THE USE OF HIGH MODULUS SELF COMPACTING CONCRETE FOR INTERNATIONAL COMMERCE CENTRE

Eddie Ho

28 February 2007

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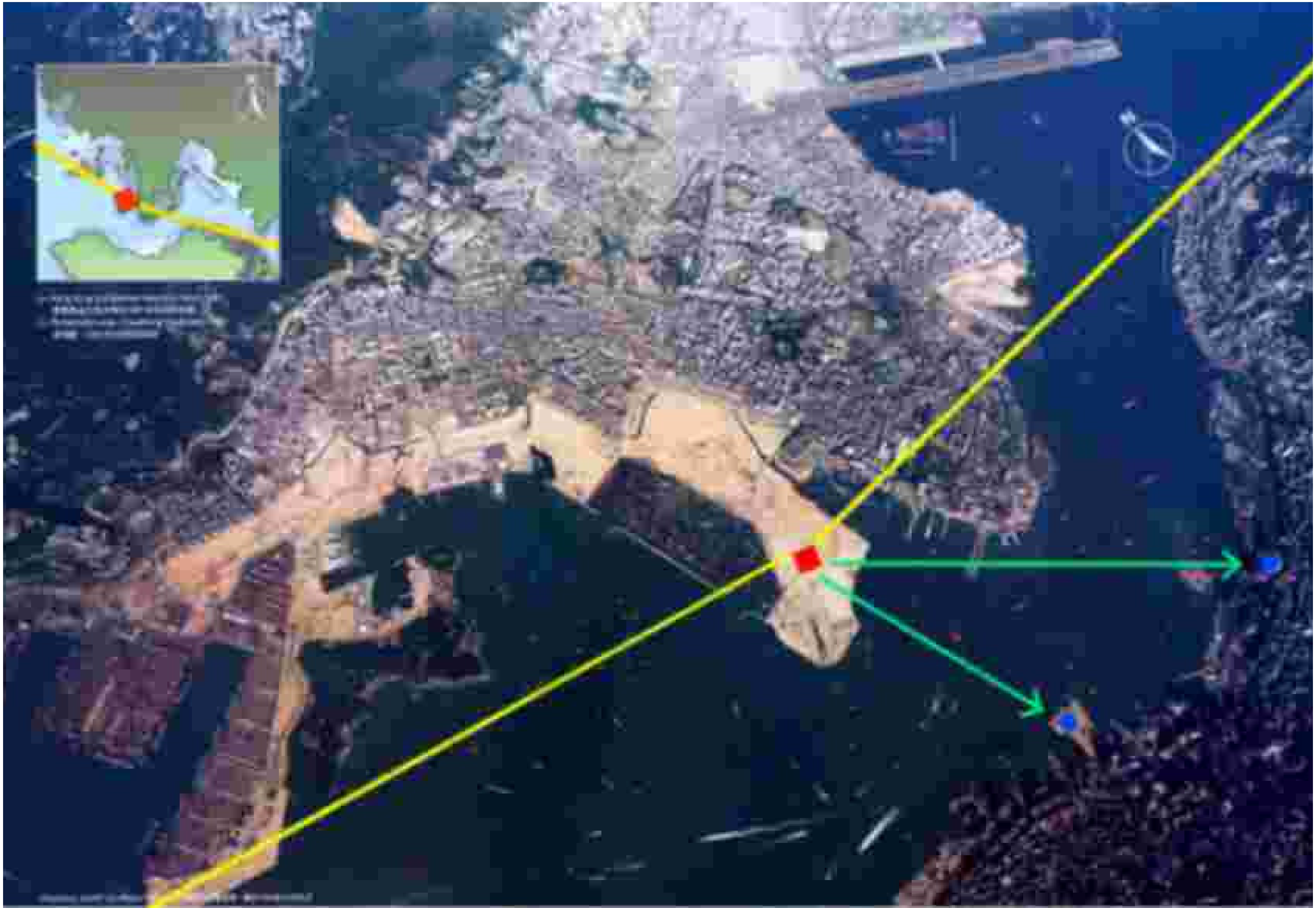

SITE LOCATION

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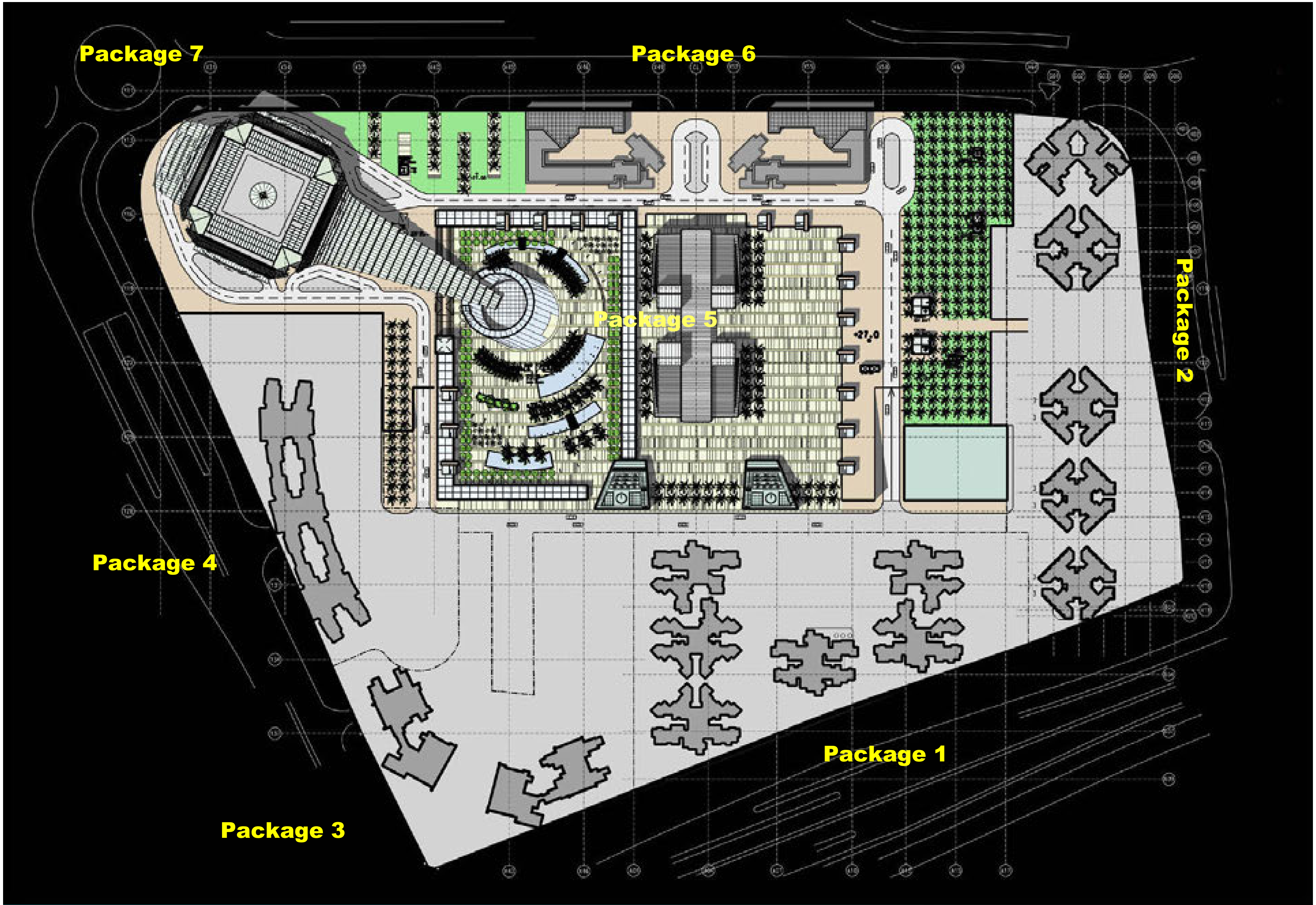

