



# Case Study- BURJ-AL-ARAB, Dubai

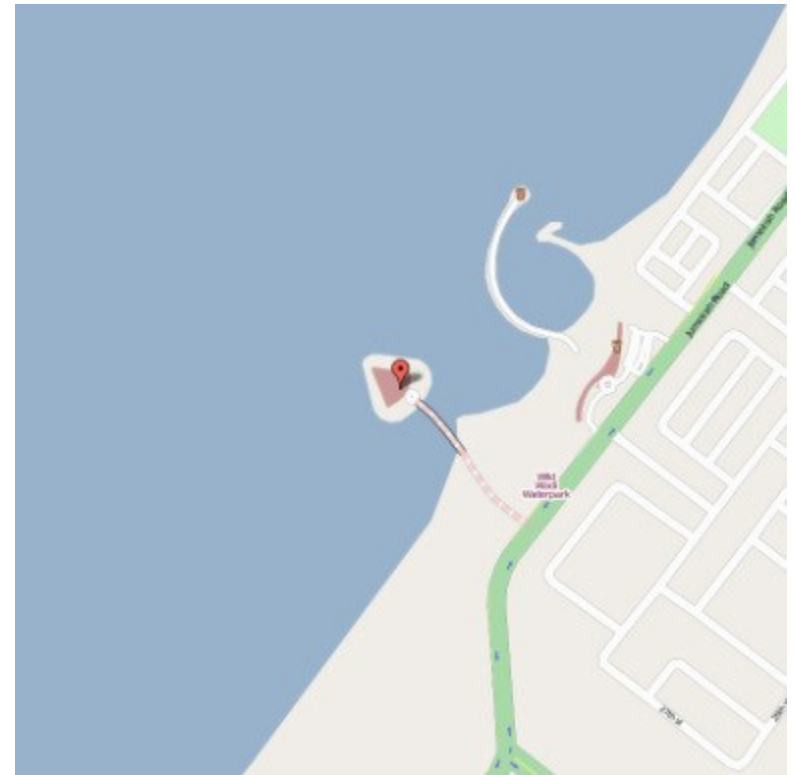
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Prodipta Chatterjee

# LOCATION

# BURJ AL-ARAB



- United Arab Emirates – Dubai
- Private Island (280 m Offshore)



# BURJ AL-ARAB



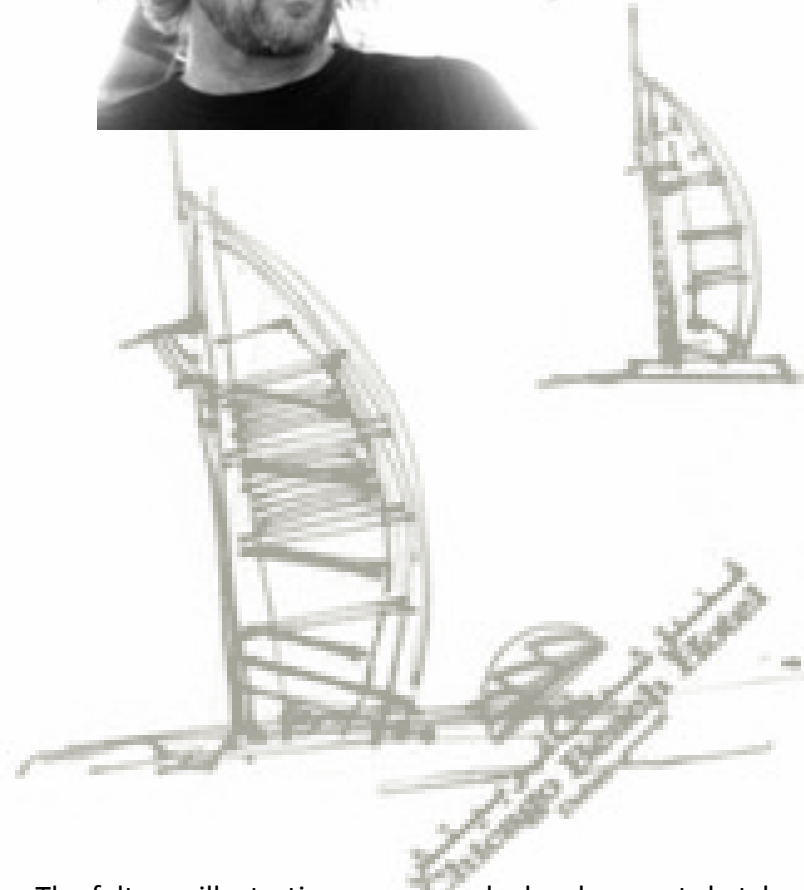
- Building Name: **Burj-Al-Arab Hotel.**
- Other/Former Names: Arab Sail.
- Chief Architect: The primary architect who designed the building ***Tom Wright of Atkins.***
- Chief Contractor: WS Atkins Partners Overseas.
- Construction Contractor: Murray & Roberts.
- Construction : 1993 – 1999.
- Floors : 60.
- Floor Area : 111,500 m<sup>2</sup> (1,200,000 sq ft)

# Architect's Background

# BURJ AL-ARAB



- **Tom Wright (formerly Tom Wills-Wright)** - The architect and designer of the Burj al Arab in Dubai, UAE.
- Tom Wright lived in Dubai during the design and construction of the project, working as the project Design Director for Atkins , one of the world's leading multi discipline design consultancies.
- Tom Wright is British, born in Croydon a suburb of London on 18th September 1957.
- Educated at the Royal Russell School and then Kingston Polytechnic school of Architecture.
- Wright became a member of the Royal institute of British Architects in 1983 and has been in practice ever since.



The felt pen illustration was an early development sketch of the hotel drawn by Wright .

# Introduction

# BURJ AL-ARAB



- The Burj Al Arab - Tower of the Arabs , also known as "Arab Sail".
- A luxury hotel located in Dubai, United Arab Emirates.
- At 321 m (1,050 ft), it is the third tallest building in the world used exclusively as a hotel.
- Stands on an artificial island 280 m (920 ft) .
- Connected to the mainland by a private curving bridge.
- It is an iconic structure, designed to symbolize Dubai's urban transformation and to mimic the sail of a boat.



