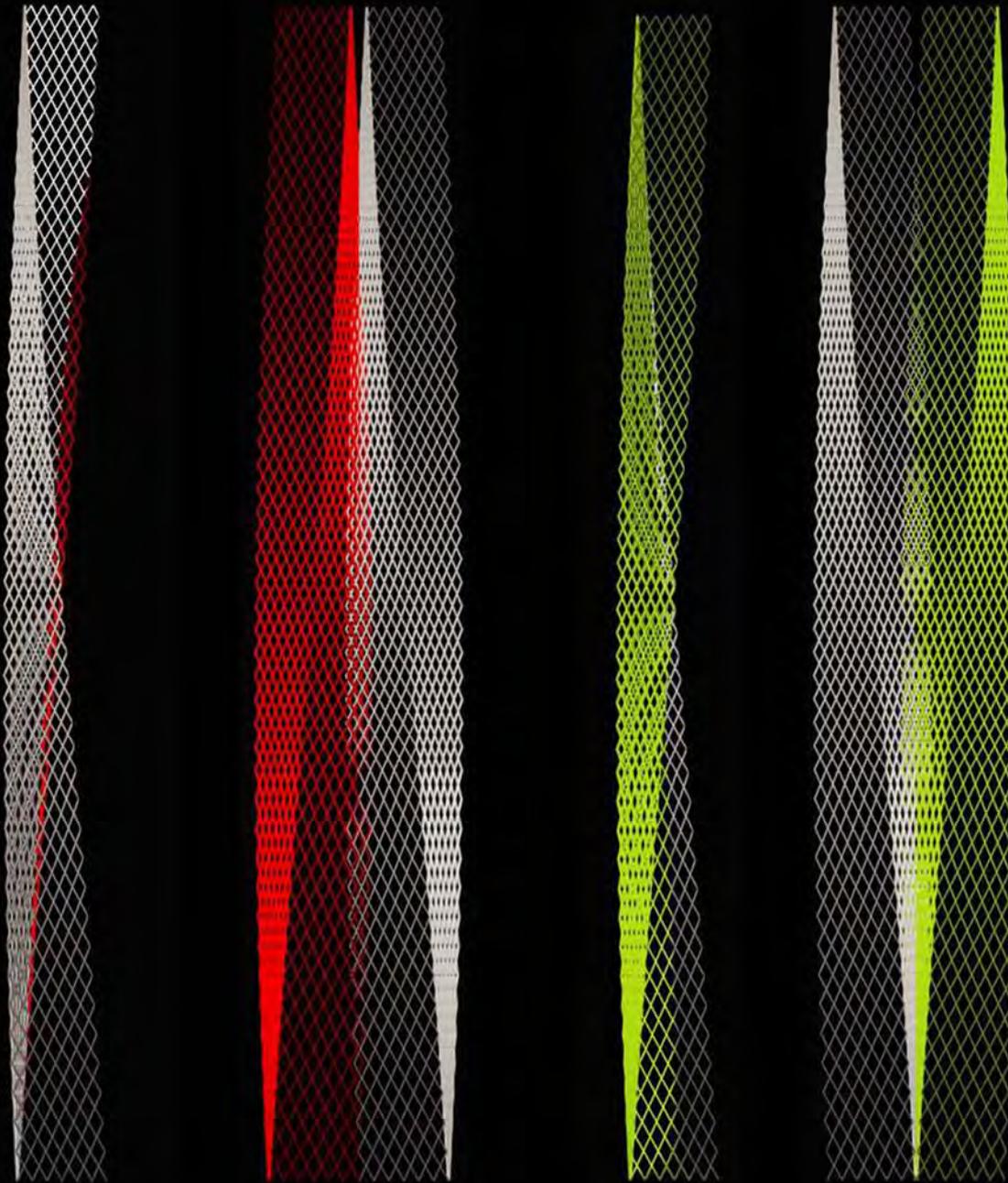


# Nature and the Tall Building

SEMM Seminar  
University of California, Berkeley  
18 October 2010

Mark Sarkisian, PE, SE, LEED AP  
Director of Structural Engineering  
Skidmore, Owings & Merrill LLP  
San Francisco





SOM







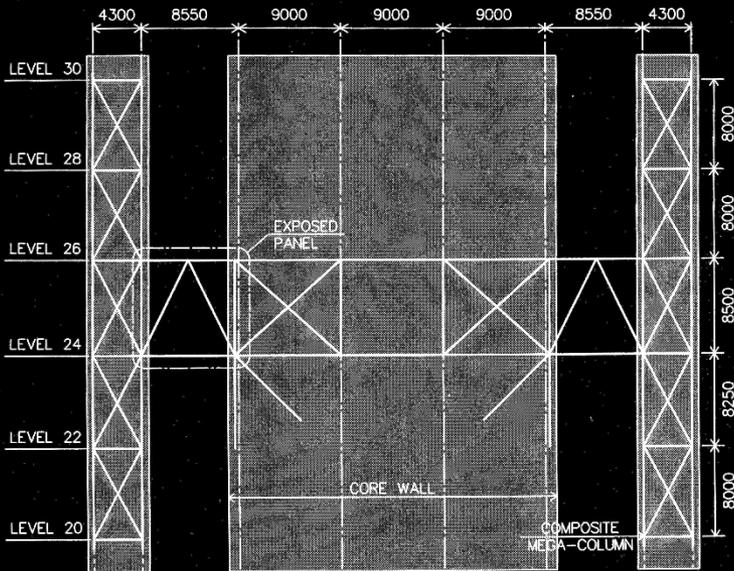
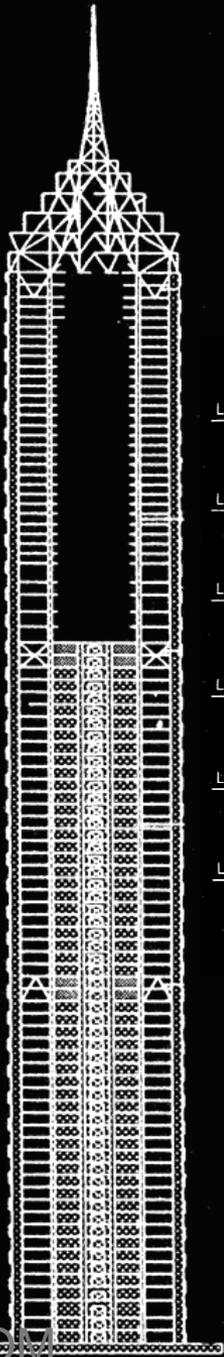




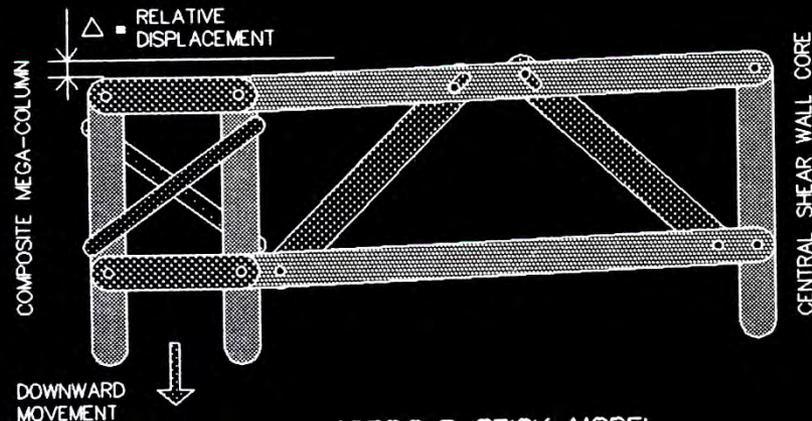
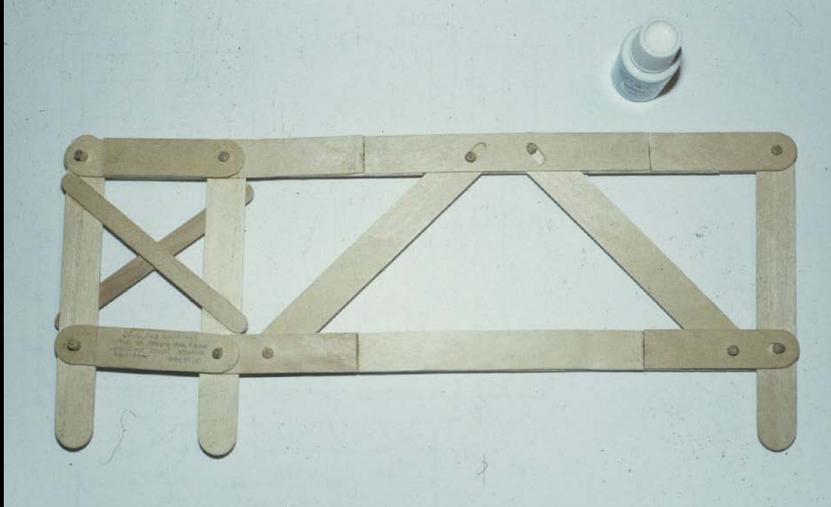




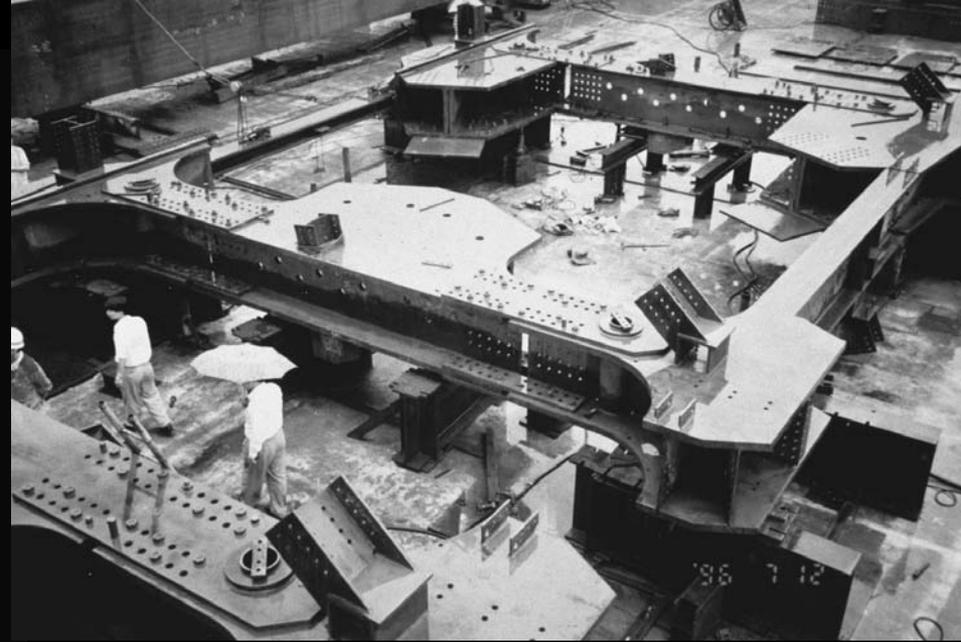
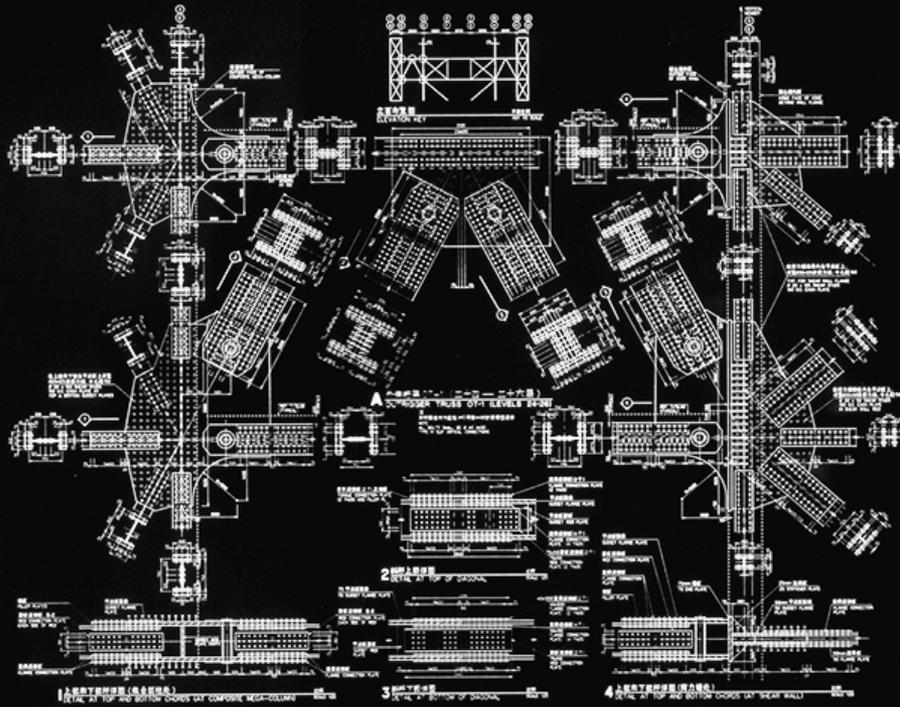
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71-80	Office	100,000
81-90	Office	100,000
91-100	Office	100,000
101-110	Office	100,000
111-120	Office	100,000
121-130	Office	100,000
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141-150	Office	100,000
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161-170	Office	100,000
171-180	Office	100,000
181-190	Office	100,000
191-200	Office	100,000
201-210	Office	100,000
211-220	Office	100,000
221-230	Office	100,000
231-240	Office	100,000
241-250	Office	100,000
251-260	Office	100,000
261-270	Office	100,000
271-280	Office	100,000
281-290	Office	100,000
291-300	Office	100,000
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711-720	Office	100,000
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761-770	Office	100,000
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881-890	Office	100,000
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901-910	Office	100,000
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981-990	Office	100,000
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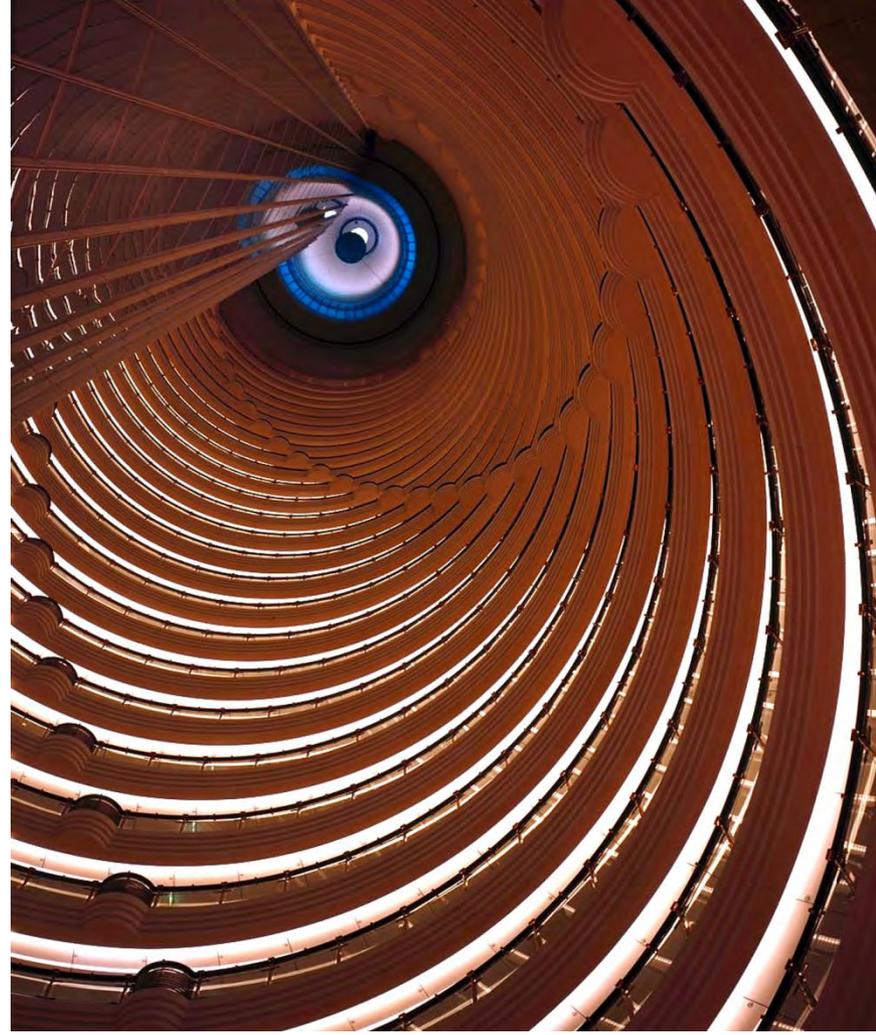
OUTRIGGER TRUSS ELEVATION - LEVELS 24-26



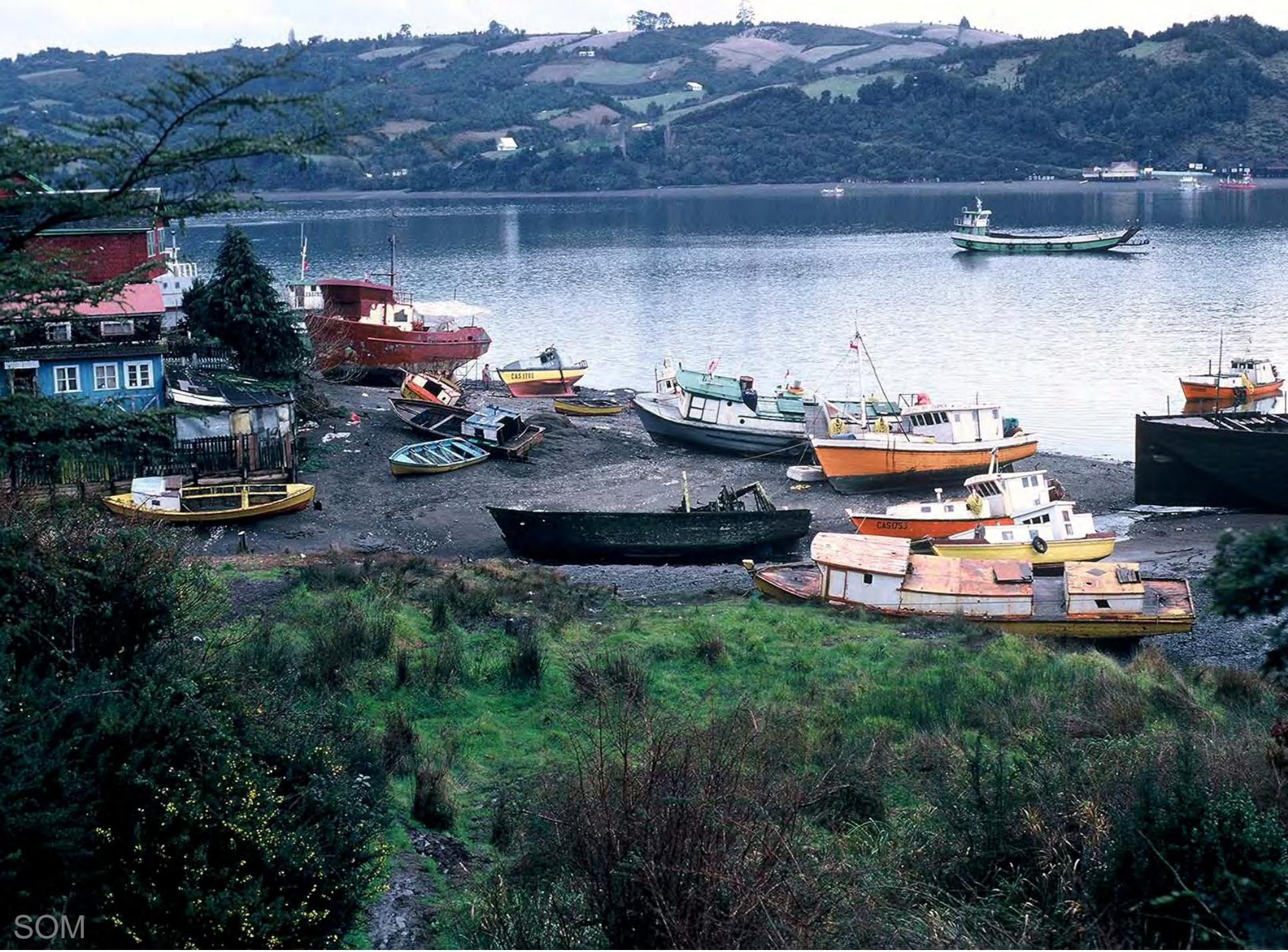
POPSICLE STICK MODEL  
RELATIVE MOVEMENT OF  
OUTRIGGER TRUSS SYSTEM









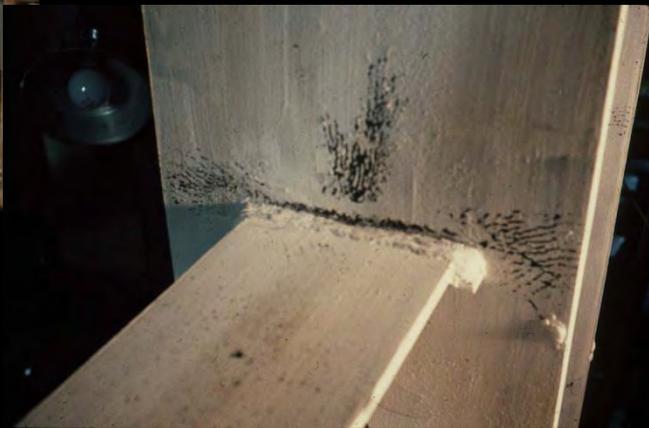
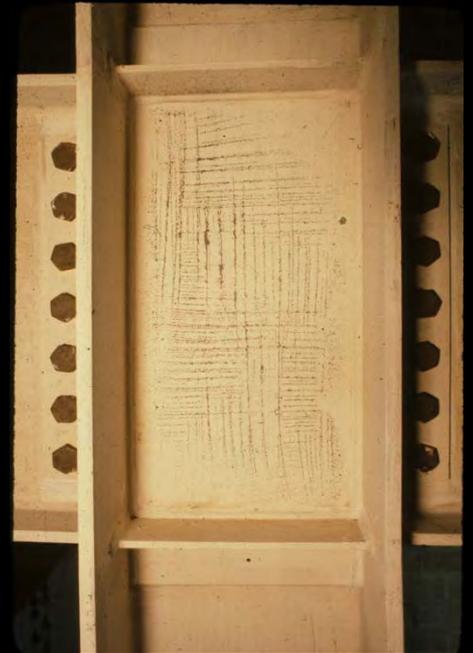
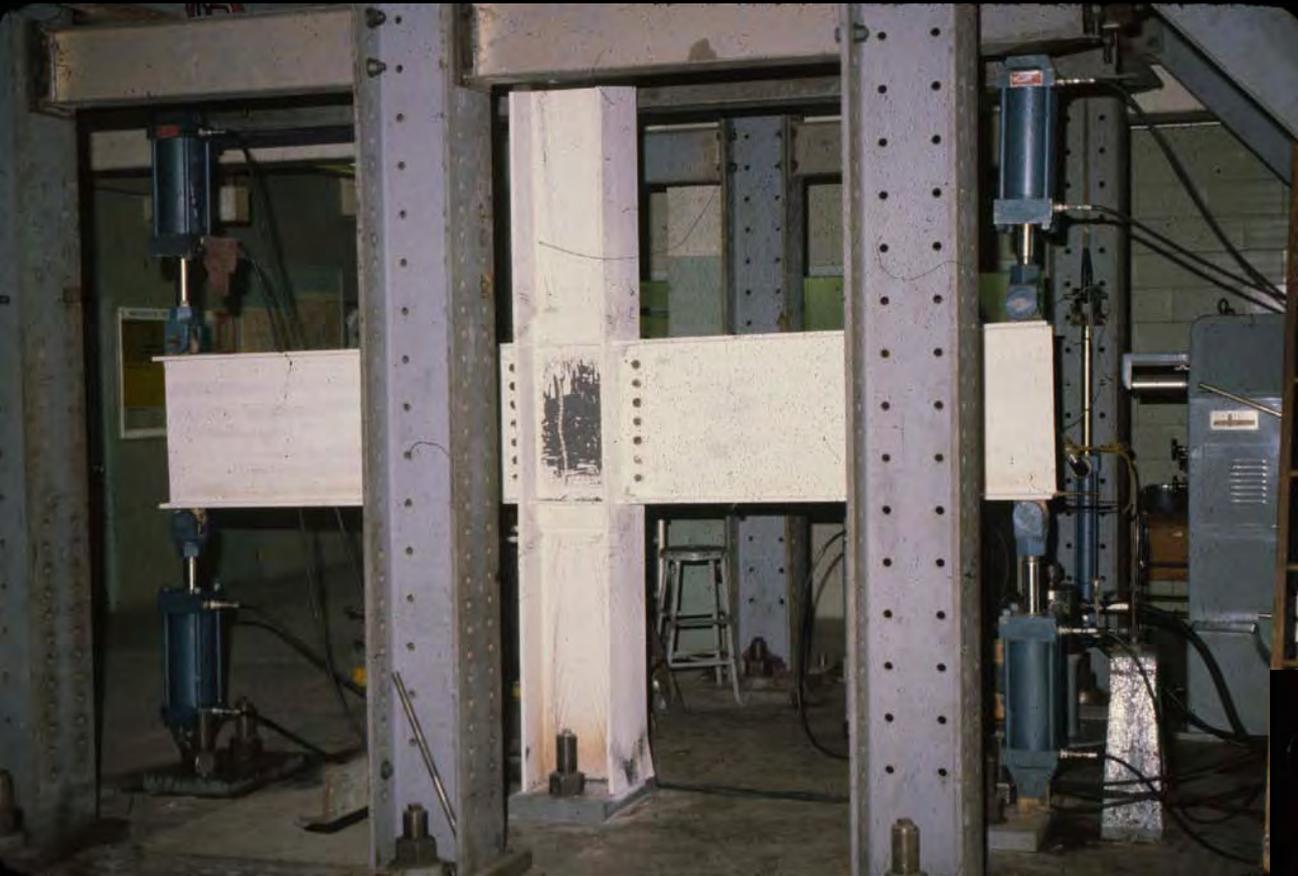


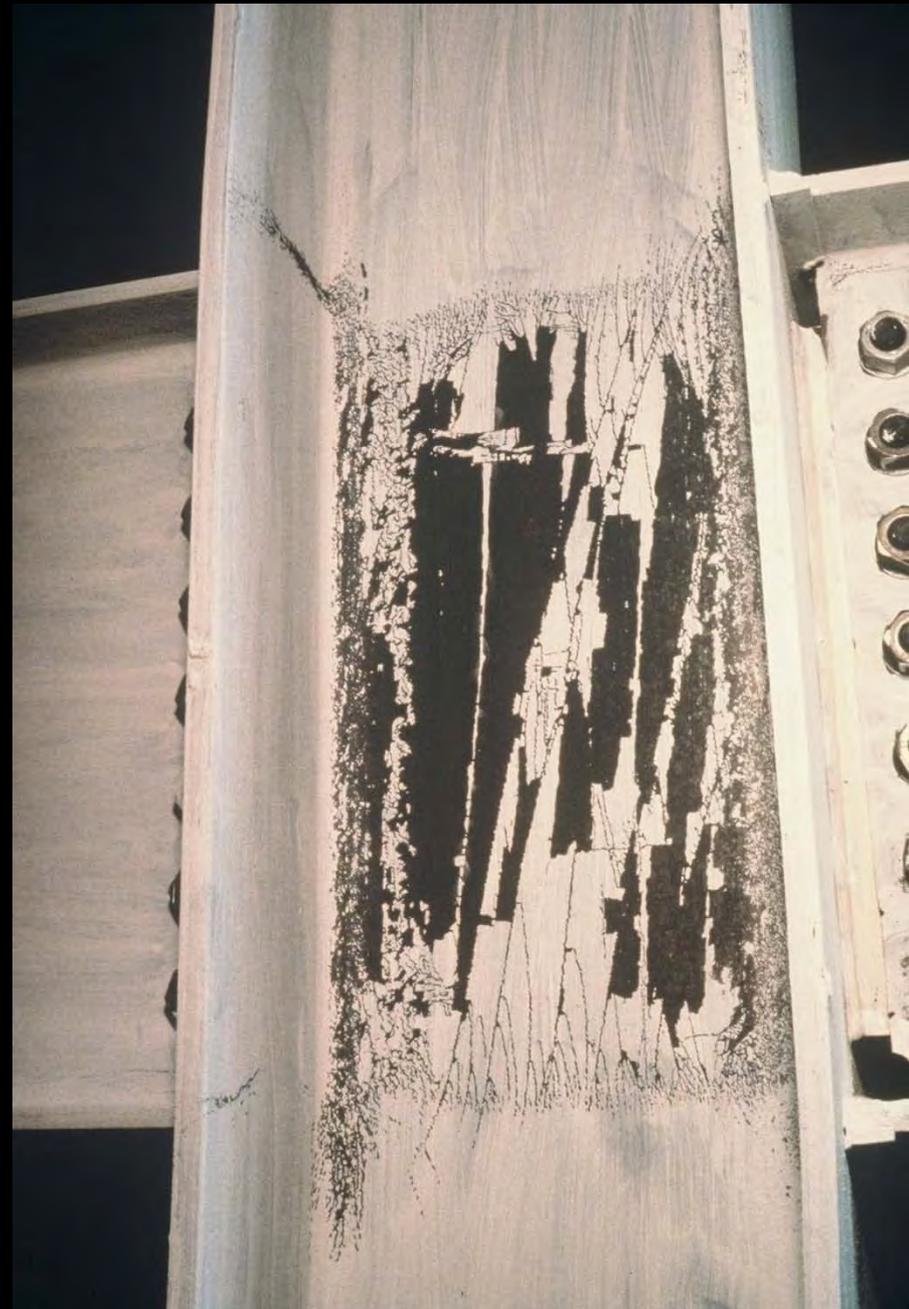




“All-wood” Jesuit Churches  
Dowels from the Alerce Tree

Island of Chiloe



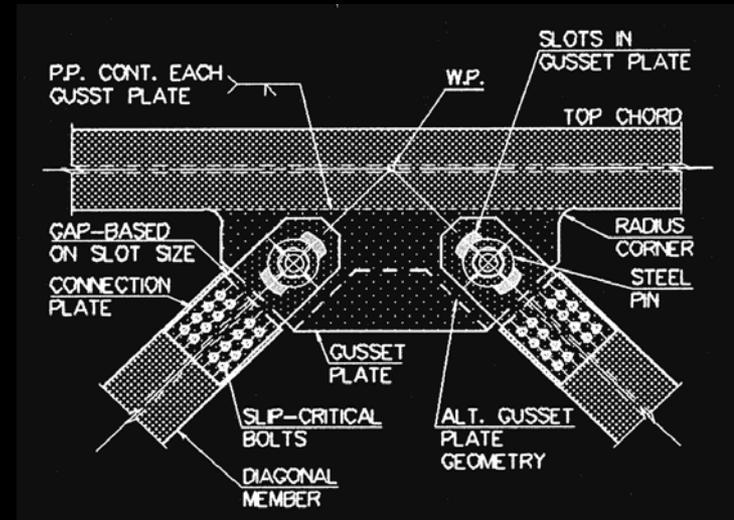
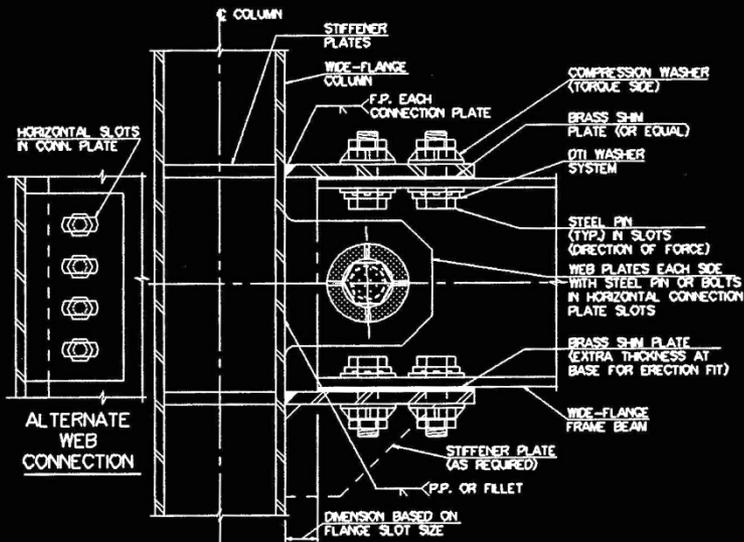


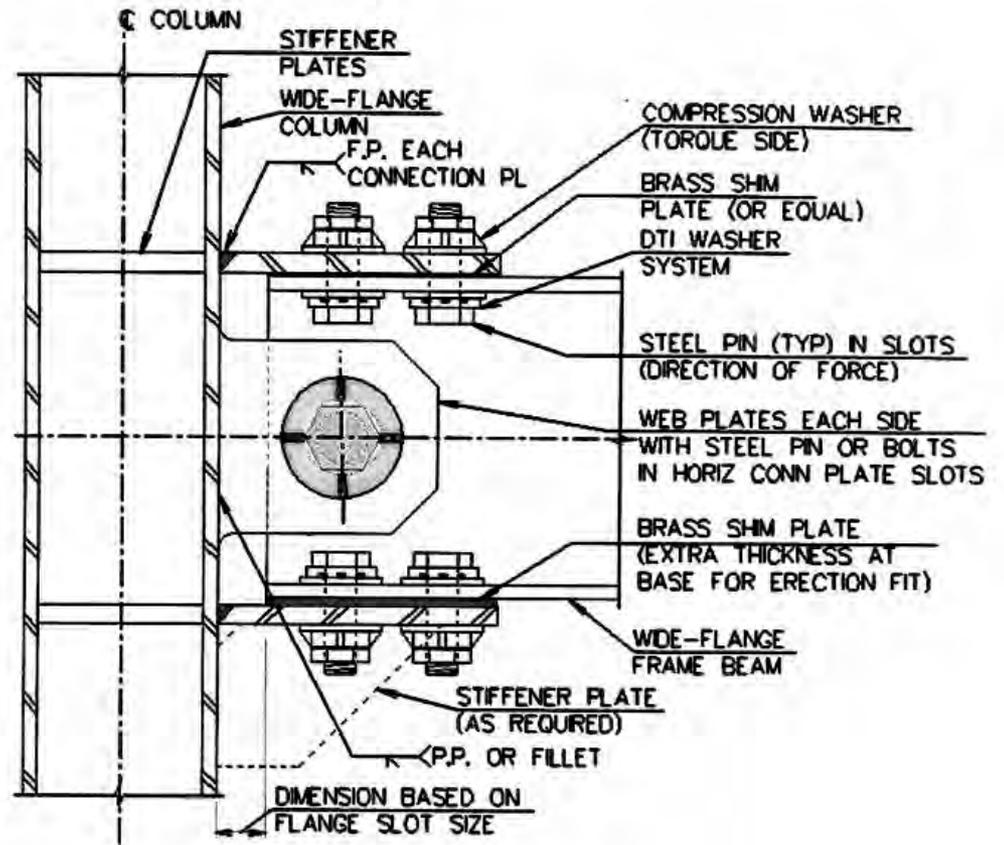
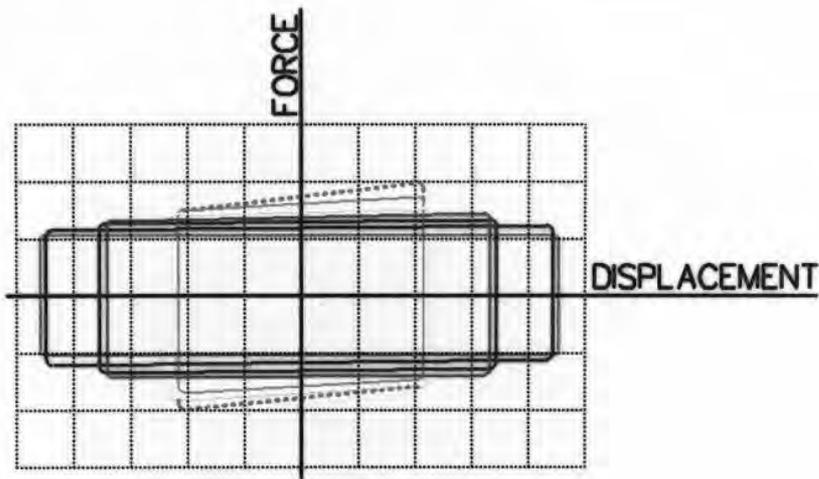


Conventional Moment Frame

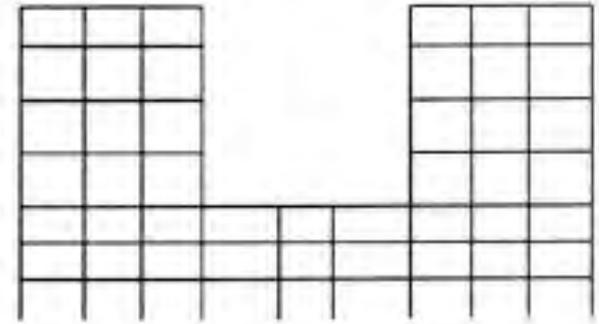
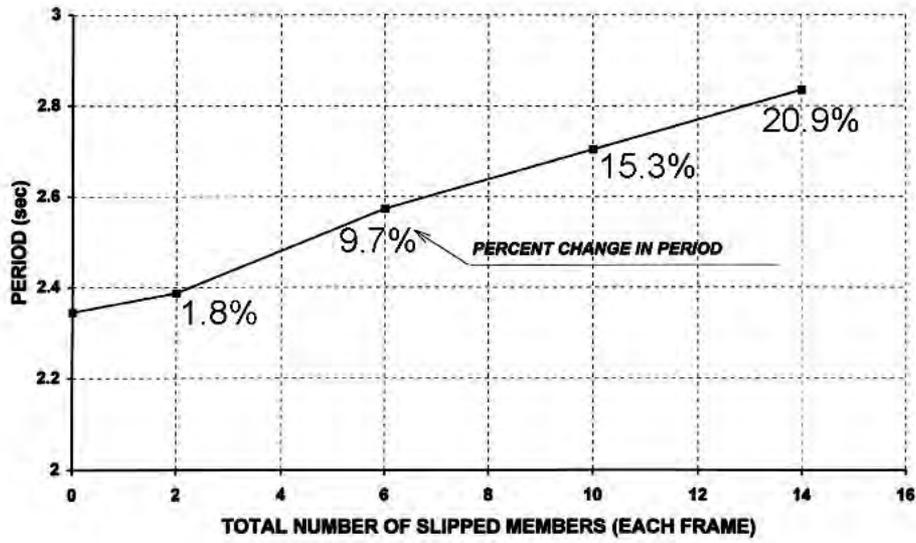


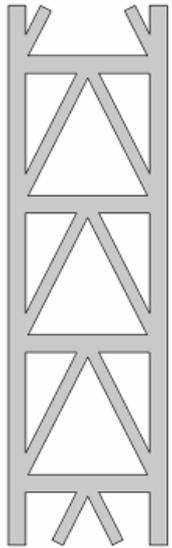
Conventional Braced Frame



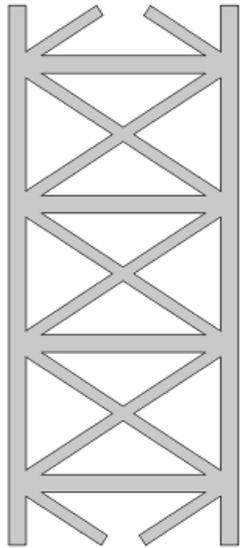


**PERIOD VS. TOTAL NUMBER OF SLIPPED MEMBERS**

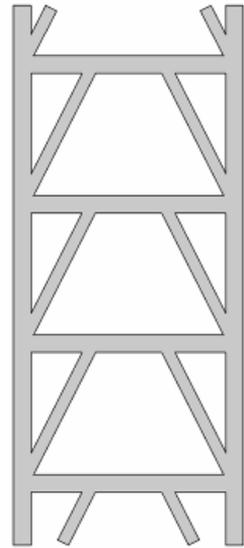




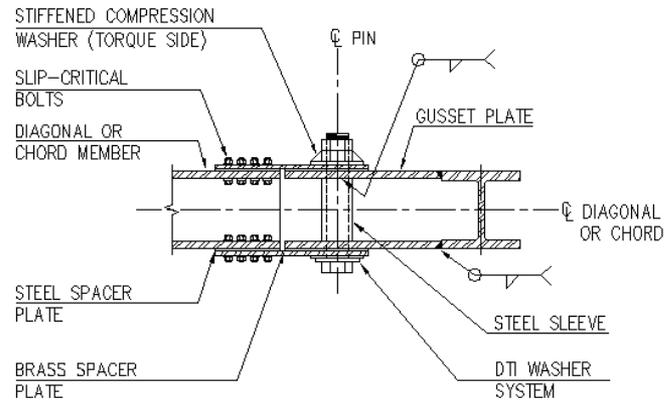
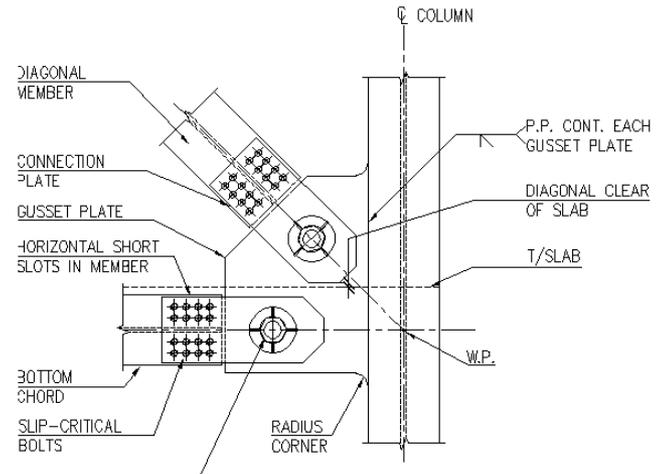
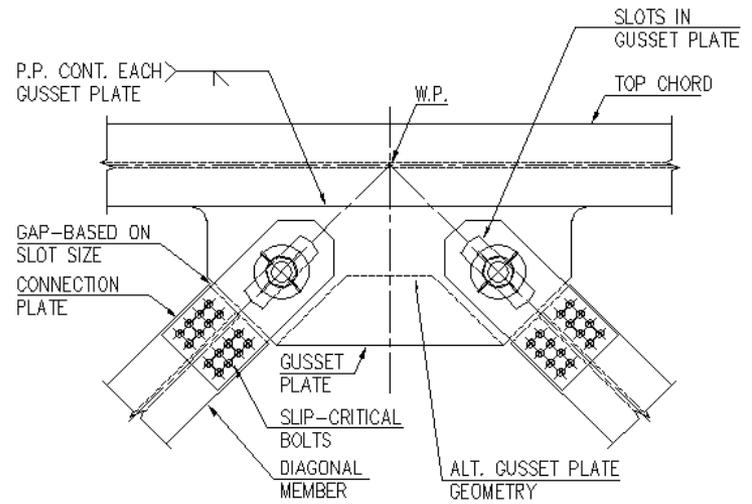
K-BRACED SYSTEM



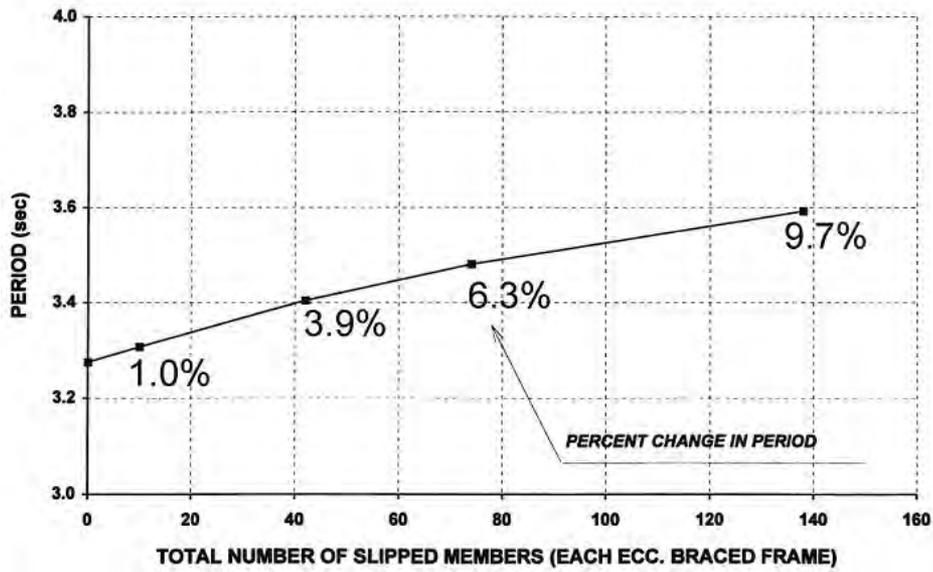
X-BRACED SYSTEM

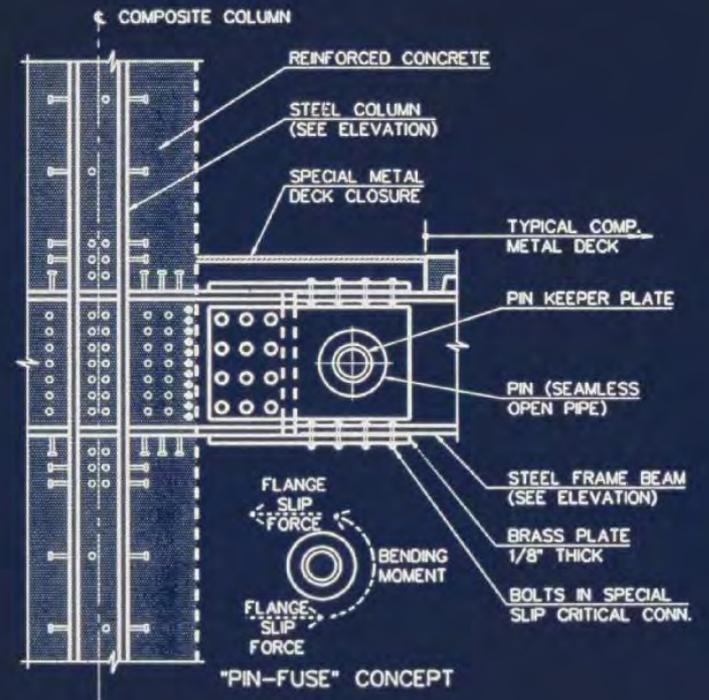


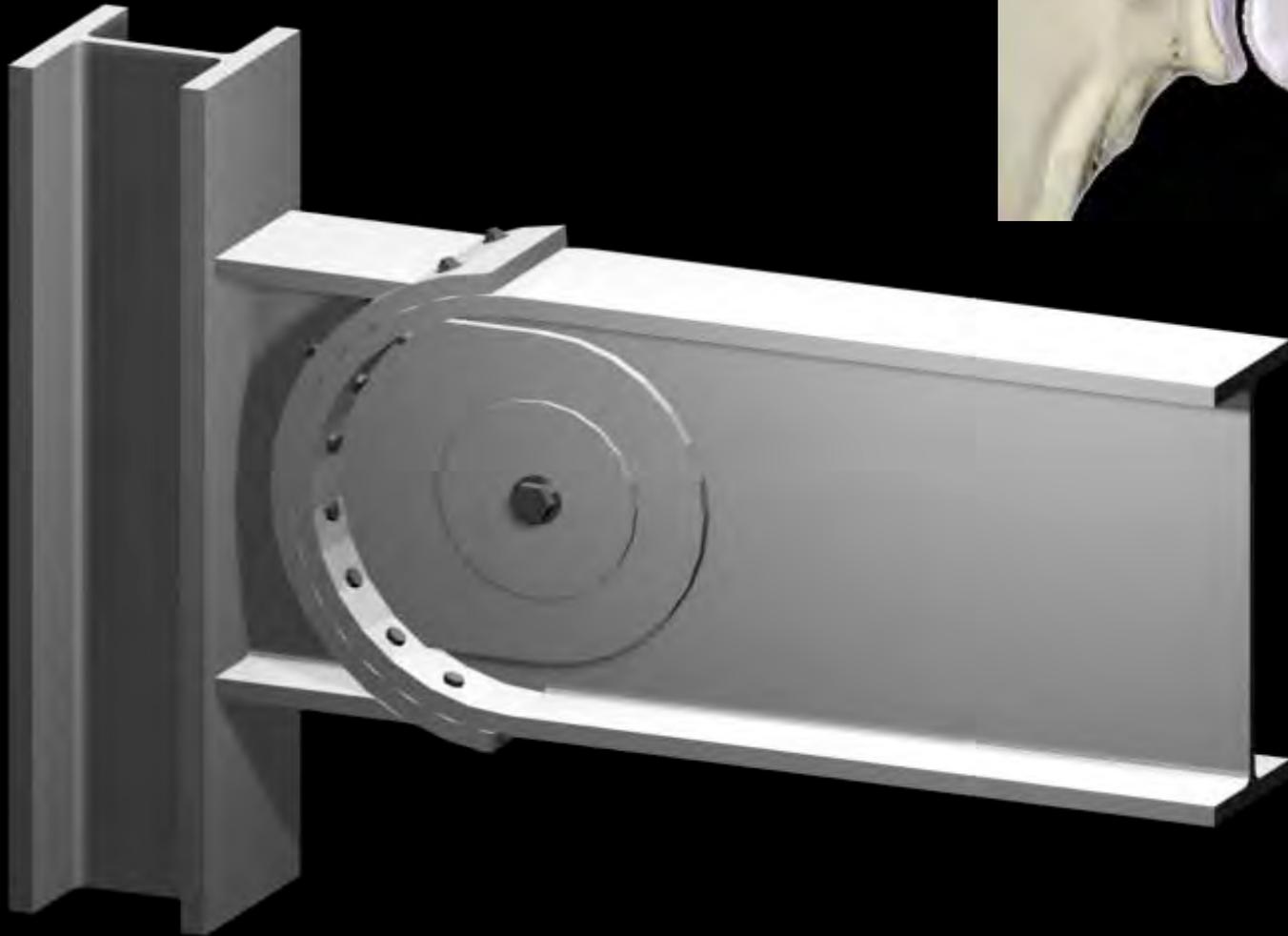
ECCENTRICALLY BRACED SYSTEM

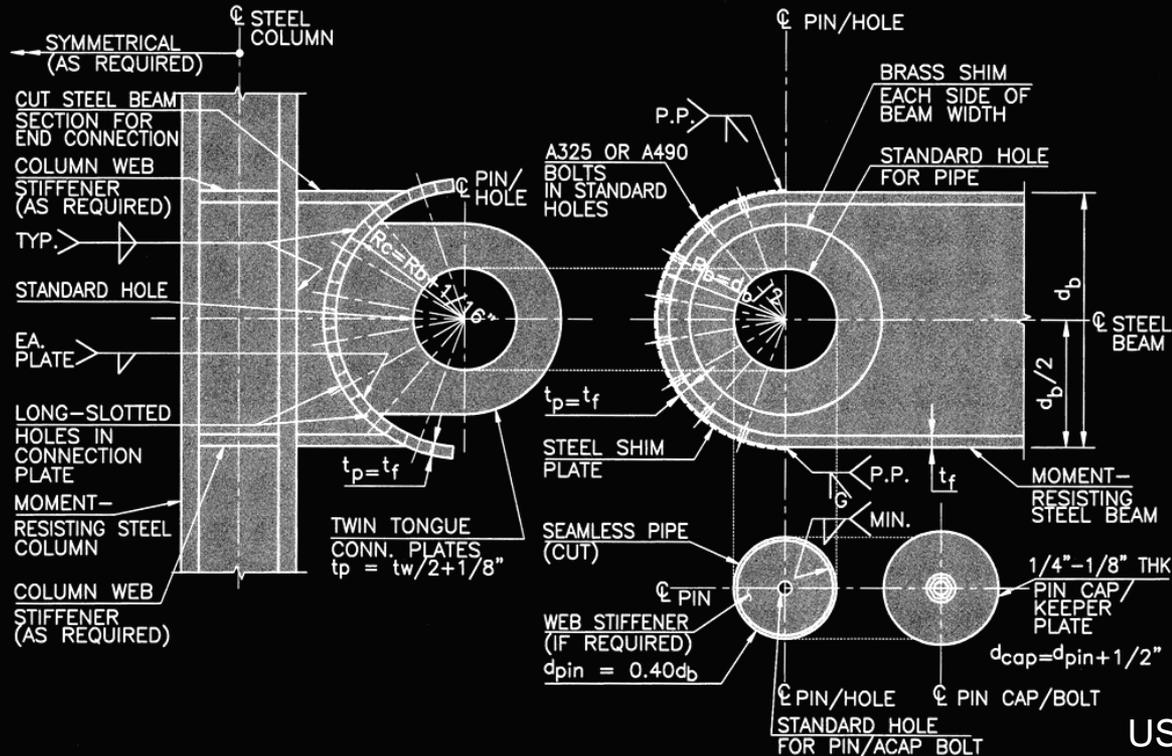
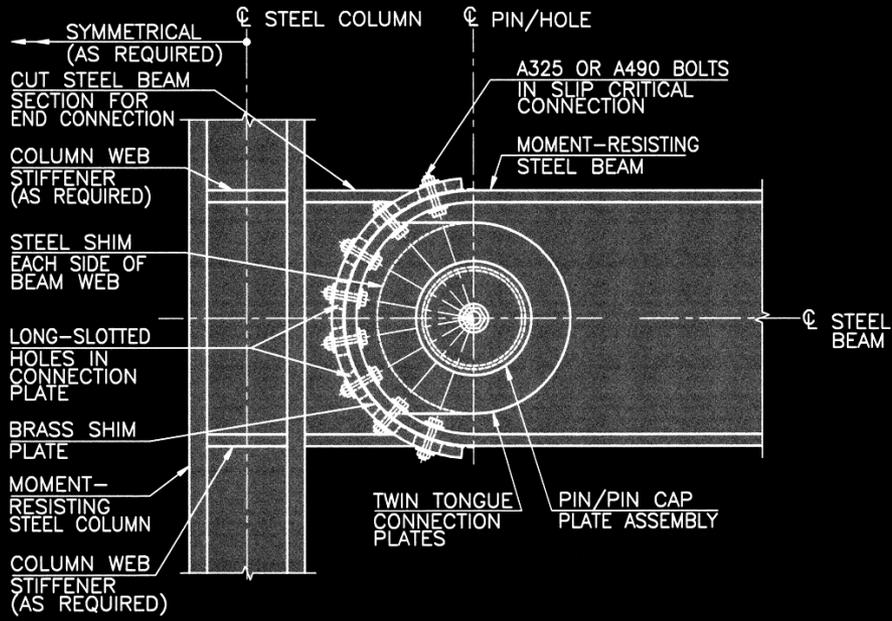


