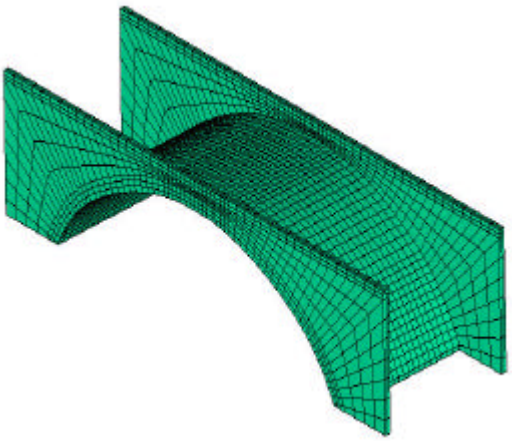
Bridge Research Group
University College Dublin

BRIDGE ENGINEERING RESEARCH IN IRELAND

PROCEEDINGS OF THE 2002 SYMPOSIUM



University College Dublin
August 30, 2002

Editors: Dr. Ciaran McNally & Mr. Sean Brady

FOREWORD

The Bridge Engineering Research Group in the Department of Civil Engineering at University College Dublin is delighted to be hosting, and to welcome you all to, this 1st Symposium on Bridge Engineering Research in Ireland.

The Bridge Research Group was formed in the Department of Civil Engineering in June 1999. The primary objectives of the group are to foster and develop both nationally and internationally focused research programs in the area of Bridge Engineering, and to enable young engineers to specialise, through post-graduate study and post-doctoral programs, in the area of Bridge Engineering. Currently there are four academic staff members, three post-doctoral researchers and eight full time post-graduate students.

In Ireland the nature of existing and new bridges is very varied with many masonry arch bridges dating from the 17th and 18th centuries still in service in parallel with newer steel and concrete bridges. The breath of topics covered by papers scheduled for presentation reflects this variety with researchers working, in both national and international contexts, in areas such as bridge loading, masonry arch bridge monitoring and assessment, concrete durability, fatigue, bridge deck analysis, bridge – vehicle interaction for both rail and road networks, cable stayed bridges and bridge modelling and assessment.

One objective of this 1st Symposium on Bridge Engineering Research in Ireland is to provide a forum for bridge researchers and engineers to meet, discuss and develop further their research programs and ideas. A further objective is the establishment of an "All-Ireland Bridge Engineering Research Network". It is believed that many benefits would accrue from such a network, including greater collaboration between Universities, between Universities and Industry and increased success rates in lobbying for and attracting EU and national research funds.

On behalf of the Bridge Research Group at UCD, I would like to thank all the authors and presenters for their contributions, without which we would not have been able to schedule what promises to be a very interesting day. Additionally we hope that ideas, research directions and collaborations initiated at, or by, this first symposium might form the basis for a series of annual symposia dedicated to Bridge Engineering Research in Ireland.

Dr Paul Fanning
Director – Bridge Engineering Research Group, UCD

First Symposium on
Bridge Engineering Research Activity
in Ireland

Friday 30th August 2002
Room 326 Engineering Building
University College Dublin

Agenda	
09:00 – 09:20	**Registration**
09:20 – 09:25	**Welcome** Professor Eugene O'Brien, University College Dublin

Session 1	**Bridge Engineering Research Needs for Ireland** Chair – Dr Paul Fanning
09:25 – 09:35	**Requirements of the National Roads Authority** Pat Maher The National Roads Authority
09:35 – 09:45	**Bridge Related Research – Areas of Interest** Brian Madden Parsons Brinkerhoff Consulting Engineers
09:45 – 09:55	**Bridge Research Requirements – A Consultant's Perspective** Tony Dempsey Roughan O'Donovan Consulting Engineers
09:55 – 10:05	**Potential Research Directions in Bridge Engineering** Adrian Duffy Arup Consulting Engineers
10:05 – 10:15	**Discussion**

