



# Al Hamra Tower Survey & Monitoring

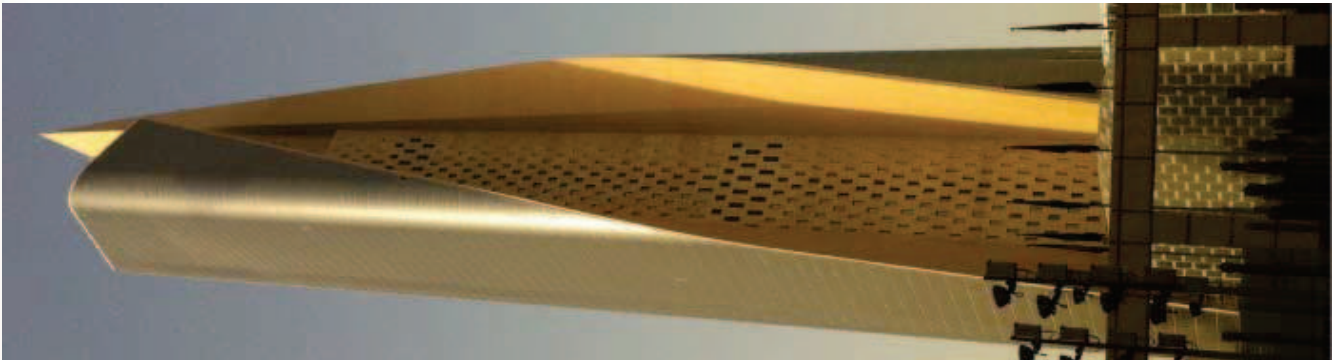
FIG 2012 High Rise Conference in  
HongKong

**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).**

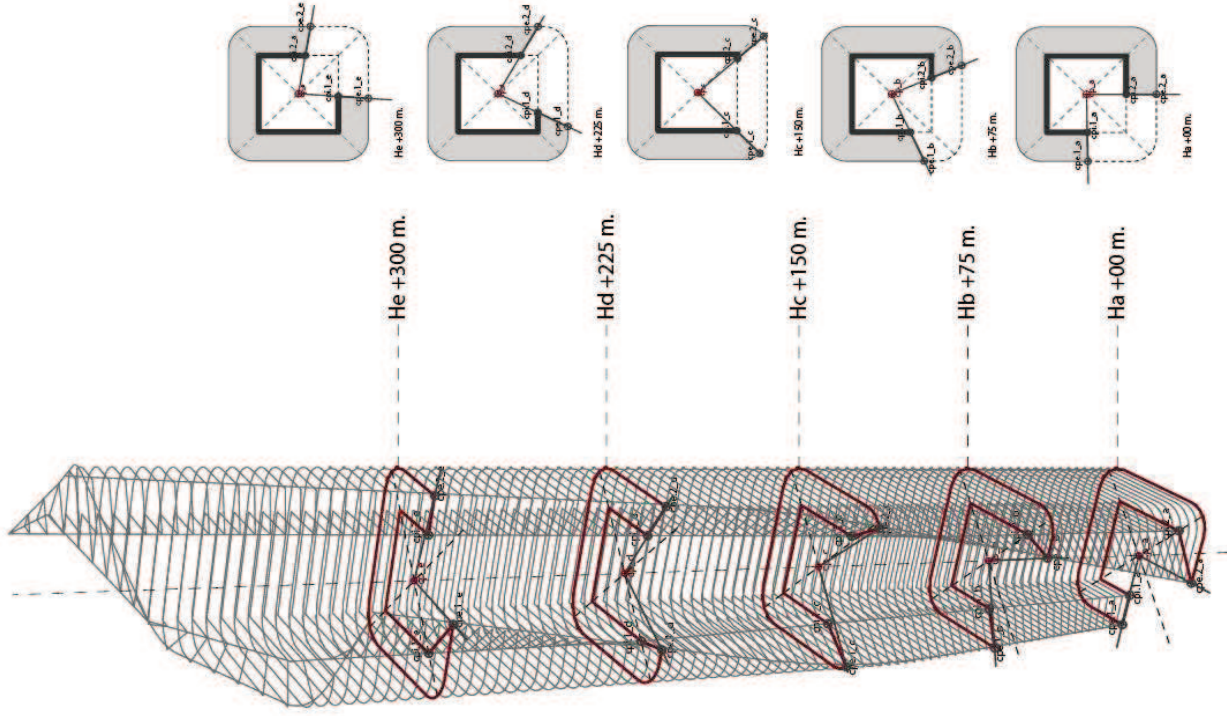
**The tallest sculpted tower in the world.**



## 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

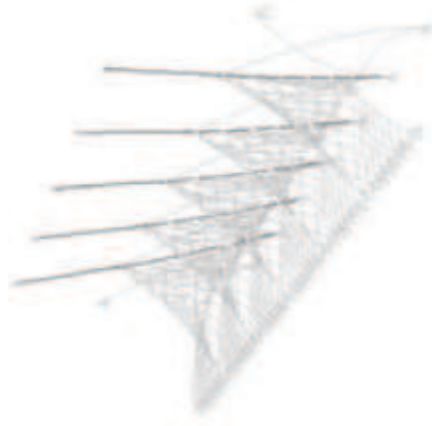
20m-tall highly articulated lamella structure on ground lobby,

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.

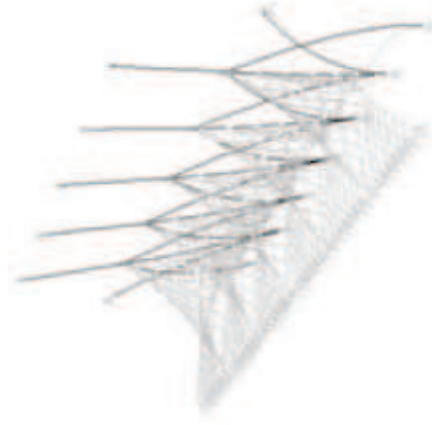


## Lamella Structure

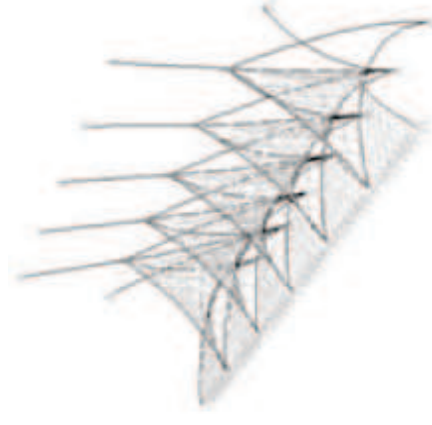
The geometry of the lobby area is generated by applying the principles of lamella structures



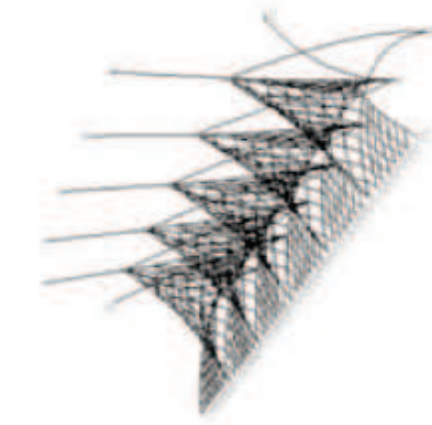
Model 1 - 41 Elements  
Column Demand: 98.000KN  
Buckling Load (Capacity): 25.000KN



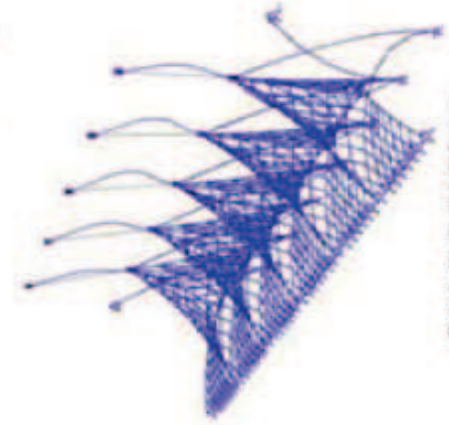
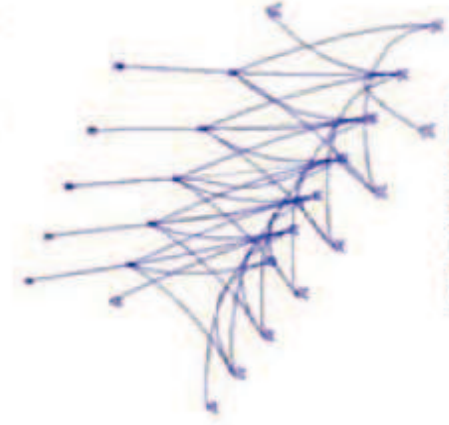
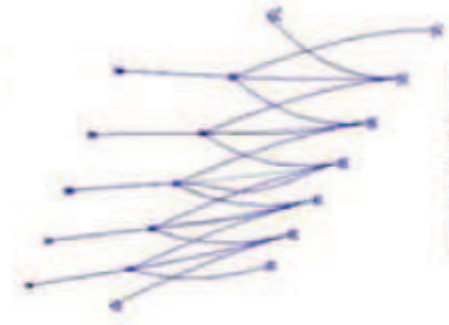
Model 2 - 48 Elements  
Column Demand: 98.000KN  
Buckling Load (Capacity): 43.000KN

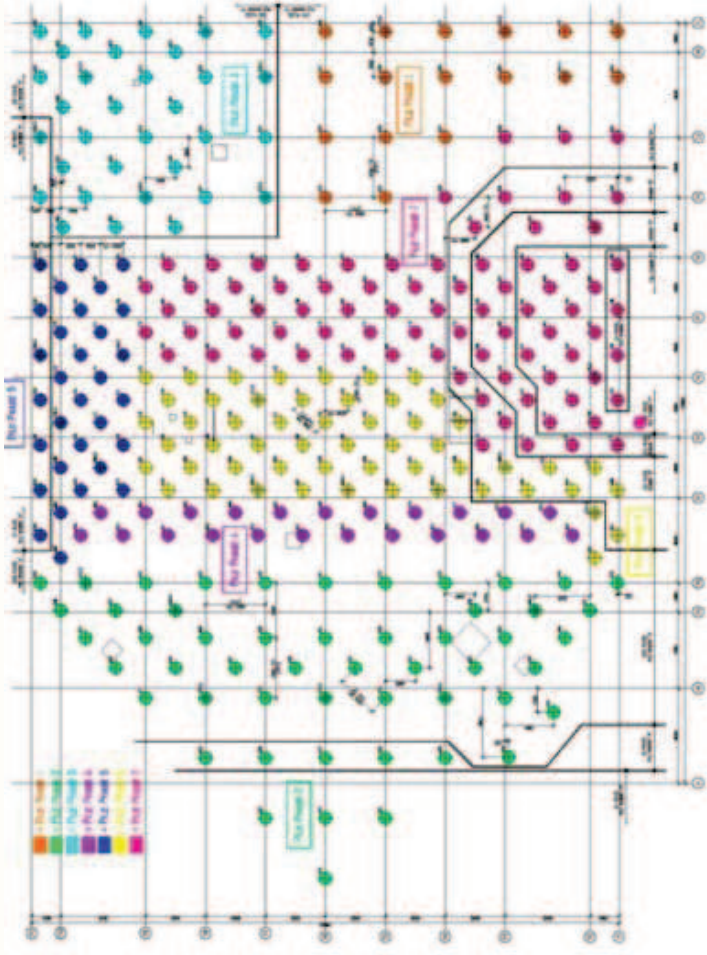


Model 3 - 56 Elements  
Column Demand: 98.000KN  
Buckling Load (Capacity): 48.000KN



Model 4 - 107 Elements  
Column Demand: 98.000KN  
Buckling Load (Capacity): 100.000KN





