Recent Trends in Civil Engineering and Built Environment Vol. 4 No. 2 (2023) 109-117
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RTCEBE

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/rtcebe
e-ISSN :2773-5184

Investigation of Heat of Hydration on Conrete Containg Used Glass as Replacement of Fine Aggregate

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DOI: https://doi.org/10.30880/rtcebe.2023.04.02.013
Received 06 January 2022; Accepted 15 January 2023; Available online 20 July 2023

Abstract: Malaysia's production of the fine aggregate increase's significantly every day. The usage of river sand as fine aggregate depletes environmental assets. Along with that, glass waste contributes significantly to the landfilling issue. This research aims to reduce the production of fine aggregate and replaced it with glass waste which will eventually reduce waste production. This study investigates the heat hydration of concrete, consisting of glass as a partial replacement to fine aggregate. For the determination of concrete hydration temperature, plywood with the size 300 mm x 300 mm x 450 mm cube was used as the exterior mould. It was packed with 150 mm thick polystyrene acting as the insulator. Polyvinyl chloride (PVC) pipe with a diameter of 150 mm and a height of 300 mm is used to fill the concrete mix. A thermocouple (Type K) was inserted into the centre of each box and was connected to a data logger system. The temperature rises due to heat of hydration in all mixes were recorded for 72 hours. The results revealed that the replacement of the glass with fine aggregate was slightly reducing the temperature. The most effective percentage of replacement is 10% of waste glass in concrete.

Keywords: Heat hydration, Used glass, Sustainable Concrete

1. Introduction

Concrete is the most widely used building material. It could be used alone as mass concrete or in combination with steel as reinforcement or concrete that has been pre-stressed [1]. Concrete has many benefits for example, concrete is sturdy, long-lasting, and simple to produce. According to [2], Concrete is commonly used because of its outstanding water resistance, structural concrete components can be moulded into a wide range of shapes and sizes, and it is typically the easiest and most readily available material for the job. Concrete is used in the construction of towers, bridges, dams, tunnels, sewerage networks, pavements, runways, and highways [3]. However, according to [4] Concrete production consumes a huge demand of natural capital. Because of the rising cost of raw materials and the increasing loss of natural resources, the use of waste materials in the building sector is a viable option. Reusing waste products helps to save and preserve renewable resources that cannot be replenished,

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reduces exposure to the ecosystem, and saves and recycles energy manufacturing practices. Concrete, due to its many uses in architecture, can be regarded as playing an important role in building projects. It is practically difficult to construct a building project without concrete. As a result, even in countries with an abundance of aggregates, it is essential to explore alternate aggregate supplies in order to aim for and ensure more renewable, environmentally friendly concrete.

Malaysia's waste generation rate is rising, encompassing community activities such as commercial, academic, industrial, and business operations. It is also linked to the economic status of various community sectors such as squatter settlements, low, medium, and high-class residential neighborhoods. According to Saeed [5] The rate varies depending on the type of waste generator and the land usage. The per capita solid waste generated varies according to the economic condition of the city, ranging from 0.45 to 1.44 kilogrammes per capita per day Currently, the average per capita production of municipal waste in Malaysia is about 0.85 kg/person/day, based on a region's economic and social status. It is reported that waste generated in major cities such as Kuala Lumpur is about 1.5 kg/person/day. 3 Authorities in most major cities in Malaysia are looking for an alternative waste management solution as the landfill approach currently used becomes unsustainable due to rapid globalization and a shortage of new landfill areas [6] However, because of the consumption of glass materials, the quantity of waste glass has increased significantly over the years. The majority of the waste glasses have been disposed of in landfills. Landfilling of waste glasses is counterproductive because they are not biodegradable, making them less environmentally sustainable. The use of waste glass in the concrete construction sector has tremendous potential. The use of waste glass in the concrete construction sector is beneficial because it reduces the cost of concrete manufacturing. Concrete production expenses can be minimized if waste glasses are reused in the production of concrete materials [7].

In this research, beverage glass is chosen as the alternative material to replace natural material. Municipal waste management remains a major challenge in urban areas around the world, especially in the developed world's rapidly growing cities and towns. The community has suffered as a result of the lack of an adequate and safe urban waste management system. Malaysians produce more than 25,000 metric tonnes of household waste every day, with population of over 31 million in 2016 [8].The strength and durability of concrete can be observed and compared in this study by replacing a different proportion of fine aggregate with beverage glass waste. This research may help to reduce our dependency on natural resources. The construction industry is being encouraged to make good use of waste in order to reduce waste and resolve construction material shortages.

