

Structural Design of Taipei 101 Tower

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Assistant V.P.

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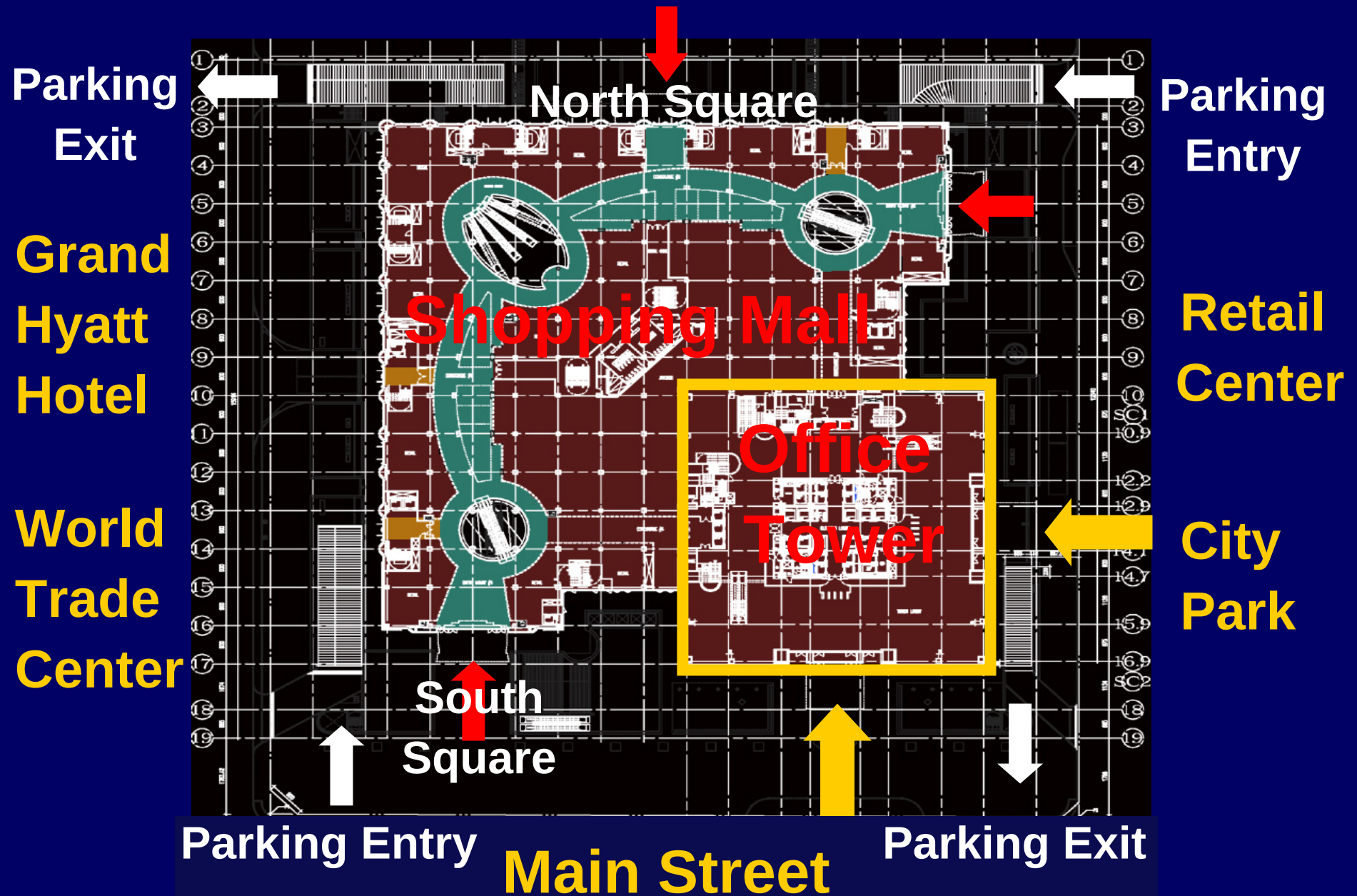
Evergreen Consulting Engineering, Inc.

永峻工程顧問股份有限公司

- Structural Design and Site Supervision for Taipei 101
- Over 30 Years in Practice, Since 1974
- Specialize in Building Structural Consulting Services



Site Plan





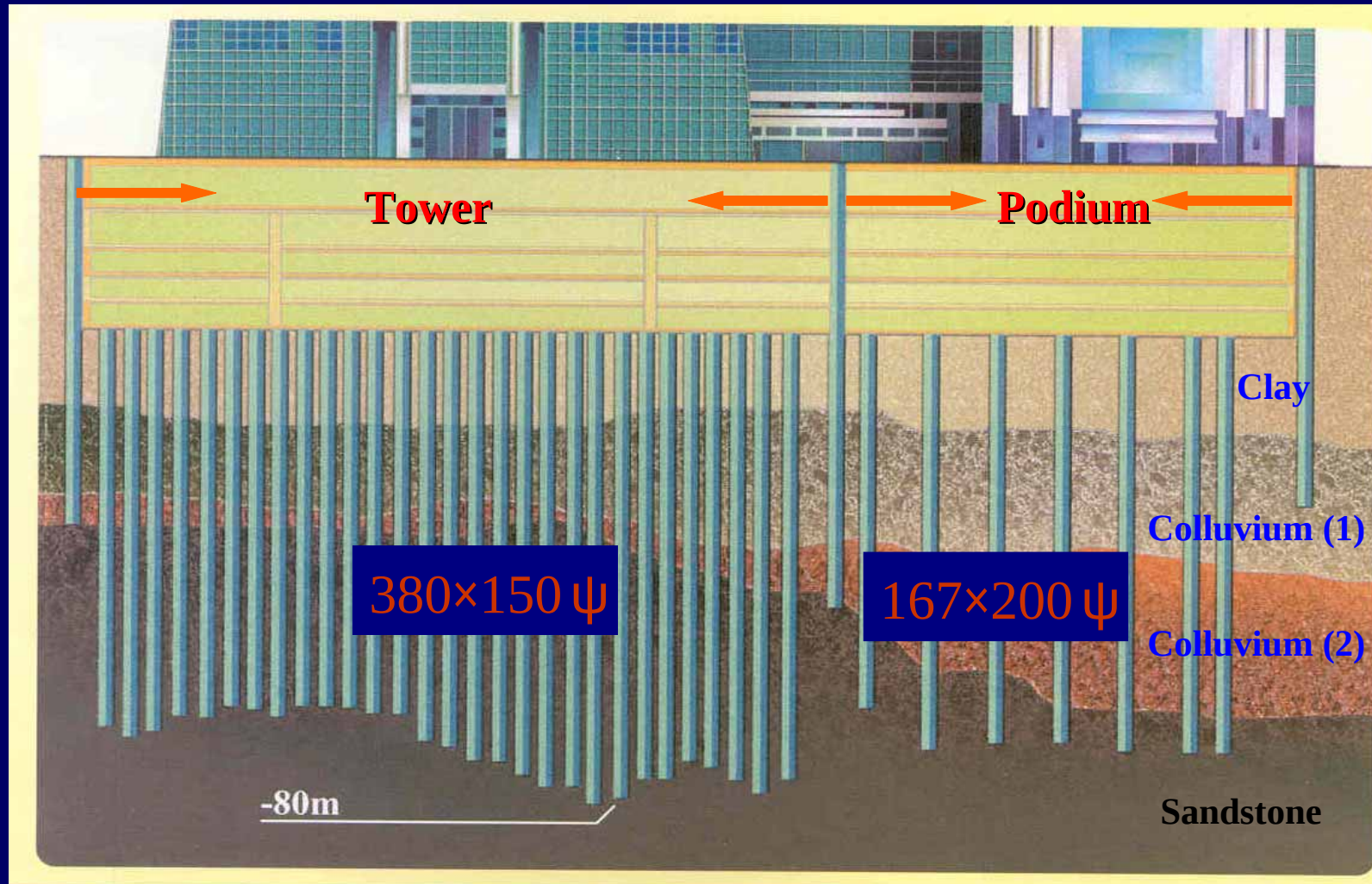
PROJECT PROFILE

- **Site Area** 30,277 m²
- **Floor Area** 373,831 m²
- **Height** 508 m
- **Floors**

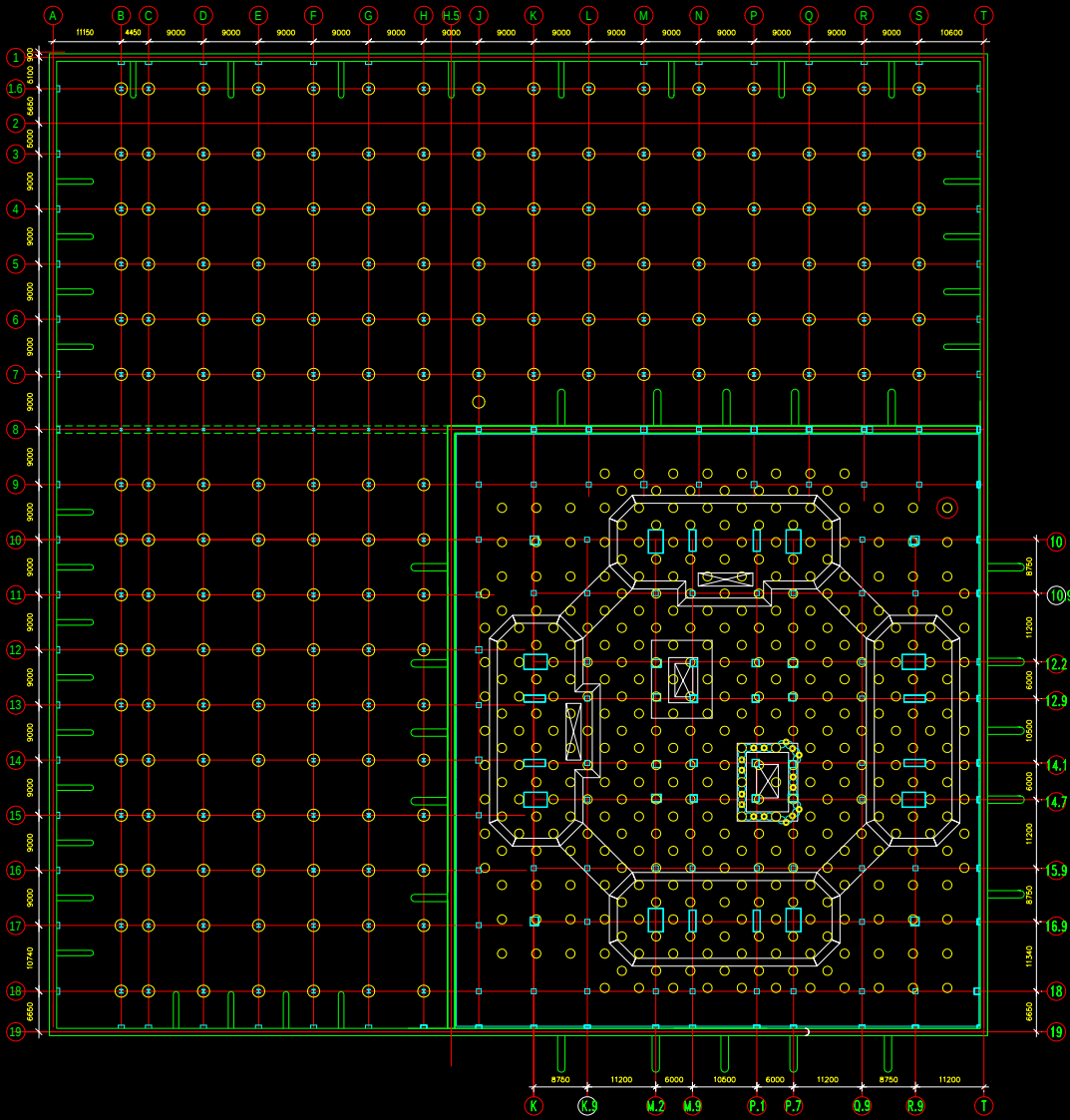
Main Tower	101
Podium	6
Basement	5

- **Main Usage**

Main Tower	Office	(7F – 84F)
	Mech. Level	(Every 8F)
Podium	Shopping Mall	(B1F – 5F)
Basement	Parking	(B2F – B5F)

