EFFECT OF PRELOADING AND ENDPLATE IMPERFECTIONS IN BOLTED CONNECTIONS: MOMENT-ROTATION CHARACTERISTICS THROUGH EXPLAINABLE ARTIFICIAL INTELLIGENCE

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Stainless-steel is a popular engineering material due to its durability, high resistance to corrosion, aesthetic appeal, ease of construction and maintenance, recyclability, and ductility. It is often used in a wide range of structural engineering applications such as frames, buildings and bridges. Across these diverse applications, steel connections are a crucial component as they ensure the unified performance of the structure. This study investigated the effect of bolt preloading, endplate imperfections, and geometric parameters on the connection moment rotation response of extended endplate bolted connections.

This study employed a validated numerical model against experimental results from the structural testing laboratory of the University of Moratuwa, further validated against experimental results available in the literature. The validated numerical model was then used to investigate the impact of varying levels of bolt preloading and imperfections on rotational stiffness. The results showed that rotational stiffness increases by 134% with ultimate preloading.

Residual deformation from welding causes initial imperfections in bolted endplate connections, with V-shape, C-shape, and W-shape imperfections identified in the literature. This study examines the impact of C-shape and V-shape imperfections on rotational stiffness. The results indicate that V-shape imperfections have minimal influence if the level of imperfection is limited to the criterion of (endplate depth)/300, while C-shape imperfections significantly affect rotational stiffness, even within acceptable limits.

A novel explainable machine learning approach was utilized to investigate the influence of geometric parameters on the moment-rotation response of connections. A comprehensive numerical modelling approach (validated using related work) was used to generate data for various input features, such as endplate thickness, bolt diameter, overall section width, overall depth, web thickness, flange thickness, vertical bolt spacing, and horizontal bolt spacing. An artificial neural network (ANN), extreme gradient boosting (XGB), random forest (RF), and k-nearest neighbours (KNN) were employed alongside Shapley additive explanations (SHAP) to interpret the trained models. Analysis shows that endplate thickness strongly governs the moment-rotation behaviour of the bolted endplate connections. Moreover, SHAP explanations align with the generally accepted behaviour of steel extended endplate bolted connections according to EN 1993-1-8.

Keywords: Machine learning, Bolt preloading, Explainable AI, Endplate imperfections, Bolted connections, Rotational stiffness

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Effect of Preloading and Endplate Imperfections in Bolted Connections: Moment-Rotation Characteristics through Explainable Artificial Intelligence

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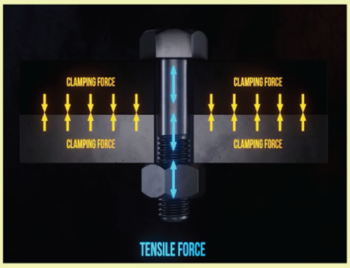
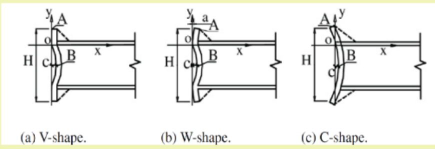
BACKGROUND

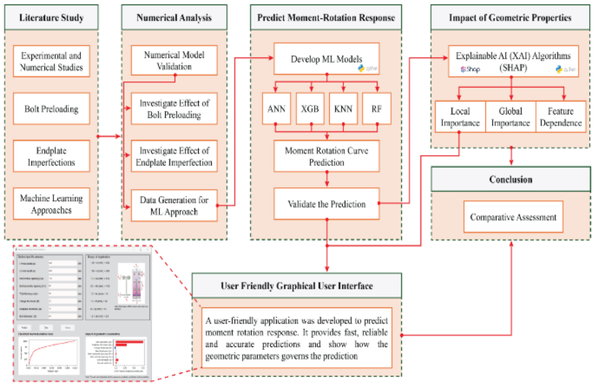


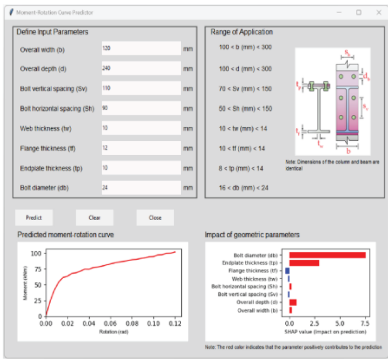
Bolt Preloading



Types of Endplate Imperfections

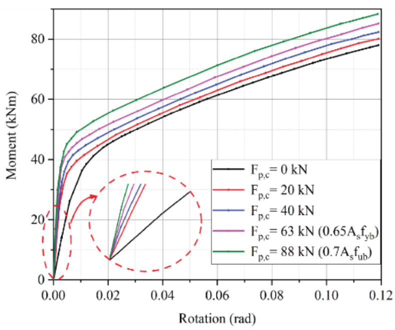
METHODOLOGY



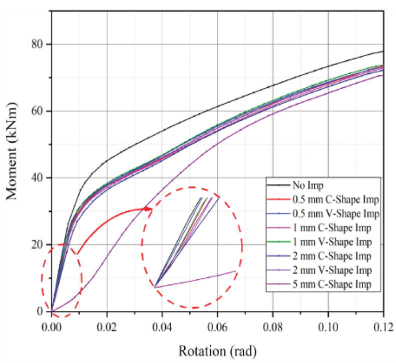


GUI: Moment-Totation Curve Predictor

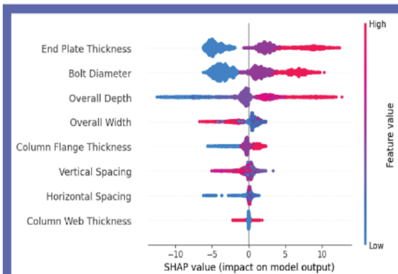
RESULTS



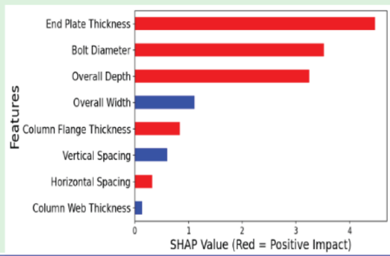
Effect of Bolt Preloading



Effect of endplate Imperfection



SHAP Global Explanation



Average Feature Impact