Influence of Ballast Voids on Dynamic Responses of Concrete Sleepers

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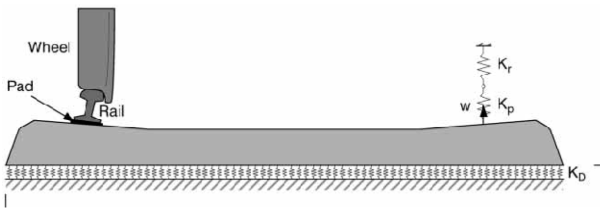
ABSTRACT

The concrete sleeper that is one of the major part of ballast railway tracks are installed on ballast and subgrade to transfer any train wheel loads to the ground support subgrade in operation period that a wide range of loading conditions has been observed. In most of the cases, train wheel impact loads due to asymmetrical cause voids and pockets in contact interface of sleeper and ballast. When the ballast was damaged, the stiffness in ballast supporting of the sleeper will reduce. Voids of ballast can effects in-suit sleeper vibration responses. In order to analyses finite-element can model free – free and in suit sleeper with using 50 Timoshenko beam elements with a trapezoidal cross-section while the rail pads and the ballast system were modeled using a spring damper element and the elastic beam support feature in STRAND7,accordind to fig.1.

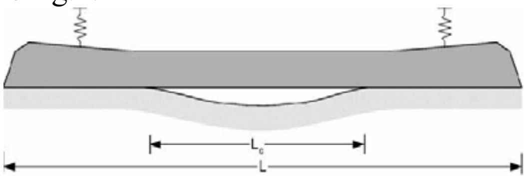
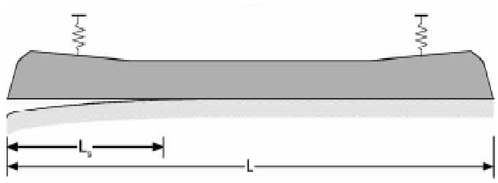
free–free sleeper model



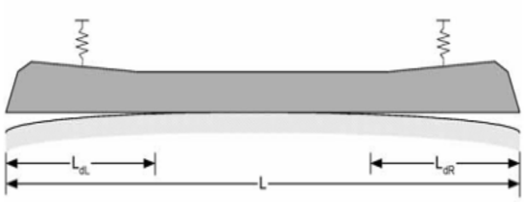
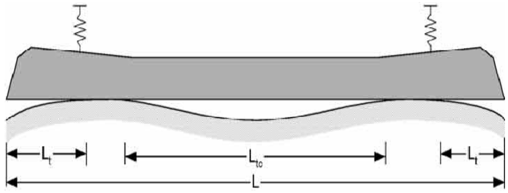
in situ sleeper model

Fig. 1: Typical models of railway concrete sleepers

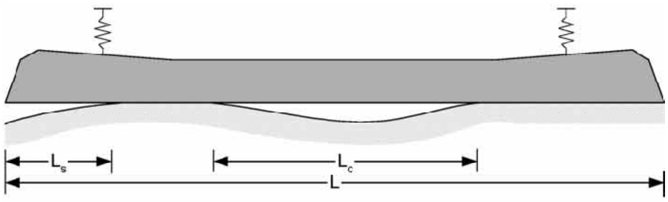
The damage of sleeper and ballast contact can consider five different patterns, central void, single hanging, double hanging, triple hanging, and side – central voids illustrated according to fig.2.

