Blackwell

Reciprocal Framing Systems

David Bowick, P.Eng.

Blackwell

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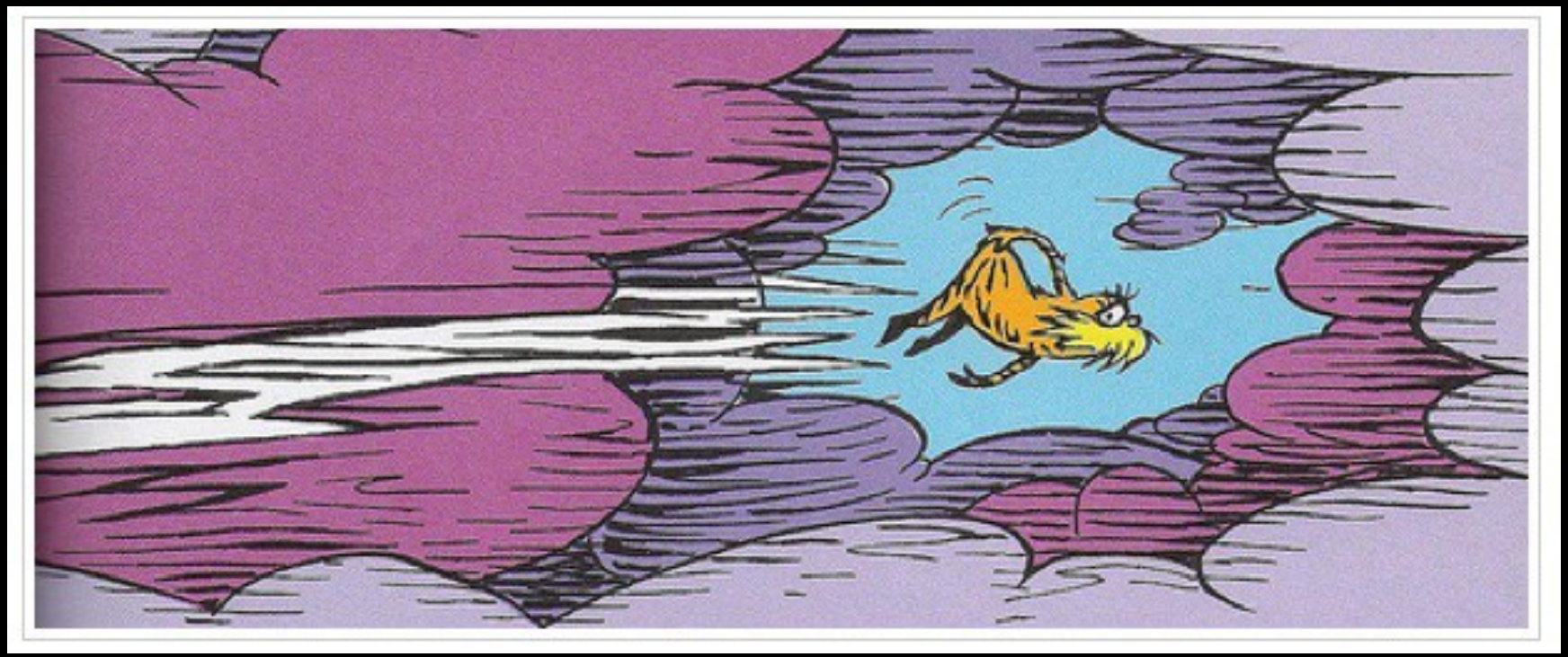
WHAT

Reciprocal Frame - “A structure made up of mutually supporting beams in a closed circuit”

Reciprocal Frame Architecture
Olga Popovic Larsen, 2008

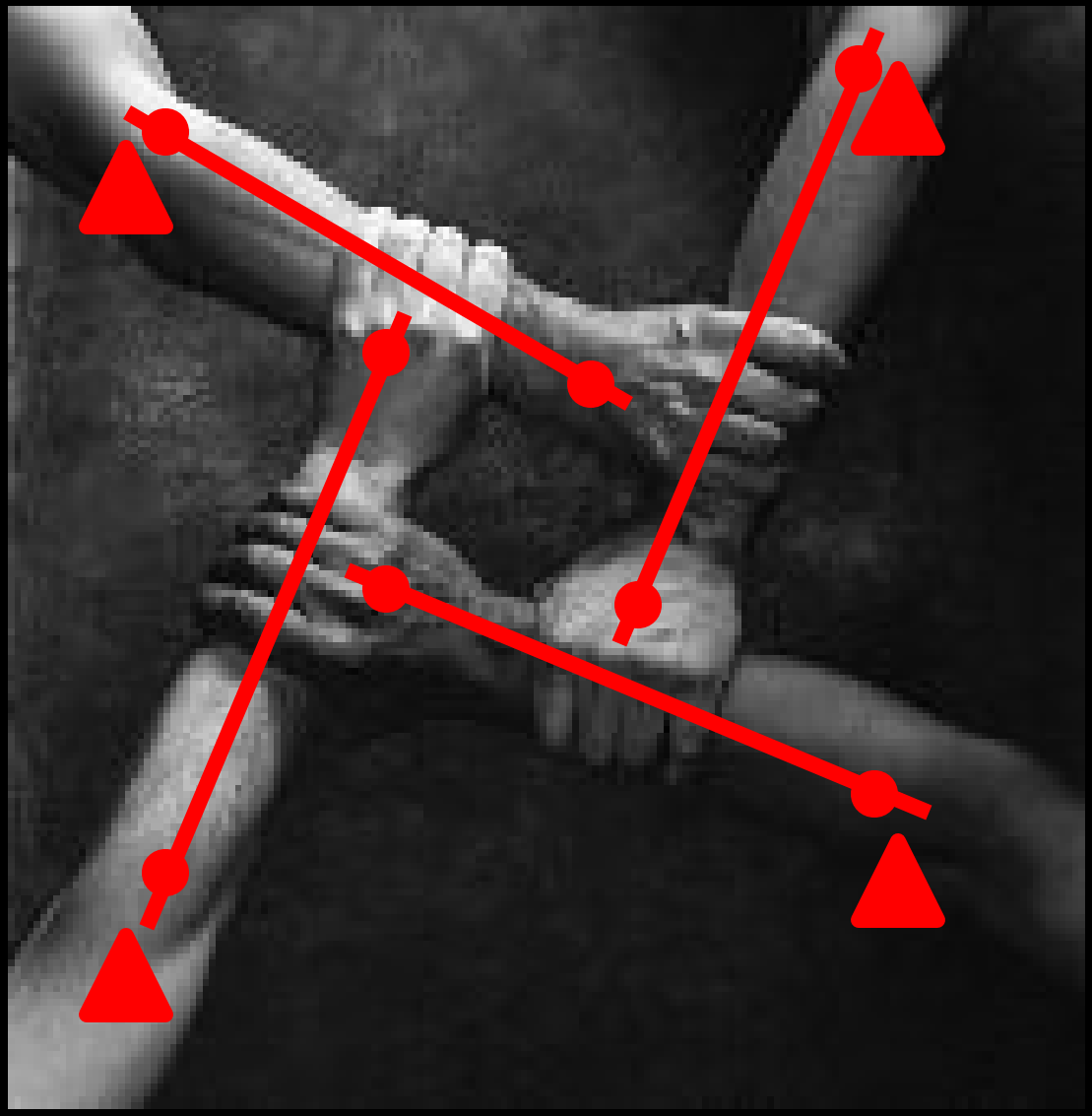
“He lifted himself by the seat of his pants
and I'll never forget the grim look on his face
as he hoisted himself and took leave of this place “

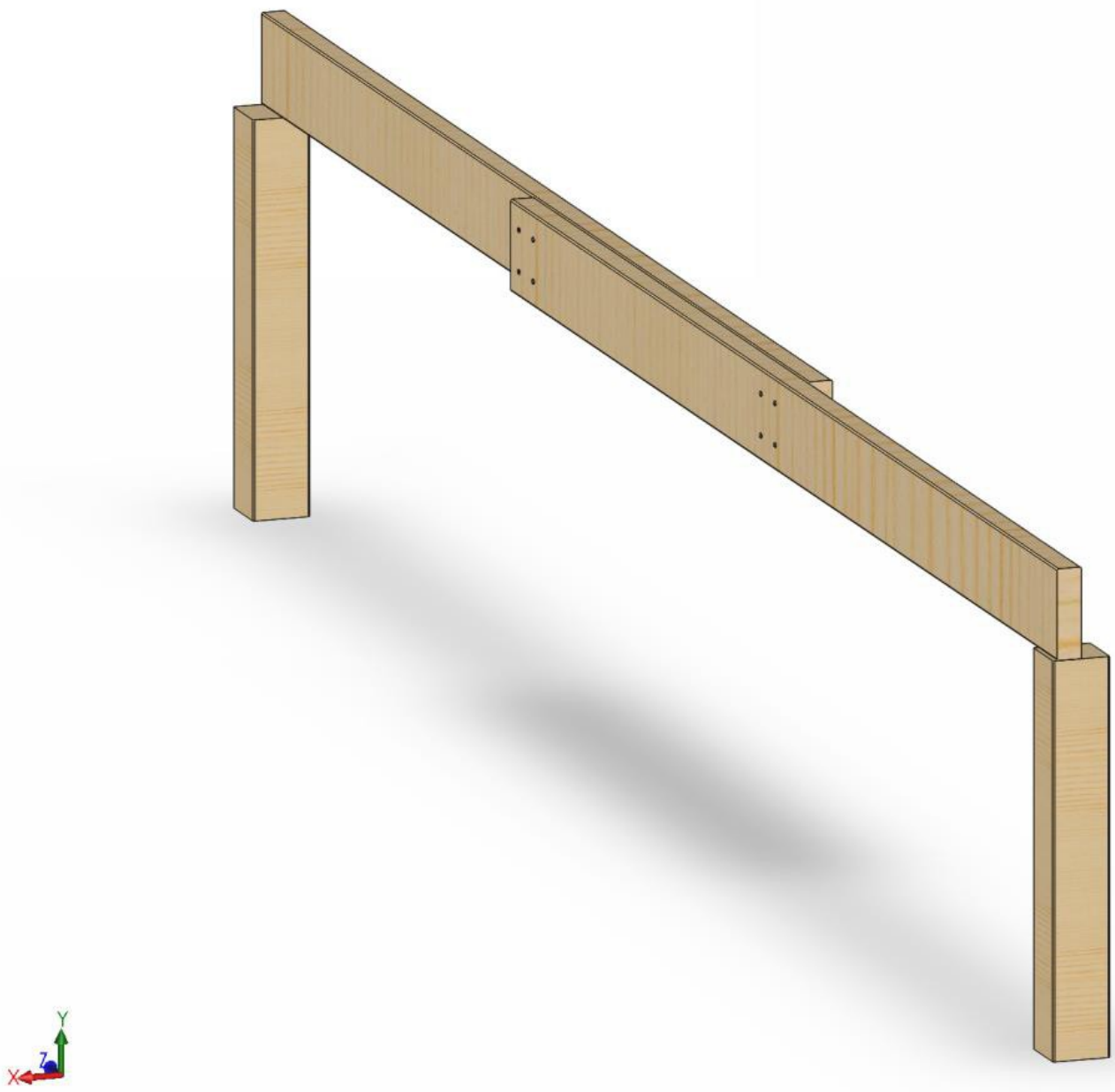
- The Lorax
Dr Suess, 1971



Reciprocal Frames

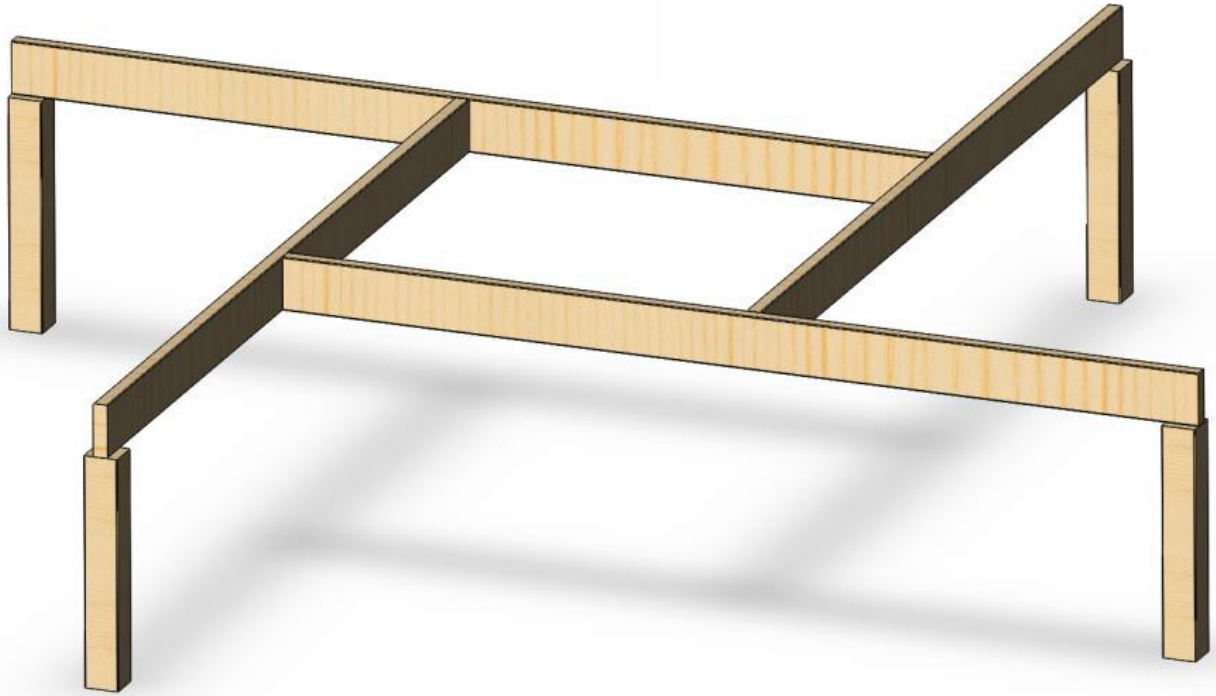
How it Works




Y
Z
X

100% of 1 Beam

100% of 1 Beam



100% of 1 Beam

100% of 1 Beam

WHY

- Span
- Geometric Complexity
- 2-Way Action
- Folly

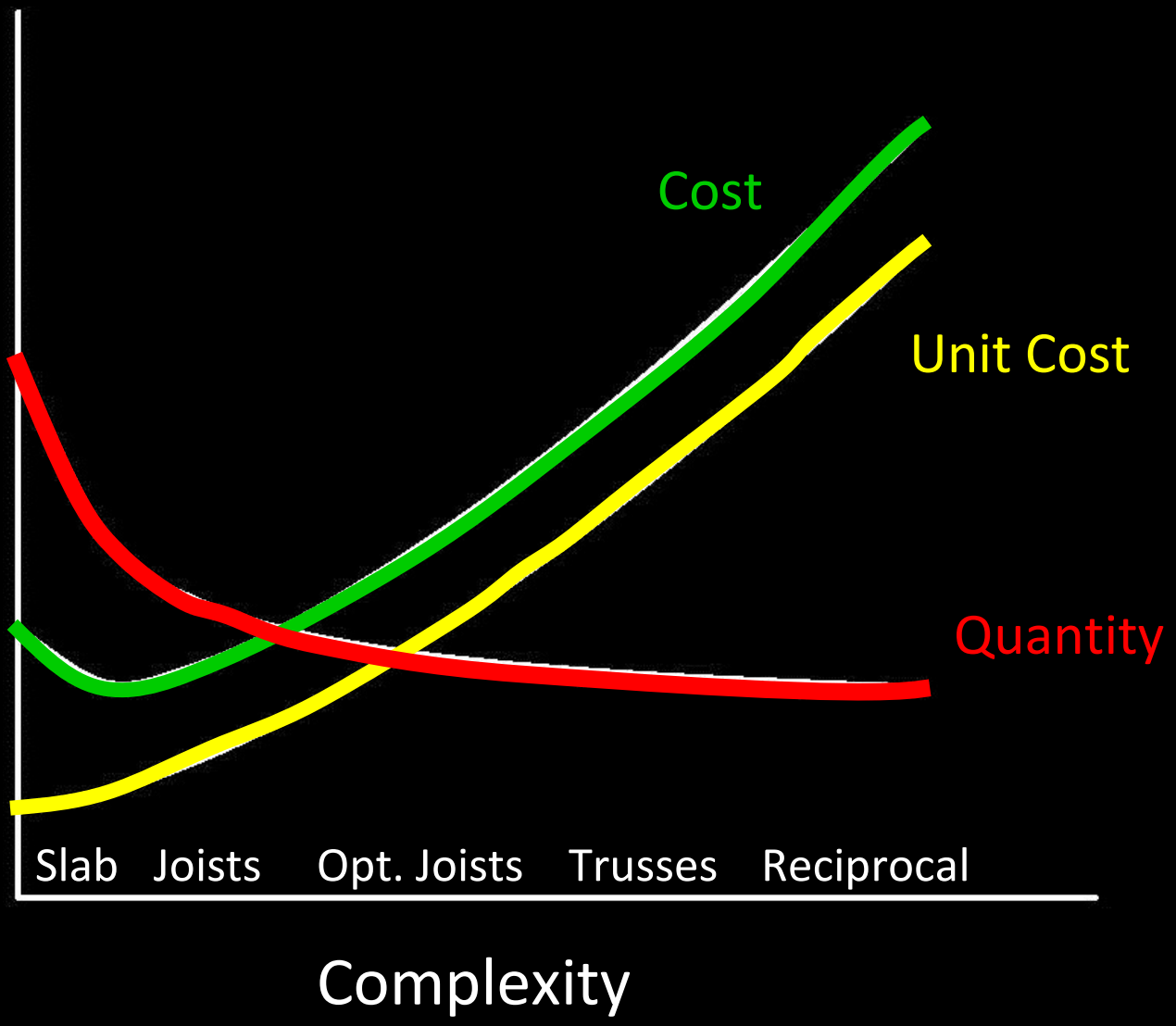
Efficiency – The great Myth

Taught the answer is usually repetition, but is that true?