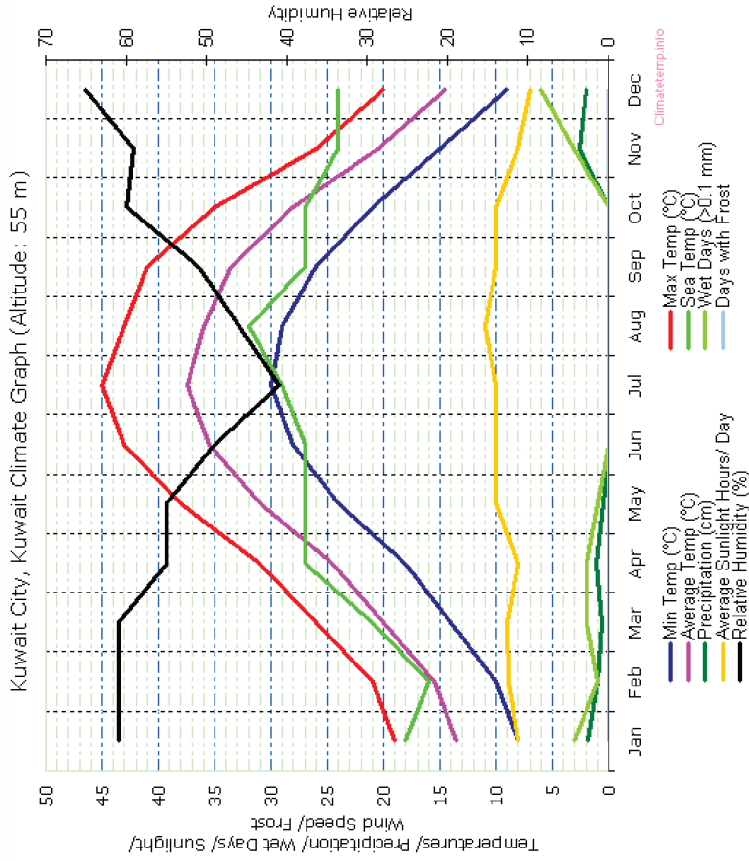
## Foundation

Maximum pile diameter 1200mm  
Spacing 3600mm center to center

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



# Project Features



## 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

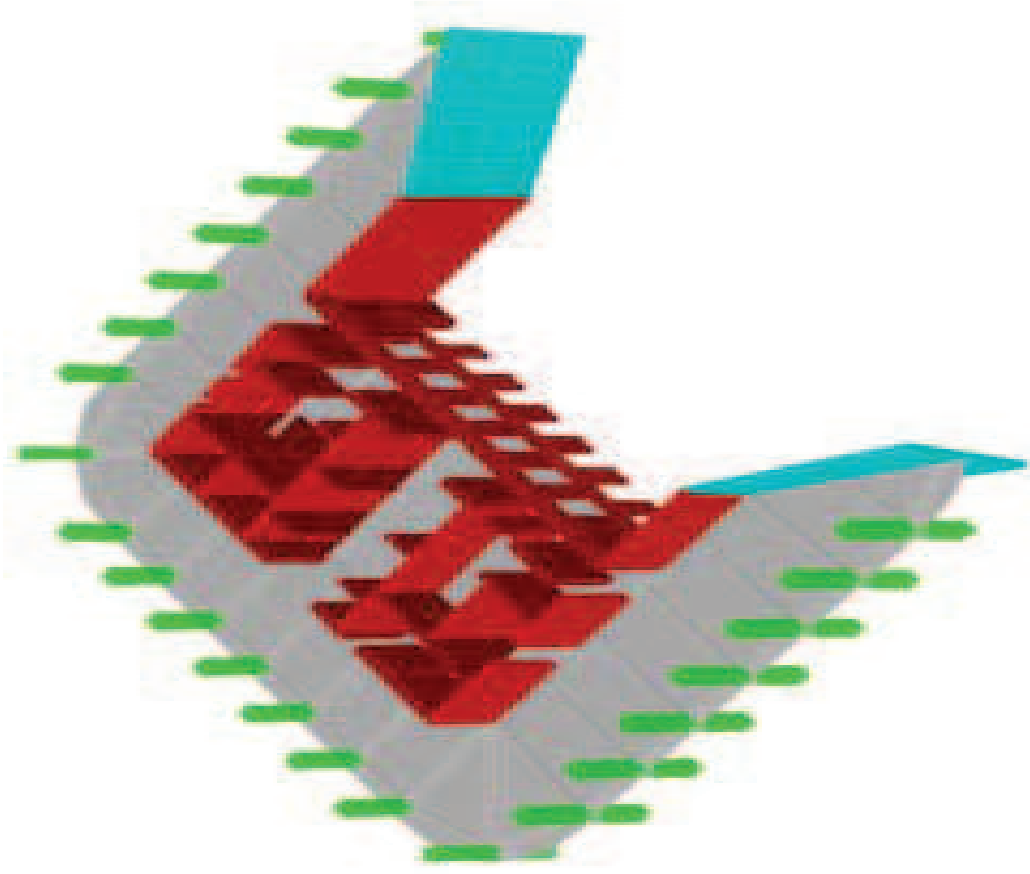
Thickness 1000mm-700mm  
Concrete Strength C70- C60

Core Wall High Floors 600mm

Thickness start from 600m – 450mm  
Concrete Strength C50

Columns

Start from 1200mm to 700mm top







## 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

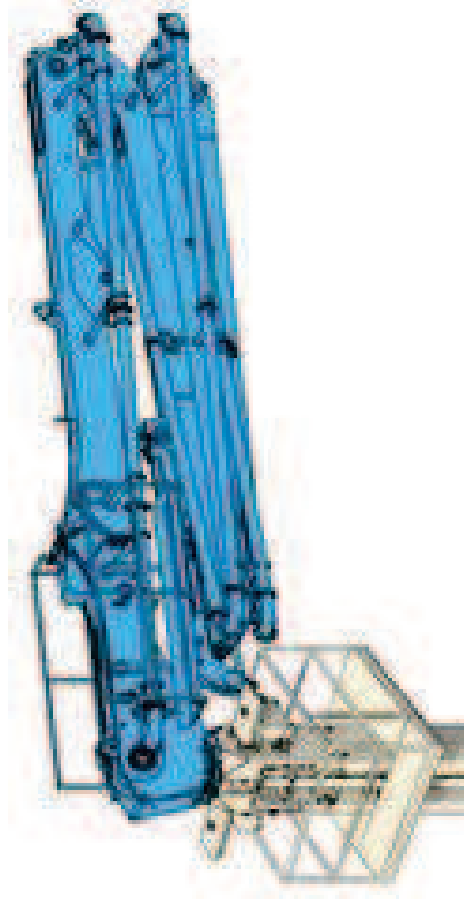
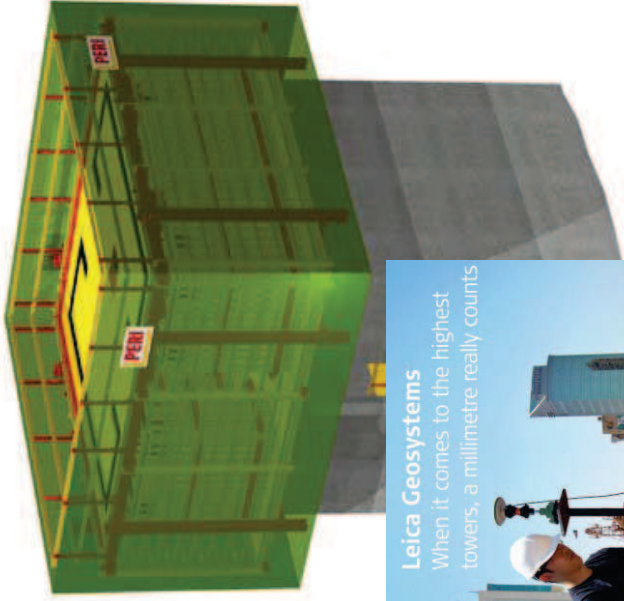
GNSS survey system and monitoring system ;  
Leica Geosystems

Steels ; Kharafi  
6000 tons of structural steel

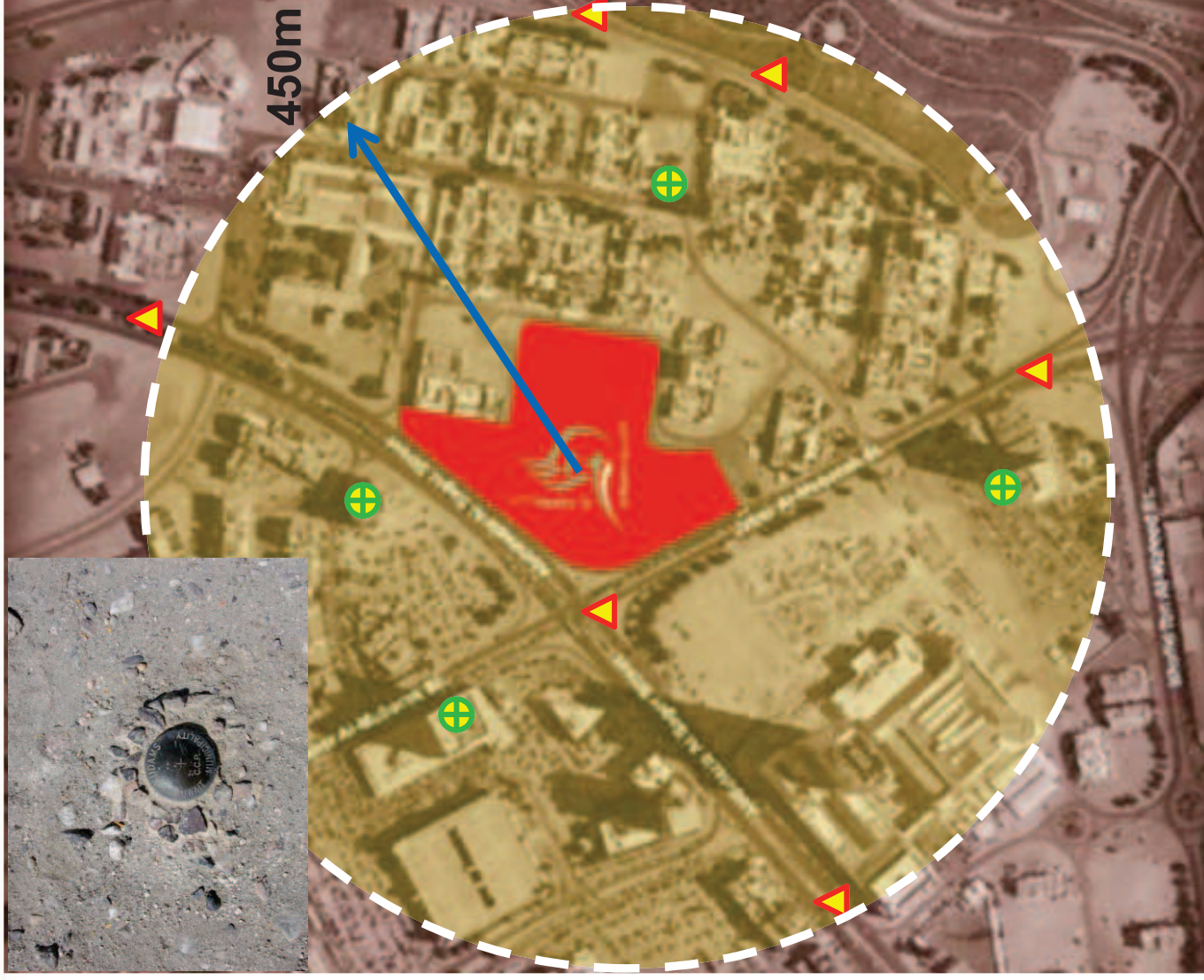
The tallest stone clad structure on earth  
258,000 square meters of limestone

Wuhan Curtain wall

Auto window cleaning system







## Offsite BM

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



**Building BM :**  
Set on the top of the Vicinity Buildings,





## 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

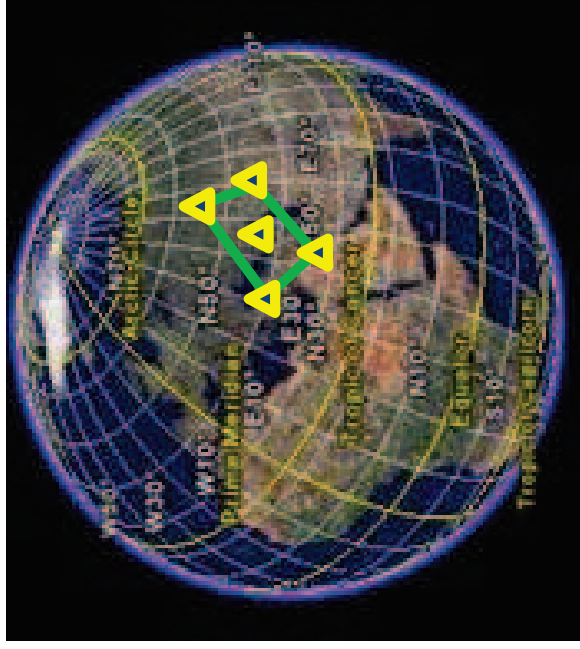
**Located in the low building top ;**  
Analysis the 24 hours data,  
verifying signal quality and  
availability



## GNSS BM – Coordinate Transformation

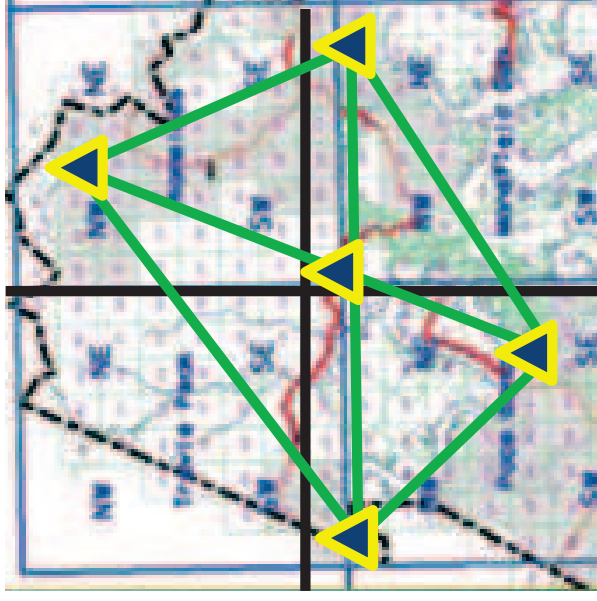
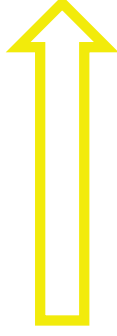
GNSS system references to WGS84 Global coordinate system

