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FATIGUE ANALYSIS OF A STEEL BRIDGE STRUT UNDER COMPRESSION AND BENDING

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ABSTRACT

Steel truss members are typically made up of rolled structural steel sections which joined by are welded, bolted or riveted connections. Steel bridge trusses are often under repeated loads. Hence, it is vital to ascertain the fatigue life of steel truss bridges. Efforts have been made to demonstrate the description of fatigue life. A crack has been considered in the chord of an angle section of steel truss bridge and a study has been carried out for ascertaining safe number of cycles for the section under anticipated cyclic loads. This study adopts a fracture mechanics based approach to determine the crack propagation characteristics and number of cycles to failuredue to cyclic loads have been studied using Paris' law. Finite element model has been developed in Ansys to simulate crack growth. Fatigue life of a crack in the chord has been estimated. The adopted approach gives vital information regarding the fatigue life and crack propagation characteristics.

Keywords: Fatigue, Crack Growth, Finite Element Analysis, Fracture Mechanics, Steel Bridges, Compression, Bending, Torsion, Shear.

I. INTRODUCTION

Steel truss bridge [1] are usually constructed from rolled steel sections that are either bolted, riveted or welded together. This type of girder is usually used to make certain types of bridges and other industrial structures. Truss bridges are efficient and economical structural systems, since the members experience essentially axial forces and hence the material is fully utilised. Due to their efficiency, truss bridges are built over wide range of spans. Truss bridges compete against plate girders for shorter spans, against box girders for medium spans and cable-stayed bridges for long spans.

Steel trusses are usually analysed considering joints to be pinned. This means that the moment at joints is assumed to be zero and the members are assumed to be able to rotate freely with respect to each other. Thus, truss members are purely under axial load. However, in reality the joints are seldom pinned. Further, the members are fabricated from rolled angle sections having their shear centre outside the section thereby inducing torsion when off-axis load is applied. Thus, a typical chord in a steel truss is under axial compression, bending and torsional moments along with shear. Bolting and riveting are the common choice because of the simplicity involved in fabrication of the joints. However, bolting and riveting operations require drilling of bolt or rivet holes in the members. There is a very high possibility of micro or macro-cracks developing around the bolt holes, which would seriously hamper the performance of the joints. Bolt or rivet holes also produce stress concentration and are potential sites for initiation of cracks or damage. While welding is a good choice, it offers a potential threat of transfer of crack from one part of the component to the other. Further, the truss bridgestructures are often subjected to cyclic loads, which may introduce number of fatigue cracks in the chord after some number of cycles. It becomes imperative then to determine the remaining life of the sections or members based on fatigue crack propagation studies [2,3].

Fracture mechanics [4, 5] is a branch of solid mechanics that deals with the study of stress and strain fields around existing cracks in a structure and tries to describe the behaviour of the structure under effect of existing and propagating cracks. A structure may be subjected to static or repetitive or cyclic loads. A structural component may fail under the effect of repeated cyclic loads which may be of much smaller magnitude than the static failure loads. Such a failure of a component is termed as a fatigue failure. Steel bridges are usually subjected to cyclic loads and are prone to fatigue failure [6]. It is extremely common to observe fatigue cracks emanating in the joints/members. The probable locations from where the cracks may emanate are called hot-spots. Since the analysis is carried out using finite element method, the crack propagation problem becomes mesh sensitive. Fatigue is the degradation of material and subsequent crack propagation under the influence of repeated cyclic loads on a structure. Commonly, the fatigue life of a component can be described by the well-known Paris' law [7]. Paris law requires two material constants for characterization of the crack propagation behaviour; viz., m and C. Experiments are required for determination of m and C [8].

II. FATIGUE ANALYSIS OF THE CHORD

An angle section of a truss bridge of length 4m has been taken into consideration for analysis here. The cross-section dimensions of the chordwere 150mm x 150mm and 20mm thick. A crack of 1 mm was introduced in the chord which was underaxial compression, bending, shear and torsion. A schematic of plate girder cross section is shown in Figure 3.1 and 3.2. The cross section has been modeled in Ansys using 442096 nodes and 30521510 noded tetrahedrons. The finite element mesh is depicted in Figure 3.3.The actions and the boundary conditions were observed to be symmetric. Hence only half member has been modeled by giving symmetric boundary conditions at the mid length. The support condition and the loading has been shown in Fig. 3.4.

