Project Update: May 2022

The lightweight eco-concrete with reduced carbon footprint has been successfully developed using crushed seashells as replacement for coarse aggregates in the concrete (Fig. 1). We found that replacing the coarse aggregates with kenaf fibres was not feasible as it resulted in a weaker concrete. Table 1 compares the carbon footprint between Portland cement concrete and the eco-concrete produced using crushed seashells. The eco-concrete which was formulated using food (crushed seashells) and construction waste (GGBS and quarry dust) had an approximately 60% reduction in carbon footprint compared to conventional concrete (Fig. 2).

Fig. 1. Eco-concrete produced with quarry dust and crushed shells as coarse aggregate.

Table 1. Carbon footprint of Portland cement concrete and eco-concrete. CEM I concrete = Portland cement concrete.

Component	CEM I concrete		Eco shellcrete	
	Ratio	kg of CO_2/t	Ratio	kg of CO_2/t
OPC	0.3	229.50	0.15	114.75
GGBS	0	0	0.15	10.20
Sand	0.7	3.50	0	0
Quarry dust	0	0	0.35	0.04
Seashell	0	0	0.35	-32.17
Total		233.00		92.83

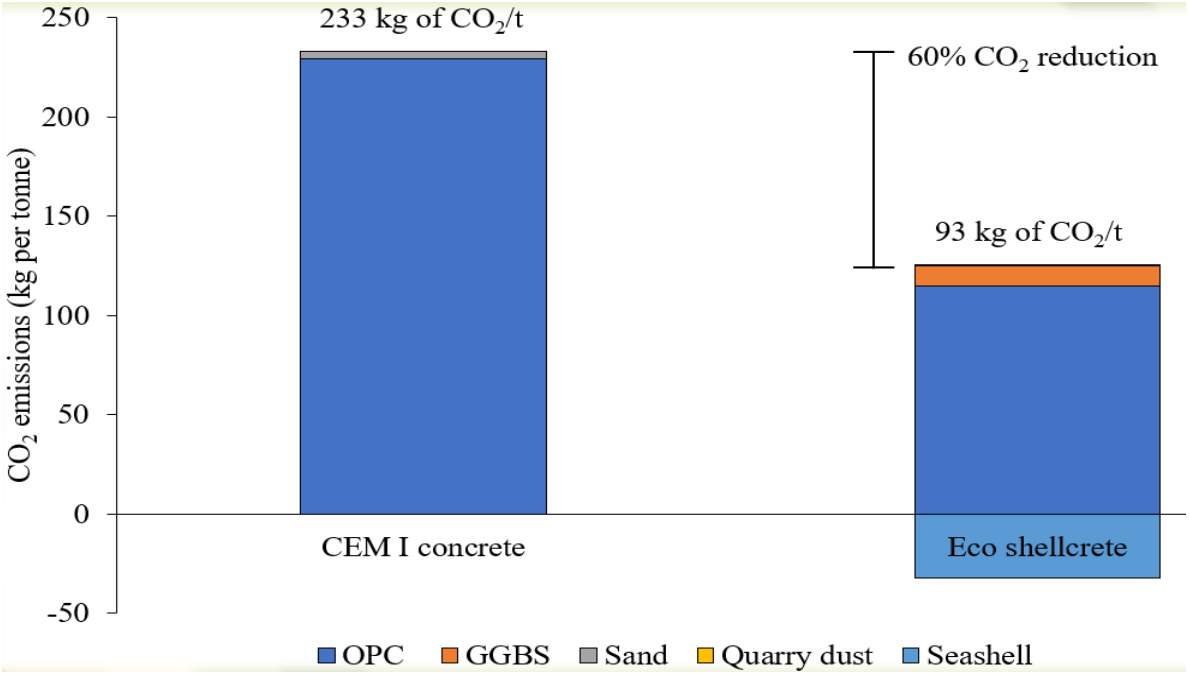

Fig. 2. Carbon dioxide emissions of Portland cement concrete and eco-concrete. CEM I concrete = Portland cement concrete.

The concrete mix we selected to produce the tiles is mix designation B2 (Table 2). This mixture is a combination of 50% OPC (ordinary Portland cement), 50% GGBS, 50% QD (quarry dust) and 50% SS (seashells) based on all tests conducted. Using the B2 mix designation, we managed to maintain approximately 44 Mpa for its compression strength over the course of 90 days via water curing (Fig. 3). Its flexural strength is average at approximately 7 Mpa (Fig.4) but despite this we also consider the other tests when deciding on the overall conclusion to use B2 mix designation which will be further explained below. The controls for mix designation mirroring each concrete mix are A1, B2 and B3 respectively. For the following bar graphs, we focus on the results in 90 days.

