Design of floor diaphragms in multi-storey timber buildings

D. Moroder, T. Smith, S. Pampanin, A. Palermo &
A.H. Buchanan

Department of Civil and Natural Resources Engineering, University of Canterbury, Christchurch

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ABSTRACT: This paper discusses the design of timber diaphragms, in response to the growing interest in multi-storey commercial timber structures, and the lack of guidance or regulations regarding the seismic design of timber diaphragms.

Proper performance of floor diaphragms is required to transfer all lateral loads to the vertical systems that resist them, but design for earthquake loads can be more complex than design for wind loads. This paper confirms that the seismic design of a diaphragm is intimately linked to the seismic design of the whole building. Diaphragm failure, even if restricted to a limited diaphragm portion, can compromise the behaviour of the whole building. It is therefore necessary to design and detail diaphragms for all possible load paths and to evaluate their influence on the load distribution within the rest of the structure. It is strongly recommended that timber diaphragms be designed as elastic elements, by applying dynamic amplification and overstrength factors derived from the lateral load resisting system.

This paper shows that some current design recommendations for plywood sheathing on light timber framing can be applied to massive wood diaphragms, but for more complex floor geometries an equivalent truss method is suggested. Diaphragm flexibility and displacement incompatibilities between the floor diaphragms and the lateral resisting systems also need to be accounted for.

1 INTRODUCTION

Recent years have seen a growing interest in engineered multi-storey timber buildings around the world. A number of tall timber buildings have been built in Europe, followed by a 10 storey building in Melbourne (Binational Softwood Lumber Council et al. 2014). Both Canada and the US have set up design competitions in order to promote timber as the construction material for tall buildings. The New Zealand construction sector is part of this trend, with a number of commercial timber buildings already built (Ministry for Primary Industries 2014) or in the design process. The local availability of glued laminated timber (glulam), Cross Laminated Timber (CLT), Laminated Veneer Lumber (LVL) as well as prefabricated Light Timber Frame (LTF) elements and the soon to be released new NZ Timber Structures Standard are all encouraging the use of timber for new multi-residential, commercial and industrial buildings.

This new global interest in medium to high-rise multi-storey timber buildings creates the need for a more rigorous approach in design. Furthermore, the presence of some of these structures in seismically active countries has highlighted knowledge gaps regarding their performance under earthquake loading and especially in the design of diaphragms.

1.1 Role of diaphragms

Independently of the construction material used, diaphragms have a multiple role in the structural behaviour of a building. Aside from acting as slabs under gravity loads, diaphragms tie all other structural elements together and transfer horizontal loads to the vertical Lateral Load Resisting System (LLRS). Being the first element to resist most gravity and horizontal forces, a loss of diaphragm action will likely compromise the behaviour of the whole structure.

Design Of Floor Diaphragms In Multi Storey Timber Buildings

Lawrence L. Kupper,Brian. H Neelon,Sean M. O'Brien

Design Of Floor Diaphragms In Multi Storey Timber Buildings:

Holistic Design of Taller Timber Buildings Gerhard Fink,Robert Jockwer,José Manuel Cabrero,2025-10-25 This open access book presents a comprehensive exploration of the challenges and innovations in designing and constructing taller timber buildings TTBs It brings together cutting edge research on key aspects such as structural design fire safety and the environmental impact of timber construction The work emphasizes a holistic approach addressing not only the technical complexities like vibration based assessments seismic resistance and long term behavior but also integrating themes of circularity adaptability and sustainability The insights shared in this book stem from the collaborative efforts of the COST Action HELEN CA20139 a network dedicated to advancing knowledge on TTBs HELEN combines expertise from multiple disciplines and aims to push the boundaries of timber construction fostering innovative methodologies that improve the durability resilience and overall performance of timber buildings Through these contributions the book presents practical solutions and visionary frameworks for sustainable multi storey timber construction aiming to shape the future of timber based architecture in urban environments Floor Diaphragms in Multi-storey Timber Buildings Daniel Moroder,2016

