George Read Hall

The University of Delaware

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Structural Option
Thesis – April 2006
Dr. Boothby

Presentation Outline

- Introduction
- Existing Structural System
- Problem Statement
- Problem Solution
- Depth Study
  - Alternate System Design
- Breadth Study
  - Cost Analysis
  - Construction Schedule
- Conclusions
- Acknowledgements

Introduction

Introduction

Project Team:

Architect: Ayers/Saint/Gross

Construction Manager: Whiting-Turner

Structural Engineer: Skarda & Associates

MEP & Fire Protection: Sebesta Blomberg & Associates

Civil Engineer: Tetra Tech, Inc.

Code Consultants: Koffel & Associates

Introduction

- Location: Newark, Delaware
- 5 story dormitory
- 129,000 ft^2
- Cost: $27 Million
- Construction: May 2004 – Aug. 2005
- Design-Bid-Build

Existing Structural System

Existing Structural System

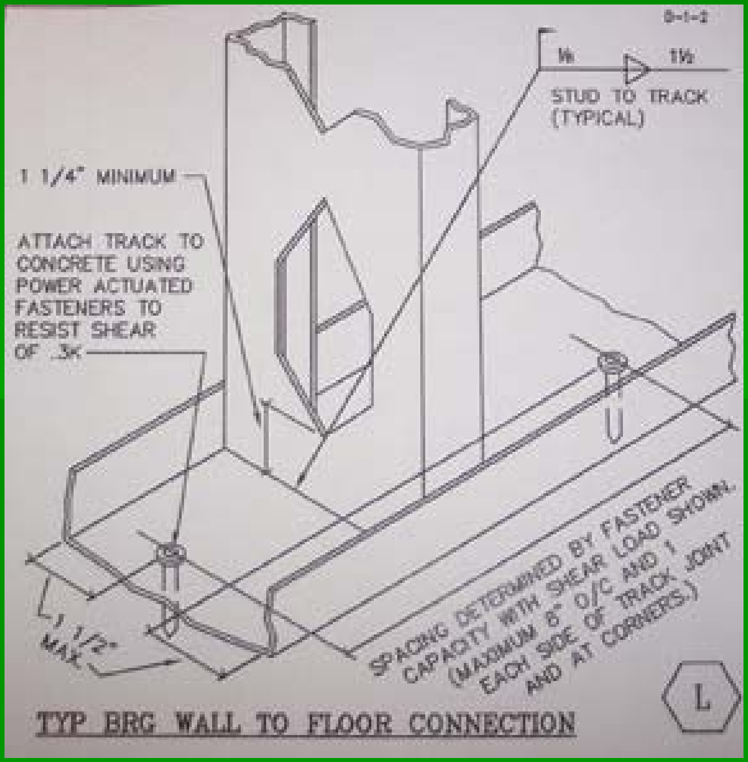
Footings and Basement Wall:

- Continuous and spread footings
  - Soil Bearing Capacity = 4000 psf
- 16” thick concrete basement walls reinforced with #4@12 both ways, both faces
- 5” thick slab with 6 x 6-W 1.4 x 1.4 welded wire mesh

Existing Structural System

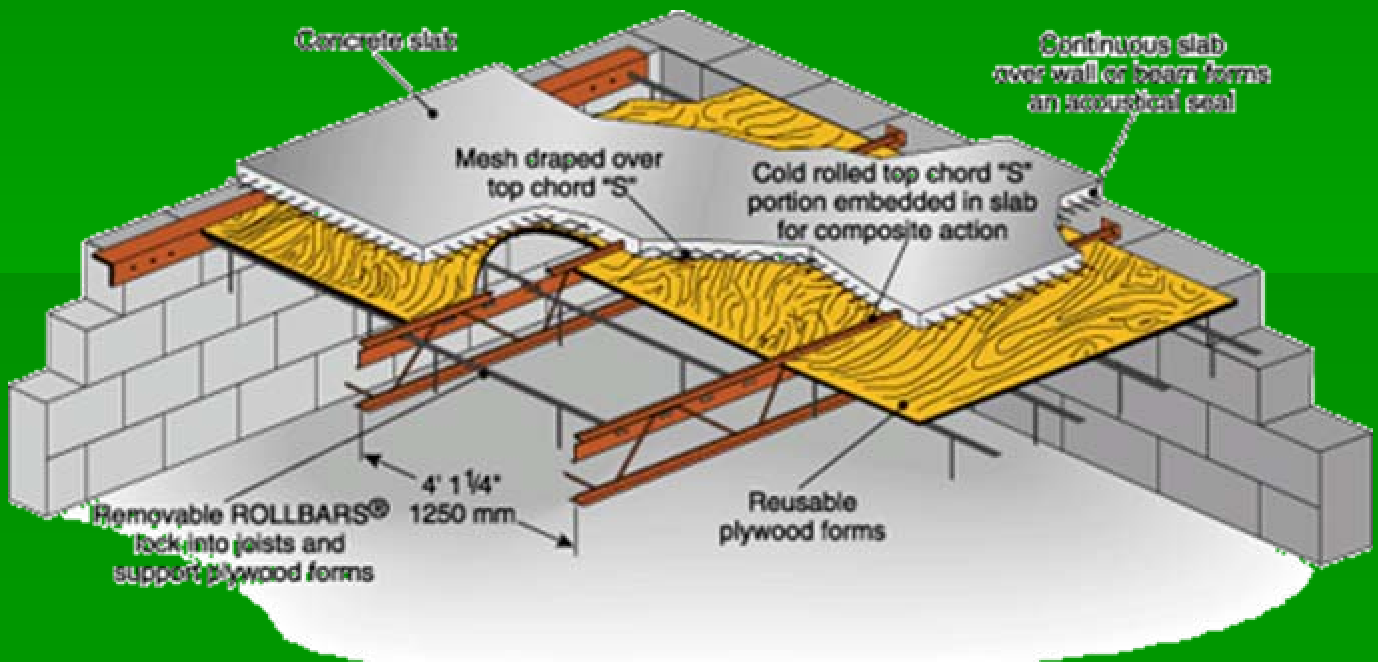
- Metal stud bearing walls
  - 16 gauge
  - 50 ksi

Bearing Wall Schedule	
Level	**Studs**
5th Floor	6@16
4th Floor	6@16
3rd Floor	2-6@16
2nd Floor	3-6@16
1st Floor	3-6@16



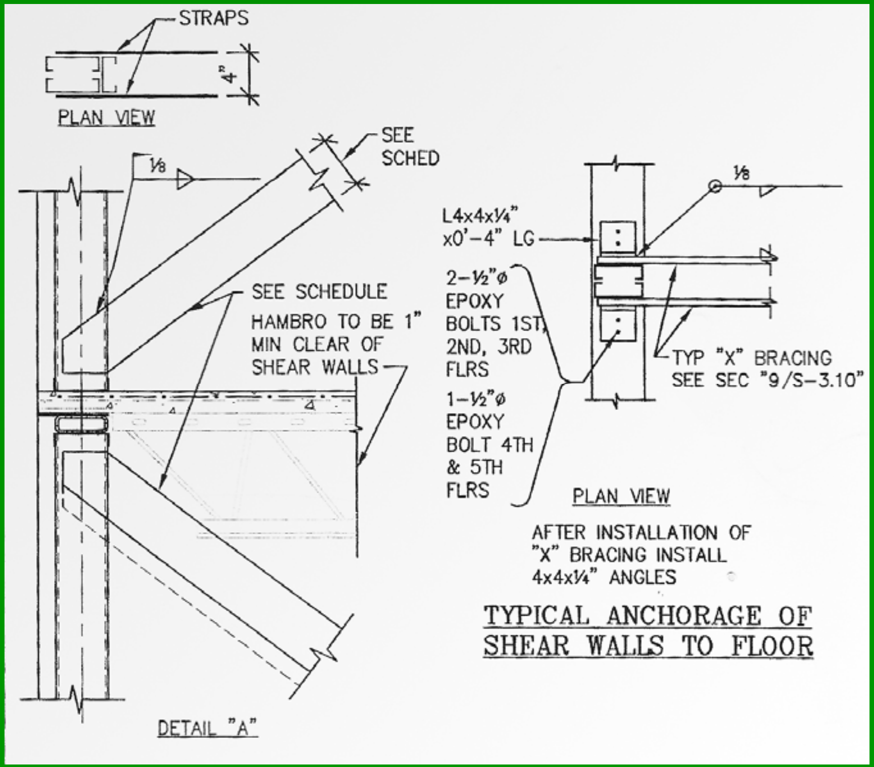
Existing Structural System

- Hambro composite floor system
  - 14” Deep Joists with a $2^3/_4$” concrete slab



