ABSTRACT

Bridges are lifeline structures in transportation network. Smooth flow of traffic through bridges is important consideration for socio-economic development of any regions. The bridges are generally designed with high factor of safety to cater for uncertainty in live load and material properties. With time, the structures may show various forms of degradation. This is mostly common where traffic growth is unexpectedly high and the structures are exposed to aggressive environment, which necessitates a more elaborate approach to estimate fatigue life in design phase itself. Burden of in-situ monitoring of crack growth may thus be reduced.

Most of the bridge design codes evaluate cumulative damage using a uniform fatigue vehicle and applying the Linear Damage Rule (LDR). The shortcomings of LDR are that it neglects the load sequence effect and does not consider the contribution of low amplitude stresses in evaluation of damage index. In the present study, fatigue damage methodology has been developed to overcome the shortcomings of LDR. Loading cycles obtained are segregated into two phases, namely Phase-1 and Phase-2 which represent crack initiation and crack propagation stages respectively. This approach has been further modified to consider opening stress in crack propagation stage. Before applying the fatigue damage analysis to numerical models of bridges, a generic structural model subjected to axially vibrating load has been first taken as pilot study to predict fatigue cycles under variation of operating frequencies, stress range and damping. Thereafter, fatigue testing of axially vibrating specimen was conducted to obtain the actual number of cycles to failure and to compare with the results obtained from presently developed fatigue damage models.

Inspired by the reasonably good agreement between the predicted results and those obtained directly from long duration fatigue testing, further studies have been undertaken to develop the fatigue damage procedure for the analytical and numerical bridge models. The bridge-vehicle dynamic system was developed using continuum bridge models with distributed system parameters. The movement of multiple vehicles has been considered where the vehicle arrival time is assumed to follow a random process. Pavement irregularity is also considered as the realization of non-homogeneous process. The damping matrix, stiffness matrix and force vector contain time dependent random variable. To solve such coupled bridge vehicle equations of motion, a semi analytical time domain approach is developed. The newly developed approach relies on the orthogonal polynomial expansion and its properties. The time domain approach so developed has been used to simulate vehicle induced stress history and to transfer the same to fatigue damage module to obtain fatigue life of single and continuous span bridges. Different bridge vehicle parameters are taken into account to observe the effect on dynamic amplification factor and fatigue life of bridge.

For real life application, an example of steel concrete composite plate girder bridge has been considered for three dimensional finite element model. Most of the commercial software allows to perform moving load analysis on finite element model of bridge. In such analysis, the dynamic load induced by vehicles due to vibration caused as a result of pavement roughness cannot be incorporated. Thus, an uncoupled iterative scheme is developed to incorporate road roughness in the numerical model. The effect of random arrival time is also considered. Vehicle induced stress history obtained using uncoupled iterative scheme has been utilised to find the fatigue life of plate girder bridge. Study of various influencing parameters on dynamic amplification factor and fatigue life, unveils the significance of vehicle speed, vehicle arrival time, pavement category, eccentricity of load and girder design variables. The detail investigation reveals that early fatigue failure may occur if vehicle arrival rate, eccentricity of vehicle load, variable speed and roughness of bridge deck increase. However, decrease of cross girder spacing and increase of flange-web thickness ratio of plate girders may prolong the fatigue life.