Final Year Project Showcase Batch 2021
Year 2024

Department: Textile Engineering
Programme: Textile Sciences

1

Project Title

High Performance Textile Composites for Retrofitting Applications

2

Project Idea

Pakistan faces considerable challenges due to its high vulnerability to natural disasters due to the topography. According to the World Bank, approximately 30 million people in Pakistan have been affected by floods in the last two decades, while the region experiences frequent seismic activity due to its proximity to the collision of the Indian and Eurasian tectonic plates. Secondly, Pakistan's urban population is expected to rise to over 100 million by 2030, according to the United Nations' World Urbanization Prospects. This rapid urbanization puts immense pressure on existing infrastructure. Most of the existing structure was not designed to withstand the increasing loads and environmental stresses of a growing population.

Currently, approximately 40% of Pakistan's urban buildings are over 30 years old, many constructed before modern building codes were implemented. The need to retrofit and strengthen these existing structures is urgent to prevent catastrophic failures and to ensure public safety. A count of fact is that seismic risk maps indicate that major cities such as Islamabad, Lahore, and Karachi lie in zones with moderate to high earthquake risk, highlighting the necessity for effective strengthening methods.

High-performance textile-based reinforcement systems, such as Fiber Reinforced Polymer (FRP) composites, offer a promising solution. These systems are lightweight, corrosion-resistant, and can be rapidly installed with minimal disruption to the building's occupants. Studies have shown that retrofitting with textile-reinforced composites can improve structural strength by up to 60% which significantly enhancing the resilience of infrastructure against seismic and load-related stresses.

This project proposes an innovative, textile-based reinforcement system designed to enhance the structural integrity of buildings, increasing their resilience to seismic and environmental stressors. By utilizing advanced materials and engaging local communities in the construction process, this initiative can improve both safety and sustainability in Pakistan's built environment. Ultimately, this project can contribute to reducing the vulnerability of millions of people to future disasters, reinforcing national resilience against the growing threat of natural calamities.

3

Process

The project process was broken down into three stages:

i. Casting of concrete structure.
ii. Development and characterization of High-Performance Fabric.
iii. Validation of High-Performance Fabric over Full Scale Structure (secondary testing of retrofitted specimen).

	In the first stage, casting of the concrete structure, i.e., cylinders (to replicate beams) and prisms (to replicate columns), using the 1:2:4 casting ratios for the prototyping of 4000 psi domestic and commercial setting of civil infrastructure. After the curing period, control specimens were tested based on their mechanical strength using standard methods ASTM D695 for compressive strength and ASTM D3518 for shear strength to create an accurate baseline for our project and to identify the increment in strength achieved with retrofitted structures. The second stage involved the development and characterization of High-Performance Fabric, which started with the selection of a high-performance fiber based on a high strength-to-weight ratio. Dyneema fiber is known for its exceptional tensile strength, durability, and chemical resistance, was chosen for its suitability in structural reinforcement. Fabric prototyping as done by arranging the Dyneema in unidirectional yarns with varying numbers of tows (10, 30, 60, and 85) to assess how tow quantity influences strength. The yarns were woven into fabric using a unidirectional weave style using a handloom, which is effective for axial load-bearing applications. Simultaneously, Epoxy resin was developed by Department of Petrochemical and Polymer Engineering, NEDUET (Interdisciplinary Collaborating Partner of the Project) to be used as a matrix material for composite system. Then High-performance fabric and resin was utilized for the initial composite fabrication. These composites were tested for the self-adhesion properties using the ASTM D3039 standard method. The last stage involved scaling up of high-performance fabric and full-scale testing. The best performing high- performance fabric from the primary testing of composites was utilized to retrofit the concrete specimens (secondary testing). This allowed to assess the performance of indigenously developed composite system for flexural strength using ASTM D3518 and for compressive strength using ASTM D695. The obtained results were compared with the results of retrofitted structures using Carbon SikaWrap (Commercially available FRP System outsourced from SikaGroup). This comparative analysis will draw evidence for the performance of newly developed FRP composite system with the commercially available one for structural reinforcement
4	**Outcome** The outcome of the project demonstrates the successful development and application of high-performance textile composites utilizing Dyneema fibers, for structural retrofitting purposes. The key findings and implications are as follows, i. Retrofitted concrete cylinders exhibited an average increase of approximately 30% in compressive strength compared to unretrofitted control specimens. This indicates a substantial enhancement in load-bearing capacity due to the application of Dyneema textile composites. ii. Prism specimens retrofitted with the Dyneema composite demonstrated an increase in flexural strength by about 25%, reflecting improved resistance to bending stresses and better energy absorption characteristics. iii. The secondary testing results showed that retrofitted specimens could sustain higher loads before failure. For instance, some samples achieved up to 75% of their original structural strength post-retrofitting, aligning with the project's objective to enhance structural capacity significantly. iv. The analysis revealed a shift towards more ductile failure modes, with retrofitted samples exhibiting increased deformation capacities around 15% more ductility reducing the risk of sudden catastrophic failure.

