# NON-LINEAR FINITE ELEMENT ANALYSIS OF PRECAST RC BEAM WITH CLOSED REBAR JOINT


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## 1. INTRODUCTION

The construction of bridges by the precast method is an emerging trend due to their faster construction, better quality control, and lower life-cycle cost. Precast technology can be used for the construction of rigid-frame railway viaducts. The performance of the connection in precast construction needs to be analyzed for the safety of the structure.

The experiment to determine the fatigue performance of the connection in a four-point bending test was conducted. In the present study, the numerical analysis of the precast RC beam with a closed rebar joint is conducted in MSC Marc to study its flexural performance.

## 2. MODEL DESCRIPTION

Figure 1 represents the details of precast segments joined by a closed rebar joint at midspan. The modeling is done for precast concrete segments and grouting mortar as structural 3D solid elements and for reinforcement as 2D truss elements. The total maximum load of 294 kN is applied to two plates placed 800 mm apart. The boundary condition for both the experiment and the FEM model is simply supported.

## 3. MATERIAL PROPERTY

A damaged plasticity law is adopted for concrete and grouting mortar. The constitutive law governing the tensile behavior of concrete and grouting mortar is derived from the uniaxial tensile stress-strain relationship. The average compressive strength of concrete in precast segments is 35.4 MPa, and that of grouting mortar is 78.7 MPa. The tensile strength of concrete is 2 MPa, and that of grouting mortar is 2.7 MPa. The elastic modulus of concrete is 34.1 GPa and that of grouting mortar is 28.4 GPa. The stress-strain law for reinforcing steel is assumed to be bilinear with the yield strain of 0.23%. The main reinforcement is D29 of grade SD390, and the shear stirrups are D13 of grade SD345.

## 4. RESULTS AND DISCUSSION

### 4.1 Load deflection curve

The load deflection curve (Figure 2) is continuous and smooth, which shows that the beam is behaving in a stable and predictable deflection pattern. The curve shows elastic behavior up to 30 kN in the FEM model, and after that, the crack initiates at the midspan. The slope of the load-deflection curve decreases as there is a reduction in the stiffness of the beam due to crack initiation.

As the load on the beam increases up to 294 kN, flexural cracks are formed that spread evenly in the tension zone away from the midspan and towards both supports.

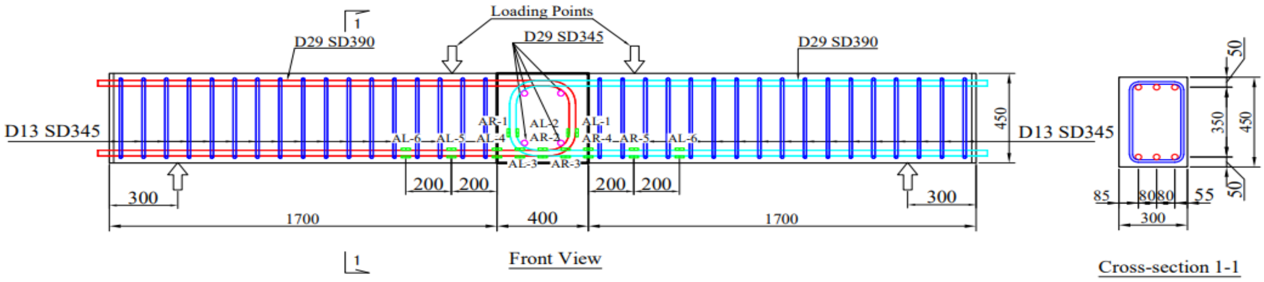


Fig 1. Precast beam in four point bending test showing loading condition, gauge locations, boundary condition and connection detailing.

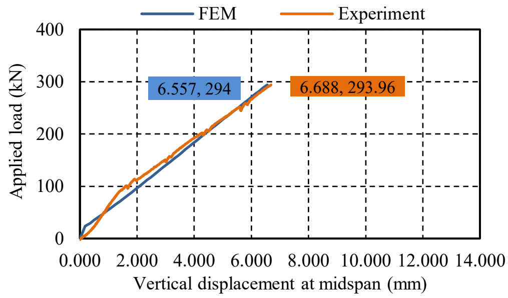

Fig 2. Applied load vs vertical displacement at midspan.

