

The Medical Office Building
Malvern, PA

The Medical Office Building

Brendon Burley
Structural Option
April 11, 2005

Advisor:
Dr. Thomas Boothby



- Introduction
- Shear Wall Analysis
- Post-Tensioned Two-Way Slab
- Underfloor Air Distribution
- Conclusions

The Medical Office Building

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Introduction: General Information

The Project

Site

East Whiteland Township — 111 acres
Tredyffrin Township — 5 acres

Building Info

235,000 sq. ft.
6 Stories — 4 stories above grade

Architecture

Pre-cast Concrete Panel & Brick Veneer
Façade
Open planned interiors surrounded by
traditional office space along the
walls
4 story semi-circular atrium on the rear
wall connects to a semi circular
patio, patterned brick link the floor
of the atrium with the patio

Costs

\$37 million in total Project costs
\$7 million parking garage
\$1.35 million AE fee

Mechanical

Generation

8 central water heat pumps
- Four 50 ton
- Three 70 ton
- One 90 ton
Chiller dedicated to auditorium

Heating Delivery

311 heat pumps provide a
thermal buffer along the
exterior wall
30 ceiling hung heat pumps

Cooling Delivery

VAV box in every office with
local and network controls

The Team

Architect

Ewing Cole Cherry Brott
100 North 6th Street
Philadelphia, PA 19106
<http://www.ewingcole.com/>

Electrical

Feeder

2 35kV lines in main-tie-main
radial configuration

Distribution

2 1500kVA Transformers
Dual UPS on transformers
4 3-Day Generators

Special

Fire Protection

Wet Type Sprinkler System
Water Curtain in atrium
Simplex 4100 Control Panel

Security

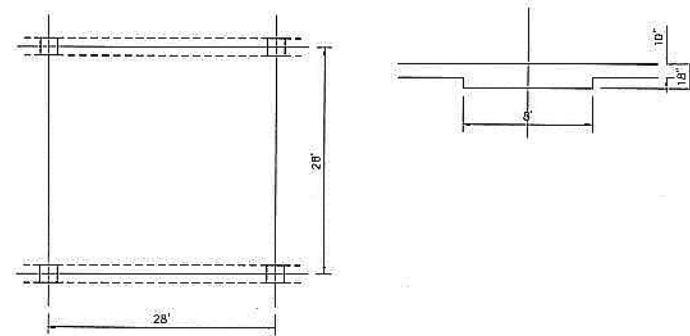
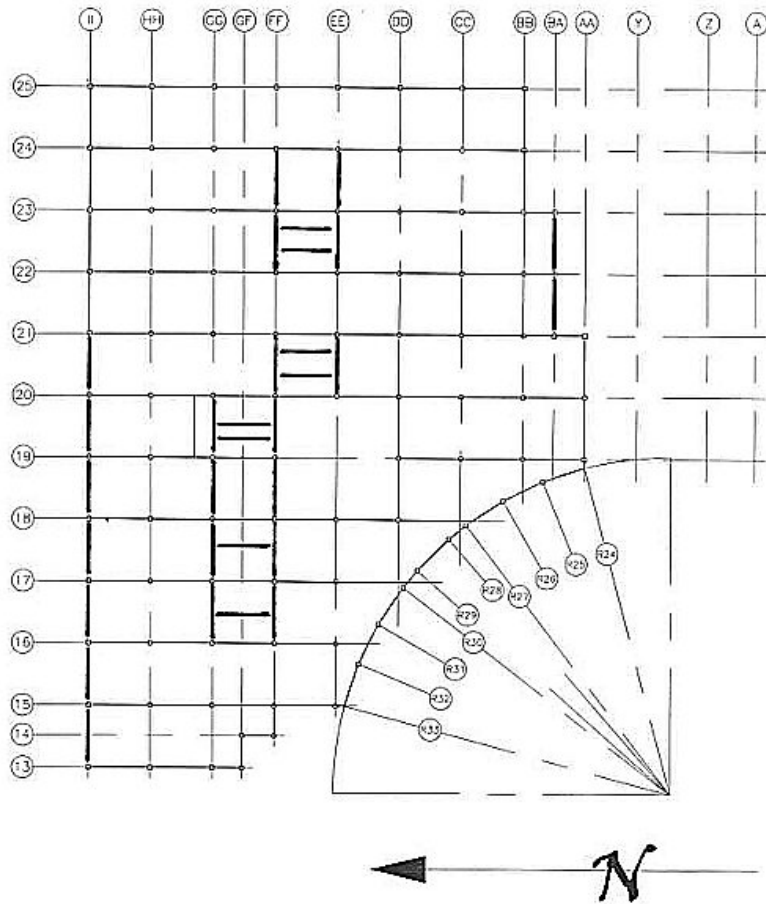
Closed Circuit Television