Building site references to local coordinate system

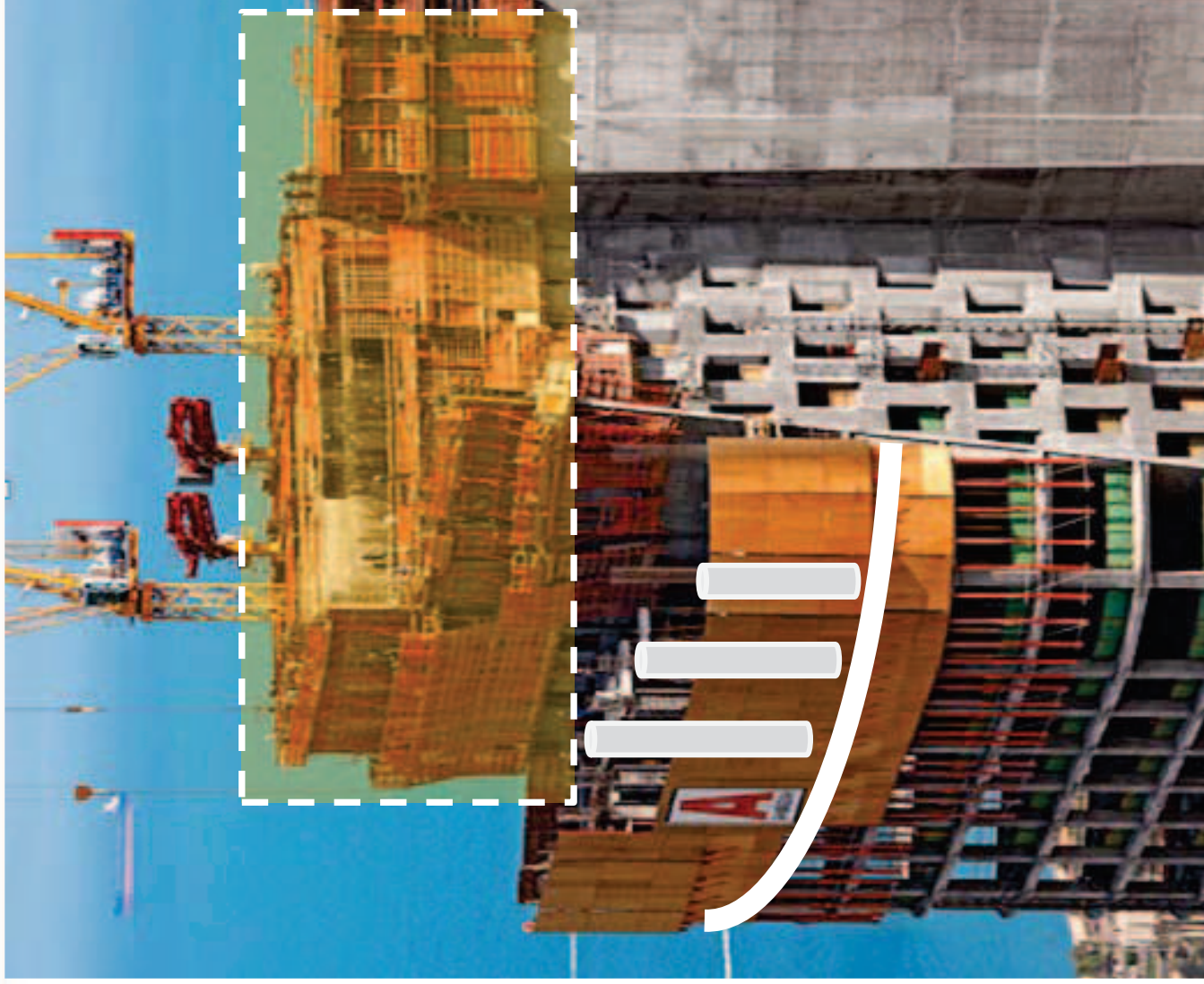


**GNSS WGS84 System**

Transformation



**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.

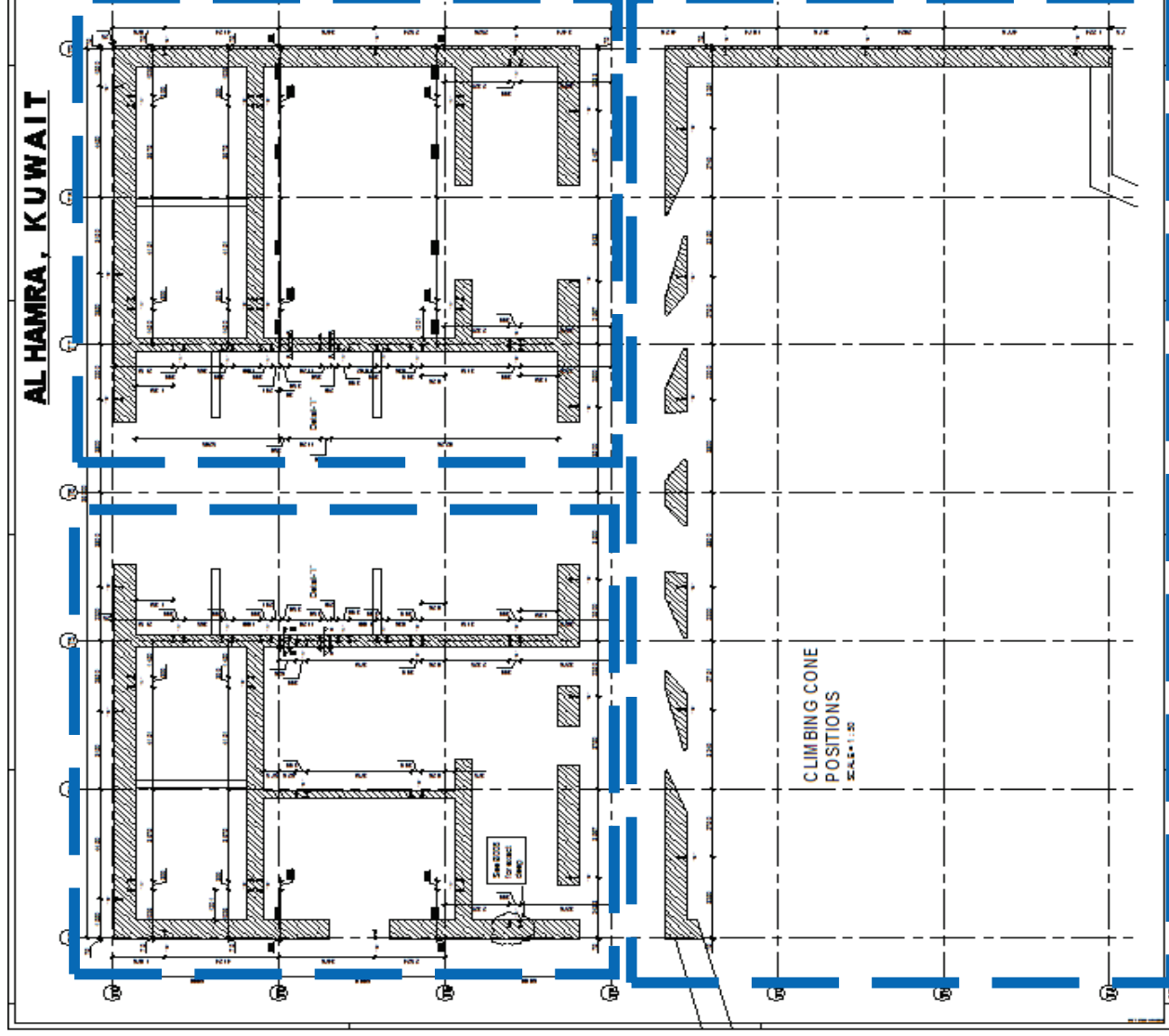
## Core Wall Concrete Pouring Cycle

7 Days cycle

Day 3  
East Core Wall pouring

Day 5  
West Core Wall pouring

Day 7  
Flare Walls and South Wall N  
pouring





## Core Wall Ref setting out

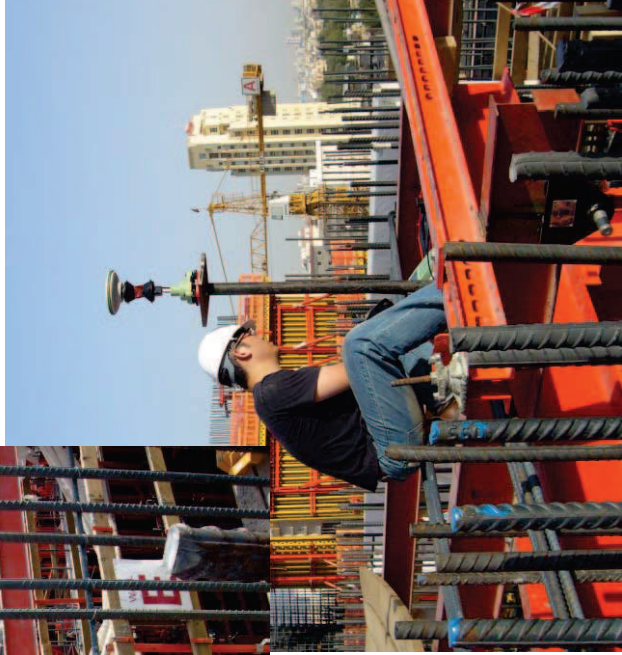


GNSS active control points setting on the core wall

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



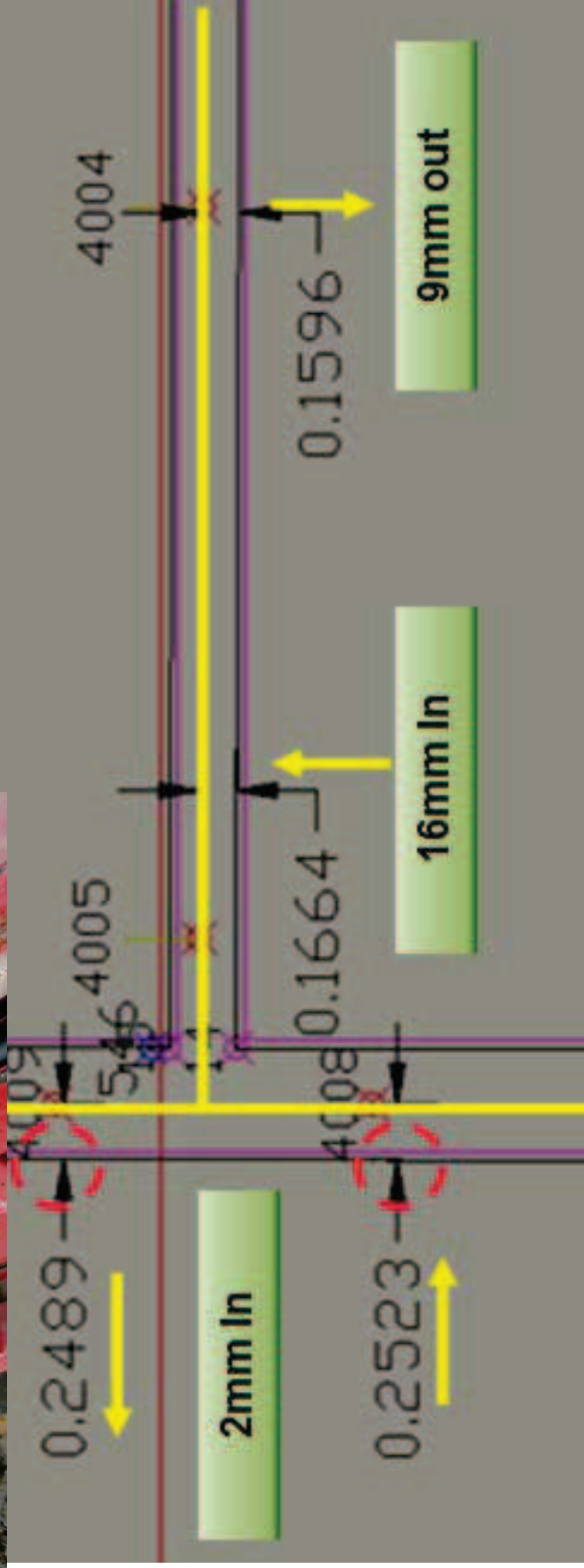
# Survey & Monitoring ; Core Wall Survey

Point ID	Theoretical design coords		As Built coords (162m)	
	X	Y	X	Y
SM	1.3410	-18.0750	1.3473	-18.0763
SN	2.3840	-29.6750	2.3944	-29.6759
SG	0.9010	-18.0750	0.9073	-18.0764
SK	1.4430	-29.6750	1.4534	-29.6762

