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Sustainable production of cement masonry blocks with the combined use of fly ash and quarry waste

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ABSTRACT

Cement-sand block is a primary construction material used for masonry house units. River sand and cement are the two main ingredients in cement block construction; however, cement is notoriously unfriendly to the environment due to excessive energy consumption during cement manufacture and considerable CO_2 and other greenhouse gas emissions. Overusing river sand has several adverse effects on the environment and society, including a deepening of the riverbed, a decline in the water table, and the extinction of freshwater aquatic life. Therefore, finding substitutes for cement and river sand has received much attention in recent years. It would be beneficial to use fly ash and quarry refuse for making masonry blocks since it would use less energy and cause less environmental damage. The present study emphasizes the combined use of quarry waste (100% substitute for river sand) and fly ash (0, 10, 20, 30 and 40% substitute for cement) for sustainable masonry block production. The physical, mechanical, and durability properties of cement blocks made using fly ash and quarry waste underwent a thorough investigation. Results showed that, even though the compressive strength and impact strength of masonry blocks decreased with fly ash content, the strength of masonry blocks with quarry waste and 40% fly ash was higher than that of conventional masonry blocks. The substitution of fly ash for cement potentially increased the alkaline and acid resistance and also improved the thermal performance. Also, the replacement of fly ash for cement in the masonry blocks significantly reduced the total cost, embodied energy and CO_2 emission. It can be inferred from the study that using quarry waste as a full river sand substitute and fly ash as a partial cement substitute in masonry blocks is a cost-effective and sustainable method.

1. Introduction

Cement-sand block is commonly used for masonry wall construction material in housing units [1]. Typical cement sand blocks constitute approximately 10 to 20% cement and 80 to 90% river sand or natural sand [2]. Cement sand blocks possess advantages of being produced with desirable strength, being manufactured locally, having a pleasing aesthetic appearance even without surface finishing, exhibiting excellent resistance against fire and flood, and minimal need for maintenance [3]. However, the manufacturing of cement-sand blocks is not eco-friendly as the production of cement and excavation of river sand lead to a lot of adverse environmental consequences. In the recent years, there has been extensive focus on using supplementary cementing materials (SCMs) such as silica fume, fly ash, limestone, metakaolin, blast furnace slag, rice husk ash, etc., to substitute cement partially or fully [4–11]. Also, river sand has been substituted with agricultural waste [12–16], industrial waste [17,18], construction and demolition waste [19], lateritic soil [20–22], offshore sand [23], quarry dust [24], etc.

According to the recent trend, using fly ash as a cement substitute in construction materials has increased considerably [25]. Fly ash has several advantages, such as:

- Hard and round-shaped particles of fly ash improve workability of wet mix with minimum water [26].
- Finer and round-shaped fly ash particles mix well with cement and generate smooth cement paste, which provides better bonding between binding gel and aggregates [27,28].
- Fly ash reacts with $Ca(OH)_2$ (calcium hydroxide, which is discharged through the hydration process of cement reacting with water) and produces calcium silicate hydrate ($CaO.SiO_2.H_2O$), which provides additional strength to mortar [29].
- Substituting cement with fly ash significantly reduces the embodied energy and CO_2 emission of concrete mix or cement paste [30–32].

Published literature show that fly ash as a cement substitute delivers good mechanical properties to cement-based materials such as concrete, cement blocks, stabilized earth blocks and binding mortar [6,7,33–35]. The spherical shape, finer size and smooth texture of the fly ash improve

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