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Early-age strength estimation using deep-learning based image segmentation with thermography and maturity modeling

Woldeamanuel Minwuye Mesfin[1)] and * Hyeong-Ki Kim[2)]

[1), 2)] *Department of Civil Engineering, KAIST, Daejeon 305-600, Korea*
[2)] *hyeongki@chosun.ac.kr*

ABSTRACT

This study proposes an integrated approach for early-age concrete strength estimation using deep-learning-based image segmentation, infrared thermography, and maturity modeling. The method begins with semantic segmentation of construction site images using pre-trained convolutional neural networks to identify concrete areas. These segmented regions are then aligned with corresponding thermal images to extract surface temperature data of the concrete. The extracted temperature histories are converted into maturity indices and used to estimate compressive strength based on modified maturity functions. Field and laboratory validations confirmed that the proposed method reliably predicts concrete strength from 1 to 7 days, with errors typically within 3 MPa. Additionally, a machine learning-based maturity model was developed to generalize strength prediction across diverse mix designs, especially those containing supplementary cementitious materials. A random forest algorithm was trained to estimate strength development parameters from mix composition and curing conditions, enabling dynamic, real-time application without prior calibration. This integrated system demonstrates both technical feasibility and economic efficiency for practical use at construction sites. The proposed method offers a non-contact, data-driven solution for strength monitoring that can support safer and more efficient construction scheduling, particularly in precast and cast-in-place operations.

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[1)] Graduate Student
[2)] Professor