EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 12(1) (2019) 36-48
DOI 10.14456/ea.2019.5
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Characteristics of Concrete Bricks After Partially Substituting Portland Cement Type 1 with Cement and Seashell Waste and Partially Substituting Sand with Glass Waste

Chanya Punthama[1], Nuta Supakata[2,3*], and Vorapot Kanokkantapong[2,3]

[1]*Program in Biotechnology, Faculty of Science, Chulalongkorn University, Thailand*
[2]*Department of Environmental Science, Faculty of Science, Chulalongkorn University, Thailand*
[3]*Research Program : Integrated Municipal Solid Waste Management , Center of Excellence on Hazardous Substance Management (HSM), Thailand*

*Corresponding author: Nuta.s@chula.ac.th
Received: May 22, 2018; Accepted: August 30, 2018

Abstract

To manage solid waste from Si Chang Island, concrete bricks were produced by partially substituting Portland cement Type 1 with green mussel/cockle seashell waste and cement waste and sand was partially substituted with glass waste. In producing bricks, water, cement, and sand were mixed at a weight ratio of 11.11:22.22:66.67. Using seashell waste (cockle seashells and green mussels) in concrete bricks as partial replacement of cement and cement waste, the results showed that the addition of seashell waste content decreased the compressive strength and increased the water absorption of the bricks. The optimal mixture of cement, cement waste, and seashell waste was at a weight ratio of 19:2.11:1.11 in which the compressive strength and water absorption of the bricks produced from cockle seashell waste were 6.41 MPa and 7.44%, respectively, and those from green mussel waste were 6.30 MPa and 7.91%. In addition, by replacing sand with glass waste, the results revealed that compressive strength and water absorption were decreased when glass waste was increased. In conclusion, concrete bricks produced by partially substituting Portland cement Type 1 with cement waste and seashell waste and partially substituting sand with glass waste are compliant with TIS 57-2533 with an optimal ratio of 19: 2.11: 1.11: 56.67: 10: 11.11 (Portland cement Type1: cement waste: seashell waste: sand: glass waste: water) by weight.

Keywords: Concrete bricks; Cement waste; Seashell waste; Glass waste

1. Introduction

Si Chang Island, with a total area of 25.61 km^2 and located in Chonburi province in the eastern part of Thailand, is an interesting tourist island with beautiful nature, a quiet atmosphere, a convenient anchorage for shipping barges, and hundred-year-old archeological sites. With the increase in activities from tourists and shipping, a high amount of solid waste is generated. At present, Si Chang Municipality has the responsibility of collecting and disposing of approximately 25 tons of solid waste per day. From the composition of solid waste on Si Chang Island, it was found that glass waste accounted for approximately 2.5 tons per day (Pantama, 2017). Due to its high weight, it is not worth transporting to the mainland for recycling (Health and Environment Division Municipality of Si chang, 2014), causing problems for Si Chang Municipality in managing this waste.

Concrete is one of the most important building materials used globally. The key element in concrete production is Portland cement. In the Portland cement process, carbon dioxide (CO_2)—one of the factors contributing to global warming—is released into the atmosphere (Ahmari *et al.*, 2012). Recently, the inclusion of waste materials in concrete has been increasing to reduce cement and concrete manufacturing costs and environmental impacts. For example, Turgut (2008) used limestone and glass waste as materials in brick production. This study showed that by increasing the amount of limestone and of glass waste, compressive strength was increased, and water absorption was not significantly higher than 0.288 g/cm^2. Aliabdo *et al.* (2016) showed that substituting 10% of cement with glass waste powder could increase the compressive strength of mortar by approximately 9% due to its pozzolanic properties and its significant effect on setting time and cement expansion. Islam *et al.* (2017) showed that substituting 20% of cement with glass waste powder could enhance the compressive strength of 90-day aged concrete by more than 2% compared with the control concrete specimen, and it could reduce the cost of cement production by up to 14%. Lee *et al.* (2018) confirmed that glass waste powder could be efficiently used as a partial replacement for cement.

Chonburi province is one of the major producers of shellfish in Thailand. In 2015, 20,668 tons of green mussel shellfish, 2,011 tons of blood cockle shellfish, and 72 tons of oyster shellfish were produced, resulting in discarded seashell waste (Department of Fisheries, 2015). Approximately 370–700 g of seashell waste is disposed of for every 1 kg of oyster shellfish produced (Mo *et al.*, 2018; Yao *et al.*, 2014). The chemical composition of seashells shows they contain chemical elements, particularly calcium carbonate ($CaCO_3$), similar to limestone which is the raw material used to produce Portland cement (Falade, 1995; Yoon *et al.*, 2003, 2004; Yang *et al.*, 2005; Ballester *et al.*, 2007). Lertwattanaruk *et al.* (2012) used four types of seashell waste (from short-necked clams, green mussels, oysters, and cockles) to produce a cement product for masonry and plastering and compared it with a control mortar made from conventional Portland cement. The results showed that all mortars containing seashell waste yielded adequate strength, less shrinkage with drying, and lower thermal conductivity compared to the conventional cement, indicating that seashell waste can be used to replace cement in mortar mixes.

