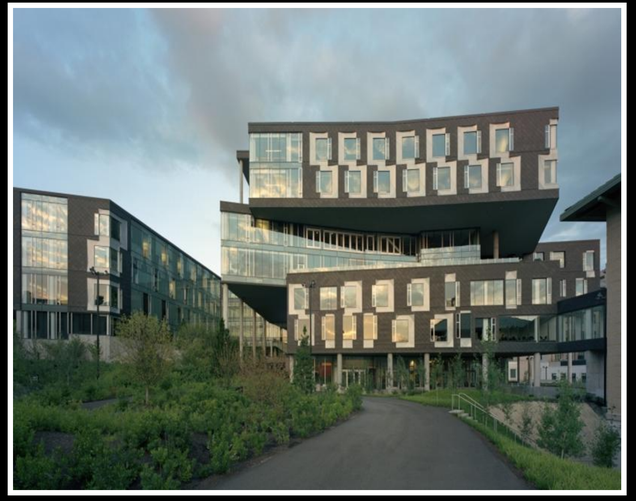
The University Sciences Building

Northeast, USA

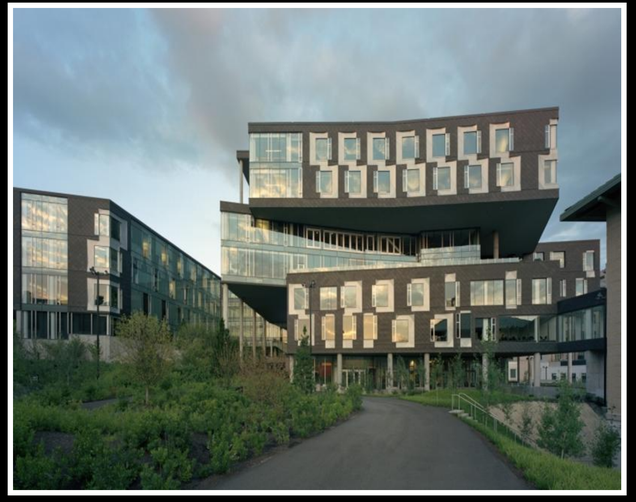
Final Presentation - 4.9.2012

Chris Dunlay | Structural Option | Dr. Boothby



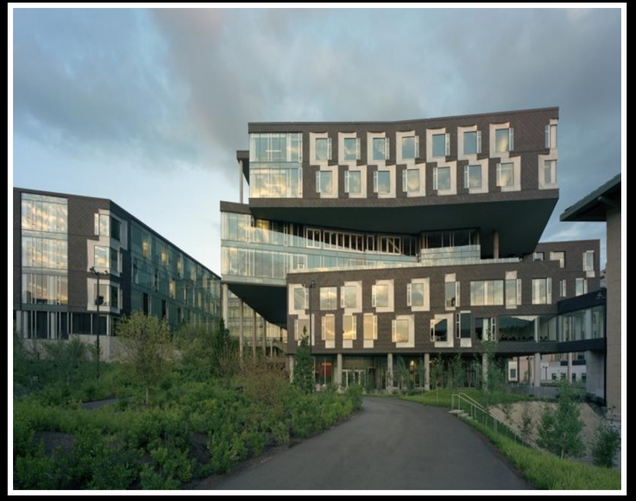
Project Facts

- Located in Northeast, USA
- 209,000 S.F.
- 2 below grade stories / 7 above grade stories
- Maximum Height: 117’-0”
- Classroom, Laboratories, and Offices
- Construction Cost: $ 80 Million
- August 2007 – December 2009
- LEED GOLD Certification



Thesis Topics

- Existing Structural System
- Problem and Solution
- Gravity Design
- Lateral Design
- Construction Management Study
- Mechanical System Study



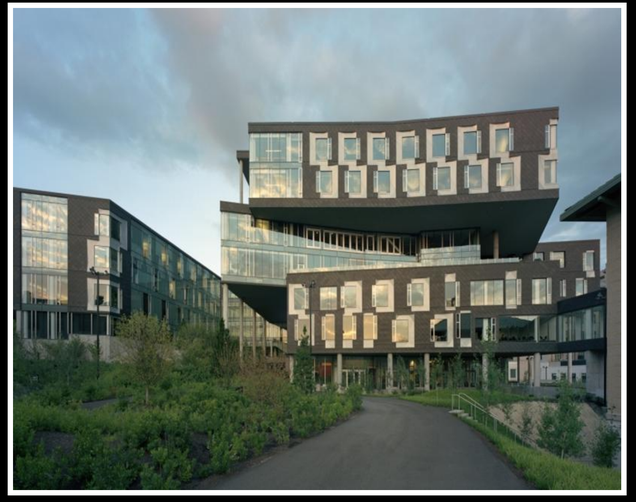
Project Team

- **Owner**: Not Release
- **Architect**: Mack Scogin Merrill and Elam
- **General Contractor:** PJ Dick
  - **WEB Contractor:** Graziano Construction
- **Structural Engineer**: ARUP – Boston
- **Mechanical Engineer**: ARUP – Boston
- **Electrical Engineer:** ARUP - Boston
- **Civil Engineer:** Civil and Environmental Consultants

PJ DICK

Mack Scogin Merrill Elam Architects

ARUP



Architecture

- Independent from surrounding campus architecture
- Unique Façade:
  - Zinc Panels
  - Aluminum Window Trim
- Multiple Atriums
- Unsymmetrical floor plans

Existing Structural System

- **Superstructure (4 – Roof)**
  - Composite Deck on steel framing
- **Foundation (Levels 1-3)**
  - Drilled caissons, strip and column footings
  - Concrete walls and columns
  - 150 car parking garage
- **Lateral System**
  - Dual Shear Walls and Braced Frames

