

MINISTER'S INNOVATION AWARD

Land Transport Authority
We Keep Your World Moving

DISTINGUISHED AWARD

FIBRE CONCRETE : TRANSFORMING TOMORROW'S INFRASTRUCTURE SUSTAINABLY

Fibre Concrete

Transforming Tomorrow's Infrastructure Sustainably



Fibre (Steel / Polymer)

+



Concrete

=



Fibre-Reinforced Concrete
Reducing usage of steel reinforcements

Applications within Land Transport Authority (LTA)



Underground Structural Slabs



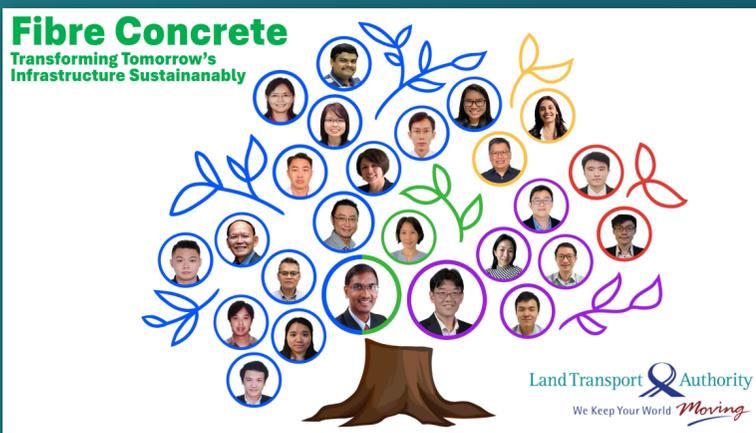
Concrete Pavement

With strong potential to be readily adopted across Built Environment projects

Value Creation & Impact

-  Faster construction
-  Lower carbon emissions
-  Mitigated cost
-  Better durability (3D reinforcement)
-  No change to equipment or process

PROJECT TEAM



Land Transport Authority

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IMPETUS FOR PROJECT

Modern infrastructure development is increasingly challenged by the limitations of conventional construction methods—especially in Singapore's dense and fast-evolving urban landscape. As projects become more complex and large-scale, persistent issues such as low productivity and safety risks continue to hinder progress. This project aims to tackle these challenges by exploring innovative applications of fibre-reinforced concrete (FRC) technologies, offering a smarter, more efficient alternative to traditional reinforcement methods.

Challenge 1: Enhancing Durability and Minimizing Steel Congestion in Underground Infrastructure Construction

As Singapore's underground infrastructure extends to greater depths in response to land constraints and urban expansion, the structural demands on deep excavation works have intensified. These demands typically require large volumes of conventional steel reinforcement to ensure stability, durability, and geotechnical compliance. However, such reinforcement-heavy approaches introduce several construction challenges.

Key issues include:

- Rebar congestion (Figure 1), which complicates concrete placement and compromising structural integrity.
- Labour-intensive installation, which slows down progress and adds to project timelines.
- Workmanship variability, which can lead to inconsistencies affecting long-term performance and durability.

These challenges are particularly acute in deep excavation zones, where spatial limitations and complex reinforcement detailing reduce construction efficiency. This underscores a growing need for alternative reinforcement solutions that ease steel congestion while maintaining structural reliability and buildability.



Figure 1: Congested steel rebars for station slab

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Challenge 2: Accelerated Delivery of Concrete Pavements for Roads and Pathways

Singapore's ongoing efforts to expand and upgrade its transport infrastructure—including roads, cycling paths, and pedestrian walkways—require efficient and minimally disruptive construction methods. In a land-scarce and high-density urban setting, the ability to deliver concrete pavements quickly is critical to maintaining public mobility and minimizing inconvenience.

Key issues include:

- Traffic congestion resulting from road closures in high-demand corridors.
- Disruption to active mobility users, affecting first-mile and last-mile connectivity.
- Operational delays and public inconvenience, particularly near transport hubs, schools, and commercial zones.

Traditional construction methods involving steel reinforcement (Figure 2) are labour-intensive, time-consuming, and difficult to execute in constrained urban settings. These limitations increase the risk of extended closures and negatively affect the project timeline.



Figure 2: Manual laying of steel mesh for pavements

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STATEMENT OF NEED

Singapore's infrastructure development is increasingly challenged by the limitations of conventional construction methods. As urban projects grow in complexity, two persistent issues—steel congestion in deeper underground infrastructure construction and limitations of existing concrete pavement construction methods—continue to impact productivity, safety, and sustainability.

