UNIVERSITI TEKNOLOGI MARA

NANOSILICA-REINFORCED HYBRID POLYMER COMPOSITES FOR RESTORATION OF DAMAGED PIPING SYSTEMS

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ABSTRACT

Development of fiber-reinforced polymer (FRP) composites, particularly those incorporating natural fibers as reinforcements, has gained significant attention as a sustainable alternative to conventional synthetic fibers. In general, this research comprises four main phases: i.e. (i) Evaluation of modified nanosilica Willkat (NSW) polymer matrix performance, (ii) Evaluation of nanosilica-modified commingled FRP composites performance, (iii) Evaluation of commingled FRP composite wrapping performance on damaged pipe, and (iv) Prediction of commingled FRP composite wrapping performance on damaged pipes using Ansys simulation. This study presents mechanical properties data of nanosilica-filled composite wrapping materials and burst pressure of damaged pipes that were wrapped with the FRP composite materials. In the first phase of the study, nanosilica contents of 1 wt% of Nanosilica willkat (1NSW), 3 wt% (3NSW), 5 wt% (5NSW), and 7 wt% (7NSW) were added into polysilicate isocyanate (Willkat) polymer to determine the best formulation resin for the fabrication of commingled FRP composites. The results indicated that 5 wt% (5NSW) is the best resin formulation since higher concentrations negatively affect the resin dispersion within reinforcement commingled fibers. In the second phase, five (5) different types of commingled fibers, i.e., Basalt/Basalt (B/B), Glass/Glass (G/G), Arenga pinnata/Arenga pinnata (AP/AP), hybrid Arenga pinnata/Basalt (AP/B), and hybrid Arenga pinnata/Glass (AP/G), and two (2) different types of the matrix resin, i.e. Pure Willkat resin (PW) and 5NSW, were used to produce ten (10) Unidirectional (UD) commingled FRP composite systems fabricated using hand layup bagging process. Hydrostatic pressure tests were conducted in the third phase of the project to reflect practical industrial conditions, using five variations of cross-ply commingled FRP composites to repair damaged PVC pipes. The results showed that Arenga pinnata fiber has good potential to substitute the synthetic fibers in structural composites. Remarkably, while the PVC pipe itself burst under pressure, the FRP-reinforced composite wrap remained intact. To assess the maximum pressure resistance of the composites, an ANSYS simulation model was developed using a high-strength steel pipe. The simulation confirmed the wrap's structural resilience and provided insights valuable for future engineering applications. Although synthetic fiber composites demonstrate superior mechanical strength, hybrid composites incorporating *Arenga pinnata* fibers have proven capable of withstanding significant pressure, highlighting their practical potential. An effective alternative to entirely replacing synthetic fibers is to wrap them with a hybrid commingled fiber. This approach can be reliably evaluated using ANSYS Workbench simulations, eliminating the need for experimental trials.

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CHAPTER 1
INTRODUCTION

1.1 Overview

Fiber-reinforced polymer (FRP) composites exhibit exceptional properties, including high strength, elastic modulus, corrosion resistance, and low density. These materials are also characterized by dimensional stability, excellent formability, and lightweight materials, making them easy to work with. Polymers serve as the matrix in fiber-reinforced composites, offering lightweight, corrosion resistance, flexibility, and ease of processing. Incorporating nanosilica enhances mechanical strength, hardness, and adhesion while reducing shrinkage and improving barrier properties. Additionally, nanosilica strengthens fiber-matrix bonding, improves stress distribution, and increases durability and efficiency for high-performance applications. Polymer composites have traditionally been reinforced with synthetic fibers. However, growing environmental concerns have increased interest in natural fiber alternatives. Arenga pinnata fiber, sourced from the tree trunk, is gaining attention as a sustainable reinforcement material. However, its inherent strength is lower than that of synthetic fibers. Advanced materials integrating natural fibers are being developed to improve their mechanical properties, focusing on commingled composite fibers and yarn formation techniques. Combining synthetic and natural fibers, hybrid fiber systems enhance the mechanical properties of repaired structures while promoting sustainability by integrating renewable fiber yarn architectures. The demand for durable and eco-friendly materials for pipeline rehabilitation has increased in recent years. Structural damage caused by mechanical stress and environmental factors poses a significant challenge to pipeline longevity and safety. Synthetic and natural fiber-reinforced composites have appeared as effective rehabilitation solutions, offering durability, cost-efficiency, and environmental benefits. This study examines the performance of hybrid fibers in pipeline wrapping techniques, evaluating their ability to mitigate structural damage and withstand extreme hydrostatic pressure. Simulations assess the materials' effectiveness across various pipe surfaces and properties.