ae senior thesis

april 26, 2013

advisor: dr. boothby

victoria interval [struc]

MTOB

multi-tenant office building

pennsylvania

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april 26, 2013

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victoria interval [struc]

MTOB

multi-tenant office building

pennsylvania

stats

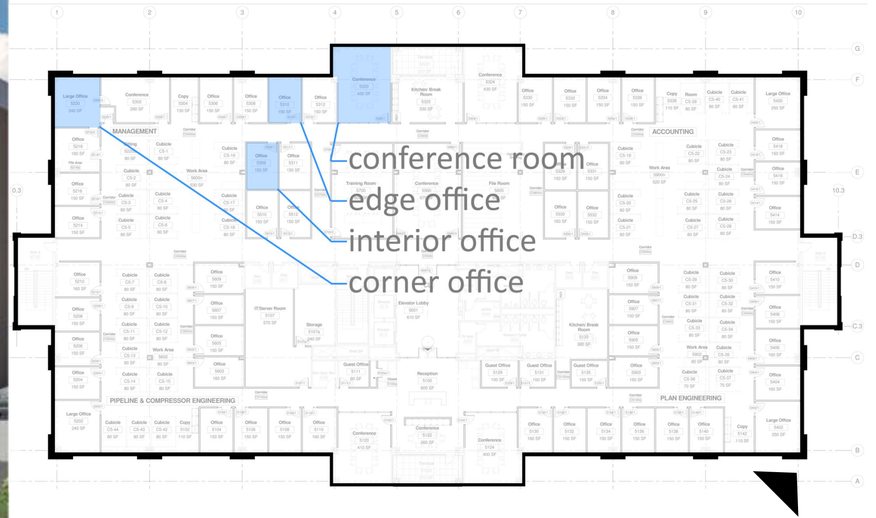
152,000 SF

5 stories

composite steel framing

construction July 2012 to July 2013

located in office park



project team

general contractor | **Rycon Construction Inc.**

architect | **Kernick Architecture, LLC**

structural engr | **Atlantic Engineering Services**

site/civil engr | **Gateway Engineers**

scenario

tenant looking for more **contemporary** high-end space:

open feel

modern materials

scenario

proposal

tenant looking for more **contemporary** high-end space:

open feel

modern materials

struc – cellular beams in exposed ceiling

scenario

proposal

tenant looking for more **contemporary** high-end space:

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modern materials

struc – cellular beams in exposed ceiling

mech – run through structure (IBC height restriction)

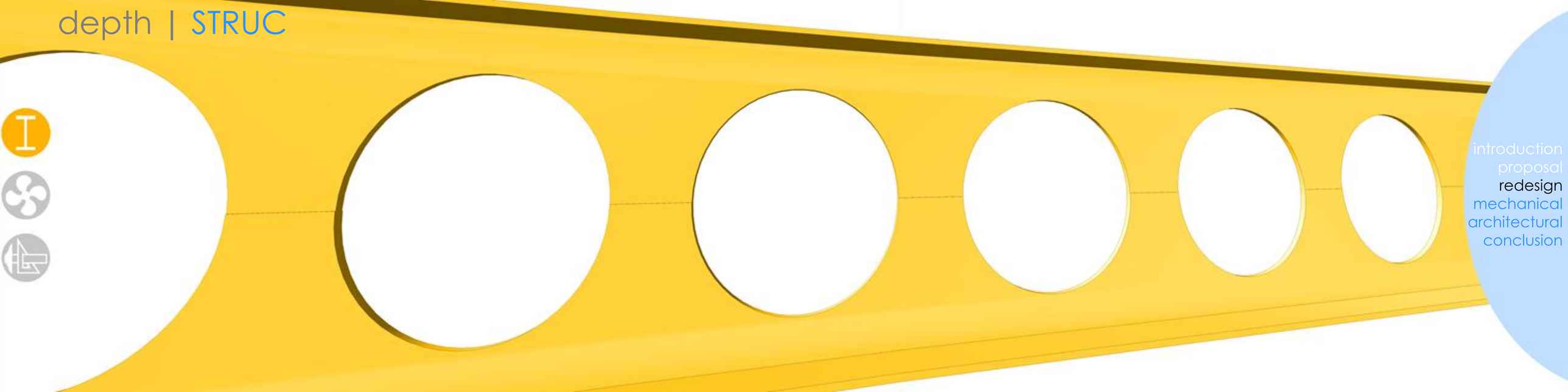
scenario

proposal

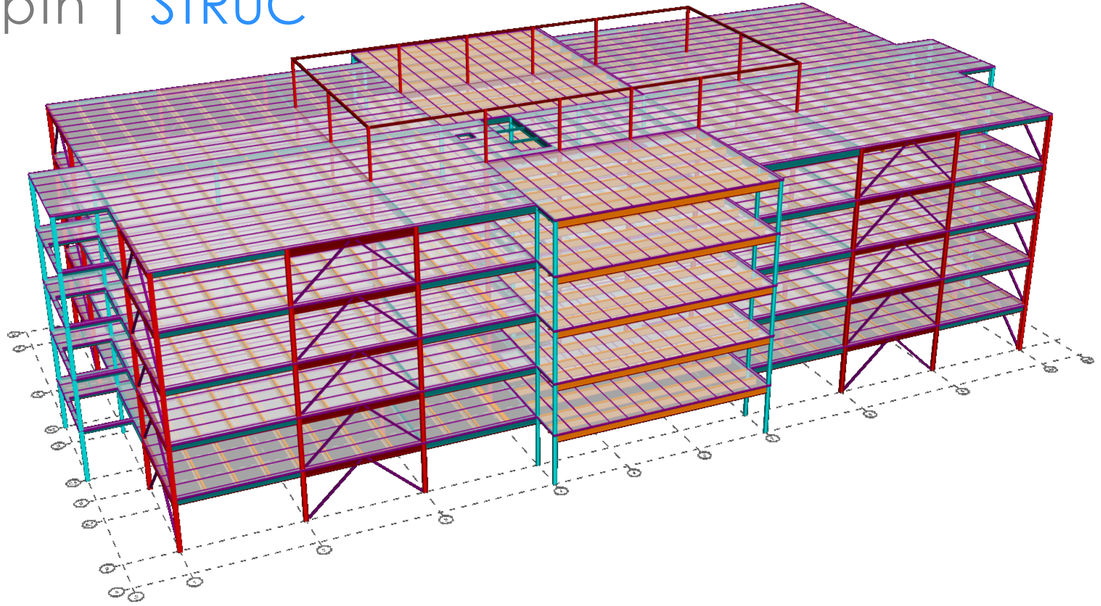
tenant looking for more **contemporary** high-end space:

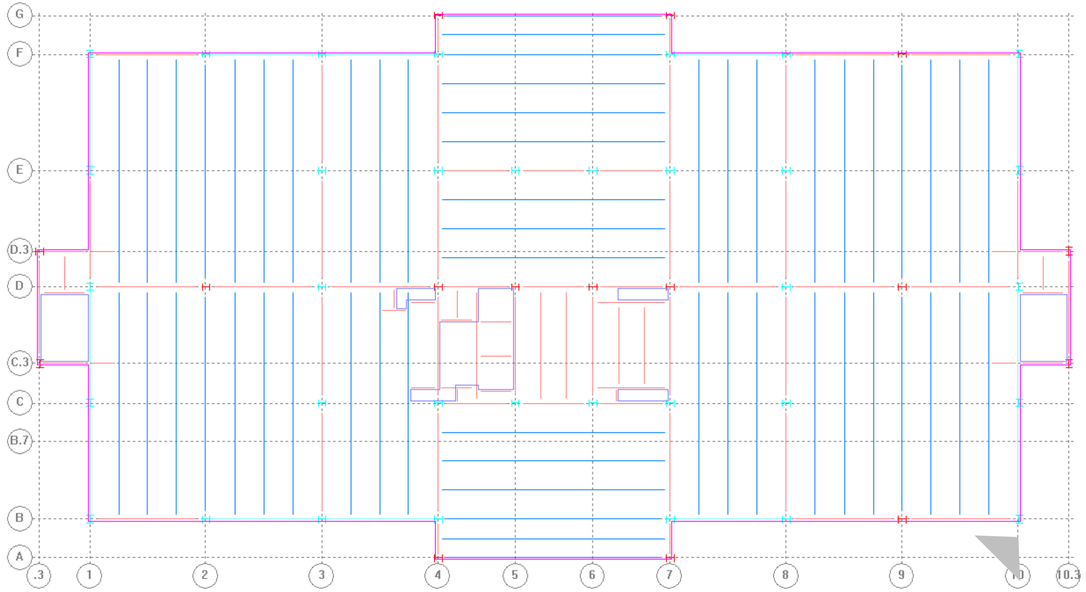
open feel → **struc** – cellular beams in exposed ceiling → **mech** – run through structure (IBC height restriction)

modern materials → **arch** – façade redesign (aesthetics + thermal)