Existing Structural System

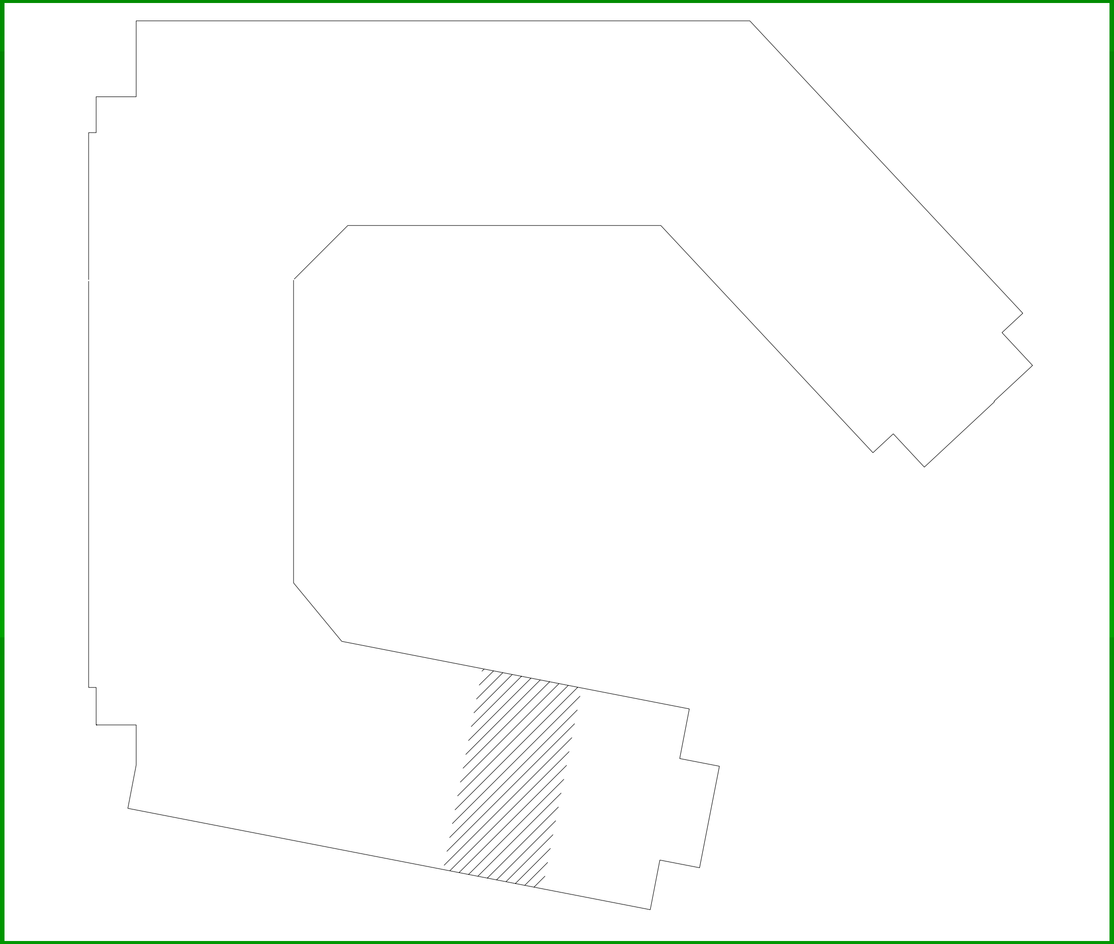
- X-braced shear walls
  - 50 ksi light gauge metal straps



Existing Structural System

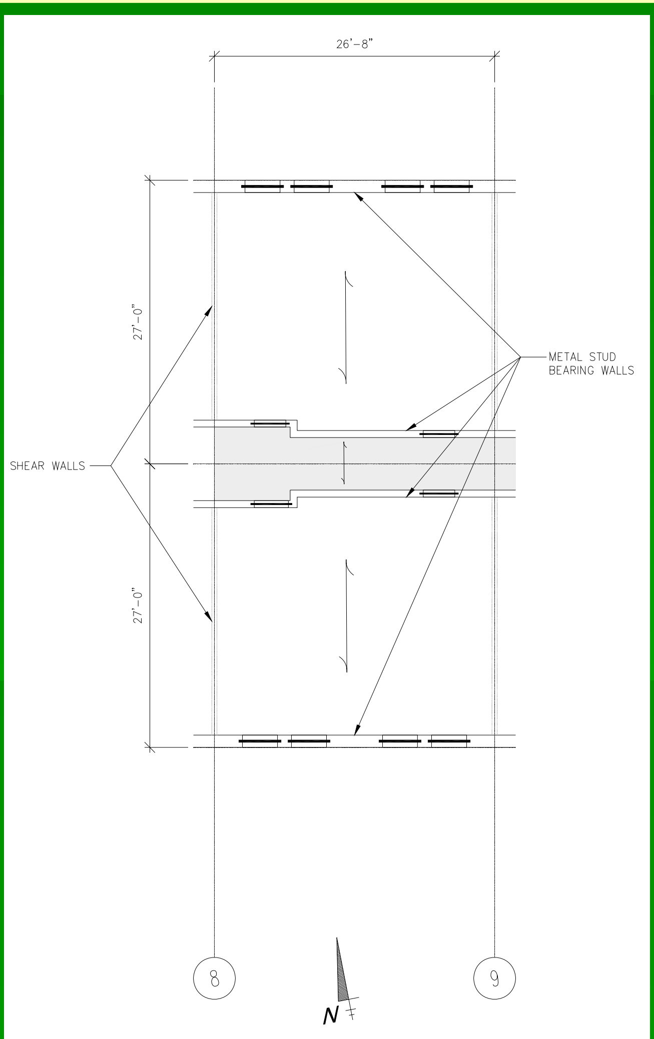
- Prefabricated light gauge metal trusses spaced at 4’-0” OC
  - 16 gauge
  - 50 ksi

