MIDDLE EAST TECHNICAL UNIVERSITY
DEPARTMENT OF ARCHITECTURE / BUILDING SCIENCE PROGRAM

BS 536
STUDIES ON TALL BUILDINGS: DESIGN CONSIDERATIONS
Spring 2009-2010

Case Study: **Bahrain World Trade Center**
by
Banu Nur Şengün

Submitted to: Assoc.Prof.Dr. Mehmet Halis Günel
Arch. H.Emre Ilgın (MSc.)

BAHRAIN WORLD TRADE CENTER

'iconic, environmental, and a bit quirky ... it gives a very strong visual nod toward sustainability…'

•Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2009/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press,pdf sent by Atkins
www.ctbuh.org/Portals/0/Media/Files/.../s-29-09%20AIA%20org.pdf

Case Study: **Bahrain World Trade Center** by Banu Nur Şengün
Submitted to: Günel, Ilgın – Spring 2010

BAHRAIN WORLD TRADE CENTER

Bahrain World Trade Centre became **the first building** in the world to incorporate large-scale wind turbines onto a building

- **Location:** Manama, Kingdom of Bahrain
- **Construction:** 2004 - April 2008
- **Use:** Office, Commercial
- **Architects:** Atkins
- **Structural Engineer:** Atkins
- **Contractor:** Nass, Murray & Roberts
- **Total Area:** 120,000m²
- **Total Height**: 240 metres
- **Total Number of Floors**: 42 (office floors) +3 floors (shopping mall) + 1 (basement carparking)
- **Structural System:** Reinforced Concrete Shear Walled Frame System
- **Facade:** Double glazing glass and insulated aluminium spandrels

Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press,pdf sent by Atkins

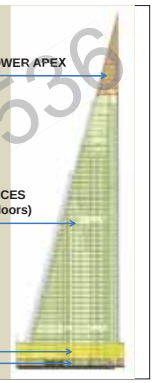
AWARDS

- CTBUH Best Tall Building Middle East & Africa 2008
- 2009 Nova Awards
- Council of Tall Buildings and Urban Habitats 2008
- Winner of 2008 'Best Tall Building Awards' MENA region
- Building Exchange Awards 2008
- Building Design Awards 2008
- Construction Week Awards 2008
- Popular Science 2008
- EDIE Award for Environmental Excellence 2007
- LEAF Awards 2006

http://www.zawya.com/story.cfm/sidZAWYA20100427i41003/Bahrain%20World%20Trade%20Center%20(BWTC)%20Scoops%20Prestigious%20Palme%20Award

FUNCTION

The towers (office blocks) are harmoniously integrated on top of a three-storied sculpted podium and basement that accommodate a new shopping centre, restaurants, business centres and car parking



http://www.ctbuh.org/Portals/0/Repository/T3_KillaSmith.cfce5b62-fc35-4de1-ba53-90eeca647d94.pdf

MASTER PLAN

The BWTC forms the focal point of a master plan to rejuvenate the 30-year-old existing hotel and shopping mall on the site

http://www.ctbuh.org/Events/Awards/BestTallBuildingWinners/08_BahrainWorldTradeCenter/tabid/3045/language/en-GB/Default.aspx

ARCHITECTURAL DECISIONS

ARCHITECTURAL DECISIONS

Shaun Killa,Design Director, Atkins Middle East

Atkins Principal Architect and keen sailor, Killa noticed the strong prevailing onshore wind and its direction being virtually perpendicular to the site .
So,He wants to convert this condition in a positive manner.

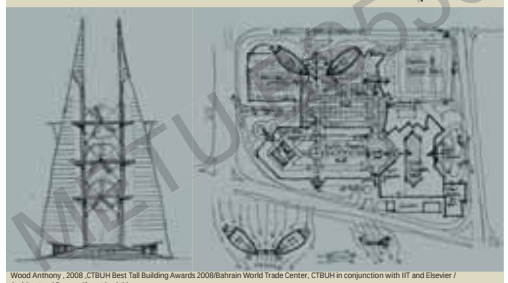
http://uscdn.creamermedia.co.za/assets/articles/images/resized/74139_resized_killaheadshot.jpg

Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press,pdf sent by Atkins

CONCEPT IDEA:

Placing horizontal-axis wind turbines with the help of the bridges between two towers

