Waste Material as Cement Replacement in Concrete

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ABSTRACT

Concrete is a construction material consists of cement, aggregate, water and admixture. To date, many researchers are ongoing into the Portland cement replacement, using many waste materials. This research will focus on waste material which is Ground Granulated Furnace Slag (GGBS), Waste Glass Powder and Fly Ash as partial replacement of cement for Early Strength in concrete. The purposes of this research is to determine the most suitable combination as well as effectiveness of concrete mixture by using GGBS, fly ash and glass powder ash as additive in cement. In addition, this research also aims to identify the workability, strength and water absorption in concrete after the combination with ratio concrete 1: 2: 4 for grade M20 (20N/mm^2). Cement with GGBS, waste glass powder and fly ash replacement has emerged as a major alternative to conventional concrete and has rapidly drawn the concrete industry attention due to its cement saving, energy savings, cost savings, environmental and social-economic benefits. This research also demonstrates, the materials could be achieved high strength compared with to conventional concrete.

Key words: Concrete, Ground Granulated Furnace Slag (GGBS), Waste Glass Powder, Fly Ash

1. INTRODUCTION

Nowadays, development of a nation not only depends upon the technology but also depends upon infrastructure such as school, shopping malls, bus stop and sky scrapers. Infrastructure without concrete is not possible. Thus, concrete is indispensable material in every construction. The usage of concrete has been increasing steadily from 2008 till now. One of the major elements of concrete is cement. It is forecasted that usage of cement increases 6% year by year (Global Cement, 2012). Ordinary Portland cement (OPC) is the most common type in general use around the world. Although the raw materials for making OPC are readily available in most countries, searching for new alternative available material is important for conservation of natural resources because increasing demand in concrete leads to the extinction of natural resources. Other than that, Portland cement concrete is prone to drying shrinkage cracking. This condition is caused by susceptible to attack by sulphates and has an undesirable reaction with certain aggregates. Thus, OPC has low early strength which does not promote precast concrete production, concrete masonry, urgent repair work and cold weather concreting. Owing to this scenario, GGBS is used to replace the ordinary Portland cement used in concrete and it improves the durability of concrete (Kankatala Jagadeep and etl., 2017).

Besides, Kankatala Jagadeep and etl.,(2017) also said that concrete technology has made tremendous changes to the construction industry. It founds that concrete is now no longer a material consisting of cements, aggregates, water and admixtures but it is an engineered material with a number of new constituents performing suitability under different exposure conditions.

In the meantime, Dhanaraj Mohan Patil and Dr.Keshav K.Sangle (2013) give a statement that many researchers nowadays are ongoing into the use of Portland cement replacement, using many waste materials and industrial by products, for example, pulverized fly ash (PFA) and ground granulated blast furnace slag (GGBS) as well as a glass powder (GLP) as a binder with partial

replacement of cement which takes some part of reaction at the time of hydration and also act as a filler material. According to this researchers, mixed-color waste glass, when milled to about the particle size of cement and used in concrete as replacement for about 20% of cement, improves the moisture barrier qualities, durability and mechanical performance of concrete.

Apart from the OPC problem, the production of glass bottles in Malaysia is also a big problem. The glass bottle manufacturers in Malaysia produce about 600 tons of new bottles daily. But only 10% of these bottles will eventually being recycled in the factories and be reused to make new ones. Glass surprisingly, may well be the least recycled discard (The Star Online, 2005). Thus, glass powder produce from waste glass is suitable to replace cement in concrete.

2. METHODOLOGY

The main focus of the study is determining the high strength of concrete produce by using GGBS, fly ash and glass powder as partial replacement of cement in production of concrete. The suitable materials was collected for the study such as GGBS, fly ash was obtained from TNB Janamanjung Sultan Azlan Shah power station, Perak and glass powder, coarse aggregates and ordinary portland cement.