Package 7
Package 6
Package 5
Package 2
Package 4
Package 1
Package 3

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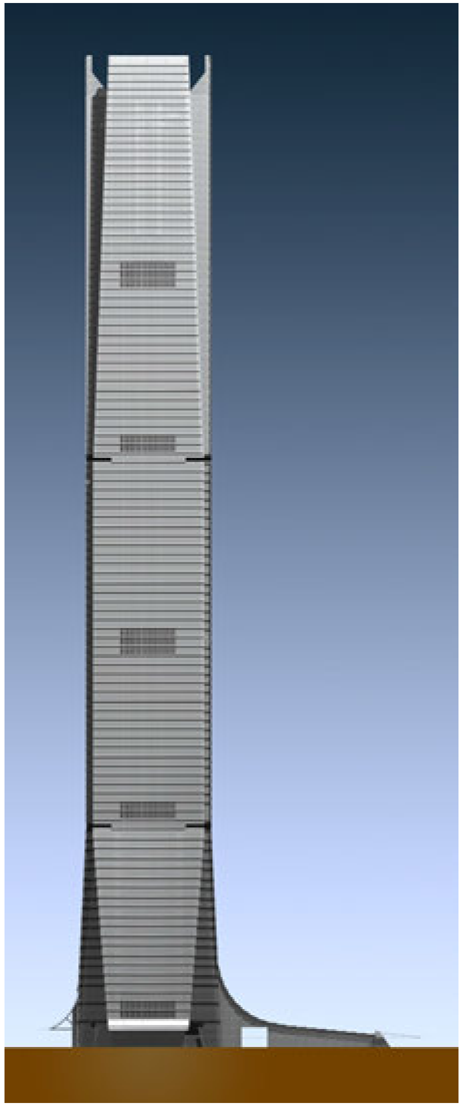
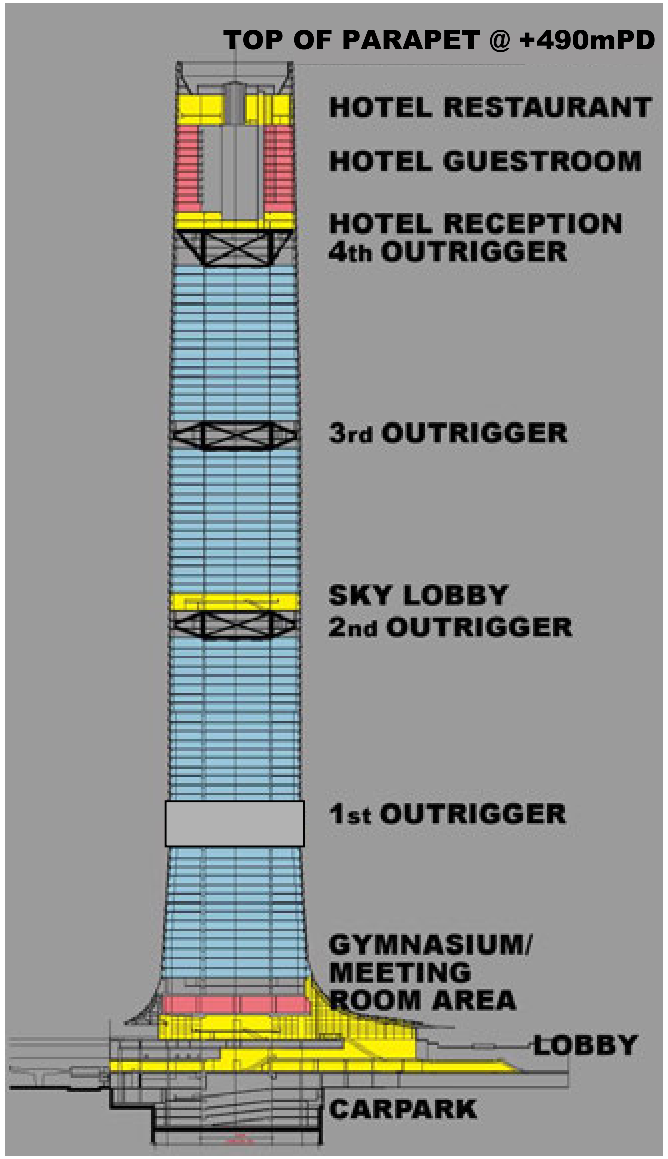
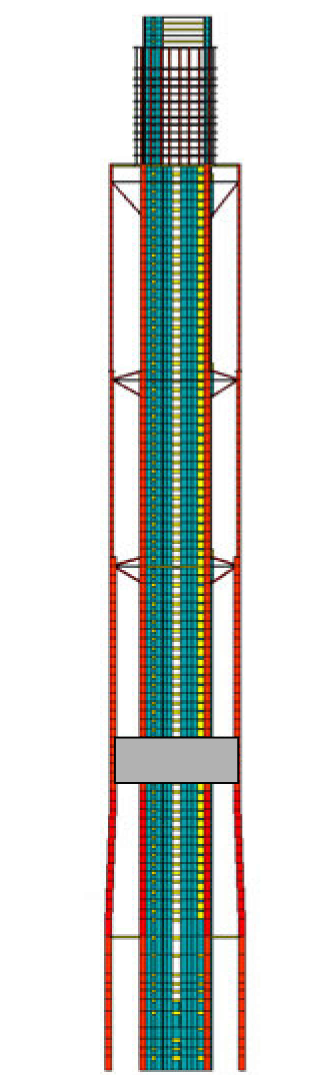
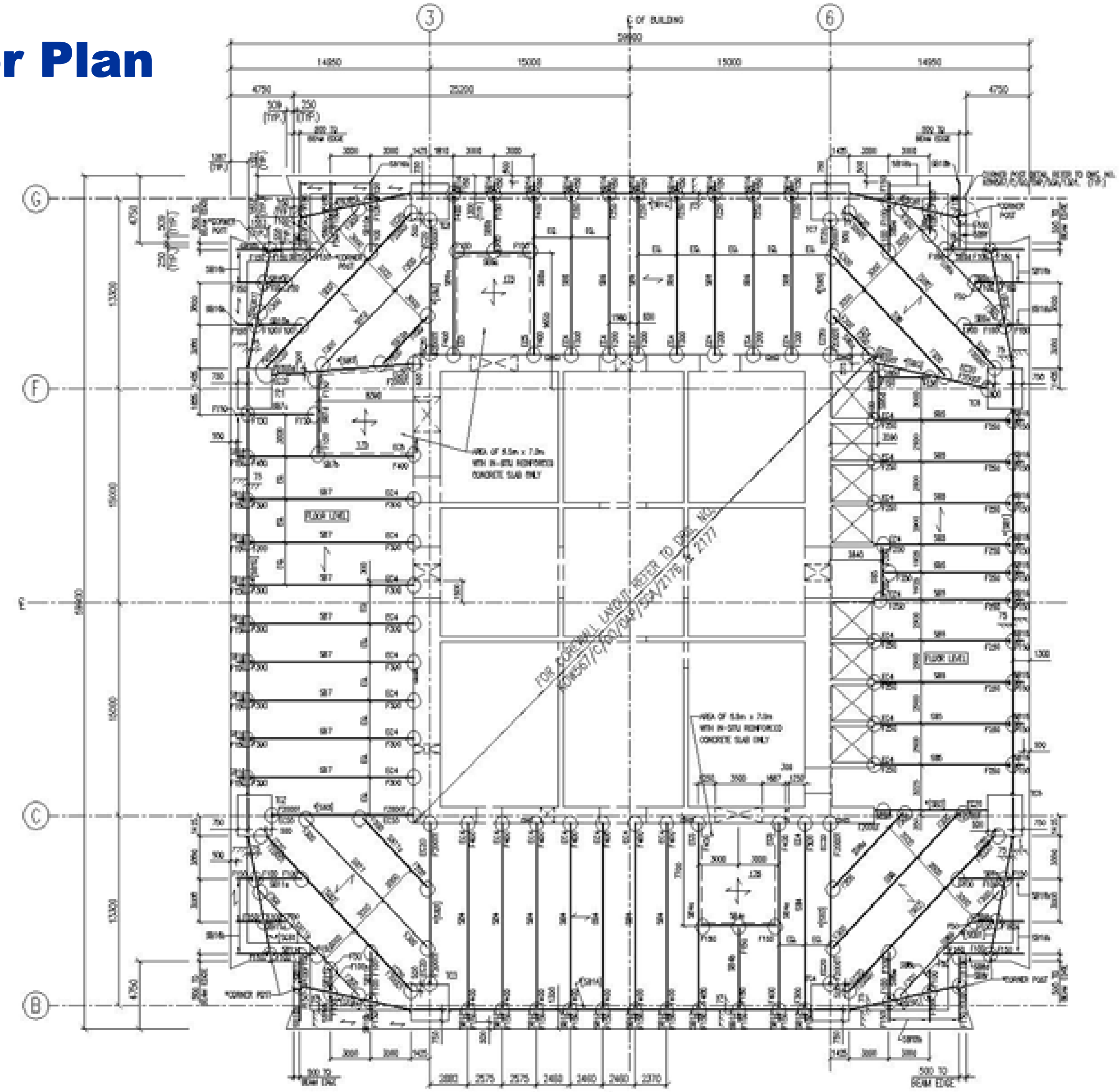
STRUCTURAL SYSTEM







Typical Floor Plan



26/F TO 39/F FLOOR PLAN

International Commerce Centre

- Building Height = 485m
- No of Stories = 118
- GFA = 270,000 sq.m.
- Foundation: Shaft Grouted Barrettes (241 Nos.)
- Basement: 4 levels with a 76mØ 1.5m-thk Circular Diaphragm Wall
- Floor System: Steel Composite
- Stability System: RC Central Core + 8 R.C. Mega Columns with 4 outriggers (1 Post Tension RC + 3 Structural Steel)
- Grade 90 High Modulus Concrete
- Design Wind Speed = 59.5 m/s

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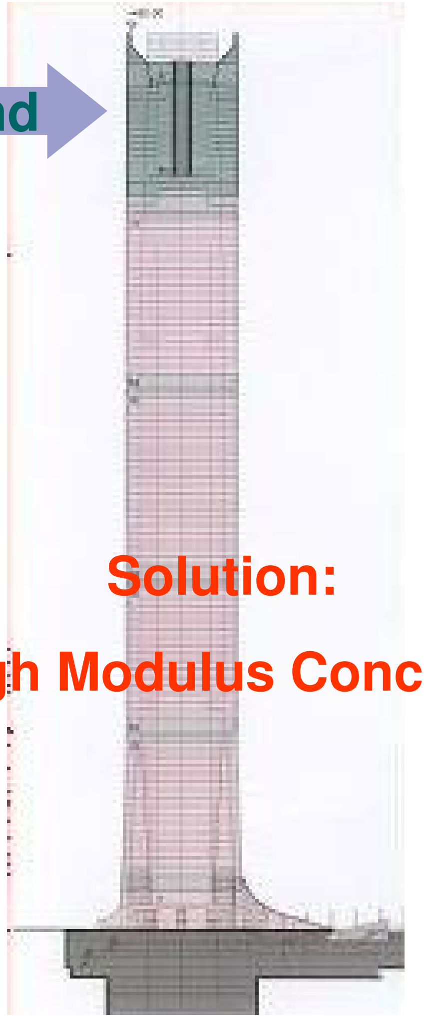
TECHNICAL REASONS TO USE HIGH MODULUS SELF COMPACTING CONCRETE

Wind



Solution:

