MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / BUILDING SCIENCE PROGRAM

BS 536
STUDIES ON TALL BUILDINGS: DESIGN CONSIDERATIONS
Fall 2014-2015

Case Study: **Al Hamra Tower**
by
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Submitted to: Assoc.Prof.Dr. Mehmet Halis Günel

ARCHITECTURE/FACTS

Al Hamra Tower


Fig.1: Al Hamra Tower

OVERVIEW:
Official Name: Al Hamra Tower [1]
Other Name: Al Hamra Firdous Tower [1]
Location: Kuwait, Kuwait City [1]
Building Height: 412 m [1]
Structural type: Shear Walled Frame System [2, 3]
Status: Completed [1]
Proposed: 2005 [1]
Construction: 2005-2011 [1]
Structural System: Shear Walled Frame System [2, 3]
Structural Material: Reinforced Concrete [2, 3]

RANKINGS:
16th tallest building in the World [1]
4th tallest building in Middle East [1]
1st tallest building in Kuwait and Kuwait City [1]

MAIN COMPANIES INVOLVED
Owner/Developer: Al Hamra Real Estate Co.
Design: Skidmore, Owings & Merrill [1]
Architect of Record: Al Jazera Consultants; Callison [1]
Structural Engineer: Skidmore, Owings & Merrill [1]
MEP Engineer: Skidmore, Owings & Merrill; Meinhardt [1]
Project Manager: Turner Construction [1]
Main Contractor: Ahmadiah Contracting and Trading Company [1]

[1] na. *The Skyscraper Center*. nd. http://skyscrapercenter.com/building/al-hamra-tower/208 (accessed 01 18, 2015).
[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
[3] Günel, M. H., and H. E. Ilgın. *Tall Buildings: Structural Systems and Aerodynamic Form*, Routledge – Taylor and Francis Group Book Company, 2014.
Fig. 1: https://www.vincentloy.wordpress.com (accessed 18 01, 2015).

ARCHITECTURE/FACTS and FUNCTIONS

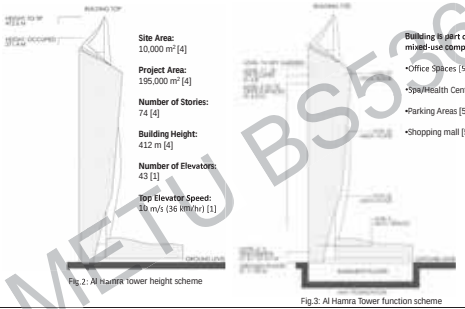


Fig.2: Al Hamra Tower height scheme
Fig.3: Al Hamra Tower function scheme

[1] na. *The Skyscraper Center*. nd. http://skyscrapercenter.com/building/al-hamra-tower/208 (accessed 01 18, 2015).
[4] na. *SOM*. nd. http://www.som.com/projects/al_hamra_tower (accessed 01 18, 2015).
[5] SOM project archive
Fig. 2: Al Hamra Tower height scheme **drawn by Yağmur Sünger** based on image and information provided by CTBUH, [5] SOM project archive
Fig. 3: Al Hamra Tower function scheme **drawn by Yağmur Sünger** based on image, information and drawing provided by CTBUH and SOM

ARCHITECTURE/AWARDS

2014 Commercial Project of the Year, Middle East Architect Awards [4]
2013 Best International Project Over $150 Million Structural Engineers Association of Illinois [4]
2013 Architizer A+ Award: Office Building High Rise, Finalist Architizer [4]
2013 Design Award AIA - New York City Chapter [4]
2012 Award of Excellence: Landmark Structures Structural Engineers Association of Northern California [4]
2012 Award of Excellence: Landmark Structures Structural Engineers Association of California [4]
2012 Best of What's New Popular Science Magazine [4]
2012 International Structures over $100 Million National Council of Structural Engineers Association [4]
2012 Award for Commercial or Retail Structure Institution of Structural Engineers [4]
2012 Best Tall Building Middle East & Africa: Finalist CTBUH [4]
2011 Skyscraper Award: Silver Medal Emporis [4]
2010 Commercial / Mixed Use Built Cityscape [4]
2008 MIPIM Future Project Award: Tall Buildings MIPIM/Architectural Review [4]
2008 MIPIM Future Project Award: Overall MIPIM/Architectural Review [4]
2008 International Architecture Award Chicago Athenaeum [4]
2008 American Architecture Award Chicago Athenaeum [4]
2007 Bronze Unbuilt Project Miami Architectural Bienal [4]