2. Glass waste as a substitute in concrete

The content and properties found on glass make it a robust, stiff and durable material. This property allows the glass to withstand a weight load over the period [9]. Glass is also resistant to irregular temperature changes. However, not all glass is resistant to heat at high temperatures. Because of its heat resistance, glass is commonly used as cutlery in the kitchen. glass is also particularly robust at low temperatures and in humid situations, making it excellent for a structure that must be created in moist environments [10].

Glass is a component that does not absorb water or absorbs significantly less water. This makes the concrete have sealing or impermeable properties [11]. These properties provide a very excellent low permeability, allowing the concrete to resist temperature and chemical action and shield the rust reinforcement from rusting. Furthermore, when heated, glass has the ability to be effortlessly shaped. This indicates that it possesses the bending force characteristic. Because good glass powder contains pozzolans qualities, it may replace cement and filler in concrete mixtures, resulting in high-pressure strength [12]. At the same time, glass also has the property of being highly fragile or damaged since the particles in the glass are not in close arrangement. This result in the presence of cavities in the glass structure. Therefore, when the glass is subjected to a certain pressure or load, it will be easy to break. glass can also enhance the properties of fresh concrete, which increases the strength of the concrete without the need for additives such as superplasticizers [13].

A previous research determined that the use of recycled glass as a replacement forsand reduced the workability of concrete due to a lack of its fine proportion [14]. Meanwhile, investigated the impact of different particle sizes of expanded glass aggregate (EGA) on the compressive strength [15]. A study was conducted which used 15% of glass sand from recycling with a particle size of up to 5 mm and obtained an 8.1% decrease in compressive strength [14]. A research determined a 9.6% decrease in the compressive strength of concrete with 60 wt.% addition of glass aggregate size of 0–2.36 mm and 40 wt.% addition of glass aggregate size of 2.36–5 mm (Ling and Poon 2014). According to Limbachiya [14]. using recycled glass sand in concrete mixes up to 15% indicates comparable strength.

3. Materials and Methods

This chapter focuses primarily on the methodological techniques that was used to accomplish this study's objectives. The flow includes preparing the components, monitoring processes procedures, and equipment used for this study and collecting result data of the study. In addition, this chapter will provide a better understanding of how to the experiment was done. Methodology was an important parameter in evaluating the overall process of a project lifecycle. To achieve the study objectives, laboratory testing was carried out to determine the best percentage of waste material to use as a fine aggregate substitute in concrete. This chapter discusses the materials used, the mixing technique, and the tests carried out to meet the research's objectives. Glass waste was used as a fine aggregate substitute in concrete for this study.

3.1 Selection and Preparation of used glass

The used glass was obtained for few places such as shops and houses. First the glass was cleaned toughly with water and soap. Secondly the used glass was hand crushed first which is shown in figure 1. In figure 2 the hand crushed glass was grinded in the machine to come out with smaller glass pieces. Figure 3 shows the sieving process of the glass waste. Sieve size 4.75 mm was used to sieve the grinded glass. This is done to make sure that the glass size is similar to fine aggregate. Figure 4 shows the final outcome of glass that was replaced in this study.

Figure 1: Hand crushed glass

Figure 2: Machine grind glass

Figure 3: Sieving glass

Figure 4: Final glass product

3.2 Mould preparation

Specimen preparation should be according to the tests conducted. In this research, specimens were prepared in the form of cylinder The detail of the mould were discussed in the subtopics below.

3.2.1 Outer plywood mould

In this study an outer layer mould was prepared using plywood for heat hydration test. Therefore, with the size of mould is of 300 mm x 300 mm x 450 mm was used. Figure 5 and figure 6 shows the outer plywood mould with its dimension

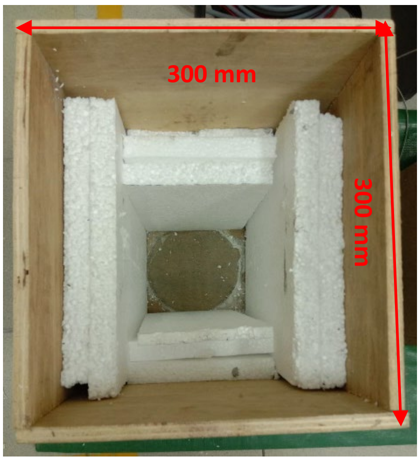

Figure 5: Outer plywood mould with dimension

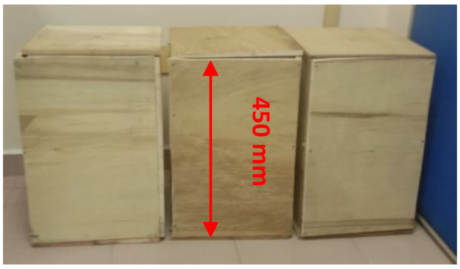

Figure 6: Height of outer plywood mould with dimension

3.2.2 Polyvinyl chloride (PVC)

In this research, polyvinyl chloride (PVC) with the size of 150 diameters and 300mm height were used as a platform to pour the concrete mixture. Figure 7 shows the PVC pipe used with dimensions

