AL HAMRA TOWER

KUWAIT CITY, KUWAIT

SARAH CLAUS, VICTORIA GARCIA, AMBER HOLDEN-O'DONNELL, ERICA SCHNEIDER, HANNAH VOSSLER

DESIGNED AND ENGINEERED BY **SKIDMORE, OWINGS AND MERRILL**
CONSTRUCTED FROM 2005-**2011**

TALLEST BUILDING IN KUWAIT AND CURRENTLY 16TH TALLEST IN WORLD AT **1,352 FT**

BUSINESS TOWER ANCHORS A COMMERCIAL COMPLEX – **2.1 MILLION SQ FEET**

BUILDING IS EXCEPTIONAL FOR BEING:

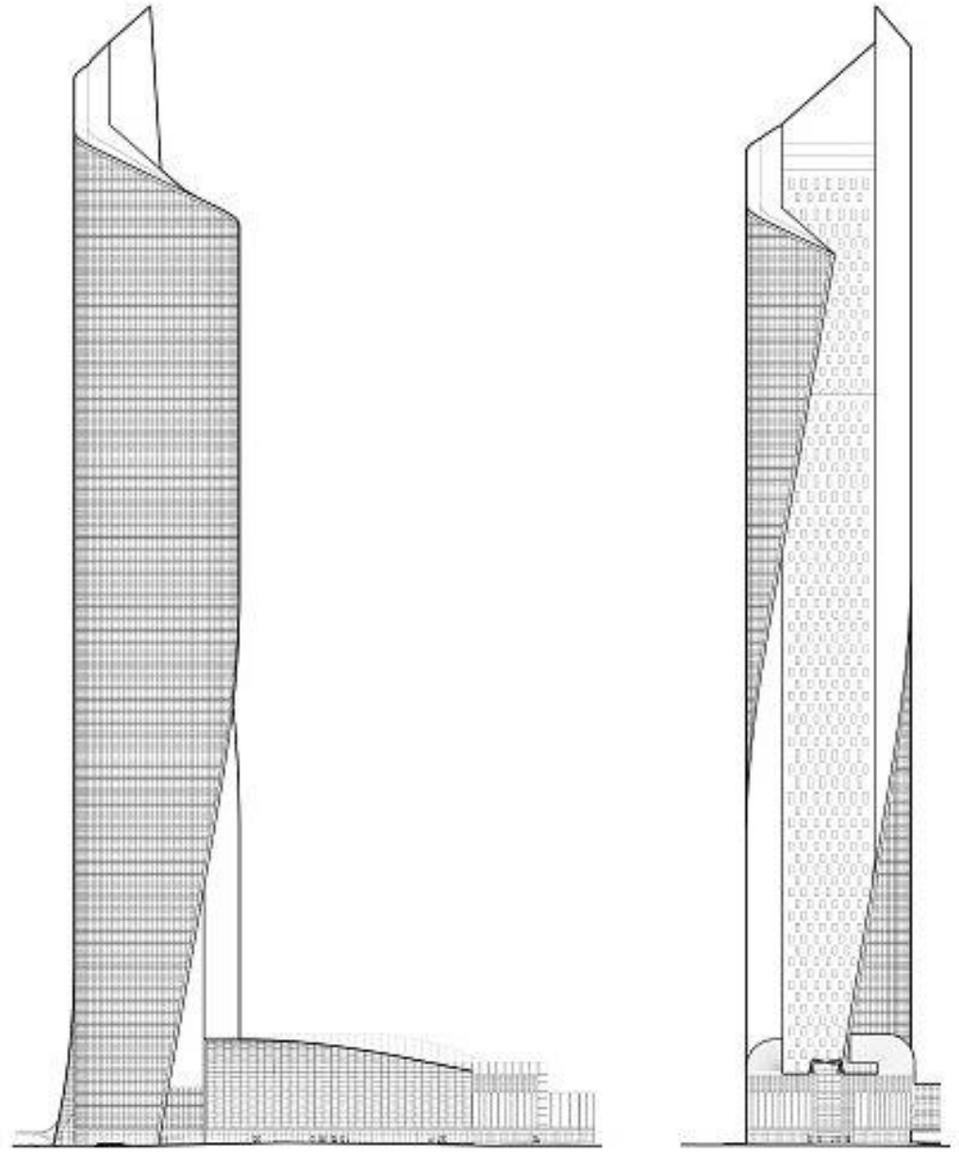
FIRST DESERT SKYSCRAPER
ONE OF FEW **REINFORCED CONCRETE HIGHRISE STRUCTURES**
SCULPTED FORM
CUT-OUTS ORIENTED TO SUN PATH

