Reefcrete

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Reefcrete: reducing the environmental footprint of concretes for eco-engineering marine structures

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Supplementary Online Material

Table 1 Carbon footprints (kg CO_2/tonne) associated with the production of each component used in the concrete blends trialed (based on published values). Negative values indicate potential net carbon storage. For hemp and shell calculations see SOM Tables 2 and 3.

Component	kg CO_2/ t	GGBS Control		Low Shell		Medium Shell		High Shell		Low Hemp		Medium Hemp		High Hemp		References
		Ratio	kg CO_2/ t concrete	Ratio	kg CO_2/ t concrete	Ratio	kg CO_2/ t concrete	Ratio	kg CO_2/ t concrete	Ratio	kg CO_2/ t concrete	Ratio	kg CO_2/ t concrete	Ratio	kg CO_2/ t concrete	
CEM I	**930.0**	0.06	55.80	0.06	55.80	0.06	55.80	0.06	55.80	0.06	55.80	0.06	55.80	0.06	55.80	(Hammond and Jones, 2008)
GGBS	**42.0**	0.14	5.88	0.14	5.88	0.14	5.88	0.14	5.88	0.14	5.88	0.14	5.88	0.14	5.88	(Ecocem, 2016)
Fine aggregate	**4.8**	0.3	1.44	0.3	1.44	0.3	1.44	0.3	1.44	0.3	1.44	0.3	1.44	0.3	1.44	(Hammond and Jones, 2008)
Coarse aggregate	**4.8**	0.5	2.40	0.375	1.80	0.25	1.20	0	0	0.475	2.28	0.45	2.16	0.375	1.80	(Hammond and Jones, 2008)
Hemp	**-1599.5**	0	0	0	0	0	0	0	0	0.025	-39.99	0.05	-79.98	0.125	-199.94	See SOM Table 2
Shell	**-91.9**	0	0	0.125	-11.48	0.25	-22.97	0.5	-45.94	0	0	0	0	0	0	See SOM Table 3
Total			**65.52**		**53.44**		**41.35**		**17.18**		**25.41**		**-14.70**		**-135.02**	

Table 2 Composition of hemp fibres (proportions of cellulose, hemicellulose and lignin components, assuming values from Mwaikambo and Ansell, 2002), the relative carbon content of these components (Couhert et al., 2009) and calculated carbon content and equivalent CO_2 storage per tonne of hemp fibre (based on the ratio of molecular masses CO_2 : C of 44g : 12g).

Component	Percentage composition in hemp fibre (%)	Carbon content (%)	kg carbon / tonne hemp fibre	kg CO_2 storage / tonne hemp fibre
Cellulose	74.0	44.4	328.6	1204.7
Hemicellulose	18.0	45.0	81.0	297.0
Lignin	4.0	66.7	26.7	97.8
Totals			436.2	1599.5

Table 3 Carbon content, equivalent CO_2 (based on the ratio of molecular masses CO_2 : C of 44g : 12g) and potential CO_2 storage of waste whelk shells. Waste shells from the UK seafood processing industry are typically disposed of by landfill (78%) and incineration (22%) routes (Fry, 2012). Shell material sent to landfill would naturally persist for an extended period before decomposition and release of CO_2, therefore only the 22% proportion that would otherwise be incinerated (i.e. with immediate CO_2 release), was used to calculate its potential carbon storage.

Component	Percentage composition in shell	Carbon content (%)	kg carbon / tonne shell	kg CO_2 / tonne shell	Percentage diverted from incineration (%)	Total kg CO_2 storage / tonne shell
$CaCO_3$	95.0[1]	12.0	113.9	417.6	22.0	91.9

[1]White et al. 2007

Table 4 Kruskal Wallis tests of significant differences in mean initial algal concentrations (total algae, green algae, blue-green algae and diatoms), mean live cover and mean taxon richness (full community, sessile community and mobile community) between hemp and shell concrete blends with "Low", "Medium" and "High" percentage aggregate replacements (n = 3, n = 2 for Medium Shell). Non-parametric tests were carried out on untransformed data because of heterogeneity of variances between groups.

Groups	Response variable	Chi-Square	d.f.	*P*
Low Hemp Medium Hemp High Hemp	Total algae	3.467	2	0.177
	Green algae	4.582	2	0.101
	Blue-green algae	1.867	2	0.393
	Diatoms	2.489	2	0.288
	Live cover	1.067	2	0.587
	Taxon richness (full community)	1.185	2	0.553
	Taxon richness (sessile community)	0.318	2	0.853
	Taxon richness (mobile community)	5.153	2	0.076
Low Shell Medium Shell High Shell	Total algae	2.489	2	0.288
	Green algae	1.156	2	0.561
	Blue-green algae	1.156	2	0.561
	Diatoms	2.756	2	0.252
	Live cover	1.770	2	0.413
	Taxon richness (full community)	2.157	2	0.340
	Taxon richness (sessile community)	0.725	2	0.696
	Taxon richness (mobile community)	2.520	2	0.284

Table 5 PERMANOVA tests of significant differences in full community, sessile community and mobile community compositions between hemp and shell concrete blends with "Low", "Medium" and "High" percentage aggregate replacements (n = 3, n = 2 for Medium Shell). Tests were carried out on fourth root transformed data to account for scale differences in abundance measures.

Groups	Response variable	d.f.	Pseudo-F	P(mc)
Low Hemp	Full community	2,8	1.680	0.133
Medium Hemp	Sessile community	2,8	1.411	0.245
High Hemp	Mobile community	2,8	2.092	0.095
Low Shell	Full community	2,7	0.798	0.611
Medium Shell	Sessile community	2,7	0.858	0.552
High Shell	Mobile community	2,7	0.690	0.671

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