WASTE GLASS AS PARTIAL REPLACEMENT FOR FINE AGGREGATE IN MORTAR

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ABSTRACT

Glass was one of the oldest man-made materials. It was a common product that can be found in variety of form. In Malaysia, less than 30% of the glass was recycle and causing solid waste impact to the environment. Research on using waste glass as aggregate has been attempted decades ago and recent research shows that it can be used as aggregate under certain measures to avoid alkali silica reaction damaging effect. In this study, the effectiveness of waste glass used as fine aggregate in mortar was studied. Four mixes mortar was prepared accordance to the percentage of replacement of 0%, 10%, 20% and 30% of waste glass as fine aggregate. The specimens were tested for its compressive strength and percentage of permeability porosity under condition of 7, 28 and 90 days age of water curing. The specimens also tested for alkali silica gel expansion. It was found out that the compressive strength and the porosity of the mortar with waste glass as fine aggregate achieved optimum result at 10% of replacement. In the finding of alkali silica gel expansion, all the mix percentage does not exceed the 0.1% limit expansion. This shows that waste glass was suitable for partially replacing fine aggregate in mortar.

ABSTRAK

Kaca merupakan salah satu bahan buatan manusia yang tertua. Kaca adalah produk yang boleh didapati dalam pelbagai bentuk. Di Malaysia, kurang daripada 30% kaca dikitarkan semula dan ini menyebabkan kesan penimbulan sisa pepejal yang akan menjejaskan kualiti alam sekitar. Penyelidikan menggunakan kaca buangan sebagai agregat telah dicuba pada dekad yang lalu. .Penyelidikan terkini menunjukkan bahawa kaca boleh digunakan sebagai agregat di bawah pengawasn langkah-langkah tertentu untuk mengelakkan tindak balas alkali silika yang mendatangkan kesan.retakan Dalam kajian ini, keberkesanan sisa kaca sebagai agregat halus dalam mortar ditentuakn melaui beberapa ujikaji. Empat jenis bancuhan mortar telah disediakan selaras dengan peratusan penggantian 0%, 10%, 20% dan 30% sisa kaca sebagai agregat halus dalam bancuhan tersebut. Spesimen diuji dengan kekuatan mampatan dan peratus keliangan kebolehtelapan selepas direndamkan dalam air selama 7, 28 dan 90 hari. Spesimen juga diuji untuk melihat kesan perkembangannya yang disebabkan oleh gel akali silika. Ujikaji menunjukan bahawa kekuatan mampatan dan keliangan kebolehtelapan mortar mencapai keputusan yang optimum pada 10% penggantian sisa kaca sebagai agregat halus dalam mortar. Didapati bahawa perkembangan berlaku pada, semua peratusan campuran tetapi ia tidak melebihi had pengembangan sebanyak 0.1% Ini menunjukkan bahawa sisa kaca sesuai dijadikan sebagai penggatian agregat halus dalam mortar.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Glass was one of the oldest man-made materials. It was a common product that can be found in variety of form. These products needed to be reused or recycle to minimum the impact of environmental issue which causes stockpiling or land filling. There were many ways implementation of reusing the waste glass (Ismail & AL-Hashmi, 2009).

Research on using waste glass as aggregate had been attempted decades ago. Recently research shows that it can be used as aggregate under certain condition to avoid alkali silica reaction damaging effect. Product that using waste glass as aggregate such as glass concrete, concrete masonry block unit and paving stone can be categorized as commodity product and value-added products. Glass aggregate products were also being used in architectural and decoration application. This indicated that glass aggregate have commercial values in the market (Meyer, Egosi & Andela, 2001).

Recycling of waste glass into aggregate save the landfills space and it also reduces the extract of raw material for construction activities.

1.2 PROBLEM STATEMENT

Over the decades, the glass products had been increasing produced for commercial purpose. According to Traeholt & Ling (2010), in Malaysia, less than 30% of new bottles were made from recycled glass compared to 80% in Thailand and 60-70% in Europe. This situation clearly described that majority of the waste glass was ending up at the landfill. This eventually raised the environmental issue.