**PERIOD VS. TOTAL NUMBER OF SLIPPED MEMBERS**











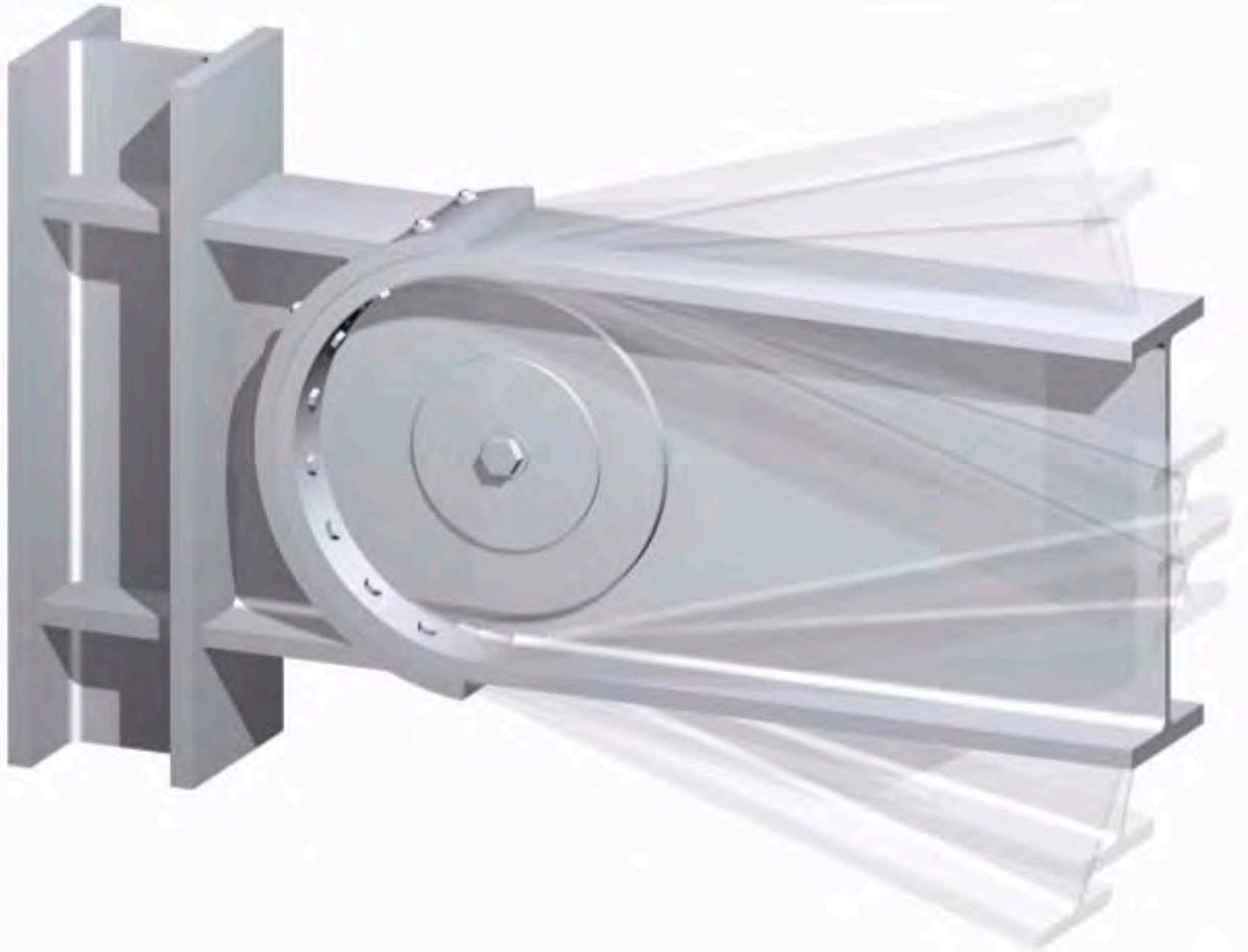


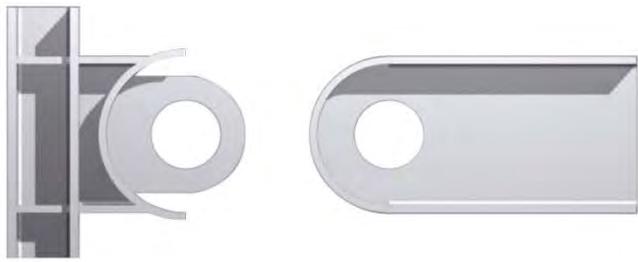


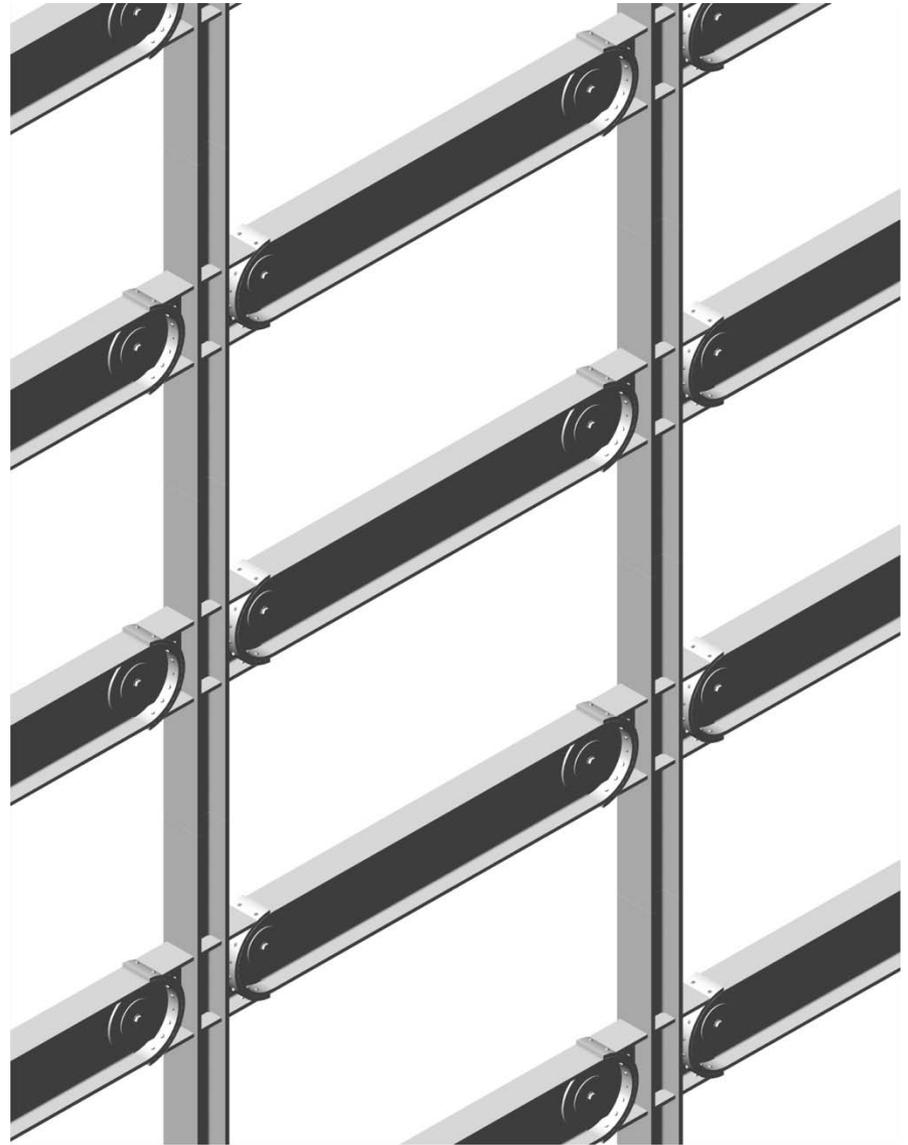
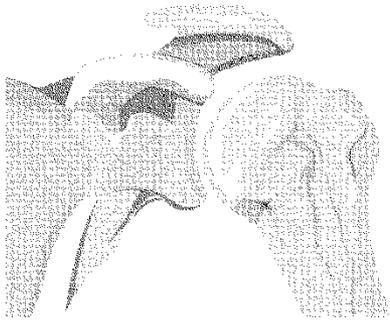
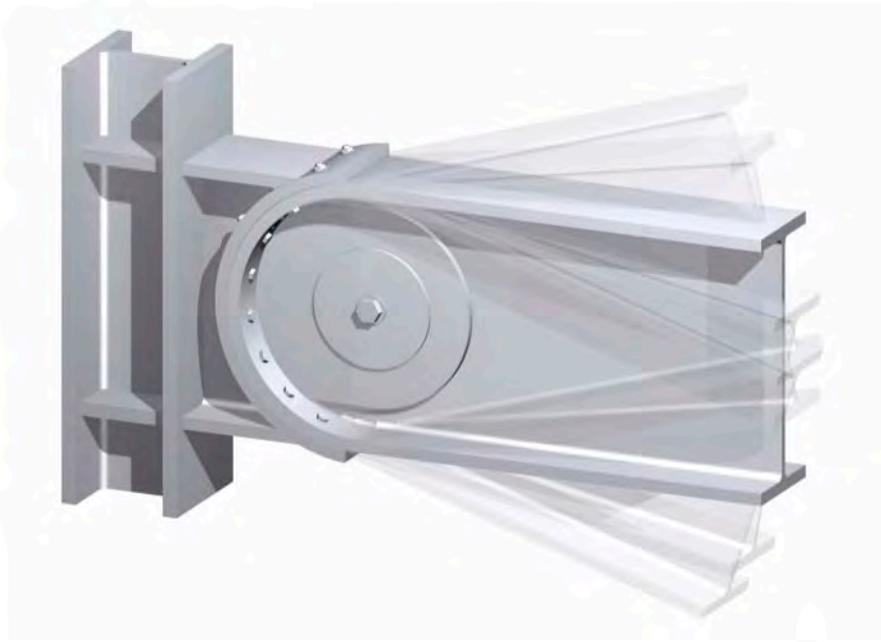






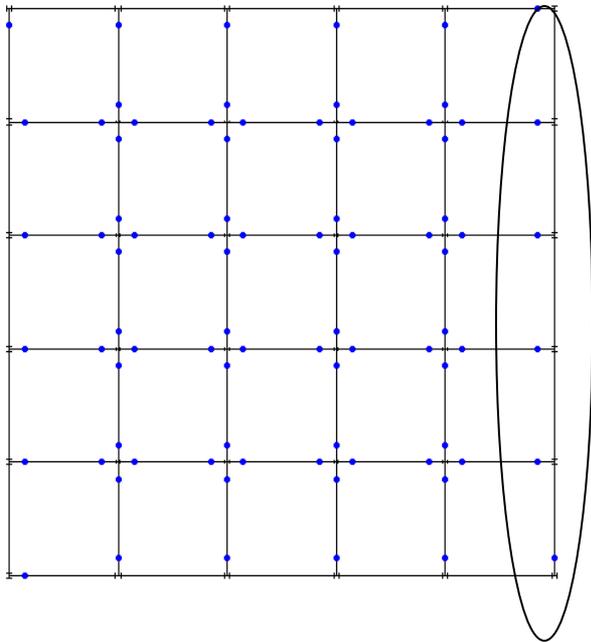




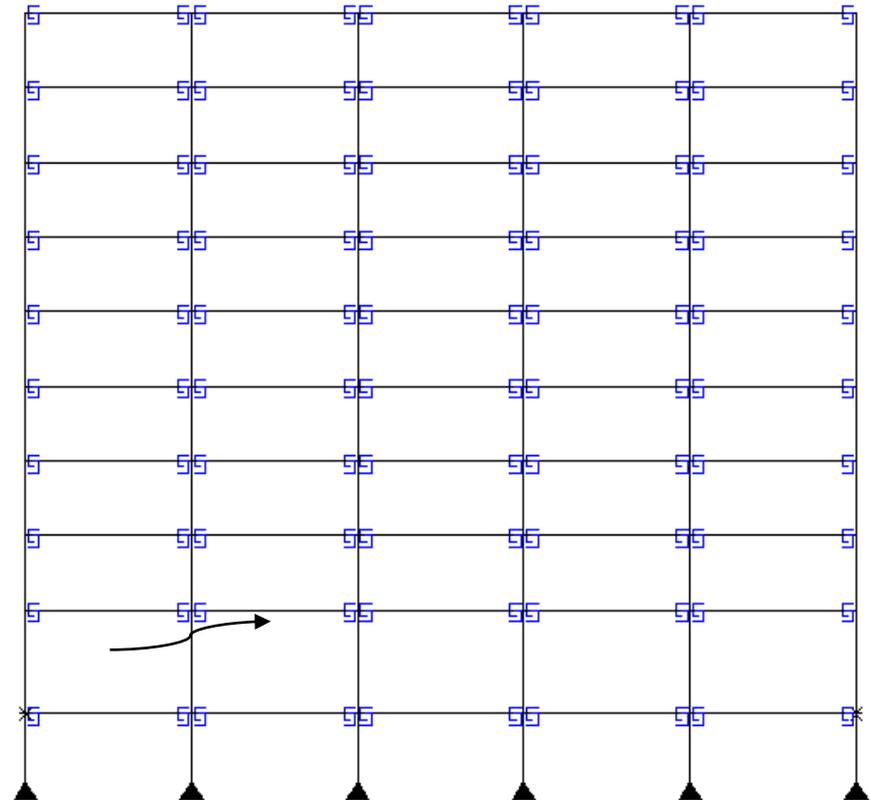


# Non-linear Analysis

- Perimeter frame of SAC 9-story building



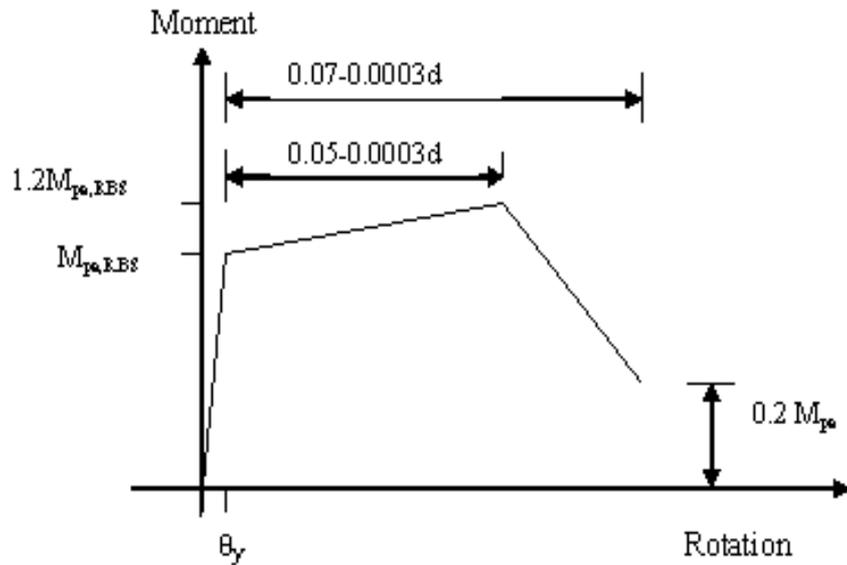
Plan



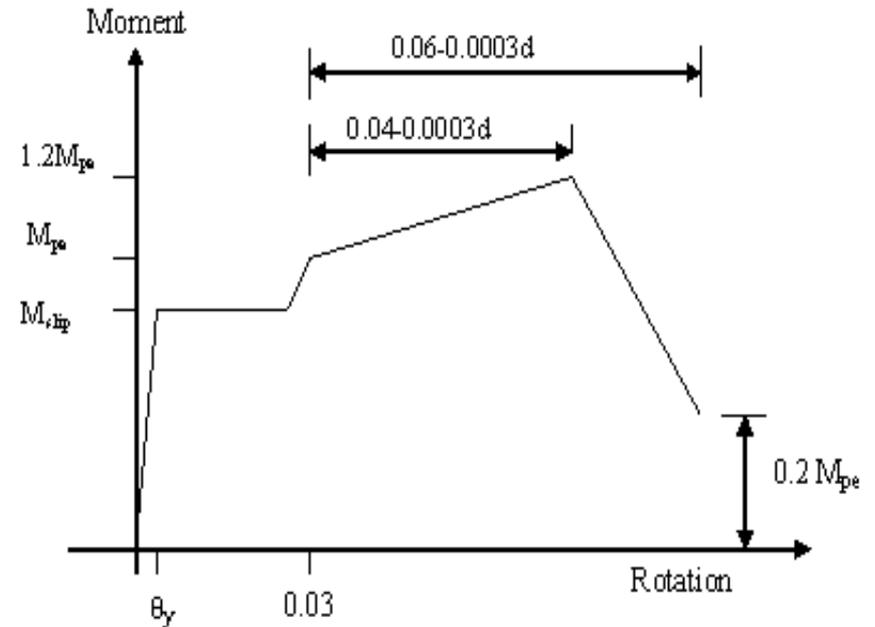
Elevation

# Hysteretic loops definition (From FEMA 356)

- RBS

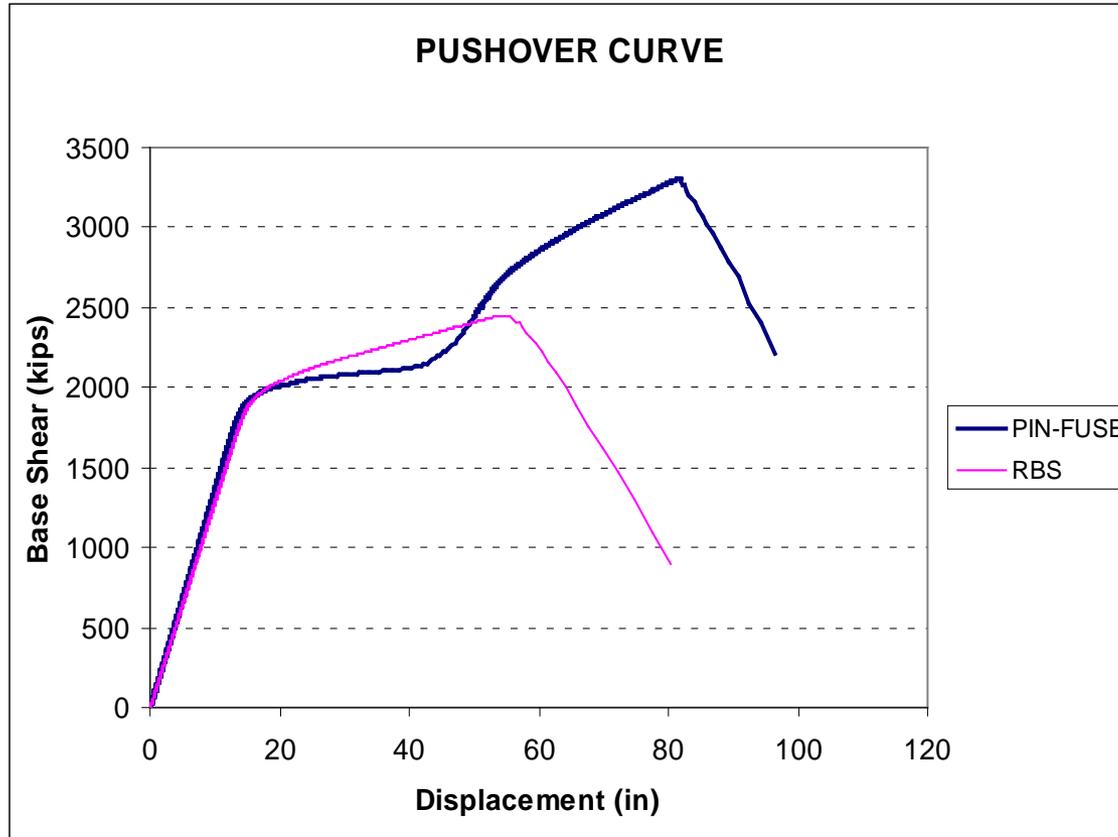


- Pin Fuse



# Results of Pushover Analysis

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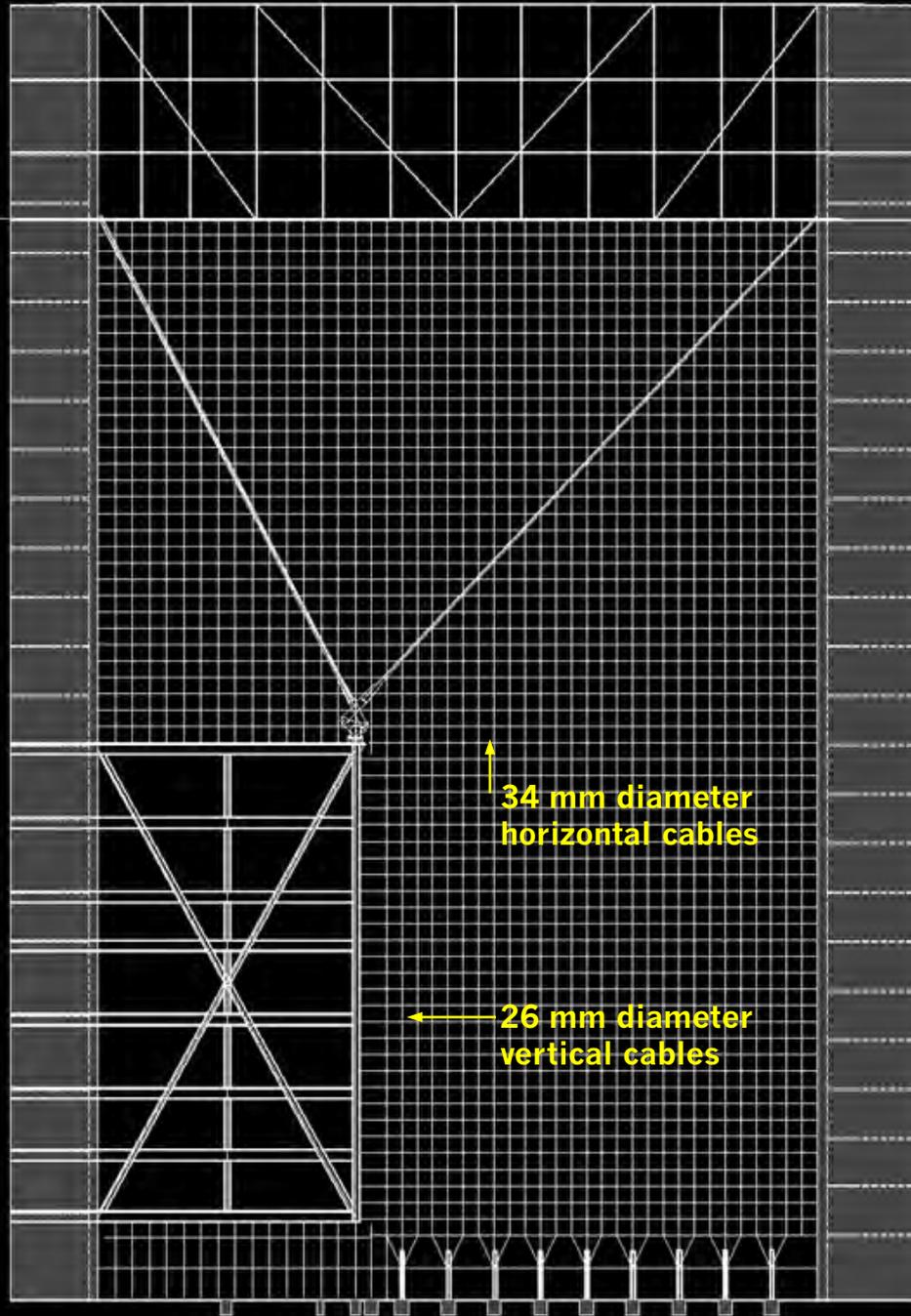


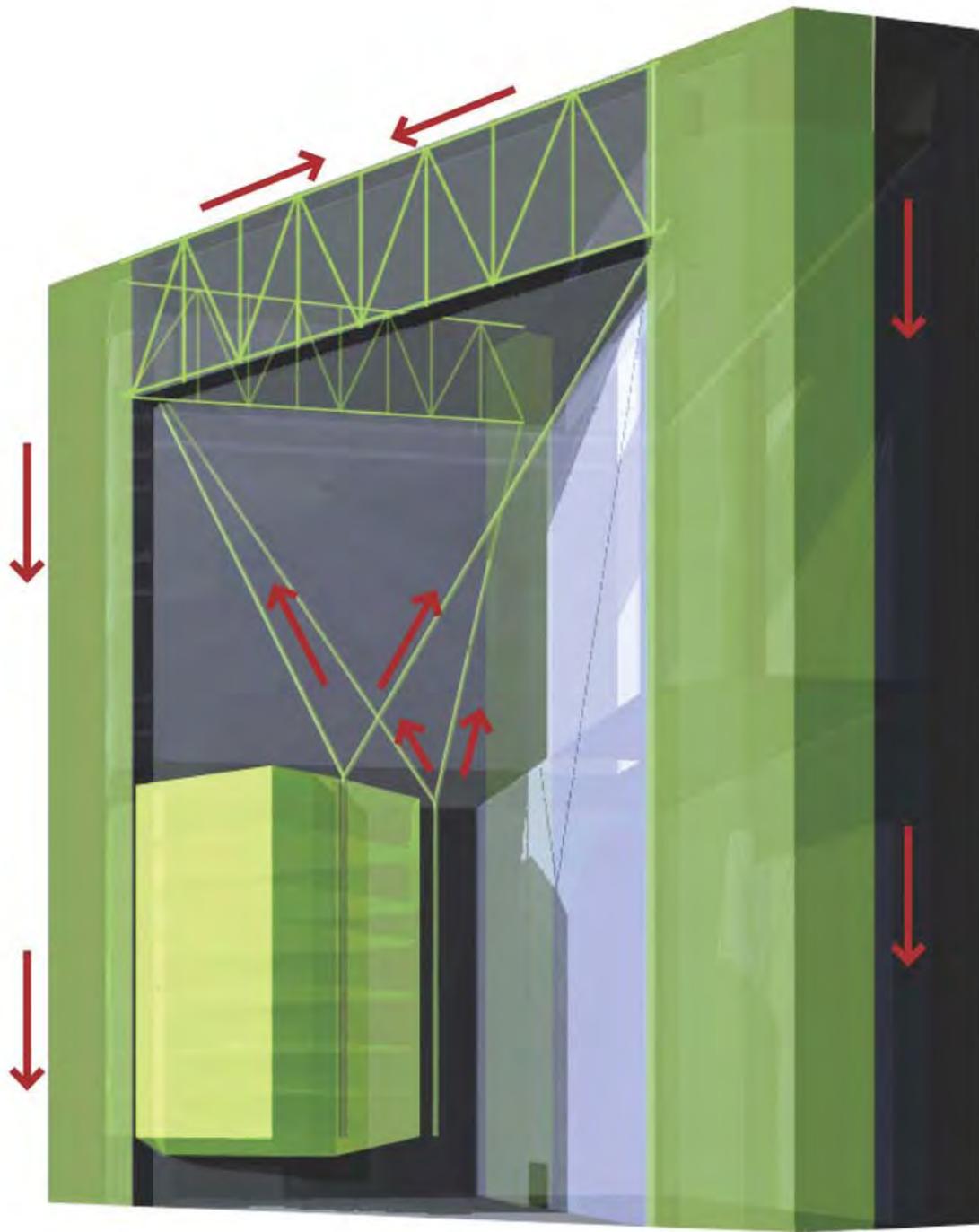


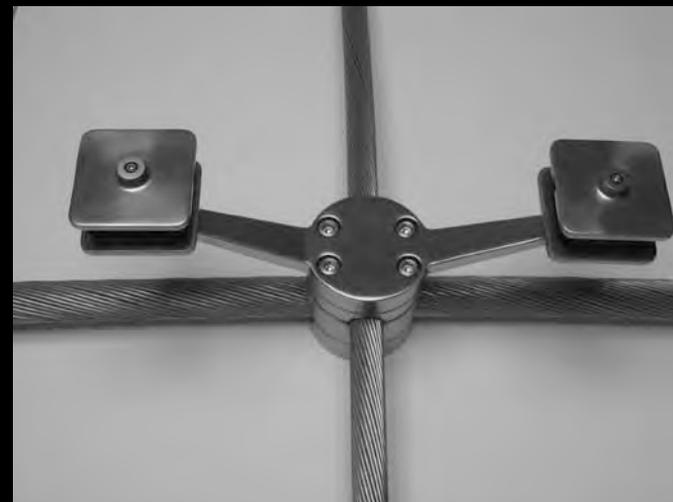


## Cable Net

90 meters tall  
60 meters wide









新保利大厦  
NEW POLY PLAZA

新保利大厦  
NEW POLY PLAZA  
4003 9999



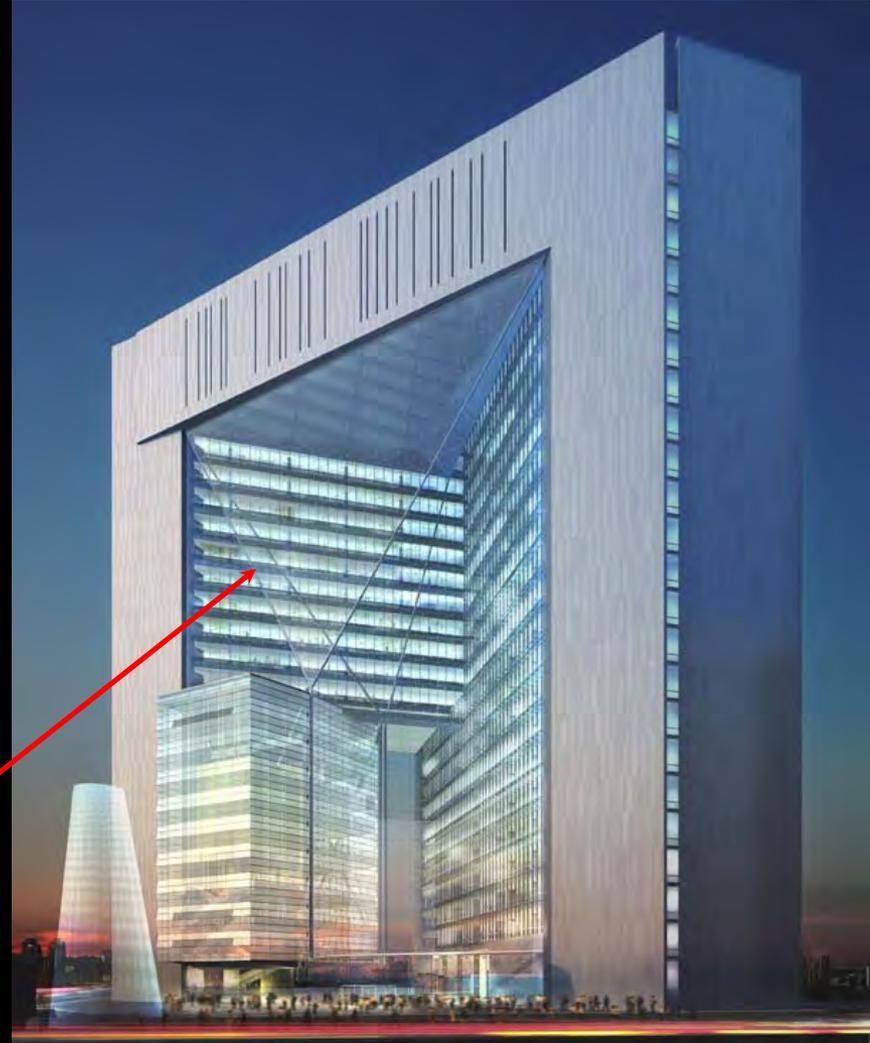
# #25 Barry Bonds

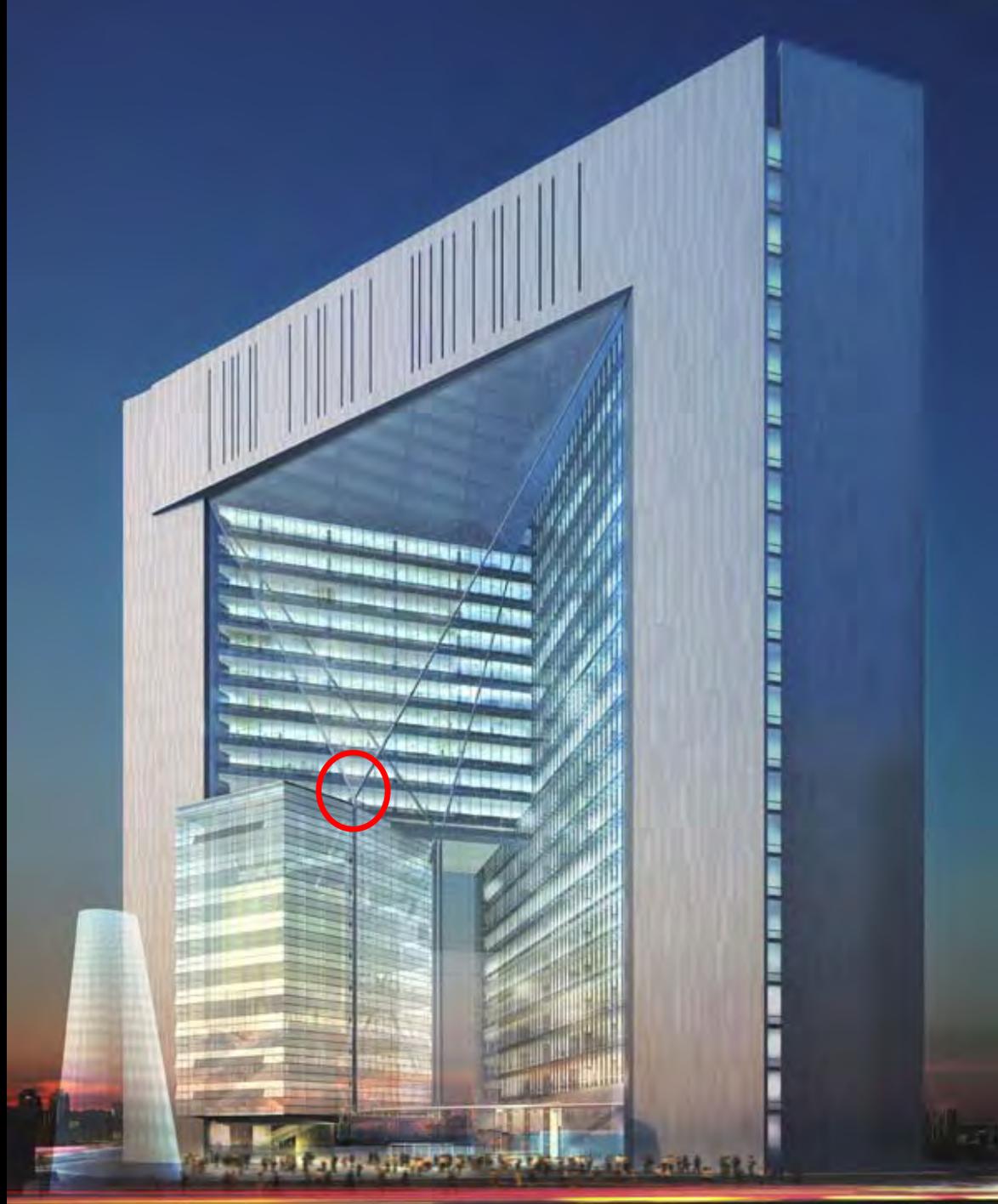


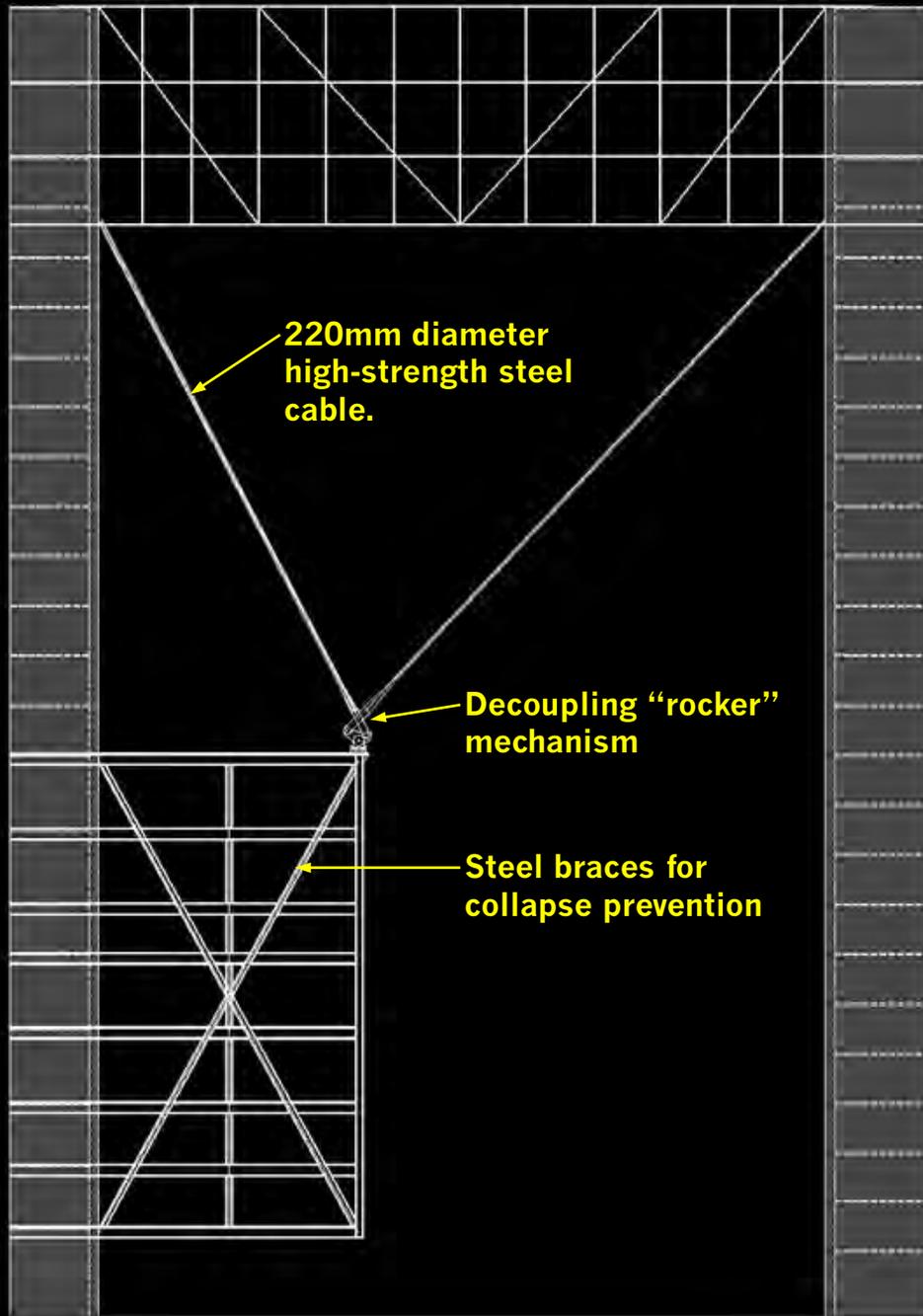
**Age:** 39  
**Height:** 6-2  
**Weight:** 228 lbs.  
**Bats:** Left  
**Throws:** Left  
**Pos:** LF

AVG	HR	RBI
<b>.358</b>	<b>14</b>	<b>29</b>

**Cable Design Force**  
**40,000 kN**



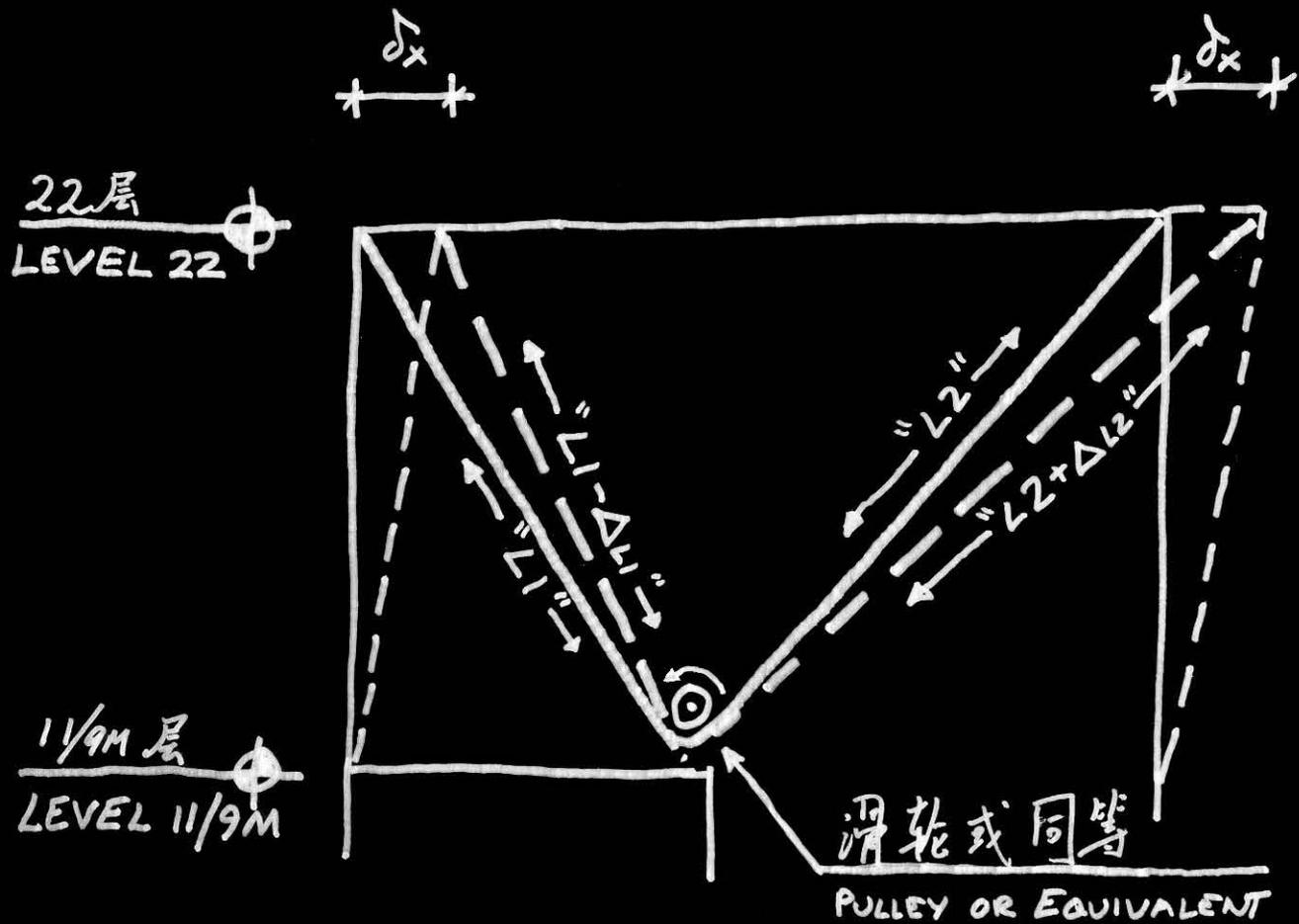




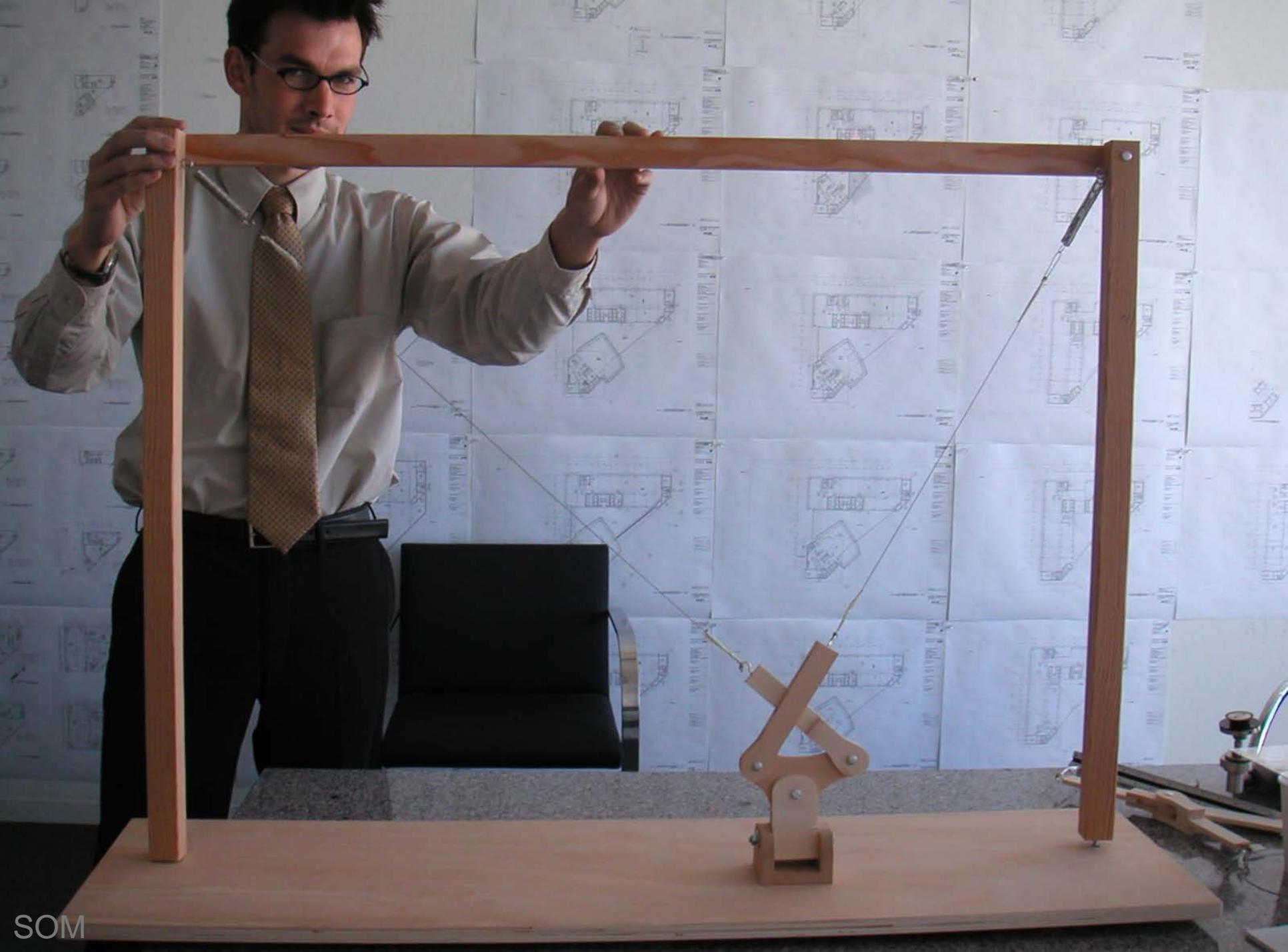
**220mm diameter  
high-strength steel  
cable.**