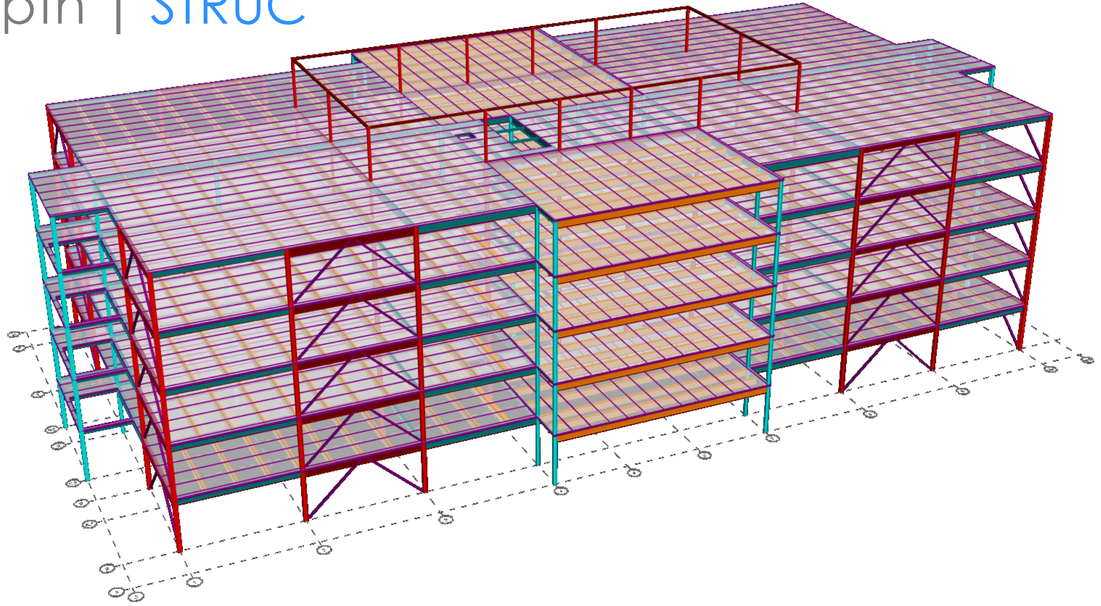


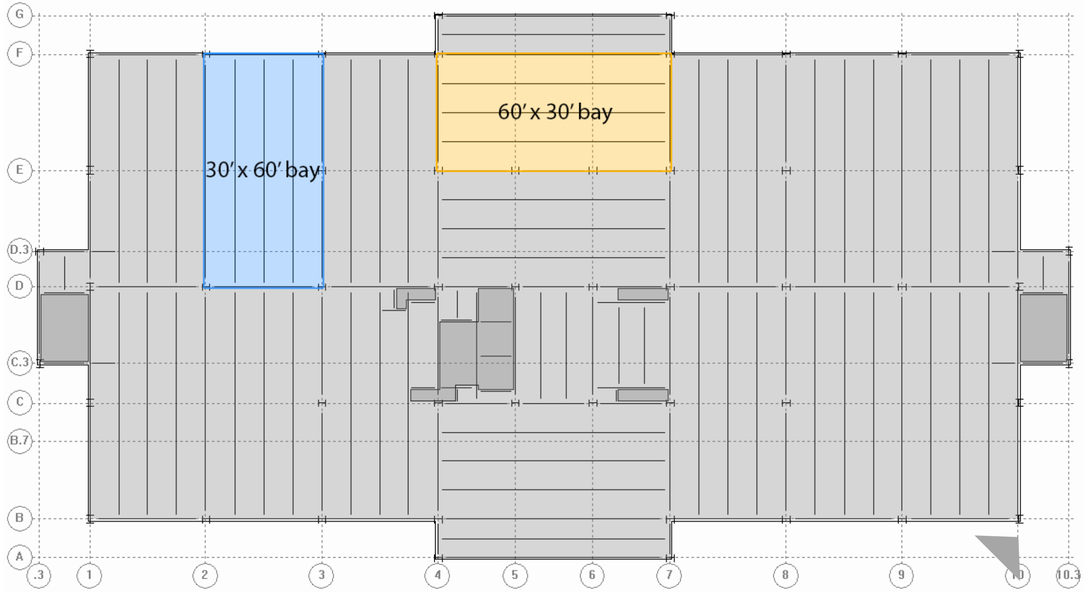
depth | STRUC





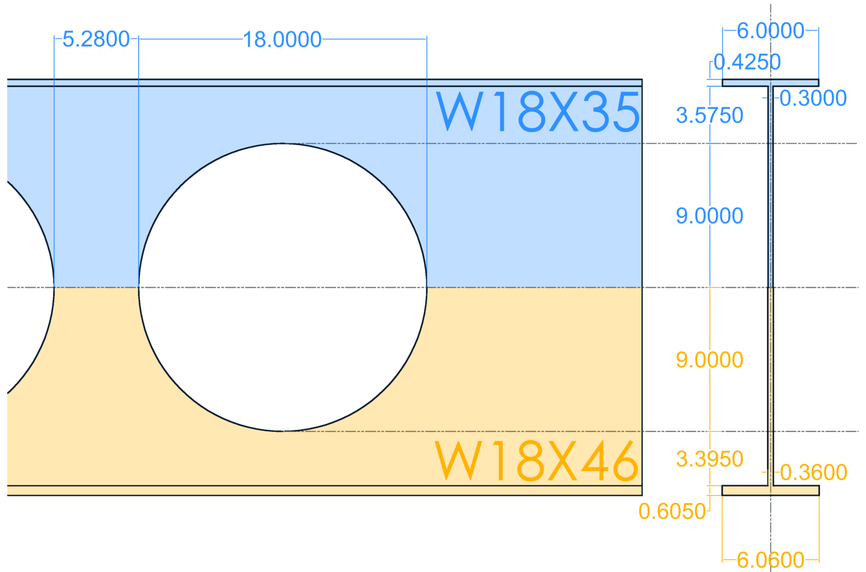
depth | STRUC





RAM optimized:

LB27x35/46



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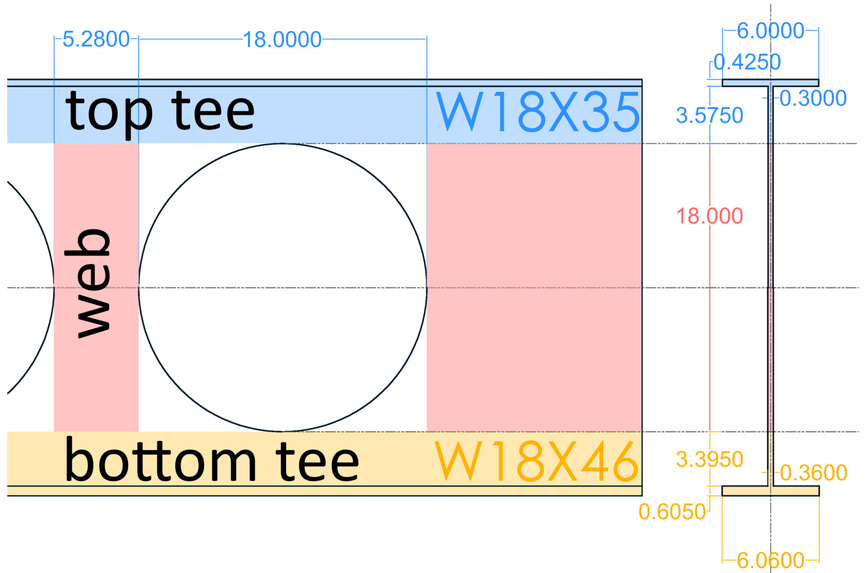
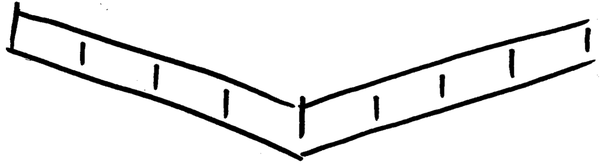