The concrete mix in the ratio 1:2:4 (cement: sand: aggregate) which is grade M20 (20N/mm^2) for main structure such as beam and column used in the study. Then concrete was tested by slump test in order to determine the workability of the concrete. The fresh concrete was poured into the mould in size 150mm x 150mm x 150mm which is suitable size for the compression test. The used percentage was 20% and fourty-eight cubes were being produced. The concrete was curing for 3, 7 and 28 days to find strength of concrete. The test was held in Concrete Work Laboratory in Politeknik Sultan Idris Shah and JKR Sabak Bernam.

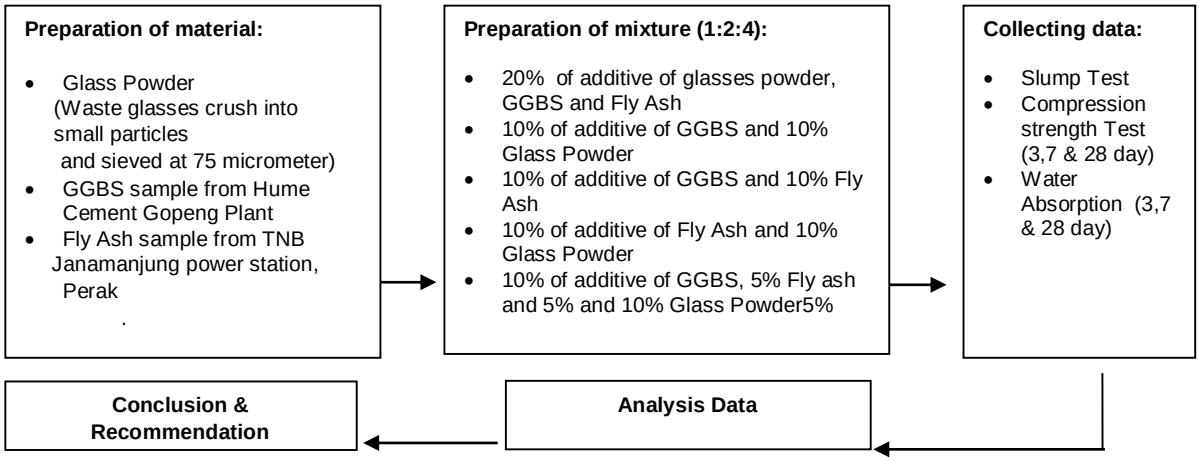

Figure 1: Schematic diagram of methodology research

a. Slump test

The concrete slump test is a method of quality control. For a particular mix, the slump should be consistent. A change in slump height would demonstrate an undesired change in the ratio of the concrete ingredients; the proportions of the ingredients are then adjusted to keep a concrete batch consistent. This homogeneity improves the quality and structural integrity of cured concrete. Many factors are taken into account when satisfying requirement of concrete strength, and to make sure that consistent mixture of cement is being used during the process of construction. The test also further determines the “workability” of concrete, which provides a scale on hoe easy, is it to handle, compact, and cure concrete. The slump test method is conduct base on MS26 Pt.1:1991 Method of Testing Concrete, which methods of sampling fresh concrete as specified in JKR Specification: Standard Specification for Building Works.

Table 1: Slump Test Table

Degree of workability	**Slump (mm)**	**Consistency**	**Use for which concrete is suitable**
Very Low	0-25	Very Dry	Very day mixes used in road making
Low	25-50	Dry	Used for foundation with light reinforcement
Medium	50-100	Plastic	Manually compacted flat slabs using crushed aggregate.
High	100-175	Sloppy	For section with reinforcement not normally suitable for vibration.

[Source: Civil Engineering Dictionary, 2014]

2.2. Compression Strength Test

Concrete normally will achieve its strength at the age of 28 days. The strength is the main feature of the concrete. However, concrete that are considered as durable will be tested using Compression Method to find out its strength. (Mahyuddin Ramli, 1991). The compression strength of a material is the uni-axial compression stress reached when the material fails completely. A set of three cubes were tasted in each case and the average value of these three was reported. All sampling, curing and testing of concrete, fresh or hardened carried out in according with MS 26 and the relevant Part of BS 1881.