Continues of mining the raw materials of aggregate were eventually exhausted its sources. This situation forced the construction field to focus on others materials as new replacement. Glass has shown a potential of replacement aggregate in construction field as its properties exhibited almost same as natural aggregate. By using glass as replacement for aggregate can solved the shortage of raw material in the near future and reduced the solid waste issue.

1.3 RESEARCH OBJECTIVE

1. To investigate the compressive strength of the mortar that fine aggregate that replaced by using waste glass.
2. To investigate the permeable porosity of the mortar where fine aggregate partially replaced by waste glass.
3 To investigate the alkali-silica reaction (ASR) of the mortar base on partially replacement fine aggregate with waste glass.

1.4 SCOPE OF STUDY

This study was to investigate the properties of mortar with waste glass partially replaced as fine aggregate in term of the compressive strength, permeable porosity and alkali silica reaction (ASR). The fine aggregate of mortar was partial replaced by waste glass in 10%, 20% and 30% in order to acquire the specimens for the study. Sieve analysis was carried out to produce waste glass with the size of fine aggregate. After casted, the mortar cube specimens were cured under water curing and air curing for 7, 28 and 90 days for compression test to determine its compressive strength. The mortar cube specimens were also tested for permeable porosity. As for the mortar bar specimens, it was cured under water curing for 28 days for ASR test to determine its expansion. The program of study was completed in several phases starting from the casting mortar specimens to laboratory testing.

1.5 STUDY OUTCOME

From the study, it was expected that objectives were able to achieve. The waste glass was suitable to be used as partial replacement fine aggregate in the construction field. The uses of glass aggregate product also have an architectural value for decoration application.

1.6 SIGNIFICANT OF STUDY

The significance of the study was the waste glass replacement as fine aggregate which was applicable for construction. Not only that, the successful of using waste glass as aggregate able to reduce the environmental impact. Waste glass used for replacing the fine aggregate can be considered as alternative material for aggregate. Besides, it was a good opportunity for supplier to open a new market for glass aggregate.

1.7 CONCLUSION

This study was about partially replacing fine aggregate with alternative material which was waste glass. The waste glass which applicable for construction activity was able to reduce the environmental impact by reused it as fine aggregate. Further studies have to be conducted to ensure that glass can fully be utilized as aggregate in construction material

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Solid waste like glass was one of the materials that can be reused. In this study the waste glass was used as fine aggregate in mortar. The samples of the mortar were prepared using the waste glass as fine aggregate (glass sand mortar) and fine aggregate, sand (normal mortar). The literature review was done for giving a better understanding of the materials use for mortar and the characteristic (mechanical and durability) of the produced mortar.

2.2 MORTAR

Mortar was composing of cement, fine aggregate and water. Common mortar that used in the construction was masonry mortar and cement mortar.

Masonry mortar and cement mortar have the same characteristic but the cement mortar air content limits maximum was lower than masonry mortar by ASTM C1329 (Portland Cement Association, 2004).

2.3 CEMENT

Cement is an adhesive substance that acts as binder to bind particles or solid matter (aggregate) together into a compact whole (Hewlett, 1998, p.1).

Portland cement was produced by mixing limestone and clay or other materials that have similarity in term of bulk composition and sufficient reactivity by heating it to the temperature of about 1450 °C (Neville & Brooks, 1987, p.8 & Taylor, 1997, p.1). According to Neville (1981, p.66), the most common Portland cement that used for the general concrete construction was Ordinary Portland cement (Type I) where it was free from sulphates attack.

In this study the type of the cement that was used is Ordinary Portland cement and the testing was done in the lab.

2.4 FINE AGGREGATE

Fine aggregate can be defined as aggregate that passed through No.4 (4.75mm) sieve and retained on a No. 200 (75 μm) sieve and the most common fine aggregate that used was river sand (Li, Liang, Wenquan, 2011, p.24).

