Feasibility of Cement Mortar System with Textile Waste

D.P.D.U. Gunathilaka
Department of Civil Engineering,
Faculty of Engineering,
University of Jaffna,
Ariviyal Nagar, Killinochchi
44000, Sri Lanka
dugi9687@gmail.com

C.S. Jayathilaka
Department of Civil Engineering,
Faculty of Engineering,
University of Jaffna,
Ariviyal Nagar, Killinochchi
44000, Sri Lanka
chamarasjt@gmail.com

H.M.C.C. Somarathna
Department of Civil Engineering,
Faculty of Engineering,
University of Jaffna,
Ariviyal Nagar, Killinochchi
44000, Sri Lanka
hmccsomarathna@eng.jfn.ac.lk

***Abstract*— Fabric wastes are commonly burned or recycled into practical goods, they do not stay usable long enough before they return to being wastes once again. Massive textile waste generation due to the high demand for textile products, textile waste management was considered as one of the critical areas that need situational awareness. Hence, implementing textile waste as part of building material is most welcome, especially in this era when waste recycling is the most discussed issue worldwide. The feasibility of textile waste used in mortar to improve the performance of traditional mortar was studied in this study. Cotton rich and Polyester rich textile fibres were used to prepare Textile Fibre Reinforced Mortar (TFRM) by varying the textile content from 0% to 25% with a 5% increment by the weight of cement. The addition of textile waste caused a considerable reduction in dry and wet density while increasing the capacity of water absorption. TFRM with 5% of textile fibre significantly improved the abovementioned properties together reducing its brittleness, and Cotton fibre showed more strength gain than Polyester fibre mixed TFRM.**

Keywords—Textile waste, Textile fibre reinforced mortar, Waste management, Sustainability.

I. Introduction

Environmental protection is one of the most serious issues at the present. Currently, a massive amount of textile waste is generated worldwide due to the growth of the population and fashion industries. In Sri Lanka, textile production is one of the huge industries for local uses and exports. Garment production annually consumes 19,000 to 38,000 tons of fabric, and 10-20 % of textile waste from total waste is generated which creates a severe environmental impact. And the composition of textile waste is recorded as 7344 tons among municipal waste collection per annum [1]. Expansion of waste generates rate, and disposal methods such as open dumping and incineration, have become major environmental issues [2]. Dumping is causing to leachate of toxic material to the soil and incinerator flue gases emit dioxins, heavy metal, acidic gases and dust [3]. Although textile wastes are commonly recycled into practical goods, they do not stay functional long enough before they return to being wastes once again. This is a big drawback since the price of raw materials such as cotton and the cost of processing textiles are very expensive. Therefore, recycling and reusing instead of disposal of textile waste materials are essential environmental approaches for a sustainable future [4].

The use of various fibre in cement composites has improved significantly due to the improvement of mechanical properties like tensile strength, compressive strength, and toughness [5]. And different types and forms of fibre have been used. Many of the available studies have focused on the use of fibres and fillers such as Nylon fibre, Wool fibre, denim powder [5]–[7]. Only a few studies have focused on the use of textile fibre from widely available cotton rich and polyester rich textile waste. Hence, these fibre also can be used as a reinforcing material to enhance the performance of traditional mortar and, in-depth studies in this area are needed to investigate its feasibility. Difference types of textile materials are available and can be categorized into two groups such as natural (cotton, wool, linen) and synthetic (rayon, nylon). Different types of textiles contain varying properties like different tensile strength, ultimate elongation, young's modulus, and specific gravity depending on the composition and the origin of the material. Additionally, some synthetic fibre such as nylon is a very common material that is used in the present day, because of their low cost and improved mechanical properties [5].

In the present study, the feasibility of the addition of waste textile as fibres in cement mortar composites was studied, which aimed to enhance the performance of traditional mortar. The proposed

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technique will be able to minimize the disposal of the textile wastes and reuse them, and subsequently, enhancement in the mechanical properties of cement mortar for a sustainable future and beneficial for environment friendly surround worldwide by eliminating the pollution threats exposed by the process. As a result, incorporating waste materials into construction and building materials is a novel way of ensuring sustainable consumption, which is a key goal highlighted by the United Nations Development Programme due to the massive consumption of natural resources and the environment, which has negative consequences for the planet [8]–[9].

