The Structural Redesign of Boyds Bear Country and its Related Systems

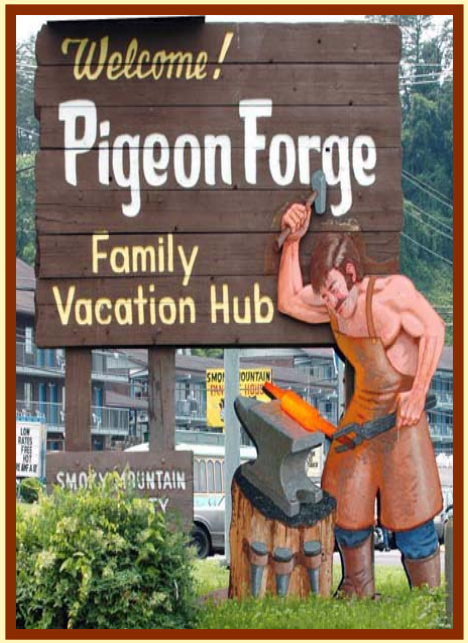
Boyds Bear Country,
Pigeon Forge, Tennessee

Lauren Wilke
AE Senior Thesis 2007

Included in this Presentation:

- Background and Existing System
- Proposal Problem / Solution
- Structural System Redesigns
  - Pre-cast Concrete
  - Engineered Wood
  - Removal of Masonry
- Cost, Schedule and Coordination Analysis
- Recommendation

Boyds Bear Country Info.



- **Location:** Pigeon Forge, Tennessee
- **Occupancy:** Assembly, Mercantile, and Business
- **Size:** 112,620 sf
- **Number of Stories**: 4 / 5

Primary Project Team:

- **Original Owner:** Boyds Collections, Ltd.
- **Architecture:** LSC Design
- **Structural:** C.S. Davidson, Inc.
- **Construction Management:** Kinsley Construction

THE BOYDS COLLECTION LTD. ACCEPT NO SUBSTITUTES

lscdesign

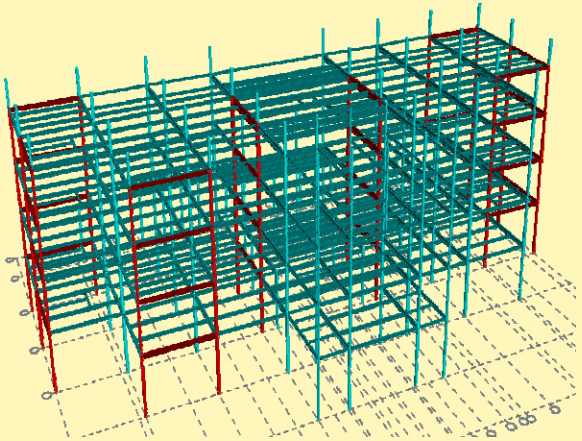
C.S.Davidson, Inc.
Excellence in Civil Engineering

KINSLEY CONSTRUCTION

Background

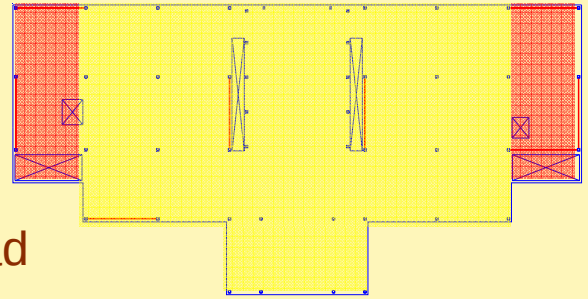
Gravity System

30’ x 30’ Typical Bays
60’ Spans in Central Atrium



W16 Beams to W24 Girders
Steel Tube Columns

3” 20 Gauge Deck
with 6½” Lightweight Concrete
Concrete Block Basement Walls
Wooden Roof Trusses



100 psf Typical Live Load
125 psf Mechanical Live Load

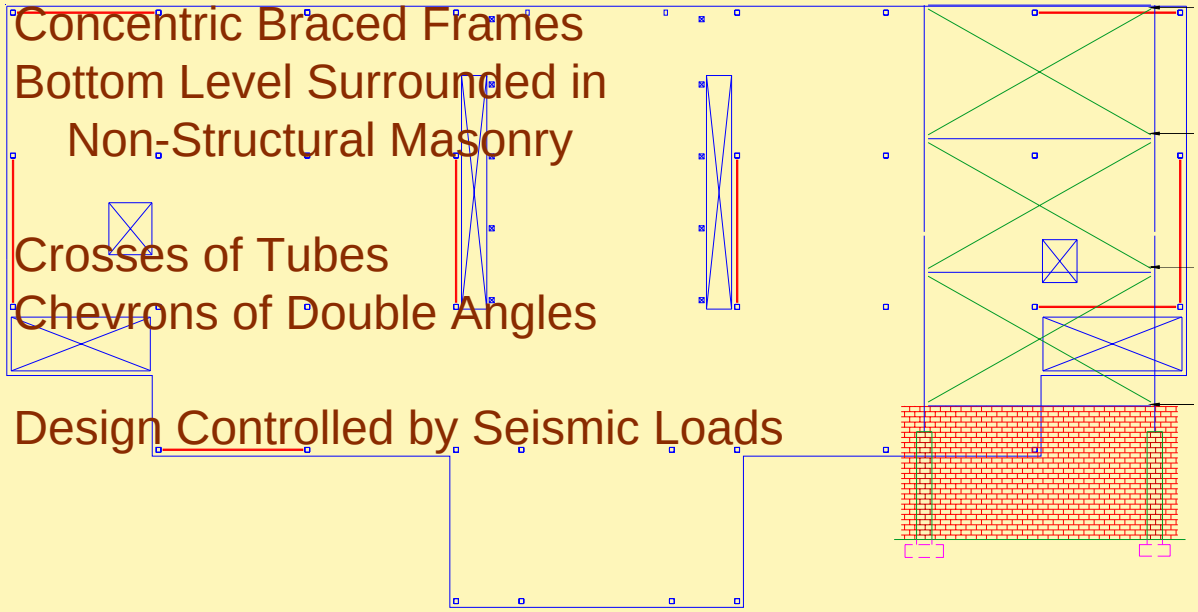
Existing Structure

Lateral System

Concentric Braced Frames
Bottom Level Surrounded in
Non-Structural Masonry

Crosses of Tubes
Chevrons of Double Angles

Design Controlled by Seismic Loads



Existing Structure

and now...

