

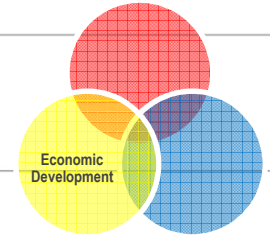


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New Design for Haiti

First Generation Solution

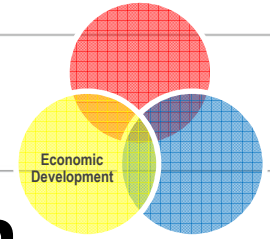
Danielle Locklar
Kelli Oura
Lauren Reinholdt



Motivation for the Project

- January 12, 2010, Haiti was hit by a 7.0M earthquake
- Death toll of over 230,000
- Millions displaced
- No simple, permanent solutions for the displaced people in sight





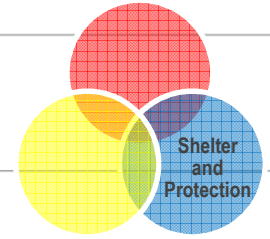
Problematic Current Situation



- **Political uncertainty**
 - Michel Martelly (new President)
 - Jean-Max Bellerive (old Prime Minister)
- **No schools or hospitals**
- **Haitians left homeless and living in tents**
 - Children and elderly left vulnerable
 - Crime on the rise
 - Cholera Breakout
 - A need for rebuilding of communities
- **Attention already moved to Japan**
- **Address homelessness**



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Who Deserves a Home? *"Everyone has a right to a home"*

- **What is the value of a house?**
 - Shelter
 - Protection
 - A place to call home
 - Building block of a community

"Engineers shall hold paramount the safety, health and welfare of the public and shall strive to comply with the principles of sustainable development in the performance of their professional duties."

– ASCE Code of Ethics

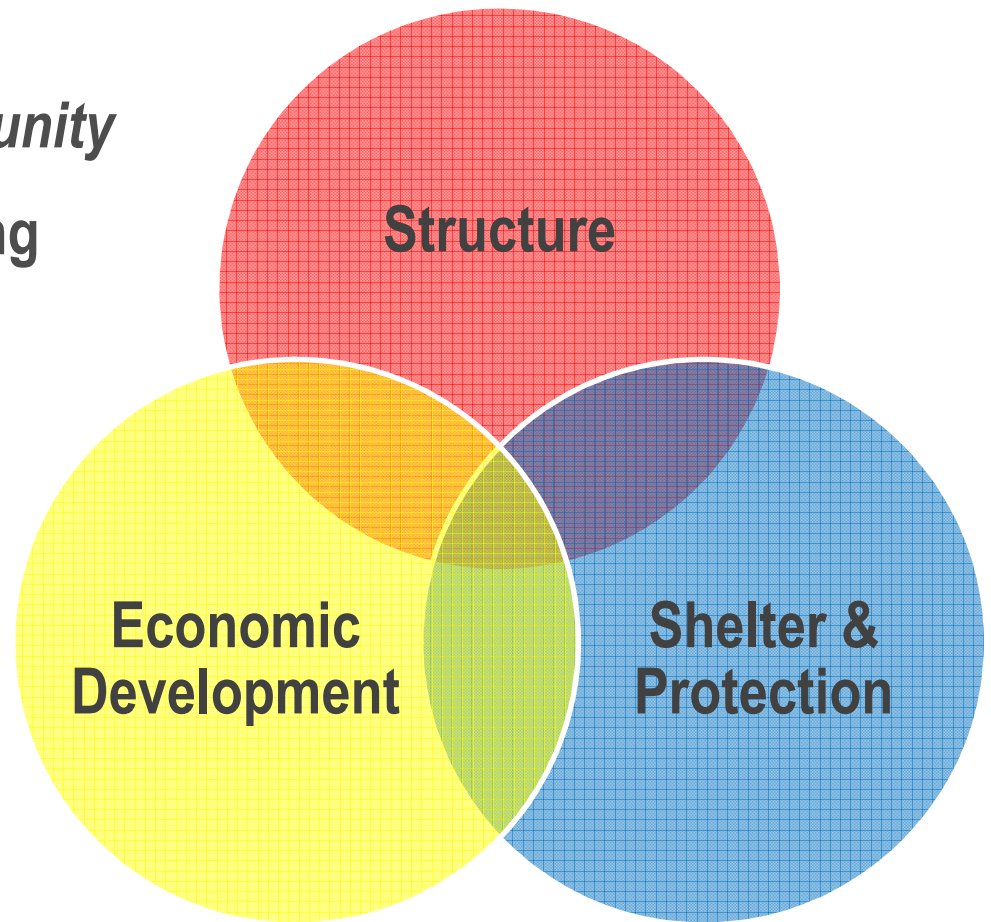


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More than a House...Today's Presentation

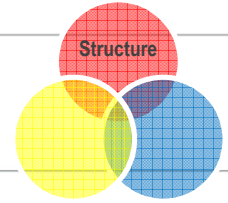
The New Design for Haiti *A Home Within a Community*

- Modular & Permanent Housing System
- Potential for Jobs & Economic Stimulation Inside and Outside of Haiti
- Elevate Haiti as People
- Structurally Insulated Panels





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Non-Technical Design Considerations

