similar water demand compared to CR, approximately about 27 kg of water for cubic meter (0.45 pcf) of concrete. Concretes manufactured with wash water B required further 24 kg/m^{3}of water (1.5 pcf) to compensate the workability loss. This effect is far more evident for concretes with 35 MPa characteristic cubic compressive strength due to lower w/c ratio. In this case, concretes manufactured with wash water B – characterized by the highest solid residue - the amount of water necessary to compensate the workability loss is about 60 kg each cubic meter of concrete (3.7 pcf).

Effect of solid residue on the compressive strength

The compressive results were normalized respect to those obtained on concretes manufactured with drinking water before ("pre") and after ("post") the process of retempering (**Figure 7** and **Figure 8**). The compressive strength results at 1 day showed a slight increase before the retempering process. This fact can be ascribed to an improvement of the cement paste/aggregates interface produced by the higher amount of fine particles. Moreover, this effect was only evidenced at early ages and becomes negligible at longer ages. At 28 days, the compressive strengths of the concretes manufactured with wash waters are close to those obtained on reference concrete CR manufactured with drinking water. The compressive strength after the process of retempering showed a marked decrease by increasing the solid residue in wash water. The higher the amount of fines in the wash water, the higher the water addition to compensate the slump loss and the higher the compressive strength decrease, as a consequence. The penalization at 28 days, is up to 12% for concretes manufactured with wash water C, and up to 20 and 25% for concretes manufactured with wash water A and B, respectively.

Effect of the mix design modification on rheological and mechanical behaviors of concrete

The mix design of concrete belonging to the second series was modified in order to reduce the amount of fine particles in wash water. The aggregate grading was modified by reducing fine aggregates amount.
The results of the slump tests and compressive strength tests are reported in **Figure 9** and **Figure 10**,respectively.
The reduction of fine particles amount causes a significant reduction in terms of slump loss, which becomes comparable to reference mixture manufactured with drinking water. This fact is fundamental to avoid unsuitable jobsite water additions in the truck mixer. As a matter of the fact, the water addition to attain slump class S5 at 60 minutes was comparable respect to CR. However, CB Mod concretes showed slightly lower compressive strength -before and after the retempering- compared to reference manufactured with drinking water only. This effect can be ascribed to the lack of the improvement of the quality of cement paste/aggregates interface at early ages observed in the presence of a higher amount of fine particles (first series of concrete).

CONCLUSIONS

The experimental results presented in this paper demonstrate that -in the range of solid content considered- wash waters can be used as a partial of full substitution of drinking water for manufacturing of new concrete. This can be considered both to reduce disposal or treatment costs of such waters and –especially- to reduce water consumption and improving sustainability in the building industry.
The use of wash water-in the range of solid content considered by this experimental work- did not affect both air entrapping and concrete specific weight.
Concretes manufactured with the wash water C (0.14 % solid residue content) showed similar rheological and mechanical behaviors compared to concretes manufactured with drinking water. On the other hand, the concretes manufactured with the wash water B (5.53 % solid residue) showed slightly higher compressive strengths values at early ages compared to reference due to the improvement of the cement paste/aggregate interface. However, relevant workability loss was observed especially at 60 minutes, which can enhance the risk of unsuitable jobsite water addition and compressive strength decrease, as a consequence. This effect can be mitigated by modifying the aggregate grading curve to take into account about the fine particles amount in wash water.
The experimental work has confirmed the possibility to fully or partially replace the mixing water in order to manufacture new concrete but in field and laboratory pre-qualification tests are necessary to determine limits and performances of such substitution.