High Modulus Concrete

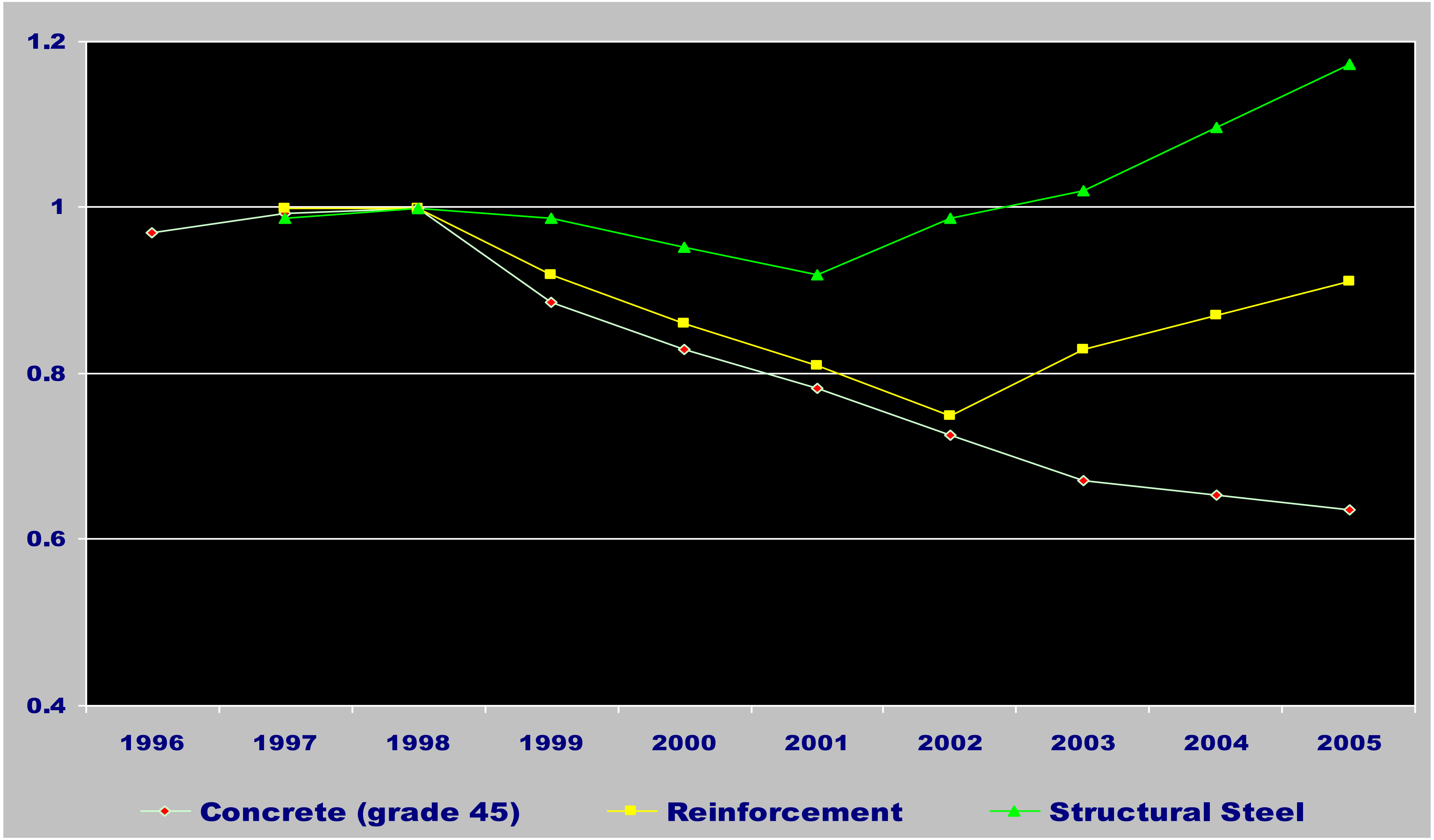
Large Deflection

Solution:

Self Compacting Concrete

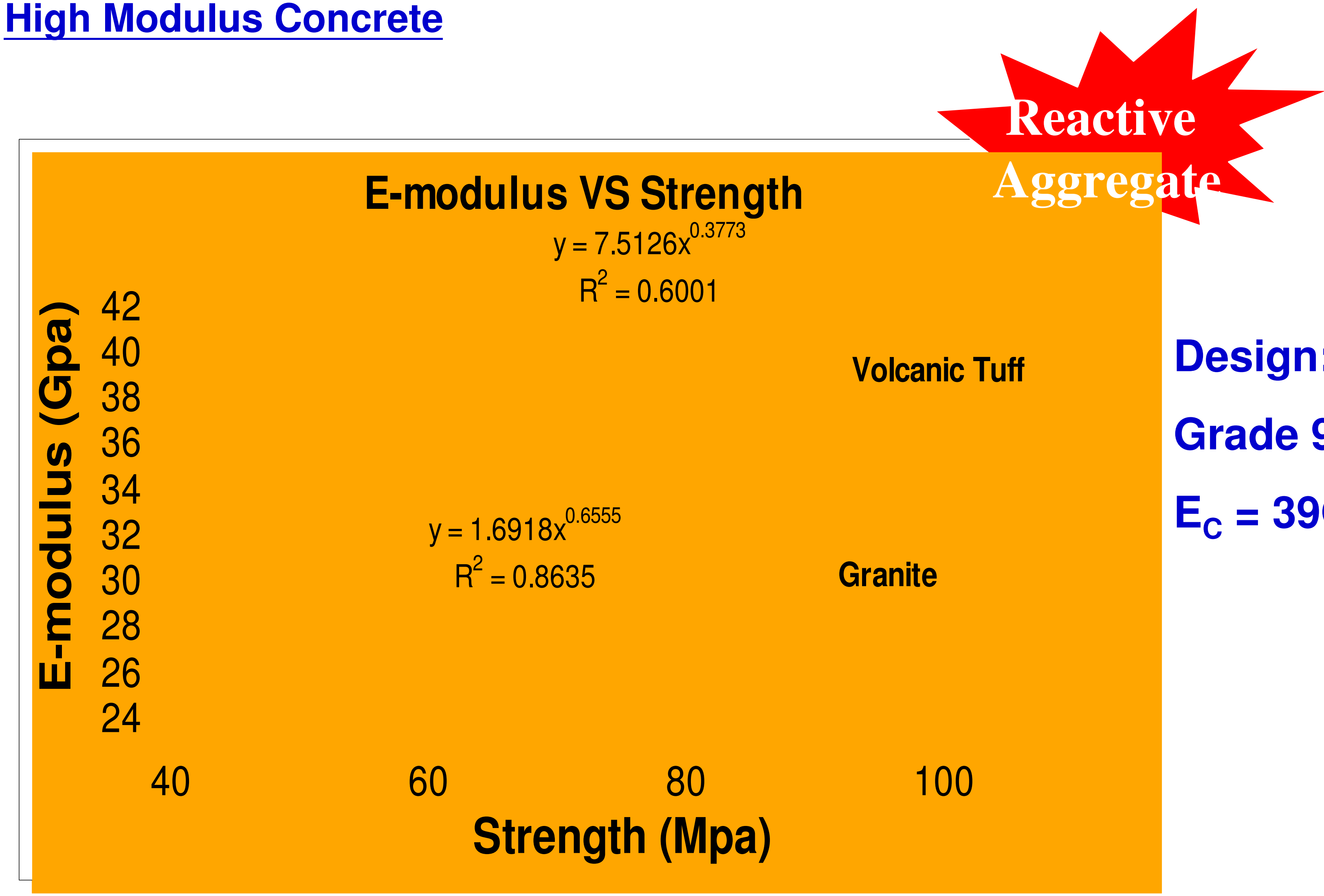
Congested Reinforcement

TREND OF MATERIAL COST



HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

High Modulus Concrete



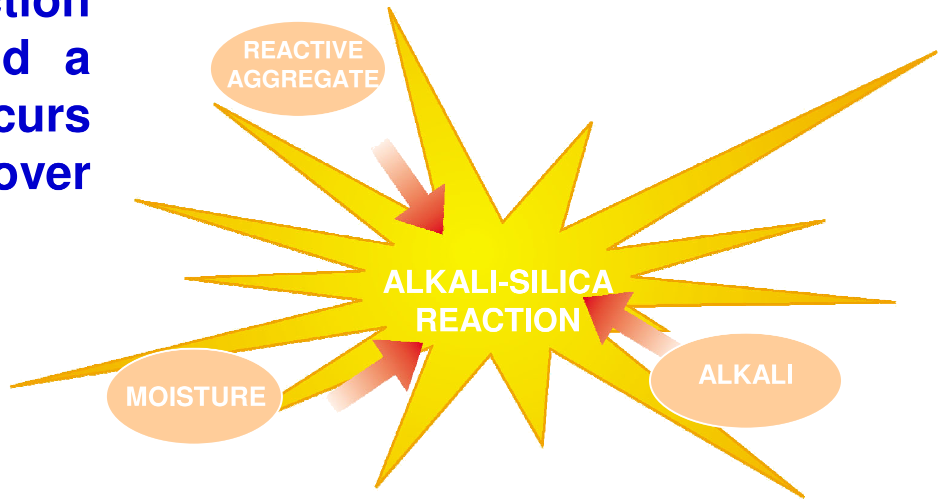
Design:

Grade 90

E_C = 39GPa

What is ASR?

- An expansive chemical reaction between excessive alkalis and a reactive aggregate which occurs inside the hardened concrete over a long period of time



SYMPTOMS

…….internal expansion…

BD APPROVAL PROCESSES

Before the new concrete is being used, the proposed materials shall go through a stringent testing, classification, assessment and evaluation process to the satisfaction of RSE.

- **Taking Representative Samples**

  Sample from each aggregate stockpile on a 3-monthly basis for 9 months.

- **Petrographical Assessment**

  Characterise the aggregate source, identify mineralogy, rock type, assess variability and any potential reactive components.

- **Aggregate Reactivity Classification**

  Conduct RILEM AAR2 Ultra-Accelerated Mortar Bar test and classify the aggregate reactivity based on the degree of expansion resulted.

- **Environmental Exposure Risk**

  Environmental risk shall be determined by RSE, i.e. Dry, Exposed and Severe.

MEASURES TAKEN TO CONTROL ASR

- **Moisture Contact**

  Temporary Waterproofing Plaster to Mega Column & Central Corewall made of G90 during Construction Stage.

  Permanent Waterproofing Plaster to Perimeter Mega Columns at Mechanical Floors.

  Permanent Waterproofing Plaster to Walls Exposing to Toilet/Shower Room.

- **Sufficient Alkaline Pore Solution**

  Limit Alkali Level to Maximum of 3 kg/m^3

- **Reactive Aggregate**

  Use of Secondary Cementitious Materials, e.g. PFA, Microsilica

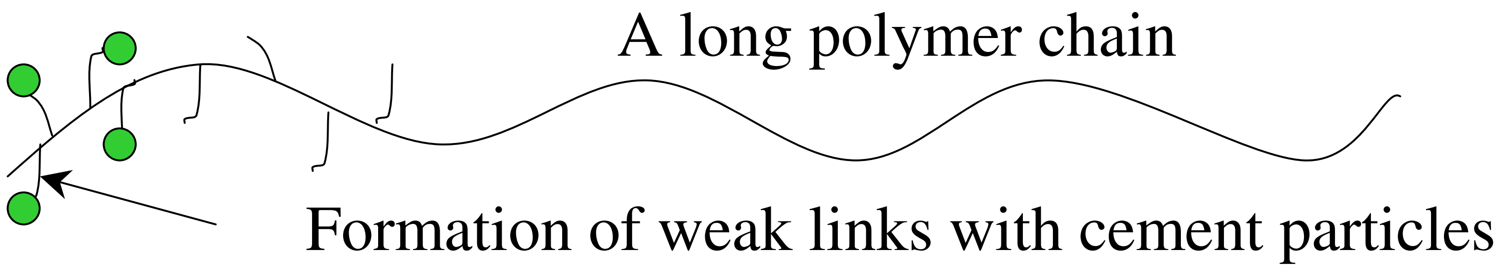
Eliminating one or more of the above components!

HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete

How to produce SCC?