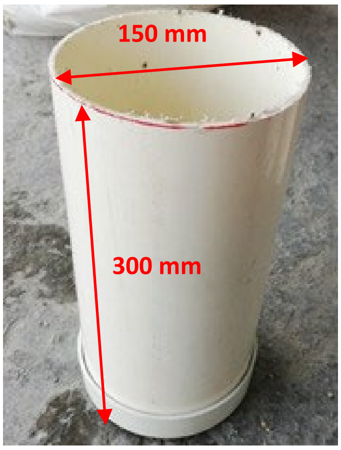

Figure 7 : Polyvinyl chloride mould with dimension

3.3 Design of Normal Concrete Mix

In this research, the concrete ratio is determined using the Normal concrete mix design. The size of the Polyvinyl chloride PVC pipe with a diameter of 150 mm and a height of 300 mm is used. The fine aggregate is replaced with glass in different percentage. The concrete is designed to achieve a strength of 30 MPa at the age of 28 days. Computation method, the mix design for normal concrete was summarised in Table 1. While the concrete samples with different percentage of glass waste is presented in Table 2:

Table 1: Mix design 1 m^3 of normal concrete

Quantities	Cement (kg)	Water (kg)	Sand (kg)	10mm. Aggregate (kg)	20mm. Aggregate (kg)
1 m^3	375	205	735	365	735

Table 2: Concrete mix design for each percentage of waste glass

Name of specimen	Cement (kg)	Water (kg)	Sand (kg)	Waste glass (kg)	10mm Aggregate. (kg)	20mm Aggregate (kg)
CONTROL	2.58	1.41	5.07	-	2.52	5.07
G5	2.58	1.41	4.81	0.25	2.52	5.07
G10	2.58	1.41	4.56	0.49	2.52	5.07
G15	2.58	1.41	4.31	0.74	2.52	5.07
G20	2.58	1.41	4.05	0.99	2.52	5.07
G25	2.58	1.41	3.80	1.23	2.52	5.07
TOTAL	15.51		26.59	3.70	15.09	30.39

3.4 Heat hydration test

The specimen was observed for 72 hours Starting from Monday 12pm to Thursday 12pm The thermocouple was connected to the data logger which obtained the temperature of the concrete for every 30 minutes. The data was analysed for every 6-hour interval period.

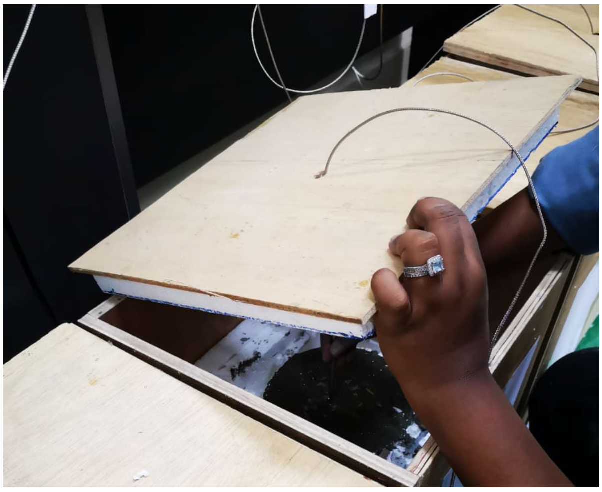

Figure 8: Inserting thermocouple inside concrete

Figure 9: Final setup for data reading process for 72 hours

4. Results and Discussion

This part presents the results of the experiment and analysis data. The result is presented using tables and graphs. In this study fine aggregate was replaced with 5%,10%,15%,20% and 25% waste glass.

4.1 Heat hydration on concrete results

Table 3 shows the temperature change for 72 hours for normal concrete and concrete consist of 5%,10%,15%,20% and 25% of waste glass. Figure 10 shows the relationship between time and temperature for normal concrete and concrete consist of 5%,10%,15%,20% and 25% of waste glass.