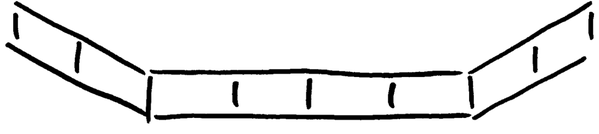
plastic analysis assumptions

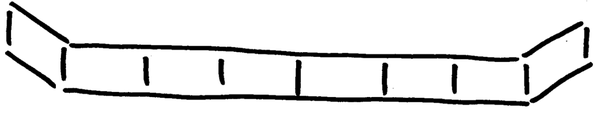
+ behaves like Vierendeel Truss

+ failure mechanism will be symmetrical

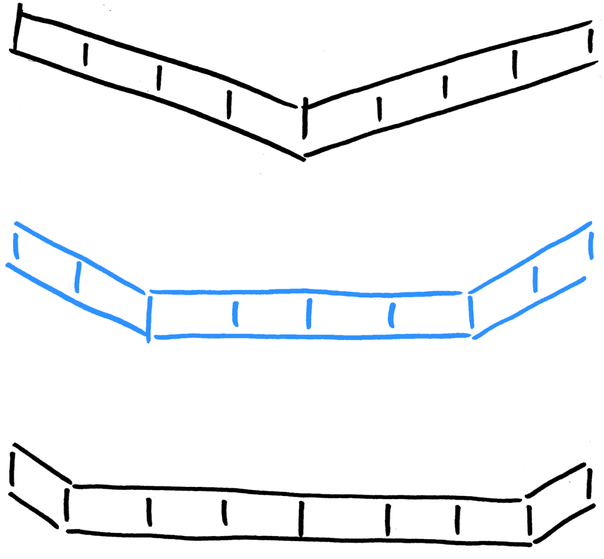
depth | STRUC plastic analysis

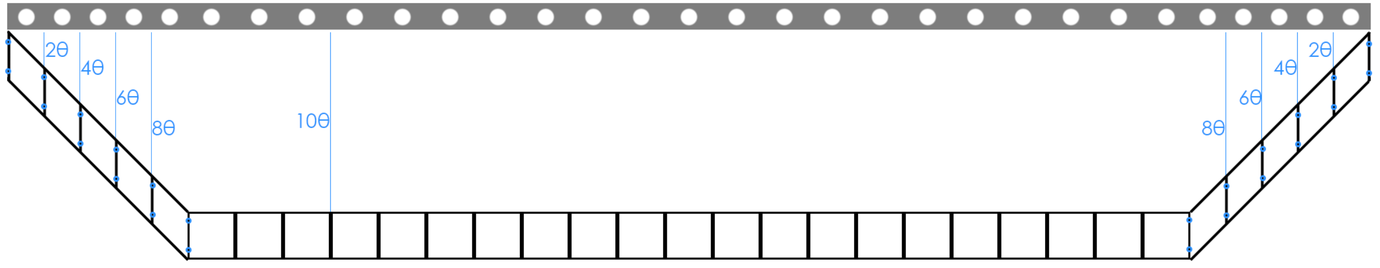






depth | STRUC plastic analysis



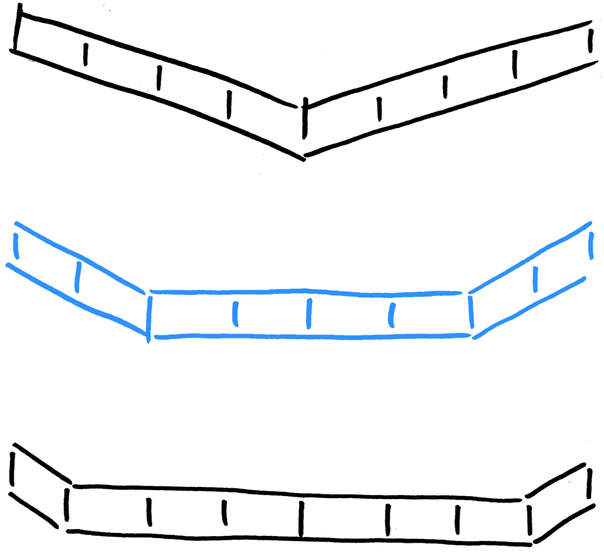


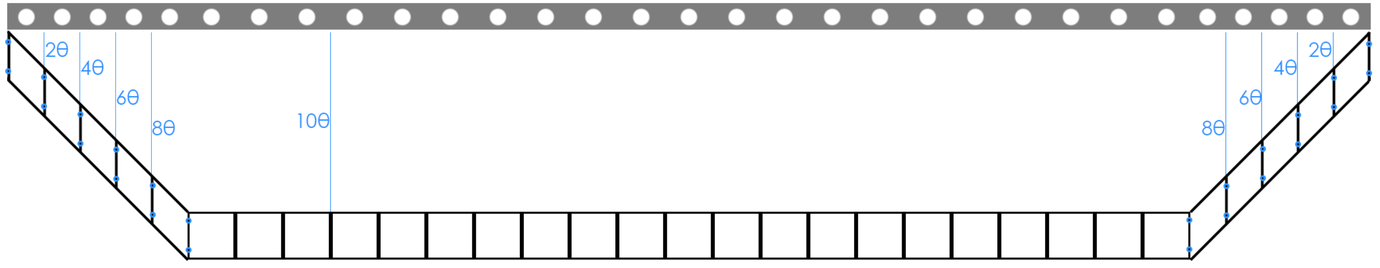
controlling collapse mechanism

failure load P = 11 k = 5.5 klf

actual load = 0.9 klf

depth | STRUC plastic analysis





controlling collapse mechanism

failure load P = 11 k = 5.5 klf

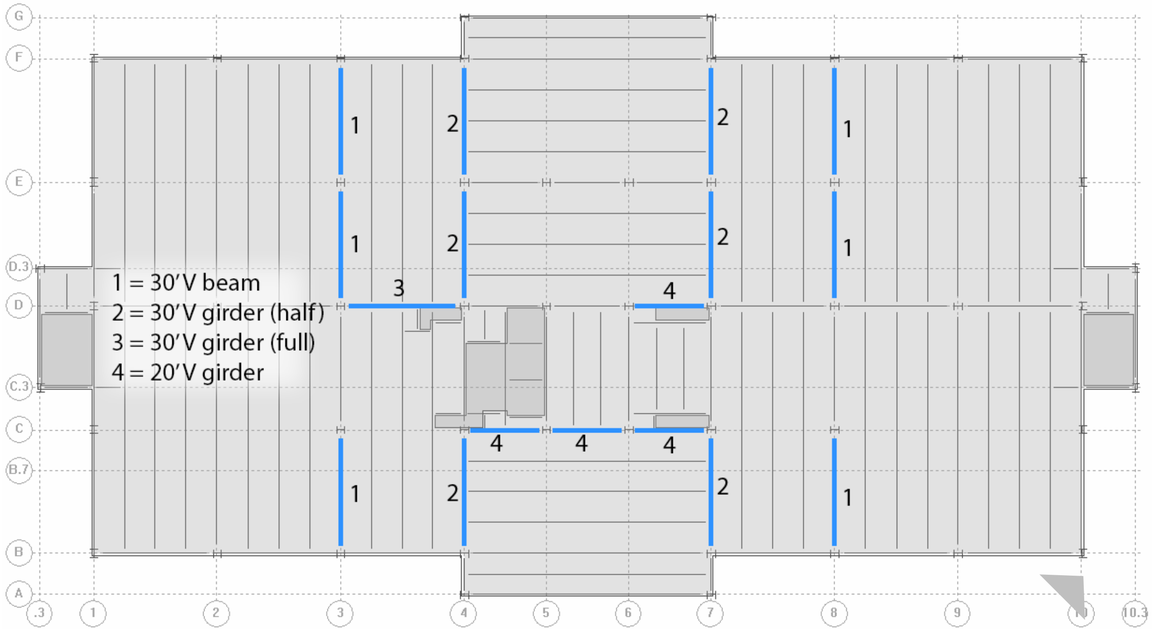
actual load = 0.9 klf

+ axial force in flanges

+ deflection

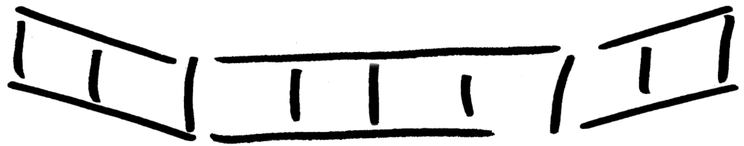
+ web buckling

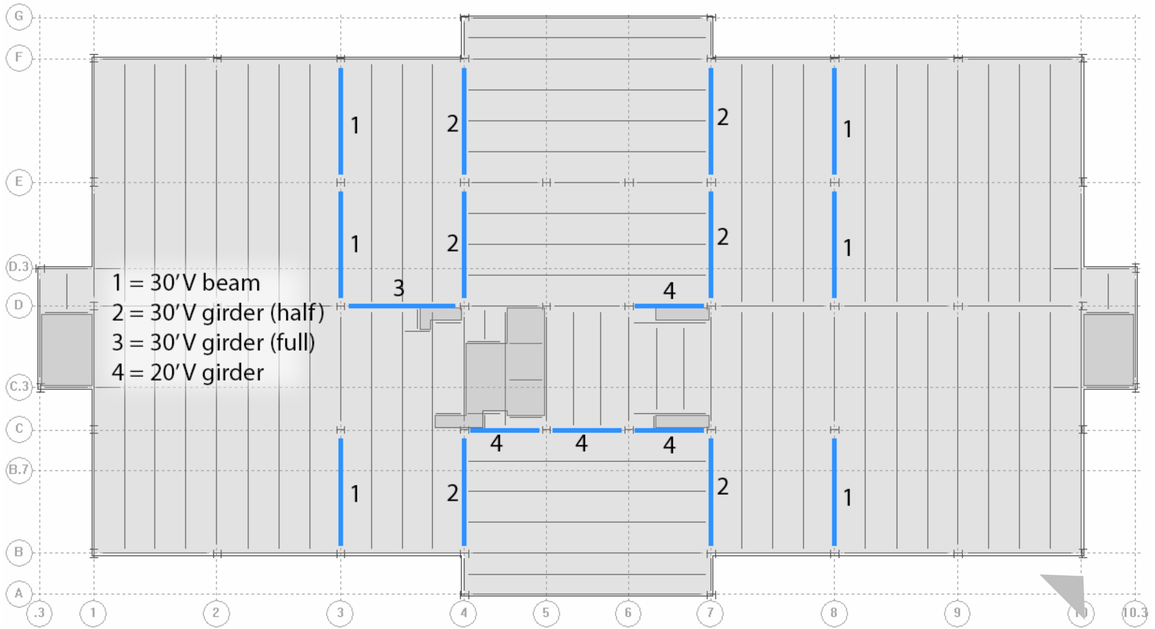
depth | STRUC vierendeel trusses

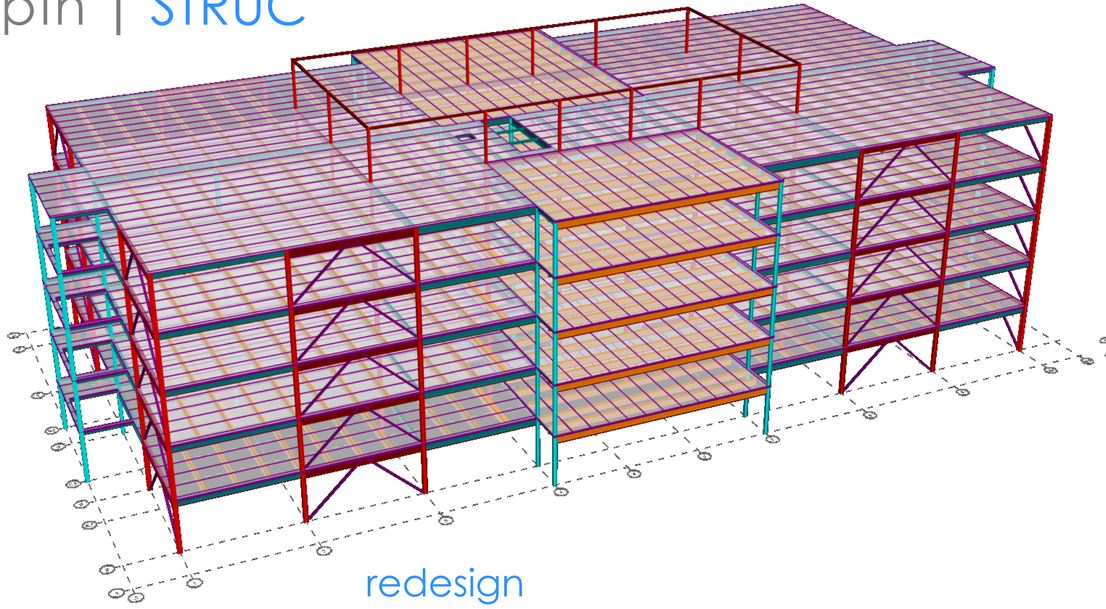


depth | STRUC vierendeel trusses

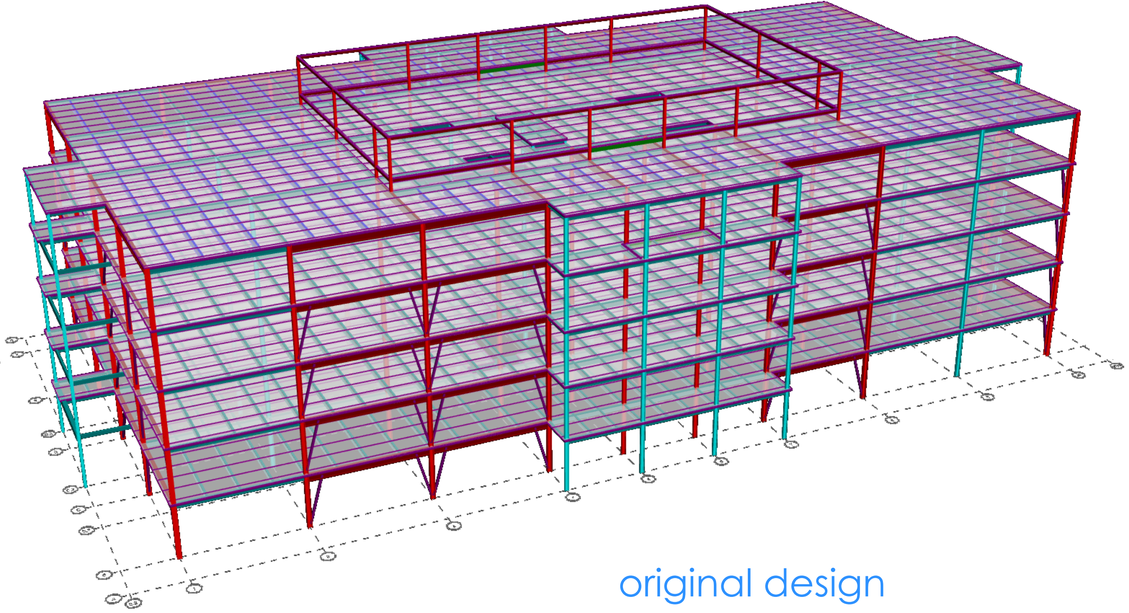
Vierendeel Truss Designs					
Description	Span ft	# panels	Depth in	Size (each member)	quantity
"1" Beam	30	8	27	W8x10	6
"2" Girder (half load)	30	8	27	W8x18	6
"3" Girder (full load)	30	8	27	W8x31	1
"4" Girder	20	6	27	W8x10	4





