

# COMPARISON OF ANALYTICAL AND NUMERICAL MODELS FOR PREDICTING THE CAPACITY OF DAPPED-END CONNECTIONS

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## Abstract

Reinforced concrete (RC) dapped-end connections are widely used in precast concrete structures; however, their abrupt geometric discontinuity results in complex stress distributions and brittle failure mechanisms, making the accurate prediction of their load-carrying capacity a significant engineering challenge. This study compares the predictive performance of representative analytical and numerical models for estimating the ultimate capacity of RC dapped-end connections. Three analytical models, namely the classical Strut-and-Tie Model (STM) proposed by Schlaich and Schäfer, the Precast/Prestressed Concrete Institute (PCI) design method, and the Kinematics-Based Model (KBM), were evaluated using the experimental results of eight large-scale, orthogonally reinforced dapped-end specimens from a previous experimental programme. In addition, a nonlinear finite element model was developed in VecTor2 using the Disturbed Stress Field Model (DSFM) and validated against the experimental data. The predicted capacities obtained from each model were compared with the measured ultimate loads. The results showed that the KBM provided the most accurate analytical predictions, while the VecTor2 model also demonstrated excellent agreement with the experimental results. The findings highlight the effectiveness of mechanics-based analytical and nonlinear numerical models for the reliable assessment of reinforced concrete dapped-end connections.

**Keywords:** Dapped-end connections, Strut-and-tie model, Kinematics-based model, Nonlinear finite element analysis, VecTor2

## 1. Introduction

Reinforced concrete (RC) dapped-end connections, also known as half-joints or Gerber joints, are widely used in precast concrete structures due to their structural efficiency and reduced construction depth. However, the geometric discontinuity at the re-entrant corner creates a disturbed region (D-region) with highly concentrated stresses, making the accurate prediction of their load-carrying capacity a challenging task. Several analytical approaches, including strut-and-tie models, empirical and semi-empirical methods, and kinematics-based models, have been developed to estimate their ultimate capacity, while nonlinear finite element analysis (NLFEA) has become an effective numerical tool for simulating their structural behaviour [1], [2], [5]. This study evaluates the predictive accuracy of representative analytical models and a validated VecTor2 finite element model by comparing their predictions with the experimental results of eight orthogonally reinforced dapped-end specimens tested by Rajapakse et al. [3].

## 2. Analytical and Numerical Models

Three representative analytical models were used to evaluate the capacity of reinforced concrete dapped-end connections: the classical Strut-and-Tie Model (STM) proposed by Schlaich and Schäfer [5], the Precast/Prestressed Concrete Institute (PCI) [1] design method, and the Kinematics-Based Model (KBM) proposed by Rajapakse et al. [2]. The STM and PCI

approaches estimate the ultimate capacity based on force equilibrium and load-transfer mechanisms, whereas the KBM predicts the capacity using the kinematics of the critical re-entrant corner crack. In addition, a nonlinear finite element model was developed in VecTor2 based on the Disturbed Stress Field Model (DSFM) to replicate the experimental specimens tested by Rajapakse et al. [3]. The model incorporated the specimen geometry, reinforcement layout, boundary conditions, and loading configuration, with concrete modelled using the Popovics constitutive model and the Vecchio (1992) compression softening relationship. The analytical and numerical predictions were validated against the experimental results of eight orthogonally reinforced dapped-end specimens, and the developed finite element model provided a reliable framework for predicting the structural behaviour and ultimate capacity of RC dapped-end connections, as shown in Figure 1.