2.a: Central void of contact pattern2.b:single hanging of contact pattern

2.c: double hanging of contact pattern2.d: triple hangingof contact pattern



2.e: side-central voidsof contact pattern

Fig. 2: Sleeper/ballast contact patterns

Based on any sleeper and ballast contact can use following non – dimensional parameters that refers voided concrete sleepers in railway track system and effect of non – dimensional parameters analysis in finite – element model. Effect of those non – dimensional parameters analysis in any different contact pattern on the dynamic responses of sleeper, flexural modes and rigid body modes: translation and rotation. In Central void of contact pattern refers $\alpha_c = \frac{L_c}{L}$ as ratiocentral void length to thesleeper length, in single hanging of contact patternreferres$\alpha_S = \frac{L_s}{L}$as the ratio of thesingle-side void length to the sleeper length, in double hanging of contact patternrefers$\alpha_d = \frac{L_{dl}}{L}$ as,$\beta_d = \frac{L_{dR}}{L}$, in triple hangingof contact patternreferresα_t= $\frac{L_t}{L}$,$\beta_t = \frac{L_{tc}}{L}$,and in side-central voids of contact patternreferres B_{s-c} =$\frac{L_c}{L}$,$\alpha_{s-c} = \frac{L_{s-c}}{L}$. In all of the patterns In order to analysis the dynamic behavior of sleeper refers the normalized frequency,$W_N = \frac{W_{Voided}}{W_{Ideal}}$as a ratio between the deteriorated sleeper's frequencyW_{voided} and the frequency of the in situ sleepers W_{ideal} in the ideal contactcondition.Inorder to analysis free vibrations of in suit sleeper model employed the following equations:

$$\frac{\partial}{\partial x} KAG\left[\left(\psi(x,t)\right) - \frac{\partial z(x,t)}{\partial x}\right] + m_s \frac{\partial^2 z(x,t)}{\partial x^2} + c_b \frac{\partial z(x,t)}{\partial x^2} + k_b z(x,t) = \vec{F}(x,t)$$

$$\frac{\partial}{\partial \mathrm{x}} EI\left(\frac{\partial \psi(\mathrm{x},\mathrm{t})}{\partial \mathrm{x}}\right) - KAG\left[\big(\psi(x,t)\big) - \frac{\partial \mathrm{z}(\mathrm{x},\mathrm{t})}{\partial \mathrm{x}}\right] - M_S R_S^2 \frac{\partial^2 \psi(\mathrm{x},\mathrm{t})}{\partial \mathrm{x}^2} = 0$$

$$\vec{F}(x,t) = \sum_{i=1}^{2} \left\{K_{pt}[w(x_t,t) - z(x_t,t)] + C_{pi}[\dot{w}(x_t,t) - \dot{z}(x_t,t)]\right\} \delta x_i$$

$$K_e = {K_r K_P}/{K_r + K_p} \qquad KGA = \sqrt{(KGA_r)(KGA_c)} \qquad EI = \sqrt{(EI_r)(EI_c)}$$

$k_b$and c_b : the stiffnessand damping constant of ballast support system; $K_P$and C_p : the stiffness and damping constant of railpads; z(x, t) : vertical deflection of sleeper; ψ(x, t): the rotation angle of sleeper about neutral axis; EI : the effective sleeper flexural rigidity; KGA : the effective sleeper shear distortion rigidity; M_S : the sleeper mass per unit length; R_s: the radius of gyrationof sleeper cross-section.EI_candEI_r : sleeper flexural rigidity at centre,and at rail seats, κGAc and κGAr : the sleeper shear distortion rigidity at centre and atrail seats.
Voided ballast supporting affects free vibrations frequencies of the in suit sleepers and cause increasing damage of track element and crack in sleeper. Flexural vibration of damaged sleeper affects not as substantial as on the rigid body vibrations, but in result of track dynamic instability. Results of analyses free vibrations of sleepers of finite – element formation shows that symmetrical contact pattern decrease rotation, translation, first flexural mode, and no affect other flexural modes increasing voids. Effects of asymmetrical conditions observe in dynamic responses of the rotation and translation that should attention in result of effect of ballast supporting damage. For example, In contact pattern of central void, frequencies of rotation and translation mode decrease increasing voids between 25 percent and 30 percent and frequency of first flexural mode decrease increasing voids 10 percent and the other flexural modes change a little.

Keywords: Sleeper-ballast interaction‹Voids of ballast‹Free frequency‹In-suit railway concrete sleeper ‹finite element