Traditional steel reinforcement techniques are labour-intensive and difficult to execute in constrained environments, leading to delays, quality risks, and traffic disruption. This project introduces fibre-reinforced concrete technologies to enhance current practices—reducing rebar congestion, streamlining installation, and improving overall construction efficiency. It offers a practical solution to deliver stronger, faster, and more resilient infrastructure in Singapore's dense urban environment.

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EXTENT OF INNOVATIVENESS

Concrete has low tensile strength and can easily crack in tension. To compensate the low tensile capacity, steel reinforcements are added to resist the tensile force.

Fibre reinforced concrete is explored as a way to reduce reliance of conventional steel reinforcements. Added directly into the concrete mix, fibres function as micro-steel reinforcements (Figure 3) to increase the concrete tensile capacity.

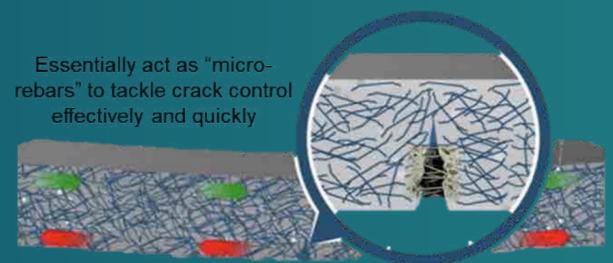


Figure 3: Manual laying of steel mesh for

Innovative Application: Steel Fibre Reinforced Concrete (SFRC) for Underground Infrastructure Elements

Since 1998, LTA has been exploring the use of Steel Fibre Reinforced Concrete (SFRC) in tunnel linings – a thin slab application. Gaining confidence over time in its structural performance through years of practical implementation and monitoring, SFRC has demonstrated its effectiveness in enhancing crack control, ductility, and durability in tunnel linings.

Building on this proven track record, LTA is now advancing the boundaries of SFRC application by its use in thicker, cast in-situ underground structural elements – a first in Singapore. However, applying SFRC in thicker, cast in-situ structural elements introduces new uncertainties, particularly regarding fibre distribution, performance consistency, and long-term structural behaviour, which warrant further study and validation.

To address this, a two-staged research and development programme – initiated by the Project Team in collaboration with Singapore Institute of Technology (SIT) - was conducted to evaluate the feasibility and study the implementation of hybrid SFRC in underground structures.

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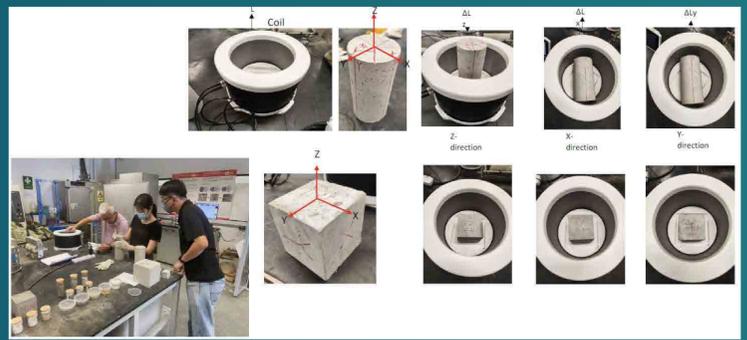
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EXTENT OF INNOVATIVENESS

Stage 1 focused on a comparative study between hybrid Steel Fibre Reinforced Concrete (SFRC) and conventional reinforced concrete (RC). A detailed parametric analysis reveals quantifiable benefits in partially replacing traditional steel reinforcement with steel fibres. The findings show that hybrid SFRC provides comparable structural performance, particularly in crack control, while offering several practical advantages. The reduction in reinforcement bar usage improves concrete flowability during casting, which enhances durability and extends service life. Additionally, the use of SFRC contributes to overall construction cost savings by reducing the quantity of reinforcement required and lowering labour costs associated with bar installation and handling. These findings provide a strong basis for further exploration of SFRC as a viable alternative to traditional reinforcement methods in appropriate structural applications. Next, laboratory testing was conducted to explore the design mix and validate key performance parameters of SFRC. Through a series of controlled experiments (Figure 4), various mix designs were assessed to determine the optimal fibre dosage, distribution, and workability required for structural performance, providing confidence in the performance requirements of SFRC for underground structures application.