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TABLES AND FIGURES

Table 1-Mix designs and experimental data collected for concretes manufactured with drinking water (CR)

	f_{ck} 30			f_{ck} 35		
	CEM II/B-LL	**CEM IV/A V**	**CEM II/A-LL**	**CEM II/B-LL**	**CEM IV/A V**	**CEM II/A-LL**
Cement kg/m^3 (pcf)	350 (21.9)	340 (21.2)	310 (19.4)	380 (23.7)	370 (23.1)	340 (21.2)
Water kg/m^3 (pcf)	175 (10.9)	180 (11.2)	178 (11.1)	176 (11)	183 (11.4)	182 (11.4)
w/c	0.50	0.53	0.57	0.46	0.49	0.54
Sand kg/m^3 (pcf)	754 (47.1)	763 (47.6)	795 (49.6)	727 (45.4)	735 (45.9)	768 (47.9)
Fine Gravel kg/m^3 (pcf)	497 (31)	494 (30.8)	496 (31)	499 (31.1)	493 (30.8)	495 (30.8)
Coarse Gravel kg/m^3 (pcf)	553 (34.5)	551 (34.4)	553 (34.5)	555 (34.6)	552 (34.5)	553 (34.5)
Superplasticizer kg/m^3 (pcf)	3.0 (0.19)	2.5 (0.16)	2.3 (0.14)	3.2 (0.2)	2.7 (0.17)	2.5 (0.16)
Entrapped air (%)	2.5	2.2	2.0	2.3	2.0	1.7
Slump at 0' (mm)	210	215	210	250	235	220
Slump at 60' (mm)	190	165	90	100	160	140
Spread at 0' (mm)	645	590	627.5	645	640	605
Spread at 60' (mm)	505	465	415	430	445	445
Specific weight	2.332	2.331	2.334	2.340	2.336	2.341
Compressive strength pre retempering at 1 day (MPa)	16.2	11.5	17.6	18.3	12.3	18.8
Compressive strength pre retempering at 7 days (MPa)	33.5	23.8	33.4	37.9	26.9	36.2
Compressive strength pre retempering at 28 days (MPa)	43.1	35.6	42.6	45.5	38.8	44.1
Compressive strength post retempering at 1 day (MPa)	11.8	7.3	13.8	13.5	10.1	15.1
Compressive strength post retempering at 7 days (MPa)	25.5	19.4	28.0	30.0	22.1	29.5
Compressive strength post	32.4	30.3	34.8	37.1	32.3	35.6

retempering at 28 days (MPa)						