**Decoupling "rocker"  
mechanism**

**Steel braces for  
collapse prevention**



最终方案 — “V”底相似滑轮  
FINAL SCHEME — PULLEY EQUIVALENT AT BASE OF “V”

















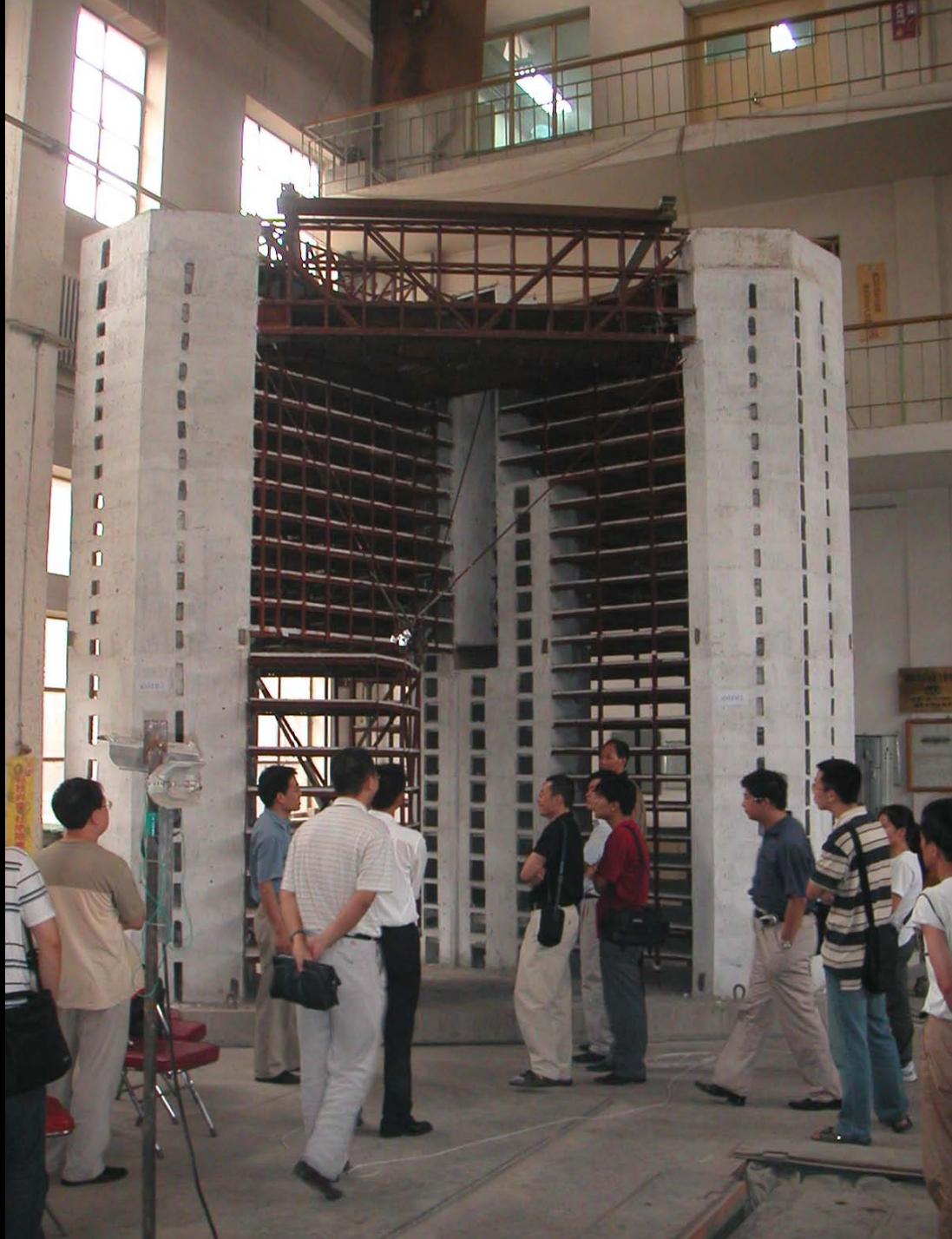














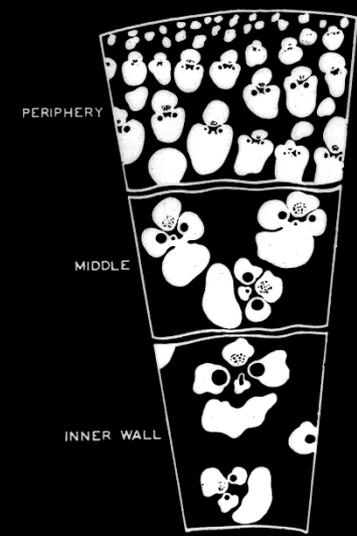
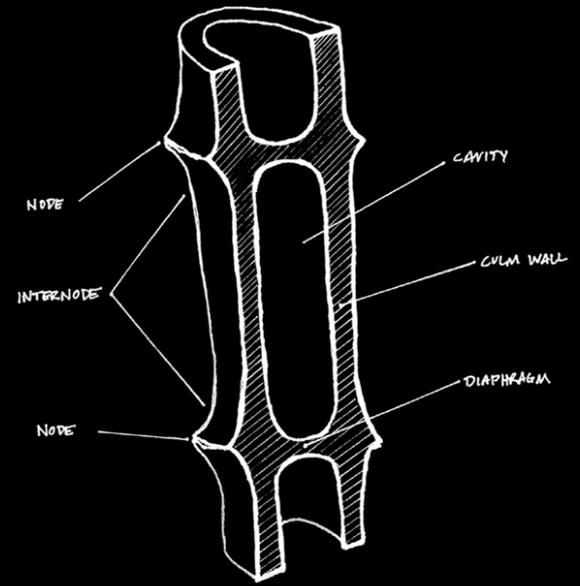






P+ 世纪华创  
CENTURY HUACHUANG

世纪华创 6506505-6506988



$$y = 25.13 + 4.8050 x - 0.0774 x^2$$

## Bamboo Culm Diameter Equations

$$y = 97.5 - 0.212x - 0.016x^2 \quad (\text{lower region})$$

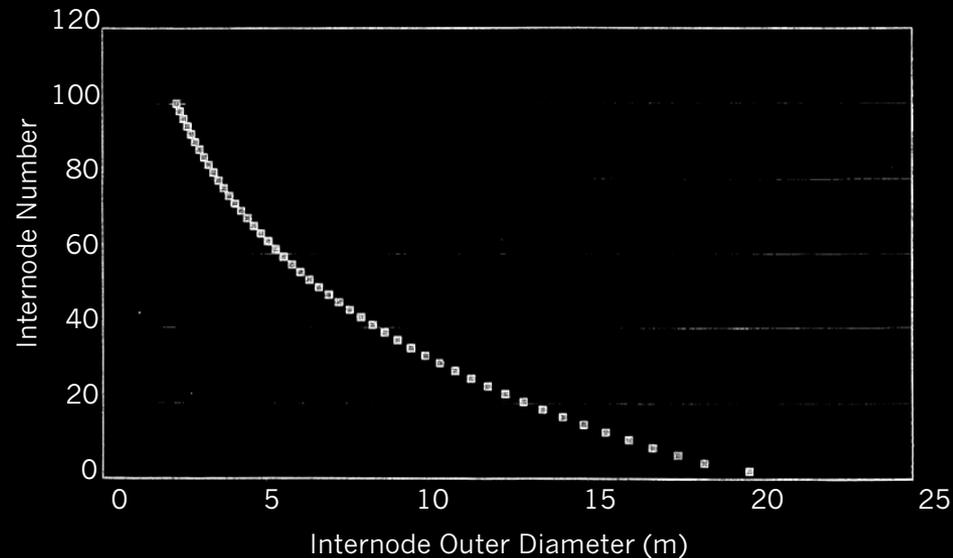
$$y = 157.6 - 2.868x + 0.013x^2 \quad (\text{upper region})$$

$$y = 101.8 e^{0.022x} \quad (\text{entire length})$$

Where:

y = diameter of the culm

x = internode number



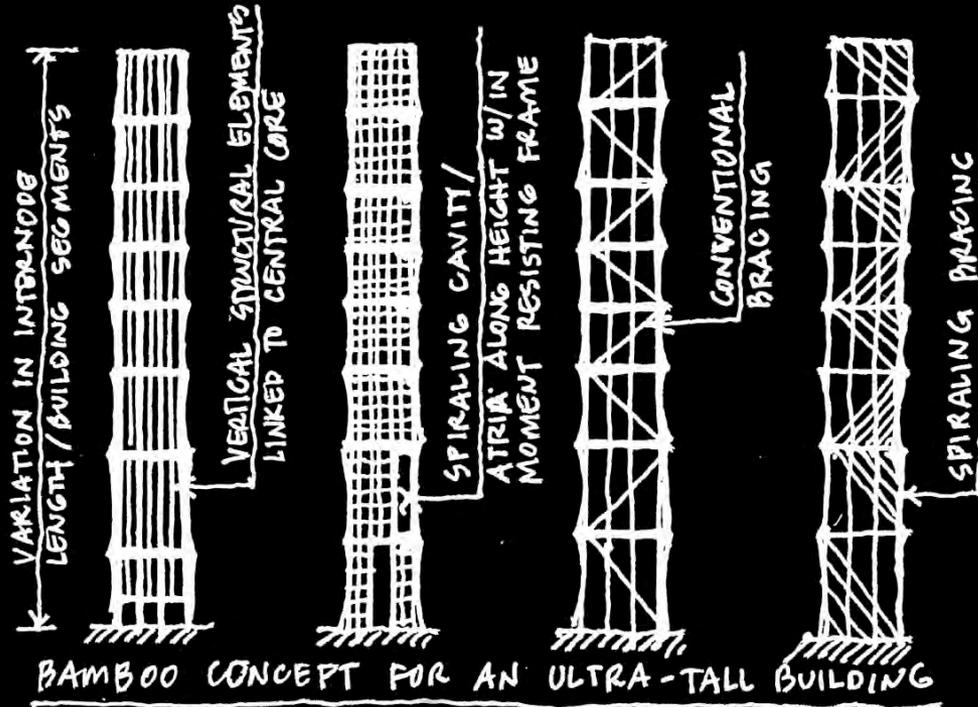
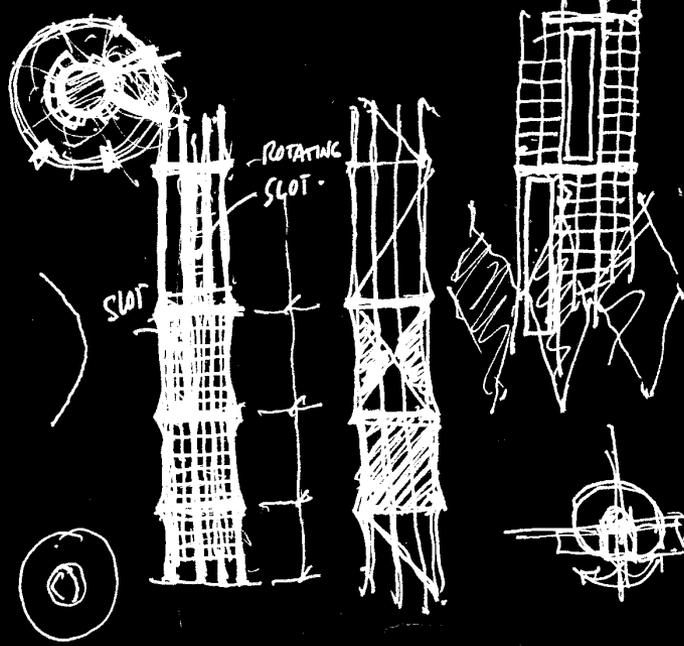
## Bamboo Culm Wall Thickness Equation

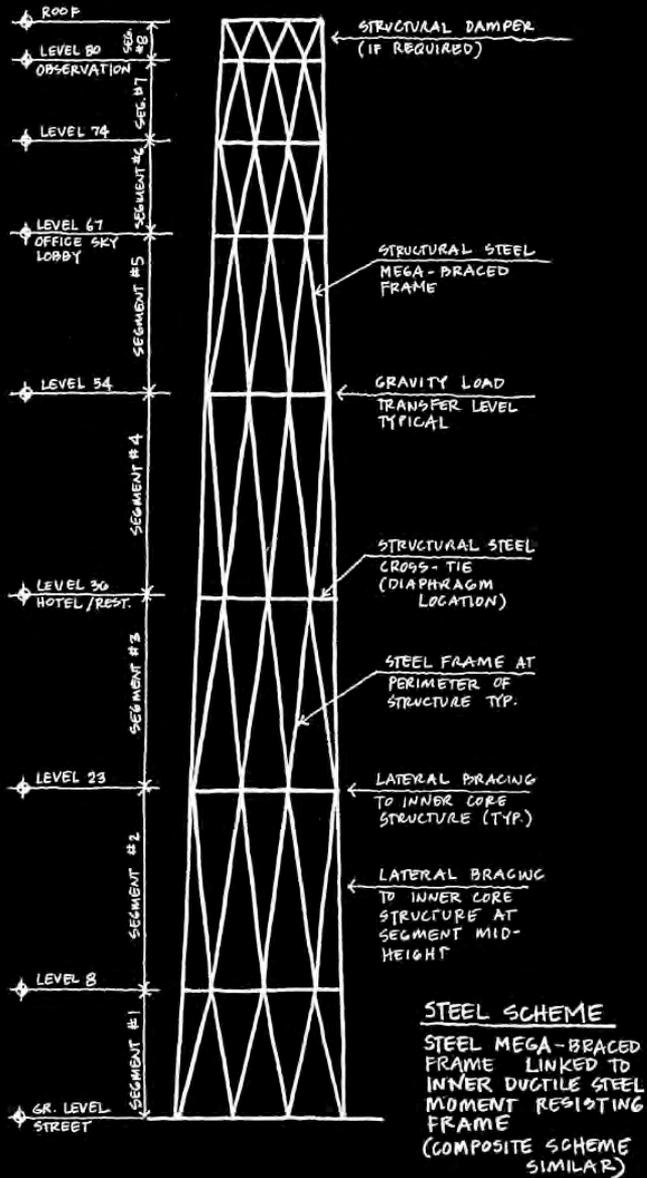
$$y = 35 + 0.0181(x - 35)^{1.90}$$

Where:

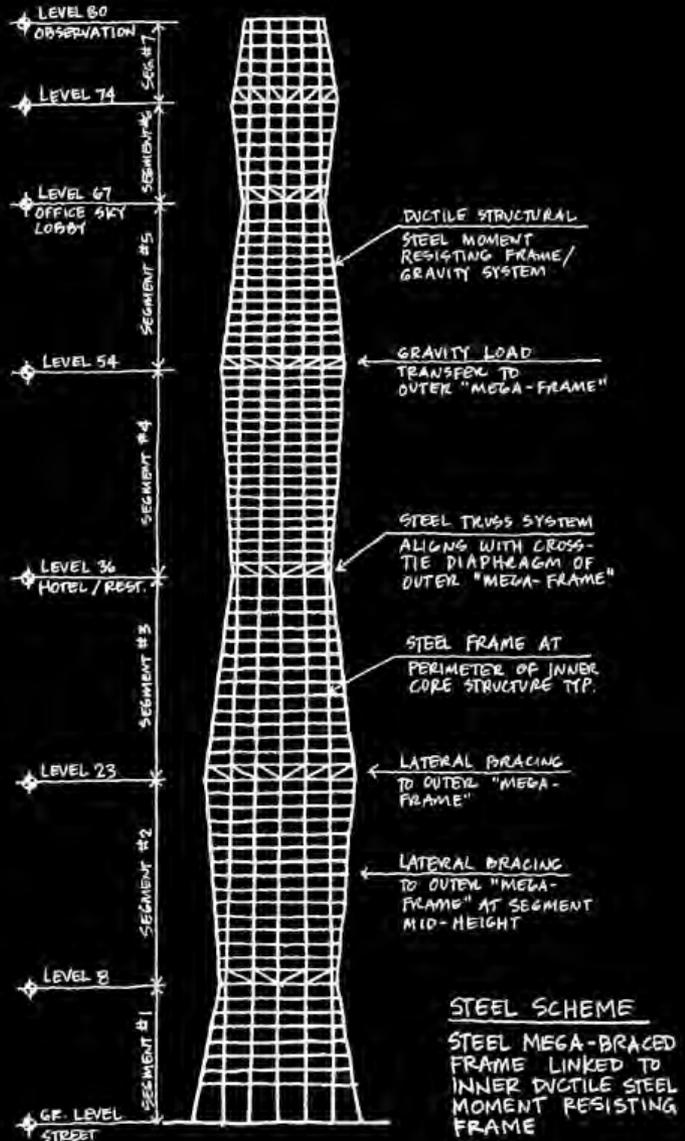
y = culm wall thickness

x = internode number





**A** ELEVATION - OUTER STRUCTURAL FRAME  
NOT TO SCALE



**B** ELEVATION - INNER STRUCTURAL FRAME  
NOT TO SCALE





long legs and excel at picking insects off water surfaces.

The wings of the adult dragonfly are one of its most striking physical characteristics. Just as large and just as prominently displayed as those of butterflies and moths, dragonfly wings are at the same time less colorful but more intricate. As we have seen, the wing veins serve important functions both during the final molt and in flight. Since many dragonfly species can be identified from the wings alone, the arrangement of the major veins and cells can also determine family groupings. This means of classification, along with eye placement, became the basis for our pictorial key to the seven North American and

{ FIGURE 40 }

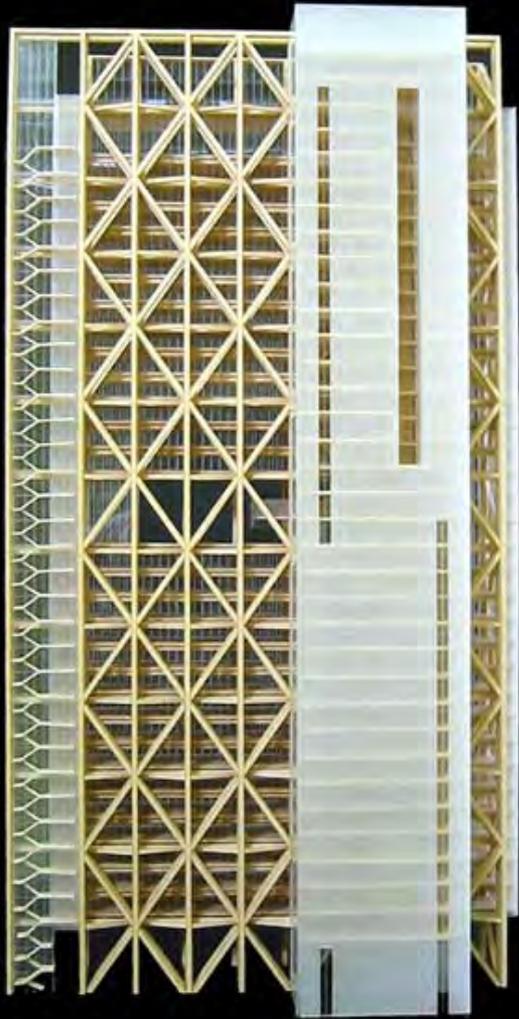
*A collage of the abdomens of several different skimmer species (family Libellulidae) showing differences in terminal appendages. The tails (abdomens) were digitally removed from the scanned images of live dragonflies. Scans provided by authors.*

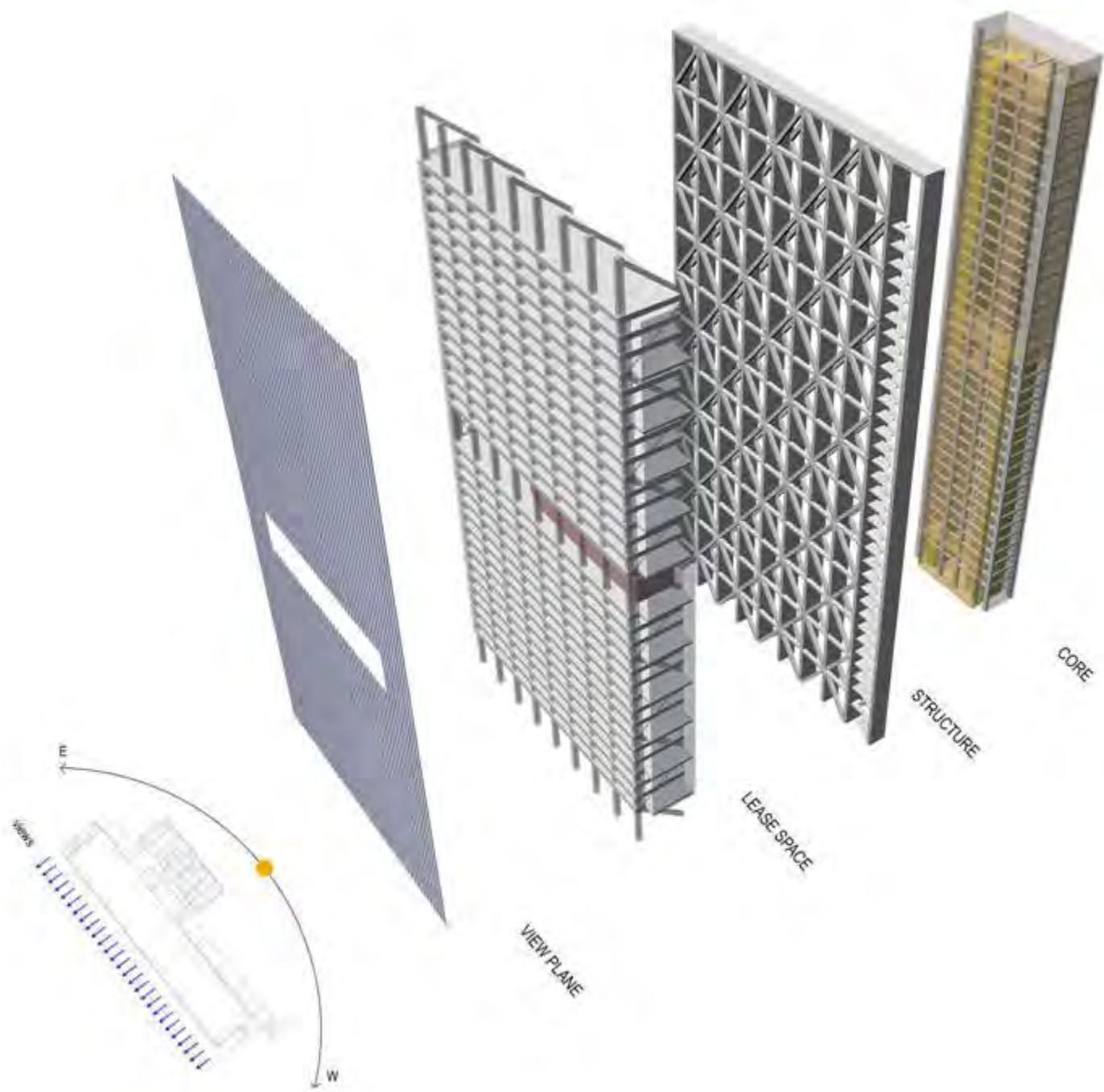






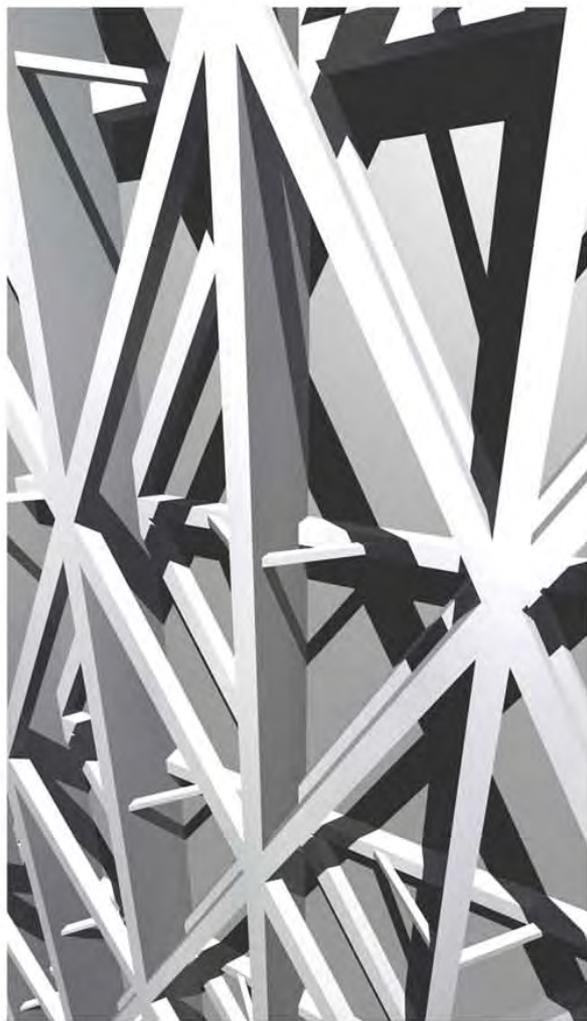








9 am



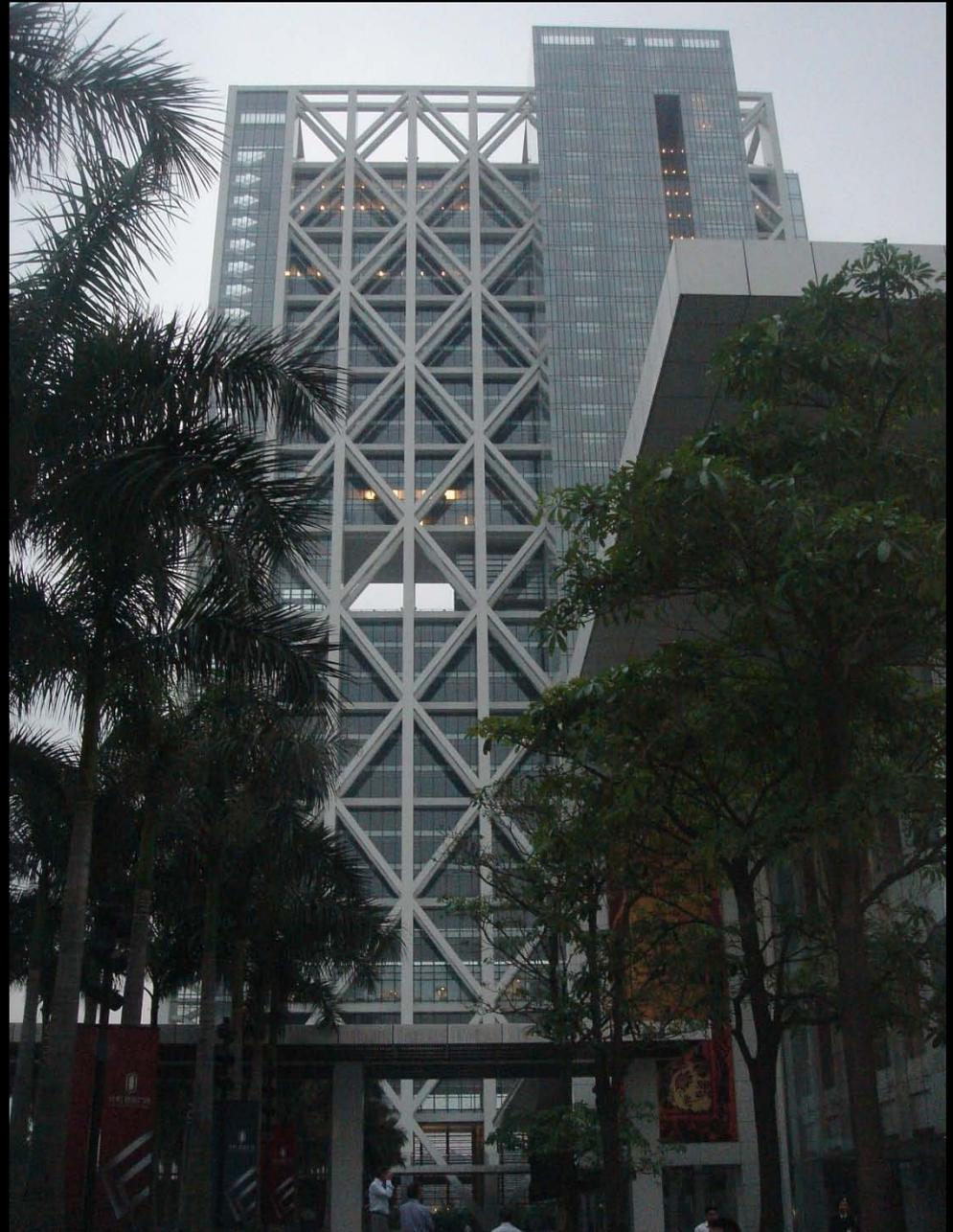
12 pm

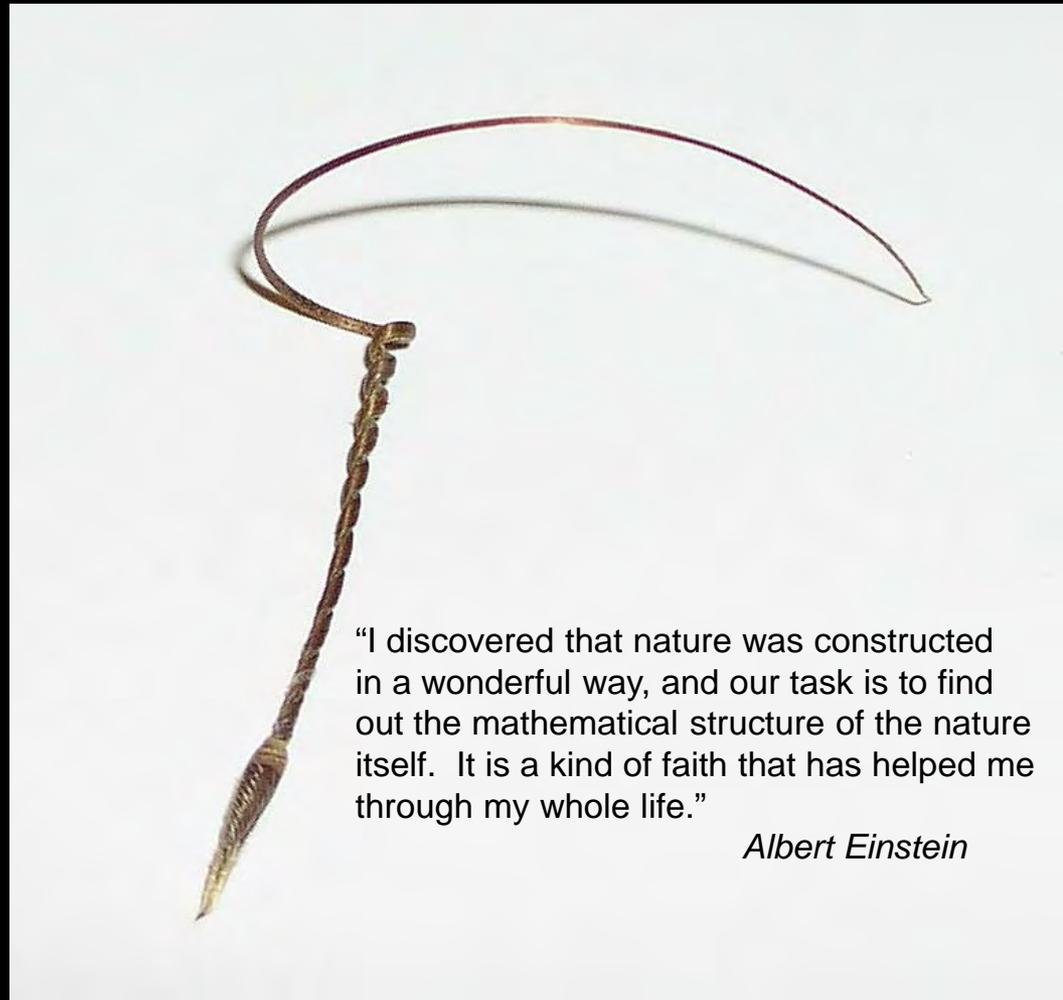


3 pm

ALIGNED DIAGONALS | Vernal Equinox ~ March 21



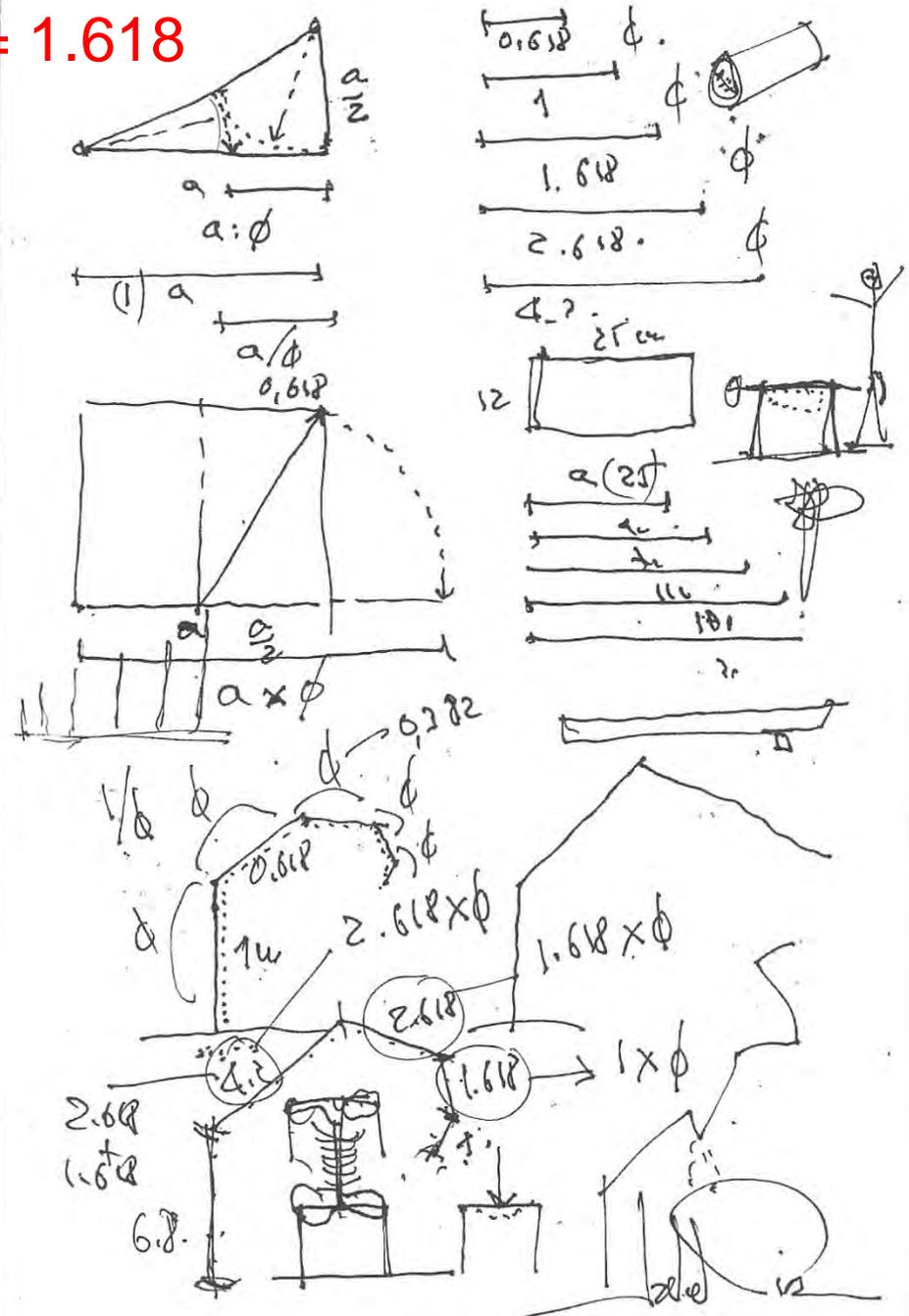
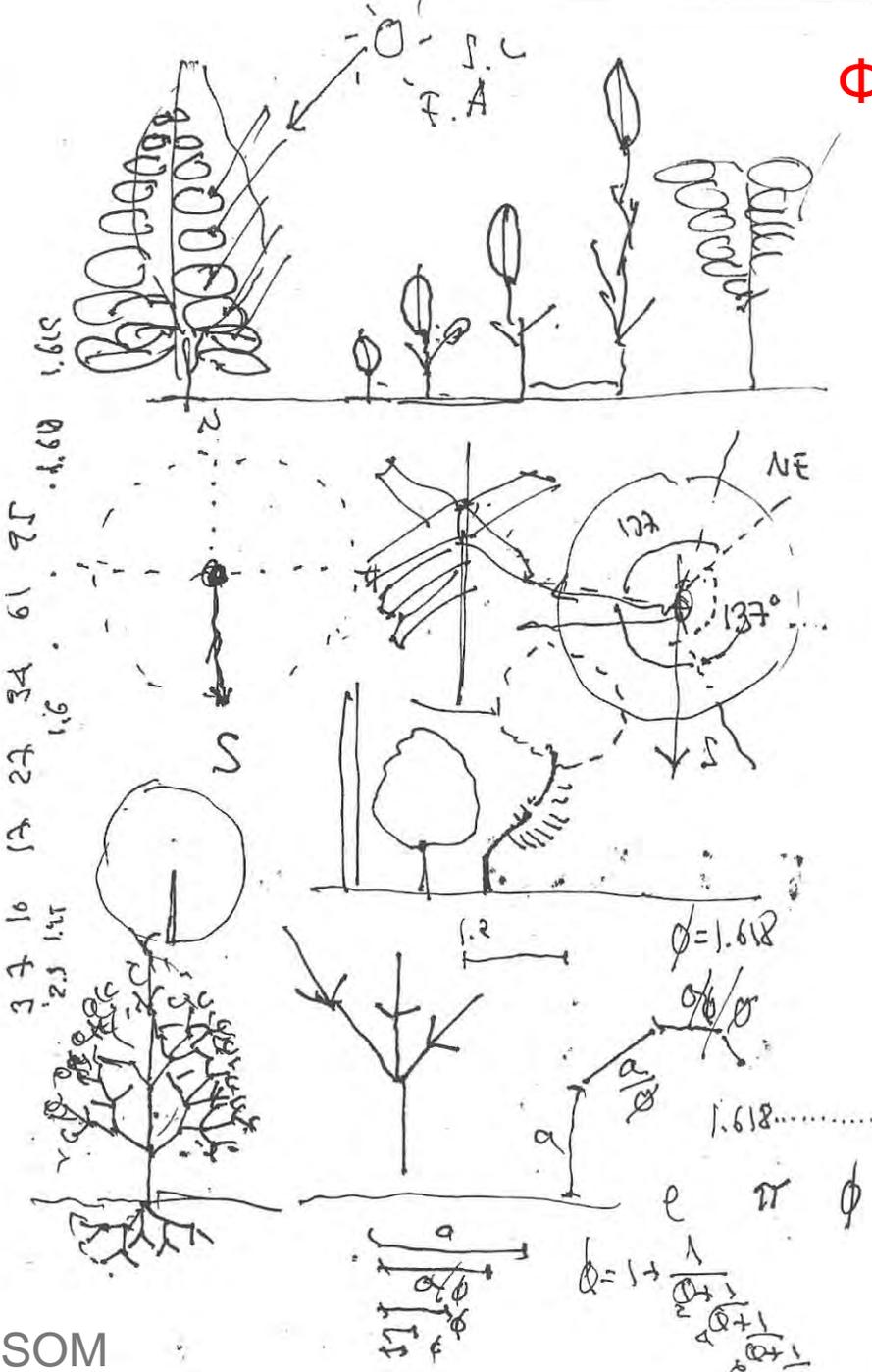




“I discovered that nature was constructed in a wonderful way, and our task is to find out the mathematical structure of the nature itself. It is a kind of faith that has helped me through my whole life.”