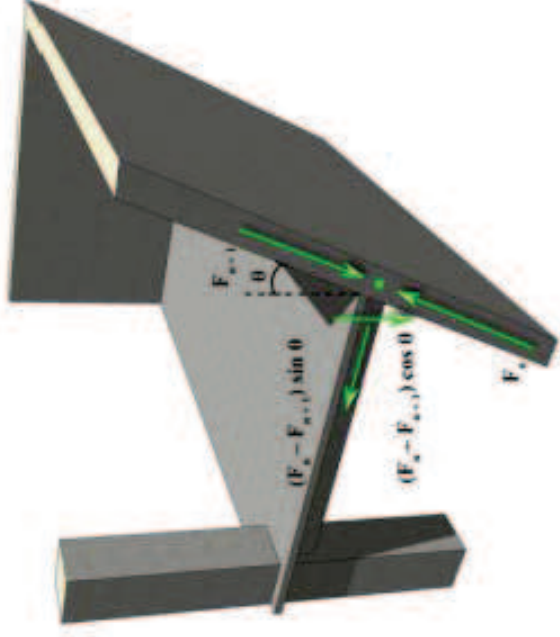
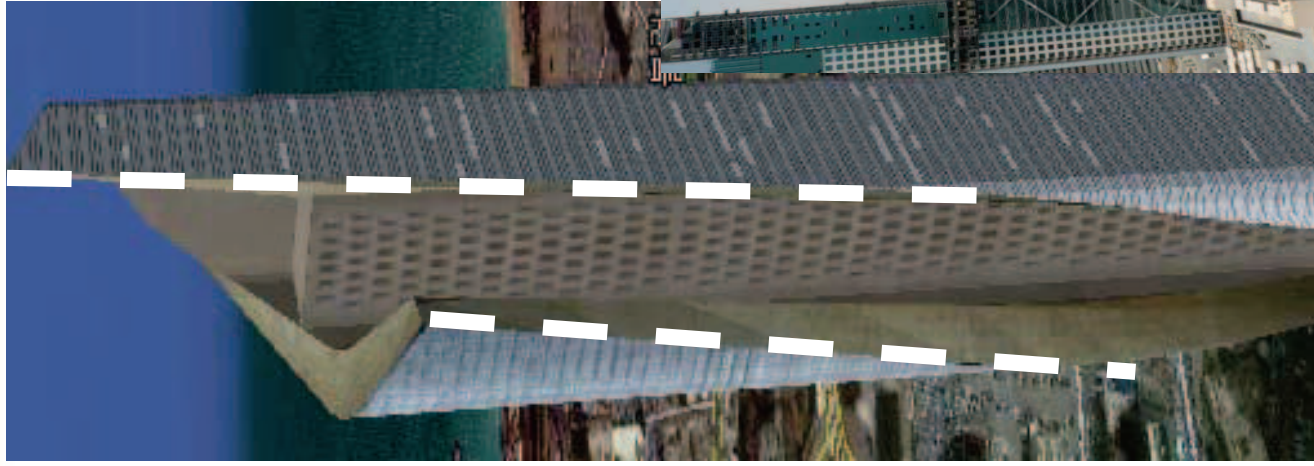
Difference	
dX	dY
0.0063	-0.0013
0.0160	-0.0009
0.0063	-0.0014
0.0104	-0.0012



# 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.



## 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.





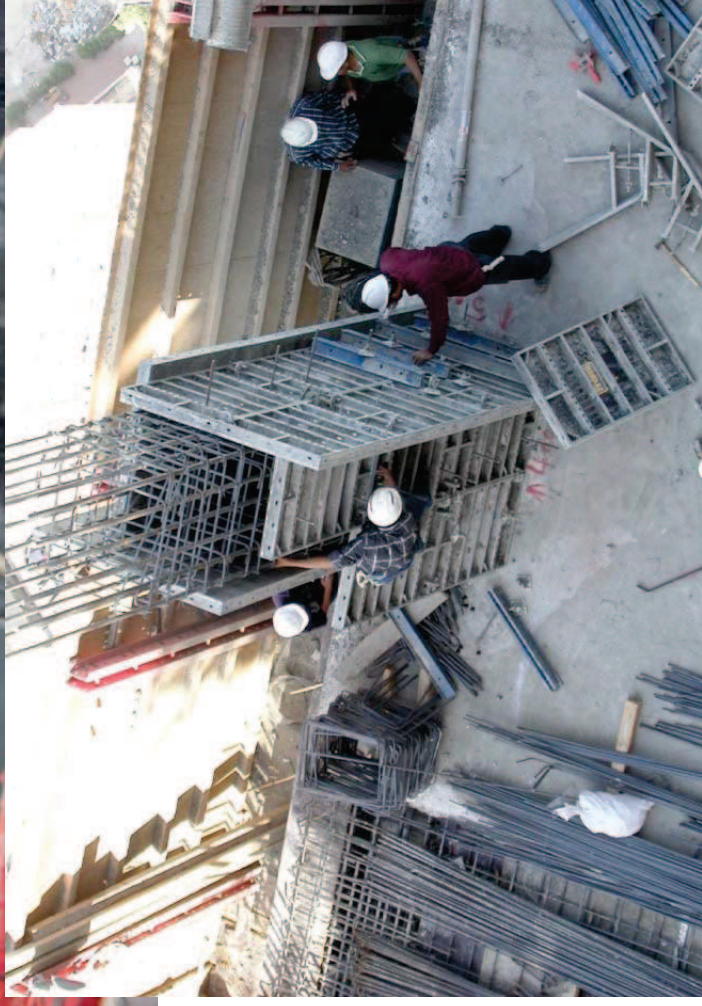
## Slab

4.2m Typically floors

5.6m Mezzanine floors (Mechanical Floors)

11.0m High intermediate floors

21.5m Sky lobby above 75F



## 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



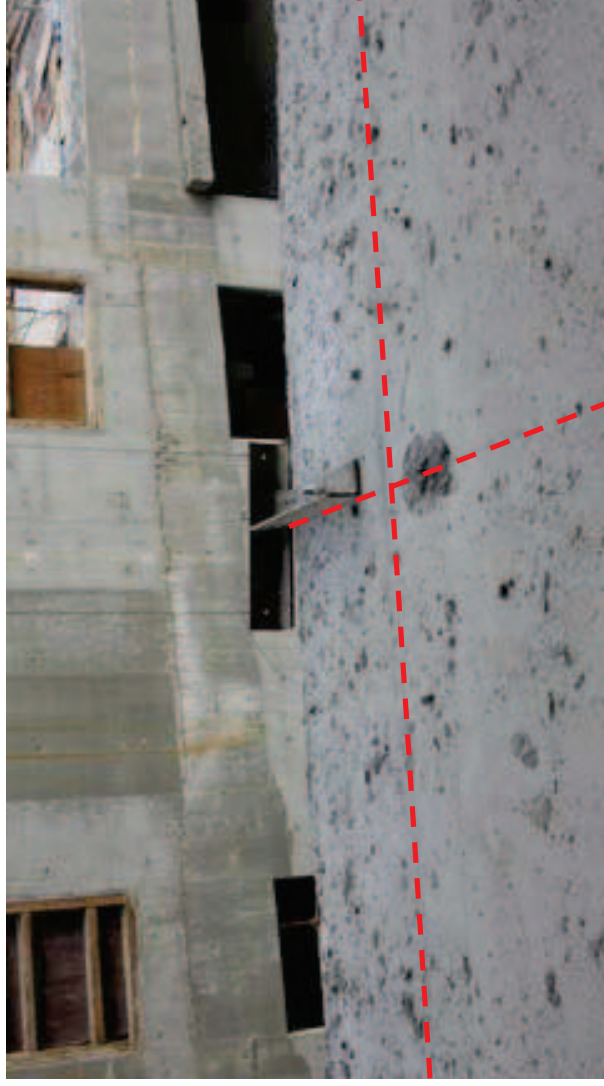


## Curtain Walls

Reference marked on the slab edge

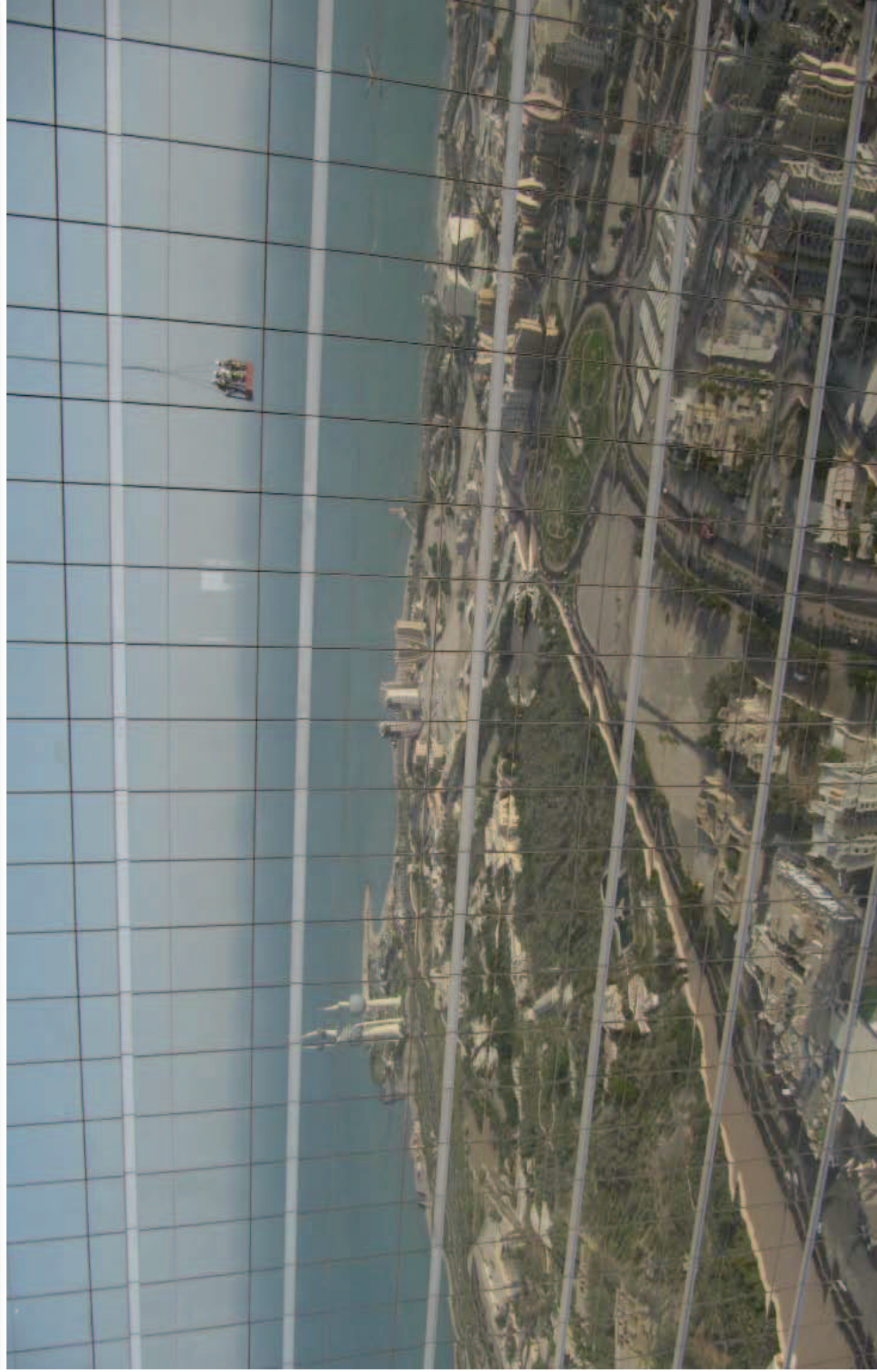
Every 50m marking and put plumb steel line.

