Global/Local FEA for the strain in the welding areas of steel bridge deck

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1. INTRODUCTION

An orthotropic steel bridge deck (OSD) is a large-scale structure but includes complicated and critical parts like a welding area, where the stress, namely hotspot stress, is important in assessing the structural life or strength. However, to obtain this stress accurately from the finite element method (FEM), it is inefficient and computationally intensive to model and analysis for the whole including the detailed welded area. Fortunately, a Global/Local technique in FEA method provide a possible efficient solution.

Global/Local analysis is one of the computationally efficient methods for performing stress analysis [1]. This method uses two distinct models, global model and local model. The global model with a relatively coarse mesh is employed to model the whole structure and obtain the displacements along the boundaries between the global and local models. Then, using the boundary displacements, the local model with a refined mesh is employed for the local regions of interest to achieve an accurate stress calculation.

In this study, firstly, the accuracy of Global/Local FEA is confirmed. Secondly, the effect of the mesh size is investigated with local models with different levels of refinement. Thirdly, the refined local model with and without welding are compared using an appropriate mesh size determined from step 2.

2. ANALYSIS

In this study, the Global/Local FEA is performed by using the software MSC/Marc.

2.1. Global model

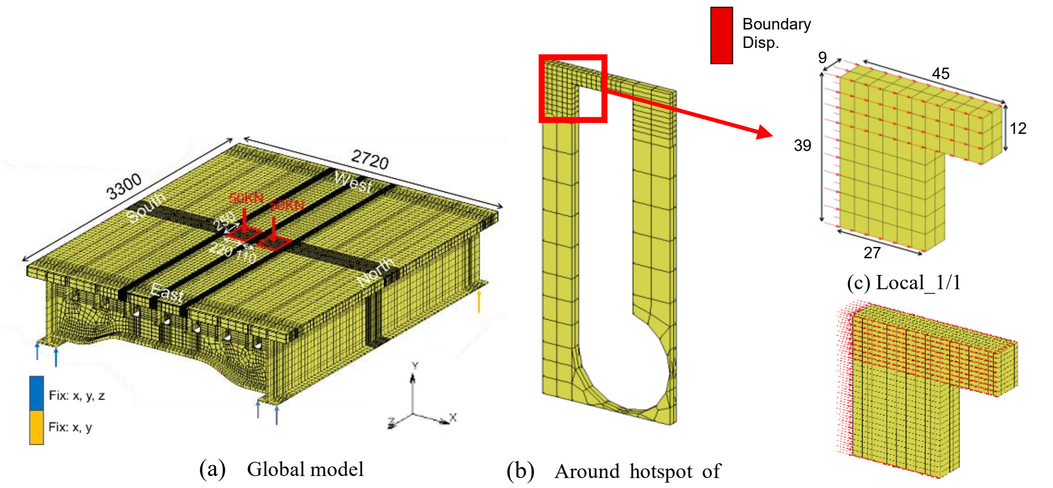
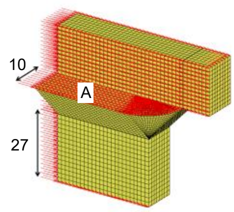
The global model is an OSD which was tested under a moving wheel load in Civil Engineering Research Institute for Cold Region. The deck plate with a dimension of 2720×3300×12 mm is supported by 7 longitudinal and 3 transverse ribs as shown in **Fig. 1(a)** together with the loading and boundary conditions. All elements are modeled as 3-D solid elements with 8 nodes. The welding area is not included in this model. Basically, the mesh is appropriate for analyses aiming at global behaviors but is not fine enough for the stresses at the local hotspot area even with a locally refined mesh as shown in **Fig. 1(b)**. Elements with a 4.5mm side length are used around the hotspot. The Young's modulus and Poisson ratio are assumed as 200GPa and 0.3, respectively for all the steel members.

2.2. Local model without welding

As shown in **Fig. 1**, the local models are identical to an area around hotspot of the global model in dimensions, but can have different mesh size. According to the number divisions (N) of each element side in the global model, the local models are named as local_1/N. To check the accuracy of the Global/Local FEA, a local model without refined, i.e. local_1/1, is exploited as shown in **Fig. 1(c)**. For all local models, the displacements obtained from the global analysis are applied as boundary conditions to the nodes at the boundary with the global model like **Fig. 1(c).** The material properties and element types are same as global model.

2.3. Local model with welding

To evaluate the effect of the welding, the model of local_1/4

(a) Global model　(b) Around hotspot of global model　(c) Local_1/1　(d) Local_1/3　(e) Local_1/4 with weld

Fig. 1 Dimensions and boundary conditions (Unit: mm)

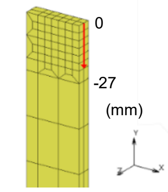


Fig. 2 Arc length

with the welding area is also exploited as shown in **Fig. 1(e)** together with the dimension and boundary conditions. The weld dimension is measured from the tested OSD. Besides, it is found that an additional global/local boundary is included on the top surface of the welding, i.e. A surface.

