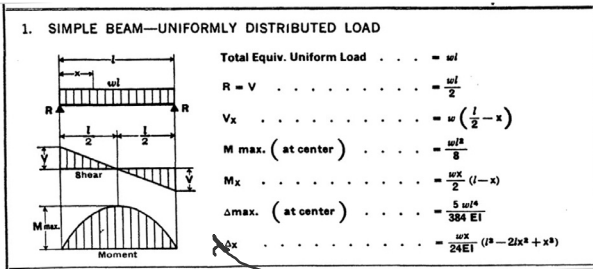


Gerber Beams

- Continuity in Beams
- Gerber Beams

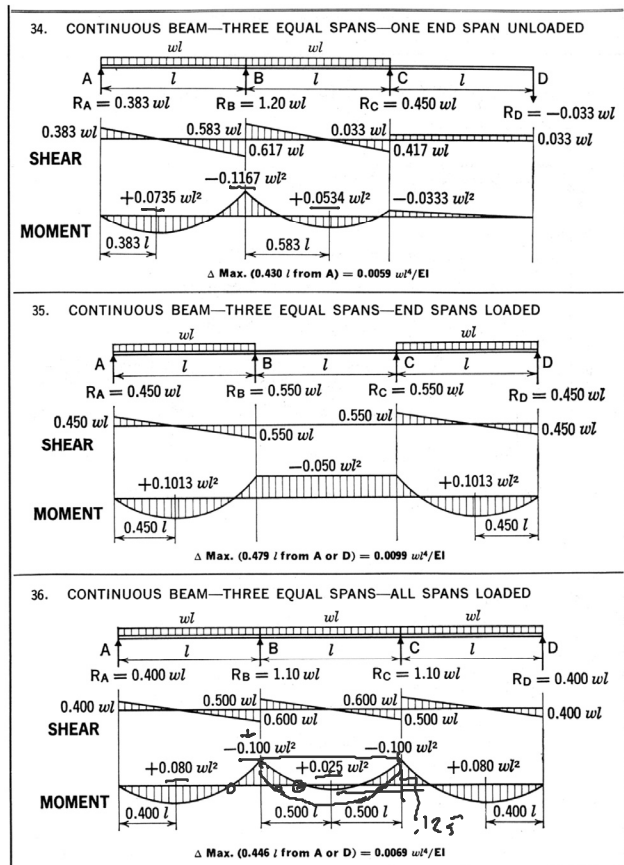


Simple vs. Continuous Beams



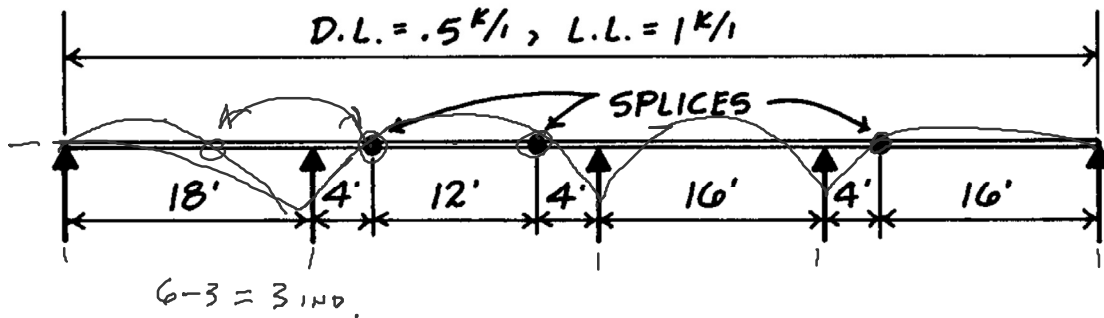
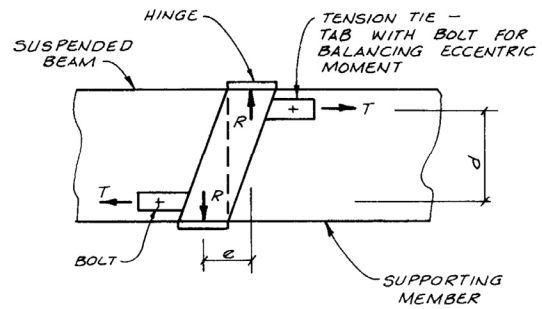
- Simple Beam
 - End moments = 0
 - M_{max} at C.L = $\frac{wL^2}{8} = 0.125wL^2$
- Continuous Beam
 - Exterior end moments = 0
 - Interior support moments are usually negative
 - Mid-span moments are usually positive
 - End + Mid = $0.125wL^2$

Note: moments shown reversed



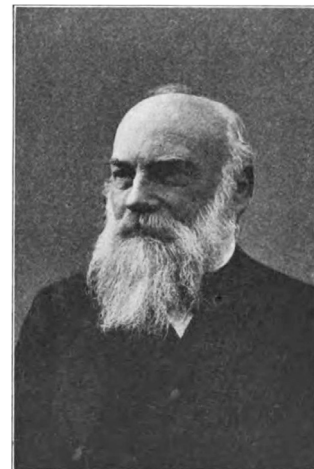
Splice or Hinge

- Can add one hinge for each redundant reaction
- Reduces length for transport
- Moment = 0 at hinge
- Can be used to balance – and + moments for optimization

