

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):

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

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.

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**Carlos Chastre, José Neves, Diogo
Ribeiro, Maria Graça Neves, Paulina
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Track Design Handbook for Light Rail Transit, 2012 TCRP report 155 provides guidelines and descriptions for the design of various common types of light rail transit LRT track The track structure types include ballasted track direct fixation ballastless track and embedded track The report considers the characteristics and interfaces of vehicle wheels and rail tracks and wheel gauges rail sections alignments speeds and track moduli The report includes chapters on vehicles alignment track structures track components special track work aerial structures bridges corrosion control noise and vibration signals traction power and the integration of LRT track into urban streets

Bridge Engineering Handbook Wai-Fah Chen, Lian Duan, 2019-09-11 First Published in 1999 The Bridge Engineering Handbook is a unique comprehensive and state of the art reference work and resource book covering the major areas of bridge engineering with the theme bridge to the 21st century

Marks' Standard Handbook for Mechanical Engineers, 12th Edition Ali M. Sadegh, William M. Worek, 2017-11-10 The 100th Anniversary Edition of the Bible for Mechanical Engineers Fully Revised to Focus on the Core Subjects Critical to the Discipline This 100th Anniversary Edition has been extensively updated to deliver current authoritative coverage of the topics most critical to today's Mechanical

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structure interaction repair rehabilitation and retrofitting of the structures new technologies in structural design and construction bridge engineering structural dynamics earthquake engineering etc This book will be useful for beginners researchers and professionals working in the different areas of civil engineering *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 sleepered track 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

Bridge Engineering Handbook, Five Volume Set Wai-Fah Chen, Lian Duan, 2014-01-24 Over 140 experts 14 countries and 89 chapters are represented in the second edition of the Bridge Engineering Handbook This extensive collection provides detailed information on bridge engineering and thoroughly explains the concepts and practical applications surrounding the subject and also highlights bridges from around the world This second edition of the bestselling Bridge Engineering Handbook covers virtually all the information an engineer would need to know about any type of bridge from planning to construction to maintenance It contains more than 2 500 tables charts and illustrations in a practical ready to use format An abundance of worked out examples gives readers numerous practical step by step design procedures Special attention is given to rehabilitation retrofit and maintenance Coverage also includes seismic design and building materials Thoroughly revised and updated this second edition contains 26 new chapters **An Introduction to Design of Railroads for**

Professional Engineers J. Paul Guyer, P.E., R.A., 2022-08-19 Introductory technical guidance for professional engineers and construction managers interested in design and construction of railroads Here is what is discussed 1 ROADWAY DESIGN 2 GRADES AND TRACK PROFILE 3 HORIZONTAL CURVES 4 CLEARANCES 5 TRACK STRUCTURE 6 TRACK DESIGN METHODS 7 AREMA DESIGN PROCEDURE 1995 MODIFIED 8 SUBGRADE 9 FROST DESIGN MODIFICATIONS 10 DRAINAGE 11 GEOTEXTILES 12 BALLAST 13 SUB BALLAST 14 TIES AND TIE SPACING 15 RAIL 16 OTHER TRACK MATERIAL 17 TURNOUTS AND CROSSOVERS 18 TRACK CONNECTIONS AND LADDER TRACKS 19 RAIL CROSSINGS

InCIEC 2015 Marina Yusoff, Nor Hayati Abdul Hamid, Mohd Fadzil Arshad, Ahmad Kamil Arshad, Ahmad Ruslan Mohd Ridzuan, Haryati Awang, 2016-06-18 The special focus of these proceedings is on the areas of infrastructure engineering and sustainability management They provide detailed information on innovative research developments in construction materials and structures in addition to a compilation of interdisciplinary findings combining nano materials and engineering The coverage of cutting edge infrastructure and sustainability issues in engineering includes earthquakes bioremediation synergistic management timber engineering flood management and intelligent transport systems