Table 2: Propotion and Comptessive Strength Requirements for Prescribed Mix

Mix Proportion (Grade)	Strength of Concrete	
	At 7 days (N/mm2)	At 28 days (N/mm2)
1:1:2 (30P)	20	30
1:1.5:3 (25P)	17	25
1:2:4 (20P)	14	20
1:3:6 (15P)	11	15

2.3. Water Absorption Test

The durability of concrete subjected to aggressive environments depends largely on transport properties, which are influenced by the pore system. Three main mechanisms govern transport in cementitious systems: permeability, diffusion and absorption. Permeability is the measure of the flow of fluids under a pressure gradient, while diffusion is the movement of ions due to a concentration gradient. Absorption can be described as the ability to take in water by means of capillary suction. All three mechanisms are heavily influenced by the volume of pores as well as the connectivity of the pore network (C.Javier etl., 2011). According to C.Javier etl., (2011) again, ASTM C1585 is commonly used to determine the absorption and rate of absorption (commonly referred to as sorptivity) of water in unsaturated hydraulic cement concretes.

3. RESULTS AND DISCUSSION

In this study, total of eight group concrete (sample A – sample G) including standard concrete were prepared in laboratory. Samples were prepared according to mix proportion and by replacing cement with GGBS, fly ash and glass powder in different proportion. As for compressive strength, samples were cast and tested by using a compressive testing machine for 3 days, 7 days and 28 days.

Table 3: Sample details of Cube

Cube Number	Waste materials used as partial replacement of cement in the sample
A	GGBS + Cement
B	Glass Powder + Cement
C	Fly Ash + Cement
D	GGBS + Glass Powder + Cement
E	GGBS + Fly Ash + Cement
F	Fly Ash + Glass Powder + Cement
G	GGBS + Glass Powder + Fly Ash + Cement

3.1 Degree of Workability

Generally, the strength of concrete of a given mix proportion is seriously affected by the degree of its compaction. It is therefore important that the consistency of the mix is such that the concrete can be transported, placed and finished sufficiently easily and without segregation. A concrete satisfying these conditions is said to be workable. Workability is a physical property of the concrete depending on the external and internal friction of the concrete matrix; internal friction being provided by the aggregate size and shape and external friction being provided by the surface on which the concrete comes into contact with. Besides, consistency of concrete is another way of expressing workability but it is more confined to the parameters of water content. Thus concrete of the same consistency may vary in workability. One test which measures the consistency of concrete is the slump test. It does not measure the workability of concrete but it is very useful in detecting variations in the uniformity of a mix of given nominal proportions. Mixes of stiff consistency have zero slump. Thus, in this dry range no variation can be detected between mixes of different workability. As for lean mix with a tendency to harshness a true slump can easily change to the shear slump or even to collapse. Different values of slump can be obtained from different samples of the same mix. Despite the limitations, the slump test is very useful on site as a check on the day-today or hour-to-hour variations in the materials being fed into the mixer. In addition, an increase in slump may mean, for instance, that the moisture content of aggregate has unexpectedly increased; another cause would be a change in the grading of aggregate, such as a deficiency in sand. Too high or too low a slump gives immediate warning and enables the mixer operator to remedy the situation (Standard Test Procedures, 2011).

Table 4 shows slump test reading and degree of workability of GGBS, Fly Ash and Glass Powder. Based on figure 2, sample D has the highest slump reading which is 9.4 cm following by sample A and G have second highest slump reading which is 9.3 cm.