CONCEPT

STRIVED TO CREATE A CENTER OF EXCELLENCE
USING STATE OF THE ART TECHNOLOGY

BUILDING RESEMBLES AN ELEGANT
HIDDEN FIGURE WITH A DELICATE
GLASS VEIL REFLECTING THE
SILHOUETTE OF THE CITY

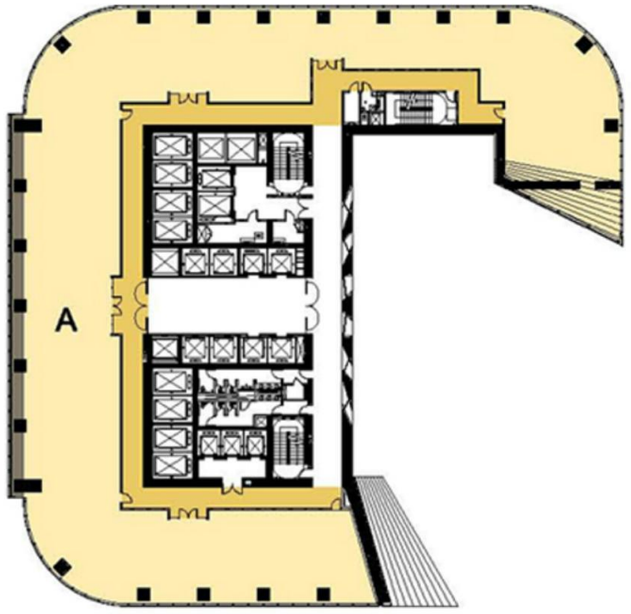
BASED ON SITE ALLOTMENT AND SUN PATH

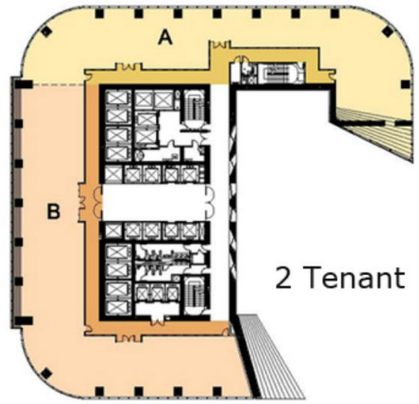


LAYOUT

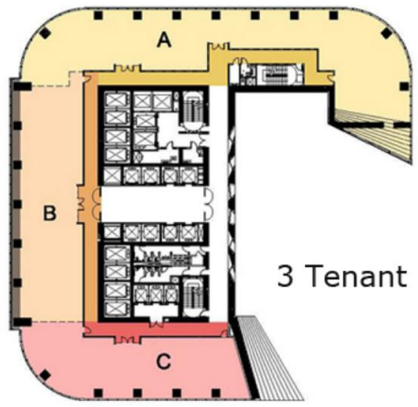
Low Rise - Low Zone

Single Tenant Layout





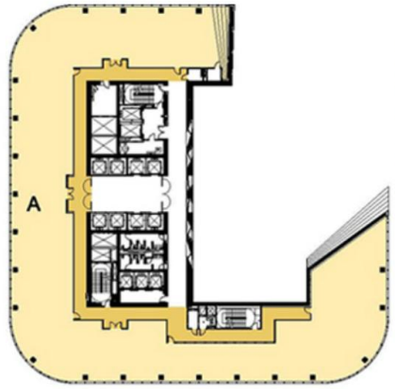
2 Tenant



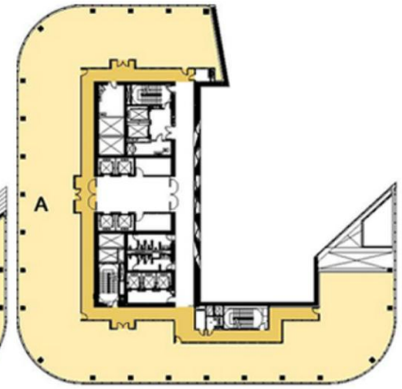
3 Tenant

High Rise - High Zone

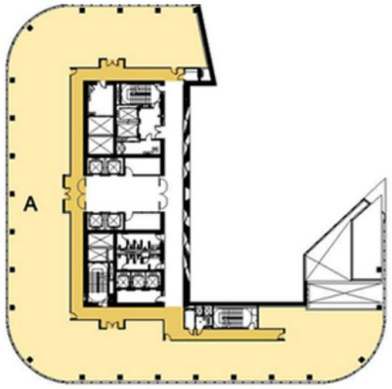
Single Tenant Layout



Floors 66 - 71



Floor 72



Floor 73

- CENTER CORE- CIRCULATION, BATHROOMS
- PERIMETER OFFICE SPACE WITH VIEWS
- REVELATION OF FLOOR SUBTRACTIONS

- STRIVE FOR EQUILIBRIUM

STRATEGICALLY PLACED

HIGH OCCUPANCY AREAS

AND MECHANICAL ROOMS

WATER STORAGE AND

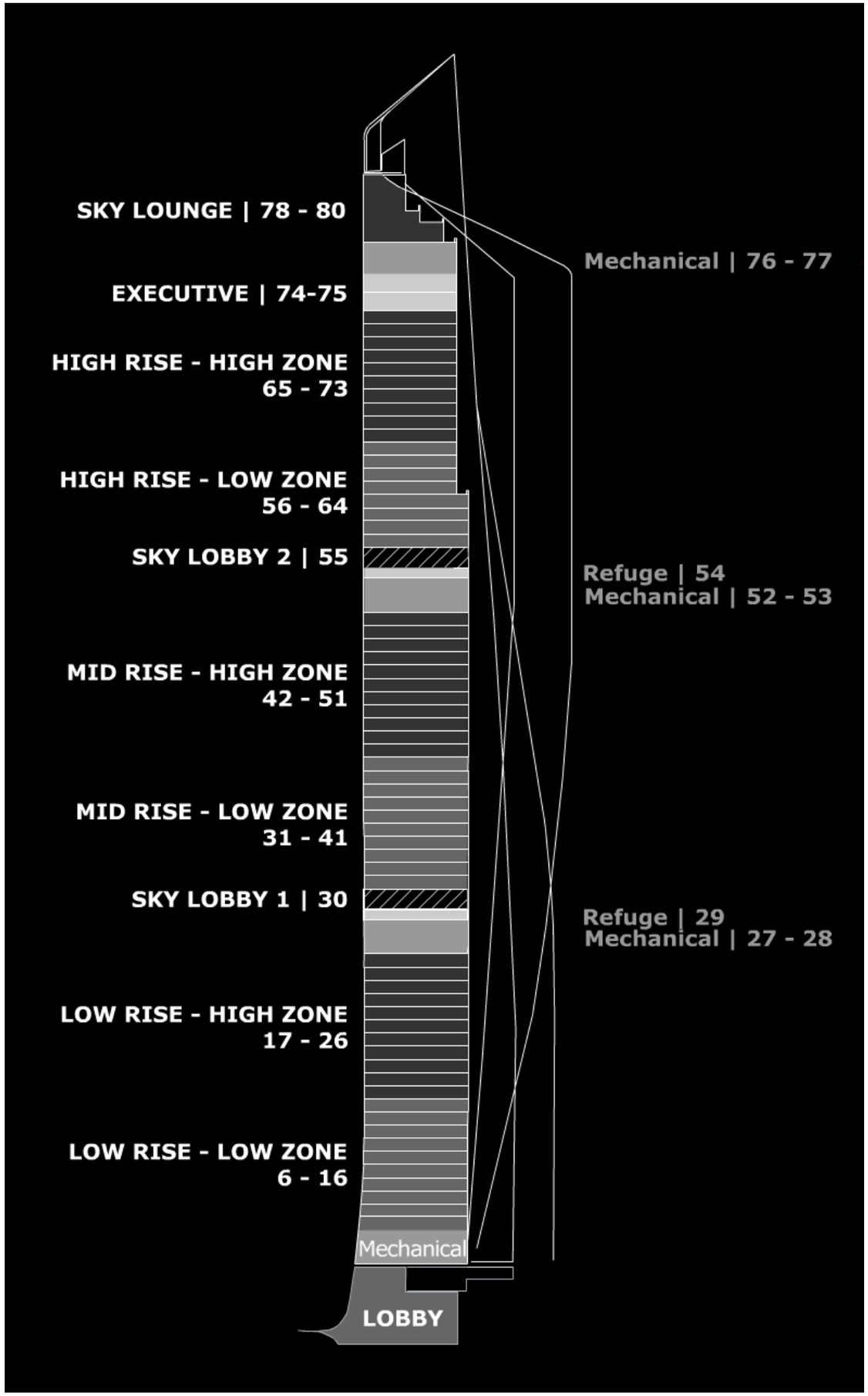
HEAVY EQUIPMENT PLACED

AWAY FROM SOUTHWEST

FLARED WALL

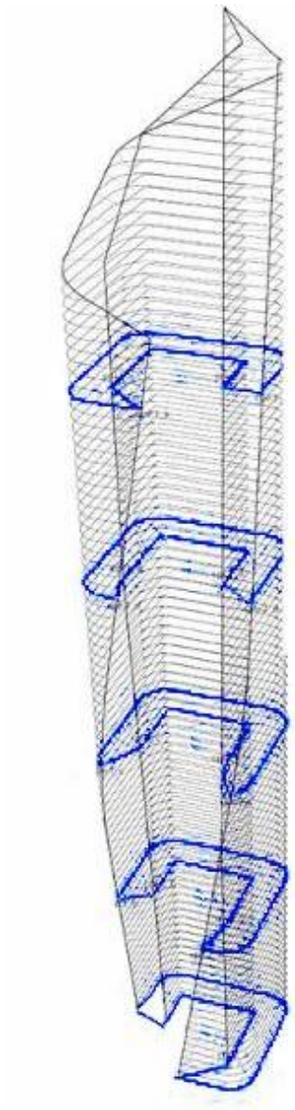
- GROUND CONNECTION TO

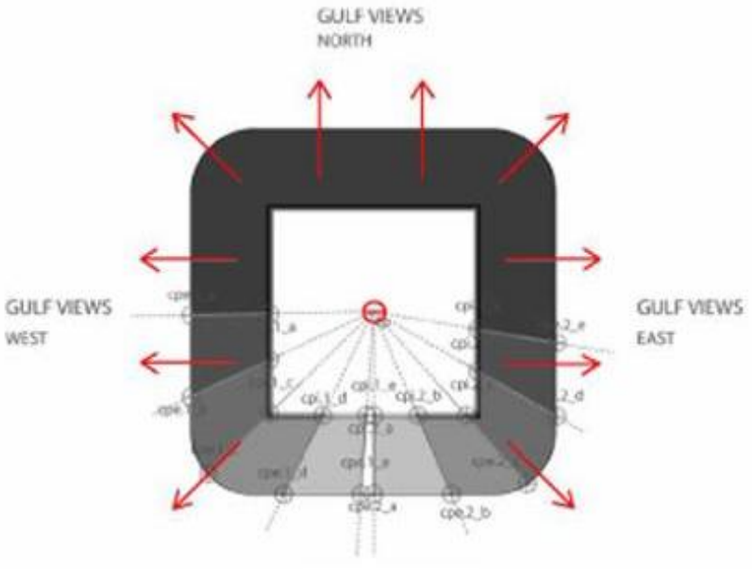