*Albert Einstein*

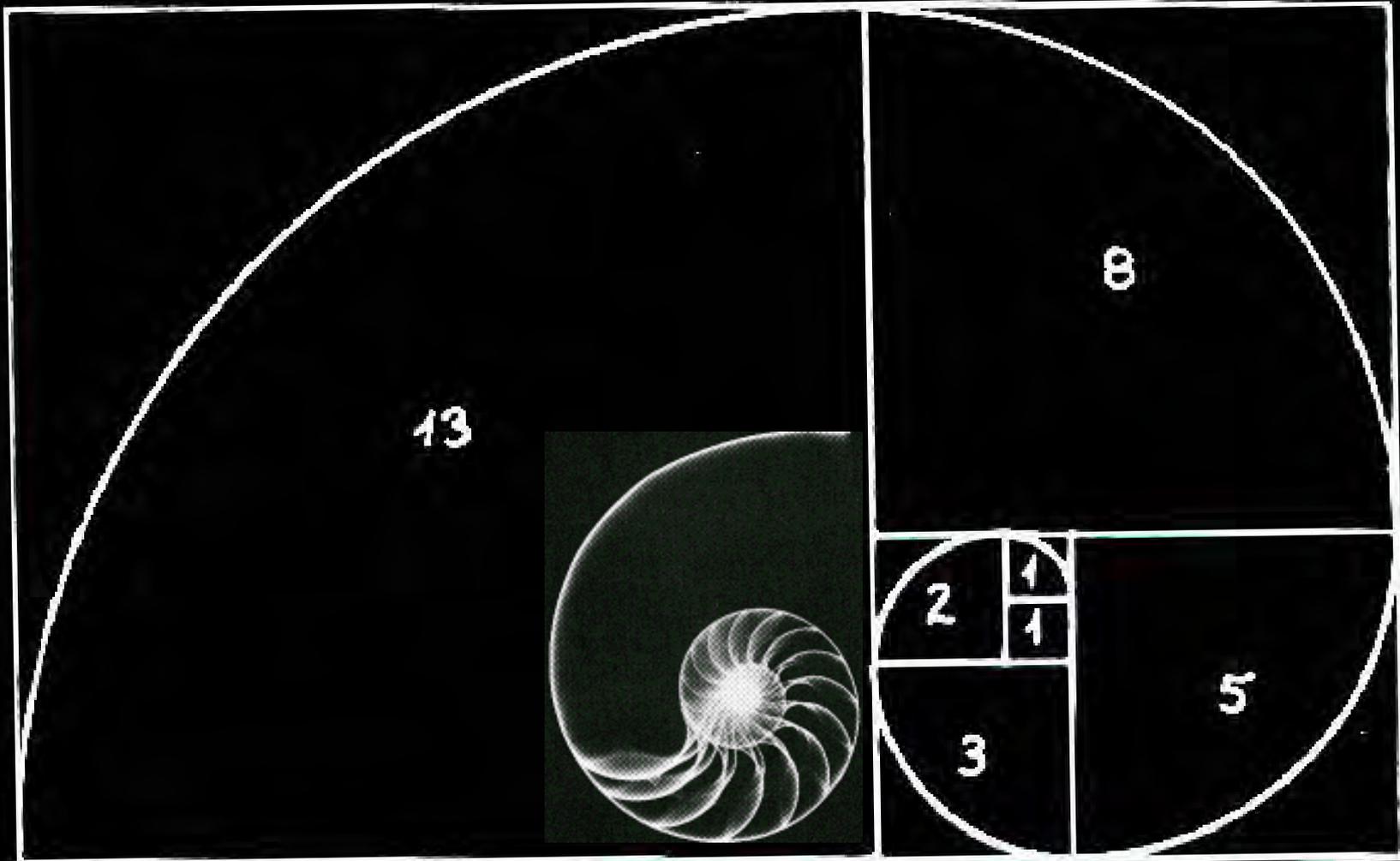
$\Phi = 1.618$



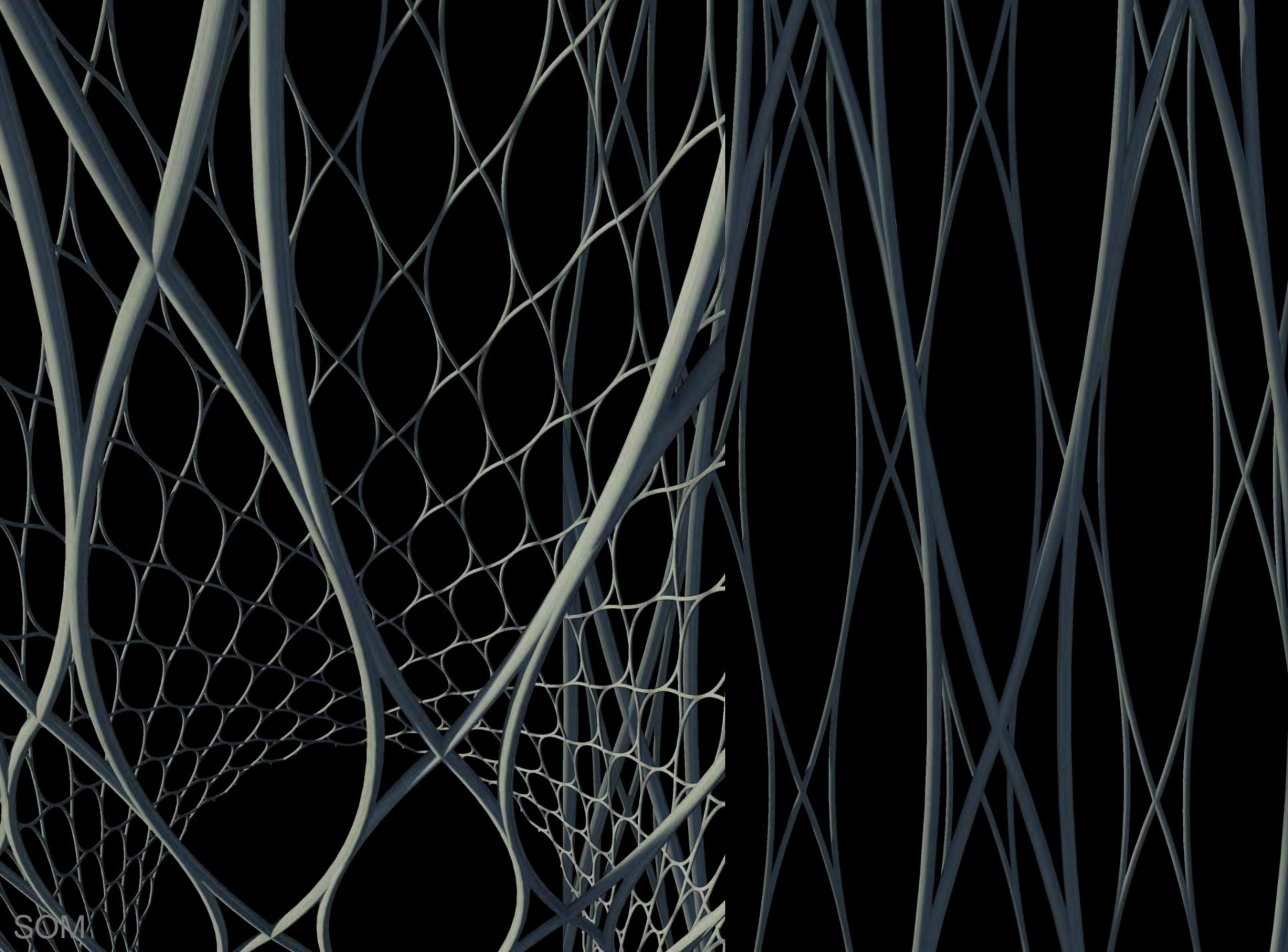
$$\Phi = 1.618$$

1.0

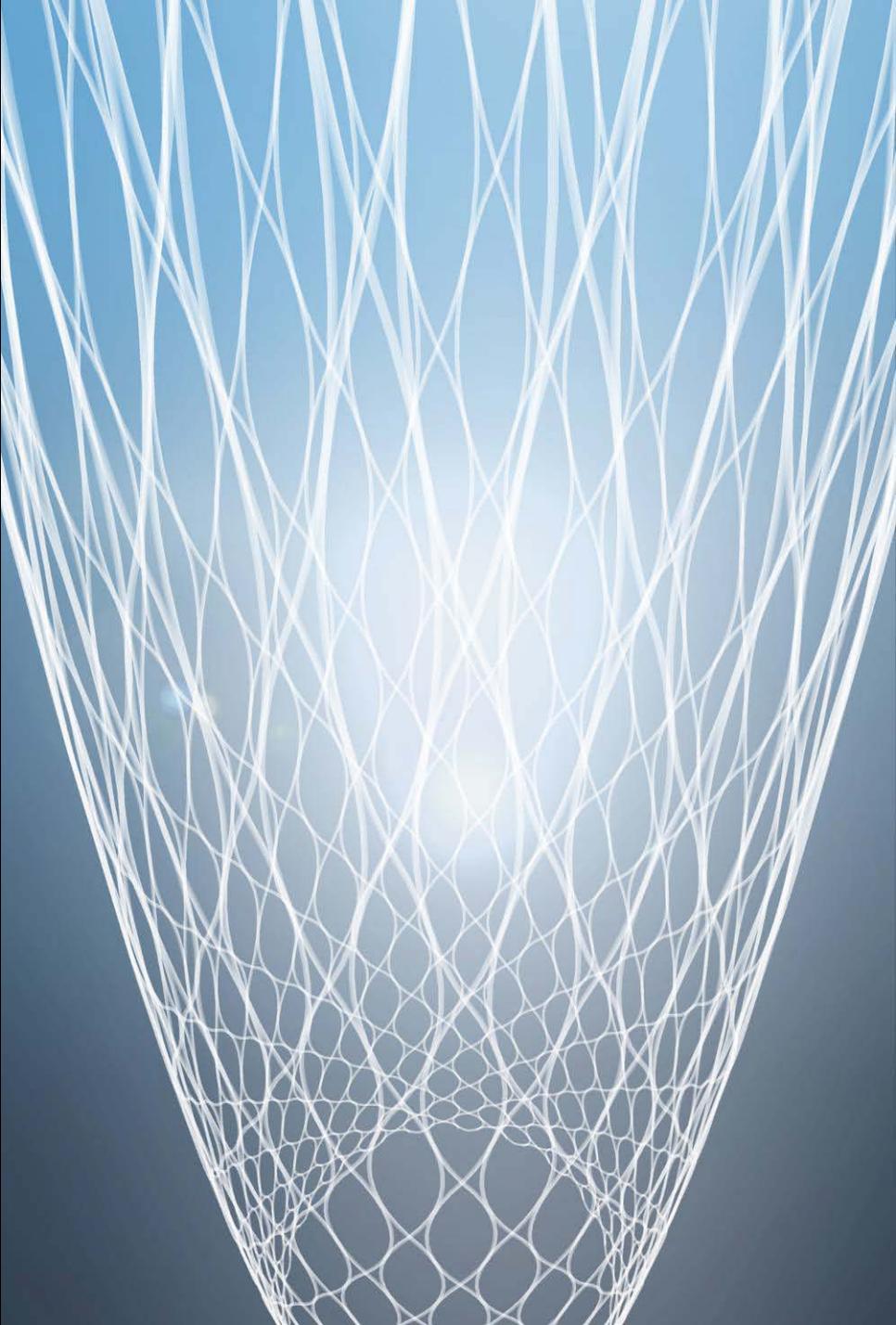
$$1/\Phi = 0.618$$



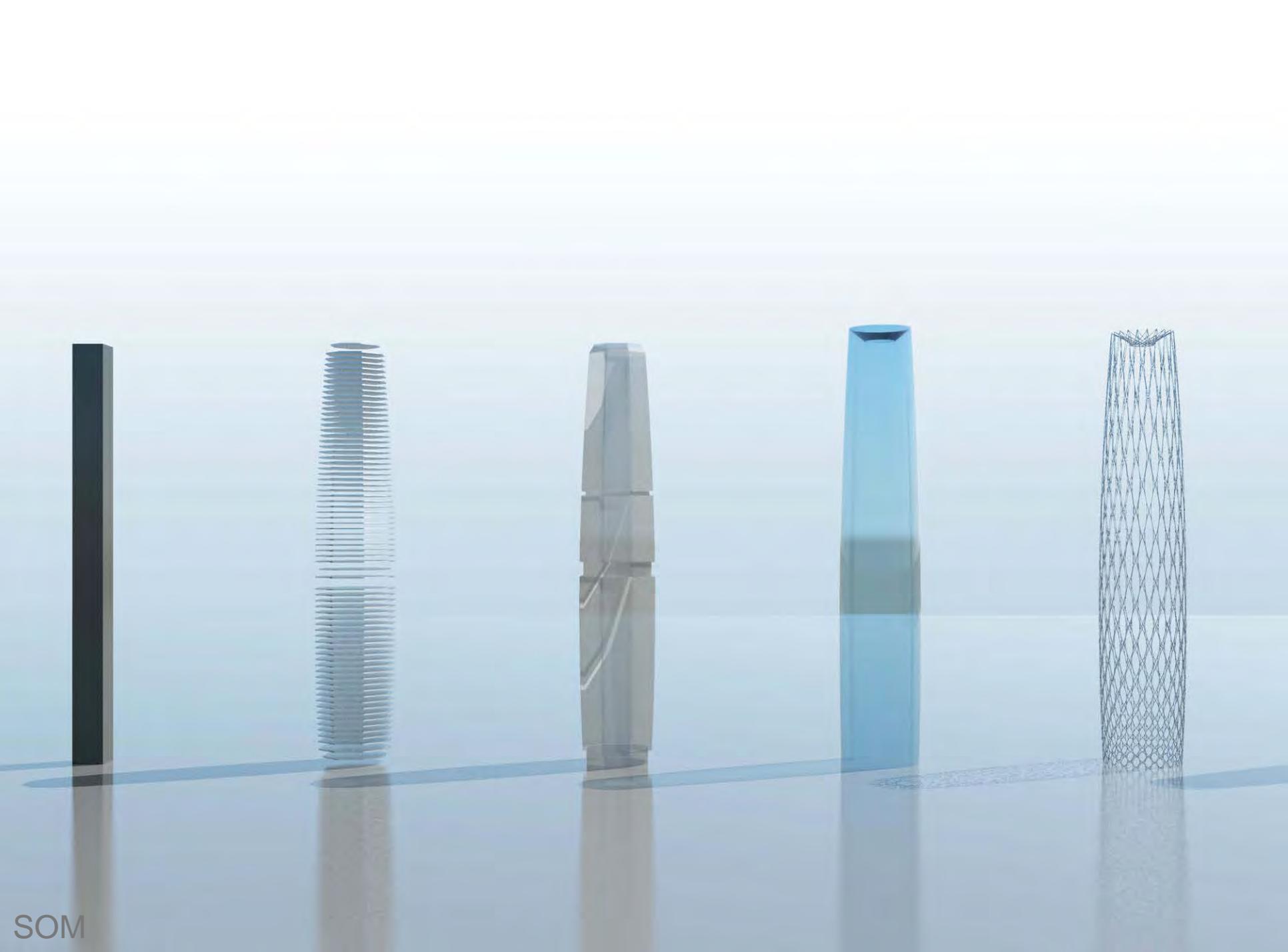


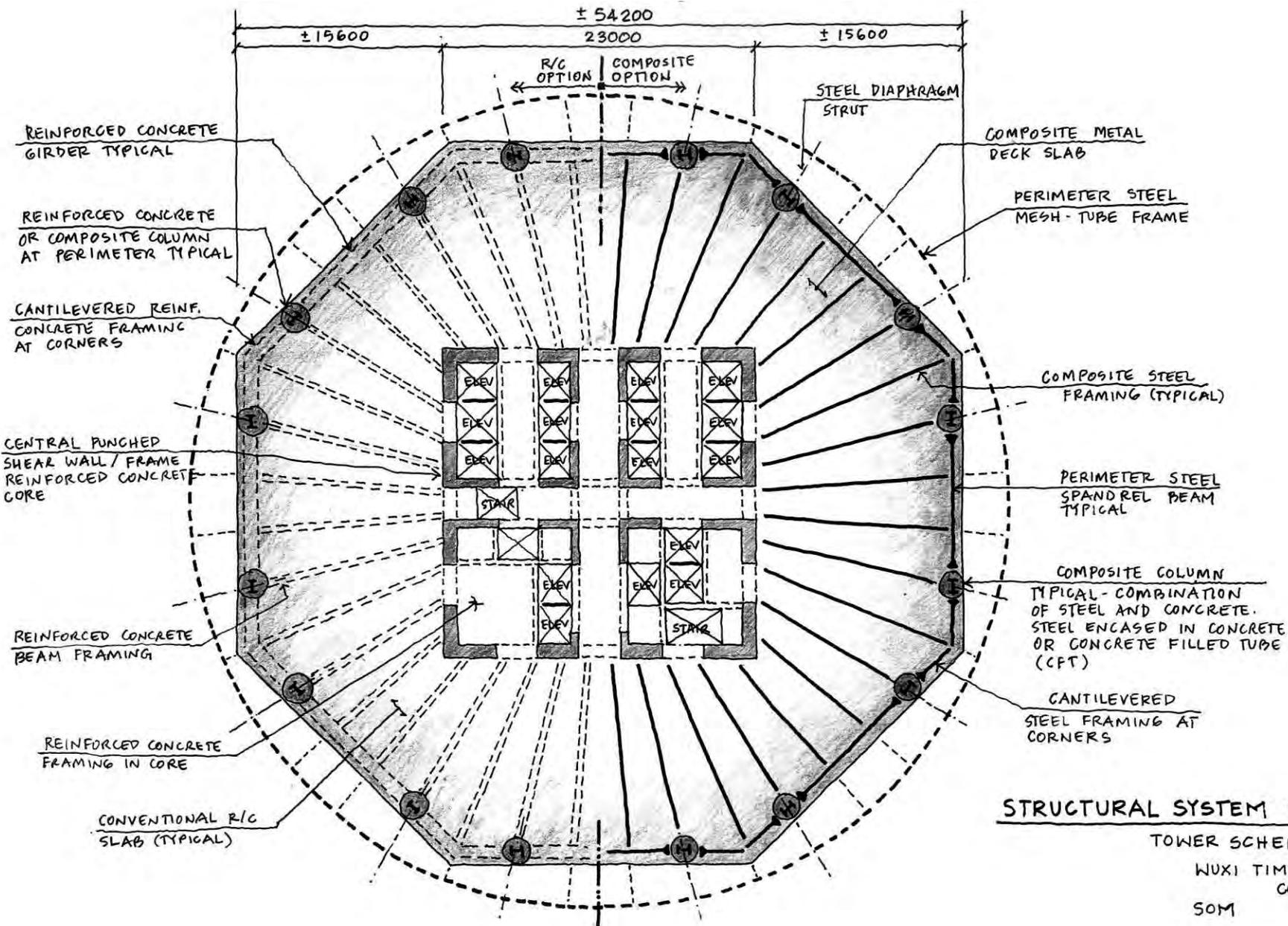


SOM



SOM

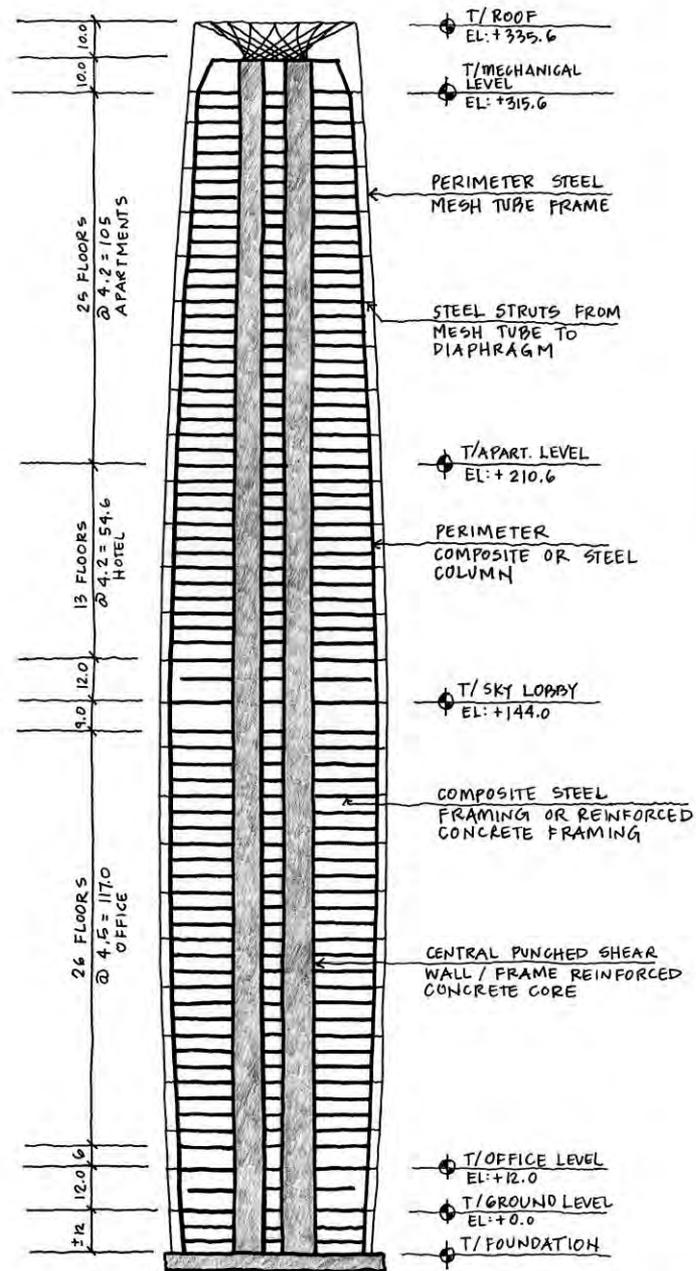




**STRUCTURAL SYSTEM PLAN**

TOWER SCHEME A

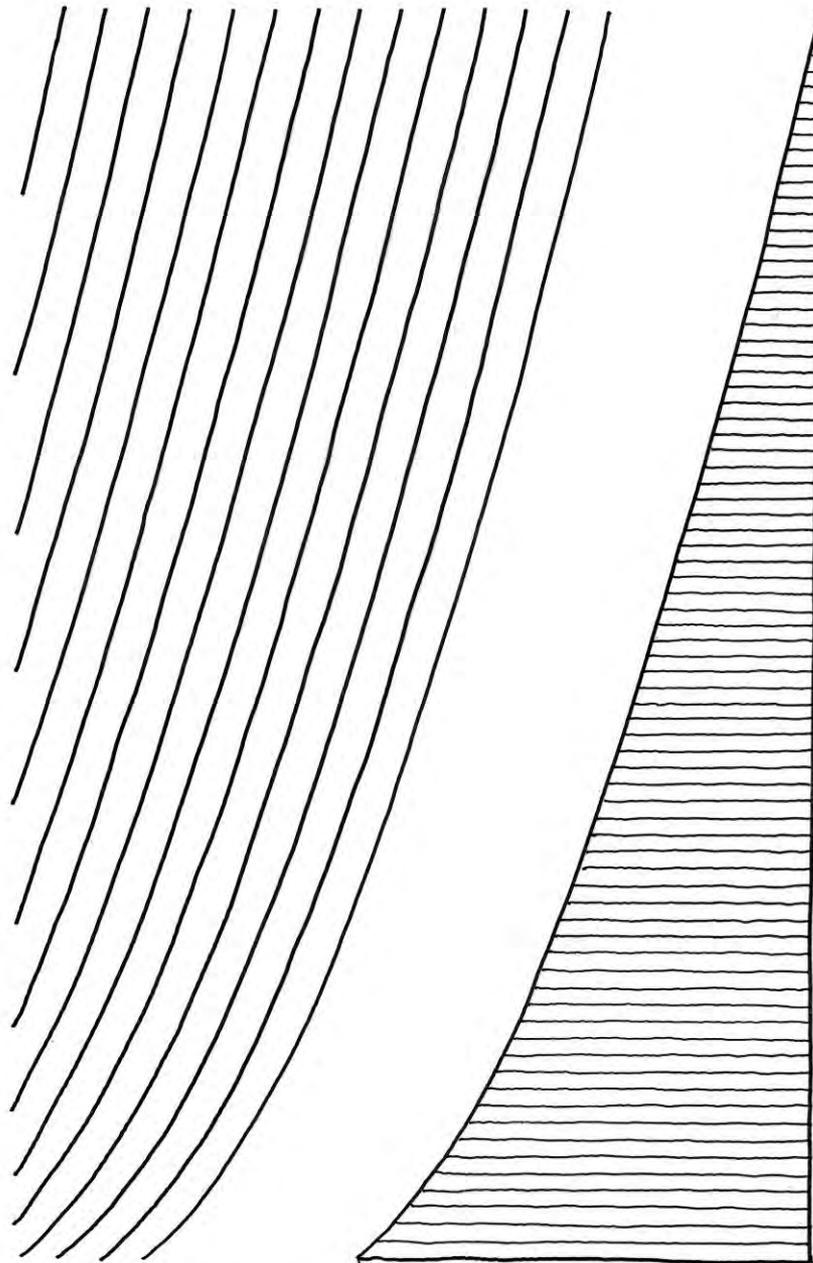
WUXI TIMES SQUARE  
 CONCEPT DESIGN  
 SOM      26 FEB 07



**STRUCTURAL SYSTEM ELEVATION**

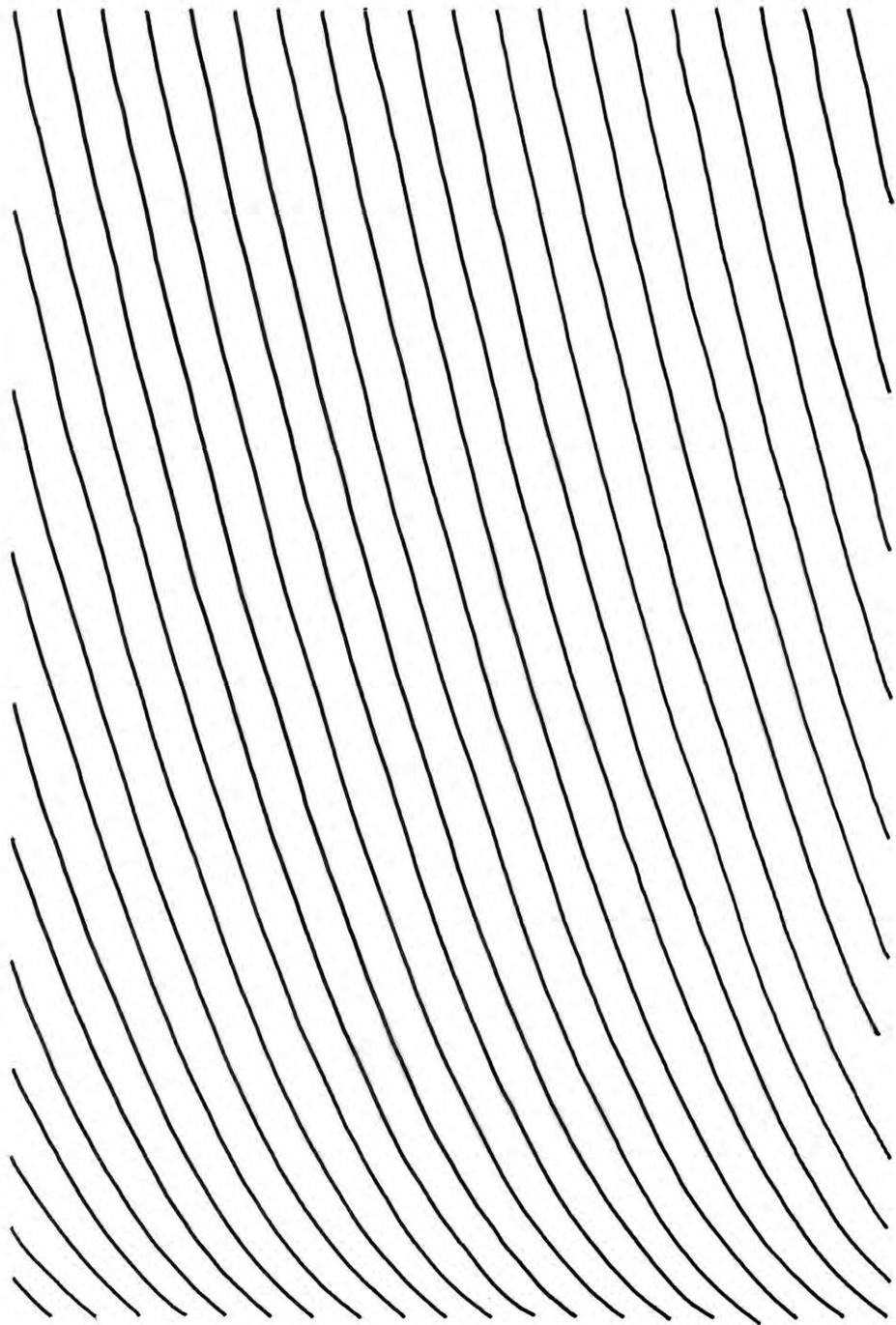
TOWER SCHEME A

WUXI TIMES SQUARE  
CONCEPT DESIGN  
SOM 26 FEB 07

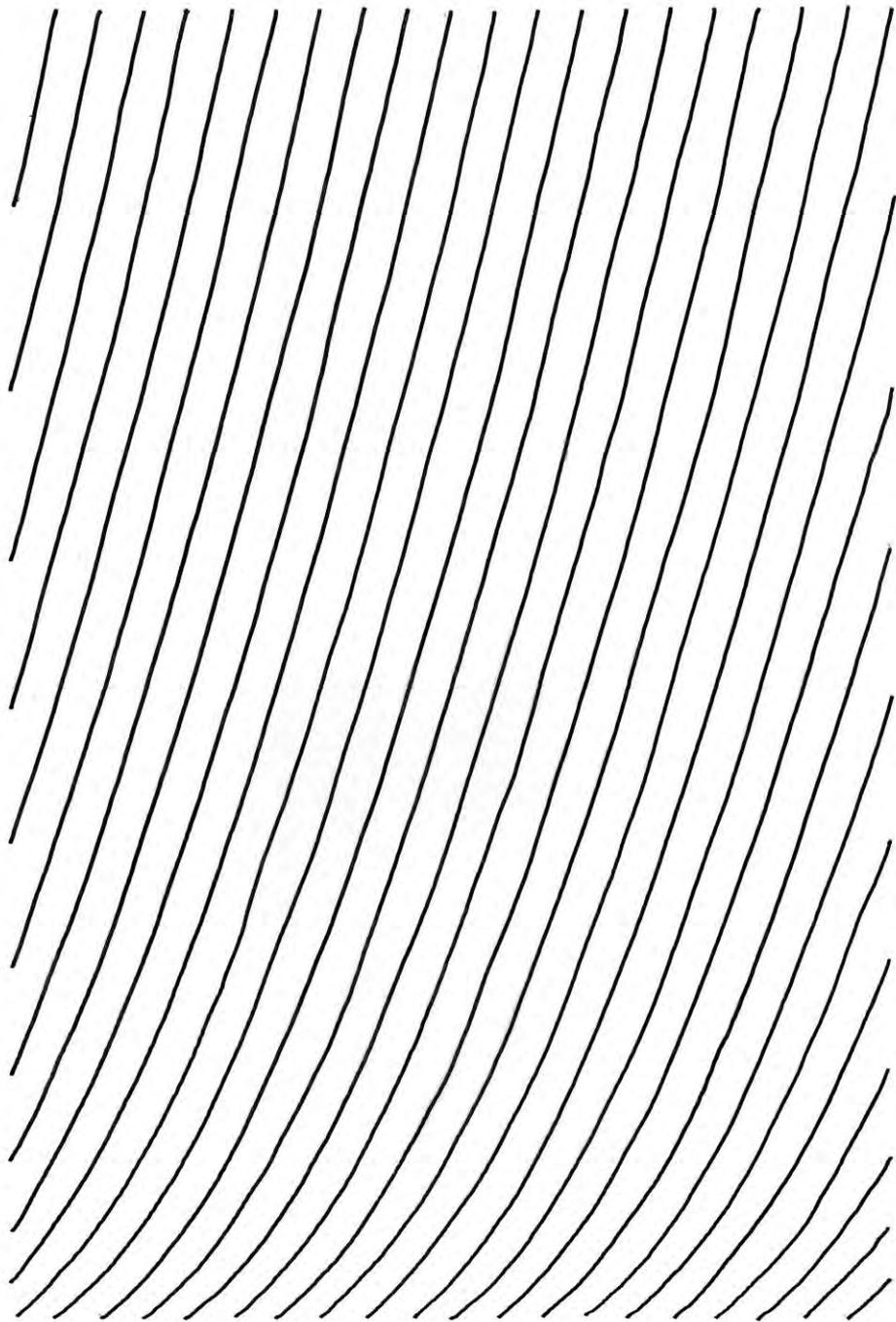


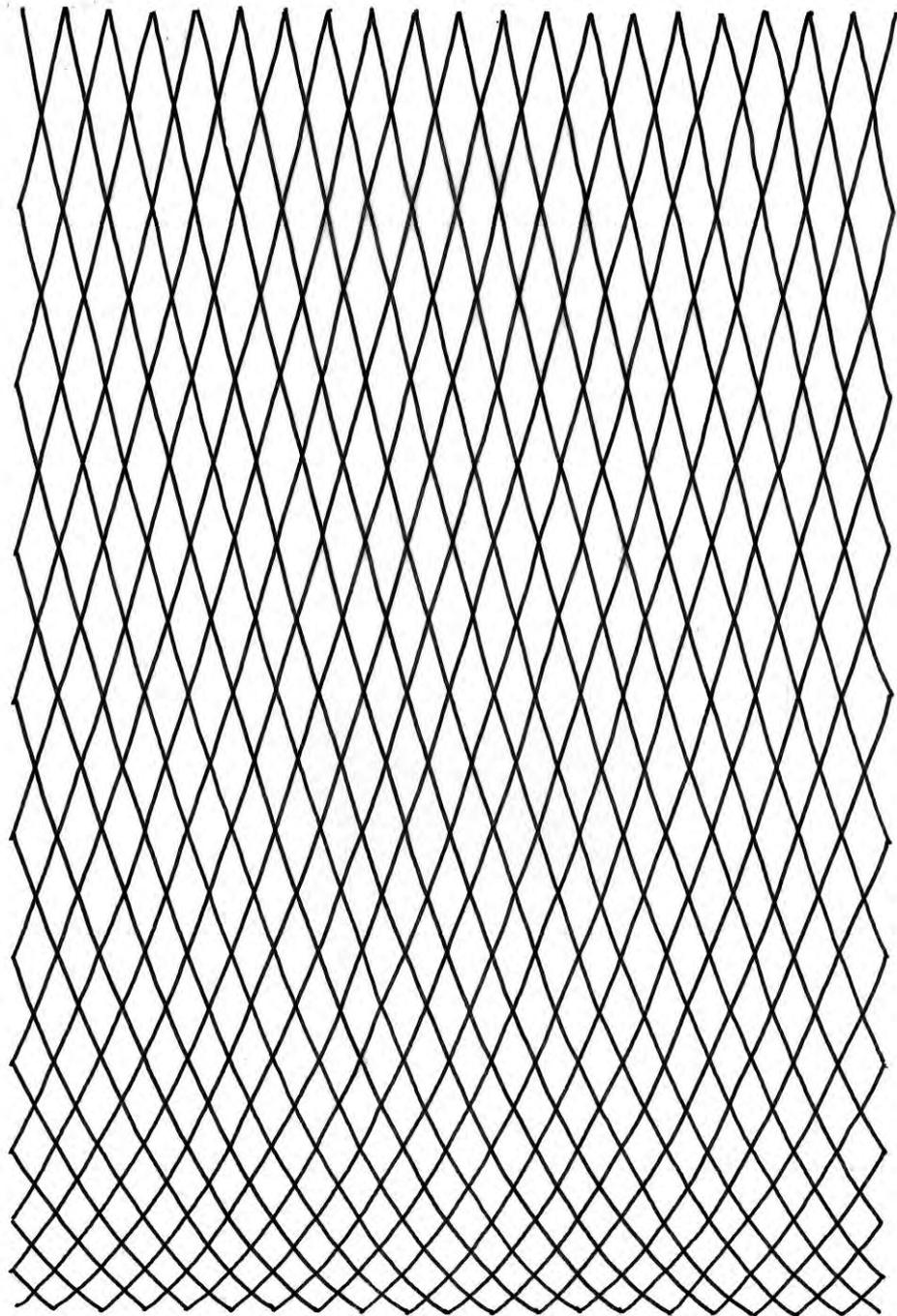
BRACING GEOMETRY

BENDING MOMENT DEMAND  
CANTILEVER SUBJECTED TO  
LATERAL LOAD



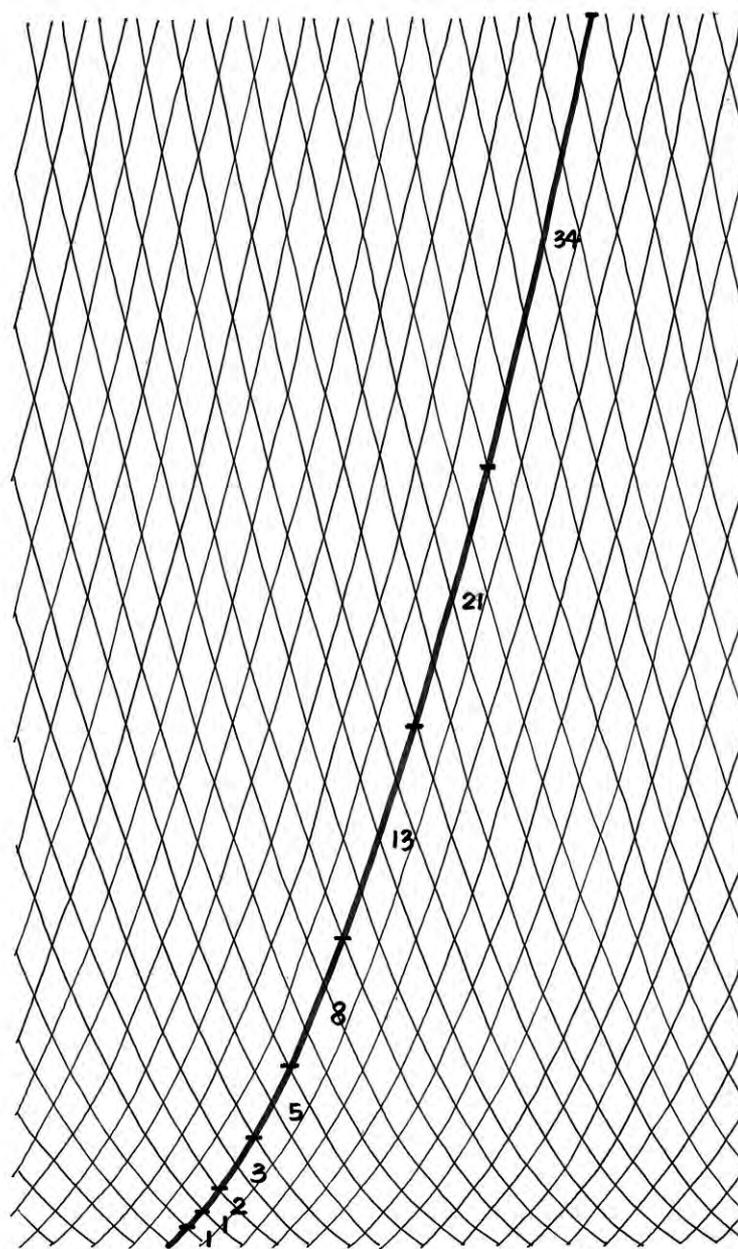
SOM





SOM

$$\begin{aligned}\Phi &= N_2 / N_1 \\ &= 13 / 8 \\ &= 1.6\end{aligned}$$



$$F_N = \sum_{N=3}^{\infty} F_{N-1} + F_{N-2}$$

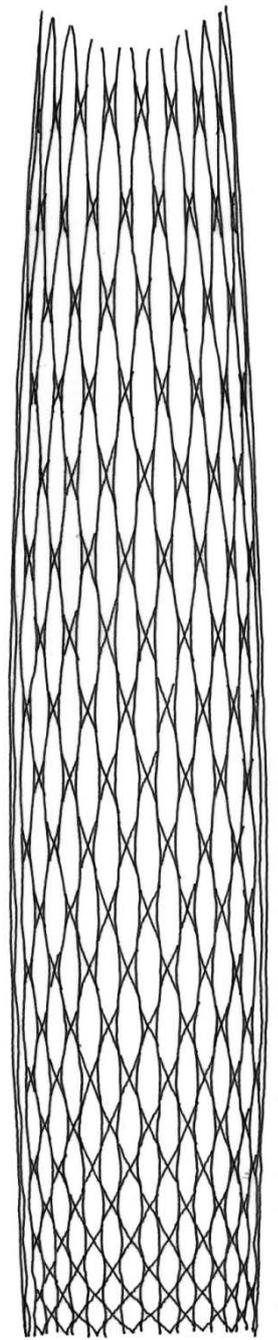
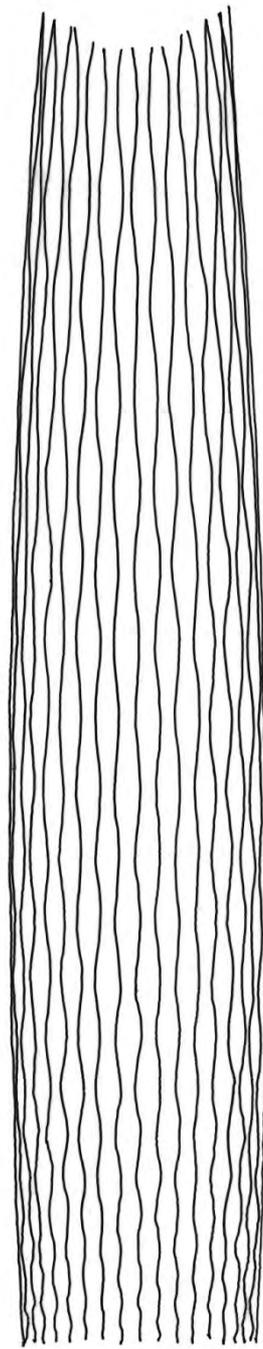
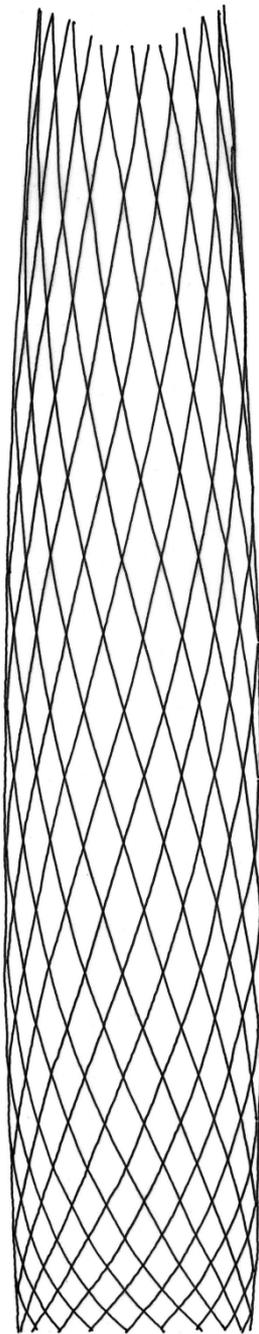
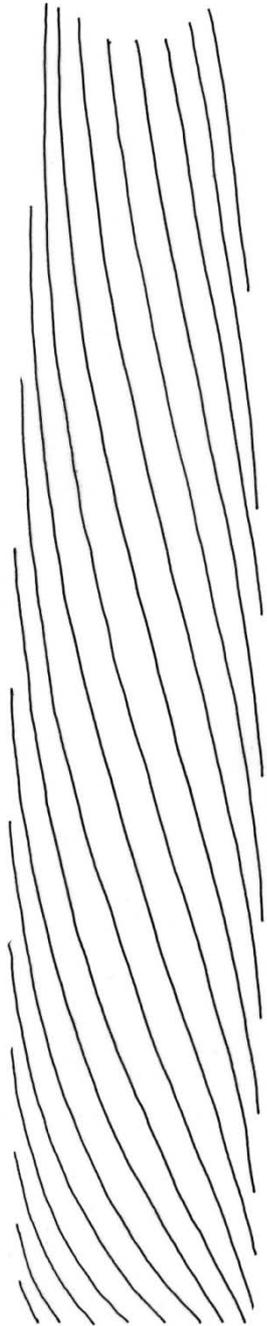
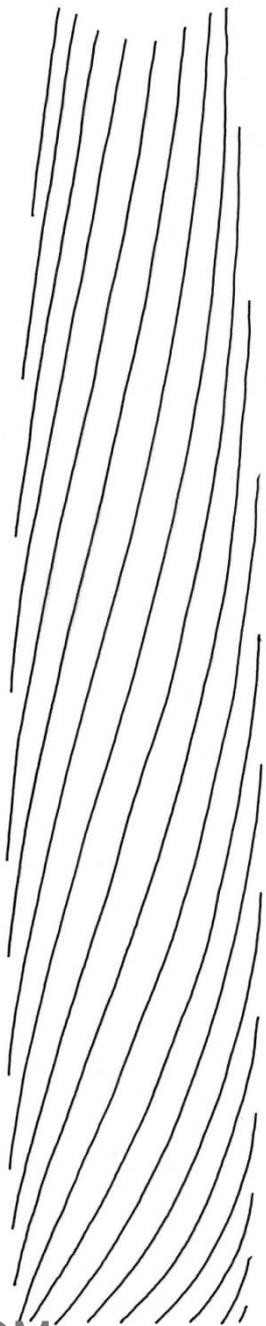
$$F_1 = 0, F_2 = 1 \text{ (binary)}$$

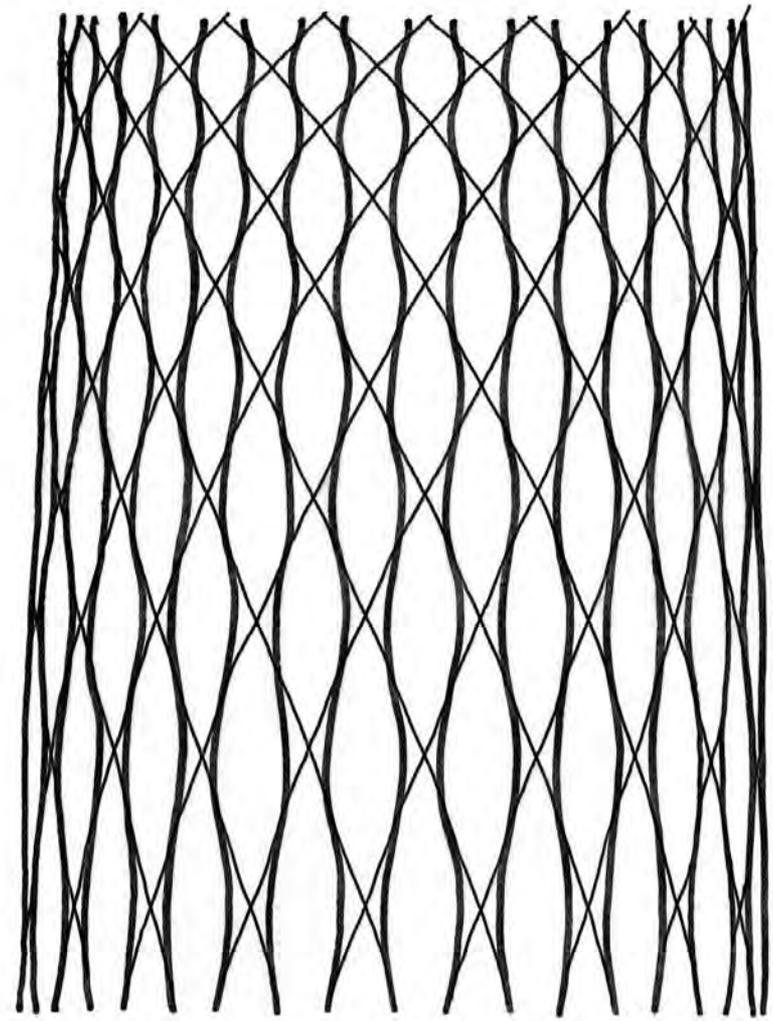
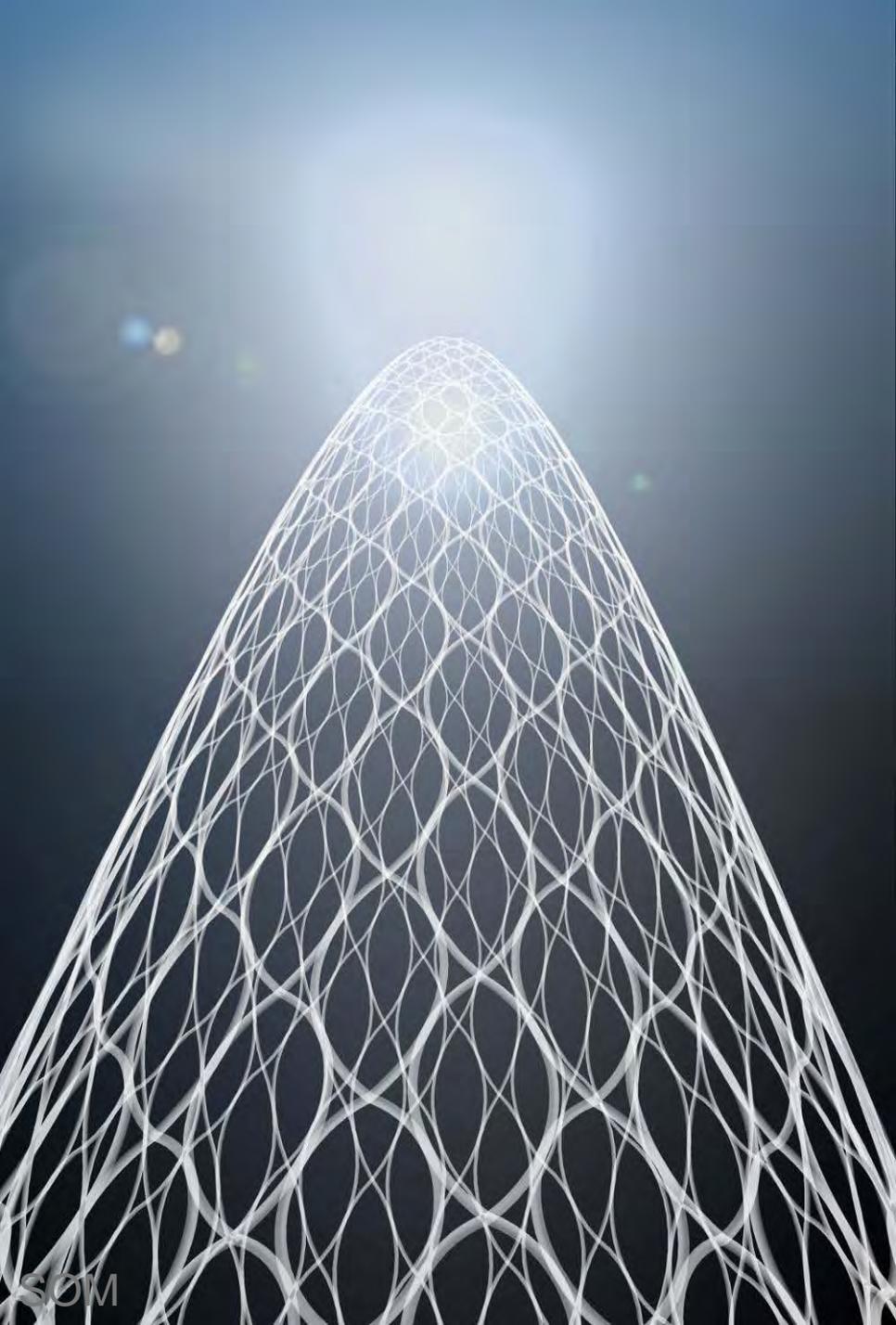
1 1 2 3 5 8 13 21 34 = 88

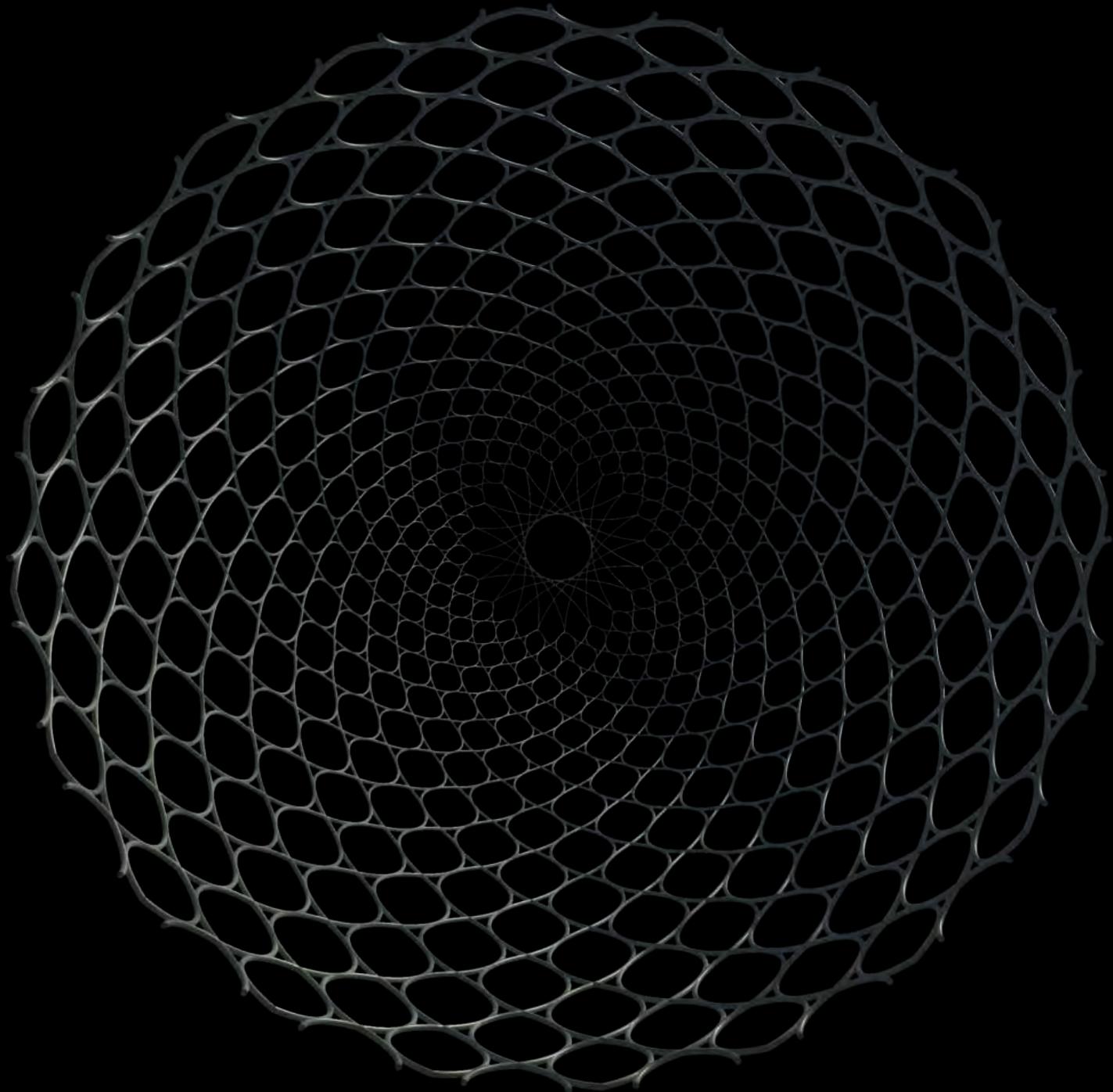
FIBONACCI SEQUENCE

55 89 144 233 377 610 987 1597 2584 4181 6765 10946  
17711 28657 46368 75025 .....