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  - Pre-cast Concrete
  - Engineered Wood
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- Recommendation

Proposal
Problem

Multiple Materials

Steel
- Hot rolled structural members
- Metal decking
- Shear studs
- Bolted / welded connections
- Light gauge steel framing

Concrete
- Cast-in-place elevated slabs
- Lightweight cast-in-place elevated slabs
- Cast-in-place slab on grade
- Shallow foundations

Masonry
- Normal CMU block
- Ivany (high strength) CMU block
- Structural Piers

Wood
- Manufactured trusses
- Timbers

Variety of Finish Materials
- Gypsum board
- Plywood, etc….

Proposal
Problem

Precast Concrete System

Steel
- Hot rolled structural members
- Metal decking
- Shear studs
- Bolted / Welded connections
- Light gauge steel framing

Concrete
- Cast-in-place elevated slabs
- Lightweight cast-in-place elevated slabs
- Cast-in-place slab on grade
- Shallow foundations

Masonry
- Normal CMU block
- Ivany (high strength) CMU block
- Structural Piers

Wood
- Manufactured trusses
- Timbers

Variety of Finish Materials
- Gypsum board
- Plywood, etc….

Additionally
+ Precast concrete members
+ Concrete member toppings
+ Cast-in-place basement walls

Proposal Solution

Engineered Wood System

Steel
- Hot rolled structural members
- Metal decking
- Shear studs
- Bolted / welded connections
- Light gauge steel framing

Concrete
- Cast-in-place elevated slabs
- Lightweight cast-in-place elevated slabs
- Cast-in-place slab on grade
- Shallow foundations

Masonry
- Normal CMU block
- Ivany (high strength) CMU block
- Structural Piers

Wood
- Manufactured trusses
- Timbers

Variety of Finish Materials
- Gypsum board
- Plywood, etc….

Additionally
+ Manufactured wood floor trusses
+ Laminated structural wood
+ Wooden floor planks
+ Stud wall framing
+ Cast-in-place basement walls
+ Precast concrete shearwalls

Proposal Solution

and now...

- Background and Existing System
- Proposal Problem / Solution
- Structural System Redesigns
  - Precast Concrete
  - Engineered Wood
  - Removal of Masonry
- Cost, Schedule and Coordination Analysis
- Recommendation

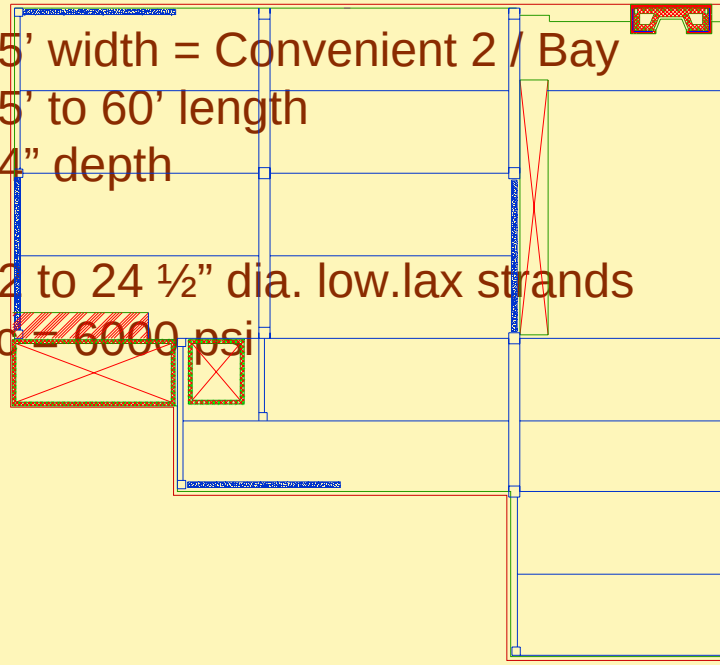
Structural
Precast Concrete

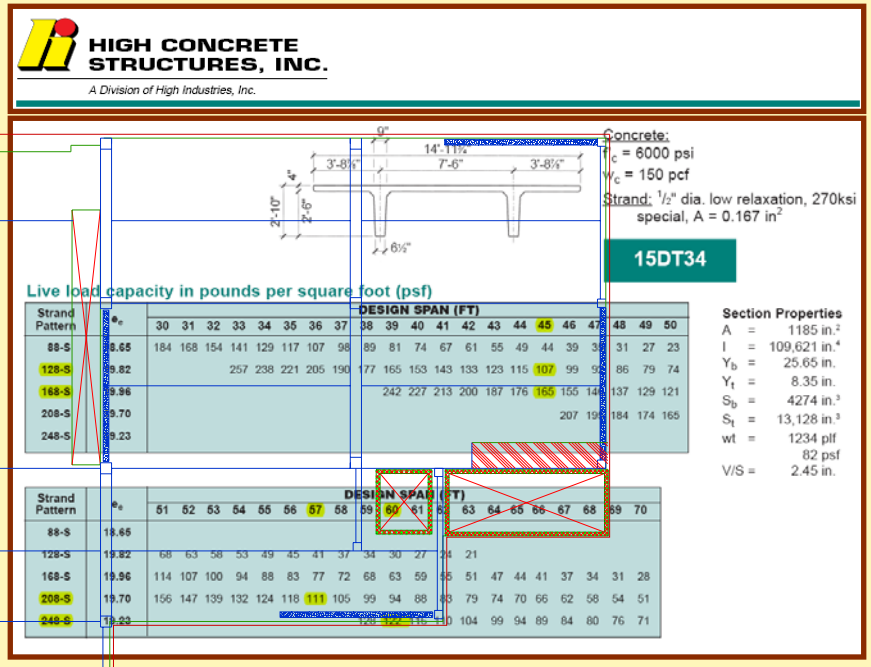
Floor System – 15’ Double Tees

30’ x 45’ Bays

15’ width = Convenient 2 / Bay
45’ to 60’ length
34” depth

12 to 24 ½” dia. low.lax strands
f’c = 6000 psi





HIGH CONCRETE STRUCTURES, INC.
A Division of High Industries, Inc.

Concrete:
f'_c = 6000 psi
w_c = 150 pcf
Strand: ½" dia. low relaxation, 270ksi special, A = 0.167 in²

15DT34

Live load capacity in pounds per square foot (psf)

Strand Pattern	e_s	DESIGN SPAN (FT) 30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
88-S	8.65	184	168	154	141	129	117	107	98	89	81	74	67	61	55	49	44	39	35	31	27	23
128-S	9.82				257	238	221	205	190	177	165	153	143	133	123	115	107	99	92	86	79	74
168-S	9.96									242	227	213	200	187	176	165	155	146	137	129	121	
208-S	9.70																	207	195	184	174	165
248-S	9.23																					

Strand Pattern	e_s	DESIGN SPAN (FT) 51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70
88-S	18.65																				
128-S	19.82	68	63	58	53	49	45	41	37	34	30	27	24	21							
168-S	19.96	114	107	100	94	88	83	77	72	68	63	59	55	51	47	44	41	37	34	31	28
208-S	19.70	156	147	139	132	124	118	111	105	99	94	88	83	79	74	70	66	62	58	54	51
248-S	19.23														104	99	94	89	84	80	76	71

Section Properties
A = 1185 in.²
I = 109,621 in.⁴
Y_b = 25.65 in.
Y_t = 8.35 in.
S_b = 4274 in.³
S_t = 13,128 in.³
wt = 1234 plf
82 psf
V/S = 2.45 in.

