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Performance of coconut coir reinforced hydraulic cement mortar for surface plastering application

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HIGHLIGHTS

- Possibility of coconut coir for surface mortar reinforcement was investigated.
- Coconut coir in the mortar tends to slightly reduce bulk and dry density.
- Water absorption, porosity, sorptivity were increased with coconut coir fraction.
- The strength of mortar improved with additions of coconut coir up to 0.5% fraction.
- Presence of coconut coir improve post-crack behavior of mortar.

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ABSTRACT

This study was to investigate the effect of coconut coir on the strength and durability properties of cement-lime surface plaster mortar. The purpose of adding coconut coir into the mortar was due to coconut coir had a capacity in controlling cracking in the mortar. In this study, total 115 samples were prepared which were 100 cubes (150 mm × 150 mm × 150 mm) and 15 beam prisms (100 mm × 100 mm × 500 mm). Testing was included; water absorption, porosity, sorption rate for physical properties; acid attack resistance, alkaline attack resistance for durability properties; compression and flexural bending for strength properties. The samples were tested with mortar containing 0.125%, 0.25%, 0.50% and 0.75% of coconut coir. The percentage of coconut coir fraction was calculated based on the cement, lime, sand mix by mass. Test results show that, although compressive and flexural bending strength are not improving, but post crack properties such as ductility, residual strength, and toughness are increased with higher coconut coir fraction in the matrix.

1. Introduction

Masonry is brittle materials that are stronger in terms of compression, while weaker in terms of shear and flexural bending. Because of masonry is a quasi-brittle material and it has not any significant post crack strength, once a crack initiates, the masonry experiences a sudden failure [1].

Based on post-earthquake damage surveys [2–4], the major types of masonry failure modes have been identified as in-plane diagonal cracking, out-of-plane wall collapse, separation of adjacent walls, differential settlement, torsional stress, and cracking due to stress concentrations around openings.

There are various reinforcement/retrofitting technologies had been developed. They can mainly categories as follows;

- Restoration: Surface treatment using shotcrete, Ferro cement, Stitching and grout/epoxy injection, re-pointing with ordinary Portland cement, install/upgrade of wall/diaphragm connection [5–8].
- External reinforcement: Bamboo with the horizontal wire band, Seismic Wallpaper, polymer plate bonding, jacketing, near surface mounted reinforcement [9–11].
- Post-tensioning: Rubber tires [12], Steel bars [13].
- Mesh type reinforcement: Steel mesh [14], Polymer mesh [15], Polypropylene band [16], Bamboo mesh [17], Plastic carrier bag mesh [18].

Research done on this retrofitting method for masonry structures shows that these methods have improved the seismic behavior of the masonry structures. However, suitability of any retrofitting technique should guarantee not only its efficiency in terms of improvement of the seismic behavior of the masonry

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structure but also the procedure for retrofitting techniques for masonry buildings should be as simple as possible to be applicable in developing countries [19].

Therefore, In the last few years, more research focused toward the application of Fibre Reinforced Polymer materials added surface mortar as strengthening technic for masonry retrofitting. Due to their easy application and their favorable structural performances, it is a possible solution for retrofitting of masonry structures and especially low seismic region like SriLanka. Generally, unreinforced cementitious matrices as a surface plaster for masonry only improve the appears, but not in structural behavior. However, an inclusion of fibres in cementitious matrices is an improvement in the post-crack behavior. A wide variety of fibres has been proposed by the researchers such as steel, glass, polypropylene, etc. [20,21].

The other side, SriLanka as an agricultural country has many source natural fibres, such as coconut coir, banana fibre, sugarcane pulp, pineapple leaf. Most parts of the SriLanka, natural fibres such as coconut coir is available as waste. So, here an attempt has been made to investigate the possibility of reusing coconut coir waste for surface mortar reinforcement. Past studies have reported several benefits of the incorporation of coconut fibres into concrete, cement paste, cement: sand mix [22–24]. Coconut fibre in these materials can enhance the ductility, flexural toughness, and energy absorption capacity. A review of past studies indicates that in spite of numerous researches done on coconut coir reinforced concrete, little attention has been paid to evaluate the durability and mechanical behavior of coconut coir reinforced cement-lime-sand mortar, which is commonly used for the surface plastering work of masonry. There is little previous research about the effect of coconut coir, incorporated into surface plaster mortars [23]. But, study on durability and strength behavior coconut coir added surface plastering mortar, still scarce. Therefore, this study was aimed at understanding of the coconut coir effect on durability and strength of surface plastering mortar by experimental programs.

