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Green artificial aggregates as self-curing agent in concrete

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Abstract. Improper curing during concreting on site causing low quality of concrete. The concept of self-cured concrete capable to mitigate the process of water evaporation and increase the capacity of water retention in concrete. Thus, the process of hydration occurred continuously and developed dense concrete. This paper presents the potential of green artificial aggregates as self-curing agent for normal strength concrete. In this study, normal granite aggregates were replaced by 10%, 20% and 30% of green artificial aggregates. Two types of curing regime were applied to the concrete specimens which is wet curing and air curing. The effectiveness of the green artificial aggregates as self-curing agent was evaluated in terms of workability, ultrasonic pulse velocity, and compressive strength at 3 and 7 days. The results showed that concrete with green artificial aggregates produced comparable performance with control sample. This shows that the green artificial aggregates have potential to be used as self-curing agent in concrete.

1. Introduction

Curing of concrete is an important practice in construction to gain optimal performance in any environment or application. Curing is the process of controlling the rate of loss of moisture and temperature in concrete during cement hydration and evaporation process [1,2]. Proper curing of concrete is important to ensure that it achieves its intended strength and durability. If the concrete is improperly cured, then the upper layer about 30 to 50 mm [3-5], is most affected due to the potential for excessive evaporation of water from the concrete surface. Thus, leads to the low quality of concrete such as plastic shrinkage cracks, poorly formed hydrated products, finishing problems and other surface defects [6]. Several researchers introduced the concept of self-curing concrete [7-9]. The concept of self-curing concrete is to increase the capacity of water retention in concrete and mitigate the process of water evaporation compared to conventional concrete [10, 11]. Many researchers have studied self-curing concrete using different materials such as lightweight aggregate [12-14], superabsorbent polymers [15], Polyethylene Glycol [16, 17] and natural fibres [18] as self-curing agents.

Previous researchers [19-21] reported many kind of porous aggregates or lightweight aggregates were used as the water reservoirs in self-curing concrete due to its water absorption ability subsequently provide additional water for shrinkage mitigation, improve hydration and decreasing the process of water evaporation in concrete. However, the reduction of the compressive strength in internally cured concrete were frequently observed in porous aggregate [22-24]. Higher densities porous aggregates for instance waste ceramic aggregate [25, 26] developed to eliminate the problem of reducing compressive strength. There are approximately about 30% of the daily production in the ceramics industry reported goes as waste and currently they are not beneficially utilized [27, 28]. Numerous researchers have

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investigated the crushed and sieved waste ceramic aggregate in their study whereby the water absorption are not more than 10 % [26, 29, 30]. However, not many of them studies on ceramic waste artificial aggregate. Therefore, investigation on physical and mechanical properties of ceramic waste artificial aggregate is carried out to determine whether it can be used as self-curing agent besides capable to maintain the required compressive strength.

2. Experimental programme

2.1. Materials and mixture proportion

Table 1 shows the properties of the materials used in the study. Ordinary Portland cement Type1 that are locally available according to ASTM C150 [31], was used as binding agent. Artificial porous ceramic based coarse aggregate named green artificial aggregate (GAA) acquired from the waste of a local ceramic production were used as internal curing materials as shown in Figure 1a. The aggregates were prepared in a saturated surface-dry (SSD) condition after being soaked in water for 24 hours. The gradation of both coarse and fine aggregates were determined through sieve analysis test by following ASTM C136 method [32]. Gradation curves of both coarse and fine aggregates are shown in Figure 1b. Table 2 tabulates the mixture proportions for the four types of concrete prepared in this study. The w/c of all mixtures was 0.54. The concrete mix was designed based on the DoE method with grades of concrete are normal strength concrete (Gr 30). A mixture proportion named Control is the reference concrete to compare with other concretes using GAA. Mixtures GAA10, GAA20 and GAA30 represent concretes in which the replacement ratios of GAA are 10%, 20% and 30% in volume respectively.

Table 1. Material properties.

Materials	Type	Properties
Cement	Original Portland Cement-Type I	Density: 1280kg/m^3
Fine Aggregate	Crushed sandstone	Maximum size: 5mm
Coarse Aggregate	Crushed gravel	Density (oven dry): 2373 kg/m3 Density (SSD) : 2397kg/m^3 Water absorption : 1% Aggregate crushing value : 18% Maximum size: 10mm
	Green artificial aggregate (GAA)	Density (oven dry): 1624 kg/m^3 Density (SSD) : 1856kg/m^3 Water absorption : 14% Aggregate crushing value : 43% Maximum size: 10mm