3. RESULT AND DISCUSSION

In this study, the steel strain in y-axis is investigated along a downward line originated from the hotspot as shown in **Fig. 2**.

3.1. Accuracy of Global/Local FEA

The strain distributions of the global analysis and the Global/Local analysis using local_1/1 are shown in **Fig. 4**. It is found that the two distributions match fairly well indicating that the accuracy is very high.

3.2. Effects of refinement

Fig. 4 shows the strain distributions for several levels of refinements and the experiment result as well. In experiment, the strain was measured at a 5 mm distance away from the weld toe. It is found that as the number of divisions increases the strain distribution curves becomes smoother and the strain value at a 5 mm arc length approaches the experimental strain, which indicates that the accuracy is improved. Besides, the result stays almost unchanged from model local_1/3 to local_1/4 except for a sharp increase at the top edge due to the omitting of the weld. These mean that the welding area should be modelled to have an accurate calculation of the hotspot stress and a mesh size similar to the local_1/4 is enough for strain in this case. Thus, the model of local_1/4 is used in next section. In addition, the caluclation time of different models are listed in **Table 1**. It is found that the caluclation of the local models is very fast even for the refined the model. This demonstrates the efficiency and convenience of using the Global/Local FEA. Furthermore, the strain distributions of the local models are shown in **Fig. 6**, where the local_1/4 model exhibits smoother strain contours and a smaller distance between the top edge and the critical location (dark blue region) than the local_1/1 model.

3.3. Effects of modeling weld

Fig. 5 shows the strain distributions for the model local_1/4 with and without welding. The curve of the model with welding shows the strain distribution from the weld toe which is the critical point. It is found that at a 5 mm of distance from the toe the model with welding gives a higher strain than the other model and the experimental data. This is because due to the omitting of the weld in the global model, the boundary displacements applied on the A surface in the **Fig. 1(e)** should be larger than the local displacements in the tested OSD with weld. Therefore, to have an accurate calculation using the local model with the weld, a coarse mesh of the weld should be included in the global model as well, which is one of the future works. The strain distribution of the model local_1/4 with weld is shown in **Fig. 6** as well. It is found the critical location (dark blue region) is shift from the region adjacent to the top edge in the local_1/4 model to the weld toe.

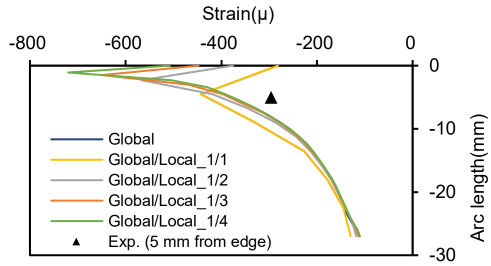


Fig. 4 Strain result of Global/Local FEA

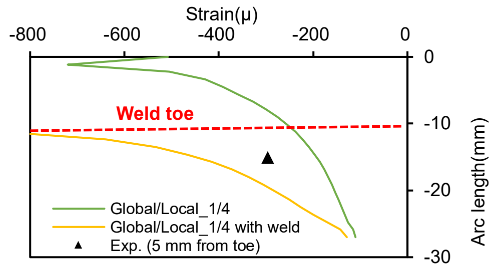
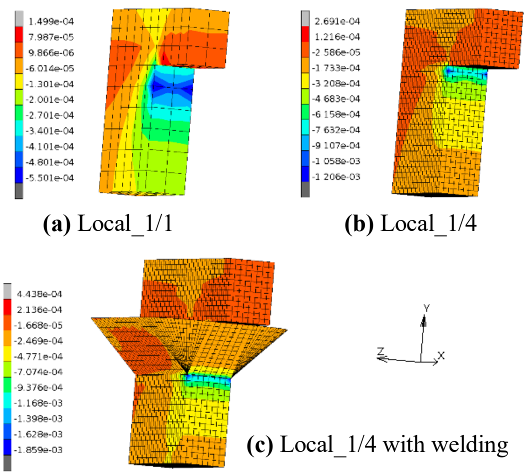


Fig. 5 Strain result of various local models

Table.1 Calculation time

Model	Global	Local_1/1	Local 1/4 without weld	Local_1/4 with weld
Time (s)	41.17	1.25	5.69	9.27



(a) Local_1/1　**(b)** Local_1/4　**(c)** Local_1/4 with welding

Fig. 6 Strain distribution

4. CONCLUSION

The Global/Local FEA is used to obtain the hotspot stress of an OSD. The accuracy of this method, the effects of refinement, and the effects of modeling weld are investigated step by step. It is found that an about 1mm mesh size is appropriate and required for the hotspot area. Besides, the weld should be included to have an accurate strain calculation at the weld toe. Furthermore, the efficiency of exploiting the method on structure like OSDs is confirmed by the short calculation time.

ACKNOWLEDGEMENT

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REFERENCES

1）J. D. WHITCOMB: Iterative global/local finite element analysis, Computers & Structures Vol. 40, No. 4, pp. 1027-1031, 1991