Electromagnetic Compatibility Donald G. Baker, 2015-12-30 Explains and resolves the electromagnetic compatibility challenges faced by engineers in transportation and communications This book is a mathematically rich extension of courses required to maintain the Federal Communications Commission FCC the Canadian Standards Association CSA and the European Union certifications The text provides an in depth study of the electromagnetic compatibility EMC issues related to specific topics in transportation and communications including Light Rail Transit shadow effects and radio dead spots through the analysis of real world case studies in the United States and Europe The author provides Cartesian cylindrical and spherical solutions that can be applied to Maxwell's and Wave Equations The book covers topics such as SCADA Systems shielding and complexities of radio frequencies and their effect on communication houses The author also provides information for alternative industries to apply the solutions from the case studies and background content to their own professions Presents a series of over twenty real world case studies related to EMC in transportation and communications Covers power line radiation shadow effects on subway cars train control systems and edge distortions Includes the OATS testing method and Department of Transportation DOT test Provides access to a companion website housing power point slides and additional appendices **Electromagnetic Compatibility Analysis and Case Studies in Transportation** is a reference for practicing engineers involved in transportation and communications as well as post graduate engineering students studying transportation and communications in engineering

Bridge Manual Illinois. Bureau of Bridges and Structures, 2002

Handbook of Railway Vehicle Dynamics, Second Edition Simon Iwnicki, Maksym Spiryagin, Colin Cole, Tim McSweeney, 2019-11-14 Handbook of Railway Vehicle Dynamics Second Edition provides expanded fully updated coverage of railway vehicle dynamics With chapters by international experts this work surveys the main areas of rolling stock and

locomotive dynamics Through mathematical analysis and numerous practical examples it builds a deep understanding of the wheel rail interface suspension and suspension component design simulation and testing of electrical and mechanical systems and interaction with the surrounding infrastructure and noise and vibration Topics added in the Second Edition include magnetic levitation rail vehicle aerodynamics and advances in traction and braking for full trains and individual vehicles

Mechanics of Ballasted Rail Tracks Buddhima Indraratna,Wadud Salim,2005-08-11 In this book the authors discuss testing of ballast including the strength deformation and degradation aspects of fresh and recycled ballast under monotonic and cyclic loading The effectiveness of geosynthetics in stabilising recycled ballast has also been examined A new stress strain constitutive model for ballast incorporating particle breakage is presented Finally a new range of particle gradations balancing the strength and permeability requirements has been proposed for future rail tracks This book is intended as a reference text for final year civil engineering students and postgraduates and for practicing railway engineers with the task of modernizing existing designs

Advanced Rail Geotechnology - Ballasted Track Buddhima Indraratna,Wadud Salim,Cholachat Rujikiatkamjorn,2011-03-16 Ballast plays a vital role in transmitting and distributing train wheel loads to the underlying sub ballast and subgrade Bearing capacity of track train speed riding quality and passenger comfort all depend on the stability of ballast through mechanical interlocking of particles Ballast attrition and breakage occur progressively under heavy cyc

Advances on Testing and Experimentation in Civil Engineering Carlos Chastre,José Neves,Diogo Ribeiro,Maria Graça Neves,Paulina Faria,2022-08-17 The book presents the recent advances on testing and experimentation in civil engineering especially in the branches of geotechnics transportation hydraulics and natural resources It includes advances in physical modelling monitoring techniques data acquisition and analysis and provides an invaluable contribution for the installation of new civil engineering experimental facilities The first part of the book covers the latest advances in testing and experimentation in key domains of geotechnics soil mechanics and geotechnical engineering rock mechanics and rock engineering and engineering geology Some of the topics covered include new developments in topographic survey acquisition for applied mapping and in situ geotechnical investigations laboratory and in situ tests to estimate the relevant parameters needed to model the behaviour of rock masses and land structures monitoring and inspection techniques designed for offshore wind foundations The second part of the book highlights the relevance of testing and monitoring in transportation Full scale accelerated pavement testing and instrumentation becomes even more important nowadays when for sustainability purposes non traditional materials are used in road and airfield pavements Innovation in testing and monitoring pavements and railway tracks is also developed in this part of the book Intelligent traffic systems are the new traffic management paradigm and an overview of new solutions is addressed here Finally in the third part of the book trends in the field and laboratory measurements and corresponding data analysis are presented according to the different hydraulic domains addressed in this publication namely maritime hydraulics surface water and river hydraulics

and urban water **Design and Construction of Modern Steel Railway Bridges** John F. Unsworth, 2017-08-03 This new edition encompasses current design methods used for steel railway bridges in both SI and Imperial US Customary units It discusses the planning of railway bridges and the appropriate types of bridges based on planning considerations *Surface Transportation Board Reports* United States. Surface Transportation Board, *Customs Bulletin and Decisions* ,2003

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