Concept sketches



Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press,pdf sent by Atkins

There are 2 main **problems:**

1) **Need of continuous wind energy and orientation**
The blades of the turbines could not orient itself for the changing wind directions due to its stable position

2) **The position of the turbines**
The highest level of the turbine may wear out working more than the others due to increasing wind velocity with height

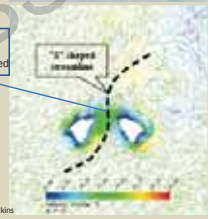
Typical horizontal wind turbine

National Geographic Documentary,Bahrain World Trade Center

SOLUTIONS

1) The building's shape and position is designed to **direct wind toward the turbines in order to create greater wind speed**.
- funneling the onshore winds between them and creating a negative pressure zone behind

Passing between towers:
•Wind routes S-like direction
•Accelerates % 20 of the speed



National Geographic Documentary,Bahrain World Trade Center

Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press,pdf sent by Atkins

SOLUTIONS

Elliptical Forms and Sail-like Profiles of The Towers

2) The **vertical tapering** of the towers influences airflow dynamics and encourage **a near equal distribution on all three turbines** despite wind velocity increasing with height

It allows the turbines to rotate at the same speed and generate the same energy levels

Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press,pdf sent by Atkins

SITE PROGRESS

October 2004

March 2005

December 2005

November 2006

March 2007

November 2007

February 2008

Wind Tunnel Testing = Problems & Solutions

Wind Tunnel Testing = problems & solutions

BRIDGES

Three bridges at the different level **span 31.7 m**, weight **70 tones** are made from steel

Problem 1:
Bridges should be steady against wind and can carry 11 **tones weight turbines**.

Blades rotate **38 times in a minute**, weight down strong impact on bridges
This togetherness may cause '**resonance** '.If the vibration of the bridge and turbine reach same level, they enforce each other.In this position, bridges may collapse.

Solution:

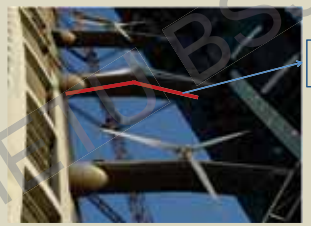
To prevent resonance risk, bridges are designed very **stiff** to vibrate more rapid than the turbine .

National Geographic Documentary,Bahrain World Trade Center
Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press,pdf sent by Atkins

Problem 2:
If the wind changes direction or gain sudden speed, the propeller of the turbines may hit to the bridges

Solution:

The bridge is a shallow **V-shape** in plan **(173°)** to take account of blade deflection
This shape provides **1.7 metres** distances between blades and the bridges



National Geographic Documentary,Bahrain World Trade Center
http://www.ctbuh.org/Portals/0/Repository/T3_KillaSmith.cfce5b62-fc35-4de7-ba53-90eeca647d94.pdf

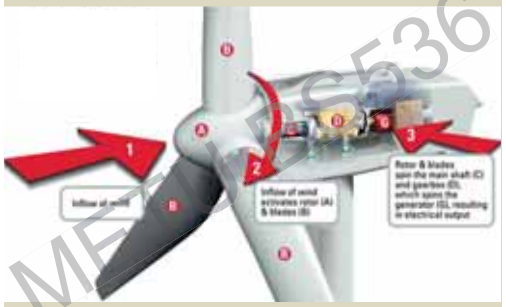
Horizontal-axis wind turbines

- Each **29 m** turbine diameter weigh 11 **ton**.
- They are designed to stand against **252** km speed of wind
- The three wind turbines, mounted at **60m**, **98m** and **136m** high between the two towers.
- The wind tunnel tests indicates that wind coming with **45 angle** can also rotate the turbines

Three massive wind turbines suspended from bridges spanning between the two towers energy yield is **1,100 ~ 1,300** MWh per year which is approximetly **11~ 15%** of the office tower's likely consumption

http://www.designbuild-network.com/projects/bahrain/
http://www.earchitect.co.uk/bahrain/bahrain_wtc_wind_turbines.htm

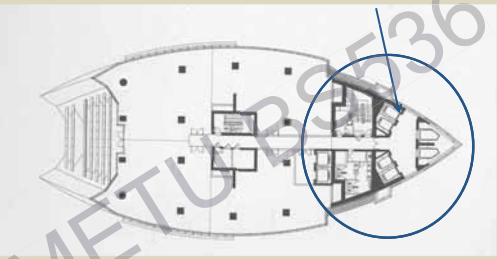
How Does A Wind Turbine Work?



