The Institution of Structural Engineers

Celebrating Excellence
in Structural Engineering

Proceedings of the Conference on STRUCTURAL WONDERS

23 November 2012, Singapore

Edited by

C. M. Wang, T. S. Lok, Y. C. Mak
and Steve Yeung

Organised by

Singapore Regional Group

The Conference on
STRUCTURAL WONDERS
23 November 2012, Singapore

Conference Organising Committee

Prof. Wang Chien Ming	(Chairman)
Er. Dr Ho Kwong Meng	(Vice-Chairman)
Er. A/Prof Lok Tat Seng	(Hon. Secretary)
Dr Boh Jaw Woei	(Hon. Treasurer)
Er. Wijaya Wong	(Asst Hon. Secretary)
Er. Ms Jeslin Quek	(Asst Hon. Treasurer)
Er. Ang Chee Keong	
Er. Ms Cong Zhengxia	
Er. Reve Chin	
Er. Kang Jianhan	
Er. Mah Guan Pang	
Er. Mak Yew Cheong	
Er. Seow Hong Chiow	
Er. Steve Yeung	
Er. Sam Tan	

Disclaimer

Copyright © 2012 reserved by IStructE Singapore Group

Printed by Research Publishing Services
ISBN: 978-981-07-4194-5

Preface

Since 2008, the IES/IStructE Joint Committee has been organising biannual conferences with the view to celebrate excellence in structural engineering. The first is the *Conference on Iconic Structures in Singapore and Asia* which was organised in 2008 and held at the Hyatt Hotel. The conference is part of the IStructE Centennial Celebration activities in Singapore. The second conference is the *Conference on Structural Marvels* which was held at the Marina Bay Sands Convention Centre in 2010. This *Conference on Structural Wonders* is a continuation of the beautiful story of the contributions of structural engineers to make wonderful structures become a reality.

Structural wonders continue to inspire people and they do bring a sense of happiness and pride to the population and nation. These structures are powerful magnets that draw tourists to visit or professionals to migrate to the centres of attention. Singapore has seen a fair share of the emergence of structural wonders in the last decade. More iconic structures will be built in Singapore in the next decade. So it is appropriate that a *Conference on Structural Wonders* is organised in Singapore to capture the beauty of these structures and the achievements of structural engineers.

In this Conference Proceedings, we feature only 7 papers due to time limitation for the lectures to be delivered within one day. The first paper presents a reflection of the IStructE Structural Awards since its inception in 1967. The paper provides more than a glimpse of the many inspiring and wonderful structures of our time. The second paper is concerned with the engineering of the structural wonders in the United Arab Emirates and a detail treatment of the DIFC Lighthouse in Dubai. The third paper describes two landmark structures in the fast developing city of Ho Chi Minh, namely, the Bitexco Financial Tower and the Crescent Residence 2. The fourth paper presents the spectacular Sports Hub of Singapore which has the world's largest dome structure – a magnificent new sculpture to light up the Singapore skyline. The fifth paper showcases a unique vertical arrangement of residential apartments in the Interlace which keeps the residents completely connected with the communal spaces that are integrated into its lush surrounding greenbelt. The sixth paper is on The South Beach Development which is a structural landmark that showcases sustainability strategies. For example, its "environmental filter" canopy enables the adjustment of the microclimate to suit specific activities. Finally, the seventh paper on bridge construction features the world's two longest cable-stayed bridges - the Stonecutter Bridge in Hong Kong and the Sutong Bridge in Jiangsu, China. The paper on the wonderful design and construction of the Gardens by the Bay Conservatory Enclosure – yet another iconic structure to embrace the landscape is, however, not included in the proceedings due to a confidentiality request from the designer.

We hope that the structural wonders described in the Conference Proceedings will inspire structural engineers, contractors and architects to create, innovate and build even more awesome and eco-friendly iconic structures that nourish the human body, soul and spirit.

C.M. Wang, T.S. Lok, Y.C. Mak and Steve Yeung
Editors of Conference Proceedings

Contents

Preface iii

Acknowledgements iv

Conference Programme v

Supreme Structures: Reflections on the IStructE Structural Awards 1
David A. Nethercot

Engineering the Structural Wonders of the UAE: The DIFC Lighthouse, Dubai 27
Matthew J. Esther

Bitexco Financial Tower and Crescent Residence 2 in Ho Chi Minh City of Vietnam 49
Luong Van Hai and Le Phu Cuong

Designing the World's Largest Dome: The National Stadium Roof of the Singapore Sports Hub 69
Clive Lewis and Mike King

The Interlace: Integrating Bridge Engineering in Building Design 99
Serena Yap, Yee Yee Nwe, Wong Keam Tong and Iwan Susanto

South Beach Development 117
Russell Neil Cole, Soh Seng Siong and Edwin Ong Beng Koon

