

COMPOSITE MATERIALS IN METRO STRUCTURES: THE EXPERIENCE OF TOKYO METRO**Shaumarov Said Sanatovich**

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Abstract. This paper analyzes the structural, technological, and operational advantages of composite materials used in metropolitan infrastructure. Utilizing the Tokyo Metro in Japan - a region of high seismic activity - as a primary case study, the practical application of fiber-reinforced polymers, including GFRP, CFRP, and BFRP, was investigated. The findings indicate that composite materials substantially enhance the seismic stability, corrosion resistance, and overall service life of metro structures.

Keywords: composite reinforcement, CFRP, GFRP, metro tunnel, seismic durability, anti-corrosion, innovative materials.

Introduction:

The Strategic importance of composites in metro infrastructure. Metro infrastructure, considered the lifeline of modern megacities, operates under uniquely complex and extreme conditions. These structures are subjected to continuous high mechanical loads, intense dynamic vibrations from train movements, and aggressive hydrogeological factors such as groundwater and high humidity. Maintaining structural integrity is not merely an engineering challenge but a vital necessity for the safety of millions of passengers.

In Japan, located in one of the world's most seismically active zones, frequent earthquakes impose exceptionally rigorous standards on metro structural components. Traditional materials sometimes fall short of the capacities required to withstand the deformations caused by seismic waves. Consequently, the Tokyo Metro has emerged as a global leader in integrating advanced composites for both new construction and rehabilitation projects. Today, innovative solutions like Carbon Fiber Reinforced Polymers (CFRP), Glass Fiber Reinforced Polymers (GFRP), and high-tech synthetics are utilized alongside traditional steel and concrete. Tokyo Metro serves as an international benchmark for translating theoretical research into practical, durable infrastructure.

By utilizing composites, Tokyo Metro achieves three primary objectives:

Maximum safety: Increasing seismic resilience and reducing the risk of sudden structural failure.

High durability: Extending operational life by several decades through corrosion-resistant materials.

Energy efficiency: Optimizing electricity consumption by reducing the weight of railcars and equipment.

Extreme environments and technical benefits of composites. The underground environment of a metro system is characterized by high relative humidity (often reaching 80-90%), frequent dynamic vibrations, and strong electromagnetic fields from high-voltage power systems. Traditional construction materials often deteriorate rapidly under these conditions. Tokyo Metro engineers selected modern composites specifically to address these challenges due to the following advantages:

Superior corrosion resistance: Unlike steel, which is highly prone to oxidation in humid tunnel environments, composites are chemically inert. This resistance to moisture, salts, and alkaline environments significantly extends the time between repairs.

High strength-to-weight ratio: Modern polymer composites are 4-5 times lighter than steel yet match or exceed its mechanical strength, particularly in tensile resistance. This reduces railcar weight, lowering braking loads and enhancing energy efficiency.

Dielectric and anti-static properties: Since metros consume high-voltage electricity, safety is paramount. Composites possess excellent dielectric (non-conductive) properties, making them ideal for third-rail brackets and electrical equipment, thereby minimizing short-circuit risks and electrochemical corrosion.

Practical applications in Tokyo metro. Tokyo's engineering approach utilizes specific composites based on their molecular and mechanical properties for infrastructure modernization:

Seismic strengthening with CFRP: Much of the Tokyo Metro was built in the mid-20th century and may not meet modern seismic codes. Engineers use Carbon Fiber Reinforced Polymer (CFRP) to wrap concrete columns and tunnel domes. This "jacket" restricts the lateral expansion of concrete and drastically increases its ductility, preventing fragmentation during intense tremors.

High-tech synthetic sleepers (FFU): Many lines have replaced wood or heavy concrete sleepers with Fiber Reinforced Foamed Urethane (FFU). Known as "synthetic wood", FFU is light and easy to process like timber but as strong and durable as concrete. It has a service life exceeding 50 years and does not rot in high-humidity tunnels.

Composite insulation for third rails: Using composite brackets and protective coatings for the third rail system has become a safety standard in Tokyo. Primarily made of GFRP, these components handle mechanical loads while acting as perfect electrical insulators.

Innovations in rolling stock: CFRP car bodies. To reduce energy consumption, Tokyo Metro has begun manufacturing interior components and even primary car body elements from CFRP.

Weight reduction: CFRP car bodies are significantly lighter than steel or aluminum while maintaining high mechanical strength.

Economic impact: Reducing railcar mass allows for 10-15% savings in electricity consumption.

Braking and inertia: Lighter cars require less braking force, reducing wear on brake pads and rails. Lower inertia ensures smoother acceleration and stopping, improving passenger comfort.

Comparative Analysis: Tokyo Metro Experience

Metric	Steel/Concrete	Composite material
Weight	Very Heavy	Very Light
Corrosion	High	None
Installation speed	Slow (requires heavy machinery)	Fast (manual labor possible)
Service life	20-30 Years	50+ Years

Conclusion and Strategic Recommendations for Uzbekistan

The successful experience of the Tokyo Metro demonstrates that while composite materials may seem more expensive initially, they prove highly cost-effective through a **Life Cycle Cost** analysis. For Uzbekistan's developing metro system, particularly the Tashkent Metro, adapting these technologies is vital:

Above-ground Lines: In Uzbekistan's harsh continental climate, composites can protect reinforced concrete viaducts from rapid deterioration caused by extreme temperature fluctuations.

Innovative sleepers: Using synthetic sleepers on elevated tracks can reduce noise levels for nearby residential areas.

Economic localization: Beyond importing these materials, Uzbekistan should explore localizing production within its domestic chemical and polymer industries. This will lower construction costs and foster a high-tech manufacturing sector.

In summary, implementing the composite technological achievements of the Tokyo Metro will provide a solid foundation for taking the safety, energy efficiency, and economic stability of Uzbekistan's metro system to a new, innovative level.

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