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RESEARCH ARTICLE

Comparative study of fly ash and rice husk ash as cement replacement in pervious concrete: mechanical characteristics and sustainability analysis

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ABSTRACT

Pervious concrete is a special type of concrete consisting of cement, coarse aggregate and water. Cement is a widely used raw material for construction including pervious concrete and had led to the release of huge amounts of CO_2 to the environment. Therefore, there is lot of research interest in finding supplementary cementitious materials. The present study examined and compared the feasibility of using industrial waste fly ash (FA) and agricultural waste rice husk ash (RHA) for sustainable pervious concrete production. An experimental program was performed with substitution of FA and RHA contents of 5%, 10%, 15% and 20% as cement replacement and water to binder ratio of 0.3, 0.35, 0.4 and 0.45. The characteristics of pervious concrete and sustainability analysis were compared for both FA and RHA replacement with control concrete mortar. The results showed that both FA and RHA have a negative effect on permeability. The compressive strength was optimum for FA content lies between 10% and 15% replacement level and RHA content of 5% replacement level. Furthermore, the utilisation of FA and RHA decreased production cost, the total embodied energy and carbon emission, resulting in cost-effective and eco-friendly pervious concrete.

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Pervious concrete; fly ash; rice husk ash; cement

1. Introduction

Pervious concrete is a composite material comprising of cement, coarse aggregate and water. It is highly porous and so, is an environment-friendly material that is in great demand in Europe, Japan and North America for the last four decades (Aamer Rafique Bhutta *et al.* 2013). Pervious concrete is used in many applications like parking lots where there is a need for draining and permeating water-reducing surface runoff and thereby improve the environmental performance of the existing site such as maintain the water quality, reduce flooding around the site, increase base flow and reservation of parking areas for the property owner. It is also beneficial as it helps maintain a quiet environment by absorbing the noise of vehicles and also prevent flash of surface and does not glisten at night improving the comfort and safety of drivers. Moreover, the pores of pervious concrete can cumulate heat, adjusting the humidity and temperature of the earth's surface (Yang and Jiang 2003).

At the same time, cement is a widely used raw material for construction and had led to the release of huge amounts of CO_2 to the environment. It is a pressing issue in recent years challenging efforts for a cleaner environment (Poorveekan *et al.* 2021). On the other hand, after COVID 19 pandemic, there is a severe material shortage for the construction industry especially cement in Sri Lanka due to import restrictions. To overcome this issue, researchers have been focusing on finding supplementary cementitious materials. Some of the most regularly used supplementary cementitious materials are granulated blast furnace slag (GBFS) (Özbay *et al.* 2016), fly ash (Hemalatha and Ramaswamy 2017), rice husk ash (RHA) (Fapohunda *et al.* 2017, Mayooran *et al.* 2017, Seevaratnam *et al.* 2020), volcanic pozzolanas (Robayo-Salazar and Mejía de Gutiérrez 2018), silica fume (Khan and Siddique 2011), metakaolin (Saand *et al.* 2016), limestone (Panesar and Zhang 2020) and eggshell powder (Sathiparan 2021). Generally, the use of particular supplementary cementitious material depends on several factors such as local availability, quality and transportation cost. In Sri Lanka (present study area), except rice husk ash, fly ash and limestone, other materials are not readily available or in very limited supply to satisfy the demand. On the other hand, limestone is not geographically distributed and only available in the northern part of the country and transportation of it over a long distance could compensate for the environmental benefits of using it as supplementary cementitious material.

There are several studies on fly ash as supplementary cementitious materials in pervious concrete, and Table 1 summarises the recent studies conducted on fly ash incorporated pervious concrete. Al-sallami *et al.* (2020) investigated the effect of using fly ash and epoxy as partial replacement for cement in pervious concrete. In addition, the effect of sand as a partial replacement for gravel and gravel to cement ratio was also evaluated. Results showed that porosity was marginally decreased while compressive strength significantly increased for 30% fly ash replacement for cement. However, the increment in porosity and reduction in compressive strength were observed for 50% fly as replacement for cement.

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