Session 2A	**Bridge Engineering Research Activity in Ireland** Chair – Dr Paul Fanning, University College Dublin
10:15 – 10:25	**Dynamic Effects of a Five-axle Truck on a Short-span Bridge** Arturo González & Eugene O'Brien Civil Engineering Department, University College Dublin
10:25 – 10:35	**Dynamic Impact Factors on Medium Span Bridges due to Multiple Vehicle Presence** Sean Brady[†], Arturo Gonzalez[†], Ales Znidaric[‡] & Eugene O'Brien[†] [†]Civil Engineering Department, University College Dublin [‡]Slovenian National Building and Civil Engineering Institute, Slovenia.
10:35 – 10:45	**Modal Analysis of a GRP Cable Stayed Footbridge** Paul Archbold & Paul Fanning Civil Engineering Department, University College Dublin
10:45 – 11:00	**Discussion**

11:00 – 11:30	**Coffee**

Session 2B	**Bridge Engineering Research Activity in Ireland** Chair – Dr Alan O'Connor, Trinity College Dublin
11:30 – 11:40	**Monitoring of a Multi-span Masonry Arch Bridge subjected to Repeated Abnormal Loadings** David Sloan and A. Thompson School of Civil Engineering, Queen's University , Belfast
11:40 – 11:50	**An Examination of Fill Effects on Ratings for Masonry Arch Bridges** Paul Fanning and Ekhlasur Rahman Civil Engineering Department, University College Dublin
11:50 – 12:00	**Arching Action In Concrete Bridge Deck Slabs** Susan E. Taylor, GIB Rankin and DJ Cleland School of Civil Engineering, Queen's University, Belfast
12:00 – 12:15	**Discussion**

Session 2C	**Bridge Engineering Research Activity in Ireland** Chair – Dr Alan O'Connor, Trinity College Dublin
12:15 – 12:25	**Micro-Simulation Modelling Of Traffic Loading For Long-Span Congested Road Bridges** Eugene O'Brien and Alisa Hayrapetova Civil Engineering Department, University College Dublin
12:25 – 12:35	**Critical Loading Events for the Assessment of Medium Span Bridges** Colin Caprani[†], Sam Grave[‡], Eugene O'Brien[†] & Alan O'Connor[‡] [†]Civil Engineering Department, University College Dublin [‡]Civil, Structural & Environmental Engineering, Trinity College Dublin.
12:35 – 12:45	**Bridge Reliability Assessment** Abraham Belay & Alan J. O'Connor Civil Structural & Environmental Engineering, Trinity College Dublin
12:45 – 13:00	**Discussion**

13:00 – 14:15	**Lunch**

Session 2D	**Bridge Engineering Research Activity in Ireland** Chair – Dr Susan Taylor, Queens University Belfast
14:15 – 14:25	**Effectiveness of High Slag Content in Minimising the Risk of Alkali-Silica Reaction in Concrete Bridges** David Hester, Ciaran McNally & Mark G. Richardson Civil Engineering Department, University College Dublin
14:25 – 14:35	**Probabilistic-Based Durability Design For Concrete Bridges: Evaluation Of Material Parameters** Mark G. Richardson[†] & Thomas Callanan[‡] [†]Civil Engineering Department, University College Dublin [‡]Parsons Brinkerhoff Consulting Engineers
14:35 – 14:45	**Investigating the Feasibility of 'Super U' Beams for Integral Bridge Construction** Omran Kenshel & Alan O'Connor Civil Structural & Environmental Engineering, Trinity College Dublin
14:45 – 15:00	**Discussion**