Existing Structural System



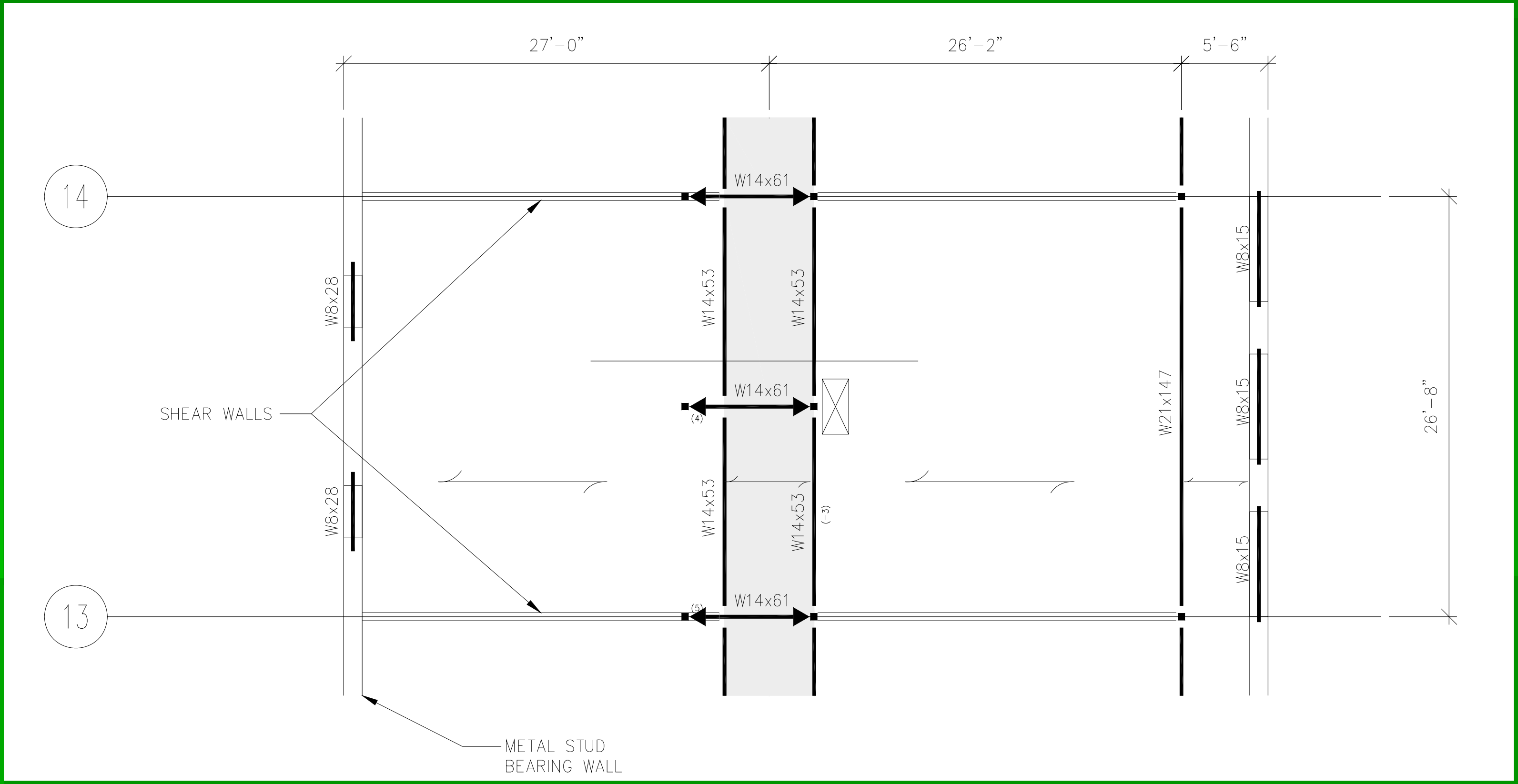
Building Footprint

Existing Structural System



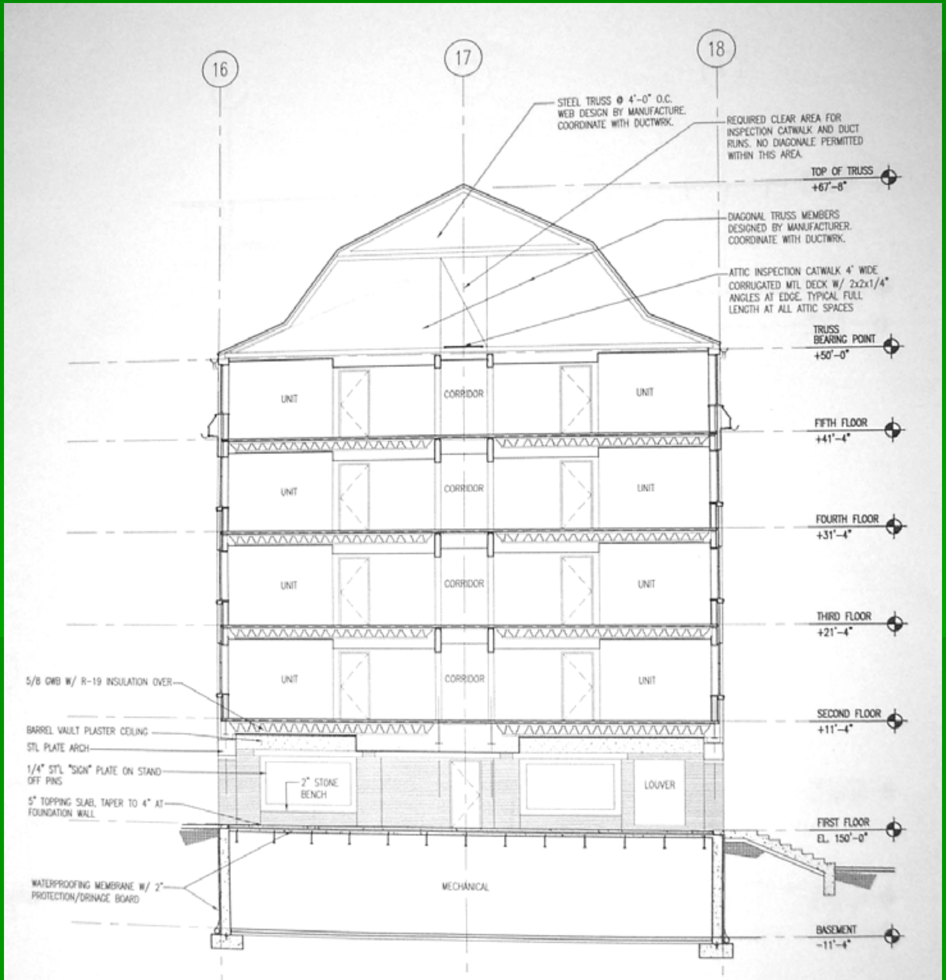
Typical Bay with Interior Bearing Walls

Existing Structural System



Typical Bay with Interior Wide Flange Beams

Existing Structural System



Building Section

Problem Statement
&
Problem Solution

Problem Statement

- The existing lateral force resisting system is inadequate to resist the calculated seismic forces.
- In Technical Assignment #2, several different floor systems were determined to be worth further investigation.
- Is there a more economical structural system?