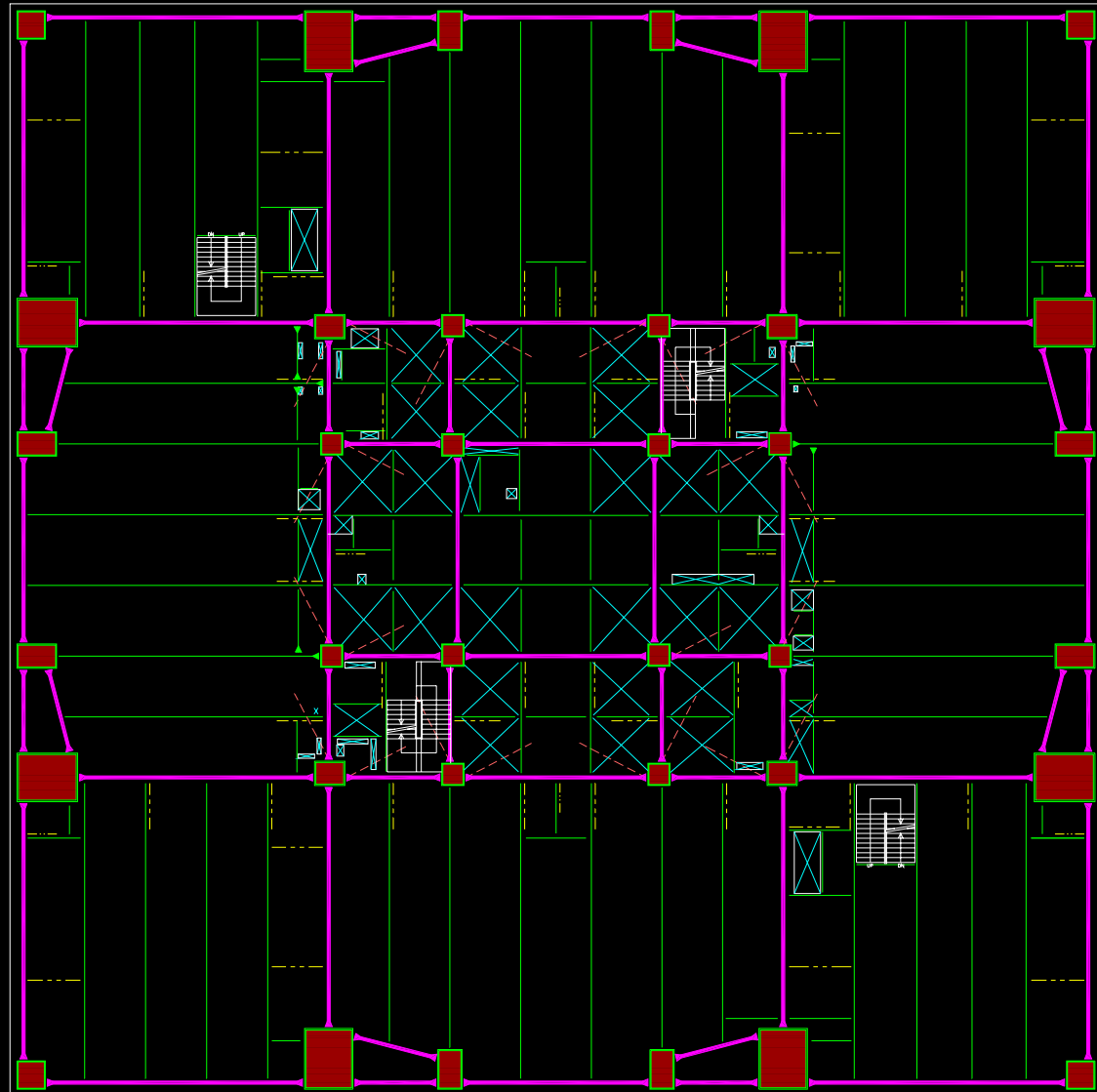
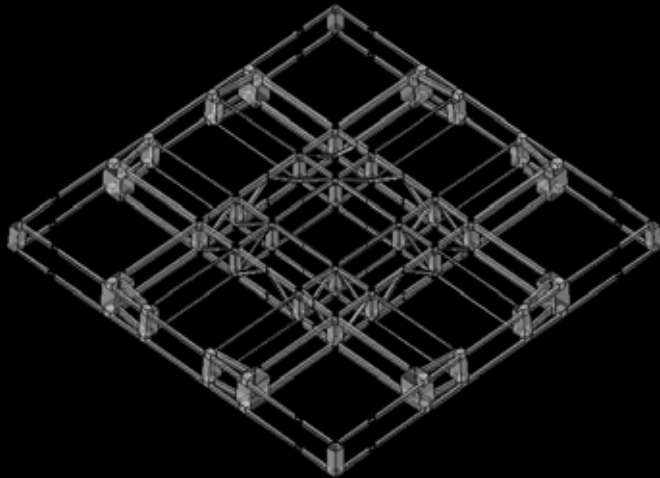


FOUNDATION PLAN



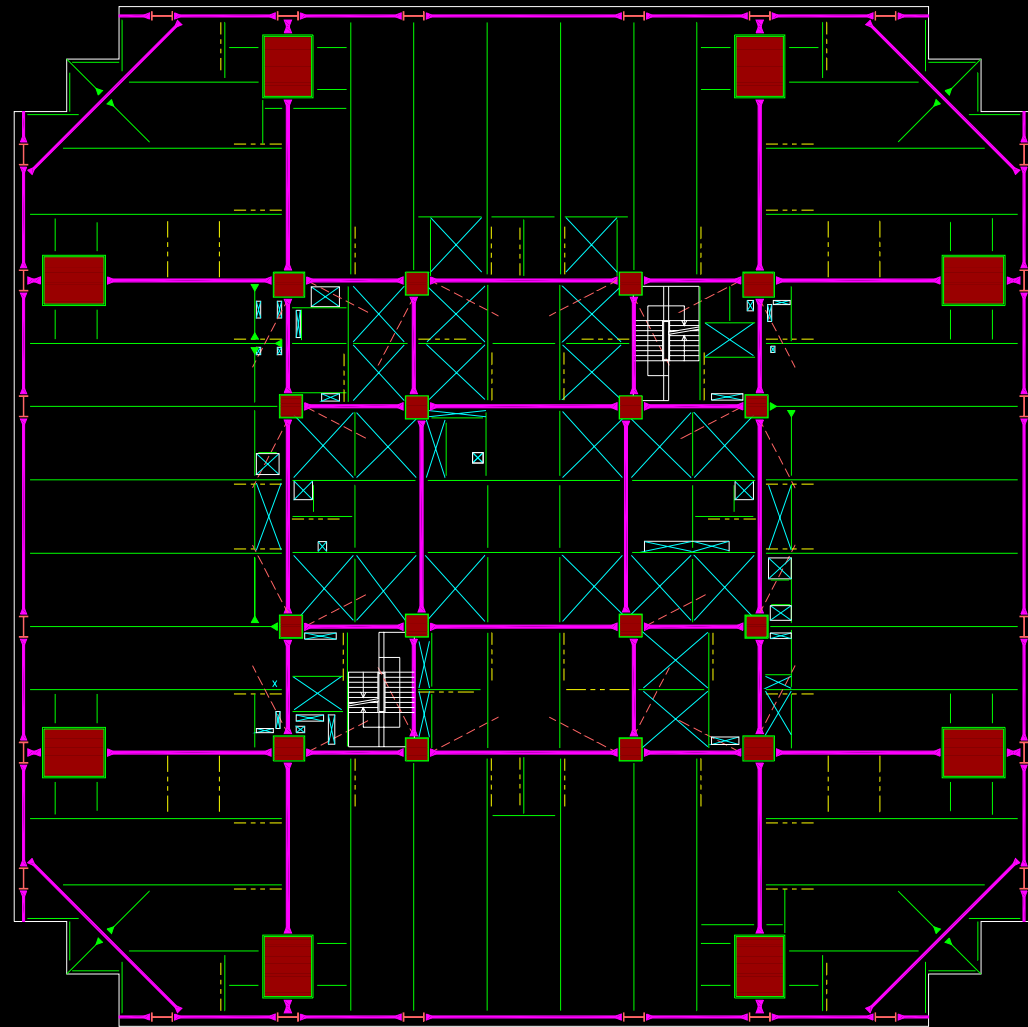
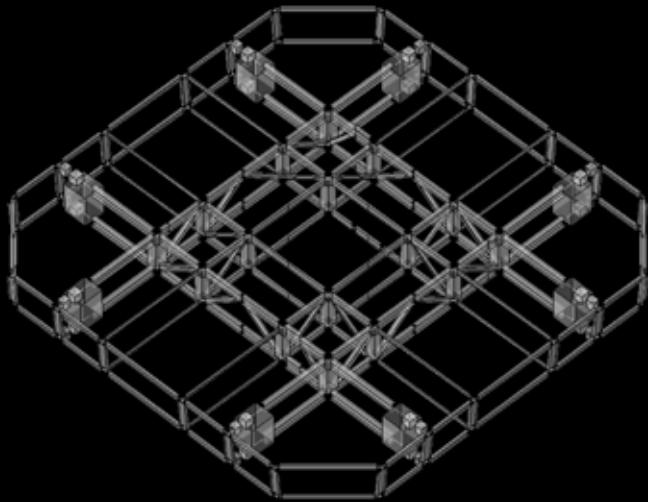
TYPICAL FLOOR FRAMING PLAN