Session 2E	**Bridge Engineering Research Activity in Ireland** Chair – Dr Susan Taylor, Queens University Belfast
15:00 – 15:10	**Bridge – Train Interaction Incorporating Rail and Wheel Irregularities and Braking Forces** Cathal J. Bowe Civil Engineering Department, NUI Galway
15:10 – 15:20	**Modelling the Effect of Track Irregularities on the Vertical Response of Railway Vehicles** David Hegarty & Dermott O'Dwyer Civil Structural & Environmental Engineering, Trinity College Dublin
15:20 – 15:30	**Fatigue Response of Steel Railway Bridges Subject of Dynamic Loading** Ronan Gallagher & Dermott O'Dwyer Civil Structural & Environmental Engineering, Trinity College Dublin
15:30 – 15:45	**Discussion**

15:45 – 16:15	**Coffee**

Session 3	**"Prospects, Opportunities and Potential for an All-Ireland Bridge Engineering Research Network"** Chair – Dr Paul Fanning, University College Dublin
16:15 – 17:00	**Panel Discussion** **Pat Maher** The National Roads Authority **Joe O'Donovan** Roughan O'Donovan Consulting Engineers **David Sloan** Queen's University **Dermott O'Dwyer** Trinity College Dublin **Brian Madden** Parsons Brinkerhoff **Adrian Duffy** Arup Consulting Engineers

17:00	**Close**

DYNAMIC EFFECTS OF A FIVE AXLE TRUCK ON A SHORT-SPAN BRIDGE

A. GONZÁLEZ
University College Dublin
Ireland

Civil Engineering degree from University of Cantabria, Spain, 1995. MSc and PhD degrees from Trinity College Dublin, Ireland, 1996 & 2001, specialising in Bridge Weigh In Motion. Currently post-doctoral Pierse Newman fellow in University College Dublin, Ireland.

Abstract

Five-axle trucks produce the critical load cases for the design of short span bridges. This paper uses theoretical simulations to analyse the effect of a five-axle articulated truck on the dynamic response of a short-span bridge. Three-dimensional finite element bridge and truck models are developed with NASTRAN software. The bridge model is a 20 m long single span structure discretised into isotropic plate elements. The truck model is composed of bar, mass, damping, friction, spring and rigid elements. The road profile is generated stochastically from power spectral density functions. Then, the dynamic interaction problem between bridge, truck and road profile is solved using a Lagrange multiplier technique. Dynamic amplification factors are obtained for a combination of static weights, speed, road roughness and damping and compared to the Eurocode recommendation.

DYNAMIC IMPACT FACTORS ON MEDIUM SPAN BRIDGES DUE TO MULTIPLE VEHICLE PRESENCE

S. P. BRADY
University College Dublin
Ireland

Graduate of Trinity College Dublin, 1998. Currently studying for PhD in Bridge Dynamic Impact Factors. Assistant Lecturer in the Department of Civil Engineering.

A. GONZALEZ
University College Dublin
Ireland

Civil Engineering degree from University of Cantabria, Spain, 1995. MSc and PhD degrees from Trinity College Dublin, Ireland, 1996 & 2001, specialising in Bridge Weigh In Motion. Currently post-doctoral Pierse Newman fellow in University College Dublin, Ireland.

A. ZNIDARIC
Slovenian National Building and Civil Engineering Institute, Slovenia

Aleš Žnidariè obtained B.Sc. and M.Sc. degrees in structural engineering from the University of Ljubljana. His main professional interests are safety of bridges, structural vibration problems, weigh-in-motion (WIM) measurements and development of bridge WIM systems.

E.J. O'BRIEN
University College Dublin
Ireland

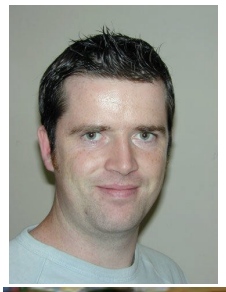
Graduate of University College Galway. Received a PhD degree from the University of Calgary in Canada in 1985. Currently Head of Civil Engineering Department at University College Dublin .