Table 4: Slump Test Reading Results of GGBS, Fly Ash and Glass Powder in Concrete

Sample Contains	Percentage Of Cement (%)	Percentage Of Waste Material (%)			Slump Reading (cm)	Consistency	Degree of workability
		GGBS	Fly Ash	Glass Powder			
A	80	20	-	-	9.3	Plastic	Medium
B		-	-	20	9.0	Plastic	
C		-	20	-	8.7	Plastic	
D		10	-	10	9.4	Plastic	
E		10	10	-	9.2	Plastic	
F		-	10	10	8.9	Plastic	
G		10	5	5	9.3	Plastic	
Standard Concrete	100		0		9.5	Plastic	

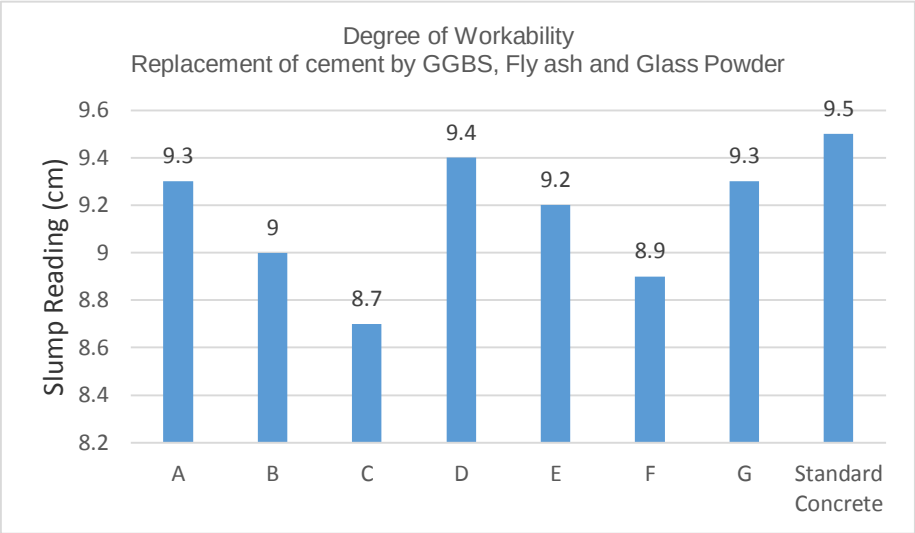

Figure 4: Slump Test Reading Results of GGBS, Fly Ash and Glass Powder in Concrete

All the samples show the slump reading are between 8.7-9.5 cm that means it have medium workability and have true slump where the concrete subsides, maintaining its general form. The sample D which contains GGBS and Glass powder together does not collapse easily. This is because the GGBS and Glass powder has an excellent bonding with concrete mixture. From the results of the slump tests, the workability of the concrete depends on the type waste materials as partial replacement for cement. 20% of cement replacement, where 10% of it is contents GGBS and another 10% Glass powder have a good workability.

3.2 Water Absorption

The objective of this test is to determine the concrete hardness, shrinkage and bond between the internal materials due to vibration and impact. Curing test normally start on the time where the concrete evaporates the rate of moisture in sample. Refer to Table 4, sample A is the lowest average water absorption on 3rd day and 7th day which are 2.29% and 2.40%, following by sample F have second lowest for water absorption on 3rd day and 7th which are 2.31% and 2.51%. For water absorption on 28th day, sample D shows lowest water absorption is 2.77%.

Table 5: Water Absorption Results of GGBS, Fly Ash and Glass powder (3,7 & 28 days curing)

Sample Contains	Percentage Of Cement (%)	Percentage Of Additive (%)			Average Water Absorption on 3rd day (%)	Average Water Absorption on 7th day (%)	Average Water Absorption on 28th day (%)
		GGBS	Fly Ash	Glass Powder			
A	80	20	-	-	2.29	2.40	2.83
B		-	-	20	2.82	2.82	2.90
C		-	20	-	2.53	2.64	2.80
D		10	-	10	2.58	2.59	2.77
E		10	10	-	2.58	2.61	3.08
F			10	10	2.31	2.51	2.93
G		10	5	5	2.40	2.61	2.88
Standard Concrete	100		0		3.10	3.81	3.92