In Pursuit of Timeless Structural Wonders in Bridge Engineering 137
S H Robin Sham

ENGINEERING THE STRUCTURAL WONDERS OF THE UAE THE DIFC LIGHTHOUSE, DUBAI

Matthew J. Esther

WS Atkins & Partners Overseas, PO Box 5620 Dubai UAE
matthewesther@hotmail.com / matthew.esther@atkinsglobal.com

ABSTRACT

Churchill's saying that '*We shape our buildings, thereafter they shape us'* has never rung more true than in our time, when every major city is striving to claim their place in the world and with their identity defined by the building of larger and taller monuments. The design and construction of skyscrapers is a field of engineering that is continuously fuelled by human endeavour and daring, with the pursuit of building higher constantly pushing the boundaries of material performance, mirroring the pace of technological progress in other engineering fields.

Today's tall buildings form a vital part of metropolitan living and are the backbone of successful urban developments: this requires innovative engineering solutions to ensure they are efficient and sustainable and achieve the necessary levels of comfort and safety for the communities they serve. Innovations in the design of super-tall structures has seen a trend evolving away from single material solutions, with the optimum design often being a concrete / steel hybrid. In a number of recent projects Atkins has made use of long span steel structures to pair concrete core walls which engage these primary structural elements to act as 'hybrid mega-frames'[2,3,4]. These have the advantage of enhancing lateral stability whilst creating large column free volumes and bringing simplicity to the potentially complex structural arrangements often associated with such bold and ambitious architecture.

The boom experienced in Dubai in the decade prior to the financial crisis saw advances in computer based technology which has enabled creative and daring engineering solutions to meet the challenges of not only building taller, but increasingly slender buildings. This paper showcases the process behind the design of a truly unique structure and how the use of technology combined with an engineered approach from first principles resolved a complex structural arrangement into a relatively simple and buildable solution.

This paper aims to give an insight into the approach to tall building design with particular reference to practices in the UAE. This project is currently on hold and at the time of writing this paper the design and peer review were complete, the building permit was issued and the foundations built. The author feels that despite this hiatus, the innovations and lessons learnt from the project deserve to be shared with the engineering community.

INTRODUCTION

The site of the Dubai International Financial Centre (DIFC) Lighthouse is located in Dubai's financial district, a 110 acre free-zone of the same name, located at the heart of this modern city which harbours ambitions of becoming a financial powerhouse located at the crossroads of Europe and Asia. This design of this building was in response to the Client's desire for an expressive and timeless building which would embody the dynamism of an upcoming international financial centre and the energy of an ambitious young nation.

The elegant lines of this building mirror that of the other rectilinear icons in the DIFC precinct particularly the Emirates Towers and DIFC Gate (Figs. 1 and 2): it adopts the cross-bracing motif which is so prominent in the DIFC Gate building and extrudes it vertically. The primary structural form is expressed in the elevations and incorporates the DIFC logo within the diamond shape formed by the criss-crossing diagonals over the height of this elegantly tapering tower. Its styling cues are reminiscent of the Bank of China building in Hong Kong and the Hancock building in Chicago, but beyond the bold expression of diagonals on elevation, these similarities end: the mega-braces do not only act to laterally brace the building but also form part of a large gravity structure that transfers loads to the two core walls creating a 40mx30m column free void 5 storeys high at the podium level of the tower.

The site for this 402m tower is on a 12,200 m^2 plot and is set to have a built up area of 173,000m^2 with 90,000m^2 of grade A office space on 64 floors, a visitor's centre, over five basements, a podium level and lower floors of the tower which accommodate a leisure deck with health club, swimming pool, executive lounge and business centre. The building is crowned at level 67 with a 123m high steel lattice tower which features a viewing deck offering uninterrupted views of the bustling city.

Figures 1 and 2: The DIFC Lighthouse depicted next to the DIFC Gate Building and Emirates Towers

REFERENCES

[1] Architecture and Urban Design - Selected and Current Works 2010, Atkins. www.atkinsglobal.com www.middle-east.atkinsglobal.com

[2] Berahman, F. and Esther, M. J. “Hybrid Solution for tall building structures” presented at CTBUH 2010 Mumbai Conference, available online at: http://www.ctbuh.org/Events/Conferences/Mumbai2010/Presentations/Mumbai2010T20SpeakersPresentations/tabid/1459/language/en-US/Default.aspx

[3] Berahman, F., Esther, M., Scott, R., Chandunni, R. and Veith, K., “The Structural Design of Icon Hotel in Dubai, United Arab Emirates” The Structural Engineer, Proceedings of the Institution of Structural Engineers, 89(7), 26-32, 2011.

