TAIPEI 101
(Taipei Financial Center)
A New Challenge in Structural Engineering

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CONTENTS

Introduction

- 2004 grand award for engineering by American Popular Science Journal
- A “BOT” project, awarded in 1997, completed in 2004.
- Impacted by natural and man made disasters
  921 Chi-Chi Earthquake (9/21/1999)
  911 terrorist attack in US (9/11/2001)
  331 Earthquake (3/31/2002)

Introduction -
Architectural Features

- Architect – C.Y. Lee
- Building height 508m (1667 ft), 101 stories
- 5 story basement
- 370,000m2 floor area
- Oriental elements in establishing the architectural form (pedals of flowers)

Introduction –
Structural Features

Mega structural system for vertical and lateral loads, including typhoon and strong earthquake

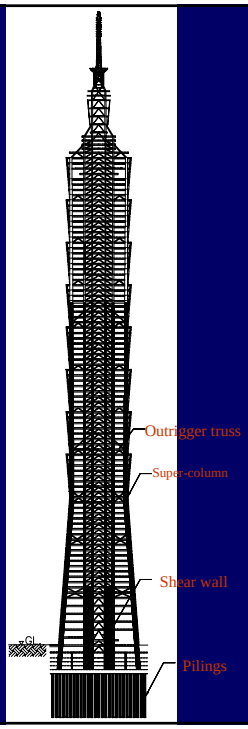
- 550 bored piles
- High strength and ductility structural steel with RBS
- Columns infilled with high performance concrete (10,000psi)
- Tunned mass damper to reduce wind vibrations
- Nonlinear time history analyses

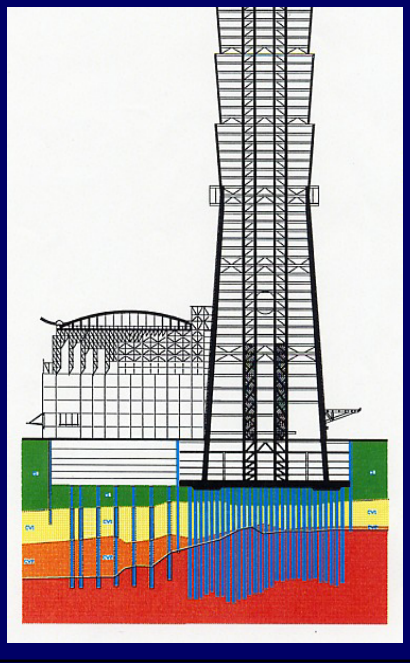
Structural Design – Gravity Load

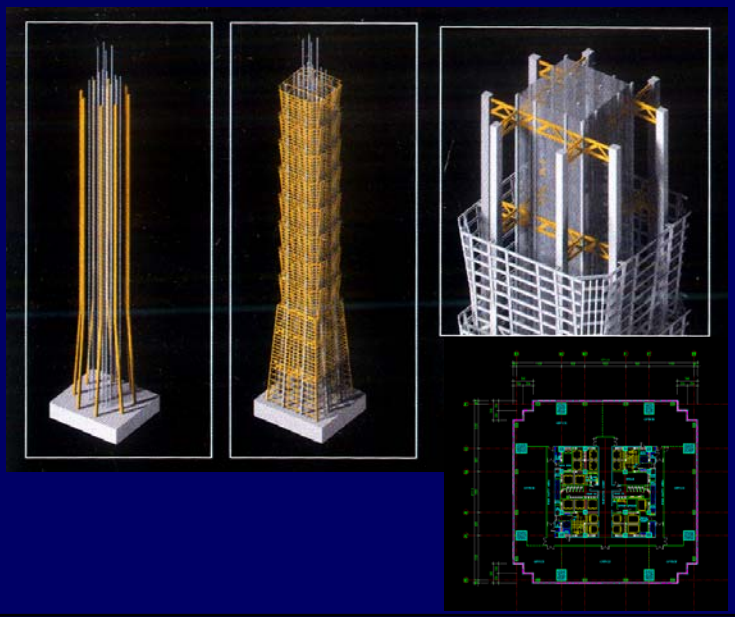
- Gravity loads are carried vertically by a variety of columns.
- Within the core, sixteen columns are located at the crossing points of four lines of bracing in each direction. The columns are box sections constructed of steel plates, filled with concrete for added strength as well as stiffness at the 62nd floor and below.
- On the perimeter, up to the 26th floor, each of the four building faces has two ‘super-columns,’ two ‘sub-super-columns,’ and two corner columns.
- Above the 26th floor has the two ‘super-columns’ continue upward.

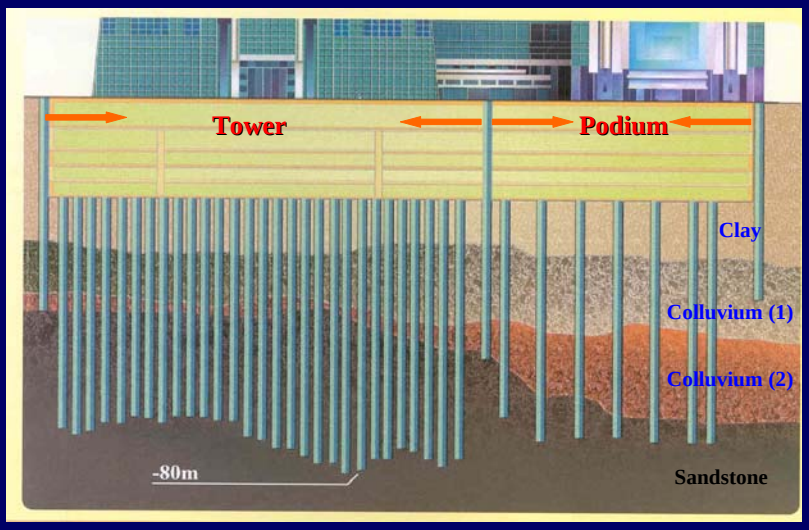
Structural Design – Lateral Load

- Lateral forces are resisted through a combination of braced frames in the core, outriggers from core to perimeter ‘super-columns’ and moment resisting frames in the perimeter and other selected locations.
- Wind Dampers are used to reduce lateral vibrations due to wind

