

Identifying optimal precursors for geopolymer composite mix design for different regional settings: A multi-objective optimization study

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SUPPLEMENTARY MATERIAL

Table S1. Energy requirement for pre-treatment.

Energy for milling materials	MJ/kg	Unit	References
Fly ash	0.108	30 kWh/t	[1]
GGBFS	0.661		[2]
Tailings	0.216	60 kWh /t	[3]
Metakaolin	2.5	2.5 MJ/kg	[4]
Steel slag	0.216	60 kWh/t	[3]
Glass waste	0.18	50 kWh /t	[5]
MSWI BA	0.18	50 kWh/t	[6]

Table S2. Electricity costs.

Electricity price	Unit (Euro/kWh)	Reference
Finland	0.0625	[7]
Belgium	0.0795	[7]

Table S3. Weighted Environmental impacts of precursors & transportation, estimated using Gabi software.

	Weighted results
GGBFS	1.64E-12
Steel slag	5.53E-13
Fly ash	2.77E-13
Tailings	5.53E-13
metakaolin	4.10E-12
glass waste	4.61E-13
MSWI BA	4.61E-13
sewage sludge ash	4.61E-13
Transportation weighted emissions	2.65e-16 km/kg

Transportation distance of precursors

The transportation distance is mainly road transportation as this study focuses on locally available materials.

Table S4. Transportation distances in km.

To concrete plant (km)	Finland			Belgium		
	Average	Min	Max	Average	Min	Max
Fly ash	424	15	961	200	90	340
GBFS	366	61	829	135	30	235
Mine tailings	460	6	1096	700		
Sewage sludge ash	376	4	948	112	1	296
MSWI BA	376	4	948	112	1	296
metakaolin	3300			800		
steel slag	424	61	829	135	30	235
glass waste	389	1	1043	112	1	296

Table S5. Procurement and transportation costs and landfill costs in Finland.

	Unit	Reference
Fly ash	0.07 euro/kg	[8]
GBFS	0.11 euro/kg	[9]
Mine tailings *	0	
Sewage sludge ash *	0	
MSWI BA *	0	
metakaolin	0.255 euro/kg	[10]
steel slag	0.0032 euro/kg	[11]
glass waste	0.0523 euro/kg	[12]
Transportation costs	0.000228 euro/km.kg	[13]
Landfill costs	0.07 euro/kg	[14]

* Considered as waste materials that are not yet commercialised

Table S6. Procurement and transportation costs and landfill costs in Belgium.

	Unit	Reference
Fly ash	0.07 euro/kg	[15]
GBFS	0.08 euro/kg	internal communication
Mine tailings *	0	
Sewage sludge ash *	0	
MSWI BA *	0	
metakaolin	0.255 euro/kg	[10]
steel slag	0.0032 euro/kg	[11]
glass waste	0.0523 euro/kg	[12]
Transportation costs	0.000228 euro/km. kg	[13]
Landfill costs	0.0675 euro/kg	[16,17]

* Considered as waste materials that are not yet commercialised

Table S7. Availability of materials in Finland.

	Tonne/year	Normalization 0 to 1	Reference
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Fly ash	348,725	0.0232	[18]
GBFS	370,000	0.0247	[19]
Mine tailings	15,000,000	1.0000	[20]
Sewage sludge ash	76,000	0.0051	[21]
MSWI BA	300,000	0.0200	[22]
metakaolin	-	0.0000	
steel slag	340,000	0.0227	[19]
glass waste	89,985	0.0060	[23]

Table S8. Availability of materials in Belgium.

	Tonne/year	Normalization 0 to 1	Reference
Fly ash	1,202,740	1.0000	[24]
GBFS	1,063,000	0.8838	[25]
Mine tailings	-	0.0000	
Sewage sludge ash	47,880	0.0398	[26]
MSWI BA	401,000	0.3334	[27]
metakaolin	-	0.0000	
steel slag	574,600	0.4777	[25]
glass waste	343,937	0.2860	[28]

Table S9. Results of linear regression analyses.

[illegible]

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