To manage the solid waste from Si Chang Island, green mussel and cockle seashell waste, cement waste, and glass waste were used to produce concrete bricks. The aim of this study was to investigate the physical and chemical properties of concrete bricks produced from the mixture of green mussel and cockle seashell waste, cement waste, and glass waste to comply with Thai Industrial Standard (TIS) 57-2533 specifications. The findings of this research should help facilitate an alternative option for managing solid waste on Si Chang Island.

2. Materials and Methods

2.1 Materials

Portland cement Type 1 was used in this study. The cement waste and glass waste (Fig. 1) used were collected from Si Chang Island in the Chonburi province of Thailand. The cement waste was sundried, ground by a fine grinding machine (cup mill, Gilson Company Model: T-100), and then passed through a No. 100 sieve with a diameter of 150 micrometers.

The glass waste was cleaned and dried before grinding and sieving. Glass waste with a particle size less than 4.75 millimeters was processed using a grinding machine (ball mill, Sprecher Schun Model 06T14FC7A) and sieving through a No. 4 sieve.

Green mussel waste and cockle seashell waste (Fig. 1) were obtained from seafood restaurants in Chonburi province. Before using the raw materials, the green mussel and cockle

Figure 1. Raw materials (waste from Si Chang island): (a) cement waste, (b) cockle seashell waste, (c) mussel seashell waste, and (d) glass waste

seashell waste were cleaned, dried, and ground using a fine grinding machine (cup mill, Gilson company Model: T-100). Then, the ground seashell waste was passed through a No. 100 sieve with a diameter of 150 micrometers, and it was heated (calcined) using a muffle furnace (LT 5/11/P 330, Germany) at a temperature of 850oC for 4 hours to gain higher calcium oxide (CaO).

2.2. Characterization of seashell waste, cement waste, and waste glass

The chemical composition of the seashell waste, cement waste, and glass waste was analyzed using an X-ray fluorescence spectrometer (Bruker model S8 Tiger). The particle sizes of the cockle seashell/green mussel waste, Portland cement Type 1, and cement waste were investigated using a laser particle distribution analyzer (Malvern Mastersizer 3000).

2.3. Preparation and characterization of concrete bricks

2.3.1. Investigating the optimal ratio of cement waste to replace Portland cement Type 1

The concrete bricks were prepared by mixing at a water:cement:aggregate ratio of 0.5:1:3 by replacing Portland cement Type 1 with 0, 10, 20, 30, 40, 50, 60, 70, 80, and 90% cement waste, as shown in Table 1. The mixtures were mixed and cast into 5×5×5 cm^3 molds. Then, the specimens were wrapped with plastic film for 24 hours to protect them from rapid moisture loss. After 24 hours, the specimens were removed from the molds and were cured in water at room temperature for seven days. The physical properties of the concrete bricks, including compressive strength and water absorption, were analyzed according to TIS 57-2533 specifications.

2.3.2. Investigating the optimal ratio of seashell waste (cockle seashell/green mussel) to replace Portland cement Type 1 and cement waste

The optimal ratio of cement waste for replacing Portland cement Type 1 (determined in section 2.3.1) was used to prepare concrete bricks in this step by replacing the mixture of Portland cement Type 1 and cement waste with 2.5, 5, 10, 15, and 20% cockle seashell waste, as shown in Table 2. The mixtures were poured into 5×5×5 cm^3 molds and wrapped in plastic film for 24 hours and then removed from the molds and cured in water at room temperature for seven days. The compressive strength and water absorption of the concrete bricks were analyzed according to TIS 57-2533 specifications.

The green mussel waste was then used by applying the same processes as those used with the cockle seashell waste mentioned in section 2.3.2.

2.3.3.Investigating the optimal ratio for replacing sand with glass waste

The optimal ratio of seashell waste (cockle seashell/green mussel waste) for replacing

Table 1. The proportions of the formulation mixtures of Portland cement Type 1, cement waste, agrregate, and water (wt. %)

Formulation mixtures	Portland cement Type 1 (wt. %)	Cement waste (wt. %)	Aggregate (sand) (wt. %)	Water
CW0	22.22	0	66.67	11.11
CW10	20	2.22	66.67	11.11
CW20	17.78	4.44	66.67	11.11
CW30	15.56	6.67	66.67	11.11
CW40	13.33	8.89	66.67	11.11
CW50	11.11	11.11	66.67	11.11
CW60	8.89	13.33	66.67	11.11
CW70	6.67	15.56	66.67	11.11
CW80	4.44	17.78	66.67	11.11
CW90	2.22	20	66.67	11.11

Table 2. The proportions of the formulation mixtures of Portland cement Type 1, cement waste, seashell waste (cockle seashell waste/mussel seashell waste), agrregate, and water (wt. %)

Formulation mixtures	Portland cement Type 1 (wt. %)	Cement waste (wt. %)	Seashell waste (wt. %)	Aggregate (sand) (wt. %)	Water
S0	20	2.22	0	66.67	11.11
S2.5	19.5	2.17	0.55	66.67	11.11
S5	19	2.11	1.11	66.67	11.11
S10	18	2	2.22	66.67	11.11
S15	17	1.89	3.33	66.67	11.11
S20	16	1.78	4.44	66.67	11.11

