Condition Assessment of Railway Bridges

Most of the railway bridges in the Indian Railway system that have been built several decades ago have deteriorated both in terms of strength and stiffness due to a variety of reasons. These bridges have been designed for live loads and service conditions that have changed drastically with time. Increased axle loads and traffic density have necessitated bridge owners to get the bridge condition assessed in order to determine their residual structural strength and identify strengthening measures to be taken for safe performance. Condition assessment provides information regarding the intensity and extent of observed defects, the cause for these defects and possible deterioration processes that have strong impact on the safety and service life of structures. Furthermore, this information forms the basis for estimating the residual structural capacity and possible remedial work that needs to be undertaken.

Studies have been done on five bridges in the South Western Railway zone. Two of these bridges are brick and stone masonry arch bridges respectively while the remaining three bridges were of steel, two plate girder and one open web girder. Over the years, the passenger and freight traffic have increased on these bridges. The permitted axle load until a few years ago was classified as 18t axle load and has subsequently undergone an upward revision to 22t axle based on an in-house assessment undertaken by the Indian Railways. At present, there has been a growth in freight traffic in this section, in particular for iron ore and coal movement, and the Indian Railways is considering the possibility of further enhancing the permitted axle load to 25t immediately with possible further upward revisions at a later date. Figure 40 is an excerpt of the test and analyses for a steel bridge in the study.

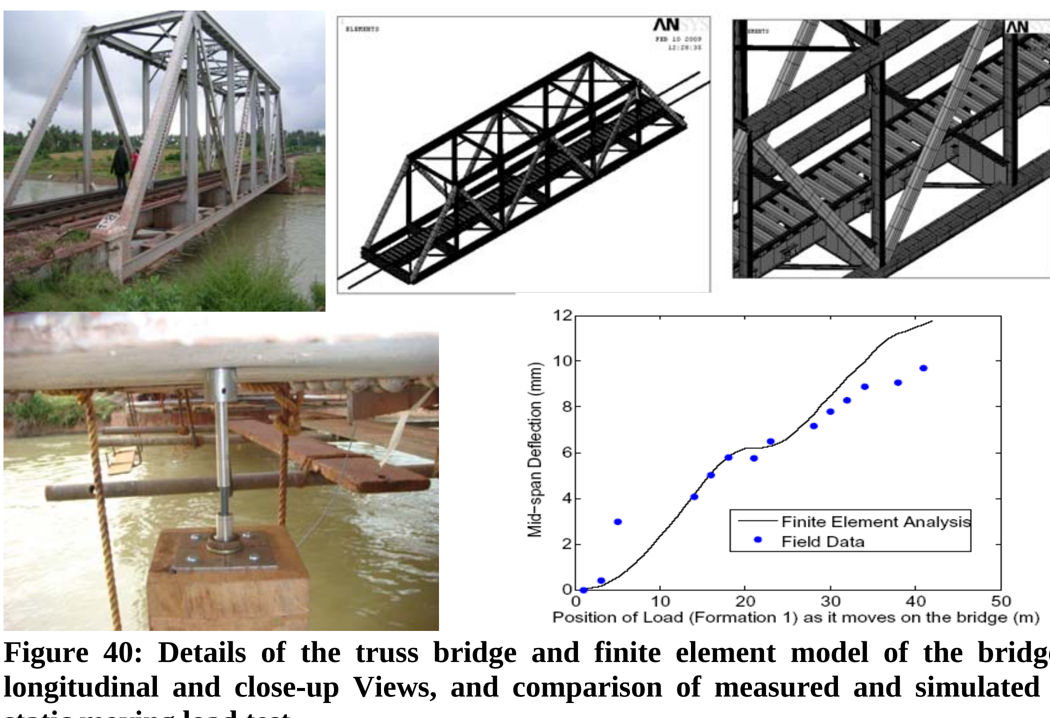
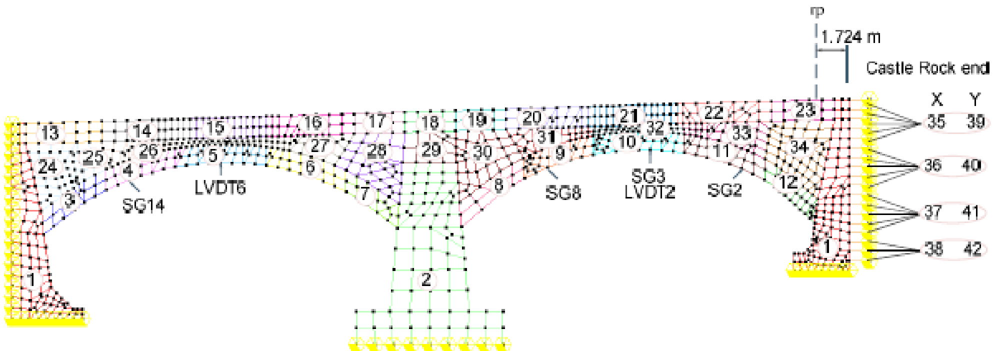