5	**Evidence (Theoretical Basis)** The effectiveness of reinforcement systems in retrofitting applications is crucial for enhancing the structural integrity and extending the lifespan of existing infrastructure. Traditional reinforcement materials like CFRP, BFRP, GFRP,etc. have been widely used due to their high strength-to-weight ratio and durability. However, the development and application of alternative materials such as Dyneema Fiber Reinforced Polymer (DFRP), derived from polyethylene fibers, present a promising approach to improving performance characteristics. **Compressive Strength Enhancement:** The project conducted reveals that CFRP systems improve the compressive strength of cylinders by approximately 50%. This enhancement can be attributed to CFRP's high tensile strength and modulus of elasticity, which allow it to effectively transfer loads and distribute stresses across the reinforced material. However, DFRP demonstrates a more pronounced effect, with a 75% increase in compressive strength. This substantial improvement is explained by the superior mechanical properties of aramid fibers, which include high tensile strength, rigidity, and resistance to deformation. Aramid fibers' molecular structure, characterized by strong hydrogen bonding and rigid chain alignment, contributes to their exceptional load-bearing capacity and durability. **Flexural Strength Improvement:** In terms of flexural strength, CFRP provides a 35% improvement in prisms. CFRP's efficiency in flexural reinforcement is linked to its ability to resist bending stresses and distribute loads evenly. The CFRP's high tensile strength and low weight allow for effective reinforcement without adding significant mass to the structure. On the other hand, DFRP results in a significant 60% increase in flexural strength, surpassing CFRP's performance by 71%. The enhanced flexural strength of DFRP can be attributed to the polyethylene fiber superior impact resistance and flexibility, which improve the material's ability to withstand bending stresses and recover from deformation. **Comparative Analysis** i. The comparative analysis of CFRP and DFRP systems revels the superior performance of DFRP in both compressive and flexural strength applications. DFRP's 50% greater increase in compressive strength and 71% greater improvement in flexural strength compared to CFRP highlight its potential as a more effective reinforcement material. Theoretical considerations, including the aramid fibers' mechanical properties and structural advantages, support these findings. ii. Polyethylene fibers, such as Dyneema, are known for their high tensile strength, low elongation, and excellent thermal stability. These properties make them highly effective in reinforcement applications where enhanced mechanical performance and resistance to environmental factors are critical. iii. The improved performance of DFRP can be attributed to its enhanced load transfer efficiency and stress distribution capabilities. The unique characteristics of aramid fibers allow for better integration with the base material, resulting in more effective reinforcement and increased overall strength. iv. The application of DFRP in retrofitting projects leads to more durable and reliable structures, which is particularly relevant for infrastructure in regions like Pakistan where environmental conditions and structural demands can be challenging. The use

	of DFRP offers a viable alternative to traditional CFRP systems, providing superior performance and potentially reducing maintenance and repair costs.
6	**Impact on Sustainability of Urban Regions or SDG-11 "Sustainable Cities and Communities"** The project contributes to making cities more sustainable by improving the quality and longevity of existing buildings. This is particularly important in Pakistan, where urban areas are rapidly expanding and require effective retrofitting solutions to ensure safety and sustainability in aging infrastructure.
P	**Competitive Advantage or Unique Selling Proposition** i. **Indigenous Production Capability:** Utilization of locally sourced textile materials and resins raw material for the development of FRP System which provides the mechanical performance as that of commercially available system will reduce dependency on international supply chains and import costs. USP: Provides a cost-effective and self-reliant retrofitting solution by providing Pakistan's own manufacturing capabilities. To advanced technology more accessible and affordable throughout the country. ii. **Solutions for Local Conditions:** Customizes composite materials to meet specific environmental and structural needs of Pakistan to enhance performance and durability. USP: Offers high-performance retrofitting solutions specifically designed to address local climatic and seismic conditions, ensuring optimal effectiveness and reliability in local applications. iii. **Advanced Material Technology:** Incorporates state-of-the-art Dyneema uni-directional technical high-performance fabrics and locally formulated resins will provide superior tensile strength and durability. USP: Delivers cutting-edge composite technology that sets a new standard in local retrofitting solutions to offer enhance structural reinforcement compared to conventional materials.
a	**Attainment of any SDG** i. **SDG 9: Industry, Innovation, and Infrastructure** Developing an indigenous retrofitting system using locally produced textile materials and resins provides innovation in the Pakistan's construction industry. This project enhances the durability and safety of buildings, which is crucial for a country like Pakistan, where infrastructure development is key to economic growth and resilience. ii. **SDG 8: Decent Work and Economic Growth** The project supports local industry growth and creates job opportunities in the manufacturing and construction sectors. By fostering domestic production capabilities, it contributes