Abstract

The Dynamic Impact Factor for Bridges is of major concern in both their design and assessment. Research to date has focused on the single truck event. However, in many bridges the critical loading case is that of multiple truck presence on the deck. To accurately determine the dynamic impact factor it is necessary to examine the effects of multiple trucks traversing a bridge. Experiments in Slovenia were carried out to examine the dynamic impact factor for single and two truck events. Numerical models were constructed and validated from these experiments. These models were then used to compare the dynamic impact factors produced from both single and multiple trucks crossing the bridge at various speeds.

MODAL ANALYSIS OF A GRP CABLE-STAYED BRIDGE

Paul Archbold
University College Dublin



Graduate of University College Dublin, 1999. Currently studying for a PhD in the area of Human - Structure Dynamic Interaction.

Paul Fanning
University College Dublin

Graduate of University College. Received a PhD from University of Surrey. Currently a Lecturer, at University College Dublin and Director of the Bridge Engineering Research Group at UCD.

Abstract

This paper describes the modal analysis of Aberfeldy Footbridge, a 115m span GRP cable-stayed pedestrian bridge in Scotland. The three-dimensional finite element modelling of the bridge is described and the numerically predicted natural frequencies and modes of vibration are compared to measured values of the same. Sensitivity studies were also undertaken for various model parameters to ascertain which parameters would best suit formal modal updating procedures in order to produce a validated numerical model which would be used to examine in detail the human-structure interaction related to flexible pedestrian footbridges. Following these sensitivity studies the model was manually updated prior to the formal process and the results of analysis of this manual updating are presented here.

MONITORING OF A MULTI-SPAN MASONRY ARCH BRIDGE SUBJECTED TO REPEATED ABNORMAL LOADINGS

T.D. SLOAN
Queen's University, Belfast

Senior lecturer in structures and computing, School of Civil Engineering, Queen's University.

A.THOMPSON
Queen's University, Belfast

Senior Research Officer, School of Civil Engineering, Queen's University

Abstract

This paper describes work done to instrument a five-span masonry arch bridge in the centre of Belfast. The bridge was subjected to a series of abnormal loads during the construction of adjacent new bridges and the opportunity was taken to collect data on the performance of the existing bridge with a view to providing calibration data for numerical models.

AN EXAMINATION OF FILL EFFECTS ON RATINGS FOR MASONRY ARCH BRIDGES

Ekhlasur Rahman
University College Dublin

Masters student at University College Dublin investigating assessment methods for masonry arch bridges.

Paul Fanning
University College Dublin

Graduate of University College Dublin. Received a PhD from University of Surrey. Currently a Lecturer at University College Dublin and Director of the Bridge Engineering Research Group

Abstract

All masonry arch bridges include fill or backing material overlaid on the arch barrel, contained within the spandrel walls, below the road surface. The fill material is generally a soil material or unbonded masonry or rubble and is often very variable in its structural characteristics. The fill material locks compressive stresses into the arch ring under dead load, distributes concentrated loads over greater lengths and widths of the arch barrel, and provides longitudinal restraint to the arch by its interaction with the surrounding soil medium. A stone backing was often used to strengthen an arch near its haunches, particularly in steeply sprung arch bridges.

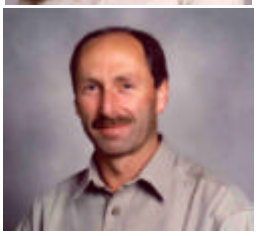
Most traditional assessment methods for arch bridges consider a representative width of the arch barrel. The self weight of any fill material is included and its presence allows for the distribution of relatively concentrated axle loads. This paper extends a two-dimensional load-rating algorithm to include any fill material explicitly. The effect of different grades of fill on bridge load ratings are examined for four different masonry arch bridges.

