# MODERNISATION, MECHANISATION & INDUSTRIALISATION of Concrete Structures

Edited by
**Kim S. Elliott**
**and Zuhairi Abd. Hamid**

WILEY Blackwell

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# About the Editors

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**Kim Stephen Elliott** is a consultant to the precast industry in the UK and Malaysia. He was Senior Lecturer in the School of Civil Engineering at Nottingham University, UK from 1987–2010 and was formerly at Trent Concrete Structures Ltd. UK. He is a member of fib Commission 6 on Prefabrication where he has made contributions to six manuals and technical bulletins, and is the author of Multi-Storey Precast Concrete Frame Structures (1996, 2013) and Precast Concrete Structures (2002, 2016) and co-authored The Concrete Centre's Economic Concrete Frames Manual (2009). He was Chairman of the European research project COST C1 on Semi-Rigid Connection in Precast Structures (1992–1999). He has lectured on precast concrete structures 45 times in 16 countries worldwide (including Malaysia, Singapore, Korea, Brazil, South Africa, Barbados Austria, Poland, Portugal, Spain, Scandinavia and Australia) and at 30 UK universities.

## Zuhairi Abd Hamid, Construction Research Institute of Malaysia (CREAM), Kuala Lumpur, Malaysia

**Zuhairi Abd. Hamid** has more than 32 years of experience in the construction industry. His expertise lies in structural dynamics, industrialised building systems, strategic IT in construction and Facilities Management. He is active in engineering education and research and has been appointed by universities in various capacities; from Adjunct Professor, Research Fellow and member of the industry Advisory Panel. He is the Regional Director of South East Asia and Guest Member for the UN support International Council for Research and Innovation in Building and Construction (CIB). Currently, as the Executive Director at CREAM, he actively engages in construction research for industrial publications in Malaysia.

# Notes on Contributors

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**Ahmad Hazim Abdul Rahim** is currently the Manager at Construction Research Institute of Malaysia. He has been involved in research and development (R&D) fields in construction and civil engineering for more than 15 years. He currently heads the structural engineering laboratory at CREAM, an ISO/IEC 17025 accredited laboratory and in charge of the technical and quality aspect of the day to day operational of the laboratory. He holds a B. Eng (Hons) in Civil Engineering and completed his Masters in Engineering Science in 2007. His area of interests is conformity assessment of structural component, full-scale structural test and construction materials testing and evaluation. He has published various publications ranging from books to peer-reviewed journals, technical papers, proceedings and articles.

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**Foo Chee Hung** is a researcher from the Construction Research Institute of Malaysia (CREAM) – a research arm under the Construction Industry Development Board Malaysia (CIDB). He is currently the Head of Consultancy and Technical Opinion Unit.

He obtained both his first (Environmental Engineering) and master (SHE Engineering) degree at the University of Malaya. He then further pursued his PhD (Urban Engineering) in the University of Tokyo. His research interest is in sustainability, affordable housing, green building, building quality assessment, Industrialized Building System (IBS), and urban ecosystem.

He is a member of the Institution of Engineers Malaysia (IEM), and the GreenRE manager.

## Gan Hock Beng, G&A Architect

**Gan Hock Beng** is the Founder of G&A Architect. He is currently engaged in a number of residential and commercial projects in Georgetown, Penang. The projects he has worked on include landmarks like Times Square, Moonlight Bay, University Place, The View, etc. He has been the invited speaker at conferences organized by the Singapore Ministry of Housing, and the South Korea Ministry of Housing. He was given the award of "Most Innovative Design" in a competition organized by the Ministry of Housing Malaysia.

## Susanne Schachinger, Precast Software Engineering, Wals-Siezenheim, Austria

**Susanne Schachinger** is an International Sales Representative at Precast Software Engineering. As a co-author she brings in expertise from her daily work with precast companies in various countries. University studies in Graz (Austria), Volgograd (Russia) and Prague (Czech Republic) led her to the consumer goods industry before she joined Precast Software Engineering in 2011. She represents the company at IPHA (International Prestressed Hollowcore Association).

## Thomas Leopoldseder, Precast Software Engineering, Wals-Siezenheim, Austria

**Thomas Leopoldseder** works as an international BIM Consultant and Product Manager of TIM (Technical Information Manager) at Precast Software Engineering in Austria (Part of Nemetschek Group) which is developing high-end CAD and BIM solutions for the precast industry. After studying at the Vienna University of Economics and Business, he first worked as an IT consultant and then at various levels (CFO, General Manager) in the precast industry. He is now one of the leading experts in BIM solutions concerning the precast industry.

## Robert Neubauer, SAA Software Engineering GmbH, Austria

**Neubauer** has been a Managing Partner at SAA Software Engineering in Vienna, Austria since 1999, leading the development of CAM and Control-Software for the precast concrete manufacturing industry. In 1986 he was engaged in automation in the construction industry, realizing the first control- and master-computer-software for the first automated precast concrete plant. After graduating in mechanical engineering at the Technical University of Vienna in 1993 he was previously at Ainedter Industry Automation and at Sommer Automatisierungstechnik (Austria).