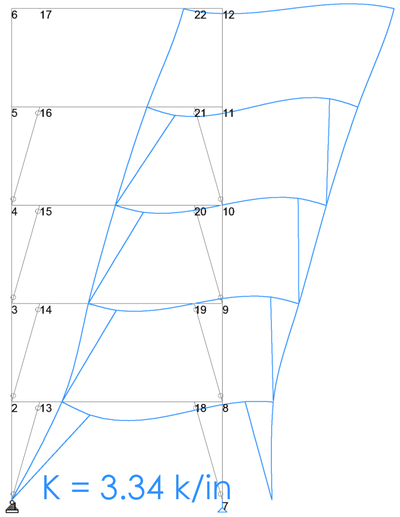


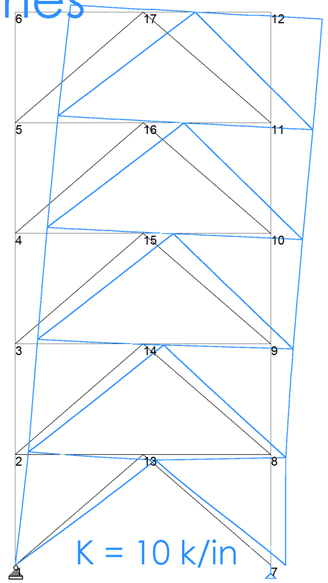
redesign

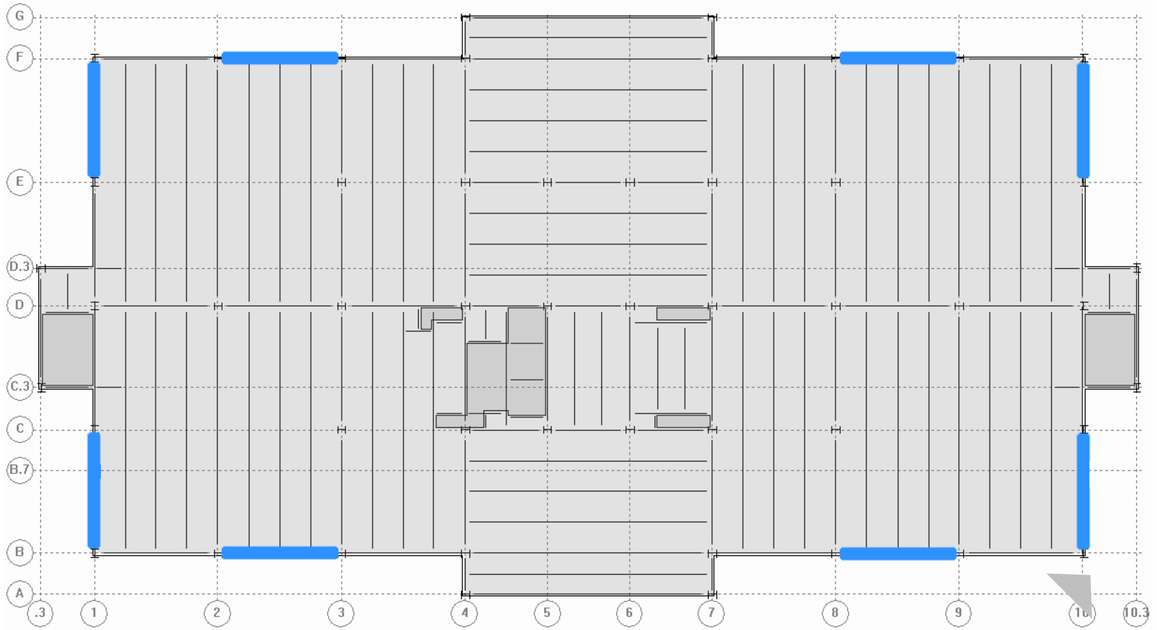


original design

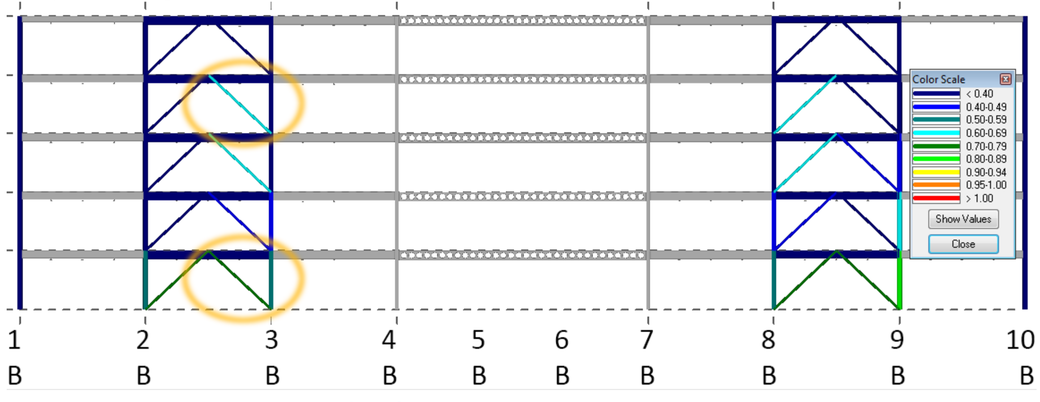
depth | STRUC braced frames



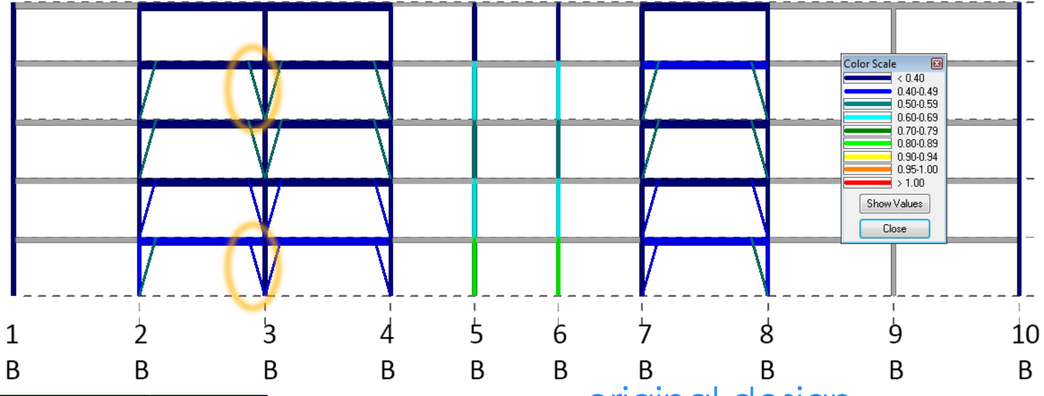




depth | STRUC efficiencies



redesign



original design

≈15% more efficient

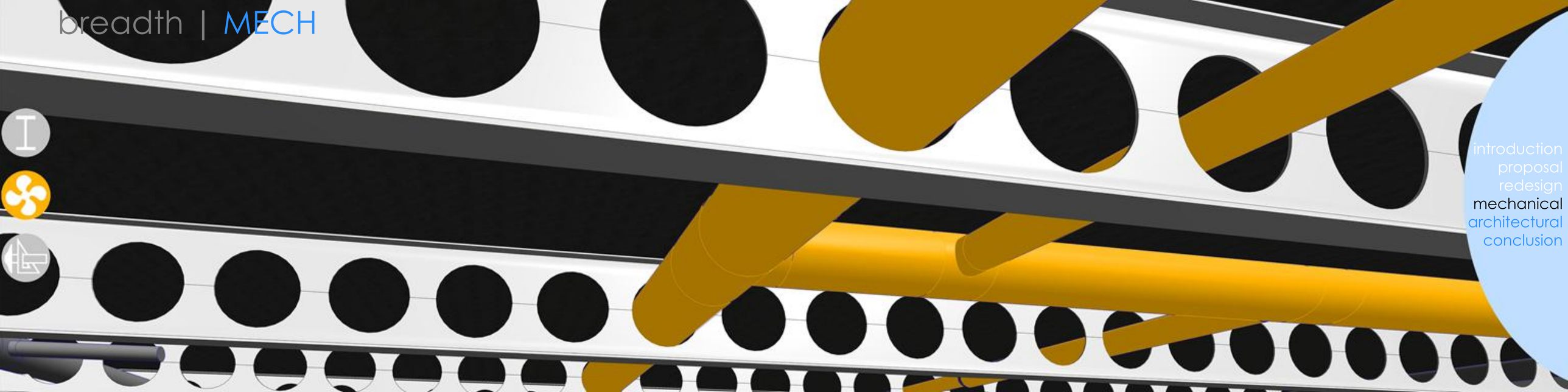
model	floor	size	max axial (k)	efficiency
original	4th floor	HSS6x6x3/8	71.69	.484
	1st floor	HSS6x6x1/2	85.91	.509
redesign	4th floor	HSS6x6x3/8	62.58	.626
	1st floor	HSS6x6x1/2	84.36	.768