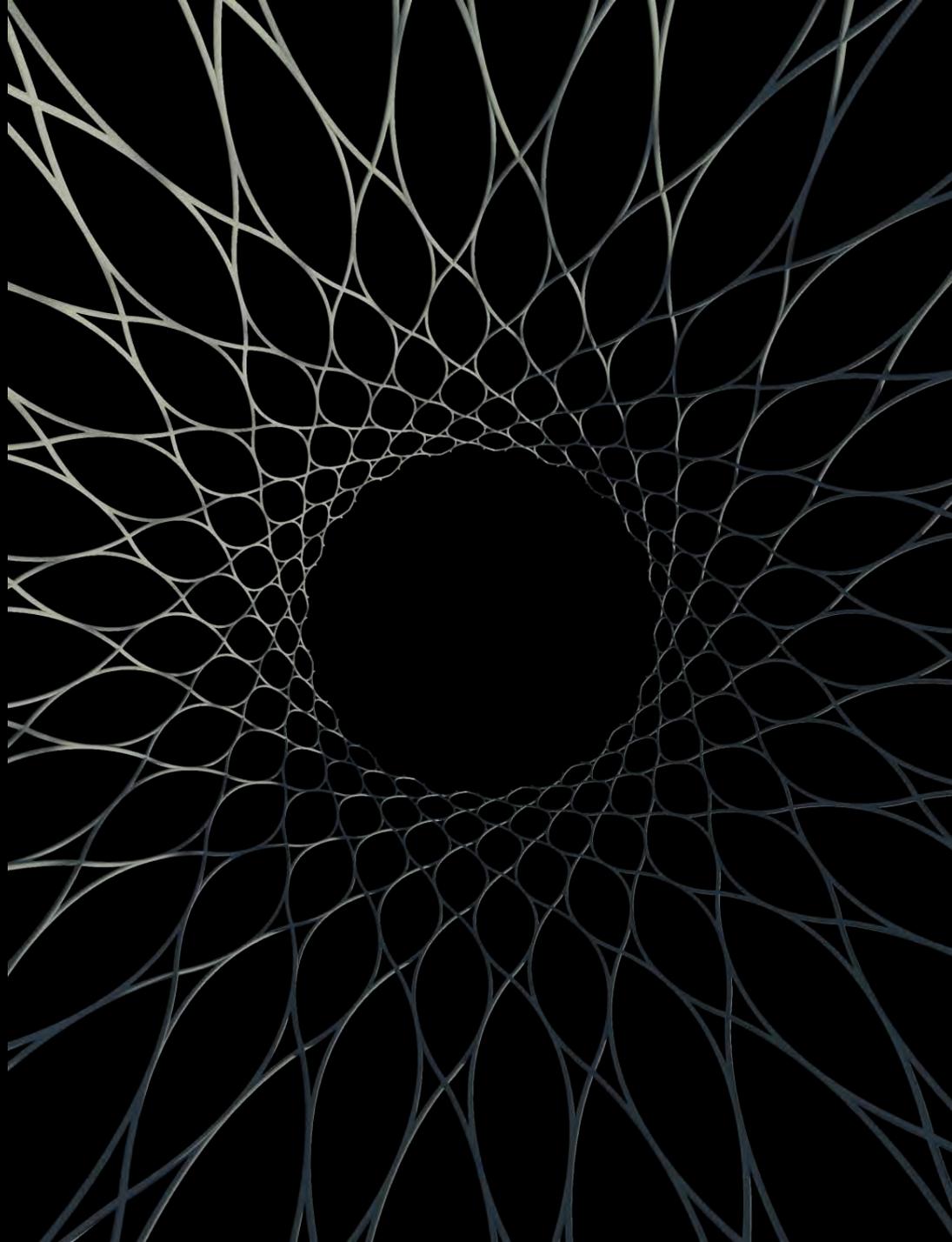
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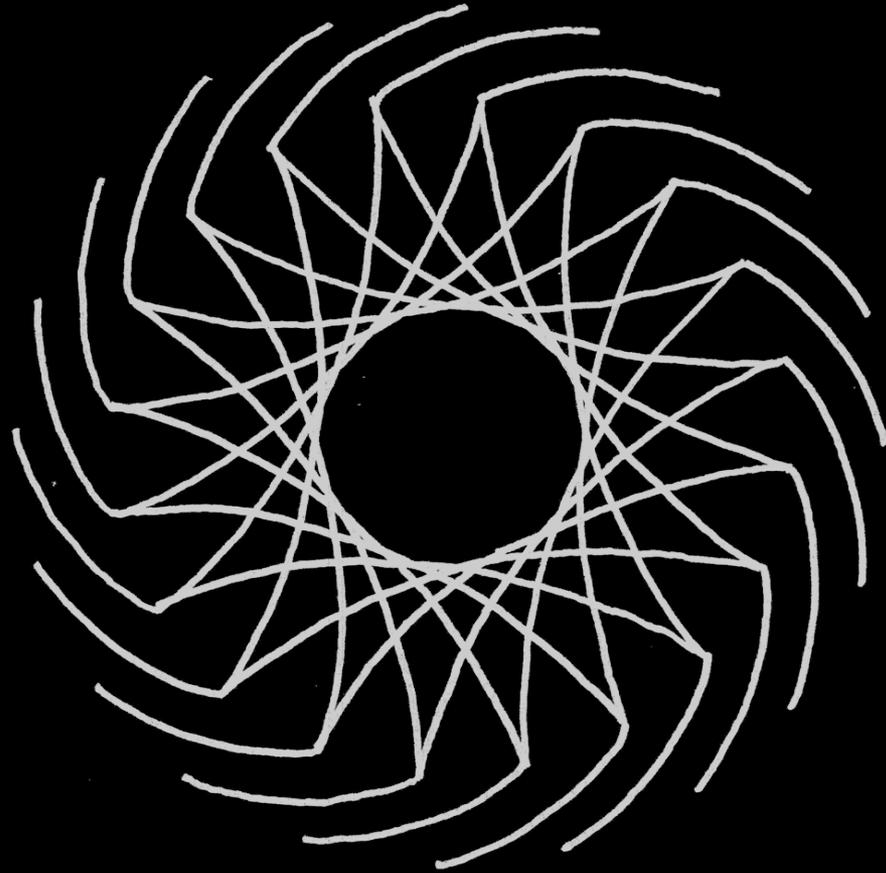


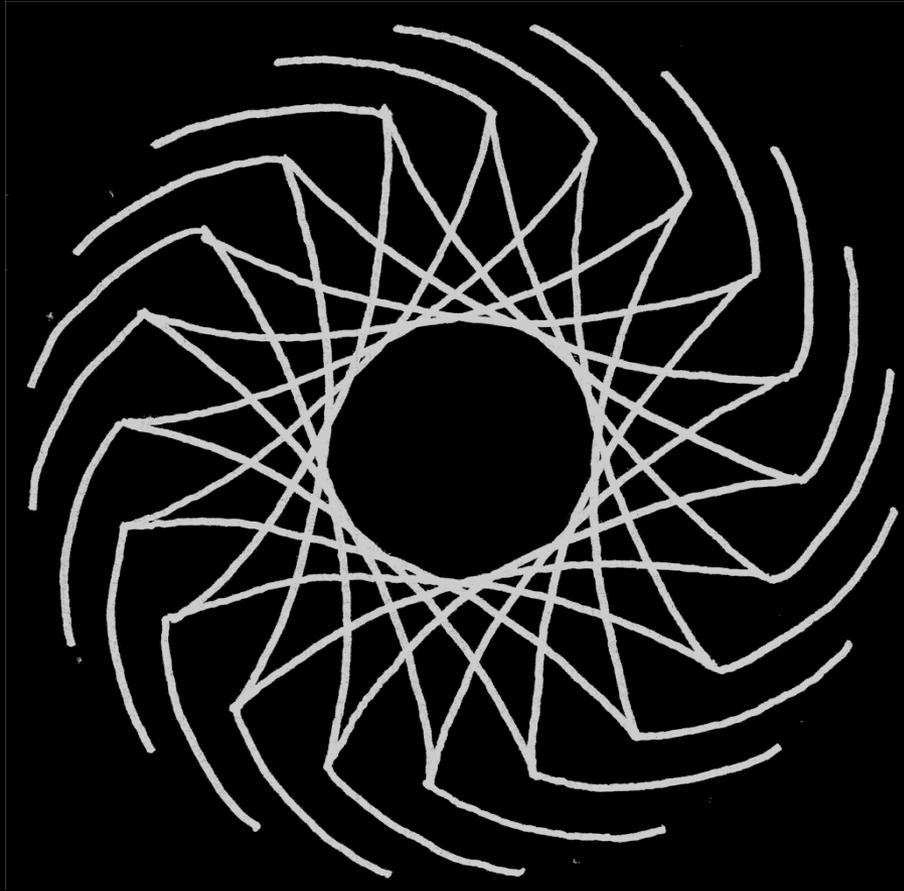


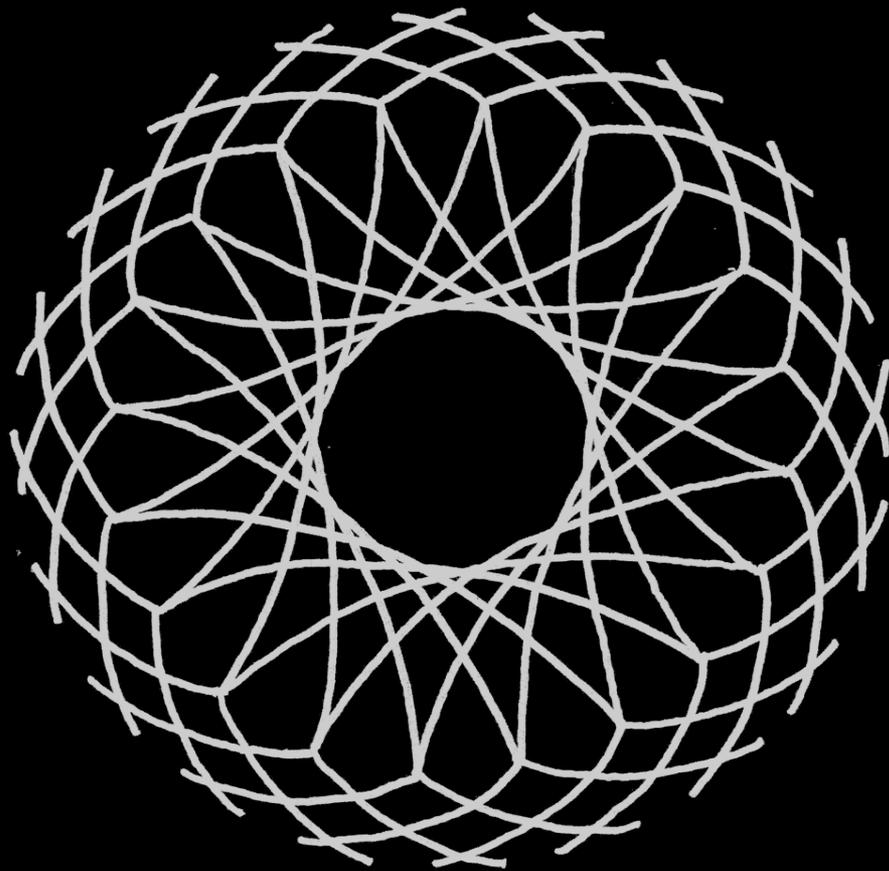


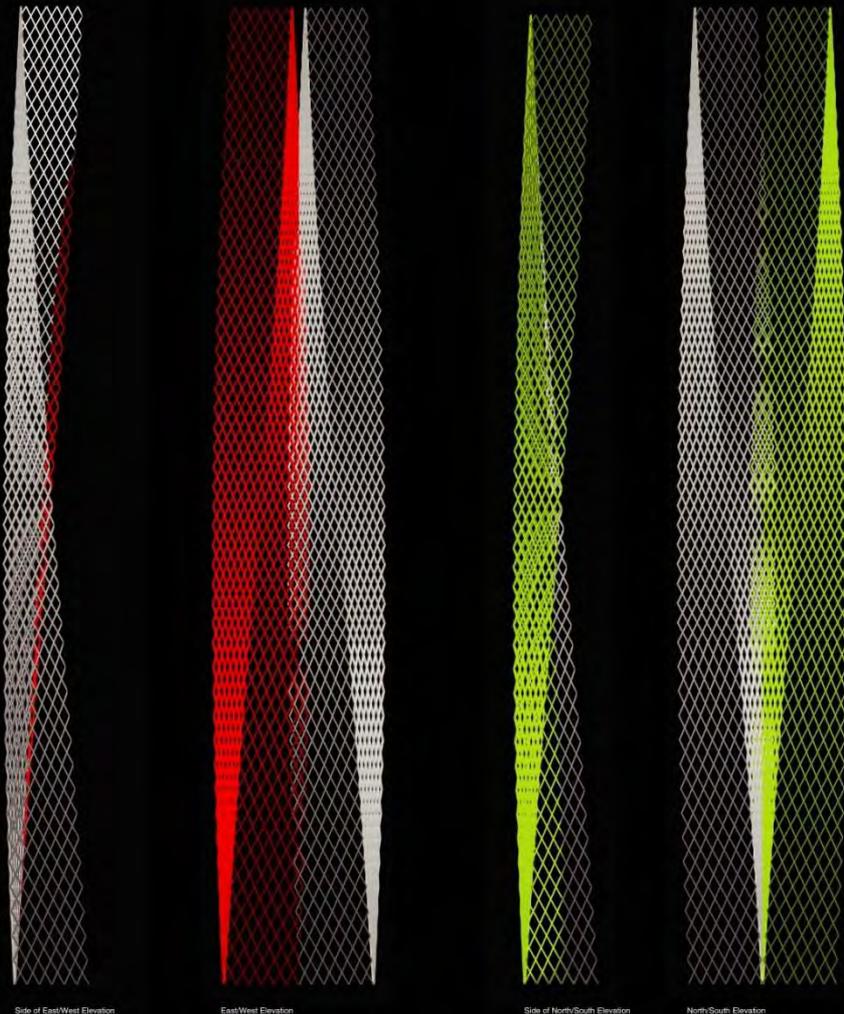
SOM











Side of East/West Elevation

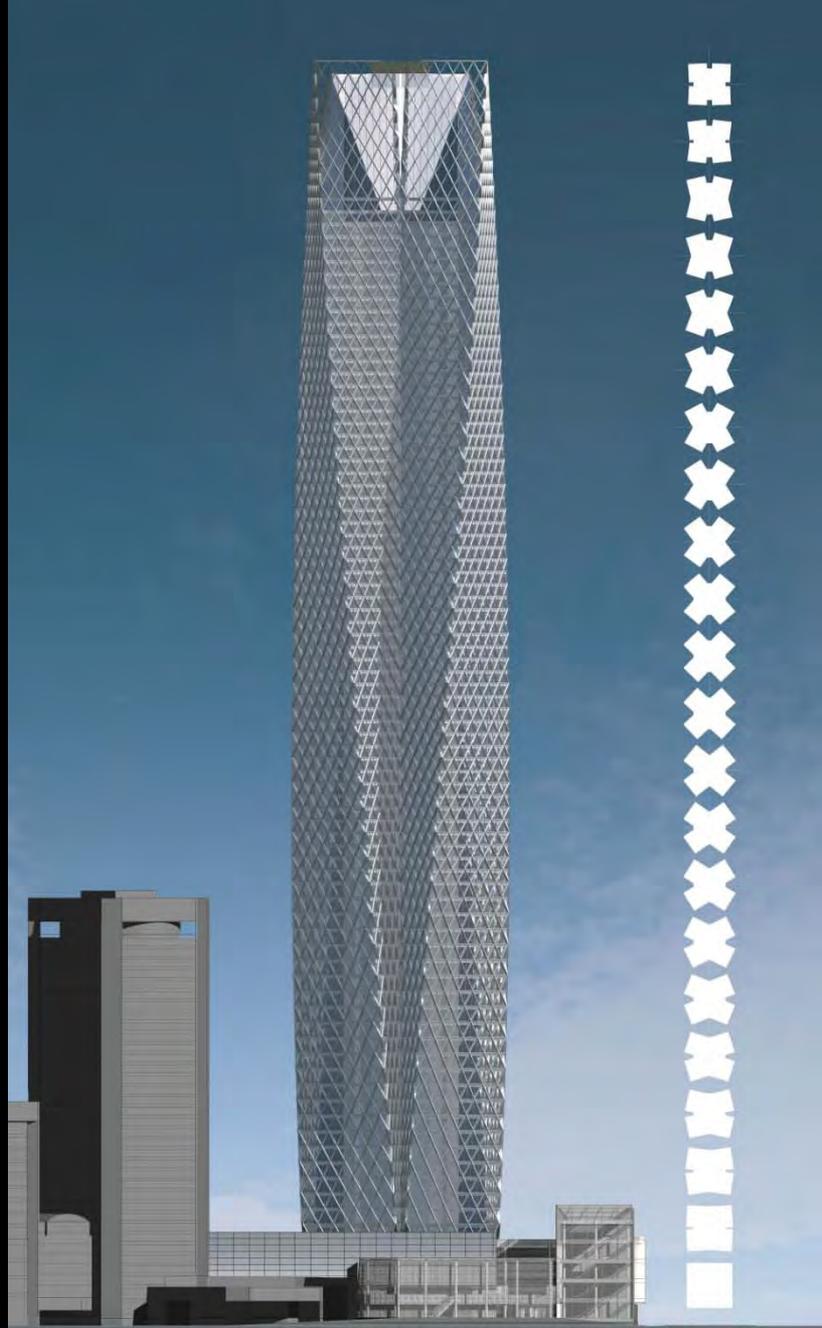
East/West Elevation

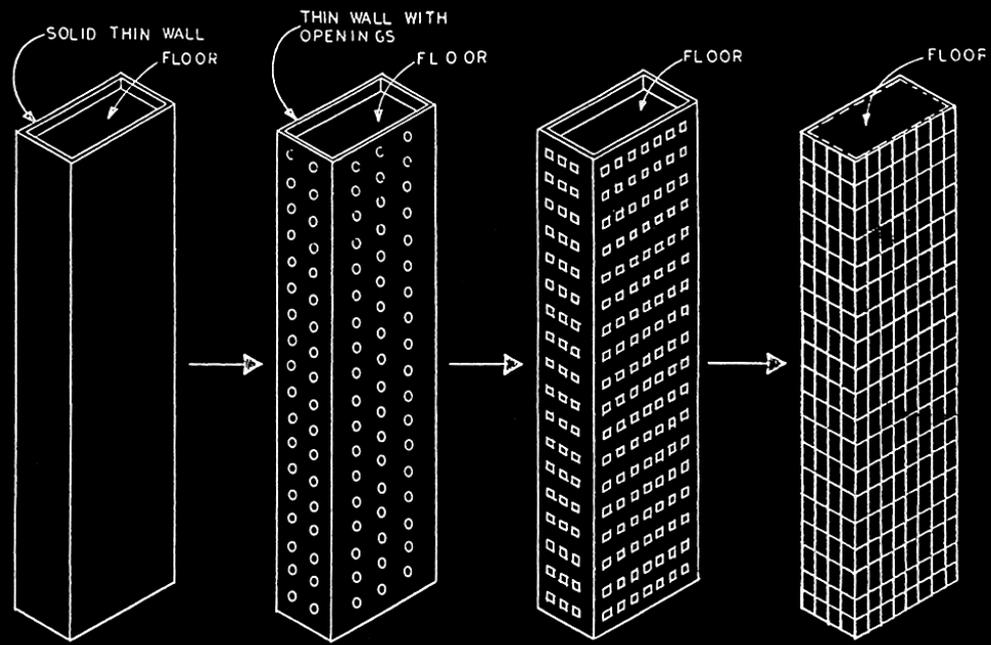
Side of North/South Elevation

North/South Elevation

$$\frac{\Delta_{CS}}{\Delta_T} = 0.99$$

(Essentially 100% Efficient)



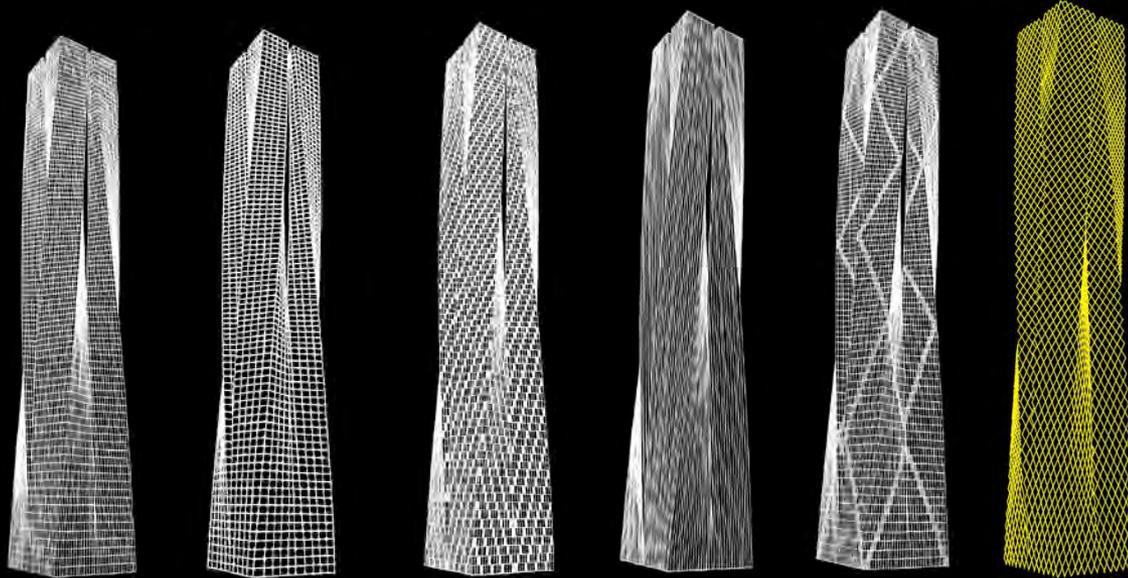


HOLLOW TUBE WITH  
SOLID WALL

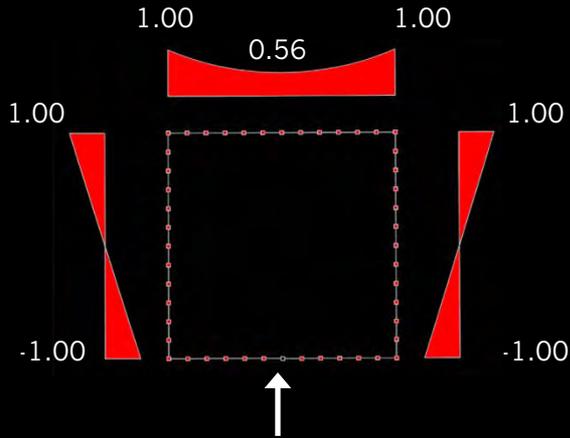
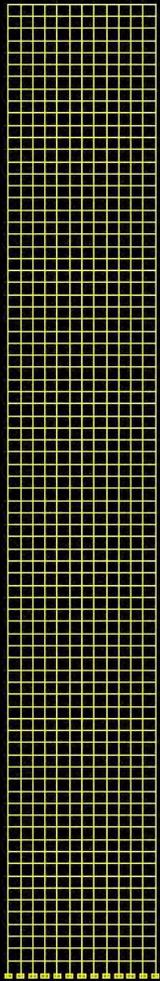
HOLLOW TUBE WITH  
PUNCHED HOLES

HOLLOW TUBE WITH  
REGULAR HOLES FOR  
WINDOWS

FRAMED TUBE WITH  
CLOSELY SPACED  
PERIMETER COLUMNS



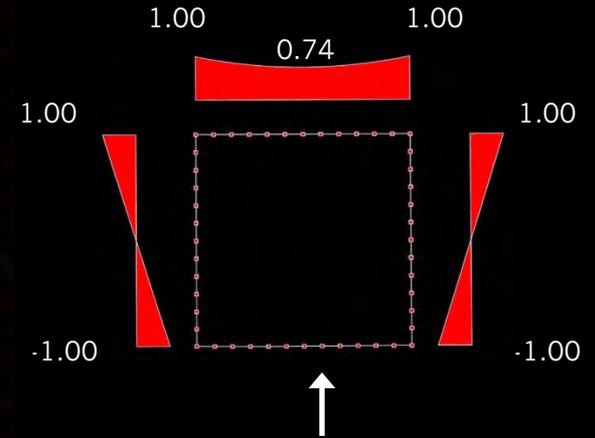
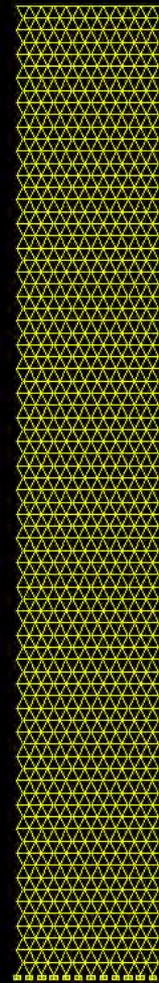
## 常规的框架筒 Conventional Tube Frame



Axial Load Due to Wind

$$\frac{\Delta_{CS}}{\Delta_T} = 0.62 \quad (62\% \text{ Efficient})$$

## 网状斜杆框架筒 Diagonal Mesh-Tube Frame



Axial Load Due to Wind

$$\frac{\Delta_{CS}}{\Delta_T} = 0.99 \quad (\text{Essentially } 100\% \text{ Efficient})$$

筒型作用比较研究  
Parametric Study of Tubular Behavior

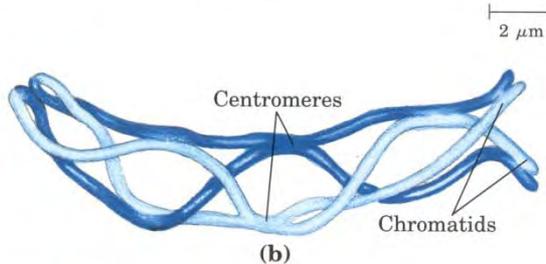
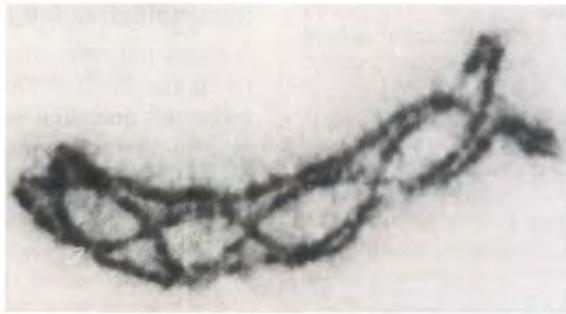








Integration of Form & Structure



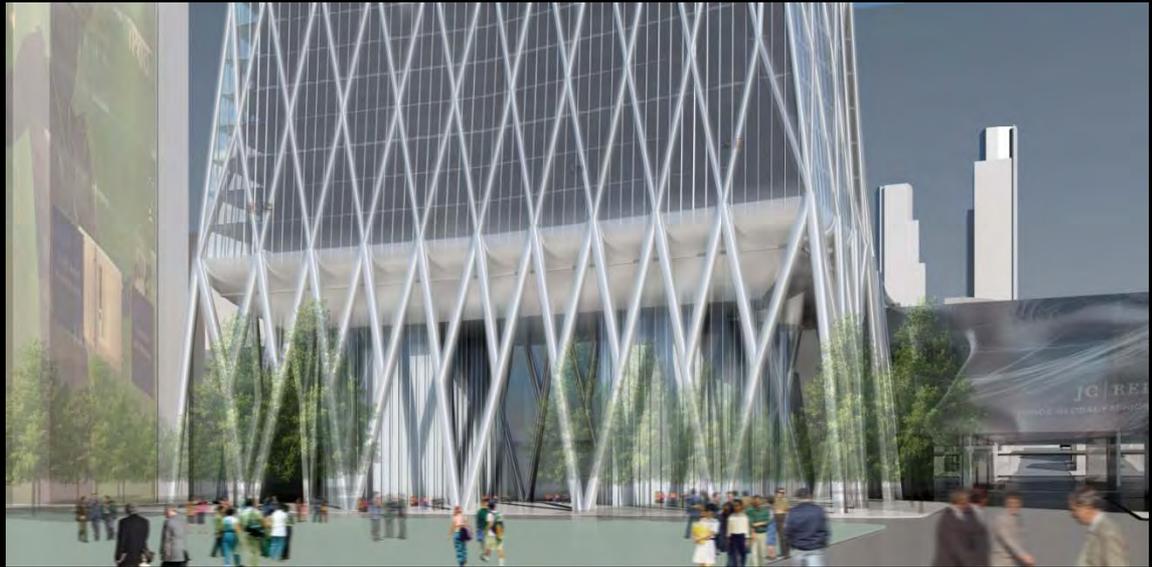
**figure 25–28**

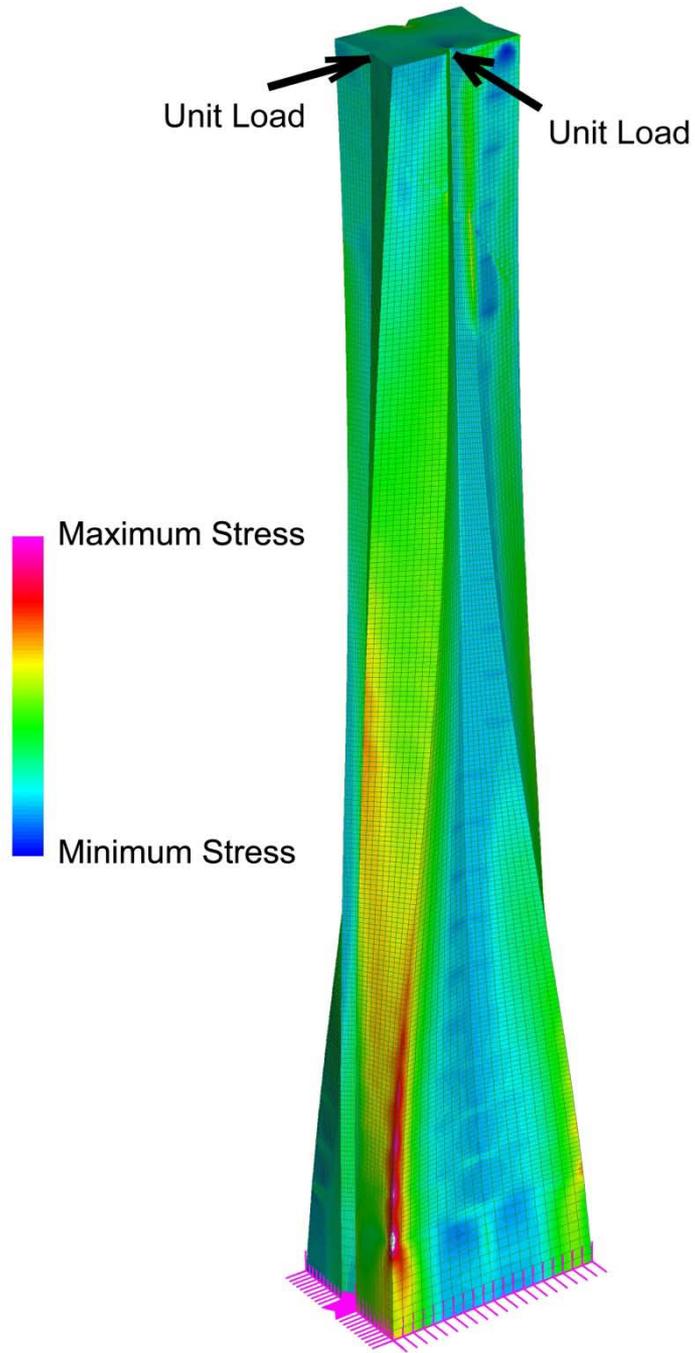
**Crossing over.** (a) Crossing over often produces an exchange of genetic material. (b) The homologous chromosomes of a grasshopper are shown during prophase I of meiosis. Multiple points of joining (chiasmata) are evident between the two homologous pairs of chromatids. These chiasmata are the physical manifestation of prior homologous recombination (crossing over) events.

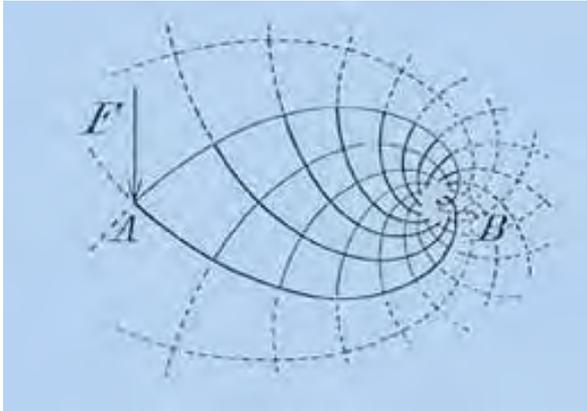
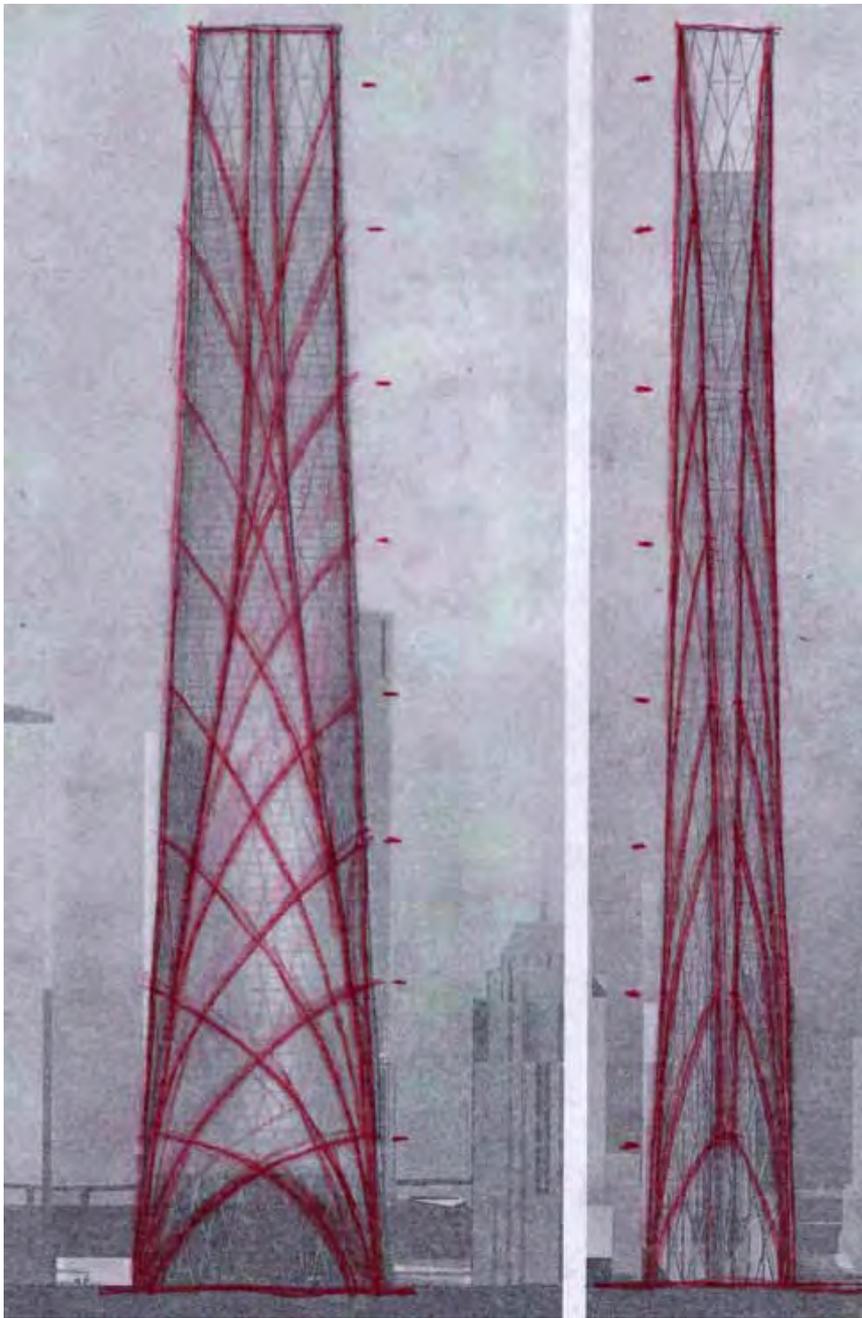


“One of our strongest human instincts is to try to stand up against what Rudolf Otto called the ‘numinous’ – the unknown and compelling – but also frightening – mysteries of the created and creative forces of the universe. To resist their energies – energies so powerful they can make us feel insignificant in contrast.”

*Rev. Dr. Philip Butin*

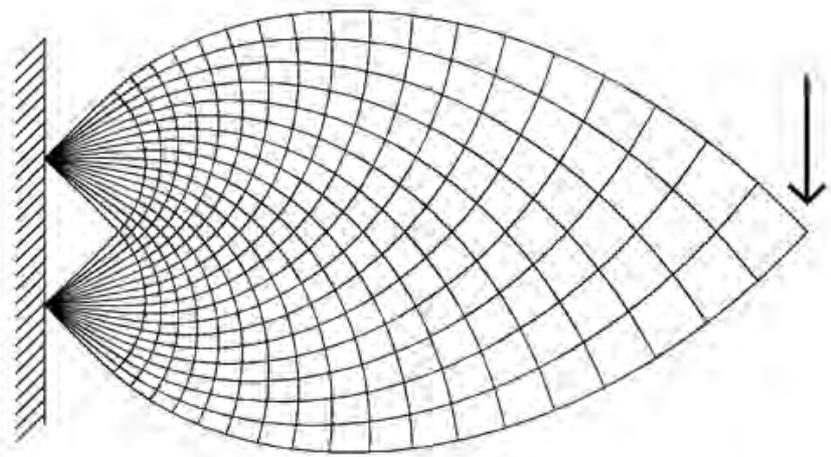






SOM

Initial Concept Sketch



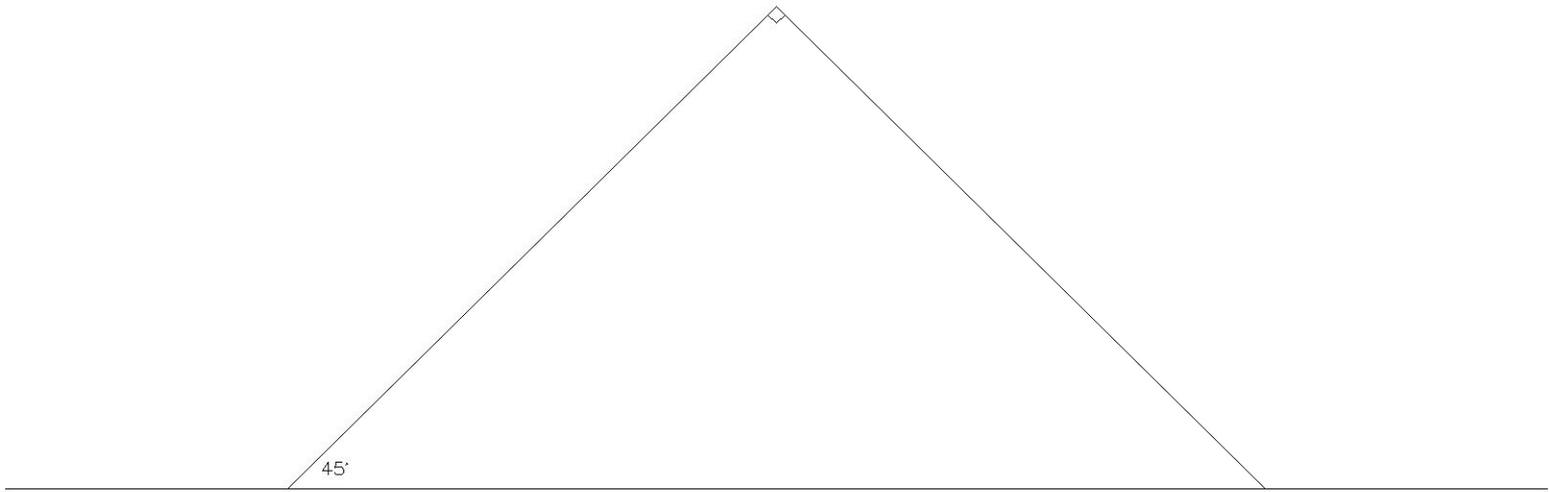
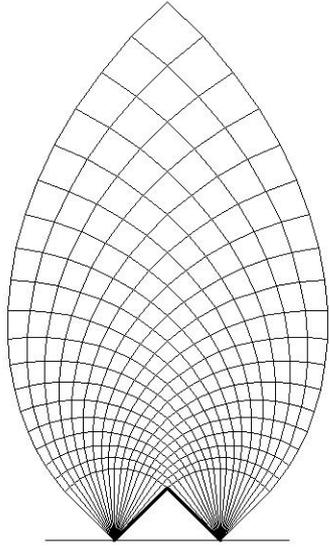
$$x(t) = r \cos(t) = ae^{bt} \cos(t)$$

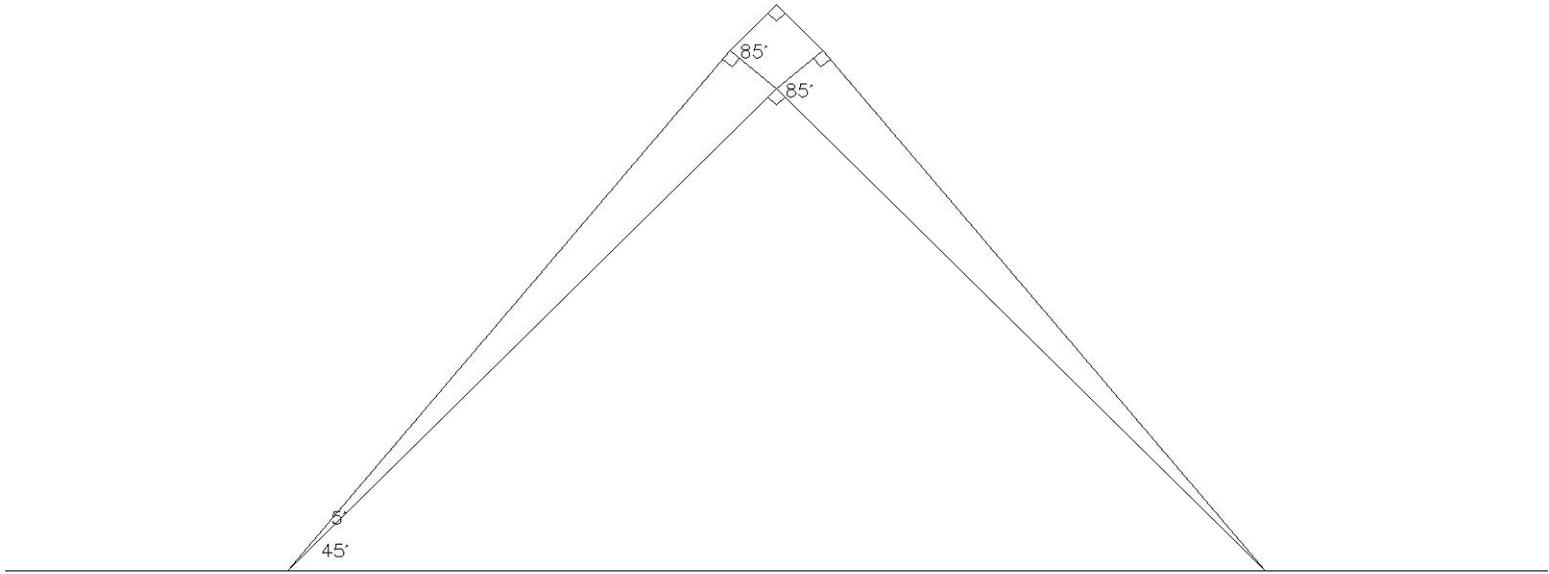
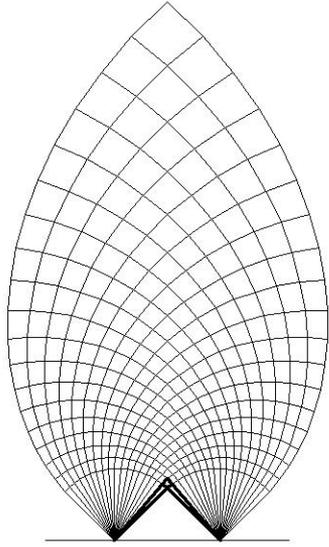
$$y(t) = r \sin(t) = ae^{bt} \sin(t)$$

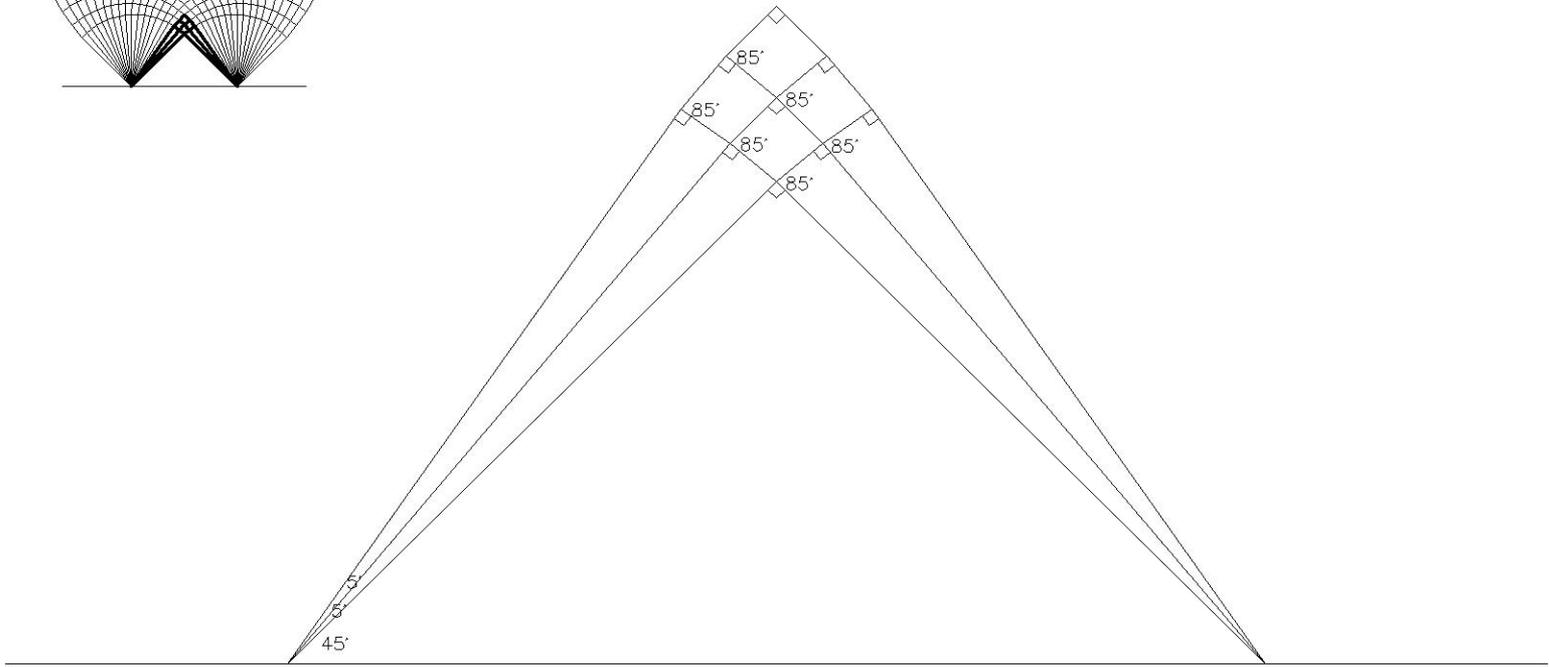
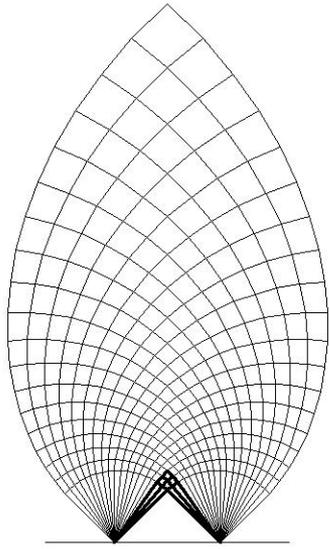


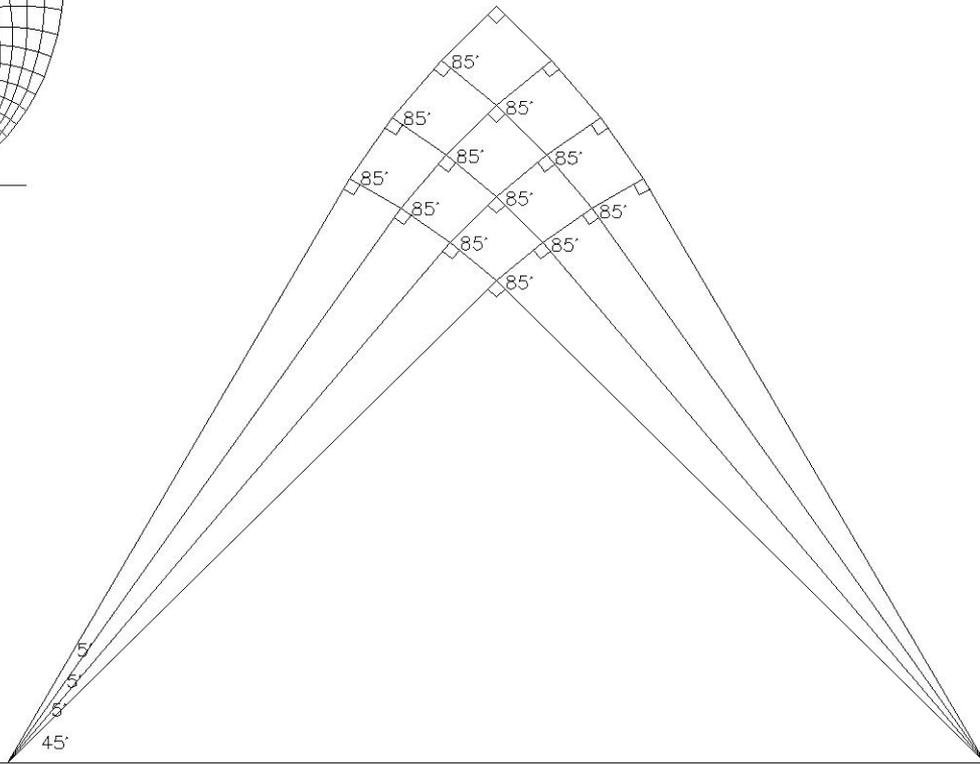
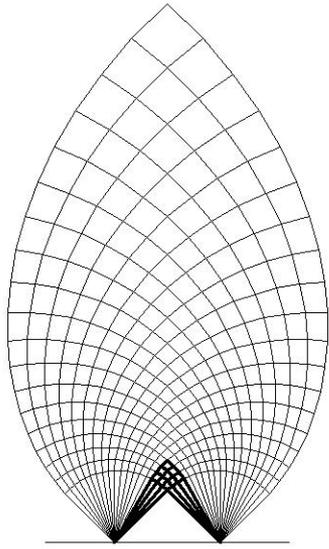
“What if you could develop strong, flexible, responsive, adaptive, sustainable human buildings based on the intrinsic architecture of the hurricane? Buildings that exist in harmony with – instead of trying to resist and stand up against and conquer – the powerful creative forces that might otherwise threaten and endanger us?”