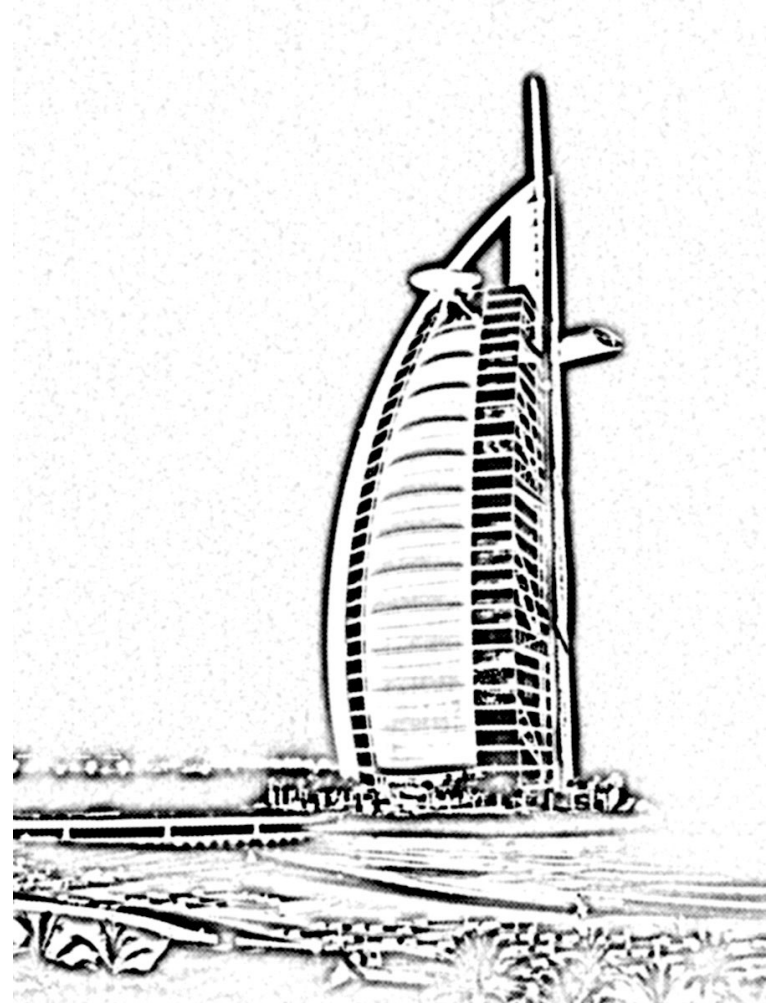
Burj Al Arab - the world's third tallest hotel.

# Concept

# BURJ AL-ARAB



- The instruction from the client (the Crown Prince of Dubai) was to design, not just a hotel, but also a signature building; one that would announce, "Welcome to Dubai".
- The client wanted a dramatic statement with imagery that would immediately conjure up images of the city.
- The building is built on sand, which is unusual as most tall buildings are founded on rock. The Burj al Arab is supported on 250, 1.5M diameter columns that go 45 meters under the sea. As there is only sand to hold the building up the columns rely on friction.



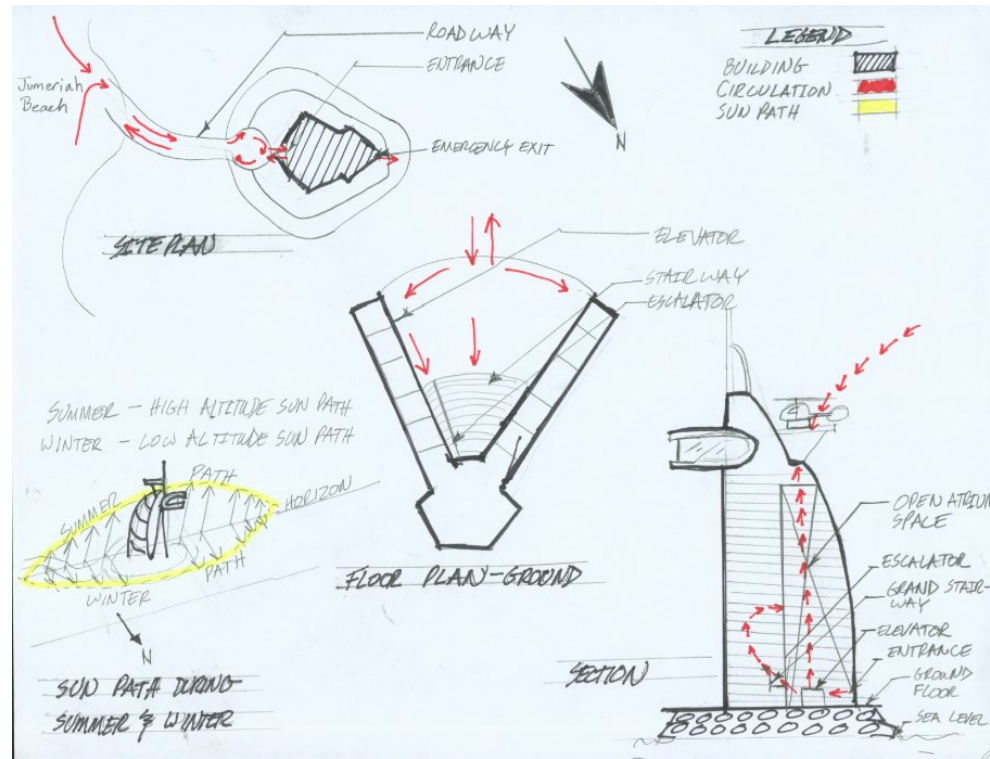
# Concept –

# Orientation and Circulation

# BURJ AL-ARAB



- The orientation of the building minimizes the heat gain during the summer seasons.
- The south elevation has the most exposed surface area. As a result, it has the maximum capacity for heat absorption.
- For people, there is access to the hotel through the roof via a helicopter. At the main entrance there is a grand stairway, an escalator and elevators.
- For air, the revolving door located at the main entrance acts as a locking mechanism to prevent a phenomenon known as the stack effect, which occurs when the hot air rises and the cool air falls in a tall building.



<https://sites.google.com/site/ae390spring2012burjalarab/architectural-systems/1-drawings-diagrams>

# Environmental Approach

BURJ AL-ARAB



## Wind Effects Dubai's

- Geographic location subjects the hotel to severe weather conditions including strong winds and occasional violent thunderstorms.
- Due to the structure's proximity to its adjacent hotel resort, wind tunnel testing was considered to ensure a safe design.
- wind speed of 45 meters per second, under the recommendations of Dubai Municipality, was adopted for the design.

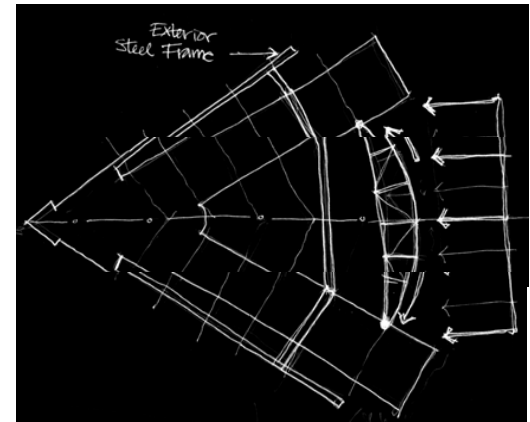
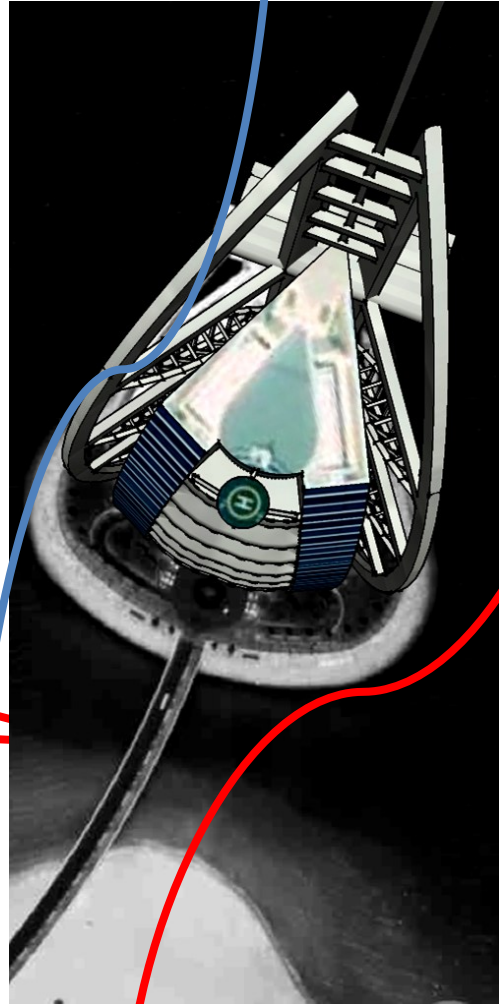
## Seismic Impact Dubai