Repetition
Piece Count
Volume

More complex can be cheaper

Complexity Curve



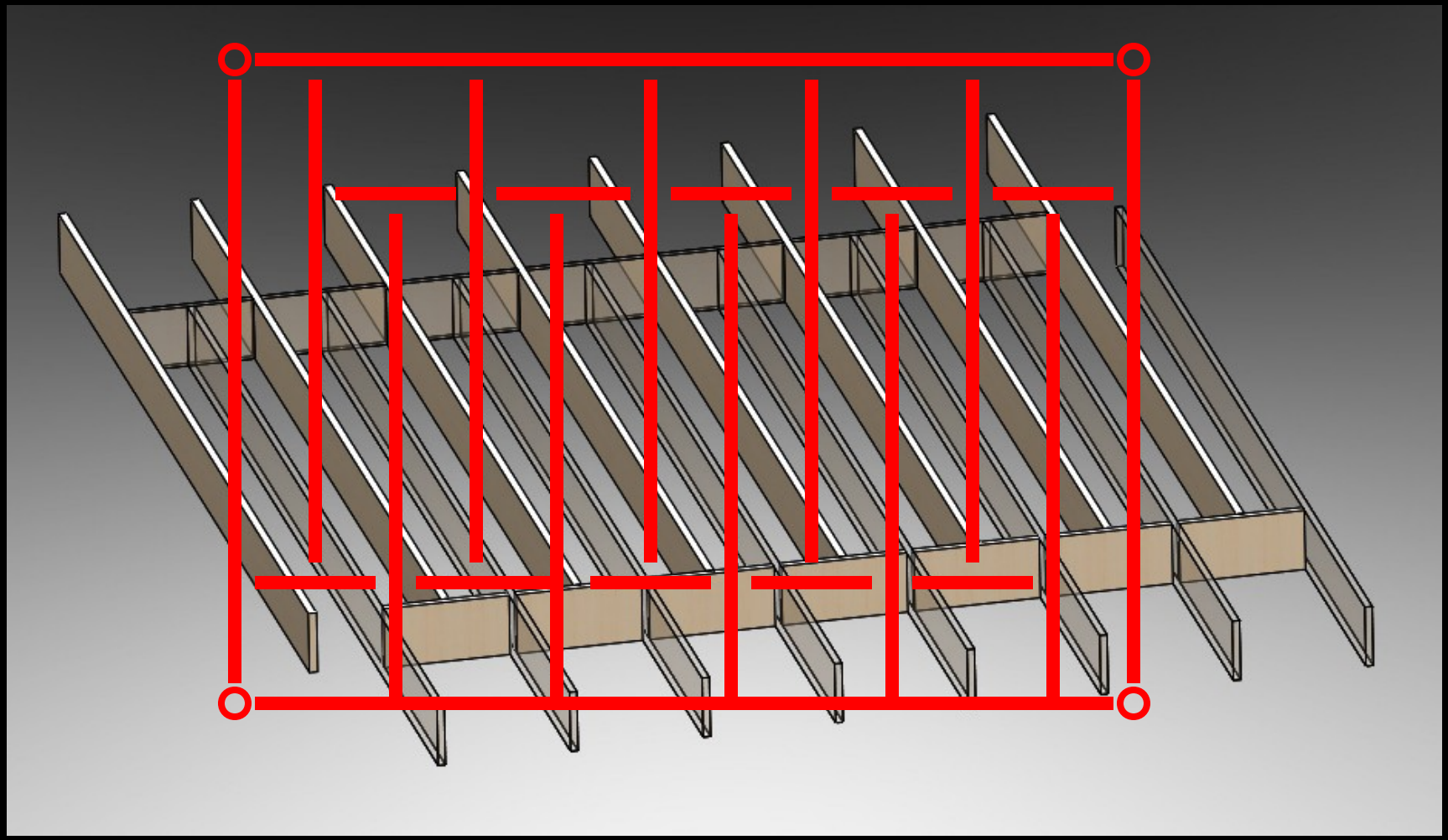
Price vs. Cost

$

“But Dave, we want an example of efficient, complex construction!”

SPAN

How do you use a 16’ joist to span 20’?



FOLLY

When a problem is redefined to suit a preferred solution.

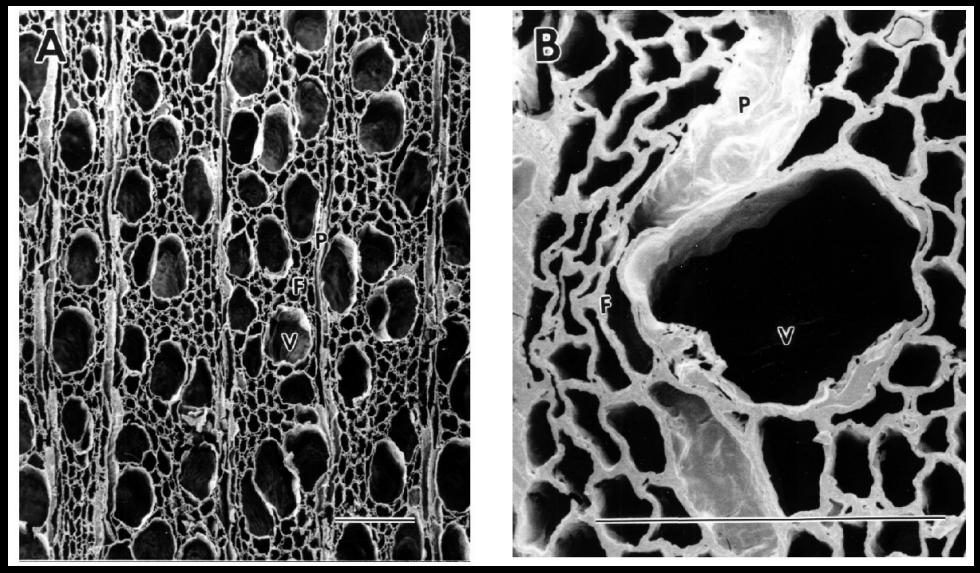
Image from minktoast.net

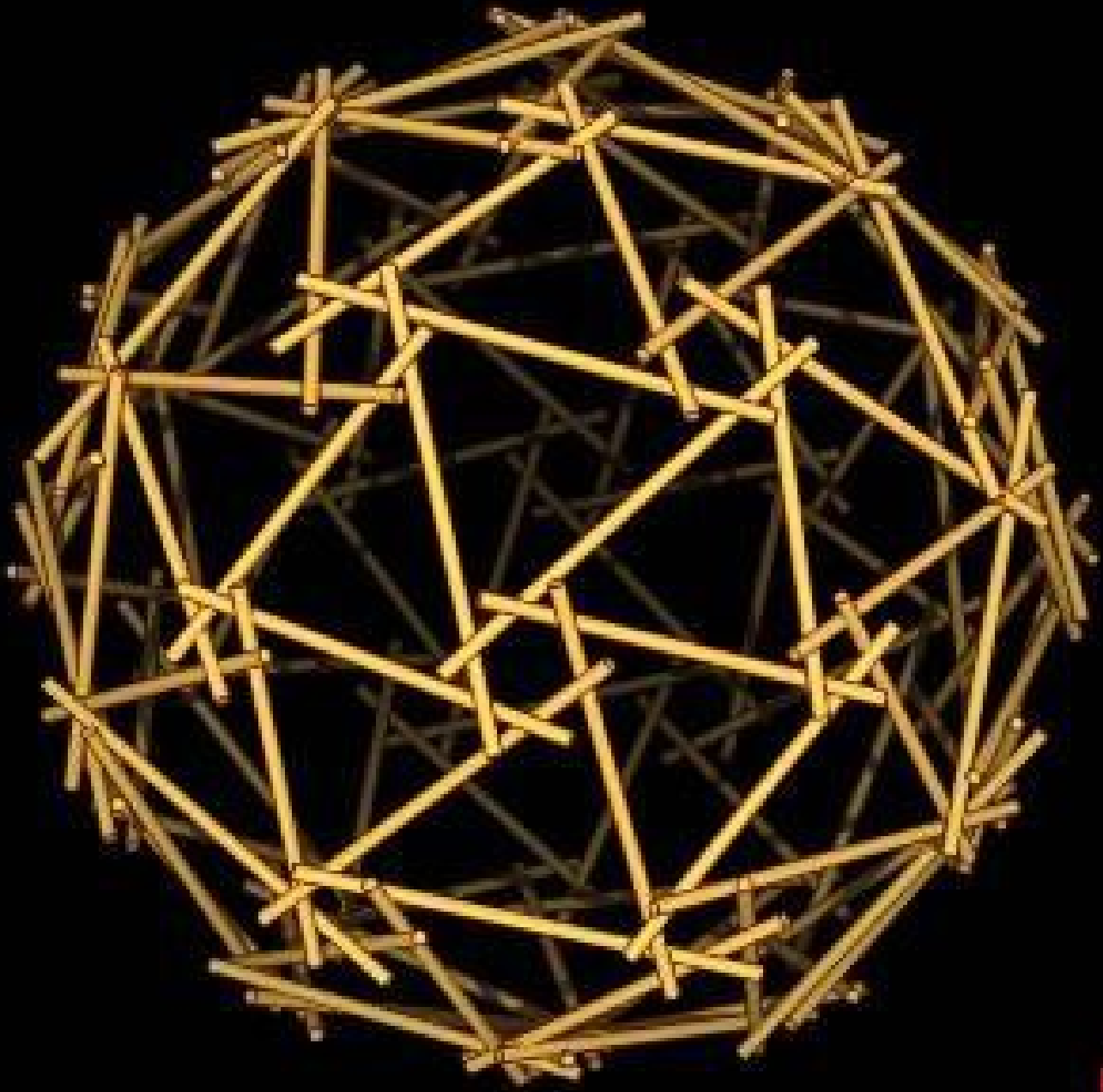
COMPLEXITY

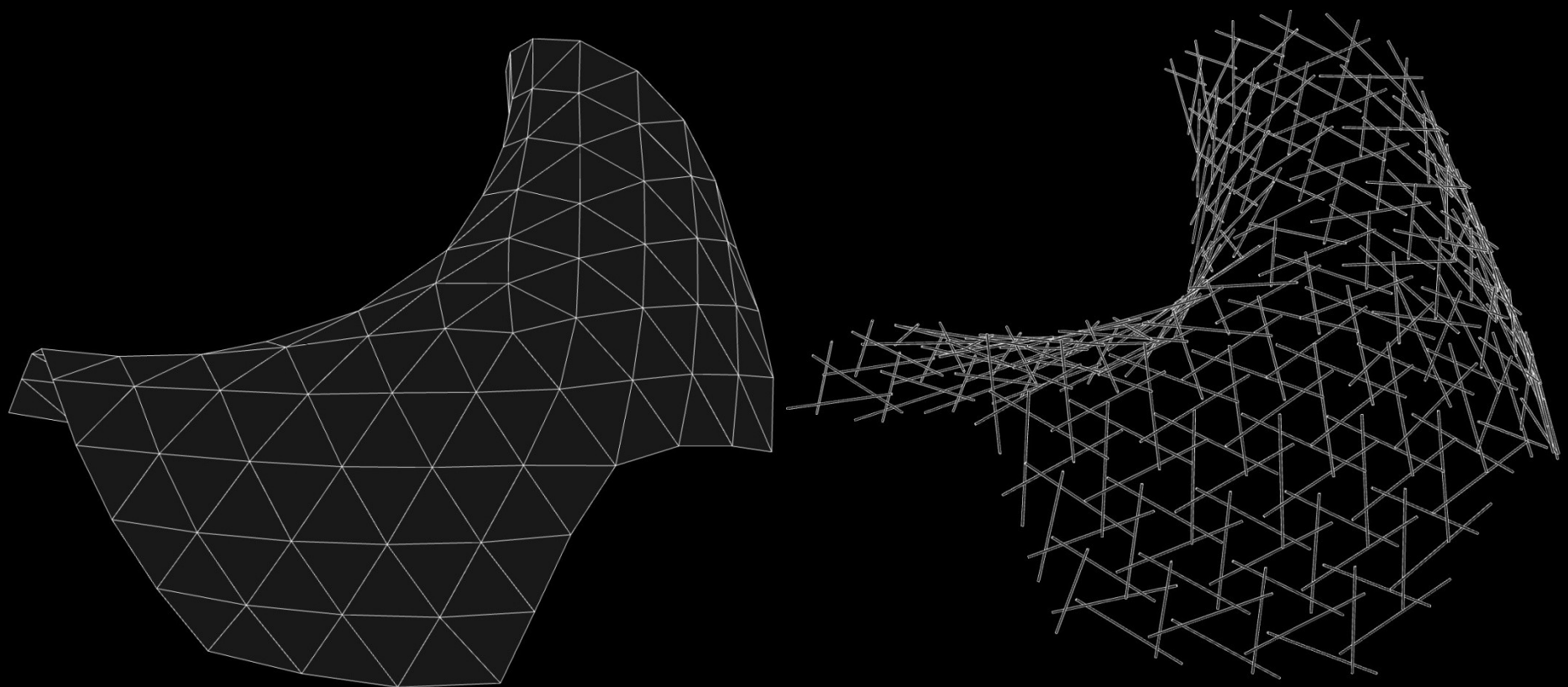
Lamella

-“A thin scale, plate, or laye
r of bone or tissue…”

- The American Heritage®
Dictionary of the English
Language

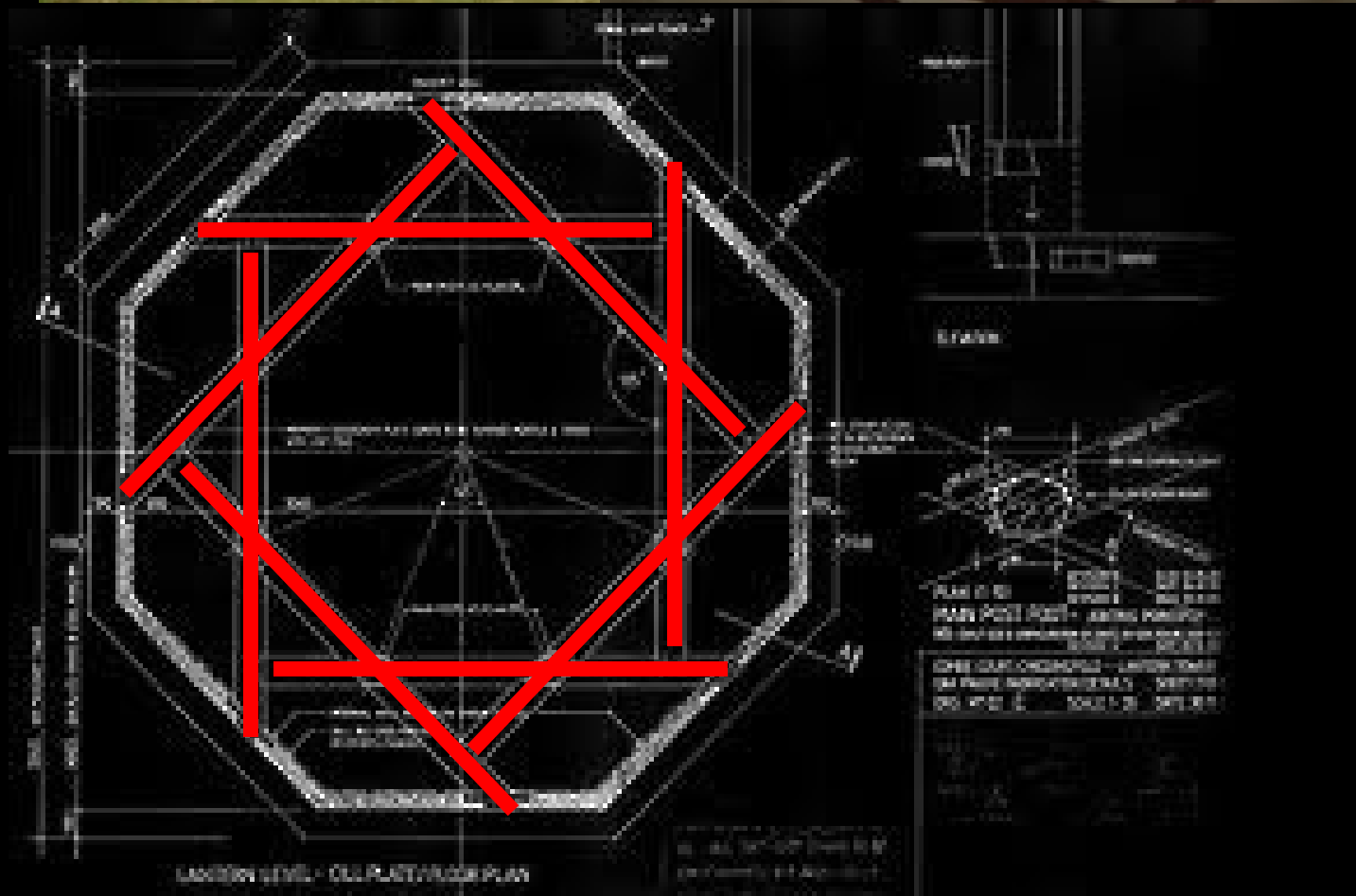






http://www.grasshopper3d.com/

2-WAY



“But Dave, show us some examples!”