Lower Story



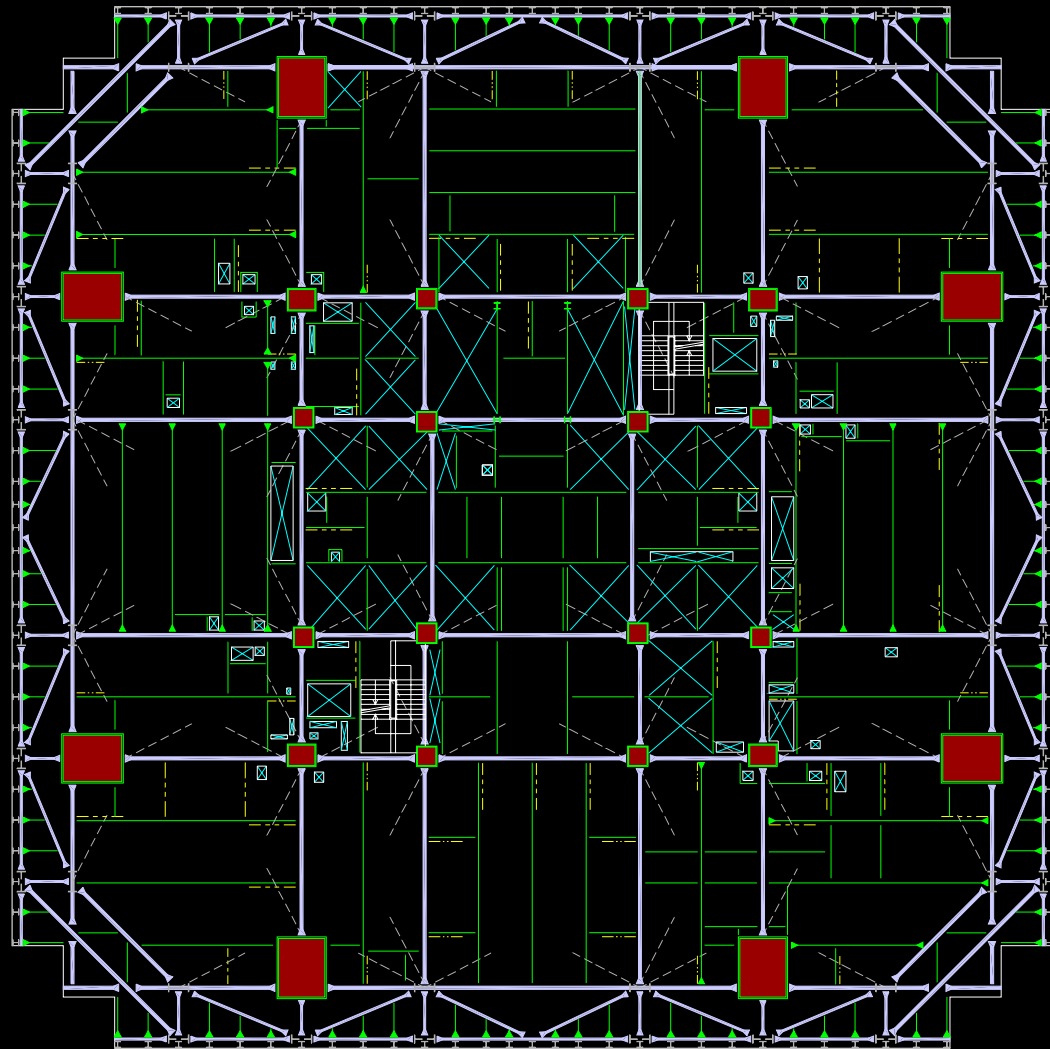
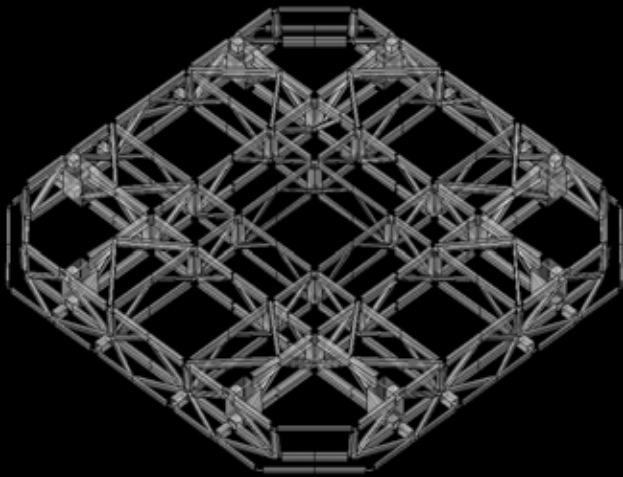
TYPICAL FLOOR FRAMING PLAN

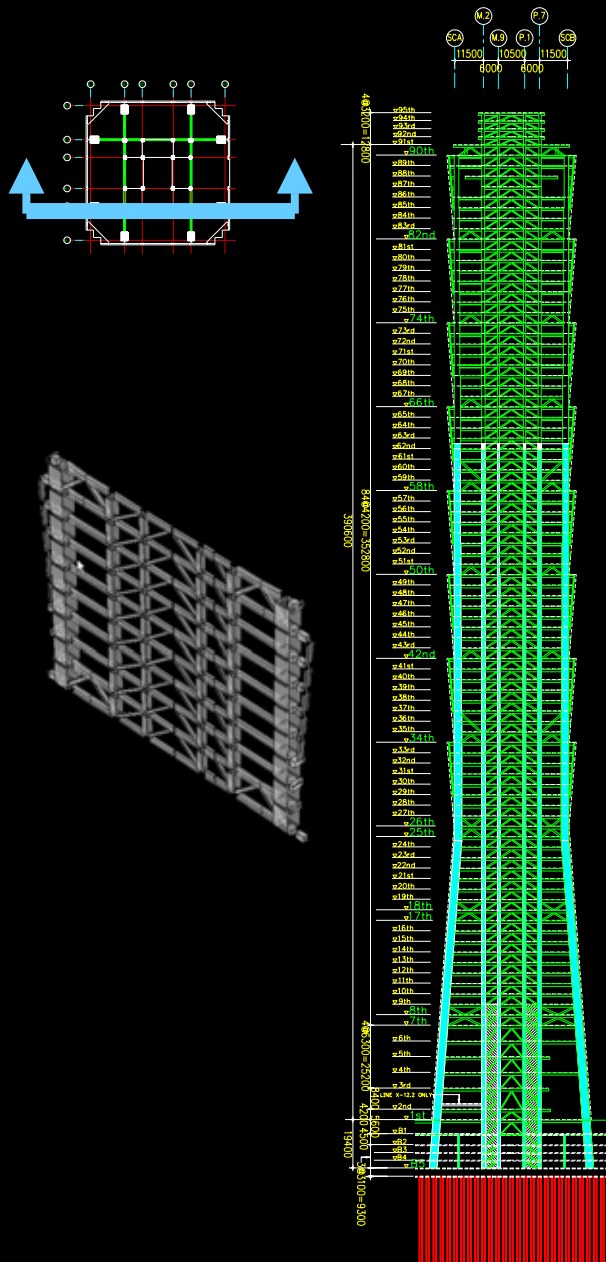
Upper Story



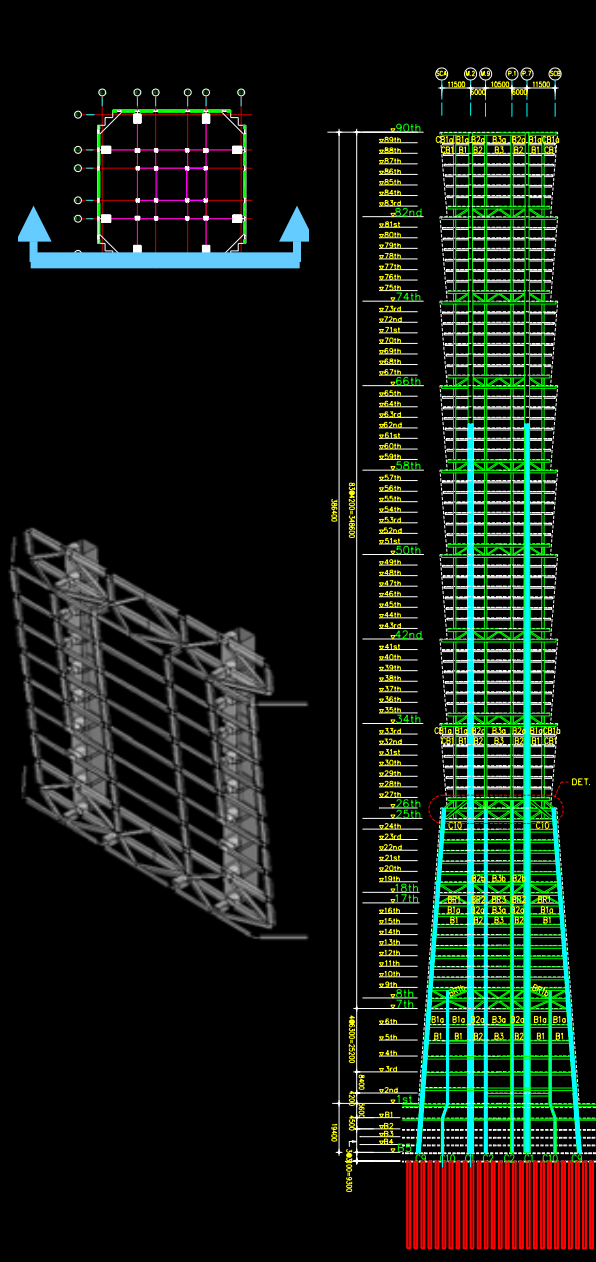
MECHANICAL FLOOR

2X4=8 outriggers,
1 vertical belt truss,
1 horizontal belt truss,
SMRF

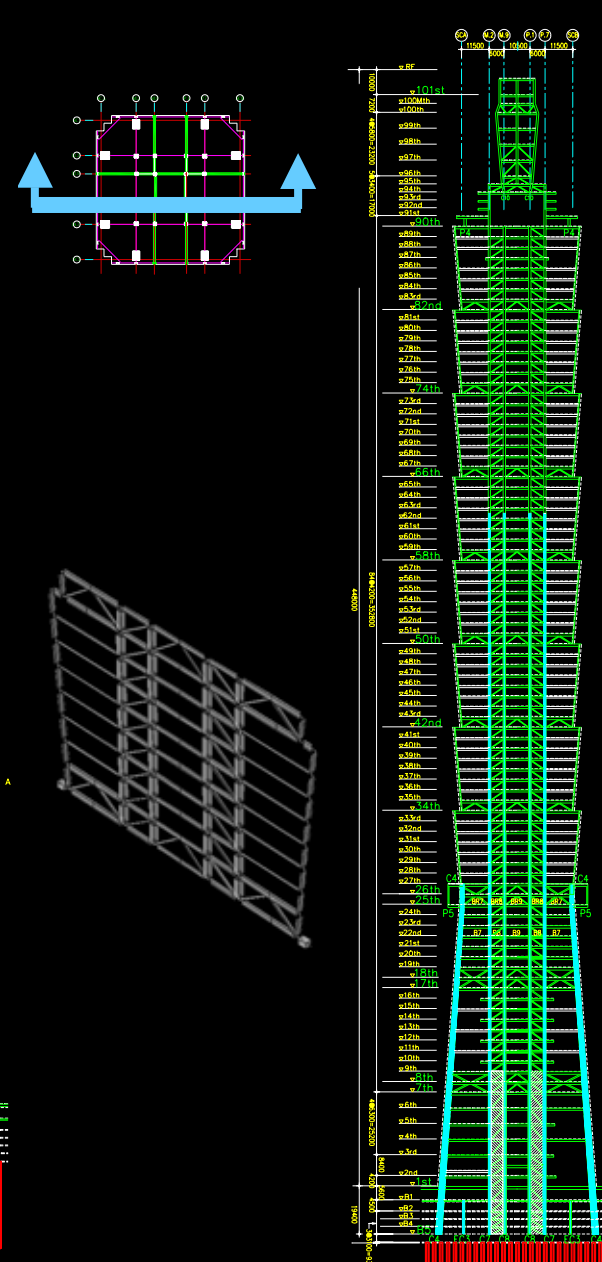




I2.2,14.7,Y-M.2,P.7 立
AME ELEVATION @ LINES 12.2 & 14.7 & M.