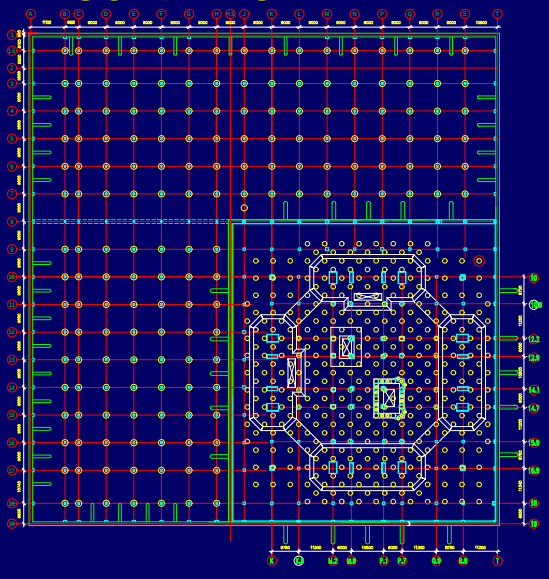




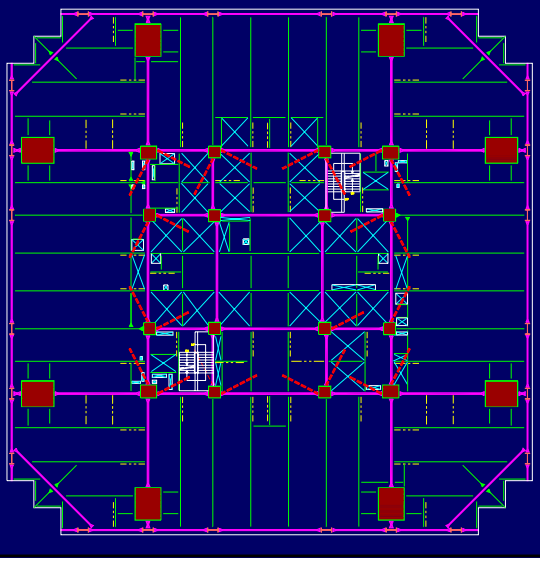




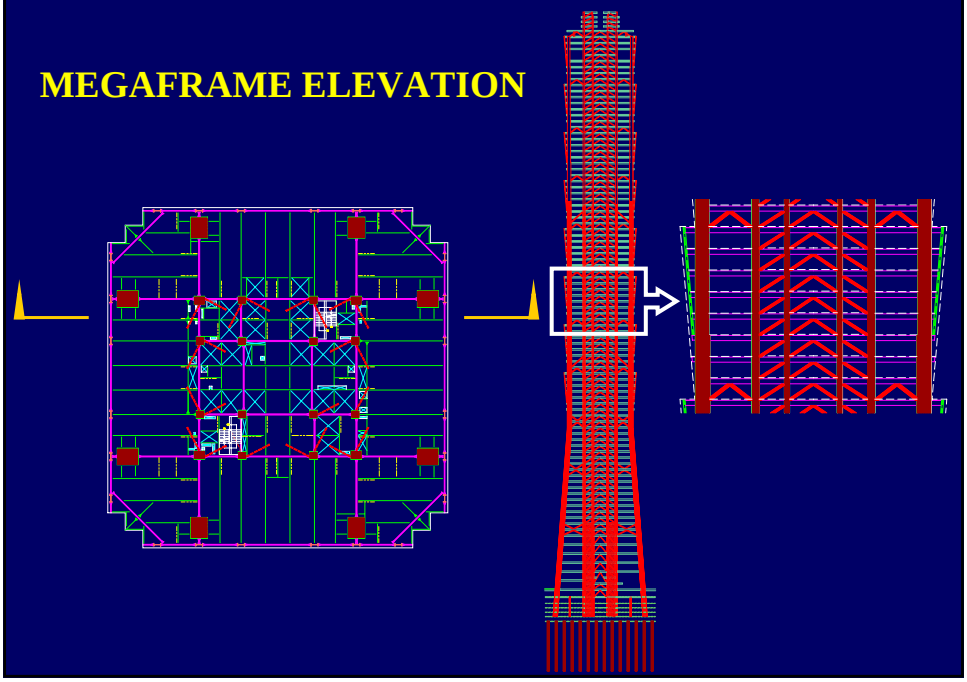
FOUNDATION PLAN



TYPICAL FLOOR FRAMING PLAN



MEGAFRAME ELEVATION



DESIGN CRITERIA

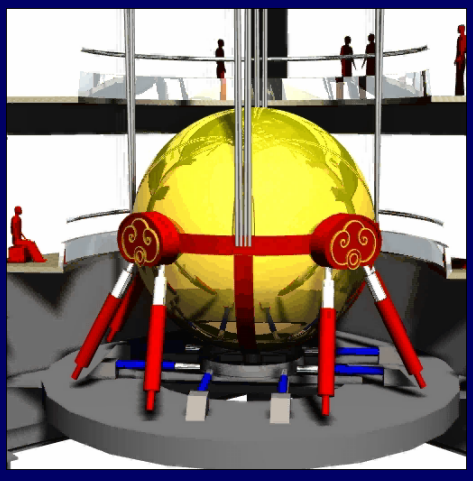
WIND (Wind Tunnel test)

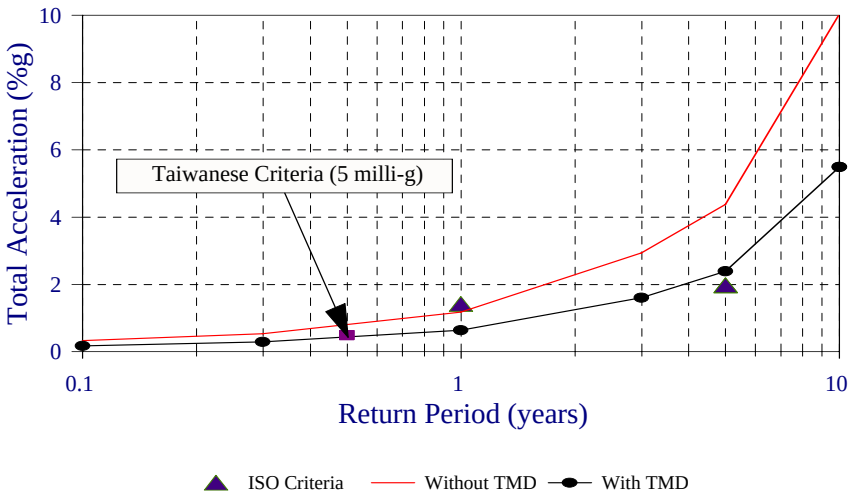
- ½ YEAR - HUMAN COMFORT
- 50 YEAR - DRIFT RATIO
- 100 YEAR - STRESS

SEISMIC

- 100 YEAR - REMAIN ELASTIC (0.13g)
- 950 YEAR - RETAIN STABILITY (0.39g)

BUILDING TMD





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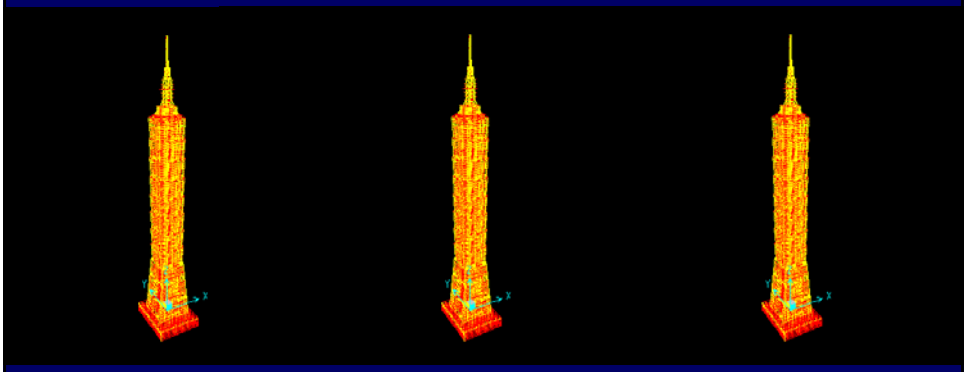
SPECIAL MEASURES TO RESIST WIND AND SEISMIC FORCES