Problem Solution

- New Structural System
  - Reinforced Masonry Shear Walls
  - Precast Hollow Core Planks
  - Masonry Bearing Walls
- Cost Analysis
- Construction Schedule

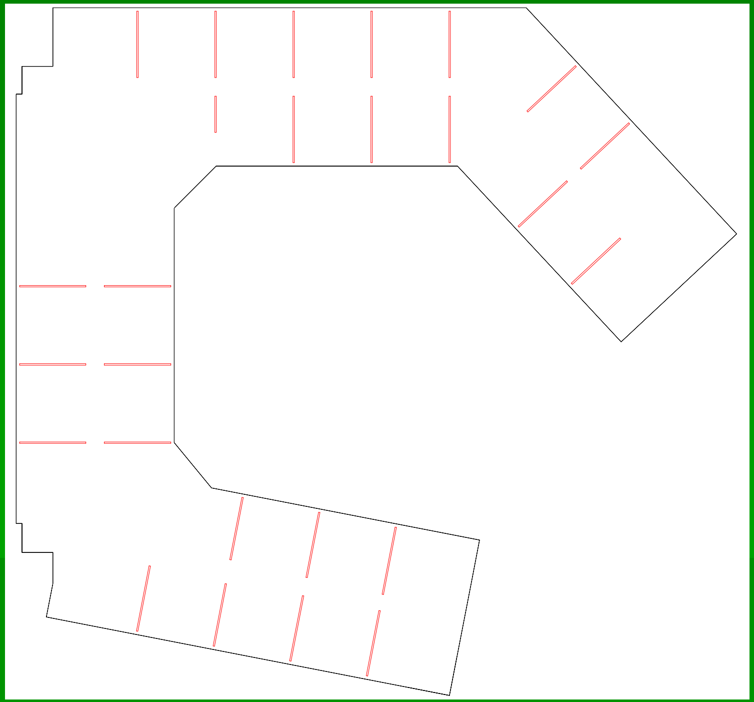
Depth Study:
Alternate Structural System Design

Masonry Shear Walls

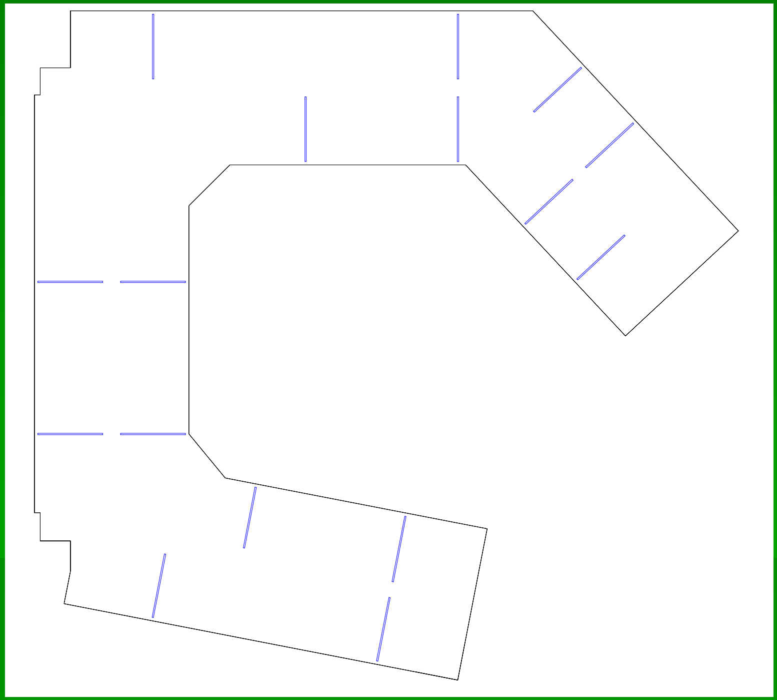
- Seismic analysis controls lateral force resisting system design

Level	w_x	h_x	$w_x h_x^{1.0}$	C_{vx}	F_x	Shear
Roof	411.3	50	20565	0.048654	23.43	-
5	3871.6	41.333	160024.8	0.378594	182.33	23.43
4	4075	31.333	127682	0.302076	145.48	182.33
3	4075	21.333	86931.98	0.205668	99.05	327.81
2	4239.2	11.333	48042.85	0.113662	54.74	426.86
Base	-	-	-	-	481.6	481.6
			422681.6	1		