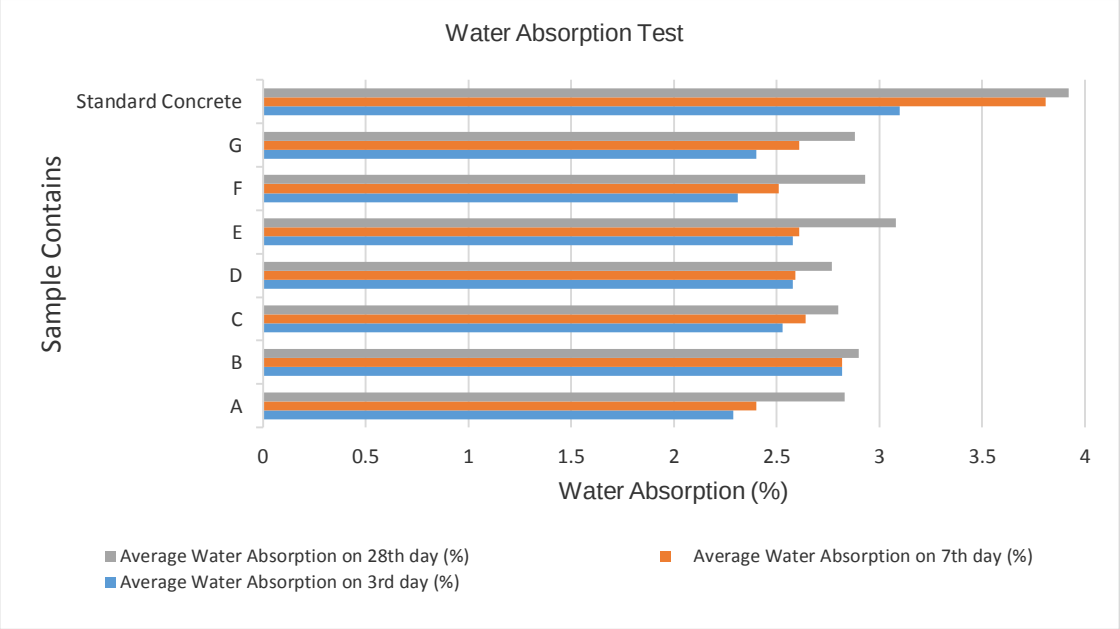

Figure 3: Water Absorption Results of GGBS, Fly Ash and Glass powder (3,7 & 28 days curing)

According to data, all the samples A-G are water absorption in range 2.29% to 2.93%. The percentage of water absorption is less than 5% and standard concrete, it can be concluded samples replacement with GGBS, fly ash and glass powder can absorb water in small amount especially GGBS (sample A) .

3.1 Analysis of Compression Test

The compressive strength of material is the uni-axial compressive stress reached when the material fails completely (G.M.Sadiqul Islam et *al.,* 2016) A set of three cubes were tasted in each case and the average value of these three was reported. Refer to Table 6, sample D has the highest average compressive strength which is 29.67 N/mm², following by sample A is 26.82 N/mm² and Sample G is 26.45 N/mm² for 28 days curing days. For 7 days curing days sample A has average compressive strength is 12.30 N/mm² and Sample D has the highest average compressive strength which is 17.88 N/mm² for 7 days curing days.