- **High Strength and High Ductility Steel Plates**
  - **SM570M**
- **High Strength and High Performance Concrete**

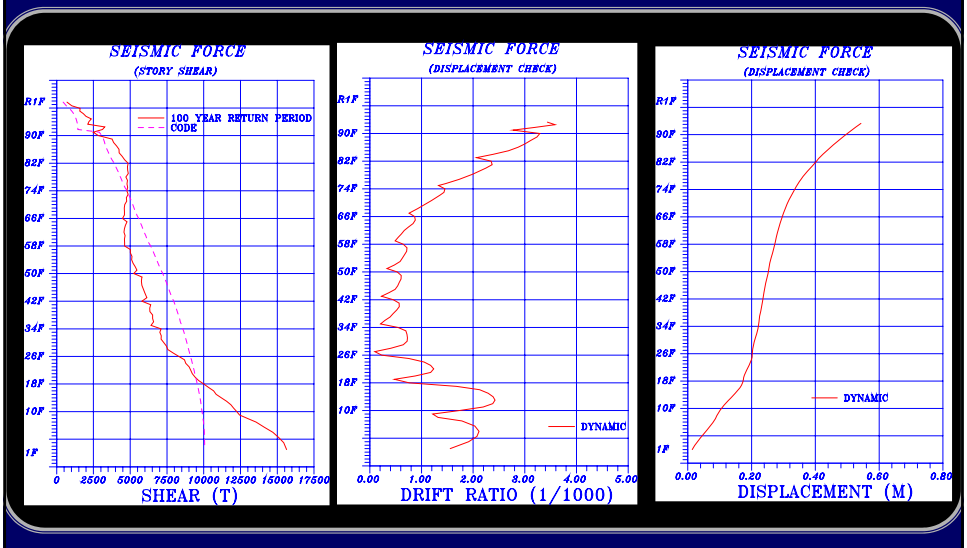
  Infilling Columns - 10,000 psi
- **High Ductility Beam-Column Connection**
  - **Reduced Beam Sections**
- **Tuned Mass Damper - Tower**
- **Smaller Tuned Mass Dampers - Pinnacle**

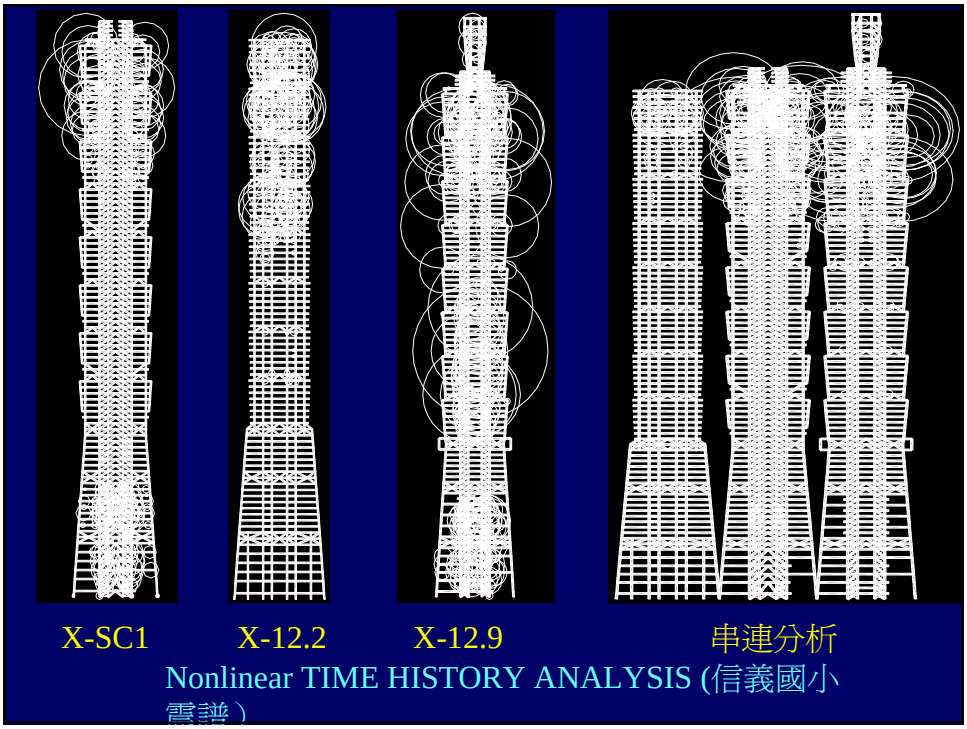
BUILDING MODE SHAPES



1st mode 2nd mode 3rd mode

Seismic Analysis

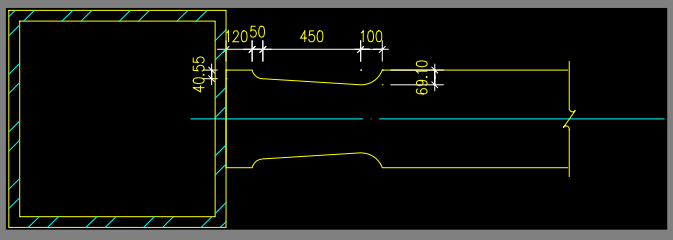




X-SC1　　X-12.2　　X-12.9　　串連分析

Nonlinear TIME HISTORY ANALYSIS (信義國小震譜)

Construction Techniques - RBS



HIGH PERFORMANCE STEEL PLATES - SM570M

- Used for tower columns, girders & braces
- High strength : 60 ksi≦Fy≦74 ksi
- High ductility :

  Yield ratio≦80% For girders & braces (t ＞40 mm)
  ≦85% For girders & braces (t ≦40 mm), columns
- High weldability : Ceq ≦ 0.44 % (t ＜40 mm)
  ≦ 0.47 % (t ≧40 mm)
- Through-thickness ductility
- Impact absorption energy