Use of Timber in Tall Multi-Storey Buildings Ian Smith,Andrea Frangi,2014-01-01 Since the dawn of civilization timber has been a primary material for achieving great structural engineering feats Yet during the late 19th century and most of the 20th century it lost currency as a preferred material for construction of large and tall multi storey building superstructures This Structural Engineering Document SED addresses a reawakening of interest in timber and timber based products as primary con struction materials for relatively tall multi storey buildings Emphasis throughout is on holistically addressing various aspects of performance of complete systems reflecting that major gaps in knowhow relate to design concepts rather than technical information about timber as a material Special con sideration is given to structural form fire vulnerability and durability aspects for attaining desired building performance over lifespans that can be centuries long **Timber Structures and Engineering** De Proft, K.,Brebbia, C. A.,Connor, J.,2018-02-06 This book contains papers presented at the 1st International Conference on Timber Structures which was held in collaboration with the Technical Centre of Wood Industry in Belgium It explores the latest developments in wood products and their application as structural components The focus of the included works is to draw attention to new research and real applications from both researchers and practitioners and to present new and innovative ideas in this significant field Rapid advances have recently been made in the development and processing of innovative ecologically friendly wood products A variation of new structural shapes can now be fabricated and used to construct buildings and bridges which have minimal impact on the environment Wood is particularly appealing since it is renewable and has no carbon footprint when it is harvested in a sustainable way Timber structures are ecologically sound and comparatively low cost The material lends itself to ground breaking designs and new types of composites offer reliable robust and safe materials The content of this book comprises a range of topics Material

properties of wood Durability aspects service life modelling Fire safety of timber structures Protection against decay Non destructive inspection and monitoring Glued laminated structures Xlam and CLT Timber joints and connections Vernacular wood and heritage timber structures Timber housing and eco architecture Timber bridges Large span timber roof structures Shell structures in timber Mixed composite and hybrid structures Computational analysis and experimental methods Structural engineering and design Seismic behaviour of timber structures Protection of timber Repaired timber structures Rapidly assembled and transferable timber structures Guidelines codes and regulations Structural failures Art and craftsmanship **Designers' Guide to Eurocode 5: Design of Timber Buildings** Jack Porteous,Alexander Porteous,Peter Ross,Haig Gulvanessian,2013-04-26 Interprets and assists in the use of EN 1995 1 1 structural timber This guide shows typical material properties and dimensions modifiers and structural responses It also explains relationships with other Eurocodes particularly those for EN 1990 Basis of Design **Displacement-based seismic design for multi-storey cross laminated timber buildings** Hummel, Johannes,2017 Key Terms cross laminated timber displacement based seismic design time history analysis multi storey timber structures hysteretic behaviour **Timber Engineering - Principles for Design** Blass, Hans Joachim,Sandhaas, Carmen,2017-09-19 This comprehensive book provides in depth knowledge and understanding of design rules according to Eurocode 5 It is based on the first edition of the STEP Structural Timber Education Programme series which was prepared in 1995 by about 50 authors from 14 European countries The present work updates and extends the STEP compilation and is aimed at students structural engineers and other timber structure professionals **Buildings and Structures under Extreme Loads** Chiara Bedon,Flavio Stochino,Daniel Honfi,2020-11-25 Exceptional loads on buildings and structures may have different causes including high strain dynamic effects due to natural hazards man made attacks and accidents as well as extreme operational conditions severe temperature variations humidity etc All of these aspects can be critical for specific structural typologies and or materials that are particularly sensitive to external conditions In this regard dedicated and refined methods are required for their design analysis and maintenance under the expected lifetime There are major challenges related to the structural typology and material properties with respect to the key features of the imposed design load Further issues can be derived from the need for risk mitigation or retrofit of existing structures as well as from the optimal and safe design of innovative materials systems Finally in some cases no appropriate design recommendations are available and thus experimental investigations can have a key role within the overall process In this Special Issue original research studies review papers and experimental and or numerical investigations are presented for the structural performance assessment of buildings and structures under various extreme conditions that are of interest for design Current Perspectives and New Directions in Mechanics, Modelling and Design of Structural Systems Alphose Zingoni,2022-09-02 Current Perspectives and New Directions in Mechanics Modelling and Design of Structural Systems comprises 330 papers that were presented at the Eighth International Conference on Structural