Contractor

Torcon, Inc.
214 East Grove Street
West Field, NJ 07091

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Introduction: Structural System



Filigree Beams (above)

Moment Frames (left)

Advantages

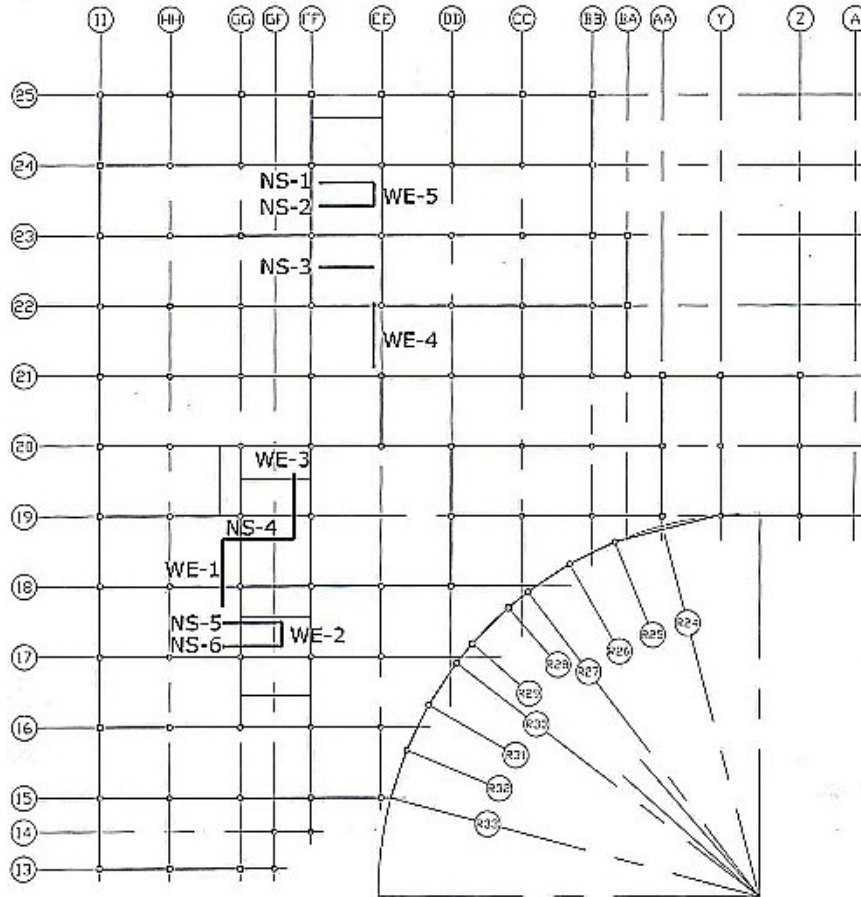
- Thin (18") system depth
- Fast construction
- Less on-site work
- Less seasonal dependence

Disadvantages

- Black box design
- No lateral restraint
- Few experienced contractors

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Shear Wall Analysis: Proposed Walls



Shear Wall Systems:

- NS-1,2,3,4,5,6
WE-1,2,3,4,5
- NS-1,2,5,6
WE-2,5
- NS-3,4
WE-1,4
- NS-2,3,4,5
WE-1,4,5
- NS-2,3,4,5
WE-3,4

| Walls | X-eccentricity | Y-eccentricity |
|-------------------------------|----------------|----------------|
| NS-1,2,3,4,5,6 & WE 1,2,3,4,5 | -10.18' | 1.22' |
| NS-1,2,5,6 & WE-2,5 | -8.77' | -8.42' |
| NS-3,4 & WE-1,4 | -10.08' | 12.49' |
| NS-2,3,4,5 & WE-1,4,5 | -9.21' | 5.04' |
| NS-2,3,4,5 & WE-3,4 | 5.16' | 5.04' |

System with least eccentricity was chosen.

