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Application of Data-Driven Material Model for Nonlinear Finite Element Analysis

*Hyunseung Chung[1] and Hyo-Gyoung Kwak[2]

[1], [2] Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Korea
[1] hyunseungchung@kaist.ac.kr
[2] kwakhg@kaist.ac.kr

ABSTRACT

Finite element analysis (FEA), especially nonlinear FEA, has been extensively implemented in numerical analysis methodology for a long time, and the material model used for analysis is one of the critical components during the analysis. With the development of data-driven computing, material models defined by various machine learning technology directly from the experimental data are suggested. Especially the Gaussian Process Regressor (GPR) algorithm is capable of defining stochastic nonparametric material models directly from the experimental data. Conventionally, typical constitutive material models, composed of simple arithmetic calculation and a couple of parameters, are widely applied to the nonlinear FEA and proved to be successful. However, those models rely on discretizing, idealizing, and simplifying, which can lead to sensitivity issues, especially dependency on mesh configuration and load step size.

In this research, the GPR material model, which is intentionally matched to the constitutive material model, is defined and applied during the implicit static numerical analysis of reinforced concrete (RC) beams with well-known experimental data to verify the compatibility between the two models. The response of the beam showed corresponding data with the experimental data and showed less sensitivity to the load step size and typical sensitivity to the mesh size. As the GPR model was a nonparametric model, the training process of the GPR model does not differ between the concrete and steel material models and is directly defined from the experimental data. This new approach is expected to ease the process of applicating newly developed materials with complicated and unconventional stress-strain responses to numerical analysis while delivering an accurate response to the structures.

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[1] Graduate Student
[2] Professor, Corresponding author.