Al Hamra Tower Survey & Monitoring

FIG 2012 High Rise Conference in Hong Kong
The Al Hamra Tower is a topped out skyscraper in downtown Kuwait City, Kuwait.

Designed by architectural firm Skidmore, Owings and Merrill.

It is the tallest building in Kuwait on completion in 2011 at 414 m (1,358 ft).

The tallest sculpted tower in the world.
Unique Geometry Design

Twisting core walls

Innovative design includes a facade with a 130-degree sweeping turn and two fins that sprout from the top and bottom of the structure in opposite direction.
Lamella Structure

20m-tall highly articulated lamella structure on ground lobby,

The geometry of the lobby area is generated by applying the principles of lamella structures. The continuous structure acts as a completely integrated strengthening component in the lobby, while creating a dramatic lobby experience for Al Hamra's visitors.
Lamella Structure

The geometry of the lobby area is generated by applying the principles of lamella structures.
Project Features

Foundation

Maximum pile diameter 1200mm
Spacing 3600mm center to center

Concentrated gravity load to the mat foundation at the southwest flared wall
Climate

Altitude; 55 m (180 ft).
The average temperature in Kuwait City, Kuwait is 25.8 °C (79 °F).
The range of average monthly temperatures is 24 °C.
The warmest average max/ high temperature is 45 °C (113 °F) in July.
The coolest average min/ low temperature is 8 °C (46 °F) in January.
Mean relative humidity for an average year is recorded as 55.3% and on a monthly basis it ranges from 41% in July to 65% in December.
Hours of sunshine range between 7.0 hours per day in December and 11.0 hours per day in August.
On balance there are 3347 sunshine hours annually and approximately 9.2 sunlight hours for each day.
Core Wall & Columns

Thickness and Strength;

Core Wall Lower Floors
Thickness 1200mm – 700mm
Concrete Strength C70- C80

Core Wall Mid Floors
Thickness 1000mm-700mm
Concrete Strength C70- C60

Core Wall High Floors 600mm
Thickness start from 600m – 450mm
Concrete Strength C50

Columns
Start from 1200mm to 700mm top
Project Features

Tower Crane Placing Boom

Two Tower Crane;

Every 3 Floors climbing by hydraulic pump, fixed on main Core Wall.

Two Placing booms, climbing together with the PERI ACS platforms Fixed on main Core Wall.
Technology

Concrete pumping system ; Putzmeister

Self rising formwork system ; Perri

High speed elevator ; Hitach

GNSS survey system and monitoring system ; Leica Geosystems

Steels ; Kharafi
6000 tons of structural steel

The tallest stone clad structure on earth
258,000 square meters of limestone

Wuhan Curtain wall

Auto window cleaning system
Survey & Monitoring; BM (Bench Mark)

**Offsite BM**

**Ground BM:**
4 Original BMs from Municipality, established 6 BMs altogether between 30-450m range

**Building BM:**
Set on the top of the Vicinity Buildings,
Survey & Monitoring; BM (Bench Mark)

Onsite BM

Ground Floor Tower Mat;
4 ground mat TPs

Parking;
2 TPs on the parking top floor
2 TPs on the parking ground

Shopping Mall;
2 TPs on the Mall top floor
Visible CP from offsite

Periodically updated;
Monthly base in the beginning of the project
Bi-monthly in mid after
CORS

Located in the low building top; Analysis the 24 hours data, verifying signal quality and availability
GNSS BM – Coordinate Transformation

GNSS system references to WGS84 Global coordinate system

Building site references to local coordinate system
Construction procedure

Core Wall constructs 3-4 floors above the slab level.

Slabs follow up core wall construction and column by beams.

Columns are elected after slab construction.
Survey & Monitoring; Core Wall Survey

Core Wall
Concrete Pouring Cycle

7 Days cycle

Day 3
East Core Wall pouring

Day 5
West Core Wall pouring

Day 7
Flare Walls and South Wall N pouring
Survey & Monitoring; Core Wall Survey

Core Wall Ref setting out

GNSS active control points setting on the core wall

GNSS observation as kinematic mode

Total station set up in stable location

Survey active points and core wall as-built in dummy mode.
### Survey & Monitoring; Core Wall Survey

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<th>Theoretical design coords</th>
<th>As Built coords (162m)</th>
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Survey & Monitoring; Core Wall Survey
Survey & Monitoring; Core Wall Survey

Flare walls

Last stage of the core wall concrete pouring.

Survey Base plate form; East, West, and N wall

Linear calculate in each floor, most critical survey and monitoring part of the project.
Survey & Monitoring; Slab

**Slab**

Following 3-4 Floors below level from the core wall.

**PERI SKYDECK Formwork**

Steel beams 400x400mm beams, Linking core walls and columns

Typical floor 4.2m heights 200mm thickness

Reference to the grid line and level marked on the previous slab and columns.

Survey sleeves are installed in this stage.
Survey & Monitoring; Slab

**Slab**

4.2m Typically floors

5.6m Mezzanine floors (Mechanical Floors)

11.0m High intermediate floors

21.5m Sky lobby above 75F
Survey & Monitoring; Columns

Columns

Following 3-4 Floors below level from the core wall.