Table 3. The proportions of the formulation mixtures of Portland cement Type 1, cement waste, seashell waste (cockle seashell waste/mussel seashell waste), agrregate, glass waste and water (wt. %)

Formulation mixtures	Portland cement Type 1 (wt. %)	Cement waste (wt. %)	Seashell waste (wt. %)	Aggregate (sand) (wt. %)	Glass waste	Water
GW0	19	2.11	1.11	66.67	0	11.11
GW10	19	2.11	1.11	56.67	10	11.11
GW 20	19	2.11	1.11	46.67	20	11.11
GW 30	19	2.11	1.11	36.67	30	11.11
GW 40	19	2.11	1.11	26.67	40	11.11
GW 50	19	2.11	1.11	16.67	50	11.11

Portland cement Type 1 and cement waste (determined in section 2.3.2) was used to prepare concrete bricks in this step by replacing sand with 15, 30, 45, 60, and 75% glass waste, as shown in Table 3. The mixtures were then poured into 5×5×5 cm^3 molds and wrapped in plastic film for 24 hours. The specimens were removed from the molds and were cured in water at room temperature for seven days. The compressive strength and water absorption of the concrete bricks were analyzed according to TIS 57-2533 specifications.

A summary of concrete brick production in this research is shown in Figure 2.

2.4 Statistical analysis

The data were subjected to the one-way analysis of variance (ANOVA) using SPSS for Windows. Duncan's multiple range test was used to assess the significance of the effects of green mussel and cockle seashell waste mixed with cement waste and glass waste on the compressive strength and water absorption of concrete bricks according to TIS 57-2533 specifications.

3. Results and Discussion

3.1 Characterization of Portland cement Type 1, cement waste, seashell waste (cockle seashell/green mussel waste), sand, and waste glass

The chemical composition of the Portland cement Type 1, cement waste, seashell waste (cockle seashell/green mussel waste), sand, and glass waste was analyzed using an X-ray fluorescence spectrometer (Bruker model S8 Tiger), as shown in Table 4. It was found that Portland cement Type 1 and cement waste had a relative amount of major chemical components, including CaO (62.40% and 59.90%, respectively) and silicon dioxide (SiO_2; 15.90% and 16.80%, respectively), meaning cement waste

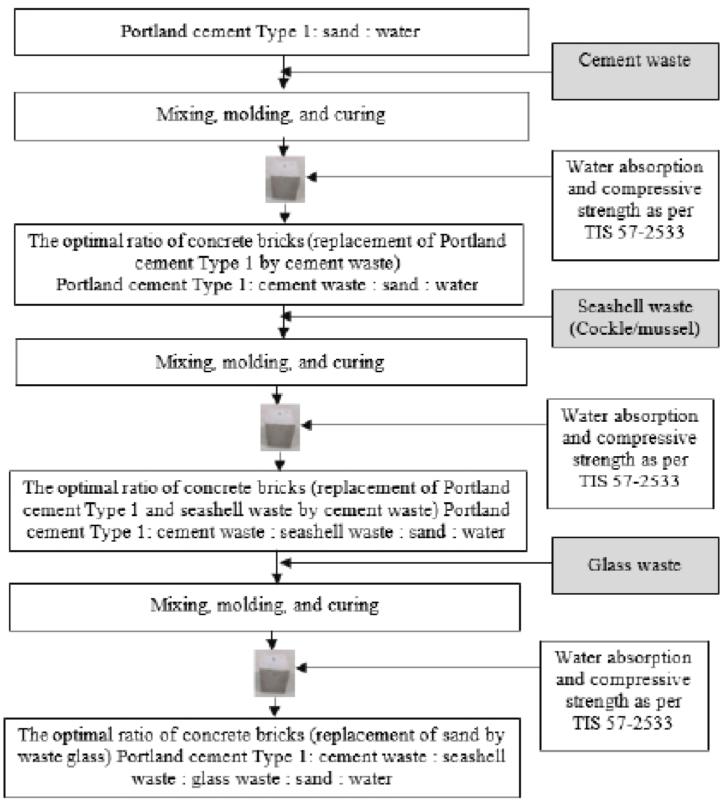

Figure 2. Summary of concrete brick production

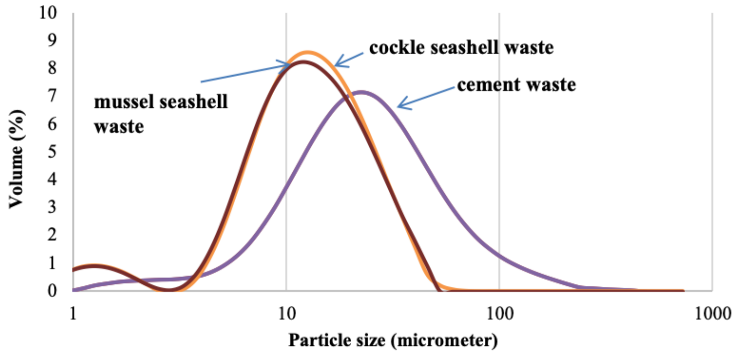

Figure 3. Particle size of raw materials

tends to be used as an alternative material for cement substitution.