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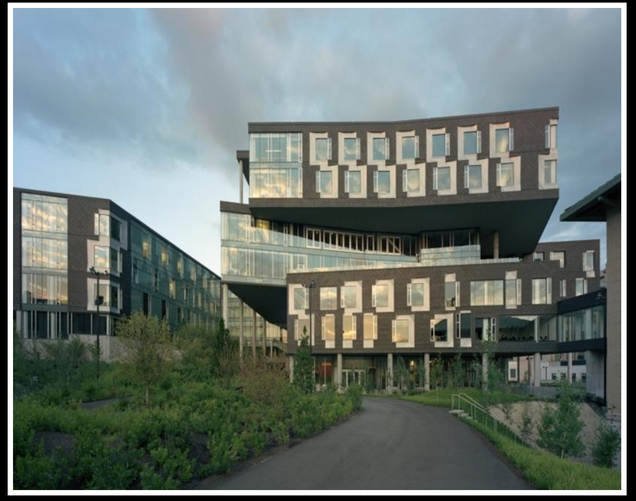
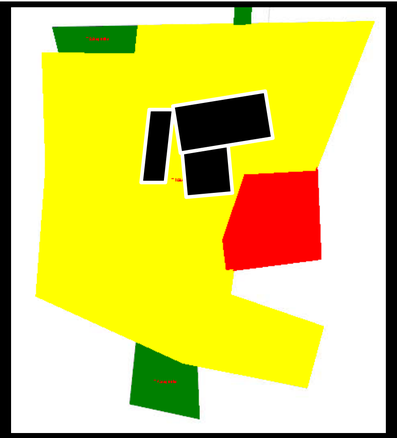
Braced Frame

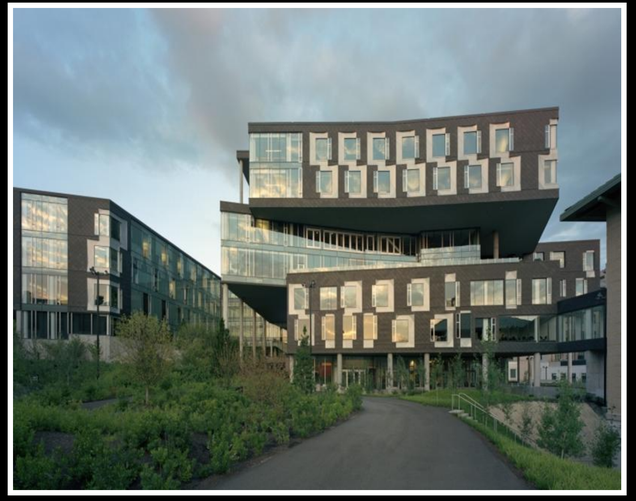
Shear Wall



Roof Elevations

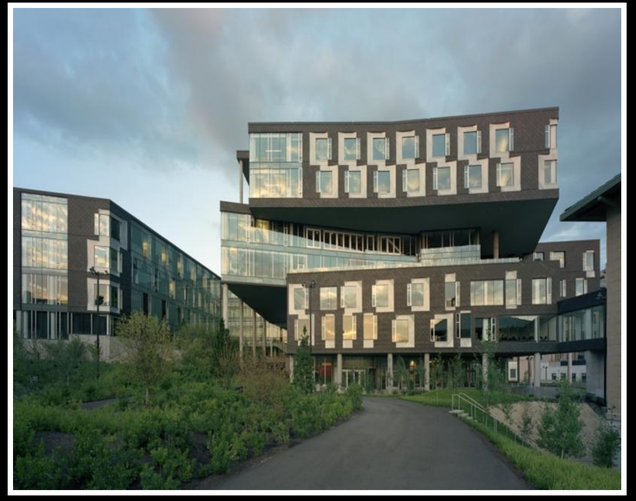
- 6th Level Roof – 61’-0”
- 7th Level Roof – 75’-0”
- 9th Level Roof – 103’-0”
- Mechanical Penthouse – 117’-0”





Problem Statement

- **Superstructure Schedule**
  - Erection and detailing of steel put project 2 months behind schedule
- **Incurred Costs**
  - Delayed schedule added general condition costs
  - Change orders were frequent
  - Other trades inherently feel behind schedule



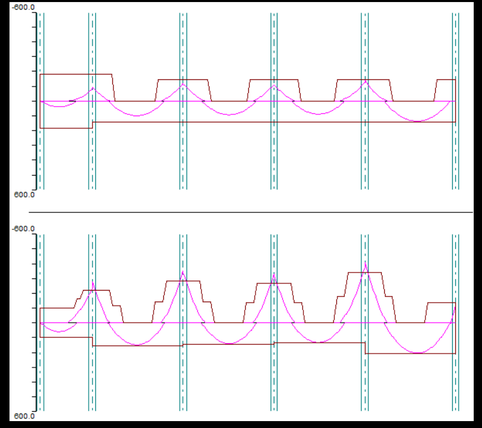
Problem Solution

- **Concrete Structure**
  - One trade
  - No ‘Connections’
  - Predictable and efficient schedule
- **Structural Systems**
  - Two Way Flat Plate
  - Shear Wall-Moment Frame Interactive System

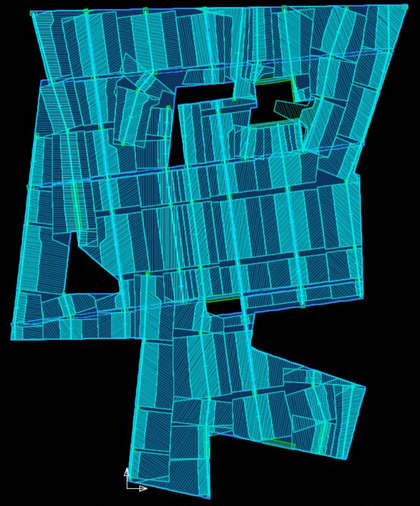
Goals

- **Concrete Design**
  - Manageable budget and schedule
  - Shear wall core
  - Moment frames to help reduce torsion
- **Truss**
  - Design truss to resist gravity loads on west cantilever

