RBSM ANALYSIS FOR FAILURE BEHAVIORS OF HORIZONTAL LOOP JOINTS IN PRECAST BEAMS

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1. INTRODUCTION

In loop rebar joints, since the bond stress of straight portions and bearing pressure of curved portions can be utilized, the joint length can be shortened as compared with the conventional lap joint. From such an advantage, adoption of loop rebar joints is increasing. Performance evaluation of loop joints has been studied under various specifications and conditions according to various structural conditions of the site, although there are many researches on loop joints arranged vertically to beams or slab members. The horizontal loop joints (Fig.1 and Fig.2) are also useful depending on construction conditions, however, they have not been investigated sufficiently yet, and the failure mechanism is unknown. In this study, the failure mechanism of the precast beam using the horizontal loop joints and the influence of the reinforcing bars inside the loop were investigated by experiments and numerical simulations.

2. NUMERICAL MODELS

Concrete is modeled using 3D RBSM based on the formulation of Yamamoto et al. (2008). The proposed model has been proven to be an effective tool to reproduce nonlinear mechanical behaviors of concrete, such as cracking, shear transfer behavior of cracked surfaces, and compression failure behaviors including constraint pressure dependence. In RBSM, concrete is modeled as an assemblage of rigid particles interconnected by springs along their boundary surfaces. Cracks initiate and propagate through the interface boundaries and thus is strongly affected by the mesh design. To address this, random geometry of rigid particles is generated using Voronoi diagram. The models proposed by Yamamoto et al (2008) are also applied to the constitutive models of the spring. Reinforcing bar is modelled as a series of beam elements that can be freely located within the structure, regardless of the concrete mesh design. The reinforcing bar is attached to the concrete particles by means of zero-size link elements. For the reinforcing bar, the bilinear kinematic hardening model is applied. The bond stress–slip relation is provided in the spring parallel to the reinforcement of linked element. For the bond stress–slip relation, a model including softening is based on the assumption that applied cover thickness is relatively small (Yamamoto et al. 2014).

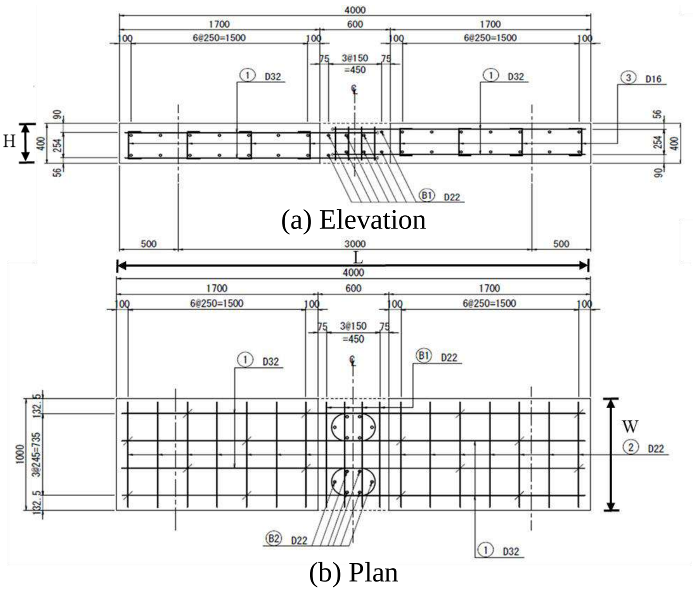
3. SIMULATION OF HORIZONTAL LOOP JOINTS IN PRECAST BEAMS

3.1 Test overview and numerical model

Two different type of specimens are discussed here, horizontal type loop joints with (Case2-1) and without (Case2-2) inner reinforcing bars within the loop. The geometrical dimensions (all are in mm) of the beams are shown in figure 1. The broken lines represent cast in situ, the concrete compressive strength of the adjoining precast beams is 56.8 MPa, and of cast in situ is 43.4 MPa. Figure 2 shows the numerical model of the test beam. A half model is used in consideration of symmetry in the width direction of the test. The cover thickness of the inner reinforcing bar within the loop is much larger than that of the loop reinforcing bar. It is well known that the bond strength depends on the concrete cover thickness, and in this investigation, a simulation in which the bond strength of the inner reinforcing bar is evaluated as being double (Case2-1 2NBS) is also performed.