- **Increase paste volume**
- **Reduce Volumetric Ratio of Aggregate to Cementitious materials**
- **Optimize Particle Size Grading**
- **Use of SCC Admixture → Polycarboxylate Type (w/o viscosity modifier)**



HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete

Three Key Characteristics:

Filling Ability

- Able to flow into all the spaces within the formwork under its own weight. This is related to workability

Passing Ability

- Able to flow through tight openings such as spaces between steel reinforcing bars under its own weight. They must not ‘block’ during placement.

Resistance to Segregation

- Able to meet the above two requirements while it’s original composition remains uniform

HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Filling Ability Test)

700mm x 700mm Flow in 2 minutes

Slump Flow Test

- assess the horizontal free flow distance.
- as the acceptance criteria for workability because of its simplicity.

HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Passing Ability Test – L Box Test)

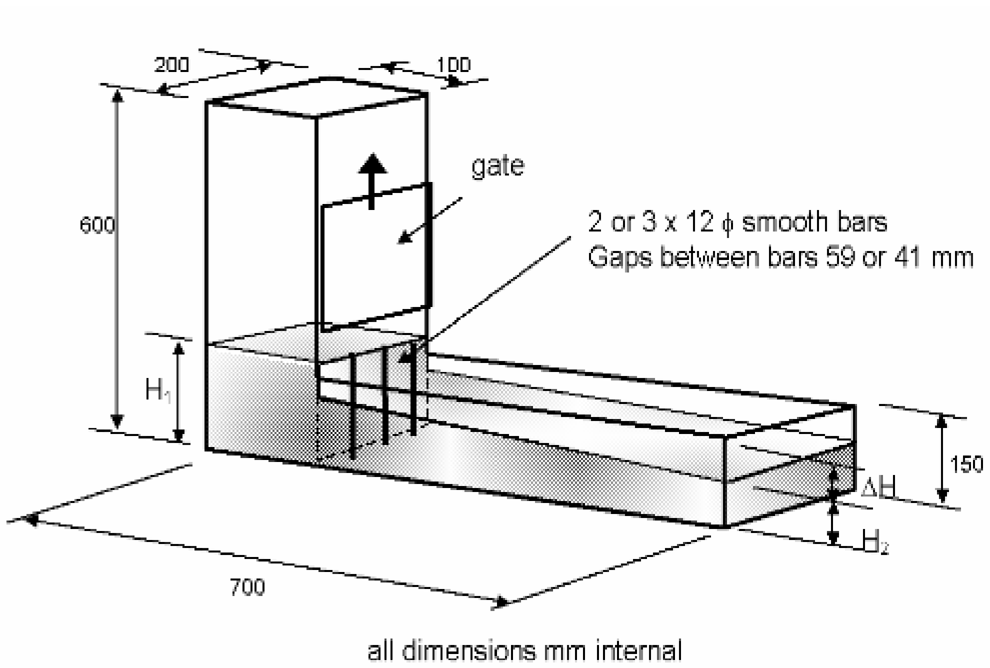


Figure 1 — General assembly of L-box

Done on the laboratory and plant trials to demonstrate the passing ability

HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Passing Ability Test – L Box Test)

Measure concrete ability to flow in the present of reinforcement

HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Segregation Resistance Test)

- Visual Inspection slump flow and L-box test
- GTM Screen Stability

Step 1: Allow 10 Litre of concrete to stand for 15 min.

HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Segregation Resistance Test)

GTM Screen Stability

Step 2: Extract fine materials on the top layer by sieve

Step 3: Weight the percentage of fine materials

HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Acceptance Criteria Summary)

Method	Property	Brief description	Typical Range of Values		
			Unit	Min.	Max.
Slump flow test	Filling ability	Assess Horizontal Free Flow Distance in the absence of obstructions	mm	650	800
T_{50cm} slump flow	Filling ability	Assess Time Required to flow 50cm Horizontally in the absence of obstructions	sec	2	5
L-box	Passing ability	In a rectangular section box with an 'L' shape, vertical section is filled with concrete and then gate lifted to let concrete flow into the horizontal section. Measure the height of concrete at the end of the horizontal section (H2) and remaining vertical section(H1)when the flow start	h_2/h_1	0.8	1
GTM screen stability test	Segregation resistance	Allow 10 liter of concrete to stand for 15 minutes for internal segregation to occur, then pouring half of it onto a 5mm sieve of 350mm diameter which stands on a sieve pan on a weight scale. After two minutes, mortar which pass through the sieve is weighted and expressed as a percentage of the weight of the original sample on sieve.	%	0	15

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HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Site Trials)

Trial Block – Casting of SCC into Formwork

Trial Column Construction

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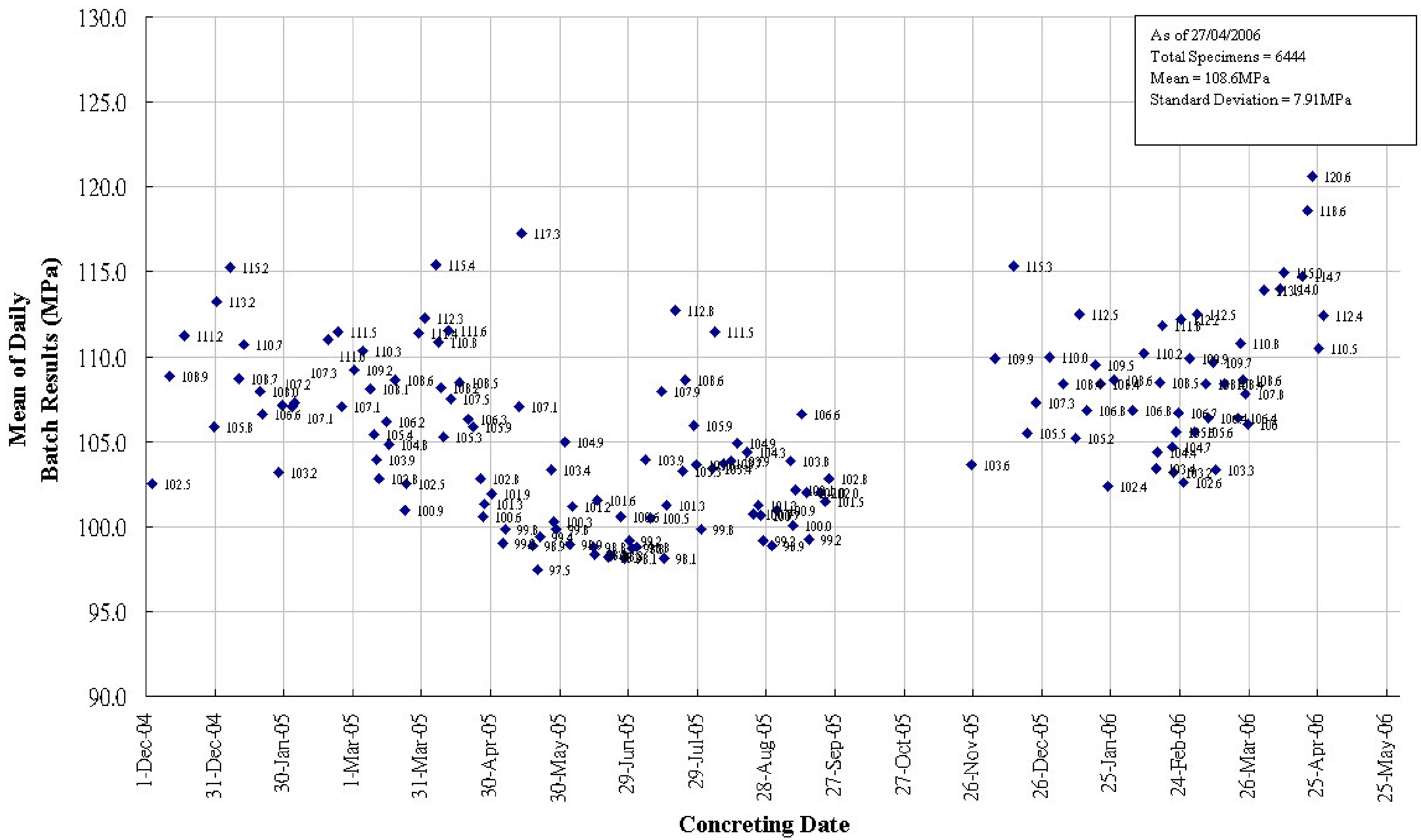
HIGH STRENGHT HIGH MODULUS SELF COMPACTING CONCRETE

Self Compacting Concrete (Actual Site Construction)