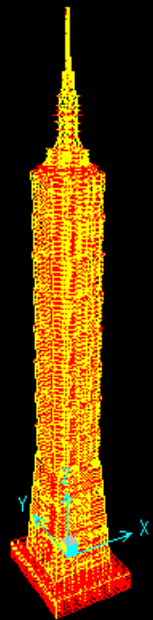
X-SC1 立面構架圖
FRAME ELEVATION @ LINE SC1



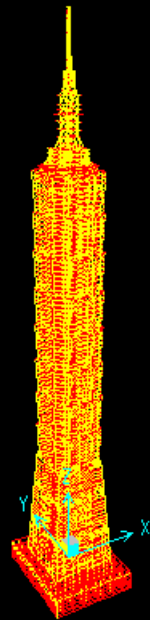
X-12.9 立面構架圖
FRAME ELEVATION @ LINE 12.9

Elevation

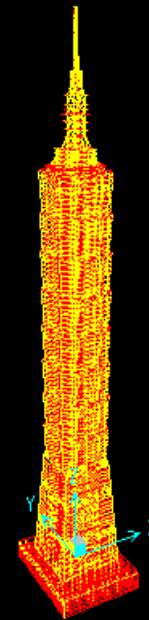
BUILDING MODE SHAPES



1st mode



2nd mode



3rd mode

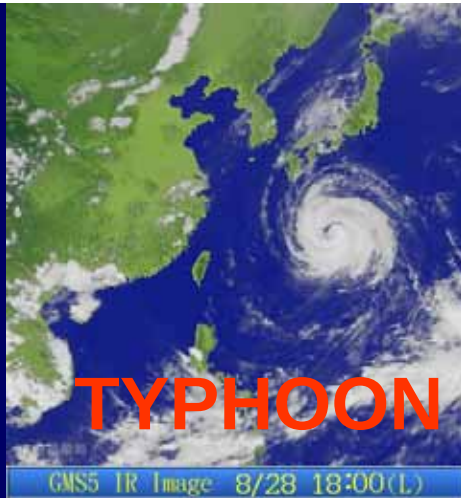
Structural Design

- Structural System
- Analysis & Design

Wind Design

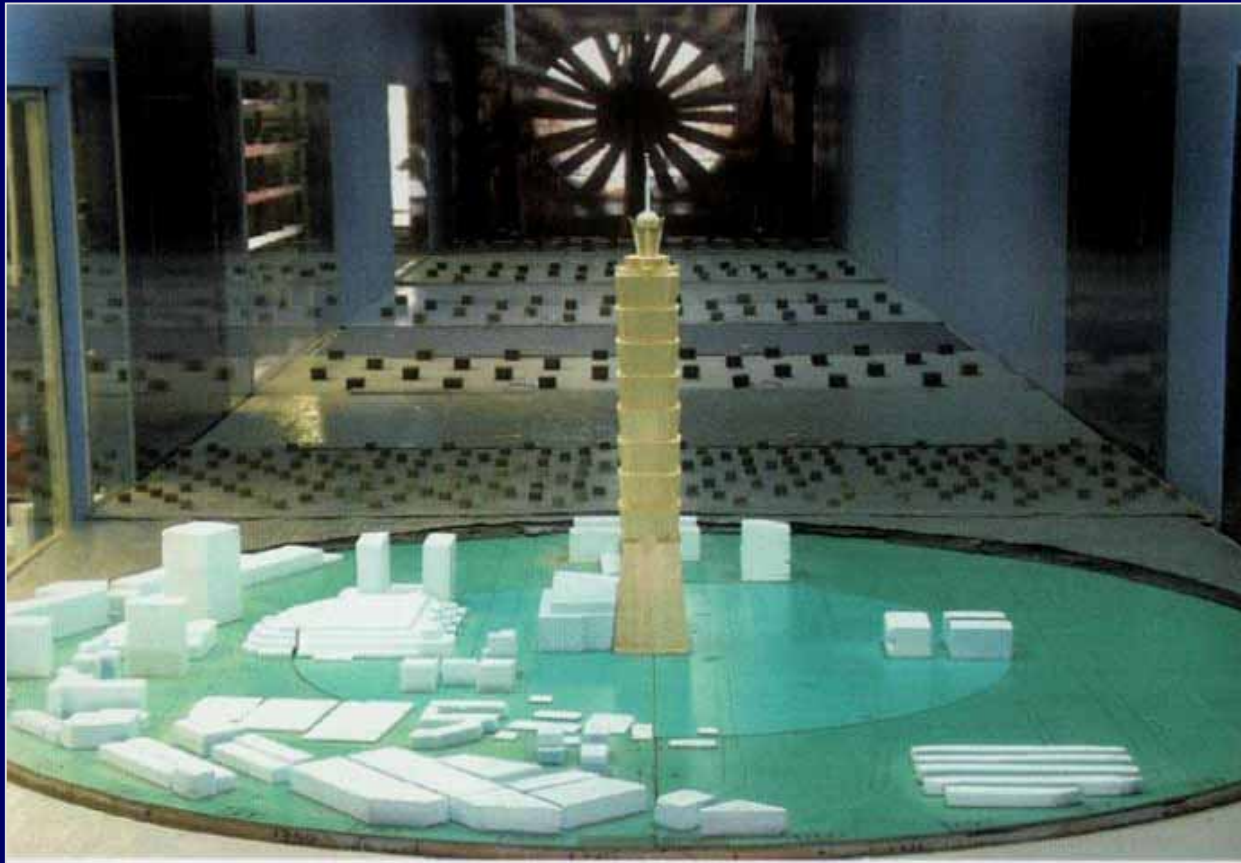
Seismic Design

Special Measures



Wind Design

Wind Tunnel Test

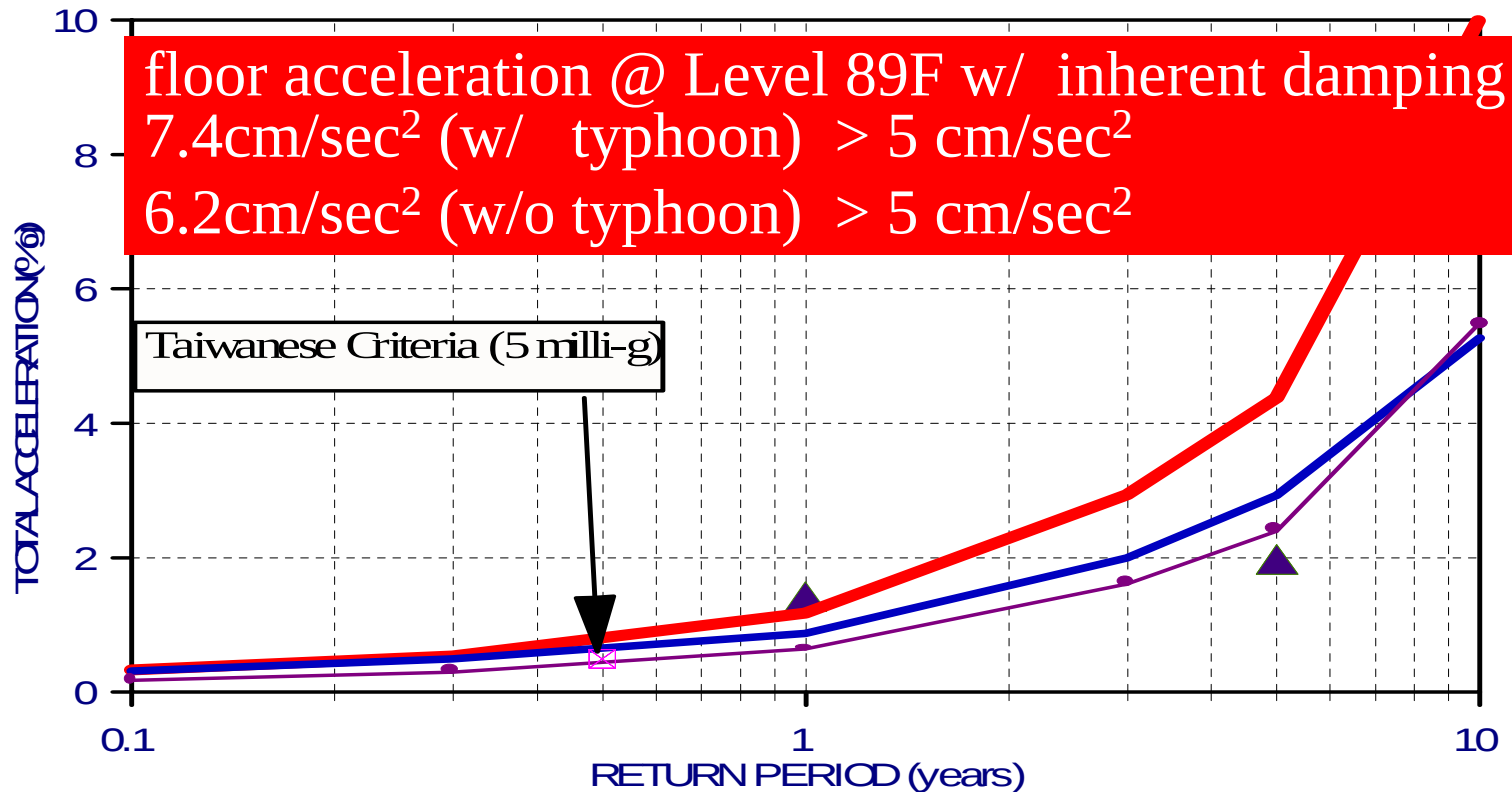


DESIGN CRITERIA

WIND

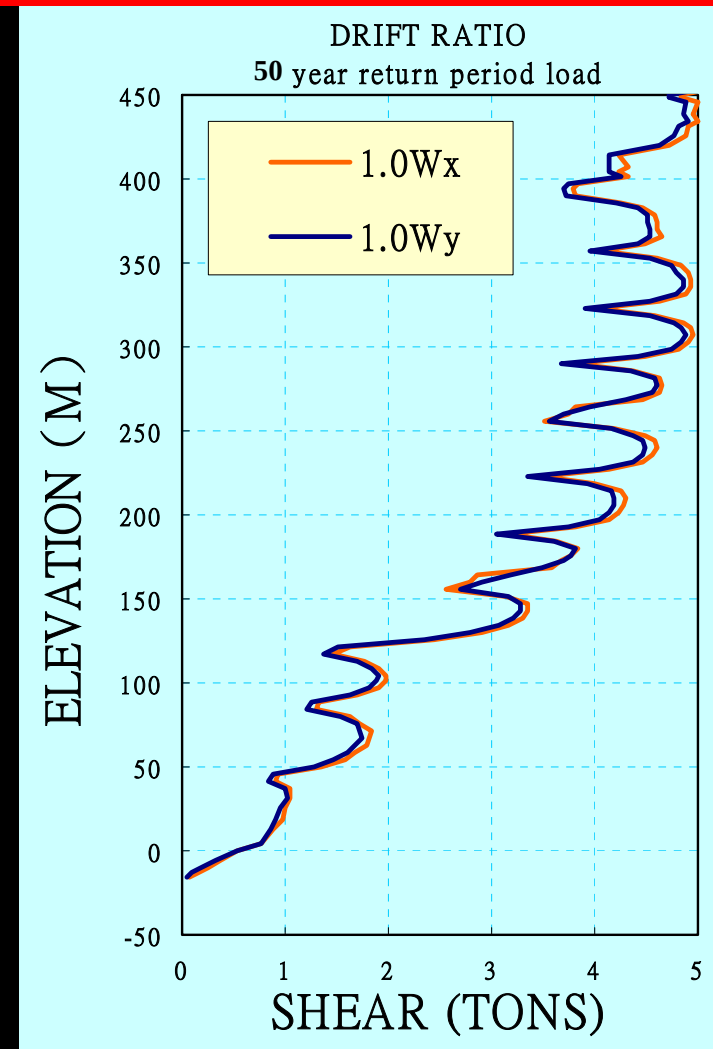
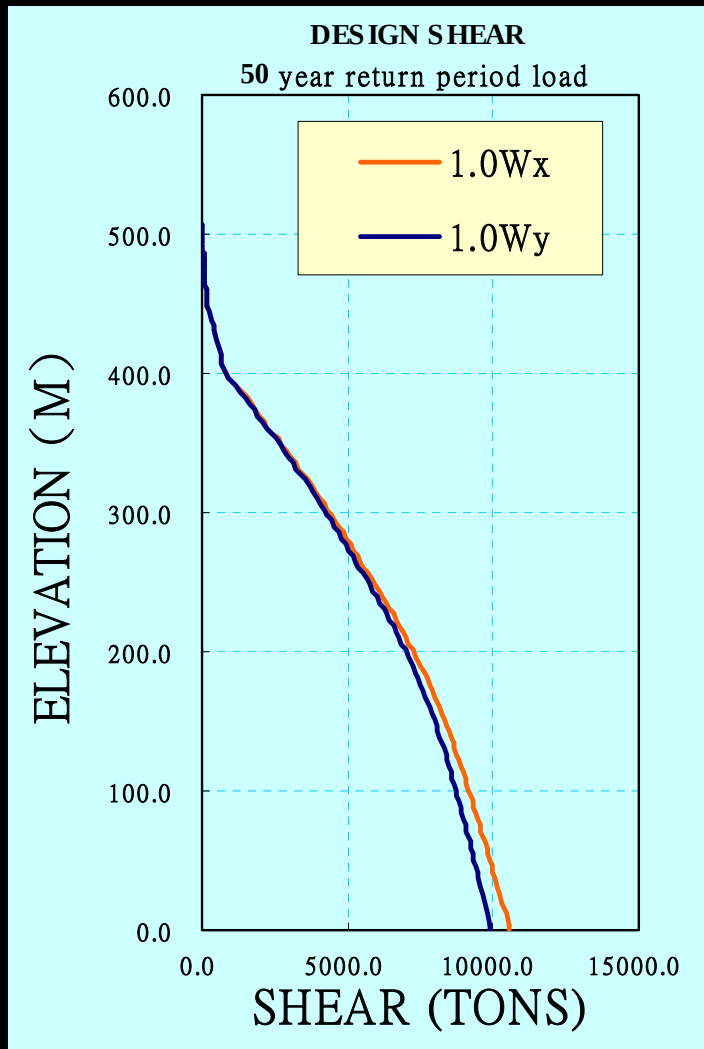
- **½ YEAR (14 m/s) - HUMAN COMFORT ($a < 5 \text{ cm/s}^2$)**
- **50 YEAR (39.9 m/s) - DRIFT RATIO < 5/1000**
- **100 YEAR (43.3 m/s) - STRESS CHECK (factored load)**