Final design summarized below

| Wall | b (in.) | d (ft.) | h(ft.) | V_ult | f (psi) | V_n |
|---------|---------|---------|--------|--------|---------|--------|
| N-Frame | - | - | - | 13.59 | - | - |
| S-Frame | - | - | - | 3.91 | - | - |
| NS-2 | 16.00 | 14.00 | 37.50 | 75.48 | 54.15 | 174.56 |
| NS-3 | 16.00 | 10.00 | 37.50 | 29.01 | 30.52 | 67.10 |
| NS-4 | 16.00 | 16.00 | 37.50 | 118.05 | 230.35 | 273.01 |
| NS-5 | 20.00 | 14.00 | 50.00 | 45.41 | 123.36 | 105.01 |
| WE-3 | 16.00 | 20.00 | 37.50 | 109.14 | 230.57 | 252.40 |
| WE-4 | 16.00 | 16.00 | 37.50 | 63.64 | 138.57 | 147.18 |

| | Shear Wall | Moment Frame |
|------------------------------|------------|--------------|
| CMU Block | \$35,728 | \$0 |
| Footing Formwork | \$4,301 | \$0 |
| Footing Rebar | \$2,895 | \$0 |
| Footing Concrete & Placement | \$21,904 | \$0 |
| Beam Formwork | \$0 | \$3,960 |
| Beam Rebar | \$0 | \$33,780 |
| Beam Concrete & Placement | \$0 | \$96,540 |
| TOTAL | \$64,828 | \$134,280 |

Advantages

- Savings of \$70,000
- More uniformity

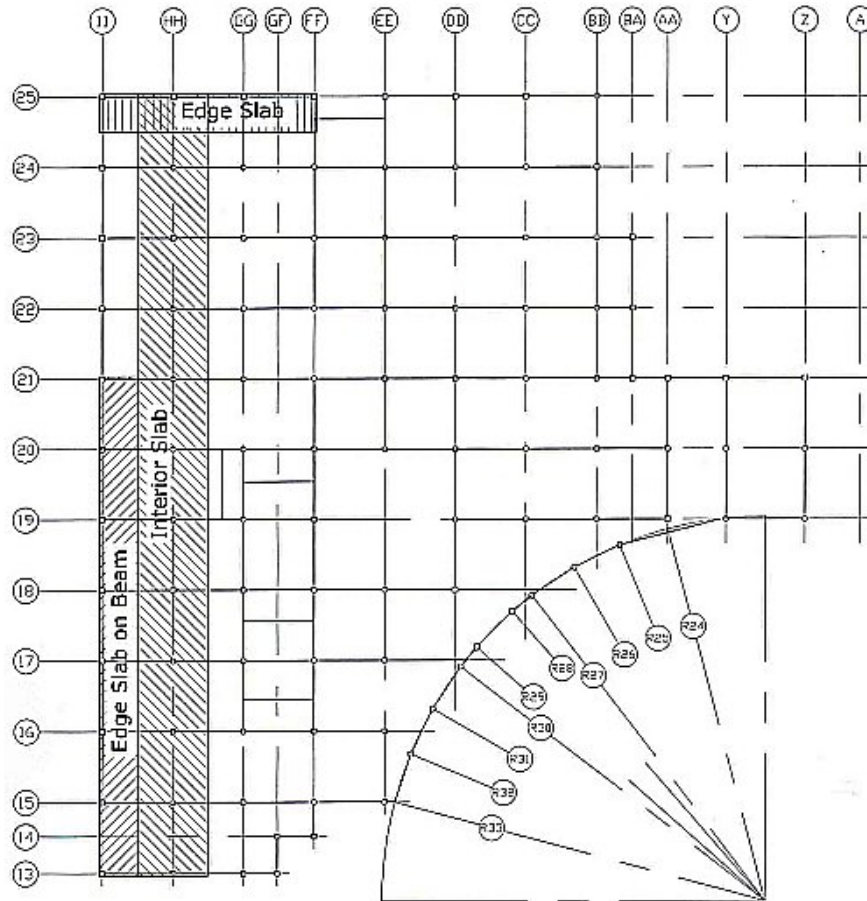
Disadvantages

- Requires new footings
- Interferes with MEP

Use Shear Walls

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Post-Tensioned Two-Way Slab: Load Analysis