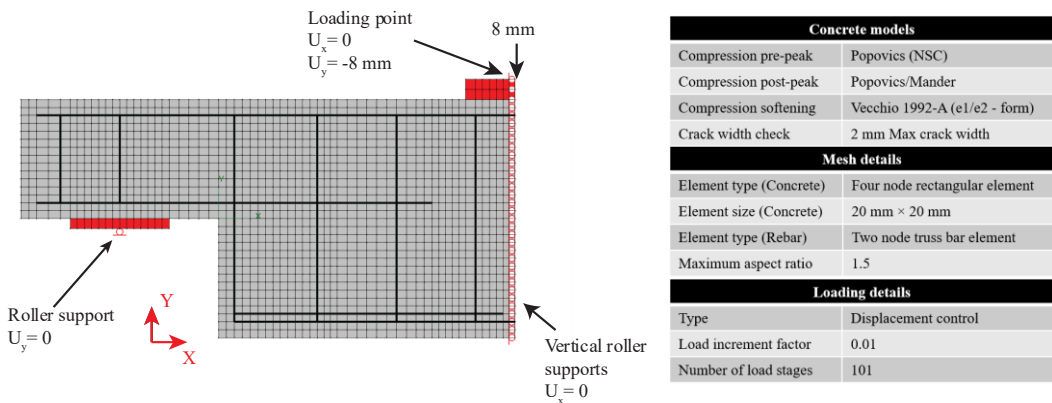


Figure 1: Finite element model developed in VecTor2 showing the mesh, boundary conditions, loading configuration, and modelling parameters.

### 3. Results and Discussion

Figure 2 compares the experimental peak capacities with the predictions obtained from the analytical and numerical models. The Kinematics-Based Model (KBM) [2] showed the closest agreement with the experimental results, with most predictions closely following the 1:1 line and remaining within the  $\pm 20\%$  error band, indicating that the consideration of the kinematics of the critical re-entrant corner crack provides an effective basis for predicting the ultimate capacity of dapped-end connections. The VecTor2 nonlinear finite element model also demonstrated good agreement with the experimental results, with most predictions falling within the  $\pm 20\%$  error band and successfully capturing the overall capacity trend and structural behaviour. Among the conventional analytical approaches, the PCI Design Approach [1] generally produced conservative predictions with relatively larger deviations from the experimental capacities. The classical Strut-and-Tie Model (STM) proposed by Schlaich and Schäfer [5] exhibited greater variability, with both conservative and unconservative predictions, indicating that the idealised load-transfer mechanism may not fully capture the complex behaviour of the disturbed region in dapped-end connections. Overall, the KBM provided the highest analytical prediction accuracy, while the validated VecTor2 model demonstrated comparable predictive performance, highlighting their potential for reliable assessment of the ultimate capacity of reinforced concrete dapped-end connections.