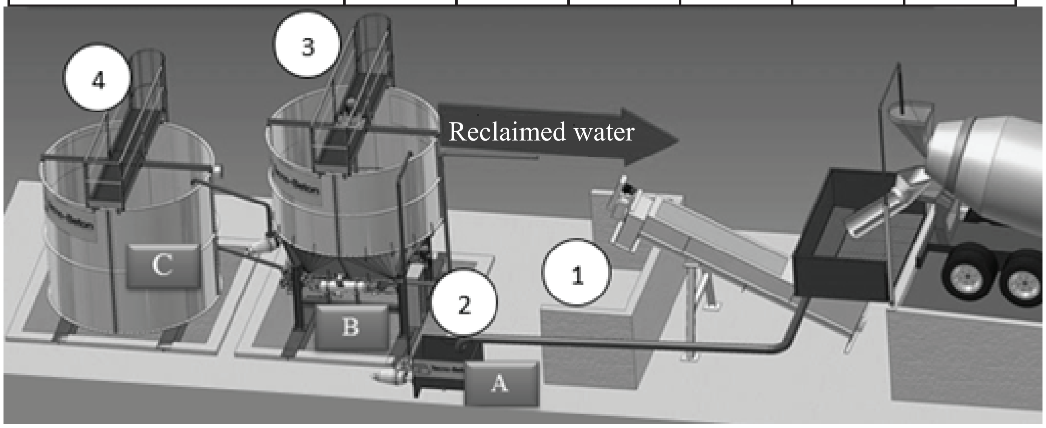


Figure 1-Structure of the recycling plant of wash water

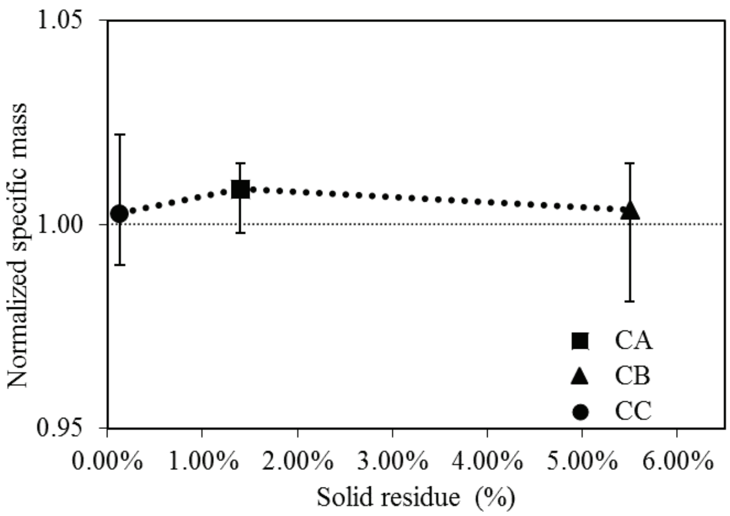


Figure 2-Normalized specific weight (respect to drinking water) vs. solid residue

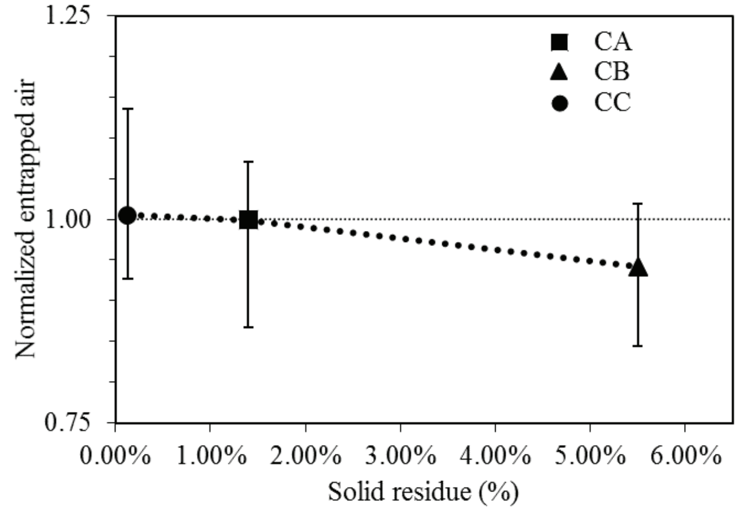
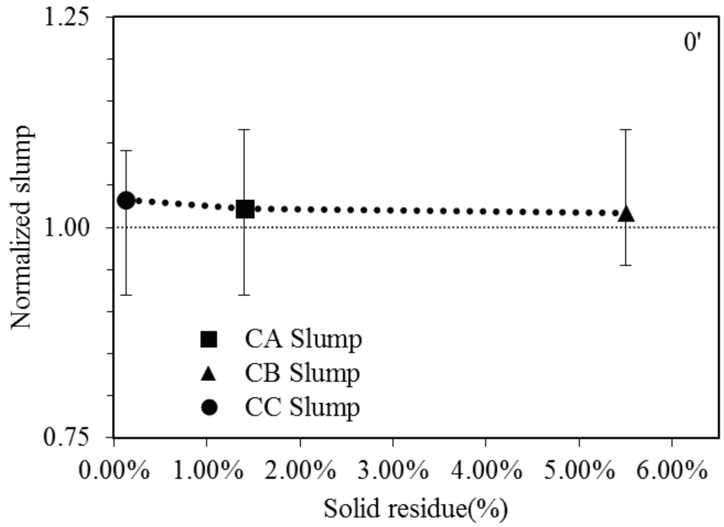


Figure 3-Normalized entrapped air (respect to drinking water) vs. Solid residue - 60'