Install steel beam in high floor to support curtain walls

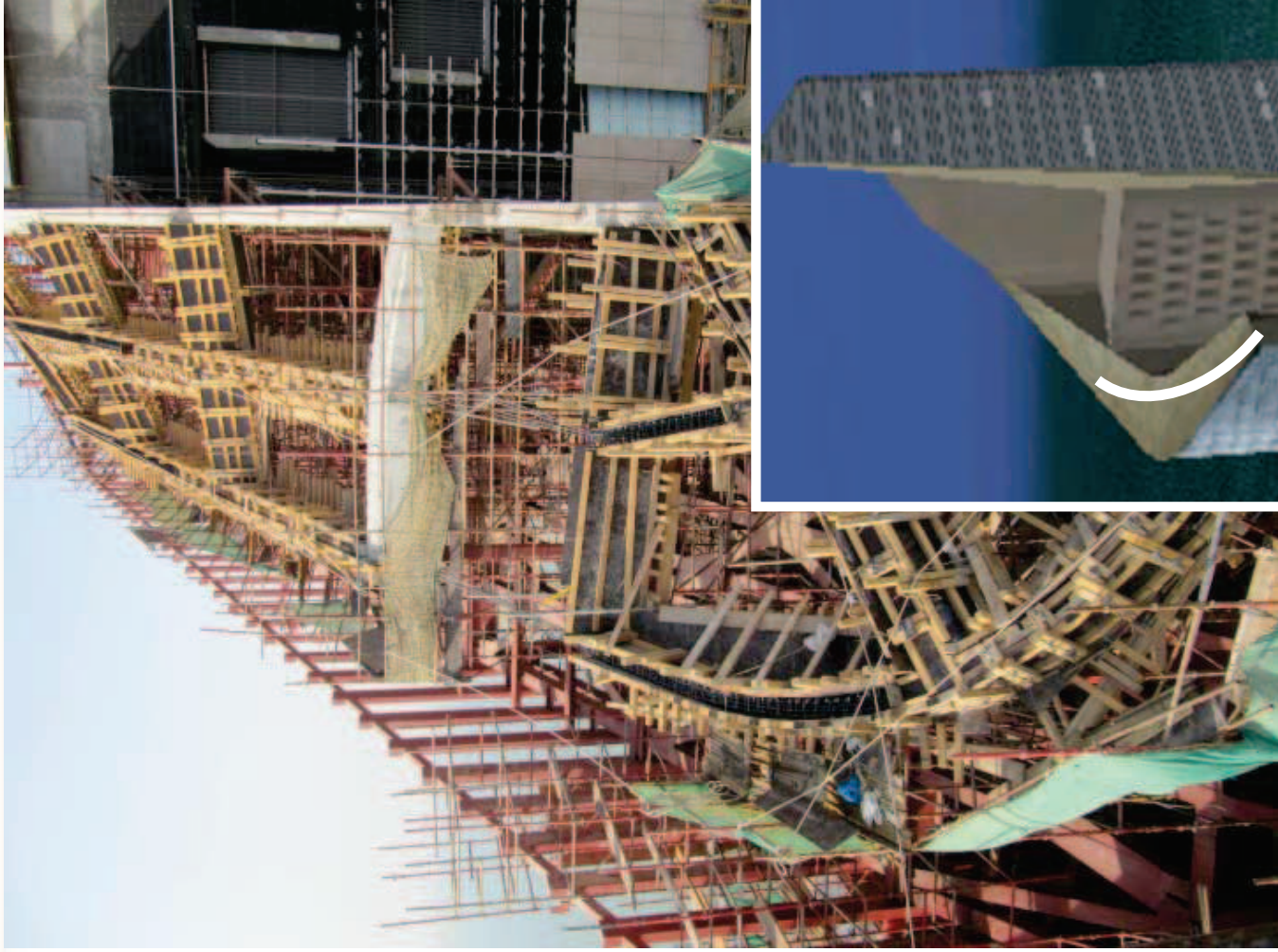




# Survey & Monitoring ; Curtain Walls







## 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.





## 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

## Horizontal compensation

The design coordinate shall be adjusted by the compensation program

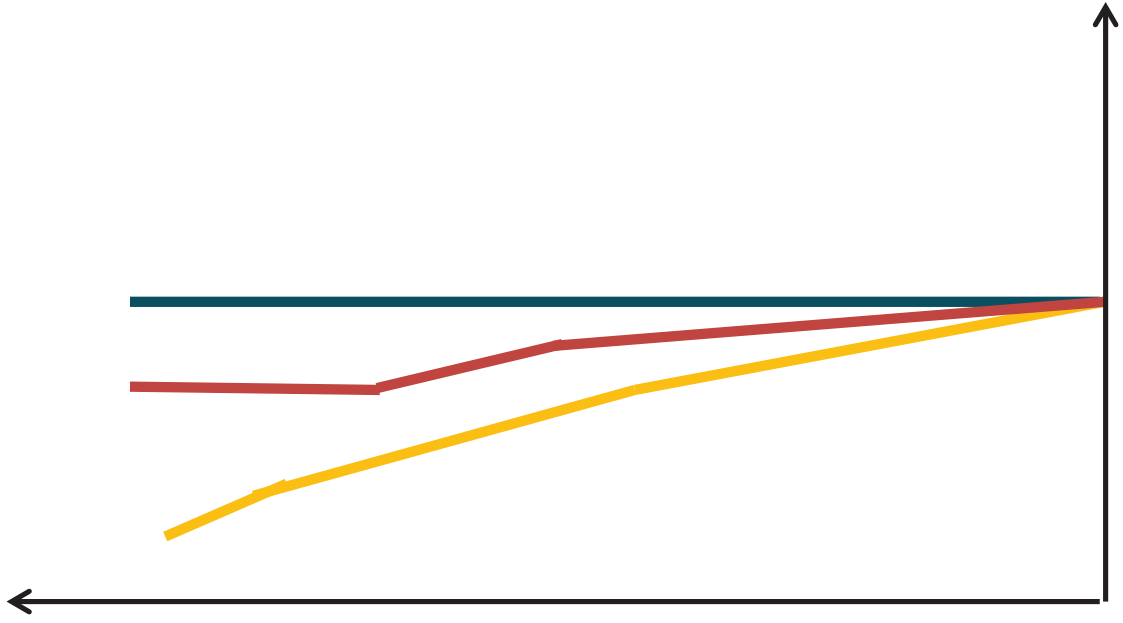
Each floor setting out shall be away and set and then the coordinate shall be expected to come back to design location

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

SUPERSTRUCTURE TORSIONAL COMPENSATION	
CORRECTION OF ROTATIONAL ALIGNMENT OF SUPERSTRUCTURE FLOORS ABOVE AND BEYOND SPECIFIED DESIGN ALIGNMENT	
CORRECTION LEVEL	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)
74+	150
73-73M	170
69-72	180
65-68	190
61-64	200
57-60	200
52-56	200
50-51	200
44-49	200
38-43	190
33-37	180
28-32	170
26-27	160
21-25	150
16-20	125
11-16	100
06-10	80
04-05	60
02-03	40
MZ-01	20
B2-GR	0

## Horizontal Compensation



Adjusted Set out line

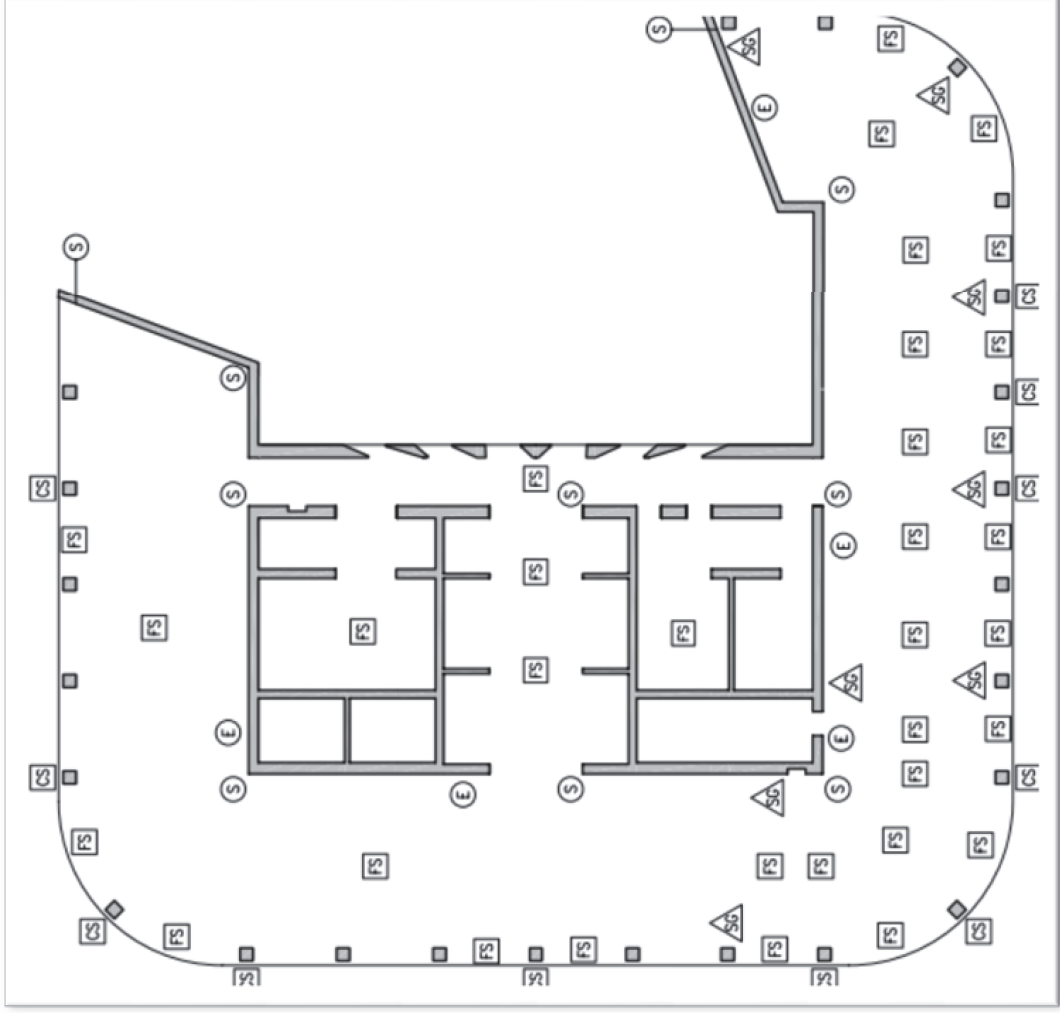
As Built line

Theoretical line(Gravity)



## Structure Monitoring

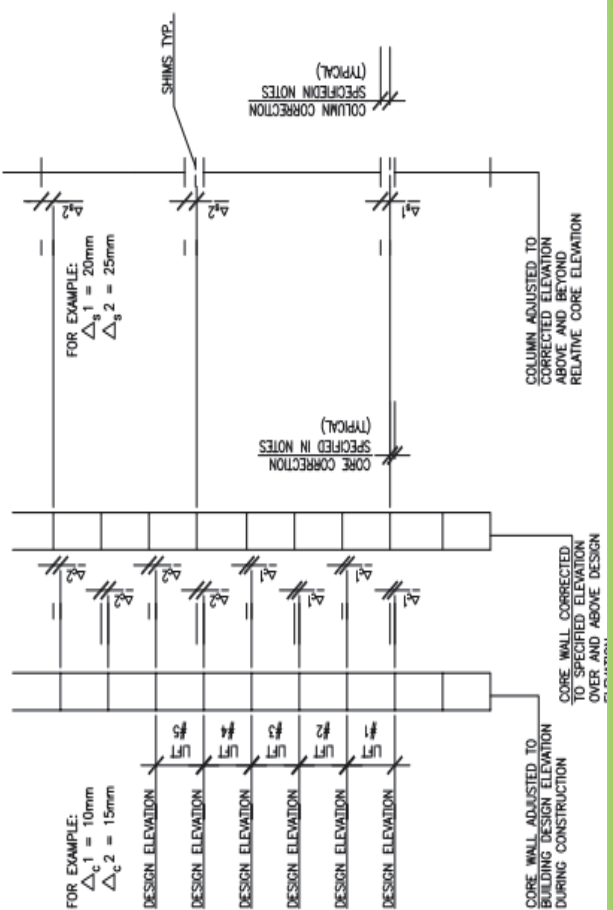
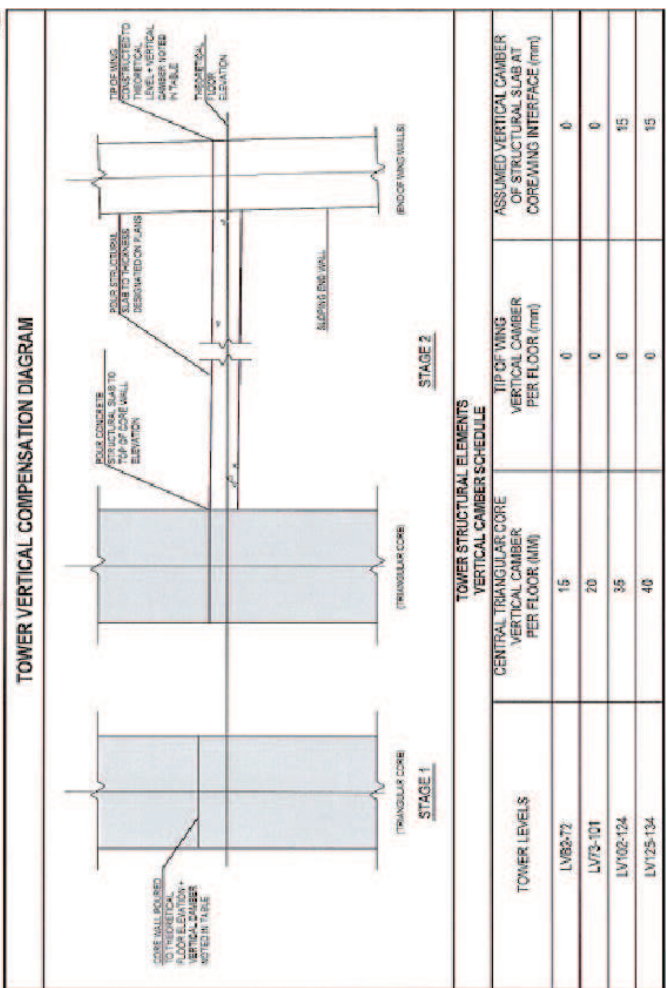
Periodical Vertical(shortening) displacement monitoring