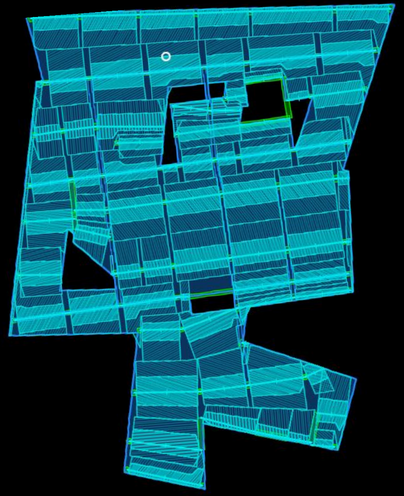
Two Way Flat Plate Design



spSlab: Level 6 Equivalent Frame Analysis

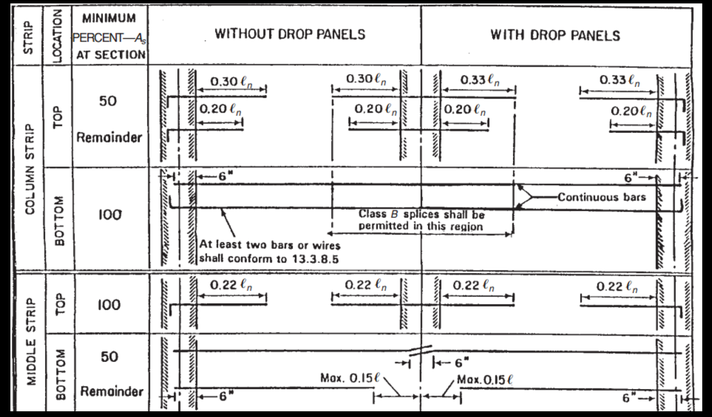


RAM Concept: Level 6 Longitudinal Design Strips

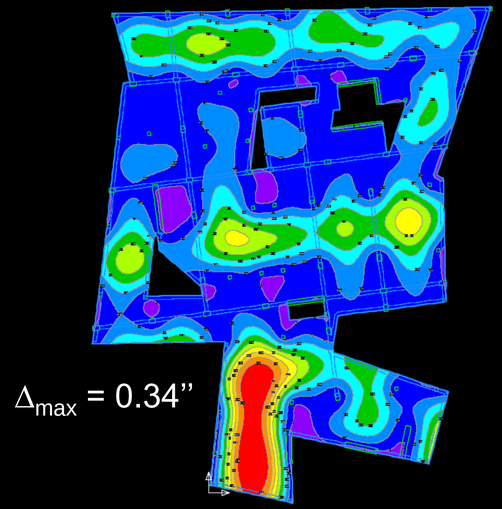


RAM Concept: Level 6 Latitude Design Strips

Two Way Flat Plate Design

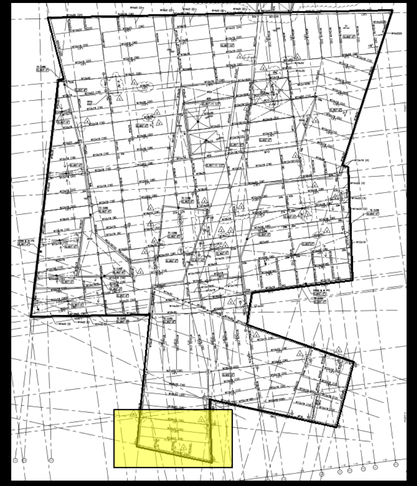


ACI § 13.3.8.1 Minimum slab reinforcement extension



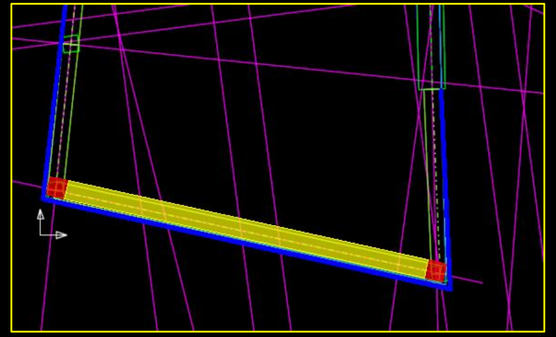
Δ_{max} = 0.34”