3.2 Results and discussion

Fig. 3 shows that the proposed model can capture the brittle behavior before the loop reinforcing bar yields in the absence of the inner reinforcing bar (Case2-2), although the numerical simulation results tend to evaluate larger maximum load compared to the experi-



(a) Elevation
(b) Plan
Fig. 1 Test specimen

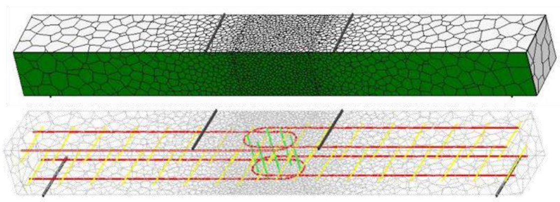


Fig. 2 Numerical model

Keywords: 3D RBSM, Cast in situ joints of precast elements, Horizontal Loop connection, Cottering bar, Bond strength
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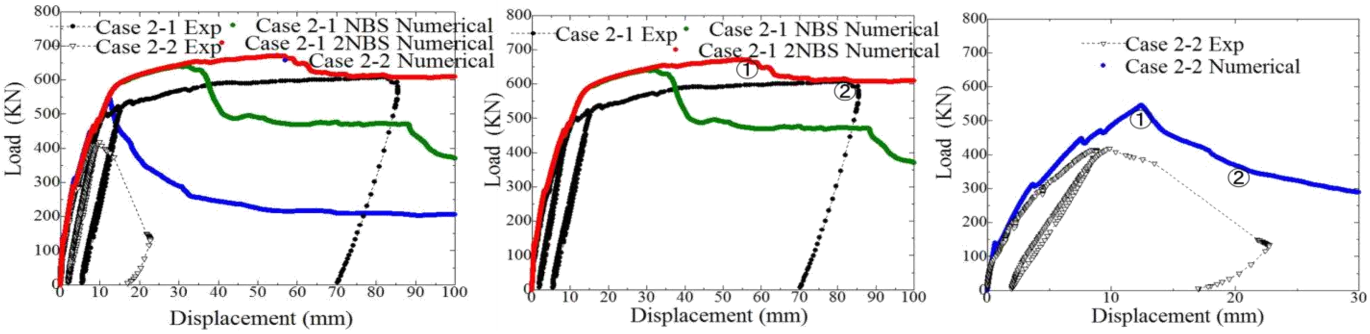