Manufacturer Load Tables

Structural
Precast Concrete

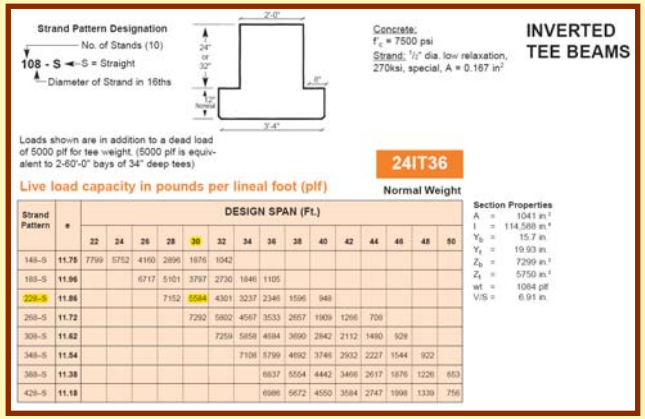
Boyds Bear Country,
Pigeon Forge, Tennessee

Lauren Wilke
AE Senior Thesis 2007

Floor System - Girders

IT Beams for traditional girder loading
- 30’ length
- 2’ width
- 36” depth
- (26) ½” dia. lo-lax strands

L Beams for edge loading
- 30’ length
- 1’ width
- 36” depth
- (18) ½” dia. lo-lax strands



Strand Pattern Designation
No. of Stands (10)
108 - S — S = Straight
Diameter of Strand in 16ths

Concrete: f'_c = 7500 psi
Strand: ½" dia. low relaxation, 270ksi, special, A = 0.167 in²

INVERTED TEE BEAMS

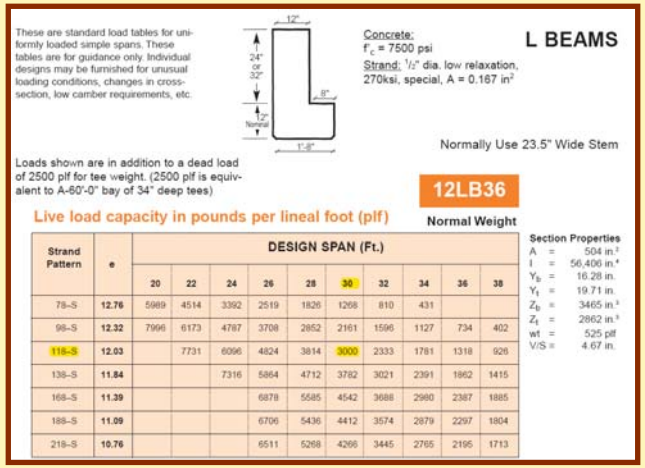
Loads shown are in addition to a dead load of 5000 plf for tee weight. (5000 plf is equivalent to 2-60'-0" bays of 34" deep tees)

24IT36
Normal Weight

Live load capacity in pounds per lineal foot (plf)

Strand Pattern	e	DESIGN SPAN (Ft.) 22	24	26	28	30	32	34	36	38	40	42	44	46	48	50
148–S	11.75	7799	5752	4160	2896	1876	1042									
188–S	11.96			6717	5101	3797	2730	1846	1105							
228–S	11.86				7152	5584	4301	3237	2345	1596	948					
268–S	11.72					7292	5802	4567	3533	2657	1909	1266	708			
308–S	11.62						7259	5858	4584	3490	2642	2112	1480	926		
348–S	11.54							7108	5799	4492	3746	2932	2227	1544	922	
388–S	11.38								6837	5554	4442	3466	2617	1876	1226	653
428–S	11.18								6986	5672	4550	3584	2747	1998	1339	756

Section Properties
A = 1041 in.²
I = 114,588 in.⁴
Y_b = 15.7 in.
Y_t = 19.93 in.
Z_b = 7299 in.³
Z_t = 5750 in.³
wt = 1084 plf
V/S = 6.91 in.



These are standard load tables for uniformly loaded simple spans. These tables are for guidance only. Individual designs may be furnished for unusual loading conditions, changes in cross-section, low camber requirements, etc.

Concrete: f'_c = 7500 psi
Strand: ½" dia. low relaxation, 270ksi, special, A = 0.167 in²

L BEAMS

Normally Use 23.5" Wide Stem

Loads shown are in addition to a dead load of 2500 plf for tee weight. (2500 plf is equivalent to A-60'-0" bay of 34" deep tees)

12LB36
Normal Weight

Live load capacity in pounds per lineal foot (plf)

Strand Pattern	e	DESIGN SPAN (Ft.) 20	22	24	26	28	30	32	34	36	38
78–S	12.76	5989	4514	3392	2519	1826	1268	810	431		
98–S	12.32	7996	6173	4787	3708	2852	2161	1596	1127	734	402
118–S	12.03		7731	6096	4824	3814	3000	2333	1781	1318	926
138–S	11.84			7316	5864	4712	3782	3021	2391	1862	1415
168–S	11.39				6878	5585	4542	3688	2980	2387	1885
188–S	11.09				6706	5436	4412	3574	2879	2297	1804
218–S	10.76				6511	5268	4266	3445	2765	2195	1713

Section Properties
A = 504 in.²
I = 56,406 in.⁴
Y_b = 16.28 in.
Y_t = 19.71 in.
Z_b = 3465 in.³
Z_t = 2862 in.³
wt = 525 plf
V/S = 4.67 in.