II. MATERALS AND METHODS

A. Materials

Textile fibre recovered from pre-consumer textile waste was used for the preparation of test specimens. Textile waste material were collected from MAS Kreeda Shadeline, Uva Gamunupura, Mapakadawawe, Mahiyangana, Sri Lanka. Collected textile waste comprised cotton-rich textile and polyester rich textile representing a mix of natural and synthetic fibres. The textile fibre was obtained using a shedder machine by placing said textile waste, and particles passed through 4.75 mm and retained on 1.70 mm were used as shown in Fig.1. 4.75 mm downgraded river sand that is free from clay, loam, dirt and any organic or chemical matters was used as fine aggregates. Sieve analysis was conducted to determine the gradation of fine aggregates used for Textile Fibre Reinforced Mortar (TFRM). The particle size distribution of fine aggregates showed a distribution within the acceptable range according to the ASTM C33 standard. The average bulk density of fine aggregate was 1672.8 kgm^{-3}, whereas the relative density of fine aggregate was 2.517. Commercially available ordinary Portland cement with the strength class of 42.5N that is conformed under SLS 107:2008 was used.

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Fig. 1. Waste textile (Cotton) fibre.

B. Preparation of Textile Fibre Reinforced Mortar Specimens

The control mortar specimens were prepared using the cement: aggregate ratio of 1:5 and cement: water ratio of 0.5. Other test specimens were prepared by adding the textile fibre according to cement weight, and the addition was varied from 0-25% with 5% intervals. Two types of textile were used which are cotton rich and polyester rich. 50 × 50 × 50 mm cube specimens were prepared adhering to ASTM C109/109M to investigate the behaviour of TFRM as discussed in the nest section.

C. Investigation of the Characteristic of Textile Fibre Reinforced Mortar

Hardened test specimens cured for 28 days were used to determine the densities, and the determination of dry bulk density was carried out according to BSI - BS EN 1015-10. The compressive strength of TFRM was evaluated at three ages (i.e. 3, 7 and 28 days after casting) according to ASTM C109/C109M standards. Six specimens were used to determine each characteristic.

III. RESULTS AND DISCUSIION

A. Bulk Density

The density of the hardened mortar specimens was determined under dry and wet conditions after 28 days of curing. The dry and wet density of reference mortar was 1810.21 kgm^{-3} and 2040.88 kgm^{-3} respectively and the density variation with the textile fibre content is shown in Fig. 2, and Fig. 3 for each dry and wet conditions respectively. Fig.2 clearly shows that the dry density of TFRM is reduced as the percentage of textile increases. The addition of 25% textile caused a 20% reduction in density. The main reason was when the percentage of textile increased it replace some extent of fine aggregates and it lead to reduce the dry density. Because fine aggregates were replaced by low-density material. According to incremental analysis, the density reduction of polyester added TFRM was higher than, the density reduction of cotton added TFRM. The bulk density of polyester was lower than cotton, and hence for a particular textile percentage polyester occupies more volume than cotton. Therefore, more aggregates were replaced by polyester fibre causing higher density reduction compared with cotton fibre added TFRM.

