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Comparison of the physical and mechanical properties of CEM I with blends of CEM I replaced by recycled concrete up to 10 wt.%

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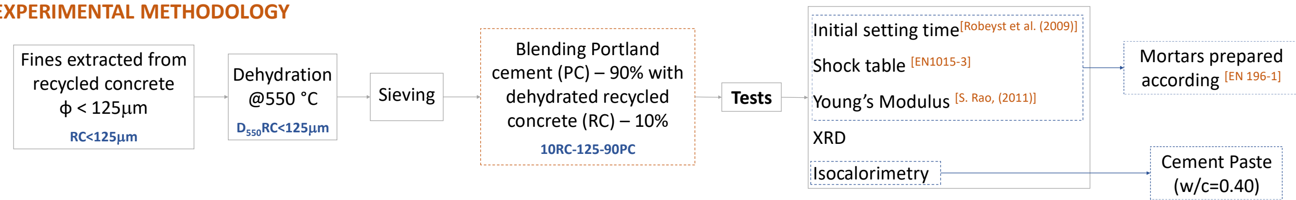
The cement industry is responsible for 13% (by mass)[IPC, (2014)] of anthropogenic carbon dioxide (CO_2) emissions around the world, and clinker production corresponds to 90% (by mass)[IEA, (2009)] of these emissions. Consequently, the cement industry worldwide is facing growing challenges in conserving material and energy resources, as well as reducing its CO_2 emissions. The recycling of end-of-life concrete structures to lower CO_2 emission, protect natural resources, and reduce environmental pollution is of special importance[Miller et al. (2018)]. A key priority for the cement industry remains the reduction of the clinker factor. A previous study on the characterization of fines from recycled concrete showed that the highest ratio of hydrated cement could be recovered from fractions below 125 µm. Thus, in this work, a blend of dehydrated recycled concrete recovered from fines below 125 µm with pure CEM I was tested. The mineralogical composition and physical properties as consistency, initial setting time, and Young's Modulus were compared. The hydration heat of the studied blends has also been measured by isothermal calorimetry for different temperatures, from which the apparent activation energy was determined.

EXPERIMENTAL METHODOLOGY



MATERIALS

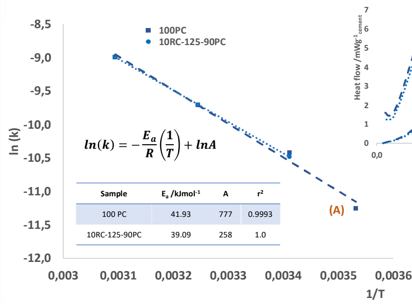
CEM I – 52.5R → 100%(PC) 100PC

Blended Portland cement with dehydrated recycled concrete → 10%(RC)+90%(PC) 10RC-125-90PC

Physical Properties	100PC	10RC–125–90PC
Setting time /min	122	129
Slump value /mm	103	101
Shock value/mm	152.5	155
σ_{28days} /MPa	64.0	64.1
E_{28days} /GPa	39.1	38.7

Mineralogical composition (%)	100 PC	RC <125 µm	D_{550}RC<125µm	10RC–125–90PC
C_3S monoclinic	61.7	0.8	1.5	54.5
C_2S beta	16.7	3.0	3.5	17.7
C_3A cubic	5.8	0.4	0.3	5.0
C_4AF	9.8	0.1	2.2	9.3
Bassanite	1.8	-	-	2.1
Gypsum	0.2	-	-	0.07
Periclase	0.9	0.3	0.4	0.6
Calcite	-	46.9	52.7	4.5
Quartz	0.4	23.6	30.2	2.4
Dolomite	1.3	4.7	3.6	1.9
Anhydrite	0.3	-	-	0.4
Albite	-	1.2	1.5	-
Microcline	-	2.4	2.6	-
Muscovite	0.3	1.2	1.6	-
Lime	-	0.1	-	-
Portlandite	0.7	3.8	-	1.5
Ettringite	-	2.1	-	-
Hydrotalcite	-	3.2	-	-
Aragonite	-	1.7	-	-
Chlorite	0.2	2.0	-	-
$Ca\text{-}Al\text{-}CO_3\text{-}OH\text{-}H_2O$	-	2.7	-	-

RESULTS



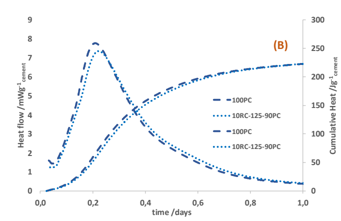


Figure 1: Determination of apparent activation Energy from the plot of ln (k) versus 1/T, according Arrhenius equation **(A)**. Calorimetry results (normalized heat flow and total normalized heat released over time) for pastes produced with blended materials (10% dehydrated RC – 90% PC) and 100% PC **(B)**.

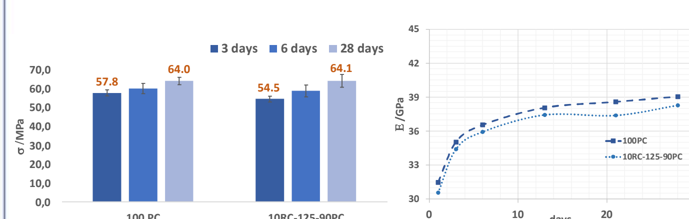


Figure 2: Compressive strength (left) and Young's Modulus[S. Rao, (2011)] (right) for standard mortars made according to EN 196-1 using PC or blended cementitious material, and Norm sand.

CONCLUSIONS

The proportion of recycled materials in the cement mix is very limited, thus the physical properties and mineral composition are very close to pure Portland cement. As a consequence the Young's Modulus and apparent activation energy are very similar.

The higher setting time of mortar 10RC-125-90PC is a consequence of its dry consistence.

Although the mineralogical composition of samples originated from recycled concrete (10RC-125-90PC) is similar to 100PC, it is important to notice the quantities of quartz and calcite in the raw material.

The mechanical tests showed promising results for the replacement of clinker by recycled concrete up to 10 wt.% there only small differences between the properties of pure Portland cement and recycled containing concrete.

Beton naar hoogwaardig beton

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