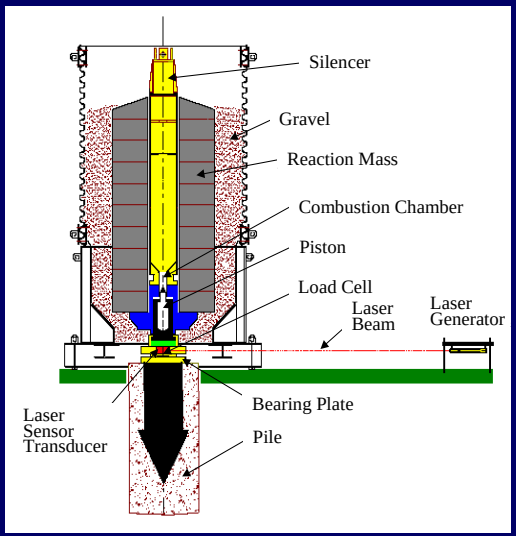
REVERSE CIRCULATION PILE

STATIC TESTING OF PILES

COMPRESSION: **4000 TONNES**

TENSION: **2200 TONNES**

DYNAMIC TESTING OF PILES



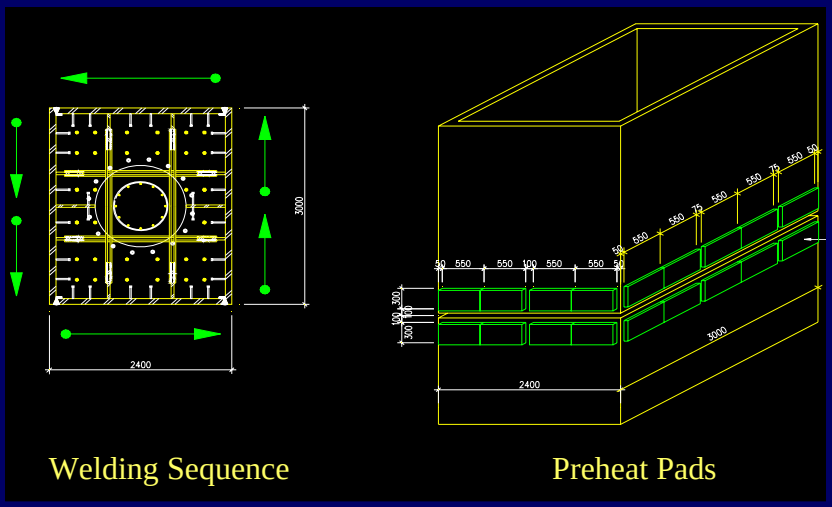
COMPRESSION:

