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Surrogate models for the prediction of damage in reinforced concrete tunnels under internal water pressure

Keywords Gene expression programming (GEP); Taguchi method; Finite element (FE) analysis; The effective tensile plastic strain (ETPS); Deflection; Damage

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The purpose of study

Evaluating the performance of reinforced concrete tunnel (RCT) under internal water pressure using nonlinear finite element analysis and surrogate models

The importance of research

- The significance of RCTs in conveying water from resource to hydro-power plants
- The parameters affecting the stability of RCTs and water losses as two main concerns in designing RCTs
- The time and cost of nonlinear finite element analysis and how to reduce them by implementing prediction models

Input variables → compressive and tensile strength of concrete, the size of the longitudinal reinforcement bar, the transverse bar diameter, and the internal water pressure

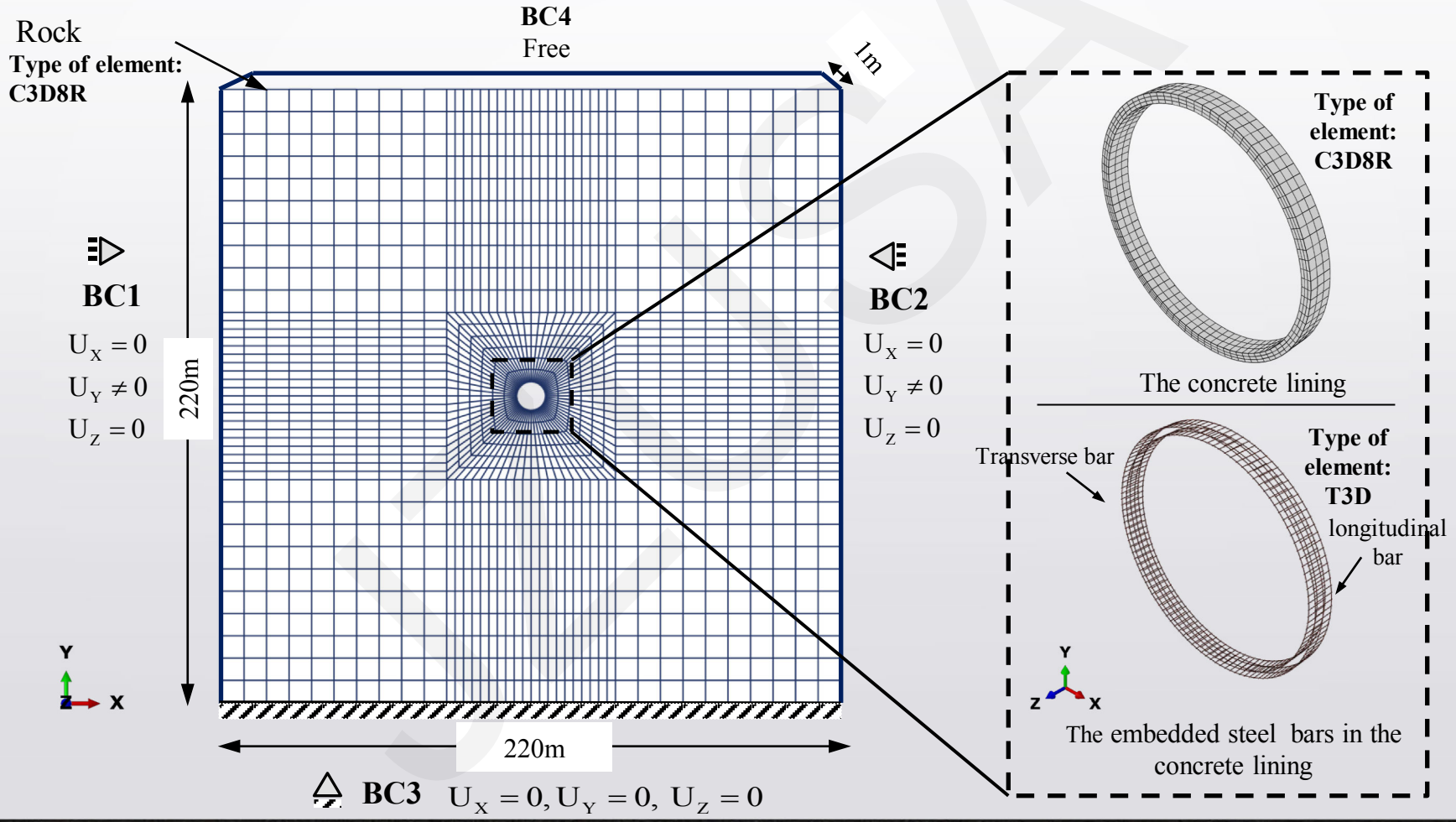
Investigated parameters → percentage of damaged surfaces (PDS) of the RCT, the effective tensile plastic strain (ETPS), the maximum deflection of the RCT, and the deflection of crown of RCT

Pressure tunnel modeling

- Using concrete damaged plasticity (CDP) model to simulate nonlinear behavior of concrete
- Implementing elastic and plastic behavior for steel bars and using isotropic hardening rule with the von Mises yield criterion to account nonlinearity of the steel rebars
- Choosing finite block with 220 m in depth and width for the rock, and the tunnel length equal to 1 m
- Simulating the RCT with six steps: 1-intial condition 2-tunnel excavation 3-rock settlement 4-installing reinforced concrete lining 5-grouted zone modeling 6-imposing internal water pressure load
- Selecting 36 design by the Taguchi method, and 12 other mix based on utilizing carbon fiber reinforced concrete (CFRC) and glass fiber reinforced concrete (GFRC)
- Performing numerical model's validation and mesh sensitivity analyses by computing tangential stress values in the concrete lining