(a) SFRC Prism Testing



(b) Samples with different fibre orientations

Figure 4: Assessment of Fibre Orientation and Distribution

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EXTENT OF INNOVATIVENESS

Stage 2 involved a full-scale prototype testing (Figure 5) to validate the real-world performance of hybrid SFRC in thick structural elements. A 3m x 3m x 2m hybrid SFRC mock-up to replicate in-situ construction of a typical underground base slab was cast using a truck-mounted concrete pump. The reinforcement layout and concreting methods closely replicated in-situ construction practices. Core samples (Figure 6) taken from the mock-up were tested to assess mechanical performance of hybrid SFRC, with particular attention to fibre distribution and orientation. These findings provide critical insights into SFRC behaviour under actual construction conditions, strengthening confidence in its use for deep underground applications.



Figure 5: Full-scale Mock-up Prototype Testing to replicate In-Situ Construction



Figure 6: Core samples extracted from Mock-up Prototype for Assessment

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EXTENT OF INNOVATIVENESS

Innovative Application: Polymer Fibre Reinforced Concrete (PFRC) for Pavements

To address Challenge 2: Accelerated Delivery of Concrete Pavements for Roads and Pathways, the team explored an alternative to conventional steel mesh reinforcement. Steel fibres deliver high tensile strength and durability, making them highly effective for structural applications. For surface-level pavements, additional finishing treatments are required to address exposed fibres and maintain user comfort and long-term aesthetics.

Recognizing these issues, the project team initiated a collaboration with Samwoh Innovation Centre and Contec Fiber AG, to evaluate the suitability of polymer fibre reinforced concrete (PFRC) for road-related applications, specifically bus bays.

New Solution

This project marks one of the first full-scale trials of PFRC in Singapore's transport infrastructure. It replaces traditional steel mesh with polymer macrofibres (Figure 7), offering key advantages:

- Reduced installation time, as fibres are mixed directly into the concrete—eliminating the need for manual steel reinforcement work on-site.
- Improved safety, with no sharp or rust-prone elements exposed at the surface.
- Enhanced durability and aesthetics, especially critical in exposed pavements such as bus bays, footpaths, and cycling tracks.

A key innovation is the use of locally available raw materials (e.g. cement, sand) in combination with proprietary fibre blends to produce a pavement-grade fibre-reinforced mix—achieved without changes to existing equipment or processes.



Figure 7: Polymer Fibres used for the study

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EXTENT OF INNOVATIVENESS

Response to Challenges

Initial trials were conducted at Commonwealth Avenue West and Sengkang East Road, where short sections of PFRC pavement were constructed alongside conventional mesh-reinforced pavement for performance benchmarking. One challenge encountered was fibre balling during mixing (Figure 8), which was resolved by slightly increasing the mixing time by approximately two minutes—a minor yet effective adjustment that enabled successful casting.



Figure 8: Fibre Balling (lump of fibre in concrete affecting concrete mixture performance)

Building on these learnings, the team proceeded to full-scale implementation under Contracts DE113 and DE159 (Figure 9), working closely with road construction teams and contractors to refine key construction parameters:

- Slab thickness and joint detailing were optimized for PFRC use.
- Workability and durability were validated through testing (Figure 10), including slump tests, cube strength tests, and tensile splitting tests.



Figure 9: Different bus bays constructed using PFRC under DE113 and DE159

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EXTENT OF INNOVATIVENESS

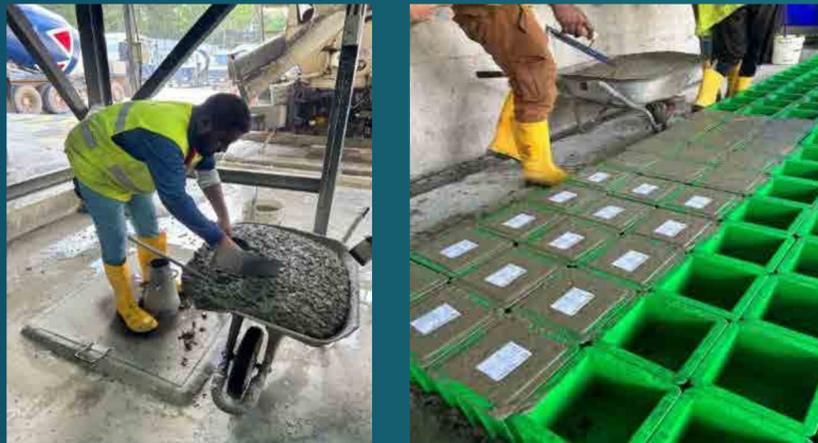


Figure 10: Testing performed to ensure consistency and durability of PFRC

With demonstrated success in heavy-traffic environments such as bus bays, the team subsequently extended the use of this innovation to lighter-traffic applications, including the cycling path project (AM102) along Ubi Avenue 2 (Figure 11), enabling faster construction with reduced disruption to road users and active mobility pathways.