2000 TONNES MAX.

SLURRY WALL

SUPER-COLUMN FABRICATION

WELDING OF SUPER-COLUMN

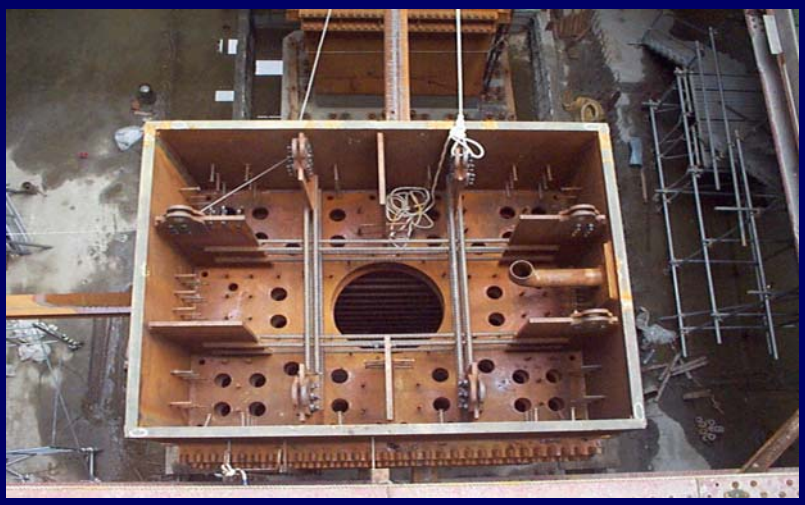


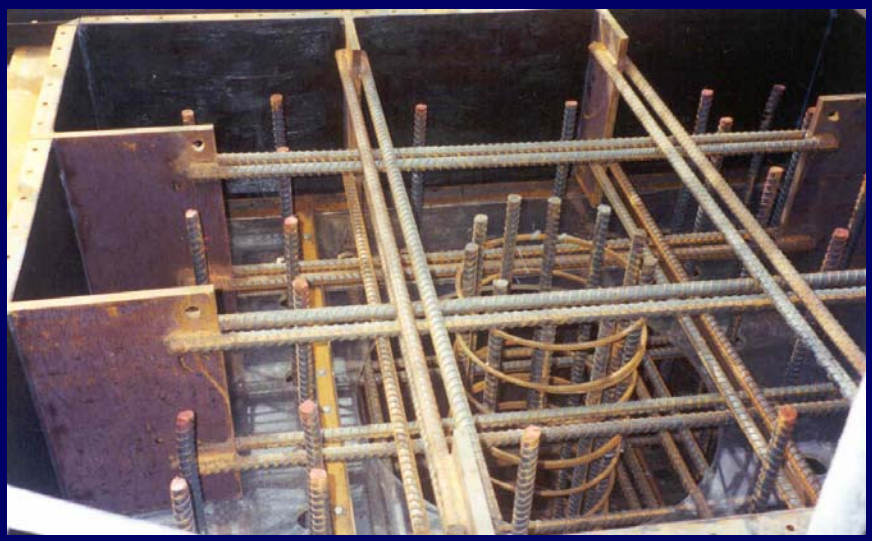
Welding Sequence

Preheat Pads

WELDING OF SUPER-COLUMN

CROSS-SECTION OF SUPER-COLUMN

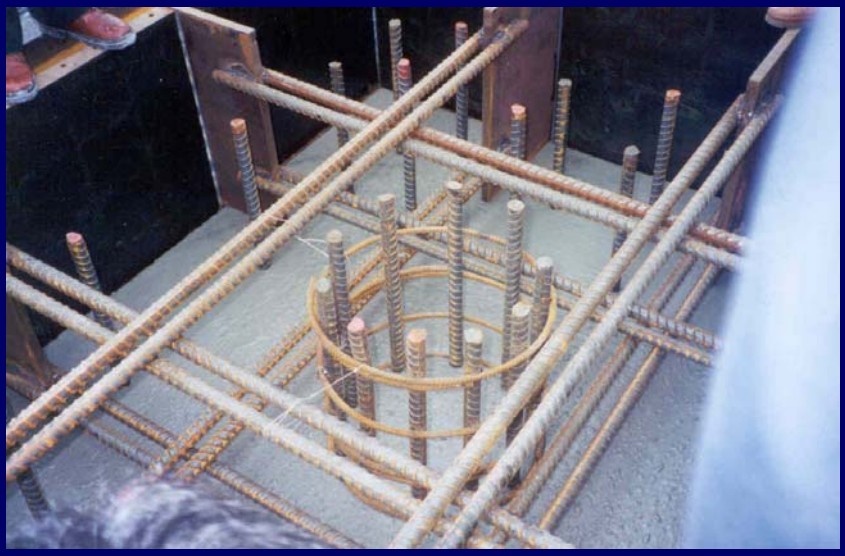




10000 psi HIGH PERFORMANCE CONCRETE

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

COLUMN INFILL MOCKUP TEST



REDUCED BEAM SECTION

TMD CONSTRUCTION




CONSTRUCTION PROGRESS

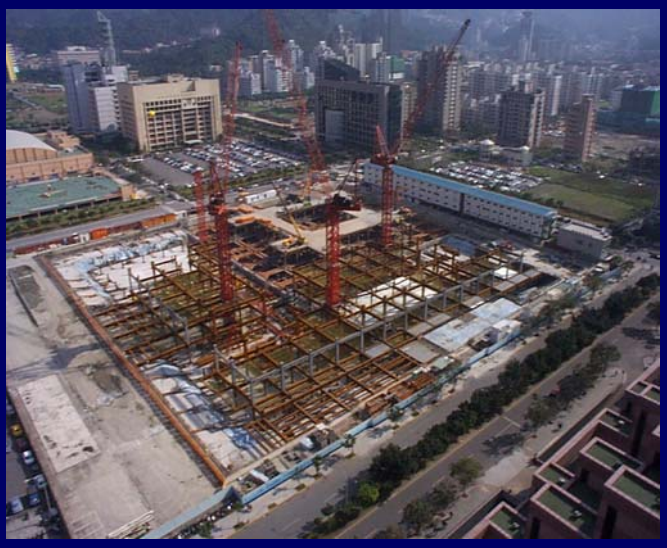
1998

CONSTRUCTION PROGRESS
1998

CONSTRUCTION PROGRESS
1998

CONSTRUCTION PROGRESS
1999

CONSTRUCTION PROGRESS
1999



CONSTRUCTION PROGRESS
2000

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2001

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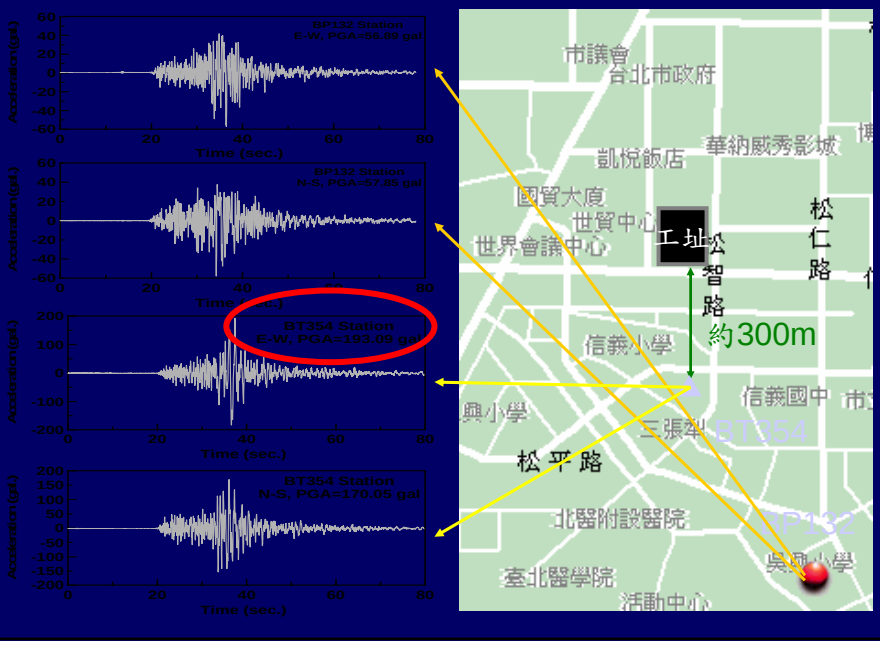
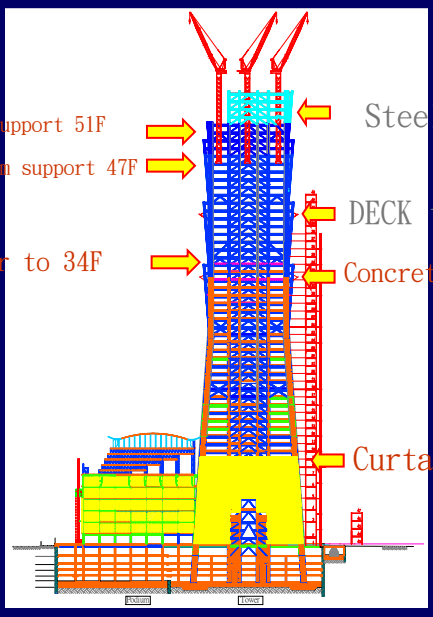
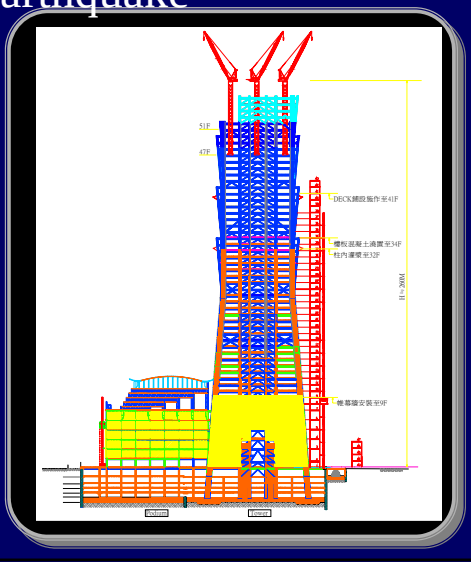


Status of Construction before 331 Earthquake

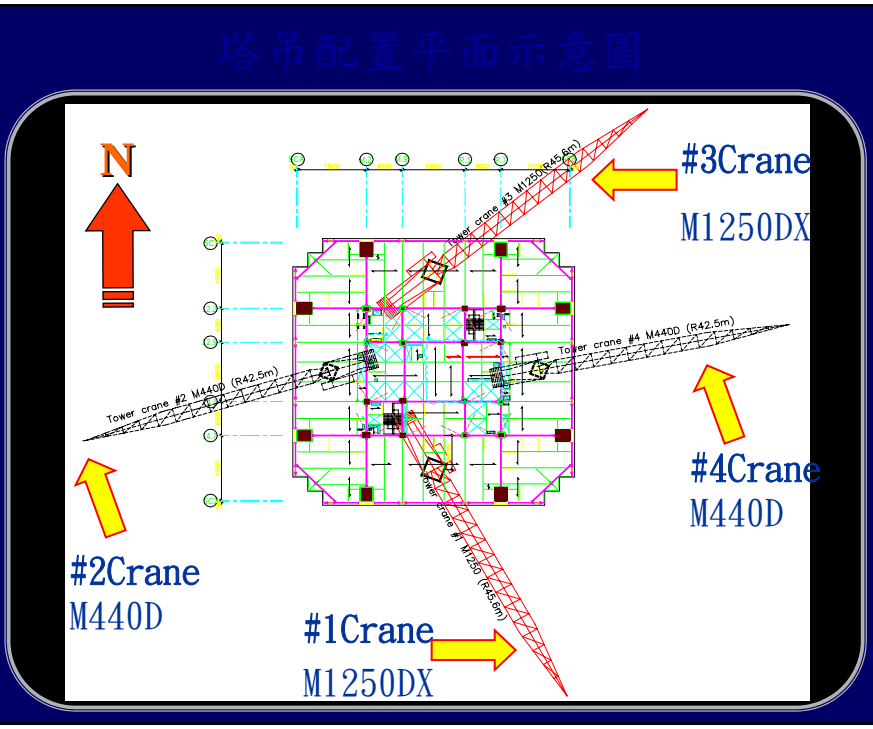


Estimated Fundamental Periods at time of Earthquake

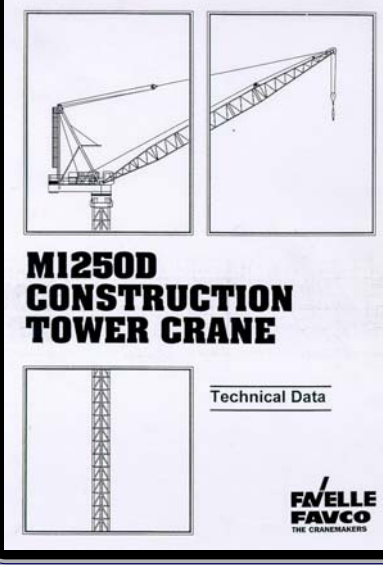
- Structure (with cranes) under construction 2 ~ 3sec.
- Crane fixed at ground 2 ~ 3sec