Wind Analysis – 1/2-yrs

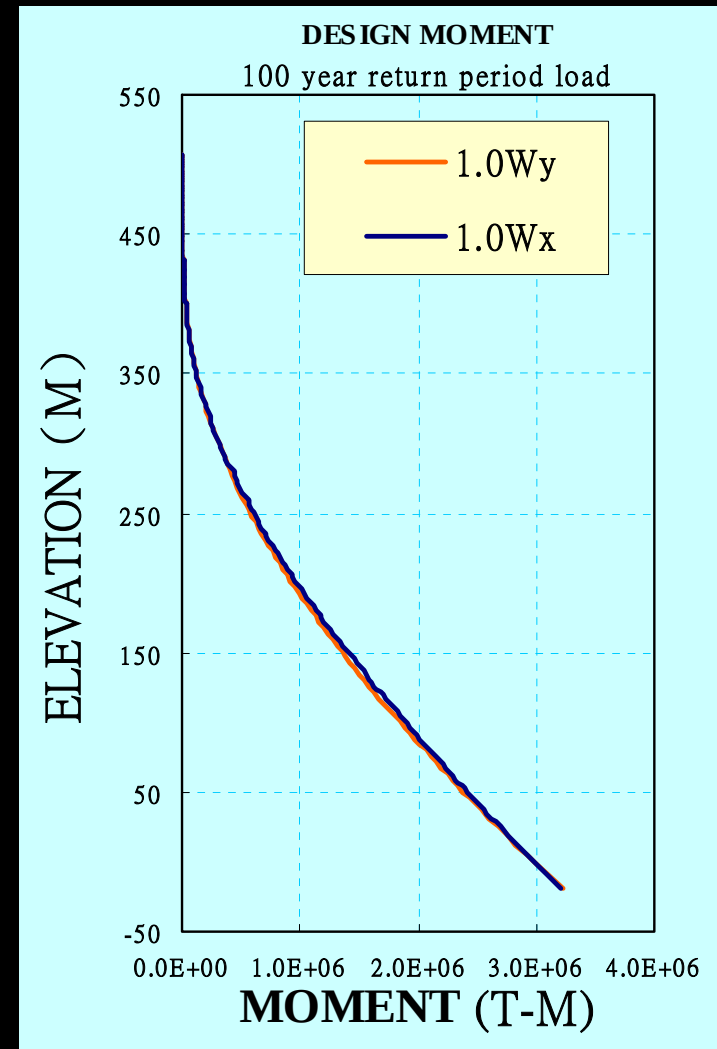
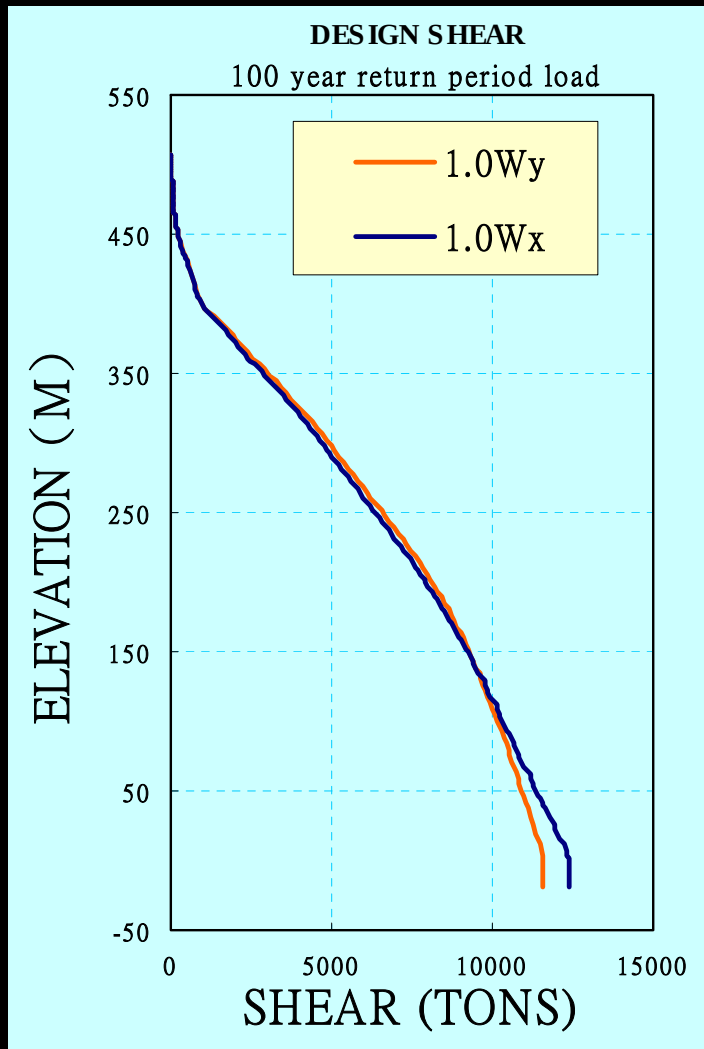


Wind Analysis – 50-ys

Maximum drift ratio < 5/1000



Wind Analysis – 100yrs



RESULTS OF WIND ANALYSIS

- For 0.5 year return period of wind:
floor acceleration without damper= 7cm/sec^2
- For 50 year return period of wind:
max story drift = $0.499\% < 0.5\%$ allowable
- For 100 year return period of wind:
max member stress ratio < 1.00
max story drift= 0.57%