Masonry Shear Walls

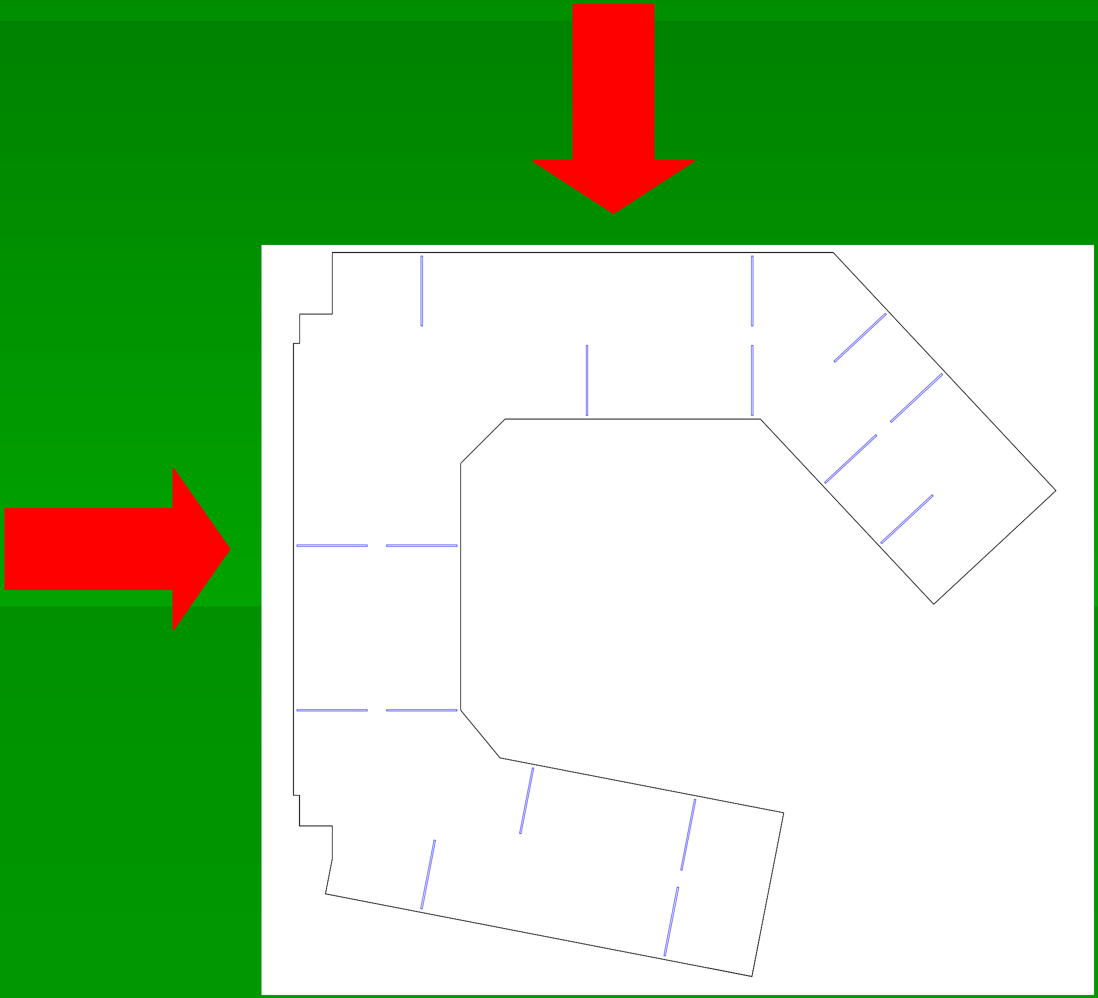


Existing Shear Wall Layout



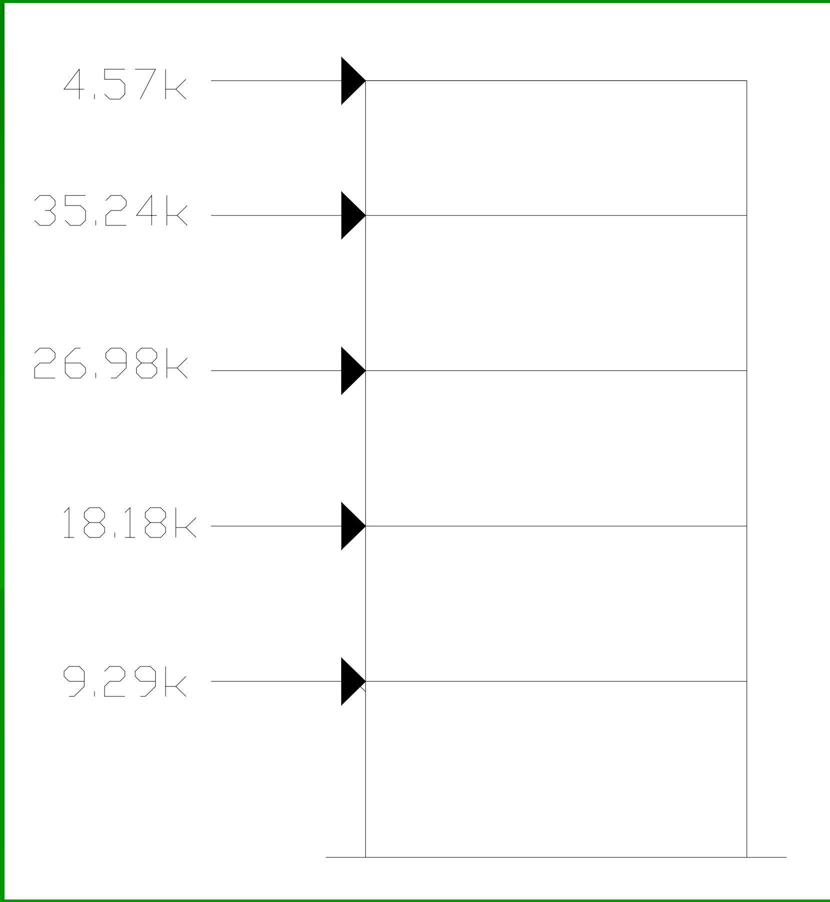
New Shear Wall Layout

Masonry Shear Walls



Masonry Shear Walls

- Seismic forces distributed according to rigidities
- Direct Shears + Torsional Shears

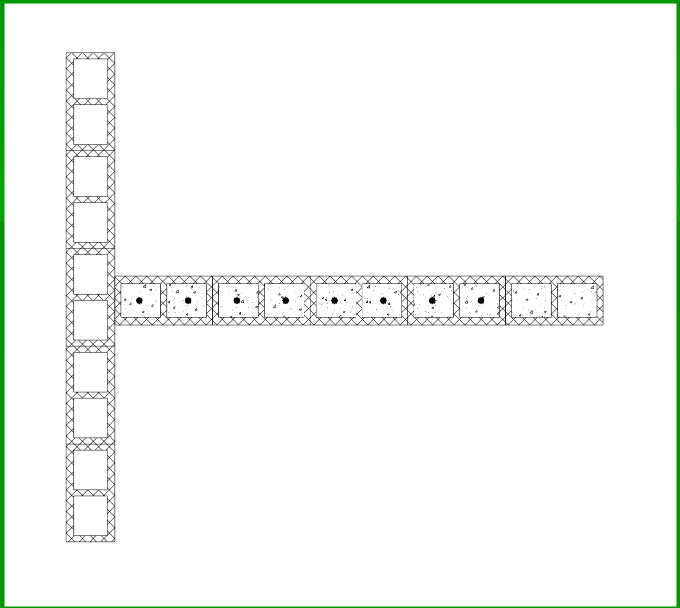


Design Shear Wall Loading

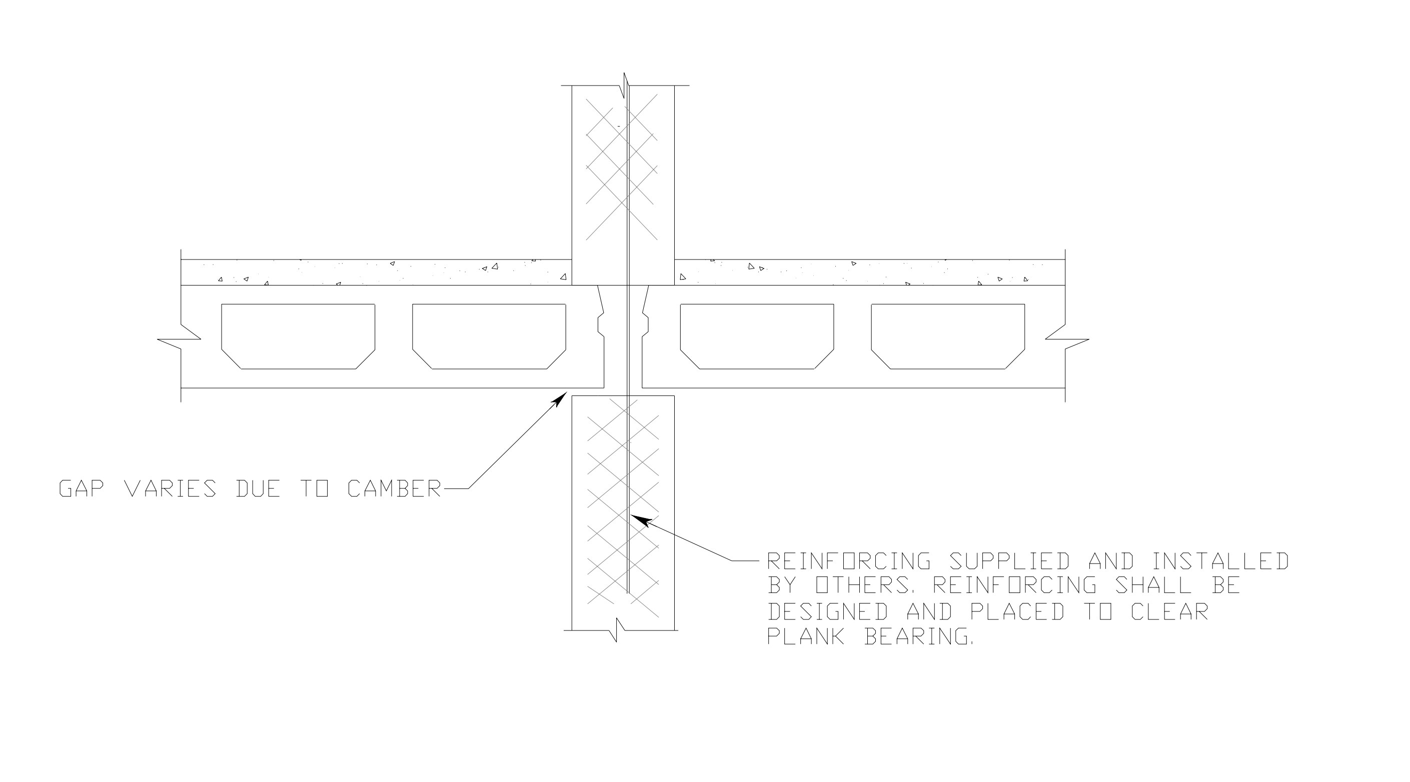
Masonry Shear Walls

- 8" Grouted CMU's
- No shear reinforcement required
- #8 Bars for flexural reinforcement

Floor	Reinforcing
5	1-#8 Bar
4	1-#8 Bar
3	3-#8 Bars
2	5-#8 Bars
Base	8-#8 Bars



Masonry Shear Walls



Typical Shear Wall Reinforcing Detail

Hollow Core Planks

Superimposed Dead Load = 25 psf

Live Load = 40 psf

Total Load = 1.2(25) + 1.6(40) = 94 psf

Span = 23'-6"

Hollow Core Planks

- 8” Deep
- 4’-0” Wide
- Lightweight concrete
- 6 – $^{3}/_{8}$”ø straight prestressing strands
- 2” Normal weight concrete topping

Strand Pattern Designation

76-S
- S = straight
- Diameter of strand in 16ths
- No. of strand (7)

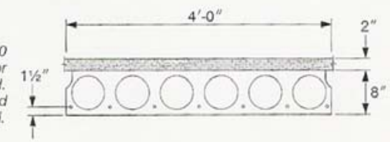
Safe loads shown include dead load of 10 psf for untopped members and 15 psf for topped members. Remainder is live load. Long-time cambers include superimposed dead load but do not include live load. Check availability of lightweight sections.