RAM Concept: Level 6 Deflection Plan



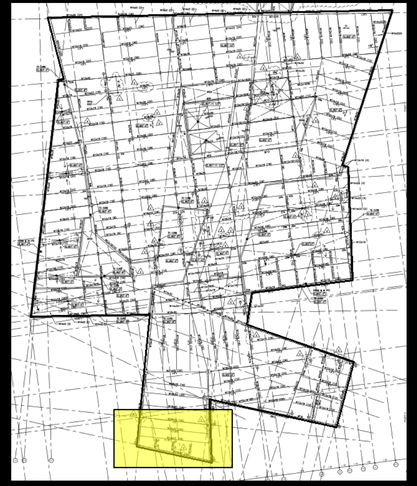
Beam Edge Location

Edge Beam Design

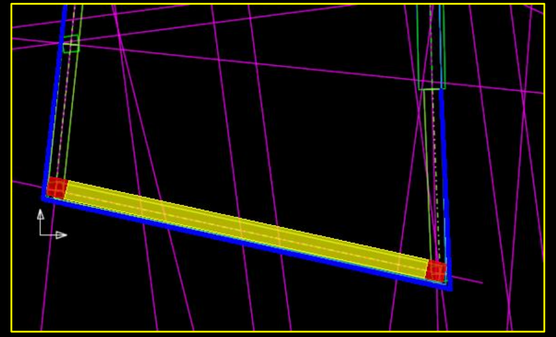


Design Edge Beam Span

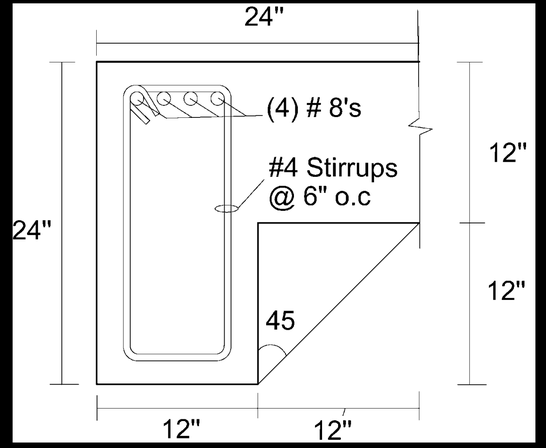
Edge Beam Design



Beam Edge Location

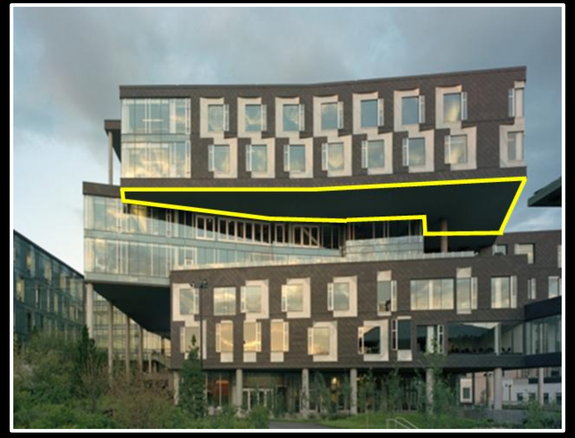


Design Edge Beam Span



Designed Edge Beam Section

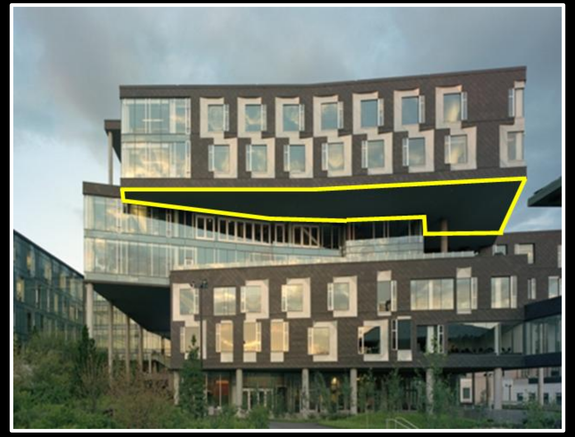
Truss Design



West Elevation: Cantilever Highlight

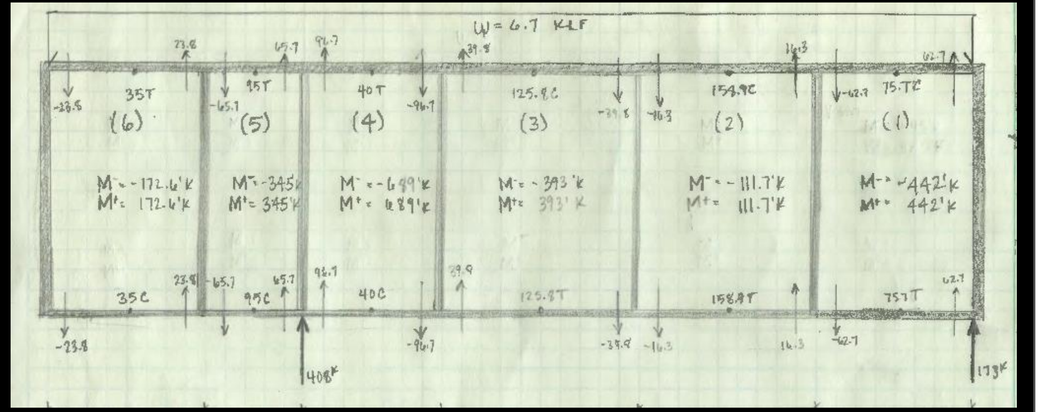
Level 6 Truss Plan

Truss Design



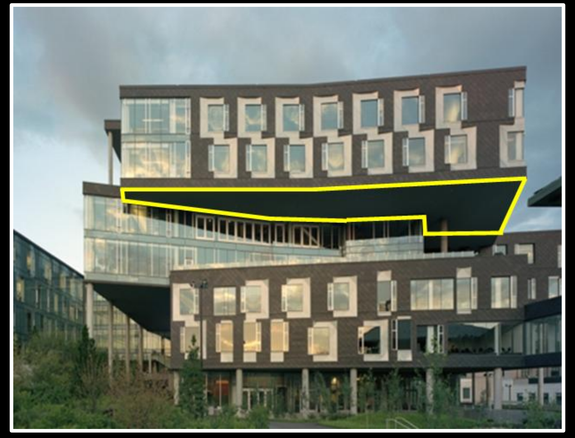
West Elevation: Cantilever Highlight

Level 6 Truss Plan – Frame GO Highlight



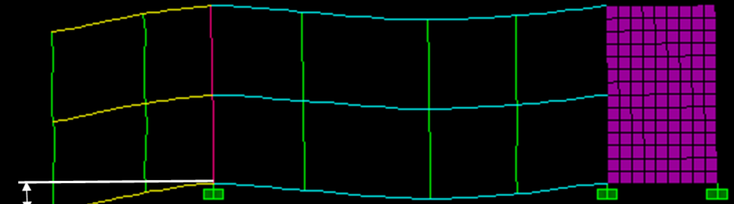
Frame GO: Portal Frame Analysis

Truss Design



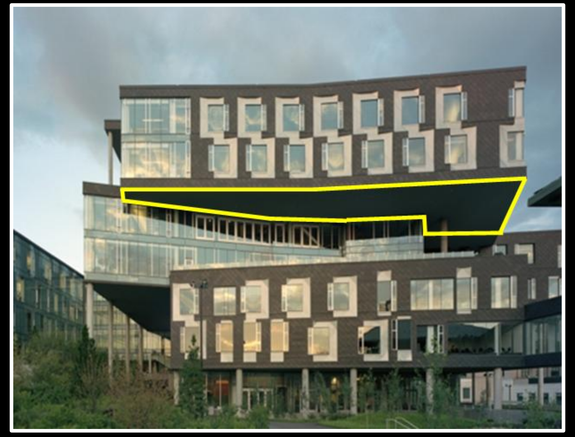
West Elevation: Cantilever Highlight

Level 6 Truss Plan – Frame GO Highlight

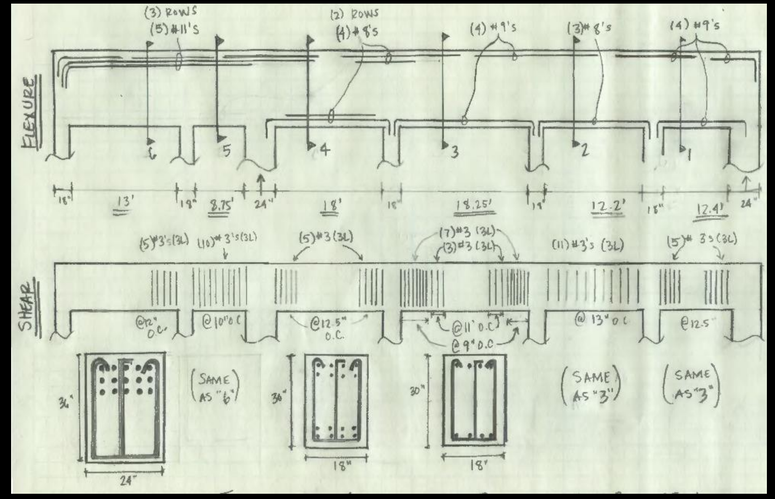


Frame GO: ETABS Analysis

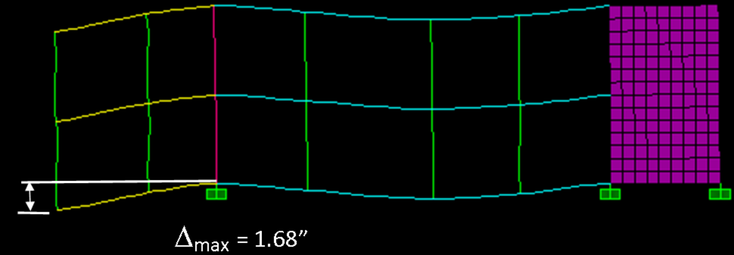
Truss Design



West Elevation: Cantilever Highlight

