Use of recovered resources in construction industry: cellulose fibres from urban wastewater

~~Valorization of by-products in building materials:~~
~~cellulose fibres from urban wastewater~~

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Introduction: In water purification implants some products as cellulose fibres are commonly recovered. Cellulose fibres from toilet paper are collected into the sieves and they are a problem for wastewater treatment because of their insolubility in water (Ruiken *et al.*, 2013). Generally cellulose is used as a reinforcing component in a wide range of applications, from structural to biomedical (Huber *et al.*, 2012, 2016). Recently, the use of renewable natural cellulosic materials, such as wood, plants, and waste paper in the preparation of building materials has attracted significant interest for their advantageous properties, low environmental impact and low cost. In fact, building sector consumes the 40% of world total energy (Kockal, 2016). Concrete and mortars are the most important materials in buildings and the use of recovered materials can help to reduce waste and increase energy efficiency promoting the concept of sustainability (Dittenber and Gangarao, 2012, Senff *et al.*, 2018). The aim of this paper is to investigate the influence of recovered cellulosic fibres (added at the amount of 5%, 10%, 15% and 20% by mix volume) on the properties of hydraulic lime based mortars.

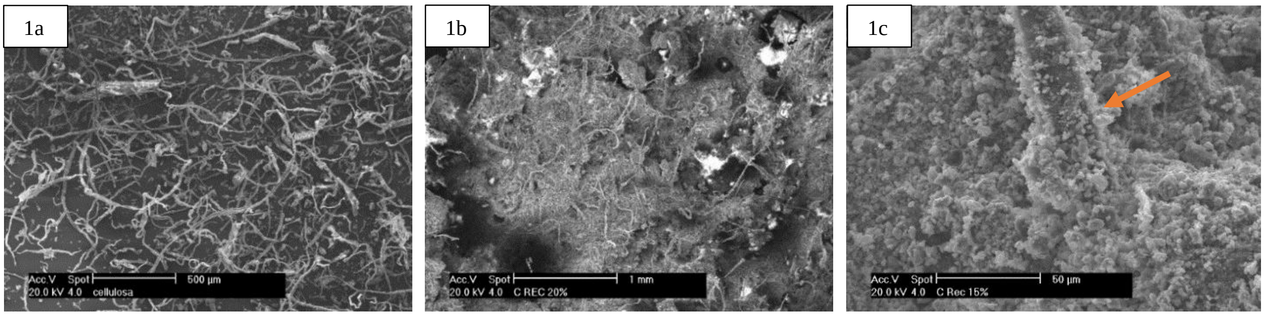

Figure 1 SEM Images of: a) Recovered Cellulose Fibres (CREC), b) mortar CREC 20%, c) Interfacial Transition Zone (ITZ) between mortar and fibre.

Materials and methods: Mortars were prepared mixing Natural Hydraulic Lime (NHL) 5 with calcareous sand (D_{max} = 400 µm) as aggregate (CA400), water and, if present, recovered cellulose fibres (CREC). Mixes have the same water-NLH and aggregate-NHL ratio equal to 0.65 and 3 by weight, respectively. The reference (REF) has 0% in volume of cellulose, the other specimens have an increasing amount of cellulose on the total volume of mix equal to 5%,10%,15% and 20%. Specimens are labelled as C REC5%, C REC10%, C REC15% and C REC20%, respectively. The mix design of different mortars is reported in Table 1, both cellulose and aggregate were added in Saturated Surface Dry (SSD) condition.