Capacity of sections of other configurations are similar. For precise values, see local hollow-core manufacturer.

Key
- 346 — Safe superimposed service load, psf
- 0.3 — Estimated camber at erection, in.
- 0.4 — Estimated long-time camber, in.

HOLLOW-CORE

4′-0″ x 8″
Lightweight Concrete



f'_c = 5,000 psi
f'_{ci} = 3,500 psi

Section Properties

		Untopped		Topped	
A	=	215	in²	—	
I	=	1,666	in⁴	3,529	in⁴
y_b	=	4.00	in.	5.70	in.
y_t	=	4.00	in.	4.30	in.
S_b	=	416	in³	619	in³
S_t	=	416	in³	821	in³
b_w	=	12.00	in.	12.00	in.
wt	=	184	plf	272	plf
		46	psf	68	psf
V/S	=	1.92	in.		

4LHC8+2

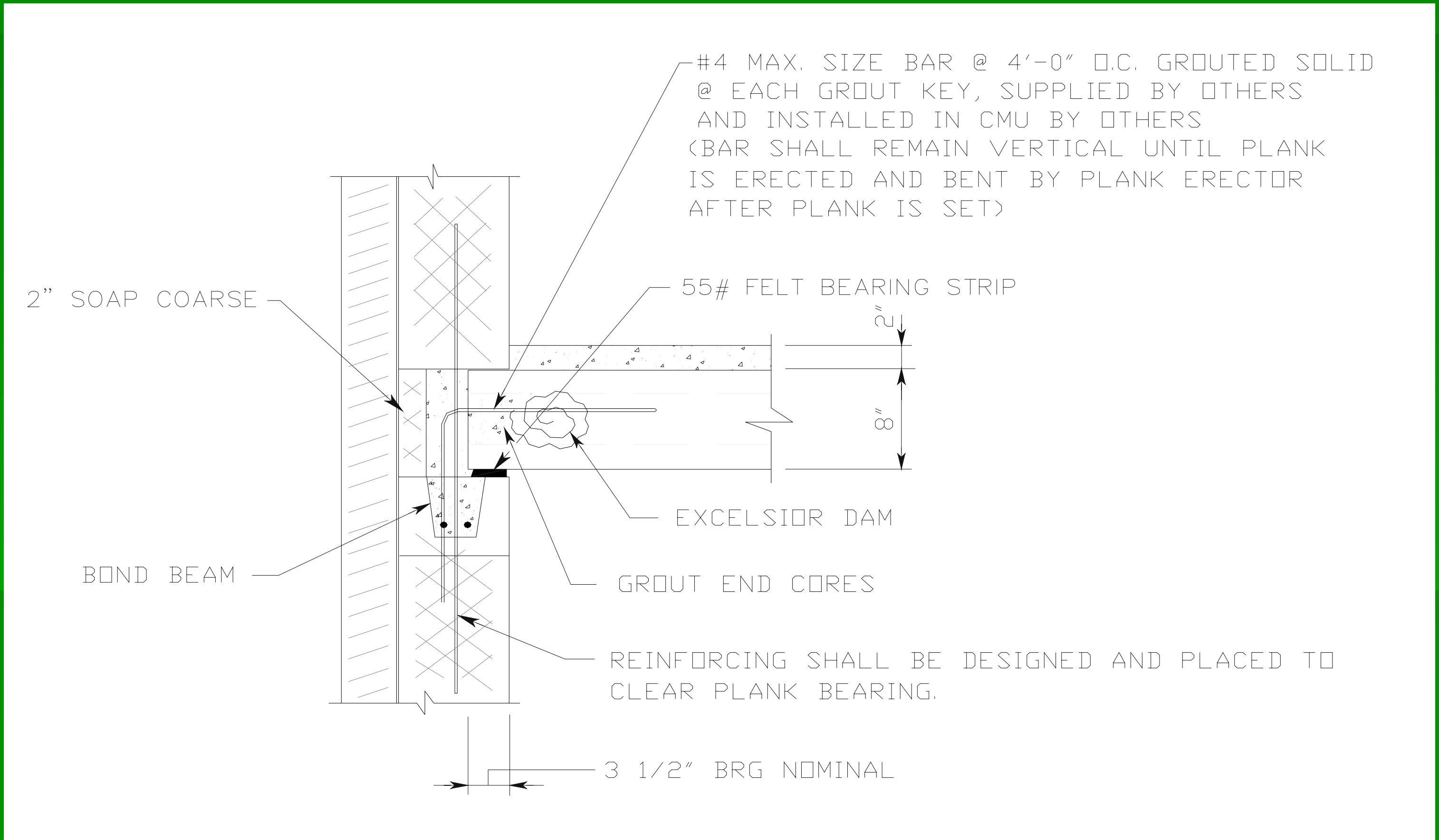
Table of safe superimposed service load (psf) and cambers (in.) — **2″ Normal Weight Topping**

Strand Designation Code	Span, ft																						
	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
66-S	320	277	242	211	186	163	144	127	113	100	88	78	69	60	53	45							
	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.2							
	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.3	0.3	0.2	0.0	−0.1	−0.3	−0.5	−0.7	−1.0							
76-S		327	286	251	222	196	174	155	[illegible]	123	109	98	87	77	69	61	52	43					
		0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.4	0.3					
		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.4	0.3	0.2	0.1	−0.1	−0.3	−0.6	−0.9	−1.2					
58-S				327	290	258	231	206	185	167	150	135	122	110	99	90	81	72	62	53	45		
				0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0	1.0	0.9	0.8	0.7		
				0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.7	0.6	0.4	0.2	0.0	−0.2	−0.5	−0.9	−1.3		
68-S					323	304	278	250	225	204	184	167	151	138	125	114	103	93	83	73	64	56	48
					1.1	1.1	1.2	1.3	1.3	1.4	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.5	1.5	1.4	1.3	1.2
					1.2	1.3	1.3	1.4	1.4	1.4	1.4	1.3	1.3	1.2	1.1	0.9	0.8	0.6	0.3	0.0	−0.3	−0.7	−1.2
78-S					332	313	297	279	263	238	216	197	179	163	149	136	125	113	102	91	81	72	64
					1.3	1.4	1.5	1.6	1.7	1.7	1.8	1.9	2.0	2.0	2.1	2.1	2.1	2.2	2.2	2.2	2.1	2.1	2.0
					1.5	1.6	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.7	1.8	1.5	1.3	1.1	0.9	0.6	0.2	−0.1

Strength based on strain compatibility; bottom tension limited to $6\sqrt{f'_c}$; see pages 2-2–2-6 for explanation.