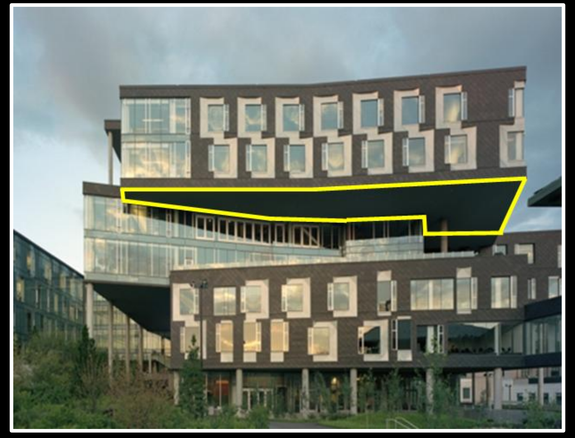


ETABS: 3D Truss

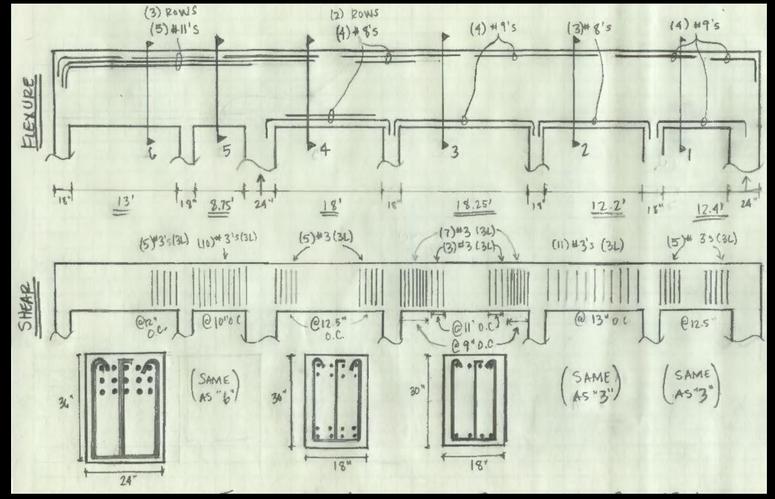


Frame GO: ETABS Analysis

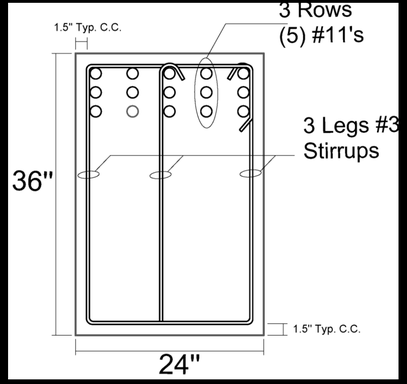
Truss Design



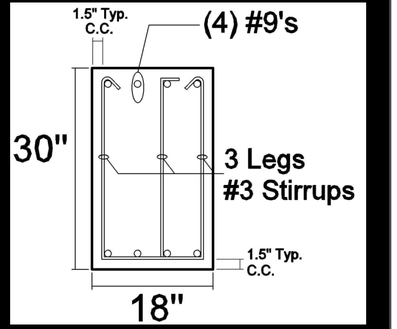
West Elevation: Cantilever Highlight



ETABS: 3D Truss

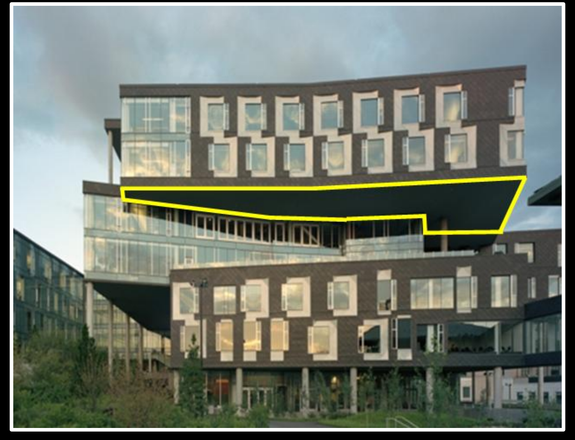


Cantilever Design Section

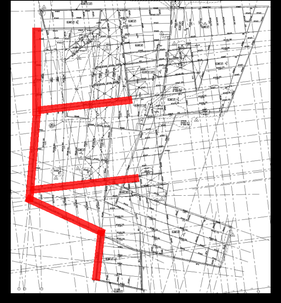


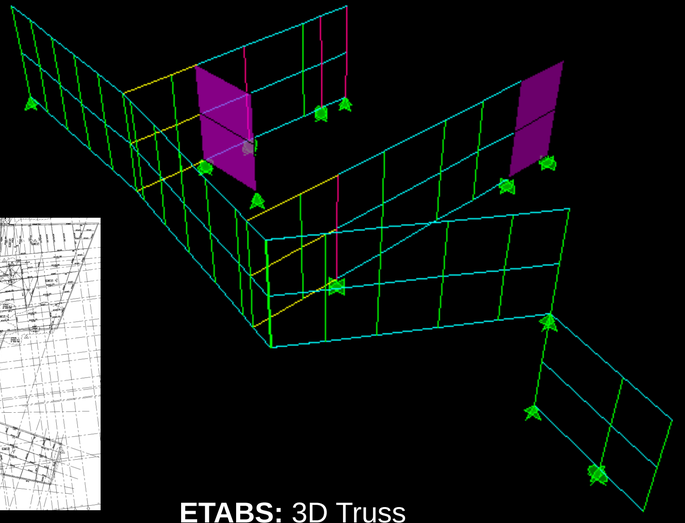
Mid-span Design Section

Truss Design



West Elevation: Cantilever Highlight

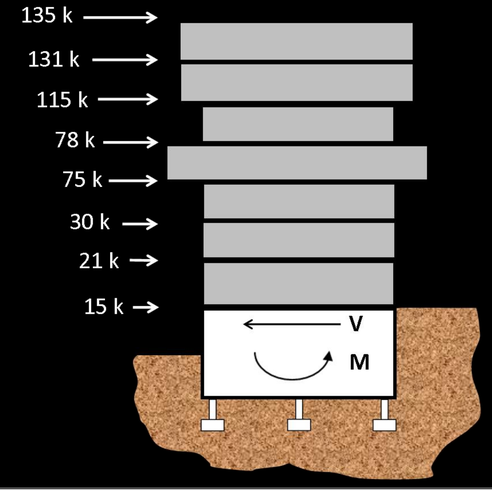




ETABS: 3D Truss

Lateral Analysis

- **Seismic Design Category "B"**
- **ASCE7-05** §12.8 Equivalent Lateral Force Procedure
- **Shear Wall-Moment Frame Interactive System**
- **ASCE7-05** §12.3.2.1 Horizontal Irregularity
  - Type 1b: Extreme Torsional Irregularity
- **ASCE7-05** §12.5: Directional Loading
  - Orthogonal Loading Only

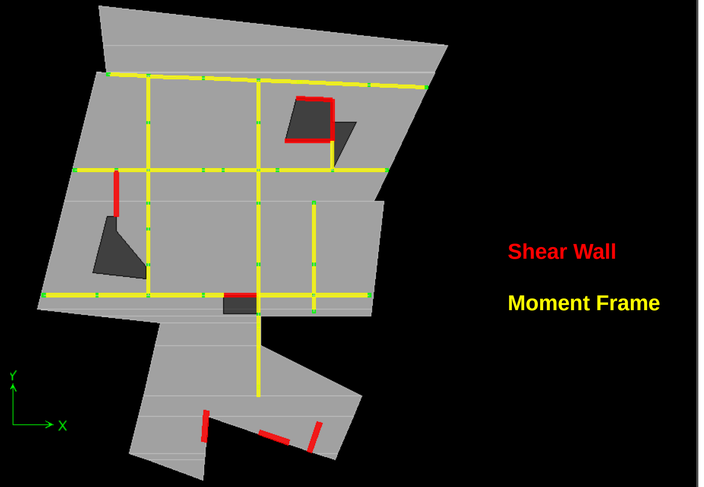


V = 588 k

M = 54,134 ft-k

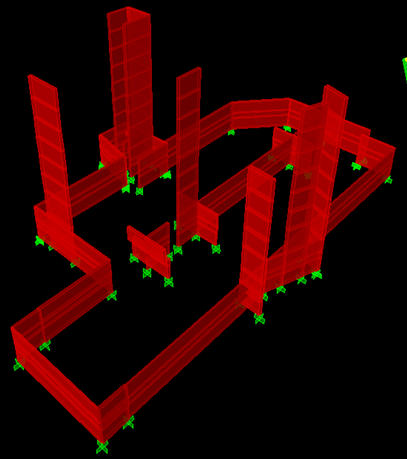
Lateral System

- **Shear Wall-Moment Frame Interactive System**
