Comparison study on modelings of PC girder with corrugated steel web

○ Kyushu University, Student Member, **Takanori Matsumoto**
Kyushu University, Member, **Ling Huang**
Kyushu University, Fellow, **Hiroshi Hikosaka**
Kyushu University, Student member, **Yusuke Genkawa**

1. RESEARCH OBJECTIVE

A simple 2D analysis model has been proposed to simulate the accordion effect of corrugated steel web in hybrid PC girders[1)]. In this study, the accuracy and effectiveness of the proposed 2D modeling are compared to the results obtained from the 1D beam theory, the 3D finite element analysis and the experiment. The advantages and disadvantages of different modelings are also discussed.

2. Test specimen description

The dimensions, loading conditions and boundary conditions of the test specimen analyzed are given in **Fig.1a**[2)]. The width of the top and bottom concrete flanges is 80cm. The corrugated web is made of SS400 steel plate with a thickness of 3.2 mm, having an equal longitudinal and inclined panel length of 109mm. The upper and lower steel flanges (SM490Y) of 250x16 mm are welded to the corrugated web. Material parameters reported on the beam examined here include: concrete compressive strength f_c' =58 MPa and Young's modulus E_c=39 GPa.

3. Finite element model of the specimen

The 2D finite element idealization of the test specimen and boundary conditions is shown in **Fig. 1b**. Due to symmetry, only half of the beam is modeled. Plane stress elements represent both the concrete flanges and the steel web. Solid circular symbols represent the 2D accordion link elements[1)]. The commercial program MARC was used for the 3D analysis, in which the concrete flanges and the corrugated web were modeled by 3D solid elements and shell elements, respectively.

Perfect bond is assumed at the interface between the steel and concrete flanges in the analyses. The numbers of elements used for both the 2D and 3D analyses are given in **Table 1**.

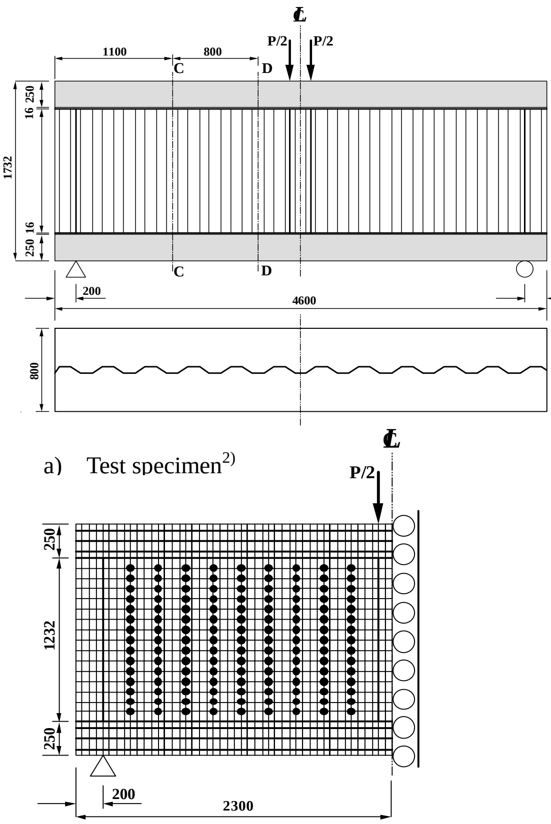
4. Material model

The 3D analysis takes into consideration both the material and geometric nonlinearities, whereas only the material nonlinearity is considered in the 2D analysis. The modified von. Mises yield criterion is employed for the concrete in the 3D analysis, while a plasticity-based constitutive model combined with a smeared crack model is used for concrete in the 2D analysis. The material model of steel web is based on a plasticity theory under von-Mises yield criterion in both the 2D and 3D analyses. The steel flanges and reinforcing bars are idealized as bilinear elastic-plastic.

5. Comparison of the results from different modelings

5.1 Distribution of axial strains

Fig 2 compares the experimental and numerical distributions of axial strains across two cross-sections C-C and D-D in **Fig. 1a**, for the load level of P=1314 kN. Due to the accordion effect of corrugated web, the distribution of axial strain over each cross-section is



a) Test specimen[2)]

b) 2D finite element mesh

Fig. 1. Specimen (dimensions in mm)

Table 1. Types and numbers of elements

Material	elements	Numbers: Elements	Numbers: Nodes
Concrete	Solid (3D)	11640	16234 (3D)
	Plane (2D)	552	1498(2D)
Corrugated web	Shell (3D)	736	
	Plane (2D)	736	
Steel flange	Solid (3D)	736	
	Truss (2D)	92	
Reinforcing bars & tendons	Truss (3D)	1339	
	Truss (2D)	274	
Stiffener	Shell (3D)	144	
	Truss (2D)	32	

Key words: corrugated web, accordion effect, hybrid structure, prestressed concrete, finite element analysis
Address: Dept. Civil Engineering, Kyushu University, Hakozaki 6-10-1, Higashi-ku, Fukuoka 812-8581, TEL 092-642-3262

extremely different from the linear distribution by the beam theory. A dominant positive bending occurs in the concrete flanges on section D-D, developing a large tensile strain even at the lower surface of the top flange. The axial strains in the corrugated web show good agreement between the numerical and experimental results, and the predictive capability of the proposed 2D modeling is satisfactory considering its simplicity.