Fig. 4: Al Hamra Tower

[4] na. *SOM*. nd. http://www.som.com/projects/al_hamra_tower (accessed 01 18, 2015).
Fig. 4: Al Hamra Tower : http://agstudio.me/2011/12/19/al-hamra-tower/ (accessed 18 01, 2015).

ARCHITECTURE/DESIGN FACTORS


Fig. 5: Al Hamra Tower Model

Unique sculpted form [2]
Architectural expression through the structural form [2]


Fig. 6: Aerial Photo of Site


Fig. 7: Al Hamra Tower Settlement

Spiraling geometry:
Tower geometry is developed by subtracting a quadrant of a typical filleted square floor plan and incrementally rotating the subtracted portion at each higher level. [2]
Flared walls:
Flared walls can be defined as hyperbolic paraboloid shear walls generated by slab edges of subtracted spiraling slices which extend from the southwest and southeast corners of the central core and the roof of the tower. [2]

Factors effective on defining the **"Spiraling geometry"** building form and its settlement: [2]
- Requirement for reduction of the floor [2]
- The desire to maximize the views towards the water [2]
- The desire to minimize solar heat [2]
- Wind studies [2]


Fig. 8: Al Hamra Tower Geometry and Structure

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
Fig. 5: Al Hamra Tower Model: http://www.designbuild-network.com/projects/al-hamra/al-hamra2.html (accessed 18 01, 2015).
Fig. 6: Aerial Photo of Site: Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
Fig. 7: Al Hamra Tower Settlement: Google Earth
Fig. 8: Al Hamra Tower Geometry and Structure: Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.

ARCHITECTURE/PLANS and ELEVATIONS

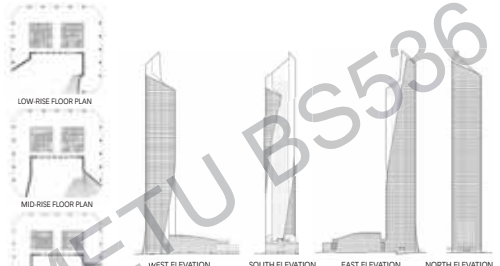


Fig. 9: Al Hamra Tower Floor Plans

Fig. 10: Al Hamra Tower Elevations

Fig. 9: Al Hamra Tower Floor Plans: Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
Fig. 10: Al Hamra Tower Elevations: http://www.inhabitat.com (accessed 18 01, 2015

ARCHITECTURE/FAÇADES

Northern façade:
- Tectonic glass cladding; to provide panoramic gulf view [2]

Southern façade:
- Adhered lime stone cladding with minimized openings; to control heat gain and get light into interiors [2]
- Staggered pattern of punched windows at souther façade [2]
- Opening locations calculated according to the view from inside [2]


Fig. 11: Al Hamra Tower Southern Wall


Fig. 12: Al Hamra Tower Southern Wall

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
Fig. 11: Al Hamra Tower Southern Wall: http://commons.wikimedia.org/wiki/File:Hamratower3.jpg (accessed 18 01, 2015).
Fig. 12: Al Hamra Tower Southern Wall: http://www.desmena.com (accessed 18 01, 2015).

ARCHITECTURE/FAÇADES

World tallest stone cladded Tower: [6]
- Al Hamra Tower is covered with 258,000 m² of jura limestone, (enough to tile all of New York City's Central Park). [6]
- Small randomized tiles adhered directly to the concrete substrate. [2]
- A much lighter solution is achieved by adhering, also provided easy cladding of curved surfaces. [2]


Fig. 13: Al Hamra Tower Limestone cladding


Fig. 14: Al Hamra Tower

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
[6] Tresser Kon. *Al Hamra Tower, Kuwait City Project Spotlight: October 2011*. nd.
Fig. 13: Al Hamra Tower Limestone cladding: http://agstudio.me/2011/12/19/al-hamra-tower/ (accessed 18 01, 2015).
Fig. 14: Al Hamra Tower: http://www.som.com/projects/al_hamra_tower (accessed 18 01, 2015).