[4] Berahman, F. “Performance based seismic design of Icon Hotel in Dubai” presented at LATBSDC annual conference in Los Angeles on 7th of May 2010 and published online in Wiley online library in the special issue of Journal of Structural Design of Tall and Special Buildings, December 2010. http://peer.berkeley.edu/tbi/events.html.

[5] Stafford Smith, B. and Coull, A. “Tall Buildings Structures: Analysis and Design,” John Willey and Sons, Inc. 1991.

[6] Naeim, F. “The Seismic Design Handbook,” Kluwer Academic Publisher, USA, 2011.

[7] Fintel, M., Ghosh, S.K. and Iyengar, H. “Column Shortening In Tall Building Structures-Prediction and Comparison,” Portland Cement Association, 1987.

[8] Beedle, L. "Structural Systems for Tall Buildings,” International Edition, McGraw-Hill 1995.

[9] Seismic Design Guide "Recommendations for the Seismic Design of High-Rise Buildings", Council for Tall Buildings and Urban Habitat 2008.

[10] Mendis, P., Ngo T., Haritos N., Hira A., Samali B. and Cheung J., “Wind Loading on Tall Buildings”, EJSE Special Issue: Loading on Structures.1-14, 2007.

[11] Computers and Structures Inc (CSI) “ETABS nonlinear version 9.5, extended 3D analysis of building systems” CA, USA, 2008.

[12] MIDAS Information technology “MIDAS Gen Version 7.4: User manual” 2008.

[13] Computers and Structures Inc (CSI) “SAP 2000 Linear and Nonlinear Static and Dynamic Analysis and Design of Three-Dimensional Structures V11” CA, USA, 2006.

[14] BS EN 1994-1-1:2004 " Eurocode 4: Design of Composite Steel and Concrete Structures - Part 1-1: General Rules and Rules for Buildings" BSI 2004.

[15] ISO 6897:1984 "Guidelines for the evaluation of the response of occupants of fixed structures, especially buildings and off-shore structures, to low-frequency horizontal motion (0,063 to 1 Hz)".

[16] NBCC, "The National Building Code of Canada", The Institute for Research in Construction (IRC) 2005.

[17] ASCE7-05, "Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineers, 2006.

[18] ACI318/05, "Building Code Requirements for Structural Concrete and Commentary," An ACI Standard, The American Concrete Institute, 2005.

[19] ANSI/AISC 341/05, "Seismic Provision for Structural Steel Buildings," American Institute of Steel Construction, 2005.

[20] ANSI/AISC 360/05, "Specification for Structural Steel Buildings," American Institute of Steel Construction, 2005.

[21] International Conference of Building Officials (ICBO), “Uniform Building Code” Whittier, 1997, CA.
[22] BS 8100-1:1986 "Lattice Towers and Masts - Part 1" BSI 1986.
[23] "The Building Regulations 2000 - Document A3" 2004 Edition, NBS 2006.
[24] BS 5950-1:2000 "Structural Use of Steelwork in Building - Part 1: Code of Practice for Design - Rolled and Welded Sections", BSI 2000.
[25] Robertson, L., "Gold Medal Address, Presented at The East Winter Garden, Canary Wharf, 9 March 2005" The Structural Engineer, Proceedings of the Institution of Structural Engineers, 20-27, 2005.

ABOUT THE AUTHOR

Matthew J. Esther

BEng (Hons) CEng EurIng FIStructE MICE MSFE

Associate and Senior Structural Engineer
WS Atkins and Partners Overseas, PO Box 5620 Dubai UAE
matthewesther@hotmail.com / matthew.esther@atkinsglobal.com

Matthew J. Esther is a Chartered Civil and Structural Engineer whose areas of expertise are in the design of tall buildings, long span structures, geometrically complex roof structures and stadia. He has previously worked in the UK and Greece and is currently based in Dubai, UAE where he is an Associate with WS Atkins.

Matthew has held senior design positions for a number of years where he has been responsible for the technical direction, management and delivery of a range of large projects. His key project experience to date also include Trump International Hotel and Tower, Icon Hotel, Anara Tower, Gulf News HQ (UAE), ITC Tower and Namaste Tower (India), Padideh Shandiz Waterpark and the Esfahan Convention Centre (Iran), Lusail LRT and Doha Metro (Qatar), the Hellinikon Olympic Stadium and the Thessalonica Metro (Greece), the Millennium Dome, Wembley Stadium, the Hertfordshire University Campus, Vertex Chineham Court and Thames Barrier Point (UK).

Matthew has been an active member of the UAE Division of the Institution of Structural Engineers since its inception and has served in various capacities as committee official which included tenure as Chairman in 2011. He is the organiser and principal lecturer for the Chartered Membership Exam Preparation Course in the UAE and in 2011 was the first recipient of the President’s Award for contributions to the advancement of the Institution in the region. He lectures frequently at Heriot-Watt University in Dubai, on their BEng / MEng Civil Engineering course.