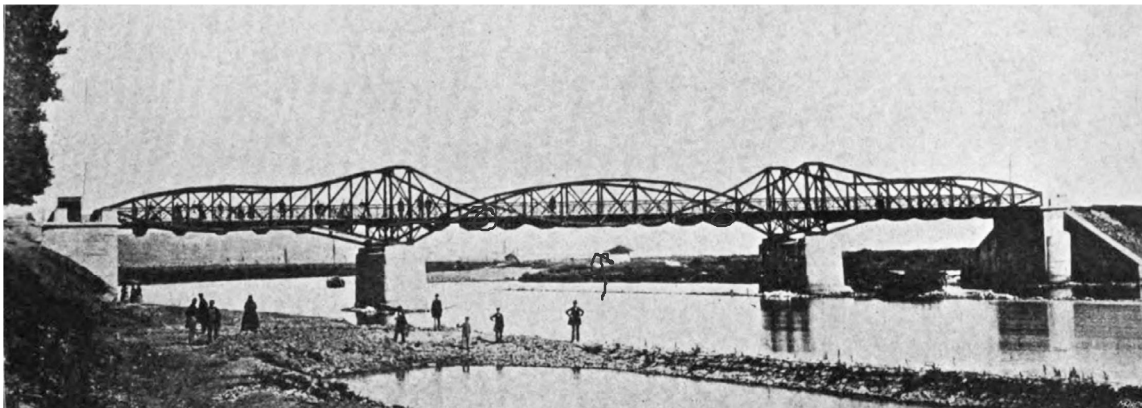


Gottfried Heinrich Gerber (1832-1912)

Developed a cantilever bridge spanning system used in many bridges worldwide. The system became known as the "Gerber Beam" and uses cantilever segments to support a simple span.



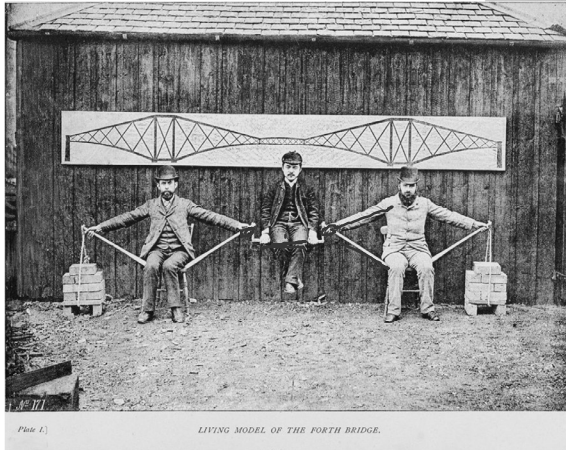
Haßfurter Brücke, 1864. Span of 38 m over the Main River.



Examples of the Gerber system

Firth of Forth Bridge, 1890

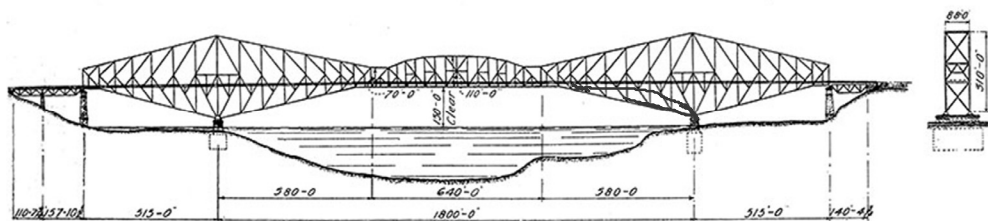
- total length 8094 ft.
- central span 1700 ft.
- Design Fowler & Baker
- Construction 1882 - 1889



Static modeling of the Firth of Forth Bridge by Fowler & Baker



Quebec Bridge Final Completion 1917



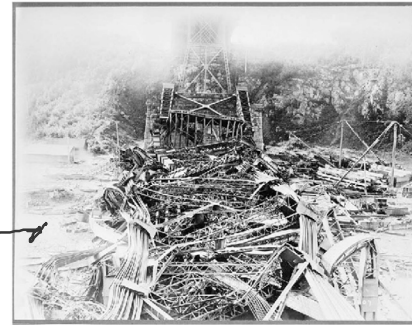
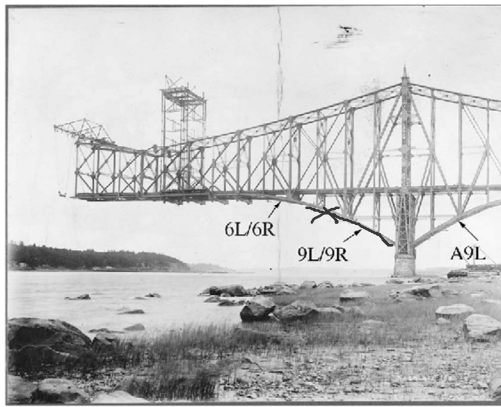
ST. LAWRENCE BRIDGE COMPANY DESIGN AS FINALLY APPROVED AND BUILT



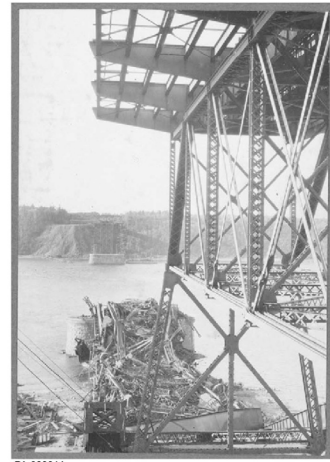
Final successful completion 1917

Quebec Bridge failure – 1907 and 1916

Compression members that failed in 1907



1916 hoisting failure



1907 failure due to miscalculation of the steel strength and dead load.