Table 1 Mix design

		Water	NHL5	CA400	CREC	Slump
Density	g/cm^3	1.00	2.65	2.65	0.75	-
Reference	g	294	467	1401	0	118 cm
CREC 5%	g	280	445	1335	22	117 cm
CREC 10%	g	267	424	1274	42	115 cm
CREC 15%	g	256	406	1218	60	111 cm
CREC 20%	g	245	389	1168	77	109 cm

Fresh behaviour of mortars in terms of workability was estimated by flow table test in accordance to standard (UNI EN 1015:3:2007). Density of mortars was calculated after 28 days of curing using weight and dimensions of the specimen. Morphological observations were conducted with SEM on fibres (Figure 1a) and mortars (Figure 1b). Mercury Intrusion

Porosimetry (MIP) was performed to measure the total porosity of mortars. Mechanical resistance in terms of flexural and compressive strengths were tested according to UNI EN 1015:11:2007. A simplified version of NORDEN TEST was performed to evaluate the Moisture Buffering Value (MBV).

Results and Discussion: All mortars have the same stiff workability (according to UNI EN 1015-6:2007). SEM observation of mortars confirms the good dispersion of cellulose fibres in the matrix (Figure 1b).
The increased volume of fibres implies a reduction in density (Figure 2a) and compressive strength (Figure 2b) from 46% to 100% compared to reference without fibres, owed to the lower density of cellulose and the increased volume of pores (Figure 2c). Despite this, flexural strengths (R_{fmax}) of mortars increase gradually with the increase of fibres percentage, up to 205% for CREC20% (1.05 MPa) (Figure 2b). This is due to the optimal Interfacial Transition Zone (ITZ) between cellulose fibres and the binder paste as shown in Figure 1c. The increase in cellulose implies a positive increase in MBV as shown in Figure 2d since the higher the porosity of mortars, the higher the moisture penetration depth (Giosuè *et al.*, 2017); moreover cellulose fibres, thanks to their molecular structure, tend to adsorb and release water vapour.

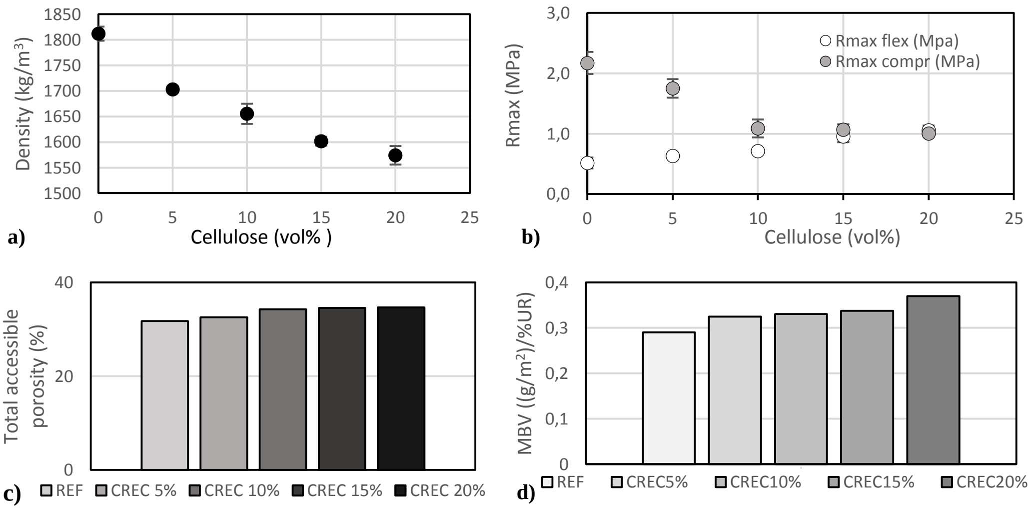

Figure 2 a) Correlation between density of different mortars and CREC's volume; b) Correlation between R_{max} (flexural and compressive) of different mortars and CREC's volume; c) Total accessible porosity of different mortars; d) MBV of different mortars. ~~cambiare le virgole con i punti~~

Conclusion: The inclusion of recovered cellulose fibres from urban wastewater, despite a reduction in compressive strengths, can lead to an improvement of the final performances of mortars, in terms of decreased density and increased flexural strength and MBV, together with a viable technological solution for waste management.

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