Manufacturer Load Tables

Structural
Precast Concrete

Boyds Bear Country,
Pigeon Forge, Tennessee

Lauren Wilke
AE Senior Thesis 2007

Concrete Columns

Typical Loading:

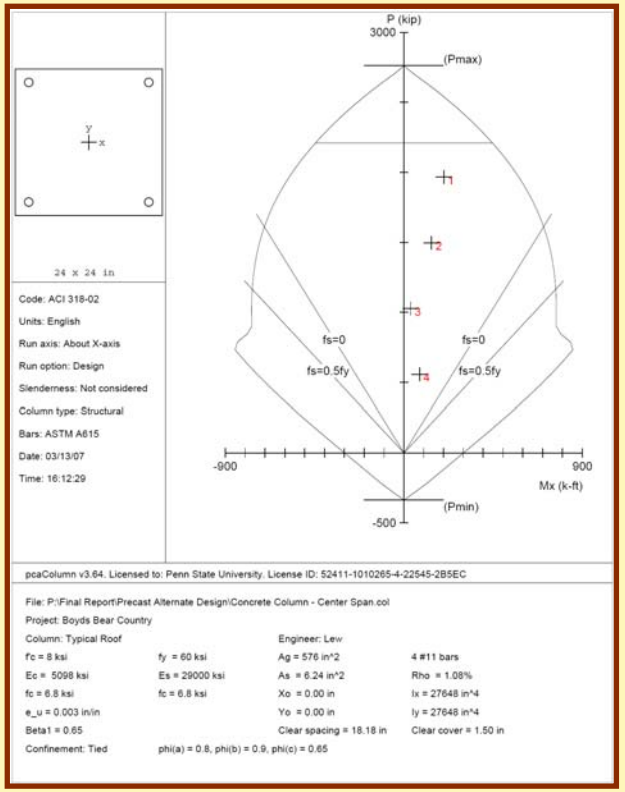
24”x24” square
17’-8” height per floor

(4) #11 bars longitudinal
f’c = 8000 psi

Edge Loading:

18”x18” square
17’-8” height per floor

(8) #10 bars longitudinal
f’c = 6000 psi

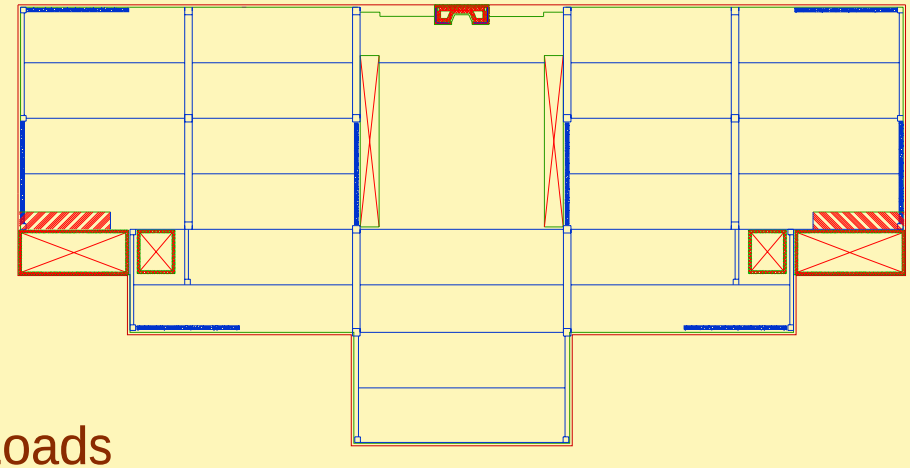


RISA-3D and
PCA Column

Structural
Precast Concrete

Lateral System – Precast Panels

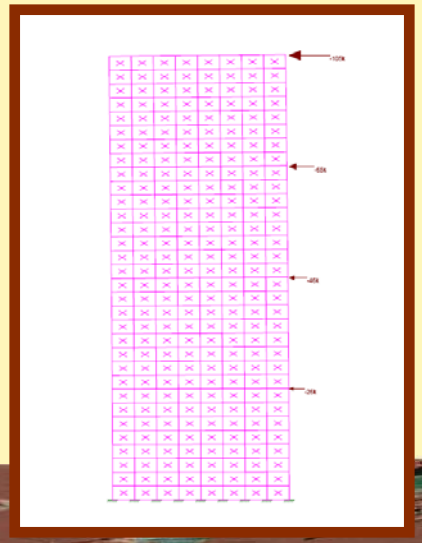
One panel at each floor
- 26.5’ wide 14” thick
- f’c = 7,000 psi
- #5’s at 18” o.c.
- (4) #11’s for uplift



Design Controlled by Seismic Loads

Base Resistance = 111.8 klf
< 155.2 klf = $5\sqrt{f'c}\cdot b\cdot d$

Max Deflection = 0.17”
< 2.3” = L/360



RISA-3D
Finite Element

Structural
Precast Concrete

Boyds Bear Country,
Pigeon Forge, Tennessee

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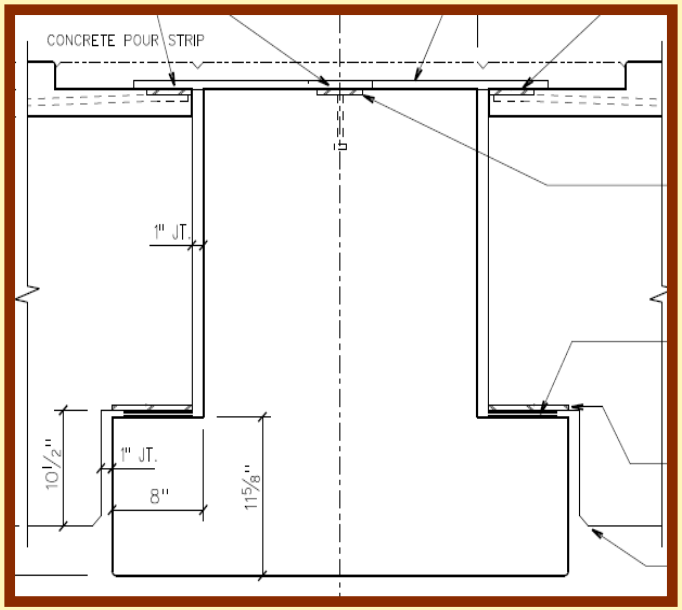
Lateral System - Diaphragm

Reinforcing Steel in Pour Strips

(2) #6's in North-South Direction

(4) #6's in East-West Direction



Hand Calculations
in MathCAD

Structural
Precast Concrete

Effects on Foundation

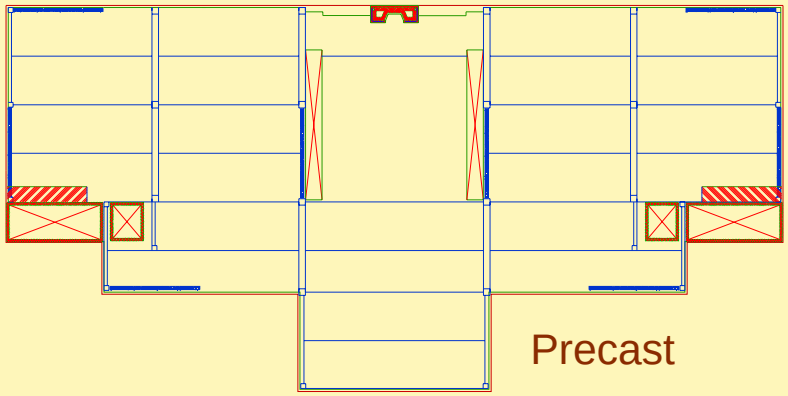
Number of columns decrease
Number of footings decrease