STRUCTURE/THE SUPER STRUCTURE

THE SUPER STRUCTURE:

The super structure of the building can be defined as **"SHEAR WALLED FRAME SYSTEM"** [2-3]

The material of the structural system can be defined as **"REINFORCED CONCRETE"** [2-3]

Main elements which participate in the lateral and gravity force resisting system :

•The shear wall core [2]
•The flared walls [2]
•The perimeter moment resisting frame [2]

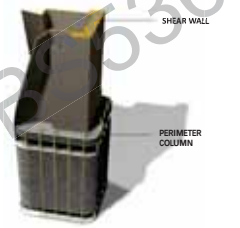


Fig. 15: Al Hamra Tower's Superstructure

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
[3] Günel, M. H., and H. E. Ilgın. *Tall Buildings: Structural Systems and Aerodynamic Form*, Routledge – Taylor and Francis Group Book Company, 2014.
Fig. 15: Al Hamra Tower's Superstructure: Asci, A., and M. Sarkisian. "CTBUH AWARDS 2012 Best Tall Building Featured Finalist - Middle East & Africa Region Al Hamra Firdous Tower: The Sculpted Tower." *CTBUH AWARDS 2012*. 2012.

STRUCTURE/THE SUPER STRUCTURE

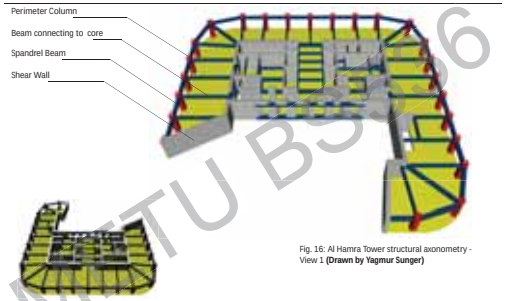


Fig. 16: Al Hamra Tower structural axonometry - View 1 **(Drawn by Yagmur Sunger)**

Fig. 17: Al Hamra Tower structural axonometry - View 2 **(Drawn by Yagmur Sunger)**

Fig. 16: Al Hamra Tower structural axonometry drawn by Yağmur Sünger based on drawing provided by SOM
Fig. 17: Al Hamra Tower structural axonometry drawn by Yağmur Sünger based on drawing provided by SOM

STRUCTURE/15th FLOOR PLAN

15th FLOOR PLAN

Perimeter columns:
Dimensions: 110x110 cm [2, 5]
Material: Composite columns-reinforced concrete [2] with embedded I-profile steel

Shear walls:
Dimensions: 30 cm to 90 cm in thickness [2, 5]
Material: Reinforced concrete [2]

Spandrel beams:
Dimensions: 80 cm wide, 60 cm deep [2]
Material: Reinforced concrete [2]

Beams connecting to core:
Dimensions: variable wide, 70 cm deep [2]
Material: Reinforced concrete [2]

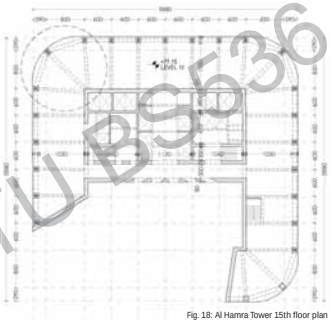
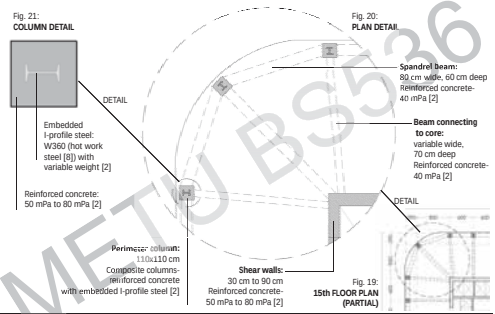


