CHAPTER 2

LITERATURE REVIEW

This chapter gives a review of literature concerned with the present subject under investigation. A more comprehensive literature review on topics related to the interaction between the vehicle and the track, various approaches to vehicle/track system modelling, and research with respect to track settlement is given in Appendix A.

Although nonlinear and spatially varying track stiffness was measured as early as 1918 (Talbot, 1980), only a few researchers have attempted to model its effect on track deterioration. In 1982, Lane started to study the effect of ballast stiffness variations on track roughness. Lane showed that "static effects" caused by the variability in the ballast and the sub-grade properties make a significant contribution to the development of track roughness. The research work also showed that if larger freight cars are used to reduce unit costs, considerable benefit can be realised if the specification of the ballast is tightened to reduce its variability.

Realising the possible consequences of spatial track stiffness variations, Shenton (1985) used the computer programs developed by British Rail (Lane, 1982) to simulate the deterioration of a section of track. The dynamic wheel loads were calculated, and from the maximum load seen by a particular sleeper its settlement was in turn calculated, taking into account the variation in the track stiffness. The resulting deteriorated shape of the track was then used to re-calculate new dynamic loads and by repetitive cycling of this procedure track deterioration was simulated. Shenton observed that it is the top ballast layer which is subjected to the highest stress and it is also this particular layer which is constantly disturbed by track maintenance and traffic. Furthermore, Shenton observed that the rate of track deterioration decreases with accumulating traffic or time. This stable condition is reached once the loads have been re-distributed among the sleepers. Shenton claimed that after this re-distribution the settlement of all sleepers is uniform.

A few years later, simulation runs with inhomogeneous track beds were carried out by Schwab and Mauer (1989) to gather more insight into the settlement behaviour at points where the track stiffness varied. Two sections of different track stiffness but equal damping were used in their investigations. In the model, the wheel/rail forces were distributed through the rails and sleepers, resulting in sleeper/ballast forces to be lower in the region of lower track stiffness. This indicated a better distribution of the vehicle forces to track in a softer region. As a result, higher track settlement was predicted in the stiffer region where the vehicle forces are poorly distributed and higher sleeper/ballast forces occur. It should be noted that Schwab and Mauer predicted track settlement using an identical settlement rate in the two different stiffness regions.

In a workshop devoted to "Interaction of Railway Vehicles with the Track and its Substructure" (Knothe *et al.*, 1995) three papers concerned with the influence of spatial track stiffness variations were presented (Li and Selig, 1995; Sato, 1995; Ford, 1995). In the paper presented by Li and Selig (1995), two mathematical models are discussed. The more comprehensive model is a finite element model which is used to determine the vertical dynamic deflection and acceleration of the rail and the sleepers as a function of spatial track stiffness variations. The other model is a simplified lumped-parameter model in which conversion equations are used to determine values for the lumped-mass and the lumped-stiffness of the vehicle/track system. In these equations the spatial track stiffness variations are represented by a single factor. Using these models the authors predicted track settlement using an equivalent number of maximum wheel loads. The work done by Li and Selig showed that the factor most affecting the track modulus is the characteristic of the subgrade, including both the resilient modulus and the thickness of the subgrade layer. They stated that the influence of the subgrade condition on track modulus is further enhanced by the fact that the subgrade resilient modulus is the most variable quantity among all the track parameters. The next most important factor effecting the track modulus is the thickness of the granular layer which consists out of a ballast and a sub-ballast layer.

The paper by Sato (1995) described Japanese studies with respect to the settlement of ballast and the growth of track irregularities. An average growth of track irregularities was defined.

Ford (1995) describes research done to evaluate the influence of differential ballast settlement on the growth of track irregularities. Assuming an initially continuous sinusoidal perturbation in the vertical profile of the track, and assuming that the vertical response of the vehicle is in phase with the wave in the track, the deterioration of the track geometry was investigated in terms of changes in vehicle load and ballast parameters. Although the model is essentially qualitative, it offers a greater understanding of the physical phenomena underlying the way that vehicle/track interaction contributes to the deterioration of track geometry.

Recent research work done by Hunt (1996) on track settlement adjacent to bridge abutments shows that settlement near an abutment can be controlled to some extent by a careful selection of the subgrade stiffness profile. Considering the variation of subgrade stiffness between the ballast and the abutment, numerical computations were carried out in the time domain using linear track and vehicle models. A logarithmic deformation law was used to adjust the track geometry with accumulating traffic.

Summary

The literature review shows that although several attempts have been made to model the effect of nonlinear and spatially varying track stiffness on track deterioration there are always limitations. However, having realised the possible consequences of spatial track stiffness variations on track deterioration, the research work done to date has already contributed significantly towards understanding the qualitative influence of various vehicle and track parameters. Research in this field is still ongoing.