

# Shear and anchorage behaviour of fire exposed hollow core slabs

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The fire resistance of hollow core slabs is currently assessed considering flexural failure only. However, fire tests showed that shear or anchorage failure can also govern the load bearing behaviour. As the shear and anchorage capacity of these slabs rely on the tensile strength of the concrete, the load bearing capacity with respect to these failure modes decreases dramatically during fire due to the impact of thermal stresses. This paper presents a FE model for the shear and anchorage behaviour of fire exposed hollow core slabs, comprising new constitutive models for concrete and bond of prestressing strands at high temperatures. The constitutive models were calibrated with 60 new small scale tests carried out at elevated temperatures up to 600 °C. The FE model was validated on the basis of 25 full scale fire tests on hollow core slabs loaded in shear. Finally, a parameter study was carried out with the FE model. The results showed that the thermal expansion of concrete, the ductility of concrete in tension and the restraint against thermal expansion by the supports are the main influencing factors. It is recommended to control these factors in design in order to improve the safety level. This paper is an extended summary of the dissertation by the first author [10].

*Key words:* Fire resistance, shear failure anchorage failure, bond, prestressing strand, FE modelling

## 1 Introduction

### 1.1 HC slabs

Hollow core (HC) slabs are made of pre-cast concrete with pre-tensioned strands. The slabs consist of pre-cast units of typically 1.2 m wide. The cross sectional depth depends on the intended span and ranges between 150–400 mm reaching spans up to 16 m. The number and shape of the hollow cores is adjusted to the depth of the slab. These slabs are very popular in offices and dwellings, thanks to the large span to depth ratio. This is a result of the reduction of weight, maintaining the effectiveness of the cross section, due to the hollow cores in combination with a relatively high strength of the concrete, typically C45 to C60.

# Shear Anchorage Behavior Of Fire Exposed Hollow Core Slabs

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## **Shear Anchorage Behavior Of Fire Exposed Hollow Core Slabs:**

**Shear and Anchorage Behaviour of Fire Exposed Hollow Core Slabs** Joris H. H. Fellingner, 2004-01-01 This is a Ph D dissertation Hollow core HC slabs are made of precast concrete with pretensioned strands These slabs are popular as floor structures in offices and housing At ambient conditions the load bearing capacity can be dominated by four diff 12th PhD Symposium in Prague Czech Rep FIB - International Federation for Structural Concrete, 2018-08-01 Structures in Fire Venkatesh Kodur, Jean-Marc Franssen, 2010 **Construction Materials and Structures** S.O. Ekelu, M. Dundu, X. Gao, 2014-12-05 The two volumes of these Proceedings contain about 200 conference papers and 10 keynote papers presented at the First International Conference on Construction Materials and Structures held in Johannesburg South Africa from 24 to 26 November 2014 It includes sections on Materials and characterization Durability of construction materials Structural implications performance service life Sustainability waste utilization the environment and Building science and construction Structural Design for Fire Safety Andrew H. Buchanan, Anthony Kwabena Abu, 2017-01-30 Structural Design for Fire Safety 2nd edition Andrew H Buchanan University of Canterbury New Zealand Anthony K Abu University of Canterbury New Zealand A practical and informative guide to structural fire engineering This book presents a comprehensive overview of structural fire engineering An update on the first edition the book describes new developments in the past ten years including advanced calculation methods and computer programs Further additions include calculation methods for membrane action in floor slabs exposed to fires a chapter on composite steel concrete construction and case studies of structural collapses The book begins with an introduction to fire safety in buildings from fire growth and development to the devastating effects of severe fires on large building structures Methods of calculating fire severity and fire resistance are then described in detail together with both simple and advanced methods for assessing and designing for structural fire safety in buildings constructed from structural steel reinforced concrete or structural timber Structural Design for Fire Safety 2nd edition bridges the information gap between fire safety engineers structural engineers and building officials and it will be useful for many others including architects code writers building designers and firefighters Key features Updated references to current research as well as new end of chapter questions and worked examples Authors experienced in teaching researching and applying structural fire engineering in real buildings A focus on basic principles rather than specific building code requirements for an international audience An essential guide for structural engineers who wish to improve their understanding of buildings exposed to severe fires and an ideal textbook for introductory or advanced courses in structural fire engineering *Life-Cycle of Engineering Systems: Emphasis on Sustainable Civil Infrastructure* Jaap Bakker, Dan M. Frangopol, Klaas Breugel, 2016-11-18 This volume contains the papers presented at IALCCE2016 the fifth International Symposium on Life Cycle Civil Engineering IALCCE2016 to be held in Delft The Netherlands October 16 19 2016 It consists of a book of extended abstracts and a DVD with full papers including the Fazlur R Khan lecture keynote

lectures and technical papers from all over the world All major aspects of life cycle engineering are addressed with special focus on structural damage processes life cycle design inspection monitoring assessment maintenance and rehabilitation life cycle cost of structures and infrastructures life cycle performance of special structures and life cycle oriented computational tools The aim of the editors is to provide a valuable source for anyone interested in life cycle of civil infrastructure systems including students researchers and practitioners from all areas of engineering and industry