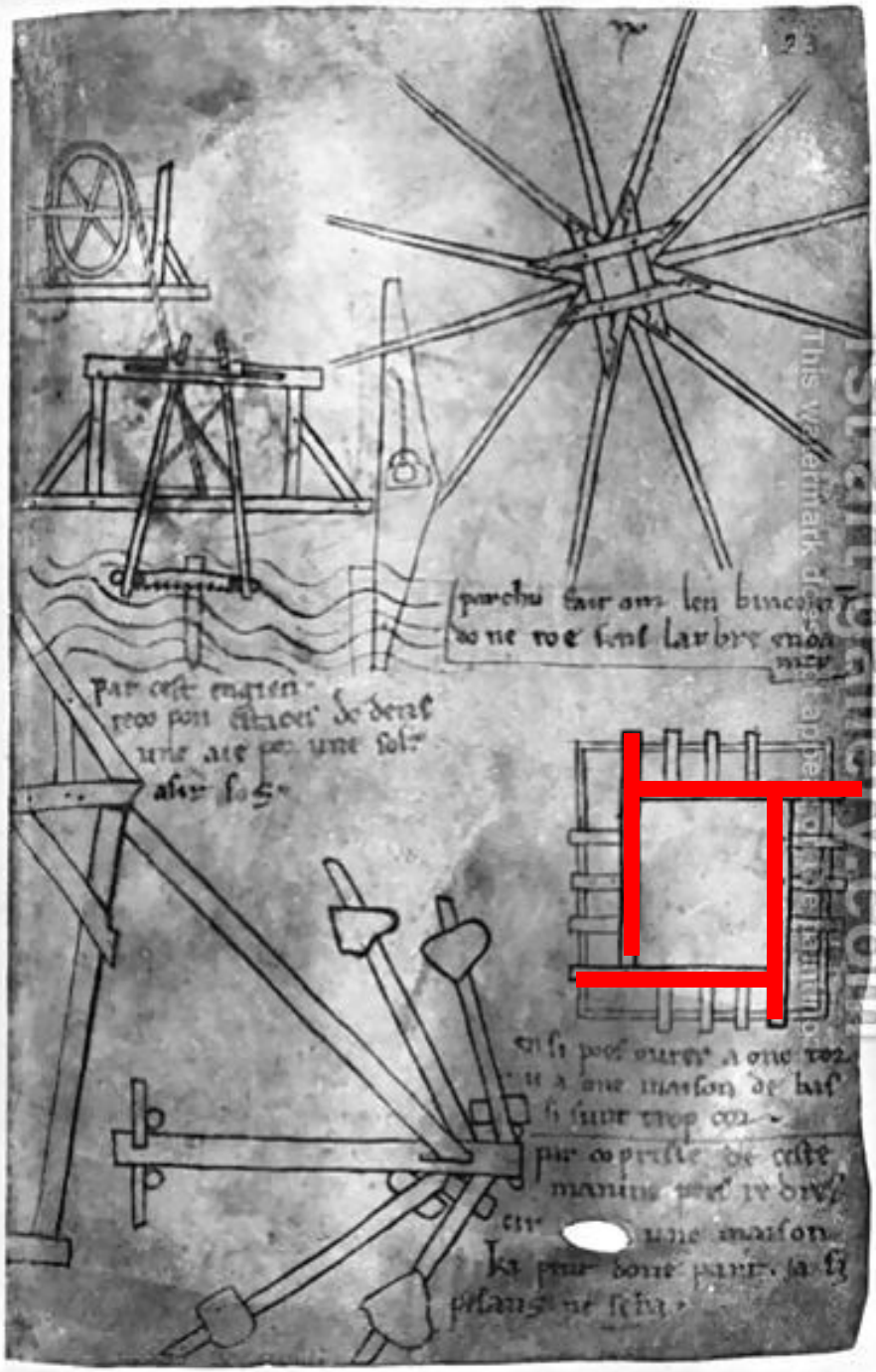
HISTORY

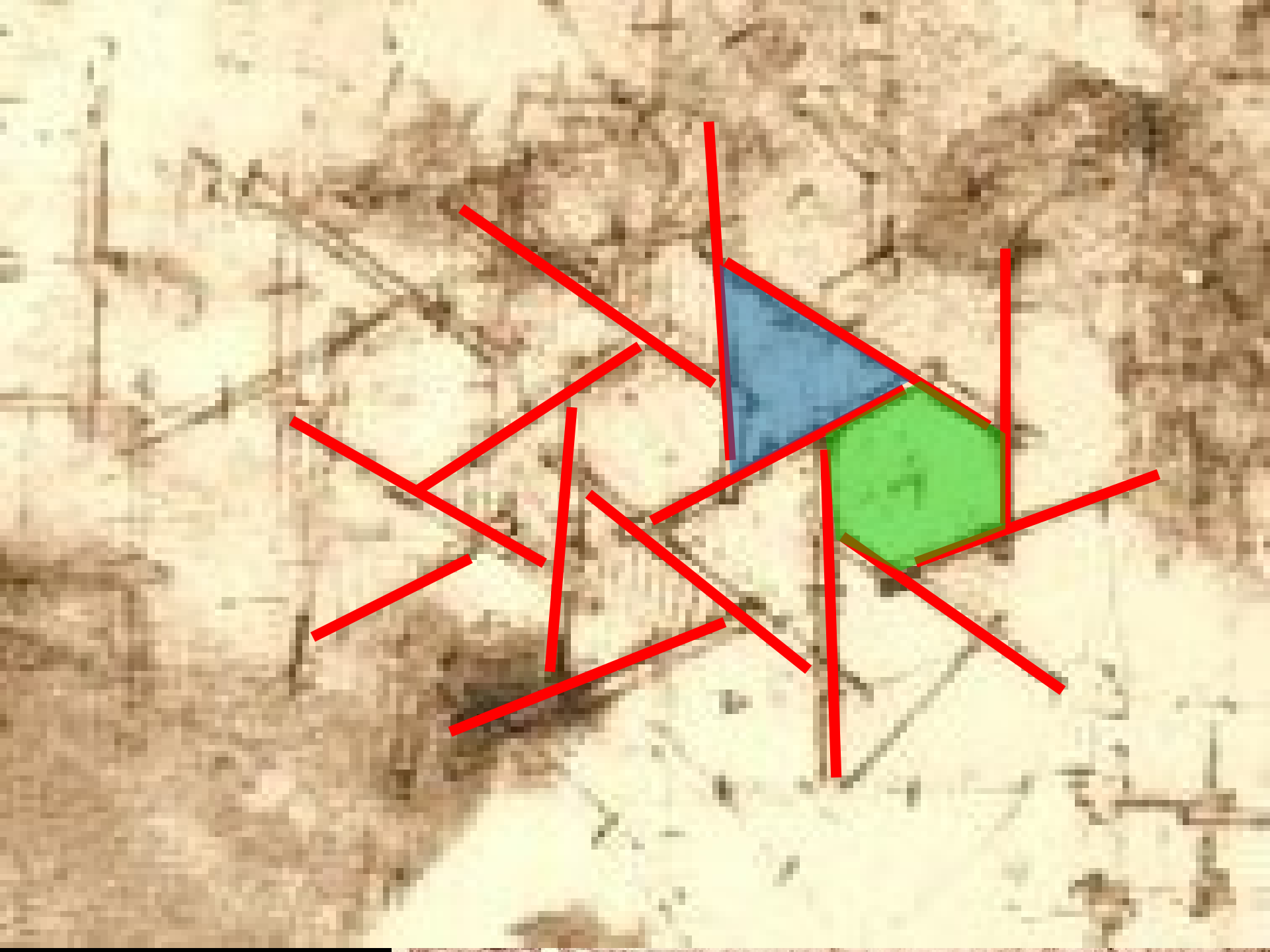
1270 - Present

Villard de Honnecourt

Reciprocal frame Sketches

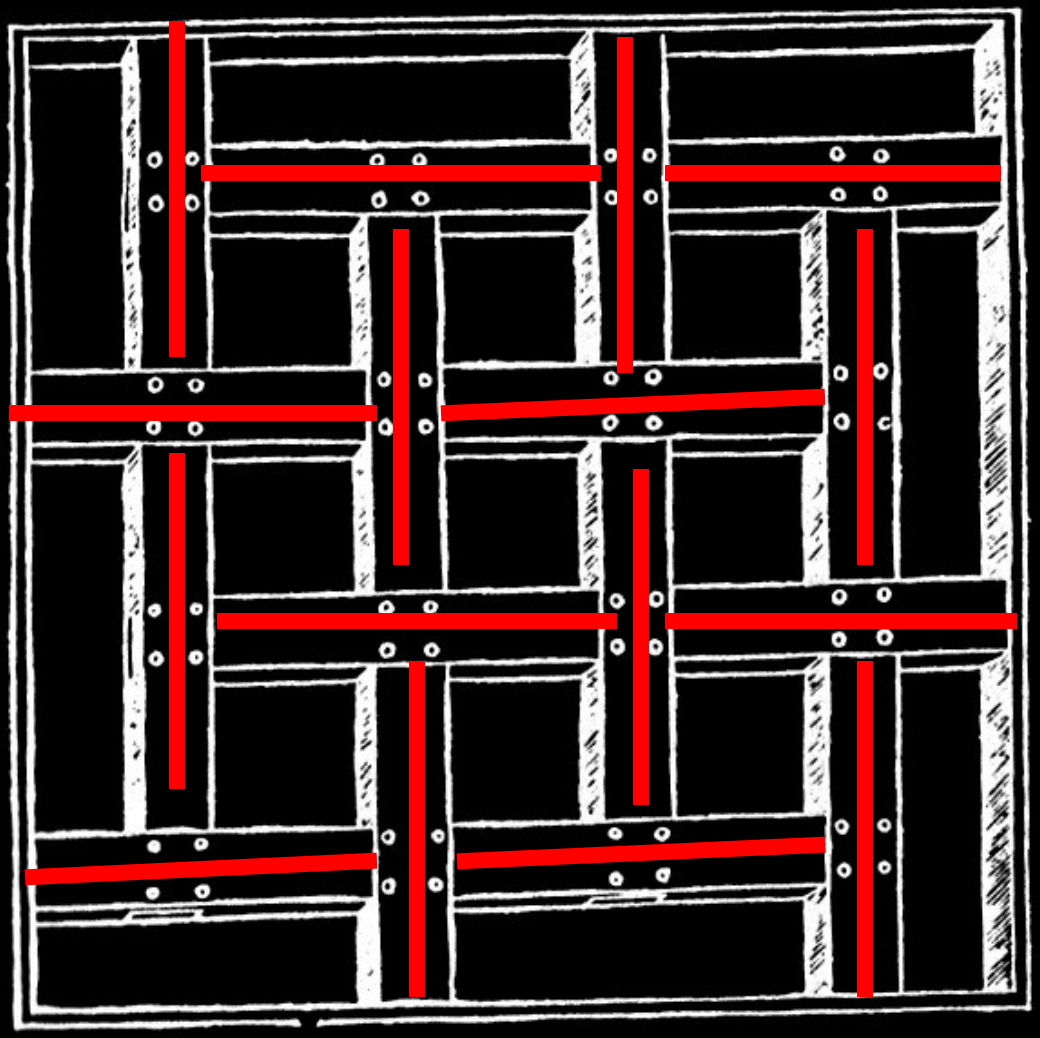
1270





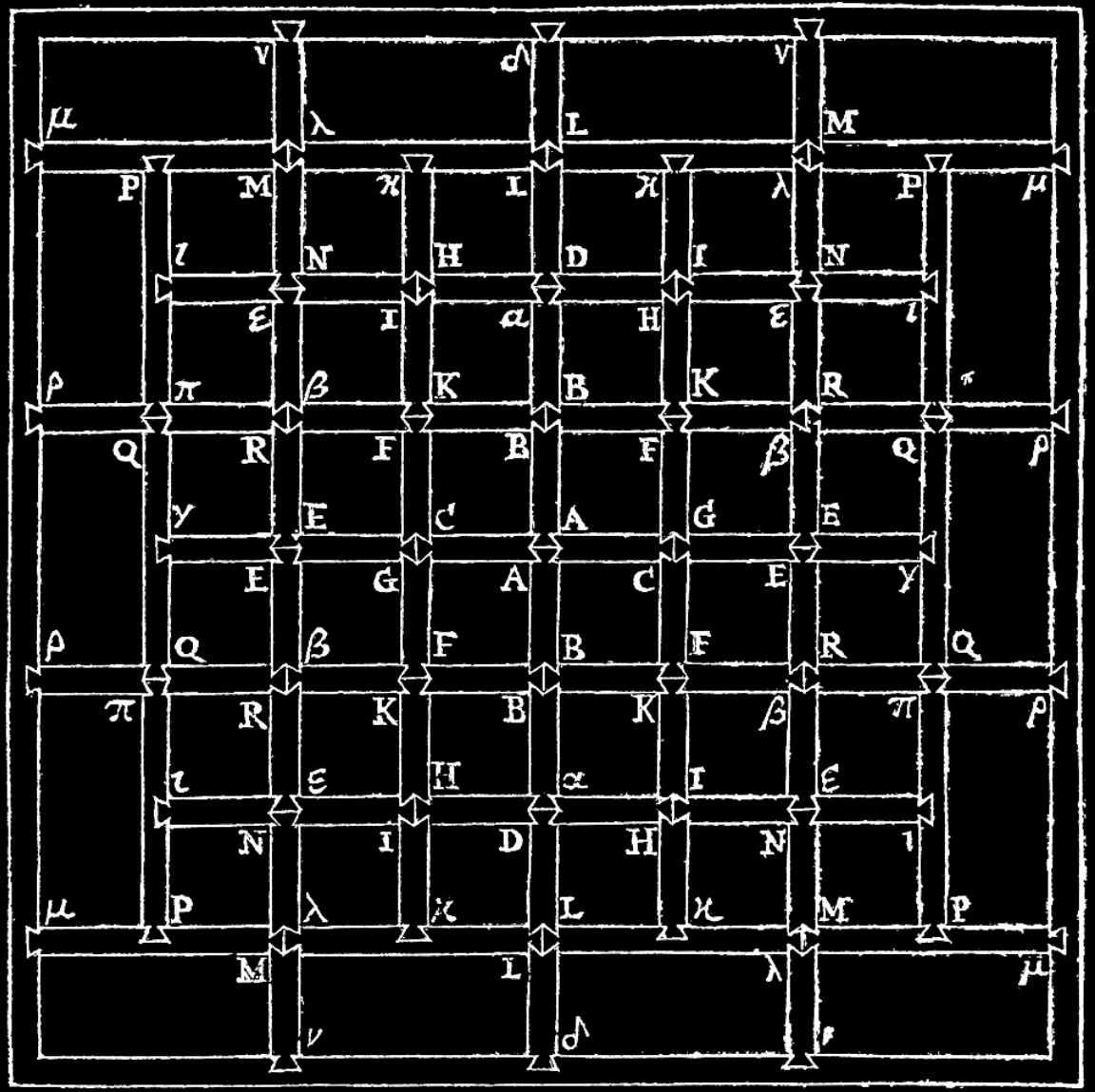
Sebastiano Serlio 1475-1554

Italian Architect wrote the "7 books on Architecture"