  - **Shear Walls**
    - 4 - North/South
    - 4 - East/West
  - **Moment Frames**
    - 4 - North/South
    - 3 - East/West

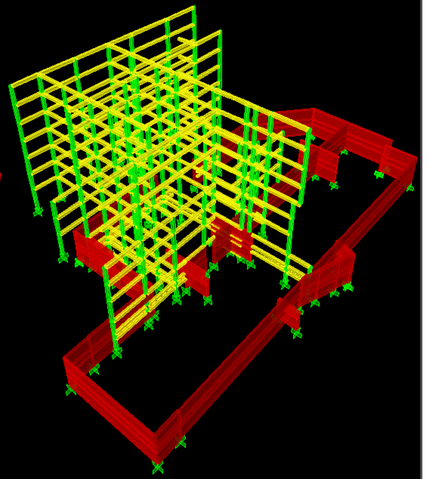


ETABS Analysis

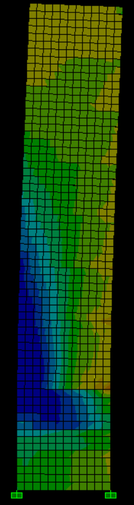
- **Shear Walls**
  - 8000 psi
  - Membrane
  - $I = 0.35I_g$
- **Moment Frames**
  - 6000 psi
  - $I_{col} = 0.7I_g$
  - $I_{bm} = 0.35I_g$
  - Rigid End Offset = 0.5
- **Rigid Diaphragm**



ETABS: 3D Shear Walls

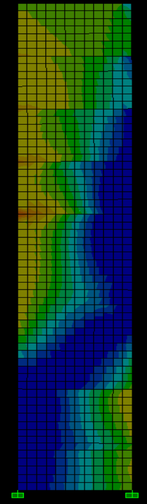


ETABS: 3D Moment Frames



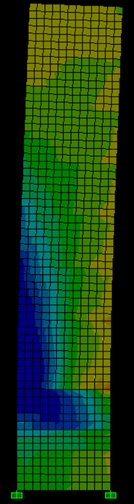
Shear Wall G7 (N/S)

- **Design Values**
  - V_{max} = 157.5 k
  - M_{max} = 9642 ft-k
  - P_{max} = 1704 k



Shear Wall GG (E/W)

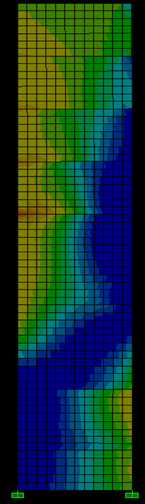
- **Design Values**
  - V_{max} = 196 k
  - M_{max} = 15,000 ft-k
  - P_{max} = 960 k



Shear Wall G7 (N/S)

Flexural Reinforcement				
As,min	5.8	in2		
As	**17.78**	**in2**	Try (14) #10's	
As,max	54.6	in2		
ε_s=	0.01848		>.00207	OK!
			>.005	ϕ= 0.9
ϕ**Mn**	**10,997**	**ft-k**	> 9641.7	OK!