Gerber system in building frames

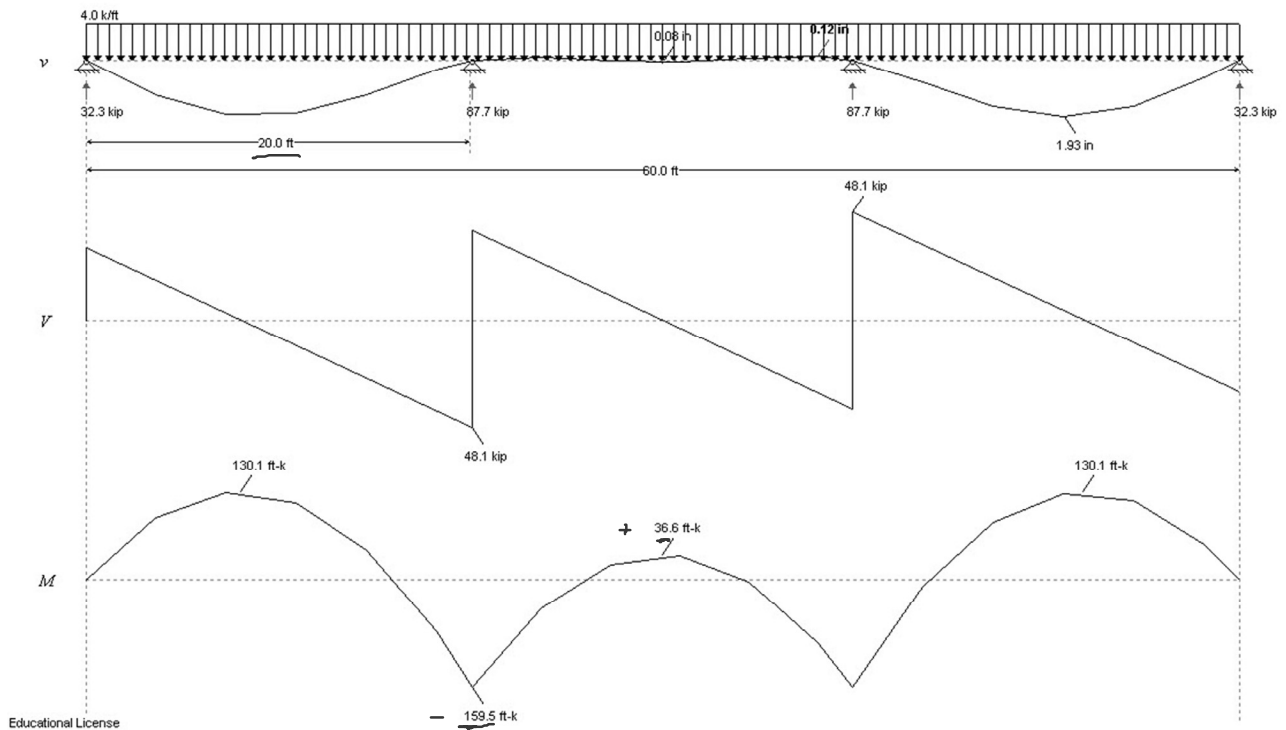


Speicherstadt Hamburg Kaffeerösterei
1888

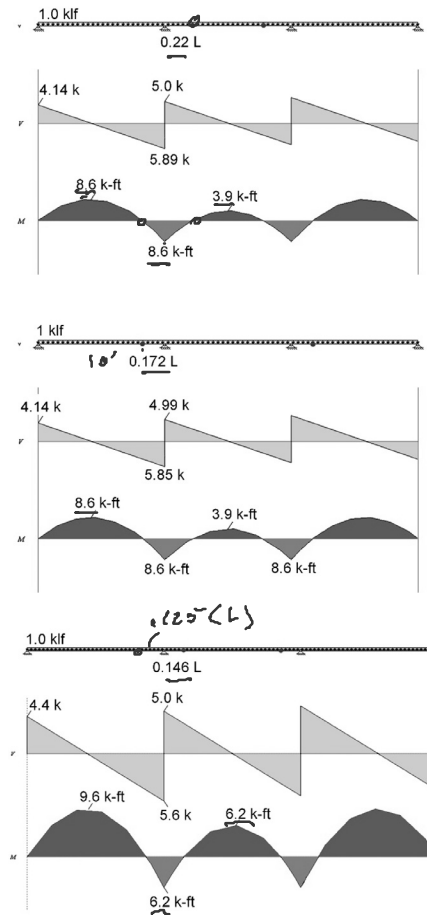
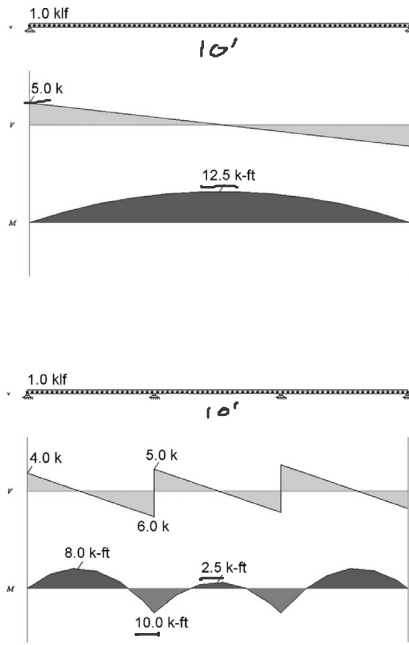
Gerber Beams in Detroit