- Itself is not located in an earthquake intensive zone. However, southern Iran which is only 100 miles away to the north is subjected to moderate earthquake risk and in turn which could create tremors in Dubai if a seismic event were to occur in Iran.
- To reinforce the structure from any potential swaying, two tuned mass dampers, weighing about 2 tonnes each, limit vibrations in the tubular steel mast that projects 60 m above the building.



# Environmental Approach

# BURJ AL-ARAB





## VORTEX SHEDDING

- Analysis were done with respect to Building response under wind loads
- Wind tunnel could threaten the entire skeleton. Wind blowing away sharp edges can cause destruction.
- Vibration may cause due to vortex shedding



## RESPONSE

- First option was to change the shape but Architect was against and forced the engineer to re-think.
- Ingenious hanging weight were installed at variable places - when wind blows, 5 ton weight will swing and damp down the vibrations to safety limits (refer image for locations highlighted in red)

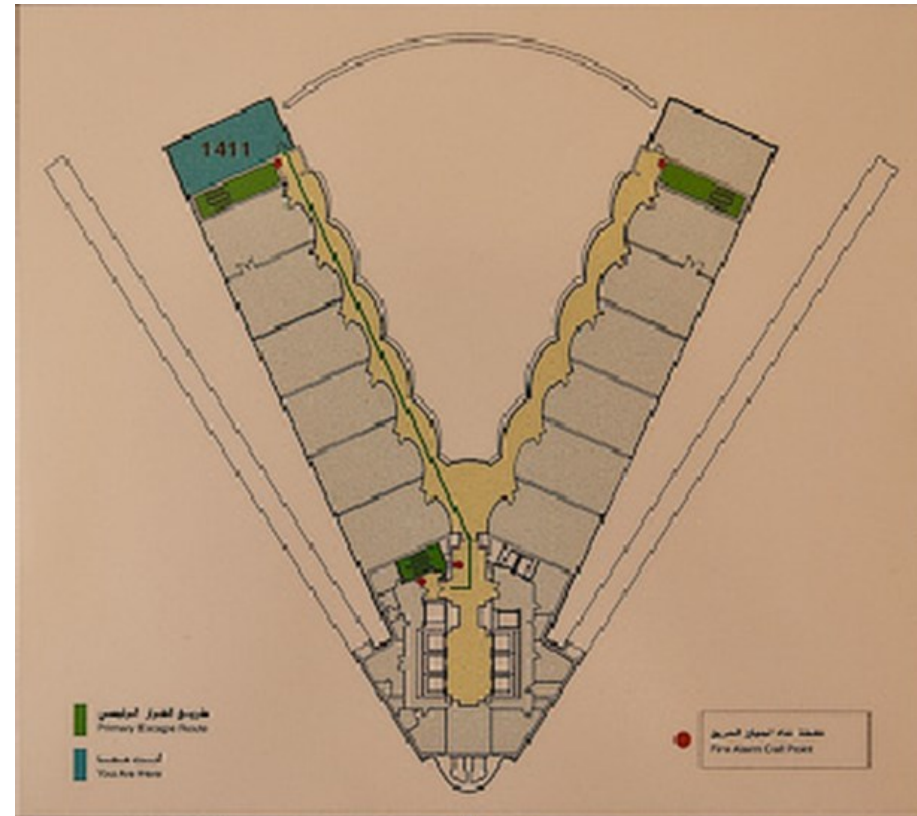


# Typical Floor Plan

# BURJ AL-ARAB

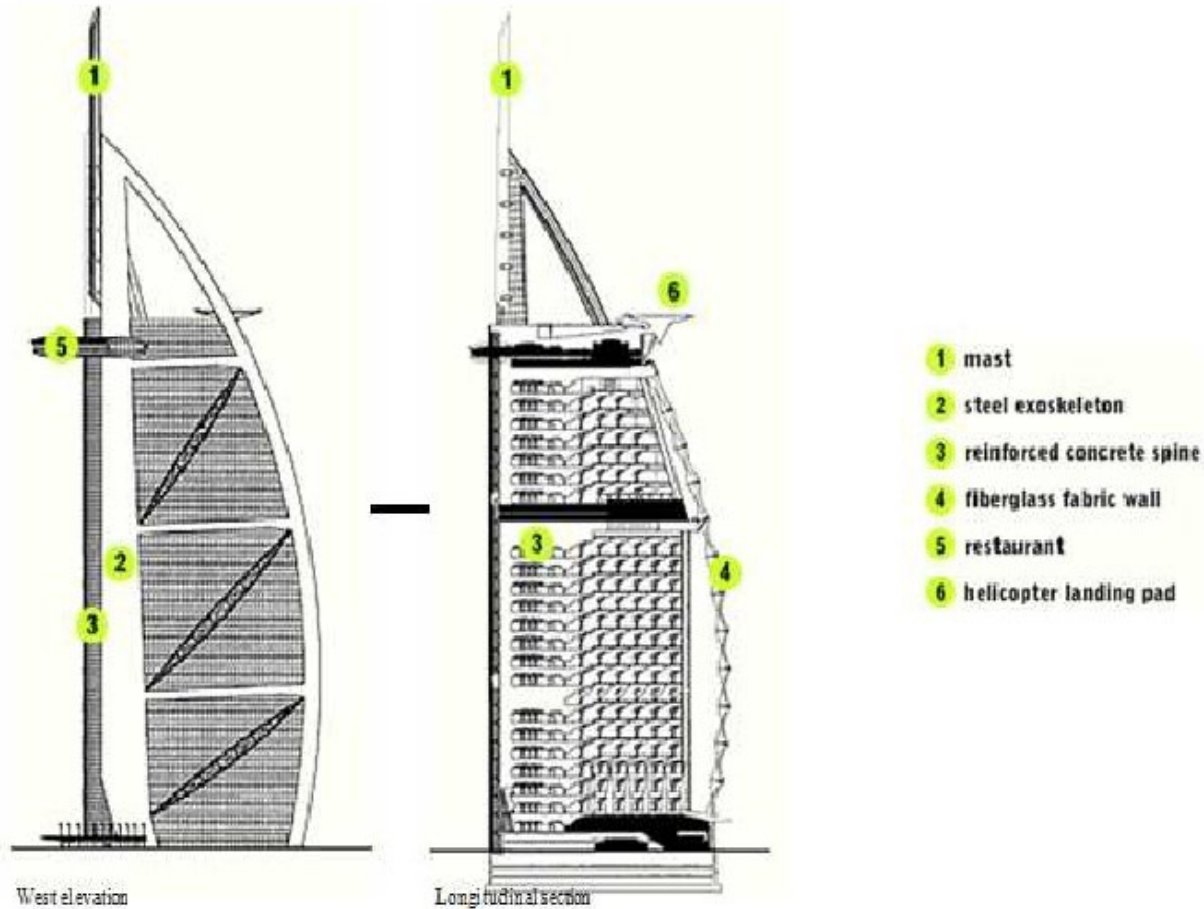


- Building is a hybrid “V” shape structure constructed in concrete and blended with structural steel.
- The “V” shape steel frame wraps around the reinforced concrete tower inhabiting hotel rooms and lobbies.
- The two wings enclose space in center to form largest atrium in the world standing about 180m height.
- Burj al Arab is made up of 28 storeys of split levels (56 storeys) with 10,000 Sqmt floor area, 60,000 Sqmt of concrete and 9,000 ton of reinforced steel.
- The roofs and walls of the building are made of prefabricated concrete