Table 2. Mix designations incorporated with different amounts of binder phase (s) and aggregate(s).

		Binder Phase(s)		**Aggregate(s)**	
Mix Designation	**OPC (%)**	**GGBS (%)**	**PFA (%)**	**QD (%)**	**SS (%)**
A1	100	0	0	100	0
A2	100	0	0	50	50
A3	100	0	0	0	100
B1	50	50	0	100	0
B2	50	50	0	50	50
B3	50	50	0	0	100
C1	50	40	0	100	0
C2	50	40	10	50	50
C3	50	40	10	0	100

Abbreviations

OPC : Ordinary Portland cement
GGBS : Ground-granulated blast-furnace slag
PFA : Pulverized fly ash
QD : Quarry dust
SS : Seashells

Despite the highest compressive strength in the following groups, A, B and C which are A1, B1, and C1 respectively (they act as controls in their respective groups), we move our focus to the remaining mix designations instead. Here, ruling out the controls, mix designation B3 is the highest among all of them followed by A2 and B2.

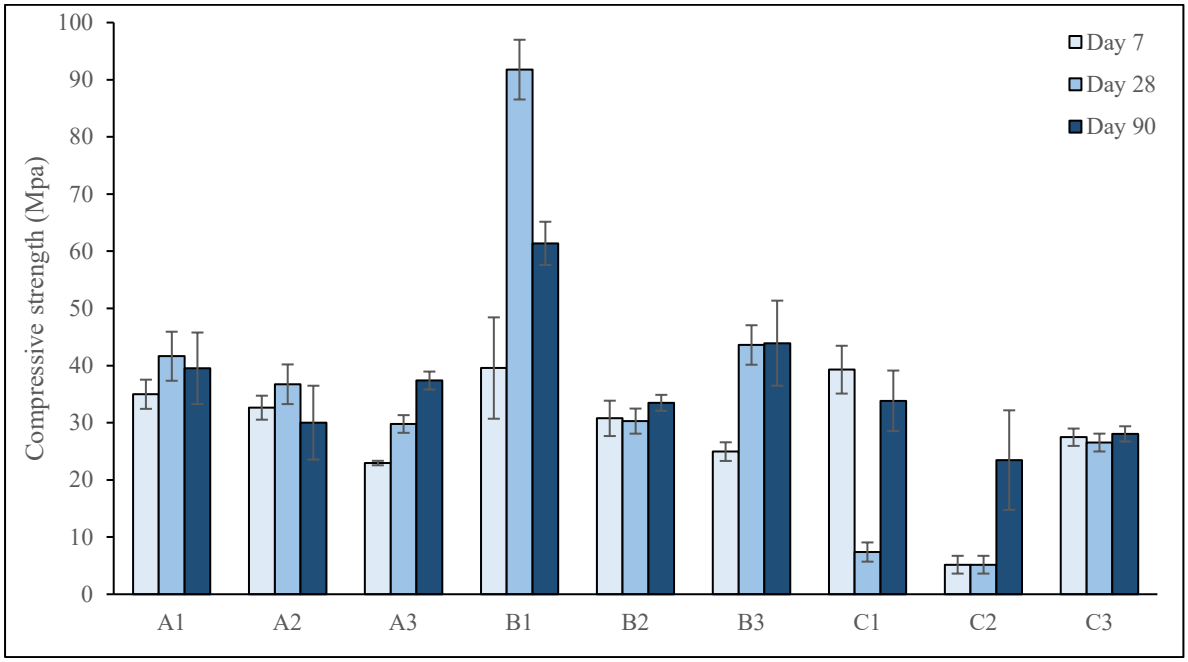

Fig. 3. Compressive strengths of different mix designations on day 7, 28 and 90 (%).