Moment control in beams



Moment control in beams



Example Problem

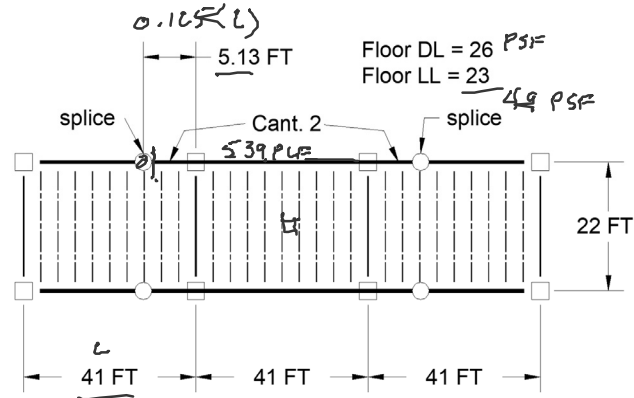
Given:

Span and loading

- D + L = 49 psf
- $49 \text{ psf} \times 11 \text{ ft} = 539 \text{ plf}$

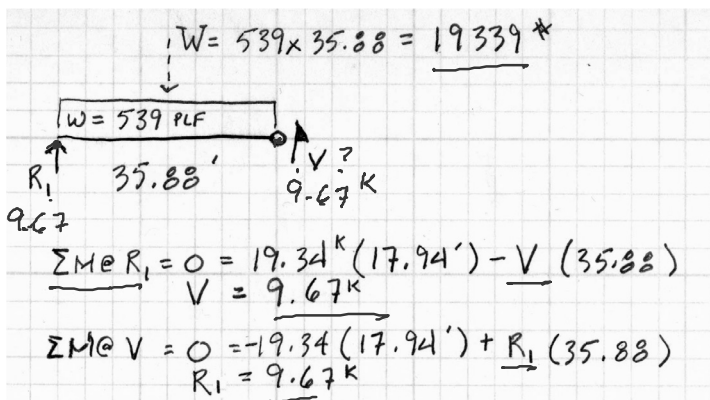
Find:

shear and moment
beam section



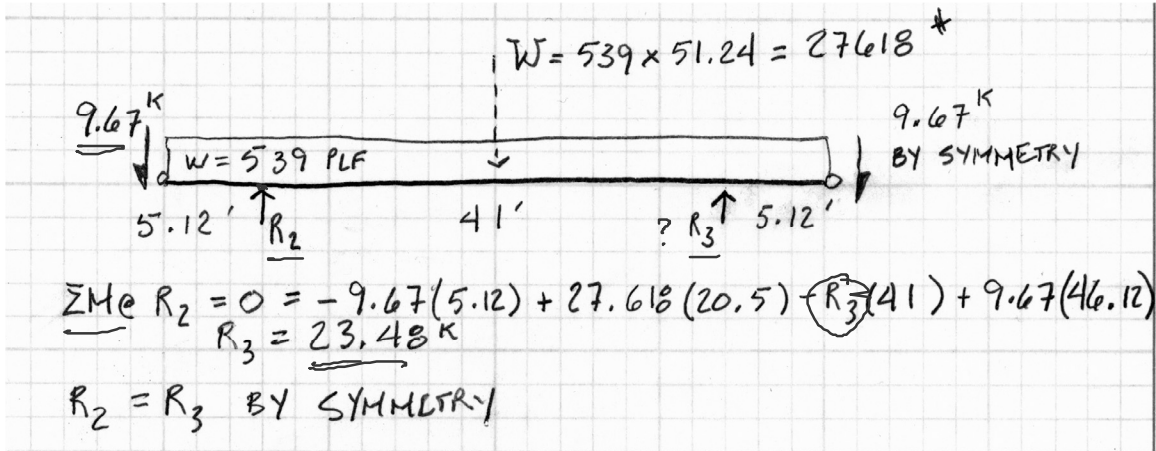
FBD 1

Reactions



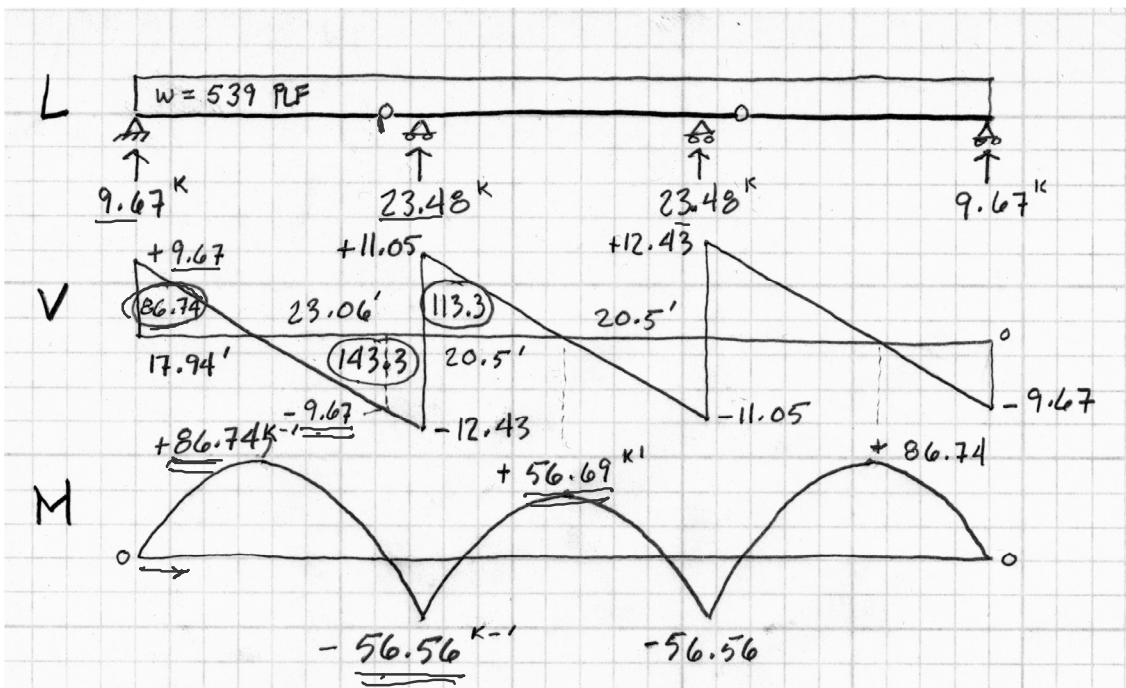
Example Problem cont.

FBD 2
Reactions



Example Problem cont.

Force Diagrams



Example Problem cont.