- There is a concrete core at the back of the building which forms the base of the V-shape and the trusses are connected to it.



<http://www.scribd.com/doc/61292707/Design-and-Construction-of-Burj-Al-Arab#scribd>

# BURJ AL-ARAB



<http://www.scribd.com/doc/61292707/Design-and-Construction-of-Burj-Al-Arab#scribd>

- Burj al Arab has the structural expressionism.
- Structural Expressionism basically means that the structural components of the building are visible on the inside as well as outside.
- This includes features such as exposed truss work and complex shapes.

# Island Construction



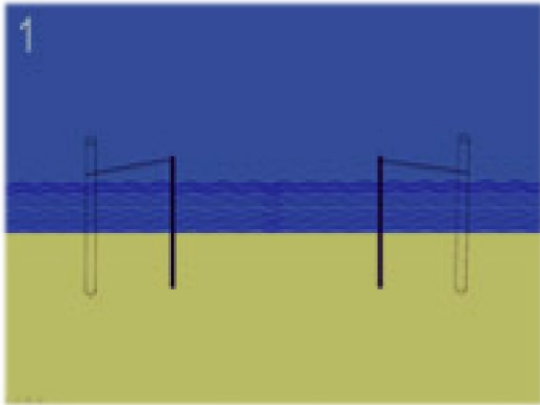
- It took 3 yrs to reclaim the land from sea and less than 3 yrs to construct the building.
- Island rises 7 and a half meters above the waves.
- Island protected by concrete honeycomb shape solid blocks designed to reduce the impact of waves.
- No one in the gulf had ever used these blocks before

## CONCEPT AND DESIGN

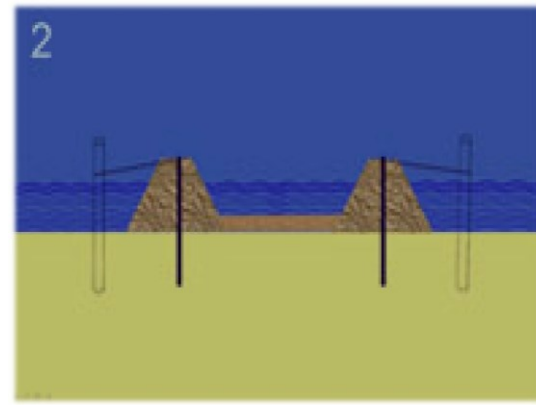
- Main concern was protection of island, waves breaking over island and impacting the structure.
- Initial proposal was by rock which was easily available and supported the existing technologies.
- Architect-Wright however rejected the proposal because this would make island too high and his concept was –sail rising from water-people close to sea.
- There were lot of debate on height of island.
- Then Nicholas experimented with pioneering concrete blocks- specially designed to reduce impact of waves. Testing were done to ensure island was safe-3 weeks of testing came up with positive results.



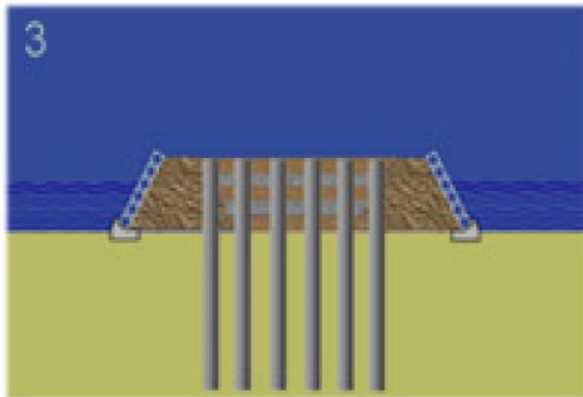
# BURJ AL-ARAB



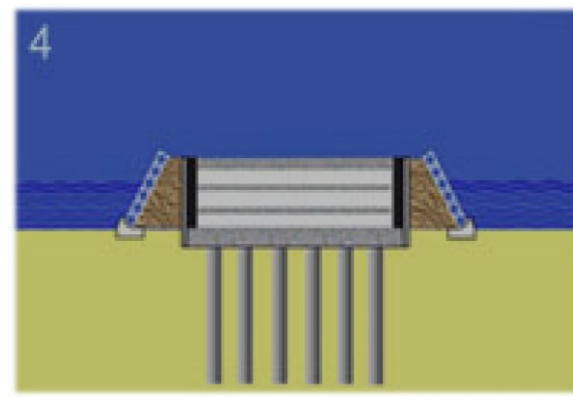
- Temporary tube piles driven into sea bed
- Temporary sheet piles and tie rods driven into seabed to support boundary rocks