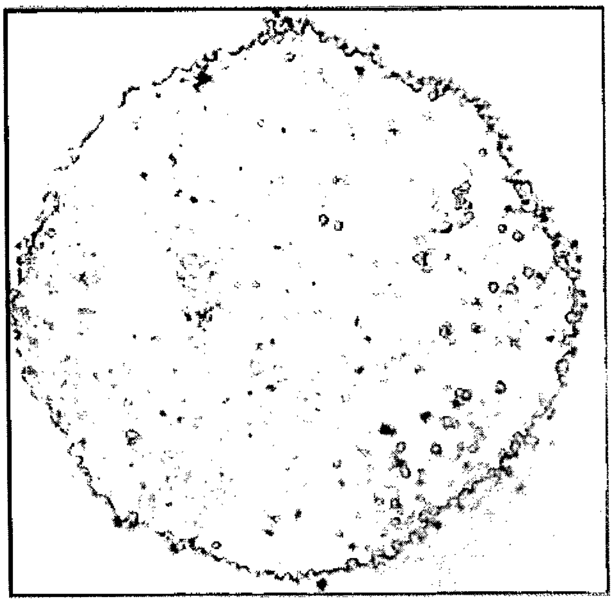

Figure 2.1: The profile of sand (Li, Liang, Wenquan, 2011)

Portland Cement Association (2004) stated that the masonry mortar fine aggregate grading should follow ASTM C144.

Table 4. Aggregate Gradation for Masonry Mortar

		Gradation specified. percent passing	
Sieve size no.		ASTM C144**	
U.S.	(Metric)	Natural sand	Manufactured sand
4	(4.75 mm)	100	100
8	(2.36 mm)	95 to 100	95 to 100
16	(1.18 mm)	10 to 100	70 to 100
30	(600 µm)	40 to 75	40 to 75
50	(300 µm)	10 to 35	20 to 40
100	(150 µm)	2 to 15	10 to 25
200	(75 µm)	0 to 5	0 to 10

** Additional requirements: Not more than 50% shall be retained between any two sieve sizes, nor more than 25% between No. 50 and No. 100 (300 µm and 150 µm) sieve, sizes. Where an aggregate fails to meet the gradation limit specified, it may be used if the masonry mortar will comply with the property specification of ASTM C 270 (Table 2).

Figure 2.2: The table of fine aggregate sieve. (Portland Cement Association, 2004)

2.5 WATER

Water that used for the batching mortar should be cleaned and freed from any concentrated minerals (Portland Cement Association, 2004). Neville & Brook (1987, p.74) indicated that drinking water with low concentration of sodium and potassium and washing water can be used for mixing accordance to ASTM C 94 (1992a).

2.6 MORTAR PROPERTIES

The properties of mortar can be divided into two categories which were hardened properties and the plastic or wet properties. "The hardened properties were the properties involving strength, durability, dimension stability and the ability to exclude water sufficiently and to have adequate thermal and acoustic properties" (Newman & Choo, 2003, p.7/2).

2.7 COMPRESSIVE STRENGTH

Type and quantity of cementitious material used for preparing mortar play an important role contributing its compressive strength (Portland Cement Association, 2004).Hydration process or chemical reaction of the cement with the water and aggregate was the process contributing to the compressive strength (Newman & Choo, 2003, p.4/3-4/4). Neville (1981, p.269) stated that increases of water/cement ratio decreased the compressive strength.

2.8 PERMEABLE POROSITY

"The permeable porosity affects the transport properties and durability of concrete." It was connected to many deterioration process driven by transport properties of concrete. One of the deterioration processes involving permeable porosity was sulfate attack and alkali aggregate reactivity. It also has major effect on concrete strength and other mechanical properties (Safiuddin & Hearn, 2005).

2.9 ALKALI SILICA REACTION (ASR)

Alkali silica reaction was chemical reaction between the active silica that found in aggregate and the alkalis in the cement. Alkali silicate gel was formed during the reaction of siliceous minerals in the aggregate with alkaline hydroxides derived from the alkalis. This gel causes expansion and map cracking on concrete by absorption or osmosis of water (Neville & Brooks, 1987, p.273).