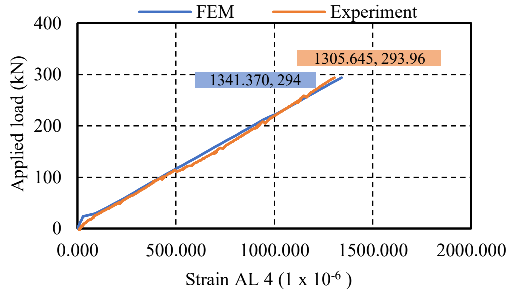

Fig 3. Applied load vs rebar strain at AL4.

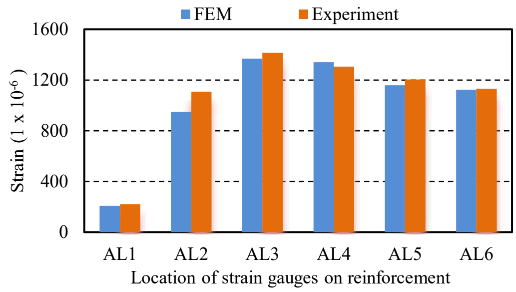

Fig 4. Variation of strains in reinforcement at different locations at maximum load of 294 kN

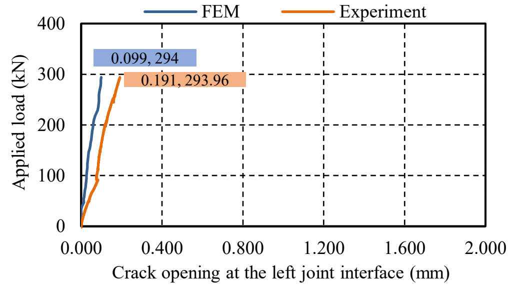

Fig 5. Applied load vs crack opening at left joint interface.

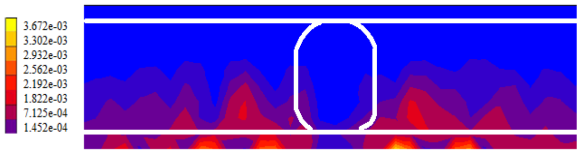

Fig 6. Contour band of cracking strain in the beam at the load of 294 kN

### 4.3 Crushing of concrete

There is no localized crushing of concrete in the joint region. The concrete inside the loop at the central portion of the beam is intact, showing no signs of crushing, and thus fully participating in load carrying up to the maximum load of 294 kN.

### 4.4 Strain in reinforcement

Figure 3 represents the variation of rebar tensile strain at AL4 with the applied load, where AL4 is the location of the strain gauge on reinforcement at the joint interface location. The strain values in the reinforcement are less than yield strain (0.23%) at the maximum load level of 294 kN.

Figure 4 represents the variation of strains in reinforcement at different locations at a maximum applied load of 294 kN. There is a smooth transition of strain in the rebar from midspan towards the precast concrete segment (i.e., from AL1 to AL6). In the experiment, it is also observed that there is no debonding of reinforcement at the interface location.

### 4.5 Crack opening

Figure 5 represents the variation of crack opening with the applied load at the bottom fiber of the left joint interface. The increase in crack opening at the joint interface is gradual and within the permissible range of 0.25 mm (JSCE). The crack is perceived as a normal flexural crack, and there is no visible delamination at the interface between concrete and grouting mortar in the experiment. Even though there is a change in stiffness between two materials, the interface still maintains sound structural integrity.

### 4.2 Cracking pattern

The tensile stresses due to bending are distributed relatively evenly throughout the beam, with vertical cracks at the midspan and diagonal flexural cracks away from the midspan (Figure 6). However, there is cracking strain in concrete along the reinforcement loop of 294 kN, although the strain value is too small to be noticeable by the naked eye.

## 5. CONCLUSIONS

The analytical results of the four-point bending test on the precast beam with a closed rebar joint show evenly distributed flexural cracks, no crushing of concrete at midspan, and a smooth transition of rebar strain at the interface. This indicates that the precast beam can safely support the intended load.

## REFERENCES

1. K. Maekawa, H. Okamura, and A. Pimanmas, Non-linear mechanics of reinforced concrete: CRC Press, 2003.
2. Lee, J. & Fenves, G. (1998). Plastic-Damage Model for Cyclic Loading of Concrete Structures. Journal of Engineering Mechanical, 124(8), 892–900.