In addition, calcined cockle seashell waste and calcined green mussel waste were mostly composed of CaO, 71.90% and 69.40%, respectively, close to the amount of CaO in Portland cement Type 1 and cement waste. Due to the relative amount of SiO_2 in sand (79.30%) and glass waste (60.50%), glass waste was used to partially replace sand in this study.

The particle sizes of cement waste, cockle seashell waste, and green mussel waste were investigated using a laser particle distribution analyzer (Malvern Mastersizer 3000). The results showed that the average particle sizes (d_{50}) of Portland cement Type 1, cement waste, cockle seashell waste, and green mussel waste were 9.20, 24.20, 13.49, and 13.18 micrometers, respectively, as shown in Figure 3

3.2. Characterization of concrete bricks

3.2.1 The optimal ratio of concrete bricks after replacing Portland cement Type 1 with cement waste

The water absorption value of the concrete bricks after replacing Portland cement Type 1 with cement waste, as shown in Figure 4, adheres to TIS 57-2533, which should be lower than 17.14%. It can be observed that the water absorptions of CW0, CW10, CW20, CW30, CW40, CW50, CW60, CW70, CW80, and CW90 were 7.64%, 7.88%, 7.88%, 8.12%, 7.94%, 7.98%, 8.02%, 8.01%, 8.51%, and 8.55%, respectively, in compliance with TIS 57-2533.

The compressive strength of the concrete bricks with some Portland cement Type 1 replaced with cement waste, as shown in Figure 5, adheres to TIS 57-2533, in which the compressive strength value should be higher than 5.0 MPa. It can be observed that the compressive strength values of CW0, CW10, CW20, CW30, CW40, CW50, CW60, CW70, CW80, and CW90 were 10.59, 8.08, 5.84, 5.51,4.32, 4.15, 3.18, 2.91, 2.21, and 1.84 MPa, respectively; therefore, CW0, CW10, CW20, and CW30 were the only ratios compliant with TIS 57-2533.

The results of the compressive strength test showed that the compressive strength decreased as the amount of Portland cement Type 1 decreased, resulting in a lesser hydration reaction to form CSH. According to the results mentioned above, in concrete bricks in which Portland cement Type 1 has been replaced by cement waste, only bricks with 10%, 20%, and 30% cement waste meet the TIS 57-2533 standard requirement.

Thus, considering both the compressive strength and water absorption characteristics of concrete bricks with some Portland cement Type 1 replaced by cement waste, the optimal ratio was CW10 (replacement of some Portland cement Type 1 with 10% wt. cement waste). This mixture of CW10 (with a ratio of 20 Portland cement Type 1:2.22 cement waste:66.67 sand:11.11 water) was used in section 3.3.2 to investigate the optimal ratio of replacing Portland cement Type 1 and cement waste with seashell waste (cockle seashell/green mussel waste).

Table 4. The chemical composition of Portland cement Type 1, cement waste, seashell waste (cockle seashell waste/mussel seashell waste), sand and glass waste

Oxides	Materials (wt. %)					
	Portland cement Type 1	Cement waste	Calcined cockle seashell	Calcined mussel seashell	Sand	Glass waste
SiO_2	15.9	16.8	0.07	0.04	79.3	60.5
Al_2O_3	3.73	3.22	0.03	0.01	3.69	2.13
Fe_2O_3	2.99	2.73	0.04	0.02	0.36	0.5
CaO	62.4	59.9	71.9	69.4	0.76	9.89
MgO	0.88	1.11	0.11	0.12	0.51	1.7
K_2O	0.62	0.31	0.01	0.02	2.35	0.24
Na_2O	0.24	0.25	1.28	1.43	0.21	10.6
SO_3	3.49	0.36	0.11	0.23	0.58	0.54
Cl	0.03	0.02	0.02	0.08	0.23	0.28
TiO_2	0.23	0.22	-	-	0.63	0.98
SrO	-	-	0.16	0.22	-	0.13

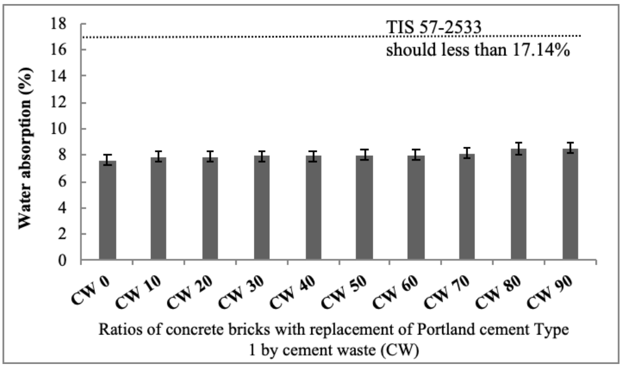

Figure 4. Water absorption of concrete bricks with replacement of Portland cement Type 1 by cement waste

