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INVESTIGATION ON COMPRESSIVE STRENGTH OF OPC-WASTE MATERIAL GEOCOMPOSITE

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Abstract

This study investigates the compressive strength of cement (OPC) bound waste material geocomposite. Two different waste materials namely tire shred and rubber shred were investigated in this project. Laboratory compression tests were conducted on the OPC-waste material geocomposite specimens involving investigation on repeatability of specimen, effect of curing day and effect of OPC content. High repeatability with less than 5% difference was observed either in terms of densities or compressive strength of geocomposite. The compressive strength of the geocomposite was found to stabilise after 7 days curing. The compressive strength of the geocomposite was also found to increase with increasing OPC content.

Keywords : cement bound waste material geocomposite, compressive strength, curing day, OPC content.

Introduction

Waste materials such as waste tire are generated at astronomical scale every year. This has created environmental hazards associated with the storage of these waste materials. The use of waste materials as construction materials in civil engineering applications is one of the better ways of recycling waste material. Ahmed and Lovell (1993) cited some examples of waste materials as lightweight embankment fill materials namely sawdust, fuel ash, shell, expanded polystyrene and scrap tires. Among these waste materials, scrap tire is one of the most widely researched as it was found that there are several advantages of using scrap tire in civil engineering applications. Scrap tire is abundantly available, lightweight, non biodegradable and thus more durable. Scrap tires can be managed as whole, slit, shred, chip, ground rubber, or crumb rubber (Young et al., 2003). Some reported applications of scrap tire in civil engineering include as lightweight fills for embankment and retaining structures (Yoon et al., 2006; Tandon et al., 2007), drainage media in landfill (Reddy and Marella, 2001) and as aggregate replacement in concrete and asphalt mixture (Ghaly and Cahill IV, 2005; Cao, 2007).

Previous studies focus mainly on use of tire alone or tire-soil mixtures in civil engineering. It was reported that use of tire alone caused high settlement in addition to potential self-heating problem due to exothermic reaction (Humphrey et al., 1998). On the other hand, tire-soil mixture was found to have lower compressibility and higher shear strength thus perform better than only tire (Yoon et al., 2006). However, both types of applications still depend greatly on on-site installation and also subject to influence of vibration loading. Abdul Naser Abdul Ghani (2003) introduced binder bound shredded scrap tire geocomposite in which cement and cement replacement materials (styrene butadiene rubber latex, rice husk ash and aqueos foam) were used to bind the shredded tire. Introduction of binder eliminates the need of onsite compaction in which pre-cast geocomposite can be used. In addition, the properties of the binder bound geocomposite can be pre-engineered by modifying the mix design to suit various engineering applications.

As most previous studies were found to focus on shred tire, lacking in information on other waste materials has restricted their use in civil engineering. In addition, data on compressive strength characteristic of waste material-OPC geocomposite is not widely accumulated in Malaysia due to different sources and sizes of waste materials used. This study therefore investigates the compressive characteristics of cement (OPC) bound waste material (in short OPC-waste material geocomposite). Two locally available waste materials namely tire shred and rubber shred were investigated. Compression tests were conducted on different geocomposite combinations using various curing days and cement contents.

Test Materials

The test materials consisted of Ordinary Portland Cement (OPC) and two types of waste materials. The Ordinary Portland Cement (OPC) acts as binder to bind the waste materials together. The two waste materials used in this study were tire shred and rubber shred as shown in Figure 1. The tire shred was recycled from vehicles tire, irregular in shape and free of metal wires. The rubber shred was recycled from diving flippers and consistent in shape. These waste materials are available locally from commercial supplier. Table 1 shows the index properties of the waste materials. All tests were conducted in accordance to BS1377:1990. It is observed that although the tire shred is bigger in size, but it is lighter as compared to the rubber shred. The particle size distribution curves of the waste materials are as shown in Figure 2. The coefficient of uniformity, C_u and coefficient of gradation, C_g were found to be 2.27 and 1.43 respectively for tire shred. As for rubber shred, the coefficient of uniformity, C_u and coefficient of gradation, C_g were found to be 1.66 and 1.16 respectively. Both waste materials can be considered as uniformly graded as their coefficient of uniformity are less than 3.