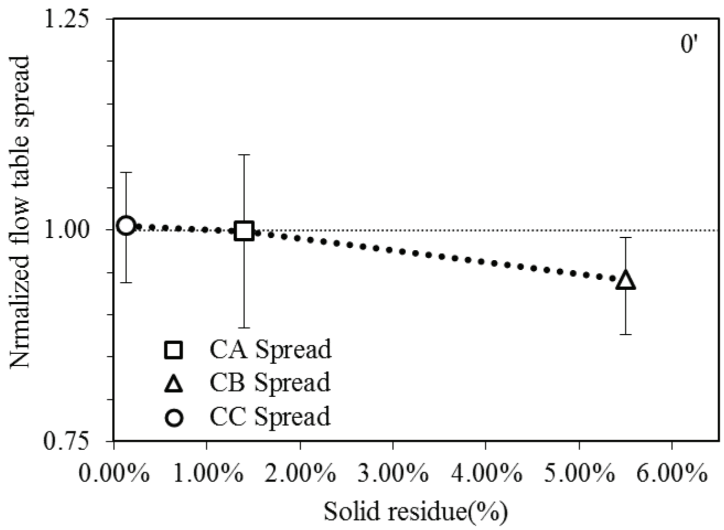


Figure 4-Normalized slump and flow table spread (respect to drinking water) vs. Solid residue at 0'

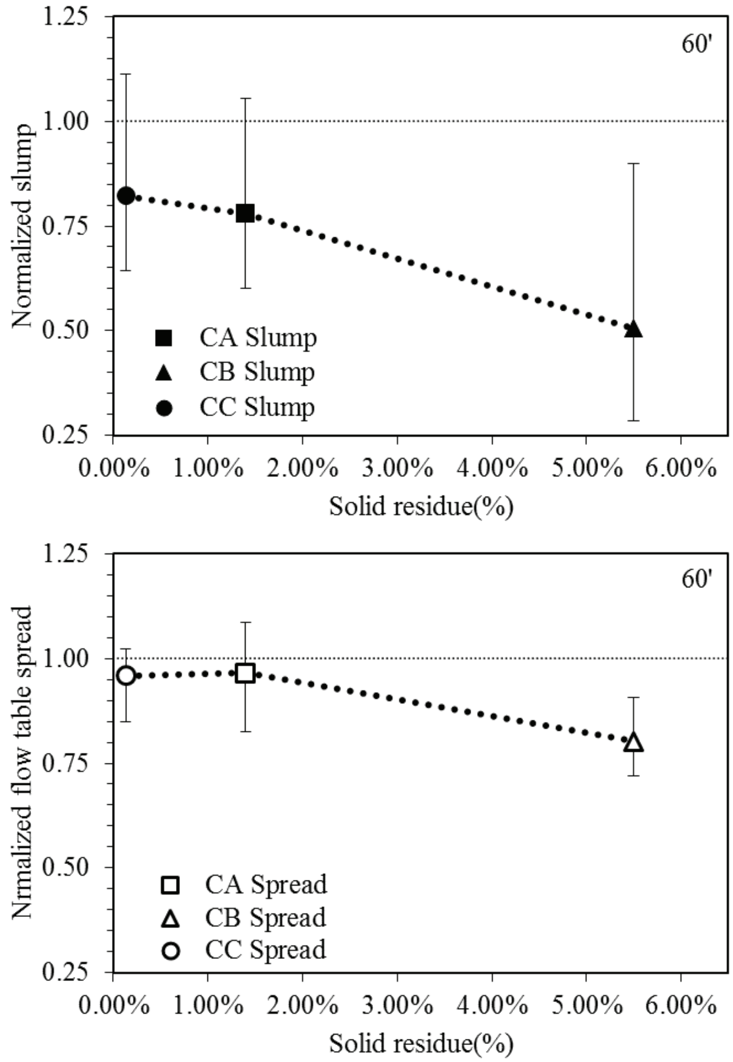


Figure 5- Normalized slump and flow table spread (respect to drinking water) vs. Solid residue at 60'