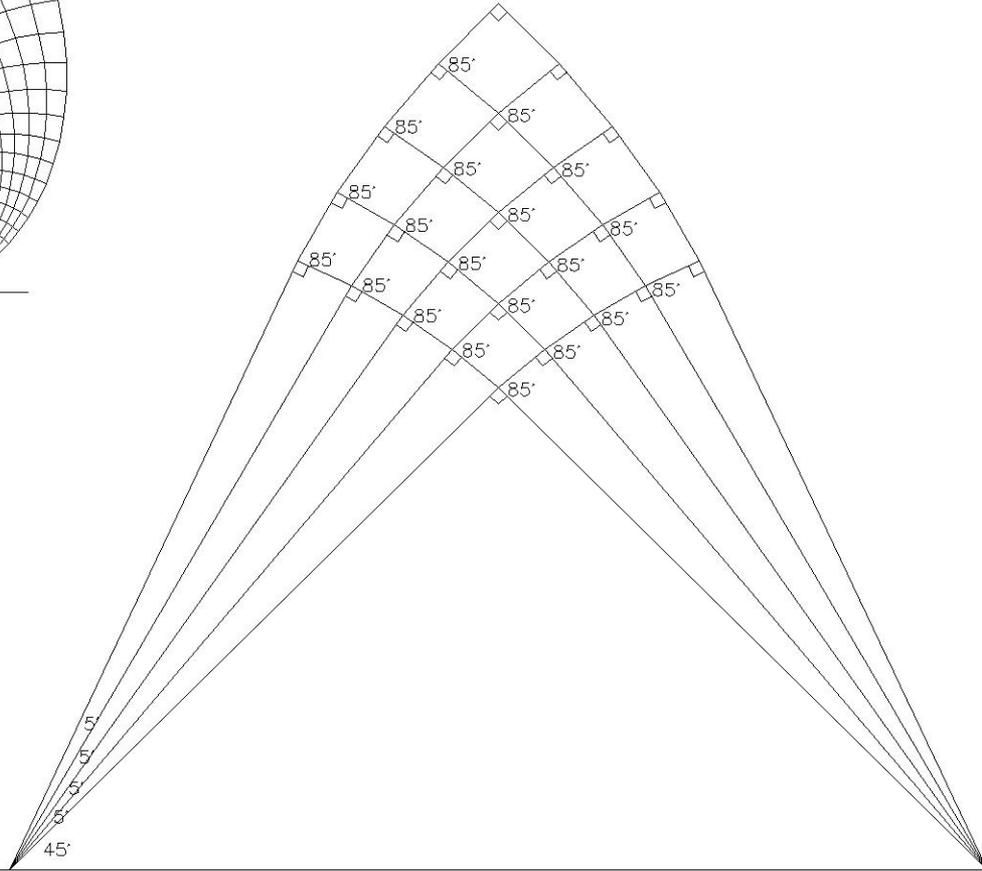
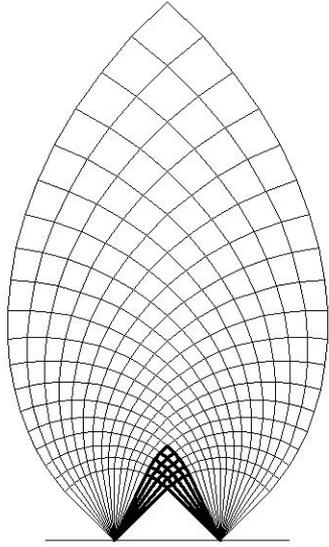
*Rev. Dr. Philip Butin*

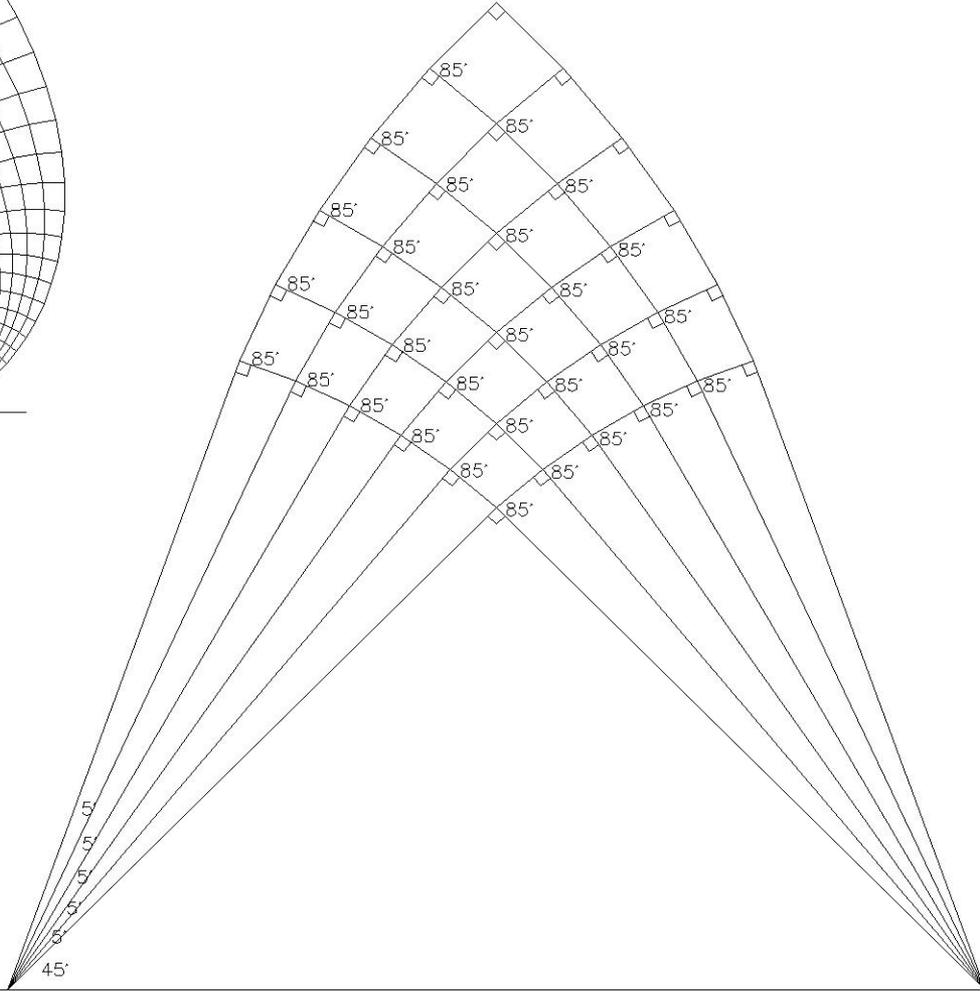
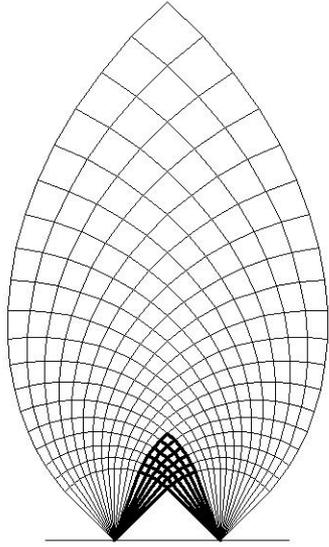


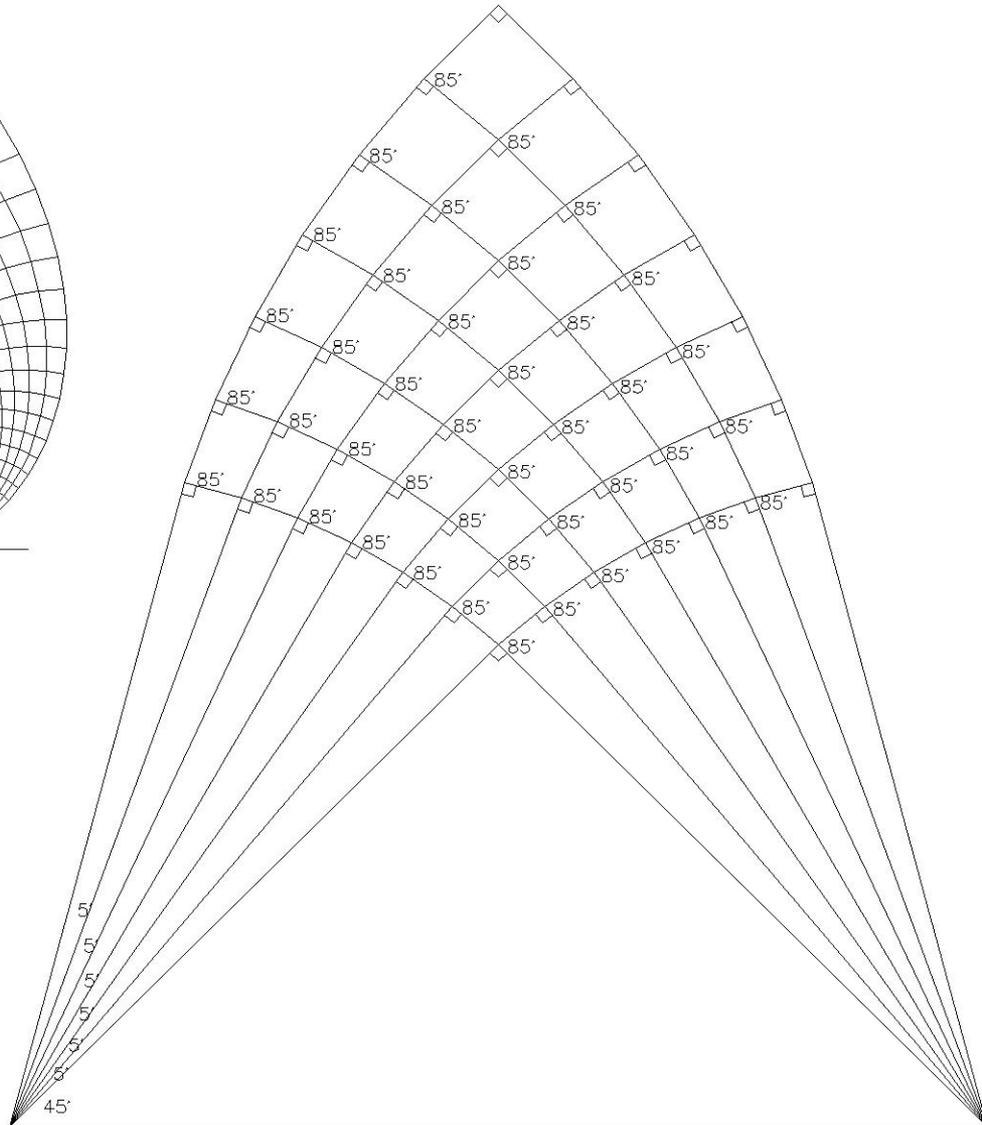
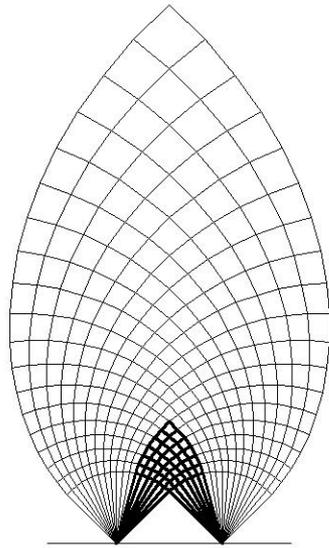


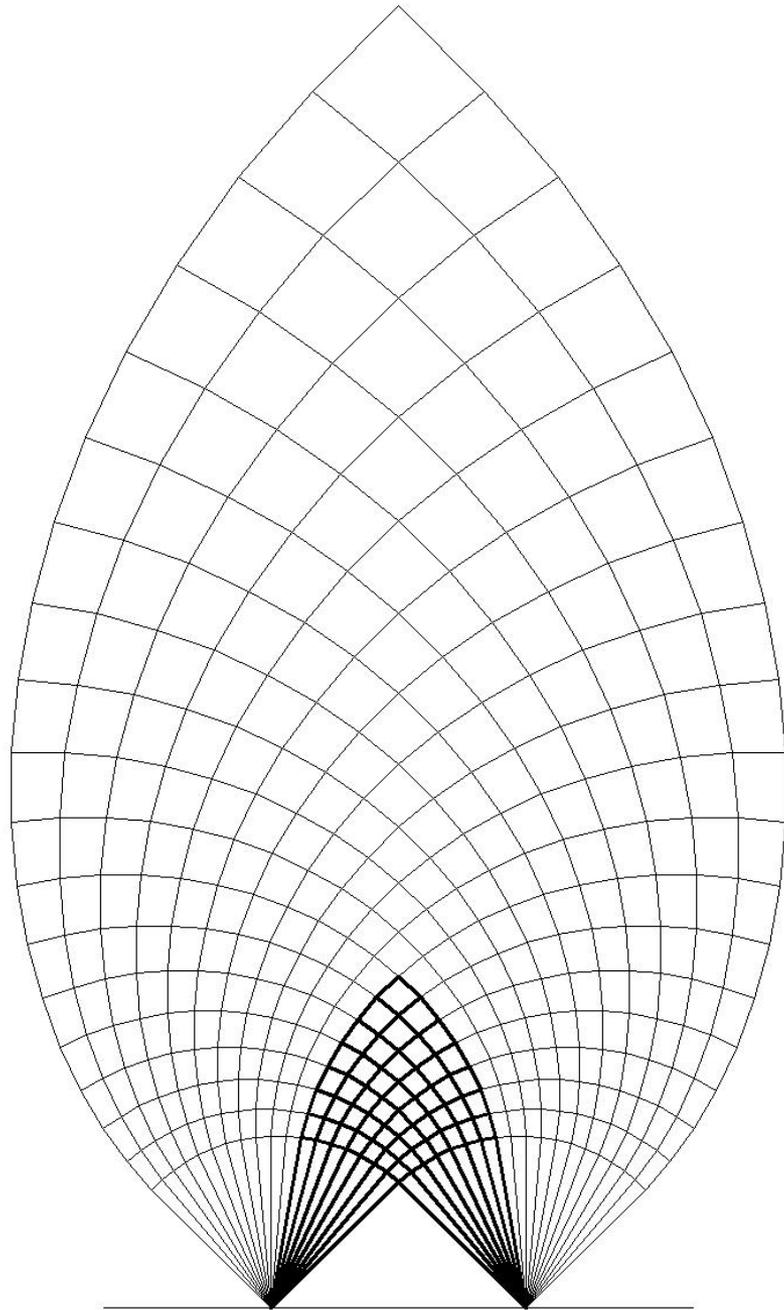






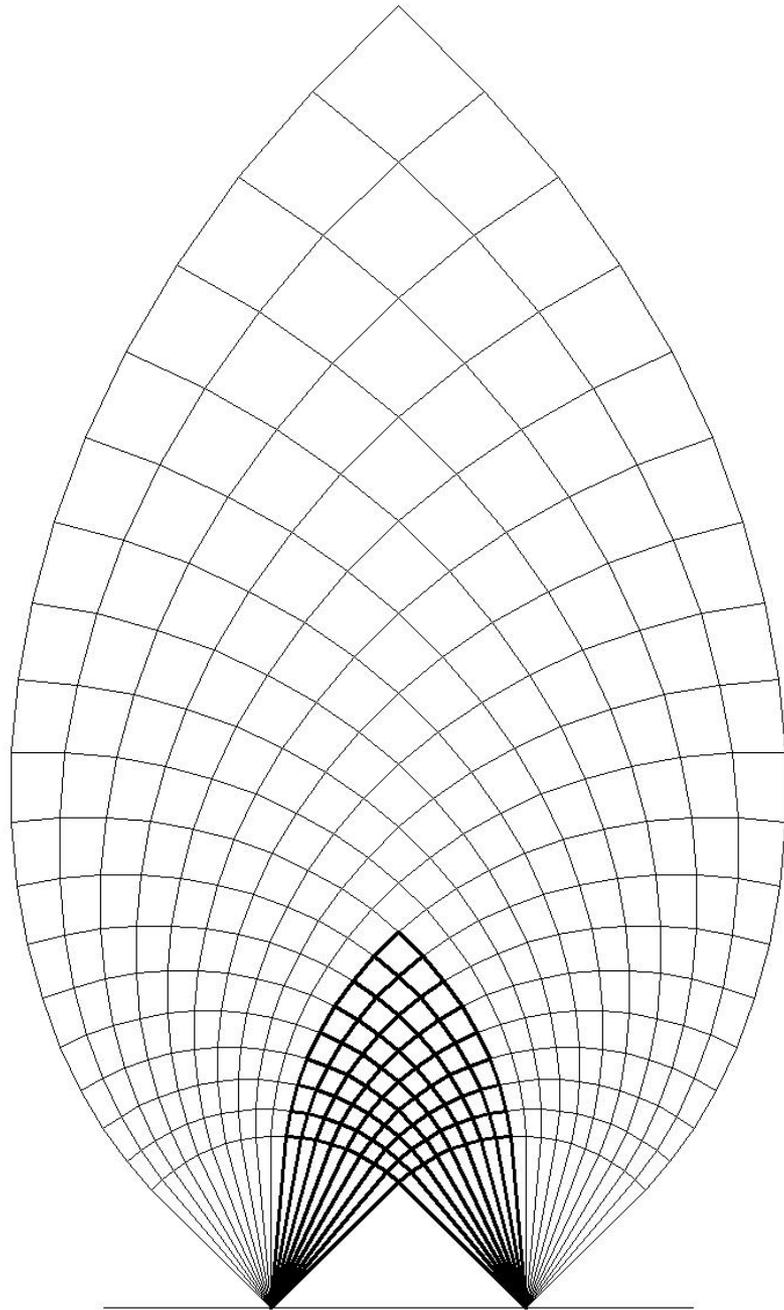






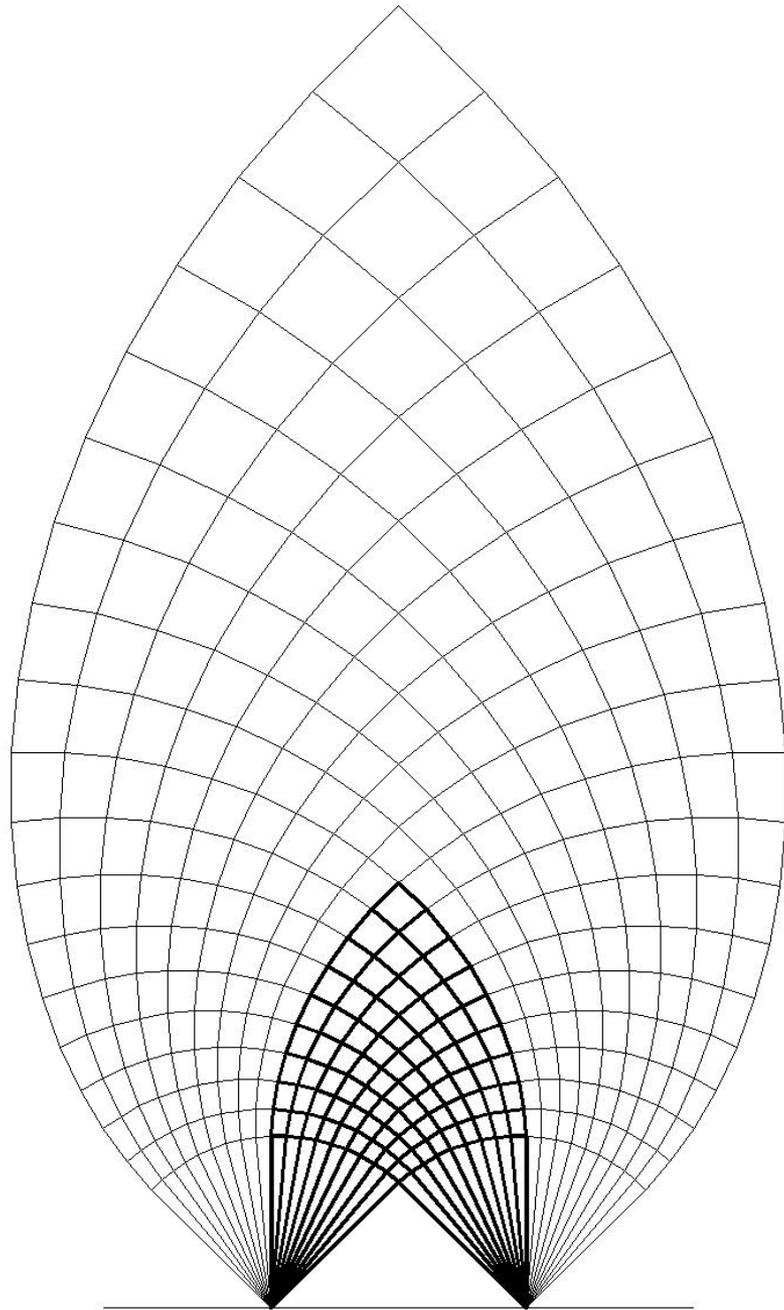
SOM

Truss Generation



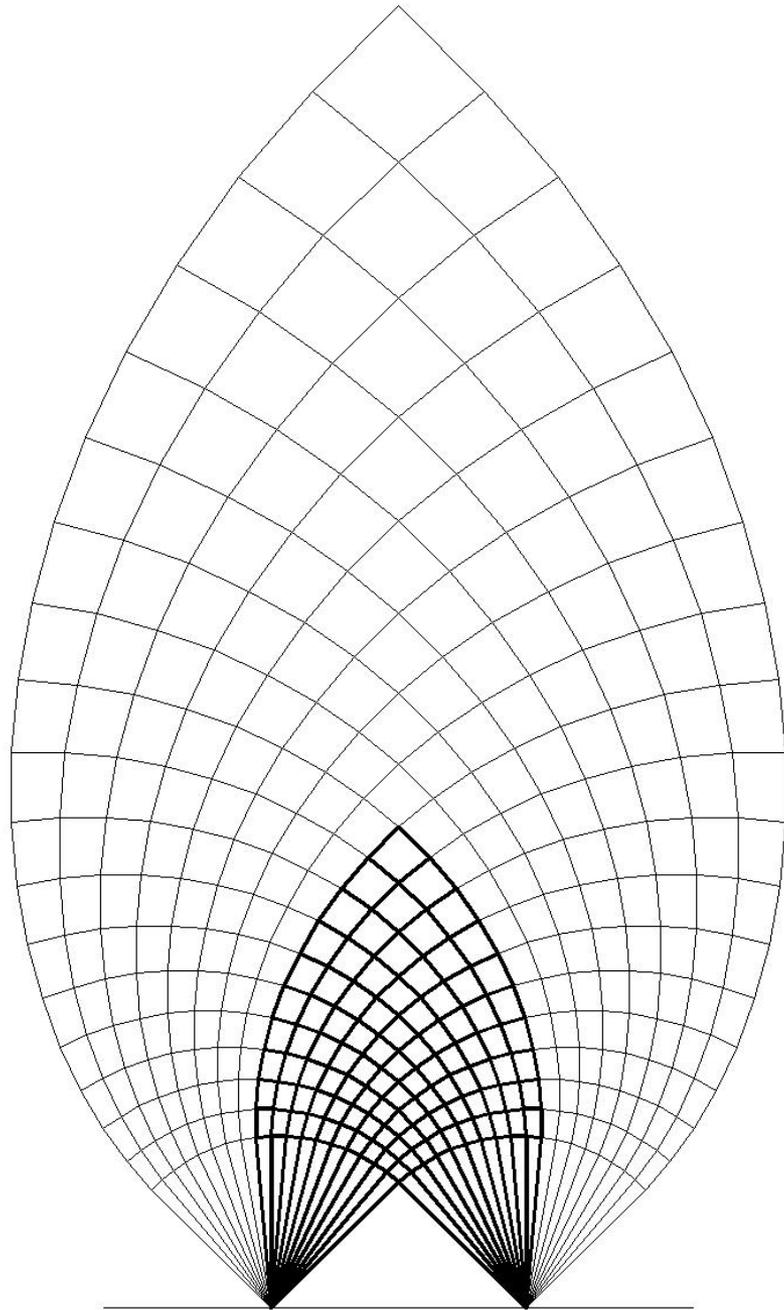
SOM

Truss Generation



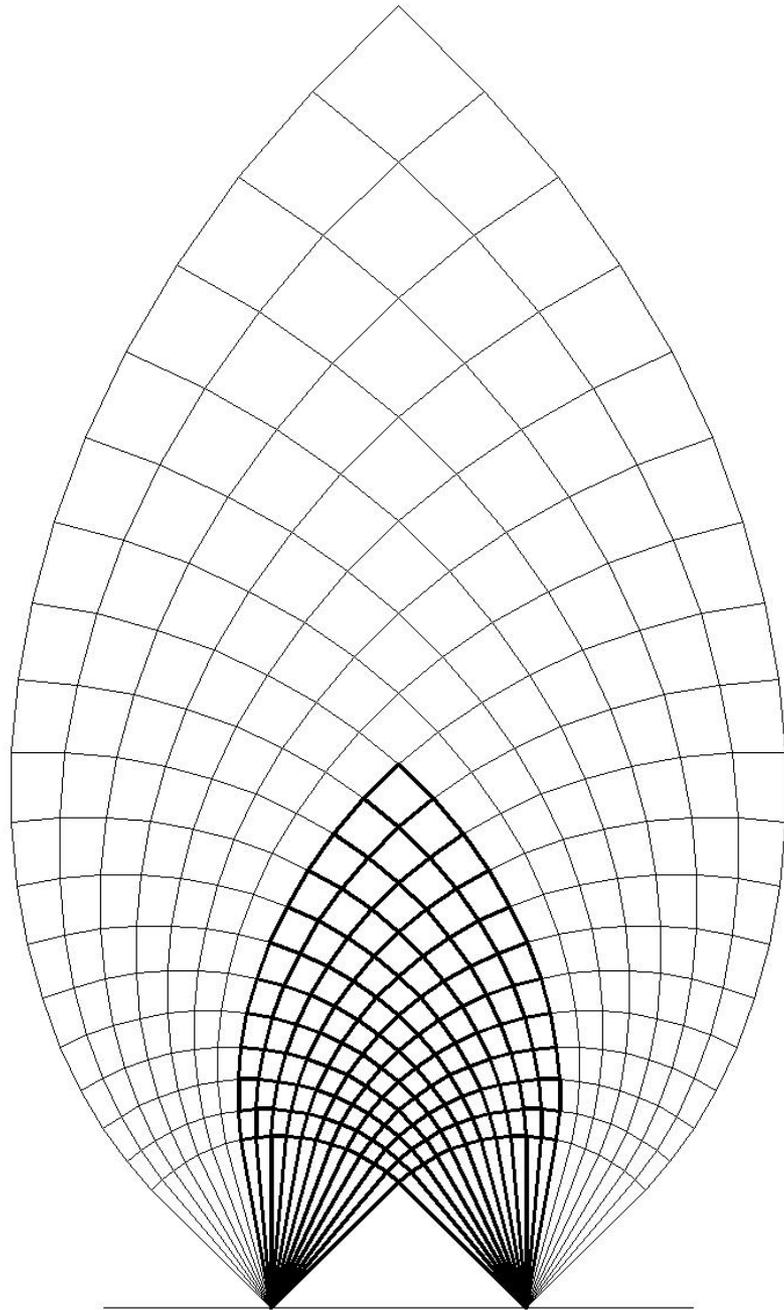
SOM

Truss Generation



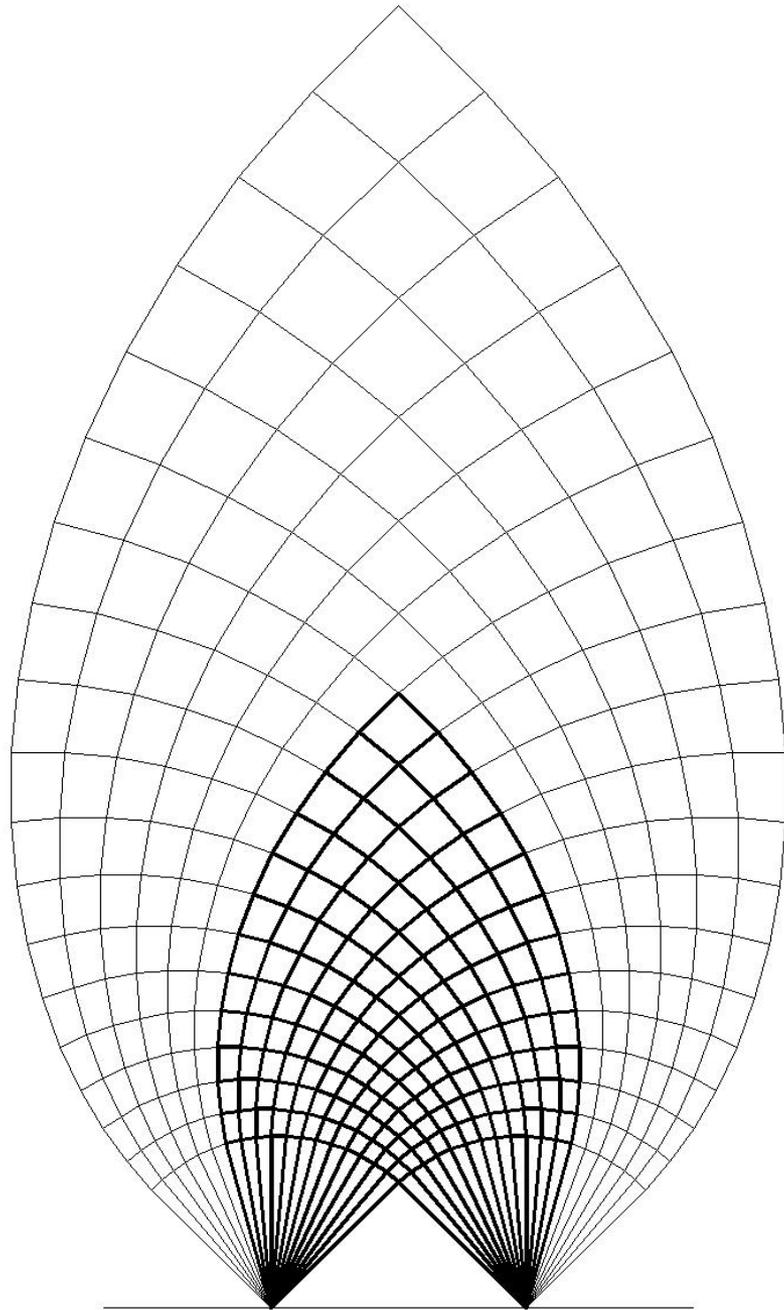
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Truss Generation



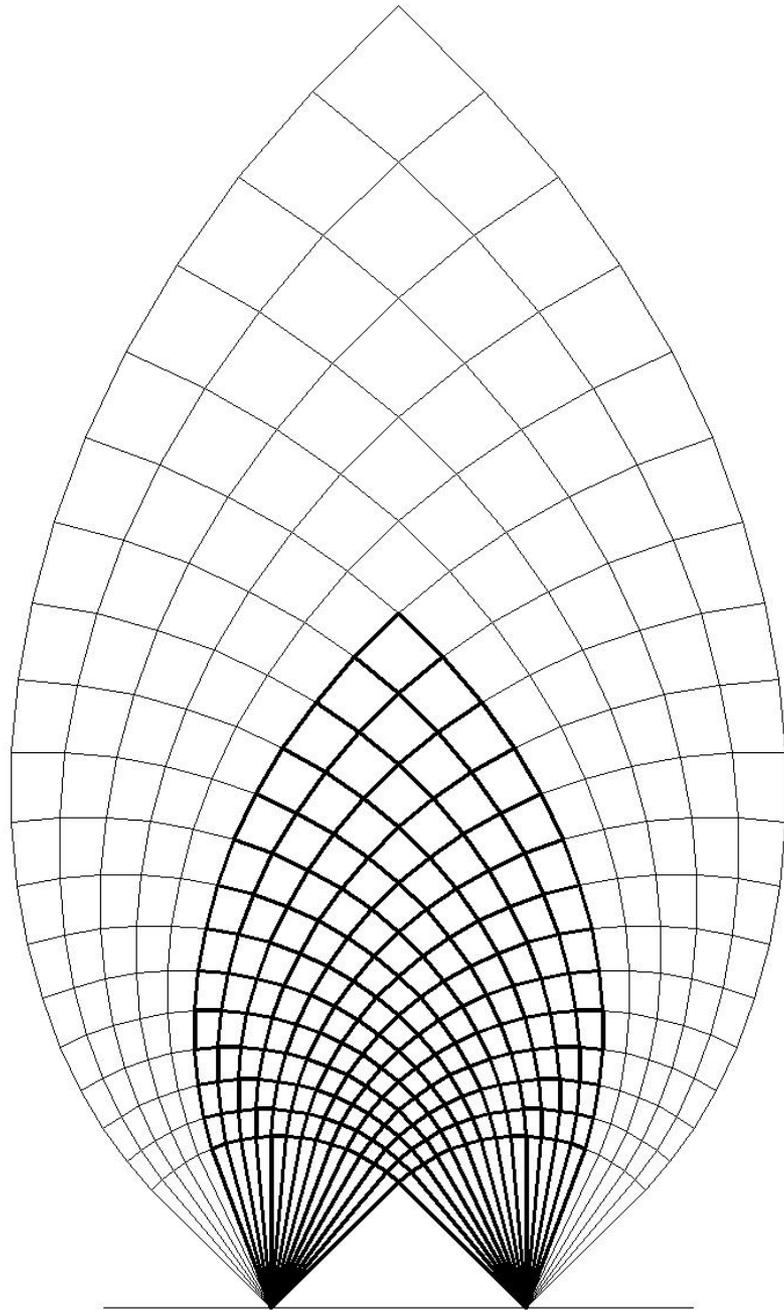
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Truss Generation



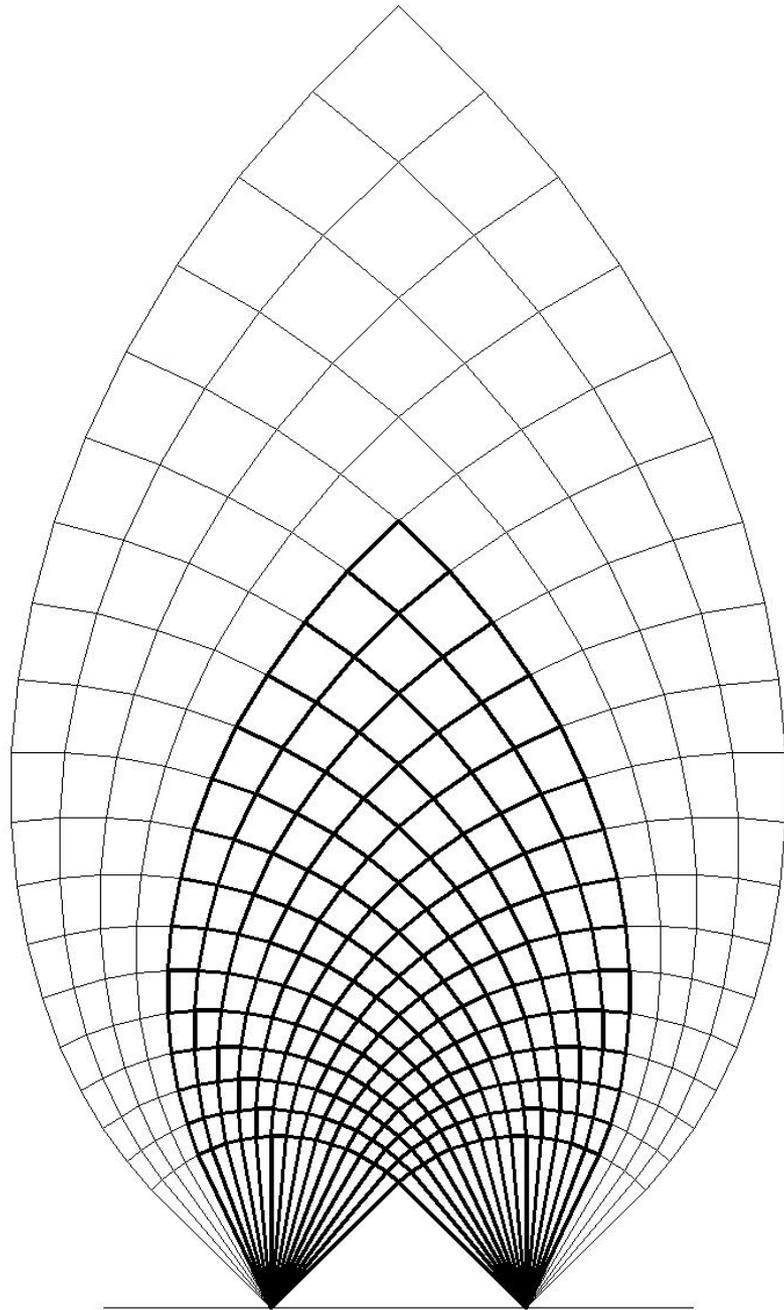
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Truss Generation



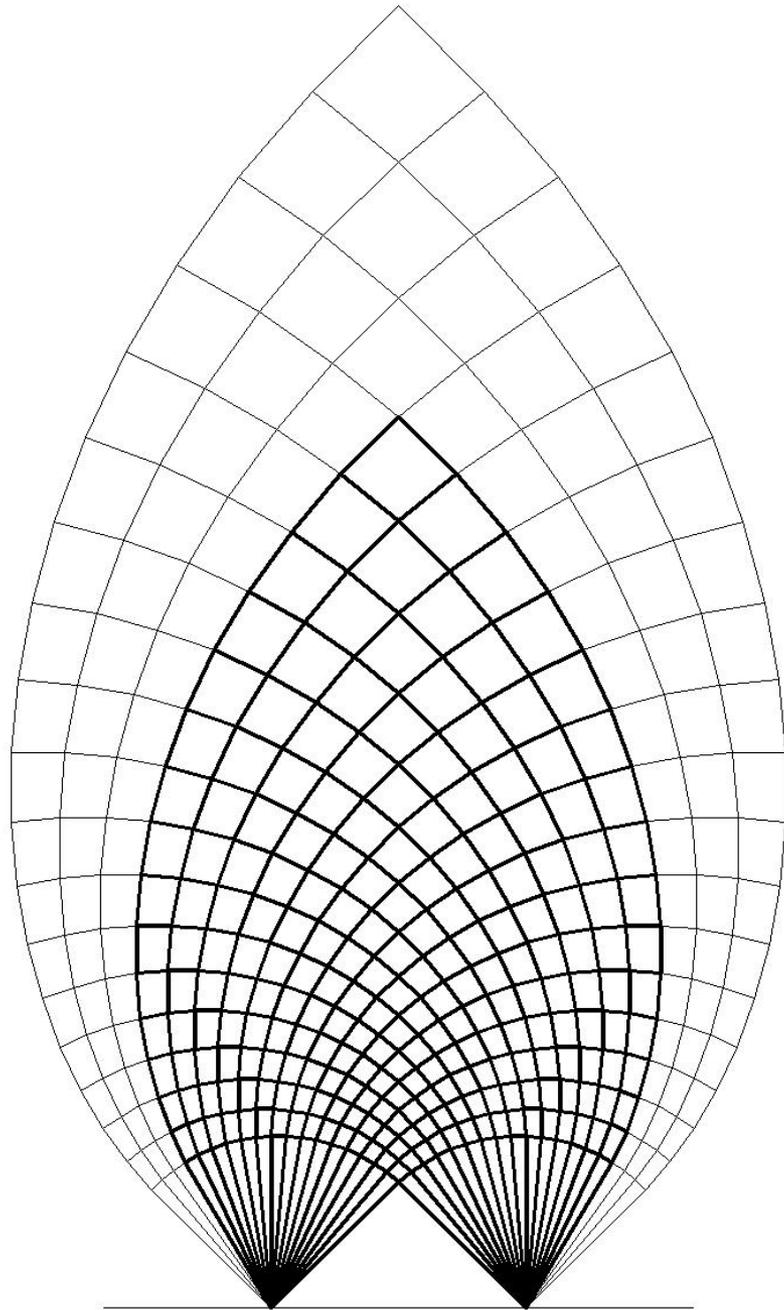
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Truss Generation



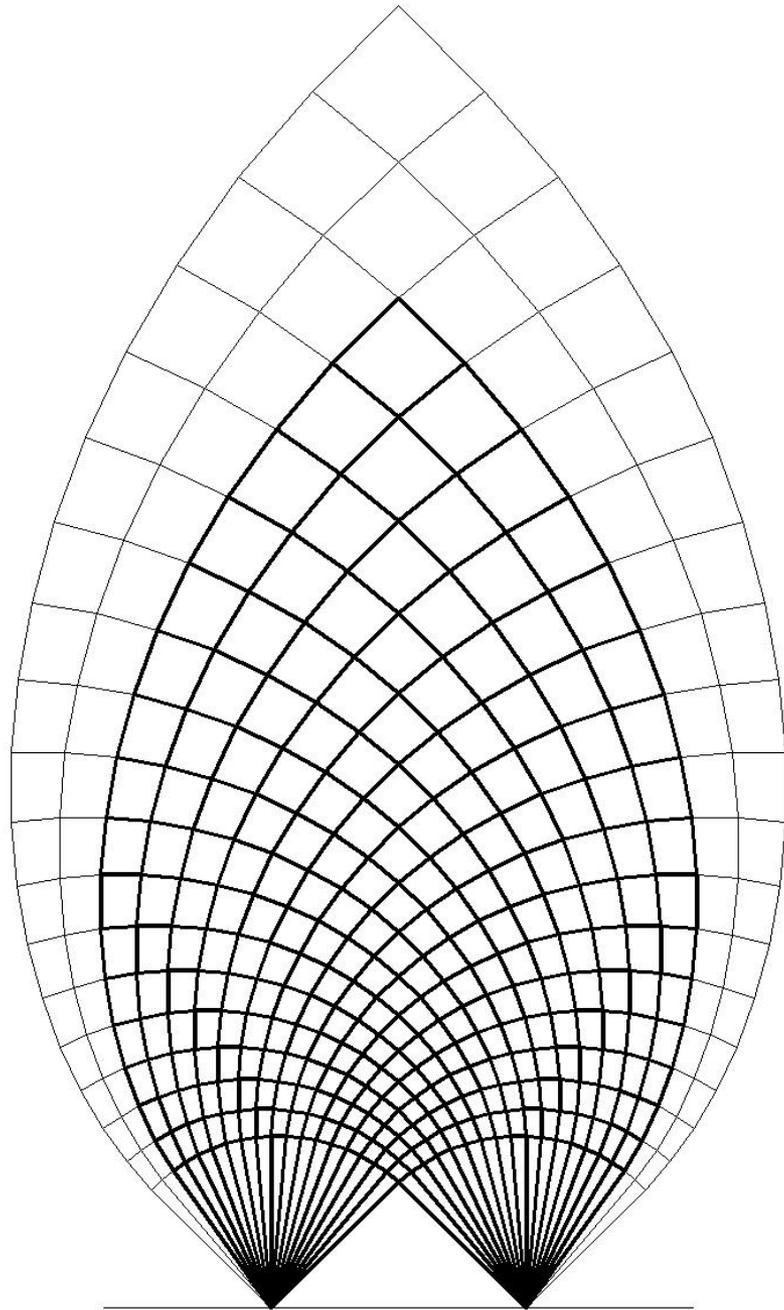
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Truss Generation



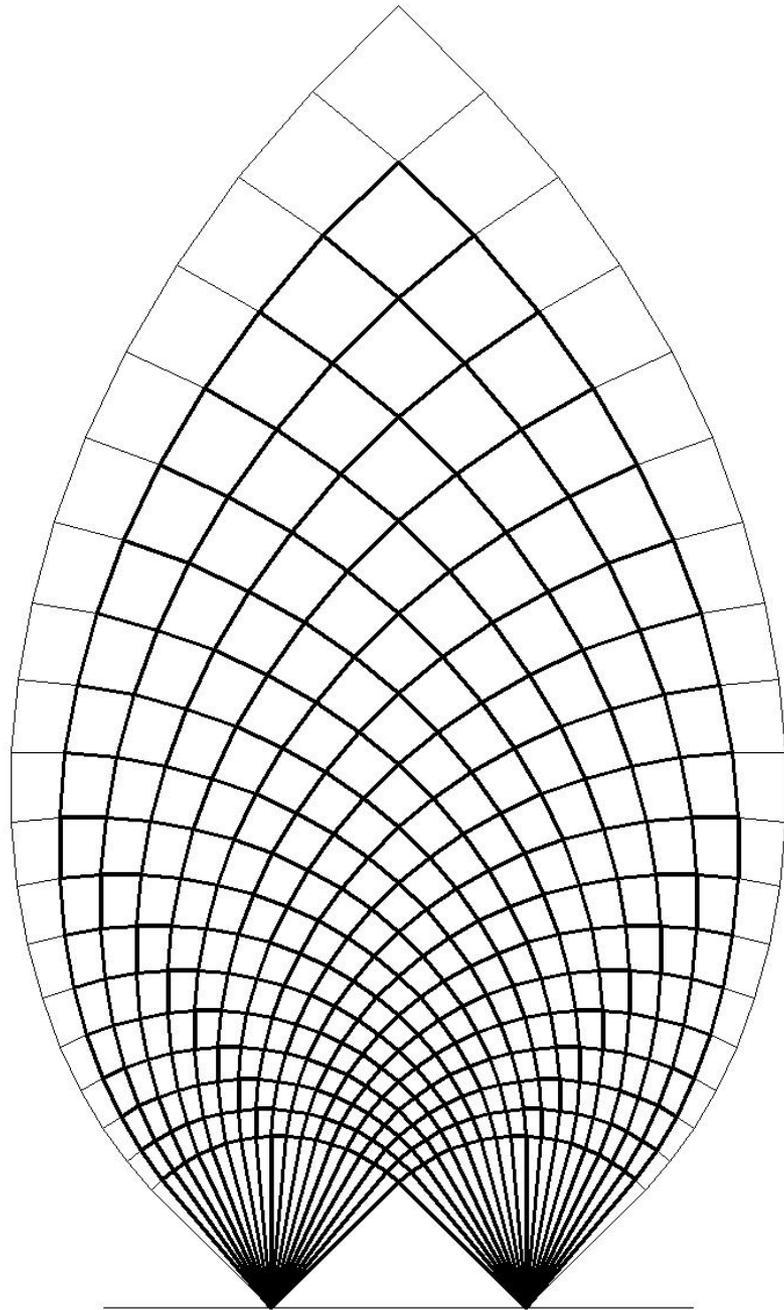
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Truss Generation