Case of study: The RCT of the upper Gotvand reservoir dam located in the southwest of Iran

Finite element model of the RCT:



Prediction models

Principal component regression (PCR)

A combination of Multi linear regression (MLR) and principal component analysis (PCA) including a technique for deleting unnecessary input variables, for finding effective input variables, and for using the MLR method

Multi Ln equation regression (MLnER)

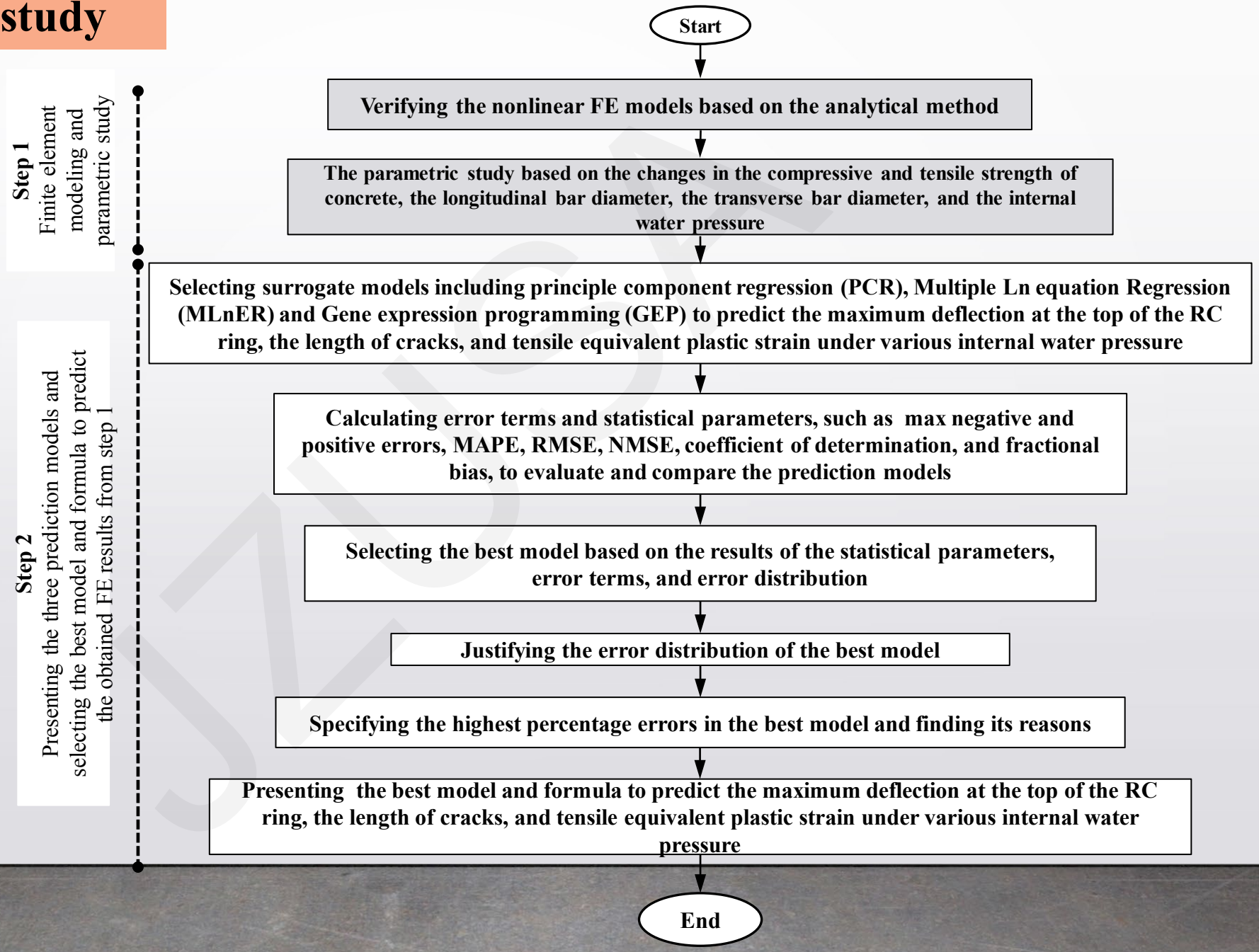
MLnER method Uses several Ln equations instead of several linear equations involving one dependent variable and several independent variables, the coefficients for each independent variable, a constant coefficient, and an error term.

Gene expression programming (GEP)

A combination of a genetic algorithm (GA) and genetic programming. This approach utilizes a set of different functions and terminals. A set of different functions involves user-defined and trigonometric functions, the main mathematic functions, and combination functions that are employed to predict the outputs

- ✓ All models Select 75% of the dataset for training the outputs and the remaining dataset is used as the validation process

The flowchart of the study



Conclusions

1. The internal water pressure has the most effect on the values of the PDS, the maximum ETPS, the maximum deflection of the RCT, and the deflection at the top of the RCT.

2. The compressive and tensile strengths have significant effects on the values of the PDS, the maximum ETPS, the maximum deflection of the RCT, and the deflection at the top of the RCT.

3. GEP predicts the damage, the maximum ETPS, the maximum deflection of the RCT, and the deflection at the top of the RCT with high accuracy.

A safety factor should be applied to the equations of the GEP model to increase the reliability, especially when the PDS and the maximum ETPS are predicted by these formulas.