depth | STRUC recap

+ verified cellular beam sizes

+ stiffer concentrically braced frames

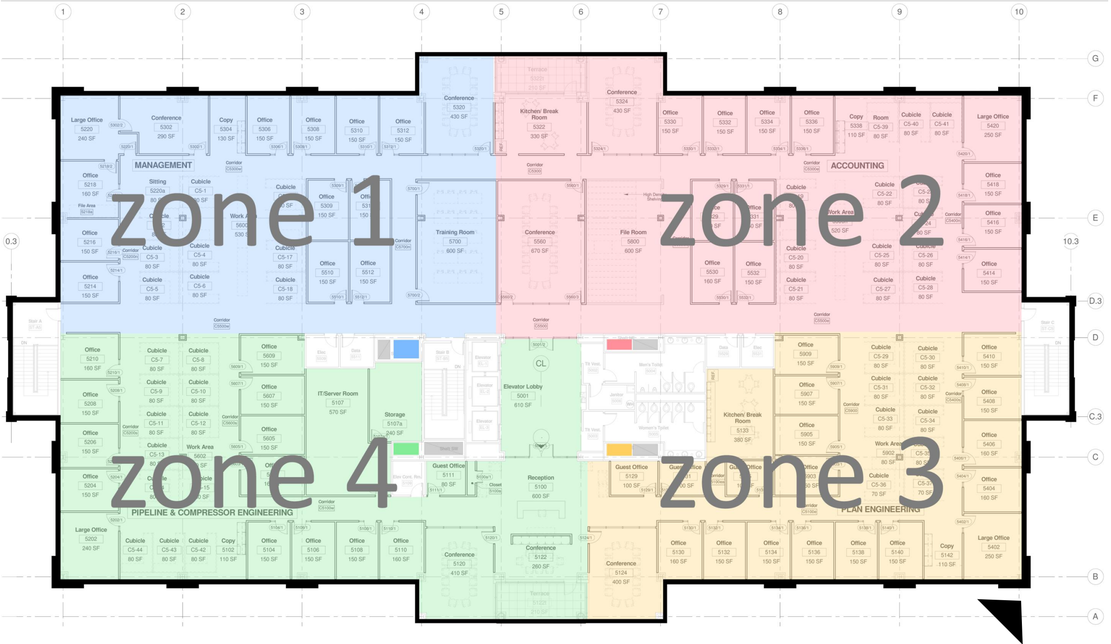
+ more efficient lateral system



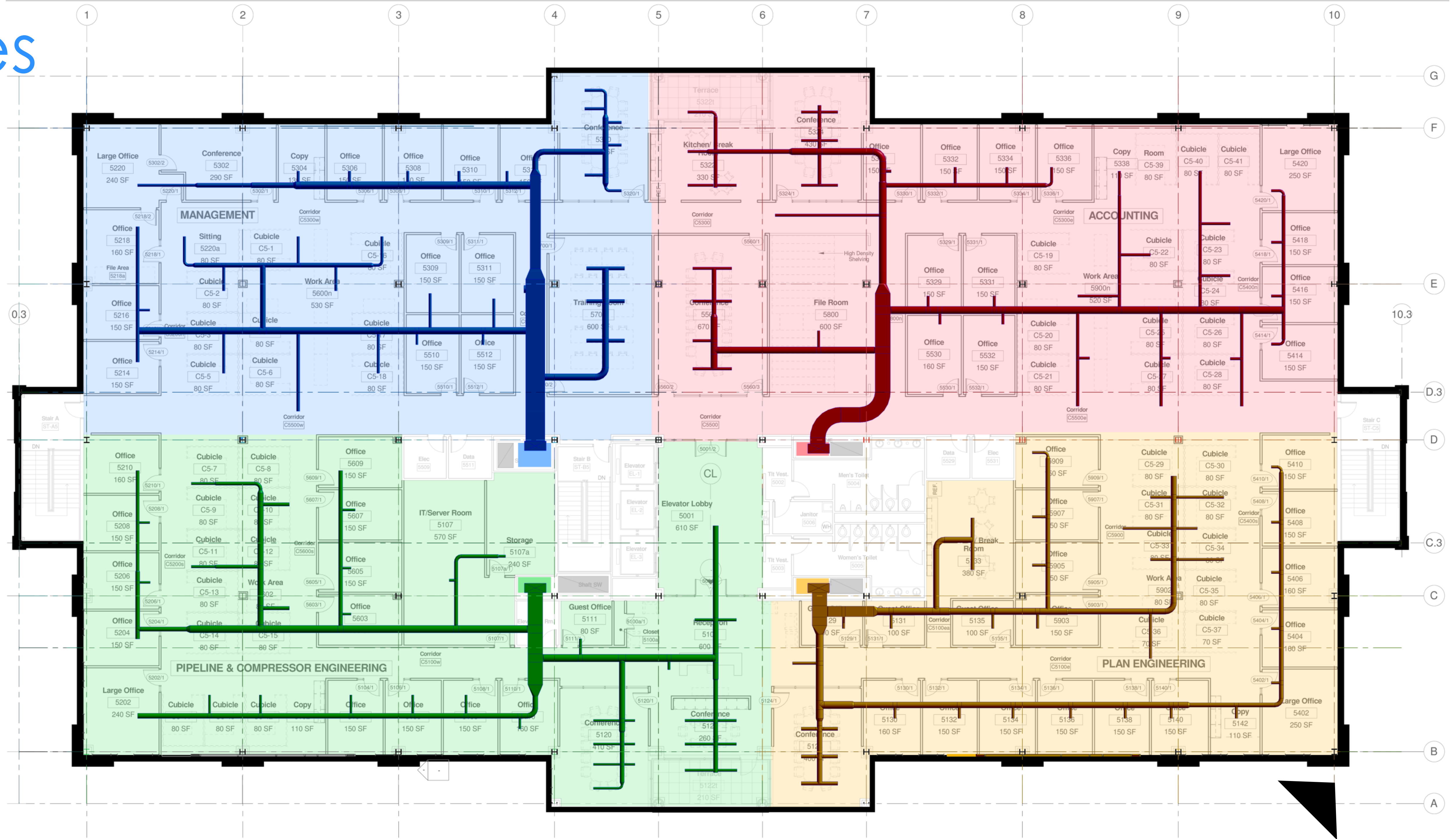
TRACE model – 15,520 CFM/floor

Excel – 14,800 CFM/floor

≈ 5% accuracy



breadth | MECH rtu zones



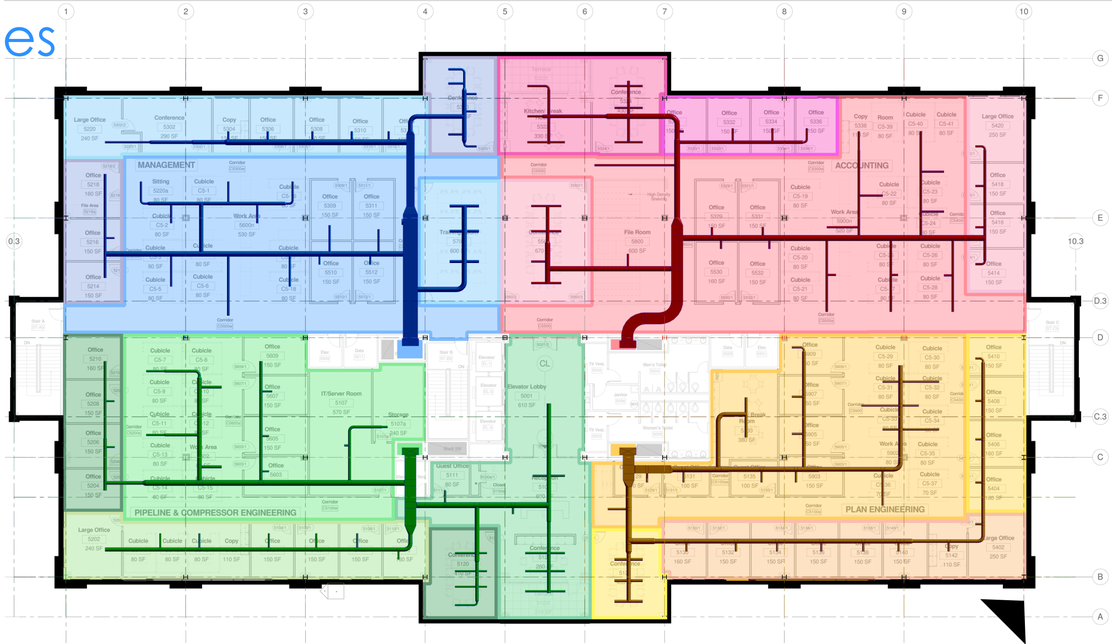
introduction
proposal
redesign
mechanical
architectural
conclusion

breadth | MECH vav zones

original – **2** Fan Powered Boxes

redesign – **19** VAV boxes

+ edge offices
+ conference spaces
+ interior offices



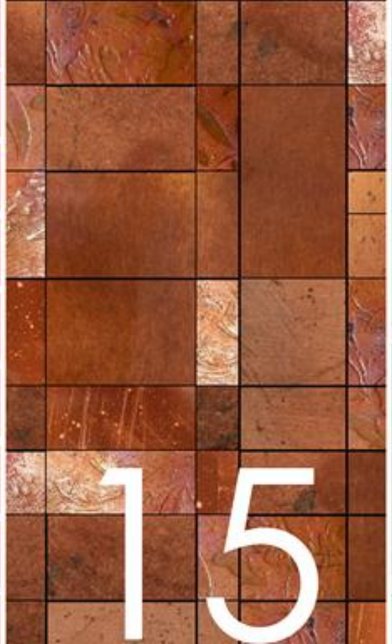
breadth | MECH recap

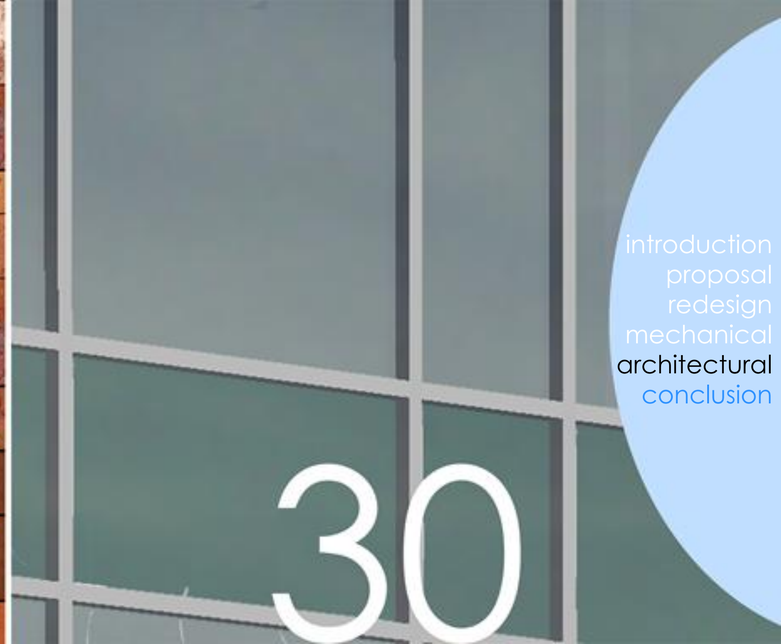
+ met IBC height restrictions

+ able to lay out ductwork through structure

+ added VAV boxes for occupant comfort

breadth | ARCH façade





breadth | ARCH façade

introduction
proposal
redesign
mechanical
architectural
conclusion

breadth | ARCH façade

photo credit:
J. Miles Wolf Photography

inspiration: The Vontz Center, Cincinnati

architect: Frank Gehry