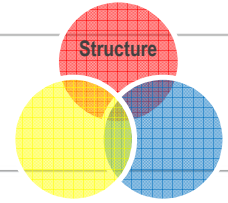
Lack of Raw Building Materials

Lack of Building Codes or Building Inspections Enforcement

Unskilled Labor

Poor Construction Quality



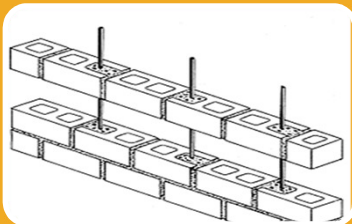


Alternative Solutions for Homes



Habitat for Humanity

- Non-profit organization
- Timber framing
- Transitional and upgradable shelters



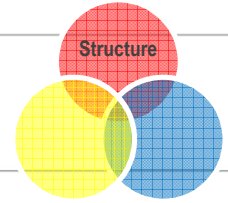
Build Change

- Non-profit organization
- Reinforced masonry
- Local materials, tools, skills, cultural preferences



Wellbilt International

- Private company
- Steel framing
- Sure-Board wall panels
- Pre-panelized system



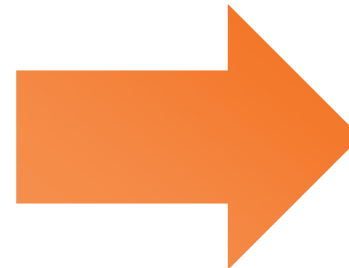
Modular Housing

Repetition

Easy/Speedy
Construction

Employment

Creation of New
Industry



**First Generation
Foam Insulated
Steel Panel**



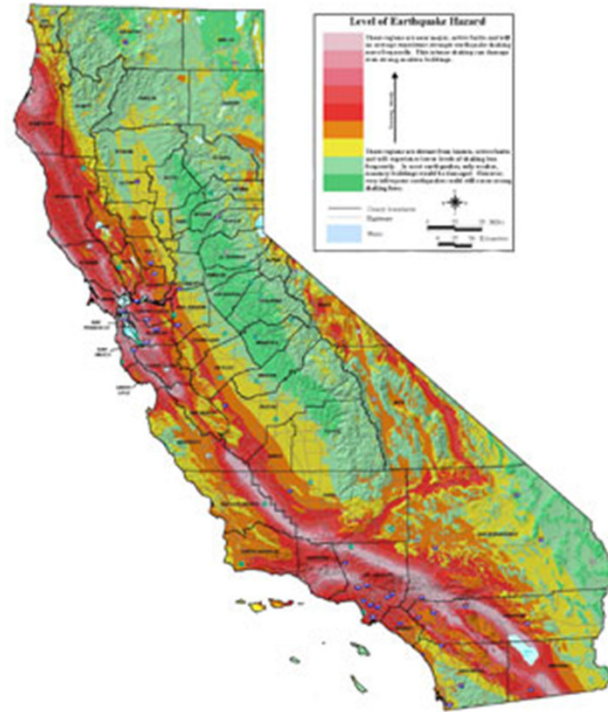
Development of “L'Union Fait La Force”

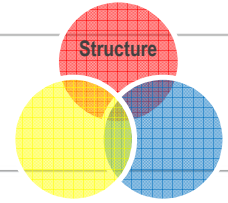
- **Design Criteria**
- **Layout of House**
- **Wall Panel Design**
- **Foundation Design**
- **Construction Process**
 - Track
 - Walls
 - Roof
- **Connections**
 - Roof
 - Anchorage to foundation
 - Walls
- **Construction Manual**
 - Color-coding
 - Step by step instruction manual
- **Fabrication of bedroom**
- **Testing of wall panel**
 - Shear Capacity
- **Future Progress**