Weight of building increase
Size of foundations increase

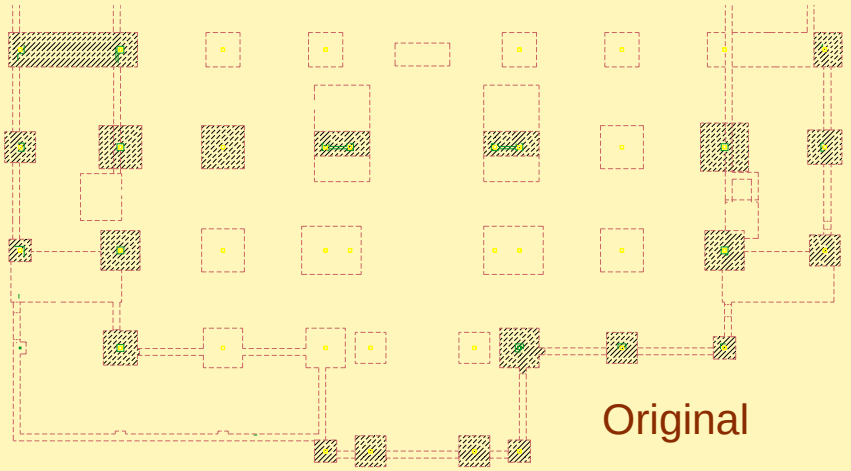
Typ. 12.5'x12.5' footing increase
from 30" deep to 36" deep

Overall ~15% volume increase

Hand Calculations
in MathCAD



Precast



Original

Structural
Precast Concrete

and now...

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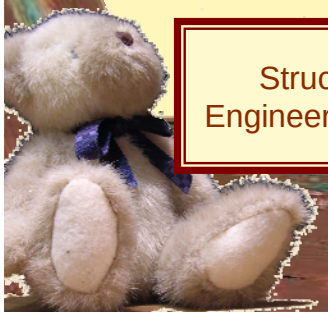
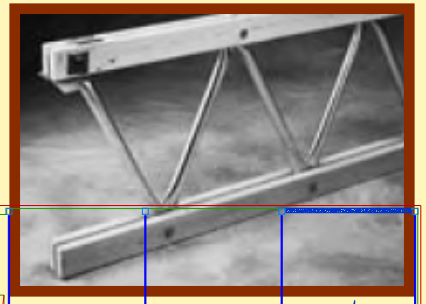


Structural
Engineered Wood

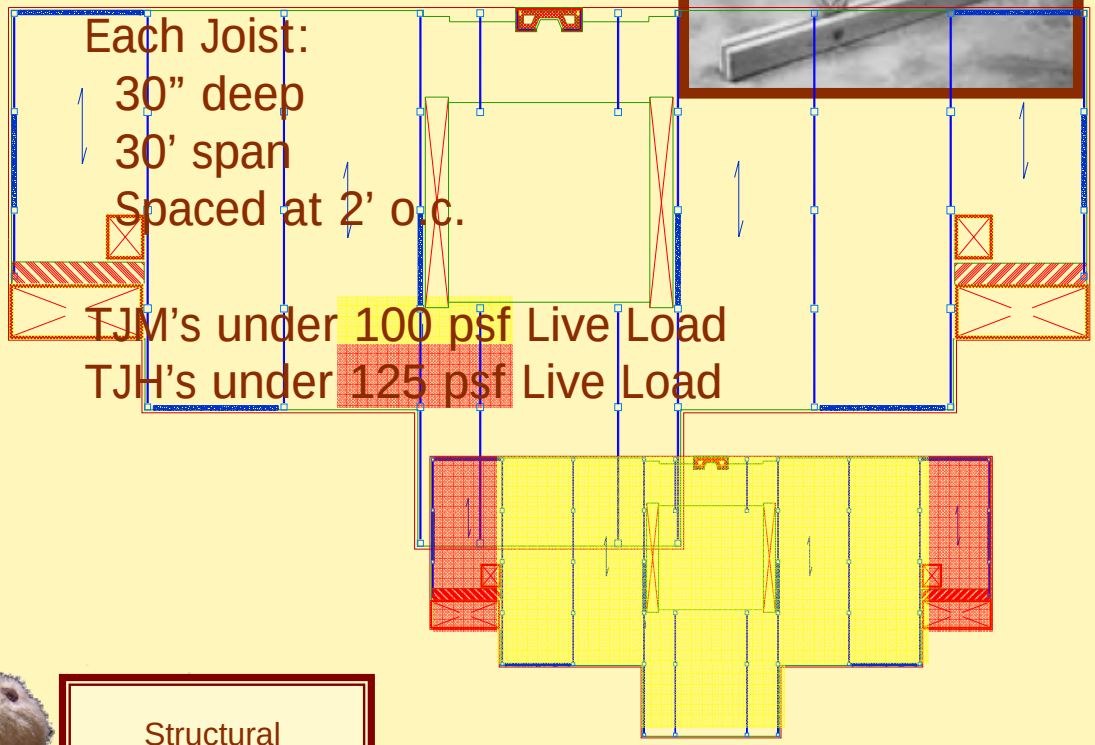
Floor System – TJM / TJH Trusses



22.5’ x 30’ Bays

Each Joist:
- 30” deep
- 30’ span
- Spaced at 2’ o.c.

TJM’s under 100 psf Live Load
TJH’s under 125 psf Live Load



iLevel TRUS JOIST commercial

TJM™ TRUSS ALLOWABLE UNIFORM LOAD

For economical truss design, see page 5.

Span	Dept 20"	22"	24"	26"	28"	30"	32"
	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL
24'	323 356 / 186 356	328 356 / 228 356	328 356 / 273 356	328 356 / 327 356	328 356 / 356	328 356 / 356	328 356 / 356
26'	275 316 / 147 329	303 329 / 183 329	303 329 / 221 329	303 329 / 257 329	303 329 / 329	303 329 / 329	303 329 / 329
28'	237 273 / 120 280	265 305 / 148 305	282 305 / 177 305	282 305 / 207 305	282 305 / 243 305	282 305 / 305	282 305 / 305
30'	207 238 / 98 258	231 266 / 120 284	256 285 / 146 285	263 285 / 175 285	263 285 / 200 285	263 285 / 230 285	263 285 / 262 285
32'	182 209 / 81 224	203 234 / 100 254	224 258 / 121 268	246 268 / 142 268	247 268 / 170 268	247 268 / 192 268	247 268 / 218 268