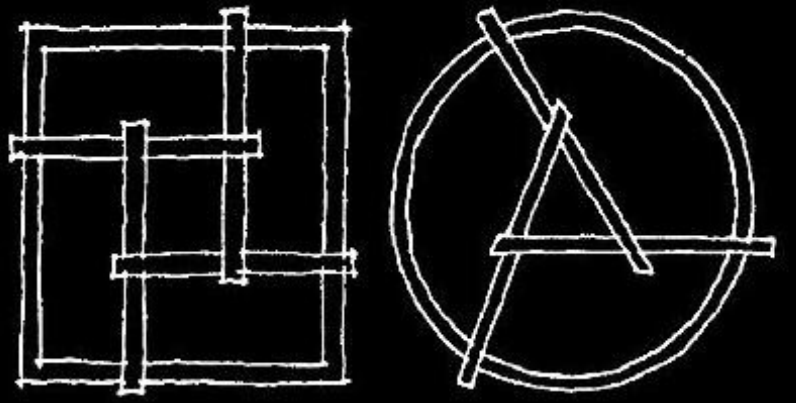


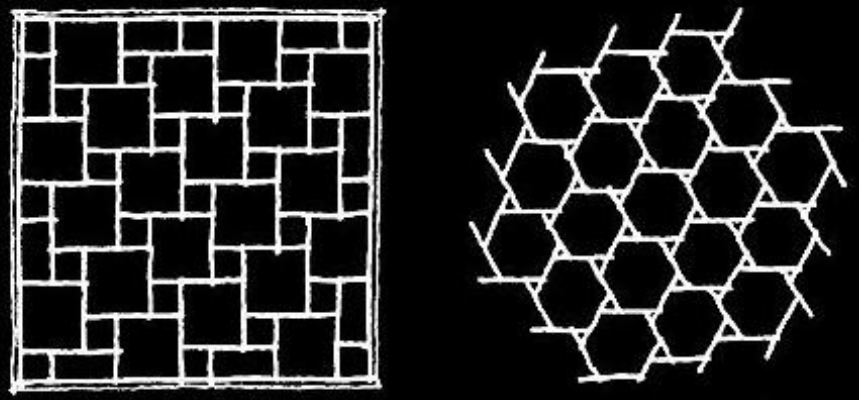
John Wallis
1616-1703

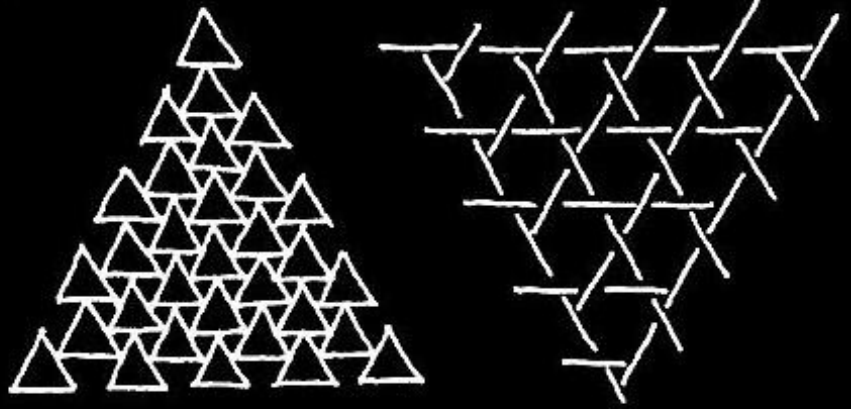
English Mathematician
Author Opera Mathematica
Gave us ∞



Other reciprocal frame systems considered by Wallis

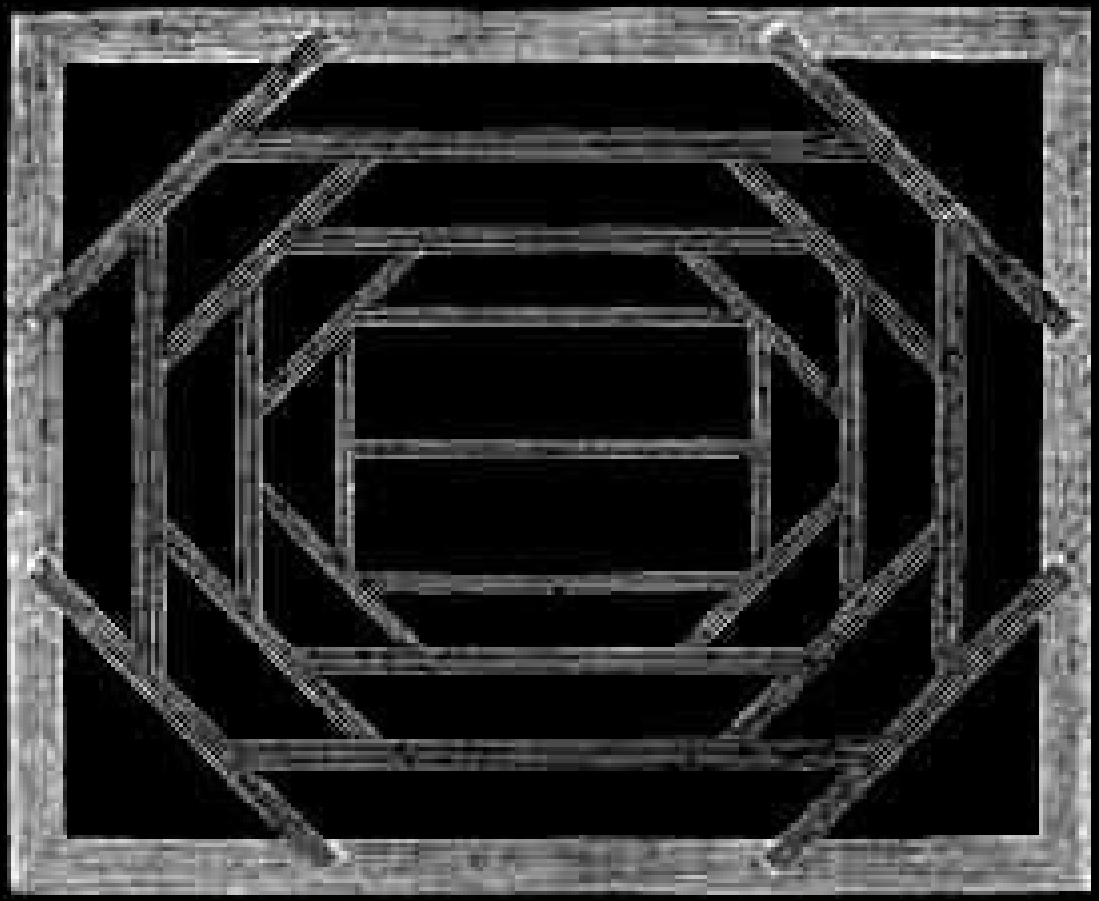




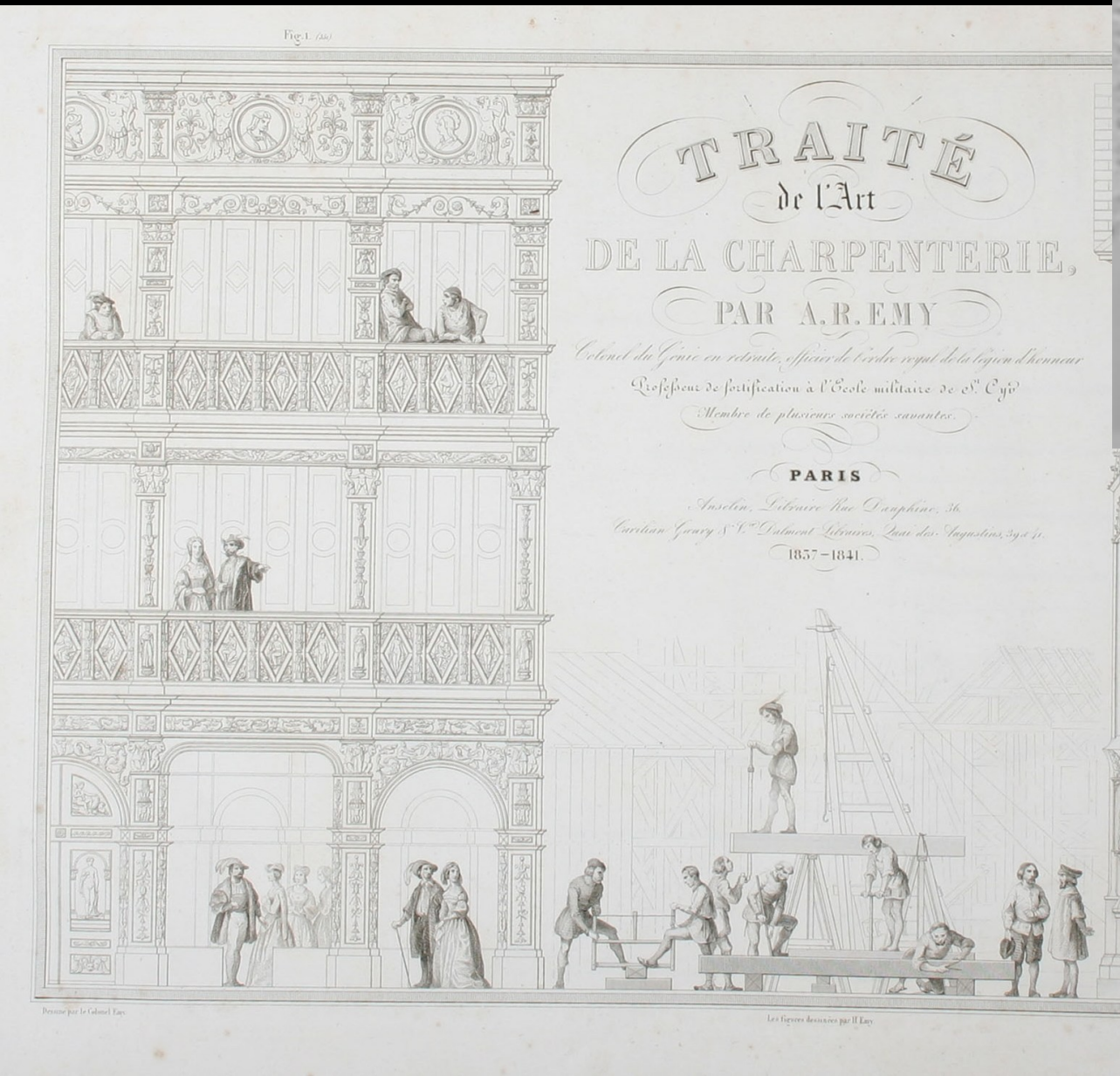


Thomas Tredgold 1788-1829

English Engineer and Author of
Elementary Principles of Carpentry



Armand Rose Emy 1841



Tower of the "Schools Quadrangle", Bodleian Library

- Built ~1617
- Removed 1953

From lecture by Guy T. Houlsby, University of Oxford

Independence Hall
Philadelphia
1732-1753

Friederich Zollinger 1880-1945
German Architect and Engineer
Lamella “Zollinger Roof”, Merseberg Germany 1920s

Bild 4. Doppelhaus mit Zollbau-Lamellen-Dach im Bau (Gensaer Straße, Merseburg 1922)
Fig. 4 Semi-detached house with „Zollbau-Lamellen" roof under construction

Hugo Häring 1882-1958
German Architect
Lamella - Gut Garkau, Germany 1923-1926

Fort York Armoury - Toronto
Built in 1935

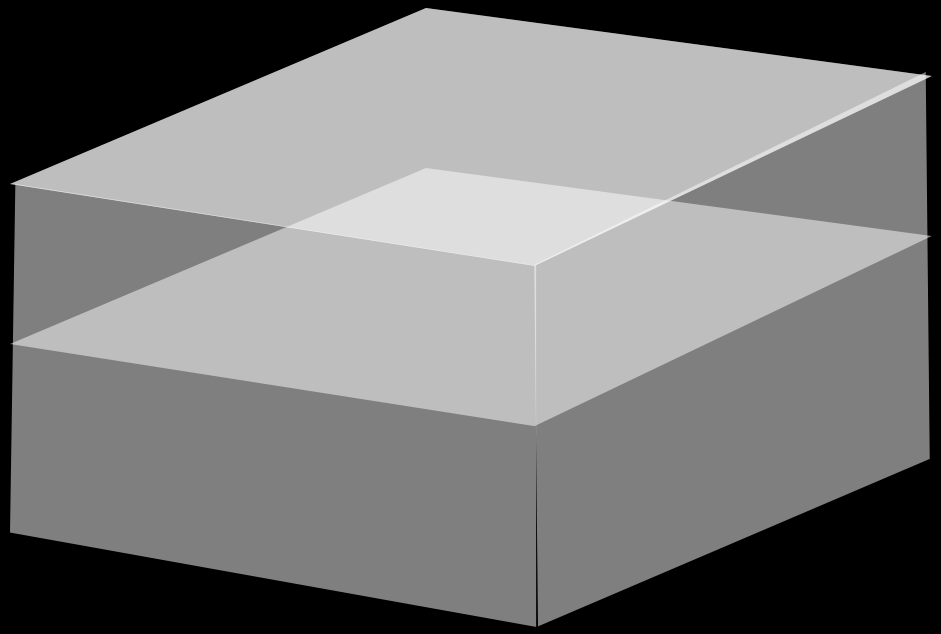
“But Dave, why would be build reciprocal frames today? And how well do they work?”