ARCHING ACTION IN CONCRETE BRIDGE DECK SLABS

S.E. TAYLOR
Queen's University of Belfast, N. Ireland

Graduate of University of Bath, 1989. Industrial work in design, assessment and construction of bridge structures in England & Wales. Completed PhD in 2000 'Arching action in high performance concrete slabs', at QUB. Currently Honorary Lecturer in the School of Civil Engineering and Research Engineer in the Construction Division, NITC, Queens University Belfast.

G.I.B.RANKIN
Queen's University of Belfast, N. Ireland



Graduate of Queens University Belfast 1978. Completed a PhD degree in 1982 entitled 'Punching failure and compressive membrane action in reinforced concrete slabs'. Currently Honorary Lecturer in School of Civil Engineering and Manager of Construction Division, NITC, Queens University Belfast.

D.J.CLELAND
Queen's University of Belfast, N. Ireland

Graduate of Queens University Belfast 1974. Completed a PhD degree in 1979. Currently Professor in structural materials and Dean of the Faculty of Engineering, Queens University Belfast.

Abstract

It has been recognised for some time that laterally restrained slabs exhibit strengths far in excess of those predicted by most design codes. This enhancement in slab strength is due to Compressive Membrane Action (CMA) and has been incorporated into a small number of design standards, such as those in Ontario, Canada and Northern Ireland. This paper presents an overview of the research carried out at Queen's up to the most recent tests on a real bridge structure in Northern Ireland which incorporated novel reinforcement position and type.

MICRO-SIMULATION MODELLING OF TRAFFIC LOAD ON LONG-SPAN CONGESTED BRIDGES

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Ireland

Graduate of University College Galway. Received a PhD degree from the University of Calgary in Canada in 1985. Currently Head of Civil Engineering Department at University College Dublin (UCD)

A.A. HAYRAPETOVA
University College Dublin
Ireland

Graduate of Yerevan Institute of Architecture and Construction, Armenia, 1994, and of American University of Armenia, 1998. Currently a post-graduate student at UCD, Ireland

Abstract

This paper presents an alternative approach to the modelling and assessment of congested traffic loading events for long-span bridges. Micro-simulation, the process of modelling individual vehicles that is widely used in traffic engineering, is presented here as a means of predicting imposed traffic loading on long-span bridges. The traffic flow on congested bridge is modelled using a random mixing process for trucks and cars in each lane, calibrated to match driver behaviour. The method has been tested using a multi-span bridge in the Netherlands, which is heavily congested on regular basis.

CRITICAL LOADING EVENTS FOR THE ASSESSMENT OF MEDIUM SPAN BRIDGES

C.C. CAPRANI
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Ireland

Graduate of D.I.T. Bolton St., 1999. Worked for 2 years in the design of building structures. Currently PhD research student at University College Dublin.

S.A. GRAVE
Trinity College Dublin,
Ireland

Graduate of INSA Lyon (France), 1997. Completed PhD in 2001 on truck traffic modelling on short to medium span bridges. Currently working for Hyder Consulting Ltd (UK).

E.J. O'BRIEN
University, College Dublin,
Ireland

Graduate of University College Galway. Received a PhD degree from the University of Calgary in Canada in 1985. Currently Head of Civil Engineering Department at University College Dublin .

A.J. O'CONNOR
Trinity College Dublin,
Ireland

Completed PhD in 2001 on probabilistic modelling of truck traffic on bridges. Currently Lecturer in Civil Engineering at Trinity College Dublin.

Abstract

This paper describes the simulation of free-flowing traffic across bridges to predict the characteristic values for bridge load effects such as bending moment and shear force. The results of these simulations are then used to demonstrate that, in predicting the characteristic extreme load effects to which a bridge may be subjected, it is not sufficient to solely model one- or two-truck presence events. It is shown that loading events involving three or more trucks may need be included in the model for short to medium spans. The critical loading events for a particular load effect are strongly dependent on the span and the shape of the influence line.