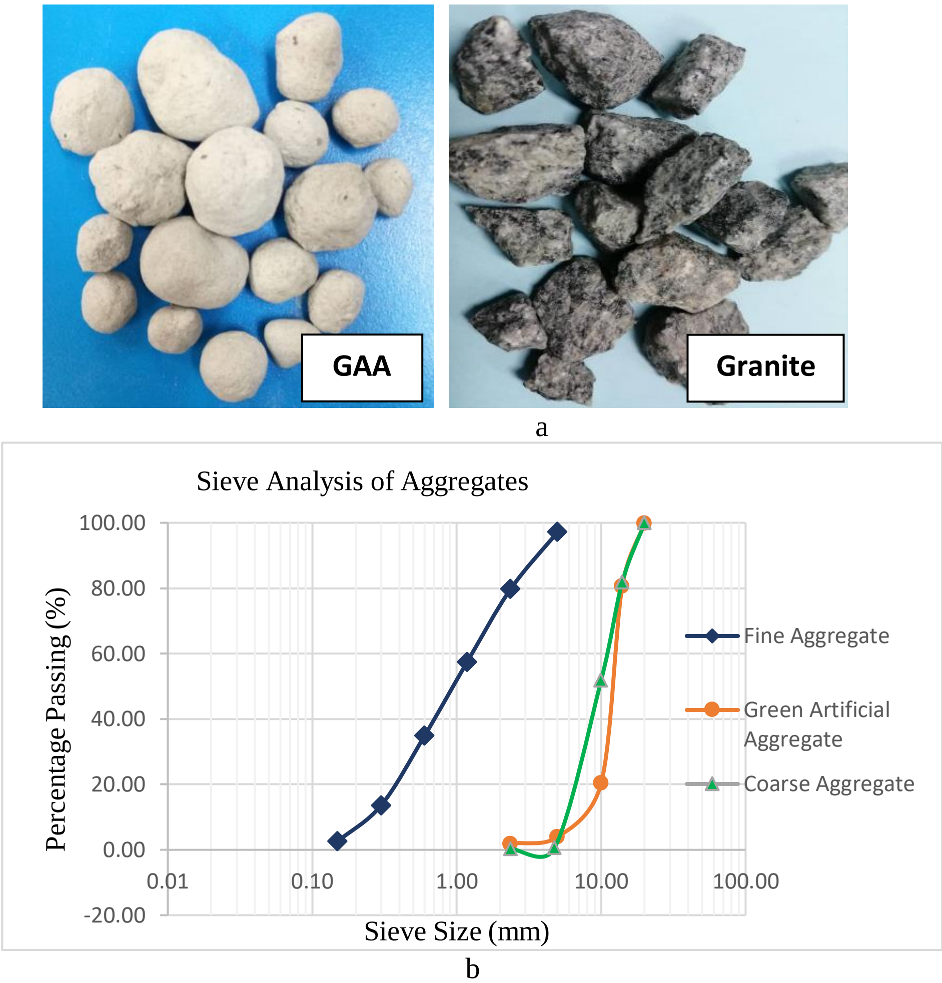

Figure 1. a) view of the GAA and granite, b) grain size distribution.

Table 2. Mix proportion (kg/m^3).

Concrete mixes	Cement (Kg)	Water (Kg)	Aggregate (Kg)			w/c Ratio
			Sand	Gravel, 10mm	GAA	
Control	465	250	850	785	0	0.54
GAA10	465	250	850	707	79	0.54
GAA20	465	250	850	628	157	0.54
GAA30	465	250	850	550	236	0.54

2.2. Testing procedure

The concrete specimens were kept in the moulds for 24 h. After demoulding (24 h after casting), the concrete specimens were cured in two condition namely (1) water curing, (2) kept in the air curing with monitor the relative humidity. The workability of concrete is measured by the slump test according to ASTM C143 [33]. The compression test conducted is according to ASTM C39 [34] at the ages of 3 and 7 days, in which cube specimens measuring 100mm were used. Ultrasonic pulse velocity (UPV) test is a common non-destructive test used to determine the quality and the homogeneity of concrete as per ASTM C597 [35].

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3. Results and discussion

3.1 Workability

The results of workability tests are presented in Table 3. It can be seen that the slump flow values of fresh internally cured concretes using GAA with replacement 10% and 20% are almost the same with the control. Meanwhile the fresh concrete using GAA with replacement 30% show the decreasing of slump flow by 34%. This result may indicate that the GAA is crushed during concrete mixing and become small particles, as affected by the crushing value shown in Table 1.

Table 3. Value of slump with addition of green artificial aggregates.

Type	Slump (mm)
OPC	61
GAA10	62
GAA20	58
GAA30	40

3.2 Compressive strength

Table 4 and Figure 2 represent the compressive strength of each concrete specimens. As seen in the figure, there are development in compressive strength for each concrete specimens. There are no significant effect of the additional of the GAA has been observed during early age compared to the control concrete. The contribution of the GAA probably can be well identified at later ages. However, the concrete contain GAA seen to be improved in compressive strength in air cured regime from third days to seventh days with the percentage increased to 20% for GAA10, 24% for GAA20, 38% for GAA30 compared to control concrete. This result may indicate that the increment of hydration product by the internal water curing process provided by the addition of the GAA.