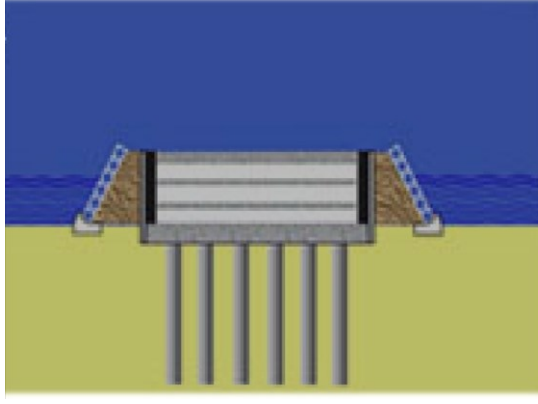
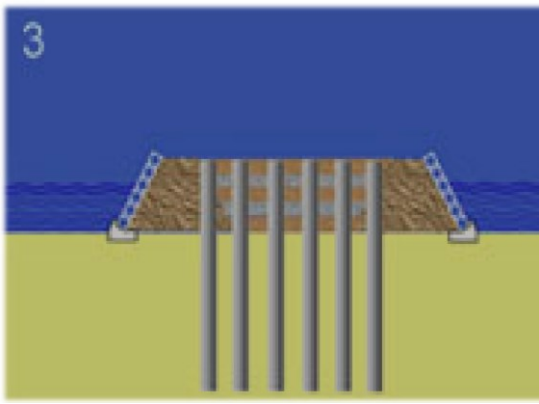
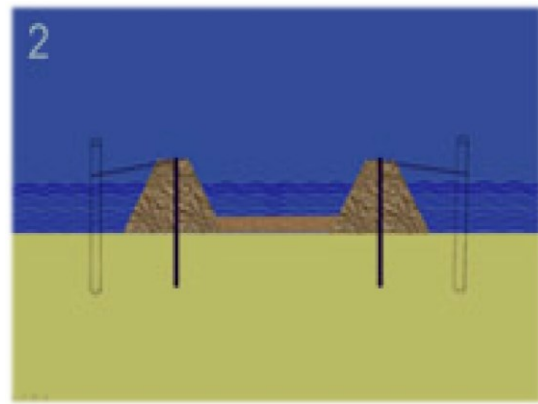
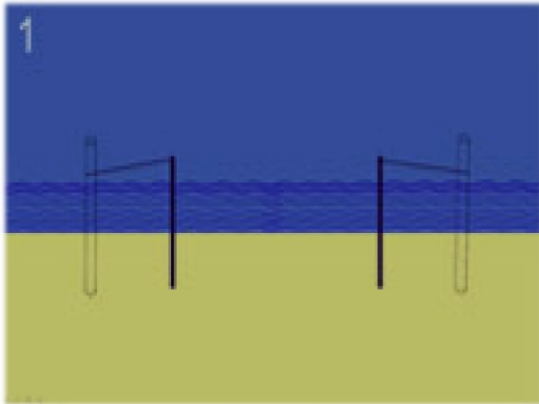
- Permanent boundary rock bunds deposited either side of sheet piles
- Hydraulic fill layers deposited between bunds to displace seawater and form island (fill layers partially complete in figure)



- Permanent concrete armor units placed around island to protect it from the waves
- 1.5 m diameter 45m deep piles driven through island and sea bed below to stabilize structure



- Island interior excavated and temporary sheet pile coffer dam inserted
- 2m thick concrete plug slab laid at base of island
- Reinforced concrete retaining wall built
- Basement floors created



# BURJ AL-ARAB



Mega-structure Construction of Burj Al Arab 2.flv



## Concrete blocks worked like sponge

- As wave hit the block, water pass inside and turn around in itself and hence force is dissipated and hence battle for secure island is won.
- Island only 7 and half meter above sea level was ready in Nov 1995.





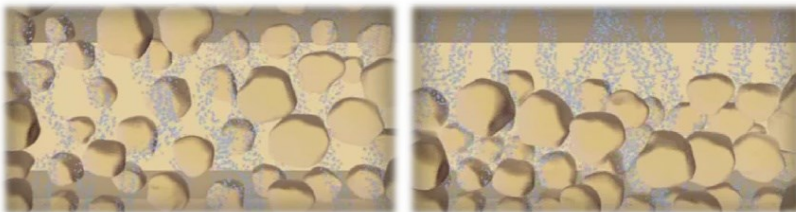
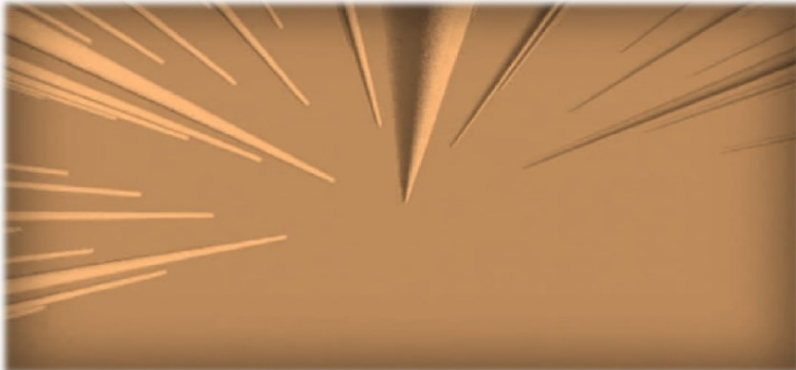
# Foundation

# BURJ AL-ARAB



## THE CHALLENGE

- It was very challenging to design foundations to Support the mega structure-270 miles off coast, 320 mtr in height on man-made island (6mts from Arabian Sea) resistant to earthquake (falling under range of major fault line) and wind that blows 90 miles per hour.
- Structure was designed to amaze-one never built before. Location on a reclaimed land was added challenge.



## TESTS AND RESULTS

- Initial core test-Drilling done 180mts down and no solid rock was formed but architect was defiant about the design and construction.
- Then, **reinforced concrete** foundation piles deep into sand with concept of skin –friction were designed.
- **Skin friction:** resistance that stops the slipping between sand and surface of piles. When friction between them is equal to impact, situation is handled.

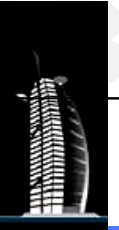


- The building is built on sand. Sand was compacted around the building to create friction against pile. This stopped the building from sinking.
- It is supported on 250 numbers of 1.5 meter diameter columns that drilled deep into the sea
- Each column is a steel reinforced concrete foundation pile with 45 meter in length.
- Piles -20 percent longer than planned were executed with combined length of six and a half miles-35 times as long as tiring hotel to support.
- Longer the pile the greater the effect of skin friction is.
- Foundations has the capacity to resists failure due to Liquefaction which is caused during earthquakes.

# CONSTRUCTION SITE PICTURES

BURJ AL-ARAB





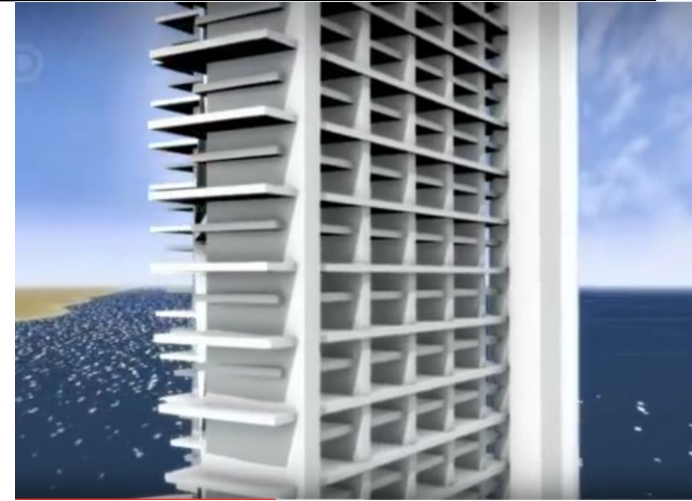
- 1.
2. Exoskeleton
- 3.
4. Skyview
5. Helipad



<http://www.arabianbusiness.com/incoming/article570447.ece/ALTERNATES/g3l/nov97.jpg>

# Core

# RIIP J AL-ARAB



-The v shape form of prefabricated concrete is hold in place with cross brace frame and a gigantic steel structure known as exoskeleton.