breadth | ARCH façade

southwest view

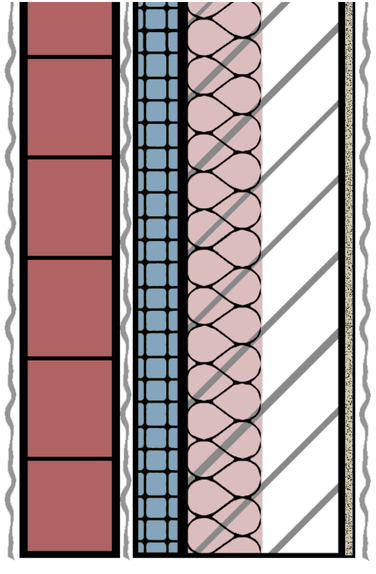
inspiration: The Vontz Center, Cincinnati

architect: Frank Gehry

breadth | ARCH envelope

original

R = 15.3

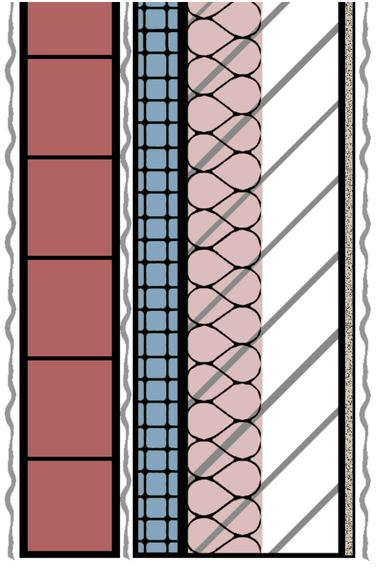


schematic section:

ext air film
brick
air gap
rigid ins
batt ins/metal studs
gypsum bd
int air film

original

R = 15.3



schematic section:

ext air film
brick
air gap
rigid ins
batt ins/metal studs
gypsum bd
int air film

rigid insulation replacement:

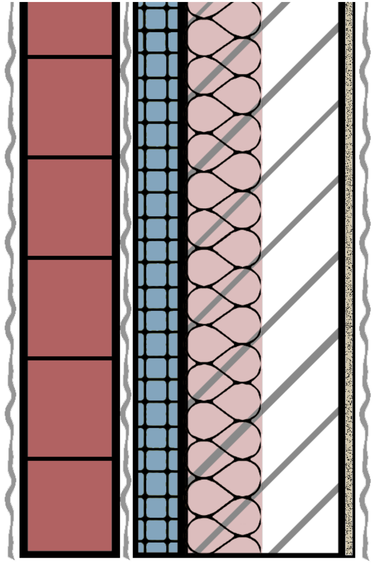
MetalWrap Series (by CENTRIA)

2" rigid insulation

36" x 20' max panel

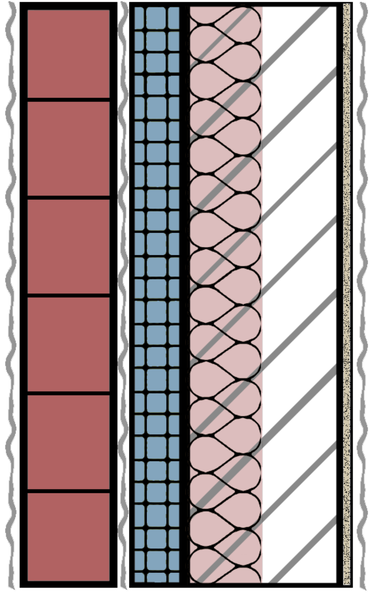
original

R = 15.3



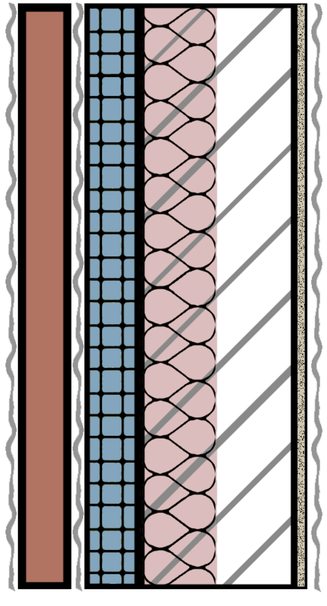
redesigned brick

R = 22.0
44% increase



redesigned metal

R = 21.6
41% increase



+ redesigned façade with modern materials

+ improved thermal properties of envelope

scenario

tenant looking for more **contemporary** high-end space:

open feel

modern materials

scenario

tenant looking for more **contemporary** high-end space:

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modern materials

conclusion

struc – cellular beams in exposed ceiling
cellular beams are appropriate to address open feel

concentrically braced frames are more efficient than previous design

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in accommodating the height restriction set by the IBC, the mechanical ductwork is able to be completely laid out within the structural cells

scenario

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mech – run through structure (IBC height restriction)
in accommodating the height restriction set by the IBC, the mechanical ductwork is able to be completely laid out within the structural cells

arch – façade redesign (aesthetics + thermal)
the façade redesign showcased the braced frames to reflect the contemporary style of the building

thermal properties were improved by switching to a higher-end rigid insulation panel envelope system

acknowledgements

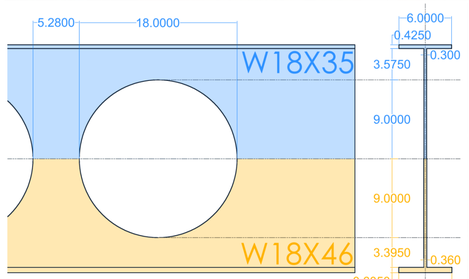
Atlantic Engineering Services
John Schneider
Angelo Maione
Justin Kovach

entire ae faculty
Dr. Thomas Boothby
Professor M. Kevin Parfitt
Professor Robert Holland

fellow ae students

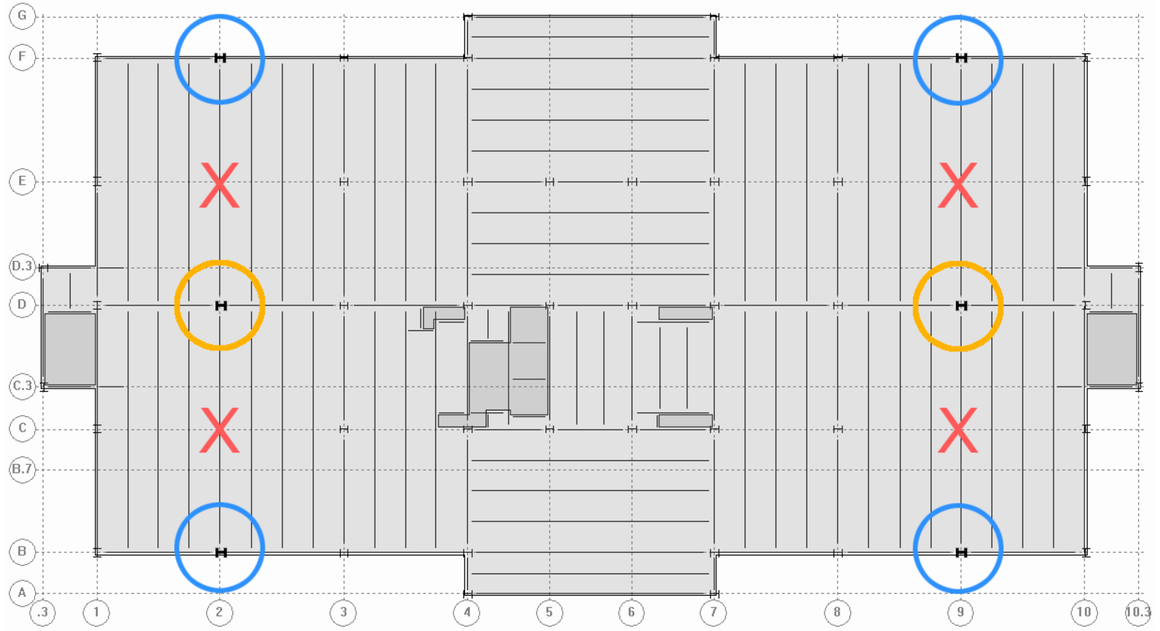
family + friends

comments

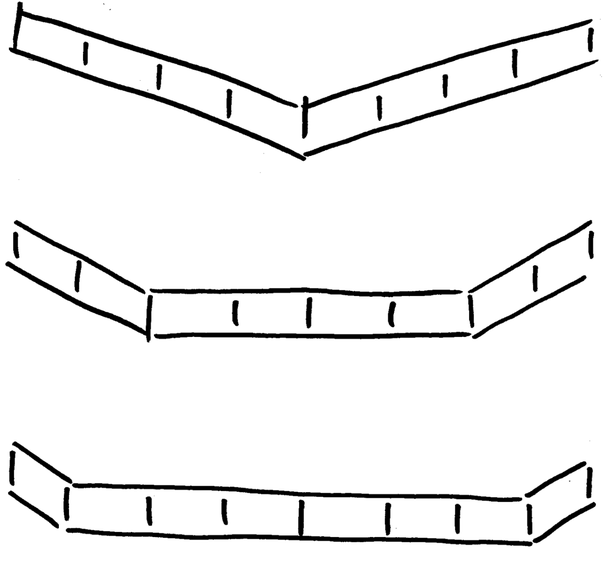


30% increase in foundation load

60% increase in foundation load



appendix



$$\delta W_{int} = \delta W_{ext}$$

$$\sum P \cdot d_i \cdot \theta = \sum M_{p,i} \cdot \theta$$

appendix

IBC 2009 height requirements

Table 503

Type II A

B (business)

5 stories max ≤ 5 stories (good)

37,500 SF max ≥ 28,800 SF (good)

65’ max < 70’

(must reduce to 65’ height)

Table 601

Type II A

Primary Structure

→ 1 hour fire rating

note d: 1 hour fire rating substituted by sprinkler

(exposed ceiling OK)

SECTION 503
GENERAL BUILDING HEIGHT AND AREA LIMITATIONS

TABLE 503
ALLOWABLE BUILDING HEIGHTS AND AREAS[a]
Building height limitations shown in feet above grade plane. Story limitations shown as stories above grade plane.
Building area limitations shown in square feet, as determined by the definition of "Area, building," per story

GROUP		TYPE OF CONSTRUCTION							
		TYPE I		TYPE II		TYPE III		TYPE IV	T
		A	B	A	B	A	B	HT	A
	HEIGHT (feet)	UL	160	65	55	65	55	65	50
		STORIES(S) AREA (A)							
A-1	S	UL	5	3	2	3	2	3	2
	A	UL	UL	15,500	8,500	14,000	8,500	15,000	11,50
A-2	S	UL	11	3	2	3	2	3	2
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,50
A-3	S	UL	11	3	2	3	2	3	2
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,50
A-4	S	UL	11	3	2	3	2	3	2
	A	UL	UL	15,500	9,500	14,000	9,500	15,000	11,50
A-5	S	UL	UL	UL	UL	UL	UL	UL	UL
	A	UL	UL	UL	UL	UL	UL	UL	UL
B	S	UL	11	5	3	5	3	5	3
	A	UL	UL	37,500	23,000	28,500	19,000	36,000	18,00
E	S	UL	5	3	2	3	2	3	1
	A	UL	UL	26,500	14,500	23,500	14,500	25,500	18,50
F-1	S	UL	11	4	2	3	2	4	2
	A	UL	UL	25,000	15,500	19,000	12,000	33,500	14,00
F-2	S	UL	11	5	3	4	3	5	3
	A	UL	UL	37,500	23,000	28,500	18,000	50,500	21,00
H-1	S	1	1	1	1	1	1	1	1
	A	21,000	16,500	11,000	7,000	9,500	7,000	10,500	7,50

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (hours)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls									
Exterior[f, g]	3	2	1	0	2	2	2	1	0
Interior	3[a]	2[a]	1	0	1	0	1/HT	1	0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and secondary members (see Section 202)	$1^{1}/_{2}$[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

For SI: 1 foot = 304.8 mm.

a. Roof supports: Fire-resistance ratings of primary structural frame and bearing walls are permitted to be reduced by 1 hour where supporting a roof only.

b. Except in Group F-1, H, M and S-1 occupancies, fire protection of structural members shall not be required, including protection of roof framing and decking where every part of the roof construction is 20 feet or more above any floor immediately below. Fire-retardant-treated wood members shall be allowed to be used for such unprotected members.

c. In all occupancies, heavy timber shall be allowed where a 1-hour or less fire-resistance rating is required.

d. An approved automatic sprinkler system in accordance with Section 903.3.1.1 shall be allowed to be substituted for 1-hour fire-resistance-rated construction, provided such system is not otherwise required by other provisions of the code or used for an allowable area increase in accordance with Section 506.3 or an allowable height increase in accordance with Section 504.2. The 1-hour substitution for the fire resistance of exterior walls shall not be permitted.

e. Not less than the fire-resistance rating required by other sections of this code.