Case Study 1

Simple Grid – Toronto
Architect - Top Secret
Blackwell Engineers

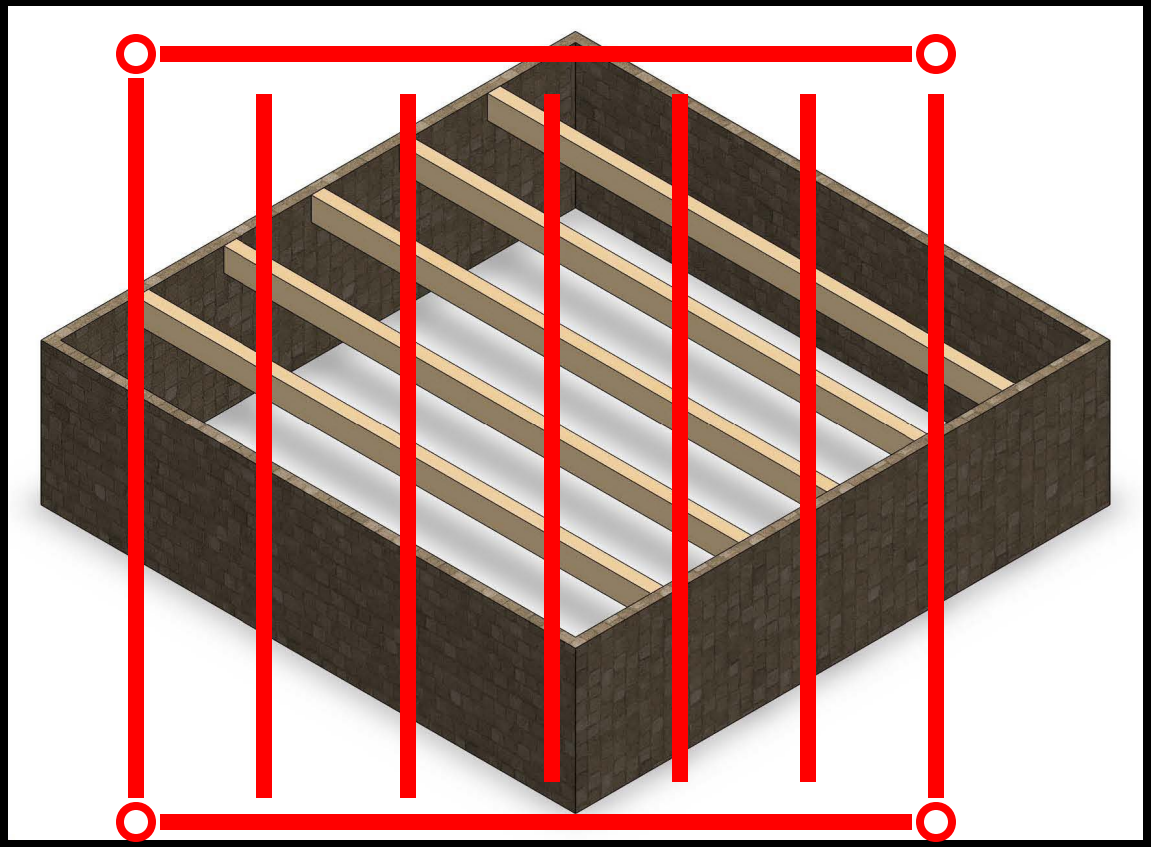
Objective

Shallow depth
Long spans
Stringent vibration criteria

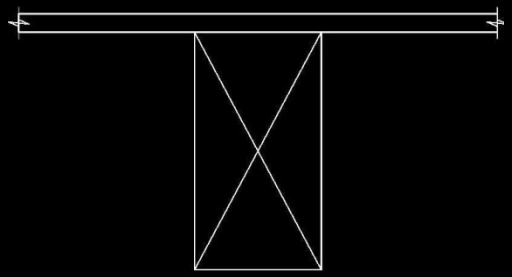


Option 1 – Conventional Framing

Designed for Strength and Deflection



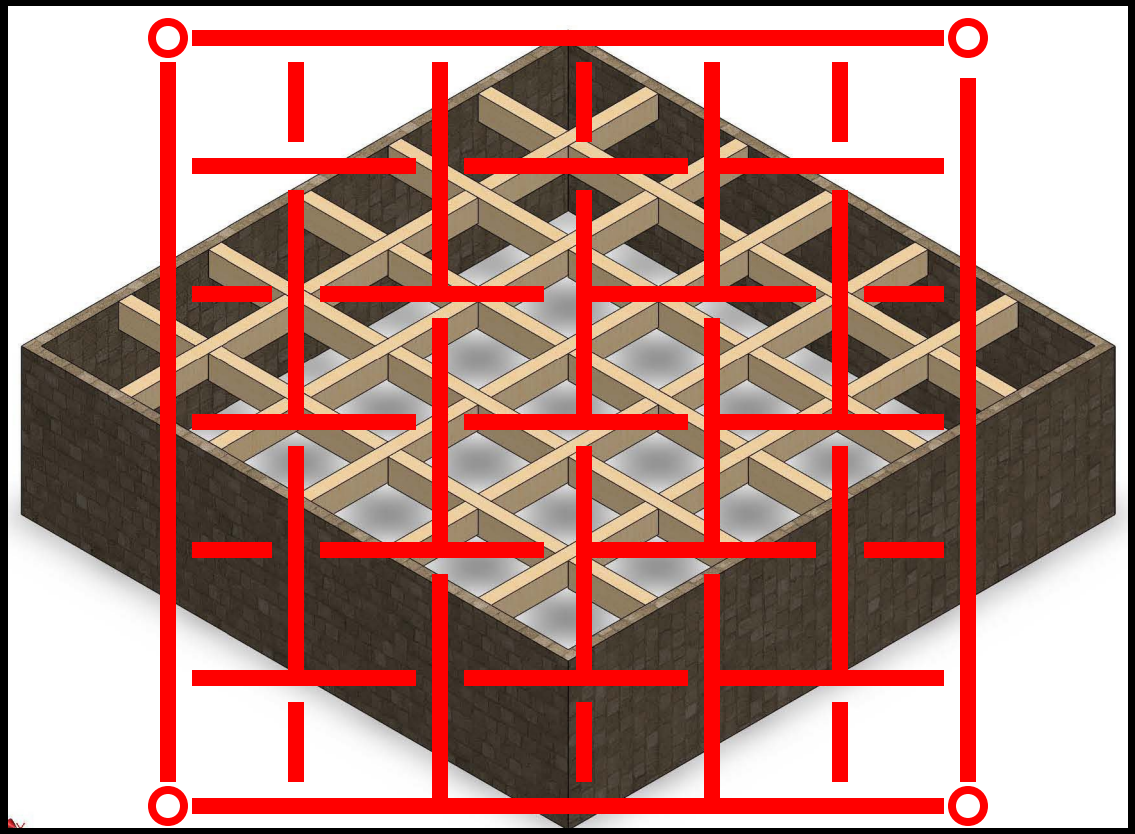
Piece Count – 5
Deepest Member – 494
Total Volume – 7.07 m^3



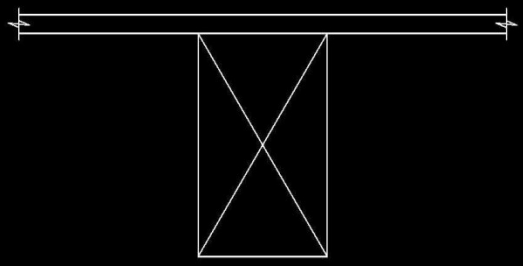
265x494

Option 2 – Reciprocal Framing

Designed for Strength and Deflection



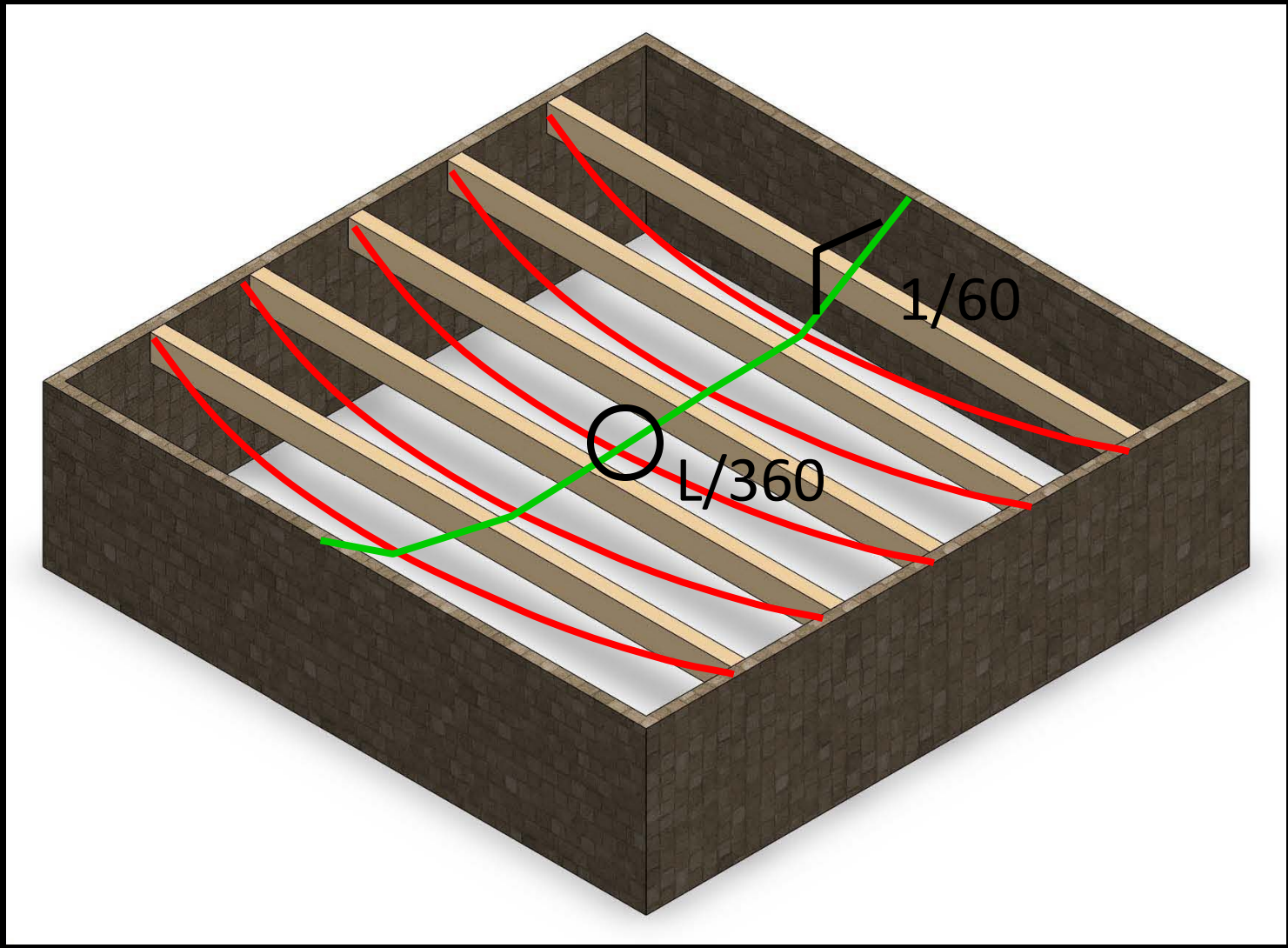
Piece Count – 10
Deepest Member – 456
Total Volume – 12.2 m^3



265x456

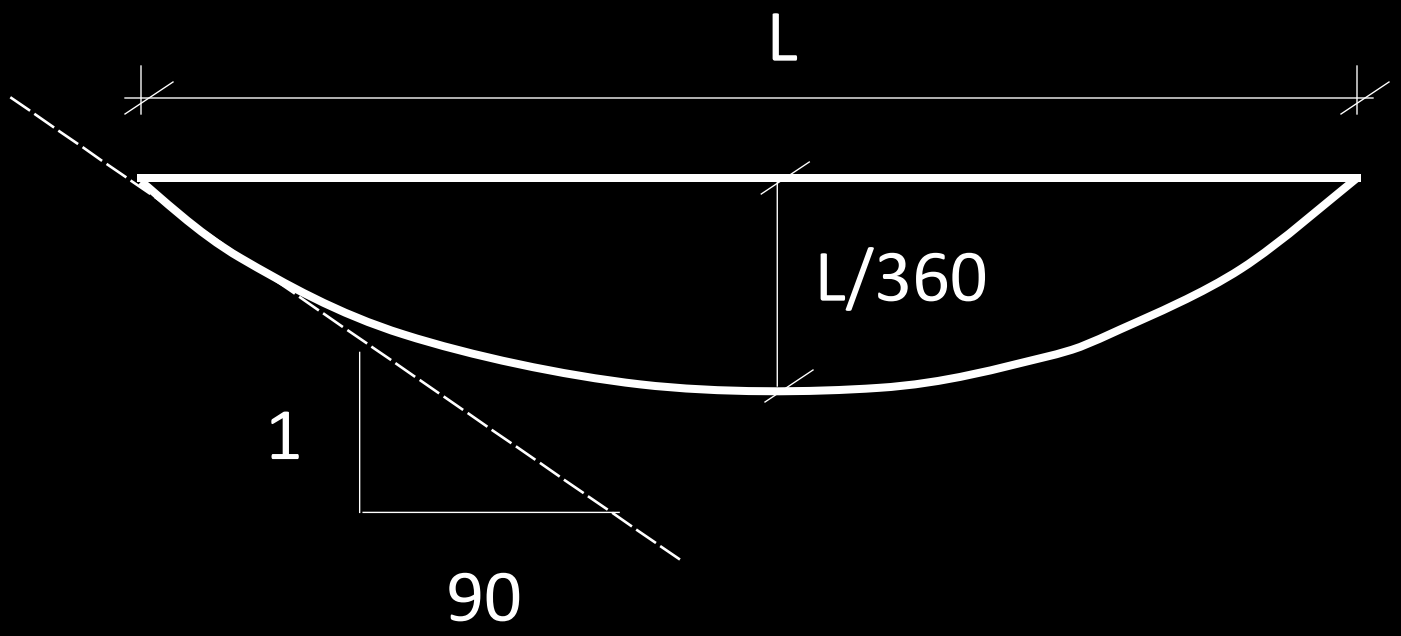
Deflection

Do we take L/360 for granted?



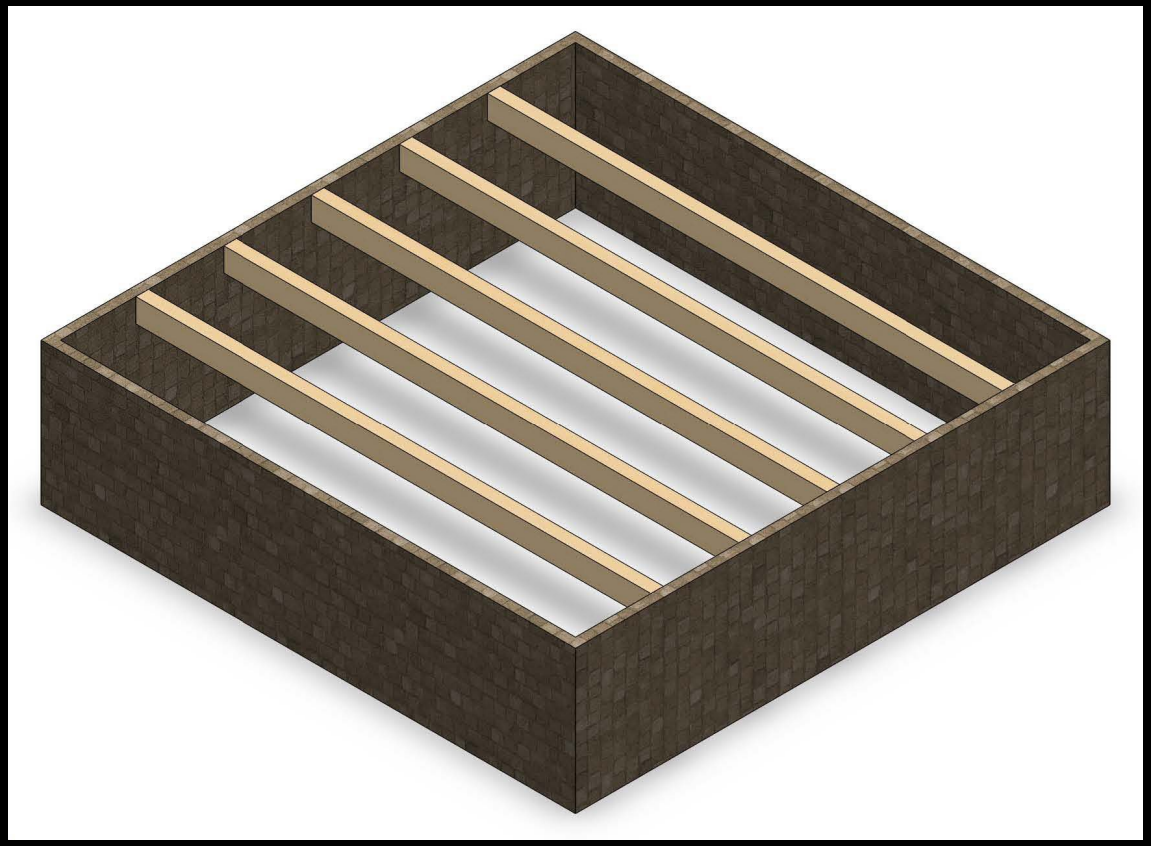
Deflection

So what do we do instead?

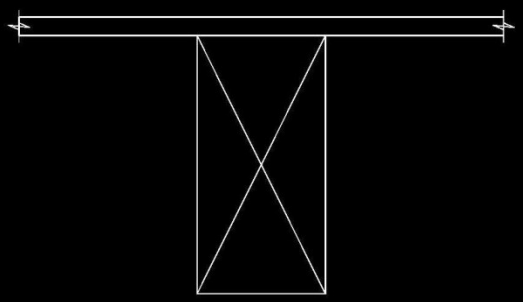


Option 3 – Conventional Framing

Designed for Strength and Updated Deflection Criteria

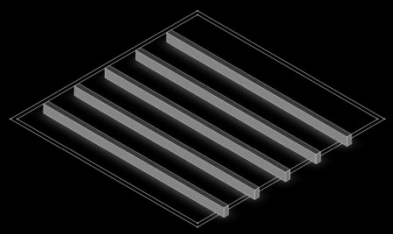


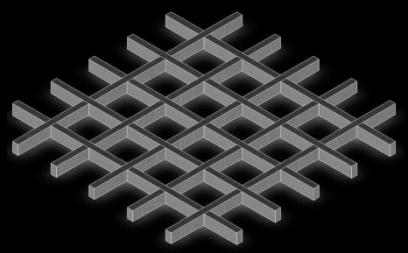
Piece Count – 5
Deepest Member – 570
Total Volume – 8.16 m^3

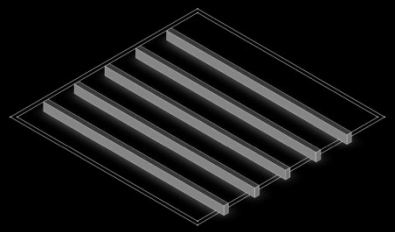


265x570

Summary

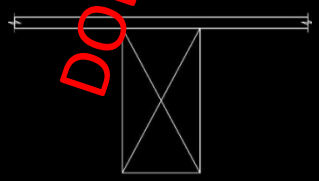


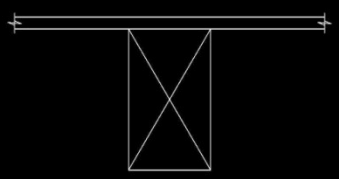


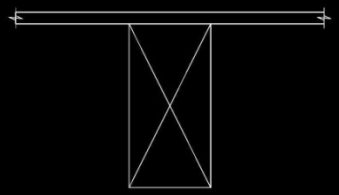


	Standard Framing	Reciprocal Framing	Standard Framing (Δ)
Piece Count	5	10	5
Depth (mm)	494	454	570
Total Volume (m^3)	7.07	12.2	8.16