STEEL BEAM DESIGN

$M_u = 86.74 \text{ K-FT}$ $V_u = 12.43 \text{ K}$

$M_u = \phi M_n$

$M_n = \frac{M_u}{\phi} = \frac{86.74}{0.9} = 96.38 \text{ K-FT}$

$M_n = F_y Z_x$

$Z_x = \frac{M_n}{F_y} = \frac{96.38(12)}{50 \text{ ksi}} = 23.13 \text{ in}^3$

LOOK UP SECTION IN Z_x TABLE

CHOOSE W12x19

$Z_x = 24.7 > 23.13$ ✓

$\phi M_n = 92.6 > 86.74$ ✓

CHECK SHEAR

$\frac{h}{t_w} = 46.2 < 59$ ✓

$A_w = t_w d = 0.235(12.5) = 2.87 \text{ in}^2$

$\phi V_n = (1.0) 0.6 F_y A_w = 0.6(50)(2.87)$

$\phi V_n = 86.01 > 12.43 = V_u$ ✓ OK ✓

Table 3-2 (continued)
W-Shapes
Selection by Z_x

$F_y = 50 \text{ ksi}$

ϕM_p

Shape	Z_x in ³	M_p/Ω_b		ϕM_p		M_p/Ω_b		ϕM_p		BF/Ω_b ASD	$\phi_B BF$ LRFD	L_p ft	L_r ft	I_x in ⁴	V_n/Ω_v		ϕV_n	
		ASD	LRFD	ASD	LRFD	ASD	LRFD	ASD	LRFD									
W14x26	40.2	100	151	61.7	92.7	5.33	8.11	3.81	11.0	245	70.9	106						
W8x40	39.8	99.3	149	62.0	93.2	1.64	2.46	7.21	29.9	146	59.4	89.1						
W10x33	38.8	96.8	146	61.1	91.9	2.39	3.62	6.85	21.8	171	56.4	84.7						
W12x26	37.2	92.8	140	58.3	87.7	3.61	5.46	5.33	14.9	204	56.1	84.2						
W10x30	36.6	91.3	137	56.6	85.1	3.08	4.61	4.84	16.1	170	63.0	94.5						
W8x35	34.7	86.6	130	54.5	81.9	1.62	2.43	7.17	27.0	127	50.3	75.5						
W14x22	33.2	82.8	125	50.6	76.1	4.78	7.27	3.67	10.4	199	63.0	94.5						
W10x26	31.3	78.1	117	48.7	73.2	2.91	4.34	4.80	14.9	144	53.6	80.3						
W8x31	30.4	75.8	114	48.0	72.2	1.58	2.37	7.18	24.8	110	45.6	68.4						
W12x22	29.3	73.1	110	44.4	66.7	4.68	7.06	3.00	9.13	156	64.0	95.9						
W8x28	27.2	67.9	102	42.4	63.8	1.67	2.50	5.72	21.0	98.0	45.9	68.9						
W10x22	26.0	64.9	97.5	40.5	60.9	2.68	4.02	4.70	13.8	118	49.0	73.4						
W12x19	24.7	61.6	92.6	37.2	55.9	4.27	6.43	2.90	8.61	130	57.3	86.0						
W8x24	23.1	57.6	86.5	36.5	54.9	1.60	2.40	5.69	18.9	82.7	38.9	58.3						
W10x19	21.6	53.9	81.0	32.8	49.4	3.18	4.76	3.09	9.73	96.3	51.0	76.5						
W8x21	20.4	50.9	76.5	31.8	47.8	1.85	2.77	4.45	14.8	75.3	41.4	62.1						
W12x16	20.1	50.1	75.4	29.9	44.9	3.80	5.73	2.73	8.05	103	52.8	79.2						
W10x17	18.7	46.7	70.1	28.3	42.5	2.98	4.47	2.98	9.16	81.9	48.5	72.7						
W12x14	17.4	43.4	65.3	26.0	39.1	3.43	5.17	2.66	7.73	88.6	42.8	64.3						
W8x18	17.0	42.4	63.8	26.5	39.9	1.74	2.61	4.34	13.5	61.9	37.4	56.2						
W10x15	16.0	39.9	60.0	24.1	36.2	2.75	4.14	2.86	8.61	68.9	46.0	68.9						
W8x15	13.6	33.9	51.0	20.6	31.0	1.90	2.85	3.09	10.1	48.0	39.7	59.6						
W10x12	12.6	31.2	46.9	19.0	28.6	2.36	3.53	2.87	8.05	53.8	37.5	56.3						
W8x13	11.4	28.4	42.8	17.3	26.0	1.76	2.67	2.98	9.27	39.6	36.8	55.1						
W8x10	8.87	21.9	32.9	13.6	20.5	1.54	2.30	3.14	8.52	30.8	26.8	40.2						

ASD LRFD

$\Omega_b = 1.67$ $\phi_b = 0.90$
 $\Omega_v = 1.50$ $\phi_v = 1.00$

* Shape exceeds compact limit for flexure with $F_y = 50 \text{ ksi}$; tabulated values have been adjusted accordingly.
* Shape does not meet the h/t_w limit for shear in AISC Specification Section G2.1(a) with $F_y = 50 \text{ ksi}$; therefore, $\phi_v = 0.90$ and $\Omega_v = 1.67$.

Structural Optimization

Optimization procedure: Find the "best" solution for a given problem.

- Describe the goal – objectives (single vs. multiple)
- Determine limitations – constraints
- Describe the parameters – variables

Optimization type: What to optimize

- Material
- Member (section)
- Geometry
- Topology



Truss: 1 weight = 25484 lb
16 joints 35 members



Truss: 2 weight = 25050 lb
16 joints 35 members



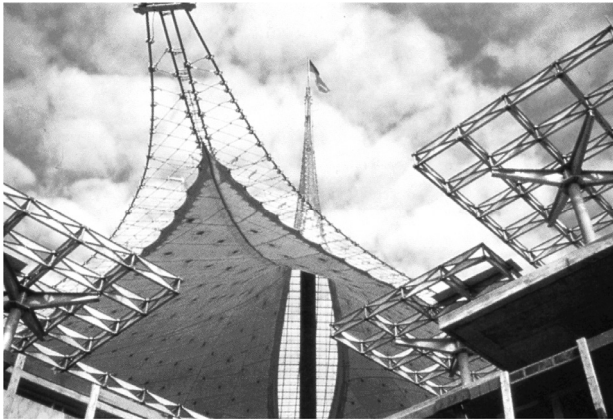
Truss: 3 weight = 24529 lb
16 joints 35 members

Optimization

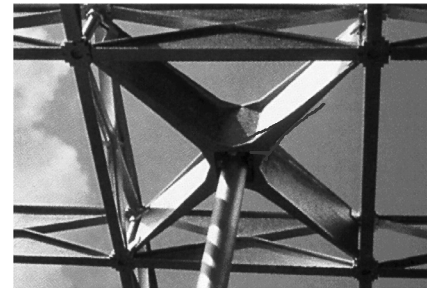
- Material
 - Composites
 - Steel vs. Aluminum
- Member and Geometry
 - Variable Depth or Width
 - Holes and Cut-outs



Biesenbach Viaduct, Blumberg Wutachtal Railroad, 1890
Eng. von Würthenau, Kräuter, Gebhard & Gernet