TJH™ TRUSS ALLOWABLE UNIFORM

Span	Dept 24"	27"	30"	33"	36"	39"	42"
	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL	100% TL 115% TL / 100% LL 125% TL
30'	353 406 / 188 441	416 480 / 246 500	473 505 / 306 509	398 513 / 378 516	454 509 / 443 521	448 512 / 526	434 499 / 524
32'	311 360 / 157 392	366 420 / 206 458	420 473 / 258 475	452 469 / 314 481	437 483 / 371 487	397 439 / 491	427 485 / 497

Manufacturer Load Tables

Structural Engineered Wood

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Pigeon Forge, Tennessee

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Floor System – PSL Girders

22.5’ long Parallam PSL

Typ. 10.5” wide x 28” deep
up to 10.5” wide x 34” deep

Standard sizes

Joist loads solved as distributed load

2.0E Parallam® PSL Headers and Beams
Allowable Design Stresses
(100% Load Duration)

Shear modulus of elasticity	G	= 125,000 psi
Modulus of elasticity	E	= 2.0×10^6 psi
Flexural stress	F_b	= 2,900 psi[1]
Tension stress	F_t	= 2,025[2] psi
Compression perpendicular to grain	$F_{c\perp}$	= 750 psi[3]
Compression parallel to grain	$F_{c\parallel}$	= 2,900 psi
Horizontal shear parallel to grain	F_v	= 290 psi

Hand Calculations in MathCAD

Structural Engineered Wood

Boyds Bear Country,
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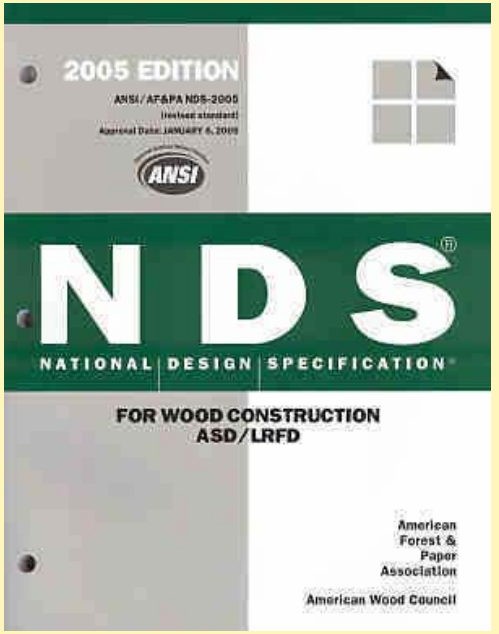
Floor System – Southern Pine Plank

Select Structural Grade Southern Pine Plank
2 x 6 boards

Span over joists spaced 2’ o.c.



Hand Calculations
in MathCAD

Structural
Engineered Wood

Boyds Bear Country,
Pigeon Forge, Tennessee

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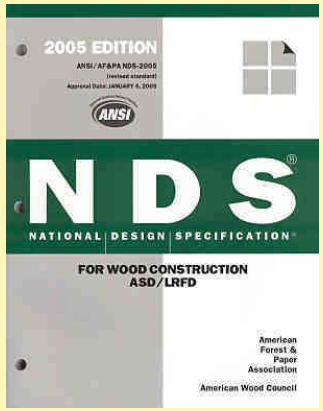
Wooden Columns

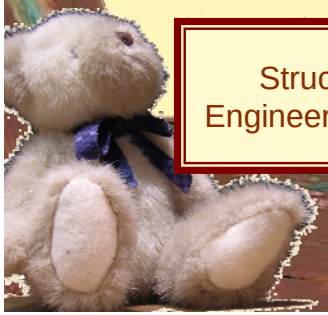
Southern Pine 50 N1D14
Engineered wood members

1st to 4th floor columns ~17' tall
braced at 10' from lower floor
Roof columns 9'-8" tall



Typical Column Sizes		[h]
	Typical Loading	Mech. Loading
Supporting Roof	7 x 7	7 x 7
4th Floor	12 x 12	12 x 12
3rd Floor	15 x 15	16 x 16
2nd Floor	18 x 18	20 x 20
1st Floor	20 x 20	22 x 22

Hand Calculations
in MathCAD



Structural
Engineered Wood

Boyds Bear Country,
Pigeon Forge, Tennessee

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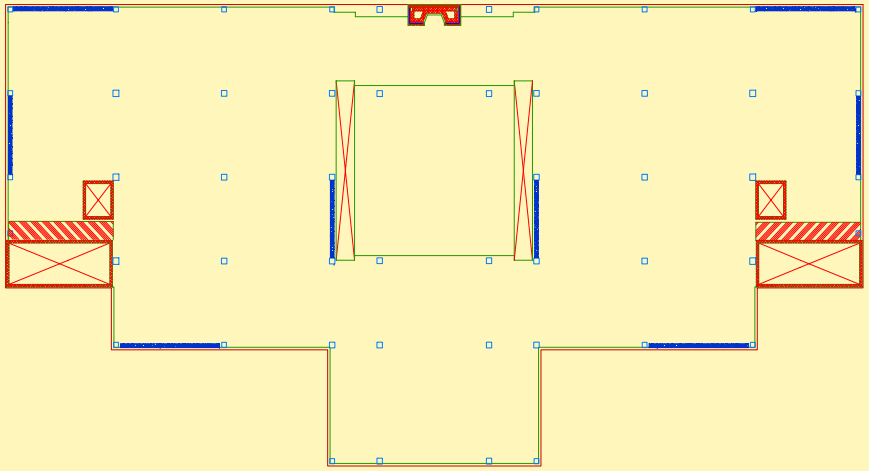
Lateral System – Precast Panels

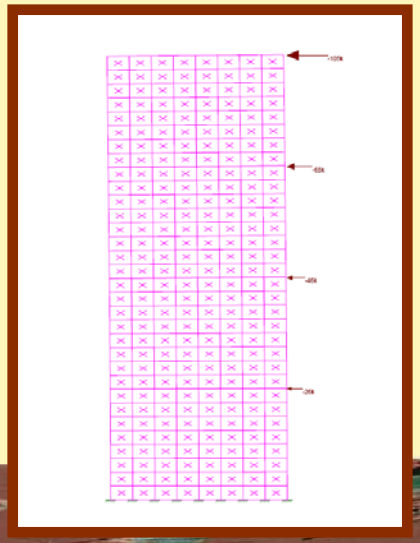
One panel at each floor
- E-W Resisting 26.5’ wide 12” thick
- N-S Resisting 20’ wide 12” thick
- f’c = 7,000 psi
- #5’s at 18” o.c.
- (4) #11’s for uplift