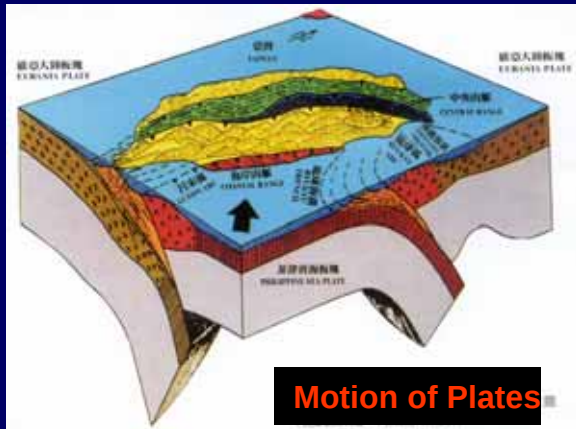
Structural Design

- Structural System
- Analysis & Design

Wind Design

Seismic Design

Special Measures



SEISMIC DESIGN CRITERIA

CODE DESIGN LOADING

DRIFT RATIO < 5/ 1000

- **100 YEAR - REMAIN ELASTIC**

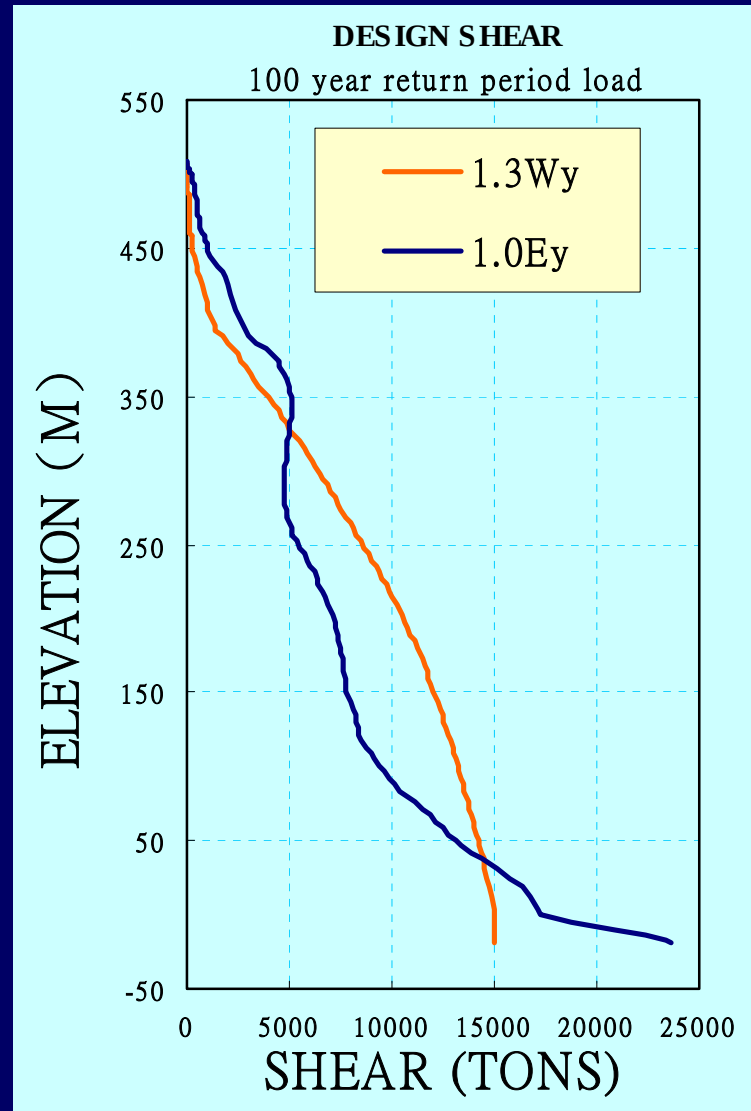
DESIGN INTENSITY:0.13G

- **950 YEAR - RETAIN STABILITY**

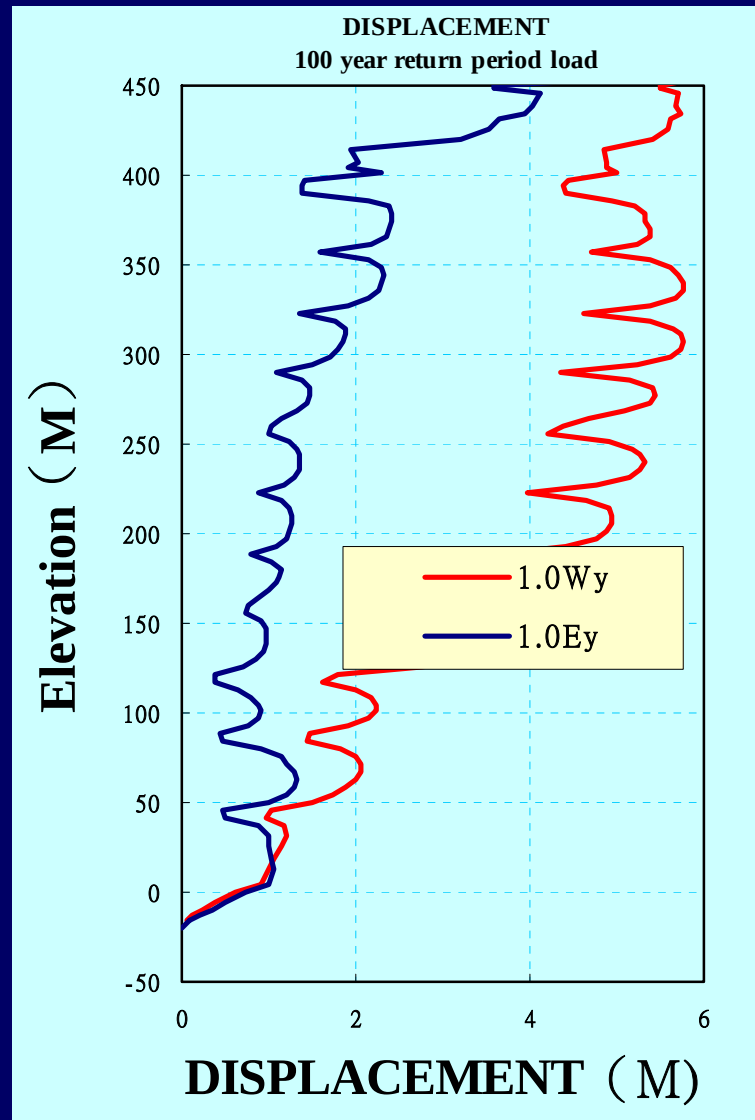
PGA=0.39G



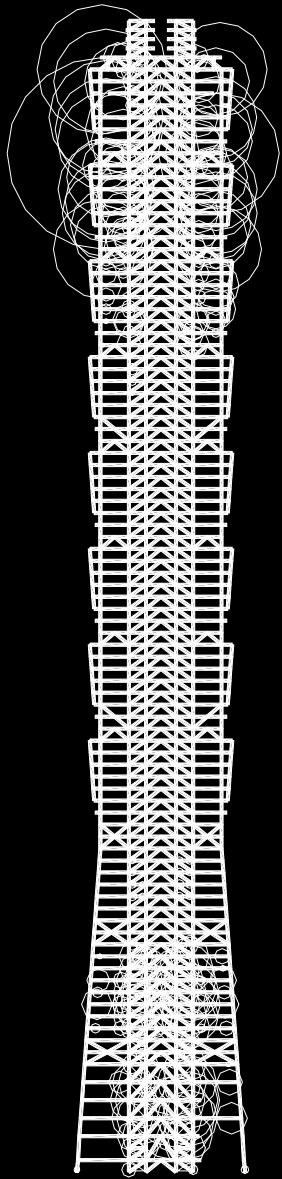
FACTORED SHEAR COMPARISON



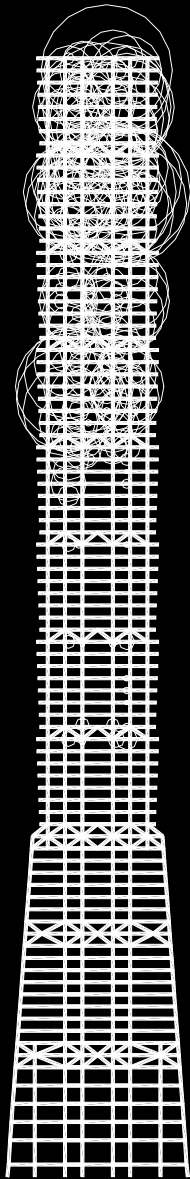
DRIFT RATIO COMPARISON



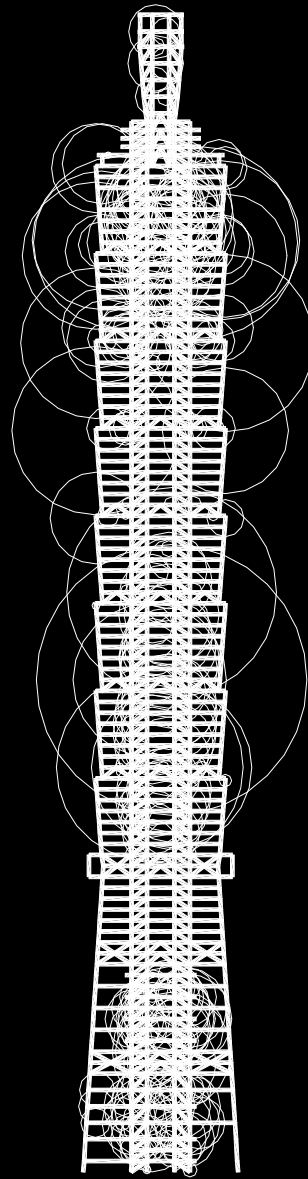
TIME HISTORY ANALYSIS (信義國小震譜)



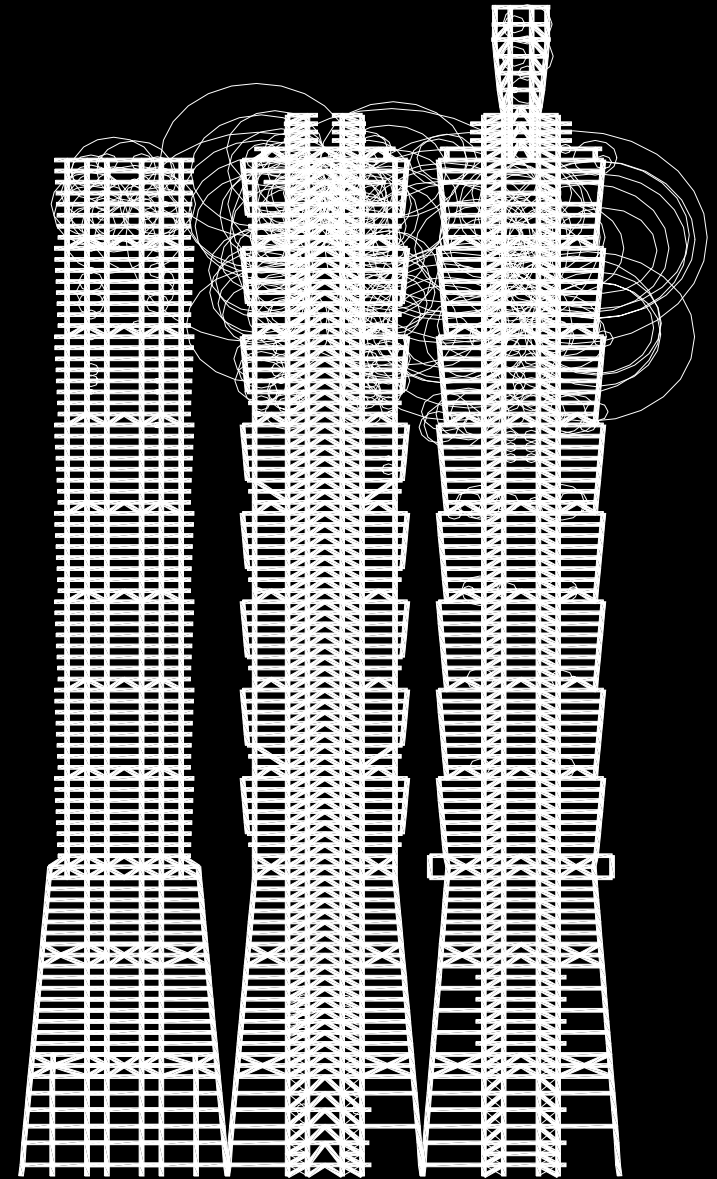
X-SC1



X-12.2

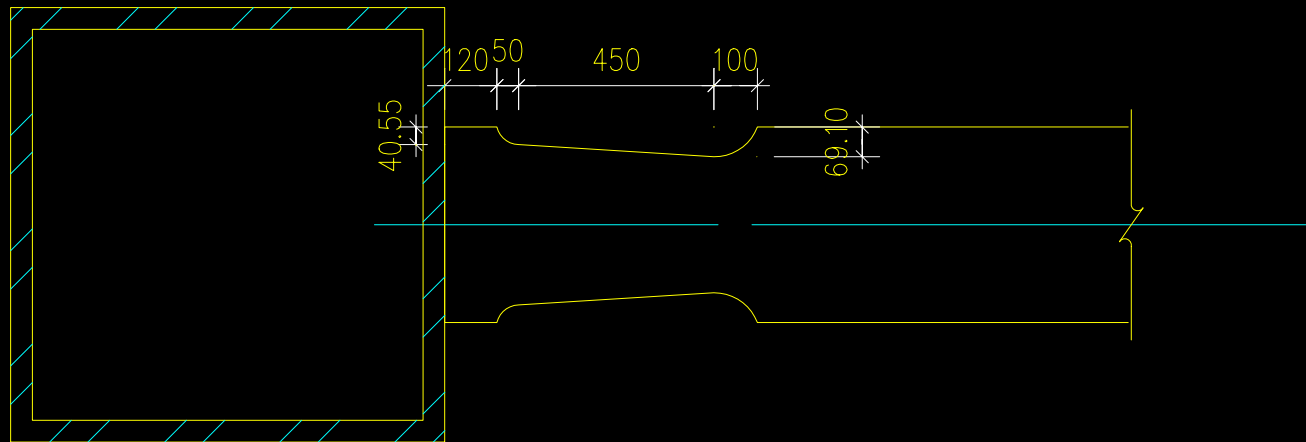


X-12.9



串連分析

HIGH DUCTILE GIRDER FLANGE PROVIDES 5% PLASTIC ROTATION



RESULTS OF EQK ANALYSIS

- Under envelope of Code shear and dynamic shear:
max story drift = $0.325\% < 0.5\%$ allowable
- For 100 year return period of earthquake:
stress ratio < 1.00 by response spectrum analysis
- For 950 year return period of earthquake:
ductility demand < 2.5 by pushover method;
plastic hinge rotation = 0.25%
- For 2500 year return period of earthquake:
plastic hinge rotation = $4\% < 4\%$ allowable
- If plastic rotation demand $> 0.5\%$, cut girder flange

Structural Design

- Structural System
- Analysis & Design

Wind Design

Seismic Design

Special Measures

SPECIAL MEASURES TO RESIST WIND AND SEISMIC FORCES

- **High Strength and High Ductility Steel Plates**
 - SM570M
- **High Strength and High Performance Concrete**
Infilling Columns - 10,000 psi
- **Pile Capacity Test**
- **Tuned Mass Damper - Tower**
- **Smaller Tuned Mass Dampers - Pinnacle**