Fig. 18: Al Hamra Tower 15th floor plan

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
[5] SOM project archive
Fig. 18: Al Hamra Tower 15th floor plan **drawn by Yağmur Sünger** based on drawing provided by SOM

STRUCTURE/DETAILS



[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd. [8] na. *Böhler*. nd. http://www.bohler.jp/english/881.php (accessed 01 18, 2015).
Fig. 19: Al Hamra Tower 15th floor partial plan **drawn by Yağmur Sünger** based on drawing provided by SOM
Fig. 20: Al Hamra Tower 15th floor plan detail **drawn by Yağmur Sünger** based on drawing provided by SOM
Fig. 21: Al Hamra Tower 15th floor column detail **drawn by Yağmur Sünger** based on drawing provided by SOM

STRUCTURE/57th FLOOR PLAN

57th FLOOR PLAN

Perimeter columns:
Dimensions: 90x90 cm [5]
Material: Reinforced concrete [2]

Shear walls:
Dimensions: 30 cm to 80 cm in thickness [2, 5]
Material: Reinforced concrete [2]

Spandrel beams:
Dimensions: 80 cm wide, 60 cm deep [2]
Material: Reinforced concrete [2]

Beams connecting to core:
Dimensions: variable wide, 70 cm deep [2]
Material: Reinforced concrete [2]

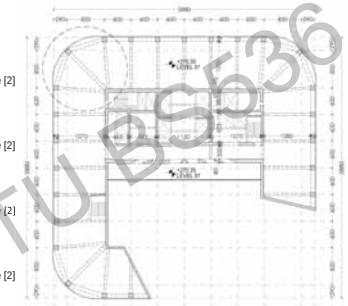
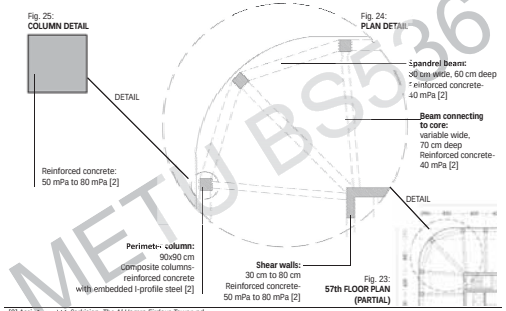


Fig. 22: Al Hamra Tower 57th floor plan

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
[5] SOM project archive
Fig. 22 Al Hamra Tower 57th floor plan **drawn by Yağmur Sünger** based on drawing provided by SOM

STRUCTURE/DETAILS



[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
Fig. 23: Al Hamra Tower 57th floor partial plan **drawn by Yağmur Sünger** based on drawing provided by SOM
Fig. 24: Al Hamra Tower 57th floor plan detail **drawn by Yağmur Sünger** based on drawing provided by SOM
Fig. 25: Al Hamra Tower 57th floor column detail **drawn by Yağmur Sünger** based on drawing provided by SOM

STRUCTURE/DIMENSIONS

Shear walls:
Thickness: vary from 30 cm to 120 cm [2]

Perimeter columns:
From mat foundation to level 4
Dimensions: 120x120 cm [2]
From level 5 to level 40
Dimensions: 110x110 cm [2]
From level 41 to level 74
Dimensions: vary from 70x70 cm to 110x110 cm [2]

Spandrel beams:
Dimensions: 80 cm wide, 60 cm deep [2]

Beams connecting to the core:
Dimensions: variable wide, 70 cm deep [2]

Slab:
Thickness: 16 cm [2]

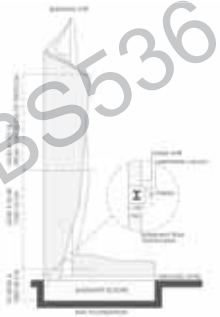


Fig. 26: Al Hamra Tower dimensional scheme of perimeter columns

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
Fig.26: Al Hamra Tower dimensional scheme of structure **drawn by Yağmur Sünger** based on image, information and drawing provided by CTBUH and SOM

