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Cost Optimization of Doubly Reinforced Concrete Beam through Deep Reinforcement Learning without Labeled Data

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Abstract: Reinforced concrete (RC) , a major contributor to resource depletion and harmful emissions, fuels research on optimizing its design. Optimizing RC structures is challenging due to the mix of discrete and continuous variables, hindering traditional differentiation-based methods. Thus, this study aims to optimize RC structures cost-effectively using deep reinforcement learning. When the Agent selects design variables, Environment checks design criteria based on KDS 14-20 code (South Korea) and calculates reward. The Agent updates its Neural Network with this reward. Target for optimization is a simply supported doubly RC beam, with design variables including cross-section dimensions, sizes and quantities of tension and compression reinforcement, and size of stirrups. We used 200,000 training sets and 336 test sets, each with live load, dead load, beam length variables. To exclude labeled data, multiple training iterations were conducted. In the initial training, the reward was the ratio of maximum possible cost at beam length to the designed structure's cost. Next iterations used the ratio of optimal values by the previous Agent to the current Agent as the reward. Training ended when the difference between optimal values from the previous and current Agent was within 1% for test data. Brute Force Algorithm was applied to the test set to calculate the actual cost-optimal design for validation. Results showed within 10% difference from actual optimal cost, indicating successful deep reinforcement learning application without labeled data. This study benefits the rapid and accurate calculation of optimized designs and construction processes in Building Information Modeling (BIM) applications.

Key words: reinforced concrete, design, optimization, deep learning

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