HIGH PERFORMANCE STEEL PLATES - SM570M

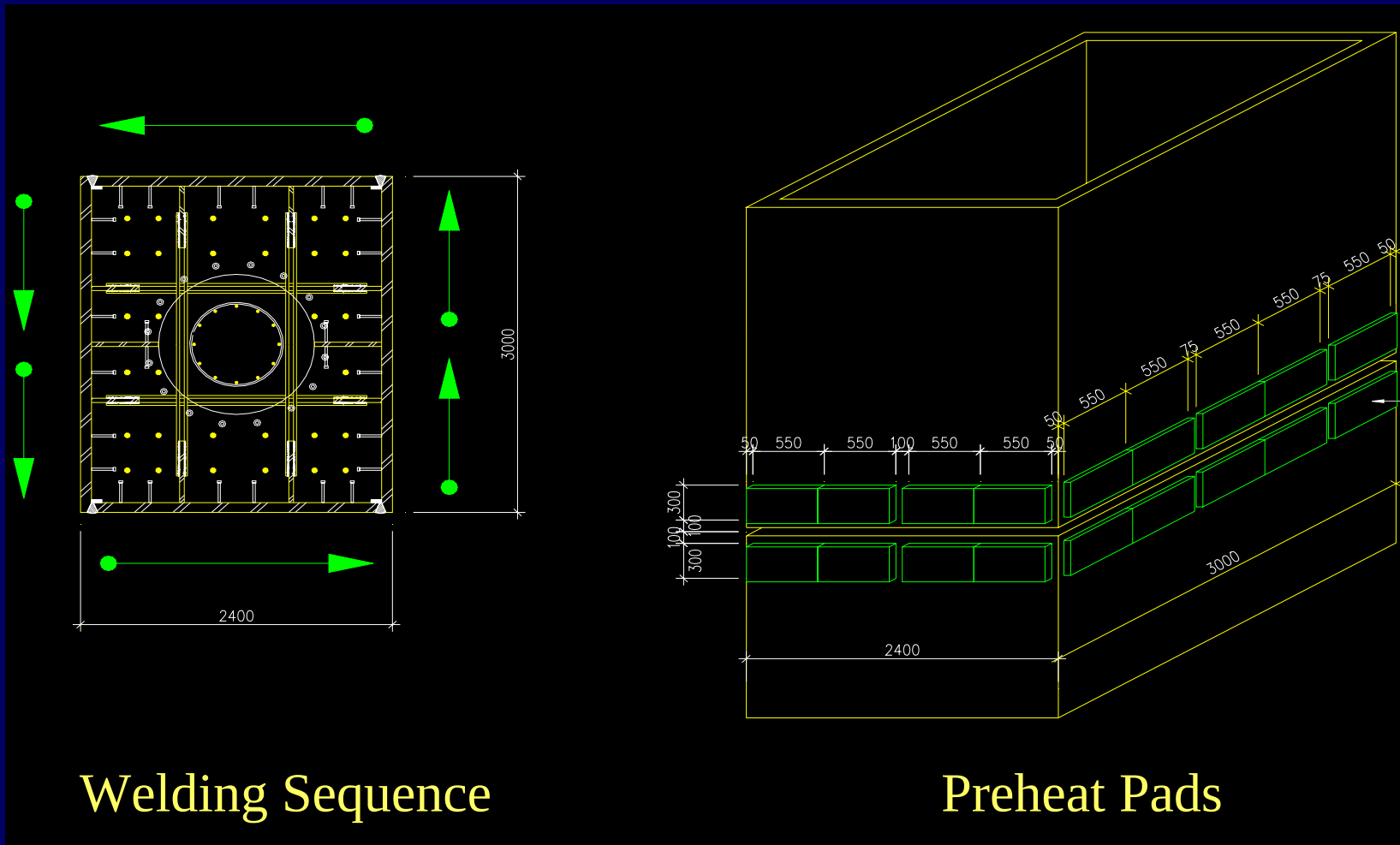
- Used for tower columns, girders & braces
- High strength : 60 ksi F_y 74 ksi
- High ductility :
 - Yield ratio 80% For girders & braces ($t > 40$ mm)
 - 85% For girders & braces ($t \leq 40$ mm),
columns
- High weldability : C_{eq} 0.44 % ($t < 40$ mm)
0.47 % ($t \leq 40$ mm)
- Through-thickness ductility
- Impact absorption energy

SUPER-COLUMN FABRICATION



•Max Col. Size:2400mm×3000mm×80mm/70MPa HPC

WELDING OF SUPER-COLUMN



WELDING OF SUPER-COLUMN



10000 psi HIGH PERFORMANCE CONCRETE

- Design strength : 10000psi @ 90 days
- High flowability: slump - 250 ± 20 mm
slump flow - 600 ± 20 mm
- 5% maximum air bubble underneath diaphragm plate
- Autogenous shrinkage 300×10^{-6} m/m @ 90 days



COLUMN INFILL MOCKUP TEST

10,000 psi HPC



REVERSE CIRCULATION PILE

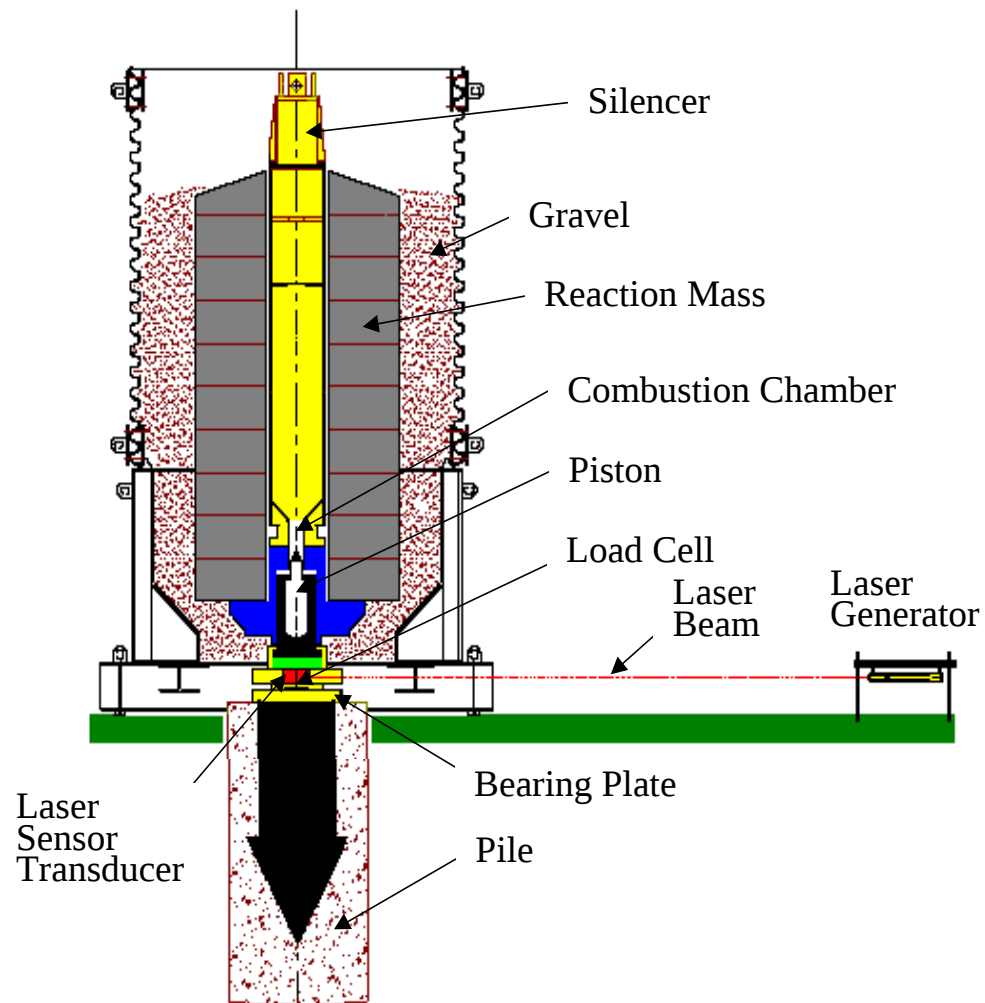


STATIC TESTING OF PILES

COMPRESSION: 4000 TONNES
TENSION: 2200 TONNES



DYNAMIC TESTING OF PILES



**COMPRESSION:
2000 TONNES MAX.**

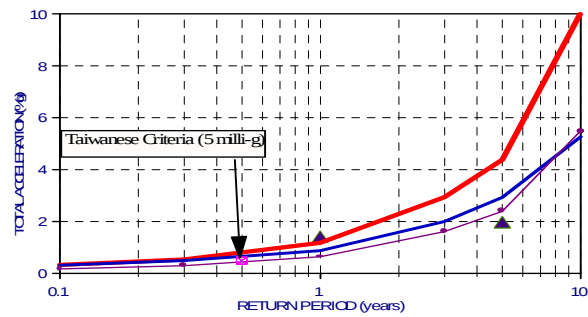


SLURRY WALL



REDUCED BEAM SECTION





▲ ISO Criteria
 — Without Typhoons (15% damping)
 — With Typhoons (15% damping)
 — with TMD (5% damping - TYRHOON)

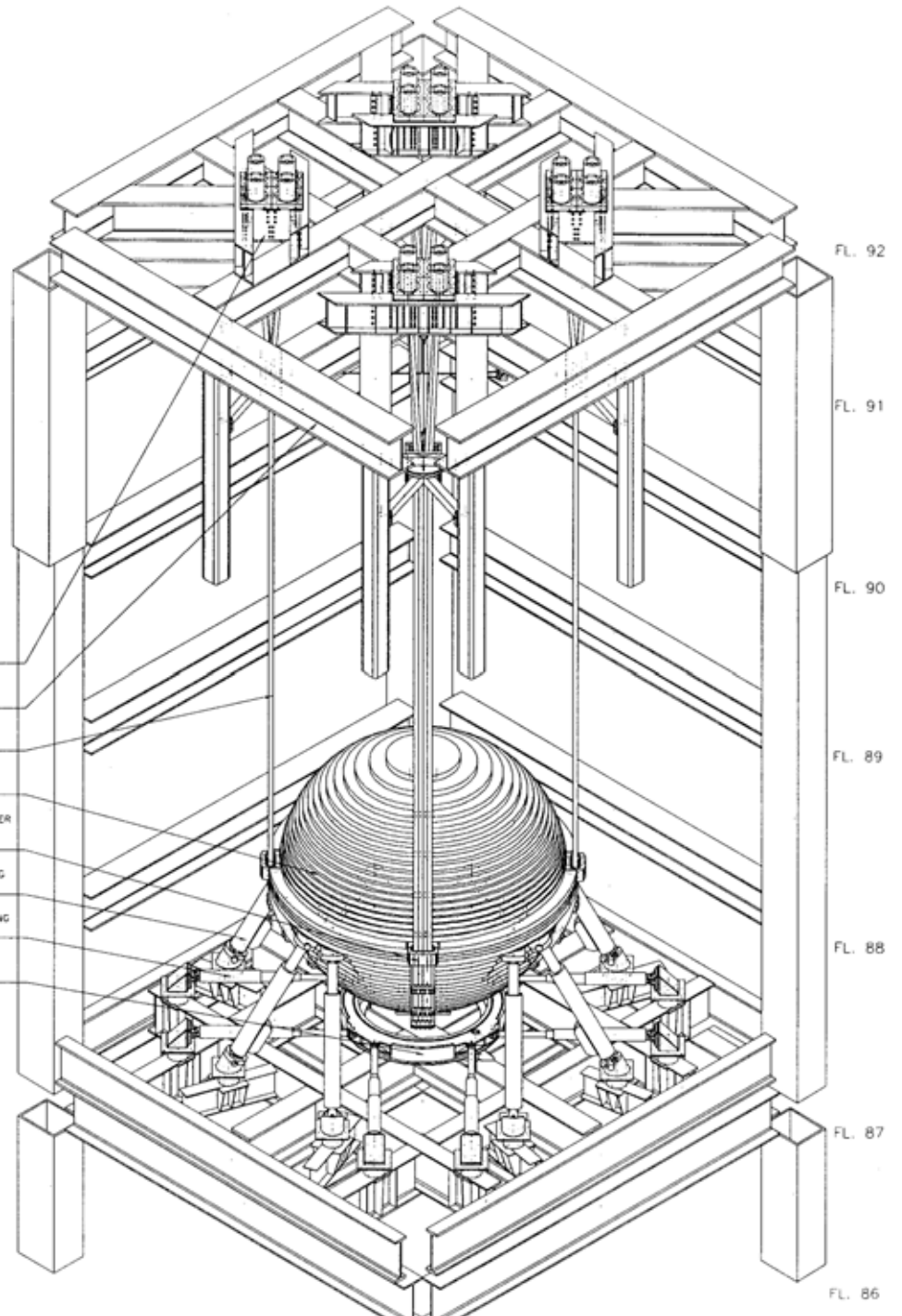
TMD

TMD COMPONENT DESCRIPTION

1. UPPER CABLE SUPPORT. SEE DRAWING TMD-020-100.
2. TUNING FRAME COMPONENTS. SEE DRAWING TMD-030-100.
3. MAIN SUPPORT CABLE ASSEMBLIES. SEE DRAWING TMD-040-100.
4. MASS BLOCK. SEE DRAWING TMD-050-100.
5. MASS BLOCK CRADLE, BUMPER PIN & LOWER CABLE HOUSING. SEE DRAWING TMD-060-100.
6. PRIMARY HYDRAULIC SYSTEM. SEE DRAWING TMD-070-100.
7. SHOCKER HYDRAULIC SYSTEM. SEE DRAWING TMD-070-100.
8. BUMPER RING. SEE DRAWING TMD-070-100.
9. MONITORING SYSTEM, COMPUTER AND ASSOCIATED INSTRUMENTS TO MEASURE BUILDING SWAY, TMD MOTION, WIND SPEED, AND WIND DIRECTION.