COMMERCIAL

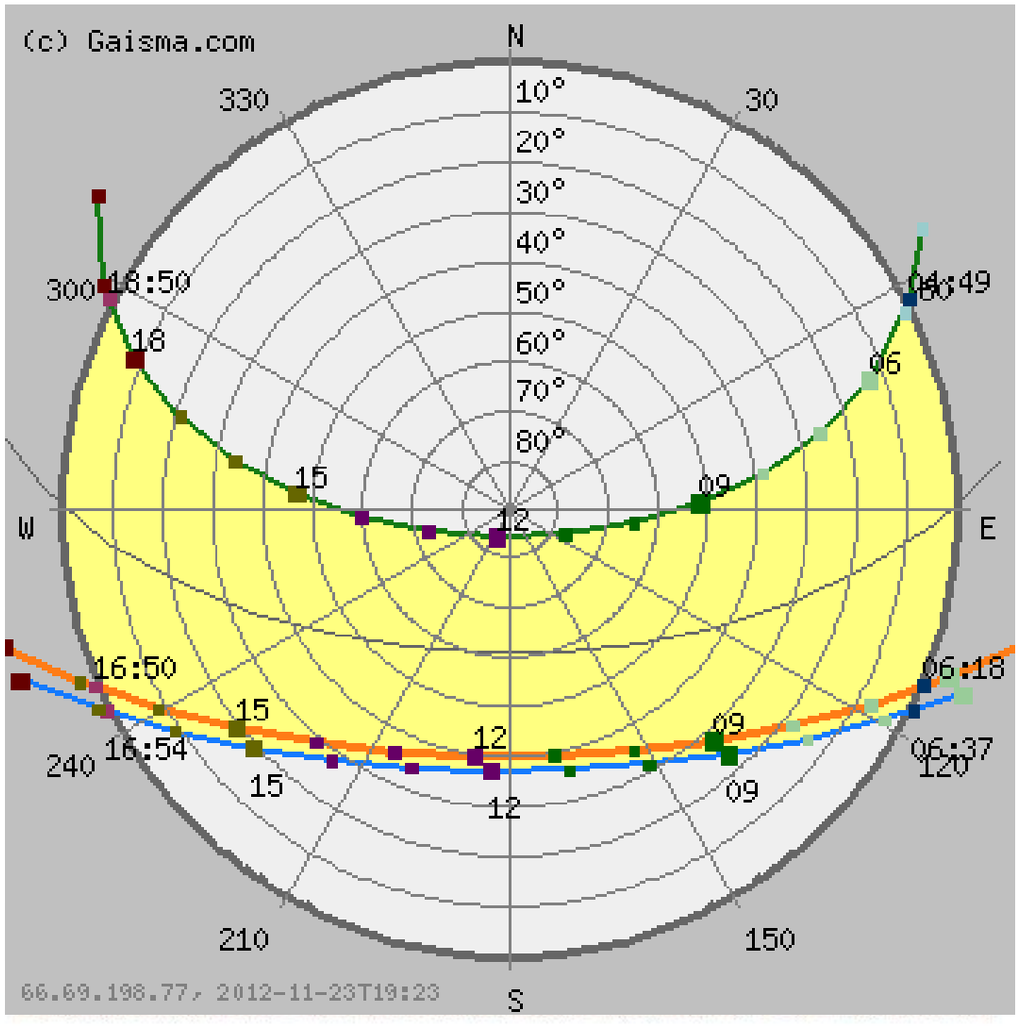


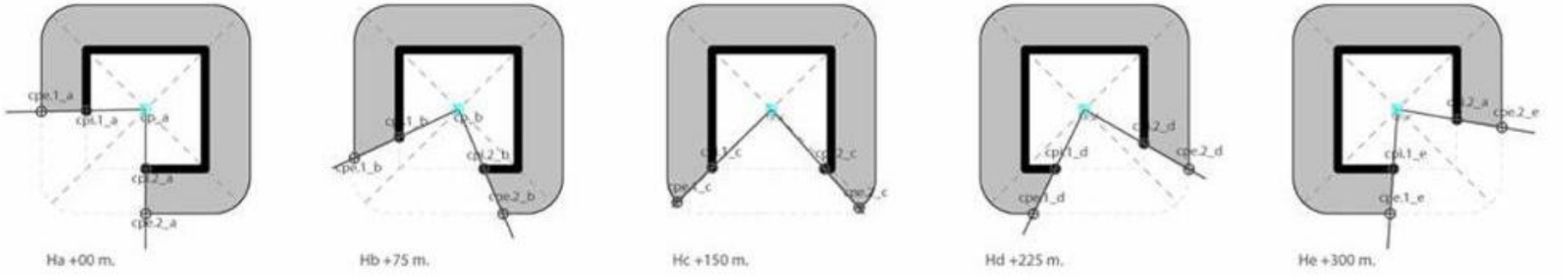
SOLAR SHADING

- FLARED WALLS BASED ON SUNPATH
- DEEP ANGLED WINDOWS
- STONE WALL
- INSULATED GLASS







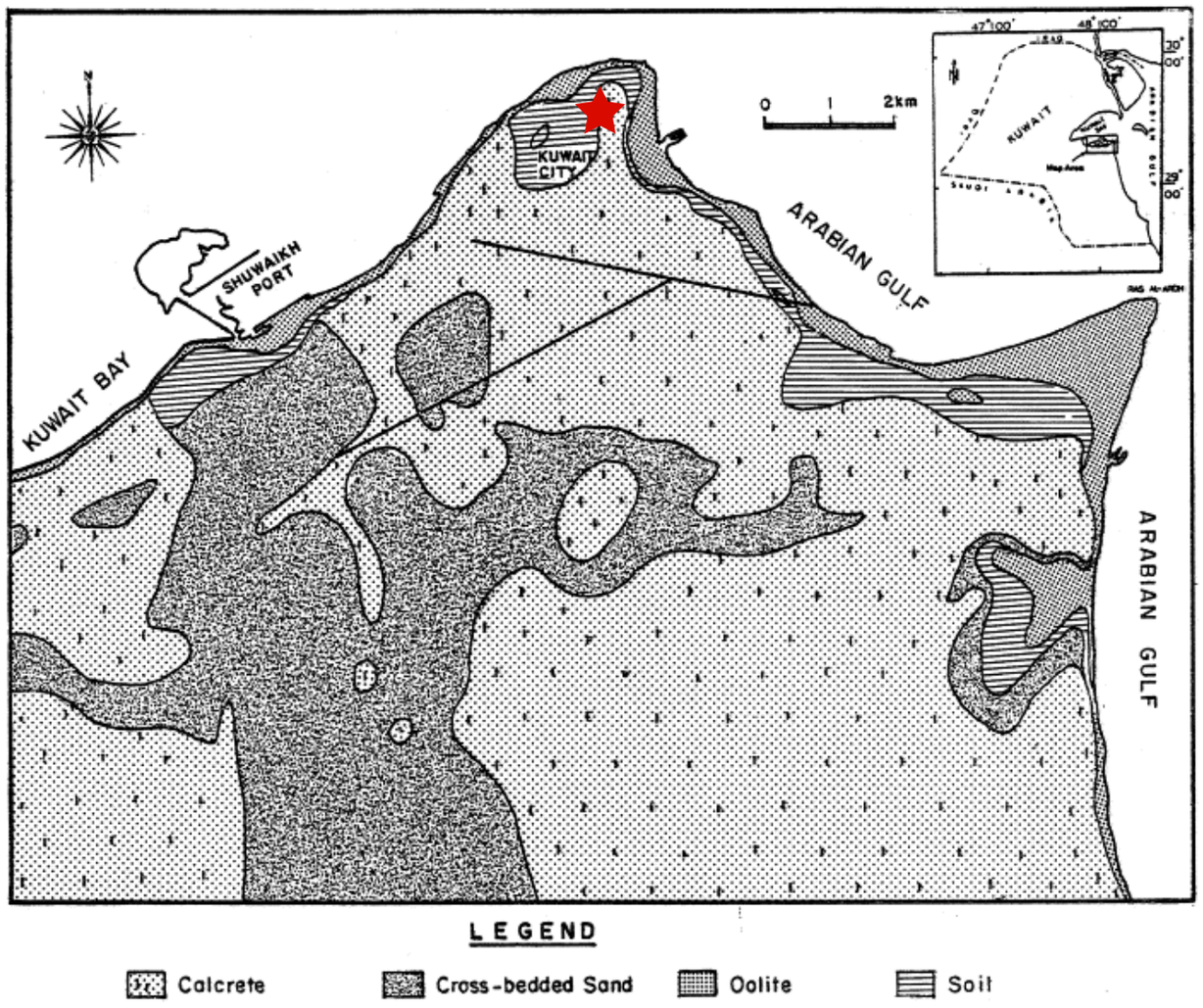


SOIL CONDITIONS

- SUBSURFACE
- SANDY, SILTY, LOOSE SOIL
- MEDIUM TO HIGH DENSITY
- 1-4M DEEP

- GROUND WATER TABLE
  MIMICS TOPOGRAPHY
- PHREATIC WATER LEVEL: 2M BELOW GRADE

- 75M BELOW GRADE
- CEMENTED SANDSTONE & SILTSTONE

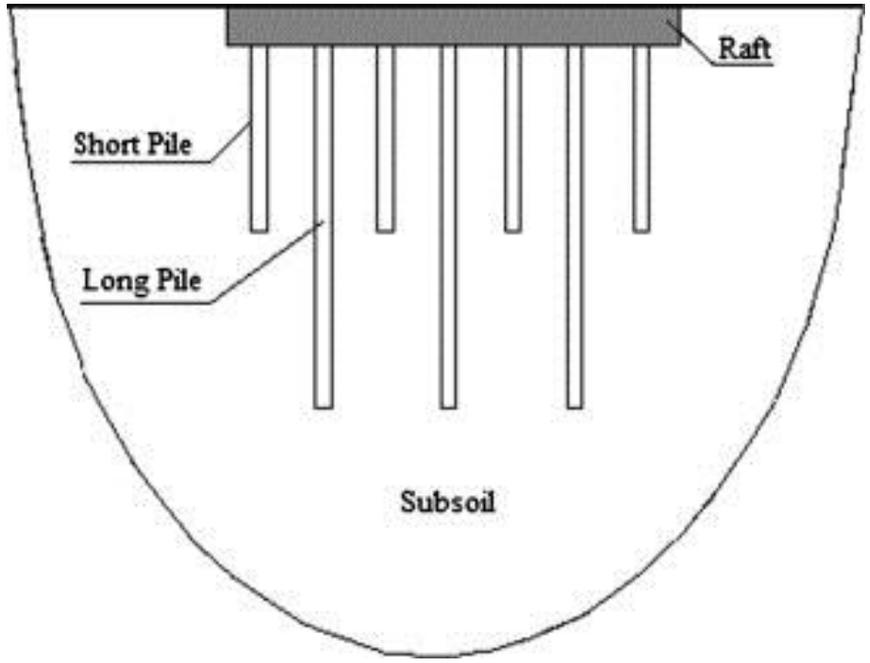


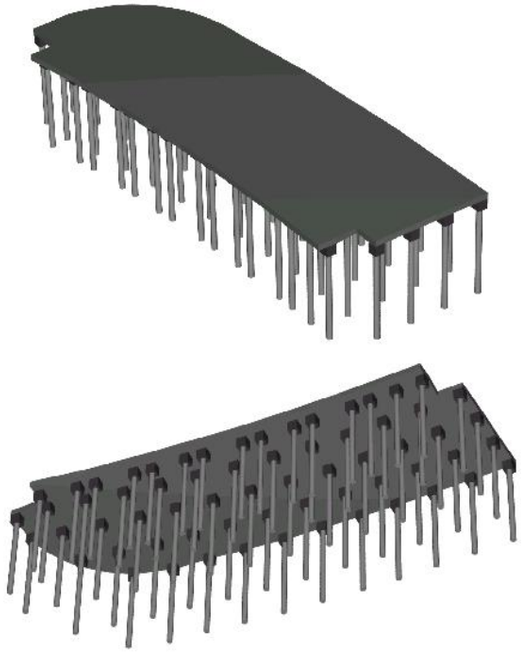
★ AL HAMRA TOWER, KUWAIT CITY

FOUNDATION SYSTEM

- REINFORCED CONCRETE RAFT
  - 13FT THICK
  - LOAD DISPERSED OVER CONCRETE SLAB
- CONSTRUCTED OVER 15 POURS OVER 4 MONTH PERIOD, ALLOWED CURING TIME FOR CEMENT

- CAST IN PLACE BORED PILES
  - ALLOWABLE SPACING: 1200 M
  - MAXIMUM PILE DIAMETER: 3600 MM CENTER TO CENTER

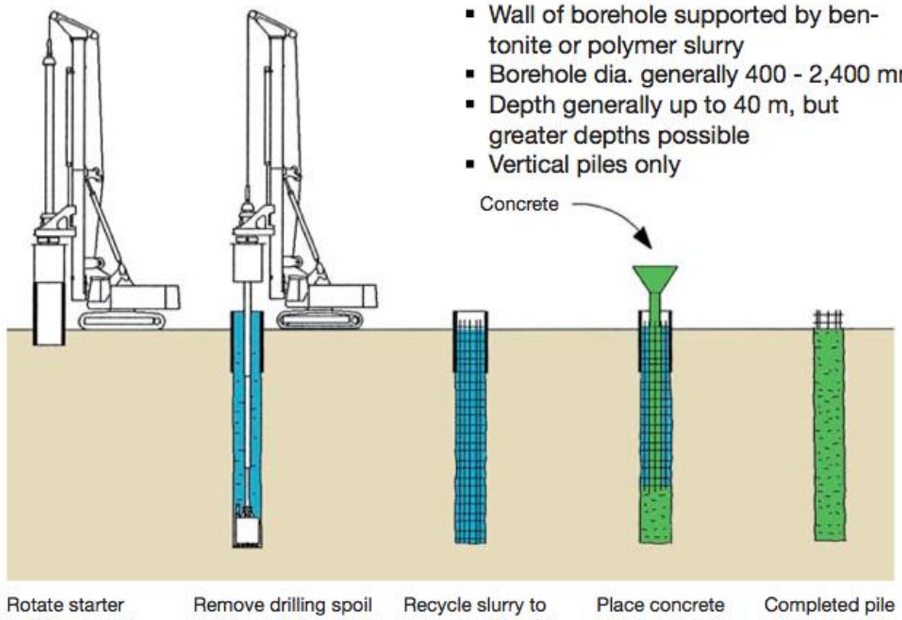




Standard cast-in-place pile

Main applications:
- In all kinds of soil, for large pile diameters and pile depths