Engineering Mechanics and Computation SEMC 2022 Cape Town South Africa 5 7 September 2022 The topics featured may be clustered into six broad categories that span the themes of mechanics modelling and engineering design i mechanics of materials elasticity plasticity porous media fracture fatigue damage delamination viscosity creep shrinkage etc ii mechanics of structures dynamics vibration seismic response soil structure interaction fluid structure interaction response to blast and impact response to fire structural stability buckling collapse behaviour iii numerical modelling and experimental testing numerical methods simulation techniques multi scale modelling computational modelling laboratory testing field testing experimental measurements iv design in traditional engineering materials steel concrete steel concrete composite aluminium masonry timber v innovative concepts sustainable engineering and special structures nanostructures adaptive structures smart structures composite structures glass structures bio inspired structures shells membranes space structures lightweight structures etc vi the engineering process and life cycle considerations conceptualisation planning analysis design optimization construction assembly manufacture maintenance monitoring assessment repair strengthening retrofitting decommissioning Two versions of the papers are available full papers of length 6 pages are included in the e book while short papers of length 2 pages intended to be concise but self contained summaries of the full papers are in the printed book This work will be of interest to civil structural mechanical marine and aerospace engineers as well as planners and architects

Timber Engineering Sven Thelandersson,Hans J. Larsen,2003-03-14 Timber construction is one of the most prevalent methods of constructing buildings in North America and an increasingly significant method of construction in Europe and the rest of the world Timber Engineering deals not only with the structural aspects of timber construction structural components joints and systems based on solid timber and engineered wood products but also material behaviour and properties on a wood element level Produced by internationally renowned experts in the field this book represents the state of the art in research on the understanding of the material behaviour of solid wood and engineered wood products There is no comparable compendium currently available on the topic the subjects represented include the most recent phenomena of timber engineering and the newest development of practice related research Grouped into three different sections Basic properties of wood based structural elements Design aspects on timber structures and Joints and structural assemblies this book focuses on key issues in the understanding of timber as a modern engineered construction material with controlled and documented properties the background for design of structural systems based on timber and engineered wood products the background for structural design of joints in structural timber systems Furthermore this invaluable book contains advanced teaching material for all technical schools and universities involved in timber engineering It also provides an essential resource for timber engineering students and researchers as well as practicing structural and civil engineers **Structural Aspects of Building Conservation** Poul Beckmann,Robert Bowles,2012-06-25 This practical guide to the assessment and repair of historic buildings is invaluable for structural engineers architects surveyors and builders working in all aspects of

building conservation Taking a practical step by step approach the authors discuss the appraisal of buildings and the differences in structural behaviour between new and existing structures Each stage in the appraisal is explained using examples from the authors own work Each major construction material is assessed in detail with separate sections on masonry concrete timber and the particularly complex issues of iron and steel framed buildings Techniques for testing the ability of a building to continue its existing use or to be converted to a new use are explained *PRO 8: 1st International RILEM Symposium on Timber Engineering* Lars Boström,1999 *Seismic Retrofit of Existing Buildings* Matthew Fox,Weng Yuen Kam,Damian Grant,2024-09-19 Seismic Retrofit of Existing Buildings is a concise and easy to use guideline for practising engineers to assess and design successful seismic retrofit interventions for existing vulnerable buildings It offers readers guidance on both conceptual design strategies and relevant detailed design considerations **Seismic Design for Architects** Andrew Charleson,2012-06-25 Seismic Design for Architects shows how structural requirements for seismic resistance can become an integral part of the design process Structural integrity does not have to be at the expense of innovative high standard design in seismically active zones By emphasizing design and discussing key concepts with accompanying visual material architects are given the background knowledge and practical tools needed to deal with aspects of seismic design at all stages of the design process Seismic codes from several continents are drawn upon to give a global context of seismic design Extensively illustrated with diagrams and photographs A non mathematical approach focuses upon the principles and practice of seismic resistant design to enable readers to grasp the concepts and then readily apply them to their building designs Seismic Design for Architects is a comprehensive practical reference work and text book for students of architecture building science architectural and civil engineering and professional architects and structural engineers