Cooling Pipes

Insulation

28-day Compressive Strength of Grade 90D/10 Concrete
Mean of Daily Batch Results



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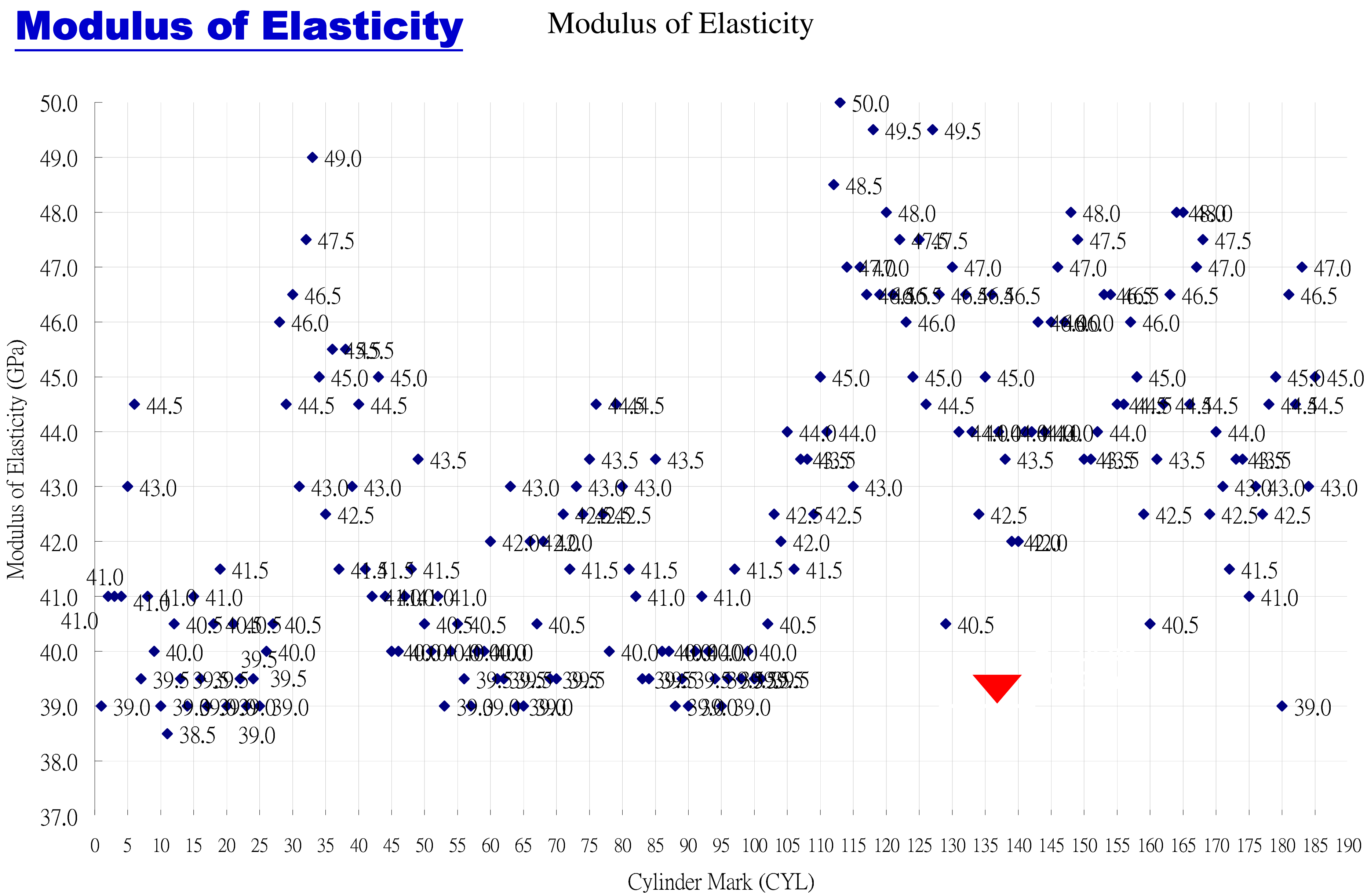
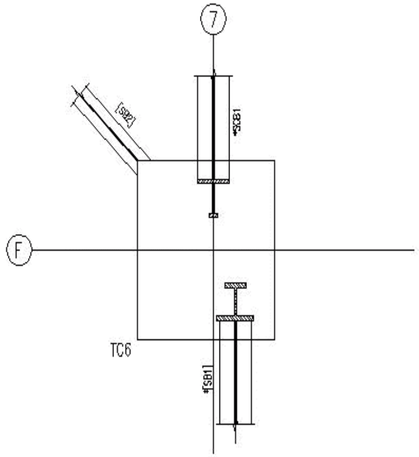
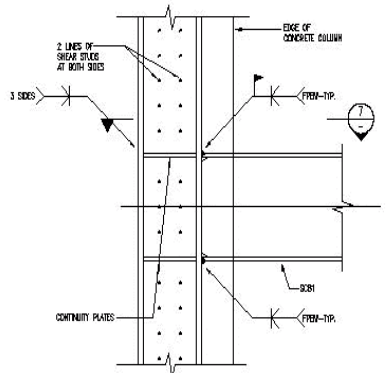
Modulus of Elasticity

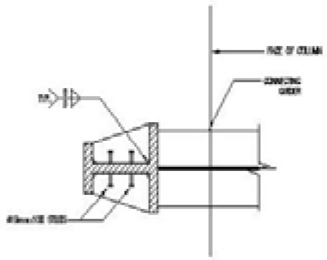


Mega Column Embed Design for Steel Plate Girder at Periphery

Conventional Design

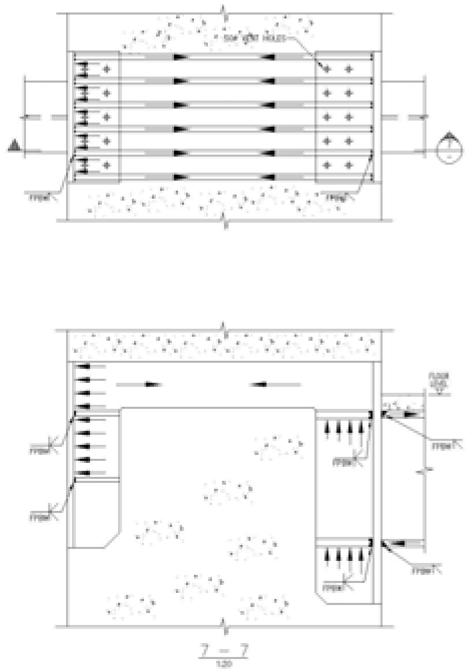






Mega Column Embed Design for Steel Plate Girder at Periphery

Anchor Embed with Vertical Plates

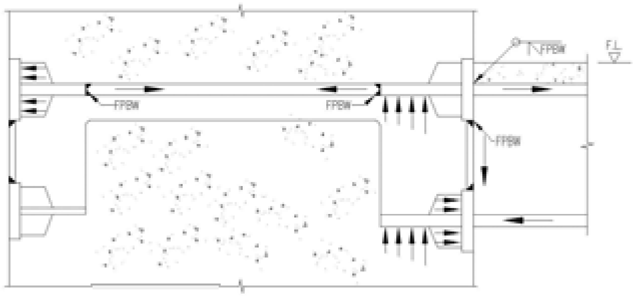


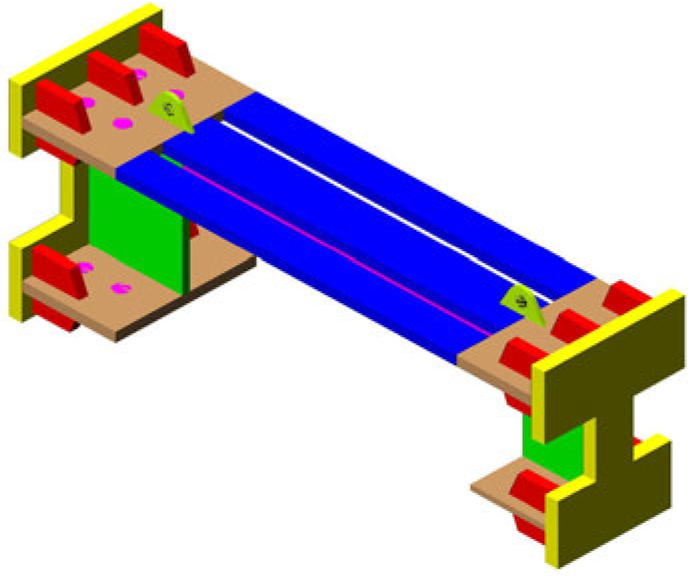
Design Principle

Fabricated Steel-Plate Embed

Mega Column Embed Design for Steel Plate Girder at Periphery

Anchor Embed with Horizontal Plates





Design Principle

A 3-D View

Remark: Higher Through Thickness Stress

Mega Column Embed Design for Steel Plate Girder at Periphery

Anchor Embed with Horizontal Plates

Full-scale Mock-up: To Investigate How High-Performance Concrete Works with Steel Embed

Mega Column Embed Design for Steel Plate Girder at Periphery

Anchor Embed with Horizontal Plates

Results showed Good Contacts between Concrete and Steel Embed, i.e. No Voids or Honeycombing

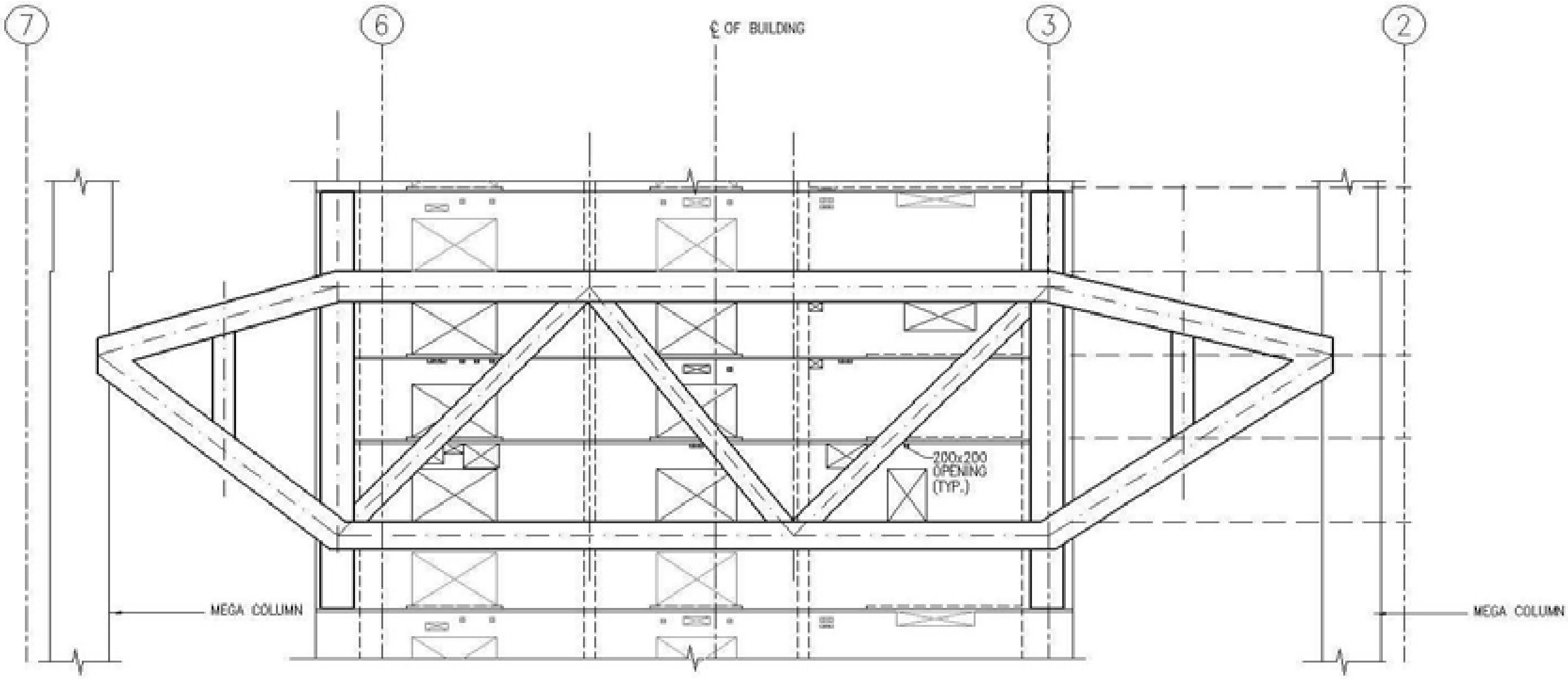
Mega Column Embed Design for Steel Plate Girder at Periphery