Special features:
- Vibration free drilling
- No casing required
- Starter casing used for top section only
- Wall of borehole supported by bentonite or polymer slurry
- Borehole dia. generally 400 - 2,400 mm
- Depth generally up to 40 m, but greater depths possible
- Vertical piles only



Rotate starter casing to depth

Remove drilling spoil with bucket attached to kelly bar with borehole supported by slurry

Recycle slurry to remove soil and insert reinforcing cage

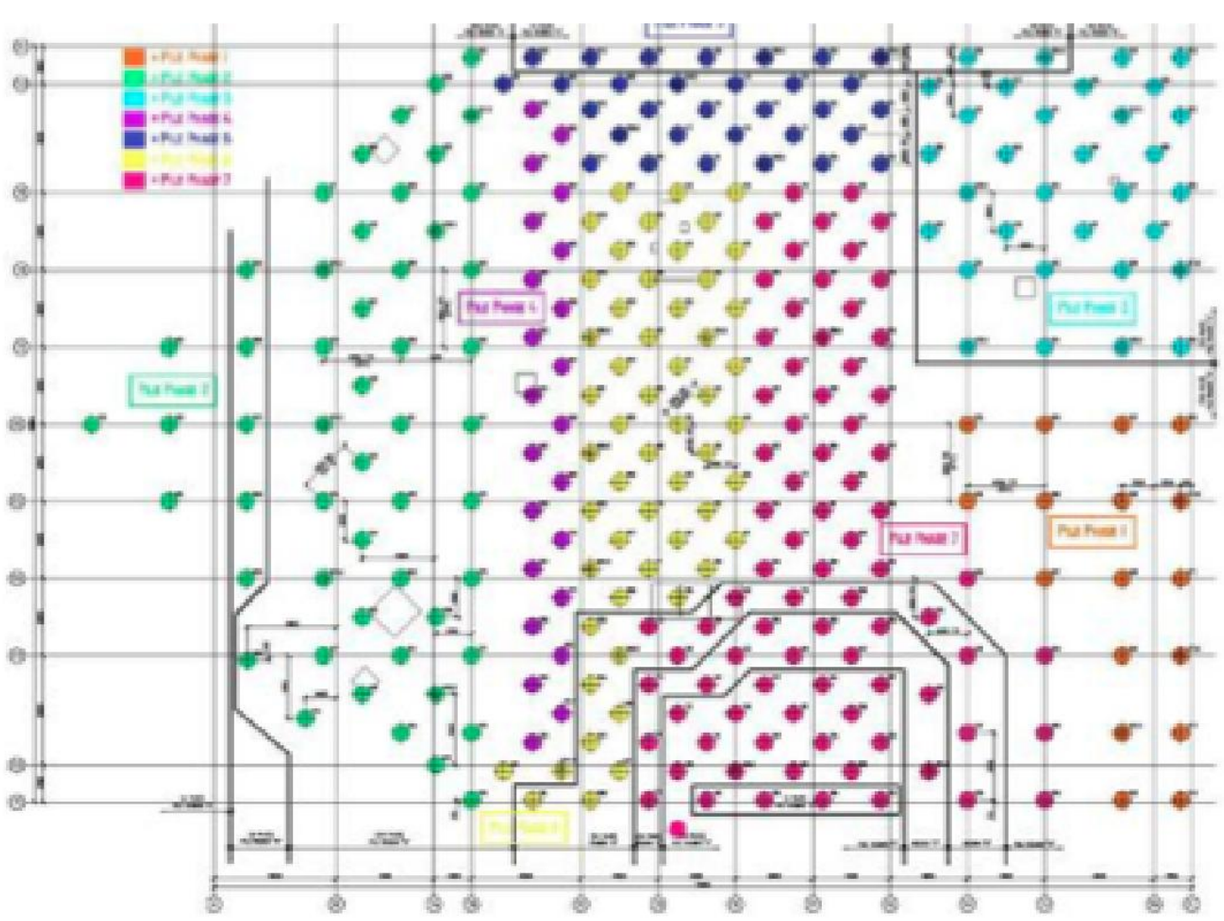
Place concrete simultaneously displacing slurry

Completed pile

PILE PHASING

- ADAPT TO SPIRALING FORM
  - ELIMINATE DIFFERENTIAL SETTLEMENT
  - DEPENDABLE FOR AREAS WITH FINE GRAINED SOILS
  - WITHSTANDS EROSION AND WASHOUTS
  - DEEPER PILES SPACED CLOSELY TOGETHER PLACED IN HIGH STRESS AREAS

- 289 PILES
  - EACH 66-89FT, RELEASED IN 7 PHASES



PILE CONSTRUCTION PHASING

ON SITE PILE LOAD TESTING

3-DIMENSIONAL NON-LINEAR ANALYSIS

-DONE BY SAN FRANCISCO OFFICE OF **URS CORPORATION (URS) & PROJECT GEOTECHNICAL ENGINEER (CONSULTANCY GROUP COMPANY) CGC**