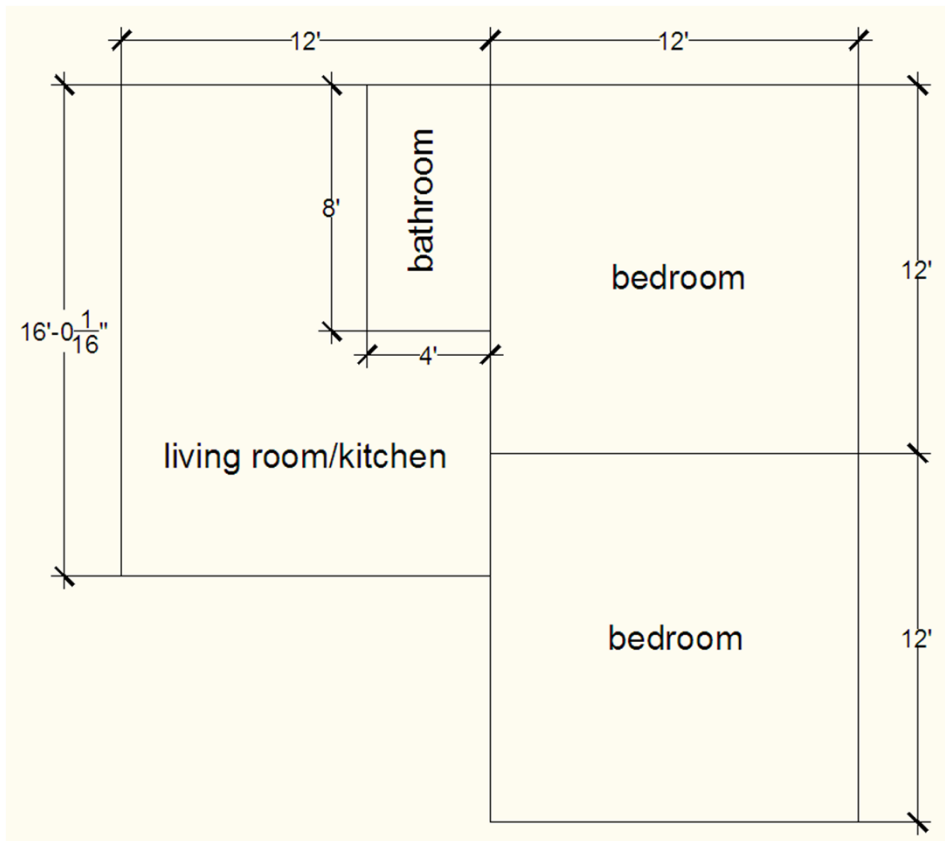
Design Criteria

- **Haiti**
 - No enforcement of building codes/inspections
- **Seismic**
 - San Francisco, CA
 - ASCE/SEI 7-10
 - Design Category: D
 - Site Class: D
 - Occupancy Category: I
- **Wind**
 - Monroe County, FL
 - 150 mph per ASCE/SEI 7- 10, IBC 09
 - Category II
 - Exposure C

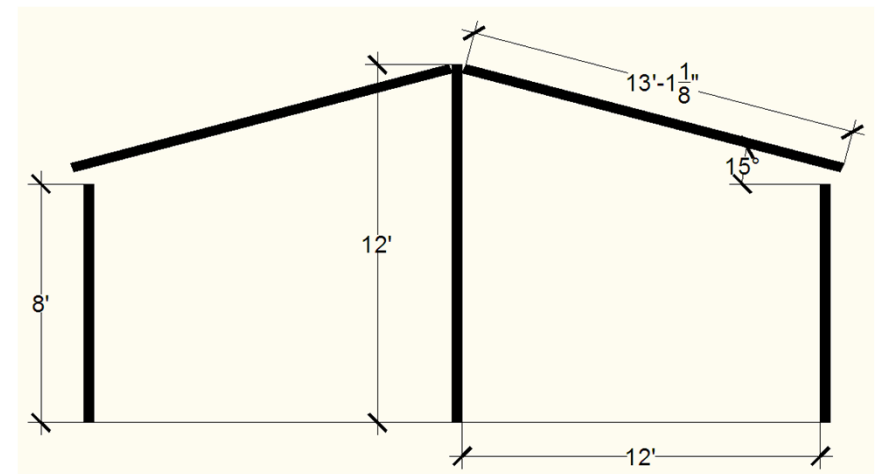


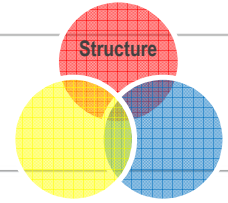


Layout of “L’Union Fait La Force”



- ~ 500 sq ft home
- Living room/kitchen, 2 bedrooms, and bathroom
- 15 degree angled roof
- 12 feet tall at highest point





Foam Insulated Steel Panels

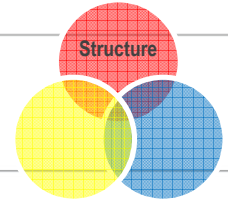
Steel

- High strength
- Green material
- Non-combustible
- Insect resistant
- Will not rot or mold

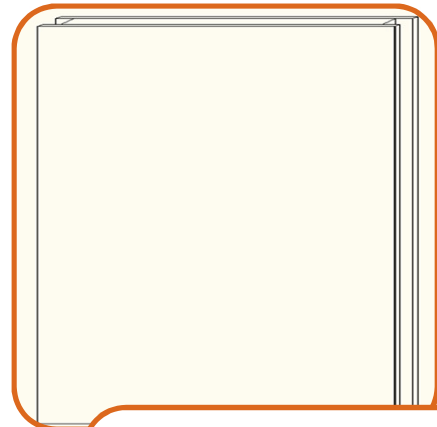
Structural Foam

- Light weight
- Reduction in steel
- Adds stiffness
- Allows for thick walls





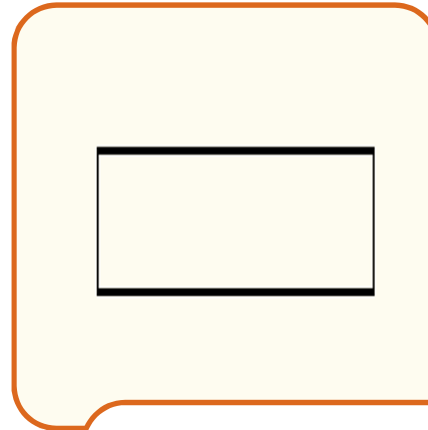
Typical Wall Panel Detail



Wall Panel

- 4' x 8' x 3.8"
- Structural foam
- Sheet steel (22 mil)
- Bonded together with adhesive