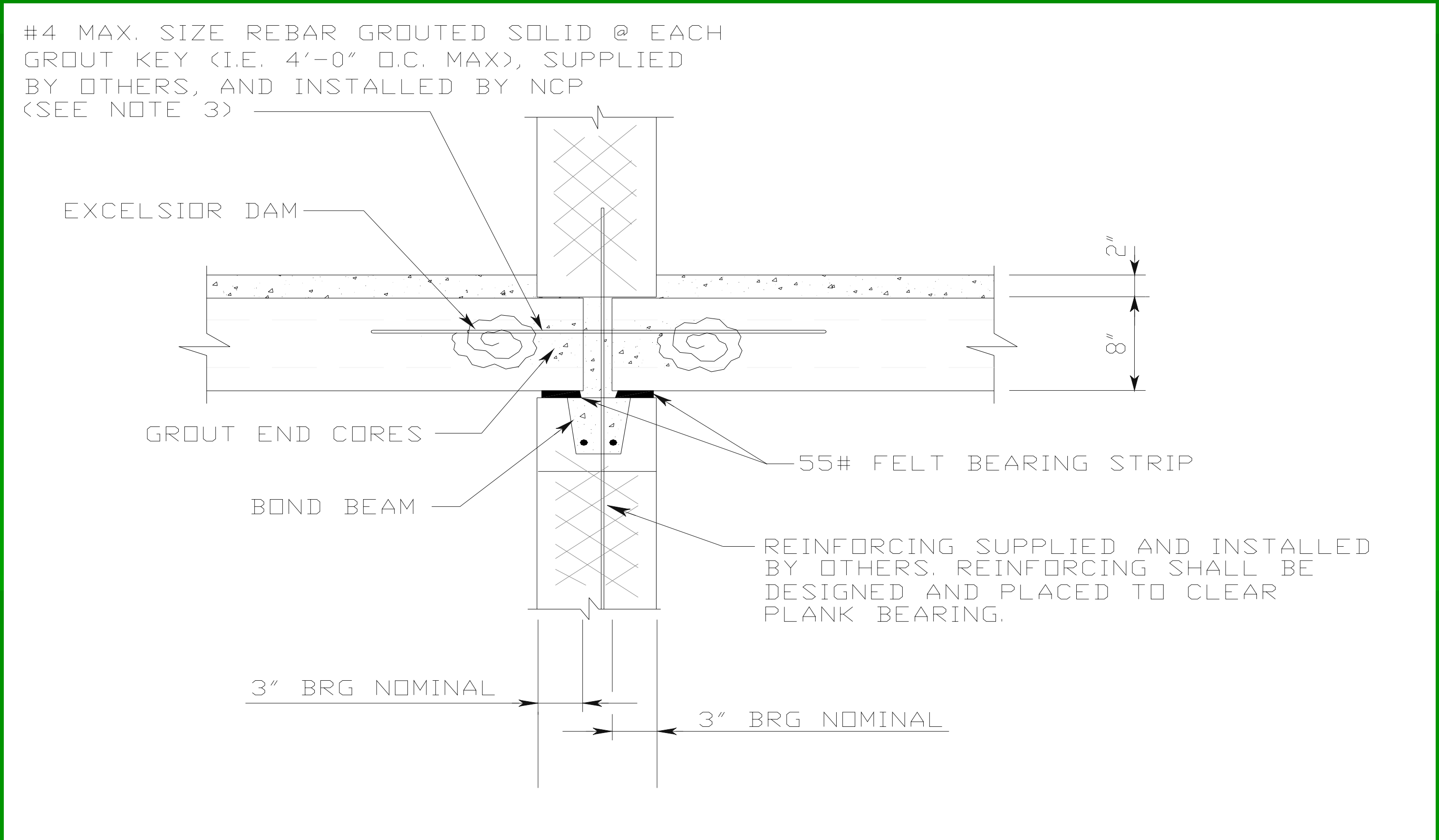
PCI Handbook Design Tables

Hollow Core Planks



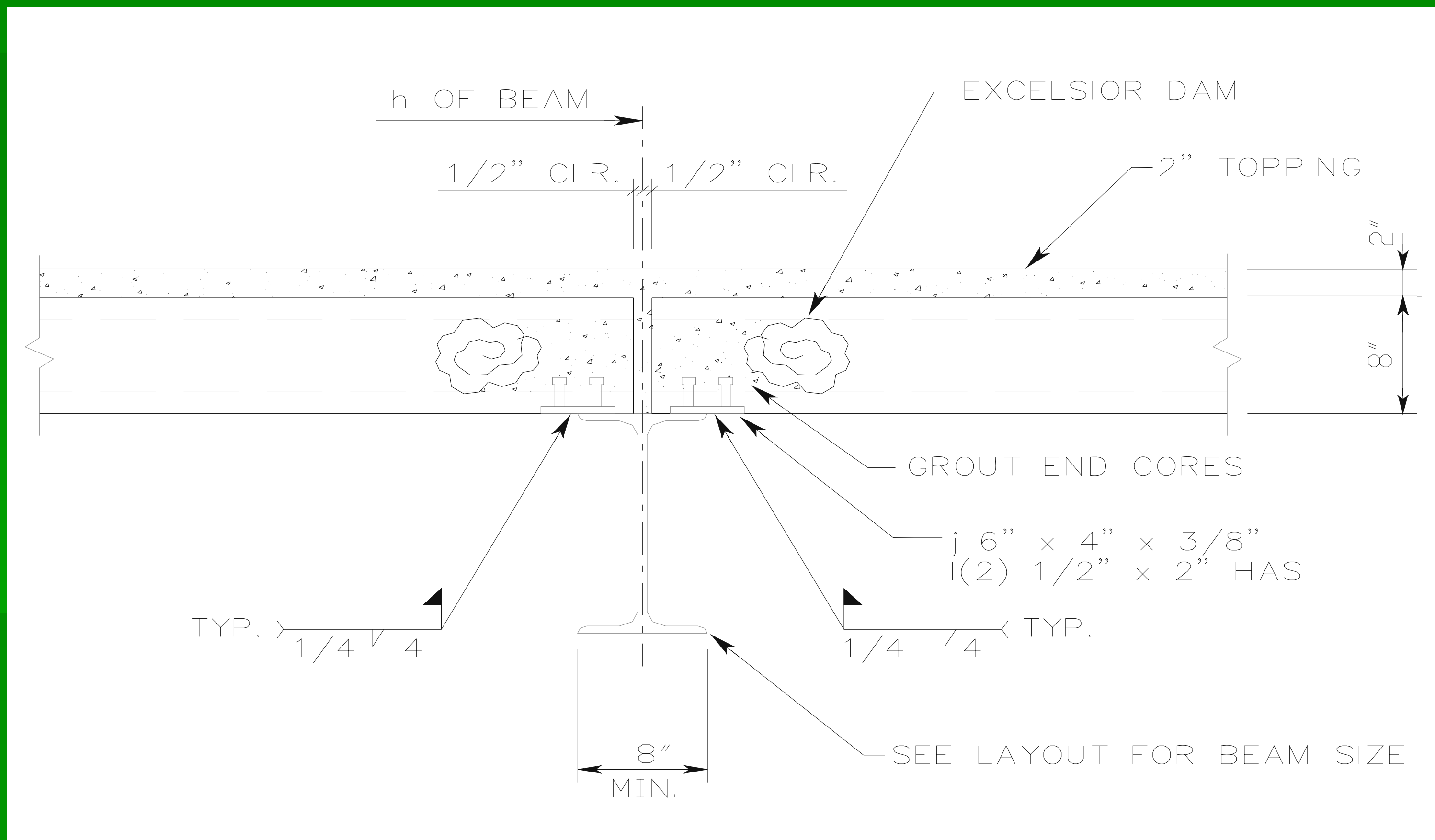
Typical Exterior Bearing Wall Detail

Hollow Core Planks



Typical Interior Bearing Wall Detail

Hollow Core Planks



Typical Interior Bearing on Wide Flange Beam

Masonry Bearing Walls

- Empirical Design Method
  - 12” Hollow CMU’s

Exterior Wall

Floor No.	Plank Size	Self-weight	Total DL	Live Load	Load from wall above	Load from supported floor	Estimated wall weight	Wall load	Wall Stress
5	8" + 2	68	93	40	-	1529.5	555	2084.5	14.5
4	8" + 2	68	93	40	2084.5	1529.5	555	4169	29.0
3	8" + 2	68	93	40	4169	1529.5	555	6253.5	43.4
2	8" + 2	68	93	40	6253.5	1529.5	555	8338	57.9