Design Controlled by Wind Loads

Base Resistance = 102.8 klf
< 155.2 klf = $5\sqrt{f'c}\cdot b\cdot d$

Max Deflection = 0.461”
< 2.3” = L/360



RISA-3D
Finite Element

Structural
Engineered Wood

Boyds Bear Country,
Pigeon Forge, Tennessee

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AE Senior Thesis 2007

Effects on Foundation

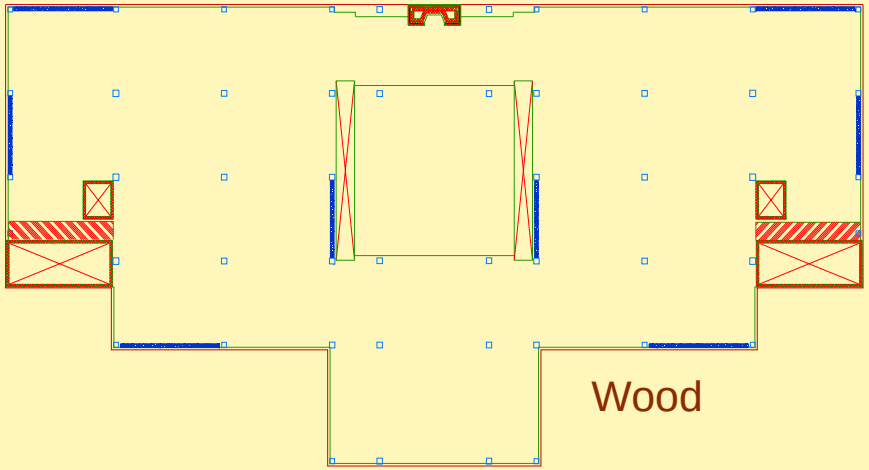
Number of columns increase
Number of footings increase

Weight of building decreases
Size of foundations decrease

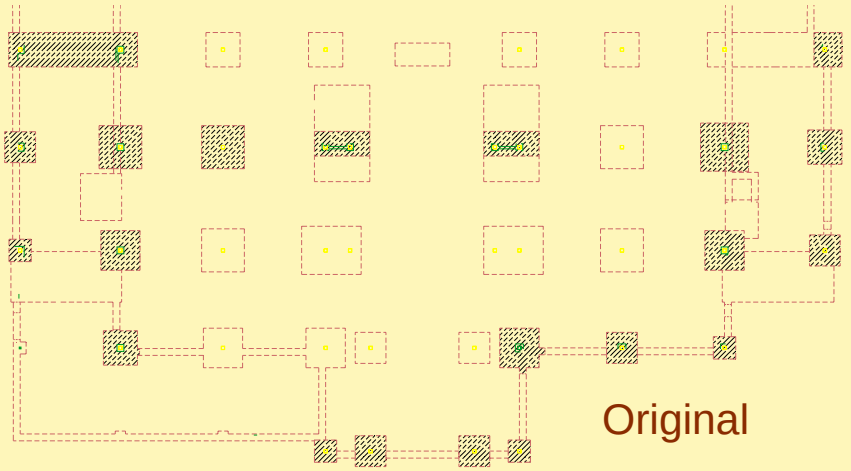
Typ. 12.5'x12.5'x30" deep to
10'x10'x28" deep

Overall ~25% volume decrease

Hand Calculations
in MathCAD



Wood



Original

Structural
Engineered Wood

Special Considerations

Deflection

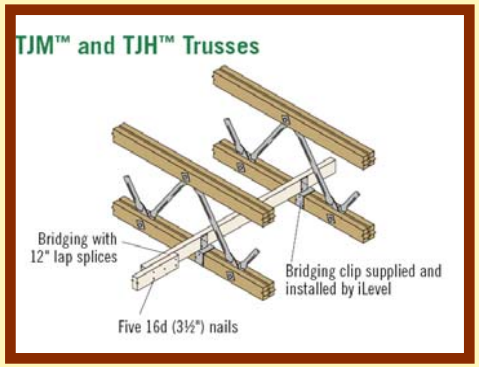
- Combination of all deformations ~1.0” under full loads
- Commercial building limit L/600
  - considers first 50 psf Live Load - under limit

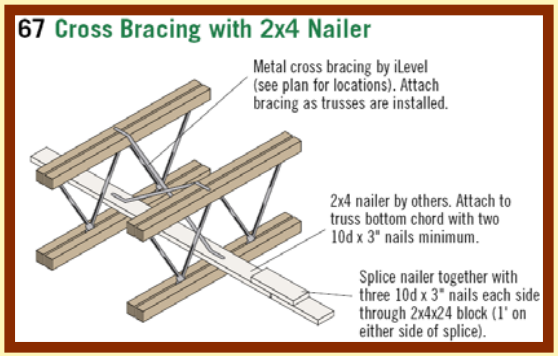
Vibration

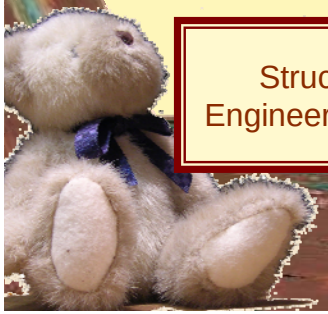
- TJH and TJM trusses reach 70’ long
- Girder spans minimized to 22.5’
- Bracing may be applied to control further if necessary

Fire-Proofing

- Verified against required APA wood dimensions
- Building fully sprinkled







Structural Engineered Wood

and now...

- Background and Existing System
- Proposal Problem / Solution
- Structural System Redesigns
  - Precast Concrete
  - Engineered Wood
  - Removal of Masonry
- Cost, Schedule and Coordination Analysis
- Recommendation

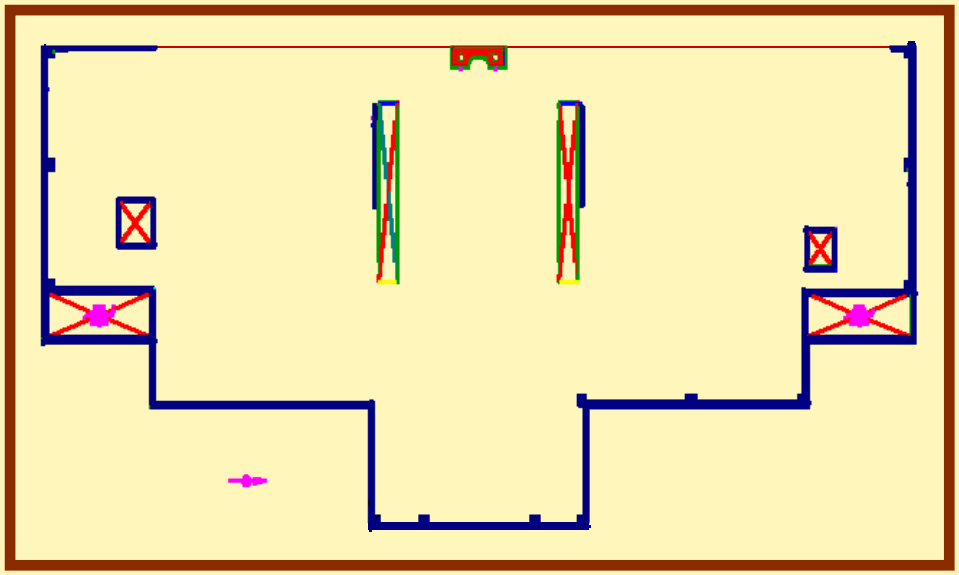
Removal of Masonry

Masonry to Concrete

8” to 16” Masonry used in
- Basement / Retaining walls
- Surrounding steel tubes
- Elevator Shafts
- Stairwells