Anchor Embed with Horizontal Plates

Fabricated Steel-Plate Embed

STEEL OUTRIGGER DESIGN

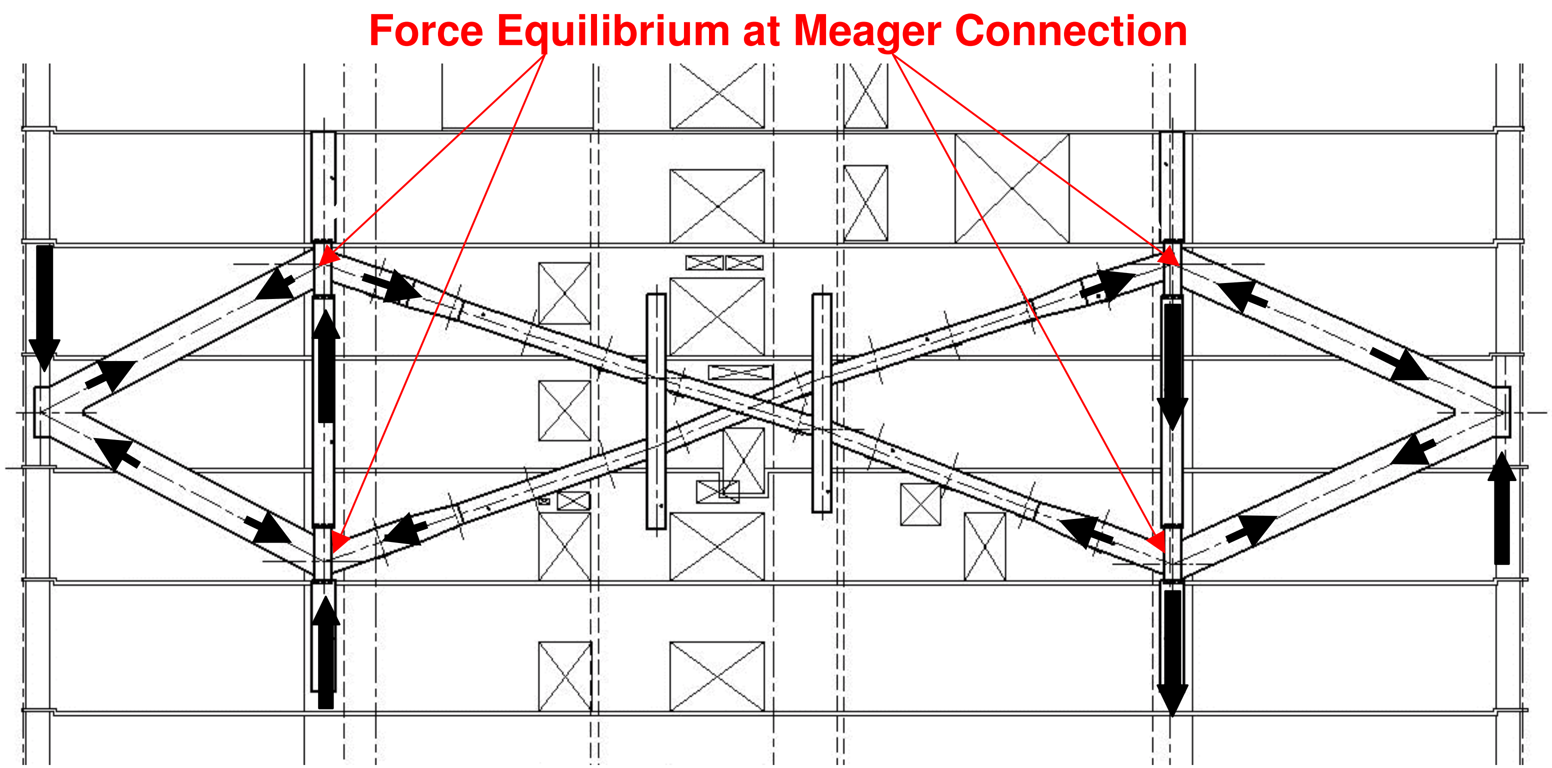
Steel Outrigger – Generation 1



Steel Truss Embedded in Concrete Corewall

STEEL OUTRIGGER DESIGN

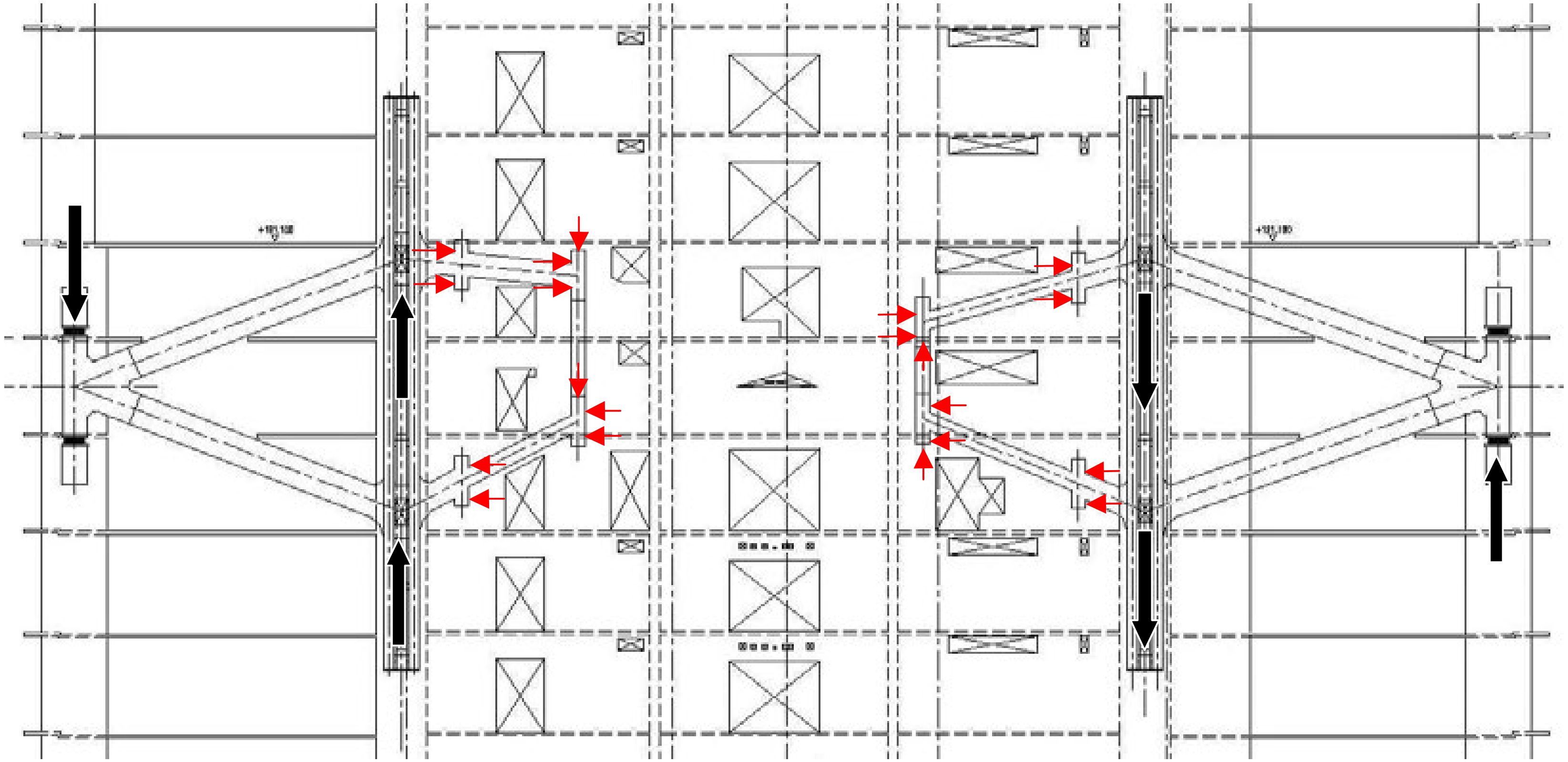
Steel Outrigger – Generation 2



2nd Generation Steel Truss Embedded in Concrete Corewall

STEEL OUTRIGGER DESIGN

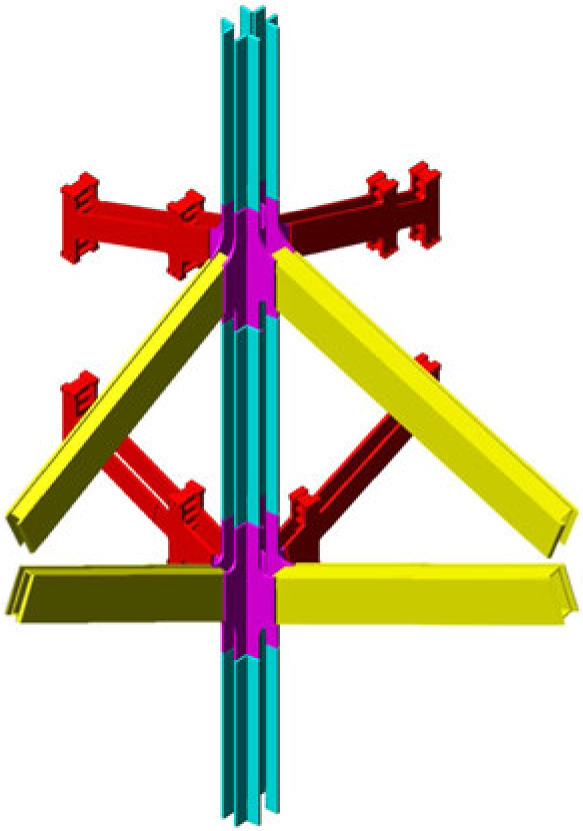
Steel Outrigger – Generation 3



Anchor Type of Embed

Steel Outrigger

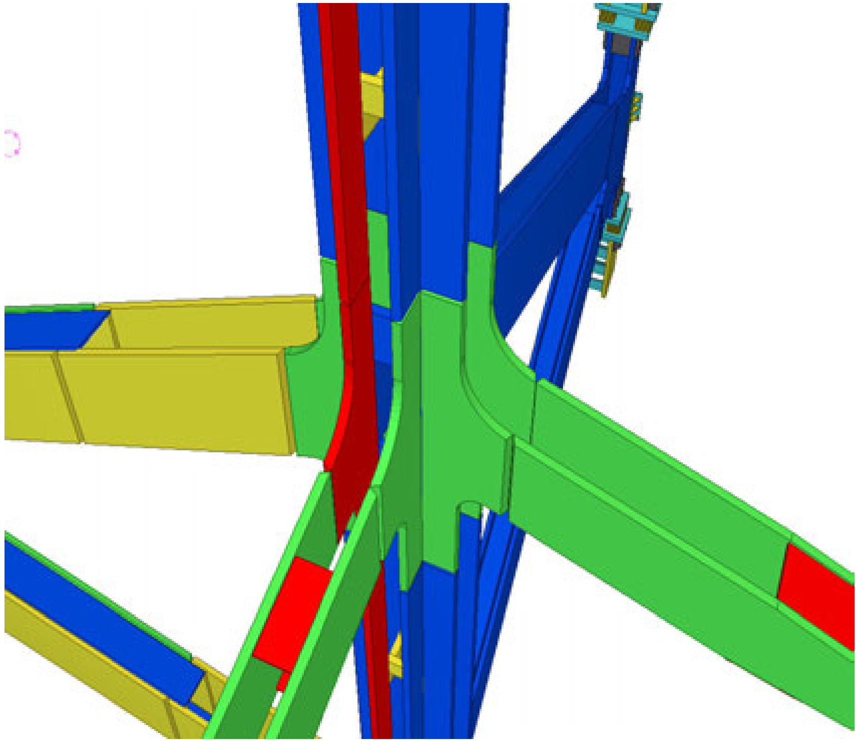
Outrigger Arms with Anchor Plates (1)



