DEVELOPMENT OF HEAVYWEIGHT CONCRETE FOR 3D PRINTING APPLICATIONS

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Radiation shielding is becoming of consideration due to increased radionuclide releases from numerous sources and environmental protection issues. In recent years, concrete 3D printing has been introduced as a promising technology for intelligent construction, providing several benefits of free-formwork, flexible design, high safety, low labour demand, and material saving. Therefore, digital fabrication of concrete can offer new structural possibilities, design of sophisticated shielding barriers, structural optimization as well as reduce the amount of the labour exposure in case of potential radiation or extreme working conditions.

The main objective of this study is to develop heavyweight concrete (3DPHWC) mixture formulations suitable for digital fabrication. To reach this goal natural aggregate was gradually replaced by heavyweight magnetite aggregate up to 100 vol.%.

A series of experiments were conducted to assess the fresh and hardened properties of newly developed mixes. In the first stage a set of tests related to fresh properties were performed including flow table, setting time, penetration, and uniaxial unconfined compression tests. Afterwards, cast and printed specimens were prepared towards determination of mechanical and radiation shielding performance. Following the 3D printing of the hollow wall segments, several other parameters, such as shape stability employing the image-based correlation test, and porosity characteristics, were examined.

As an outcome set of heavyweight concrete mixes suitable for 3D printing were developed. All mixes were found to meet the printing requirements only with small modifications in superplasticizer dosage. Despite the higher self-weight of material, the layer's strength and stiffness were sufficient to sustain the dead load during printing. Slight improvement of mechanical performance in concrete was found as a result of magnetite aggregate inclusion. Replacement of the river sand with magnetite aggregate leads to considerable improvements in the shielding performance against radiation. In both cast and printed specimens, there are no noticeable differences between attenuation performance against gamma-rays.

Fig. 1: Printing of the HWC element (left) and quality of 3D printed column after hardening (right).

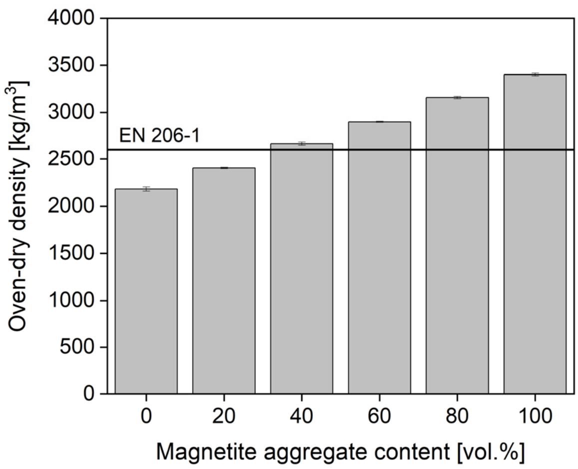

Fig. 2: Oven-dry density of the developed 3D printable mixture formulations with line indicator presenting the qualification of concrete as heavyweight.

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