Table 1: Index properties of waste materials

Properties	**Tire shred**	**Rubber shred**
Specific gravity	0.926	0.974
Minimum density (g/cm^3)	0.366	0.423
Effective size, D_{10} (mm)	6.000	3.500

(a)

(b)

Figure 1: (a) tire shred; (b) rubber shred

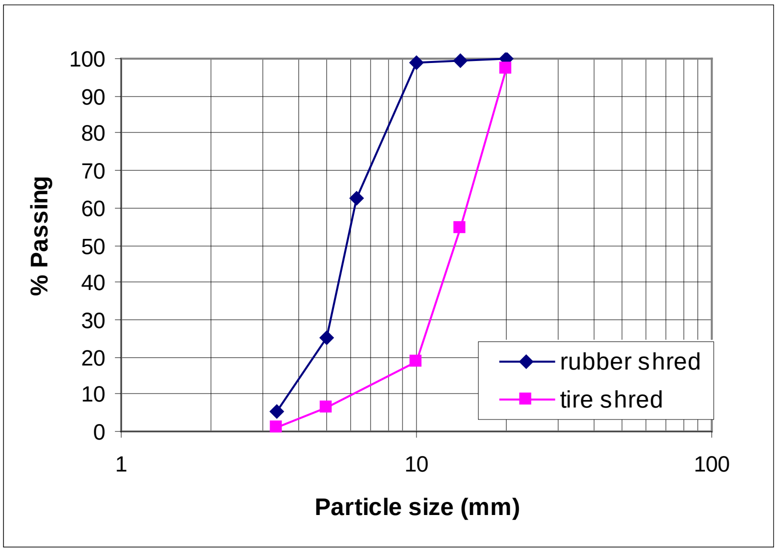

Figure 2: Particle size distribution curves for the two waste materials

Test Programme and Procedure

Table 2 shows the test program and summary of test results of the laboratory compression tests. Several variables were taken into account namely:

a) Two types of waste materials (tire shred and rubber shred)
b) Five different curing days (3, 7, 14, 21 and 28 days)
c) Five different OPC contents (0.6:1, 0.8:1, 1:1, 1.2:1 and 1.4:1 OPC : waste material ratios)

Laboratory compression tests using compressive machine were conducted on cube specimens sized 100 mm x 100 mm x 100 mm in this study. All specimens were cast using water-cement ratio of 0.5 and cured at room temperature for 7 days unless otherwise stated. A standardised specimen preparation procedure was adopted in this study to ensure the consistency of specimens. The waste material was first dried at room temperature. Then the waste material, OPC and water were weighed to the prefixed ratio and placed into the cleaned mixer and mixed for 10 minutes. The geocomposite was then placed in the mould in 3 layers. Each layer was compacted by using vibrating table for 30 seconds. The mould with the geocomposite inside was then cured at room temperature according to the curing duration. Figures 3 and 4 show the cube specimens for both types of geocomposites. For ease of referencing, the OPC bound tire shred geocomposite was named Geocomposite A and the OPC bound rubber shred geocomposite was named Geocomposite B in short in all subsequent passages.

Figure 3: Cube specimen of OPC bound tire shred geocomposite (Geocomposite A)

Figure 4: Cube specimen of OPC bound rubber shred geocomposite (Geocomposite B)

Table 2: Test program and summary of results for compression tests

No	Series	Test	Mix Design	Density (kg/m^3)	Compressive Stress (kPa)
1	Control specimen and repeatability test	1.1	1:1 OPC/Tire shred	1070	850
		1.2	1:1 OPC/Tire shred	1100	890
		1.3	1:1 OPC/Rubber shred	1190	980
		1.4	1:1 OPC/Rubber shred	1180	1000
2	Investigation on effect of curing day	2.1	1:1 OPC/Tire shred at 3-day curing	1060	240
		2.2	1:1 OPC/Tire shred at 7-day curing	1085	870
		2.3	1:1 OPC/Tire shred at 14-day curing	1070	900
		2.4	1:1 OPC/Tire shred at 21-day curing	1070	820
		2.5	1:1 OPC/Tire shred at 28-day curing	1070	800
		2.6	1:1 OPC/Rubber shred at 3-day curing	1120	840
		2.7	1:1 OPC/Rubber shred at 7-day curing	1185	990
		2.8	1:1 OPC/Rubber shred at 14-day curing	1120	940
		2.9	1:1 OPC/Rubber shred at 21-day curing	1130	1120
		2.10	1:1 OPC/Rubber shred at 28-day curing	1180	1180
3	Investigation on effect of cement content	3.1	0.6:1 OPC/Tire shred	820	110
		3.2	0.8:1 OPC/Tire shred	930	320
		3.3	1.0:1 OPC/Tire shred	1085	870
		3.4	1.2:1 OPC/Tire shred	1180	940
		3.5	1.4:1 OPC/Tire shred	1200	960
		3.6	0.6:1 OPC/Rubber shred	890	170
		3.7	0.8:1 OPC/Rubber shred	1040	800
		3.8	1.0:1 OPC/Rubber shred	1185	990
		3.9	1.2:1 OPC/Rubber shred	1280	1670
		3.10	1.4:1 OPC/Rubber shred	1340	2200