STRUCTURAL SYSTEM & PLANS

SERVICE CORE

There are 8 elevators for each towers

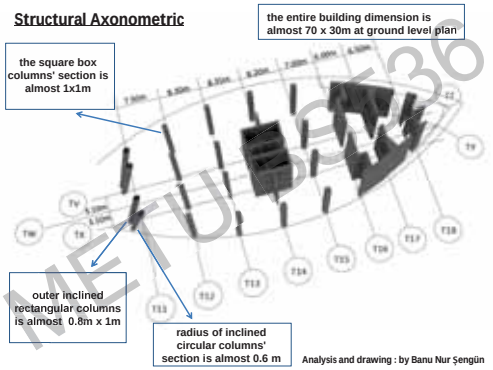


The service area is placed close to wind turbines to prevent the sense of undesirable noise and vibration in office and shopping mall area

http://en.wikiarquitectura.com/index.php?title=Bahrain_World_Trade_Center

STRUCTURE

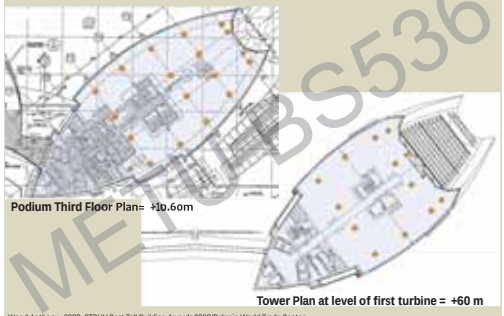
Structural Axonometric



Analysis and drawing : by Banu Nur Şengün

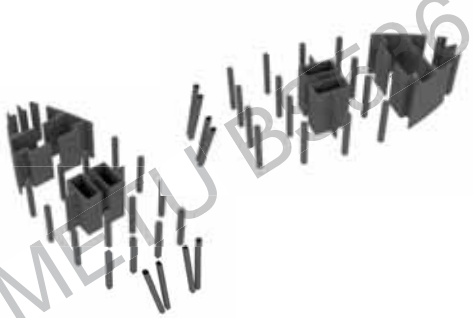
Columns

Analysis and drawing : by Banu Nur Şengün



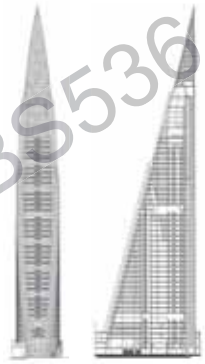
Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press.pdf sent by Atkins

Structural Axonometric

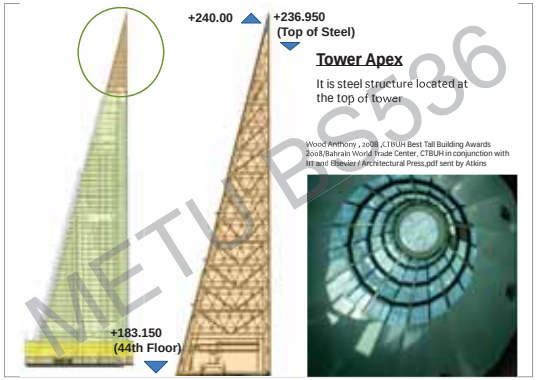


Drawing: by Banu Nur Şengün

SECTION & END ELEVATION



http://en.wikiarquitectura.com/index.php?title=Bahrain_World_Trade_Center



Tower Apex

It is steel structure located at the top of tower

Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press.pdf sent by Atkins

Environmentally Responsive Design

- Where shading is not provided to glazing, a high quality solar glass is used with **low shading co-efficient** to minimise solar gains
- **Low leakage, openable windows** to allow mixed mode operation in winter months
- Enhanced thermal insulation for opaque fabric elements
- Owing to water shortage in Bahrain, water cooled chillers are not allowed therefore district cooling system, which uses sea water cooling , is used.
- Dual drainage systems that segregate foul and wastewater and allow grey water recycling to be added at a later date