Constructed after slab

Marked reference line on the concrete slab

Single pouring in 4.2m typical height, multi pouring in high floor

Start from 1600mm to 700mm top
Survey & Monitoring; Curtain Walls

Curtain Walls

Reference marked on the slab edge

Every 50m marking and put plumb steel line.

Install steel beam in high floor to support curtain walls
Survey & Monitoring; Curtain Walls
Roof

Set out reference mark on the slab and elect columns.

Set accurate columns’ position and level as the reference of the beams and slabs on them.

22m- High floor

Complicated Steel and Concrete beam Roof Structure.

Auto Curtain Wall Cleaning Machine Track.
Survey & Monitoring; High Speed Elevator

**Elevator**

Reference marked on the slab edge

Marking top and put plumb steel line.

Stabilization the plumb in the oil, and then tie and fix in certain floors.
Survey & Monitoring; Compensation program

**Horizontal compensation**

The design coordinate shall be adjusted by the compensation program.

Each floor setting out shall be away and set and then the coordinate shall be expected to come back to design location.

The regular monitoring survey data shall be reviewed to adjust more or less the dx, dy compensation value.

All the compensation and monitoring survey shall be reference to the neutral condition of the structural element.

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**Superstructure Torsional Compensation**

**Correction of Rotational Alignment of Superstructure Floors Above and Beyond Specified Design Alignment**

<table>
<thead>
<tr>
<th>Correction Level</th>
<th>Alignment of North/South Axis of Each Floor Slab at Time of Casting, Relative to the Project North/South Axis (Degrees/1000 – Positive Values Represent a Clockwise Correction Viewed from Above)</th>
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Survey & Monitoring ; Monitoring program

Horizontal Compensation

Theoretical line (Gravity)
As Built line
Adjusted Set out line
Structure Monitoring

Periodical Vertical (shortening) displacement monitoring

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<th>MONITORING PROGRAM</th>
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Survey & Monitoring; Monitoring program

**Level Compensation**

**Structural Element Vertical Compensation**

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<th>EXTERIOR COLUMN 1</th>
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**Tower Vertical Compensation Diagram**

**Tower Structural Elements Vertical Camber Schedule**

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<tr>
<th>TOWER LEVELS</th>
<th>CENTERLINE HEIGHT VERTICAL CAMBER PER FLOOR (mm)</th>
<th>TYPICAL TOWER VERTICAL CAMBER PER FLOOR (mm)</th>
<th>ASSUMED VERTICAL CAMBER OF STRUCTURAL SLAB AT DREAMING INTERFACE (mm)</th>
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**For Example:**

- \( \Delta_{1} = 10 \text{mm} \)
- \( \Delta_{2} = 25 \text{mm} \)
Survey & Monitoring ; Monitoring program

As Built Survey ; Core Wall & Columns

Survey 10 Core Wall and 14 Columns (for 2 points)

Survey all new element right after the new concrete is poured

Survey 3 floors (2 floor increments) at the same time until the exterior wall systems is completed to the top of the tower

Specified survey for each of the referenced levels shall continue on a monthly basis until the exterior wall systems is completed to the top of the tower, Level 4, 15, 26, 38, 50, 62, 73
As Built Survey ; Slab

Floor Slabs shall be surveyed immediately after concrete has hardened.

And after the formwork has been removed.

The slabs shall be surveyed for floor flatness and levelness for each level constructed.
Monitoring Survey; Extensometer

Install extensometers on the concrete of the core wall at 6 location on the following floors:

- Level 4
- Level 15
- Level 26
- Level 38
- Level 50
- Level 62
- Level 73

The reading recorded as per monitoring survey schedule and reported to structure engineer and consultant to review it.
Exterior columns shall be strain gaged to monitor Stress levels within the columns at specific levels within the structure, Level Gr, 4, 8, 12.

Strain gages shall be located at the following column locations:

T1/TF, T1/TE, T2/TB, T3/TA, T3-T9/Tb, T10/Tb, T11/TE (14 locations)

The strain gages shall be read immediately after installation at each of the specified floors and on a weekly basis until the exterior wall is erected to the roof level.
Foundation Monitoring

Periodical foundation mat monitoring

14 monitoring points on the basement foundation mat

Weekly base monitoring in the beginning of the project

Bi weekly and monthly base mid after.

Max settlement in red circle

Min settlement in green circle

Ground Floor to top level construction period, the total amount of the settlement are 85mm(max), 64mm(min). the uneven settlement is 21mm in 42m horizontal distance.
Dynamic monitoring

Real time Inclinometer; installed from the beginning to the end of the core wall construction

Accelerometer; Installed from the end of the project

Weather station; installed from the beginning to the end of the core wall construction
Real time monitoring solution for the building tilt

It shall drive the new parameter to evaluation the current the building condition with high frequency and statistic approach to analysis the structure.
Neutral position

Is the gravity line always the reference in any time and any condition at the moments of survey?
Survey & Monitoring; Monitoring program
Thank you very much for your kind attention