**Fire Design of Concrete Structures - Structural Behaviour and Assessment** fib Fédération internationale du béton, 2008-01-01 Concrete is well known to behave efficiently in fire conditions as it is incombustible does not emit smoke and provides good thermal insulation Furthermore in reinforced concrete structures the concrete cover gives a natural protection to the reinforcement and the size of the sections often delays the heating of the core thus favouring the fire resistance of the structural members In addition concrete structures are often robust and therefore able to accommodate local damage without major consequences to the overall structural integrity However past experience with real fires shows that a thorough understanding of concrete behaviour and structural mechanics is still needed to improve the design of R C structures with respect to fire The objective of fib Bulletin 46 is to augment the current knowledge about concrete and concrete structures under fire not only for the design of new structures but also for the analysis and repair of existing fire damaged structures Both structural and materials issues are examined and the results of the most recent research activities on the structural performance of concrete subjected to fire are reported Special attention is paid to the indirect actions caused by the restrained thermal deformations and several basic examples show how a local fire influences global structural behaviour fib Bulletin 46 is intended for use by practicing engineers to improve their understanding of the behaviour of concrete structures in fire and thereby produce better and safer design standards

**Progress in Mechanics of Structures and Materials** Peter J. Moss, Rajesh P. Dhakal, 2020-10-28 This is a collection of peer reviewed papers originally presented at the 19th Australasian Conference on the Mechanics of Structures and Materials by academics researchers and practitioners largely from Australasia and the Asia Pacific region The topics under discussion include composite structures and materials computational mechanics dynamic analysis of structures earthquake engineering fire engineering geomechanics and foundation engineering mechanics of materials reinforced and prestressed concrete structures shock and impact loading steel structures structural health monitoring and damage identification structural mechanics and timber engineering It is a valuable reference for academics researchers and civil and mechanical engineers working in structural and material engineering and mechanics

Fire Safety Engineering Design of Structures, Third Edition John A. Purkiss, Long-Yuan Li, 2013-12-05 Designing structures to withstand the effects of fire is challenging and requires a series of complex design decisions This third edition of Fire Safety Engineering Design of Structures provides practising fire safety engineers with the tools to design structures to withstand fires This text details standard industry design decisions and offers expert design advice with relevant historical

data It includes extensive data on materials behaviour and modeling concrete steel composite steel concrete timber masonry and aluminium While weighted to the fire sections of the Eurocodes this book also includes historical data to allow older structures to be assessed It extensively covers fire damage investigation and includes as far back as possible the background to code methods to enable the engineer to better understand why certain procedures are adopted What's new in the Third Edition An overview in the first chapter explains the types of design decisions required for optimum fire performance of a structure and demonstrates the effect of temperature rise on structural performance of structural elements It extends the sections on less common engineering materials The section on computer modelling now includes material on coupled heat and mass transfer enabling a better understanding of the phenomenon of spalling in concrete It includes a series of worked examples and provides an extensive reference section Readers require a working knowledge of structural mechanics and methods of structural design at ambient conditions and are helped by some understanding of thermodynamics of heat transfer This book serves as a resource for engineers working in the field of fire safety consultants who regularly carry out full fire safety design for structure and researchers seeking background information Dr John Purkiss is a chartered civil and structural engineer consultant and former lecturer in structural engineering at Aston University UK Dr Long Yuan Li is Professor of Structural Engineering at Plymouth University UK and a Fellow of the Institution of Structural Engineers

#### **Futures in Mechanics of Structures and Materials** Thiru Aravinthan,Warna (Karu) Karunasena,Hao

Wang,2008-11-20 Futures in Mechanics of Structures and Materials is a collection of peer reviewed papers presented at the 20th Australasian Conference on the Mechanics of Structures and Materials ACMSM20 University of Southern Queensland Toowoomba Queensland Australia 2 5 December 2008 by academics researchers and practicing engineers mainly from Austral **American Environmentalism** J. Michael Martinez,2013-06-20 Protecting the natural environment and promoting sustainability have become important objectives but achieving such goals presents myriad challenges for even the most committed environmentalist American Environmentalism Philosophy History and Public Policy examines whether competing interests can be reconciled while developing consistent coherent effective public policy to regulate uses and protection of the natural environment without destroying the national economy It then reviews a range of possible solutions The book delves into key normative concepts that undergird American perspectives on nature by providing an overview of philosophical concepts found in the western intellectual tradition the presuppositions inherent in neoclassical economics and anthropocentric human centered and biocentric earth centered positions on sustainability It traces the evolution of attitudes about nature from the time of the Ancient Greeks through Europeans in the Middle Ages and the Renaissance the Enlightenment and the American Founders the nineteenth and twentieth centuries and up to the present Building on this foundation the author examines the political landscape as non governmental organizations NGOs industry leaders and government officials struggle to balance industrial development with environmental concerns Outrageous claims silly

misrepresentations bogus arguments absurd contentions and overblown prophecies of impending calamities are bandied about by many parties on all sides of the debate industry spokespeople elected representatives unelected regulators concerned citizens and environmental NGOs alike In lieu of descending into this morass the author circumvents the silliness to explore the crucial issues through a more focused disciplined approach Rather than engage in acrimonious debate over minutiae as so often occurs in the context of green claims he recasts the issue in a way that provides a cohesive look at all sides This effort may be quixotic but how else to cut the Gordian knot

