-	-	-	-	-
	31.8	-	-	31.7	-	-	32.0	-	32.7	-	-	-	-	-
	31.8	-	-	31.7	-	-	32.0	-	32.7	-	-	-	-	-
Sheet Glass Powder	95289 Kg/cm2	-	64444 Kg/cm2	-	75022 Kg/cm2	-	-	-	-	-	-	-	-	-
	35	-	-	-	33	-	38	-	31	-	29	-	-	-
Supplementary Cementitious Materials (SCM)														
Bagasse	15.33	-	-	-	16.2	14	13.6	-	-	-	-	-	-	-
	42	50	39	41	40	43	-	-	-	-	-	-	-	-
Metakaolin	20	25	30.9	-	-	-	-	-	-	-	-	-	-	-
	25	27	30	32	34	31	29	27	-	-	-	-	-	-
	30	31.8	31.9	24	25.2	-	-	-	-	-	-	-	-	-
Palm Oil Fuel Ash (POFA)	-	-	3	-	27.9	-	33	-	39.6	-	41.3	-	-	-
	67.1	-	-	-	-	-	-	-	-	-	69	-	68	65.5
Rice Husk Ash (RHA)	0.31	-	0.28	1.32	0.88	0.64	-	-	-	-	-	-	-	-
	30	-	32	31	28	27	-	-	-	-	-	-	-	-
Silica Fume	21	27	26	23	20	-	-	-	-	-	-	-	-	-
	22	25	26	24	22	-	-	-	-	-	-	-	-	-

Table 3: Water Absorption

Materials	Percentage													
	0	5	10	15	20	25	30	35	40	45	50	55	60	65 >
Alternative Fine Aggregate (AFA)														

Water Absorption														
Expanded Polystyrene (EPS)	5.78	-	-	-	-	4.89	-	-	-	-	6.12	-	-	-
	7.6	-	-	-	-	-	6.43	-	-	-	2.74	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Granulated Blast Furnace Slag (GBFS)	26.9	-	22.1	-	23.0	-	24.1	-	25.3	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Quarry Dust	11.7	-	-	-	11.2	-	-	-	-	-	15.4	-	-	17.3
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Copper Slag	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sheet Glass Powder	3133	-	3282	-	462	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Supplementary Cementitious Materials (SCM)														
Bagasse	7.04	-	-	-	24.1	24.3	24.4	-	-	-	-	-	-	-
	1.6	1.5	1.8	2.1	3.6	4	-	-	-	-	-	-	-	-
Metakaolin	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Palm Oil Fuel Ash (POFA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rice Husk Ash (RHA)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silica Fume	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	-	-	-	-	-	-	-	-	-	-	-	-	-	-

5. Conclusion

This research is concerned about the utilization of alternative fine aggregates (AFAs) and supplementary cementitious materials SCMs) to produce sustainable concrete bricks. The purpose of this chapter is to conclude all the findings derived from the research. It can be concluded that the best optimum for alternative fine aggregates Expanded Polystyrene, Granulated Blast Furnace Slag, Quarry Dust, Copper Slag and Sheet Glass Powder was 25.00 %, 50.00 %, 40.00 %, 40.00 % and 30.00 % respectively. While the best optimum for supplementary cementitious materials Bagasse, Metakaolin, Palm Oil Fuel Ash, Rice Husk Ash and Silica Fume was 25.00 %, 20.00 %, 50.00 %, 10.00 % and 12.00 % respectively. It can be concluded that for compressive strength test, most of the materials will increase in strength when the percentage of replacement increase. Only for several materials such as EPS, Sheet Glass Powder and RHA has a slightly decrease in strength. While for the water absorption test, all of the materials will increase the water absorption value when the percentage of replacement increase.

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