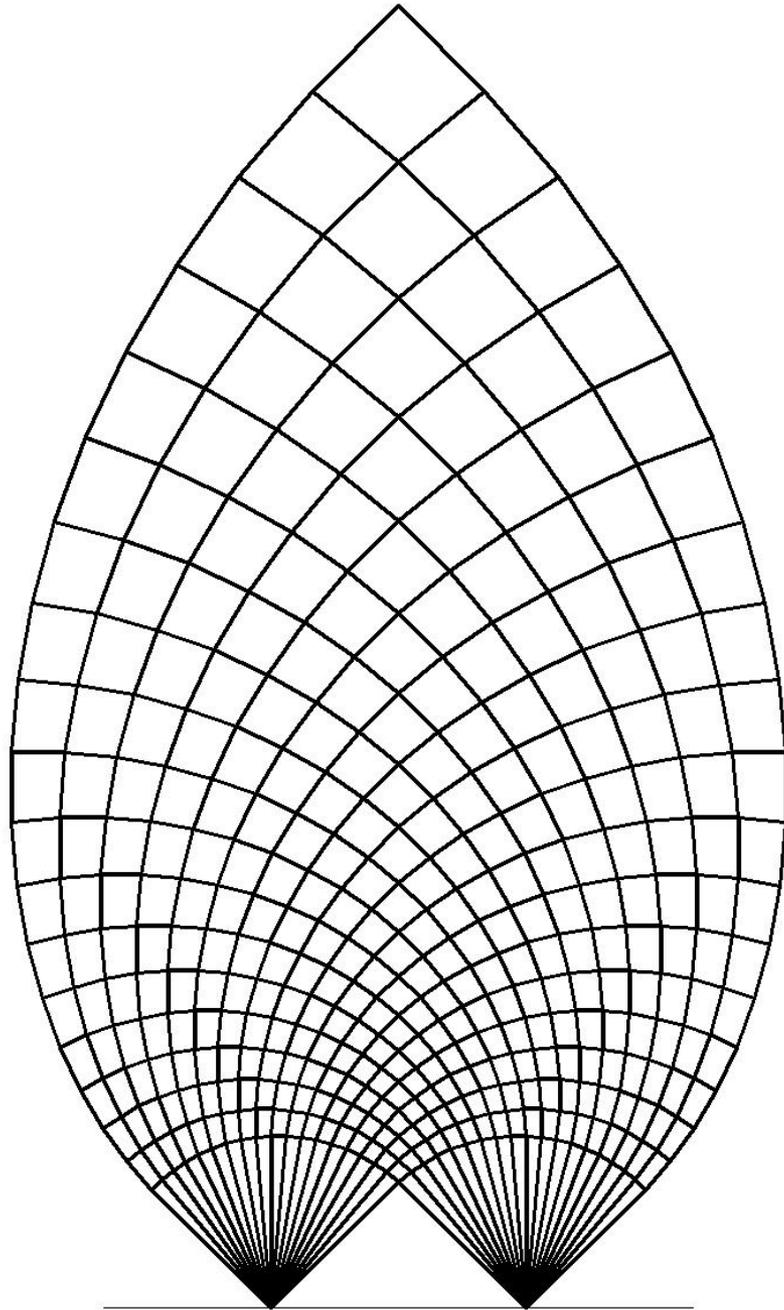
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Truss Generation



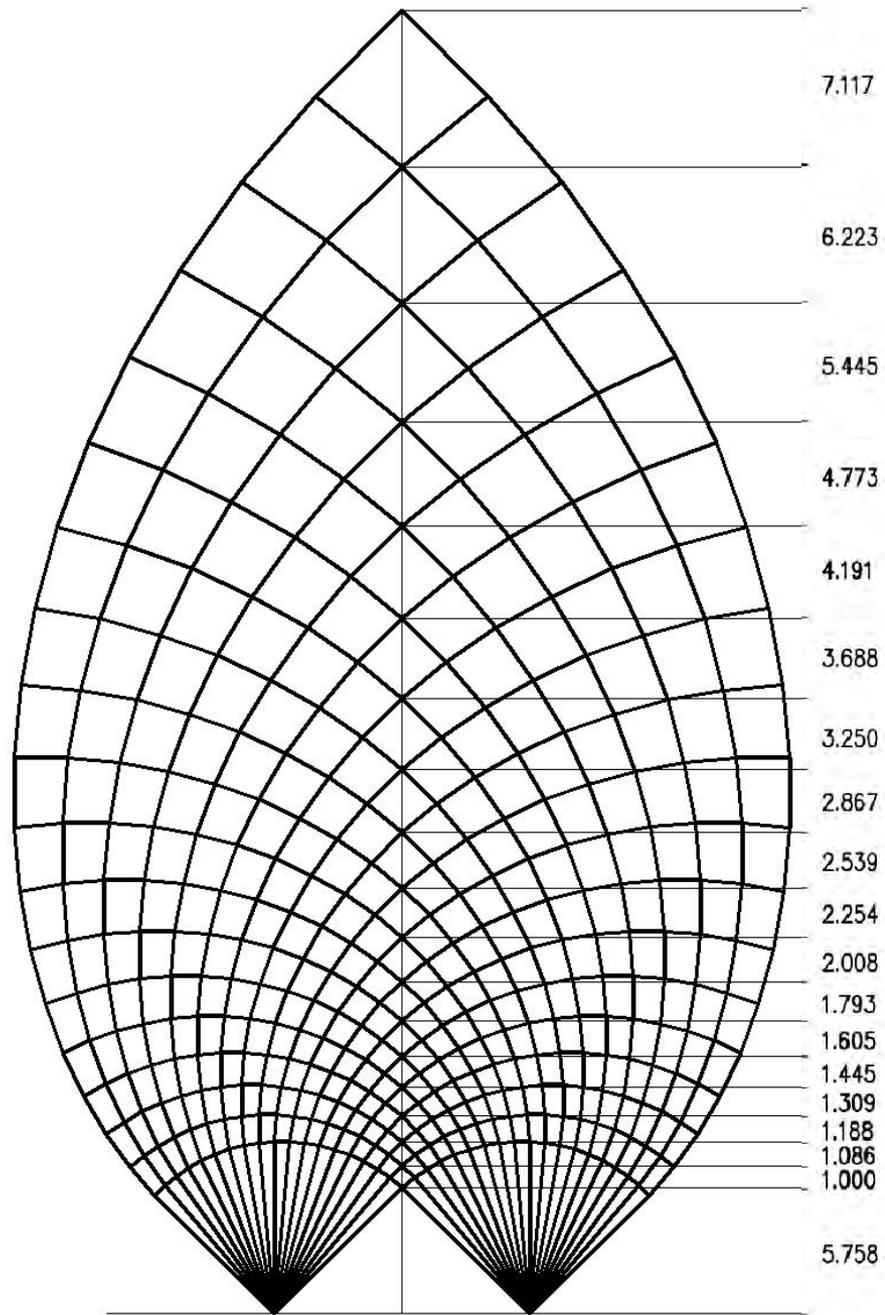
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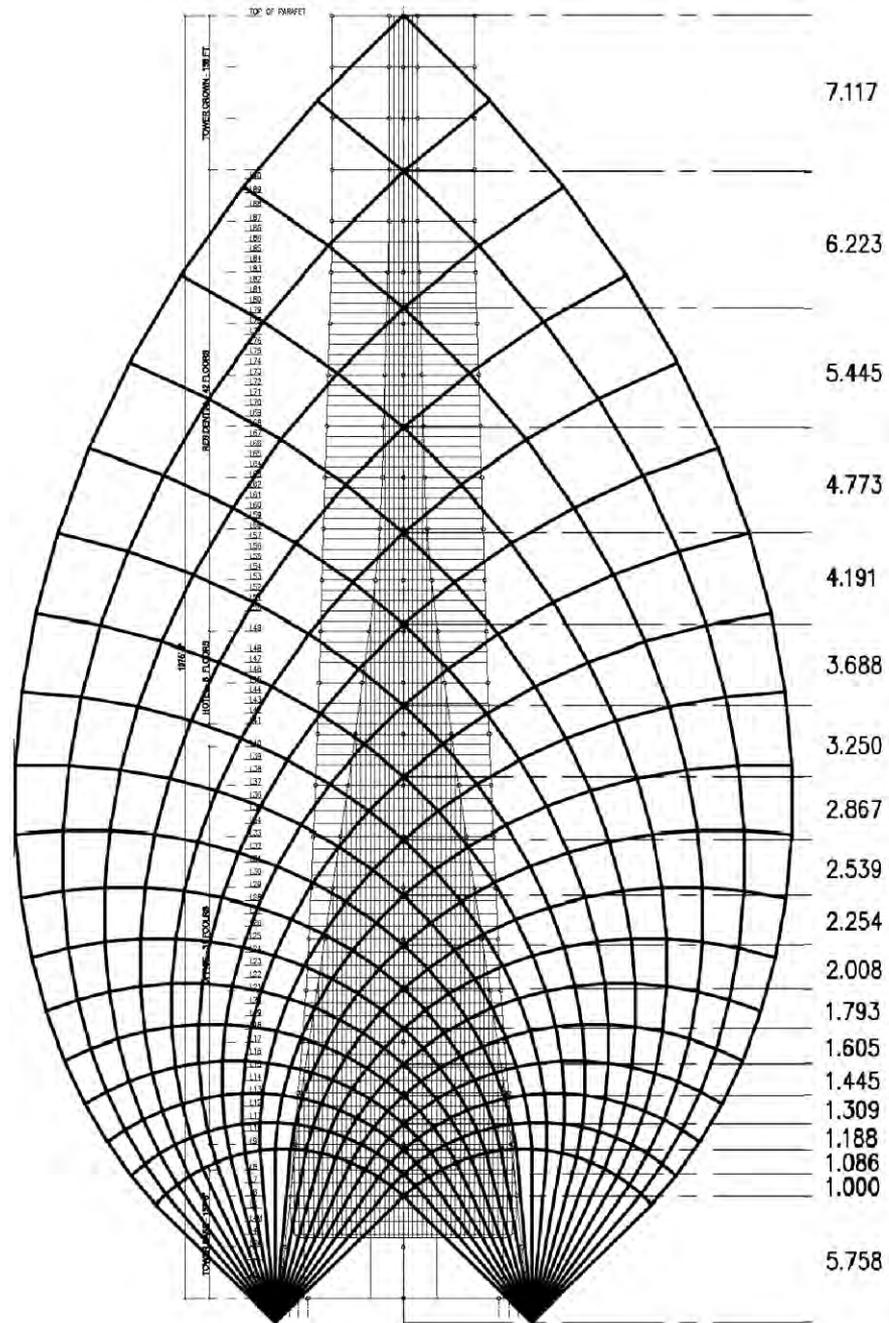
Truss Generation

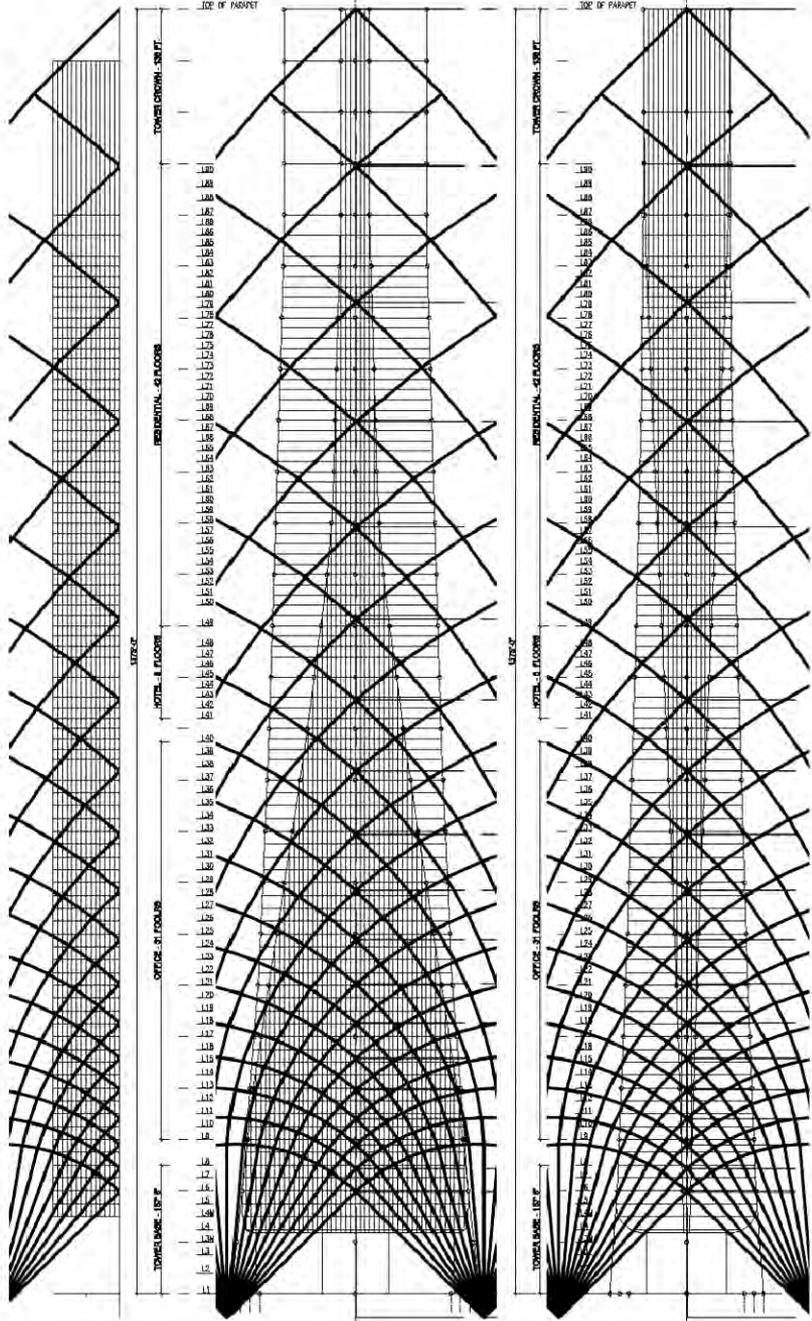


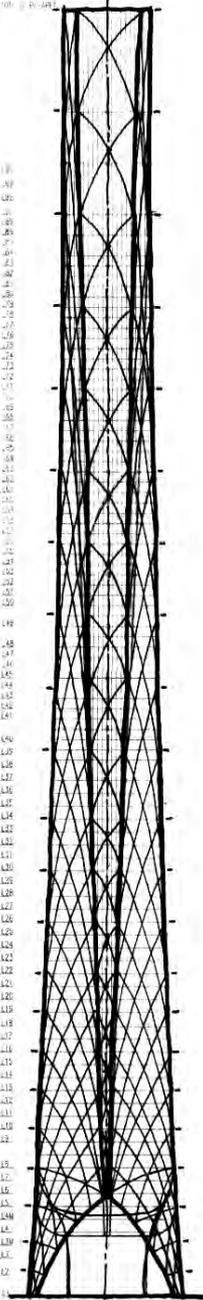
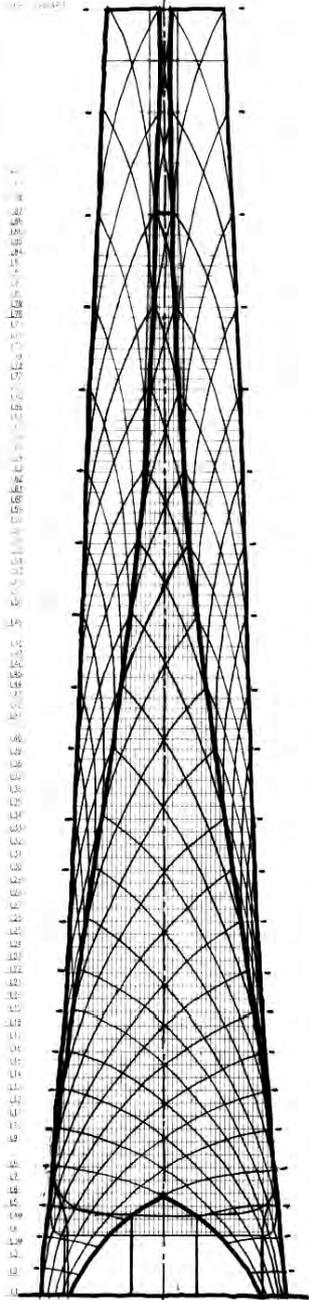
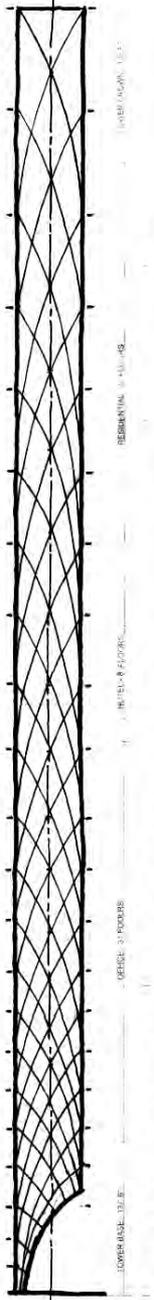
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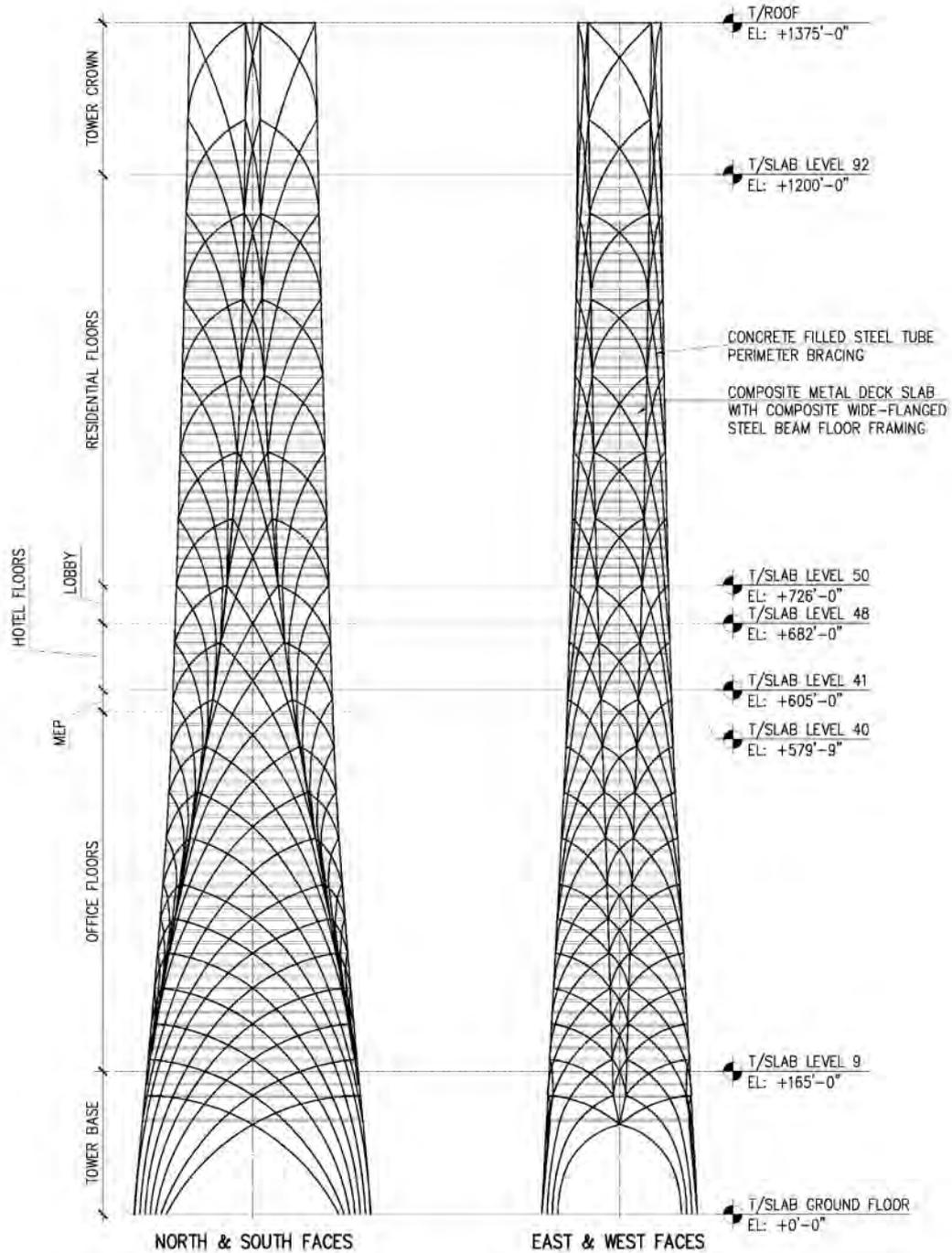
Truss Generation



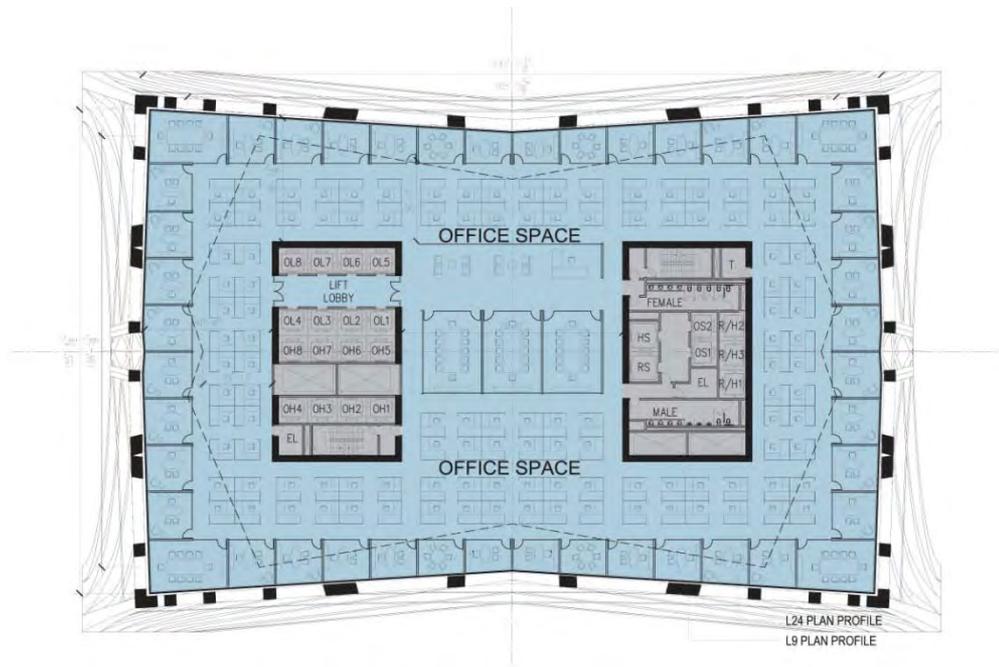
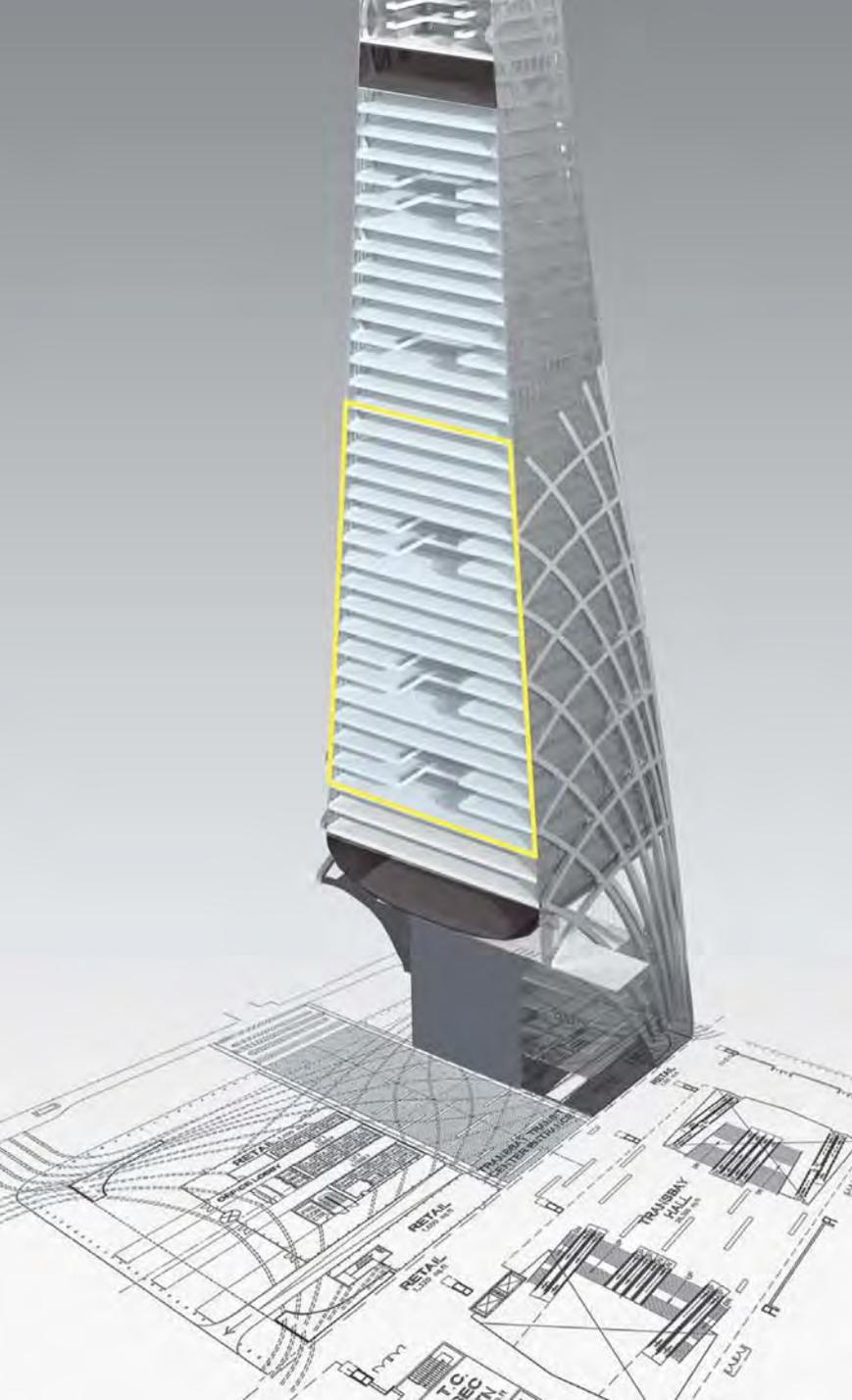






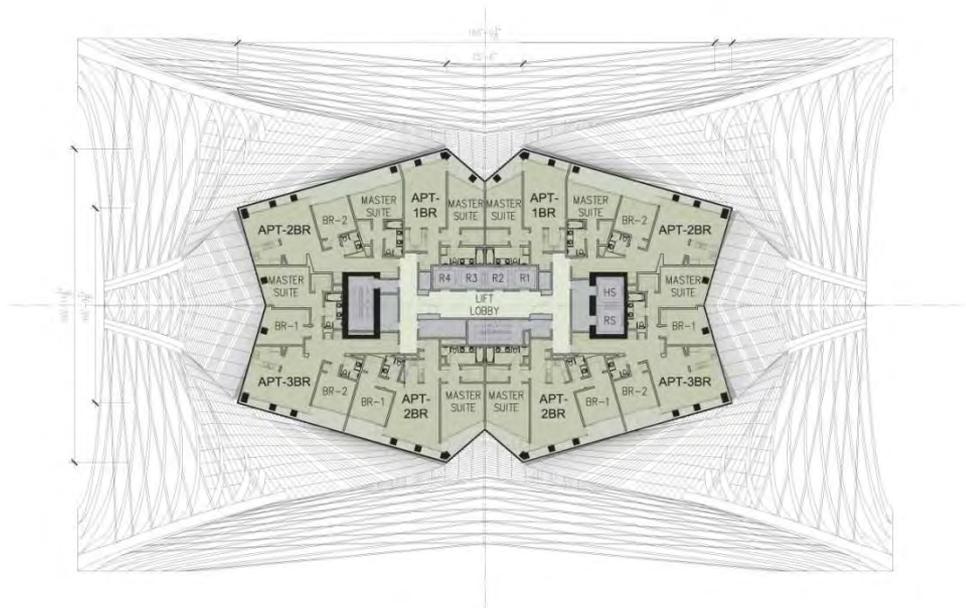




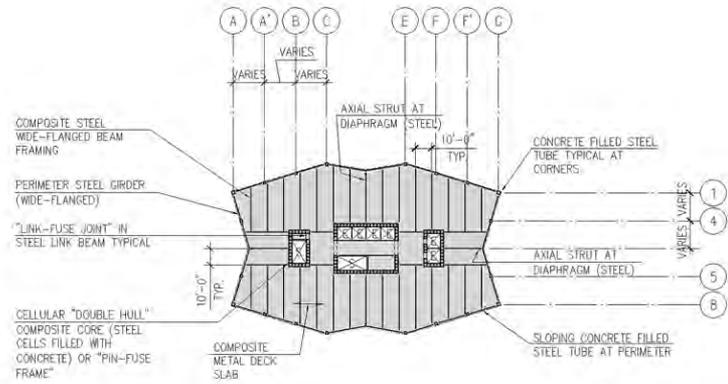
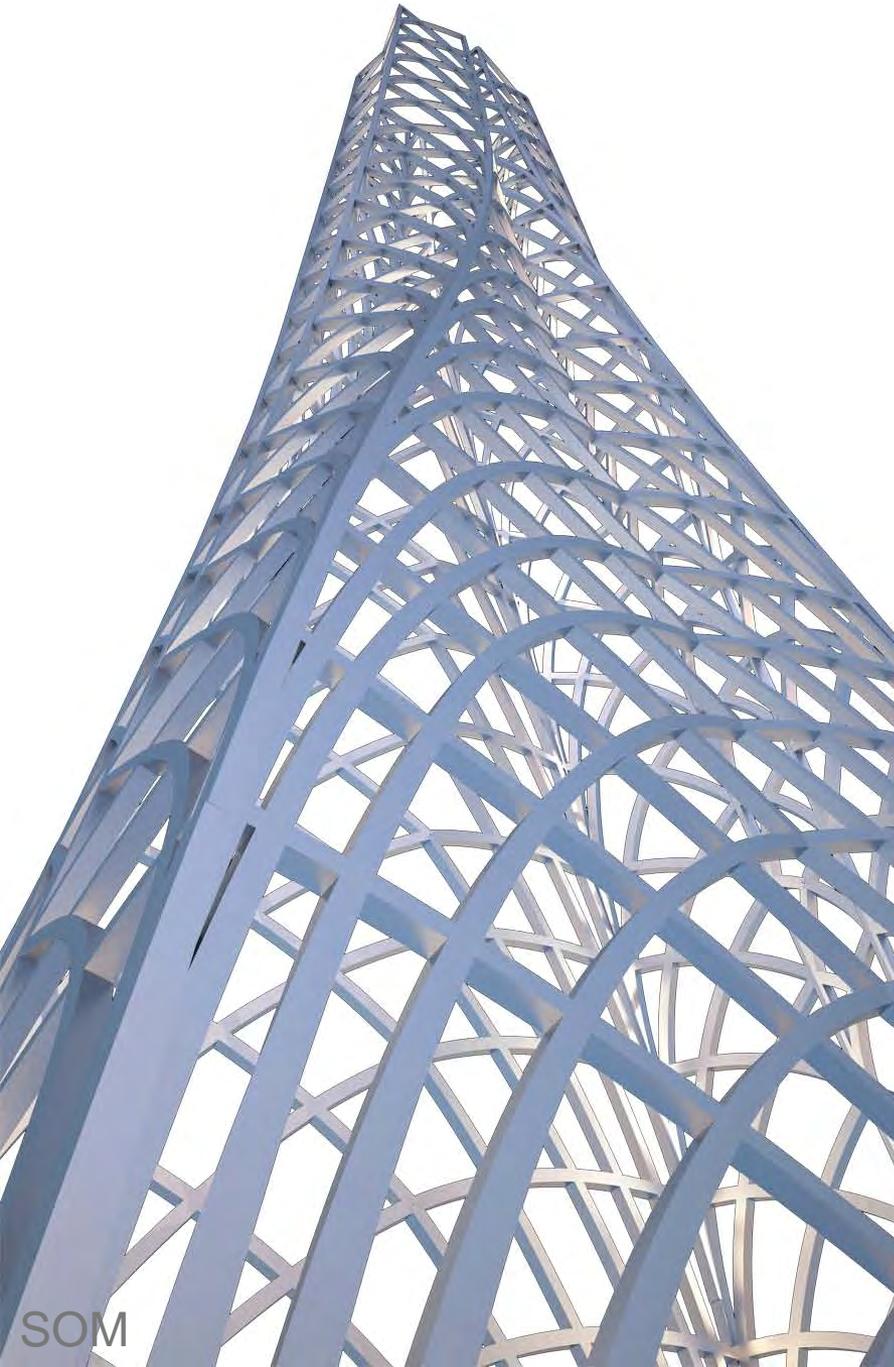


FLOOR AREA = 34,500-25,310 sq.ft.

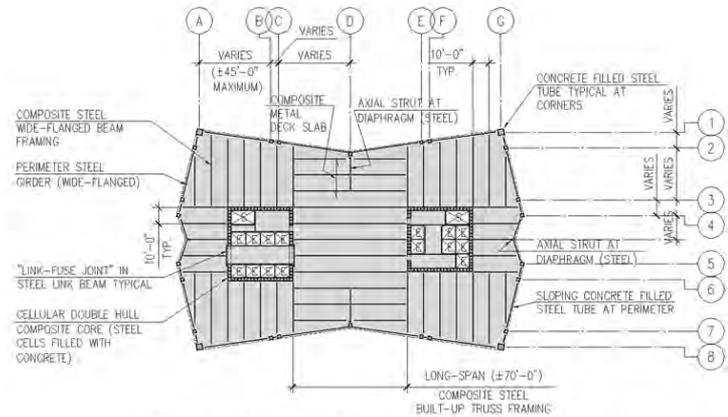
TYPICAL LOW-RISE OFFICE FLOOR PLAN(L9-24)



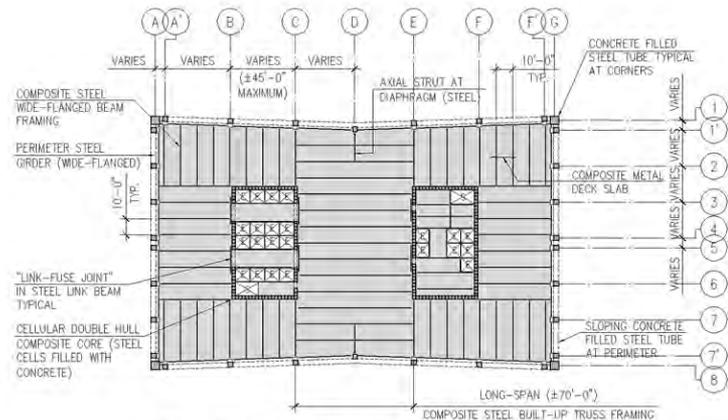
FLOOR AREA = 14,018 sq.ft.  
RESIDENTIAL L-72 FLOOR PLAN



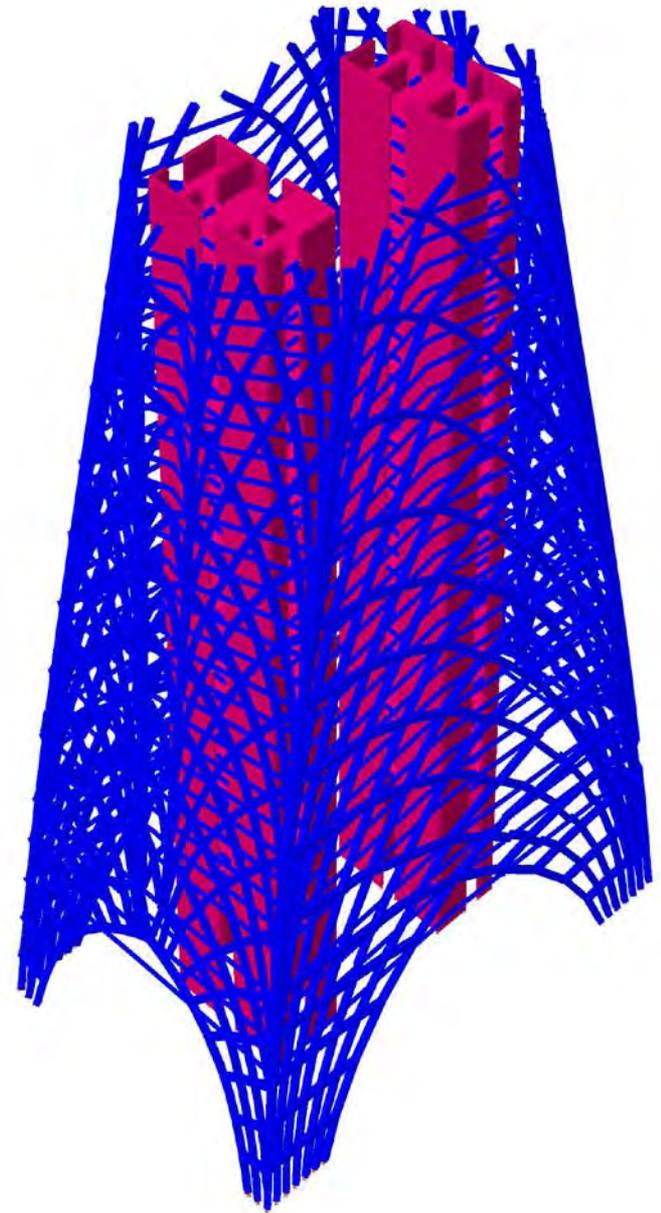
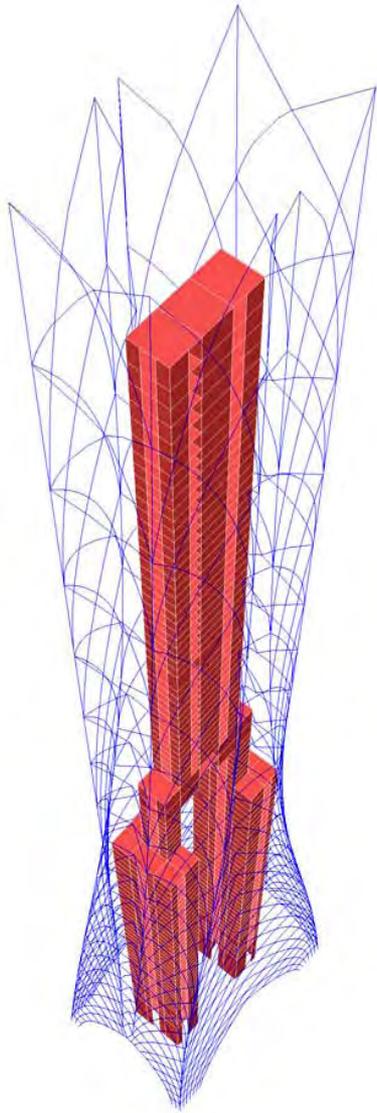
STRUCTURAL SYSTEM PLAN - TYPICAL RESIDENTIAL  
1" = 40'



STRUCTURAL SYSTEM PLAN - TYPICAL OFFICE (HIGH-RISE)  
1" = 40'

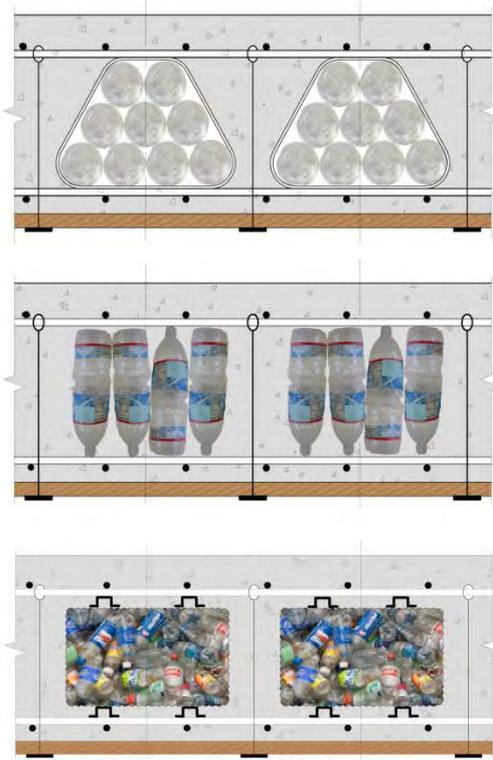
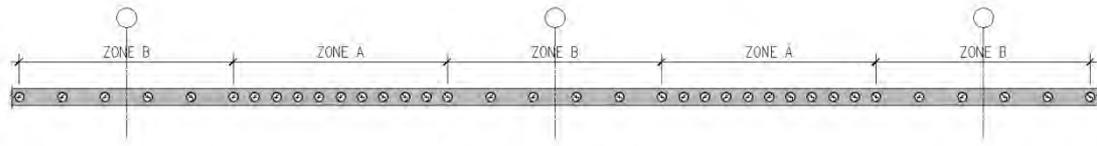


STRUCTURAL SYSTEM PLAN - TYPICAL OFFICE (LOW-RISE)  
1" = 40'

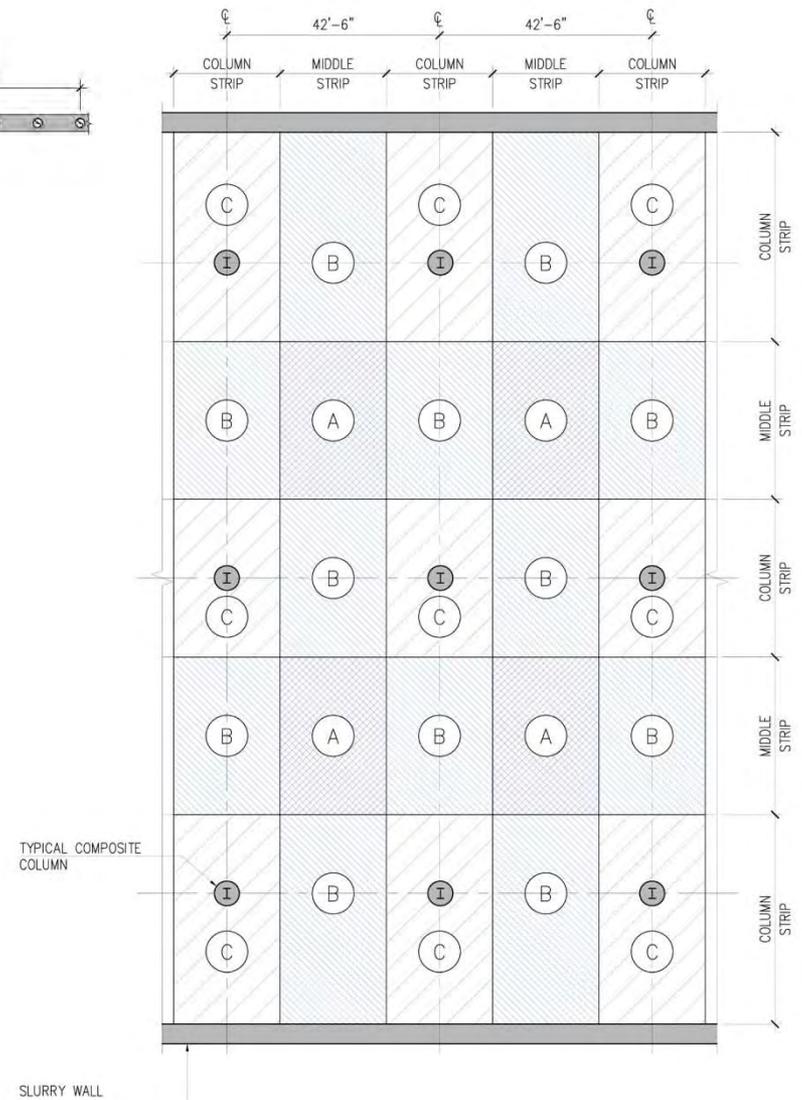


SOM

3D Finite Element Analysis Model



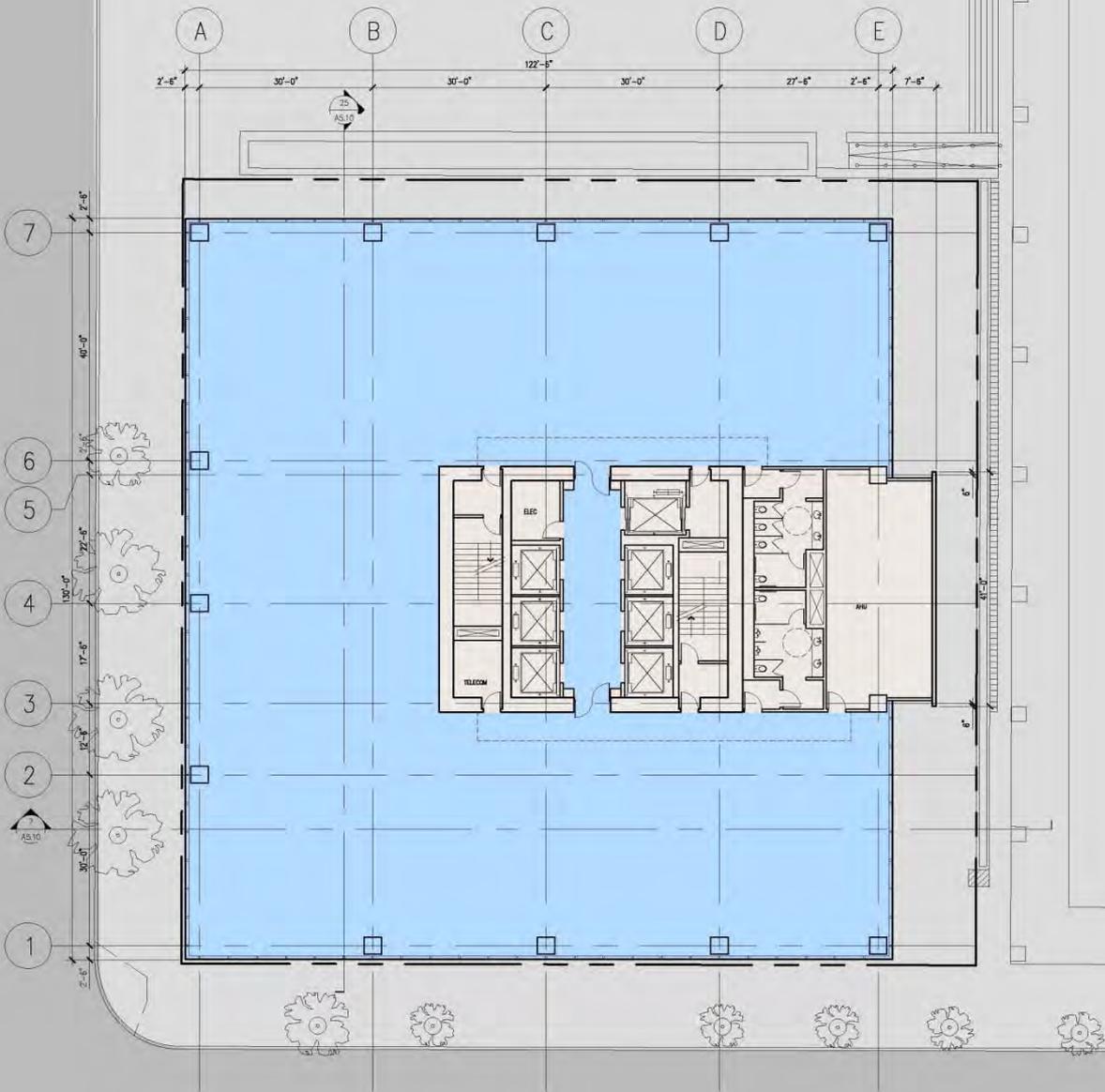
- 35% Reduction in Concrete
- Flat Slab Construction (no beams)
- Reduced Seismic Mass
- Reduced Weight to Foundations