**Fire Design of Concrete Structures - Materials, Structures and Modelling** fib Fédération internationale du béton, 2007-01-01 Fire design of concrete structures has emerged in recent years as a high profile subject of great interest to both experts and the public This has been largely prompted by severe damage to concrete in a number of recent tunnel fires as well as a considerable amount of research and development that has taken place world wide fib Task Group 4 3 Fire Design of Concrete Structures therefore took the initiative to develop this bulletin in order to present the results of this international research to a wider group of concrete professionals The report presents a general brief outline of the effect of fire on both concrete material and concrete structures with emphasis placed on the important developments of the past few years namely a the increasing use of high strength concrete HSC in buildings tunnels and bridges b the growing acceptance of the use of performance based fire engineering calculations for the structural analysis and design against fire c the problem of and solutions to explosive spalling and d fires in tunnels This report is not intended to be an exhaustive review of the effect of fire on concrete and concrete structures nor to present a database of properties at high temperature Instead the main aims of this document are to present recent trends and developments highlight key influencing factors bring together the disparate but related issues in one short document highlight the deficiencies in current practice and point to the future The basic principles of performance based codes and fire engineering are also presented on the assumption that the reader is not a specialist in this field

SFPE Handbook of Fire Protection Engineering Morgan J. Hurley, Daniel T. Gottuk, John R. Hall Jr., Kazunori Harada, Erica D. Kuligowski, Milosh Puchovsky, Jose' L. Torero, John M. Watts Jr., CHRISTOPHER J. WIECZOREK, 2015-10-07 Revised and significantly expanded the fifth edition of this classic work offers both new and substantially updated information As the definitive reference on fire protection engineering this book provides thorough treatment of the current best practices in fire protection engineering and performance based fire safety Over 130 eminent fire engineers and researchers contributed chapters to the book representing universities and professional organizations around the world It remains the indispensable source for reliable coverage of fire safety engineering fundamentals fire dynamics hazard calculations fire risk analysis modeling and more With seventeen new chapters and over 1 800 figures the this new edition contains Step by step equations that explain engineering calculations Comprehensive revision of the coverage of human behavior in fire including several new chapters on egress system design occupant evacuation scenarios combustion toxicity and data for human behavior

analysis Revised fundamental chapters for a stronger sense of context Added chapters on fire protection system selection and design including selection of fire safety systems system activation and controls and CO2 extinguishing systems Recent advances in fire resistance design Addition of new chapters on industrial fire protection including vapor clouds effects of thermal radiation on people BLEVEs dust explosions and gas and vapor explosions New chapters on fire load density curtain walls wildland fires and vehicle tunnels Essential reference appendices on conversion factors thermophysical property data fuel properties and combustion data configuration factors and piping properties Three volume set not available separately

*International Handbook of Structural Fire Engineering* Kevin LaMalva,Danny Hopkin,2021-10-12 This Handbook is focused on structural resilience in the event of fire It serves as a single point of reference for practicing structural and fire protection engineers on the topic of structural fire safety It is also stands as a key point of reference for university students engaged with structural fire engineering *Fire Safety Engineering Design of Structures, Second Edition* John Purkiss,2007

An essential resource on the design and performance of common structural materials when they are exposed to fire **2nd**

**fib Congress in Naples Italy Vol2** FIB - International Federation for Structural Concrete,2006-06-01 High Performance Materials in Bridges Atorod Azizinamini,Aaron Yakel,Magdy Abdelrahman,United Engineering Foundation (U.S.),2003 This collection contains 41 papers presented at the International Conference on High Performance Materials in Bridges held in Kona Hawaii July 29 August 3 2001 **Precast Prestressed Concrete for Building Structures** Kim S.

Elliott,Mark Magill,2024-03-21 This guide to precast prestressed concrete PSC introduces and applies principles for the design of PSC slabs thermal slabs beam and block flooring and main beams including where appropriate cantilevers and composite and continuous construction The book provides numerous worked examples for a wide range of PSC elements and covers the innovative use of PSC on several projects in the UK over the past ten years drawing on the authors first hand experience in the design and manufacture of special products The contents are in line with latest revisions of the Eurocodes and European Product Standards Precast Prestressed Concrete for Building Structures is ideal for consulting structural engineers clients PSC manufacturers and advanced undergraduate and graduate students both as a guide and a textbook

**Subject Guide to Books in Print** ,1993 **Proceedings** American Concrete Institute. Annual Convention,1961

## Whispering the Secrets of Language: An Mental Quest through **Shear Anchorage Behavior Of Fire Exposed Hollow Core Slabs**

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