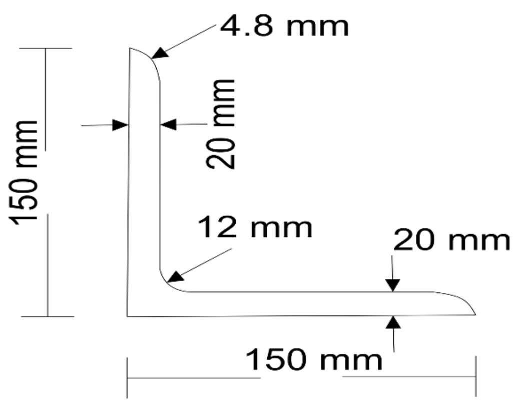

Fig. 3.1 Schematic of the Angle Section.

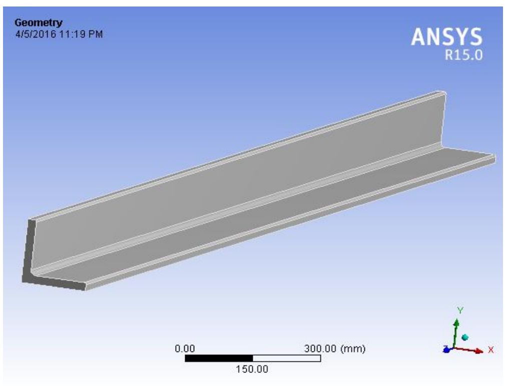

Fig. 3.2 Ansys model of the section

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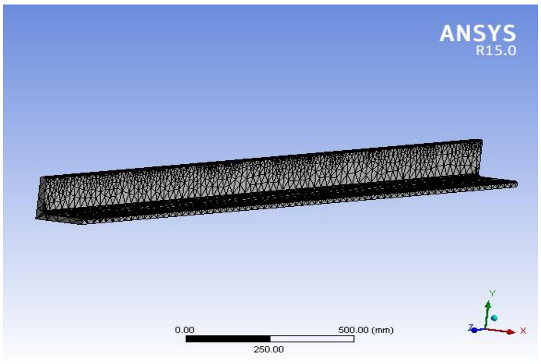

Fig. 3.3Finite Element Mesh

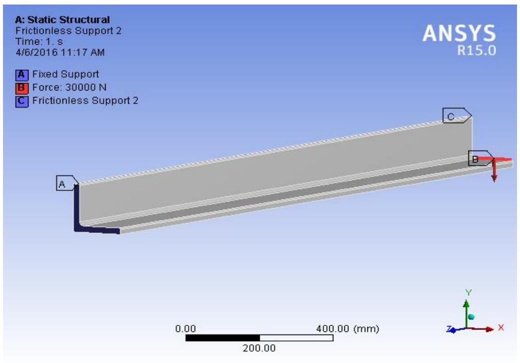

Fig. 3.4 Support and Loading of the section

The Von Mises equivalent stresses compute using Ansys have been obtained, which are shown in Fig. 3.5. The von Mises equivalent stress values reported in the plot are in MPa. Material properties of standard industrial steel have been adopted for the stress analysis. The total deformation of the structure obtained from Ansys has been shown in Fig. 3.6. The fatigue lifecorresponding to various crack lengths has been determined and has been reproduced in Fig. 3.7. The decision whether this life span is sufficient depends on the number of load cycles. The number of cycles for different cyclic loadings anticipated have been plotted in excel and the graph has been reproduced here. The results and the graph suggest that if the loading is very high then the life cycle of the section/member will be very low.