Walls replaced with
16” thick Cast-in-Place walls
with 24”x24” pilasters
f’c = 4,000 psi
- conservative design

Elevator shafts and stairwells of
precast concrete panels



Changed in both systems

Hand Calculations
in MathCAD

Removal of
Masonry

and now...

- Background and Existing System
- Proposal Problem / Solution
- Structural System Redesign
  - Precast Concrete
  - Engineered Wood
  - Removal of Masonry
- Cost, Schedule and Coordination Analysis
- Recommendation

CM Breadth

Cost Comparison

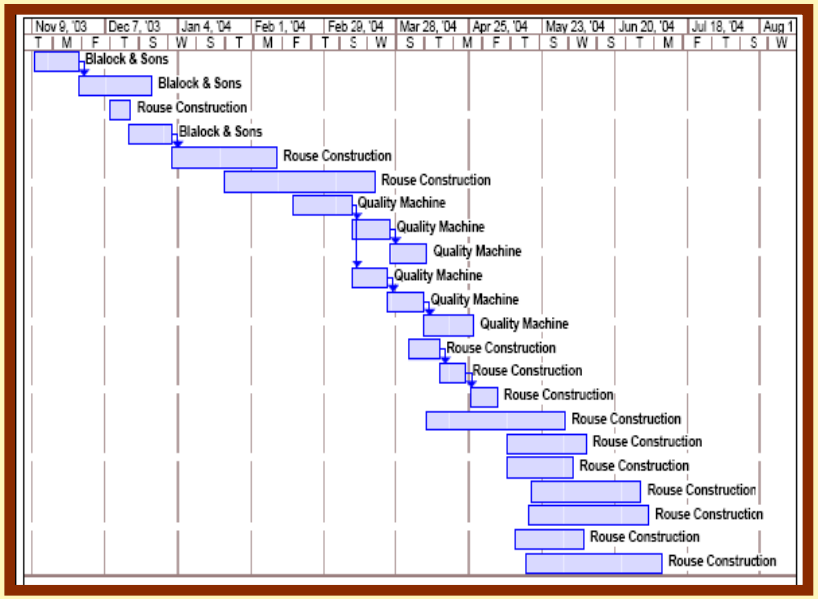
- Original Steel System
  - $3,033,683.69 (ICE 2000)
- Precast Concrete System
  - $2,244,938.39 (Supplier quote / ICE / RS Means)
  - $78,800 Savings
- Engineered Wood System
  - $1,612,566.71 (ICE 2000 / RS Means)
  - $1,420,000 Savings
- Masonry to Concrete Change Alone
  - $292,404.91 to $259,237.35 (ICE 2000 / RS Means)
  - $33,000 Savings

CM Breadth

Schedule Comparison

Original schedule set at 6 months
Required more than 9 to complete
thus difficult to accurately compare

Both systems require less work on site
lower chance for delay
faster erection time



CM Breadth

Coordination Comparison

Original System

- Steel
  - Hot rolled structural members
  - Metal decking
  - Shear studs
  - Bolted / welded connections
  - Light gauge steel framing
- Concrete
  - Cast-in-place elevated slabs
  - Lightweight cast-in-place elevated slabs
  - Cast-in-place slab on grade
  - Shallow foundations
- Masonry
  - Normal CMU block
  - Many (high strength) CMU block
  - Structural Piers
- Wood
  - Manufactured trusses
  - Timbers
- Variety of Finish Materials
  - Gypsum board
  - Plywood, etc....

Precast Concrete System

- Steel
  - Welded member connections
  - Light gauge steel framing
- Concrete
  - Pre-cast concrete members
  - Member toppings
  - Cast-in-place retaining / foundation walls
  - Cast-in-place slab on grade
  - Shallow foundations
- Wood
  - Manufactured trusses
  - Timbers
- Variety of Finish Materials
  - Gypsum board
  - Plywood, etc....

Engineered Wood System

- Steel
  - Member connections
- Concrete
  - Pre-cast concrete shear walls
  - Cast-in-place retaining / foundation walls
  - Cast in place slab on grade
  - Shallow foundations
- Wood
  - Manufactured floor trusses
  - Laminated structural members
  - Floor planks
  - Manufactured roof trusses
  - Stud wall framing
- Variety of Finish Materials
  - Gypsum board
  - Plywood, etc....

CM Breadth

Boyds Bear Country,
Pigeon Forge, Tennessee

Lauren Wilke
AE Senior Thesis 2007

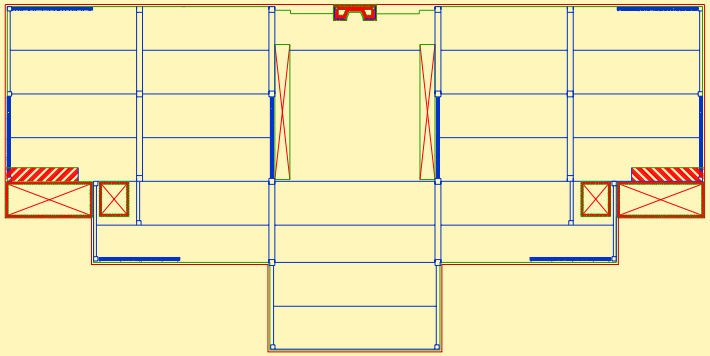
and finally...

- Background and Existing System
- Proposal Problem / Solution
- Structural System Redesign
  - Precast Concrete
  - Engineered Wood
  - Removal of Masonry
- Cost, Schedule and Coordination
- Recommendation

Recommendation

Final Recommendation: Precast Concrete System

+ Fewer materials, fewer trades on site
+ Larger bays, larger members, fewer pieces to place
+ Decreased construction time
+ $78,800 Savings on structure
+ More open floor plan



- Larger foundations
- Overall interior aesthetic to be hidden

Recommendation

Questions?

Boyds Bear Country,
Pigeon Forge, Tennessee

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