DOES NOT WORK

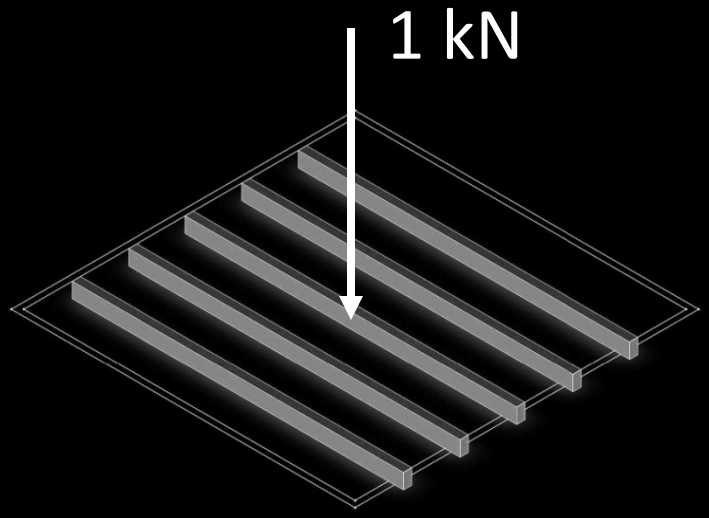




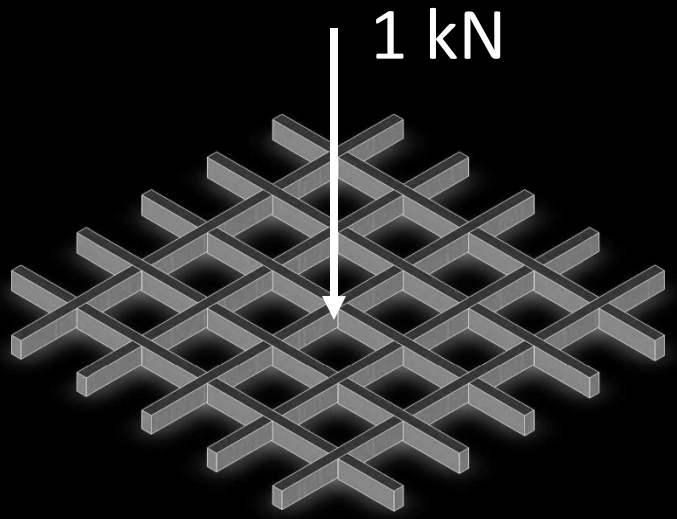


Other Considerations

Vibration



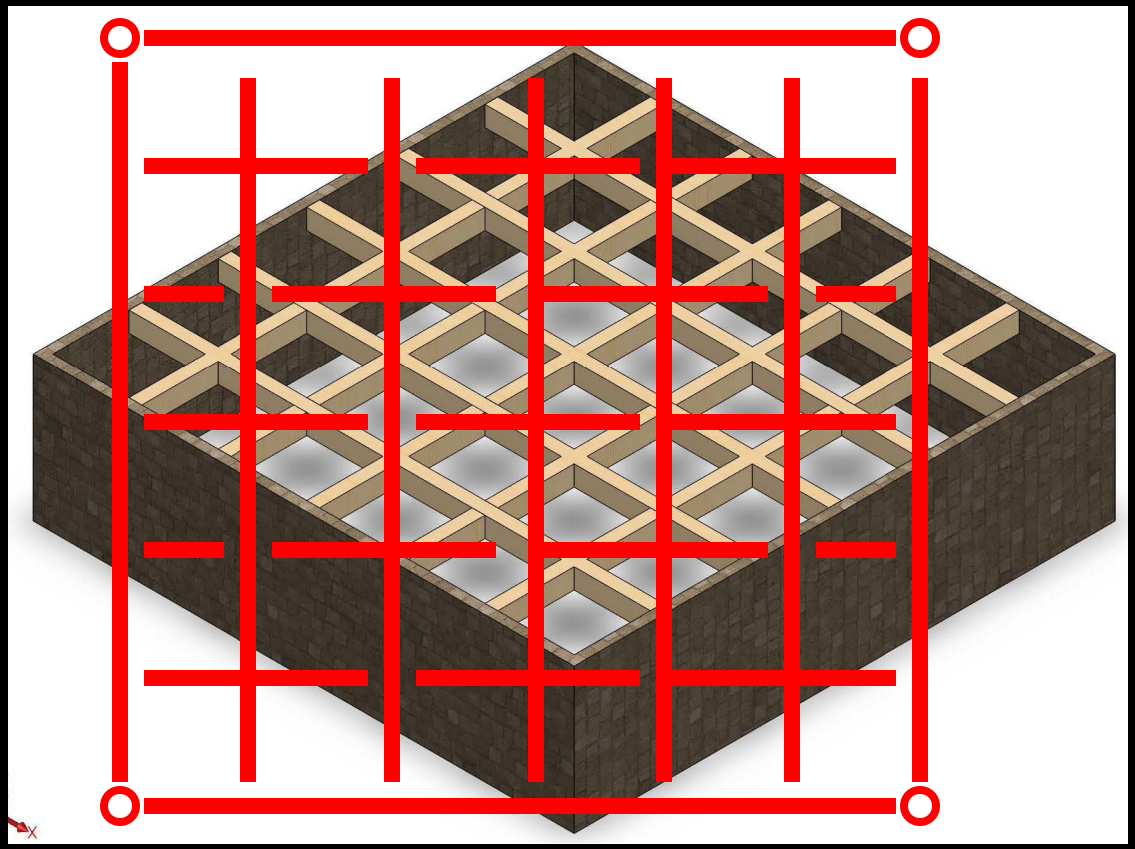
0.6 mm



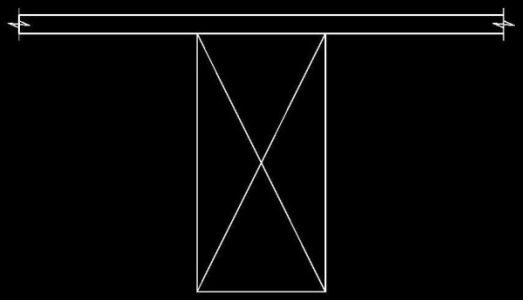
0.3 mm

Final Options – Project Specific

Introduce selected Moment Connections – Depth was everything



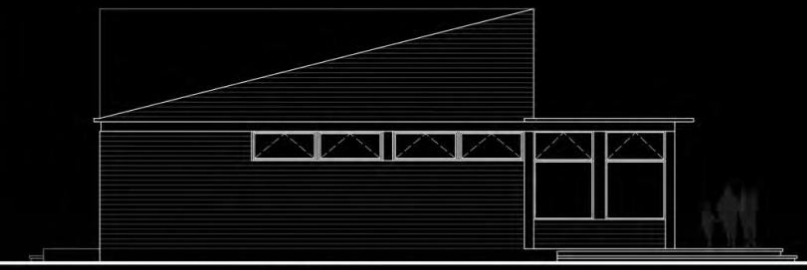
Piece Count – 5 + Infill
Deepest Member – 418
Total Volume – 11.1 m^3



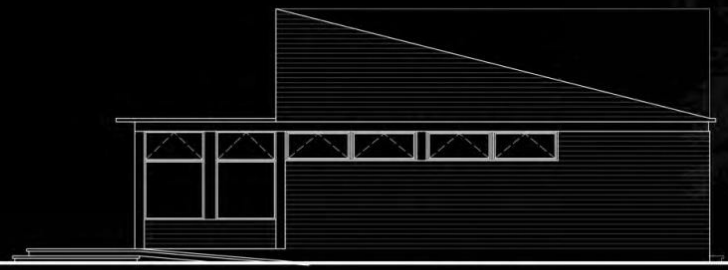
265x418

Case Study 2

Indian River Pavilion – PEI
David Sisam
Blackwell Engineers
Construction Documents



North Elevation

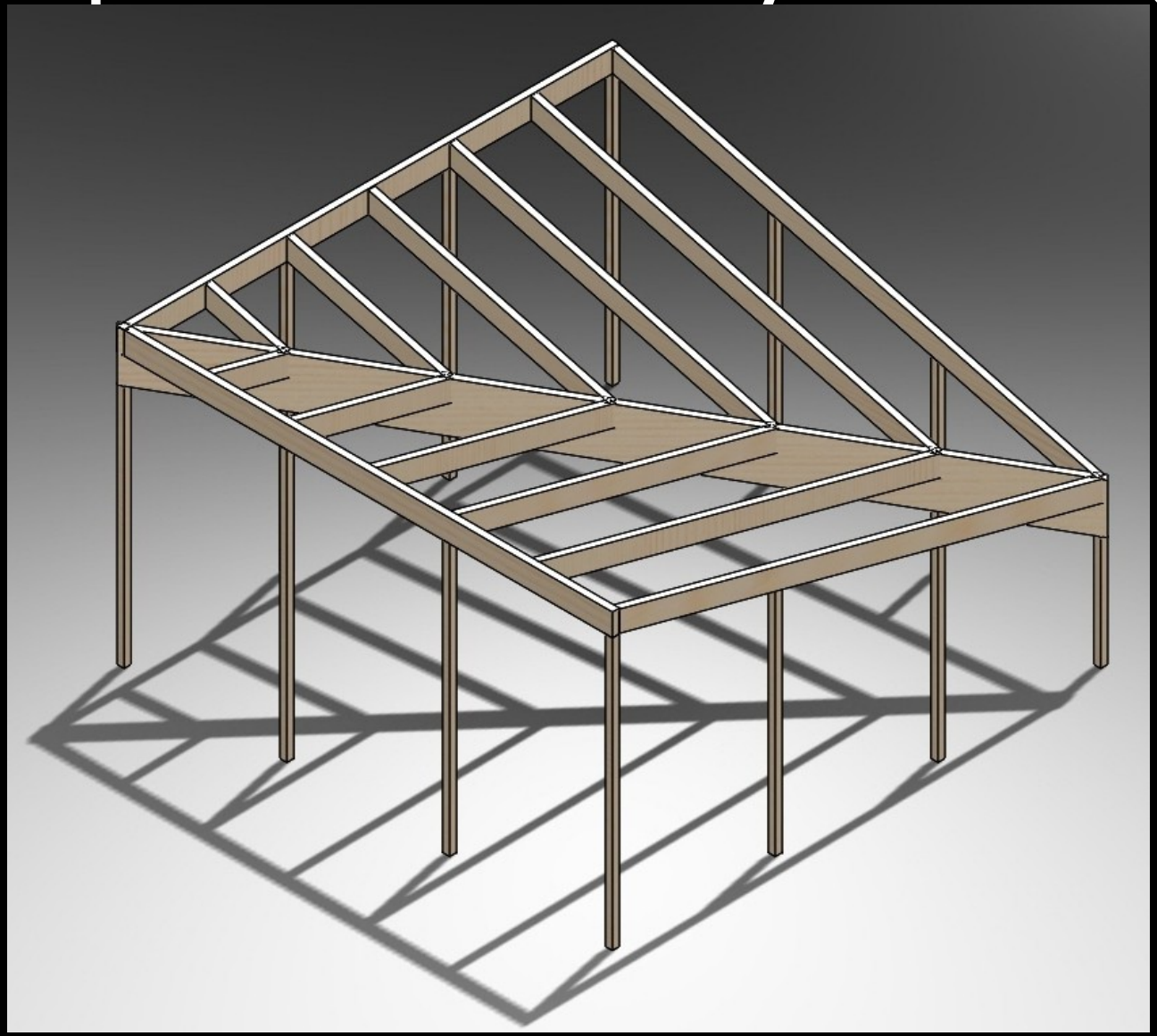


East Elevation

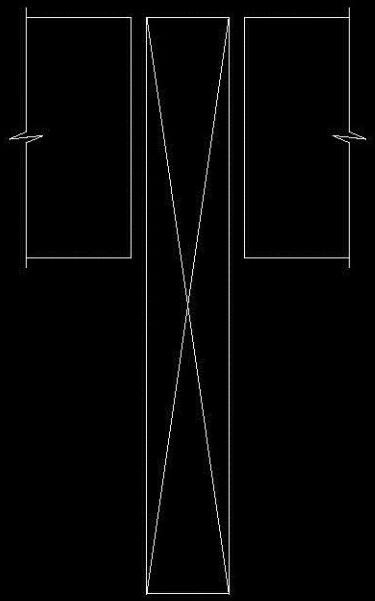
West Elevation

South Elevation

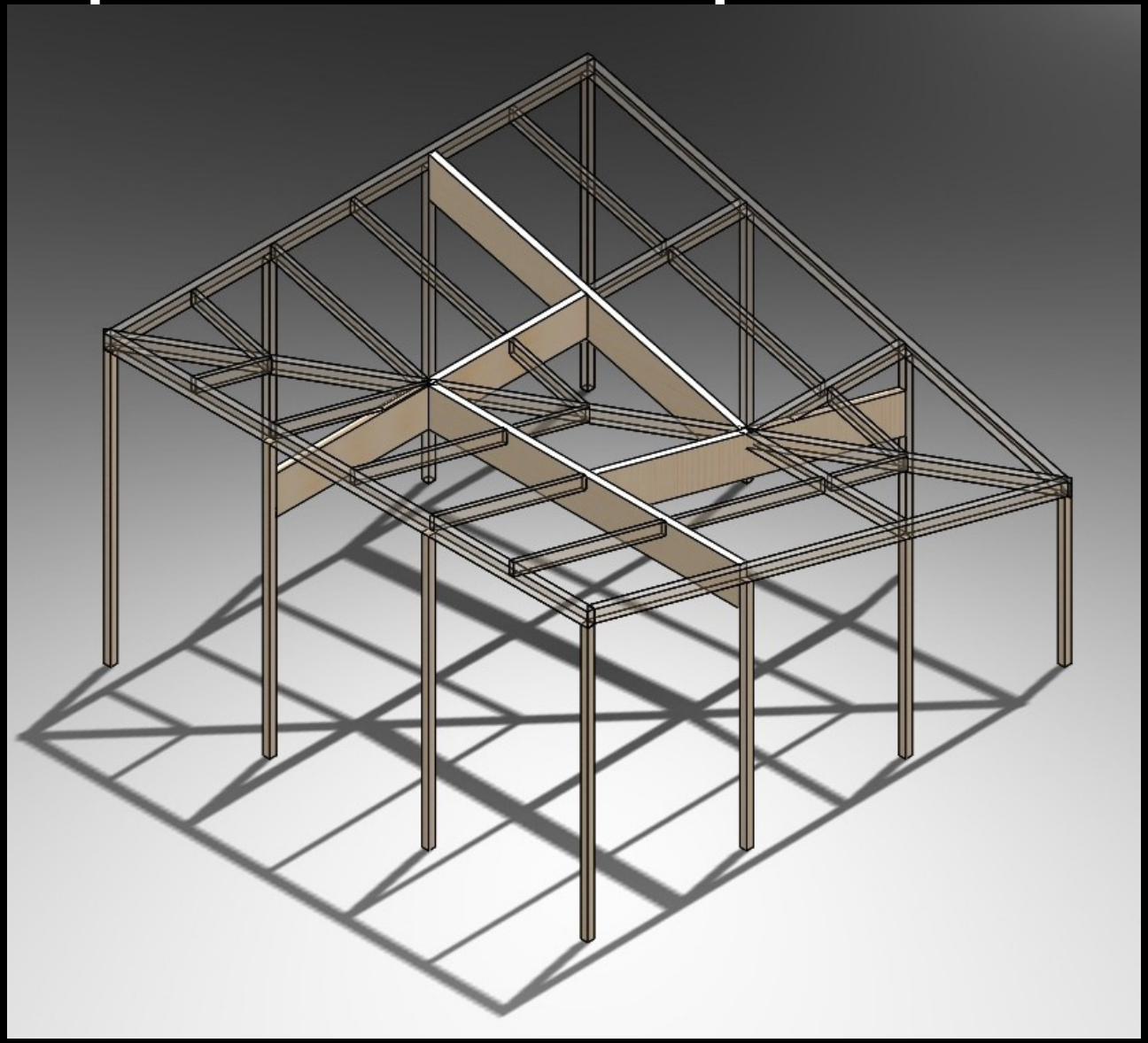
Option 1 – Valley Framing



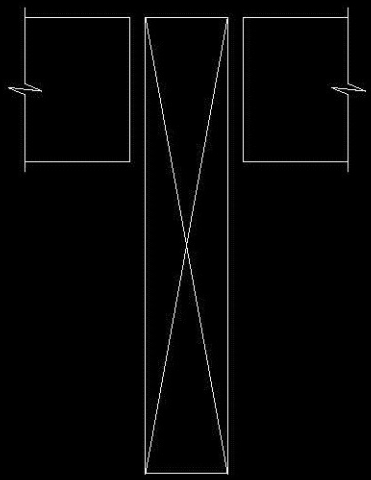
Piece Count – 15
Total Volume – 5.8 m^3
Largest Piece – 731 kg