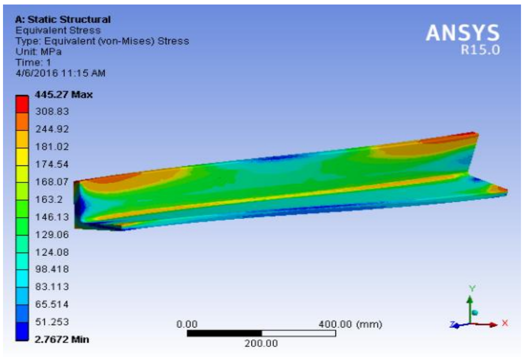

Fig. 3.5 Von Mises Equivalent Stress

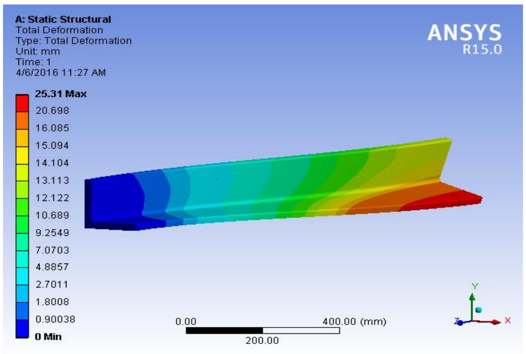

Fig. 3.6 Total Deformation of the Section

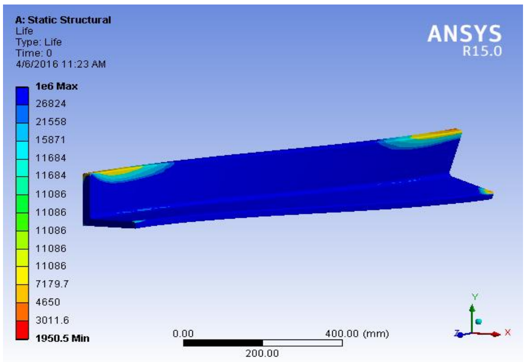

Fig. 3.7 The fatigue life of the section.

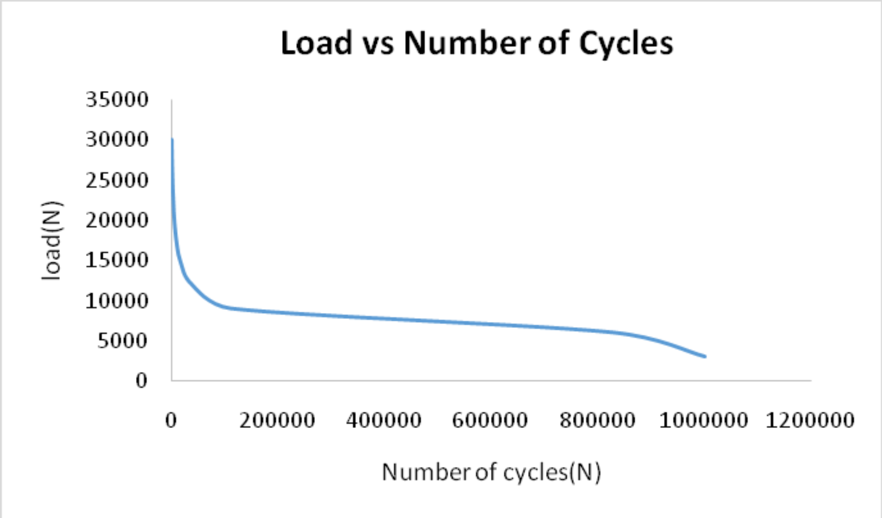

Fig. 3.8 Load Vs Number of Cycles for Angle Section.

IV. CONCLUSION

Fracture mechanics based fatigue analysis of an angle section of a steel truss bridge under service loads and in presence of detectable cracks has been carried out and described here. The life of the section as estimated by the Fracture Mechanics based fatigue analysis approach has been studied. Ansys has been used successfully for fracture analysis of cracks in the chord of the section of the truss girder. The approach adopted gives a reasonably good description of the fatigue life of the truss girder. Fracture based analysis should be adopted in the design procedure for clearer description of crack propagation and estimation of life of the truss girder.

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