2. Material and methods

2.1. Materials used

The aim of the experimental program was to investigate the mechanical and durability properties of coconut coir added mortar, which can be used as surface plaster. In this study, following materials used for mortar preparation;

- Cement: Ordinary Portland cement (OPC) as described in SriLanka standard SS855 [25].
- Sand: Sand is the major constituent of the plaster mortar mix. River sand was sieved to obtain the size range of 0.6 mm to 4.75 mm. The sand is free from organic matter, such as dirt, leaves, roots and humus.
- Lime: Commercial grade hydrated builder's lime.
- Coconut coir: Locally available untreated coir, which average length is around 24 mm and diameter is around 20 μm. The geometrical properties of the coconut coir are shown in Fig. 1.

Sieve analysis and chemical composition analysis were carried out for each material, which is used for mortar. Particle size distribution curves of the materials used for the preparation of mortar are shown in Fig. 2. Physical properties and chemical composition are summarized in Table 1.

2.2. Mix design

The selected mortar, cement: lime: sand ratio was 1:2:8 by volume, which is classified as a mortar designation (iv) in British standards. Volume proportions were converted into weight for avoiding inaccurate measurement. Mortar mix was incorporated with coconut coir fractions of 0.125%, 0.25%, 0.5% and 0.75%. The percentage of coconut coir fraction was calculated based on the cement, lime, sand mix by mass.

For mortar mix preparation, the slump was previously set to 160 mm. Table 2 summarized the material mix and amount of water required for achieving that slump value. When a higher percentage of coconut coir was used in the mortar mix, the amount of water required increased dramatically. Past research results revealed that an increase in fibre fractions significantly decreased the workability of cement mortar [26,27]. In this experimental program, the slump was previously set; the addition of coconut coir involved an increase in the required amount of water.

2.3. Specimens preparation

Cubes with dimension $150 \times 150 \times 150\ mm^3$ and beam prisms $100 \times 100 \times 500\ mm^3$ were prepared for control mortar and coconut coir added mortar. The three cubes were used to determine the density, water absorption rate,

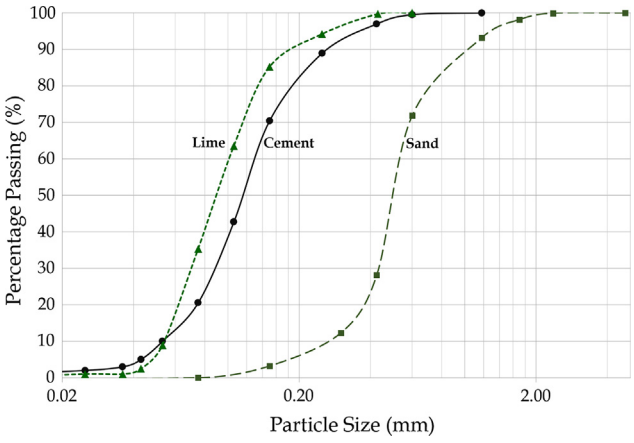

Fig. 2. Sieve analysis data for materials used.

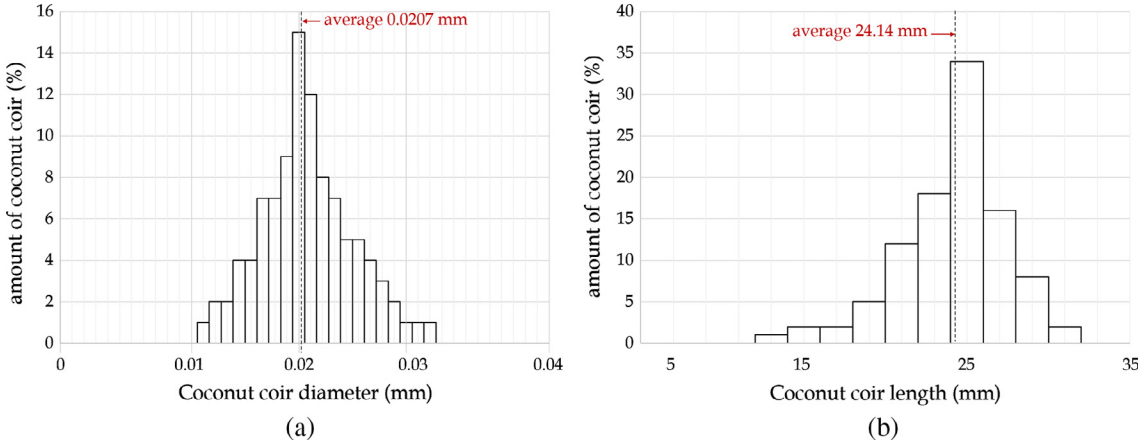

Fig. 1. Geometrical properties of the coconut coir (a) length distribution; (b) diameter distribution.