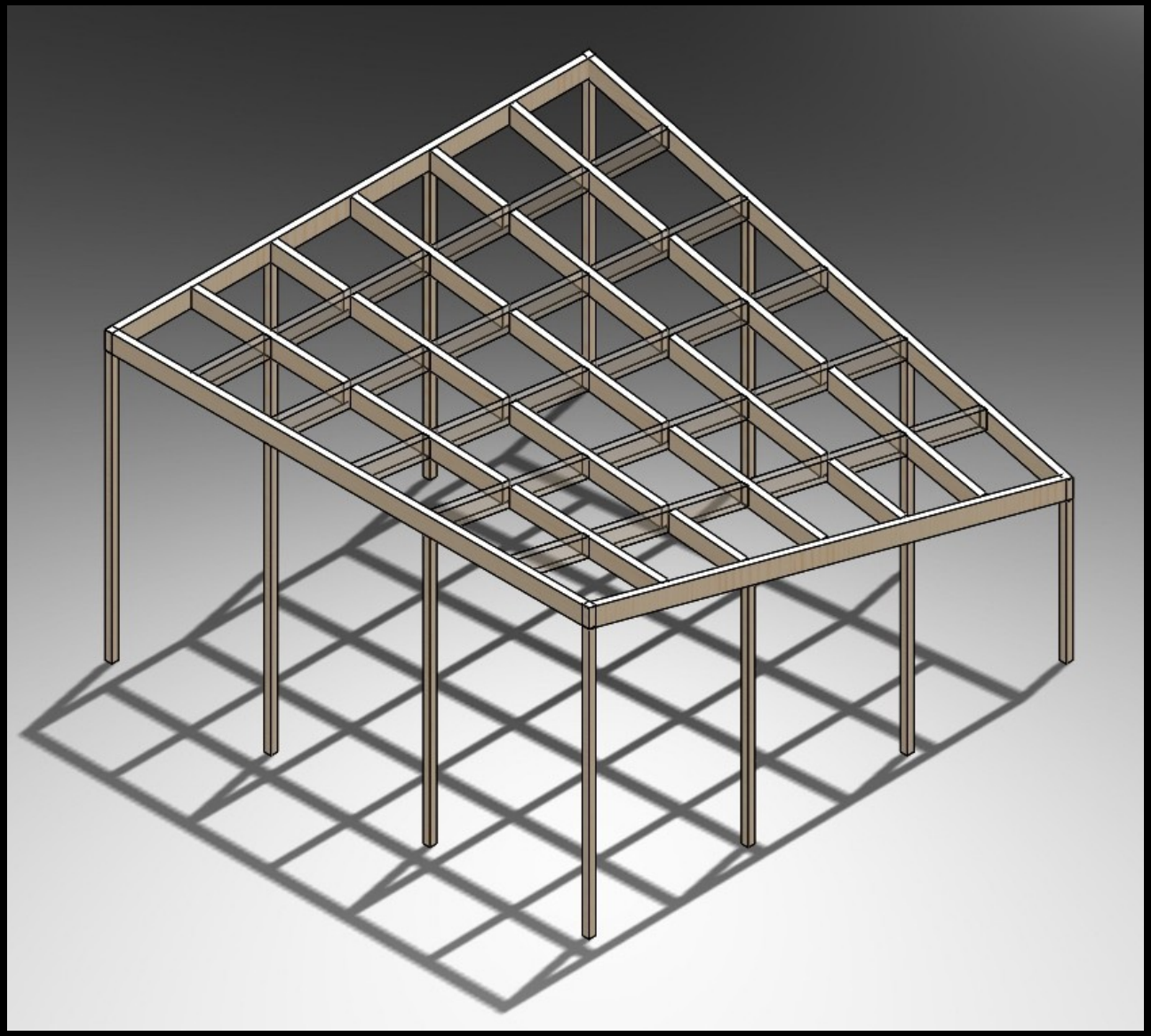
Option 2 – Reciprocal Beam



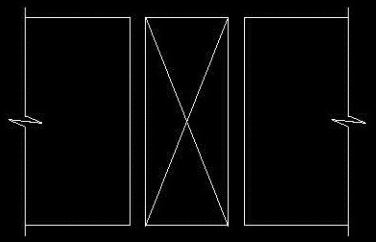
Piece Count – 37
Total Volume – 4.8 m^3
Largest Piece – 268 kg

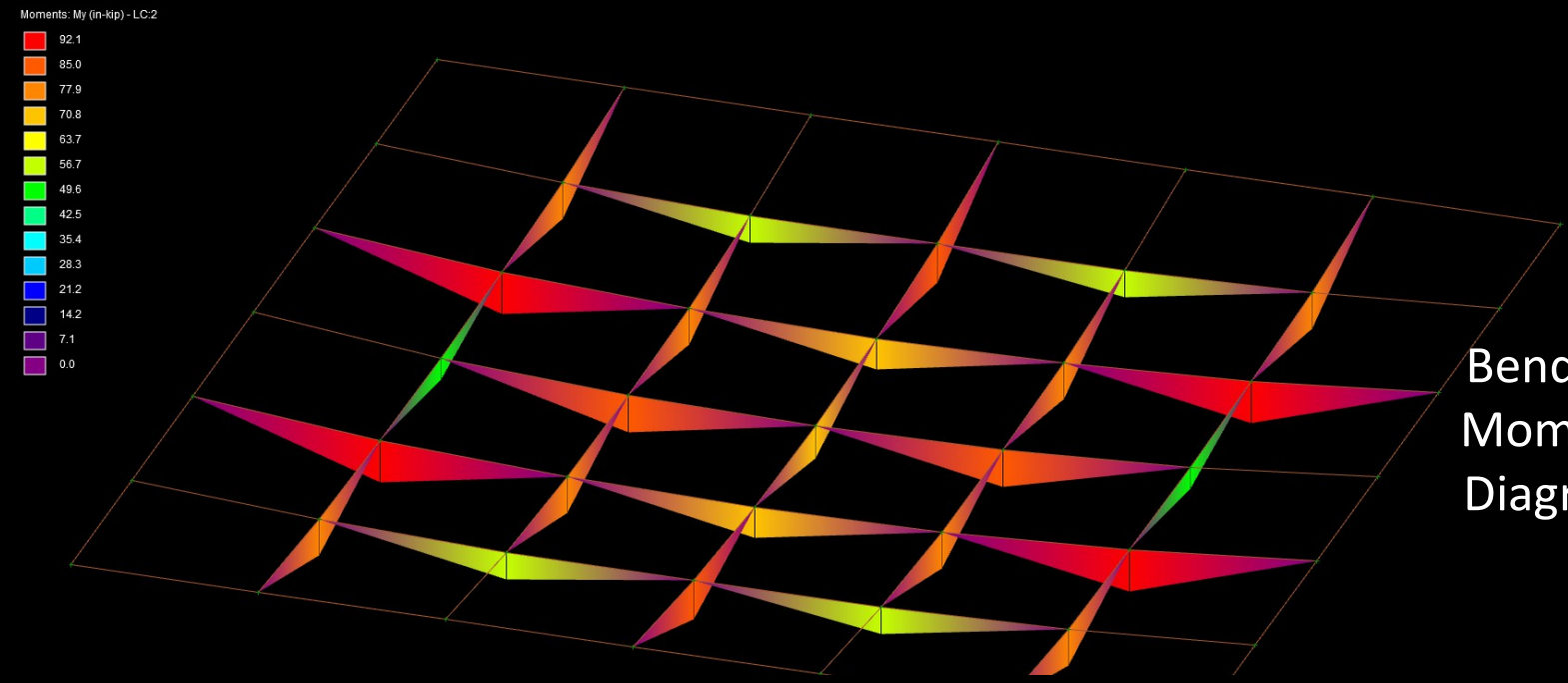


Option 3 – Reciprocal Joist

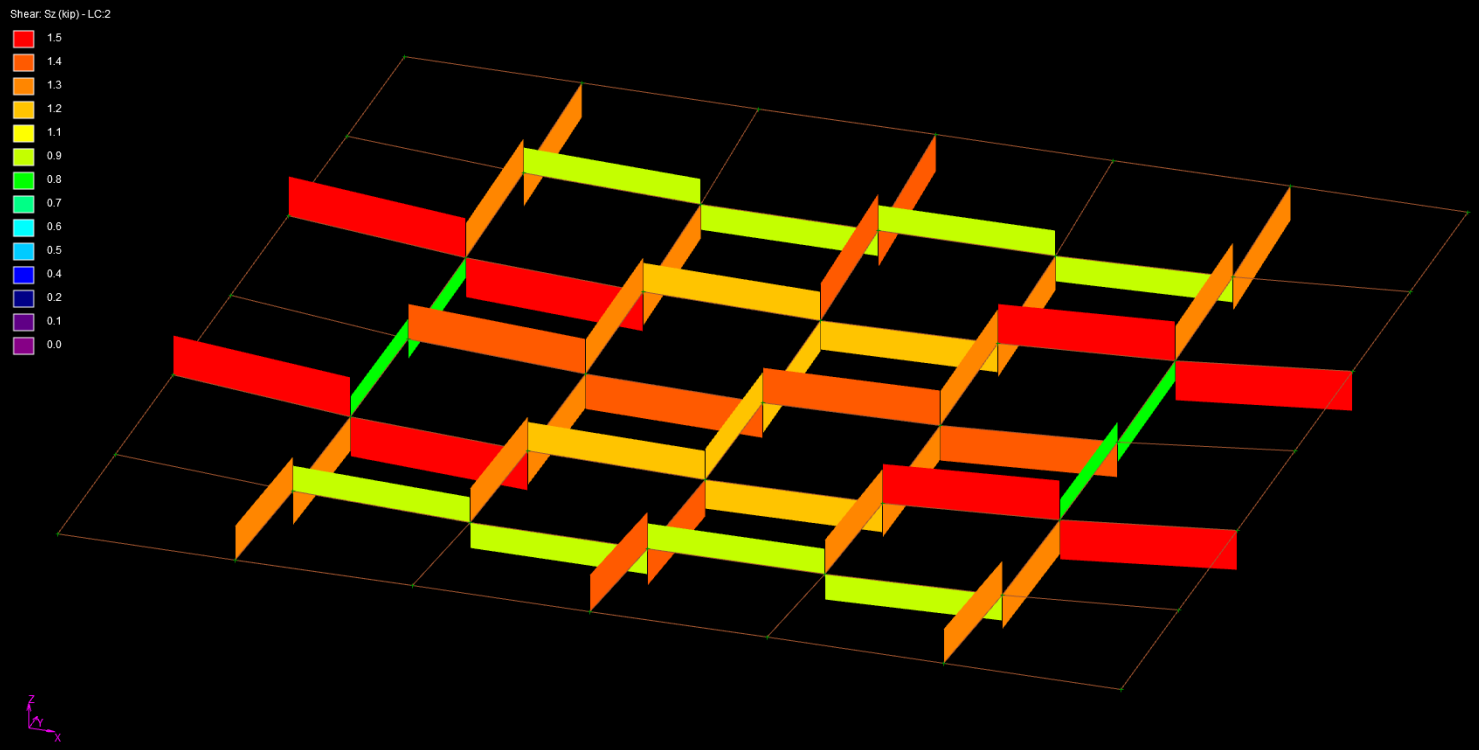


Piece Count – 47
Total Volume – 5.6 m^3
Largest Piece – 60 kg



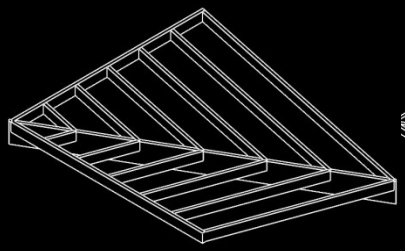


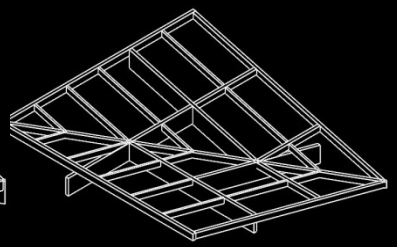
Bending Moment Diagram

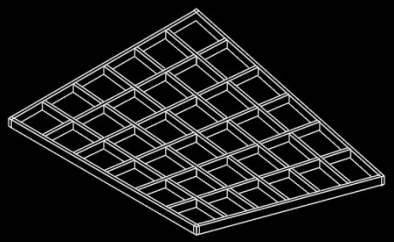


Shear Force Diagram

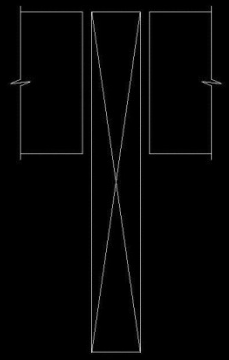
Summary

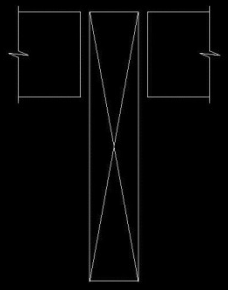






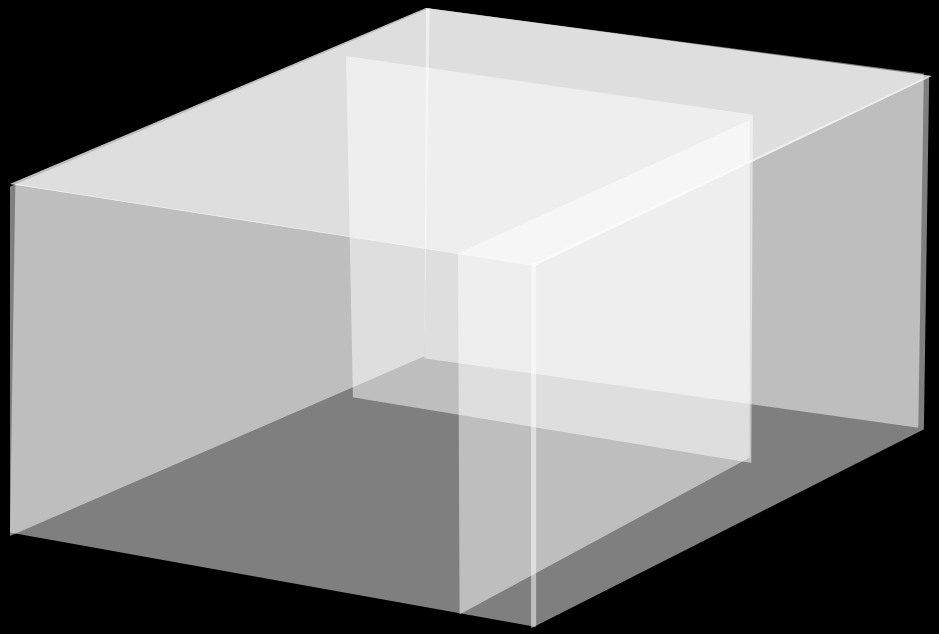
	Valley Beam	Reciprocal Beam	Reciprocal Joist
Piece Count	15	37	47
Total Volume (m^3)	5.8	4.8	5.6
Largest Piece (kg)	731	268	60