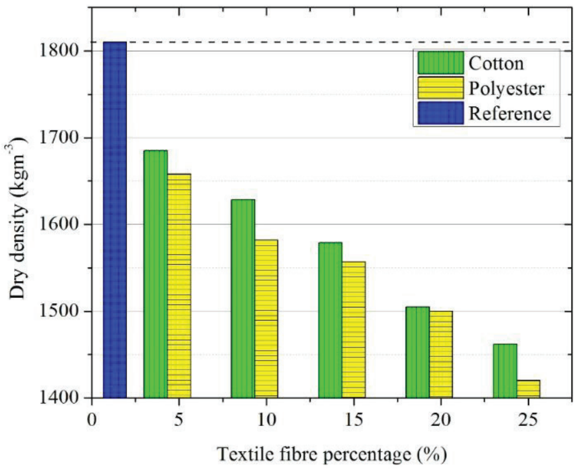

Fig. 2. Variation of dry density

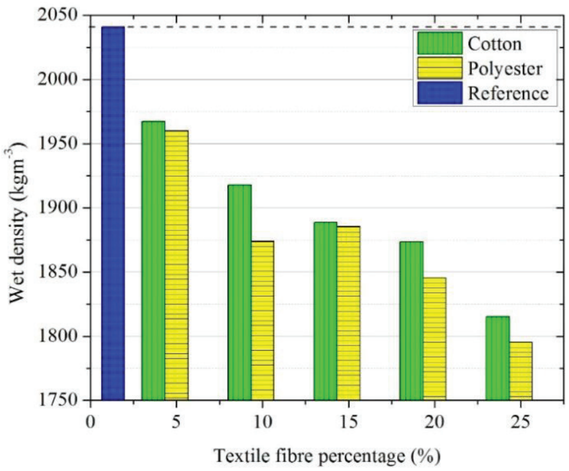

Fig. 3. Variation of wet density

B. Compressive Strength

1) 3rd-day strength: Fig. 4 shows the variation of 3rd day compressive strength with varying textile percentages. Significant enhancement of the 3rd day compressive strength was observed with the addition of textile fibre for both textile types and strength enhancement was gradually reduced with the increasing content of textile fibre. Compressive strength of cotton fibre added TFRM showed higher strength compared to reference mortar at each fibre level, while the strength of polyester rich fibre added TFRM was below the reference mortar when the fibre content is above 20%. 61.7% and 104.0% maximum strength enhancements were observed for cotton fibre and polyester fibre respectively, with 5% of fibre addition. At each fibre level, cotton fibre added TFRM showed a higher compressive strength value compared to polyester fibre added TFRM, and this was caused by the high tensile strength of cotton textile compared to polyester textile. In addition to the compressive strength values, strength/density was compared with the control mortar mix since TFRM showed lower densities compared to the control mix. All variations of TFRM with cotton fibre showed higher strength/density values compared to the value of the control mix. Though the compressive strength of TFRM with the 15% of polyester fibre is less than the compressive strength of mortar, the strength/density value was higher than the control mix as shown in Fig 5.

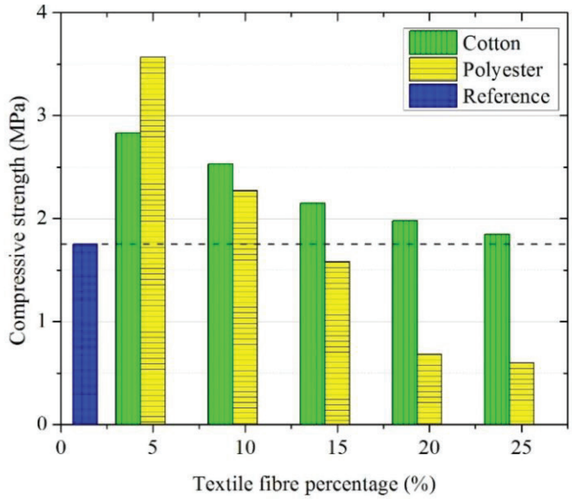

Fig. 4. 3rd-day compresive strength

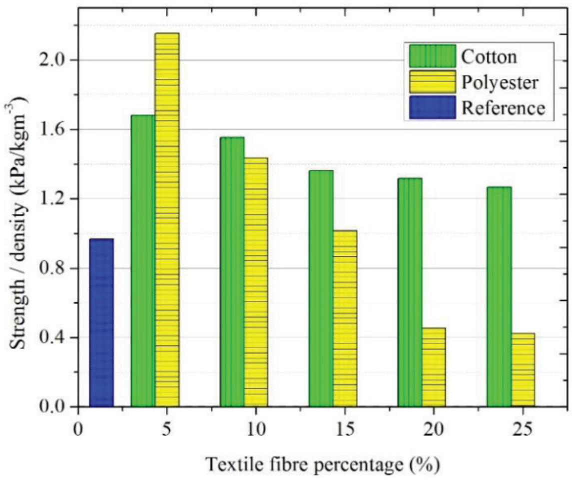

Fig. 5. Variation of strength/density on 3rd day

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2) 7^{th}-day strength: Similar to the 3^{rd}-day compressive strength, higher fibre contents resulted in a decrement of the 7^{th} day compressive strength (Fig.6). 5% of cotton fibre added TFRM showed the highest compressive strength that is 46% compared to the reference mortar. Only 5% addition showed an increment in the cotton fibre added TFRM, while the nearly equal compressive strength was shown for 5% and 10% polyester fibre added TFRM compared to the control mortar. The addition of 25% fibre resulted in 37.9% and 68.1% strength reductions in cotton fibre and polyester fibre added TFRM respectively. Except for the 10% of fibre addition, Cotton fibre added TFRM showed higher compressive strength values than polyester fibre added TFRM. Though the 10% fibre addition reduced the compressive strength of TFRM, the strength/density values were similar to the value of the control mix (Fig. 7). These findings highlighted the positive impact of the addition of textile fibre that holds acceptable strength while reducing the density.