Figure 11: Cycling paths constructed using PFRC under AM102

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EXTENT OF INNOVATIVENESS

Innovation Highlights:

This project pioneers the advanced application of Steel Fibre Reinforced Concrete (SFRC) and Polymer Fibre Reinforced Concrete (PFRC) in Singapore's underground infrastructure and surface pavements, respectively. By integrating steel and polymer fibres directly into concrete mixes, the project reduces reliance on conventional steel reinforcements, enhancing crack control, ductility, and durability while simplifying construction and reducing costs. Notably, this marks the first use of hybrid SFRC in thick, cast in-situ underground elements in Singapore, overcoming challenges related to fibre distribution and structural consistency through rigorous two-stage research and full-scale prototyping. Concurrently, PFRC introduces a safer, more durable alternative to steel mesh reinforcement for pavements, eliminating surface hazards and rust issues while accelerating installation times. Together, these innovations represent unique, practical solutions addressing emerging infrastructure needs with validated performance in real-world conditions, demonstrating significant advancements in concrete technology and construction practices.

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IMPACT AND VALUE-CREATION

The implementation of fibre reinforced concrete has delivered measurable improvements in productivity, and sustainability in construction. By eliminating the need for manual steel reinforcements installation, the project achieved increase in productivity, resulting in faster on-site construction and reduced labour demands.

In underground infrastructure, for a typical 250m length of station, the use of SFRC in a station base slab is projected to result in:

- Cost savings of \$360,000, primarily from reduced material of 522.5 tonnes of steel and reduced labour requirements;
- Time savings of over 1250 man-days per station;
- Net carbon savings of 665 tonnes of CO₂, about 10,000 tree seedlings growth over 10 years, as shown in Figure 12.



Figure 12: Estimation of Value Creation for SFRC on LTA underground infrastructure

In pavement construction, for planned 30 km of cycling paths, the use of PFRC is projected to result in:

- Cost avoidance of approximately \$1.9 million, primarily from reduced material and labour requirements,
- Time savings of over 75,000 man-hours, 30% increase in productivity, resulting in faster on-site construction and reduced labour demands,
- 20% reduction in carbon footprint, supporting Singapore's efforts toward low-carbon construction solutions, as shown in Figure 14.

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IMPACT AND VALUE-CREATION

A Fibre Dosage (kg/m ³)	B Slab Thickness (mm)	C Steel Mesh (\$ per m ²)	D Fibre in concrete (\$ per m ²)	C - D Cost Savings (\$)	C - D / C Cost Savings (%)
3	150	9.9	6.75	3.15	32
3	125	9.9	5.63	4.28	43
3	100	9.9	4.50	5.40	55

* Steel mesh cost in column C was obtained from the fixed schedule of rates (FSR) for steel mesh (A6) which includes manpower i.e delivery of steel mesh, storage of steel mesh, lifting team to unload, labour required to cut, lay and tie the steel mesh
 • Cost of fibre in Column D for 150mm thick slab is obtained as: cost of fibre \$15[^] x dosage (3kg/m³) x slab thickness (0.15m)
 • Projected area of cycling paths to be constructed , assuming width of cycling path as 2m: length (300*1000 m) x width (2m) = 600, 000 (m²)
 • Total cost of steel mesh reinforced required for 300km of cycling path = area (600, 000m²) x 9.90 (\$ per m²) = \$5,940,000

Projected savings = \$5,940,000 x 0.32 = \$ 1,900,800
Manpower Savings: Up to 50%
Reduction in Carbon Emission[#] : 20%

Note:
[^] The fibre rate was obtained from one of the fibre suppliers
[#] Carbon emissions were estimated using the demo version of the BCA carbon calculator ([Singapore Building Carbon Calculator](#))

Figure 13: Estimation of cost avoidance and carbon reduction

These gains were achieved without requiring changes to existing equipment or construction techniques (Figure 14), ensuring that adoption is both practical and cost-effective across a wide range of infrastructure projects.