<https://www.youtube.com/watch?v=312LhpyJfkg>  
connecting the two cores with cross bracings of fabricated box section, imparting stability

# Exoskeleton Frame

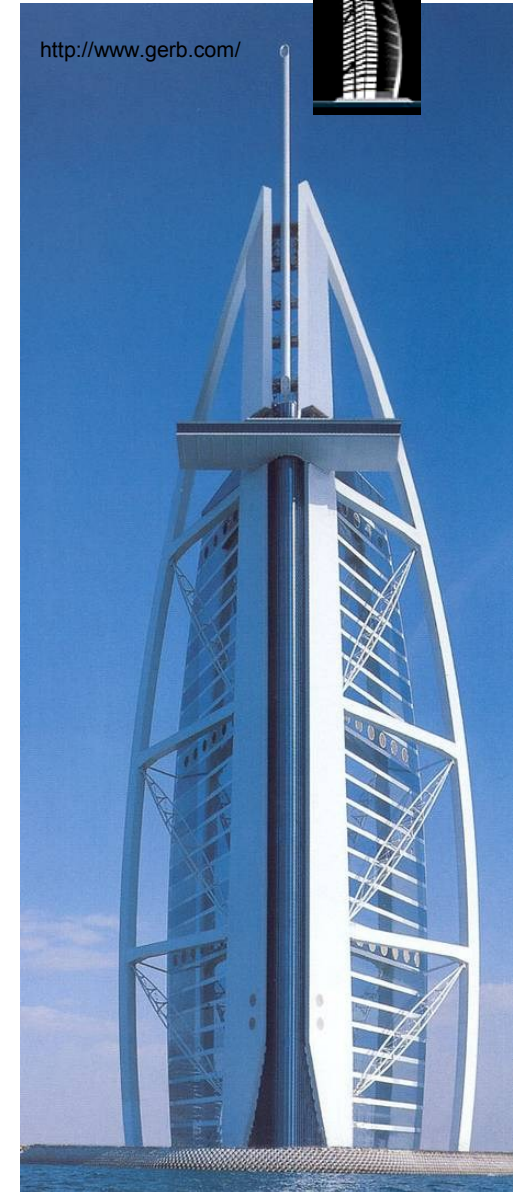
# BURJ AL-ARAB

Exoskeleton is made of two legs on each side of the structure. These Legs are built up H-Sections connected by lattice braced members.

Diagonal are huge tubular triangular trusses tied to two legs to the central core. The diagonal trusses can contract and expand up to 5 cm in 24 hours.

Horizontals-connects rear leg to core wall

-The exoskeleton bows are provided with tuned mass damper at 11 critical points with 5 ton weight which swings to damp down the vibrations caused by vortex shedding,



# Facade

# BURJ AL-ARAB

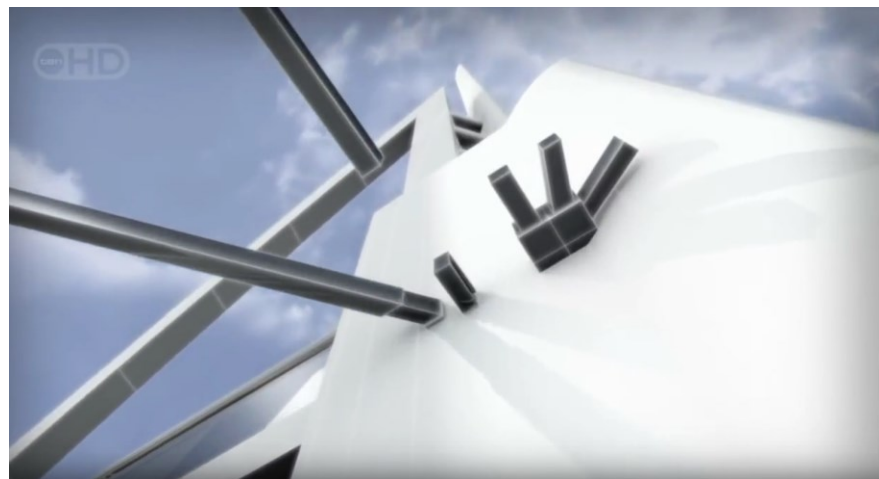


- Fabric wall stretched between horizontal beams
- stretch woven double skinned teflon coated woven glass fibre screen.
- Glazed curtain wall with aluminium cladding
- Steel structure claded with 6mm composite aluminium panels

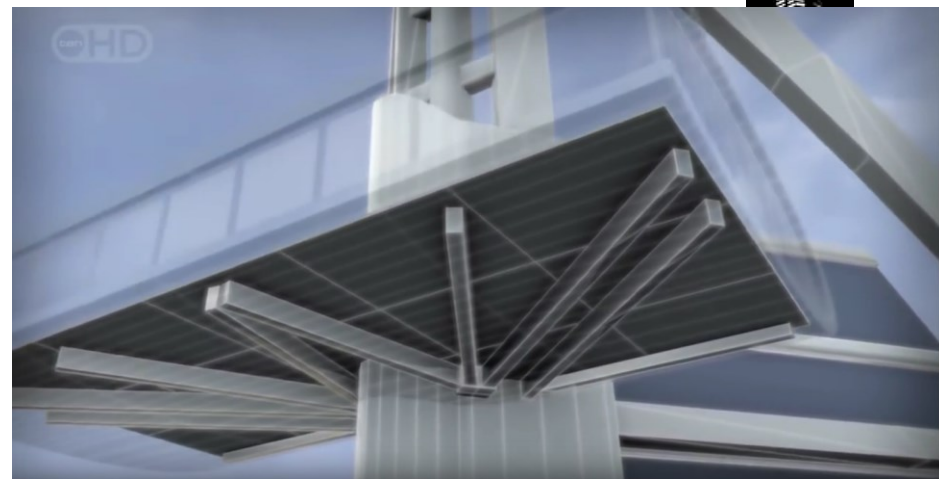


# Skyview Restaurant

# BURJ AL-ARAB



series of steel brackets cast into the core



10 girders radiates out



Sky view restaurant: survives wind 160 km/hour aluminium, glass, steel frame  
Box girders 27 m projected each side, 200m above sea



# Skyview Restaurant

# BURJ AL-ARAB



[http://m6.i.pbase.com/o4/65/355165/1/122576676.aH502UAC.IMG\\_3049.jpg](http://m6.i.pbase.com/o4/65/355165/1/122576676.aH502UAC.IMG_3049.jpg)