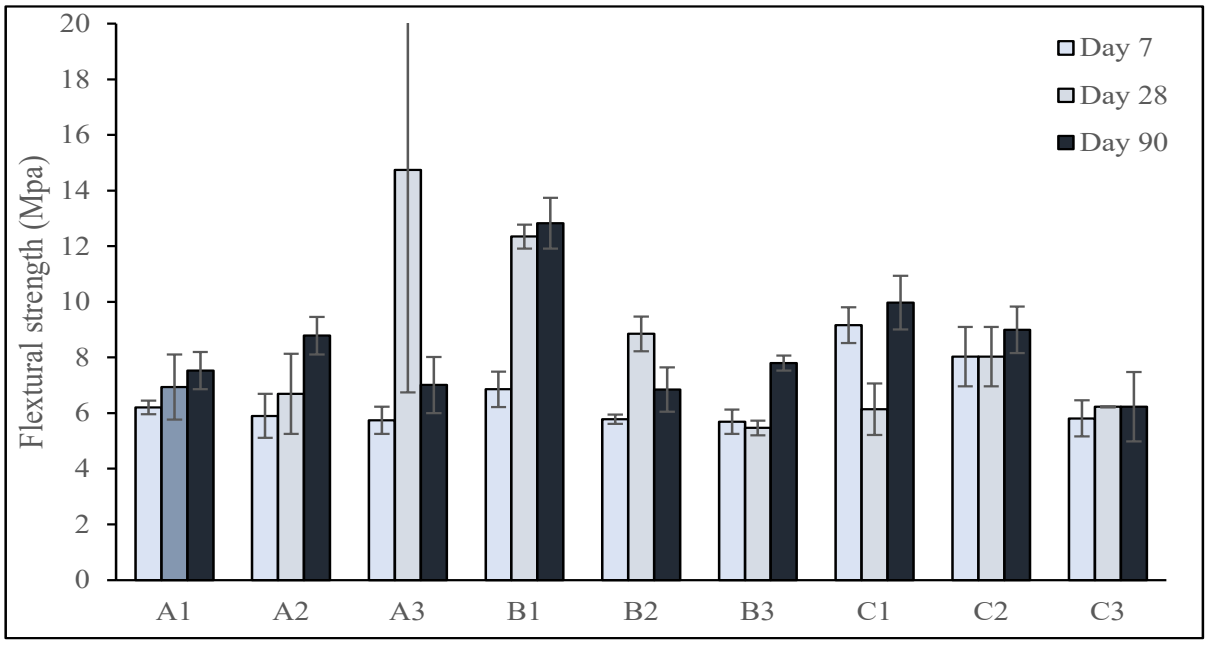

Fig. 4. Flexural strength of different mix designations on day 7, 28 and 90 (%).

For figures 5(a), (b), and (c) we vie for the lowest percentage for water absorption, porosity and air permeability as higher numbers of the will consequently affect the overall strength of concrete over time. The variety in size and type of binders and aggregates used in different mix designations will affect the following percentages. For water absorption, it can be observed that the improved formula of the mix designation (B and C) incorporating GGBS as a binder and aggregates of both quarry dust and seashells have resulted in very large decreases in water absorption over the 90 days course. This might be because the quarry dust used might have filled the voids in the concrete mix in process as a result to the different angularities of seashells incorporated in it. Thus, decreasing the percentage of porosity introduced and thus, reduces water absorption. Although B2 has one of the highest percentages in porosity (19%), this can turn out as an advantage for us - ecological perspective wise - as it might be able to facilitate the boring rate by potential, native boring organisms at the project site. Despite its high percentage in porosity, B2 has one of the lowest percentages of air permeability. Although slightly higher than both B3 and C2, its considerable amount of air sacs present in the concrete mix will probably be one solution to bring down the temperature or function as a heat insulator which will help the organisms to stay on the tile.