SITE-SPECIFIC PROBABILISTIC LOAD MODELLING FOR BRIDGE RELIABILITY ANALYSIS

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A.J. O'CONNOR
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Completed PhD in 2001 on probabilistic modelling of truck traffic on bridges. Currently Lecturer in Civil Engineering at Trinity College Dublin.

C.C. CAPRANI
University College Dublin,
Ireland

Graduate of D.I.T. Bolton St., 1999. Worked for 2 years in the design of building structures. Currently PhD research student at University College Dublin.

Abstract

Reliability assessment of a short span beam-slab reinforced concrete bridge in Vienna is proposed using site-specific traffic data recorded using the Slovenian Weigh in Motion (SiWIM) system. An initial evaluation of the bridge using a deterministic approach shows that the critical limit state is bending. This paper describes the statistical analysis of the SiWIM data and the traffic flow simulations performed to predict the characteristic extreme load effects to which the bridge may be subjected during its remaining lifetime. These values are compared to the magnitude obtained from a deterministic approach. The influence lines used in the simulations are the real structural response obtained from SiWIM instrumentation and the theoretical influence line for bending moment at mid-span. It is argued that reliability assessment of existing structures using actual traffic loading data is more realistic than the use of deterministic loading models.

EFFECTIVENESS OF HIGH SLAG CONTENT IN MINIMISING THE RISK OF ALKALI-SILICA REACTION IN CONCRETE BRIDGES

D. HESTER
Department of Civil Engineering
University College Dublin

Graduate of University College Dublin, 2000. Currently studying for a M.Eng.Sc on the influence of secondary cementitious materials on concrete durability.

C. McNALLY
Materials Ireland Research Centre
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Graduate of University College Dublin, 1995. Received a PhD from University College in 2001, specialising in concrete durability. Currently a post-doctoral researcher in the Materials Ireland Research Centre.

M.G. RICHARDSON
Department of Civil Engineering
University College Dublin

Chartered Engineer. Senior Lecturer. Chairman I.E.I./Irish Concrete Society Joint Working Party on Alkali-Aggregate Reaction.

Abstract

The contribution of alkalis from ground granulated blast furnace slag (ggbs) to the alkali load in slag concrete has traditionally been taken as half of the slag alkali content. United Kingdom guidance on specification to minimise the risk of alkali-aggregate reaction has recently been revised, resulting in a more liberal approach to the calculation of alkali load in medium to high replacement level slag concretes. The Irish guidance document, published in 1991, is currently being updated based on national and international research. A testing programme on slag concrete based on a modified BSI concrete prism test and incorporating ggbs from two sources is nearing completion at U.C.D. Three aggregate combinations of known alkali reactivity were investigated using a series of binder combinations and alkali loads. The beneficial effect of ggbs at a cement replacement level of 50% has been shown. Consideration of a less conservative approach to the alkali contribution from ggbs at high replacement levels in the forthcoming revised Irish guidance document is recommended.

PROBABILISTIC-BASED DURABILITY DESIGN FOR CONCRETE BRIDGES: EVALUATION OF MATERIAL PARAMETERS

M.G. RICHARDSON
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University College Dublin

Chartered Engineer. Senior Lecturer. Member and former chairman of the National Standards Authority of Ireland Concrete Consultative Committee.

T. CALLANAN
Parsons Brinckerhoff (Ireland) Ltd.
Consulting Engineers, Dublin

Graduate Engineer. Special interest and expertise in durability of concrete bridge structures.
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Abstract

Future code and standards development in Europe will encourage the introduction of performance-based specifications wherever possible. The use of such specifications could be very valuable in the case of bridge structures if probabilistic-based design methods are harnessed. This will require both the development of accepted models and test methods together with determination of the variability of parameters in the models. This paper identifies the research needs in respect of introducing the performance-based specification approach to Irish bridge practice. It also presents an example of research into one of the parameters involved. Experience is reported on the determination of the chloride resistance of concrete. It is shown that diffusion coefficients from laboratory immersion tests can yield values of a similar order of magnitude to those from structures in service in Ireland if the test duration exceeds 6 months.