Exercises and Solutions in Statistical Theory Lawrence L. Kupper,Brian. H Neelon,Sean M. O'Brien,2013-06-24 Exercises and Solutions in Statistical Theory helps students and scientists obtain an in depth understanding of statistical theory by working on and reviewing solutions to interesting and challenging exercises of practical importance Unlike similar books this text incorporates many exercises that apply to real world settings and provides much more thorough solutions The exercises and selected detailed solutions cover from basic probability theory through to the theory of statistical inference Many of the exercises deal with important real life scenarios in areas such as medicine epidemiology actuarial science social science engineering physics chemistry biology environmental health and sports Several exercises illustrate the utility of study design strategies sampling from finite populations maximum likelihood asymptotic theory latent class analysis conditional inference regression analysis generalized linear models Bayesian analysis and other statistical topics The book also contains references to published books and articles that offer more information about the statistical concepts Designed as a supplement for advanced undergraduate and graduate courses this text is a valuable source of classroom examples homework problems and examination questions It is also useful for scientists interested in enhancing or refreshing their

theoretical statistical skills The book improves readers comprehension of the principles of statistical theory and helps them see how the principles can be used in practice By mastering the theoretical statistical strategies necessary to solve the exercises readers will be prepared to successfully study even higher level statistical theory **New Architecture in Wood** Marc Wilhelm Lennartz,Susanne Jacob-Freitag,2015-11-27 Timber the old raw material and building material returns There are many reasons today for building with wood and there are great advantages over conventional designs Wood is not only a renewable building material that helps reduce the levels of CO2 and is hence good for climate change but due to modern computing and manufacturing processes it can also be used for a variety of construction tasks Wood possesses excellent qualities for both construction and indoor climate control and can easily be combined with other common building materials Based on 24 international projects the book provides an overview of the range of possibilities in wood construction today Texts images and plans document the architectural and constructive qualities of contemporary timber structures from the conceptual design to the structure in detail The various uses are based on current research in modern timber engineering but also on timber construction expertise that has been developing over many centuries This special discipline has evolved significantly in recent decades particularly in Germany Austria and Switzerland and is a world leader today **18th International Probabilistic Workshop** José C. Matos,Paulo B. Lourenço,Daniel V. Oliveira,Jorge Branco,Dirk Proske,Rui A. Silva,Hélder S. Sousa,2021-05-07 This volume presents the proceedings of the 18th International Probabilistic Workshop IPW which was held in Guimar es Portugal in May 2021 Probabilistic methods are currently of crucial importance for research and developments in the field of engineering which face challenges presented by new materials and technologies and rapidly changing societal needs and values Contemporary needs related to for example performance based design service life design life cycle analysis product optimization assessment of existing structures and structural robustness give rise to new developments as well as accurate and practically applicable probabilistic and statistical engineering methods to support these developments These proceedings are a valuable resource for anyone interested in contemporary developments in the field of probabilistic engineering applications **Structures and Architecture** Paulo J. Cruz,2013-06-27 Although the disciplines of architecture and structural engineering have both experienced their own historical development their interaction has resulted in many fascinating and delightful structures To take this interaction to a higher level there is a need to stimulate the inventive and creative design of architectural structures and to persua **The Structural Engineer** ,2006

Conceptos avanzados del diseño estructural con madera Pablo Guindos,2019 Este es el tercer libro de una trilog a destinada a recorrer el estado del arte en lo referente al dise o y la construcci n con madera En este volumen en particular se abordan gran parte de las ltimas tendencias y novedades internacionales con respecto al dise o estructural con madera As pues el objetivo del libro es capacitar a ingenieros y dise adores en el dise o estructural de edificios de madera contralaminada CLT la modelaci n num rica de estructuras conceptos avanzados del dise o y protecci n frente al fuego y un

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