

2. Development of Low-Carbon Sprayed Concrete

- Evaluating the Quality and Constructability of Concrete Mixtures Incorporating Fly Ash and High-Early-Strength Portland Cement -

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Reducing CO₂ emissions from concrete production is an important challenge for achieving carbon neutrality in the construction industry. The authors developed an environmentally-friendly sprayed concrete that balances environmental performance with the strength and workability required for tunnel construction. The proposed concrete mixture reduces cement consumption by partially replacing cement with fly ash, an industrial byproduct, and combining it with high-early-strength Portland cement.

Since substitution with fly ash typically reduces early-age strength, particularly under low-temperature conditions, maintaining the performance required for tunnel support throughout the year poses a key challenge. In this study, the rapid hydration characteristics of high-early-strength Portland cement were utilized to improve early-age strength development. Full-scale spraying tests with actual spraying equipment were conducted in both summer and winter to evaluate the applicability of the mixture under different seasonal conditions.

The results showed that the sprayed concrete developed by the authors achieves the early-age strength required for tunnel support in winter while maintaining adequate pumpability in summer. In addition, the study confirmed reductions in rebound rate, indicating improved material utilization efficiency. The proposed concrete mixture also reduces the CO₂ emissions associated with cement use. These findings demonstrate the feasibility of applying environmentally friendly sprayed concrete year-round while contributing to lower-carbon tunnel construction.

Keywords: mountain tunnel, high-strength sprayed concrete, fly ash, low carbon