INVESTIGATION ON STRUCTURAL BEHAVIOR OF EXISTING PRESTRESSED POST-TENSIONED CONCRETE BRIDGE SUPERSTRUCTURE

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1. INTRODUCTION

In the assessment of the residual service life of the existing highway bridges, current condition of structural performance of superstructures is necessary to be clarified. The load-carrying capacity of old bridge superstructures have been studied and the excessive load capacity yet possessed in the superstructure was reported. However, the residual load capacity has not been accurately predicted. Experimental study on post-tensioned T-girder superstructure is still limited as well. Therefore, in this study, field load test of an existing prestressed post-tension concrete bridge was conducted and analytical study was carried out to verify test observation and discuss the structural mechanism of girder assembled in bridge superstructure.

2. FIELD LOAD TEST AND ANALYTICAL MODEL USING 3D-FEA

The bridge studied was the old Chikubetsu bridge in Hokkaido constructed in 1960, consisting of five simply supported spans and length of span is 36m. Each span consisted with four post-tensioned T-girders connected by cross-beams in-between (Fig.1). For each girder, 12 PC strands was installed in longitude and transverse direction. On-site destructive load was applied at midspan of the outer girder G1 (Fig.2). Displacements at midspan of all girders and strain in prestressed tendon in girder G1 were measured throughout the test.

Analytical study based on 3D finite element model of the target span was conducted using 3D ATENA (Cervenka et al. 2016), of which solid elements were applied to concrete (Fig.3). The uniaxial stress-strain relationship and biaxial failure strength criterion was adopted in concrete constitutive model. The smeared crack combined with fixed crack principal was used for considering cracking and crushing of concrete. Compressive strength 40MPa and young's modulus 35860MPa as initial properties of the bridge was given to concrete. Bilinear strain and stress relationship was adopted in constitutive model of tendon and reinforcements. The yield strength was 1300 and 1450MPa for longitude and transverse tendons, 276MPa for reinforcements. For ordinary reinforcements, smeared element was used while prestressed tendons was modelled using discrete truss element. Perfect bond was assumed between concrete and tendons. As for boundary conditions, roller and pin support at end of each girders. In addition, linear surface springs were applied at roller end of G1, G2 and G3 to represent the longitude constrains from adjacent span observed in field test.

3. RESULTS AND DISCUSSIONS

3.1 Assessment of structural performance

Fig.4 shows load-deflection, load-strain and cracking pattern in girder web by field test and FE analysis. Load-deflection

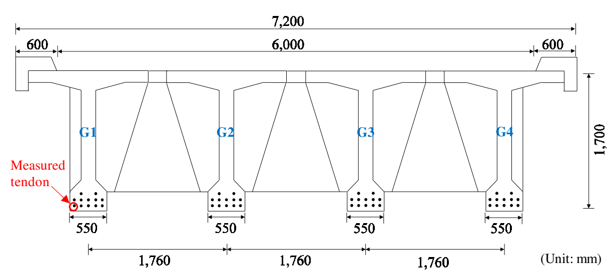

Fig.1 Cross-section of bridge superstructure at midspan

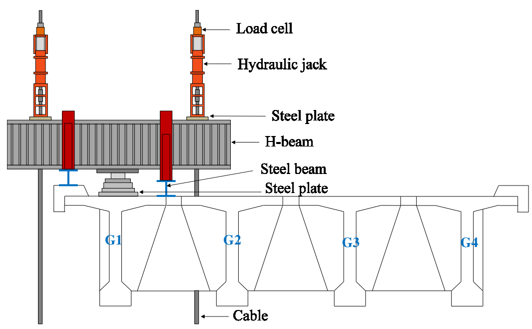

Fig.2 Loading system

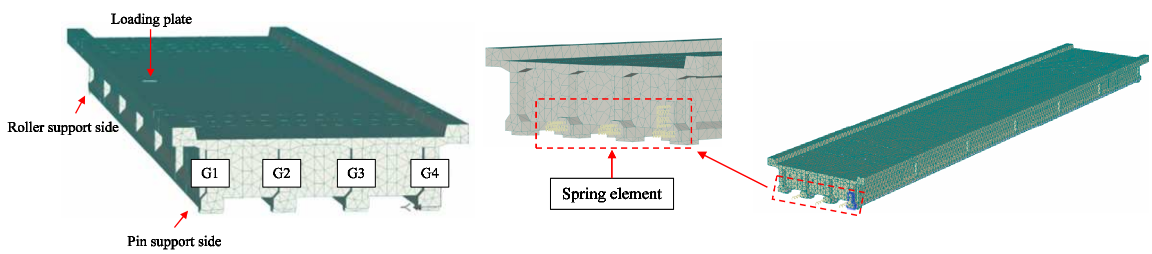

Fig.3 3D FE model of superstructure

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curves in Fig.4(a) show that analytical results have good consistency with test results in both girder G1 and G3, the midspan deflection reduces as the eccentricity between the loading point and the measured girder increase. The excessive load capacity was found in the girder which shows 2.6 times of the design capacity calculated by ACI specification. Strains in prestressing tendon and reinforcement in Fig.4(b) by analysis shows general agreement to the measurements from field test.

At ultimate stage, the web shear cracks and crushing of concrete curb can be well simulated by analytical model. It can be concluded that analytical model is able to predict not only deformational behavior but also failure mode.