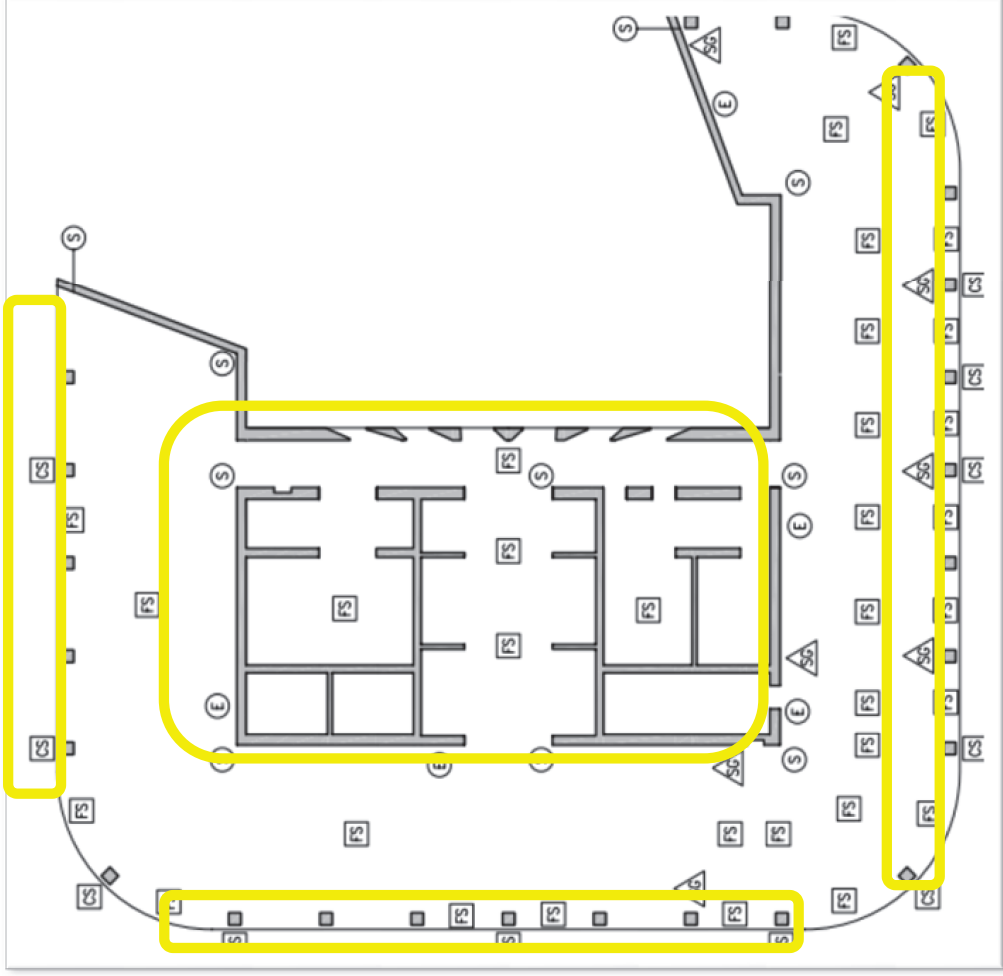
MONITORING PROGRAM		
SURVEY SYMBOL DESCRIPTION	SURVEYED LEVELS	REMARKS
(S) - SHEAR WALL CORE SURVEY POSITION	4, 15, 26, 38, 50, 62, 73	SEE NOTES FOR REQUIREMENTS
[CS] - COLUMN SURVEY POSITION		SEE NOTES FOR REQUIREMENTS
(E) - EXTENSOMETER LOCATION		SEE NOTES FOR REQUIREMENTS
[FS] - FLOOR SLAB SURVEY POSITION	ALL LEVELS	SURVEY ONCE AFTER CONCRETE HAS HARDENED OF AFTER FOAMWORK REMOVAL
△SC - STRAIN GAGE AT COMPOSITE OR REINF. CONC. WALL OR COLUMN.		SEE NOTES FOR REQUIREMENTS

## Level Compensation

STRUCTURAL ELEMENT VERTICAL COMPENSATION							
CORRECTION LEVEL	CORE WALL <sup>1</sup>	EXTERIOR COLUMNS <sup>2</sup>	CORRECTION LEVEL	CORE WALL <sup>1</sup>	EXTERIOR COLUMNS <sup>2</sup>	CORRECTION LEVEL	EXTERIOR COLUMNS <sup>2</sup>
74+	174	66	48	163	46	23	0
73M	161	61	48	191	43	22	0
73	188	63	47	160	42	21	0
72	188	64	48	178	41	20	0
71	188	66	46	178	39	18	0
70	188	66	44	178	37	18	0
69	188	65	43	175	36	17	0
68	188	66	42	174	34	16	0
67	188	66	41	172	32	15	0
66	188	66	40	171	30	14	0
65	187	66	39	169	28	13	0
64	187	66	38	167	26	12	0
63	186	64	37	166	25	11	0
62	186	63	36	163	23	10	0
61	186	62	36	161	22	9	0
60	186	61	34	169	20	8	0
59	184	59	33	157	18	7	0
58	193	58	32	166	16	6	0
57	193	57	31	163	14	6	0
56	192	58	30	160	12	4M	0
55	181	56	29	148	10	4	0
54	180	54	28	148	8	3	0
53	189	52	27	142	6	2	0
52	188	51	26M	141	4	1	0
51	188	49	26	138	2	MZ	0
50M	186	48	26	134	0		
50	186	47	24	132	0		



## As Built Survey ; Core Wall & Columns

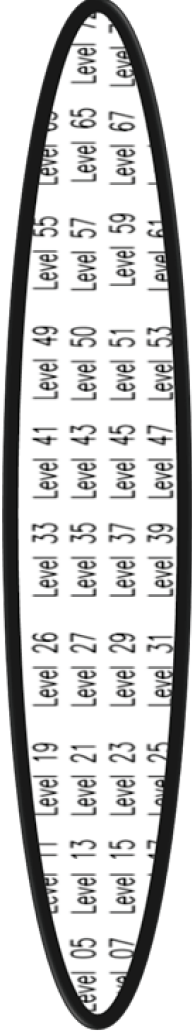


Survey 10 Core Wall and 14 Columns(for 2 points)

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



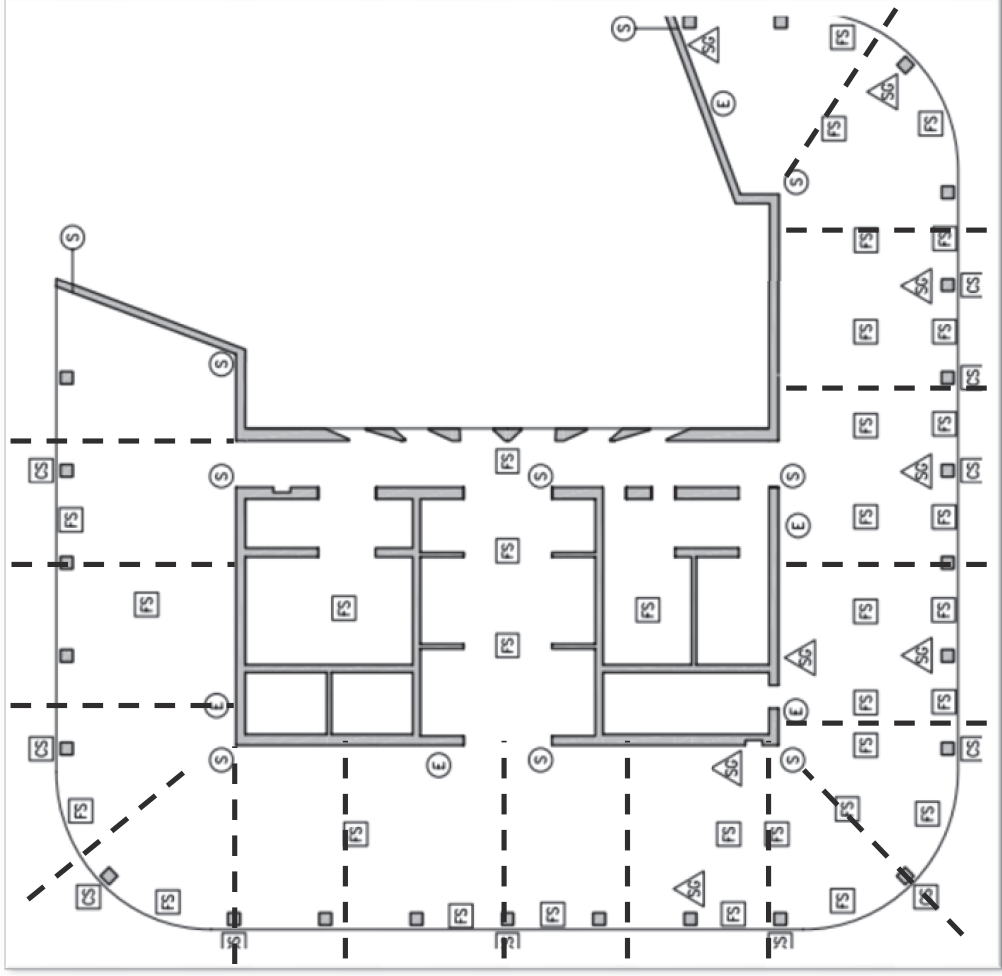


## As Built Survey ; Slab

Floor Slabs shall be surveyed immediately after concrete has hardened

And after the formwork has been removed

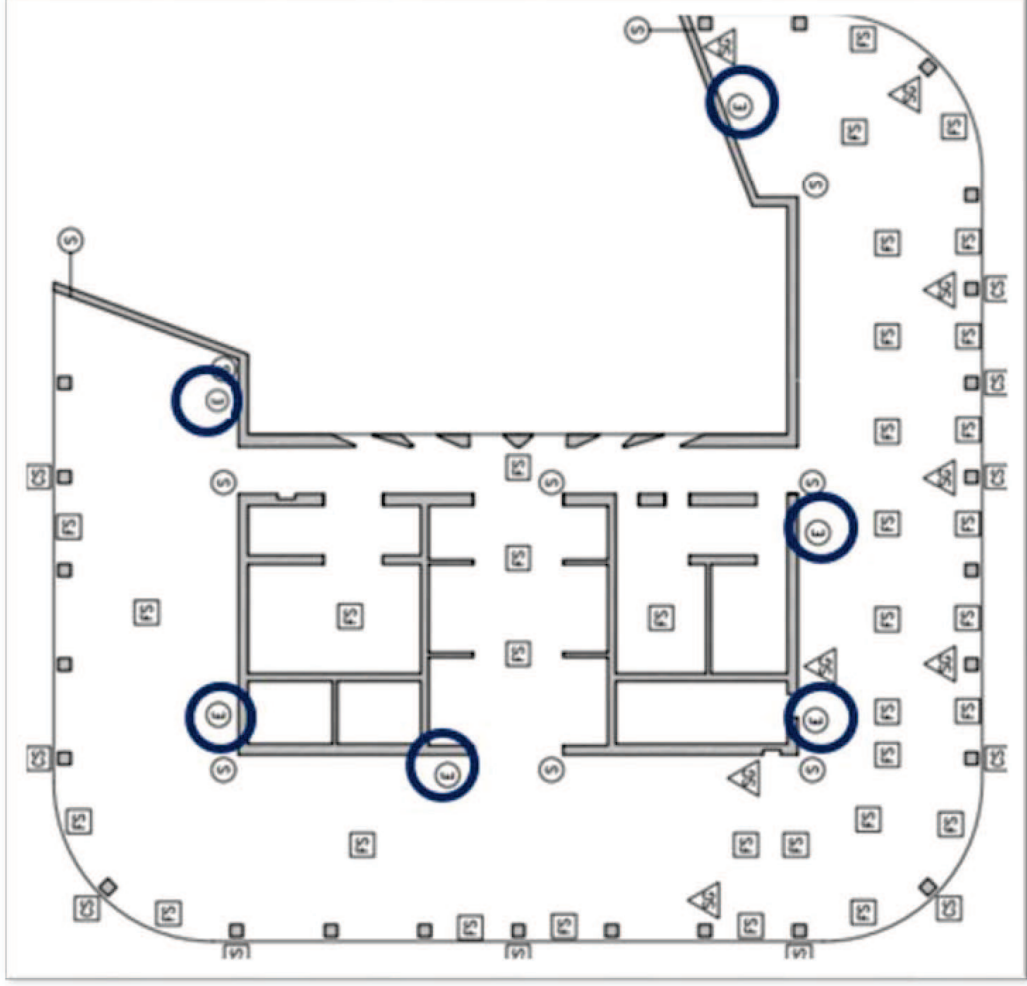
The slabs shall be surveyed for floor flatness and levelness for each level constructed