Figure 40: Details of the truss bridge and finite element model of the bridge with longitudinal and close-up Views, and comparison of measured and simulated quasi-static moving load test

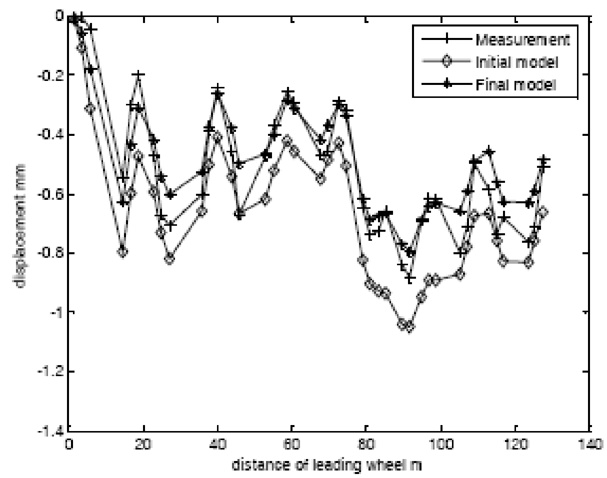
Methods for identification of structural mass, stiffness, and (or) damping characteristics of engineering structures based on measured strain, displacement, and (or) acceleration time histories have been developed. These studies form the meeting ground for mathematical and experimental modeling tools. The range of problems considered covers static and dynamic behaviors, linear and nonlinear structural models, time variant and time invariant systems, systems modeled using fractional calculus principles. The identification methods studied include frequency response function (FRF) matrix based methods, force state mapping techniques, Kalman and particle filtering based methods. A few novel elements in proposed methods include: (a) inverse sensitivity analysis of singular solutions of partially measured frequency response function matrix, (b) application of reproducing kernel particle method and kriging based methods for functional representations in 'force-state' map constructions, (c) development of sequential importance sampling based particle filtering methods for the treatment of nonlinear process and measurement equations and non-Gaussian noises, (d) introduction of a pseudo-sequencing strategy to assimilate measurement from multiple sensors and from multiple tests into postulated finite element structural models, (e) development of a statistical substructuring approach based on the application of the Rao-Blackwell theorem to identify localized nonlinearities, and (f) development of an approach based on a bank of self-learning particle filtering for identification of nonlinear structural systems. The proposed methods have been applied on synthetic models, laboratory level experimental studies on simple frames and beam systems and in condition assessment of existing railway bridge structures. The solution to the later class of problems has necessitated the development of computational tools for combining finite element structural modeling with Monte Carlo simulation based Bayesian filtering tools (Figure 41 and 4.42).

(a) (b)

Figure 41: Condition assessment of a multi-span railway bridge; (a) 5-span masonry arch bridge; (b) sleeper loaded BFR wagons used in static and dynamic load tests



(a)



(b)

Figure 42: Condition assessment of a multi-span railway bridge (a) Plane stress FE model for the bridge structure; (b) Comparison of predictions on system response from identified and initial models with corresponding measurements