3.2 Structural mechanism of bridge girder in the superstructure

In order to clarify the reason of an enhanced ultimate capacity in the girder assembled in superstructure, internal stress distribution on the cross-section at different flexural moments was compared with the single girder case. The cumulative tensile stress at centroid of all prestressing tendons were calculated by summation of stresses in 12 tendons (Fig.5(a)). In Fig.5(b), at each moment, the cumulative tensile stress in girder G1 shows smaller value than the one obtained in single girder case. Meanwhile, smaller compressive stress distributed along depth of cross-section of G1 is also obtained in Fig.5(c). The role of cross-beam and transverse prestressing may be important indexes in structural capacity of prestressed superstructure.

4. CONCLUSION

Proposed 3D FE model can well simulate the structural behavior. Resisting mechanism of bridge girder assembled in superstructure was discussed with stress distribution in the cross-section. Cross-beams and transverse prestressing presented in the superstructure strongly contribute to the reduction of tensile stress in tendon and compressive stress in concrete.

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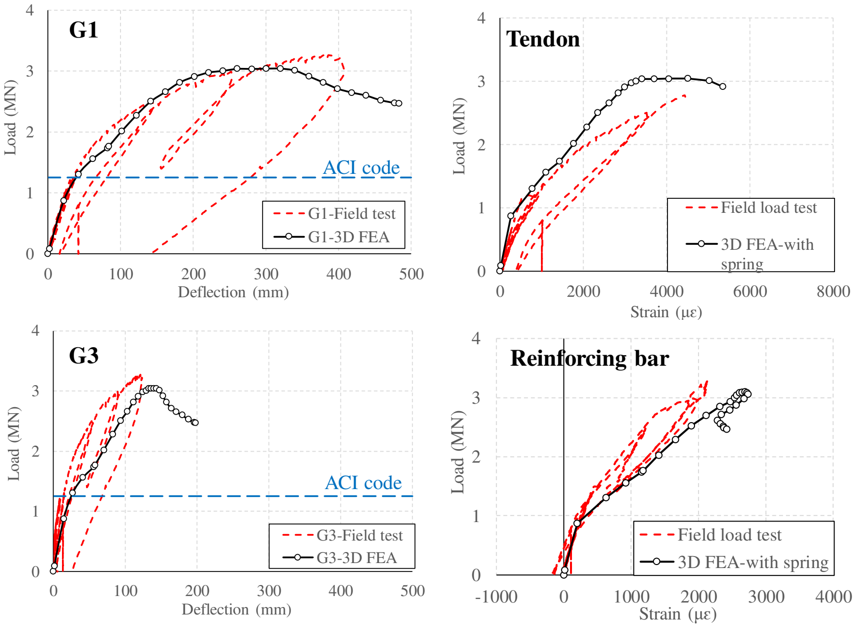
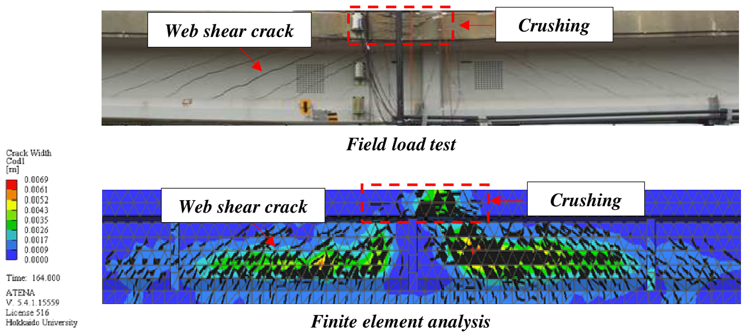
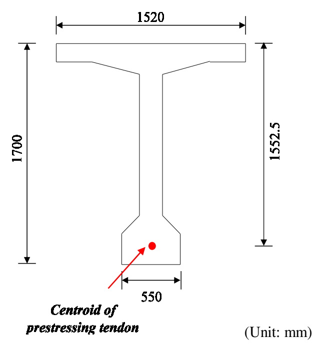


(a) Load-deflection relationship (b) Load-strain relationship

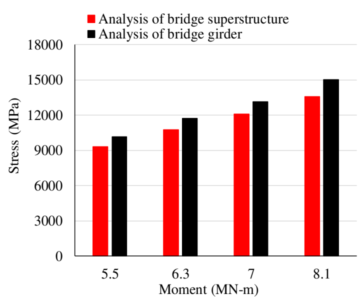


(c) Cracking pattern and crushing zone

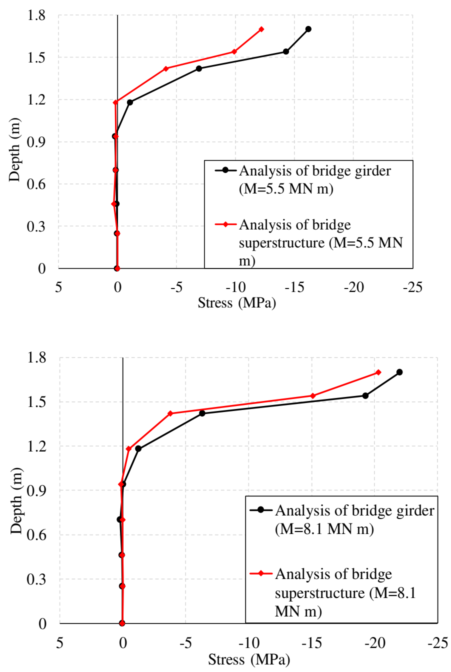
Fig.4 Structural behavior of superstructure by test and 3D-FEA



(a) Calculation of cumulative tensile stress



(b) Cumulative tensile stress



(c) Compressive stress along cross-section

Fig.5 Comparison between single girder and girder in superstructure