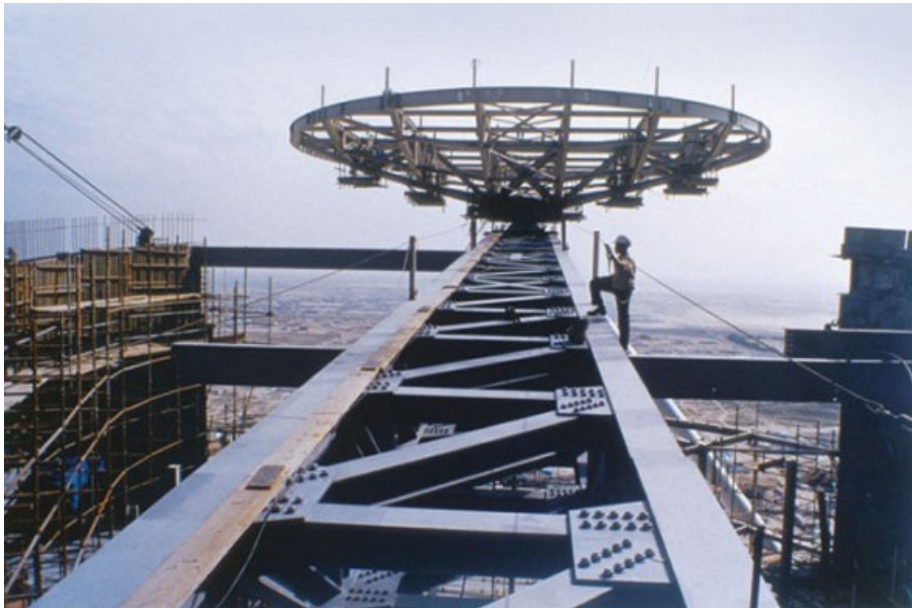


<https://blogalcer.files.wordpress.com/2012/03/imagen13.jpg?w=640>

# Helipad

# BURJ AL-ARAB

- Made of steel trusses and 20mm thick plates
- Two props circular steel pipes 1m in diameter
- Forms inverted V-shape inclined at 30 degree angle.
- Tied back to the central core by 40 metre long spine truss



[http://i.dailymail.co.uk/i/pix/2011/12/21/article-2076968-0F3DCC1400000578-347\\_964x630](http://i.dailymail.co.uk/i/pix/2011/12/21/article-2076968-0F3DCC1400000578-347_964x630)

Helipad

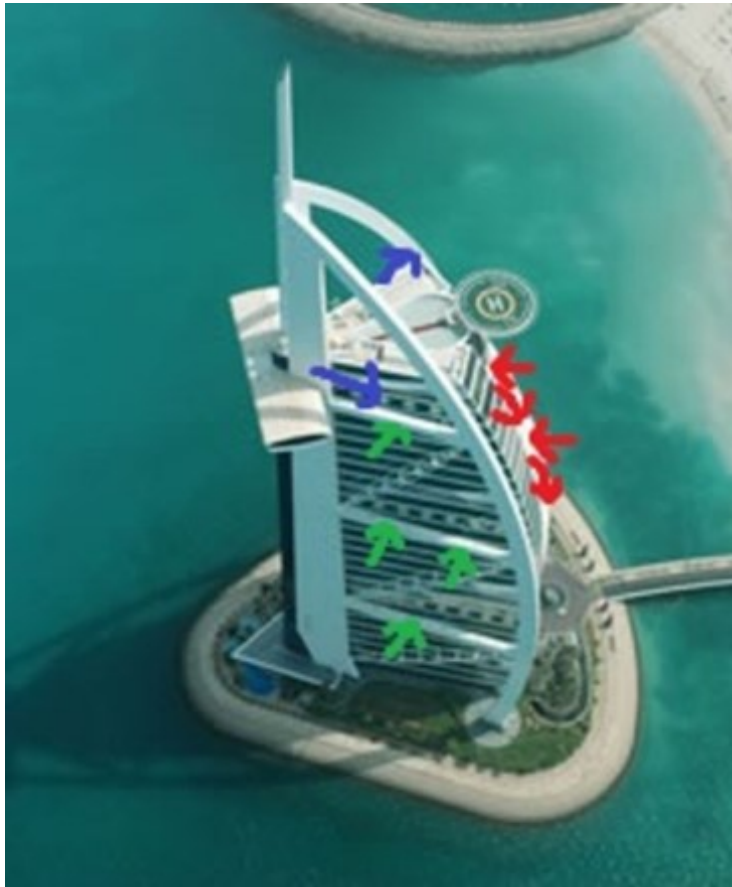
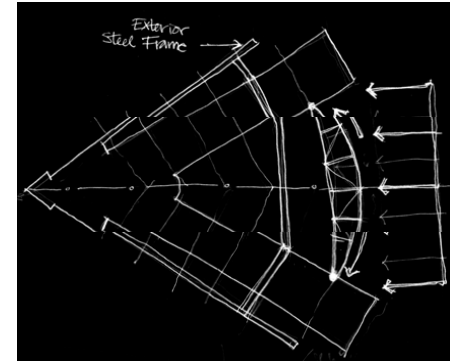
BURJ AL-ARAB



# Load Analysis

# BURJ AL-ARAB

Total dead load : 2850,000,000 lbs  
Total live load : 86,160,000 lbs  
Total load on foundation : 150,000 lbs/SF  
Maximum horizontal wind load : 2,366,000 lbs



## Lateral Loads

- The Burj Al Arab has three tubular steel trusses on the outside of the two sides of the V (in green).
- The trusses act as cross bracing to wind and earthquake forces.
- The translucent fabric wall of the atrium helps transfer lateral load (in red).
- Due to the rigidity, lateral loads are transferred to the fabric wall which acts similar to a diaphragm.
- The shape of Burj Al Arab lowers wind forces more effectively than a square building because of the streamlined V and curved fabric atrium wall (in blue).







## VERTICAL LOADS

- The structure transfers vertical loads from the top to the bottom of the structure using several different aspects.
- The structure transfers the vertical loading is through the large spine. This is the most direct way for the vertical loads to reach the ground.
- Secondly, the vertical loads transfer through the curved edge.
- The steel trusses running alongside the structure also helps in deflecting the horizontal loads.