- CALCULATED FOUNDATION SOIL STRATA & STIFFNESS ESTIMATIONS

- **URS** RESULTS:
- GROUP ACTION OF PILES
- PERIMETER PILES STIFFER
- SOIL CAUSED SKIN RESISTANCE TO BE DRUG DOWN

-**CGC** RESULTS:
- PILES ACTING INDIVIDUALLY
- ALL PILES HAD SIMILAR LOADS

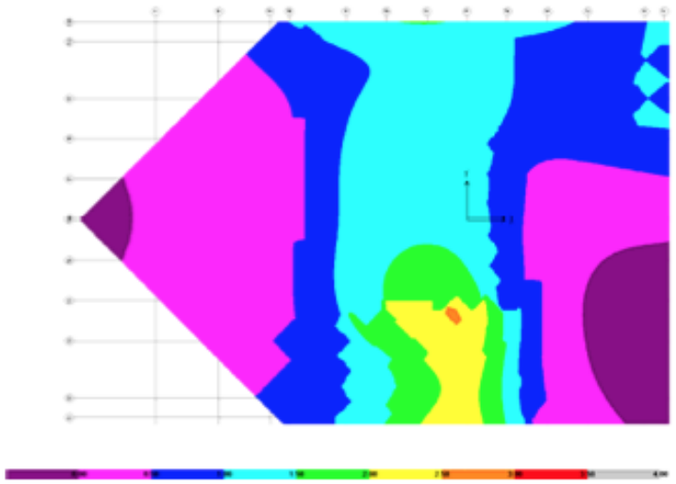


Fig. 7 Bearing Pressure (MPa) CGC Case 1

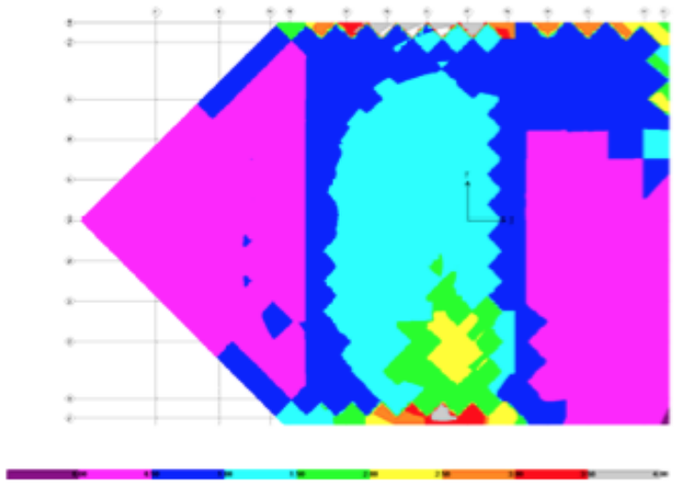


Fig. 8 Bearing Pressure (MPa) URS Case 1

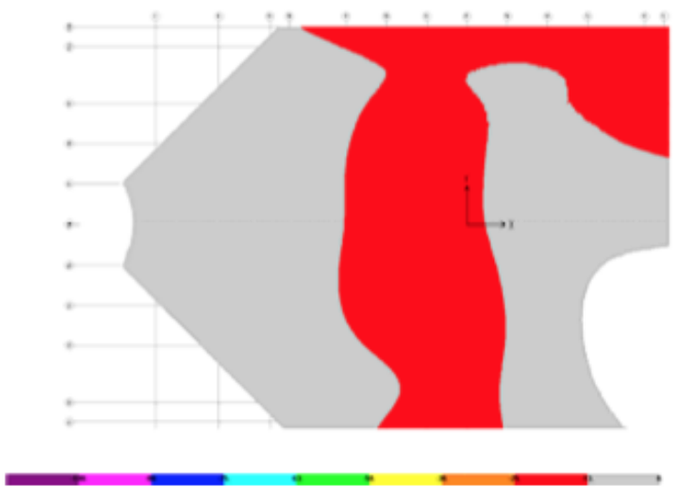


Fig. 9 Deflected Shape (mm) CGC Case 1

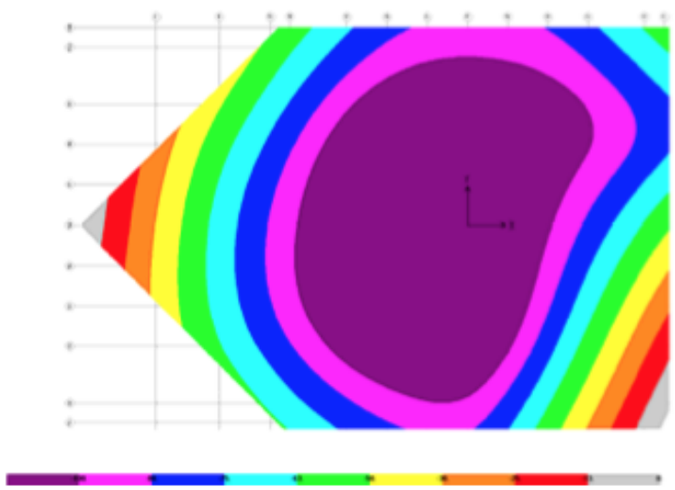


Fig. 10 Deflected Shape (mm) URS Case 1

LAMELLA STRUCTURE

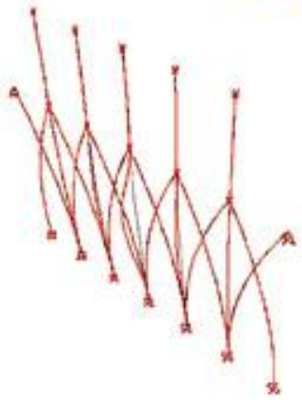
FOUR PART STRUCTURAL SYSTEM

1) PRIMARY LOAD BEARING COLUMNS
2) SECONDARY COLUMNS - REDUCE BUCKLING LENGTH
3) CURVED SIDEWAY MEMBERS
4) LATTICEWORK

