

2.5 Train-Structure Interaction

Train-structure interaction generates several force components to be considered in designing railway bridges, such as impact, rail break, and centrifugal forces. Endeavors have been made to examine these forces associated with train configurations and bridge properties.

2.5.1 Impact or DLA

Railway dynamics has a long history over a century. Various approaches have been used from analytical modeling to explicit finite element modeling (Timoshenko 1926; Hou et al. 2003; Gu et al. 2010). Dynamic factors for the displacement and bending moment of bridges are proportionally increasing with train speed (Flener and Karoumi 2009). Impact forces, therefore, need to be added to the axle loads of a train when design is carried out. Impact factor or DLA for light rail design varies from 10% to 40% of train load in the vertical direction, depending upon transit agencies. Metro (2007) specifies DLA ranging from 30% to 40%, while AECOM (2008) merely states that loads shall be increased for dynamic effects. A couple of light rail transit agencies indicate horizontal impact (e.g., Utah and Massachusetts: 10% of axle load acting normal to the track), although most agencies do not consider this force component. This 10% horizontal force appears to be arbitrary and empirical, which may not be obtainable accurately.

Refined analysis may generate uniformly applicable DLA as is for the case of AASHTO LRFD BDS. The most widely used expression for DLA or impact is:

$$DLA = \left(\frac{R_{dyn} - R_{stat}}{R_{stat}} \right) \times 100(\%) \quad (2.1)$$

where R_{dyn} and R_{stat} are the maximum dynamic and static responses of the bridge, respectively. If a massive substructure is connected to a superstructure, impact may be ignored (AREMA 2008). Other expressions such as Eq. 2.2 are alternatively used to quantify dynamic effects (Wipf et al. 2000):

$$DAF = \text{maximum dynamic deflection/maximum static deflection} \quad (2.2)$$

where DAF is the dynamic amplification factor. The Eurocode (CEN 2002) suggests $DAF = 1.141$; however, the Swedish standard (BV Bro 2006) shows $DAF = 1.134$. Other researchers recommended different values; for example, $DAF = 1.22$ (Wipf et al. 2000) and 1.45 (Flener and Karoumi 2009). Transient impact force generates higher frequencies and magnitudes than static force during a very short duration (e.g., 2 ms to 10 ms, Lee et al. 2005). Such amplified forces play an important role in design of railway structures, because track components (e.g., rail, sleepers, and fasteners) may be damaged by excessive distress, thereby influencing the safety of passengers. To reduce dynamic impact, hyperelastic pads are sometimes placed underneath track rails (Kim et al. 2009). For design convenience, DLA (or impact) is considered as an additional factor to increase static load. AASHTO LRFD BDS states an increase of 33% for highway traffic, whereas the AREMA manual specifies impact load I depending upon structure type and span length. The dynamic behavior of a wheel-track system may be solved in two distinct ways (Hou et al. 2003):

- Time-domain method: Various responses of wheel-track components (e.g., displacement, velocity, and acceleration) are solved in a time domain.
- Frequency-domain method: Receptance is engaged with external attributes using mathematical transformation, and the wheel-track interaction is solved without complex differential equations.

For continuous bridges, the shortest span controls impact force (AREMA 2008). Although the AREMA design manual stipulates that impact force shall increase by 20% for steam locomotives, this requirement may not be applicable to light rail trains.

12 Arema Manual

Wai-Fah Chen, Lian Duan



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Precast Concrete Railway Track Systems fib Fédération internationale du béton, 2006-01-01 In 1986 the FIP Commission on Prefabrication issued the state of art report Concrete Railway Sleepers which included design considerations manufacturing methods rail fastening systems and field performance During the two decades since that report precast concrete has gained importance in the field of railway track

systems for plain track switches and crossings tunnels and other applications Developments in production methods for concrete sleepers in switch and crossing layouts to cope with the complex geometry and the industry s confidence in their performance have contributed to the huge increase in the use of this type of sleeper The use of slab track for high speed track has also grown particularly where either new track is built or where existing track is renewed and long periods of track possession are possible There has also been progress in the development of plant and equipment for the installation renewal and maintenance of concrete sleepers With machines now able to replace existing track at a rate of 5000 sleepers over 3 km track per day choosing concrete sleepers can reduce the time on site meaning tracks can be reopened quickly whilst reducing labour requirements and costs Today precast concrete is considered to be the best performing and preferred material for railway sleepers due to the following factors long term durability improved geometric retention of track and greater weight vital for high speed and heavy freight lines improved elasticity of track improved ride quality low first cost minimum life cycle cost low cost of maintenance environmental friendliness no chemical treatment required and can be recycled As all aspects of precast concrete railway track systems from design through manufacture to installation and maintenance have progressed since the publication of the FIP report an update was considered timely in order to provide a synthesis of currently available information This new edition covers quality design production durability maintenance and environmental considerations and includes survey on the use of precast concrete track systems in over 30 countries

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