Table 3: Summary data for all percentage

Time (hr)	Temperature(°C)					
	Control	5% waste glass	10% waste glass	15% waste glass	20% waste glass	25% waste glass
0	24.42	24.52	24.02	23.92	24.52	23.62
6	27.74	28.14	26.83	27.03	27.44	26.23
12	35.78	35.98	34.87	35.17	34.87	34.27
18	37.48	37.59	37.48	36.38	36.48	36.18
24	33.16	33.77	34.07	32.26	32.76	32.56
30	31.05	31.56	31.96	30.35	30.65	30.45
36	30.25	30.75	30.85	29.75	29.85	29.75
42	29.75	30.15	30.35	29.45	29.45	29.34
48	29.24	29.55	29.75	29.14	29.04	28.94
54	29.04	29.24	29.45	28.84	28.84	28.74
60	28.94	29.24	29.45	29.04	28.94	28.84
66	28.94	29.14	29.24	28.94	28.84	28.74
72	28.54	28.74	28.94	28.64	28.54	28.44

4.2 Discussions

Based on Figure 1 shows the summary result for all percentage. From the graph, it is proven that as the percentage of the glass increases in the concrete composite, the temperature decreases slightly compare to the control. However, the lowest temperature gained falls on 25% replacement compare to normal concrete. According to Chang [16], as the glass powder content increases the hydration heat emission rate and hydration heat decrease steadily, but the induction and acceleration periods rises steadily. Therefore, the statement above can justify the result gained from this study.

Graph below shows the final outcome of relationship between time versus temperature for the different percentage of used glass in the concrete mixture.

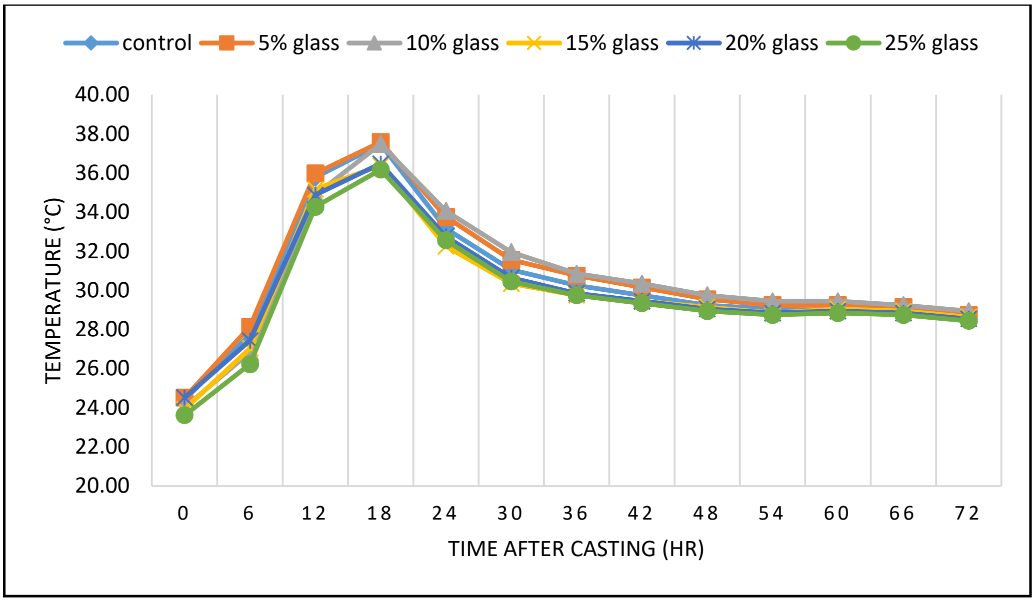

Figure 10: Relationship of time vs temperature for all the percentage

5. Conclusion

In this chapter, the conclusions derived from the findings of study and interpretation of data analysis This study has successfully achieved the first objective which is to identify the temperature change in concrete with glass as partial replacement of fine aggregate Based on the result of experiment at the 12th hour the temperature is at optimum for most of the specimen which is 35.78°C for control 35.98°C for 5%, 34.87°C for 10%, 35.17°C for 15%, 34.87°C for 20%, and 34.27°C for 25%. This is because at 12th hour the change in temperature is minimal compare with our time. This study also has achieved the second objective which is to identify the optimum percentage of glass as a partial replacement with fine aggregate based on temperature. From the data analysis, it was proven that the concrete specimen contains 10% of glass have slightly similar temperature compare with the control specimen. Based on the graph from the result obtain can be understood that the

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