Abstract

The growth of the world population causes many challenges. Increased demand for food and various materials is among the biggest challenges. The production of both generates huge amounts of waste and is a major source of greenhouse gas emissions. One of the largest sources of carbon dioxide emissions is the production of cement clinker, which is a key component of concrete. As the demand for concrete increases each year, the term green concrete has emerged in recent years to reduce both waste and greenhouse gas emissions associated with concrete production. Green concrete is a material in which part of the cement clinker or natural aggregate is replaced with secondary raw material.

To determine whether clinker and natural aggregate can be simultaneously replaced in concrete with two different waste materials, we prepared cement composites with biochar, recycled PET plastic, and a composite containing both biochar and recycled PET plastic. In the first part of the dissertation, we assessed the mechanical and physicochemical properties of the prepared mortars in accordance with the relevant standards. We found that replacing 5 vol.% of the cement clinker with biochar improved the mechanical and some physicochemical properties. Replacing 5 vol.% of the natural aggregate with PET plastic led to a deterioration of physical properties. The mortar in which 5 vol.% of the cement clinker was replaced with biochar and 5 vol.% of the natural aggregate with PET plastic exhibited the lowest thermal conductivity. To assess durability, the mortars were also exposed to freeze–thaw cycles, a sulphate-ion solution, and a NaOH solution at 60 °C. These conditions were selected to simulate those that mortars may encounter in natural environments. The mortar containing 5 vol.% PET plastic showed the lowest resistance, whereas the control mortar with no biochar and PET plastic demonstrated the highest resistance.

When exposed to various conditions, particles of secondary raw material can detach from the composite surface. Also, some substances can leach out from those particles and have a toxic impact on the ecosystem. We determined the ecotoxicological properties of the mortar leachates using ecotoxicological tests and found that their impact on organisms was low.

In the second part of the dissertation, the LCA of all the concretes was performed. From the results of the LCA analysis, we found that replacing 5 vol.% of the cement clinker with biochar resulted in a decrease in the global warming impact. Concrete with 5 vol.% biochar as a cement clinker replacement therefore had a lower carbon footprint than conventional concrete. Concrete in which 5 vol.% of the natural aggregate was replaced by PET plastic had a higher carbon footprint than conventional concrete.

Keywords: biochar, concrete, ecotoxicity, green concrete, life cycle assessment, PET plastic waste, solid waste