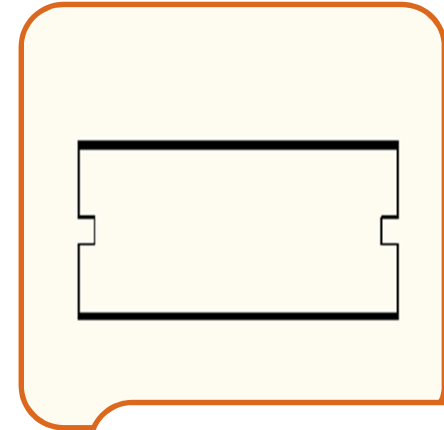
• Need to fit inside 4" wide panel connection



Flat End

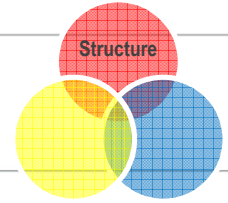
- Consider interlocking ends

• Flat ends - easier connections

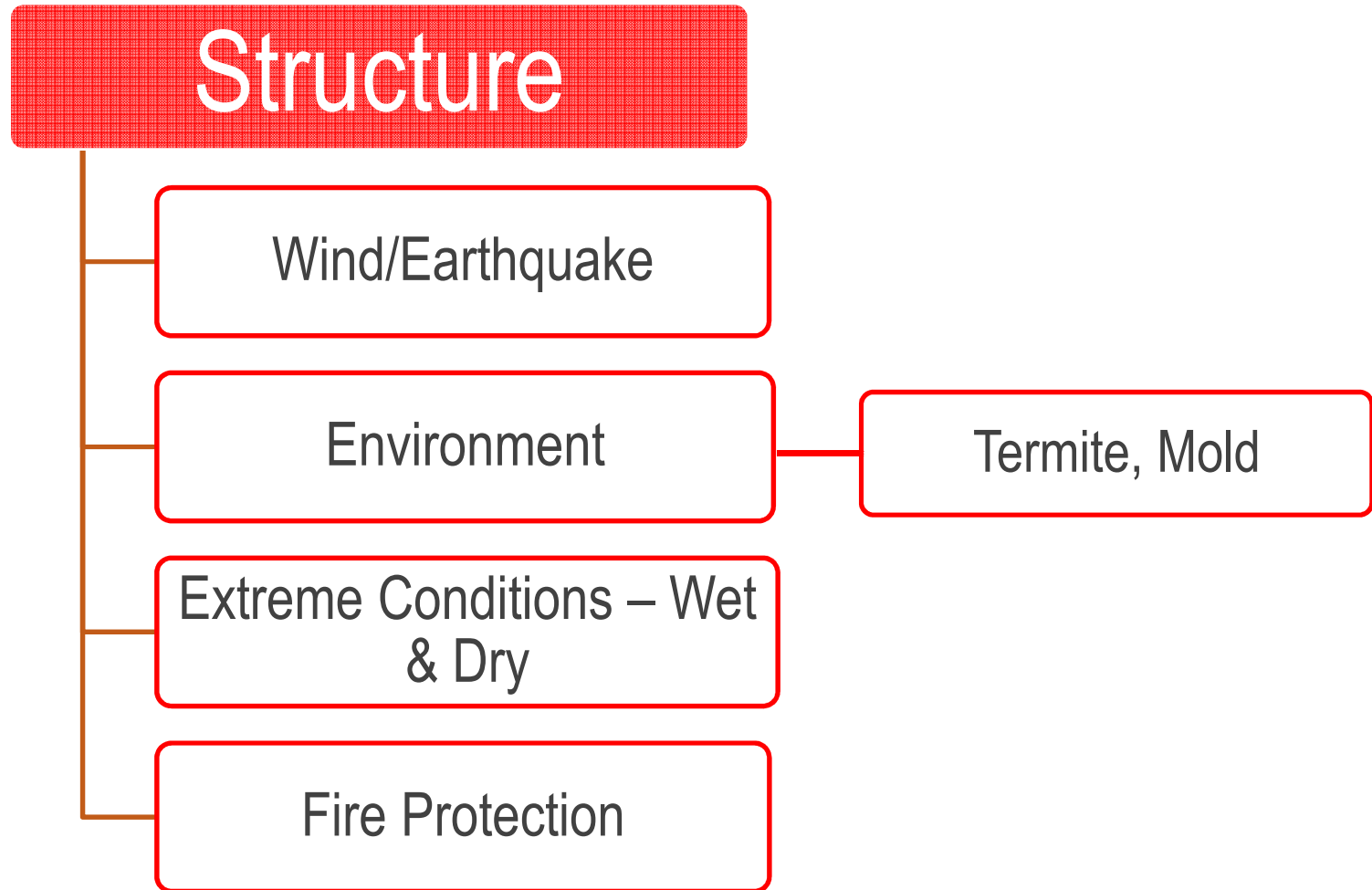


Cut Out

- 1" center cut out at both ends
- Same connections pieces
- Easier for handling in construction