Interior Wall

Floor No.	Plank Size	Self-weight	Total DL	Live Load	Corridor Live Load	Load from wall above	Load from supported floor	Estimated wall weight	Wall load	Wall Stress
5	8" + 2	68	93	40	100	-	1829.5	555	2384.5	16.6
4	8" + 2	68	93	40	100	2384.5	1829.5	555	4769	33.1
3	8" + 2	68	93	40	100	4769	1829.5	555	7153.5	49.7
2	8" + 2	68	93	40	100	7153.5	1829.5	555	9538	66.2

Masonry Bearing Walls

- Compare actual stresses to allowable
- 1000 psi unit strength required
- Type N mortar

Gross area compressive strength of unit, psi (MPa)	Allowable compressive stresses based on gross cross-sectional area, psi (MPa)[a] Type M or S mortar	Type N mortar
Solid concrete brick:		
8000 (55) or greater	350 (2.41)	300 (2.07)
4500 (31)	225 (1.55)	200 (1.38)
2500 (17)	160 (1.10)	140 (0.97)
1500 (10)	115 (0.79)	100 (0.69)
Grouted concrete masonry:		
4500 (31) or greater	225 (1.55)	200 (1.38)
2500 (17)	160 (1.10)	140 (0.97)
1500 (10)	115 (0.79)	100 (0.69)
Solid concrete masonry units:		
3000 (21) or greater	225 (1.55)	200 (1.38)
2000 (14)	160 (1.10)	140 (0.97)
1200 (8.3)	115 (0.79)	100 (0.69)
Hollow concrete masonry units:		
2000 (14) or greater	140 (0.97)	120 (0.83)
1500 (10)	115 (0.79)	100 (0.69)
1000 (6.9)	75 (0.52)	70 (0.48)
700 (4.8)	60 (0.41)	55 (0.38)
Hollow walls (noncomposite masonry bonded[b])		
solid units:		
2500 (17) or greater	160 (1.10)	140 (0.97)
1500 (10)	115 (0.79)	100 (0.69)
hollow units	75 (0.52)	70 (0.48)

NCMA TEK Notes: Allowable Stresses

Breadth Study:

Construction Management

Cost Analysis

- Using RS Means Building Construction Cost Data 2006:

Cost of New System = $3,176,357

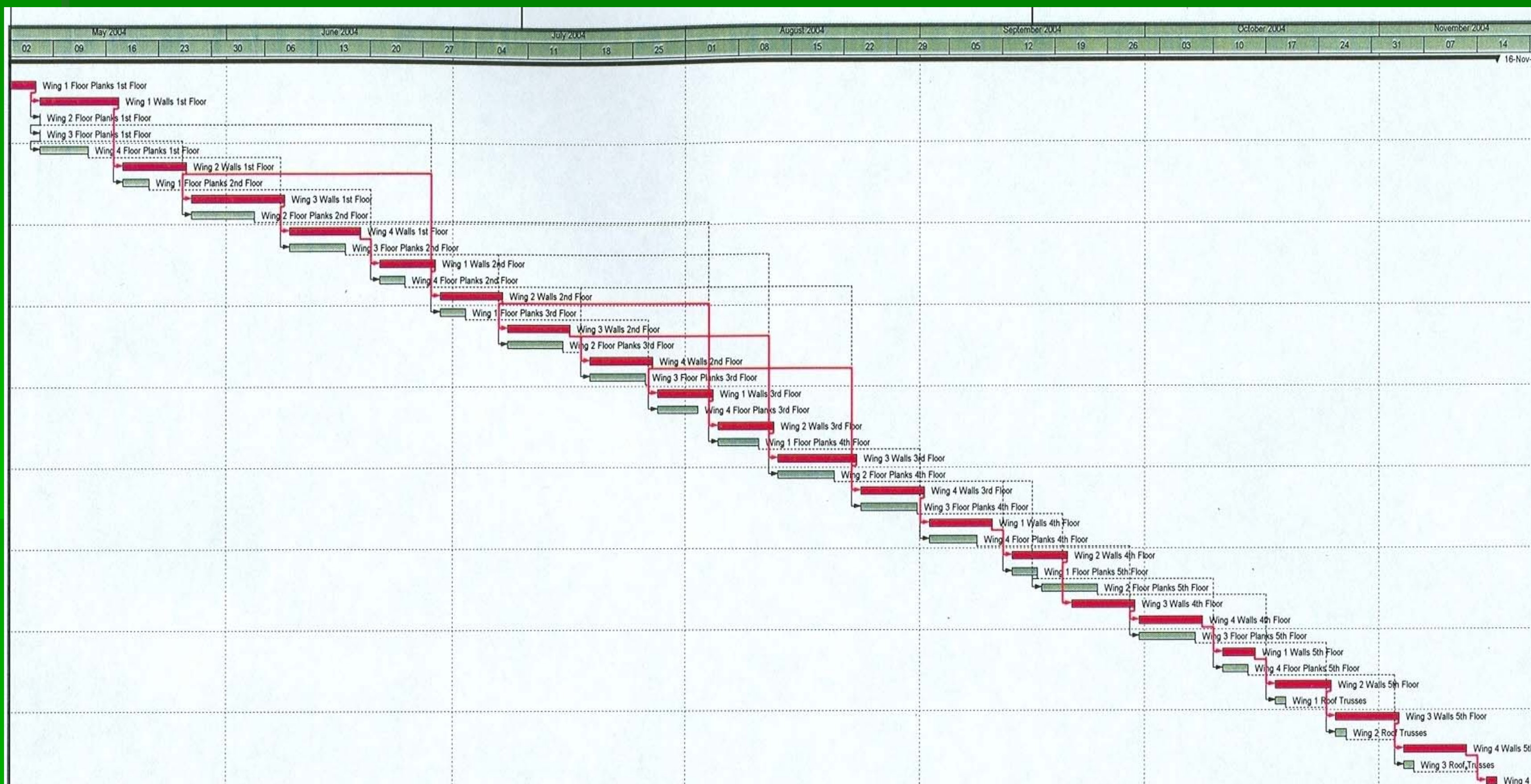
Cost of Actual System = $3,200,000

$23,643

Construction Schedule

- A construction schedule was created using Primavera Project Manager
  - Building broken into 4 sections
  - Schedule flexibility based on crew size
- Duration of new system = 6 months, 2 weeks
- Duration of actual system = 6 months

Construction Schedule



Conclusions

Conclusions

- New system is a viable alternative
  - Savings of $23,643
  - Approx. same construction time
- Recommendations:
  - More consideration for masonry construction in similar projects

Acknowledgements

- The University of Delaware
  - Mr. Joe Filippone – Plans Room Technician
  - Ms. Penny Person – Senior Project Manager
- Ayers/Saint/Gross Architects & Planners
- Sebesta Blomberg & Associates
- Skarda & Associates
- Tetra Tech, Inc.
- AE department
- Family and friends

Questions?