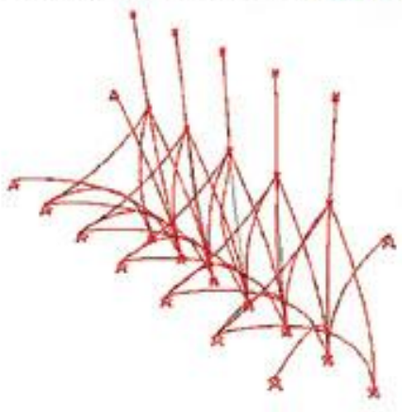
LOBBY LAMELLA BUCKLING ANALYSIS

BUCKLING CAPACITY: 25,000 KN

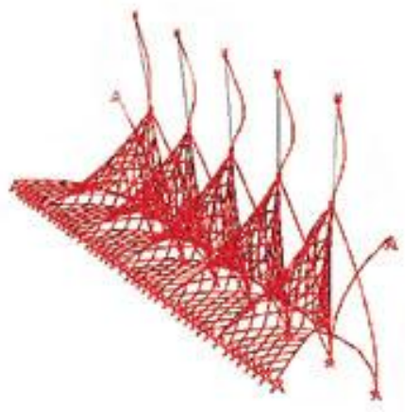
BUCKLING CAPACITY: 48,500 KN

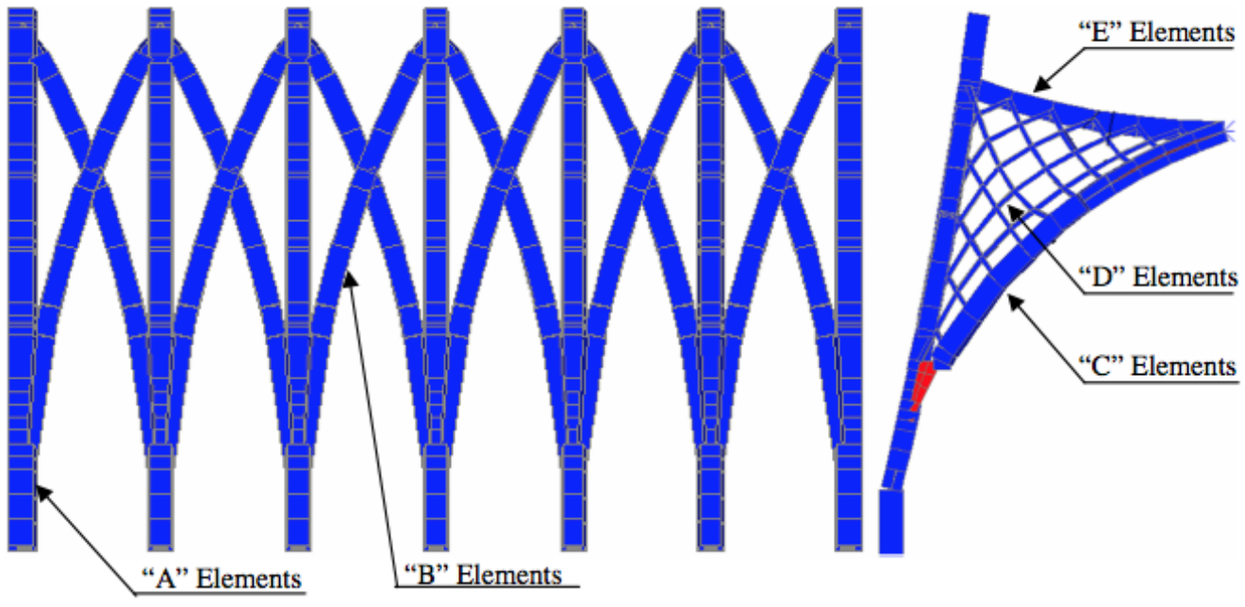


BUCKLING CAPACITY: 49,500 KN

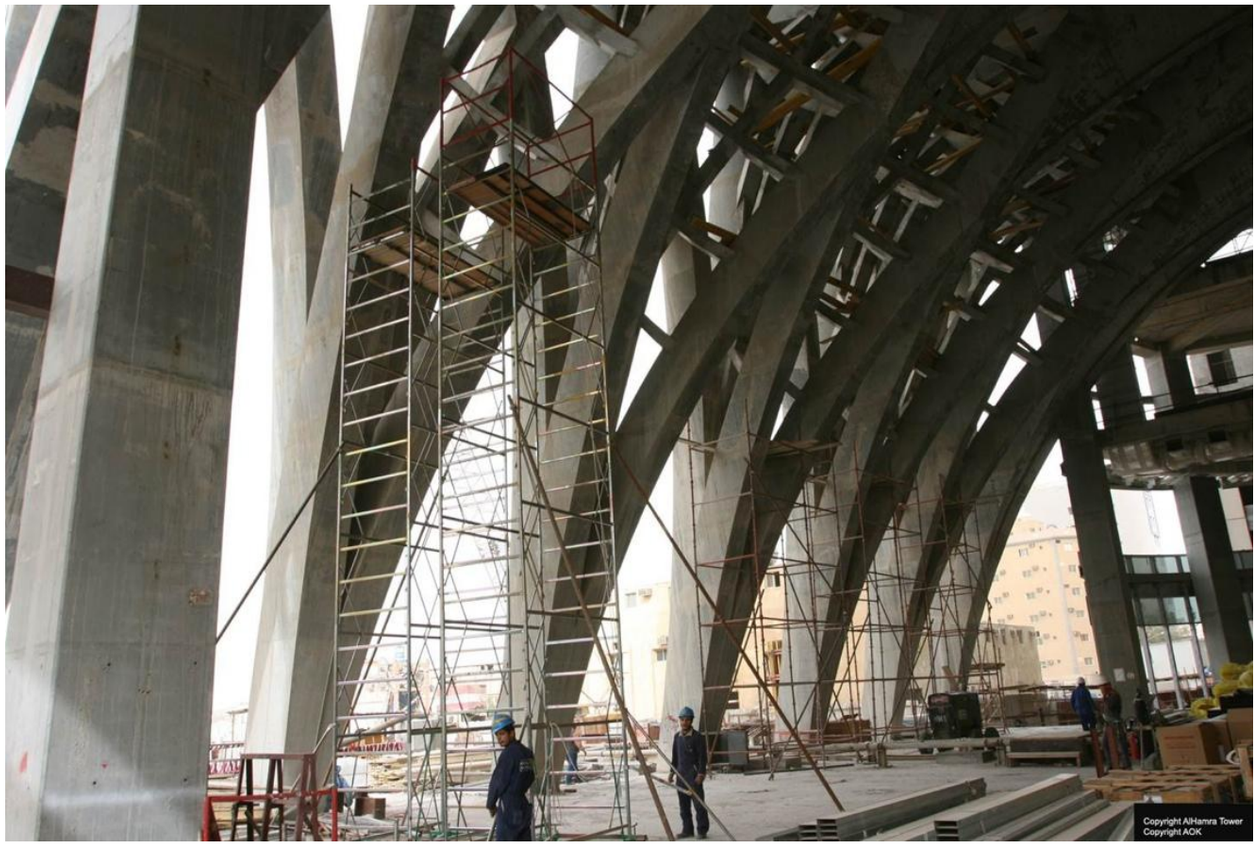


BUCKLING CAPACITY: 189,000 KN

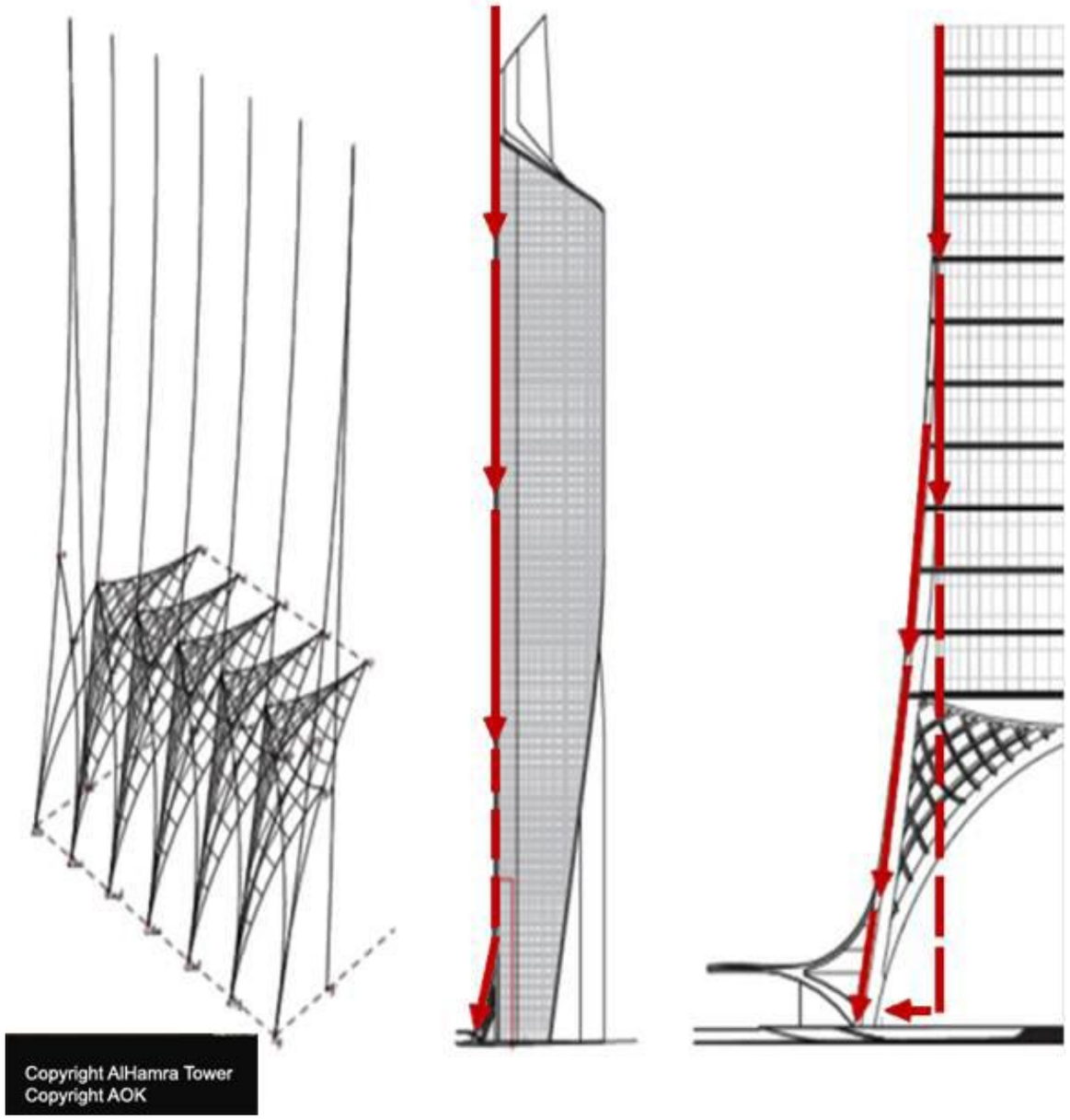




LAMELLA ELEMENTS



LAMELLA UNDER CONSTRUCTION

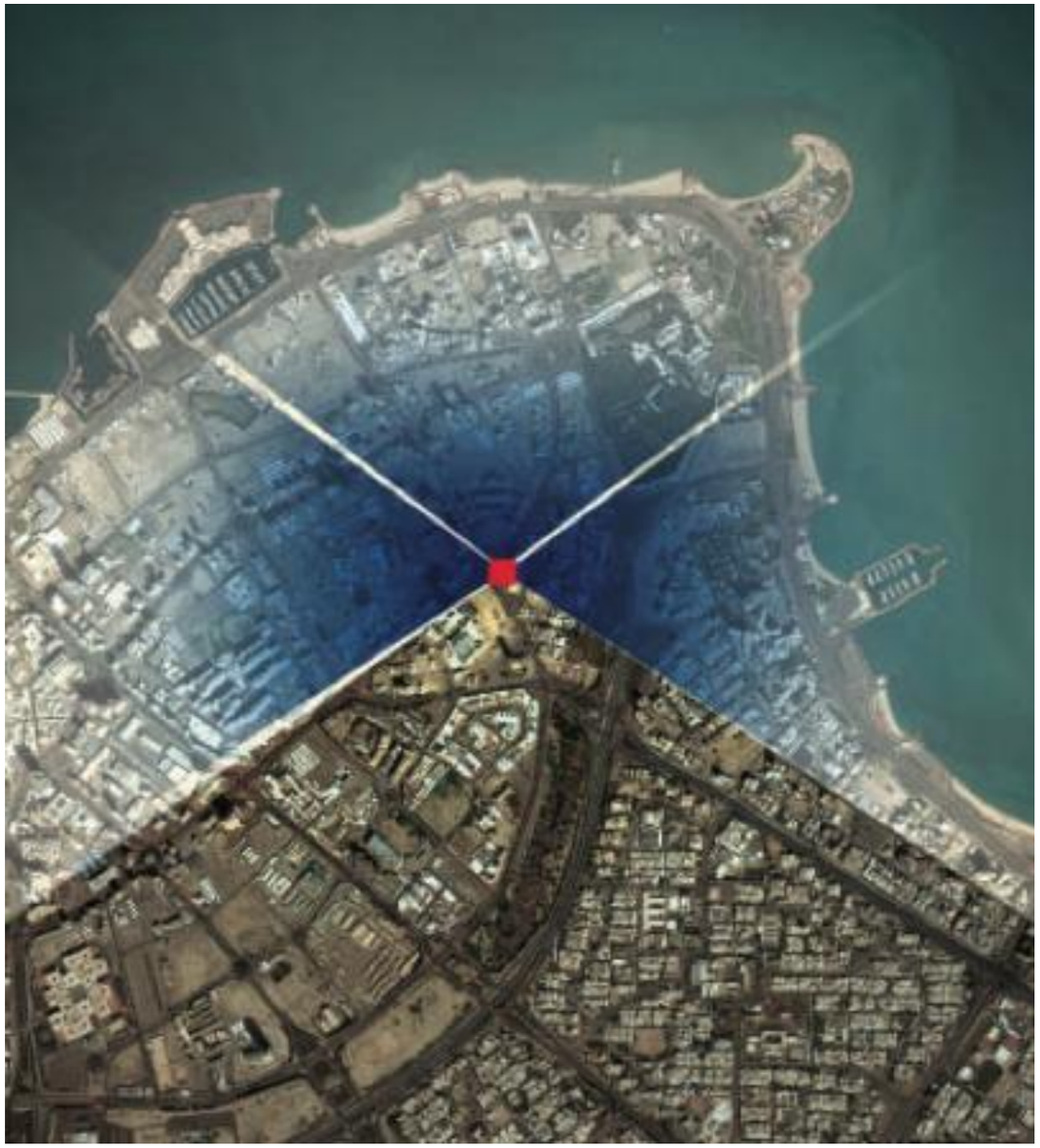


LAMELLA LOAD DISTRIBUTION

SOM RENDERING

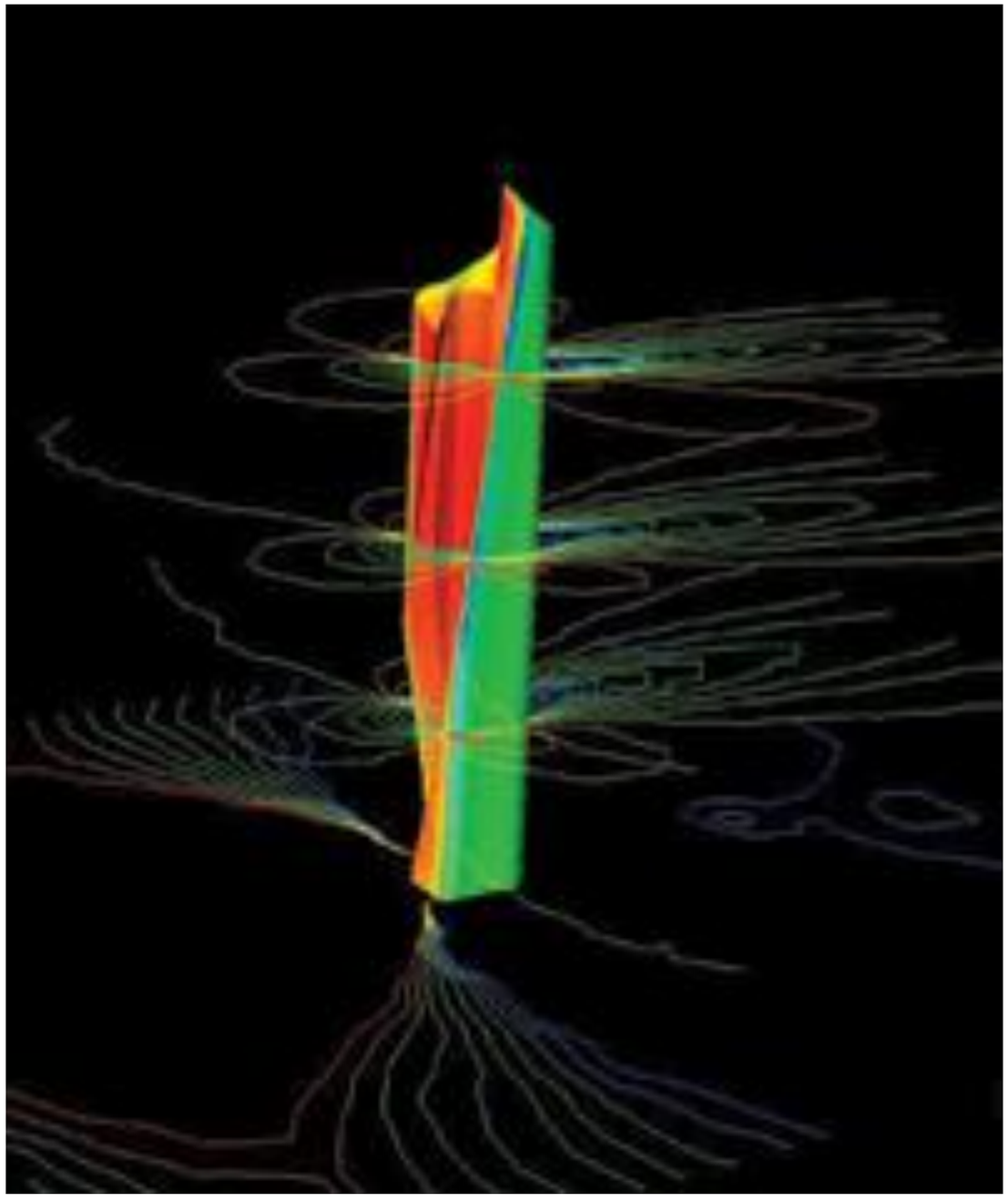
LATERAL LOADS

- IN A REGION OF LOW SEISMIC ACTIVITY
- WIND FORCES ARE PRIMARY LATERAL LOADING
  - AIR MASSES FROM GULF CAUSE BRIEF AND POWERFUL WIND DOWNBURSTS
  - ESTIMATED WIND SPEED: 23 M/S
  - WIND LOADS NOT CRITICAL ABOVE 150 METER ELEVATION