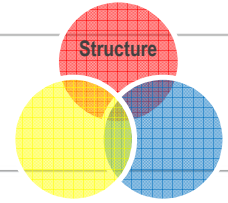


Structural Design Considerations

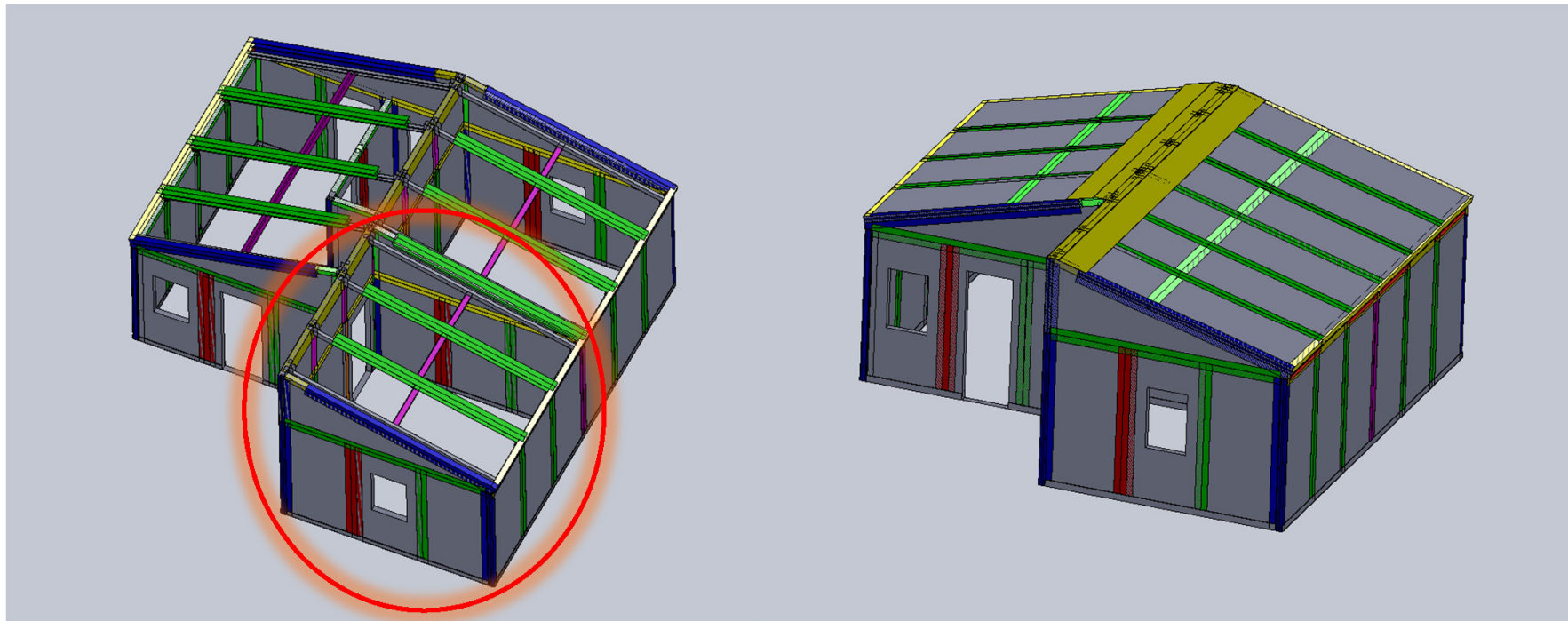


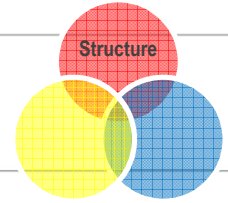


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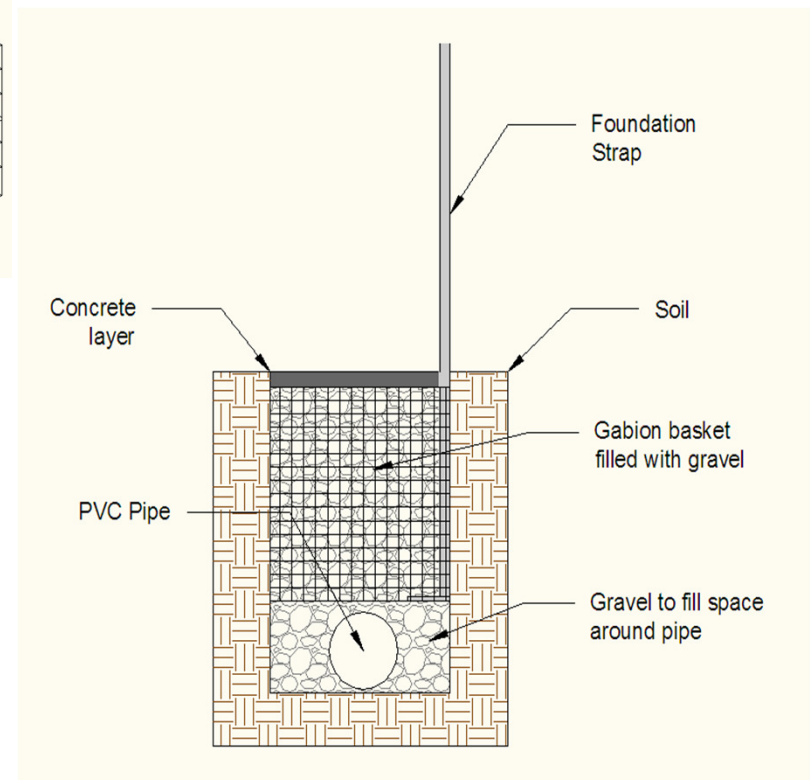
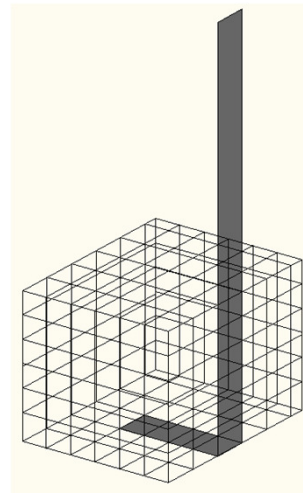
New Design for Haiti “L’Union Fait La Force”