3.2.2 The optimal ratio of replacing Portland cement Type 1 and cement waste with seashell waste (cockle seashell/green mussel waste)

As shown in Figure 6, the water absorption values of the concrete bricks in which some of the Portland cement Type 1 and cement waste were replaced with seashell waste (cockle seashell/green mussel waste) at all ratios (S0, S2.5, S5, S10, S15, and S20) were less than 17.14%, as required by the TIS 57-2533 standard. The water absorption values of the concrete bricks in which some of the Portland cement Type 1 and cement waste was replaced with cockle seashell waste at ratios S0, S2.5, S5, S10, S15, and S20 were 6.88%, 6.72%, 7.44%, 7.05%, 7.32%, and 7.77%, respectively. Adding cockle seashell waste to the concrete bricks led to an increase in water absorption, and the same results were found with green mussel waste.

The water absorption of concrete bricks in which some of the Portland cement Type 1 and cement waste was replaced with green mussel waste at ratios S0, S2.5, S5, S10, S15, and S20 were 7.46%, 7.46%, 7.91%, 8.16%, 8.11%, and 8.63%, respectively.

The compressive strength of the concrete

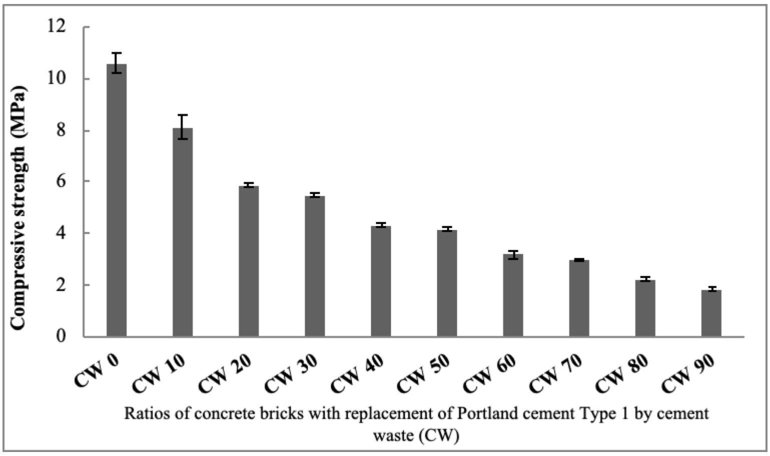

Figure 5. Compressive strength of concrete bricks with replacement of Portland cement Type 1 by cement

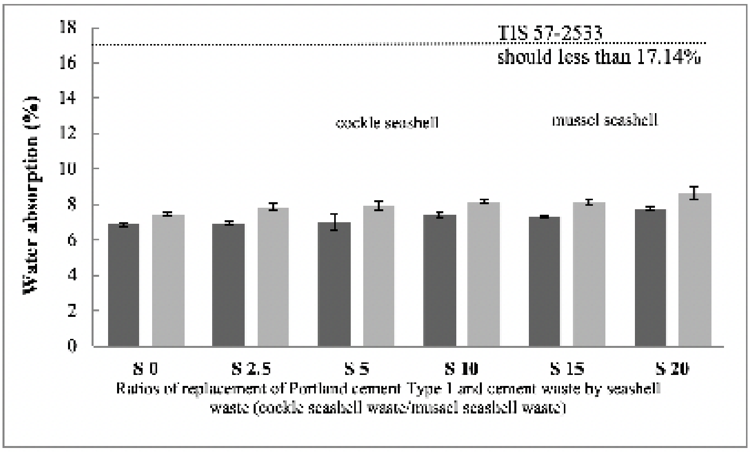

Figure 6. Water absorption of concrete bricks with replacement of Portland cement Type 1 and cement waste by seashell waste (cockle seashell waste/mussel seashell waste)

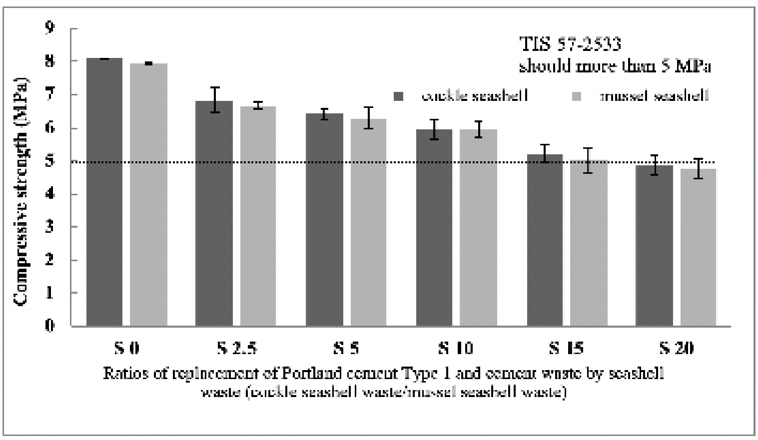

Figure 7. Compressive strength of concrete bricks with replacement of Portland cement Type 1 and cement waste by seashell waste (cockle seashell waste/mussel seashell waste)