INVESTIGATING THE FEASIBILITY OF 'SUPER U' BEAMS FOR INTEGRAL BRIDGE CONSTRUCTION

O. M. KENSHEL
Trinity College Dublin
Ireland

MSc student of Trinity College, 2002

A.J. O'CONNOR
Trinity College Dublin
Ireland

Lecturer at the Department of Civil, Structural & Environmental Engineering Trinity College Dublin.

Abstract

The typical precast prestressed U- beam superstructure is one of the most frequently used types of beams in bridge construction. The standard precast beams available cover only bridge spans up to 34-m. For longer span bridges a super U-beam (2 m deep) has been proposed for the construction and a high strength concrete material was encouraged for use. This paper investigates the feasibility of using such a beam. The beam analysis was carried out using the finite Element software 'LUSAS'.

BRIDGE-TRAIN INTERACTION INCORPORATING RAIL & WHEEL IRREGULARITIES AND BRAKING FORCES

C. J. Bowe
Dept. of Civil Engineering
National University of Ireland, Galway

B.E. (Civil) graduate of NUI Galway in 1999. Currently pursuing PhD studies on the dynamic interaction of trains and railway bridges.

Abstract

In this paper, the authors examine their model of the horizontal and vertical dynamic response of a train traversing a railway bridge. The objective in creating this system was to model the rail and wheel irregularities, which was not a feature of the contact elements in ANSYS (finite element program). The authors have also modelled the effects of braking which is easily implemented. The interaction of the wheel with the rigid rail is represented by a vertical spring, whereas the interaction of the wheel and flexible rail is much more complicated. The flexible rail is modelled as a series of beam elements and the interaction between the wheel and the beam element is represented by a series of matrices.

MODELLING THE EFFECT OF TRACK IRREGULARITIES ON THE VERTICAL RESPONSE OF RAILWAY VEHICLES

DAVID P. HEGARTY
Trinity College Dublin
Ireland

Graduate of Trinity College Dublin, 2001. Currently undertaking postgraduate research at Trinity under the supervision of Dr. Dermot O'Dwyer.

Abstract

The research described in this paper forms a component of a research project being carried out by the department of Civil Engineering at Trinity College Dublin. The department is working in cooperation with and being funded by Iarnród Éireann to develop a systematic approach for assessing the effects of dynamic loading on railway bridges. This paper describes the initial procedures and stochastic model developed to describe the loads applied to railway bridges and their resultant effects. The analysis is also relevant to the peak loads that might be applied to a highway surface as a function of the roughness of the surface.

FATIGUE RESPONSE OF STEEL RAILWAY BRIDGES SUBJECT TO DYNAMIC LOADING

RÓNÁN P. GALLAGHER
Trinity College Dublin
Ireland

Graduate of Trinity College Dublin, 1998. Completed a research masters degree in 2000 in the dynamics of railway bridges. Currently undertaking a PhD at Trinity College Dublin studying fatigue of metal railway bridges.

Abstract

This paper describes work that is being carried out to develop an approach for assessing the effects of dynamic loading on ageing metal bridges. The overall project involves work in a number of different areas: the development of bridge and rolling stock models and their interaction; the development of loading data to model variable track alignment and wheel profiles; the measurement of bridge responses to rolling loads; the calculation of cumulative fatigue damage and the evaluation of remaining fatigue life.

This paper illustrates the approach taken in assessing the fatigue loading applied to the bridge. It discusses the methodology and mechanisms of fatigue analysis. The procedure presented involves the implementation of the rain-flow algorithm. This method involves decomposing the stress history of each location on the structure into a series of stress cycles. This approach enables the application of traditional methods such as the Palmgren-Miner hypothesis. The method and its implementation are described in detail. Considerations such as material properties, stress concentrations and previous loading history are also considered and addressed.