ABSTRACT

In the past two decades, researchers worldwide have explored alternatives to steel-based reinforcements to overcome challenges such as limited formability for complex designs, susceptibility to corrosion, reduced durability, restricted ductility, heavy weight, and minimum concrete cover requirements.Continuous textile structures have emerged as promising solutions, leading to the development of alternative, sustainable materials. High-performance filaments such as AR glass, basalt, and carbon have gained significant interest in the composite industry due to their superior mechanical properties and non-corrosive nature, making them ideal for infrastructure applications in fibre-reinforced plastics (FRPs), textile-reinforced concrete (TRC), or fabric-reinforced cementitious mortar (FRCM).

High-performance filament bundles such as carbon, basalt, AR glass, and aramid possess superior mechanical properties, which, when reinforced within a mortar specimen, can significantly enhance the mechanical performance of fabric-reinforced mortar structures. However, these filament bundles often have smooth surfaces and minimal intrafilamentary spacing, posing challenges for effective bonding with the cementitious matrix. This weak bond can lead to mechanical performance issues such as telescopic failure, where the outer filaments bond with the matrix while the inner filaments slip during testing, ultimately underutilizing their full potential.

To address this, resin coating and impregnation techniques have shown promise in improving bond strength. Additionally, hybrid yarns and fabrics offer a synergistic approach by combining the high tensile strength and modulus of high-performance filaments with the ductile behaviour of thermoplastic fibres at a reasonable cost. Low-modulus fibres such as polypropylene (PP) and polyester (PET) further enhance durability, ductility, and corrosion resistance within the alkaline mortar matrix, thanks to their inherent alkali resistance.

Another promising alternative is yarn structural modification, such as introducing a ribbed texture to enhance mechanical anchorage between the filament bundle and the mortar matrix. This approach could significantly improve the overall performance of fabric-reinforced mortar composites by optimizing the interaction between the reinforcement and the matrix.

This research investigates the impact of hybrid (core-sheath) yarn structures on the mechanical properties of TRC. Hybrid yarns were developed using high-performance AR

glass, basalt, and carbon filaments with nearly identical yarn linear density (tex) to facilitate direct comparison, with thermal heat setting applied to improve weavability and structural integrity. Additionally, cable yarns were created by helically wrapping high-performance filament bundles with twisted or braided PET filaments to enhance fibre-mortar bonding through mechanical anchorage. These cable yarns were then woven into plain-weave scrim fabrics using a handloom, followed by epoxy resin coating to improve structural stability and prevent distortion during handling.

TRC elements were fabricated using these yarns and a mortar mix incorporating a small fraction (0.25%) of PP fibres to harness their benefits. Various tests were performed, including tensile tests on yarn and fabric specimens, mortar cube compression tests, cylinder split tensile tests, pull-out tests, uniaxial tensile tests, and flexural tests on FRCM specimens. The pull-out behaviour of AR glass, basalt, and carbon yarn and fabric-reinforced mortar specimens was analysed, with a focus on the influence of embedment length on yarn pull-out behaviour. Additionally, the tensile and flexural behaviour of FRCM specimens reinforced with these yarns was examined, considering mesh opening size and the number of fabric layers.

The study compared the pull-out, tensile, and flexural behaviour of AR glass, basalt, and carbon-based parent and hybrid yarn FRCM specimens. Furthermore, energy absorption during FRCM testing, along with crack and failure patterns, was analysed. Pull-out test results showed that hybrid yarn-reinforced cementitious mortar (YRCM) specimens outperformed their parent counterparts in peak pull-out load, indicating improved pull-out behaviour due to yarn hybridization. The incorporation of a helical configuration in the core high performance filament strand, using twisted and braided PET yarns, enhanced surface roughness for better mechanical anchorage, while epoxy coating and PP sheath fibres helped bind and secure the core high-performance filaments. FRCM specimens demonstrated improved pull-out behaviour compared to YRCM specimens due to the combined effect of surface roughness, epoxy coating, and the assistance provided by the weft yarns in the woven fabric structure.

Hybrid yarns, along with epoxy coating, positively influenced the tensile behaviour of AR glass, basalt, and carbon yarns, enhancing fibre load-bearing capacity, load transfer efficiency, and load-sharing performance. This improvement resulted in higher peak loads in fabric tensile tests, as well as pull-out, and tensile and flexural tests of FRCM specimens. A strain-hardening effect was observed in all FRCM specimens during tensile and flexural tests, where, after the initial crack, the load increased again, undergoing multiple cracks before achieving peak load, accompanied by enhanced ductility (greater elongation or deformation). FRCM specimens based on hybrid yarns exhibited higher tensile and flexural strength and greater energy absorption compared to their individual counterparts, with carbon-based FRCM specimens demonstrating the highest performance.

Replacing uncoated parent fabric with epoxy-coated or hybrid yarn-based fabric increased the average number of cracks and reduced crack spacing in failed FRCM specimens subjected to tensile and flexural tests, indicating more uniform load transfer and sharing between the reinforced fabric and the mortar matrix. The presence of fine cracks and multiple cracking under tensile and flexural loads proved beneficial for FRCM specimens, particularly evident in hybrid yarn-based specimens.

These findings underscore the promising prospects of utilizing hybrid yarn-based structures for FRCM (TRC) reinforcement.