## Monitoring Survey ; Extensometer

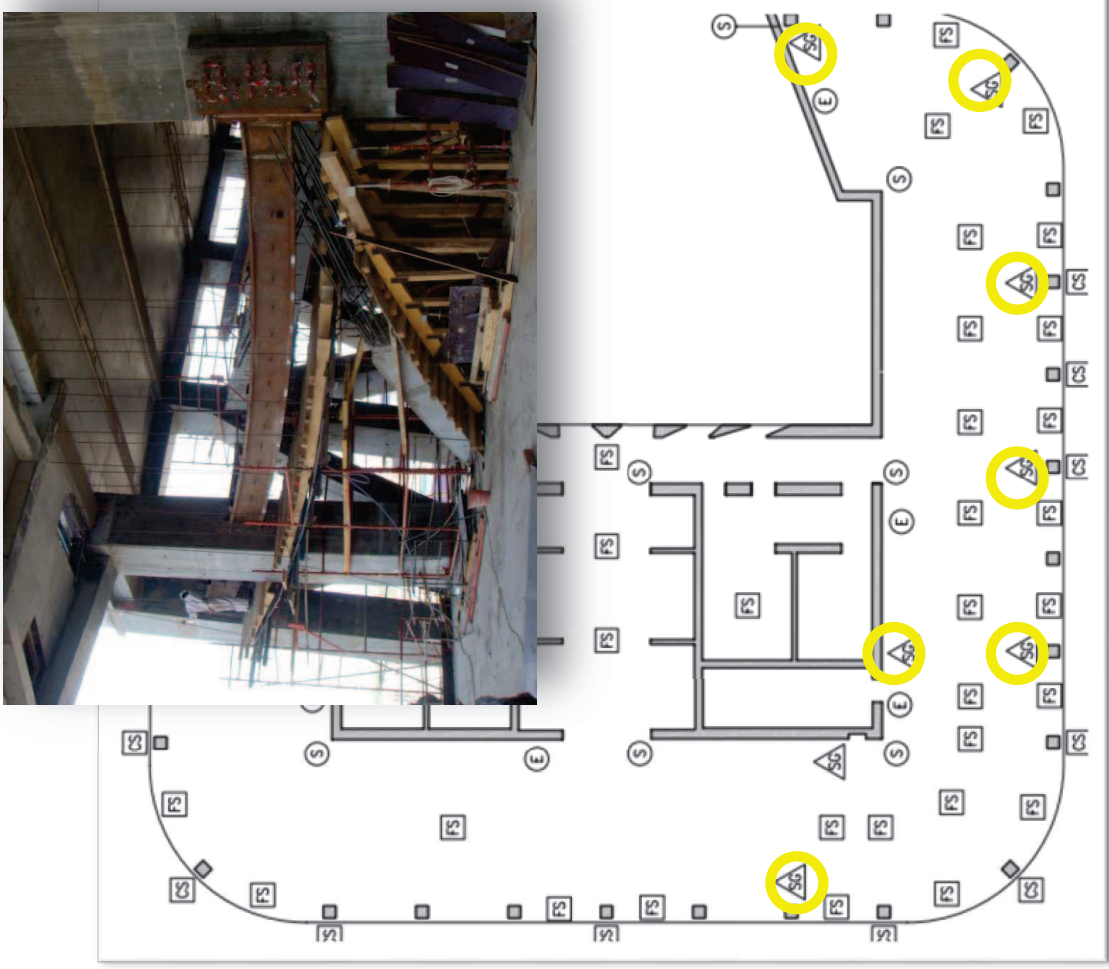
Install extensometers on the concrete of the core wall at 6 location on the following floors

The reading recorded as per monitoring survey schedule and reported to structure engineer and consultant to review it



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

## Monitoring Survey ; Strain Gages

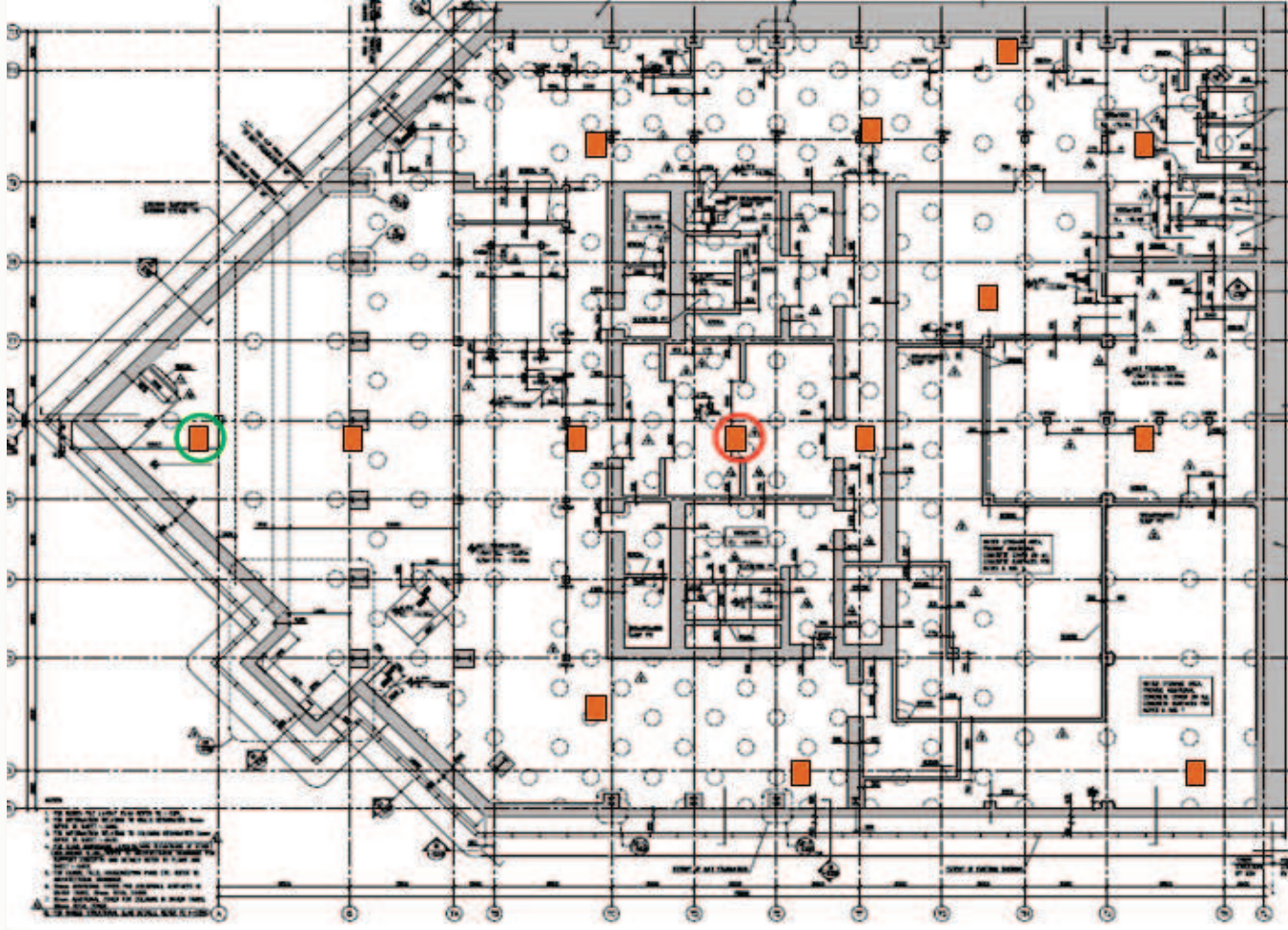


Exterior columns shall be strain gaged to monitor Stress levels within the columns at specific levels within the structure , Level Gr, 4, 8, 12

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

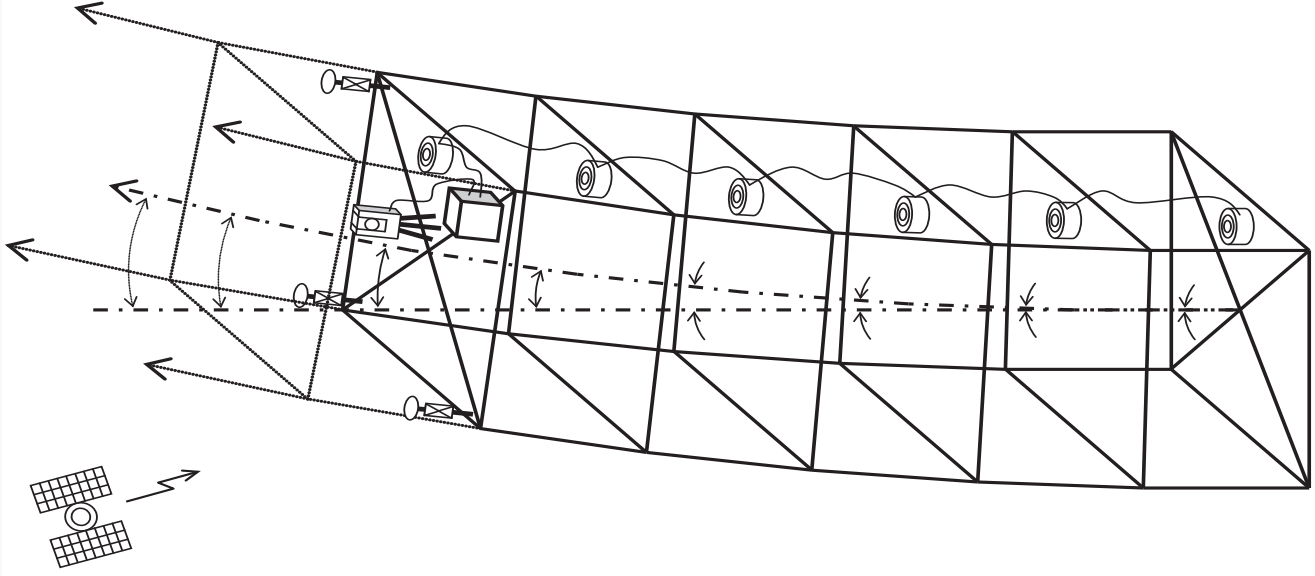
Ground Floor to top level construction period, the total amount of the settlement are 85mm(max), 64mm(min). the uneven settlement is 21mm in 42m horizontal distance.

## Dynamic monitoring

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

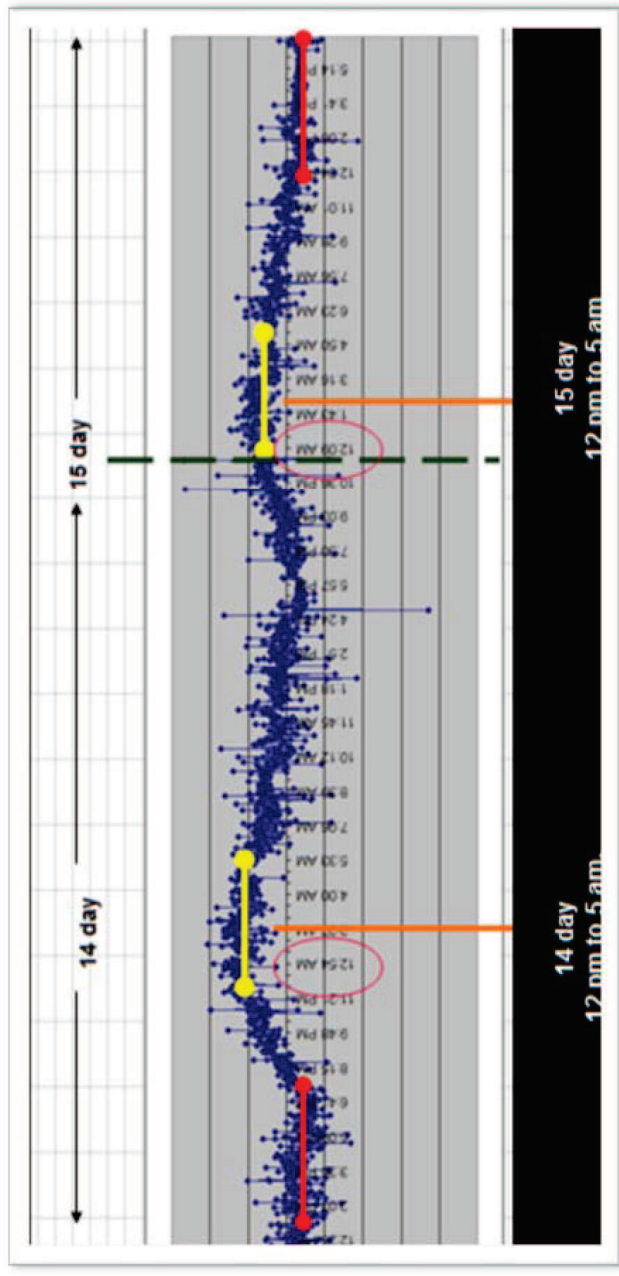
Accelerometer ; Installed from the end of the project

Weather station ; installed from the beginning to the end of the core wall construction