During the past 30 years, Mr Neubauer has been working on automation in the prefabrication industry for construction, developing and conducting development for new solutions, collaborating with different vendors for plants and machinery and leading committees. At the end of 2015, SAA merged with RIB Software AG/Germany, and as Managing Partner, he is accompanying RIB SAA Software Engineering GmbH into a BIM-5D integrated future for smart production of construction systems.

## Gerhard Girmscheid, ETH, Swiss Federal Institute of Technology, Zurich, Switzerland

**Gerhard Girmscheid,** studied construction engineering in Darmstadt (Germany), occupying management posts at German and American construction enterprises, involving assignments abroad that included major construction sites in Egypt and Thailand, as well as the fourth tunnel tube under the River Elbe in Hamburg. Since 1996, he has been Professor of Construction Business Management and Construction Process Engineering at ETH Zurich (Switzerland). He was recently awarded emeritus status.

In research and teaching, Professor Girmscheid focuses on construction processes, and strategic and operational construction enterprise management. His SysBau® research targets improved, more efficient, and new sustainable life cycle-oriented construction processes and portfolios aimed at strengthening the innovative and competitive abilities of construction industry providers. His research activities have produced numerous dissertations and research reports, together with more than 100 peer-reviewed specialist publications. He has written several books on construction enterprise and process management.

He sits on the Board of Directors of general contracting and property company Priora AG, and prefabrication specialists Müller-Stein AG. He also manages CTT-Consulting in Lenzburg (Switzerland), advising companies and training staff on improving bidding and execution processes, managing claims, and implementation.

## Julia Selberherr, ETH, Swiss Federal Institute of Technology, Zurich, Switzerland

**Julia Selberherr** received her Civil Engineering diploma from the Vienna University of Technology in 2009 as well as her Business Management diploma from the Vienna University of Economics and Business in 2010. She then conducted a research project focused on the provision of sustainable life-cycle offers in the building industry at the Institute of Construction and Infrastructure Management at the Swiss Federal Institute of Technology. Her research is dedicated to the optimization of operational and strategic processes across a building's life cycle through the integrated cooperation of the key stakeholder using customizable industrial production technologies. She has contributed several international journal papers and conference publications establishing innovative approaches to a life-cycle service provision in the building industry. Dr. Selberherr completed the project with the development of a new business model in her PhD thesis in 2014. As a renowned expert in the field of organization and process design for sustainable building, she is currently working as a senior consultant in the real estate industry in Zurich.

# Preface

The modernisation and industrialisation of concrete structures, through the means of prefabrication of concrete elements together with the computerization of design, detailing and scheduling, is taking an awful long time to come to fruition. The once aspired paperless journey from the architect's concept to the factory floor and beyond is gradually closing in. Critics may cite the post WW2 boom in the construction of high-rise apartment buildings in part of northern and eastern Europe as 70-year-old industrialisation, but it was nothing more than concrete construction on such a large scale that it was thought to be "industrialisation" - the linear and manual processes of design, detailing, scheduling and manufacture were no more advanced than early twentieth-century construction.

There was little automation in the concrete industry until the combined technologies of long line pretensioning of steel wires and the extrusion of semi-dry concrete lead to such elements as prefabricated hollow core floor slabs in the 1950s. Except for a number of step-change advancements such as (i) the hydraulic extruder, (ii) the "carousel" method of casting and moving beds, and (iii) higher performance/strength concrete, hollow core units are still made in much the same way. Changes came in the 1970s after the Japanese taught the Europeans and Americans how they made cars – with forward/sideways/up/down production of the individual components leading to the whole. We now see such automotive methods used in the carousel table-top production of concrete wall panels and façade units, and together with CAD/CAM, Auto-CAD systems, TIM scheduling, and the automated supply of drawings and component schedules to the factories, the age of modernisation, mechanisation and industrialization (MMI) of concrete structures has finally arrived.

Architects and consulting engineers are still wary of the term "building systems", with images of shoe-box designs typified by the 1960s national building frames, carelessly exploiting modularization and standardisation possible in precast concrete. Today fully bespoke and individually tailored precast concrete elements can be designed and erected into many diverse forms to cover the huge spectrum of building architecture – all of which are industrialised by MMI. The term IBS (Industrialised Building Systems) can now be used with architectural and engineering freedom, for example, Sydney Opera House's torus-shaped prestressed beams and tiled facades. During a precast concrete workshop in Singapore in the mid 2000s an architect asked (something like) "what are the major features that distinguish precast concrete buildings from cast *insitu*". The reply, given by one of the authors of this book, was that "precast is used when the client or architect sees concrete as something special – both structurally of aesthetically, and maximises the operations that you can only carry out in the controlled environment of a factory", and so on.