STRUCTURE/MATERIALS

Shear walls:
Reinforced concrete: vary from 50 mPa to 80 mPa [2]
Perimeter columns:
From mat foundation to level 29
Composite columns:
Embedded I-profile steel:
W360 (hot work steel [8]) with variable weight
Reinforced concrete [2]
From level 30 to level 74
Reinforced concrete columns [2]
*** Reinforced concrete perimeter columns' cube compressive strength varies from 50 mPa to 80 Mpa in building general [2]
Spandrel beams:
Reinforced concrete: 40 mPa [2]
Beams connecting to the core:
Reinforced concrete: 40 mPa [2]
Slab:
Reinforced concrete: 40 mPa [2]

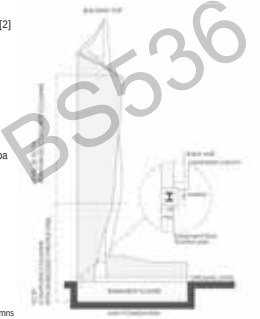


Fig. 27: Al Hamra Tower material scheme of perimeter columns

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower*. nd.
Fig. 27: Al Hamra Tower material scheme of structure **drawn by Yağmur Sünger** based on image, information and drawing provided by CTBUH and SOM

STRUCTURE/MATERIALS AND DIMENSIONS

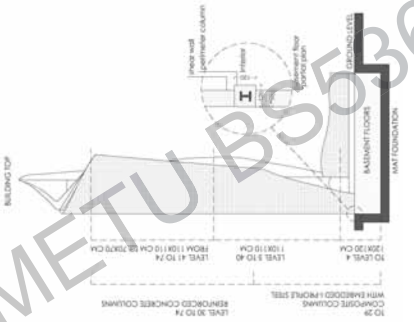


Fig. 28: Al Hamra Tower material and dimensional scheme of perimeter columns

Fig. 28: Al Hamra Tower material and dimensional scheme of perimeter columns **drawn by Yağmur Sünger** based on image, information and drawing provided by CTBUH and SOM

STRUCTURE/FLOOR HEIGHTS

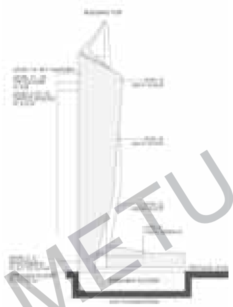


Fig. 29: Al Hamra Tower floor height scheme showing specific areas

Floor to floor heights of specific areas:

Ground floor:
11.35 m [5]

Lobby area:
24 m [5]

2nd-3rd floors - Health&Spa:
3.7 m-3.9 m [5]

Typical office floors:
4.2 m [5]

VIP floors:
5.8 m [5]

26 th-50th floors-Mechanical floors:
11 m [5]

73 th floor-Mechanical floor:
10.15 m [5]

[5] SOM project archive
Fig. 29: Al Hamra Tower floor height scheme showing specific areas **drawn by Yağmur Sünger** based on image, information and drawing provided by CTBUH and SOM

STRUCTURE/LOBBY LAMELLA STRUCTURE

- To expand the lobby area and create a column free main lobby, columns are sloped away from the building core following a circular arch. [2]
- Lamella were built with fiberglass formwork fabricated from shop drawings generated from 3D model prepared with Gehry Technologies digital software. [7]
- It consists of steel plates up to 16 cm thick, requiring nearly 400 days to complete. [7]

Fig. 30: 3D View from tower entrance showing lobby lamella structure

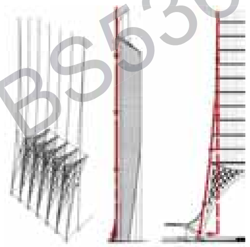


Fig. 31: Scheme showing the development of lamella structure

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower.* nd.
[7] na. *Al Hamra.* nd. http://www.alhamra.com.kw/business-tower/facts-figuress/ (accessed 01 18, 2015).
Fig. 30: 3D View from tower entrance showing lobby lamella structure: Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower.* nd.
Fig. 31: Scheme showing the development of lamella structure: http://www.archofkuwait.com (accessed 18 01, 2015).