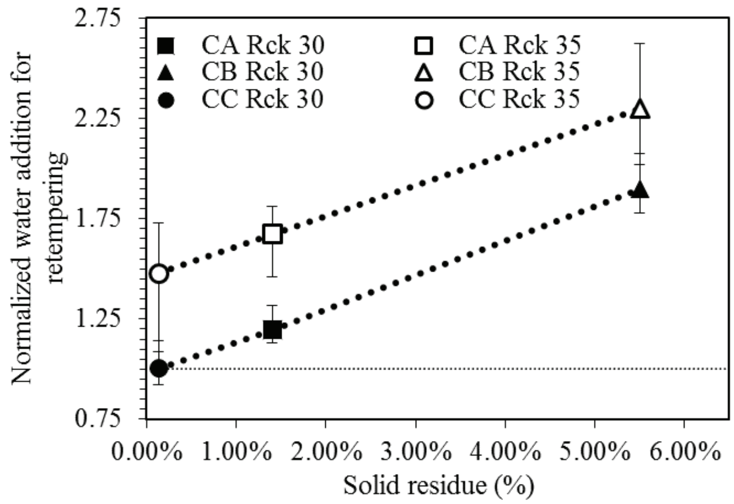


Figure 6-Normalized water addition (respect to drinking water) for retempering vs. solid residue at 60'

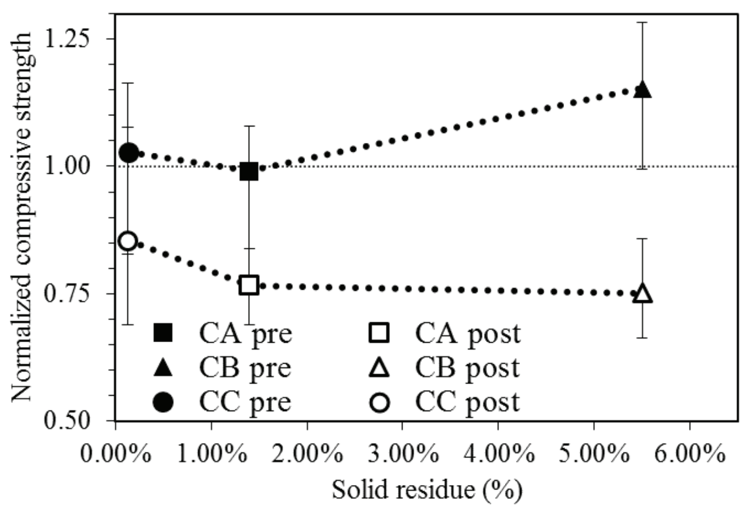


Figure 7- Normalized compressive strength (respect to drinking water) at 1 day (pre-retempering and post-retempering) vs. Solid residue

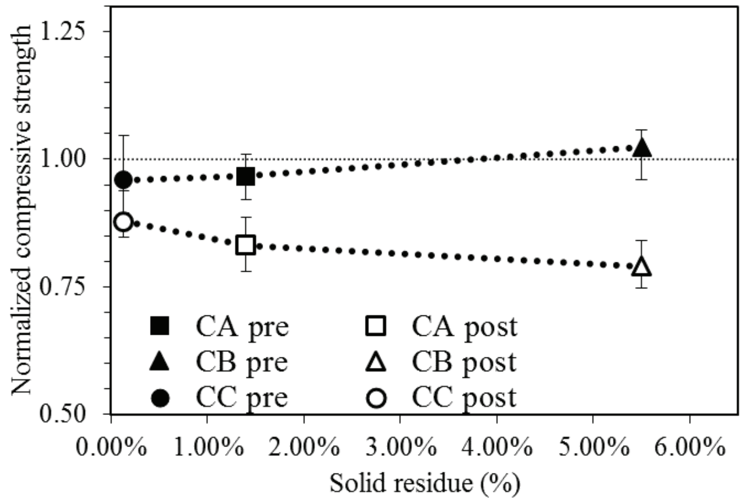


Figure 8- Normalized compressive strength (respect to drinking water) at 28 days (pre-retempering and post-retempering) vs. Solid residue