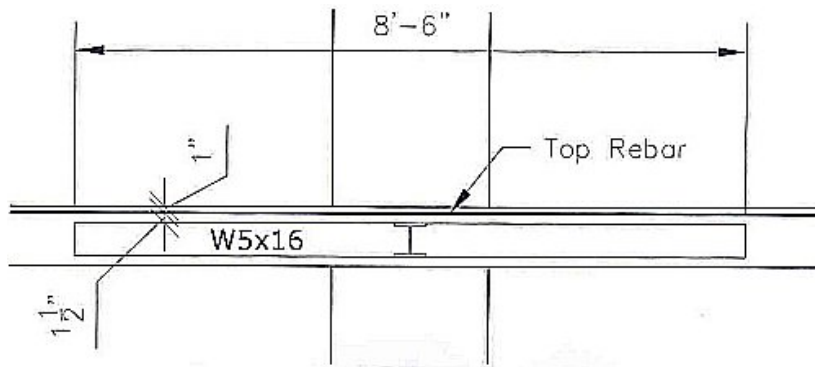
9" slab based on span

$$w_{LL} = 100 \text{ psf}$$

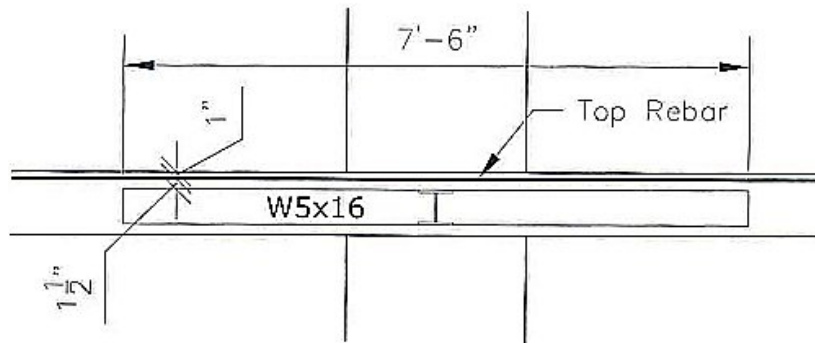
$$w_{DL} = 25 \text{ psf}$$

$$w_{SW} = 112.5 \text{ psf}$$

| Slab | M_{col} | M_{mid} | M_{beam} | v |
|--------------------|-----------|-----------|------------|--------|
| | (ft-k) | (ft-k) | (ft-k) | (psi) |
| Edge with beams | 45.3 (-) | 37.6 (-) | 256.5 (-) | 155.84 |
| | 33.0 (+) | 27.4 (+) | 186.9 (+) | |
| Edge without beams | 233.3 (-) | 77.8 (-) | - | 330.69 |
| | 136.5 (+) | 91.0 (+) | | |
| Interior | 399.3 (-) | 133.1 (-) | - | 328.03 |
| | 216.5 (+) | 144.3 (+) | | |



Exterior Shearhead



Interior Shearhead

| Segment | | A_s | Bars | Spacing (in) |
|----------------------------|-----|--------------------|----------|--------------|
| | | (in ²) | | |
| Interior Column Strip | Top | 12.74 | 64 # 4's | 2.55 |
| | Bot | 6.66 | 34 # 4's | 4.67 |
| Interior Middle Strip | Top | 4.03 | 21 # 4's | 7.30 |
| | Bot | 4.38 | 22 # 4's | 7.00 |
| Exterior Beam Column Strip | Top | 1.56 | 8 # 4's | 9.60 |
| | Bot | 1.56 | 8 # 4's | 9.60 |
| Exterior Beam Middle Strip | Top | 2.72 | 14 # 4's | 10.50 |
| | Bot | 2.72 | 14 # 4's | 10.50 |
| Exterior Beams | Top | 2.01 | 3 # 8's | 5.00 |
| | Bot | 2.79 | 3 # 9's | 5.00 |
| Exterior Column Strip | Top | 13.6 | 68 # 4's | 1.37 |
| | Bot | 4.22 | 22 # 4's | 4.00 |
| Exterior Middle Strip | Top | 2.72 | 14 # 4's | 10.50 |
| | Bot | 2.74 | 14 # 4's | 10.50 |