5.2 Rate of shear force carried by corrugated web

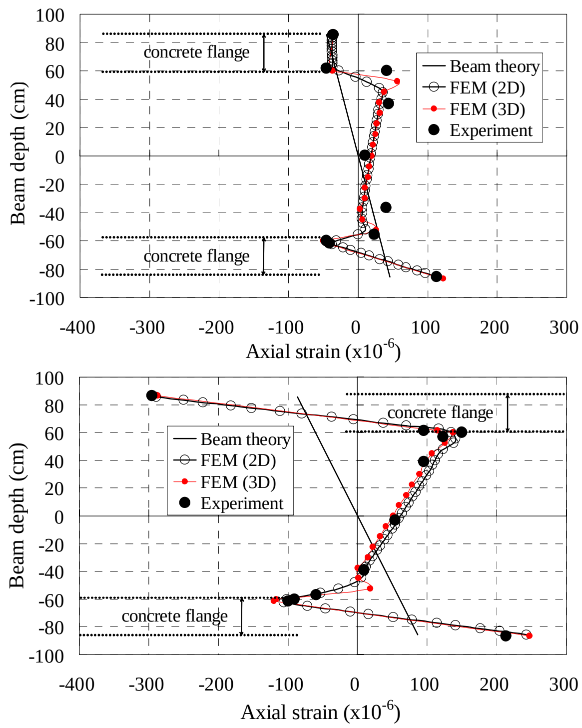
In designing PC girders with corrugated steel web, it is assumed that the steel web carries whole vertical shear force. **Fig. 3** shows the rate of shear force carried by the corrugated web of the specimen. The result from the 2D model is calculated by summing shear force *Q* in each accordion link element over a cross-section of the corrugated web, and the one from the 3D model is calculated by integrating the shear stress of the web. Both results show that the maximum rate is under 80% and the mean rate of shear carried by the web is about 62%.

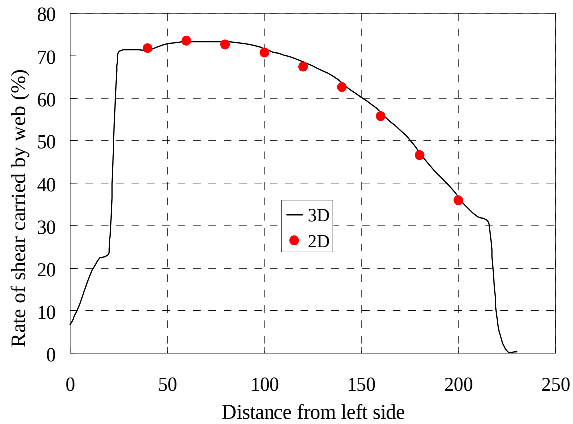
5.3 Load-deflection curve

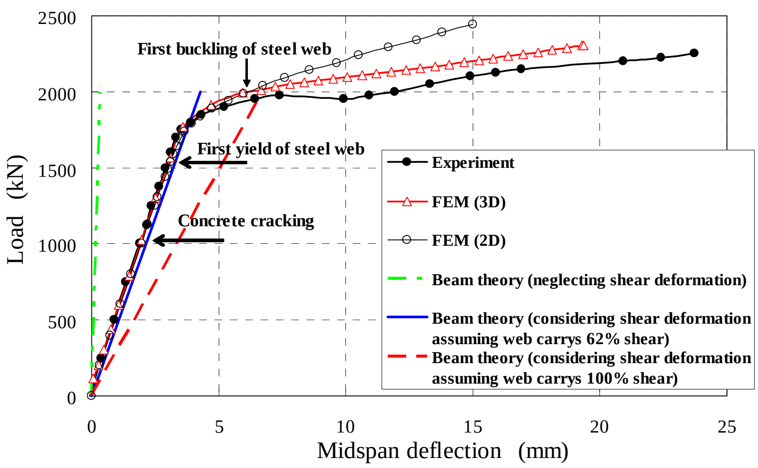
Fig. 4 compares the numerical load-deflection responses of the specimen with the corresponding experimental result. The response predicted by the 3D analysis agrees well with the experimental value, but the 2D model cannot simulate the shear buckling of the corrugated web which was witnessed during the test. Three results from beam theory are shown for comparison. Appreciable errors are introduced into the deflections by the elementary beam theory which either neglects or considers shear deformation of steel web assuming it carries 100% shear. The result using the mean shear carrying rate obtained from the 2D or 3D analyses predicts well the experimental one in the elastic region.

6. CONCLUDING REMARKS

Although accurate results can be achieved from a full 3D finite element model using 3D solid and shell elements, the high costs in preparation and data storage and in computation render the approach not suitable for practical application in designing. The proposed 2D modeling was successful in representing the 3D accordion effect of corrugated steel web on the strain distribution under vertical loading, rate of the shear force carried by the web and load-deflection response before the buckling of the web occurs. The beam theory underestimates the deflection of the PC beam with corrugated steel web when neglecting the shear deformation of the web and overestimates it when assuming that the web carries the whole shear force.







REFERENCES

1. L.Huang, H. Hikosaka and K. Komine, 2-D Modeling of Accordion Effect in Corrugated Steel Web and its Applicability, Journal of Applied Mechanics, JSCE, Vol.5, pp.93-100, August 2002.
2. Expressway Technology Center, Technical Report on Expanding the Span of Steel-Concrete Hybrid Bridge Structures with Corrugated Web, March 2001.