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PROPORTIONING OF OIL SHALE ASH FOR SUSTAINABLE 3D PRINTABLE MORTARS

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Abstract – To achieve optimal strength and printability, mortars used in 3D printing typically contain high proportions of cement and other fine-grained powders. Consequently, the majority of mixtures used in 3D printing have high carbon footprint. Hence, there arises a critical need to study alternative supplementary cementitious materials aimed at reducing the environmental impact of mortars used in 3D printing. The use of oil shale ash as a partial substitute for cement not only addresses this issue but also presents an opportunity to repurpose waste from power plants in the Baltic states, where oil shale is intensively utilized. In this study, the influence on mechanical properties and durability of cement-based mortars was evaluated by substituting cement with oil shale ash in varying quantities. Specifically, 0 % to 40 % of cement mass was replaced with oil shale ash. Life cycle assessment (LCA) was performed for each mixture. By analyzing the material properties alongside the environmental impact for each mixture, the optimal percentage of substitute was determined. For the determination of the mechanical properties of each mixture, compressive and flexural strength tests were conducted on 3D printed samples in various directions, as well as on cast samples. To assess the durability of each mixture, freeze-thaw tests were performed on both 3D printed and cast samples. From the obtained results, we developed an algorithm that chooses the optimal mixture proportioning. Depending on material performance requirements set in the beginning, this algorithm gives the exact proportions of oil-shale ash and cement for the mixture by taking into account both desired material properties and carbon dioxide emissions. As a result, an environmentally friendly cement-based mixture is obtained without losing the desired properties. By using this algorithm, it is possible to create a mortar with properties comparable to concrete with strength class C30/37 while reducing carbon emissions by 15 % to 30 %.

Keywords – Additive manufacturing; cement-based composite; Life Cycle Assessment; oil shale ash; sustainability; waste materials

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