Notes:
OPC/Tire shred denotes Geocomposite A
OPC/Rubber shred denotes Geocomposite B

Repeatability and Consistency of Specimen

Checking on specimen consistency was conducted by comparing the densities and compressive stresses for two identical specimens at same testing condition and parameter (refer Test Series 1 in Table 2). For Geocomposite A, it is observed that the densities of the two identical samples are 1070 kg/m^3 and 1100 kg/m^3 respectively indicating high consistency with only 2.8% difference. The compressive stresses were found to be 850 kPa and 890 kPa respectively, also indicating high consistency with 4.7% difference. For comparison purpose, average density and compressive stress of 1085 kg/m^3 and 870 kPa are adopted for all subsequent test series.

As for Geocomposite B, it is observed that the densities of the two identical samples are 1190 kg/m^3 and 1180 kg/m^3 respectively indicating high consistency with only 0.8% difference. The compressive stresses were found to be 980 kPa and 1000 kPa respectively, also indicating high consistency with only 2.0% difference. For comparison purpose, average density and compressive stress of 1185 kg/m^3 and 990 kPa are adopted for all subsequent test series.

In general, Geocomposite B was found with higher density and higher compressive stress as compared to Geocomposite A. Overall the difference between the densities and compressive stresses of identical specimens is less than 5%. This indicates that the standard specimen preparation and casting procedure is effective in controlling the repeatability and consistency of specimen.

Effect of Curing Day on Compressive Strength of Geocomposite

The compressive strength of Geocomposites A and B with 1:1 OPC : waste material ratio was investigated at 3, 7, 14, 21 and 28 curing days. Figure 5 shows the variation of compressive strength for both Geocomposites A and B at the different curing days. For Geocomposite A, an increasing trend of compressive stress in the range of 840 to 1180 kPa with increasing curing day is observed. However, Geocomposite B displayed a down trend upon curing day of 14-day. The range of compressive stress for Geocomposite B varies from 240 to 800 kPa.

In general, the compressive strength of both geocomposites stabilised at curing day of 7-day. Similar finding was also reported by Abdul Naser Abdul Ghani (2003). Ghaly and Cahill IV (2005) also reported an increasing trend in compressive stress with increasing curing day for rubberised concrete.

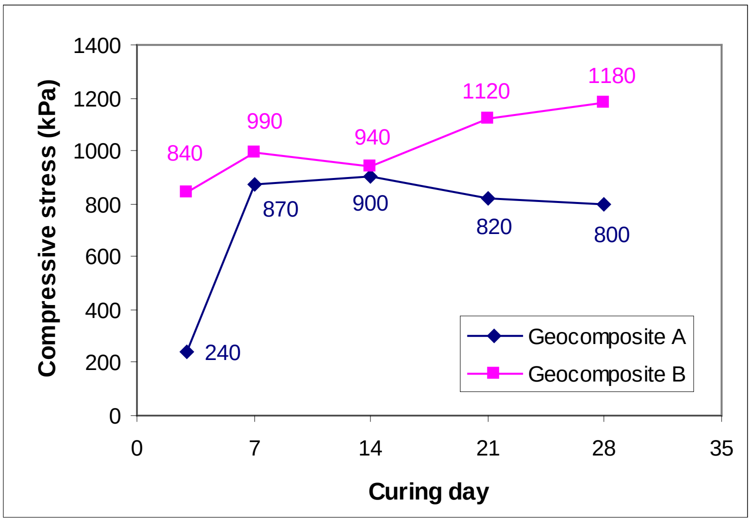

Figure 5 : Variation of compressive stress for Geocomposites A and B at different curing days

Effect of Cement Content on Compressive Strength of Geocomposite

Investigation on effect of cement content on the compressive strength of geocomposite was conducted by using five different OPC-waste material ratios namely 0.6:1, 0.8:1, 1:1, 1.2:1 and 1.4:1. Table 3 and Figure 6 present the test result for Geocomposite A. It is observed that the density of Geocomposite A increases with increasing OPC content. It is also noted that its compressive strength increased with increasing cement content. The most significant increase in compressive strength of 10.3% (as compared to control specimen) is observed when 1.4 : 1.0 OPC/rubber shred ratio is used. On the other hand, the most severe drop of 87.4 % in compressive strength (as compared to control specimen) is observed when 0.6 : 1.0 OPC-tire shred ratio is used. Table 4 and Figure 7 present the test result for Geocomposite B. Similar to Geocomposite A, its density and compressive strength increased with increasing OPC content. The most significant increase in compressive strength of 122.2% (as compared to control specimen) is observed when 1.4 : 1.0 OPC/rubber shred ratio is used. On the other hand, the most severe drop of 82.8 % in compressive strength (as compared to control specimen) is observed when 0.6 : 1.0 OPC-tire shred ratio is used.