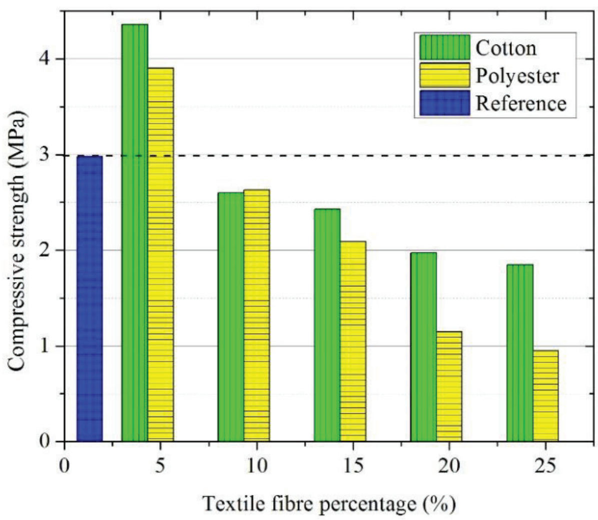

Fig. 6. 7^{th}-day compresive strength.

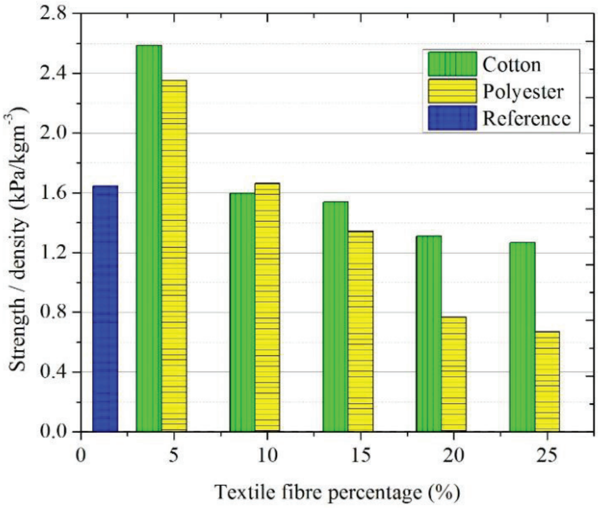

Fig. 7. Variation of strength/density on 7^{th} day

3) 28^{th}-day strength: The variation of the compressive strength of TFRM on the 28^{th} day is shown in Fig. 8. It implies that compressive strength was reduced due to the addition of textile fibre in each fibre level. Textile fibre has a lower density than aggregates and they behave as voids in the mortar mix due to the low compressive strength of textile fibre, which results in a reduction of the compressive strength. Further high textile content affects the compaction of mortar. As a result of the aforementioned reasons, compressive strength was greatly reduced in TFRM when containing high textile fibre content. The incorporation of textile fibre drastically reduces the cohesiveness of mortar mix and eventually results in reduced compressive strength. Polyester fibre added TFRM showed lower compressive strength values compared with Cotton fibre mixed TFRM in each level except 20%. The reason was poor calcium silicate hydrate formation around aggregates and Polyester fibre due to the wax-like nature of the Polyester fibre. Desperate from the dry state, textile fibre significantly improved the compressive strength in the wet state. Though the compressive strength values of all types of TFRM were less than the strength value of the control mix, the strength/density value of 5% cotton fibre added TFRM showed nearly equal value compared to the value of the control mix under dry conditions (Fig.9).