The move to increased automation in the factory has coincided with the automation of spatial design – the use of three-dimensional co-ordinate orthogonal geometry, well known to school boys, to build 3D models from rectilinear 2D building plans and elevations, now known as BIM (Building Information Modelling) and the accompanying software for the design and detailing of precast (and steel, timber, etc.) structures. Professor C. J. Anumba of Pennsylvania State University addressed a Seminar & Workshop on the Developments and Future Directions in BIM (Kuala Lumpur, 2012) thus *Developments in BIM have resulted in significant industry interest and uptake. Most new building projects are dependent on BIM for resolving coordination, schedule, integration, estimating and other functions. Advances in information and communications technologies are continuing to open up new opportunities and applications. As such, more needs to be done to fully exploit the potential of these technologies and to meet the requirements of increasingly complex projects.*

Against this background of MMI and BIM the aims and objectives of this book were, as conceived by Dr Zuhairi, from CREAM (Construction Research Institute of Malaysia), to provide a concise text to show how the modernisation, mechanisation and industrialisation of prefabricated concrete structures can be achieved through the knowledge of best practice, information modelling, and the procedures and management of factory engineered concrete products and systems. The main objectives were to:

i. show how previous R&D and present design and manufacturing techniques can be best exploited for the construction of modern precast concrete structures,
ii. show how the IBS ethos can control the supply chain from the client to sub-contractors, and can best utilise BIM methods and design/detailing software,
iii. introduce the best concepts of automation and robotics in concrete production, and
iv. exploit the industrialisation of off-site production and on-site processes, including low cost housing in south east Asia.

The authors were selected from the UK, Germany, Switzerland, Austria and Malaysia, each having expertise and a (fairly) long history in items (i) to (iv). Of significance was Mr Robert Neubauer of SAA Software Engineering, a production/structural engineer able to harmonise the requirements of prefabrication in design with automated production; Mr Thomas Leopoldseder and Ms Suzanna Schachinger, of Precast Software, with abilities to exploit BIM and related software to the full advantage of precast solutions; Prof Gerhard Girmsheid and Dr Julia Selberherr, of ETH (Swiss Federal Institute of Technology, Zurich) specialising in the respective roles of industrialisation of off-site and on-site construction; CREAM consultants Dr Zuhairi, Mr Gan Hock Beng, Foo Chee Hung and Ahmad Hazim Abdul Rahim responsible for the technical advancements of IBS for low-cost housing; and Dr Kim S Elliott, precast consultant, summarising the modernisation and optimization of precast and prestressed elements and structures.

This book is divided into three key themes, as reflected in its title:

**Part 1: MODERNISATION**

Chapter 1: Historical and Chronological Development of Precast Concrete Structures
Chapter 2: Industrial Building Systems (IBS) Project Implementation
Chapter 3: Best Practice and Lessons Learned in IBS Design, Detailing and Construction

**Part 2: MECHANISATION AND AUTOMATION**

Chapter 4: Research and Development Towards the Optimisation of Precast Concrete Structures
Chapter 5: Building Information Modelling (BIM) and Software for the Design and Detailing of Precast Structures
Chapter 6: Mechanisation, Automation and Robotics in Concrete Production

**Part 3: INDUSTRIALISATION**

Chapter 7: Lean Construction, Part 1 – Industrialisation of On-Site Production Processes
Chapter 8: Lean Construction, Part 2 – Planning and Execution of Construction Processes
Chapter 9: New Cooperative Business Model - Industrialisation of Off-Site Production
Chapter 10: Retrospective View and Future Initiatives in IBS and MMI
Chapter 11: Affordable and Quality Housing Through Mechanization, Modernization and Mass Customization

A number of chapters address the issues of modern housing. Concrete has great potential to offer building and housing construction works towards improving the function, value, and whole life performance, especially in the era where quick, efficient, and inexpensive construction and delivery are becoming the necessity and desires of the societies. Precast concrete construction is a technology that possesses the potential to eliminate building site inconveniences, reducing the lapsed time and cost of construction, and contributing to an end product that conforms to the required standards and codes.

However, buildings and houses produced with such technology have a rigid structure, an interlocking plan, and predetermined functions, where very few of them are sufficiently open plan to enable retrofitting and reconfigurations to be made quickly, economically, and repeatedly. Moreover, various negative perceptions, opinions, and images spring to mind when considering the concept of prefabrication and standardisation in housing, as a result of a number of buildings constructed in the past making use of prefabrication were judged to be of poor quality. This book will provide insight to builders of the potential for building and housing design system that makes use of the prefabrication construction to produce a variety of housing design options that meet possible user requirements not yet identified at the design stage, while retaining principal uniformity to facilitate the execution of simple but accurate construction with a minimal initial cost.

It is believed that only by having combined design and construction systems that take advantage of mass production and mass customisation, the efficient design of offices, parking structures, shopping and residential buildings, coupled with housing affordability and liveability can be achieved. A home that can be altered with minimum effort and expense at a time of change in the lives of its owners is a home that evolves with the lifecycles of its household rather than becoming rigidly obsolete in the conventional manner. As such, the affordable housing needs to be designed in such a way that it is economically and easily adjustable, as well as adheres to the context of contemporary technology, climate adaptation, and cultural responses.

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