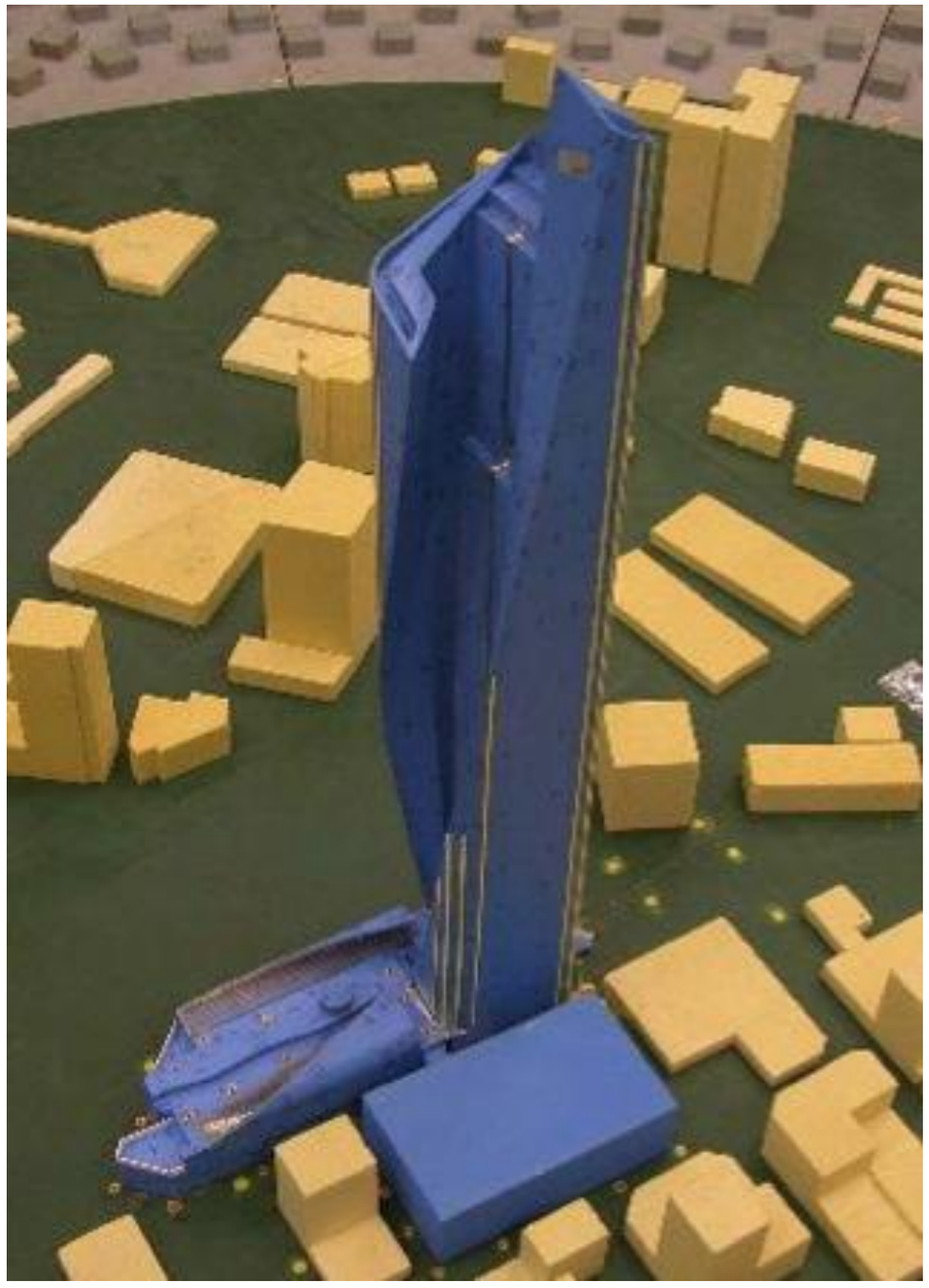


CLOSE PROXIMITY TO PERSIAN GULF = COOL PREVAILING WINDS THAT COLLIDE WITH WARM DESERT AIR AND CAUSE THUNDERSTORMS

LATERAL LOADS



AIR FLOW STUDIES



WIND TUNNEL STUDY MODEL

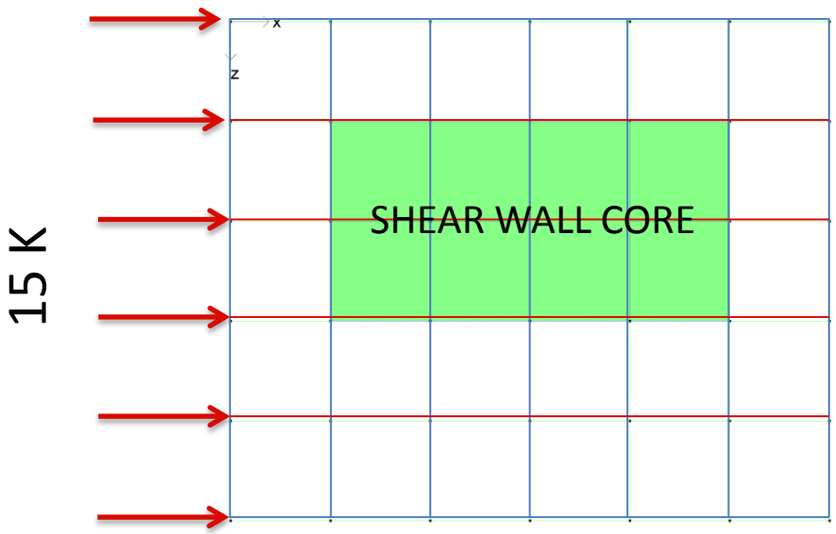
LATERAL RESISTING SYSTEM

- "CAST-IN-PLACE REINFORCED-CONCRETE **SHEAR WALL CORE** SUPPLEMENTED BY A PERIMETER MOMENT-RESISTING FRAME"
- CORE ALSO RESISTS SEISMIC LOADS
- MOMENT RESISTANCE FROM CAST-IN-PLACE FRAME BEAMS

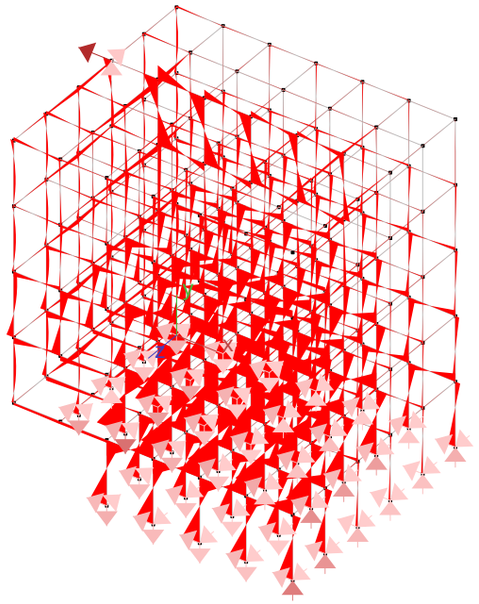
SHEAR WALL CORE

PERIMETER FRAME ON EACH FLOOR

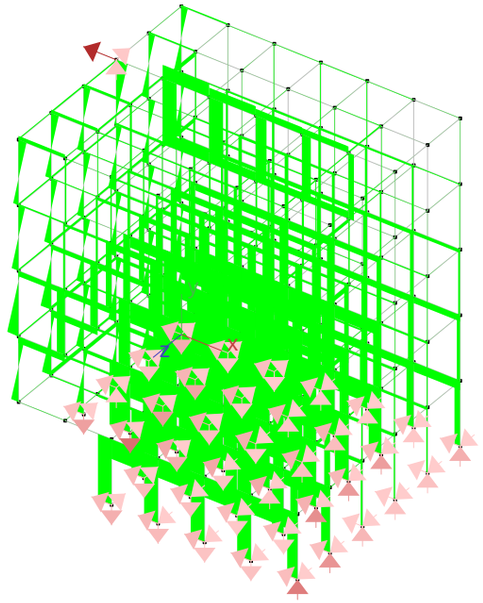
MULTIFRAME ANALYSIS



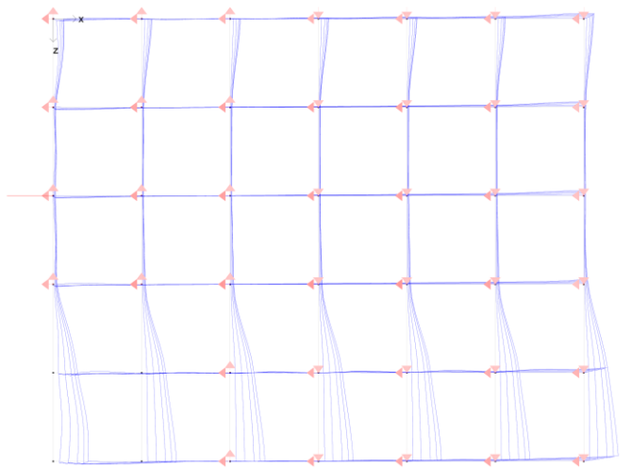
PLAN VIEW OF BUILDING WITH DIST. LATERAL LOADS