b	**Environmental Aspect** The retrofitting system enhances building resilience to climate-induced stresses, such as extreme weather and seismic activity. This mitigation strategy aligns with climate adaptation objectives by reinforcing infrastructure against environmental risk.
c	**Cost Reduction of Existing Product** To achieve cost reductions with the Dyneema Fiber Reinforced Polymer (DFRP) system, the following strategic measures are implemented, i. Bulk purchasing agreements for Dyneema fibers and establish local production facilities to lower material and transportation costs. ii. Incorporate of optimized manufacturing techniques to enhance production efficiency and reduce operational expenses. iii. Refine the resin and fiber mixture formulation to ensure that each unit of DFRP achieves the necessary strength while minimizing material costs.
d	**Process Improvement which Leads to Superior Product or Cost Reduction, Efficiency Improvement of the Whole Process** The primary issue with Carbon Fiber Reinforced Polymer (CFRP) in civil retrofitting is its high cost and potential for brittle failure, which can be a significant concern in seismic regions or for structures subjected to impact. Ultra-High-Molecular-Weight Polyethylene UHMWPE, specifically Dyneema Fiber Reinforced Polymer (DFRP), addresses these issues by offering greater toughness and impact resistance compared to CFRP. DFRP's superior ductility helps improve the durability and resilience of retrofitted structures. It makes the system more cost effective and reliable option for enhancing structural performance.
e	**Expanding of Market share** The existing market primarily offers standalone components, lacking a cohesive and high performance solution tailored to the specific needs of retrofitting applications. This fragmentation forces stakeholders to import complete retrofitting systems from international suppliers which leads to higher costs and logistical challenges. This project addresses the market gap by developing a comprehensive, locally-produced retrofitting system that integrates indigenous fabrics and resins into a cohesive FRP composite solution.
f	**Capture New Market** This project endeavors to explore the emerging market for technical textiles in the domain of fiber-reinforced polymer (FRP) applications. The primary objective is to develop a cost effective, indigenous retrofitting system for building infrastructure in Pakistan, utilizing locally sourced materials.
g	**Scope and Potential** The technical textile industry, specifically through the application of Fiber Reinforced Polymer (FRP) reinforced fabrics, offers a transformative potential for improving civil

	infrastructure in Pakistan. The country is currently facing substantial challenges in its infrastructure sector which is characterized by the urgent need for repair and modernization. As outlined in the Pakistan Economic Survey 2022-2023, there exists a significant infrastructure deficit requiring extensive investment for upgrades to roads, bridges, and buildings. FRP reinforced fabrics present a viable solution to these issues. The global FRP composites market in civil engineering was valued at approximately USD 9.2 billion in 2022, with a projected compound annual growth rate (CAGR) of around 7% from 2023 to 2030. This growth is driven by the materials' superior performance characteristics, including a strength-to-weight ratio five to ten times greater than traditional materials like steel. Such properties are particularly beneficial for reinforcing existing structures and enhancing new constructions. In Pakistan, where infrastructure deterioration is a critical concern, the application of FRP reinforced fabrics could have a significant impact. The National Highway Authority of Pakistan (NHA) estimates that over PKR 1 trillion is needed for infrastructure upgrades, including bridge and road rehabilitation. FRP technologies could notably extend the lifespan of these structures, with research indicating that FRP composites can enhance the load bearing capacity of reinforced concrete bridges by up to 50% and prolong their service life by over 30 years. Moreover, the use of FRP materials aligns with Pakistan's sustainable development goals as outlined in the Pakistan Vision 2025, which advocates for modernizing infrastructure while promoting environmentally friendly practices. FRP composites are characterized by their durability, low maintenance requirements, and reduce
8	**Target Market** Our target market for Fiber-Reinforced Polymer (FRP) systems for civil structures includes, i. **Government Infrastructure Projects:** Various government departments involved in infrastructure development, such as the National Highway Authority (NHA) or the Public Works Department, might be interested in FRP systems for strengthening and rehabilitating bridges, highways, and public buildings. i. **Construction Companies:** Both large and small construction firms involved in new builds or renovations could be interested in using FRP systems to enhance the strength and durability of structures. ii. **Engineering and Consulting Firms:** Firms specializing in structural engineering and consulting may use FRP systems in their designs and recommendations for improving the performance of civil structures. iii. **Architectural Firms:** Architects looking for innovative materials to meet aesthetic and structural requirements might incorporate FRP systems into their designs. iv. Educational Institutions and Research Organizations: Universities and research centers focused on civil engineering and materials science might be involved in studying and promoting the use of FRP systems. v. **Real Estate Developers:** Developers working on large-scale residential, commercial, or mixed-use projects could consider FRP systems for their benefits in terms of longevity and maintenance. vi. **Maintenance and Rehabilitation Specialists:** Companies that specialize in the maintenance and rehabilitation of aging infrastructure may use FRP systems as part of their service offerings.

9	**Team Members** (Names along with email address	Munazza Batool TS-21005 (batool4407898@cloud.neduet.edu.pk)

		Javeria Atiq TS-21010 (atiq4401783@cloud.neduet.edu.pk) Humna Siddiqui TS-21020 (siddiqui4403338@cloud.neduet.edu.pk) Maha Khan TS-21021 (khan4403537@cloud.neduet.edu.pk)
10	**Supervisor Name** (along with email address)	Prof. Dr. Bilal Zahid (drbilazahid@neduet.edu.pk) Engr. Shehroze Ali Baig (shehrozeali@cloud.neduet.edu.pk)