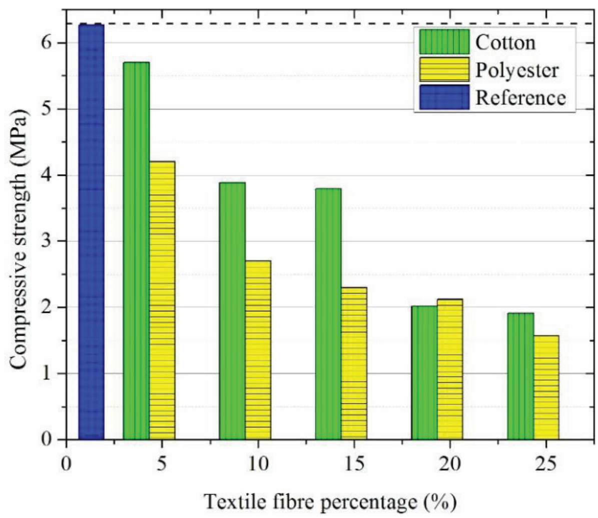

Fig. 8. 28^{th}-day compresive strength

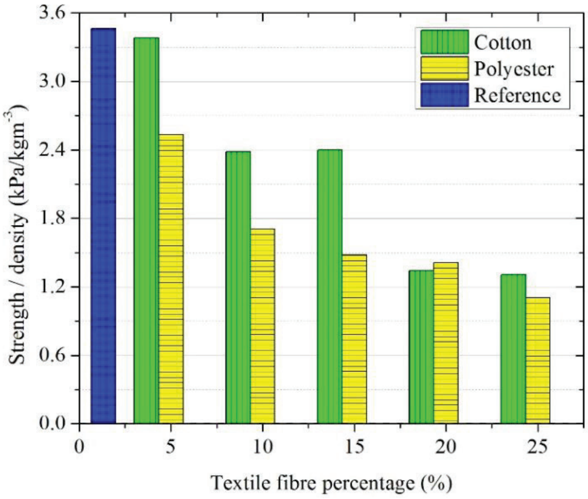

Fig. 9. Variation of strength/density on 28th day under dry conditions

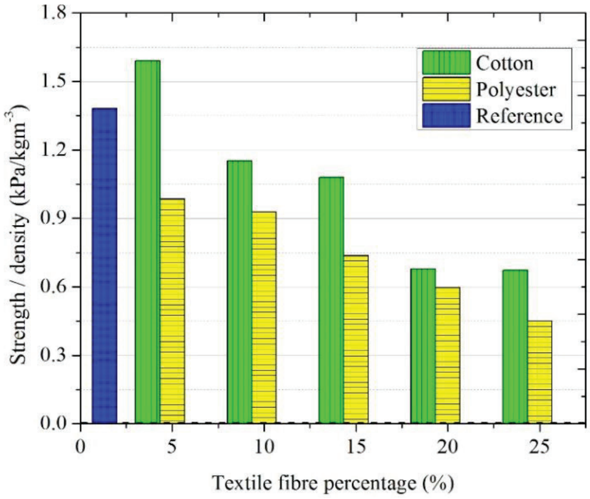

Fig. 11. Variation of strength/density at 28th day under wet conditions.

As shown in Fig. 10, 5% of cotton fibre added TFRM improved its strength under wet conditions by 11% compared with reference mortar. The reason was when cotton fibres are affected by moisture, the strength of cotton fibre increases [10]. But, due to pore water, the compressive strength values are lower than in the dry state. As displayed in Fig. 11, strength/density variation of the 28th-day values showed a similar behaviour as compressive strength variation, where the value of the 5% of cotton fibre added TFRM was higher than the value of control mortar. Fig. 12 shows the impact of textile fibre incorporation in mortar systems very clearly, and it shows the addition of textile fire reduced the brittleness of traditional mortar.

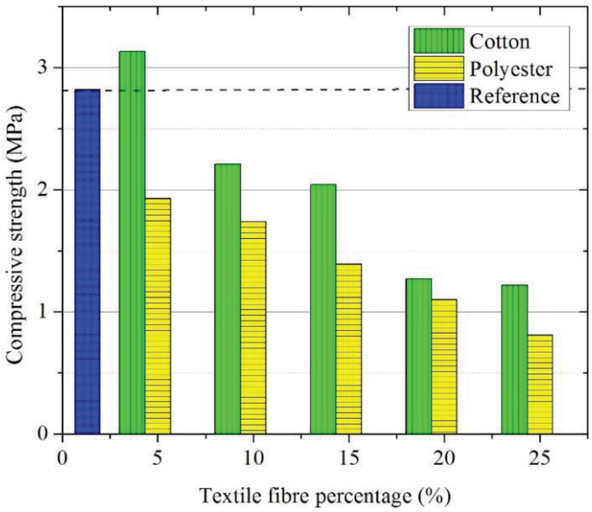

Fig. 10. 28th day compressive strength under wet conditions

(a) Reference mortar

(b) Mortar with 5% of Polyester fibre

Fig. 12. Post peak behaviour

IV. Conclusions

The density of TFRM under both dry and wet conditions was reduced when increasing the textile fibre content as fine aggregates were replaced by a material with a lower density than fine aggregates. Increasing the textile fibre content in TFRM significantly reduced the compressive strength

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since higher fibre contents reduced the integrity of TFRM and made them less stiff. According to the overall finding on the influence of fibre content, the addition of 5% of textile fibre is more pertinent as per this study. Cotton fibre added TFRM showed a higher compressive strength value compared to polyester fibre added TFRM, and this was caused by the high tensile strength of cotton textile compared to polyester textile and poor calcium silicate hydrate formation around aggregates with polyester fibre due to their wax-like nature. The strength/density values highlighted the positive impact of the addition of textile fibre that holds acceptable strength while reducing the density. In addition other mechanical properties such as toughness were improved due to the addition of aforementioned fibre which are not reported in this publication.

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