(14) #10s @ Ea. End

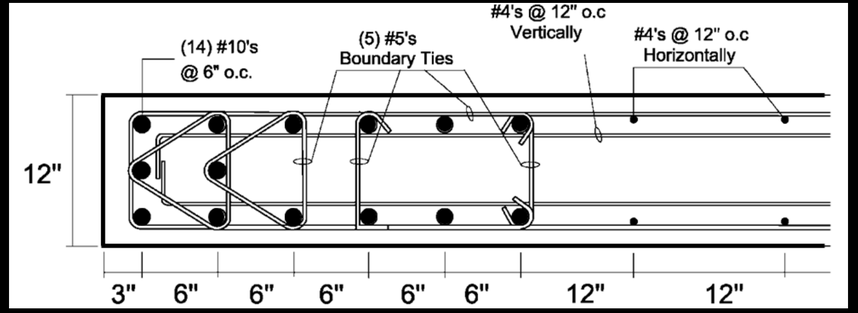


Shear Wall GG (E/W)

Flexural Reinforcement				
As,min	10.3	in2		
As	**17.78**	**in2**	Try (14) #10's	
As,max	72.7	in2		
ε_s=	0.0261		>.00207	OK!
			>.005	ϕ= 0.9
ϕ**Mn**	**15,158**	**ft-k**	> 15,000	OK!