bricks in which some of the Portland cement Type 1 and cement waste were replaced with cockle seashell waste, as shown in Figure 7, adheres to TIS 57-2533, in which the compressive strength value should be higher than 5.0 MPa. It can be observed that the compressive strength values at ratios S0, S2.5, S5, S10, S15, and S20 were 8.09, 6.83, 6.41, 5.95, 5.22, and 4.89 MPa, respectively. Thus, S20 was the only ratio that did not comply with TIS 57-2533. It was found that the higher the amount of cockle seashell waste, the lower the compressive strength and the same results are shown with green mussel waste. The compressive strength values of concrete bricks in which some of the Portland cement Type 1 and cement waste was replaced with green mussel waste at ratios of S0, S2.5, S5, S10, S15, and S20 were 7.46, 6.66, 6.26, 5.93, 5.02, and 4.77 MPa, respectively, showing that only S20 did not meet the TIS 57-2533 requirement. The results of the compressive strength test showed that the compressive strength decreased as the amount of seashell waste increased. This is because few reactive substances in the seashell waste were mixed with the Portland cement Type 1 and the larger particle size of seashell waste led to a lower particle packing density (Lertwattanaruk *et al.*, 2012; Olivia *et al.*, 2015; Mo *et al.*, 2018).

Therefore, considering both the compressive strength and water absorption characteristics of the concrete bricks in which some of the Portland cement Type 1 and cement waste were replaced with cockle seashell waste and green mussel waste, the optimal ratio was S5 (replacement of Portland cement Type 1 and cement waste with 5% wt. seashell waste).

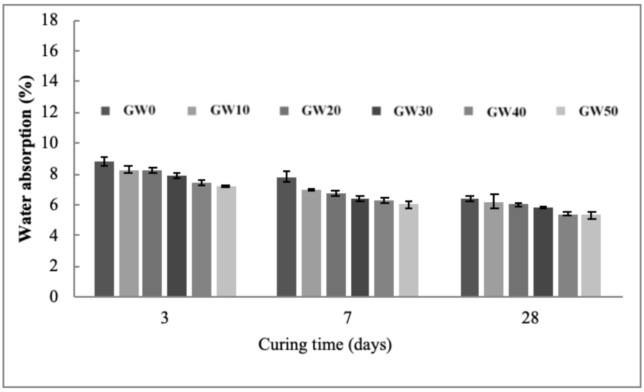

Figure 8. Water absorption of concrete bricks (ratio obtained from 3.2.3 using cockle seashell waste) with replacement of sand by glass waste

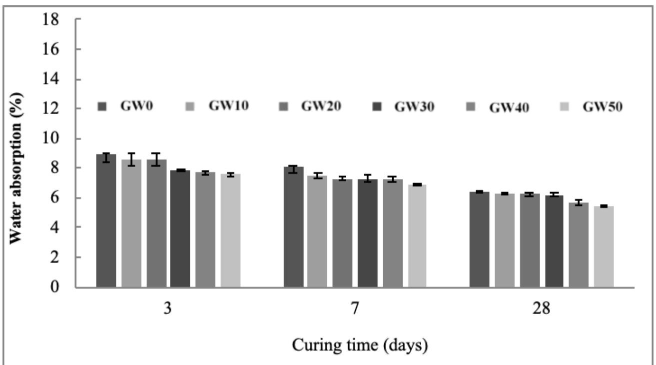

Figure 9. Water absorption of concrete bricks (ratio obtained from 3.2.3 using mussel seashell waste) with replacement of sand by glass waste

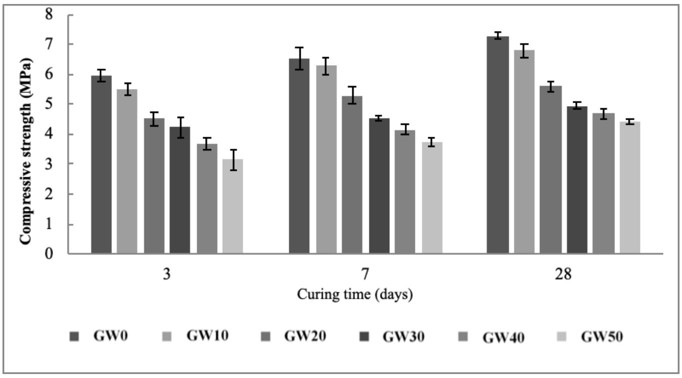

Figure 10. Compressive strength of concrete bricks with (ratio obtained from 3.2.3 using cockle seashell waste) replacement of sand by glass waste

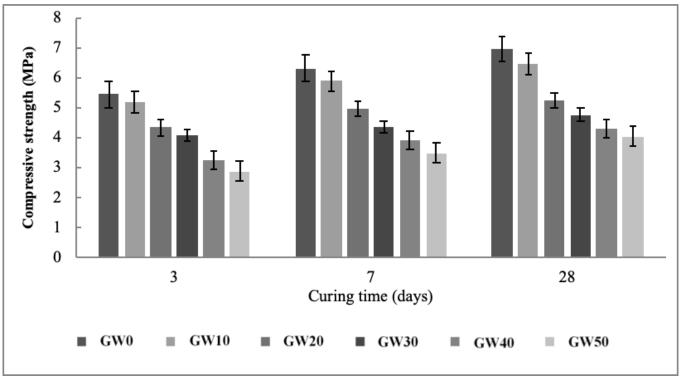

Figure 11. Compressive strength of concrete bricks (ratio obtained from 3.2.3 using mussel seashell waste) with replacement of sand by glass waste

This ratio had the highest use of seashell waste and higher water absorption and compressive strength values than the standard requirement. Ratio S5 (with a ratio of 19 Portland cement Type 1:2.11 cement waste:1.11 cockle seashell/ green mussel waste:66.67 sand:11.11 water) was used in section 3.3.3 to investigate the optimal ratio of glass waste to replace sand.

