RADAR MONITORING OF STEEL FIBRE REINFORCED CONCRETE

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Concrete composition has been transformed in the past two decades, primarily with the incorporation of industrial waste products and fibres. Steel fibres (0.1-1 mm diameter, 13-100 mm length) at 0.2-1.0% by volume is recommended in the revised Australian Standards (AS 3600 and AS 5100.5) for civil structural constructions, at 1-2% by volume for Ultra-High-Performance Concrete (UHPC) construction of critical infrastructure, and 2-4% by volume for blast and ballistic resistant structures. While Steel Fibre Reinforced Concrete (SFRC) exhibits superior mechanical strength and durability compared to conventional concrete, this improvement is strongly dependent on the orientation of the fibres, since fibres normal to a crack plane are better at arresting it than fibres parallel to the crack. Thus, biases in fibre orientation lead to anisotropy, i.e. different levels of mechanical performance in different directions. In practice, this is due to the fact that fibres are typically added to concrete during mixing and poured into place; they flow with the mix and disperse within the structure – often non-uniformly, consequently causing non-uniform mechanical strength.

Non-invasively monitoring fibre dispersion in SFRC constructions is therefore imperative for ensuring strength and safety. However, no practical method usable at site presently exists. Instead, current construction guidelines rely on expensive mechanical failure testing of full-scale structures or specimens extracted from them. Fibres were indistinct in concrete when tested using commercially available Ground Penetrating Radars (GPRs) and ultrasonic pulse velocity equipment traditionally used to detect thicker steel bars (> 8 mm diameter) in conventional concrete. On one hand, methods based on AC impedance spectroscopy, DC electrical resistivity, and magnetic induction have been demonstrated on laboratory specimens with limited success and scope. On the other hand, X-ray micro-Computed Tomography [1] is being used for high-resolution three-dimensional imaging of fibres in concrete but is limited to laboratory use due to specimen size and operational safety constraints. RF monitoring of SFRC in existing literature is limited to frequencies lower than the first resonance (half-wavelength matching fibre length) resulting in the concrete appearing as a homogenous medium with dielectric properties altered by the presence of indistinct metallic fibres [2]. These studies have shown that the effective permittivity of SFRC is proportional to the dosage of fibres, and correspondingly delays the signal propagation. However, this approach suffers from poor resolution of the spatial mapping of fibre quantity across an SFRC structure, and insensitivity to fibre orientation. In this presentation, the existing literature on radar monitoring of fibre dispersion will be reviewed. The use of high frequency signals is proposed for better sensitivity to individual fibres, spatial resolution, and detection of fibre orientation from signal polarization, with the major challenge being penetrability. These research avenues, along with preliminary modelling and experimental results will be discussed.

[1] L. M. Kumar and S. J. Foster, "X-ray Micro Computational Tomography for Quality Control of Steel Fibre Reinforced Concrete Structures: Benefits and Challenges," presented at the Concrete Institute of Australia's Biennial National Conference 2021, Australia, 2021.

[2] G. Roqueta, L. Jofre, J. Romeu, and S. Blanch, "Broadband propagative microwave imaging of steel fiber reinforced concrete wall structures," *IEEE Transactions on Instrumentation and Measurement*, vol. 59, no. 12, pp. 3102-3110, 2010.