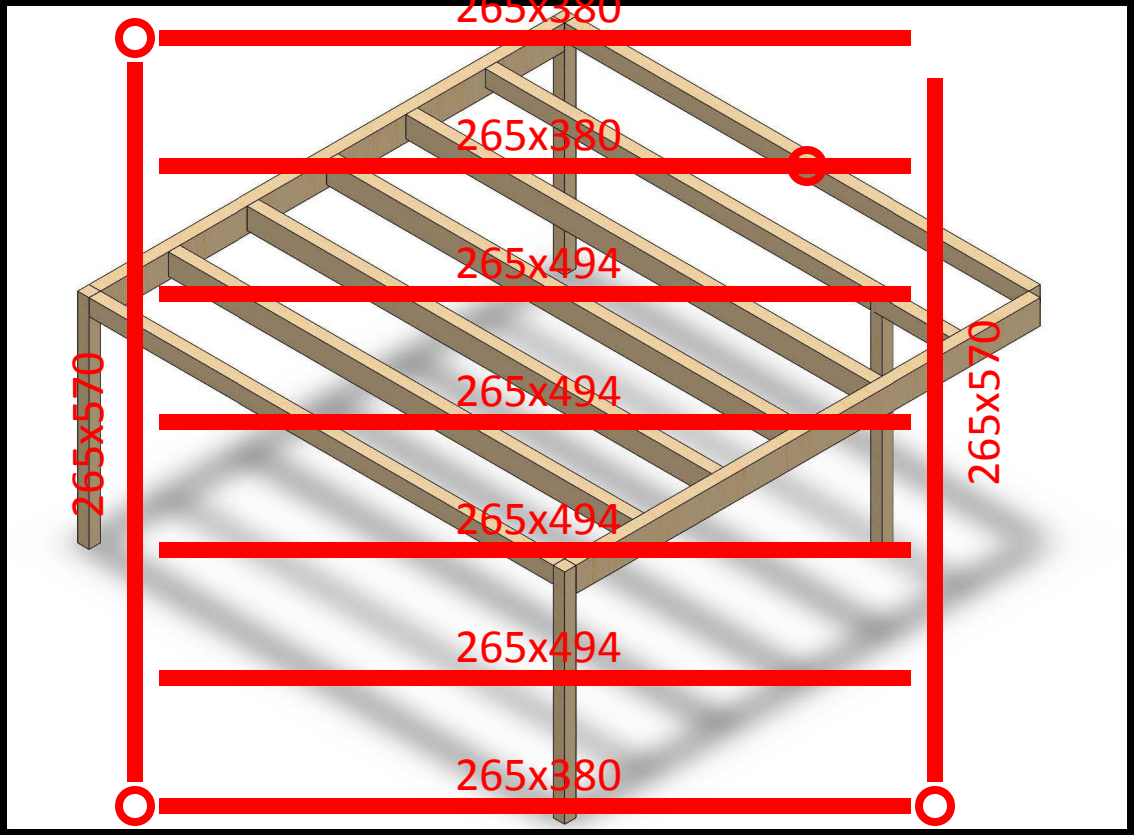
Case Study 3

Corner Conditions
Shallow Soffit
Thin Cantilevered Profile

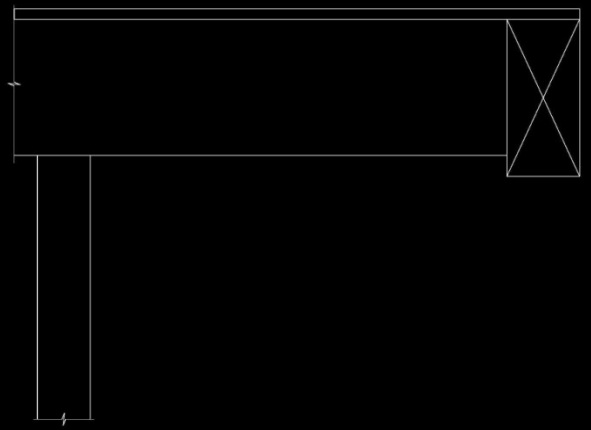


Option 1 - Conventional

Strength and Deflection
L/360 Typical
L/180 Cantilever

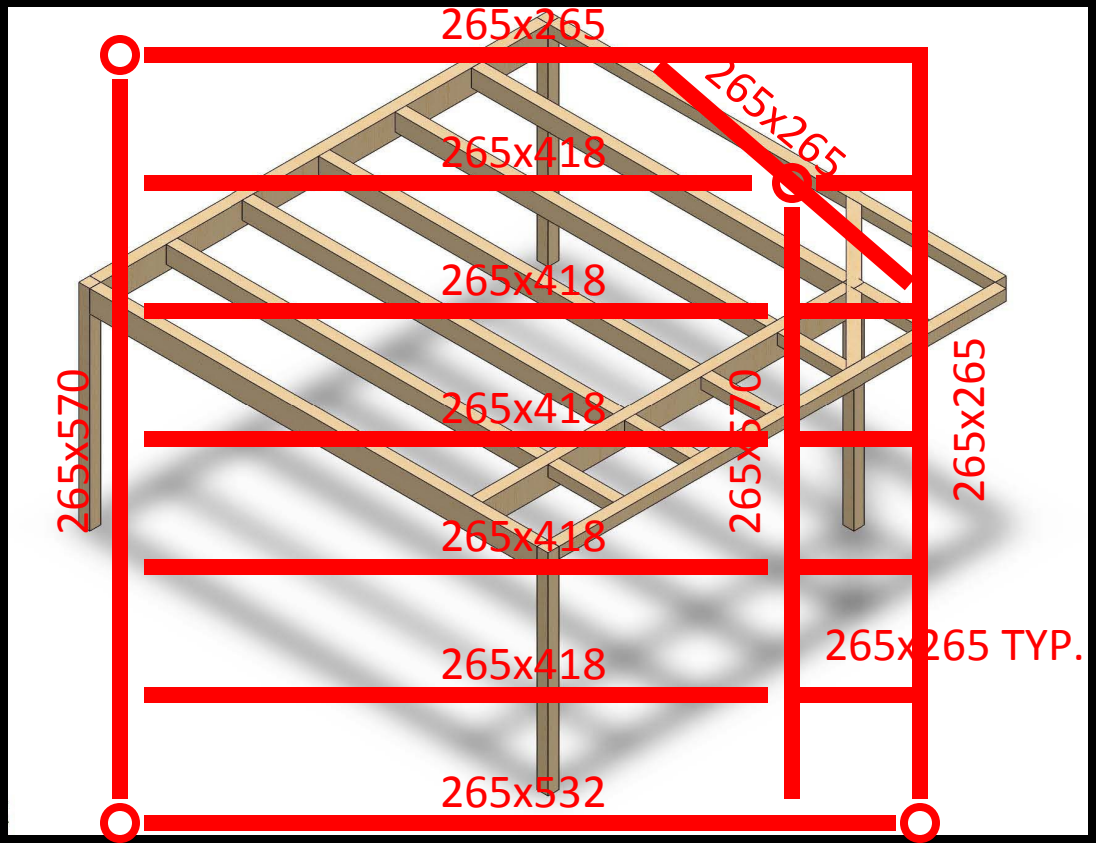


Piece Count – 9
Depth – 570/494 mm
Soffit Depth – 570 mm
Total Volume – 12.2 m^3

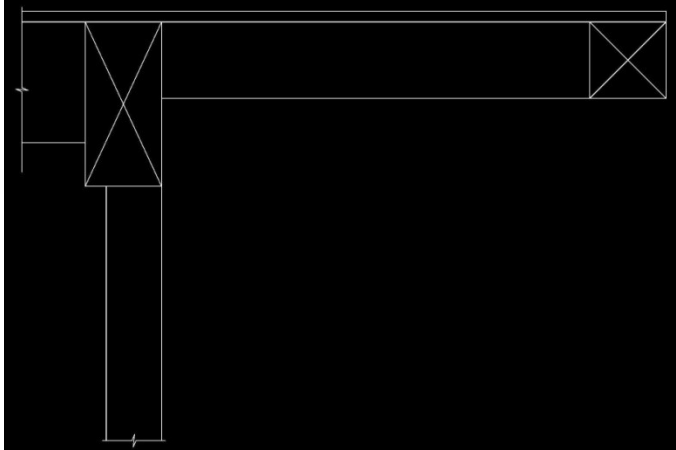


Option 2 – Reciprocal Corner

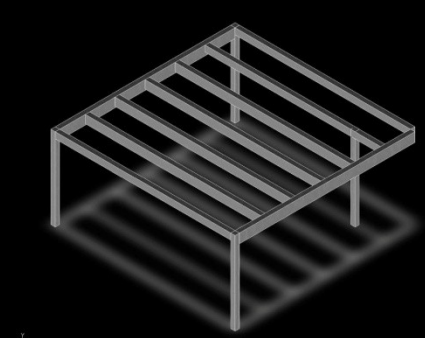
Strength and Deflection
L/360 Typical
L/180 Cantilever

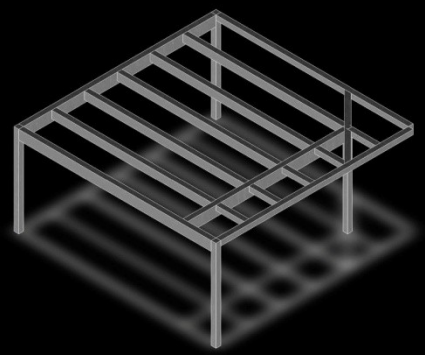


Piece Count – 16
Depth – 570/418 mm
Soffit Depth – 265 mm
Total Volume – 10.8 m^3

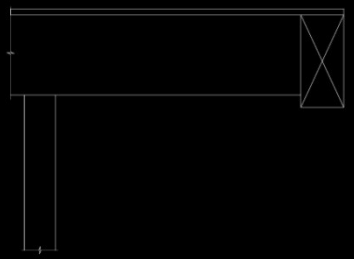


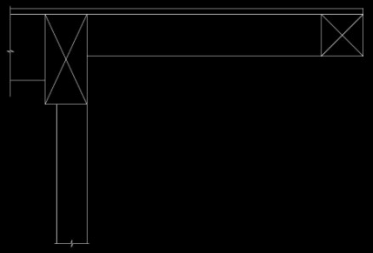
Summary





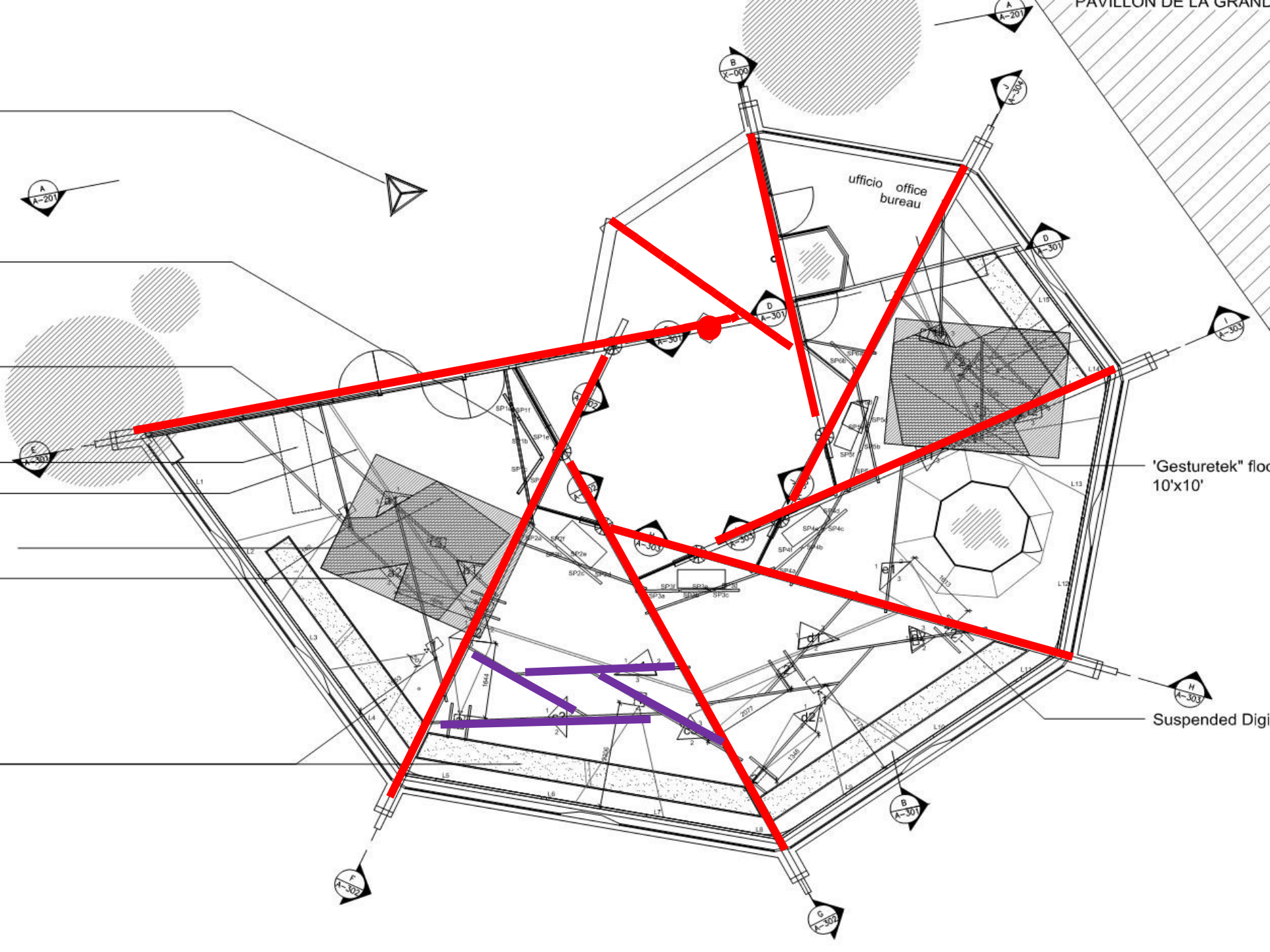
	Standard Framing	Reciprocal Framing
Piece Count	9 + Infill	16
Total Volume (m^3)	12.2	10.8
Soffit Depth (mm)	570	265





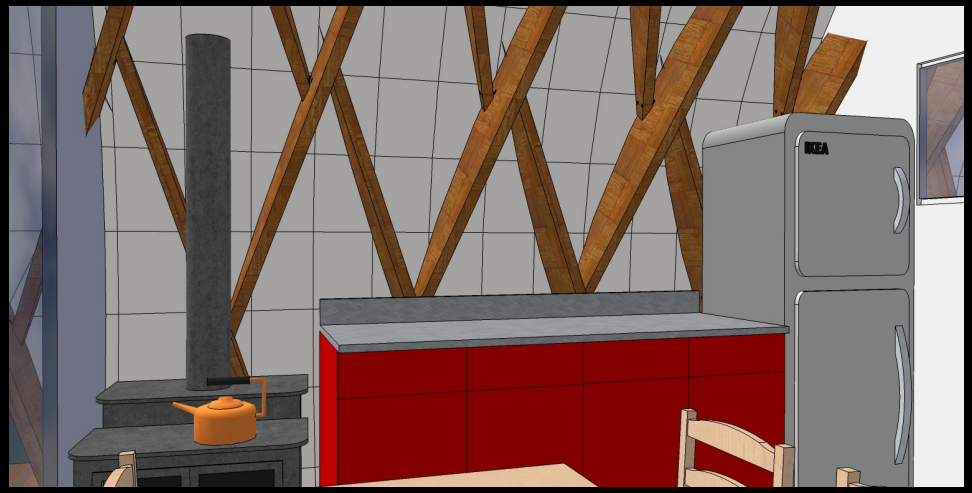
“Come on Dave! Show us modern and big!”

Discovery Center, Ventura California
Restored 1940s Lamella

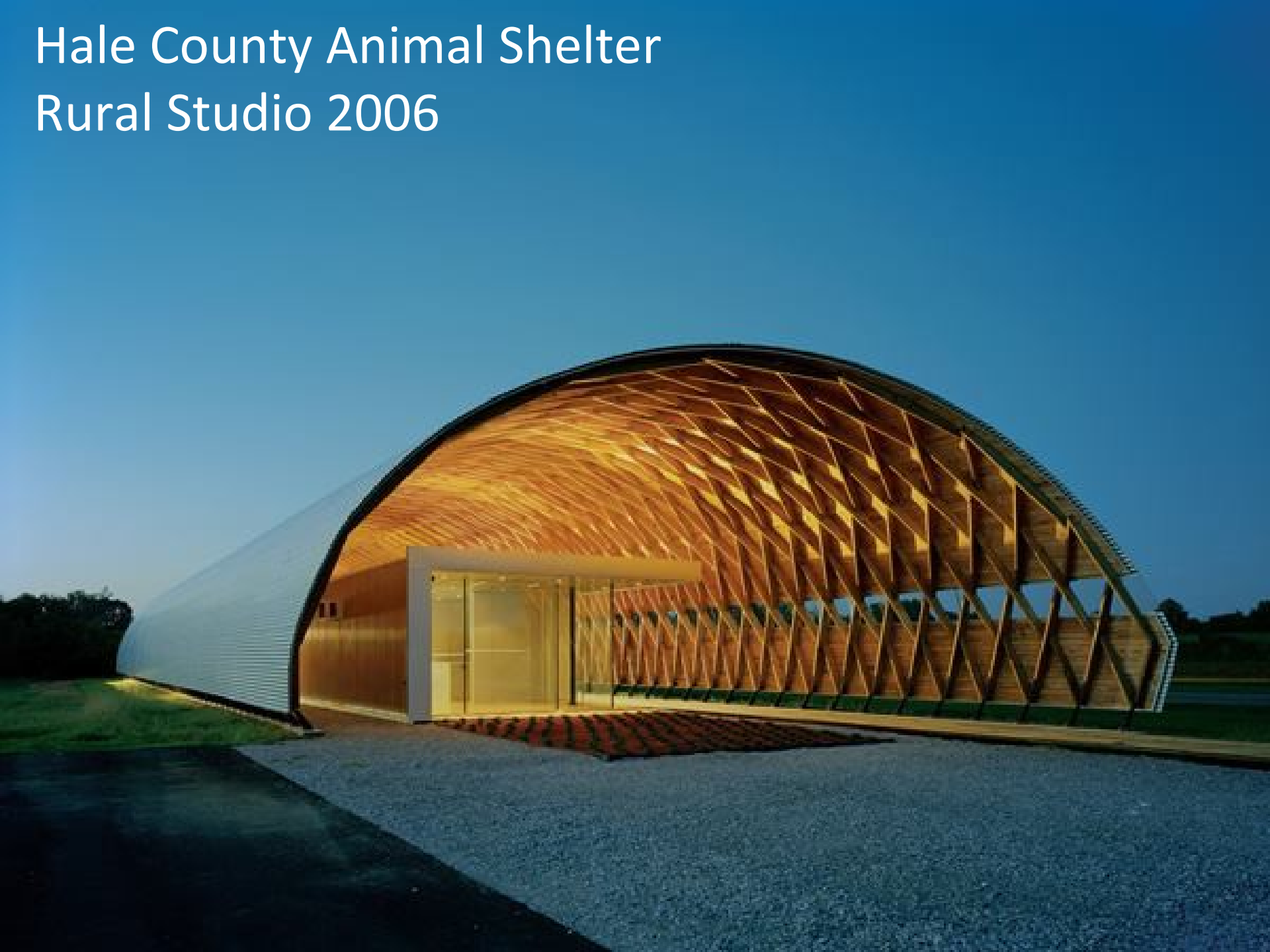

PAVILLON DE LA GRAND
ufficio office bureau
'Gesturetek" floc
10'x10'
Suspended Digi

Ontario Parks and Rec Submission

Dave and Shannon's Super Awesome Tent



Hale County Animal Shelter
Rural Studio 2006



Ross Creek Picnic Pavillion
Ted Cavanagh / Coastal Studio and Studio North 2010

Nine Bridges Country Club
Shiguru Ban

NCFS Longhouse – Toronto, 2009
Levitt Goodman Architects / Blackwell Engineers

“It is amazing how much you can accomplish when it doesn’t matter who gets the credit” – Unknown

Blackwell

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- ***American Institute of Architects***
- ***Architectural Institute of British Columbia***
- ***Engineering Institute of Canada***

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