Table 6: Results for Compression Test of GGBS, Fly Ash and Glass powder 20%

Sample	Percentage Of Cement (%)	Percentage Of Waste Material (%)			Result of Compression (N/mm²)		
		GGBS	Fly Ash	Glass Powder	3rd day	7th day	28th day
A	80	20	-	-	12.30	17.88	26.82
B		-	20	-	9.26	14.52	21.78
C		-	-	20	9.48	15.04	22.56
D		10	-	10	8.37	19.78	29.67
E		10	10	-	14.0	16.0	24
F		-	10	10	10.52	14.44	21.66
G		10	5	5	11.85	17.63	26.45
Standard Concrete	100		-		12.8	14.0	21.0

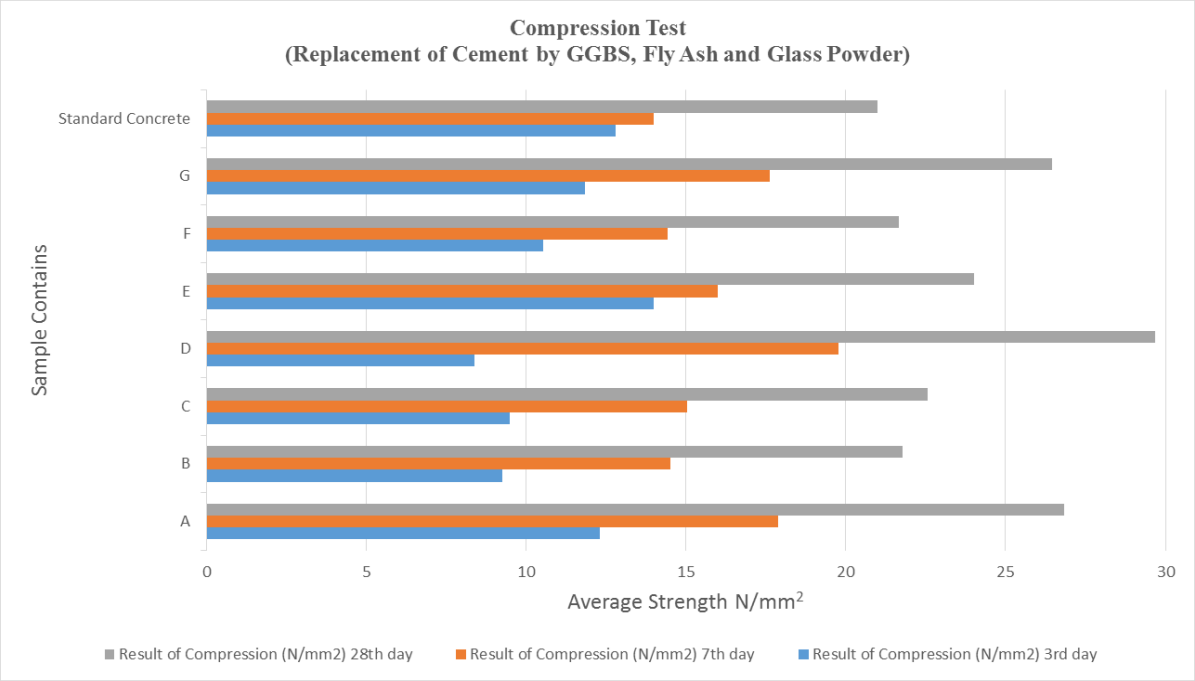

Figure 4 : Water Absorption Results of GGBS, Fly Ash and Glass powder (3,7 & 28 days curing)

According to the data, sample D which consist of 10% GGBS and 10% glass powder have the ability to replace the cement better than other combination because it has archived compressive strength 29.67 N/mm^2 for curing 28 days and 19.78 N/mm^2 compressive strength for curing 7 days. Thus, GGBS and Glass powder together replaced cement in concrete is suitable because it can endure heavy loads and reduce cracking due to heavy load.

4. CONCLUSION

As a conclusion, sample D which consists of 10% of GGBS + 10% of Glass powder is the best sample in order to replace cement in concrete. From the analysis, the value for slump test is 94mm, compressive strength for 28 days is 29.67 N/mm^2 and water absorption is 2.77% which has fulfill MS 26 and relevant part of BS181. Thus, recycle of the waste by transforming material into a useful content or products which can help to reduce environmental pollution, reduces the need to consume natural resources and would not only get rid of dumping but also decreases the C0^2 emission to atmosphere by bringing down the cement production.

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