German Pavillion at Expo 1967, Montreal
Eng. Frei Otto Arch. Rolf Gutbrot



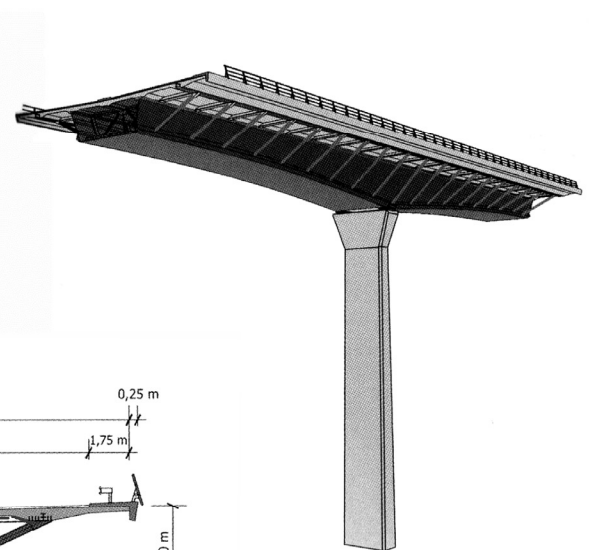
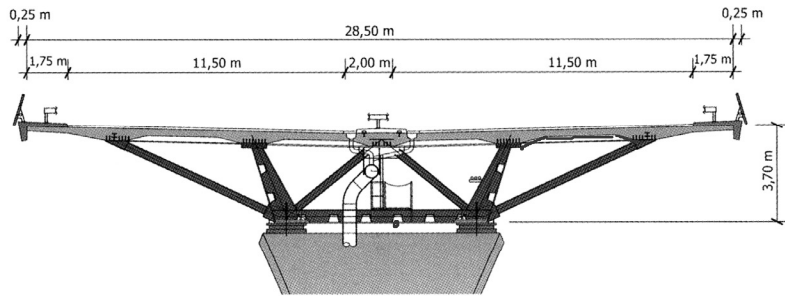
Section Optimization



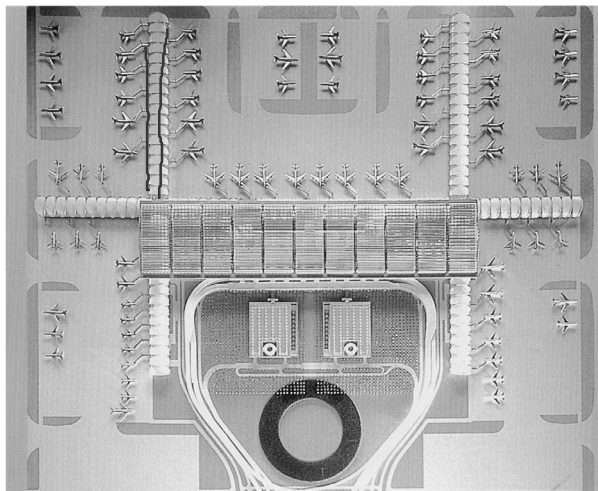
Reichenbach Valley Bridge, 2003
Eng. Büro Peter + Lochner

Section Optimization

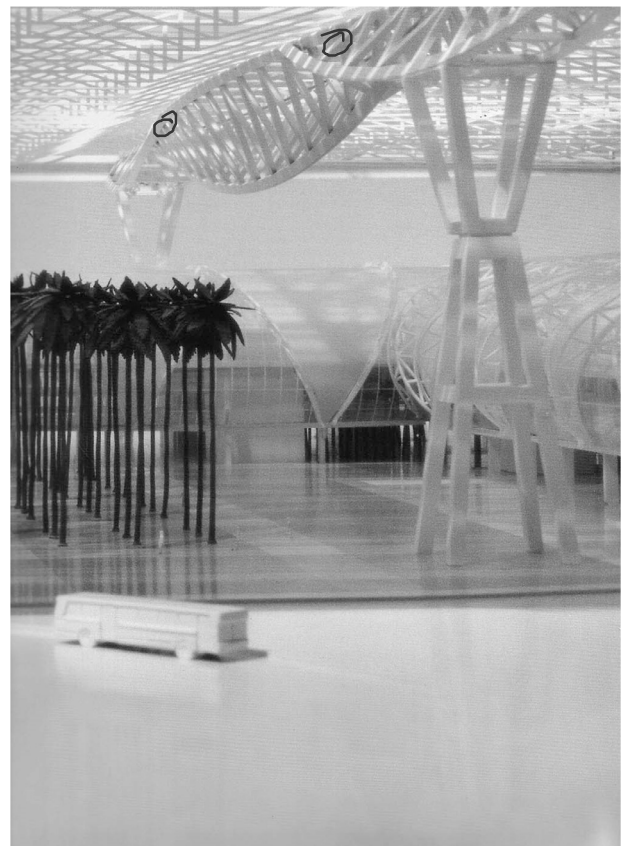
Reichenbach Valley Bridge, 2003
Eng. Büro Peter + Lochner