# Multiframe

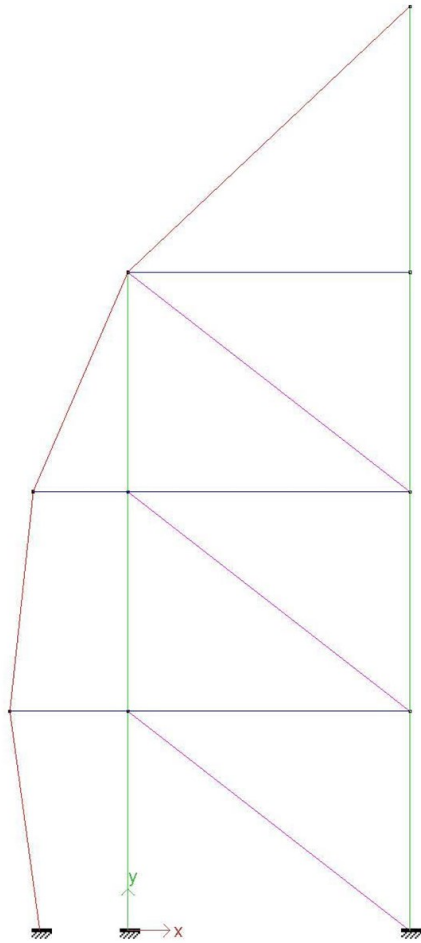
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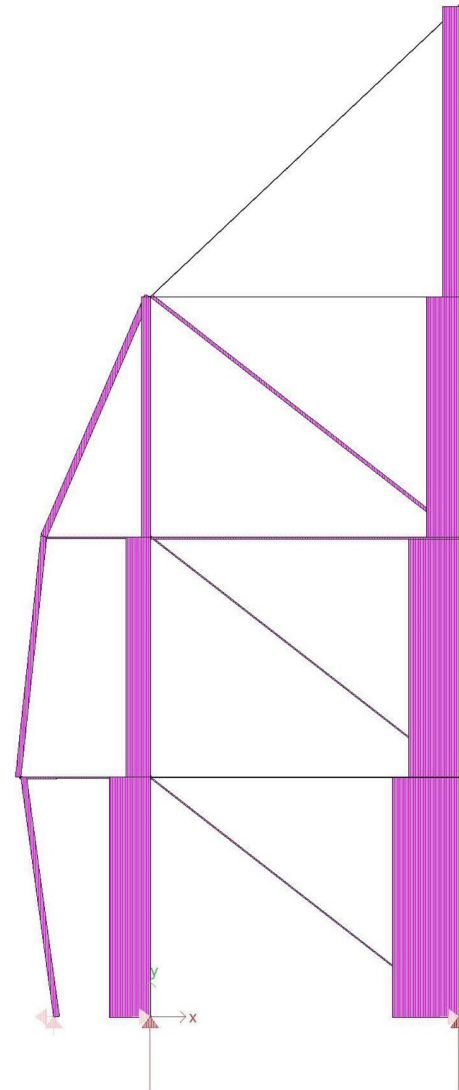
Sections	
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	W44x335
	TS20x12x1/2
	W44x290

Patch Material	
	(No Material)



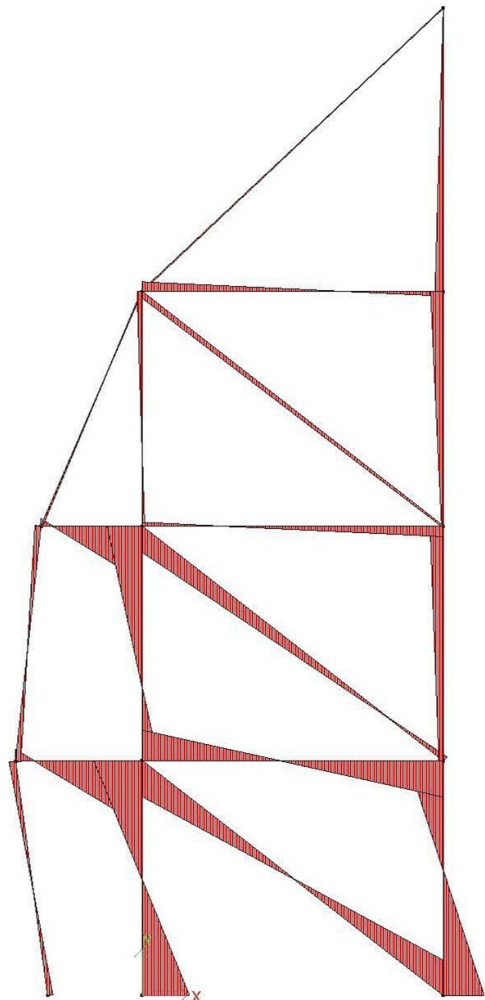
Multiframe 2D Model of Building section



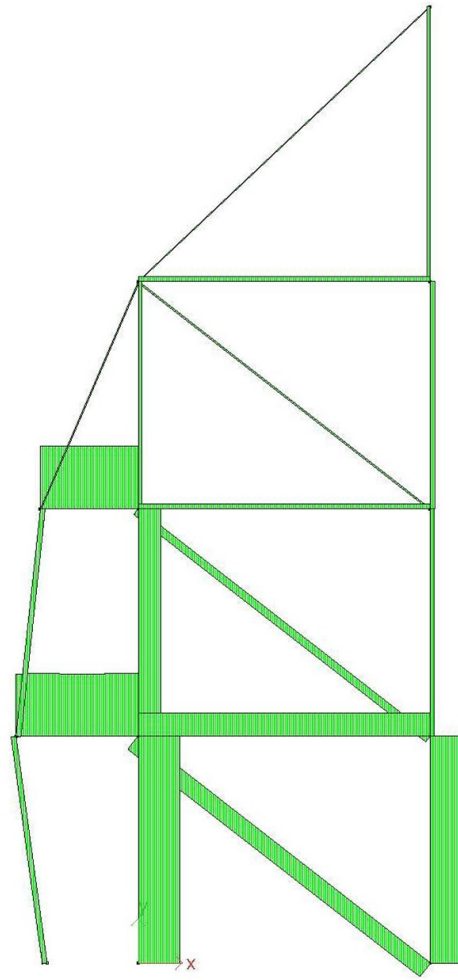
Axial Load Diagram

# Multiframe

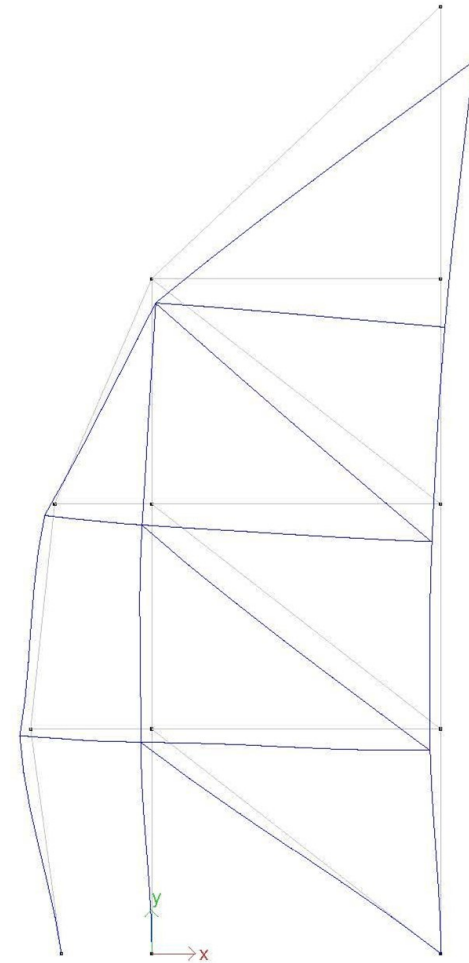
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Bending moment diagram



Shear force diagram



Deflection diagram

# Bibliography

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1. <https://sites.google.com/site/ae390spring2012burjalarab/c-structural-analysis/2-calculations>
1. <http://www.scribd.com/doc/61292707/Design-and-Construction-of-Burj-Al-Arab#scribd>.







**THANK YOU**