塔吊配置平面示意圖



塔式吊車資料概要 M1250D



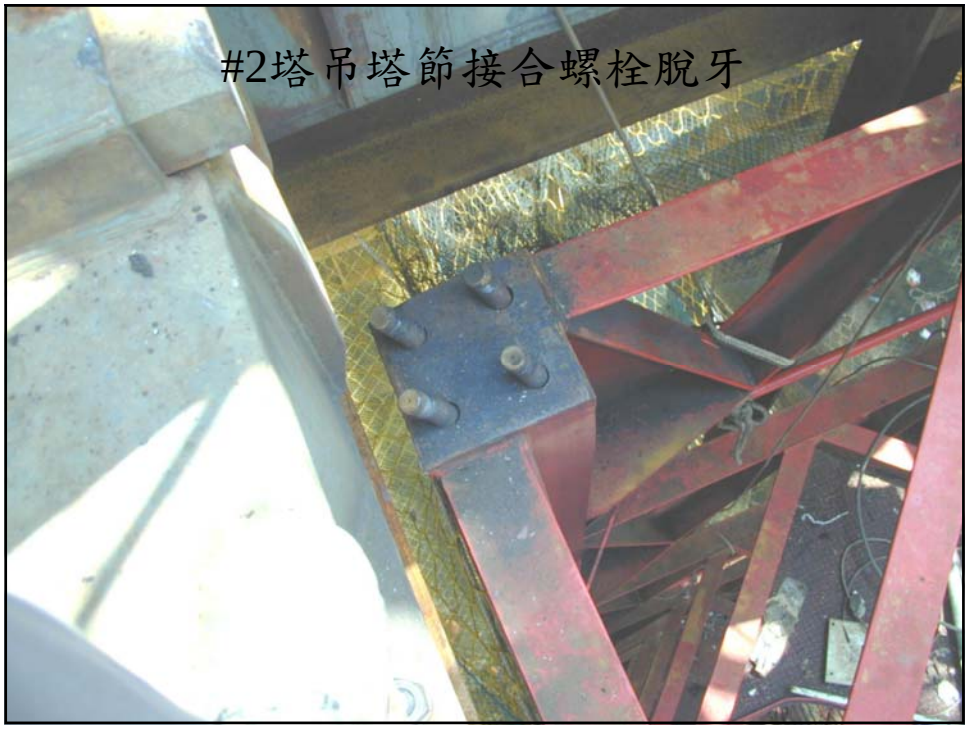
塔吊編號	**No.1 & 3**
廠牌型號	FAVCO M**1250**DX
塔節高度	48 M
固定高度	12 M
桁架長度	45.8 M
最大能量	100 T