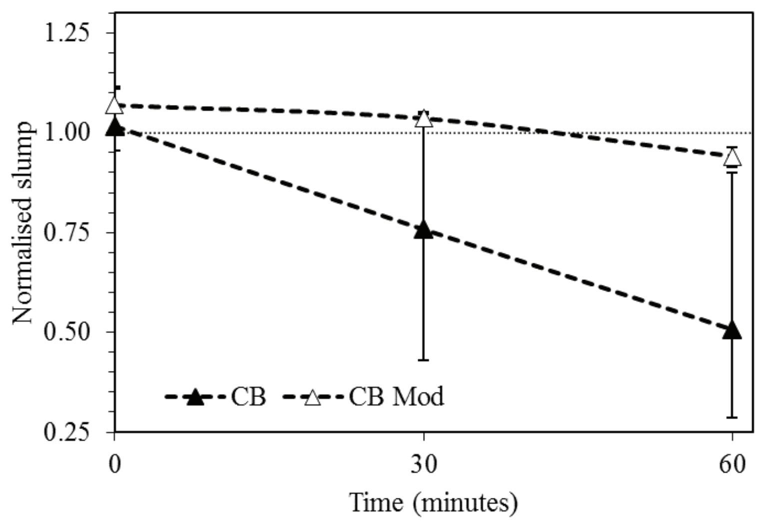


Figure 9- Normalized slump (respect to drinking water) vs. time – effect of the modification of the mix design

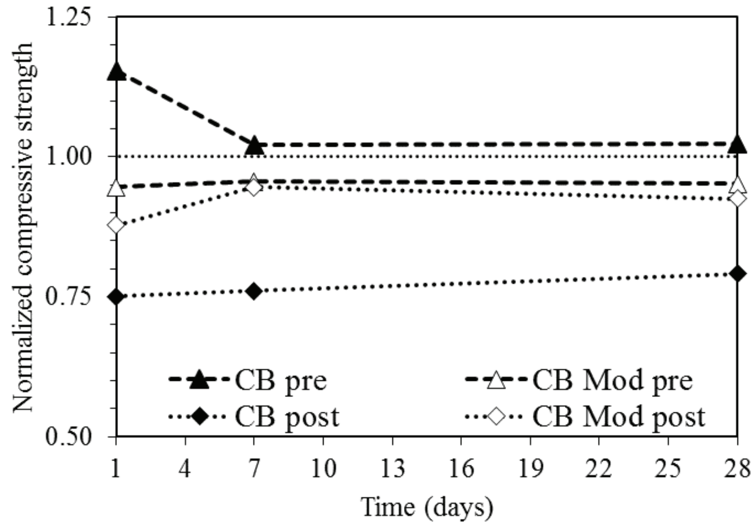


Figure 10- Normalized compressive strength (respect to drinking water) at 1, 7 and 28 days (pre and post retempering) – effect of the modification of the mix design

USE OF RECYCLED AGGREGATE AND EXPANDED CLAY FOR SELF-COMPACTING LIGHTWEIGHT AGGREGATE CONCRETES

Valeria Corinaldesi and Giacomo Moriconi

Synopsis: In this work, fiber reinforced SCLWAC (self-compacting lightweight aggregate concrete) mixtures were studied, in which synthetic fibers were used. Eight different SCLWAC mixtures were prepared, by employing either fly ash or silica fume as mineral addition. In particular, as aggregates, different combinations of fine and coarse expanded clay were tried, also partially replaced by either quartz sand or recycled aggregate coming from a recycling plant, in which rubble from concrete demolition are suitably treated. The SCLWACs were characterized at the fresh state by means of slump flow, V-funnel and L-box tests, and after hardening by means of compression, splitting tension and bending tests, as well as drying shrinkage measurements. Strength class of LC 45/50 was obtained by using synthetic macrofibres when the oven dry density of SCLWAC was about 1600 kg/m^3 [2700 lb/yd^3], while if the oven dry density of SCLWAC was lower than 1250 kg/m^3 [2100 lb/yd^3] a strength class of LC 25/28 was reached as well. Splitting tensile and flexural strength measured values were consistent with concrete strength class, while the elastic modulus was quite low with respect to normal weight self-compacting concrete (SCC). The post-cracking behaviour of SCLWAC resulted strongly improved by the addition of synthetic macrofibers, which proved to guarantee a softening behaviour in flexure. In conclusion, the addition of synthetic fibers allowed to design special concretes with excellent combination of mechanical and functional properties.

Keywords: expanded clay, fiber reinforced concrete, lightweight aggregate concrete, self-compacting concrete, polypropylene fibers, synthetic fibers, recycled aggregate concrete.