Figure 14: Mesh-free PFRC bus bay construction using standard equipment

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IMPACT AND VALUE-CREATION

Value-creation

The project directly addresses challenges faced by multiple stakeholders:

- For construction teams, the reduction in manual steel placement improves site safety, reduces fatigue, and enhances operational efficiency.
- For road users and the public, faster construction translates to minimized disruption, particularly in high-use areas like bus bays, footpaths, and cycling routes.

Throughout the project, the team engaged with suppliers, contractors, site supervisors, and quality control teams, incorporating feedback on workability, mix adjustments, and construction sequencing.

Outcome

The implementation of Fibre Reinforced Concrete (FRC) has delivered significant value across infrastructure projects by improving productivity, sustainability, and cost efficiency. In underground applications, SFRC has enabled faster construction with over 1,250 man-days saved, \$360,000 in cost savings, and 665 tonnes of CO₂ reduction per station. For surface works, PFRC has achieved 30% productivity gains, \$1.9 million in cost avoidance, and a 20% reduction in carbon footprint (1,886 tonnes of CO₂ reduction) across 300 km of cycling paths. These benefits were realised without changes to existing equipment or construction methods, making FRC a practical, scalable solution that enhances site safety, reduces disruption, and supports Singapore's low-carbon goals.

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FEASIBILITY AND SCALABILITY

Feasibility

The use of Fibre Reinforced Concrete (FRC)—including both Steel Fibre Reinforced Concrete (SFRC) and Polypropylene Fibre Reinforced Concrete (PFRC)—has proven to be highly feasible with current construction technologies and materials readily available in Singapore. This project has demonstrated that FRC can be seamlessly integrated into existing construction workflows using standard equipment, conventional practices, and locally sourced raw materials, without requiring major changes to site operations.

To ensure quality and performance, the project team conducted comprehensive on-site testing—including slump, compressive strength, fibre distribution, and orientation—which confirmed that FRC meets the structural and durability requirements of Singapore's transport infrastructure. These results underscore the material's readiness for immediate and broader implementation.

Following this validation, hybrid SFRC slab structures will be applied in upcoming rail projects such as P103 – Design and Construction of Riviera Interchange Station and Tunnels for CRL – Punggol Extension, and CR203 – Design and Construction of Turf City MRT Station and Tunnels for the Cross Island Line, marking a major step forward in the structural application of SFRC.

Similarly, the successful deployment of PFRC across multiple surface-level projects—including bus bays, junction approaches, and cycling paths—reinforces its practical benefits in real-world conditions.

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FEASIBILITY AND SCALABILITY

Scalability

The successful validation of SFRC in thicker cast in-situ structural sections represents a major advancement in construction technology, unlocking new possibilities for Singapore's underground infrastructure. For LTA, this breakthrough sets the stage for broader adoption across future underground projects—enhancing constructability, reducing rebar congestion, and improving long-term performance. More importantly, it establishes a scalable solution for the wider construction industry, offering a proven, practical alternative to conventional reinforcement in complex structural applications.

Complementing this progress, PFRC is also gaining momentum in surface infrastructure. Under Contracts DE113, DE159, AM102 and J102, PFRC has been successfully applied in a range of road and pathway features—including bus bays, junction approaches, and cycling paths—demonstrating its versatility and performance in enhancing crack resistance and durability. To accelerate adoption, PFRC will be mandated for future cycling path projects and has been formally integrated into LTA's Standard Details of Road Elements. This move not only supports consistent implementation across LTA projects but also encourages adoption by other public agencies such as HDB and JTC, driving a broader shift toward smarter, more sustainable construction practices across the industry.

Industry Engagement

To support knowledge sharing and wider adoption, the team has scheduled industry outreach efforts including:

- A presentation at the World Engineers Summit 2025 on PFRC usage
- A feature session at the Construction Technology (ConTech) at the Annual Safety Award Convention (ASAC) on PFRC usage
- A sharing of LTA's SFRC R&D findings to BCA and ACES, for their incorporation into ACES-BCA Design Guide
- A LTA-CITE seminar to share LTA's SFRC R&D findings with the industry.

These platforms will help showcase the benefits and practical know-how of FRC implementation to a broader engineering and construction audience.

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FEASIBILITY AND SCALABILITY

Potential of Project

This project has validated the practical and scalable use of Fibre Reinforced Concrete (FRC) in Singapore's infrastructure, demonstrating enhanced durability, constructability, and sustainability. With proven performance in both underground and surface pavement applications, and integration into future LTA projects and standards, FRC is poised for broader industry adoption as a smarter and greener alternative to conventional reinforcement.