Rating the Crack-Resistance effect for a Steel Truss Bridge Based on 3D Fracture Mechanics Model

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Abstract. A 3D fracture mechanics model for a 2×162m continuous steel truss bridge is modelled by mixing two different element types together, while the cracked cross-beam is meshed as solid elements and 3D-beam elements for the other truss bridge members. The static analysis result show the truss system model works well.

1. Introduction
Fatigue damage appeared in recent decades for many steel trussed bridges in service because of the heavy traffic and the material degradation. For example, lots of fatigue cracks had been found in the recent inspection in the First Jiujjiang Yangtze River Bridge, and the maximum crack length on a cross-beam web reached 230mm. Therefore, there is an urgent need to investigate effective crack-preventing measures to ensure the safety of bridge structure and pedestrian.

In recent years, the bridge has undergone many maintenance work, including strengthening the crack damage area in cross beam joints and the replacement of bridge deck. A 3D fracture mechanics finite element model of the steel truss bridge is established considering both the overall structural beam elements and the partial solid elements of cracking cross-beam. The crack near the web bolt is simulated and mechanics analysis provided under adjustable bearing pressure.

2. Fracture mechanics model
The structural model of steel truss bridge is usually simulated in two types as: 1) 3D-beam elements or 2D-link elements for all structural members(shown as figure 1), which is convenient for structure mechanics analysis; 2) 3D-solid elements(shown as figure 2) or 2D-plane elements only used for partial components, such as a damaged joint or a gusset plate, while the loads are treated as concentrated loads on nodes. The former beam element only can’t analyze fatigue damage details, and the latter can’t consider the real loads transferred from other structure members. A 2×162m continuous steel truss bridge is modelled by two types together here, while the detailed fracture mechanics model is established for a steel truss bridge which includes both 3D-solid elements for a cracked cross-beam and 3D-beam elements for the other truss members. Beam188 element are used for truss members and plane182 element used for solid elements respectively, and the whole bridge structure model includes
21,328 nodes and more than 50000 elements. The final model is shown in figure 1. The main work includes four steps as following:

1) Establish 3D beam element model for the whole bridge members, do the static analysis under dead loads, get the inner force’s distribution of bridge elements(such as bending moment, shown as figure 4), which could show the maximum force’s position recommend for further study;

2) The most vulnerable members and their locations are determined and choosen as the further research members based on the nearest inspection result(one picture shown as figure 4) and the static analysis result from step1)(shown as figure 5). In figure 4, the maxlength crack occurred in a cross beam (its location shown as figure 3(red mark)), and it’s element number is 293 in 3D beam element bridge model;
3) Establish solid element model for the cracked cross beam, couple the beam element node with the solid elements at the same location to form a complete bridge model. The crack length is 230mm, its shapes is the same as that recorded from inspection, located under the stiffening rib, shown as figure 6;

4) Simulating the connection between the cracked components and the other solid components. Tetrahedral solid elements with ten nodes is well used to simulate orthotropic materials, so element type solid45 used to mesh the whole cross-beam. In order to improve the computational efficiency, the beam element size level is 10mm (rough), and the bolt element size is 5mm.

3. Static analysis under dead load and traffic loads
According to the actual contact between girders and cross beam of steel truss bridge, surface load is applied to the area with a width of 240mm on the flange slab to simulate the dead loads and traffic
loads transferred from the bridge deck. The maximum vertical deformation is 48.18mm, shown as figure 7. And the displacement of solid elements is shown as figure 8.

![Figure 7 Vertical deformation under dead load and traffic load](image1)

From figure 8, it is easy to find the stiffener and its connection to the top flange plate undertook the largest tensile stress and the largest deformation, which caused by the local stress concentration and the structural geometric mutation. The static and dynamic loads test report of the bridge also pointed out that the stress concentration and the stress gradient caused by the vertical stiffener had significant effect on the cracking damage.

4. Conclusions
A fracture mechanics model is established for a steel truss bridge, with both beam and solid elements for further crack simulation. The internal force and displacement of the static analysis result show the model works well, and the model can be used to simulate crack growth or evaluate fatigue life further.

Acknowledgments
This work concentrates the efforts and wisdom of our colleagues from Jiangxi Traffic Science Research Institute, and is sponsored by Research and Development Center on Technologies and Equipment of Long-span Bridge Construction Ministry of Transport, Nanchang, China and Jiangxi project 2017C0002. Thanks a lot.

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