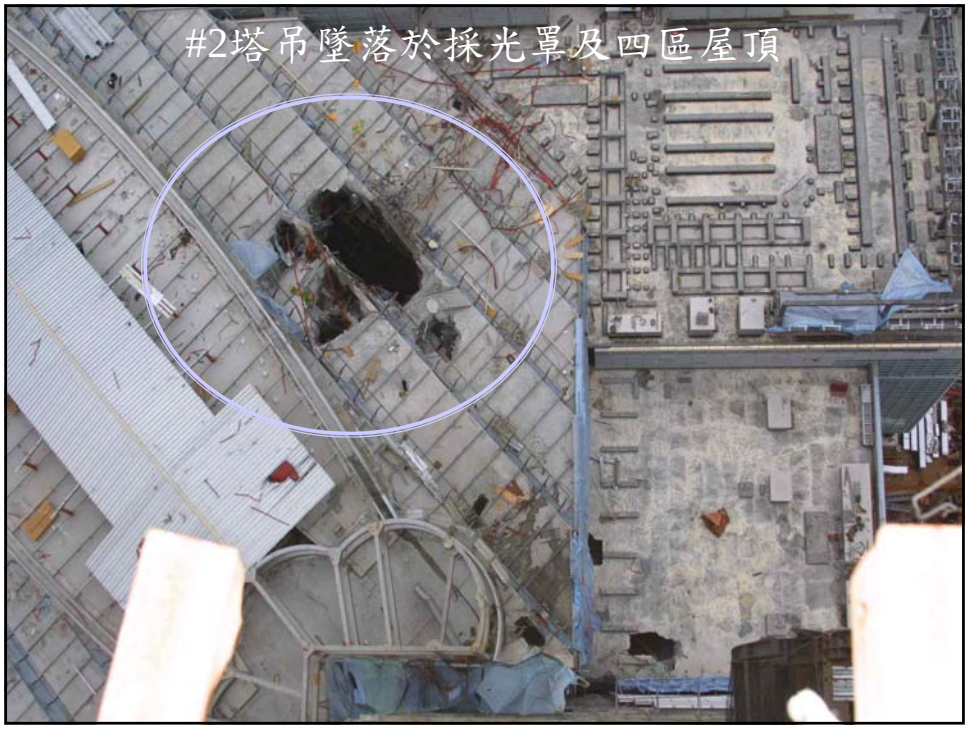
塔式吊車資料概要 M440D

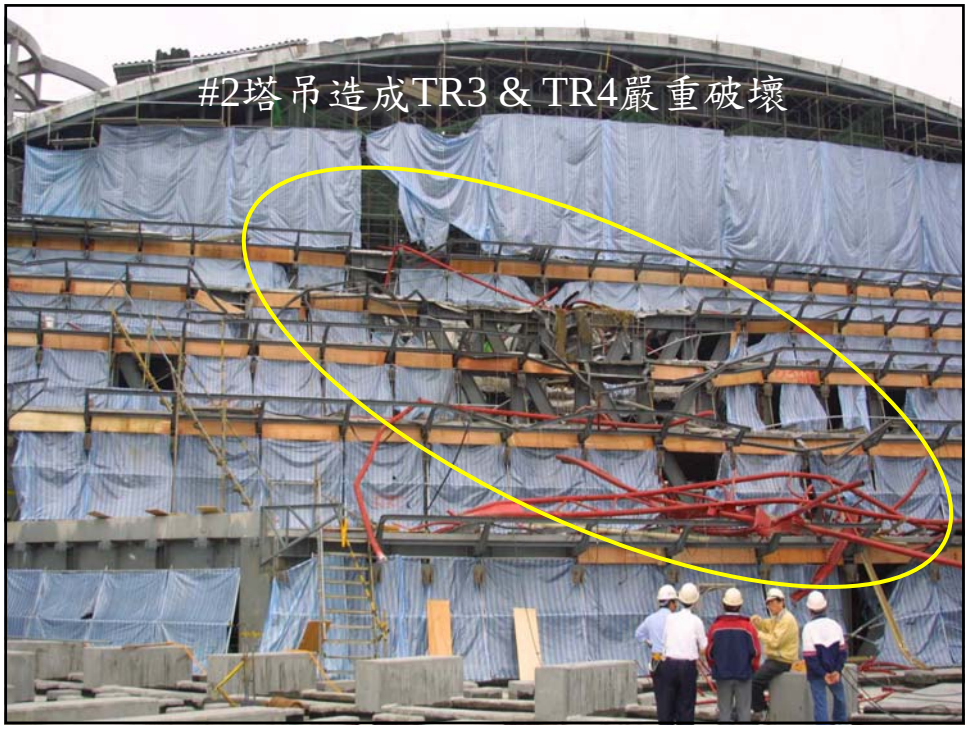
塔吊編號	**No.2 & 4**
廠牌型號	FAVCO M**440**D
塔節高度	48 M
固定高度	12 M
桁架長度	42.5 M
最大能量	50 T

