**How contact angle can help to utilize waste tires for construction industry**

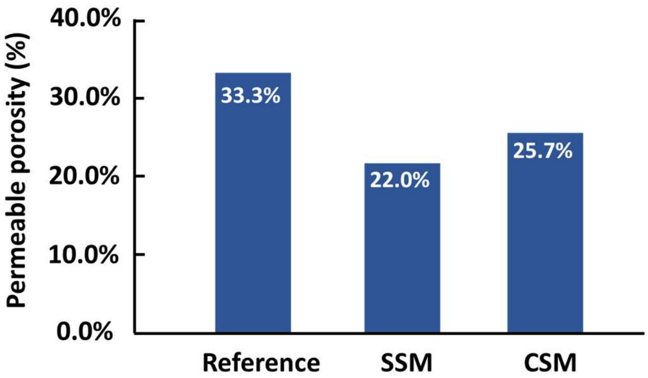

Compared to the conventional manufacturing, additive manufacturing (also known as 3D printing) has the following crucial advantages: higher fabrication speed, lower waste materials production, and a more flexible shape design. Extrusion-based methods are widely used for construction industry, in which the cement-based material is extruded by a nozzle followed by layer-by-layer deposition until the completion of the object. The composition of the materials plays a role in the final product quality such as extrudability, workability, buildability and inter-layer adhesion. Ground tire rubber can be applied for improving the physical and engineering properties of construction materials. So far researchers has often been focus on incorporating a single type of ground tire rubber as a partial substitute for fine mineral. To further improve the structure integrity and mechanical strength of the material, Valente and coworkers recently reported the modification of “printable” cement mortar by the total replacement of fine mineral aggregates with two rubber fillers from waste tires.

As test materials single-sized rubber filler mixture (SSM, 100% 0-1 mm rubber powder) and combined-sized rubber filler mixture (CSM, 25% 0-1 mm rubber powder and 75% 2-4 mm rubber granules) were mixed with cement to investigate the influence on the chemical-physical performances of the materials. The mix proportions of cementitious aggregates are shown in **Table 1**. From these mixtures slabs (220 mm × 160 mm × 55 mm) were fabricated by using 3D printing technology.

***Table 1.*** *Mix proportions of cementitious aggregates*

| Mix Design | Reference | SSM | CSM |
|---|---|---|---|
| Water/cement | 0.375 | 0.325 | 0.287 |
| Sand (kg/m$^3$) | 1100 | 0 | 0 |
| Rubber powder (kg/m$^3$) | 0 | 300 | 75 |
| Rubber granules (kg/m$^3$) | 0 | 0 | 240 |
| Additives (kg/m$^3$) | 152 | 152 | 152 |

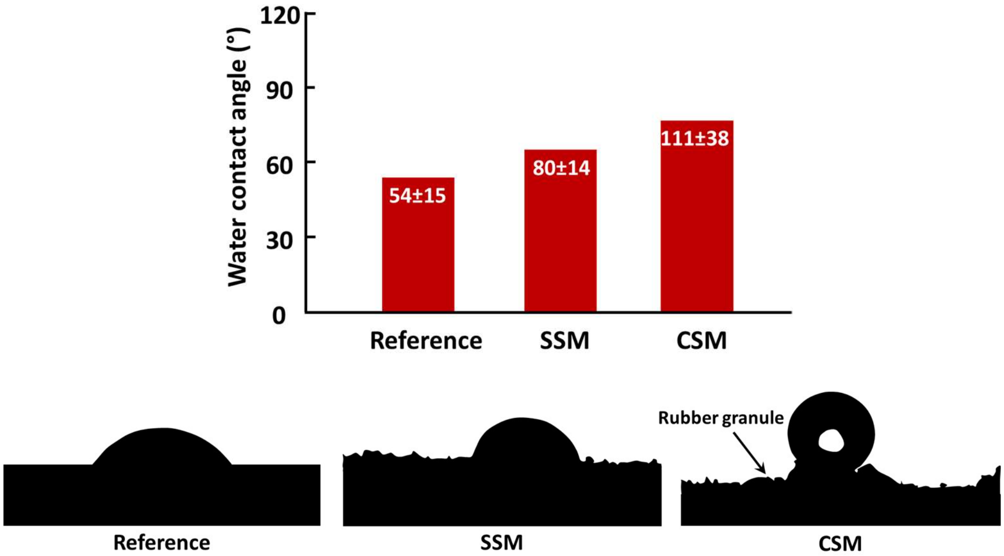
Taking sand-based mortar as a reference, they evaluated the inter-layer adhesion and structural defects of different mixtures. They observed a better uniformity of SSM and CSM compared to the reference mortar, meanwhile no defects were formed in SSM and CSM whereas inter-layer voids could be seen in the reference mortar. The reference mortar had a much higher porosity due to the usage of porous mineral aggregates (**Picture 1**). The viscoelastic property of rubber fillers could effectively hinder the cracks propagation. Notably, CSM had higher porosity than SSM which means the addition of rubber granules slightly increased the voids percentage




***Picture 1.*** *Permeable porosity (%) of three samples*

Furthermore, the researchers conducted wettability studies by measuring water contact angles with an optical contour analysis system. From the high-resolution images captured, SSM and CSM surfaces were much rougher than the reference mortar surface due to the addition of polymer aggregates, which increased the hydrophobicity of the materials. Likewise, the surface-water droplet interaction differed greatly in three samples—the reference sample produced faster water absorption and greater drop spreads on the surface when compared with SSM and CSM (**Picture 2**). SSM and CSM had higher water contact angles

(SSM 80° ± 14°; CSM 111° ± 38°) than the reference mortar (54° ± 15°) (the contact angles had a rather broad range due to surface inhomogeneities). The data in **Picture 2** also show the size effect on the wetting behavior of the material. Specifically, the addition of larger rubber granules made the CSM more hydrophobic than SSM with only rubber powder. Because the coarse rubber aggregates exposed a greater contact surface for the water drop, the water drop would keep more stable and undeformed on above surface.




***Picture 2.*** *Water contact angles and water drop-cement surface interaction of three samples*

Overall, two types of rubber fillers as substitutes for fine mineral aggregates in a cement-based material were applied, which is a useful and eco-sustainable approach for construction industry. This method effectively improved both the printability and performance durability of the materials. This work provides new insights on fabricating more eco-sustainable advanced cementitious aggregate from tire recycled rubber.

An optical contour analysis system OCA (DataPhysics Instruments GmbH, Germany) was used in this research.

For more information, please refer to the following article:

**Tire Recycled Rubber for More Eco-Sustainable Advanced Cementitious Aggregate**; Matteo Sambucci, Danilo Marini, Marco Valente; *Recycling* **2020***,* 5, 11; DOI: 10.3390/recycling5020011