Table 4. Effect of the addition of the GAA on compressive strength development.

Mix	Curing	Duration		Ratio
		3 days (MPa)	7 days (MPa)	(3/7)
Control	Water	27.00	36.42	0.74
	Outdoor	27.00	34.73	0.78
	Indoor	24.71	30.41	0.81
GAA10	Water	26.90	32.07	0.84
	Outdoor	26.39	27.78	0.95
	Indoor	21.32	26.74	0.80
GAA20	Water	24.13	32.08	0.75
	Outdoor	22.55	27.26	0.83
	Indoor	21.79	28.85	0.76
GAA30	Water	25.90	30.79	0.84
	Outdoor	23.65	26.80	0.88
	Indoor	17.85	28.59	0.62

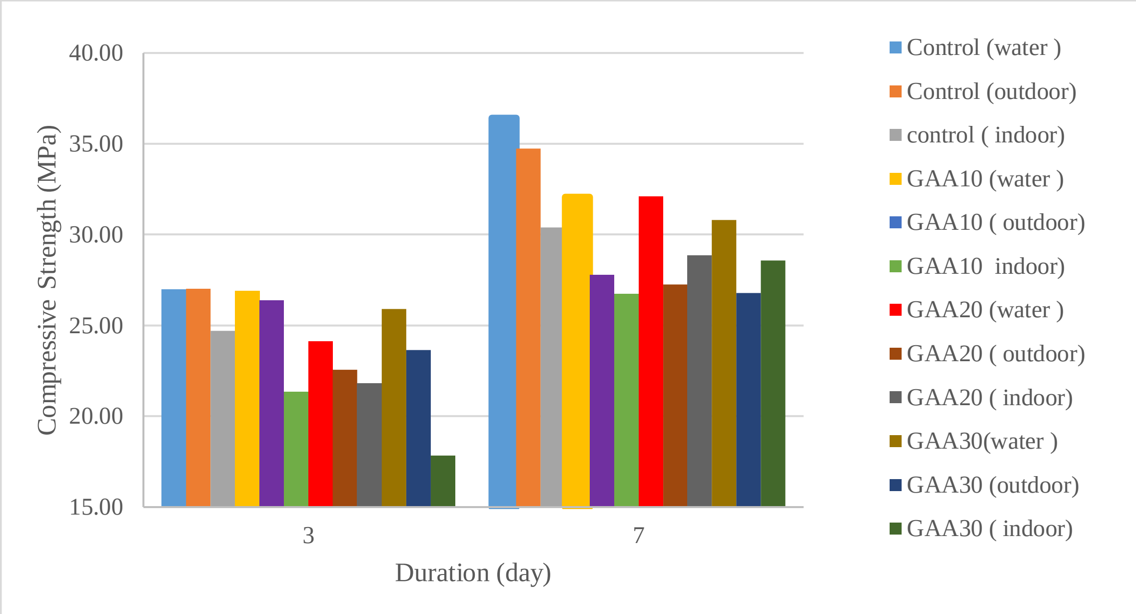

Figure 2. Histogram of GAA on compressive strength development.

3.3 Ultrasonic pulse velocity(UPV)

The velocity obtained from the UPV test is to classify the quality of concrete. Based on previous study, condition of concrete with density of 2400 kg/m³ is considered excellent for ≥ 4.5 km/s, good for 3.5-4.5 km/s, doubtful for 3.0-3.5 km/s, weak for 2.0-3.0 km/s and very weak for ≤ 2.0 km/s [36]. Table 5 shows that the value of UPV increased from third days to seventh days for all concrete specimens under both water and air curing conditions. All concrete specimens are in classified as good. The percentage of UPV containing GAA increased compared to control from 3% to 4 %. This result may due to void in concrete was filled with hydration product contributed by the water in GAA.

Table 5. Effect of the addition of the GAA on UPV.

Mix	Curing	UPV (Km/s)		Ratio (3/7)
		3 days	7 days	
Control	Water	4.08	4.26	0.96
	Outdoor	3.94	4.08	0.97
	Indoor	3.84	3.97	0.97
GAA10	Water	4.07	4.12	0.99
	Outdoor	3.87	3.89	0.99
	Indoor	3.82	3.87	0.99
GAA20	Water	3.85	4.02	0.96
	Outdoor	3.62	3.90	0.93
	Indoor	3.70	3.80	0.97
GAA30	Water	3.86	4.07	0.95
	Outdoor	3.72	3.91	0.95
	Indoor	3.72	3.89	0.96

4. Conclusion

The performance of self-curing concrete made of green artificial aggregates as self-curing agent was investigated at two different curing conditions namely water curing and air curing. From the initial finding, it can be concluded that the green artificial aggregates have a potential to act as self-curing agent. The GAA aggregates consist of micropores acting as reservoirs are added to concrete mixture capable to absorb and release gradually the water for hydration process in concrete.

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