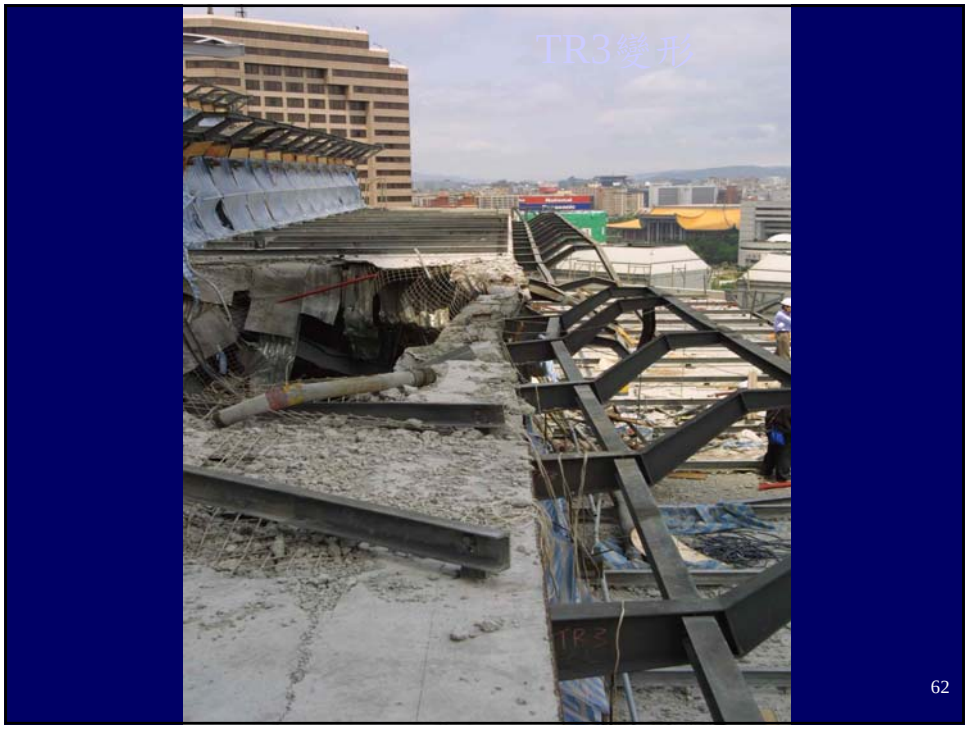
#2塔吊倒塌部分塔節

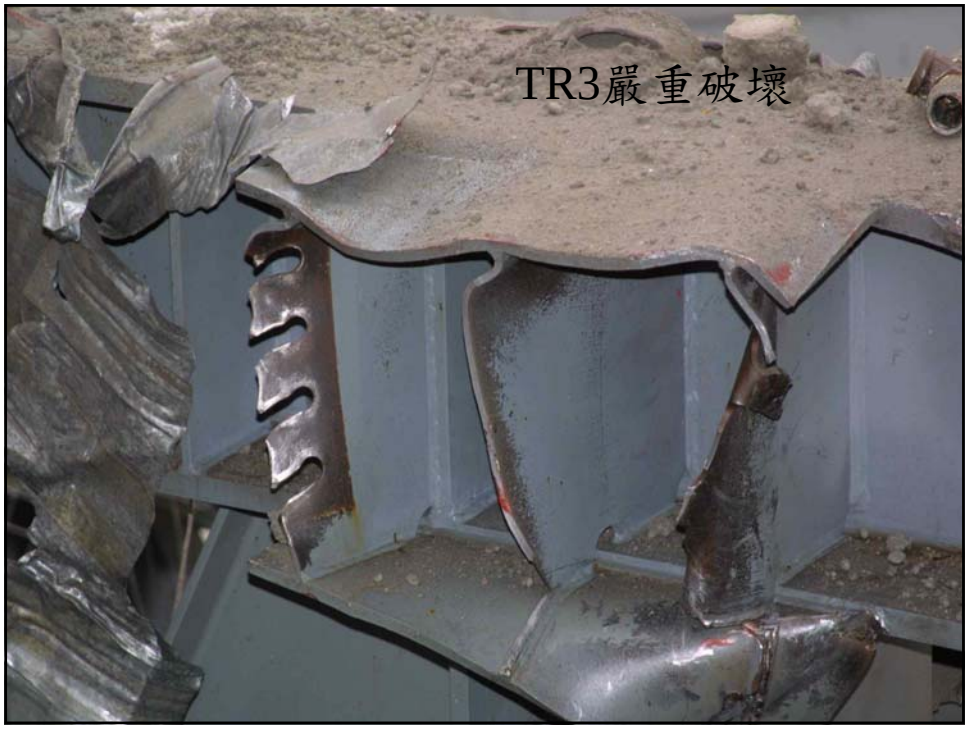
#2塔吊塔節破壞於上支撐點下方


#2塔吊塔節接合螺栓脫牙

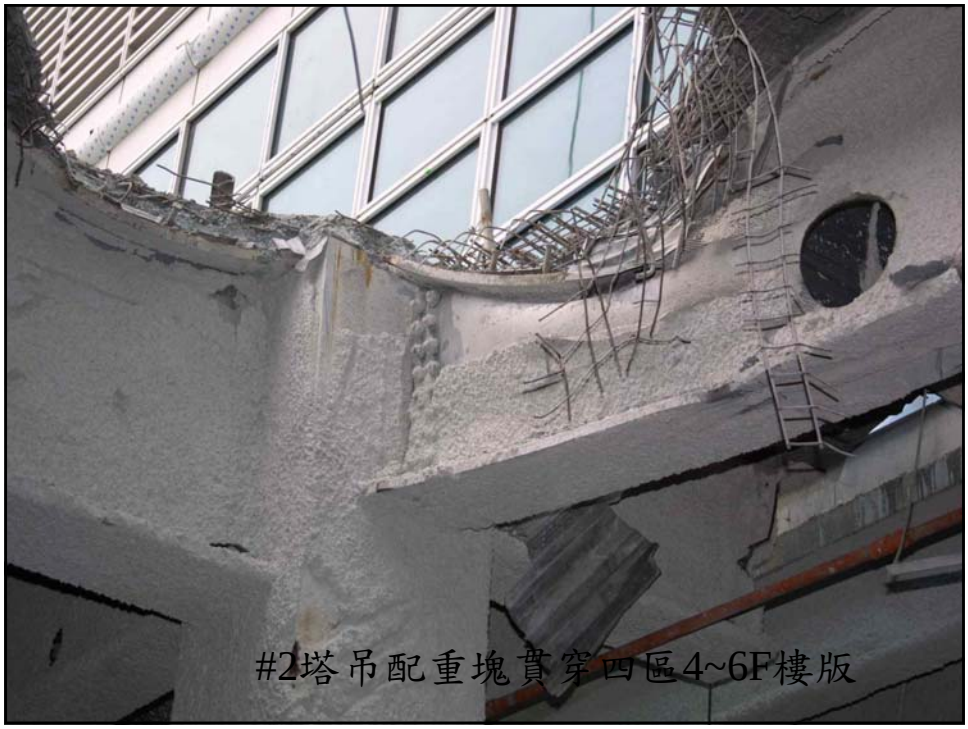

#2塔吊墜落於採光罩及四區屋頂


#2塔吊造成TR3 & TR4嚴重破壞


TR3變形


TR3嚴重破壞


裙樓四區屋頂遭#2塔吊配重塊貫穿

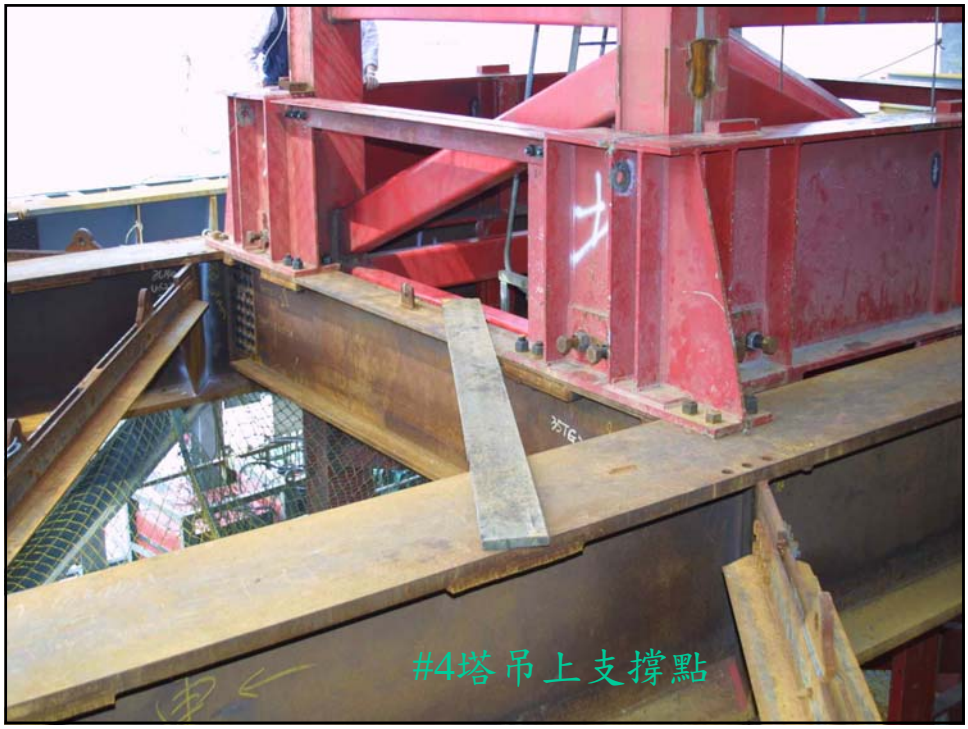


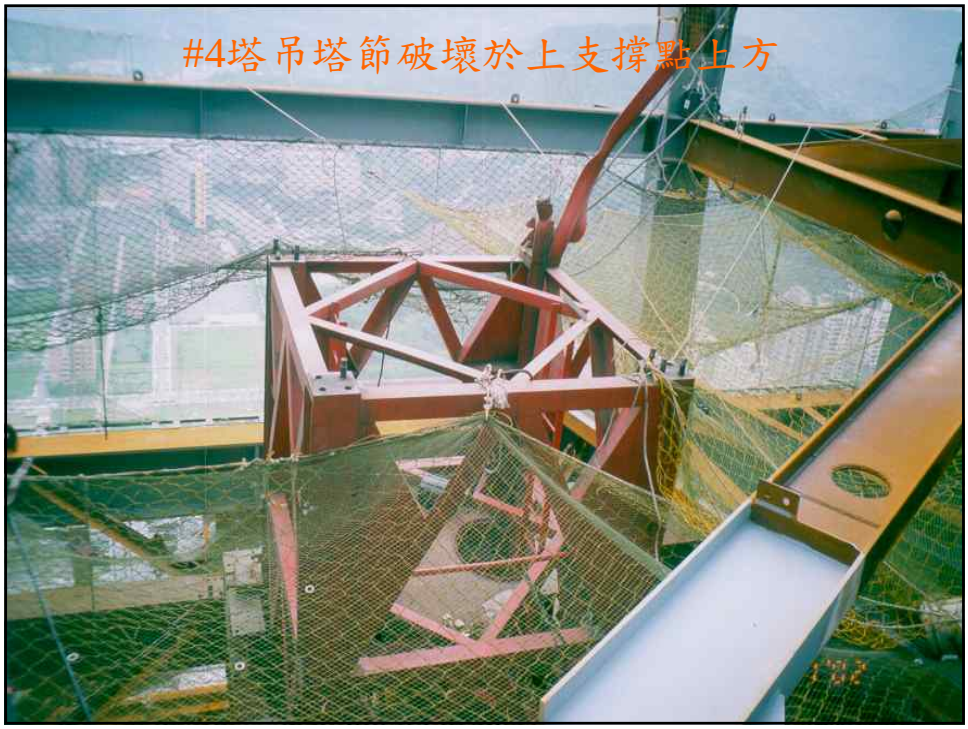
#2塔吊配重塊貫穿四區4~6F樓版

#2塔吊配重塊貫穿四區4~6F樓版

#2塔吊配重塊貫穿四區4~6F樓版

小型塔吊遭墜落物擊中


#4塔吊上支撐點


#4塔吊塔節破壞於上支撐點上方


#4塔吊塔節接合螺栓脫牙


塔節接合螺栓脫牙

- Construction resumed three months later after recommendation by Committee

CONSTRUCTION PROGRESS
2003

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2003

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2003

ACKNOWLEDGEMENT

The materials presented in this seminar are provided by Evergreen Consulting Engineering Consultants, Inc., Taipei, Taiwan