A 3-D View

Steel Outrigger

Outrigger Arms with Anchor Plates (2)

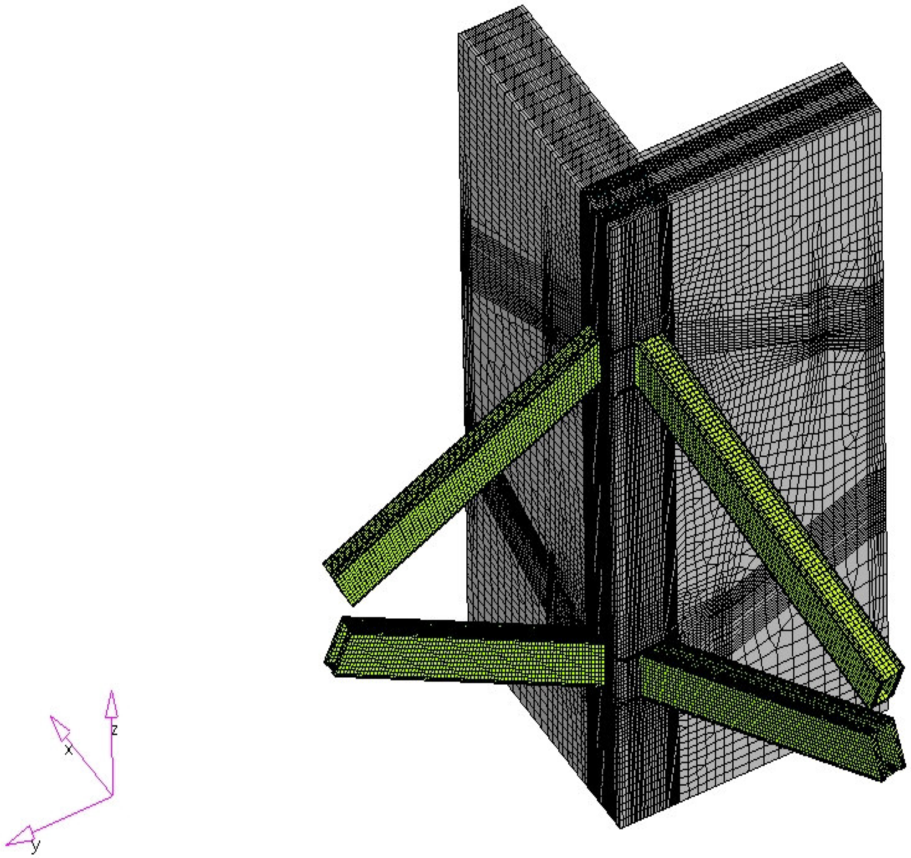


A Magnified 3-D View at Merger Details between Two Outrigger Arms at Corewall Corner

Major Advantage: To Eliminate Transfer of Tensile Forces in Through-Thickness Direction, thus No Risk of Lamellar Tearing

Steel Outrigger

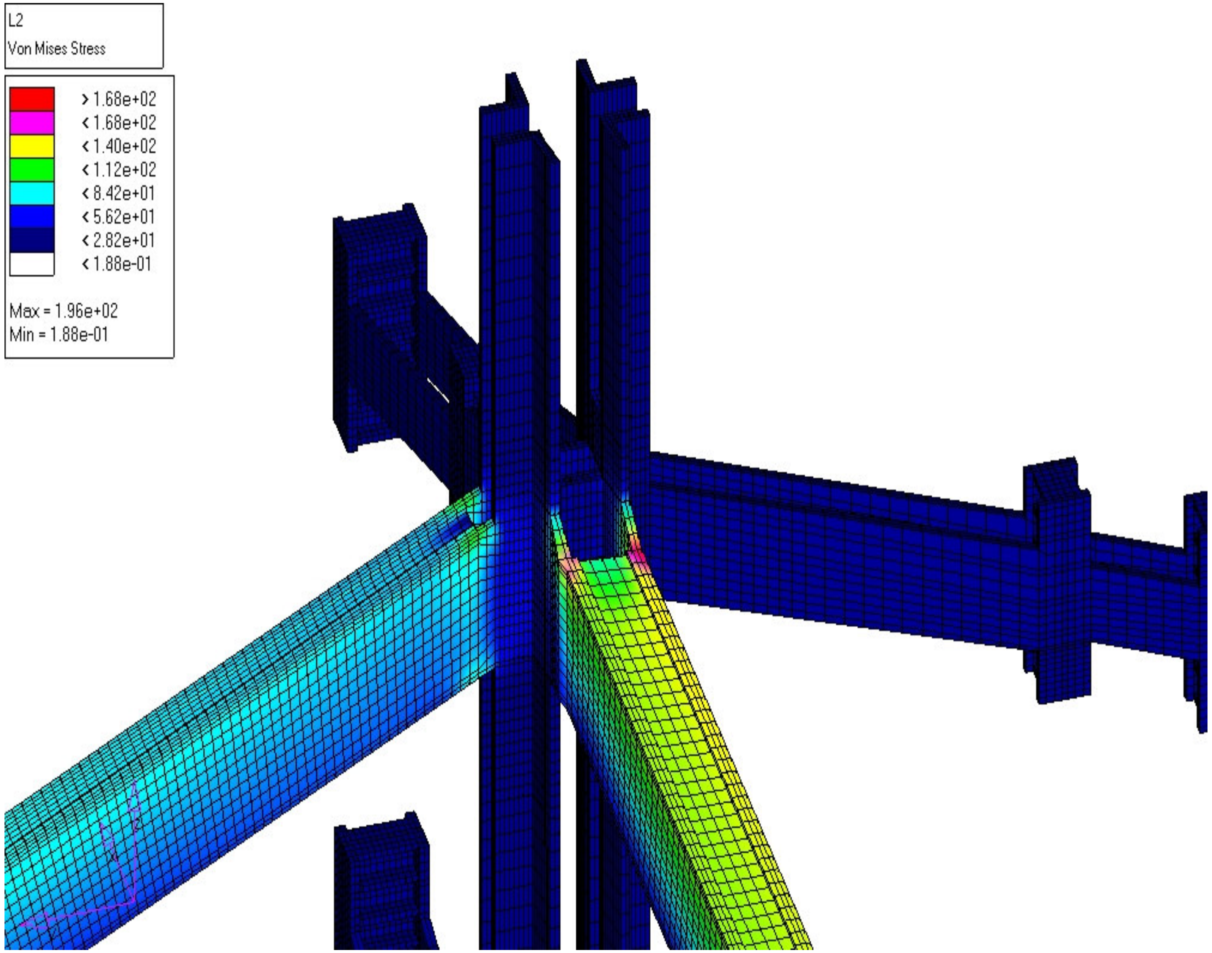
Buckling Analysis (1)



A FEM Model: To Investigate Buckling Behaviors of Steel Plates Surrounded by Concrete

Steel Outrigger

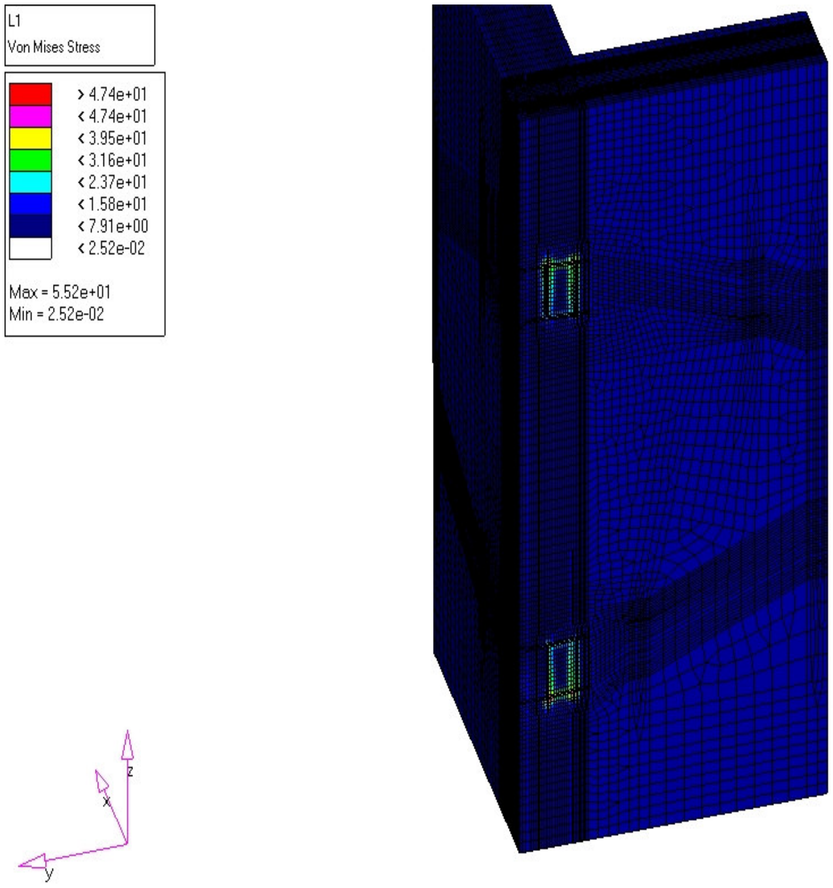
Buckling Analysis (2)