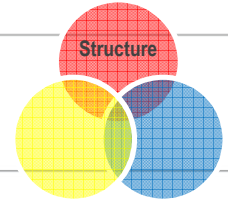




Foundation Design

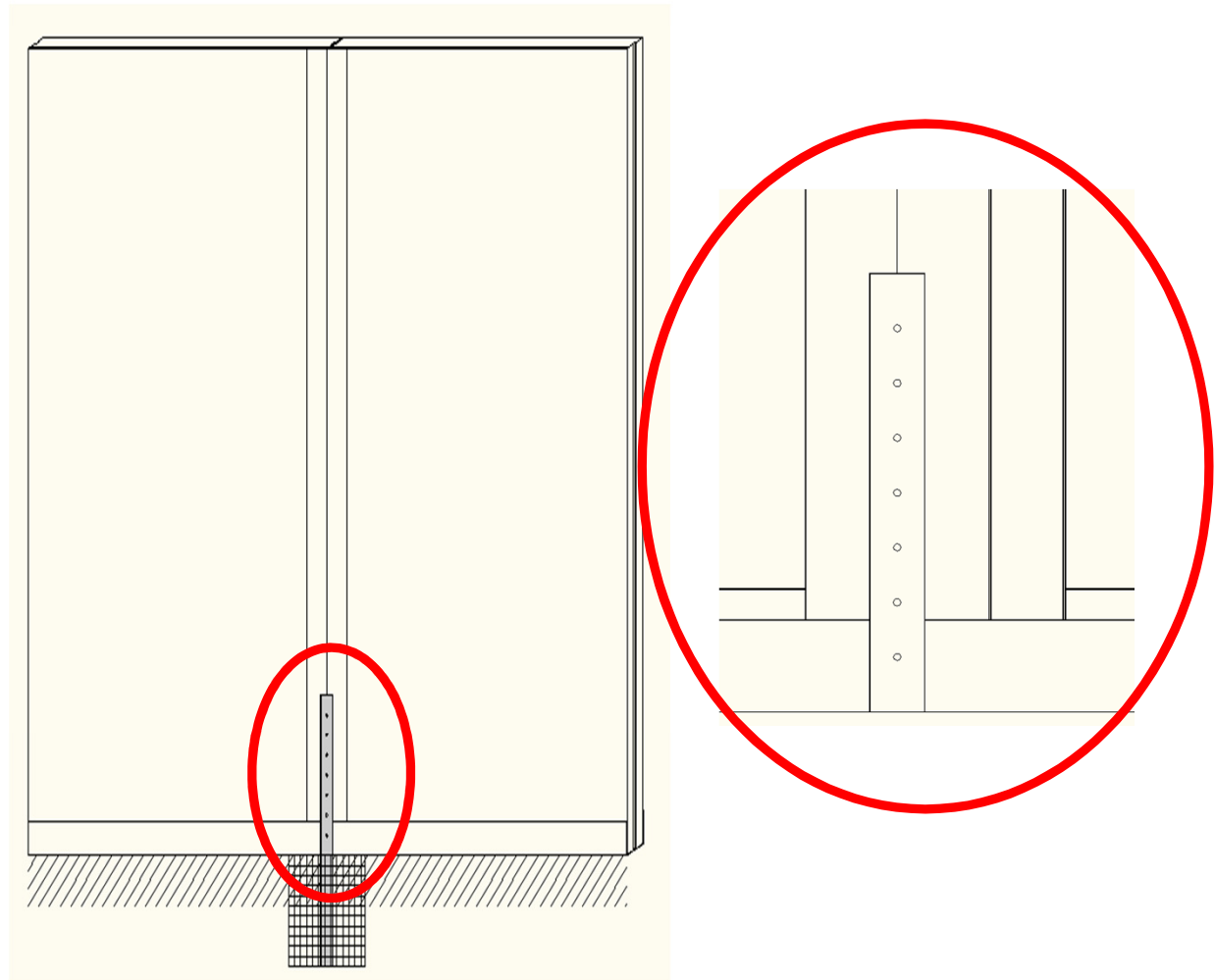
- Proposed solution – rubble trench foundation
- Less concrete needed
- Recycles the concrete rubble from destroyed structures
- Allows better drainage of water
- Inexpensive

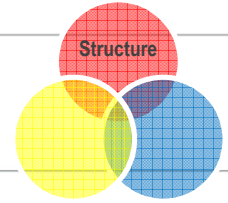




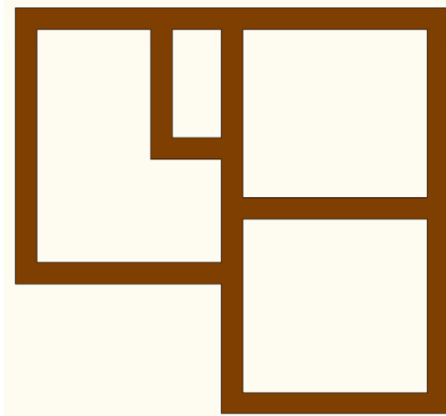
Anchorage to Foundation

- **Bend straps for correct placement**
- Allows for error
- **Straps connect to panel connectors**
- **Screw strap to connector**