3.2.3 The optimal ratio of glass waste to replace sand

As shown in Figures 8 and 9, the water absorption values of the concrete bricks in which some of the sand was replaced with glass waste at all ratios (GW0, GW10, GW20, GW30, GW40, and GW50) were less than 17.14%, as required by the TIS 57-2533 standard. Adding glass waste to the concrete bricks led to a decrease in water absorption because glass waste has a lower water absorption value than sand (Park *et al.*, 2004). The water absorption of concrete bricks decreased with an increased curing time.

The results of the compressive strength tests in Figures 10 and 11 showed that the compressive strength decreased as the amount of glass waste increased due to the weakening of the bond between the glass waste and the cement paste (Ali and Tersawy, 2012; Castro and Brito, 2013; Ismail and Al-Hashmi, 2009; Tan and Du, 2013; Topçu and Canbaz, 2004). The compressive strength of the concrete bricks increased with an increased curing time, which can be attributed to a higher hydration reaction to form calcium silicate hydrate (CSH), leading to a higher compressive strength of the concrete bricks.

Compared with TIS 57-2533, the results showed that the concrete bricks in which some of the sand was replaced by 10% glass waste (GW10, with the mixture of 19 Portland cement Type 1:2.11 cement waste:1.11 cockle seashell/

green mussel waste:56.67 sand:10 glass waste :11.11 water) at a curing time of 28 days were of the optimal ratio for replacing Portland cement Type 1 and sand with cement waste, seashell waste, and glass waste.

The compressive strength and water absorption values of this ratio are shown in Table 5.

As shown in Figure 12, the mineralogical phases of concrete bricks were identified using an X-ray diffractometer (XRD, D8- Discover). CSH is produced from the reaction of Portland cement and water in which the CSH phases show the occurrence of the hydrogenation reaction. Compared to the reference standard of the Joint Committee on Power Diffraction Standard (JCPDS), the CSH phases were presented at peaks of 28.8, 29.5, 40.4, and 50.1 degrees, respectively (Ahmari *et al*., 2012).

4. Conclusions

To manage the solid waste from Si Chang Island, green mussel/cockle seashell waste, cement waste, and glass waste were used as raw materials to produce concrete bricks by partially substituting Portland cement Type 1 with cement waste and seashell waste and partially substituting sand with glass waste. The physical and chemical properties of concrete

Table 5. The values of compressive strength and water absorption of the optimal ratio of concrete bricks

Concrete bricks (curing time at 28 days)	Compressive strength (MPa)	Water absorption (%)
19 Portland cement Type 1 : 2.11 cement waste : 1.11 cockle seashell waste : 56.67 sand : 10 glass waste : 11.11 water	6.78	6.19
19 Portland cement Type 1 : 2.11 cement waste : 1.11 mussel seashell waste : 56.67 sand : 10 glass waste : 11.11 water	6.43	6.31

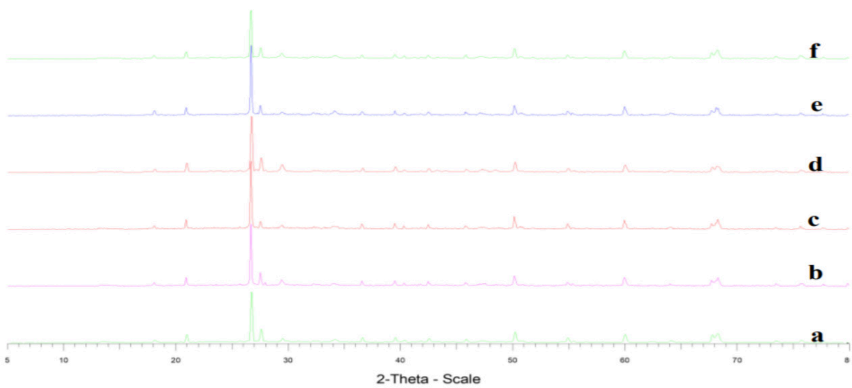

Figure 12. The mineralogical phases of geopolymer bricks: (a) the mixtures of 22.22 Portland cement Type 1 : 66.67 sand : 11.11 water, (b) the mixtures of 20 Portland cement Type 1 : 2.22 cement waste : 66.67 sand : 11.11 water, (c) the mixtures of 19 Portland cement Type 1 : 2.11 cement waste : 1.11 cockle seashell : 66.67 sand : 11.11 water, (d) the mixtures of 19 Portland cement Type 1 : 2.11 cement waste : 1.11 mussel seashell : 66.67 sand : 11.11 water, (e) the mixtures of 19 Portland cement Type 1 : 2.11 cement waste : 1.11 cockle seashell waste : 56.67 sand : 10 glass waste : 11.11 water, and (f) the mixtures of 19 Portland cement Type 1 : 2.11 cement waste : 1.11 cockle seashell waste/mussel seashell waste : 56.67 sand : 10 glass waste : 11.11 water

bricks produced from the mixture of Portland cement Type 1, green mussel/cockle seashell waste, cement waste, and glass waste to comply with TIS 57-2533 specifications were investigated.