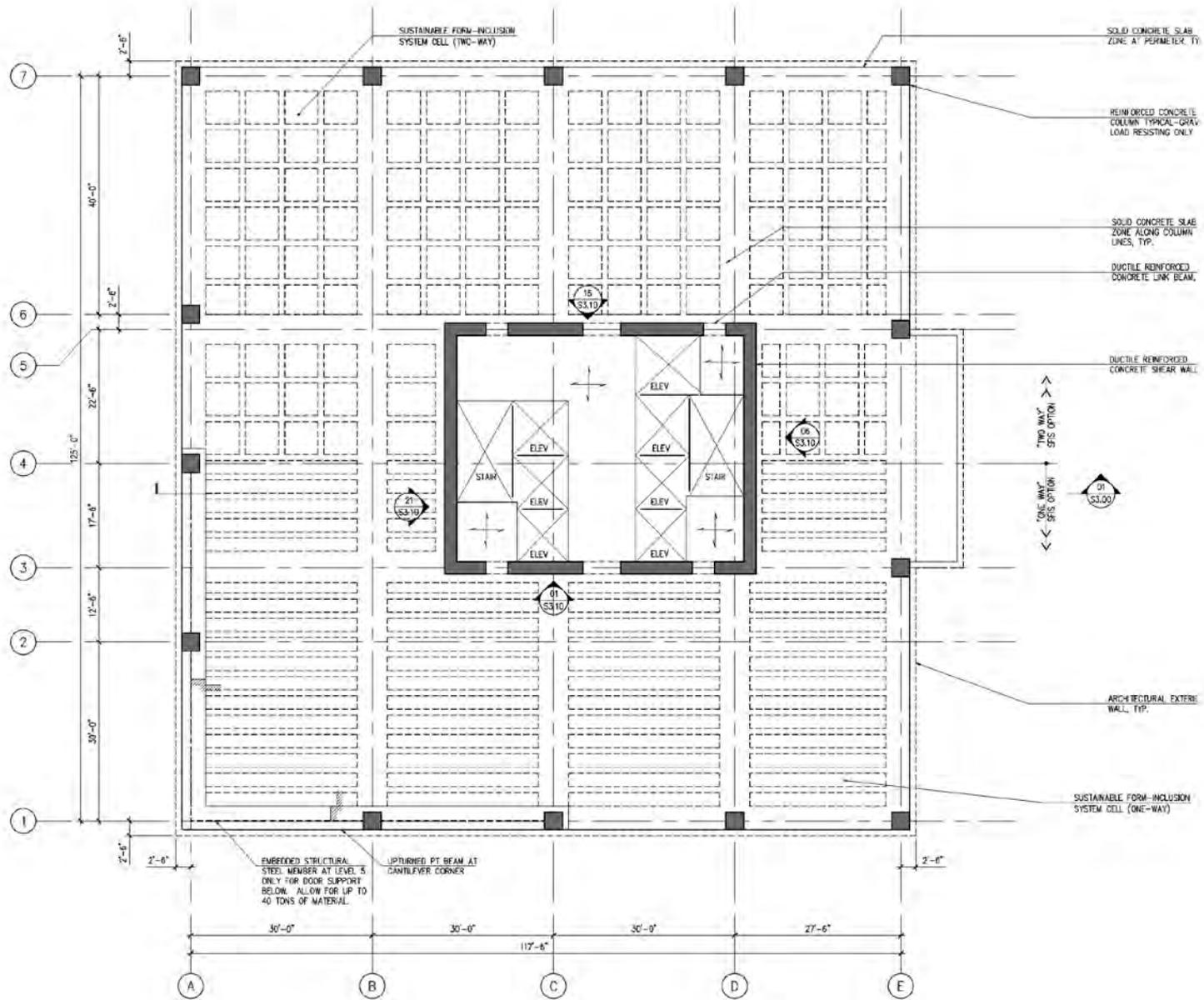
- (A) MIDDLE - MIDDLE STRIP - HIGHEST FORM INCLUSION QUANTITY
- (B) COLUMN - MIDDLE STRIP - MODERATE FORM INCLUSION QUANTITY
- (C) COLUMN - COLUMN STRIP - LEAST FORM INCLUSION QUANTITY TO NONE



FREMONT STREET

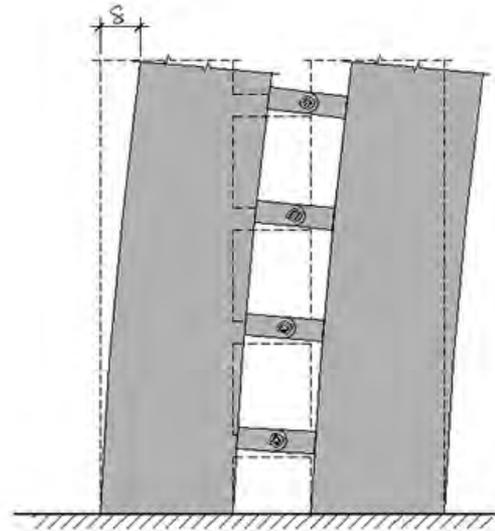
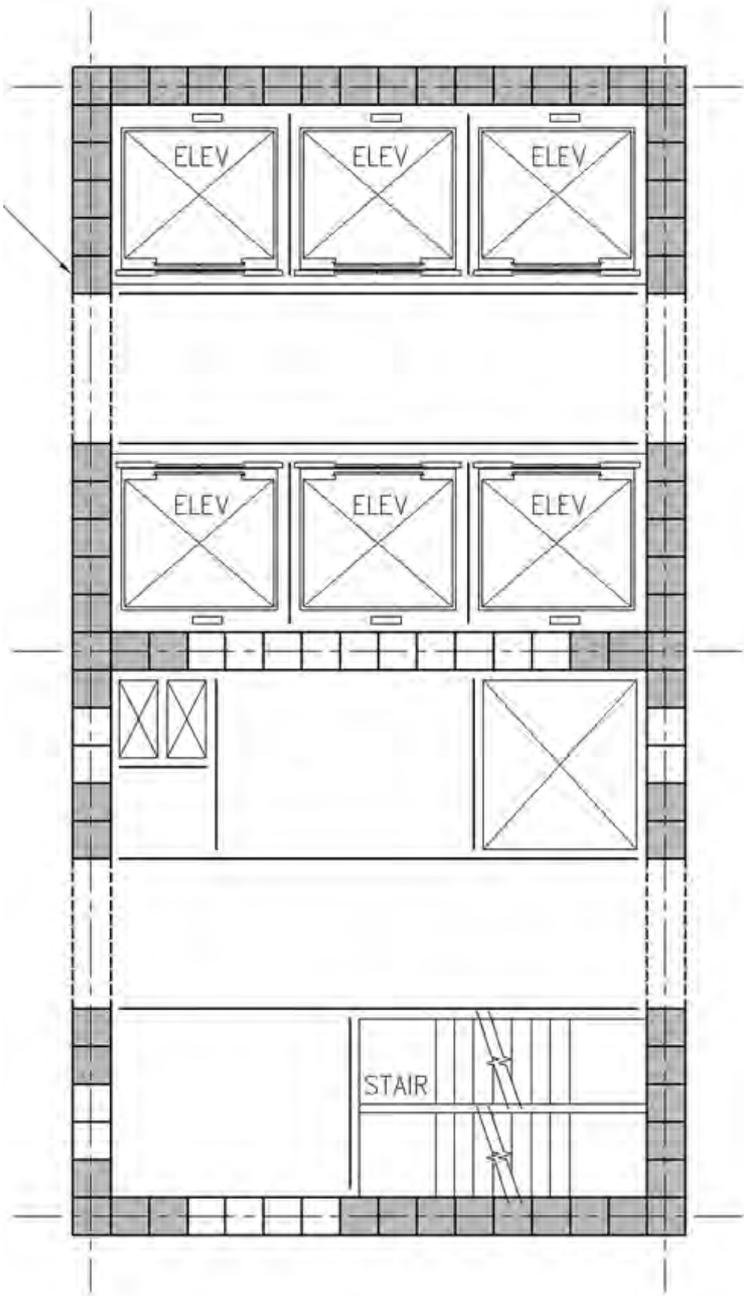


MISSION STREET

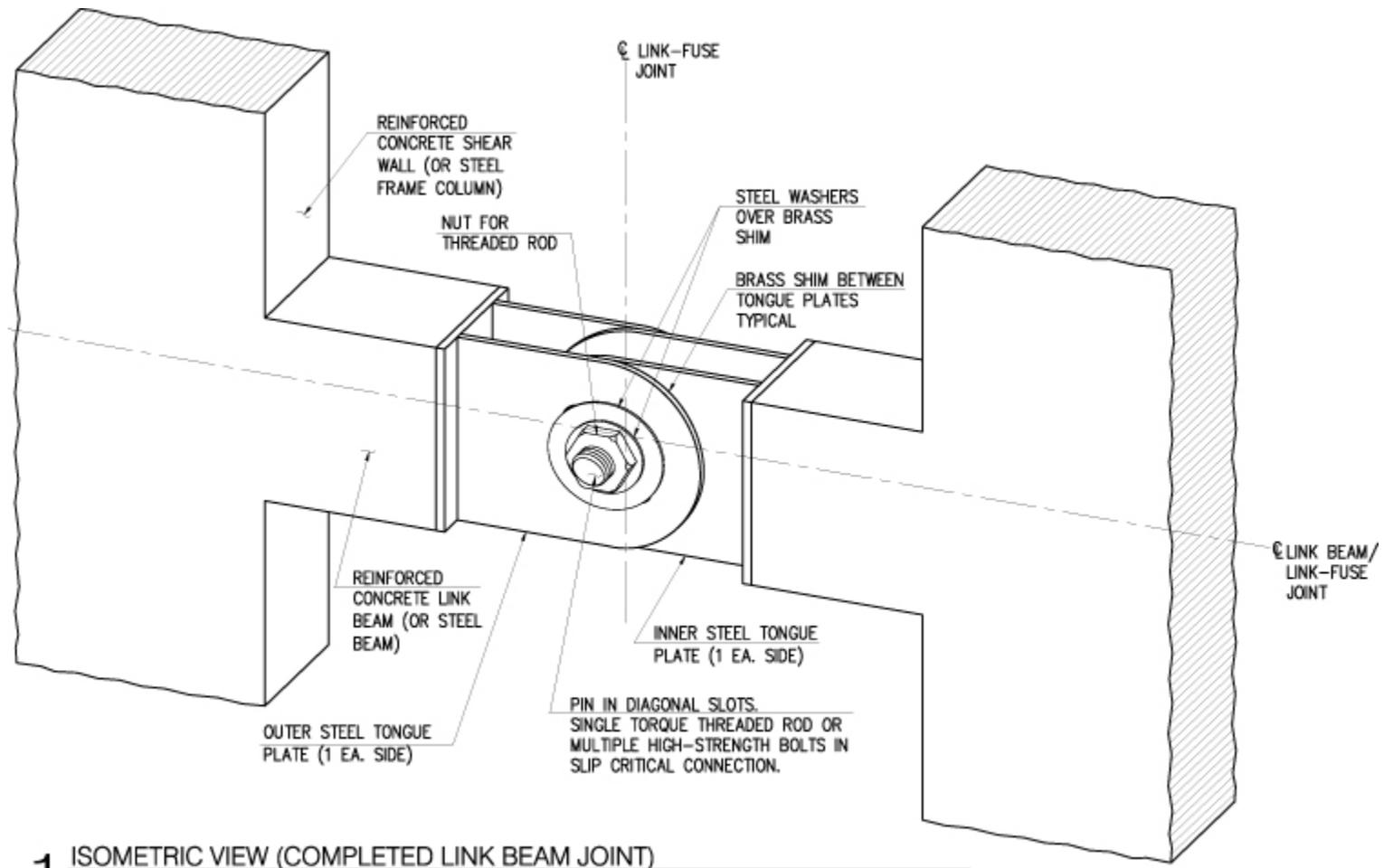








Link-Fuse Joint  
US Patent 7,647,734

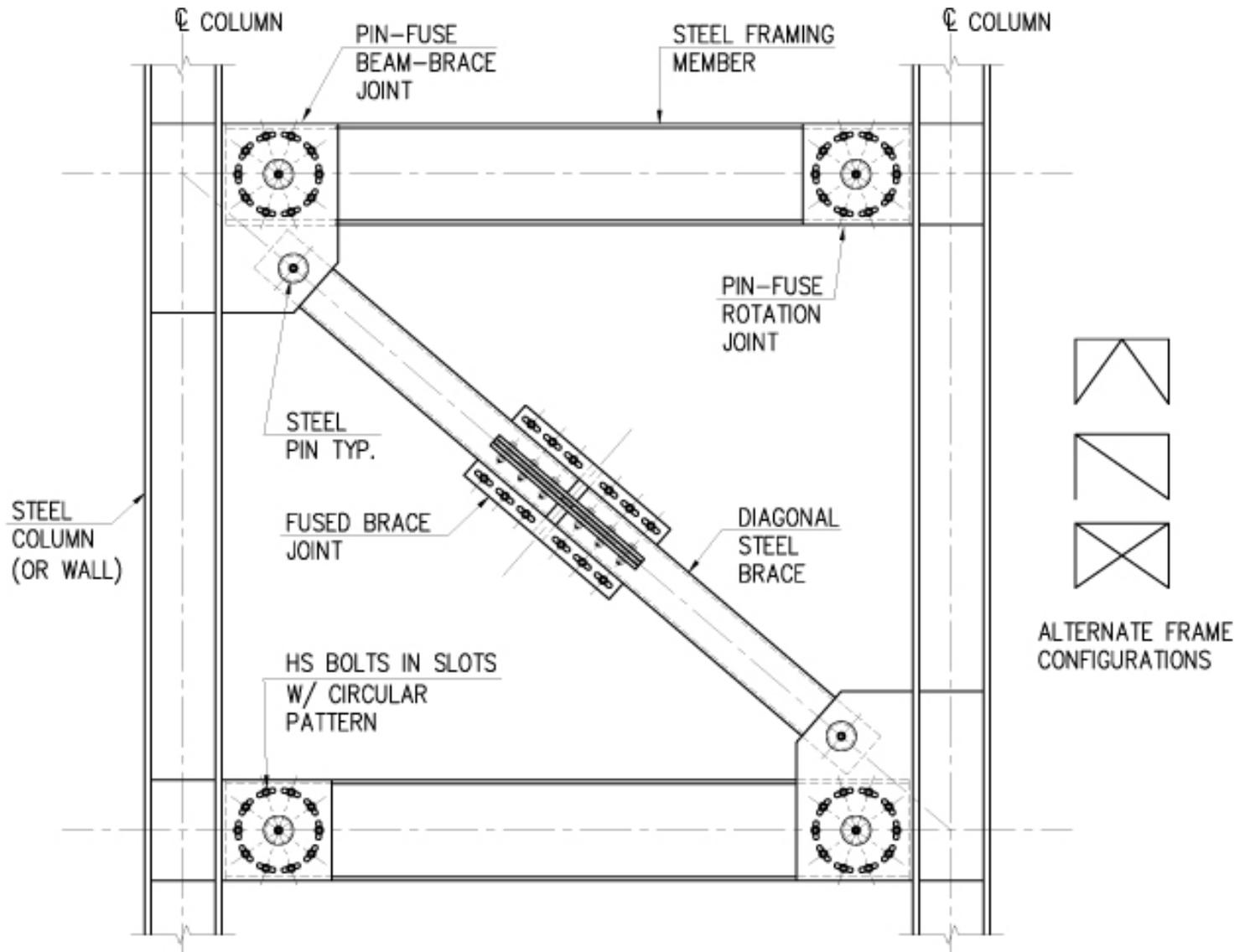


1 ISOMETRIC VIEW (COMPLETED LINK BEAM JOINT)



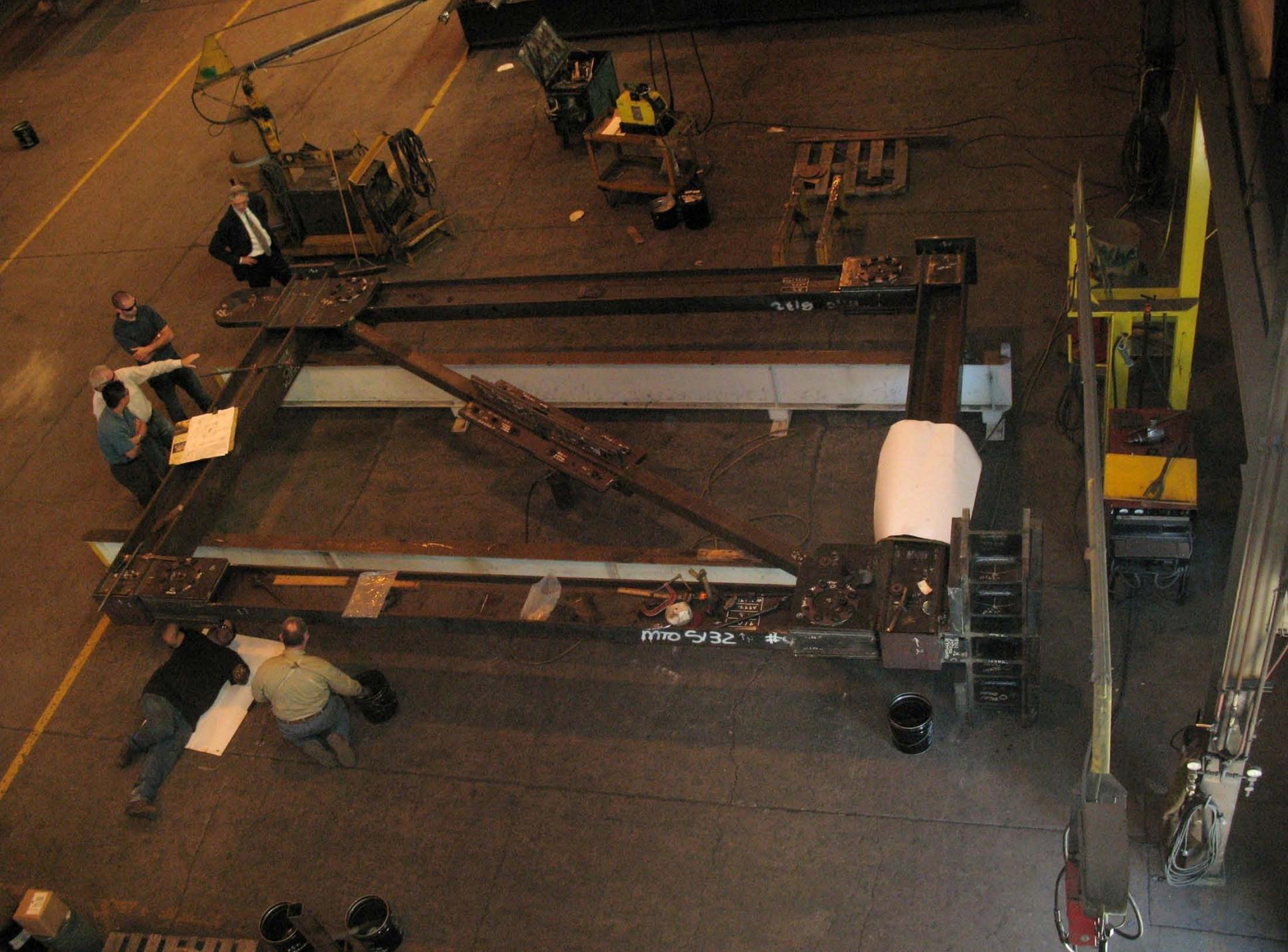
Pin-fuse Frame  
US Patent 7,712,266





## 2 ELEVATION PIN-FUSE FRAME

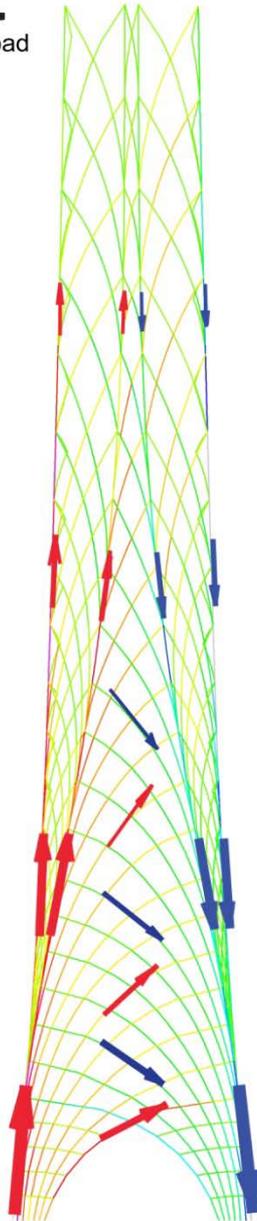
MPS  
3 MAR 07





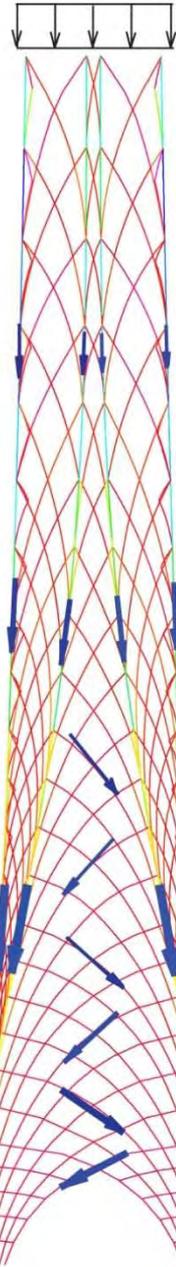


Lateral Load



Compression  
Tension

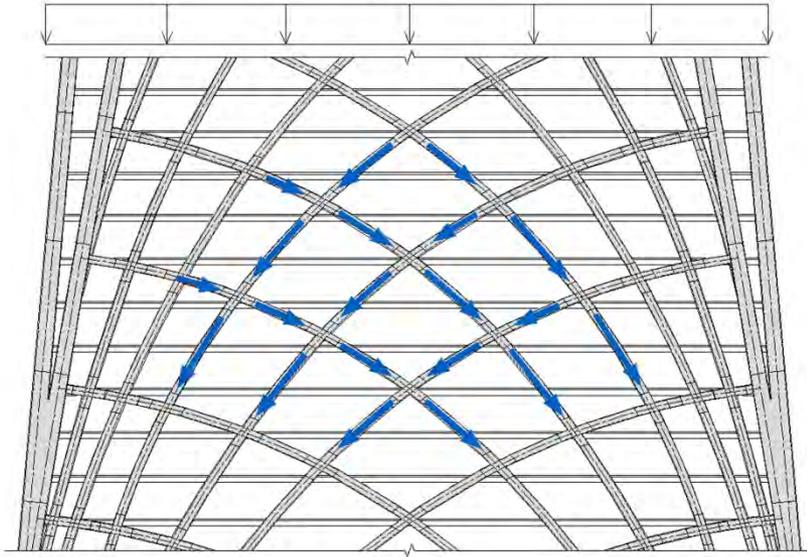
Gravity Load



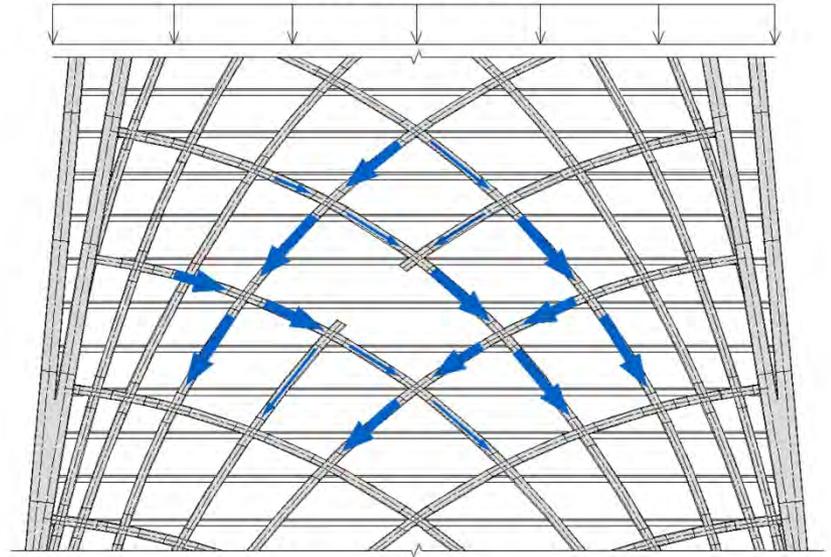
SOM

Force Flow Study

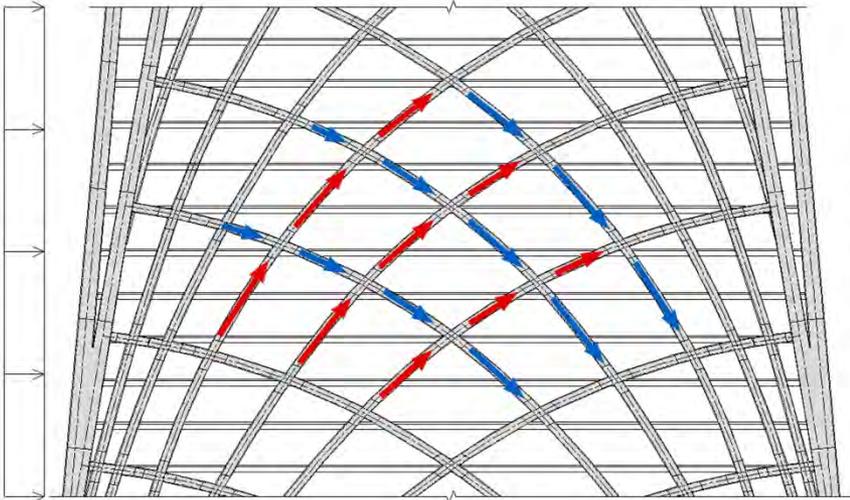
Gravity Load



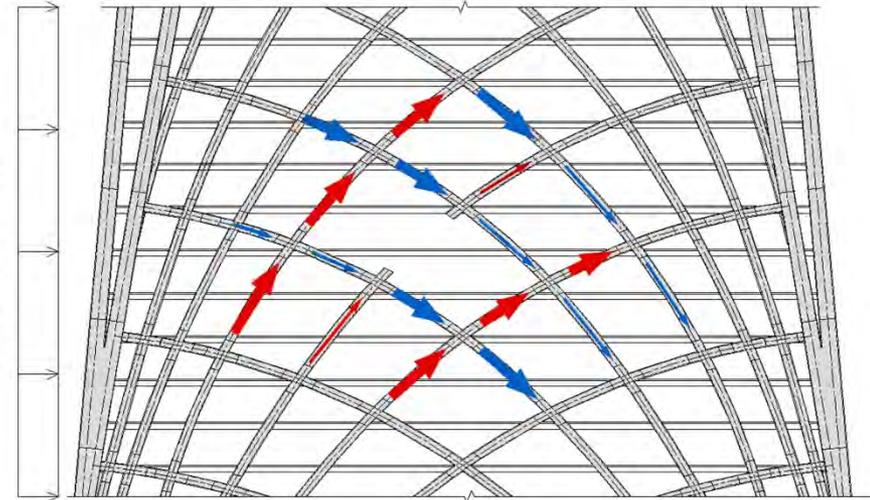
Gravity Load



Lateral Load



Lateral Load



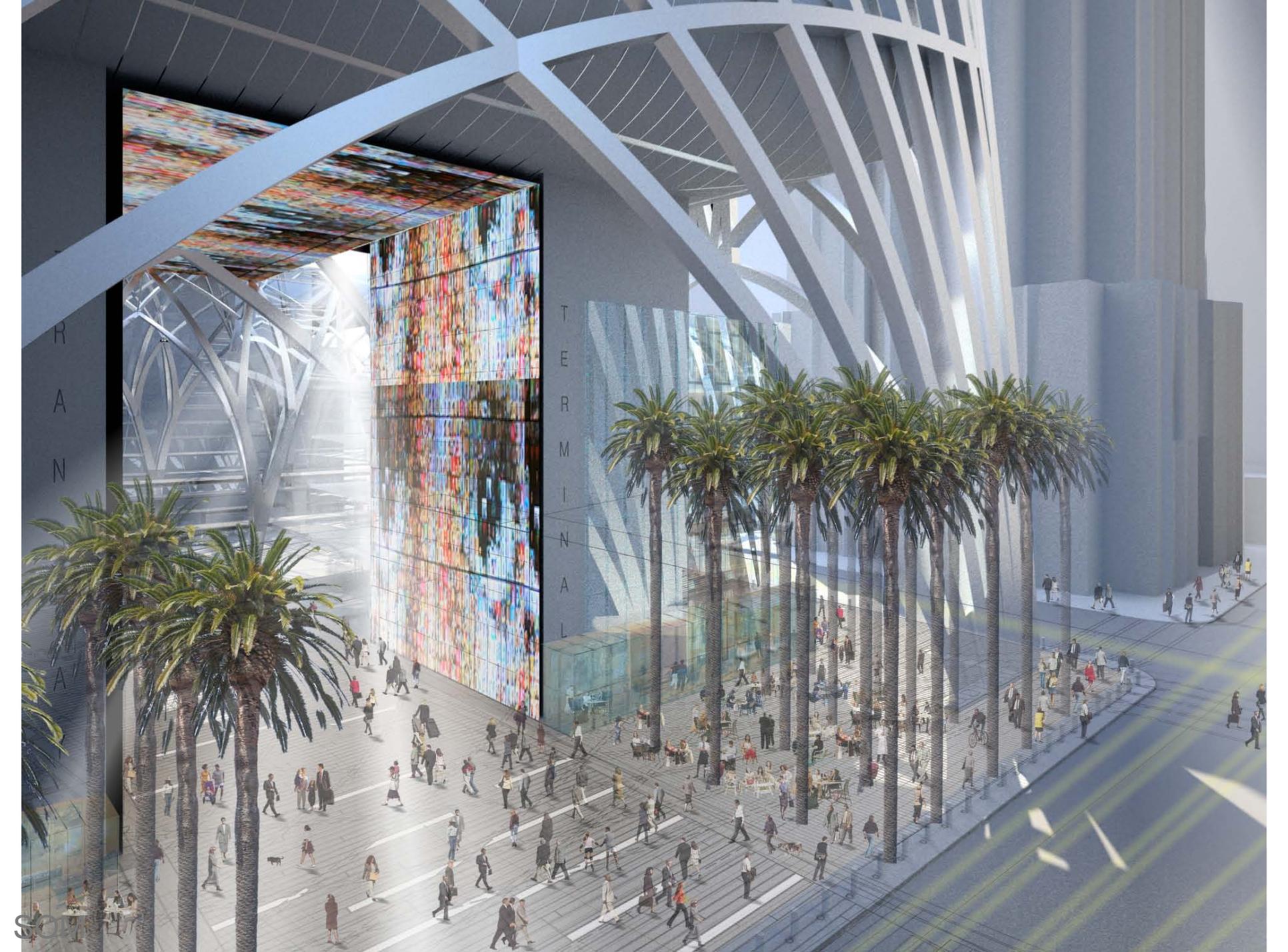






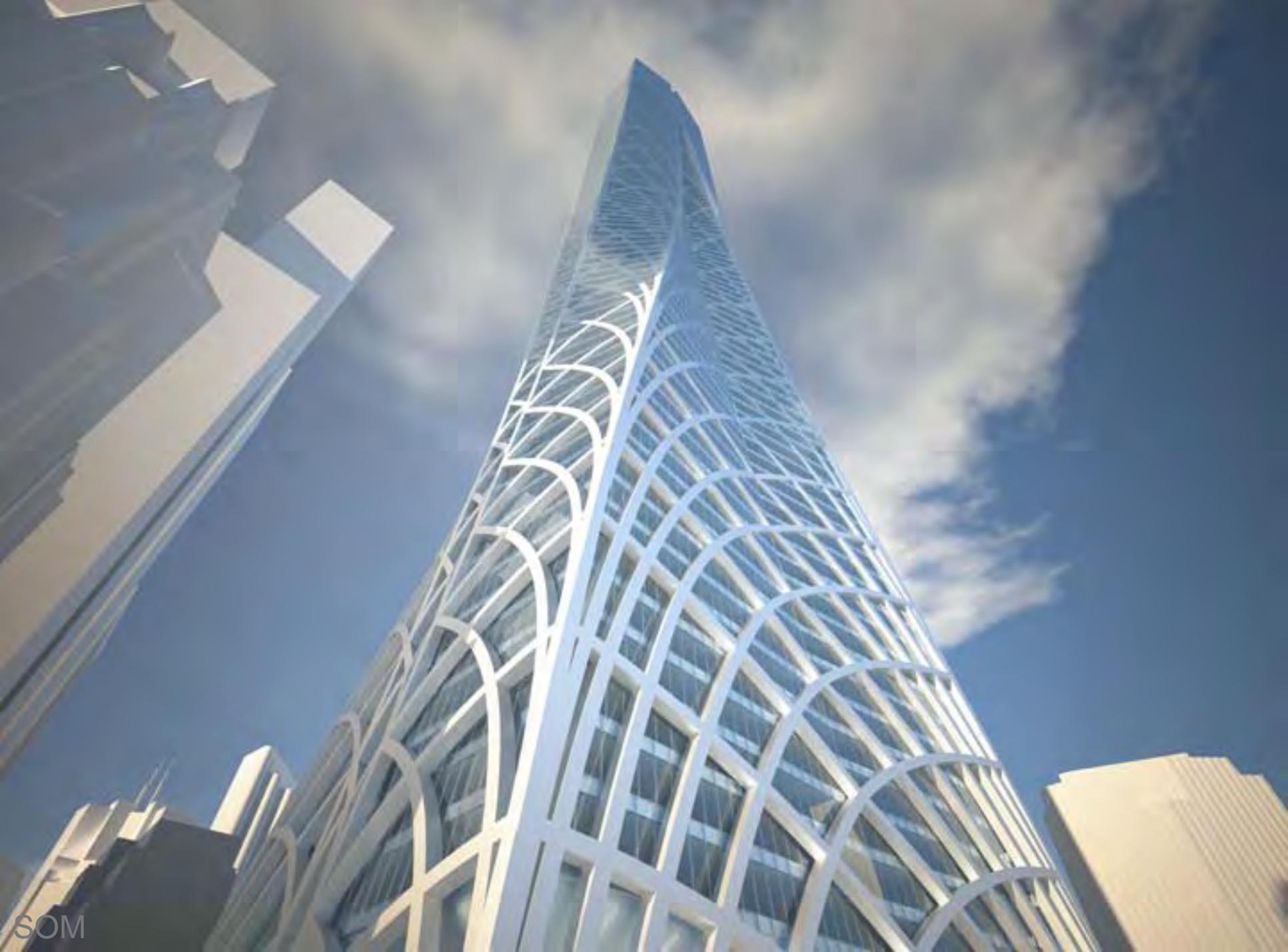


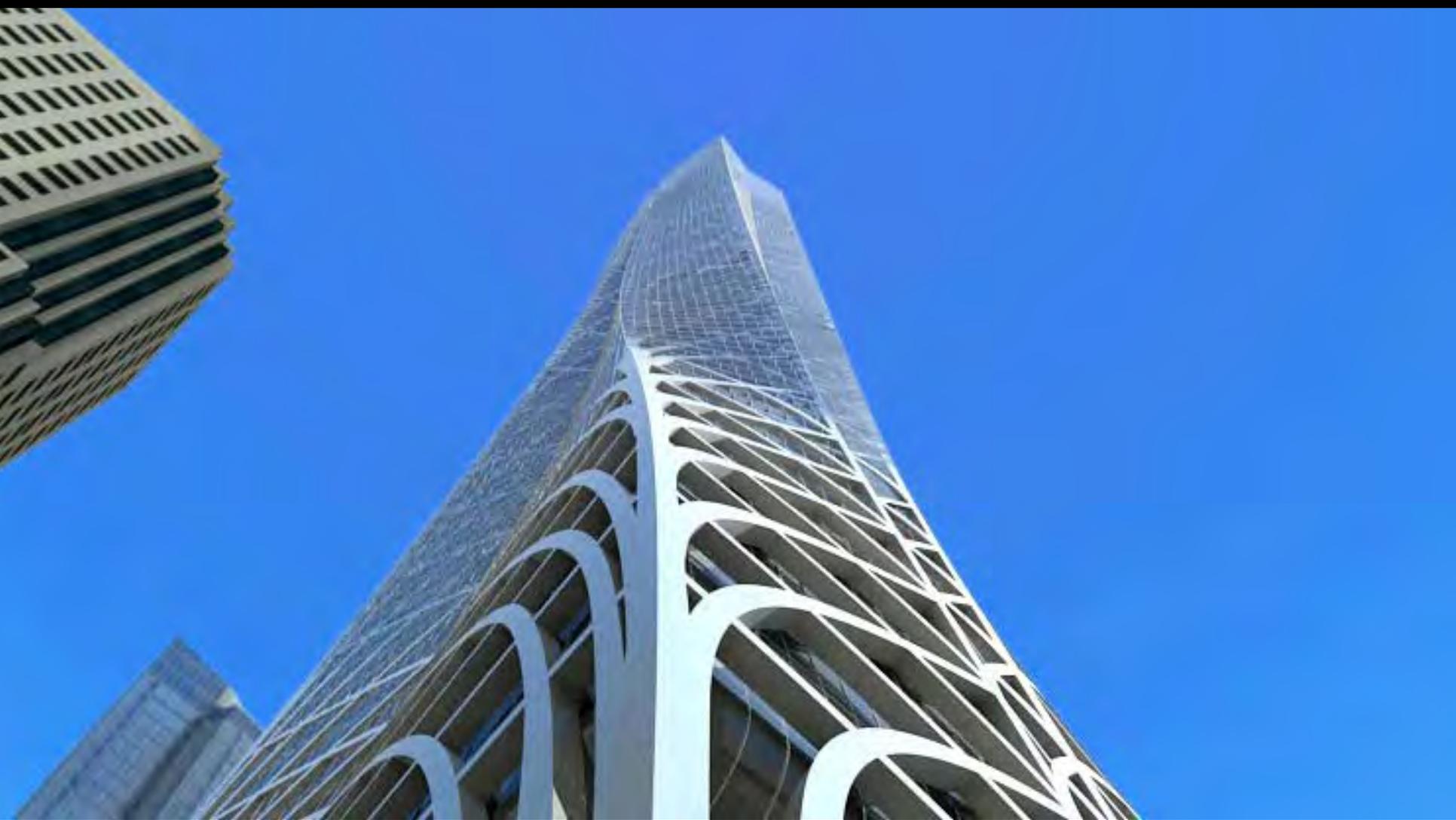




R  
A  
N

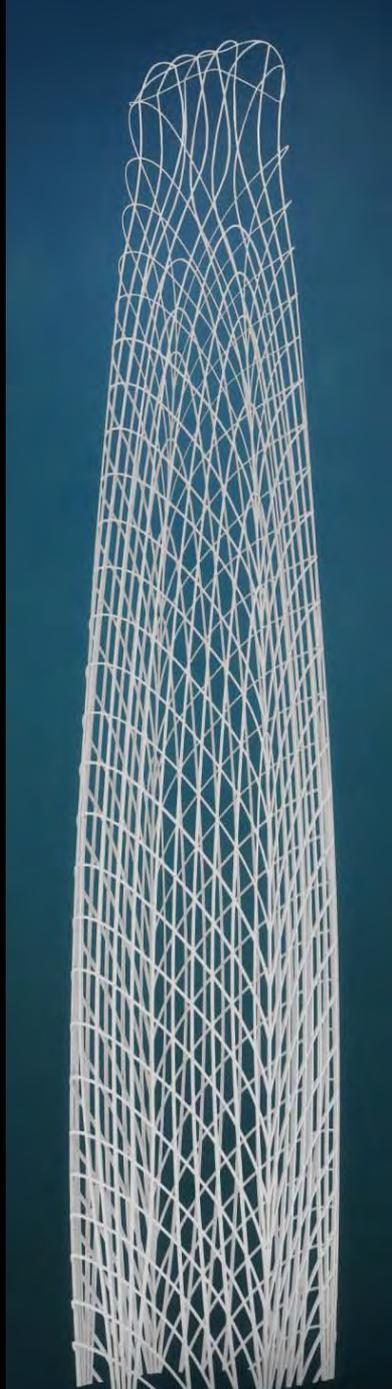
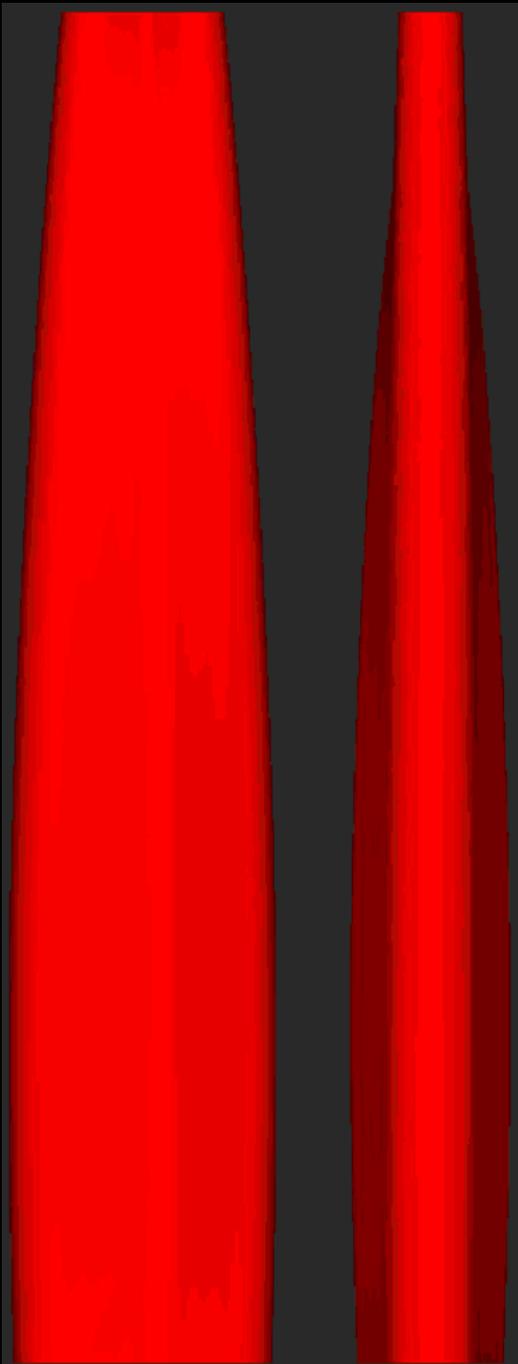
T  
E  
R  
M  
I  
N  
A  
L

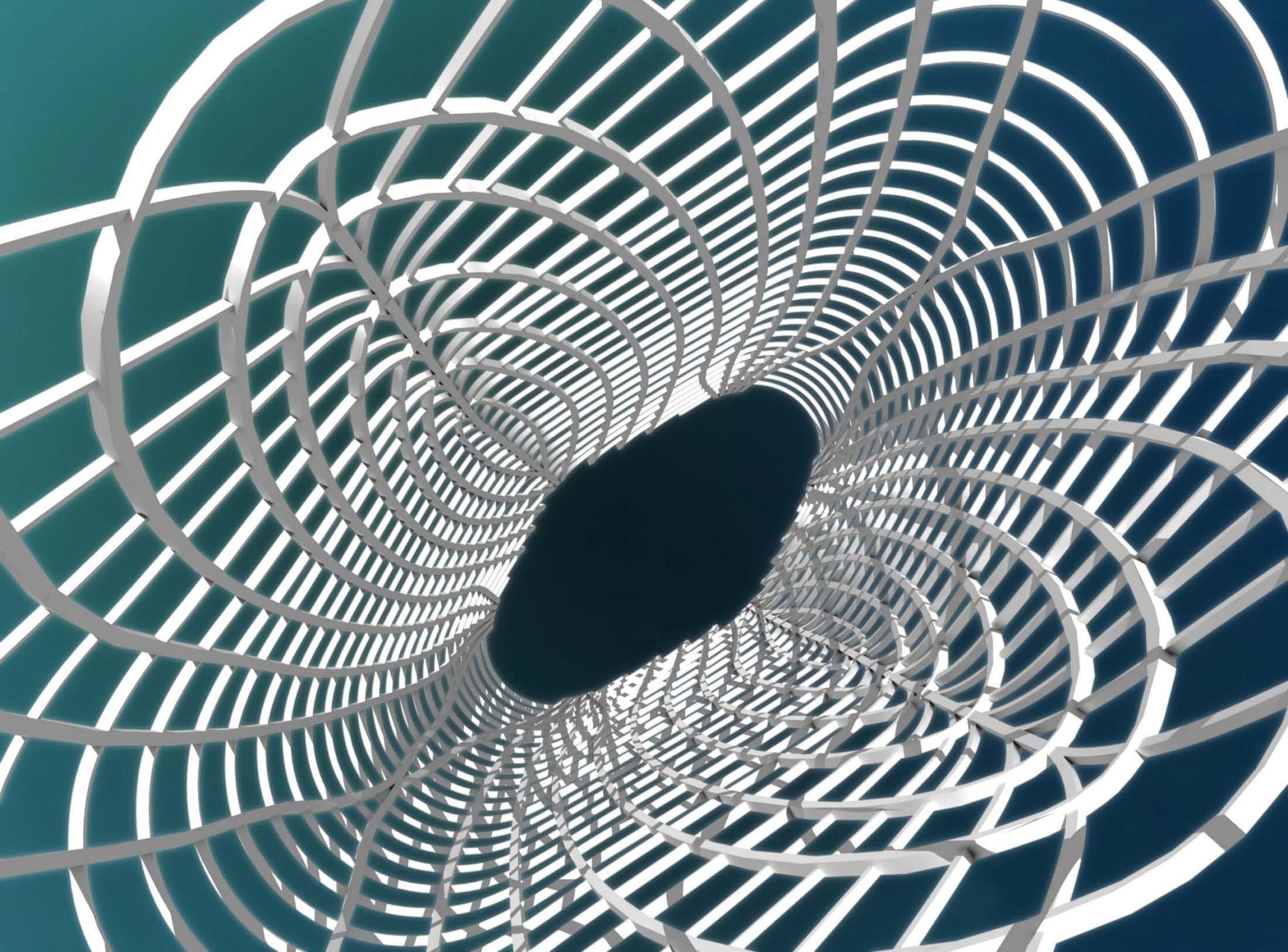


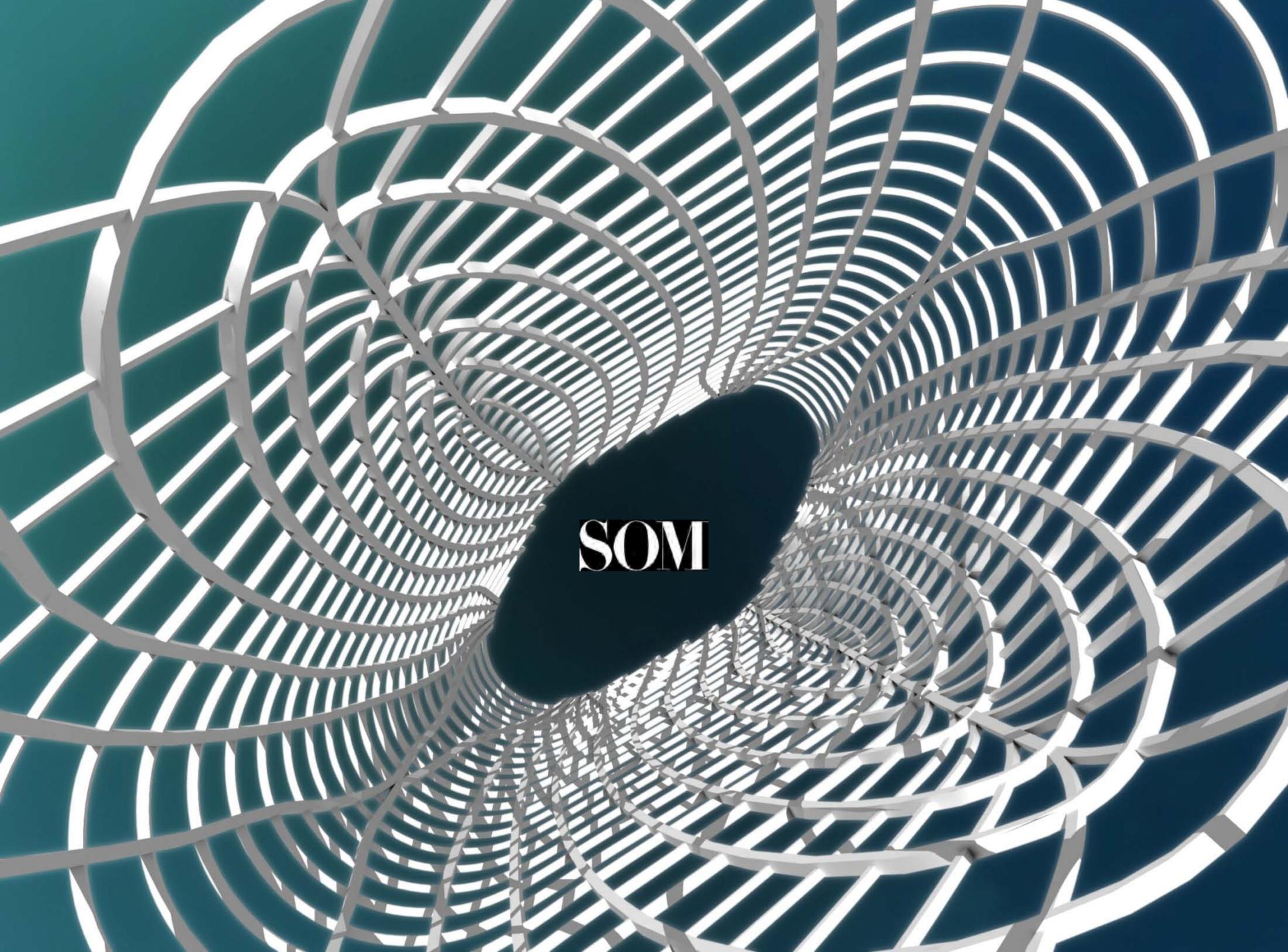










The image features a complex, three-dimensional geometric pattern of overlapping circles and lines, creating a tunnel-like effect. The pattern is composed of numerous thin, light-colored lines that form a series of concentric, overlapping circles. These circles are arranged in a way that they recede into the distance, creating a strong sense of depth and perspective. The overall color palette is a mix of light and dark teal, with the lines themselves appearing as a pale, almost white color against the darker background. The pattern is centered and fills most of the frame, with a dark, irregular shape in the middle containing the text 'SOM'.

**SOM**