Stress Diagram

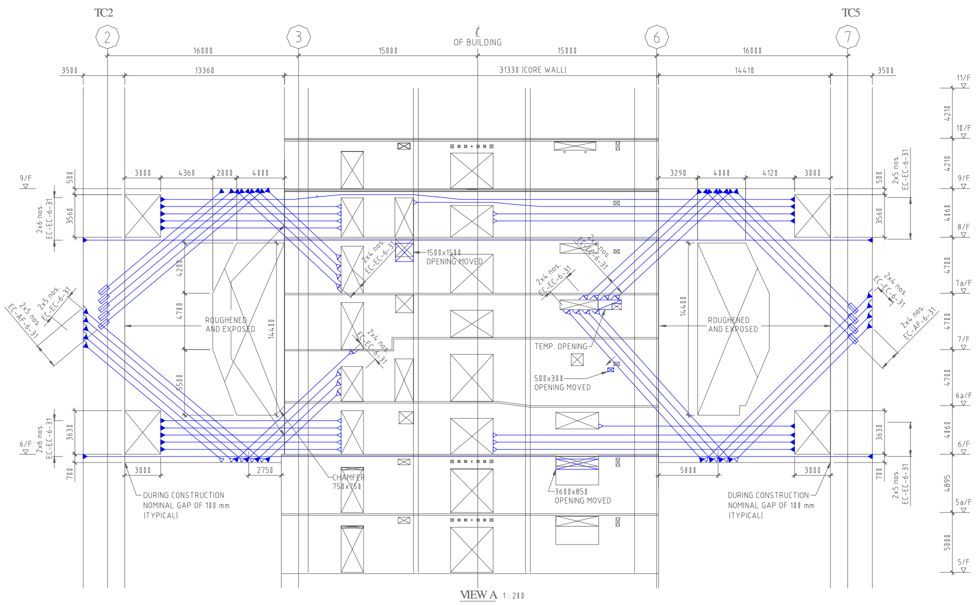
Steel Outrigger

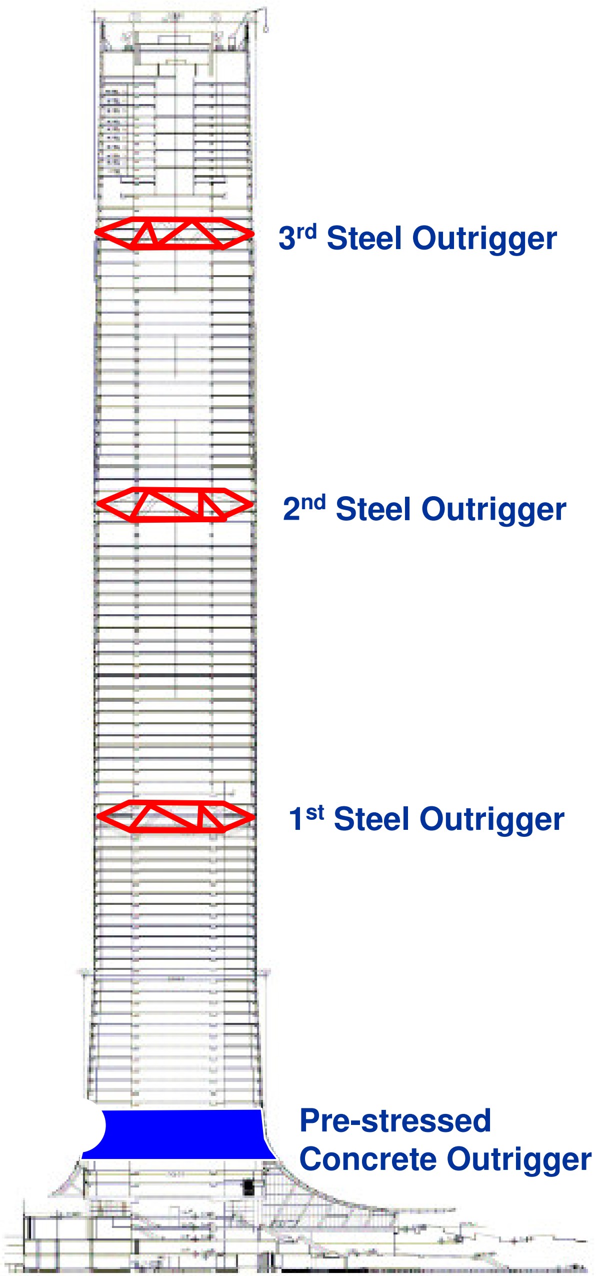
Buckling Analysis (2)



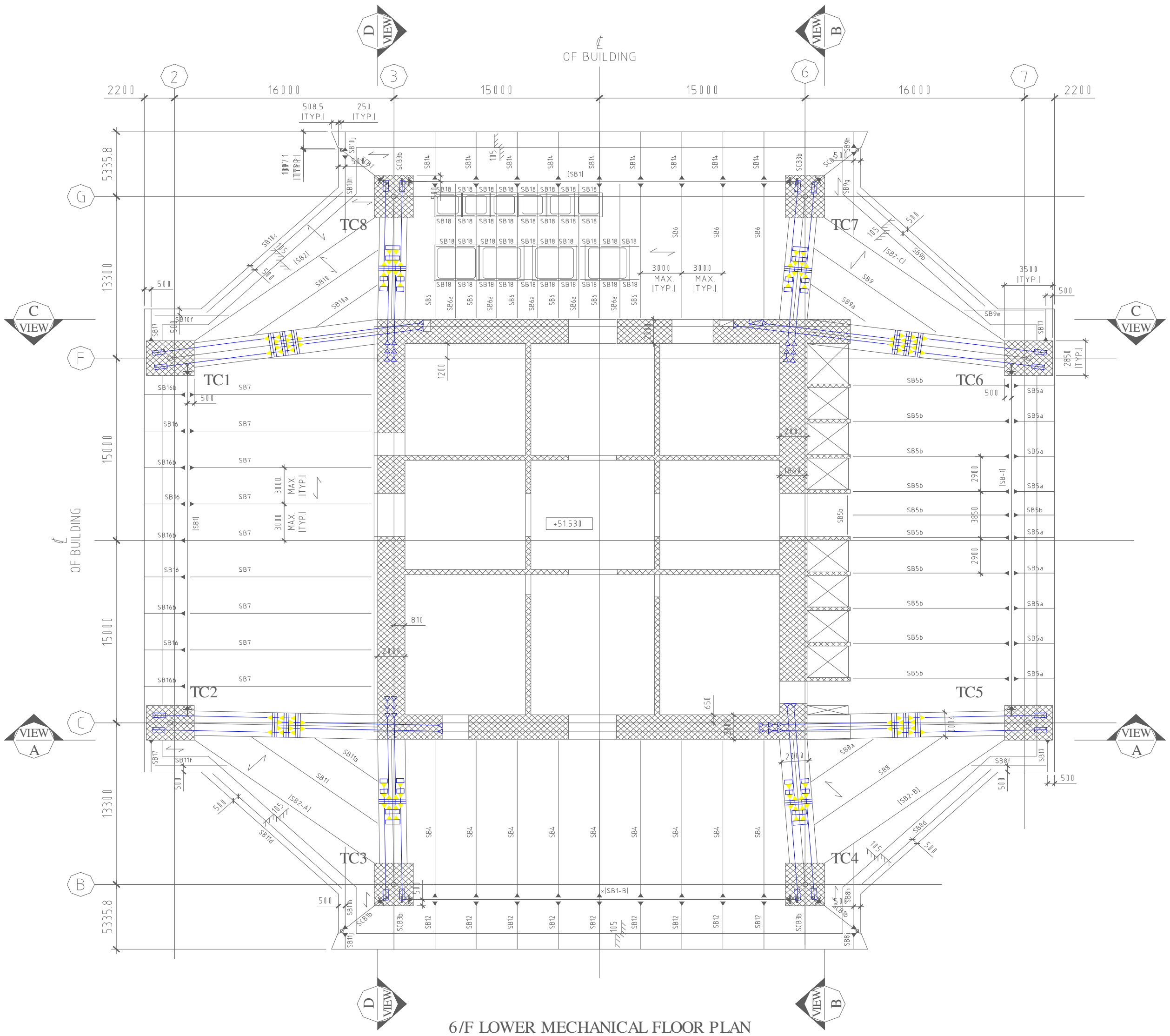
Small Force Transfer Zone in Concrete

Post Tensioning Concrete Outrigger



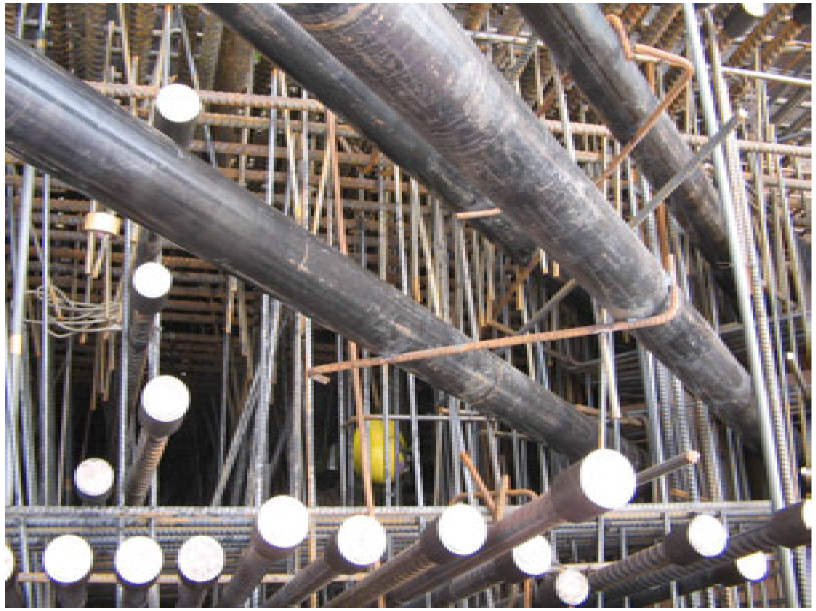


Post Tensioning Concrete Outrigger



6/F LOWER MECHANICAL FLOOR PLAN

1 : 250



Closing Up

- Super High-rise Buildings are always Steel Structures which Needs Good Planning;
- Good Planning Needs Frozen Design;
- Hong Kong is a Market Driven Society. Frozen Design before Construction are Rare
- With Advanced Concrete Technology, Concrete/Steel Composite Design Always Provides Feasibility for Design Changes
- Thorough Understanding of Interaction between Concrete and Steel therefore Becomes Important.

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ENGINEERING AT EVERY STAGE

Thank you!

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