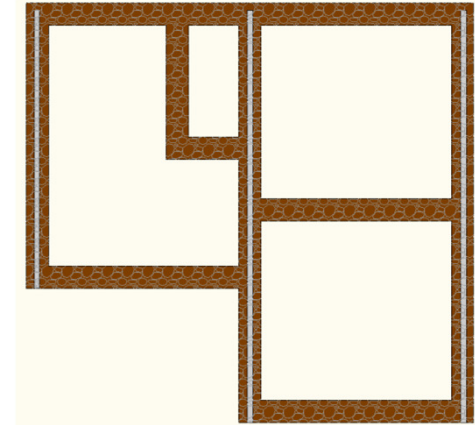
Rubble Trench Foundation



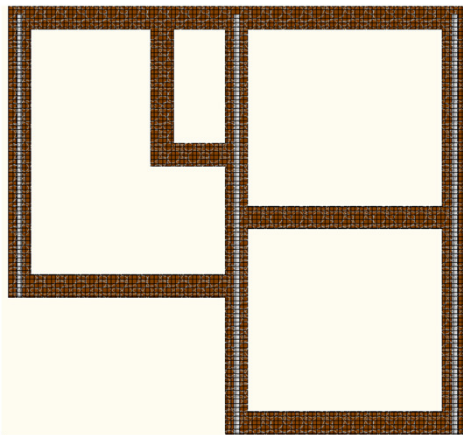
1. dig trench



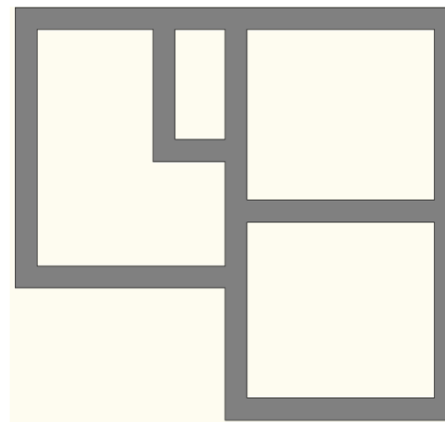
2. place pipes in trench



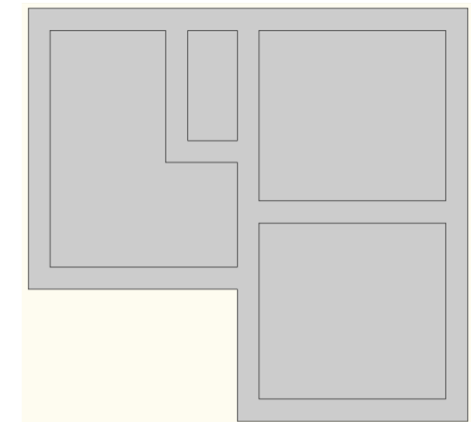
3. cover pipes with gravel



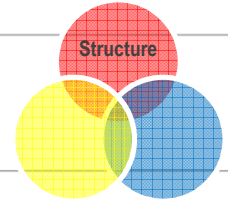
4. place in gabion baskets