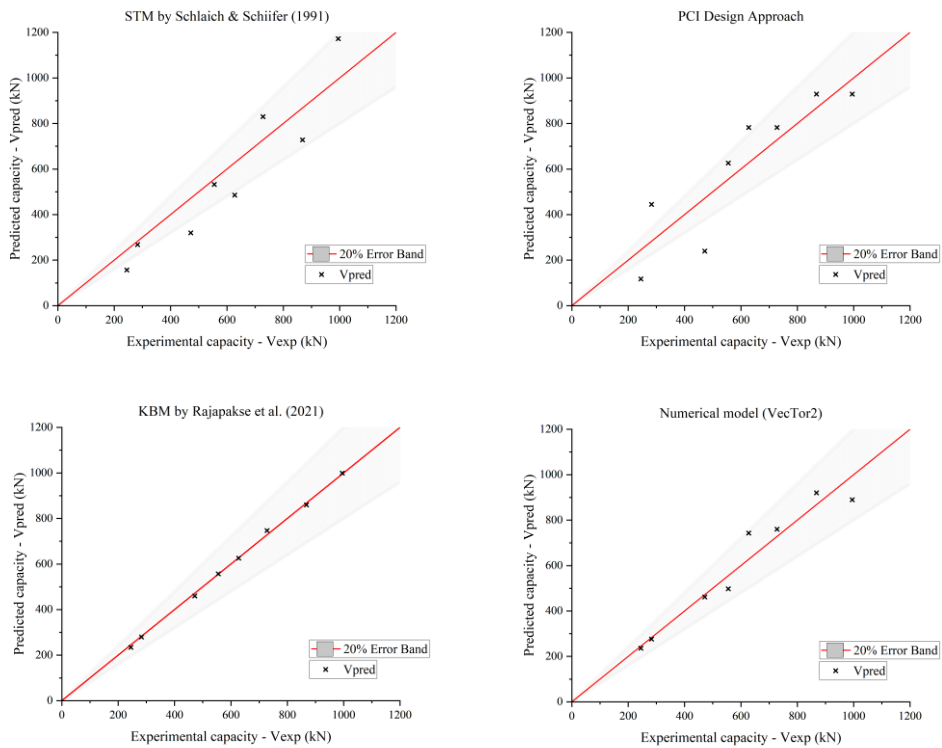


Figure 2: Comparison of experimental and predicted capacities for the analytical models and the nonlinear finite element model.

## 4. Conclusion

The Kinematics-Based Model (KBM) provided the most accurate analytical predictions, while the validated VecTor2 model showed comparable numerical performance. The PCI Design Approach and the classical strut-and-tie model exhibited greater deviations from the experimental results.

## References

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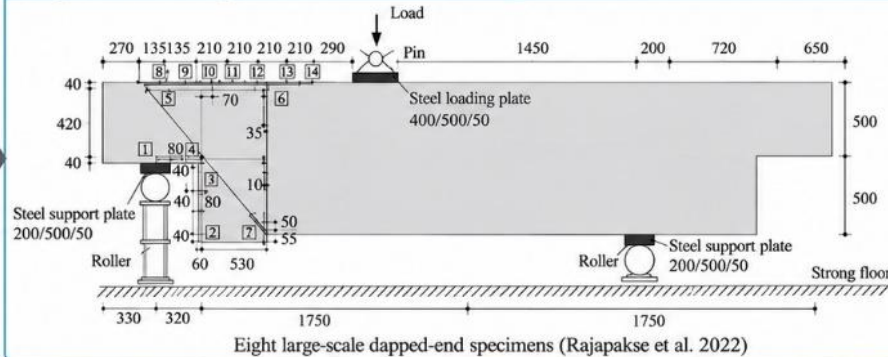
## COMPARISON OF ANALYTICAL AND NUMERICAL MODELS FOR PREDICTING THE CAPACITY OF REINFORCED CONCRETE DAPPED-END CONNECTIONS

### Motivation

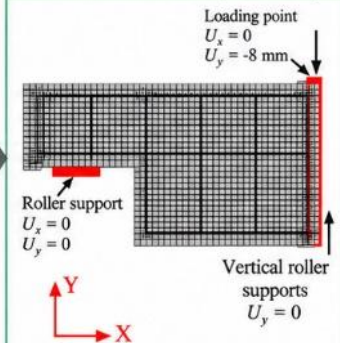


Dapped-end connections are widely used in precast concrete structures, but are vulnerable to inclined corner cracks and brittle failure.

### Experimental Program



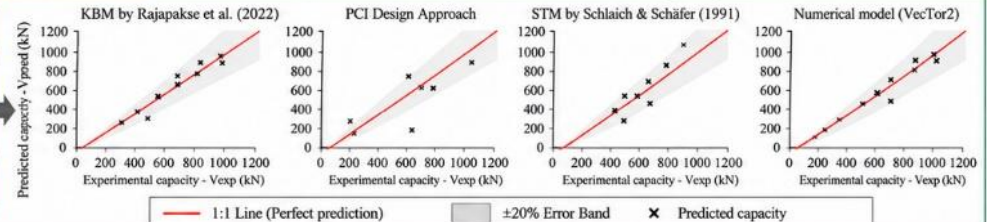
### Numerical Model (VecTor2)



### Analytical and Numerical Models

- Kinematics-Based Model (KBM)  
Rajapakse et al. (2022)
- PCI Design Approach  
(PCI, 2010)
- Strut-and-Tie Model (STM)  
Schlaich and Schäfer (1991)
- Numerical Model  
(VecTor2)

### Predicted vs Experimental Ultimate Capacity



### Key Finding

The Kinematics-Based Model (KBM) provided the most accurate analytical predictions, while the validated VecTor2 model demonstrated comparable numerical performance. Among conventional methods, the PCI approach was conservative and the classical STM showed the greatest variability.