STRUCTURE/FOUNDATIONS and WIND ENVIRONMENT

Site geology:
- Silty sand with density varying from medium dense to very dense cementation
- Dewatering required during excavation and basement construction with the outcome of water 2 m below grade [2]
- Concentrated soluble salt is produced within evaporation creating an aggresive chemical environment for below-grade contruction, resulted by using corrosion-resistant reinforcement [2]

Raft foundation:
Dimensions: 70x60 m, 4 m in thickness [2]
Dimensions: 24x12 m, 1.6 m in thickness (for the triangular section of raft, beyond the footprint of the tower) [2]
Material: Reinforced concrete, 50 mPa [2]

Piles:
Number of piles: 289 [2]
Closest spacing between piles: 3.6 m [2]
Diameter: maximum 120 cm [2]
Depth ranging: 20 to 27 m [2]
Material: Reinforced concrete, vary from 55mPa to 80mPa [2]

Wind Environment:
- Wind speed is established as 23m/s (82 km/hr) at 10 meter height in open terrain [2]
- Localized and short term wind phenomena exist in Gulf region due to thunderstorms producing downbursts close to the ground [2]
- Non-synoptic thunderstorm wind events generate greater wind speeds than synoptic events between ground level and an elevation of approximately 150 m [2]
- Aerodynamic form is accomplished by contributing rounded corners and the flared walls to design of tower geometry [3]

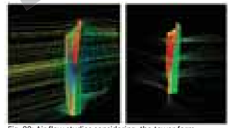


Fig. 32: Air flow studies considering the tower form

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower.* nd.
[3] Günel, M. H., and H. E. Ilgın. *Tall Buildings: Structural Systems and Aerodynamic Form,* Routledge – Taylor and Francis Group Book Company, 2014.
Fig. 32: Air flow studies considering the tower form: Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower.* nd.

CONSTRUCTION NOTES

- Maximum allowable height changed by the Kuwait City Municipality to 400m during contractor was mobilized on site after completion of old project with 200m height designed for the same site. Construction proceed parallel with designing phase of tower made by SOM. [2]
- Raft foundation was poured over a period of 4 months, as a result of the regulation set by the municipal restricting the delivery of concrete to the weekends. [2]
- The Concrete was Pumped over 400 meters height to a stationary placing boom which distribute Concrete to Every Floor. [7]
- GPS System with three antennas connected to a satellite has been used to determine the exact coordinates on every new Level during construction. [7]

Fig. 33: Construction of Al Hamra Tower

[2] Asci, A., and M. Sarkisian. *The Al Hamra Firdous Tower.* nd.
[7] na. *Al Hamra.* nd. http://www.alhamra.com.kw/business-tower/facts-figuress/ (accessed 01 18, 2015).
Fig. 33: Construction of Al Hamra Tower: http://www.som.com/projects/al_hamra_tower (accessed 18 01, 2015).

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- na. *Al Hamra.* nd. http://www.alhamra.com.kw/business-tower/facts-figuress/ (accessed 01 18, 2015).
- na. "Al-Hamra Tower Survey & Monitoring." *FIG 2012 High Rise Conference.* Hong Kong, 2012.
- na. *Best Tall Building Midlle East & Africa Finalist Al Hamra Firdous Tower.* nd.
- na. *Böhler.* nd. http://www.bohler.jp/english/881.php (accessed 01 18, 2015).
- na. *SOM.* nd. http://www.som.com/projects/al_hamra_tower (accessed 01 18, 2015).
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[3] Günel, M. H., and H. E. Ilgın. *Tall Buildings: Structural Systems and Aerodynamic Form,* Routledge – Taylor and Francis Group Book Company, 2014.
[4] na. *SOM.* nd. http://www.som.com/projects/al_hamra_tower (accessed 01 18, 2015).
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[8] na. *Böhler.* nd. http://www.bohler.jp/english/881.php (accessed 01 18, 2015).

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