FATIGUE LIFE ASSESSMENT OF A TRUSS GIRDER BRIDGE USING LINEAR FRACTURE MECHANICS APPROACH

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Abstract

In transportation system, bridges are continuously subjected to vehiclular loads that causes accumulation of stresses in different components. The weakest region are some times prone to the development of fatigue crack, that grows leading to collapse if proper maintenance and reparing are not carried out. In this paper, a method of estimation of fatigue life of a truss girder bridge has been outlined using linear fracture mechanics approach after synthesizing the vehicle induced stress history. Von-Mises stresses which accounts for all the principal stresses at a gusset plate of a critical joint was utilized to obtain stress-cycle histogram. Number of cycles required to grow an initially detected crack of very small dimension to a threshold value has been obtained to predict the fatigue failure. The effect of the length of the bridge, vehicle speed and compound traffic growth on remaining life of the bridge has been studied.

1. Introduction

In practical design of steel bridges, there are commonly two methods of fatigue life estimation. The first method which is very popular and easy for application is based on Miner's cumulative damage rule. The another method emphasizes crack growth study once it is detected in visual inspection or by other non destructive means. The crack growth is monitored based upon Paris –Erdogan equation and inspection interval can be worked out before the crack reaches threshold limit. The second method plays an important role in recent bridge management policy although it lacks adequater applications compared to Miner's rule. The second method is useful while the bridges are in service while the first one has only significant in design and planning stage. In the present study, the vehicle induced stress history is first obtained using 3D model of truss bridge in Finite element softare. The force time histories obtained from Finite Element programme has been taken as input for the connection modelled in ABAQUS. The connection at the middle of bottom chord is taken into consideration because, the failure of this will lead to the global failure of the bridge. Then the Von Mises stress time history at critical location of the gusset plate is taken for the fatigue analysis of the structure Stress range histogram has been obtained using rainflow counting method and thereafter, crack growth equation is applied to obtain the number of load cycles at each increament of crack size.The methos is illustrated with an example of Howe type truss girder bridge. The deck slab rests on the stringer and floor beam assembly. The deck slab is connected to stringers and floor beams by shear connectors. Vehicle loads corresponding to Indian Road Congress specification has been considered in the analysis. The effect of bridge span, vehicle speed, initial crack size, and compound traffic growth on the fatigue life of the bridge has been studied.

2. Results and Discussion

Nine models are prepared for gusset plate connections at the region of higher stress concentrations of a Howe type truss bridge to obtain the value of Von Mises stress at the same location throughout the time of consideration for different speed of the vehicle. Trials have been given for bridge of span 36 m, 48 m and 60 m span. Fig.1 shows the a typical Von-Mises stress time history at the critical location for the bridge of span 36 m where the speed of the vehicles was 20 m/sec, in which peak stress was found to be 0.64 times the yield stress of the material.

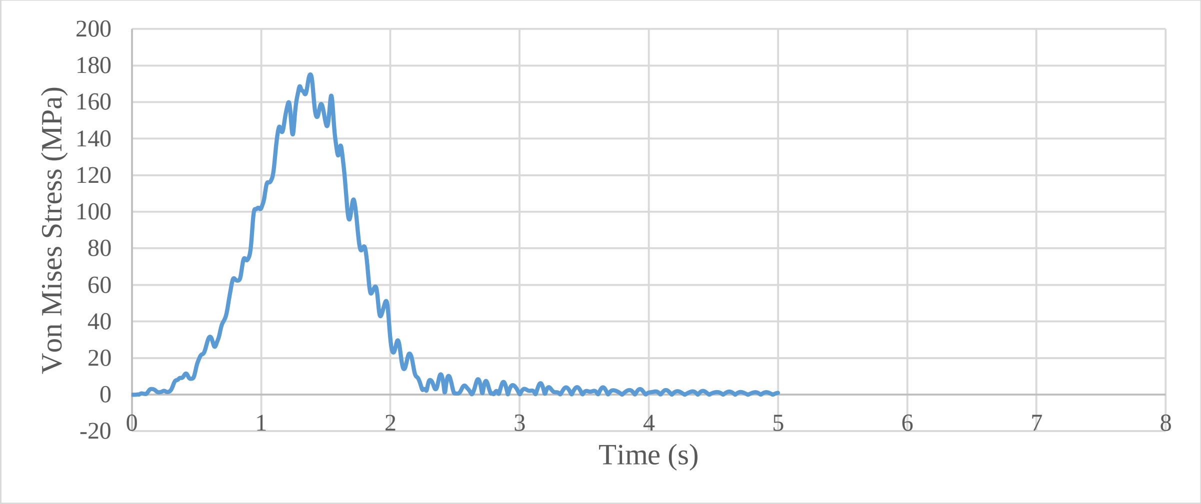

Fig.1 Von Mises stress time history for 36 m bridge length with 20 m/s vehicle speed

The remaining fatigue life of the bridge of 36 m span for different initial crack size and vehicle speeds are shown in Table-1. It is assumed that initial crack of 10 mm length increases to 35 mm length as threshold of the bridge. It is noted that increase of vehicle speed decreases fatigue life. Similar trend was observed for the bridges with 48 m and 60 m length. However, in longer span bridge, fatigue failure may occur early irrespective of vehicle speed.

Table -1 Remaining fatigue life of truss bridge of span 36 m.

Remaining Fatigue Life (in Years)				
Speed of Vehicle ($\boldsymbol{m/s}$)	Initial Crack Length, a_0 (mm)	Final Crack Length, a (mm)	Equivalent Stress Range, $\Delta\sigma_{eq}$ (MPa)	Fatigue Life, L (Years)
10	10	35	12.20	281.83
15	10	35	12.41	268.04
20	10	35	19.30	71.22

3. Conclusions

The study reveals that linear fracture mechanics approach can be integrated with the dynamic analysis of the bridge to obtain remaining fatigue life and inspection interval. It is found that the remaining fatigue life is inversely proportional to the length of the bridge as well as the speed of the vehicle. Fatigue life of a bridge decreases exponentially to a constant level when the compounding traffic growth rate increases and becomes asymptotic to a small percentage of compound annual traffic growth. The larger crack if detected during visual inspection, decreases inpection interval.