PART 1- REFERENCES

- Günel M.Halis,Ilgın H.Emre, 2007 , Rüzgar enerjisi ve Bina Tasarımı, Odtü Mimarlık Fakültesi Yayınları
- www.usgbc.org
- http://www.supereco.com/company/the-eden-project/
- http://repository.tamu.edu/bitstream/handle/1969.1/5430/ESL-IC-06-11-273.pdf?sequence=4
- http://neighborlysolar.com/blog/category/solar definitions/
- Maunsell Faber ,Tall Buildings and Sustainability Report
- http://architecture.about.com/od/saveenergy1/ig/Solar-Homes/Solar-Thermal-Collectors-.htm
- http://www.murrayolaoire.com/civic/projects/expo2000/index.html
- http://www.joelertola.com/grfx/chrt_buildings.html
- en.wikipedia.org/wiki/Sustainable_architecture
- http://www.solarenergy-solarpower.com/passive-active-solarenergy.html
- http://www.atkinsdesign.com/html/projects_offices_difc.htm
- http://blog.cunysustainablecities.org/wpcontent/uploads/2009/08/week32skyscrapers.jpg
- http://farm2.static.flickr.com/1131/1260491785_44fc3029bc.jpg

PART 1- REFERENCES

- http://www.ctbuh.org/Portals/0/Repository/
- www.wisegeek.com/what-are-building-integrated-photovoltaics.htm
- http://www.greenpix.org/press/PDF/Greenpix_press-release_EN.pdf
- http://greenerworking.com/wp-content/uploads/2009/05/green-building3.jpg
- http://www.group-asiawest.com/english/Products10_2609_EN.htm
- http://www.architecture.uwaterloo.ca/faculty_projects/terri/powerpoint/double_case_studies.pdf
- [Harrison K. & Meyer-Boake T.: The Tectonics of the Environmental Skin, University of Waterloo, School of Architecture, (2003)]
- http://www.ebd.lth.se/fileadmin/energi_byggnadsdesign/images/Publikationer/Bok-EBD-R3-G5_alt_2_Harris.pdf
- Belgian Building Research Institute [BBRI], (2002),
- http://www.crwa.org/projects/bmp/factsheets/crwa_green_roof.pdf
- http://www.moltenearbonatefuelcell.com/trigeneration_diagram.gif
- http://www.proecopolynet.info/pdf_files/URV%20%20Integration%20of%20trigeneration%20technologies%20in%20buildings.pdf

PART 2- REFERENCES

- Wood Anthony , 2008 ,CTBUH Best Tall Building Awards 2008/Bahrain World Trade Center, CTBUH in conjunction with IIT and Elsevier / Architectural Press.pdf sent by Atkins Architects
- http://www.bahrainwtc.com/
- National Geographic Documentary,Bahrain World Trade Center
- http://en.wikiarquitectura.com/index.php?title=Bahrain_World_Trade_Center
- http://www.constructionupdate.com/products/constructionworld/zu08/augustzu08/016.html
- http://www.nassgroup.com/en/projects/projects-1/completed-project/bahrain-world-trade-center.html
- http://www.ctbuh.org/Portals/0/Media/Files/2009/123-oo%2uAIA%2oorg.pdf
- http://news.bbc.co.uk/1/hi/sci/tech/7340528.stm
- http://ipac.kacst.edu.sa/eDoc/2010/183240_1.pdf
- http://www.cif.org/noms/2009/15__Bahrain_WTC_Wind_Turbines.pdf
- http://www.ctbuh.org/Events/Awards/BestTallBuildingWinners/08_BahrainWorldTradeCenter/tabid/1045/language/en-GB/Default.aspx
- http://uscdn.creamermedia.co.za/assets/articles/images/resized/74139_resized_killaheadshot.jpg
- http://www.designbuild-network.com/projects/bahrain/
- http://www.earchitect.co.uk/bahrain/bahrain_wtc_wind_turbines.htm
- http://www.zawya.com/story.cfm/sidZAWYA20100427141003/Bahrain%20World%20Trade%20Center%20(BWTC)%2bScoops%20Prestigious%20Palme%20Award
- http://highriseconstruction.wordpress.com/2008/10/02/list-of-200-tallest-buildings-in-the-world/
- http://www.ctbuh.org/Portals/0/Repository/T3_KillaSmith.cfce5b62-fc35-4de7-ba53-90eeca647d94.pdf