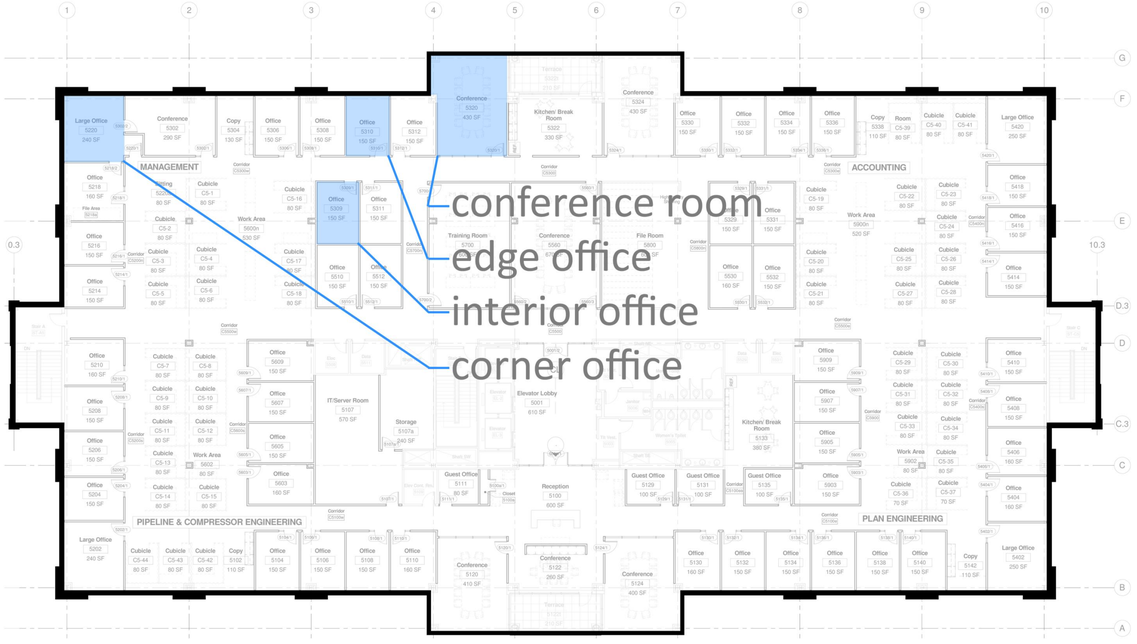
f. Not less than the fire-resistance rating based on fire separation distance (see Table 602).

g. Not less than the fire-resistance rating as referenced in Section 704.10

appendix

TRACE 700 - room checksums					excel	
room type	# people	coil airflow (cfm)	capacity (ton)	capacity (MBh)	air flow (cfm)	ventilation (cfm)
corner office	1	280	0.5	6.3	75	19.4
edge office	1	125	0.3	3.1	75	14
interior office	1	25	0.2	1.8	75	14
conference room	22	425	1.5	17.4	475	95.8

TRACE 700 - system checksums					excel
AHU	# people	coil airflow (cfm)	capacity (ton)	capacity (MBh)	airflow (cfm)
1	85	3250	9.9	118.6	3875
2	82	3450	11.2	134.4	4100
3	43	4100	8.9	106.5	3225
4	60	4720	11.6	139.4	3600
	Σ	**15520**		Σ	**14800**



appendix

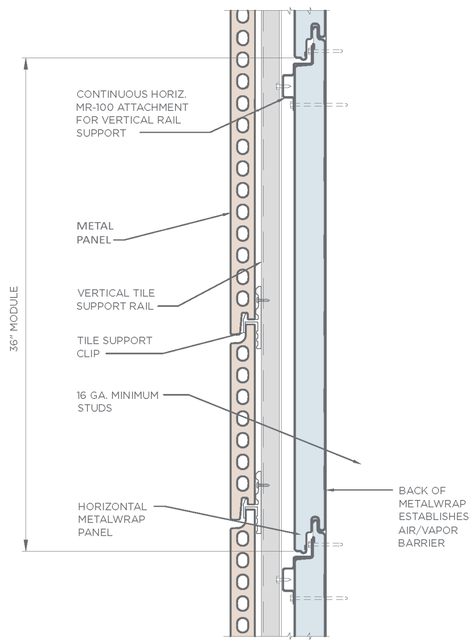
MetalWrap

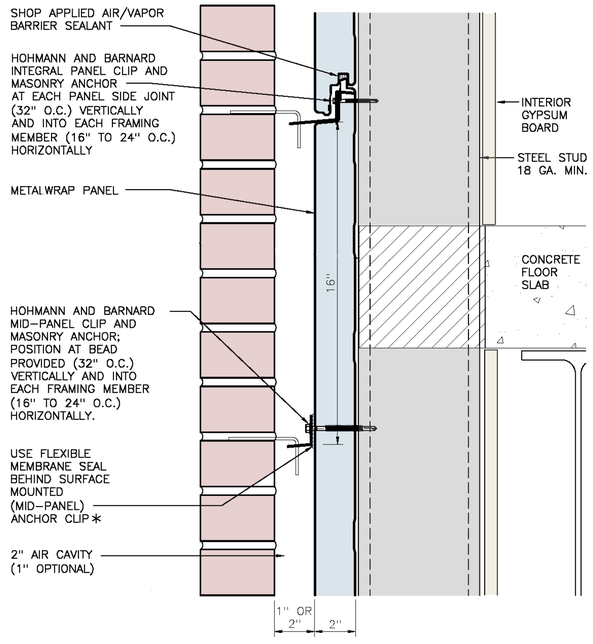
MetalWrap MR-300 (center)

36" x 20' max panel
2" rigid insulation
2.5" nominal architectural panel thickness

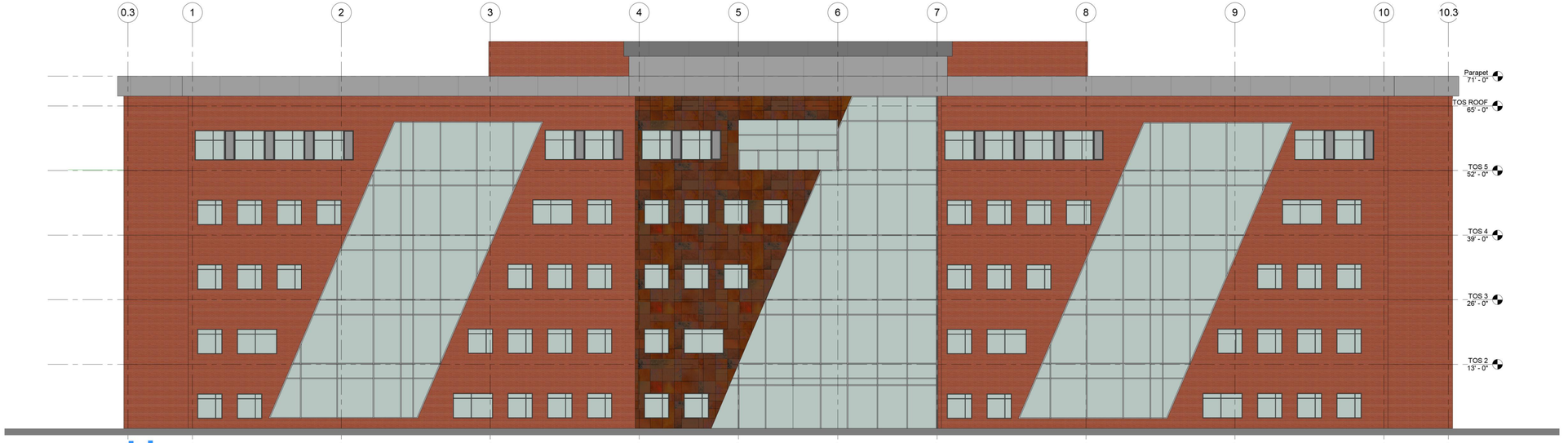
MetalWrap for Masonry (right)

2" rigid insulation
32" x 20' max panel





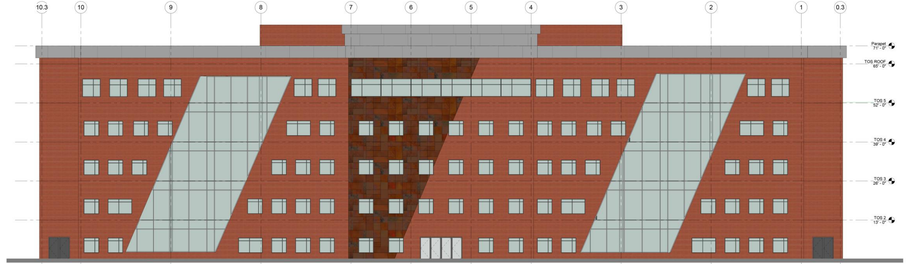
appendix



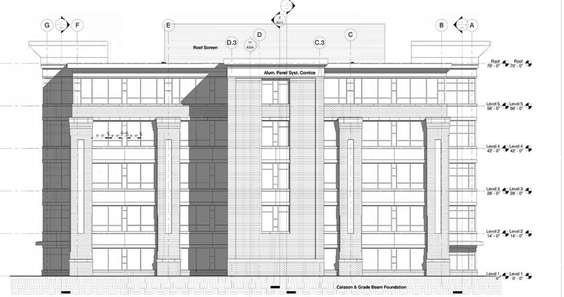
south

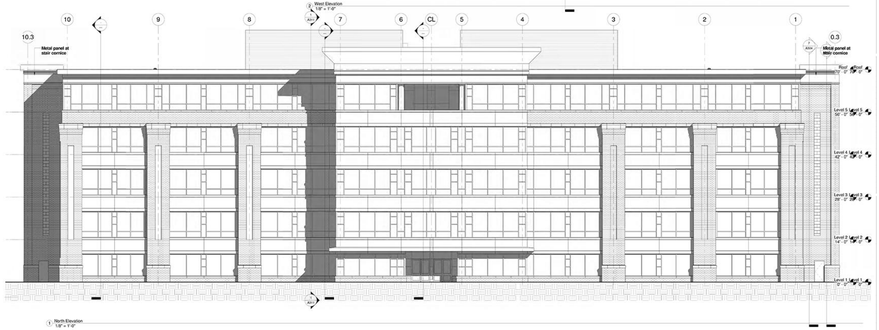
appendix

west



north





appendix

glass type

6mm Dbl Low-E (e2=0.04) Tint 13 mm Argon

U = 0.233 $\frac{BTU}{hr \cdot ft^{2} \cdot °\mathrm{F}}$

shading coefficient = 0.32