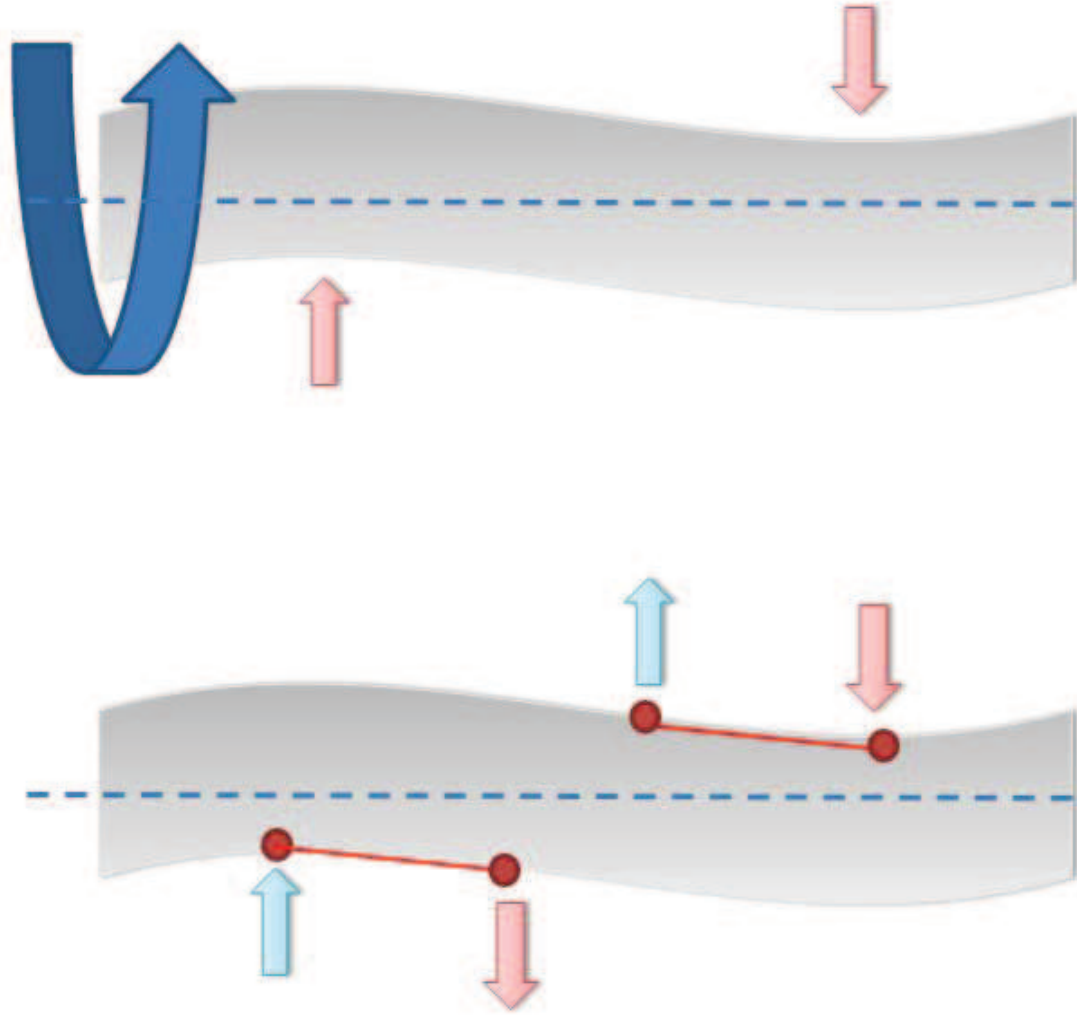


## Real time monitoring solution for the building tilt

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







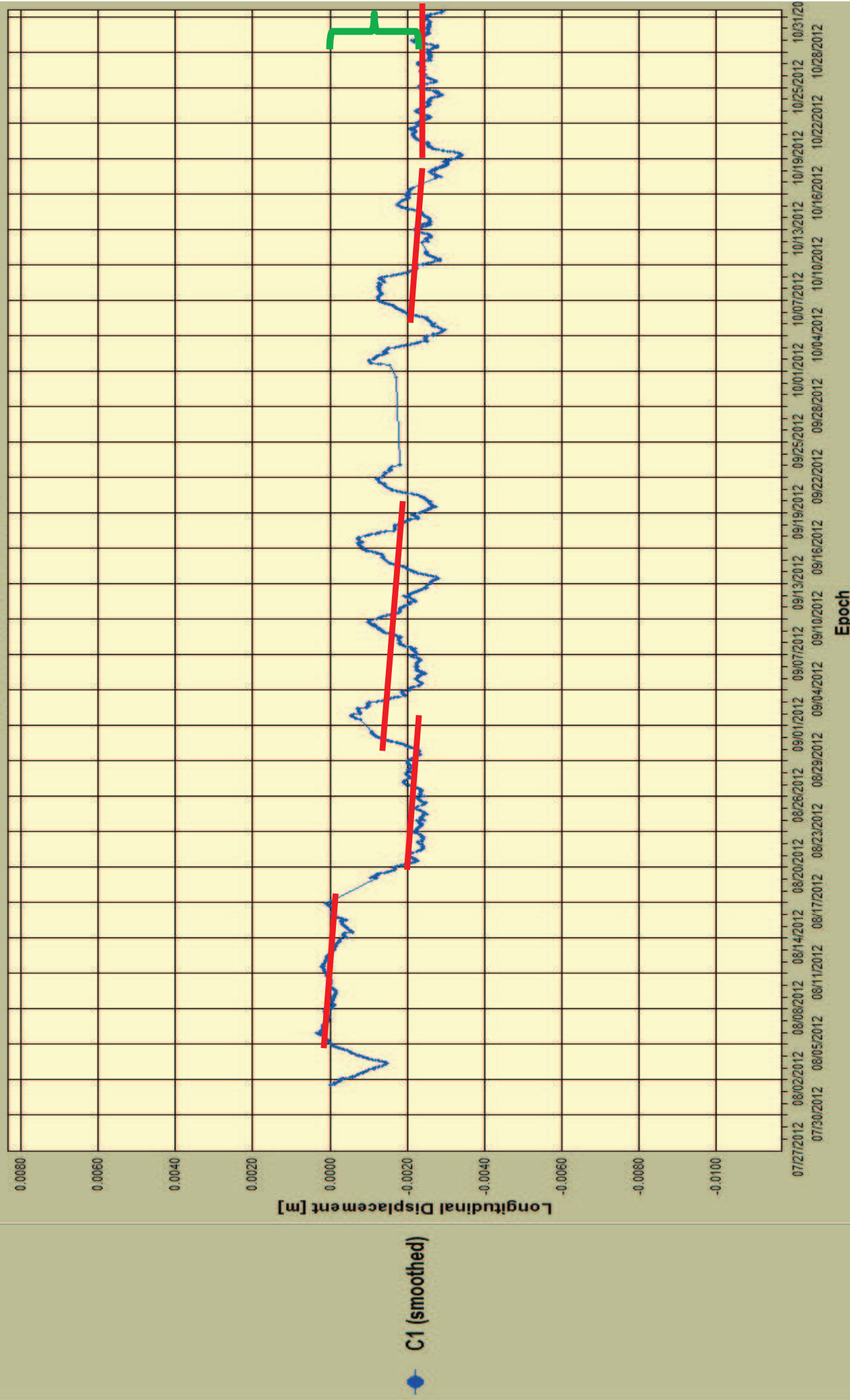
## Neutral position

Is the gravity line is the always the reference in any time and any condition at the moments of survey?

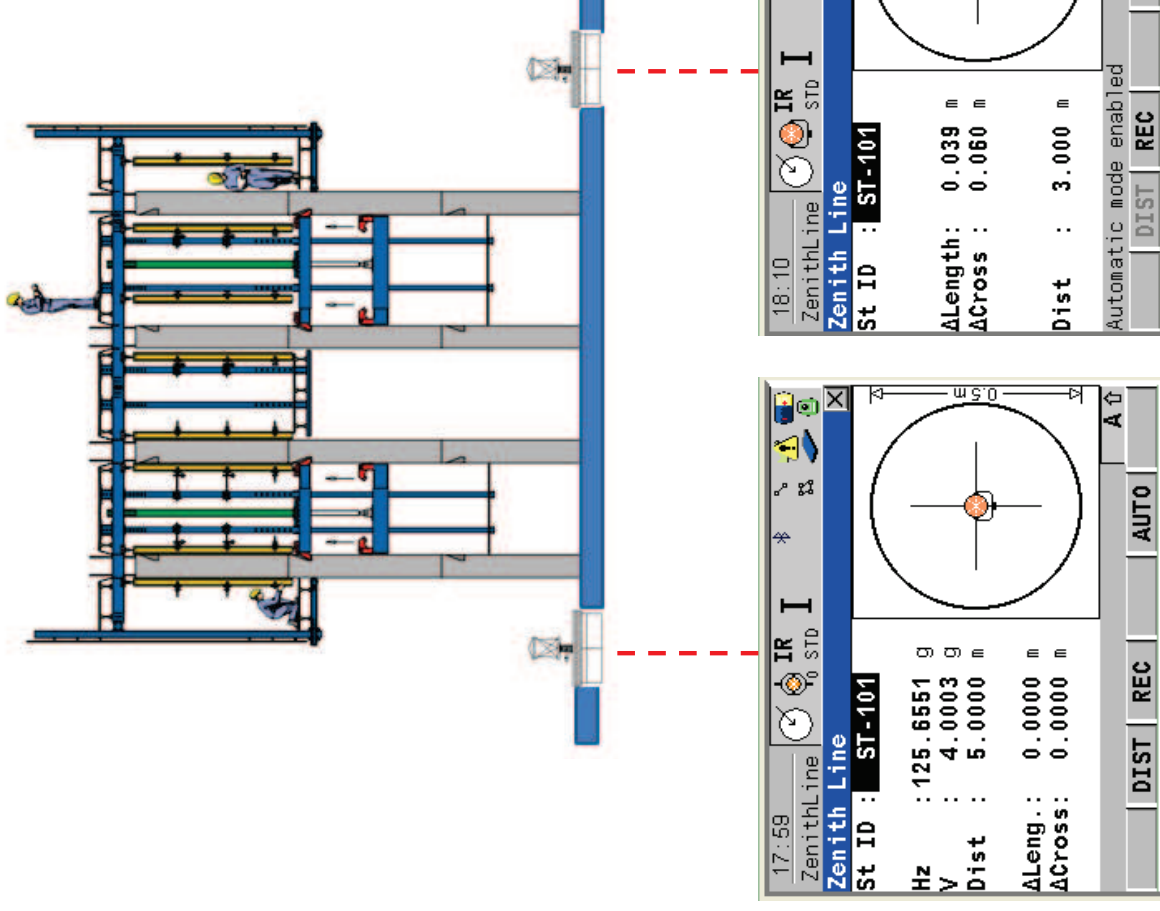
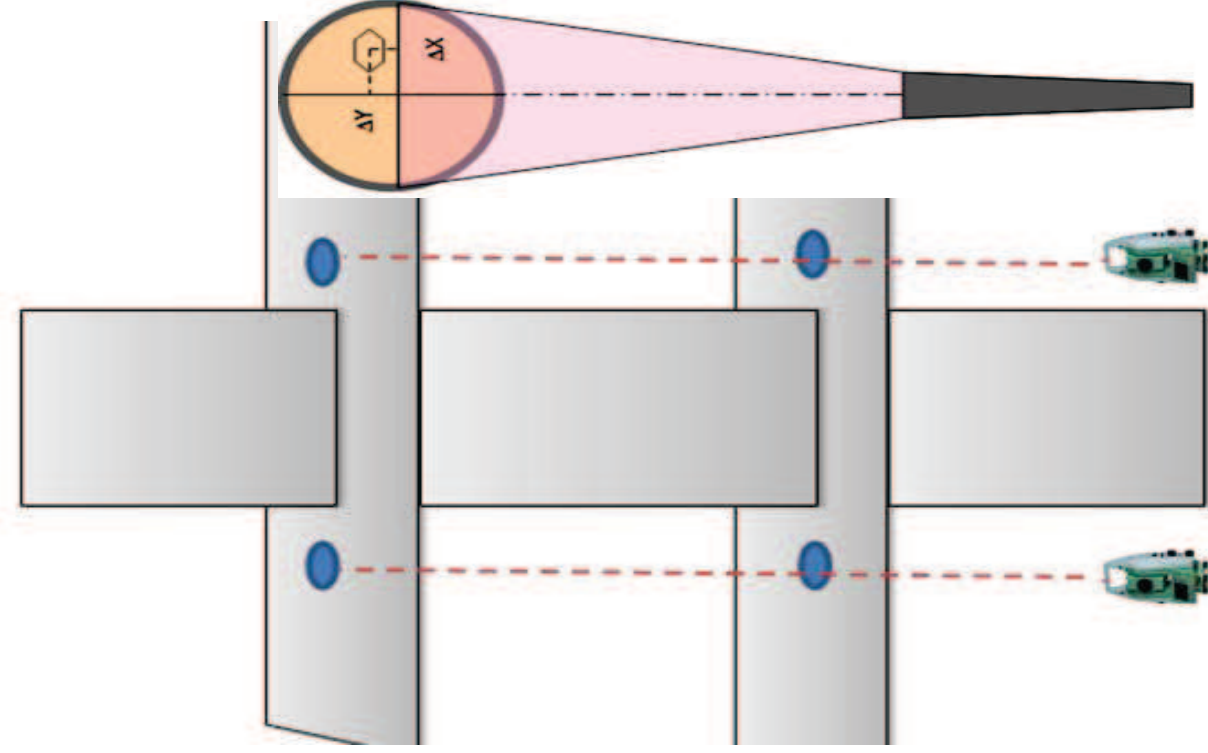
# Survey & Monitoring ; Monitoring program



Longitudinal Displacement Wall 1-4



# Survey & Monitoring ; Monitoring program





**Thank you very much for  
your kind attention**