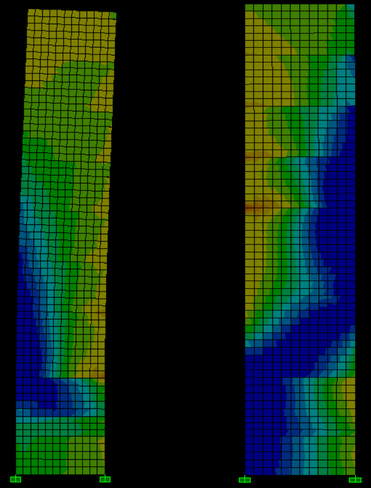
(14) #10s @ Ea. End

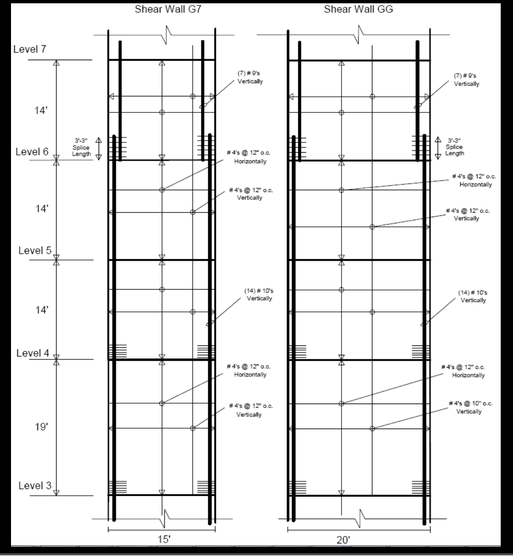
Shear Wall Design



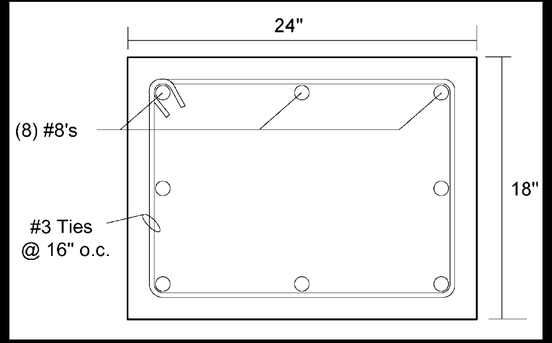
Shear Wall Design Section

Shear Wall Design

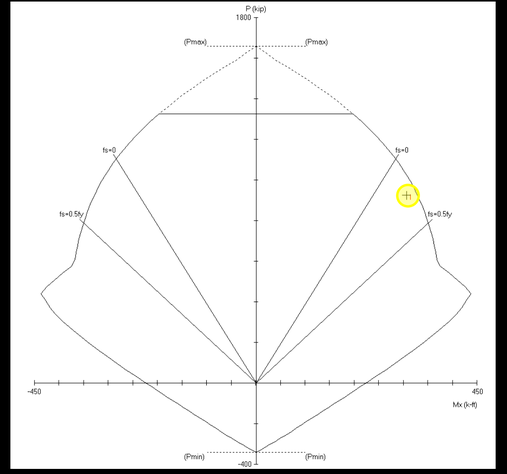




Moment Frame Column Design

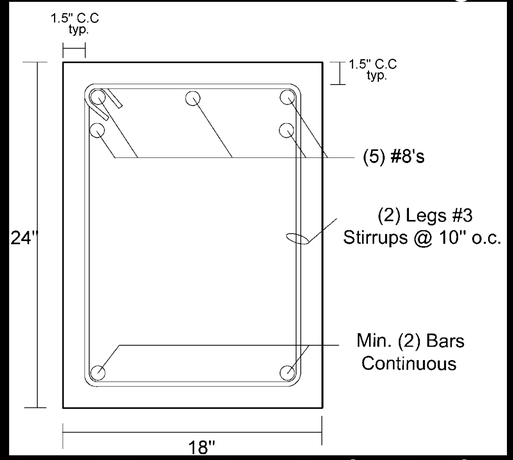


Moment Frame Column Design Section

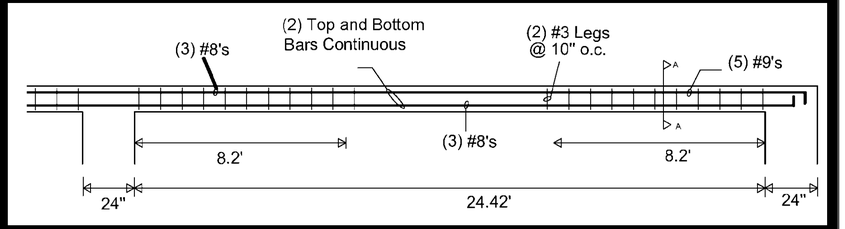


spColumn: Interaction Diagram

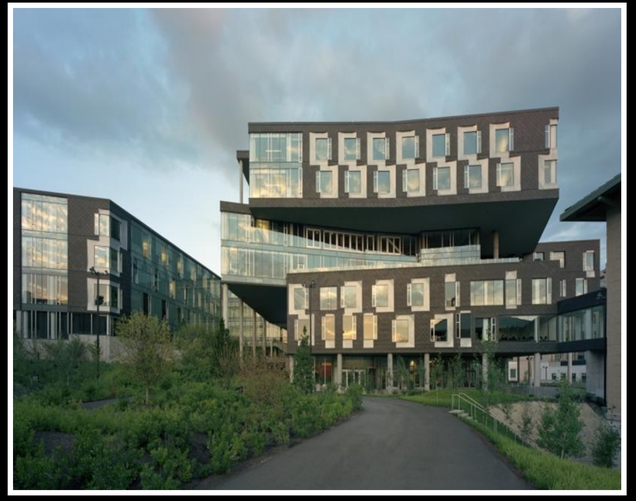
Moment Frame Beam Design



Moment Frame Beam Design Section

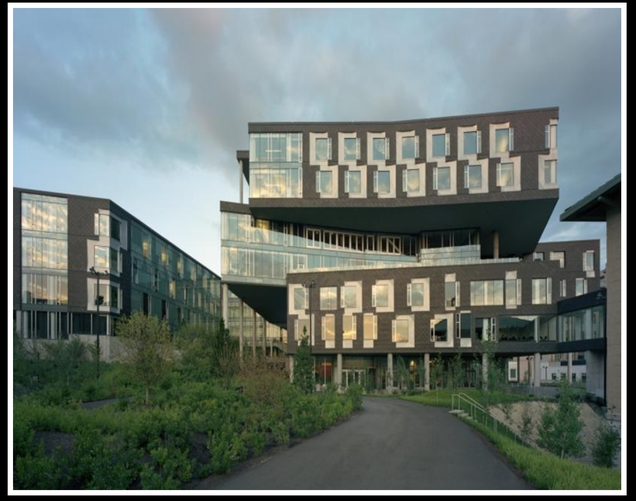


Design Beam Section: Exterior Span



Schedule Analysis

- **Existing**
  - **Start:** May 5th, 2008
  - **Finish**: November 11th, 2008
- **Proposed**
  - **Start**: May 5th, 2008
  - **Finish**: August 12th, 2008
- **Comparison**
  - 2 months more efficient



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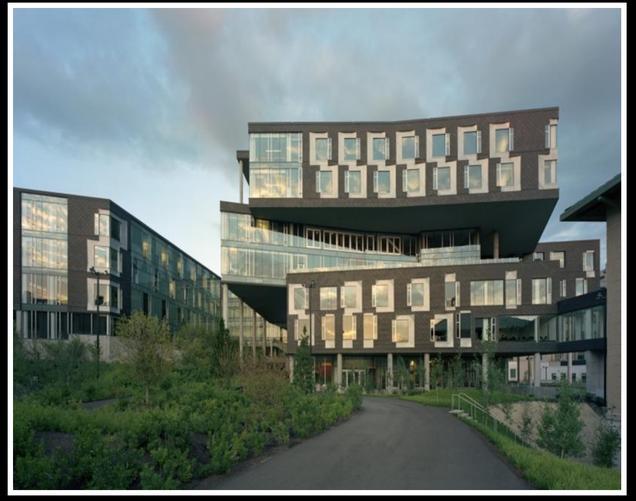
- **Comparison**
  - 2 months more efficient

Cost Analysis

- **Existing**
  - **$ 4,486,006**
- **Proposed**
  - **$ 5,281,312**
- **Comparison**
  - **($ 795,306)**



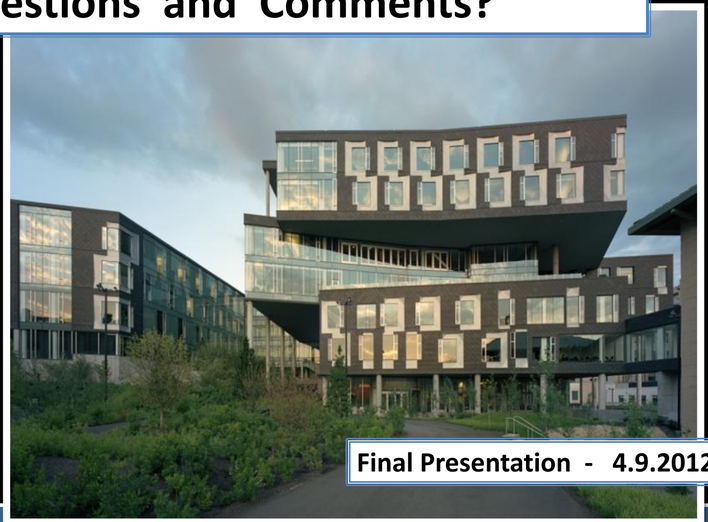
Conclusions

- **Design**
  - Strength and Serviceability Requirements
    - **Gravity System** **OK!**
    - **Lateral System** **OK!**
- **Construction**
  - Incurred cost Plausible
  - Shortened Schedule OK!

Acknowledgements

- **Dr. Boothby**
- **Professor Parfitt**
- **AE Faculty**
- **Matt Wetzel of PJ Dick**
- **Bill Hawk of Graziano Construction**
- **Family**
- **Friends for reinforcing core structural concepts**

Questions and Comments?



Final Presentation - 4.9.2012