Carbon emissions from producing an eco-clinker from concrete waste

T. Neves[1], V. Sousa[1], J.A. Bogas[1], A. Carriço[1]

[1]CERIS, Department of Civil Engineering, Architecture and Georresources, IST-University of Lisbon, Lisbon, 1049-001, Portugal

Keywords: concrete waste, recycling, eco-clinker.
Presenting author email: vitor.sousa@tecnico.ulisboa.pt

ABSTRACT
Cement GHG emission, in particular CO2, originate from two main sources: i) fuel-related emissions; and ii) process-related emissions. Fuel-related emissions are associated mostly with the thermal energy required to attain a temperature around 1450ºC so that sintering reactions take place and clinker, the key component of Portland cement, is formed. Process emissions result from the presence of carbonates in the raw material. Carbonates, in particular calcium carbonate, make up around 60% of the clinker raw material and its calcination at 800ºC results in the release of the largest portion of the cement CO2 emissions (almost 70% in the most efficient cement factories) (IEA 2018).

At the end of its life cycle, concrete represents a substantial portion of the construction and demolition waste (CDW) generated annually, estimated to be between 3 (Akhtar and Sarmah 2018) to 10 (Wu et al. 2019) billion tons worldwide. In Europe, CDW represents the largest waste stream by volume and weight (EU 2020) and the most recent amendment sets a clearer definition for backfilling operations, reducing the material use to that strictly necessary for the purpose (EC 2018). Since most waste recovery operations have involved backfilling, this amendment sets the tone for more stringent measures being adopted in the future (Moreno-Juez et al. 2020).

Producing clinker using cement paste obtained from concrete waste is a solution that contributes towards meeting the targets for both the: i) CO2 emissions from cement, in particular, the process-related emissions, and ii) the reuse and recycling of the CDW. Creating a closed cycle for cement (ECRA 2017), it is an approach aligned with the circular economy plan devised for the EU (EEA 2020) and the green deal targets set for the cement industry (CEMBUREAU 2020).

The implementation of this solution is limited by the fact that pure cement paste practically does not exist in CDW. As such, the novel method developed at IST allowing the separation of the cement paste from the aggregates unlocks the possibility of producing an eco-clinker (e-clinker) from CDW. Since aggregates contaminate the cement paste (purity of around 85%), the raw material of the e-clinker has to be mixed with natural raw material to obtain a mix with an identical composition of the reference Portland clinker (p-clinker), as detailed in Table 1.

Table 1 – Composition and process emissions of P-clinker and e-clinker

Clinker		P-clinker	e-clinker
Calcium carbonate (C)	%	29	18.6
	CO_2 (kg/ton)	386.9	
FL	%	40.3	
Marl (M)	%	65.2	52.3
	CO_2 (kg/ton)	358.2	
FL	%	36.7	
Sand (A)	%	5.4	0
	CO_2 (kg/ton)	2.2	
FL	%	1.23	
Grit	%	0.4	0.4
	CO_2 (kg/ton)	28.6	
FL	%	3	
Residue	%	0	28.7
	CO_2 (kg/ton)	-	59.5
FL	%	-	20.5
CO2 emissions from raw material (kg/ton clinker)		537.8	409.6
Raw material consumption (kg/kg clinker)		1.55	1.48

But carbon emissions are not just from the raw material. Since the process of obtaining the raw material, there are also inherent differences in fuel/energy-related emissions. Table 2 details the total CO2 emissions from

the overall production process of the e-clinker and compares with the P-clinker, revealing potential reductions between 10% and 16%.

Table 2 – Total carbon emissions from P-clinker and e-clinker production

Component	World	Europe	Portugal	
			Average	SECIL
P-clinker (PC)				
Emissions [kg CO_2 / t PC]				
Process	537.8			
Thermal	310.1	287.1	286.0	257.2
Electrical	64.7	33.6	29.8	26.5
Total	912.6	858.4	853.6	821.5
e-clinker (EC)				
Energy [MJ / t EC]				
Thermal	3402.5	3592.3	3668.0	3812.1
Electrical	600.9	447.0	626.6	527.9
Fuel (transportation)			157.8	78.9
Total	4003.5	4039.3	4452.4	4418.9
Emissions [kg CO_2/ t EC]				
Process	409.6			
Thermal	310.1	287.1	286.0	257.2
Electrical	79.3	26.8	34.5	29.1
Fuel (transportation)			33.9	16.9
Total	799.0	723.5	764.0	712.8
Reduction	**12%**	**16%**	**10%**	**13%**

ACKNOWLEDGEMENTS

The authors wish to thank the Portuguese Foundation for Science and Technology (FCT) for funding this research under project Eco+RCEB, ref. PTDC/ECI-CON/0704/2021, and under unit project UIDB/ECI/04625/2020 (CERIS), as well as Oficinas do Convento, Montemor, and SECIL for supporting the experimental work.

REFERENCES

Akhtar, A., Sarmah, A.K. (2018). Construction and demolition waste generation and properties of recycled aggregate concrete: A global perspective. J. Clean. Prod. 186, 262-281.

CEMBUREAU (2020). Cementing the European Green Deal: reaching climate neutrality along the cement and concrete value chain by 2050. The European Cement Association (CEMBUREAU), Brussels, Belgium.

EC (2018). Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste. European Commission (EC), Brussels, Belgium.

ECRA (2017). Evaluation of the energy performance of cement kilns in the context of co-processing. Technical Report A-2016/1039, European Cement Research Academy GmbH (ECRA), Duesseldorf, Germany.

EEA (2020). Construction and demolition waste: challenges and opportunities in a circular economy. Resource efficiency and waste, Waste Management, European Environment Agency (EEA).

EU (2020). Energy, transport and environment statistics: 2020 Edition. Statistical Books, EUROSTAT, European Union (EU), Brussels, Belgium.

IEA (2018). Technology Roadmap: Low-Carbon Transition in the Cement Industry. International Energy Agency (IEA), France.

Moreno-Juez J., Vegas I.J., Gebremariam A.T., García-Cortés V., Di Maioc F. (2020). Treatment of end-of-life concrete in an innovative heating-air classification system for circular cement-based products. J. Clean. Prod. 263, 121515.

Wu, H., Zuo, J., Zillante, G., Wang, J., Yuan, H. (2019). Status quo and future directions of construction and demolition waste research: a critical review. J. Clean. Prod. 240, 118163.

FCT Fundação para a Ciência e a Tecnologia

REPÚBLICA PORTUGUESA