

### Functional unit selection for Life Cycle Assessment in mixes with Supplementary Cementitious Materials: a literature review

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#### Background

- **Concrete** industry represents approx. **8% of CO<sub>2</sub> emissions**.
- **Supplementary Cementitious Materials (SCMs)** have been used to reduce this impact, reducing the use of Portland Cement, and improving the performance of mixes.
- **Environmental impact of mixes has been researched more recently**.
- **Functional Unit (declared unit)** selection has been discussed related with the proper selection for concrete and cementitious mixes.

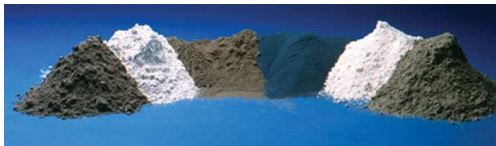


Figure 1. SCMs (Portland Cement Association, 2019)

#### Review

Three major issues were found on the literature review.

1. No proper selection of functional unit (FU). **Common use of volumetric unit (m<sup>3</sup>)**.
2. **No consensus** of the adequate FU to be used for cementitious mixes with SCM.
3. No consideration of different **performances** of concrete.

Source	SCM	Geographical Context	Functional Unit
Nakic, 2018	SSA	Croatia	m <sup>3</sup> of concrete
Gursel et al., 2016	RHA/FA/LF	USA	m <sup>3</sup> of concrete
Sagastume Gutiérrez et al., 2017	Zeolite	Colombia	CFP=m/(CS*D) CFP=Cement Functional Unit m=mass of binder CS=compressive strength at 28d D=Durability (years)
Panesar et al., 2017	Slag/LF/SF	Canada	FU <sub>1</sub> : m <sup>3</sup> ratio FU <sub>2</sub> : MPa ratio FU <sub>3</sub> : Rapid Chloride permeability ratio FU <sub>4</sub> : binder intensity (≈kg/(MPa*year)) FU <sub>5</sub> : FU <sub>2</sub> X FU <sub>3</sub> FU <sub>6</sub> : FU <sub>3</sub> X FU <sub>4</sub>
Kurda et al., 2018a	RA/FA	Portugal	m <sup>3</sup> of concrete
Yang et al., 2015	FA/GGBS	South Korea	m <sup>3</sup> of concrete
Teixeira et al., 2019	Coal/Biomass FA	Portugal	m <sup>3</sup> of mortar
Chen et al., 2010	FA/GGBS	France	kg of FA and GGBS
De Schepper et al., 2014	FA/CS	Belgium	bi=kg/(MPa*year) bi=binder index
Lee and Park, 2005	GGBS	Korea	kg of cement and GGBS
Khodabakhshian et al., 2018	SF/Marble Filler	Iran	m <sup>3</sup> of concrete
Celik et al., 2015	SF/FA	United States	m <sup>3</sup> of concrete
Robayo-Salazar et al., 2018	NP/GGBS	Colombia	m <sup>3</sup> of alkali activated mix

Literature review summary. LCA studies about SCM uses on cementitious mixes (SSA: Sewage Sludge Ash; RHA: Rice Husk Ash; FA: Fly Ash; LF: Limestone Filler; GGBS: Ground Granulated Blast-Furnace Slag; CS: Copper Slag; SF: Silica Fume; NP: Natural Pozzolan).

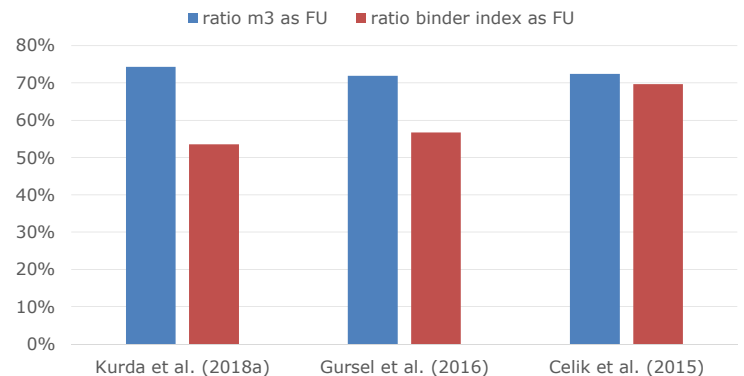
When a comparison is made between mixes within the same studies and SCM there may be a sub estimation of the impact of the use of an SCM if an incomplete FU or a FU that does not consider any performance variable is chosen.

Different indicators can be made to show the impact of the use of an SCM (Fly Ash shown below):

Source	kg Fly Ash	CO <sub>2</sub> -eq / m <sup>3</sup> with FA	CO <sub>2</sub> -eq / kg Cement	CO <sub>2</sub> -eq / kg Binder	CO <sub>2</sub> -eq / Mpa	CO <sub>2</sub> -eq/(kg binder/Mpa)
Kurda et al. (2018a)	119	269.0	1.10	0.77	6.69	48.42
Gursel et al. (2016)	117	381.5	1.38	0.96	7.95	43.82
Celik et al. (2015)	136	412.0	1.30	0.91	8.08	47.84

Summary of three studies on the use of Fly Ash as SCM. Comparison of impacts using m<sup>3</sup> as FU and normalization by kg of cement, kg of binder, Mpa and binder index.

In this case (Fly Ash as SCM) a difference between 3% and 20% was observed between data when comparisons are made in a base case scenario and a SCM use scenario, if FU is changed.



Summary of three studies on the use of Fly Ash as SCM. Comparison of ratio of impact using m<sup>3</sup> as FU and using a binder index that includes mechanical performance. Lower the percentage, better from an environmental point of view.

#### Conclusions

- The literature review shows a **short variety of SCMs studied** yet
- **Volumetric units (m<sup>3</sup>)** were the most common LCA (Declared unit) selected, **ignoring information on the performance** of the mixtures
- **Comparisons** using this FU **are difficult** between different mixes
- Some studies propose the use of a **binder index** (kg of cement/Mpa (compressive strength))
- The selection of a **proper functional unit** is related with the possibility of comparison between studies, but also with the real estimation of the impact of the use of a SCM into a cementitious matrix