Interior: $A_s=4.0\text{in}^2$ $P=900\text{k}$

Exterior: $A_s=4.0\text{in}^2$ $P=920\text{k}$

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Post-Tensioned Two-Way Slab: Conclusions

| | Two-way | Banded |
|----------------------------------|--------------------|--------------------|
| Slab Formwork | \$457,050 | \$457,050 |
| Slab Reinforcing (w/ shearheads) | \$161,020 | \$33,083 |
| Slab Post-tensioning | \$165,000 | \$0 |
| Slab Concrete and Placement | \$839,237 | \$839,237 |
| Beam Formwork | \$0 | \$173,765 |
| Beam Reinforcing | \$0 | \$63,000 |
| Beam Concrete & Placement | \$0 | \$275,229 |
| TOTAL | \$1,622,307 | \$1,841,364 |

or?

| | Two-way | Banded |
|----------------------------------|--------------------|--------------------|
| Slab Formwork | \$457,050 | \$457,050 |
| Slab Reinforcing (w/ shearheads) | \$161,020 | \$33,083 |
| Slab Post-tensioning | \$165,000 | \$0 |
| Slab Concrete and Placement | \$839,237 | \$587,466 |
| Beam Formwork | \$0 | \$173,765 |
| Beam Reinforcing | \$0 | \$63,000 |
| Beam Concrete & Placement | \$0 | \$192,660 |
| TOTAL | \$1,622,307 | \$1,507,024 |

Advantages

- 9" System Depth
- Open plenum

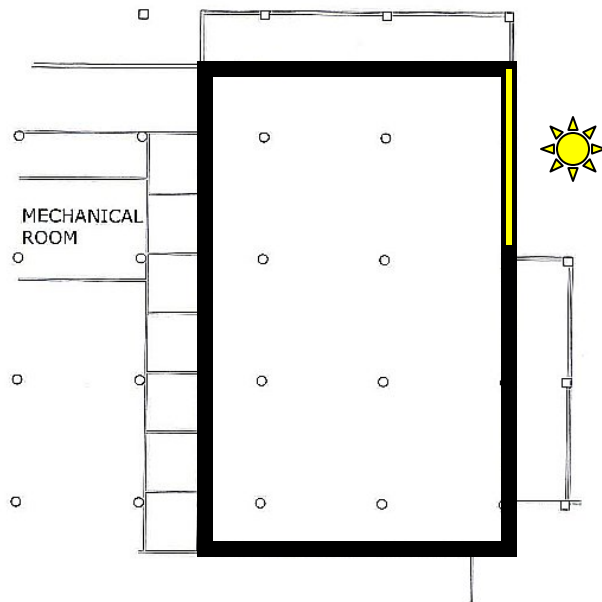
Disadvantages

- Difficult to construct
- Unclear cost benefit

Inconclusive

Assume:

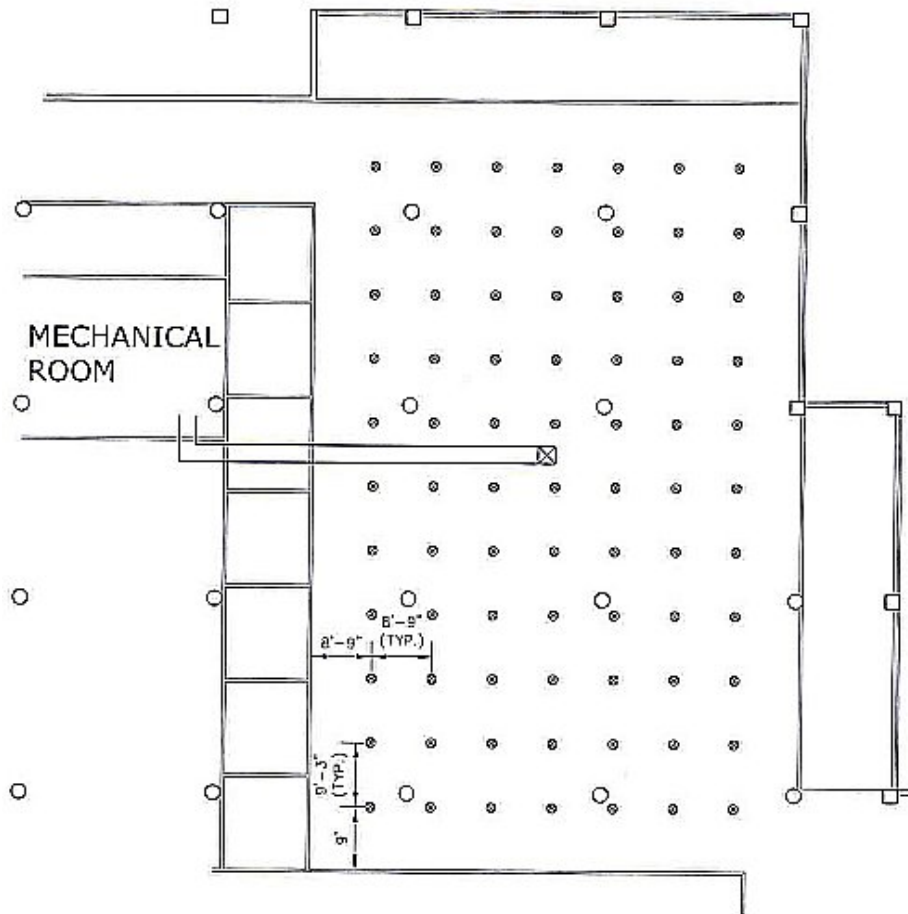
- Two-way slab system
 - Floor to Ceiling Height is 10'-5"
 - Height of the occupied zone is 6'-0"
- Interior surfaces are adiabatic



| Source | Unoccupied Load | | Occupied Load | |
|--------------|-----------------|-------------|---------------|--------------|
| | (Btu/hr) | | (Btu/hr) | |
| | Winter | Summer | Winter | Summer |
| Lighting | 7400 | 7400 | 29600 | 29600 |
| Occupants | 0 | 0 | 10800 | 10800 |
| Computers | 0 | 0 | 13226 | 13226 |
| Infiltration | -586 | 199 | -4102 | 1390 |
| Conduction | -2213 | 750 | -6935 | 2349 |
| TOTAL | 4601 | 8349 | 42589 | 57365 |

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Underfloor Air Distribution: System Design



- Pressurized Plenum
- Total Air Flow = 7600 cfm
- Total Diffusers = 77

Advantages

- Air can be provided at 65°F
- More individual control
- Less ductwork
- Useful leakage

Disadvantages

- Height dependent
- Occupancy dependent
- Excessive leakage

With Filigree Beams:

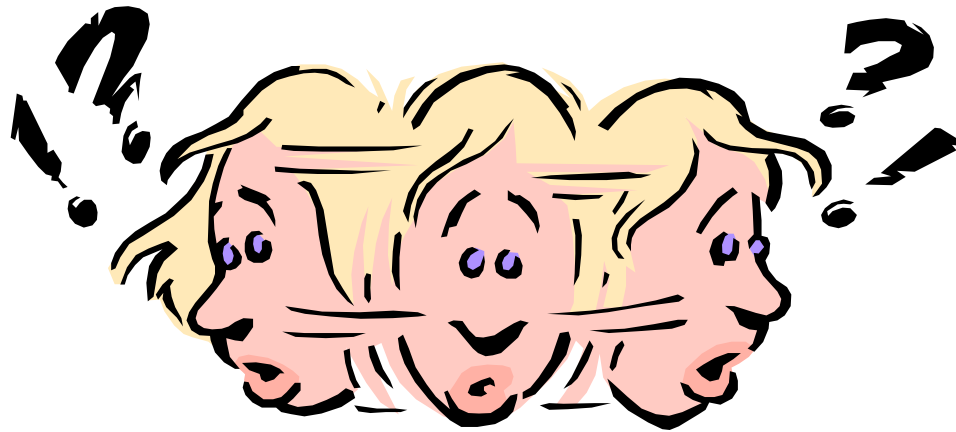
DO NOT USE UFAD

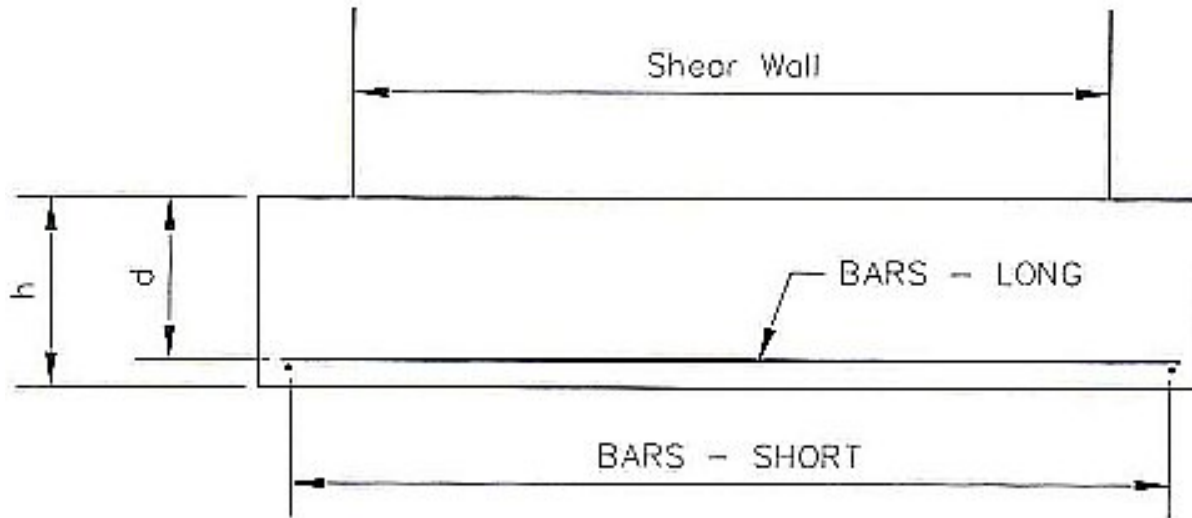
With Two-Way Slab:

Use UFAD

- Shear Walls are an efficient alternative to moment frames
- A post-tensioned two-way slab is competitive with the Filigree Beam system
- Underfloor Air Distribution can be introduced to increase the value of a two-way slab floor system

- Kevin Matthews
- Jim Kerr
- AE Faculty and Staff
 - Dr. Jelena Srebric
 - Dr. Louis Geschwindner
 - Dr. Thomas Boothby
 - Sharon Williams
- My Friends & Family
 - Tim & Ann Burley
 - Heather Lamp





| Wall | q _{design} (ksf) | d (in) | h (in) | A _s (in ²) | | Bars – Long | Bars -Short |
|------|------------------------------|-----------|-----------|-----------------------------------|-------|-------------|-------------|
| | | | | Long | Short | | |
| NS-2 | 8.62 | 36 | 39 | 0.84 | 0.84 | #6's @ 6" | #6's @ 6" |
| NS-3 | 6.6 | 17 | 20 | 0.44 | 0.43 | #6's @ 12" | #6's @ 12" |
| NS-4 | 7.85 | 45 | 48 | 1.04 | 1.04 | #6's @ 5" | #6's @ 5" |
| NS-5 | 6.11 | 27 | 30 | 0.69 | 0.65 | #6's @ 7" | #6's @ 8" |
| WE-3 | 7.07 | 29 | 32 | 0.73 | 0.69 | #6's @ 7" | #6's @ 7" |
| WE-4 | 6.38 | 21 | 24 | 0.6 | 0.52 | #6's @ 8" | #6's @ 9" |