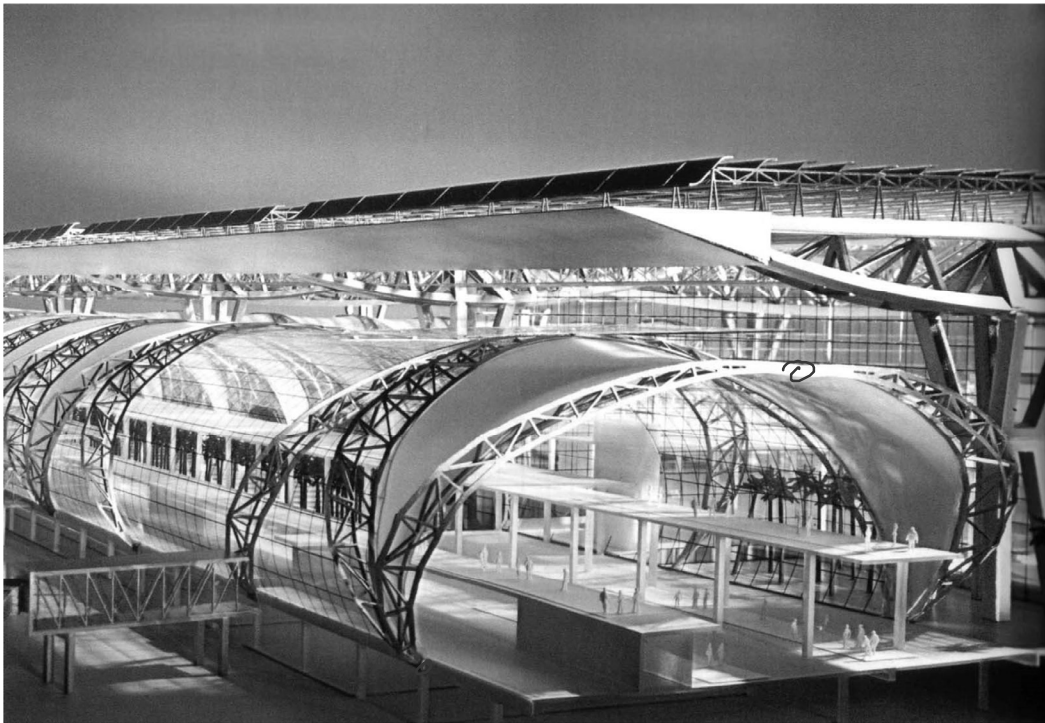
Geometry Optimization



New Bangkok International Airport, 2003
Eng. Werner Sobek Arch. Murphy Jahn

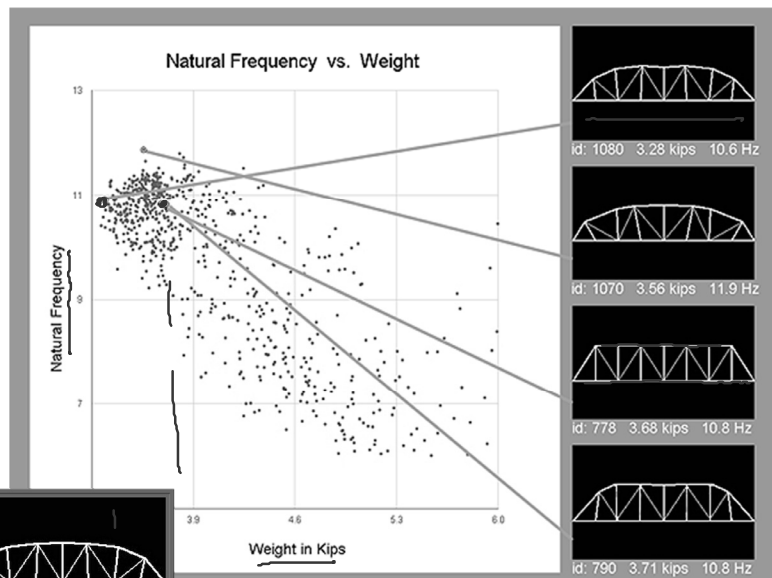
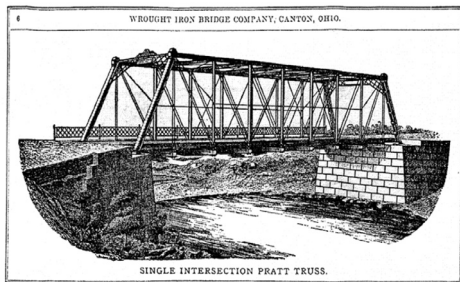


Geometry Optimization

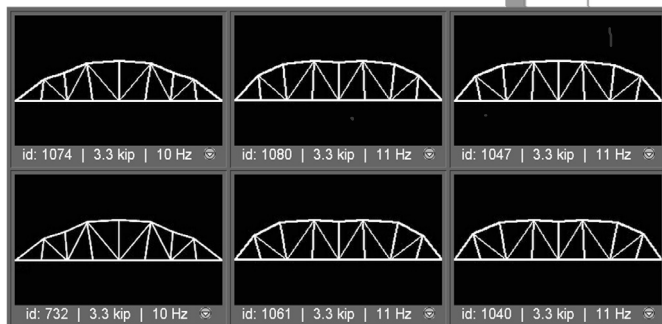


New Bangkok International Airport, 2003
Eng. Werner Sobek Arch. Murphy Jahn

Geometry Optimization - Bridges



plot of weight vs natural frequency



lightest solutions

Topology Optimization - Shukhov towers



Nizhny Novgorod, 1896