Fig. 3 Load displacement relations

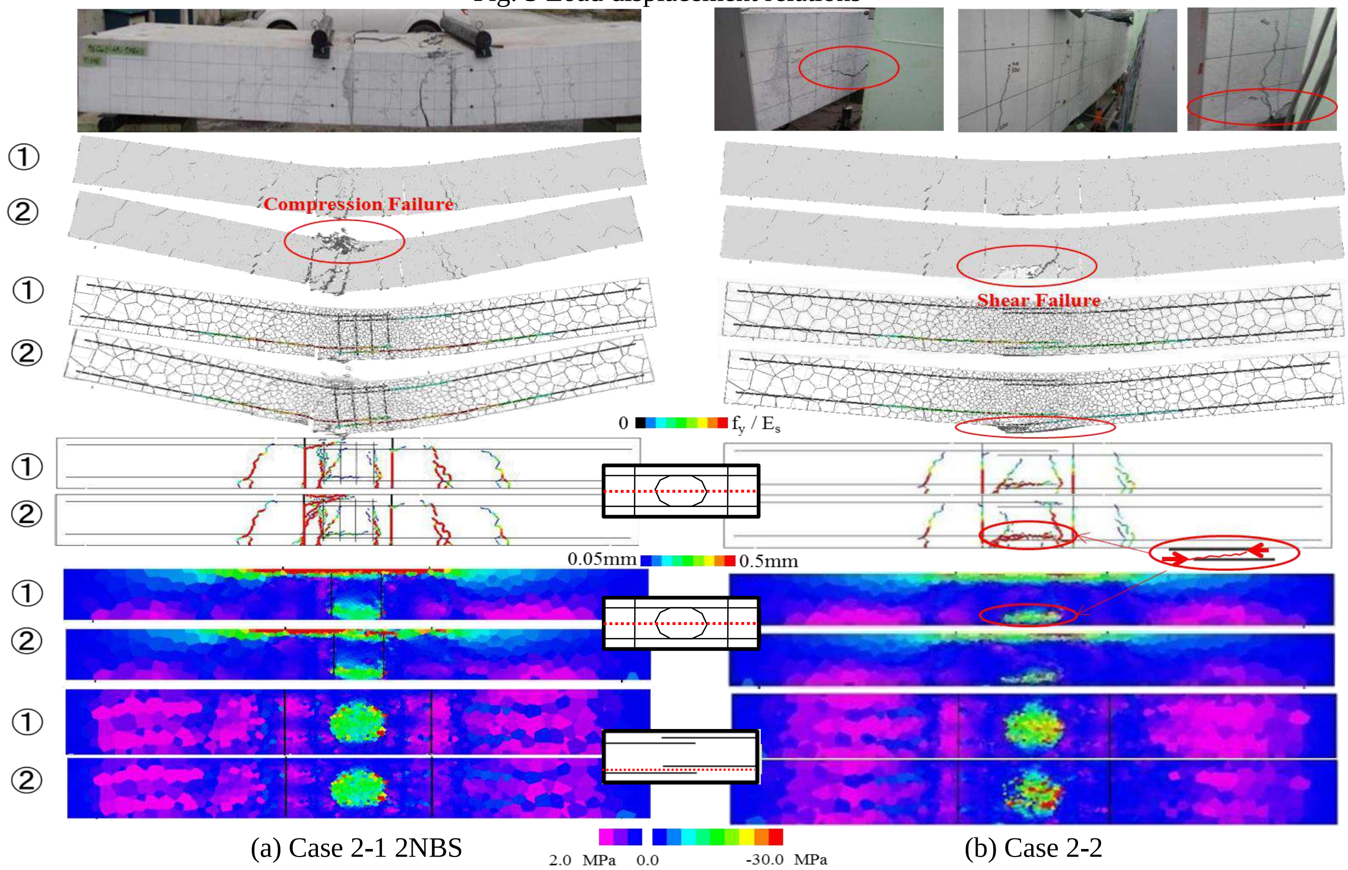

Fig. 4 Experiment photos and deformed shape, cracks pattern and stress distribution in analysis

mental results. The deformation behavior, crack pattern, and stress distribution of Case 2-1 2NBS and Case 2-2 have been shown in Fig. 4 respectively. It can be observed from the figure, the model is capable to capture the cracking patterns, deformation and failure modes. Furthermore, it can also be investigated from the crack diagram, the failure of the loop joint in the Case 2-2 is caused by the propagation of the diagonal crack due to the shear stress between the loop reinforcing bars. Inner reinforcing bars have vital role in suppressing the occurrence and development of the diagonal cracks. In the Case 2-1 NBS, although it is not shown here, after the loop reinforcing bars yield, before the compression failure occurs at the upper side of the beam, the failure mode between the loop reinforcing bars as observed in the Case 2-2 is recognized. It can be observed from the results of Case 2-1 2NBS in Fig.3 and 4, by increasing the bond strength of the inner reinforcing bar, the model can capture the deformation performance and the failure mode observed in the experiment of Case 2-1.

4. CONCLUSION

In this study, the failure mechanism of the horizontal loop joints and the role of the inner reinforcing bars were clarified by experiment and numerical simulations. For simulations with higher precision, it was found that it is necessary to adequately evaluate the bond characteristics of the inner reinforcing bars which have relatively large cover thickness.

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