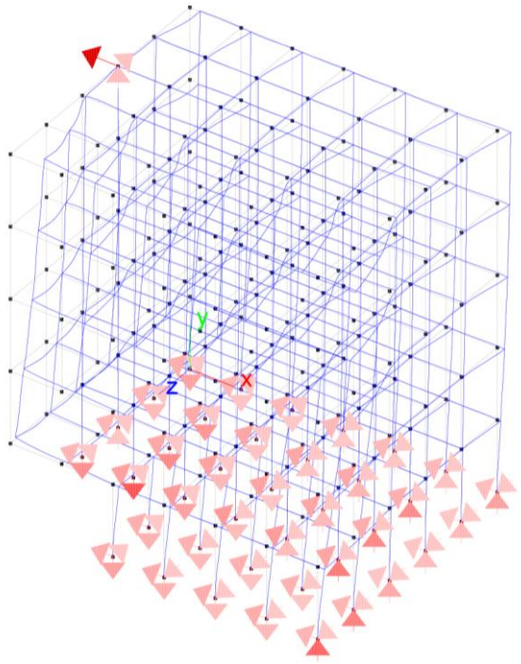
AXON MOMENT DIAGRAM



AXON SHEAR DIAGRAM



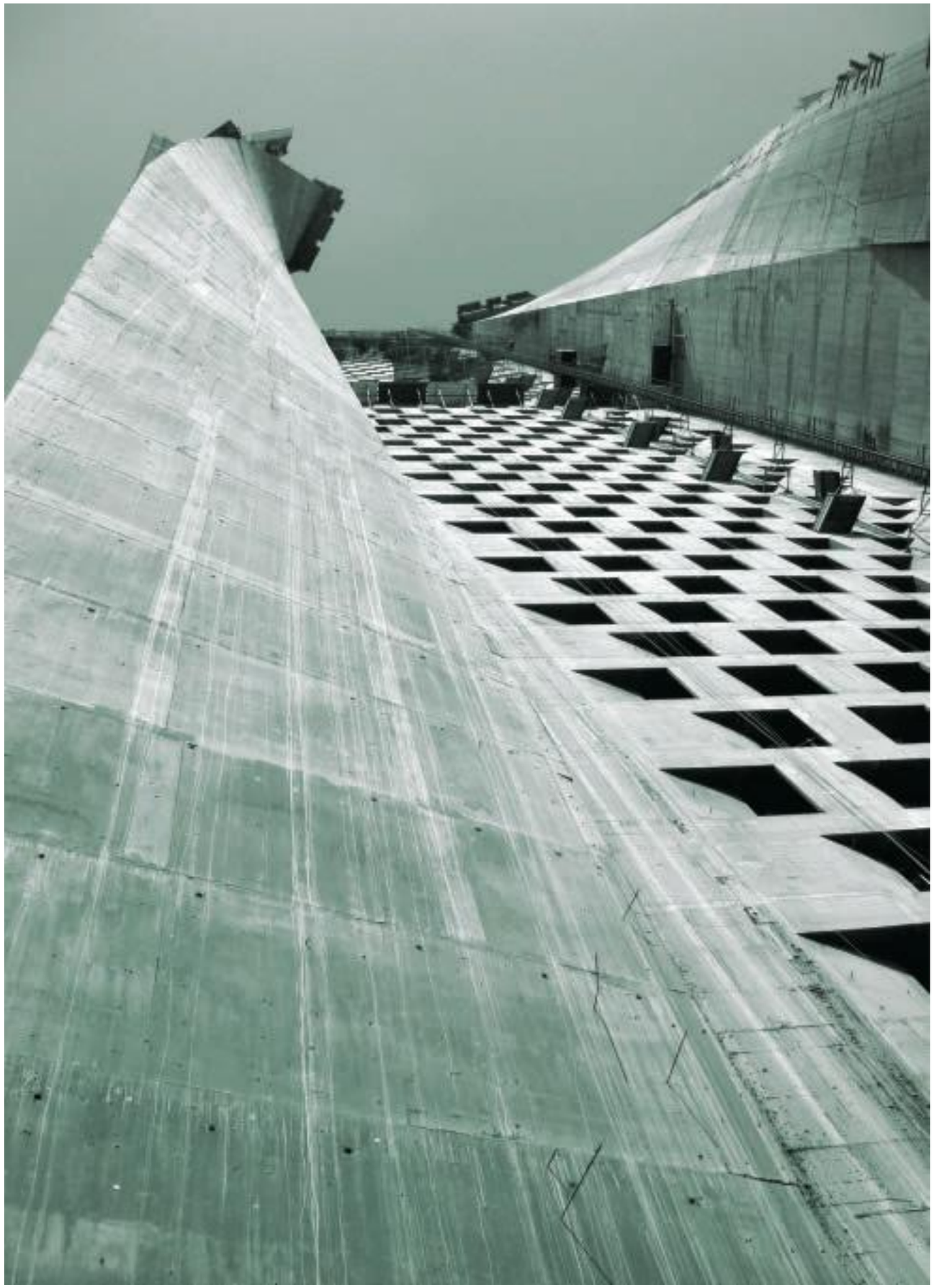
PLAN VIEW OF DEFLECTIONS



AXON DEFLECTION DIAGRAM

CONNECTIONS

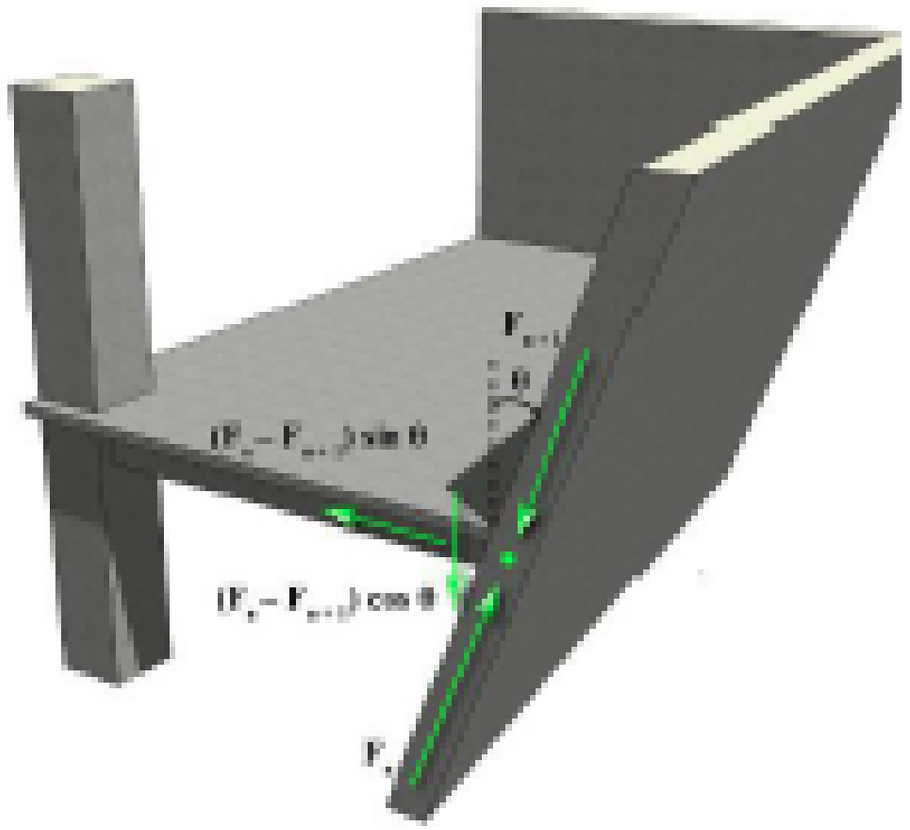
- reinforced concrete and structural steel.
- monolithically cast concrete
- Connections are rigid



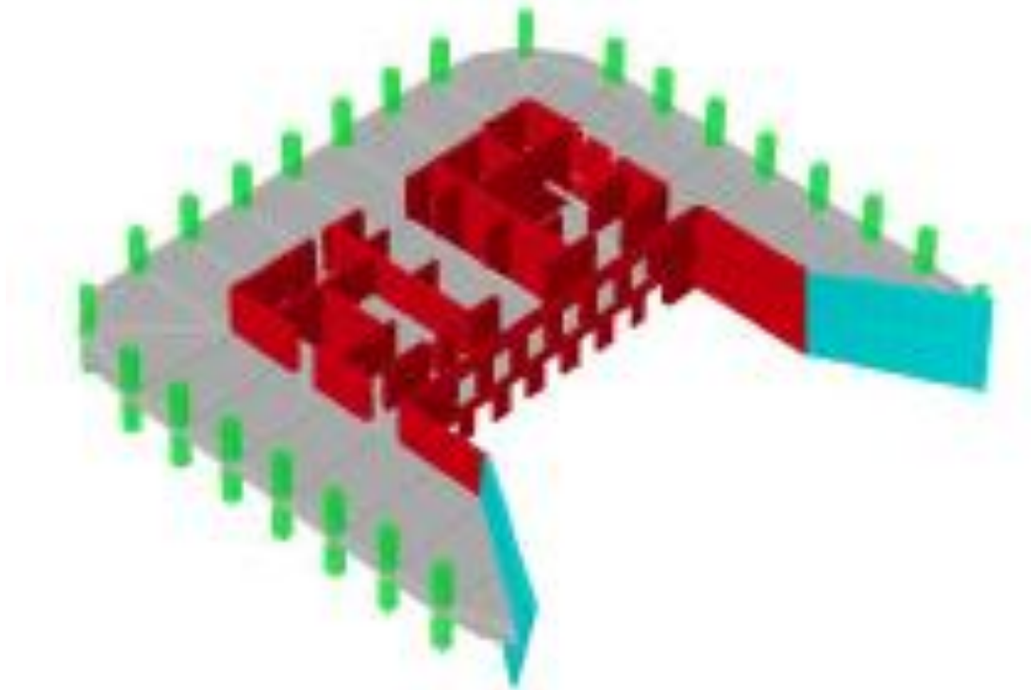
TORSIONAL RESPONSE DUE TO GRAVITY LOADS

- “flared walls” require the gravity load support
- Torsional gravity load applied to core of the structure require considerations of the long-term vertical and torsional deformation of the structure
- Southeast flared wall leans into the building
- Southwest flared wall leans away from building

- Inclined columns and walls support floor framing
- Slabs add gravity loads to inclined components, and the vertical load is increased.
- Horizontal element of force in the inclined component must increase along with the vertical component.
- Slab must apply a horizontal load to the intersection.
- Inclined components slant away from slab = tension
- Inclined components slants toward slab = compression
- Resolution static equilibrium
- Net torsional moment



Static equilibrium at flared wall



Floor analysis model

Sarkisian, Mark, Aybars Asci, Neville Mathias, and Aaron Mazeika. “Sculpting a Skyscraper.” *Civil Engineering* September 2012: 52-61. Print.

Agarwal, R., N. Atari, L. Hu, N. Mathias, A. Mazeika, M. Sarkisian. “Sculpted High-rise, The Al Hamra Tower.” *Structural Engineers World Congress* November 2007: 1-17. Print.

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