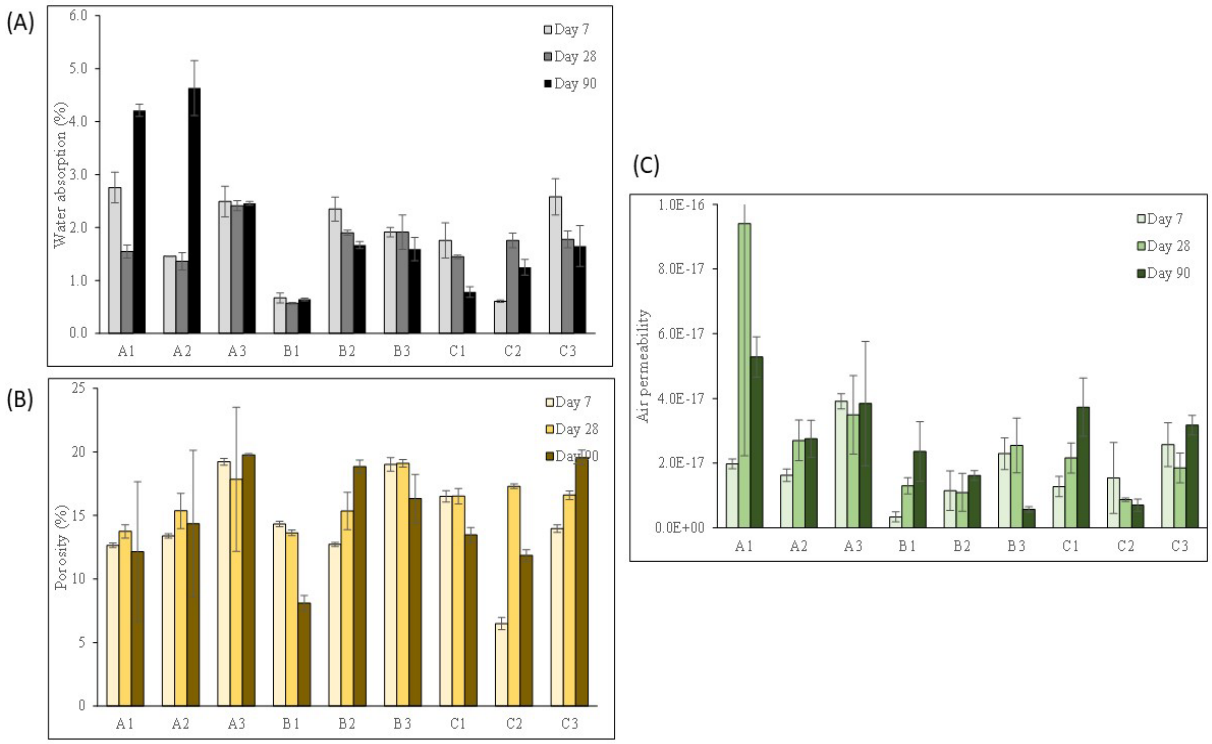

Fig. 5. Tests conducted in 7 days, 28 days and 90 days on the different mix designations (%): (A) Water permeability, (B) Porosity, and (C) Air permeability.

The design of the tiles has been expanded due to recent co-funding secured by the project leader. The new experimental design will include textured tiles (Fig. 6) in addition to the plain tiles that were proposed in the Rufford project. The texture on the tiles were designed based on the information collected from a baseline study conducted to identify the native biodiversity at the coastline of the project site.

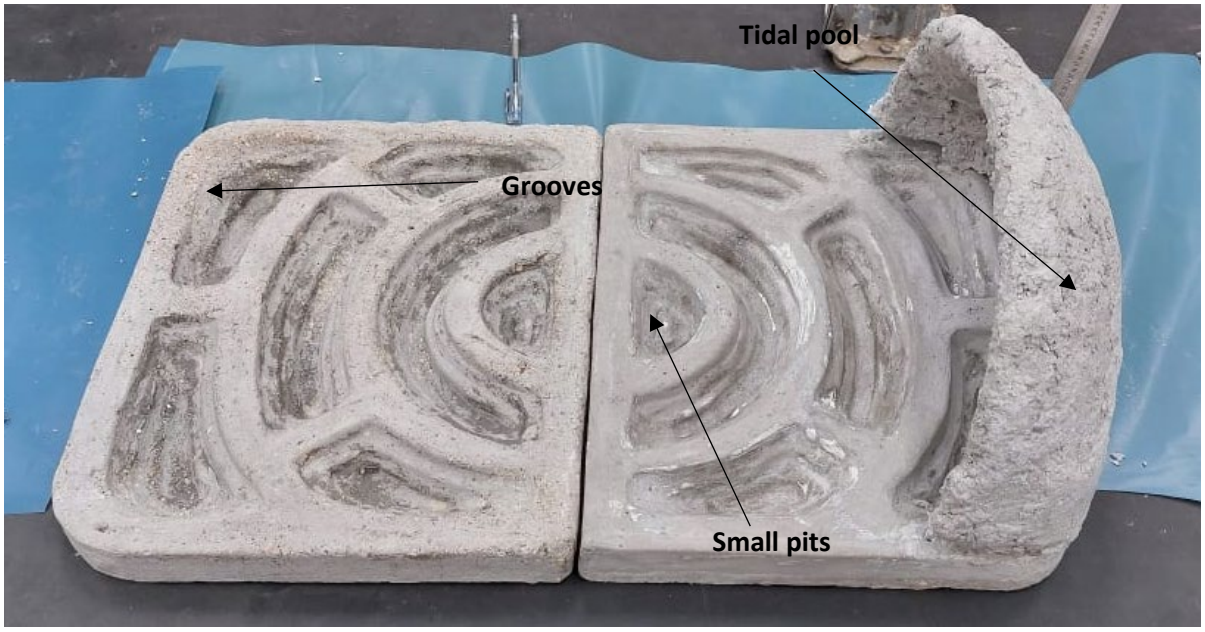

Fig. 6. Textured eco-concrete tiles.