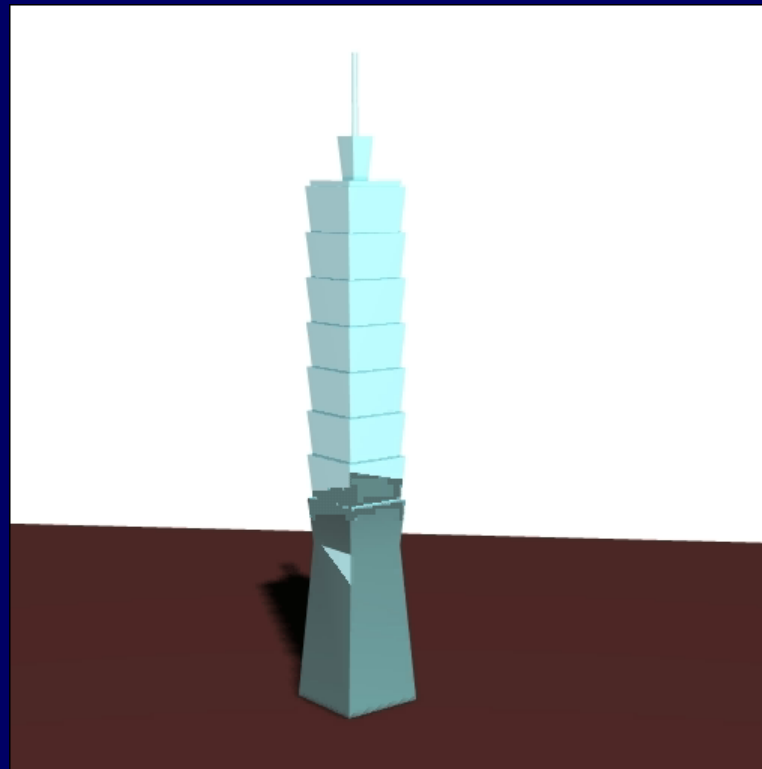
TMD 組件說明

1. 上拉鋼索支撐, 參見圖 TMD-020-100.
2. 調整構架組件, 參見圖 TMD-030-100.
3. 主要支撐鋼索組合體, 參見圖 TMD-040-100.
4. 質量塊, 參見圖 TMD-050-100.
5. 質量塊半球形滾動腳輪及下拉鋼索座, 參見圖 TMD-060-100.
6. 主要油壓系統, 參見圖 TMD-070-100.
7. 油壓緩衝器系統, 參見圖 TMD-070-100.
8. 緩衝器環, 參見圖 TMD-070-100.
9. 監視系統, 電腦及相關儀器測量結構物的搖晃, TMD 之運動, 風速及風向。



BUILDING TMD

Building Wind Damper Animation

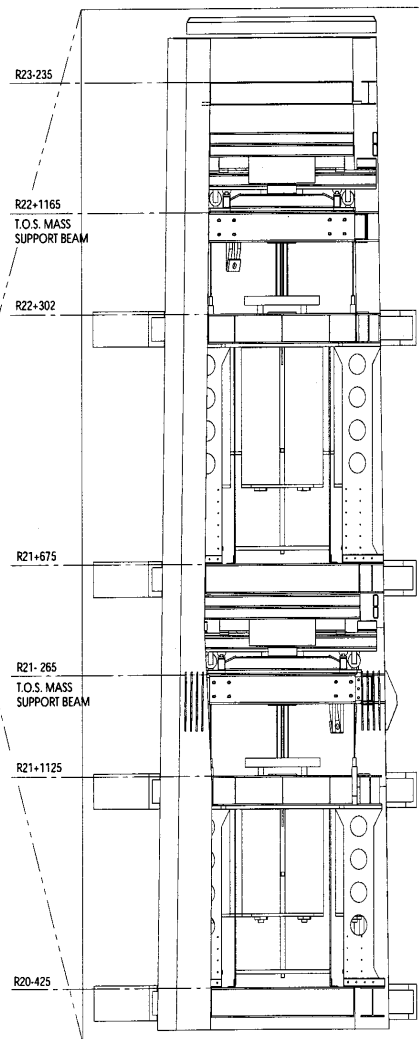
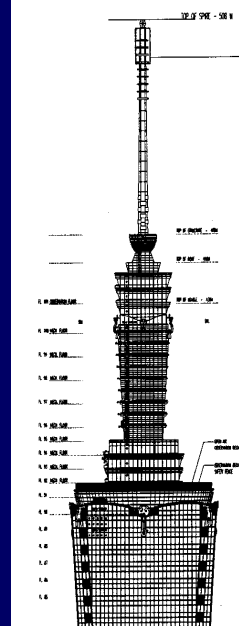


TMD CONSTRUCTION



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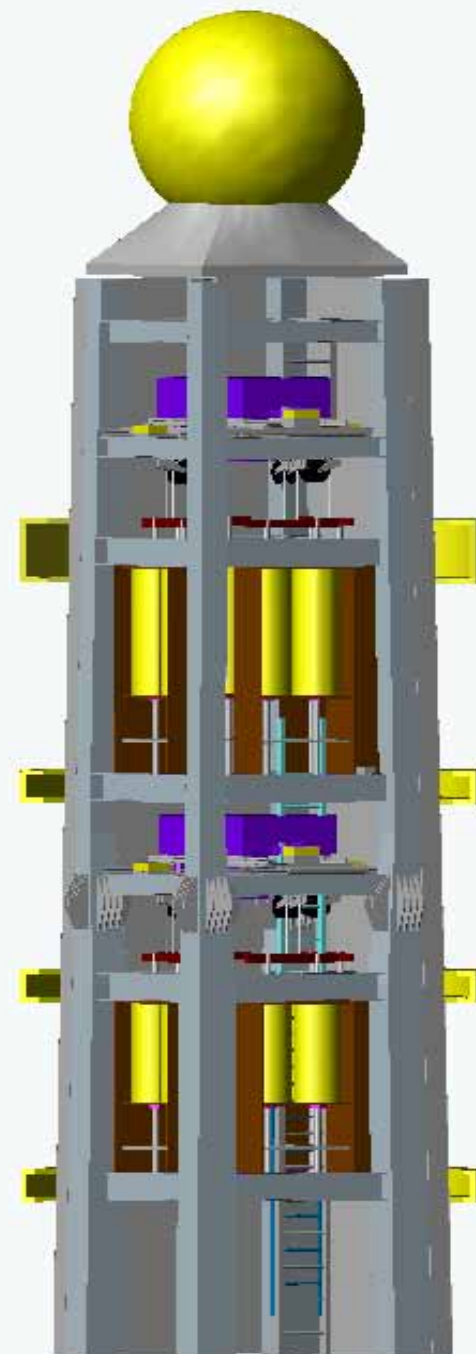
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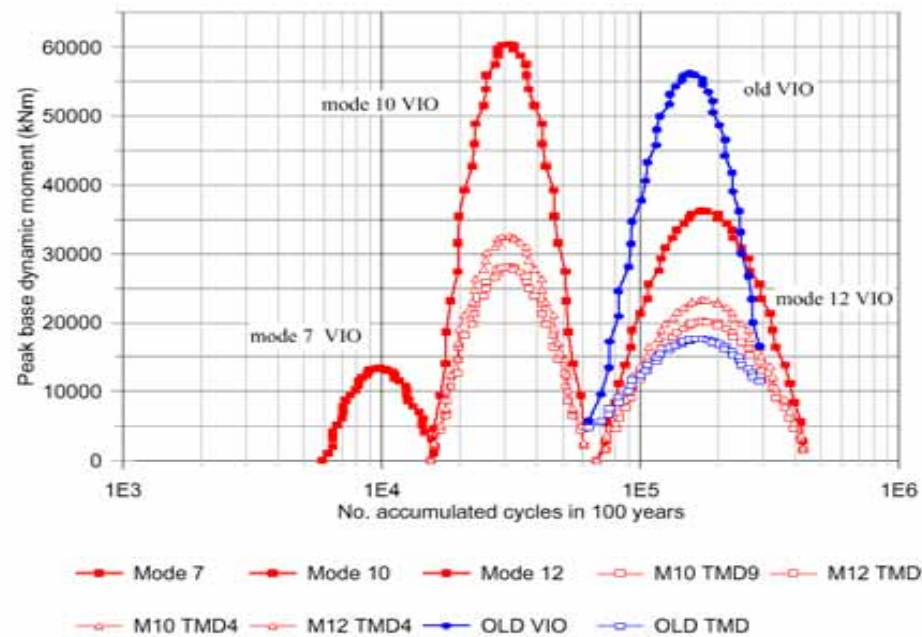


ELEVATION VIEW FROM NORTH SIDE
 OTHER ELEVATION VIEWS SIMILAR

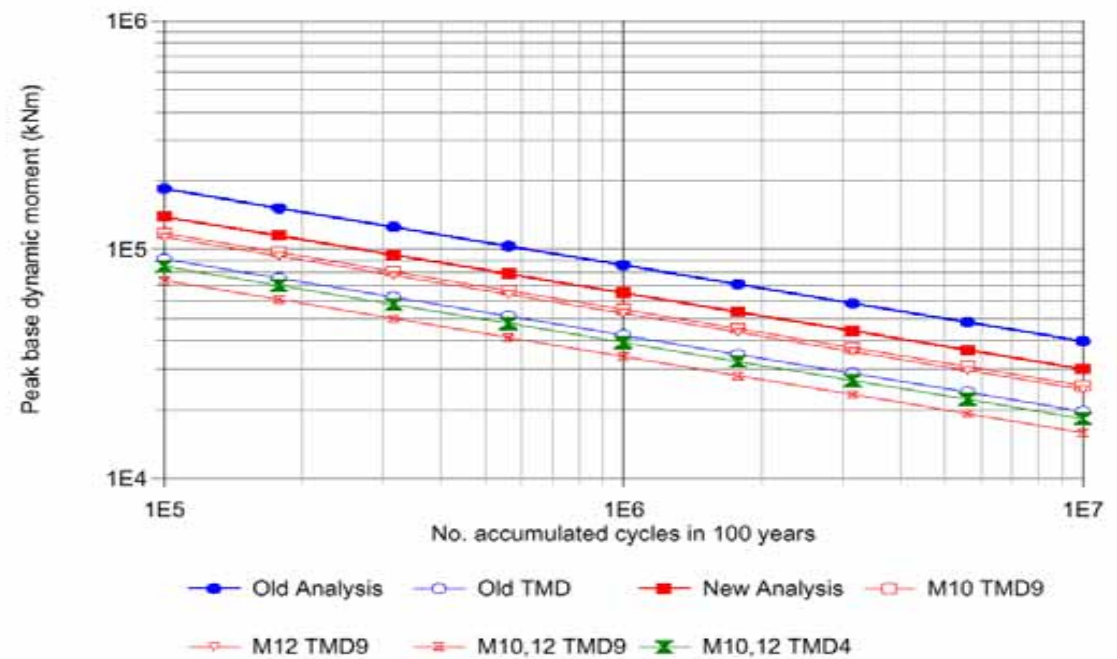
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尖塔TMD





Equivalent Cycles (Miner's Rule)



**THANK YOU
FOR YOUR
ATTENTION**