In general, a higher amount of OPC increased the compressive stress of both geocomposites. This is because OPC helps to strengthen the bonding between the waste materials thus higher compressive strength. Similar findings was also reported by Abdul Naser Abdul Ghani (2003) and Ghaly and Cahill IV (2005). It is also noted that the gain in compressive strength for Geocomposite B (122.2%) is more significant as compared to Geocomposite A (10.3%) when 40% of OPC is added to the waste material.

Table 3 : Compressive strength of Geocomposite A at various OPC content

OPC : Waste Material Ratio	Density (kg/m^3)	Compressive Stress (kPa)	% Increase As Compared to Control Specimen
0.6 : 1.0	820	110	-87.4
0.8 : 1.0	930	320	-63.2
1.0 : 1.0 (control)	1085	870	0.00
1.2 : 1.0	1180	940	8.1
1.4 : 1.0	1200	960	10.3

Table 4 : Compressive strength of Geocomposite B at various OPC content

OPC : Waste Material Ratio	Density (kg/m^3)	Compressive Stress (kPa)	% Increase As Compared to Control Specimen
0.6 : 1.0	890	170	-82.8
0.8 : 1.0	1040	800	-19.2
1.0 : 1.0 (control)	1190	990	0.0
1.2 : 1.0	1280	1670	68.7
1.4 : 1.0	1340	2200	122.2

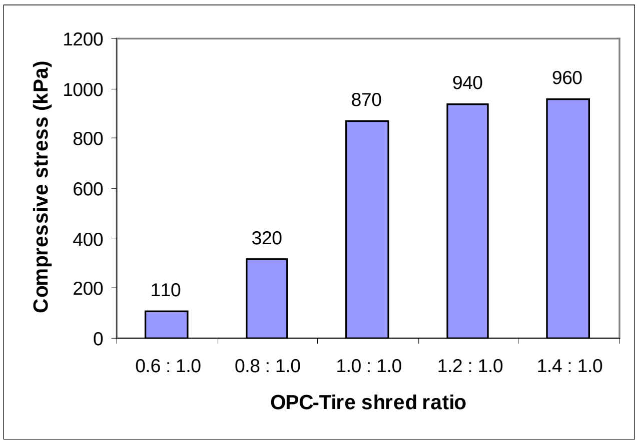

Figure 6 : An increasing compressive strength in Geocomposite A with increasing OPC content

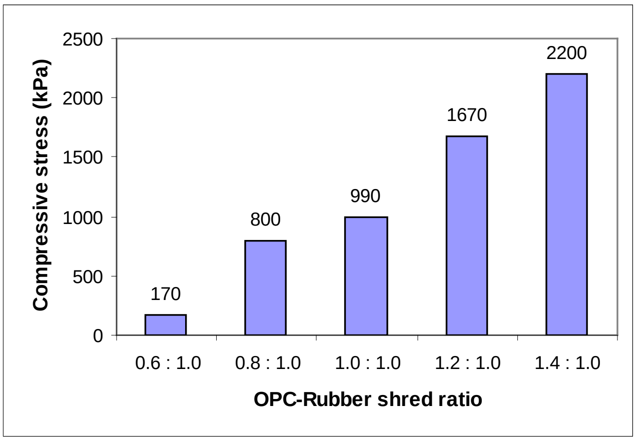

Figure 7 : An increasing compressive strength in Geocomposite B with increasing OPC content

Conclusions

This study investigates the compressive strength of cement (OPC) bound waste material geocomposite. Two different waste materials namely tire shred and rubber shred were investigated in this project. Laboratory compression tests were conducted on 100 mm x 100 mm x 10 mm OPC-waste material geocomposite cube specimens. A total of three compression test series were conducted involving investigation on repeatability of specimen, effect of curing day and effect of OPC content. High repeatability was observed with less than 5.0% difference in density and compressive strength of identical specimens. Investigation on effect of curing day involved specimens cured at 3, 7, 14, 21 and 28 days. The compressive strength of both geocomposite A and B was found to stabilise after 7 days curing. For investigation on effect of OPC content, five different OPC-waste material ratios were studied namely 0.6:1, 0.8:1, 1:1, 1.2:1 and 1.4:1. It is noticed that increasing OPC content would increase the compressive stress for both Geocomposites A and B. The stress increase is probably caused by a stronger bonding between the waste materials with increasing OPC content. It is also observed that there is a unique relationship between compressive strength and density of geocomposite. An increase in the densities of the geocomposite was found to increase the compressive strength of the geocomposite.

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