2.10 WASTE GLASS (WG)

Glass was a significant solid waste produce by the daily activities in the society. Mostly glass was used as bottle, container for storing consumables or window. Glass was one of the unique wastes if compared to the others wastes because it can be fully recycled (Traeholt & Ling, 2010).

2.11 CHEMICAL COMPOSITION OF GLASS

Properties of glass that have large quantities of silicon and calcium making it act as pozzolanic or even cementitious in nature when it was finely ground. It was suitable for replacing cement and aggregate. "Glass can be categories as vitreous silica, alkali silicates, soda-lime glasses, borosilicate glasses, lead glasses, barium glasses and aluminosilicate glasses. Among all the categories the most of the glasses that found in waste glass was soda-lime glasses" (Shi & Zheng, 2007).

Table 2.1. Chemical composition of selected commercial glasses (McLellan and Shand, 1984).

Glasses and uses	SiO_2	Al_2O_3	B_2O_3	Na_2O	K_2O	MgO	CaO	BaO	PbO	Others
Soda-lime glasses										
Containers	66-75	0.7-7		12-16	0.1-3	0.1-5	6-12			
Float	73-74			13.5-15	0.2	3.6-3.8	8.7-8.9			
Sheet	71-73	0.5-1.5		12-15		1.5-3.5	8-10			
Light bulbs	73	1		17		4	5			
Tempered ovenware	75	1.5		14			9.5			
Borosilicate										
Chemical apparatus	81	2	13	4						
Pharmaceutical	72	6	11	7	1					
Tungsten sealing	74	1	15	4						
Lead glasses										
Color TV funnel	54	2		4	9				23	
Neon tubing	63	1		8	6				22	
Electronic parts	56	2		4	9				29	
Optical dense flint	32			1	2				65	
Barium glasses										
Colour TV panel	65	2		7	9	2	2	2	2	10% SrO
Optical dense barium crown	36	4	10						41	9% ZnO
Aluminosilicate glasses										
Combustion tubes	62	17	5	1		7	8			
Fiberglass	64.5	24.5		0.5		10.5				
Resistor substrates	57	16	4			7	10	6		

Tan & Du (2013) stated a more simplified waste glass chemical composition analysis according to its color and compared it with the natural sand composition.

Table 2.2. Chemical composition of glass and natural sand (Tan & Du, 2013)

Composition (%)	Green glass	Brown glass	Clear glass	Natural sand
SiO2	71.22	72.08	72.14	88.54
Al2O3	1.63	2.19	1.56	1.21
Fe2O3	0.32	0.22	0.06	0.76
CaO	10.79	10.45	10.93	5.33
MgO	1.57	0.72	1.48	0.42
Na2O	13.12	13.71	13.04	0.33
K2O	0.64	0.16	0.62	0.31
TiO2	0.07	0.1	0.05	0.05
Cr2O3	0.22	0.01	-	-

Topcu, Boga & Bilir (2008) also stated the almost the same chemical composition. This showed that the glass chemical composition used in Topcu, Boga & Bilir research does not vary much from the commercial glass.

Table 2.3. Chemical composition of glass cullet (Topcu, Boga & Bilir, 2008)

Component	Glass color		
	Green	Brown	White
SiO2	71.3	72.1	73.04
Al2SO3	2.18	1.74	1.81
Na2O + K2O	13.07	14.11	13.94
CaO + MgO	12.18	11.52	10.75
SO3	0.053	0.13	0.22
Fe2O3	0.596	0.31	0.04
Cr2O3	0.44	0.01	-

Ali & Al-Tersawy (2012), finding on the waste glass without classified them into color or type of glasses give a different percentage of the composition of chemical but also not vary much if compare to the others.

Table 2.4. Chemical composition of waste glass (Ali & Al-Tersawy, 2012)

Chemical composition	SiO2	Al2O3 + Fe2O3	CaO	SO3	Na2O + K2O	MgO
%	67.72	3.4	6.9	0.17	10.75	6