The results showed that the concrete bricks with the ratio of 19 Portland cement Type 1:2.11 cement waste:1.11 cockle seashell/green mussel waste:56.67 sand:10 glass waste:11.11 water at a weight curing time of 28 days was the optimal ratio. The findings of this study show that green mussel/cockle seashell waste, cement waste, and glass waste (which are solid waste generated in Si Chang Island) can be used as raw materials in partial replacement of Portland cement Type 1 and sand for producing concrete bricks. In order to apply this research as an alternative solid waste management method on Si Chang Island, a pilot scale experiment, an economic feasibility study, and a life cycle assessment should be investigated.

Acknowledgements

The authors would like to thank the Office of Higher Education Commission (OHEC) and the S&T Postgraduate Education and Research Development Office (PERDO) for the financial support of the Research Program under the grant HSM-PJ-CT-17-13. We would like to express our sincere thanks to the Department of Environmental Science, Faculty of Science, Department of Mining and Petroleum Engineering, Department of Civil Engineering, Faculty of Engineering Chulalongkorn University, the Center of Excellence on Hazardous Substance Management (HSM) for their invaluable supports in terms of facilities and scientific equipment.

References

Ahmari S, Ren X, Toufigh V, Zhang L. Production of geopolymeric binder from blended waste concrete powder and fly ash. Construction and Building Materials 2012; 35: 718–729.

Ali EE, Al-Tersawy SH. Recycled glass as a partial replacement for fine aggregate in self-compacting concrete. Construction and Building Materials 2012; 35: 785–791.

Aliabdo AA, Elmoaty A, Aboshama Y. Utilization of waste glass powder in the production of cement and concrete. Construction and Building Materials 2016; 124: 866–877.

Ballester P, Mármol I, Morales J, Sánchez L. Use of limestone obtained from waste of the mussel cannery industry for the production of mortars. Cement and Concrete Research 2007; 37(4): 559-564.

Castro S, de Brito J. Evaluation of the durability of concrete made with crushed glass aggregates. Journal of Cleaner Production 2013; 41: 7–14.

Falade F. An investigation of periwinkle shells as coarse aggregate in concrete. Building and Environment 1995; 30(4): 573-577.

Health and Environment Division. Report of solid waste management in Si Chang island. Municipality of Si Chang; 2014. (in Thai)

Islam GMS, Rahman MH, Kazi N. Waste glass powder as partial replacement of cement for sustainable concrete practice. International Journal of Sustainable Built Environment 2017; 6(1): 37–44.

Ismail ZZ, Al-Hashmi EA. Recycling of waste glass as a partial replacement for fine aggregate in concrete. Waste Management 2009; 29(2): 655–659.

Lee H, Hanif A, Usman M, Sim J, Oh H. Performance evaluation of concrete incorporating glass powder and glass sludge wastes as supplementary cementing material. Journal of Cleaner Production 2018; 170: 683–693.

Lertwattanaruk P, Makul N, Siripattarapravat C. Utilization of ground waste seashells in cement mortars for masonry and plastering. Journal of Environmental Management 2012; 111: 133–141.

Mo KH, Alengaram J, Jumaat MZ, Lee SC, Goh WI, Yuen CW. Recycling of seashell waste in concrete: A review. Construction and Building Materials 2018; 162(1): 751–764.

Olivia M, Mifshella AA, Darmayanti L. Mechanical properties of seashell concrete. Procedia Engineering 2015; 125: 760–764.

Pantama J. Application of green mussel and cockle seashells mixed with waste glass and cement waste to produce concrete brick. Master thesis. Biotechnology, Faculty of Science, Chulalongkorn University; 2017. (In Thai).

Tan KH, Du H. Use of waste glass as sand in mortar: part I – fresh, mechanical and durability properties. Cement and Concrete Composites 2013; 35(1): 109–117.

Topçu IB, Canbaz M. Properties of concrete containing waste glass. Cement and Concrete Research 2004; 34(2): 267–274.

Turgut P. Limestone dust and glass powder wastes as new brick material. Materials and Structures 2008; 41(5): 805–813.

Yang EI, Yi ST, Leem YM. Effect of oyster shell substituted for fine aggregate on concrete characteristics: part I. Fundamental properties. Cement and Concrete Research 2005; 35(11): 2175-2182.

Yoon GL, Kim BT, Kim BO, Han SH. Chemical-mechanical characteristics of crushed oyster-shell. Waste Management 2003; 23(9): 825-834.