These two treatments (textured and non-textured tiles) will be attached onto a seawall (Fig. 7) to test their performance in promoting species diversity on the infrastructure. Estimated time of deployment is July 2022.

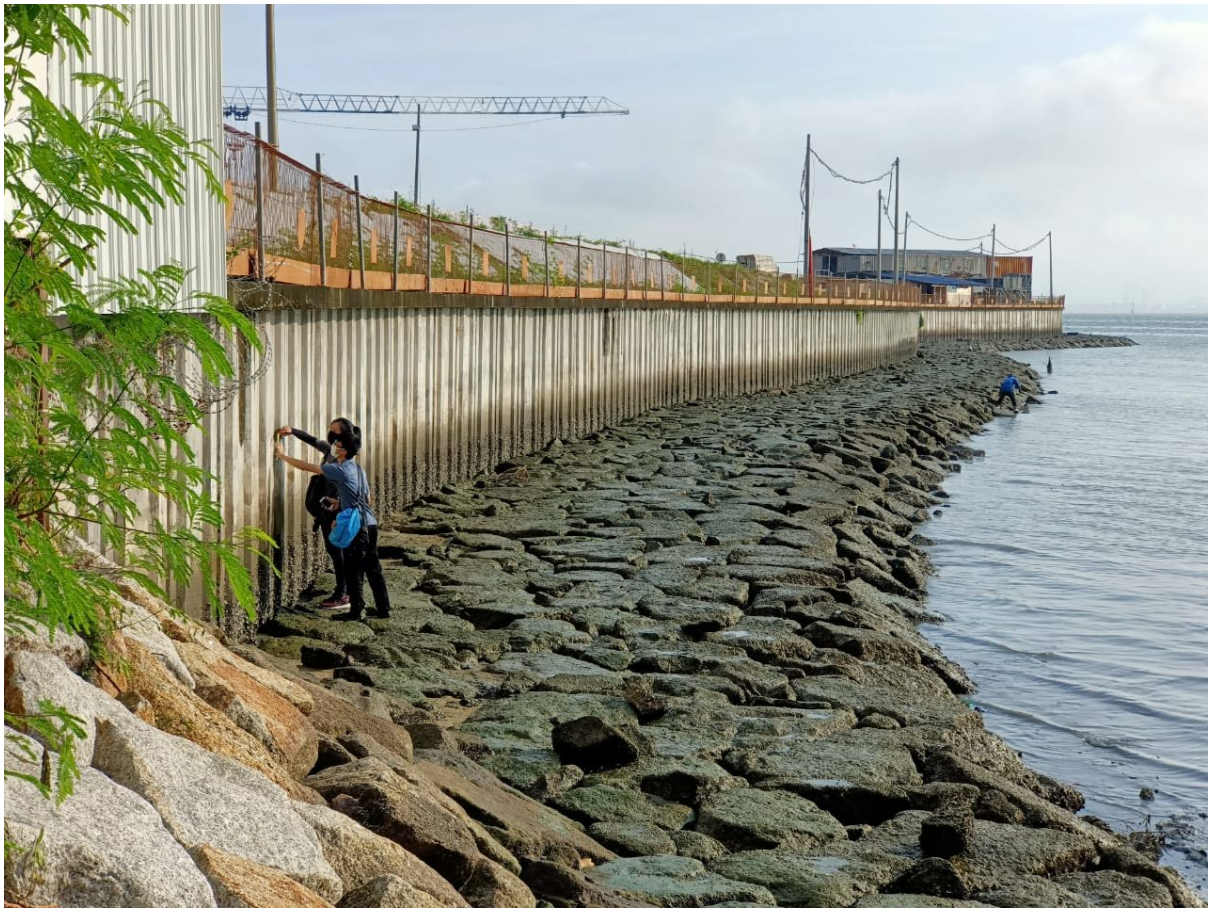
Fig. 7. Seawall at the new project location. Experimental tiles will be installed in the recesses of this wall and monitored for 9 months for its ecological enhancement capabilities.

Challenges

Due to the Covid-19 pandemic which started at the beginning of 2020 in Malaysia, we were faced with a few challenges:

1) Delay in the progress of the project due to limited movement and access to laboratories and project location.

2) Land-use change for the original project location (Clan Jetties).

Steps taken to mitigate challenges

1) Extension of the project duration was requested from The Rufford Foundation and was granted.

2) Project location was changed (with permission from Rufford Foundation) to a seawall located 5 km from the Clan Jetties.