5. fill trench with concrete

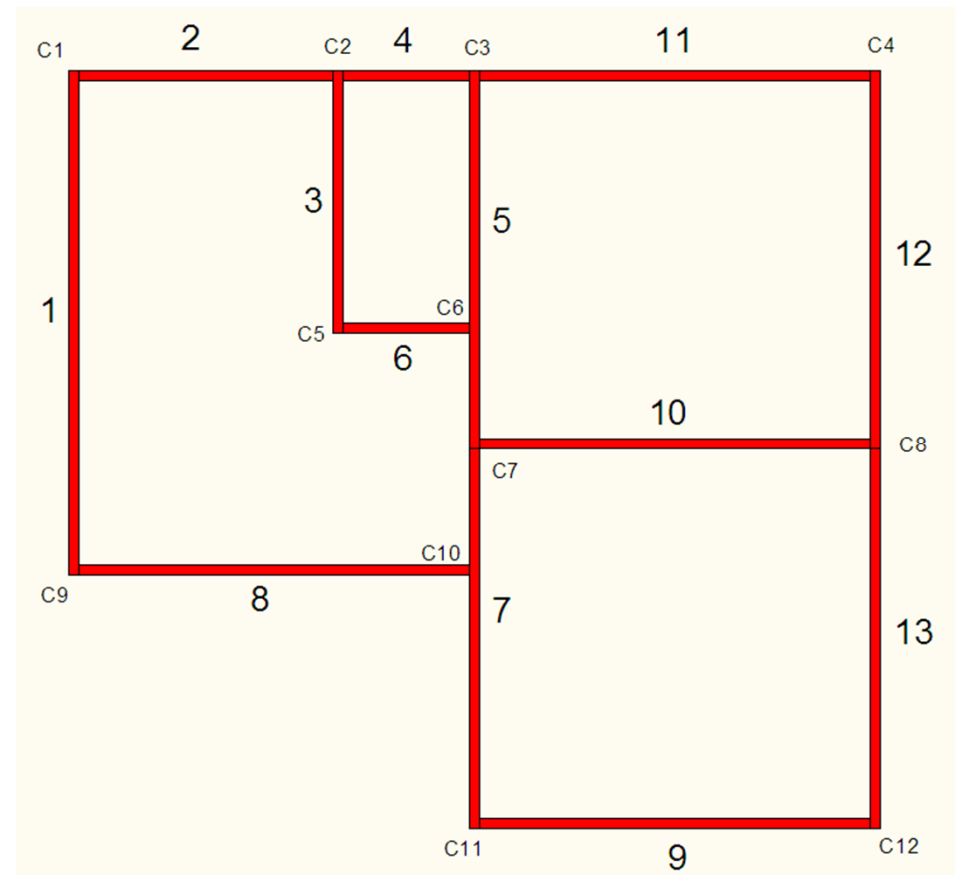


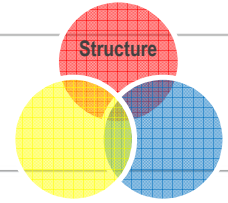
6. lay even layer of concrete



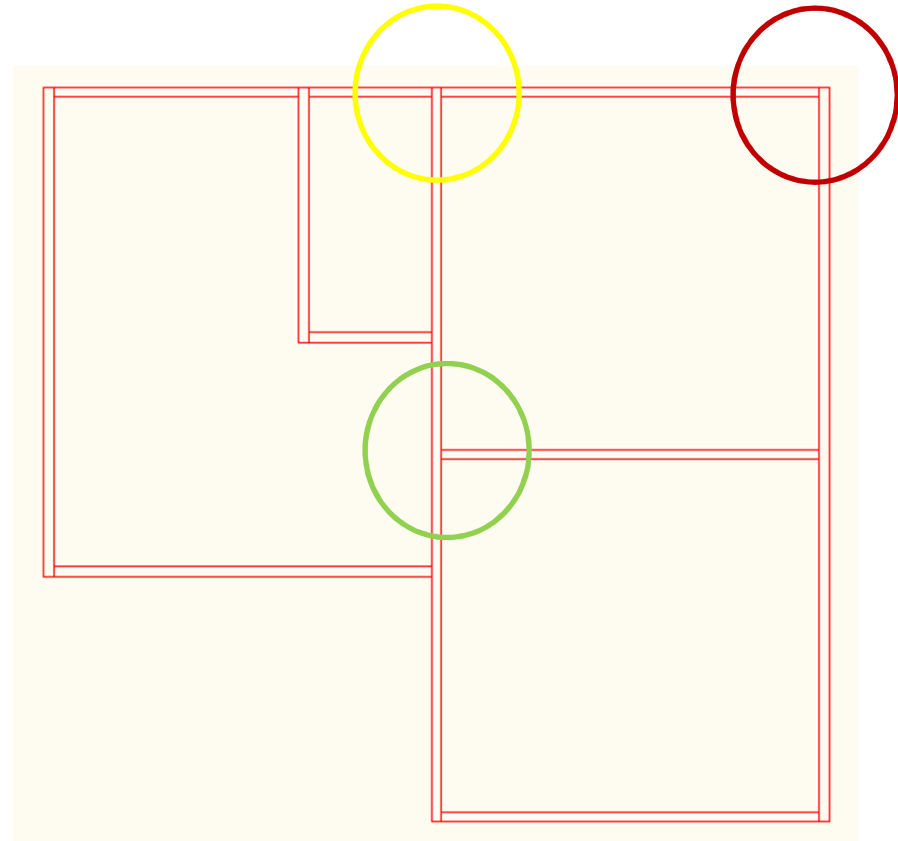
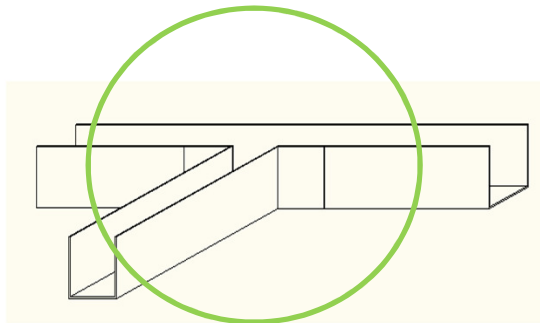
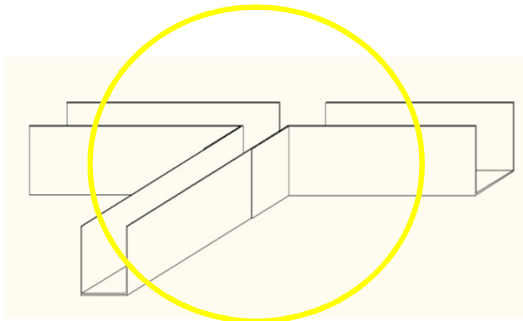
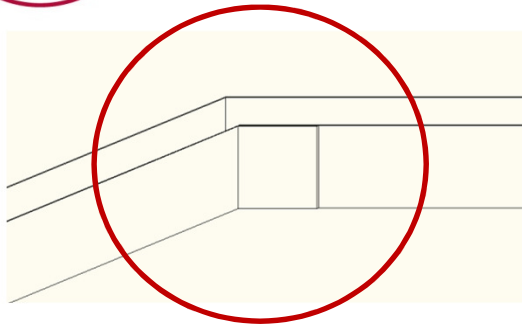
Bottom Track

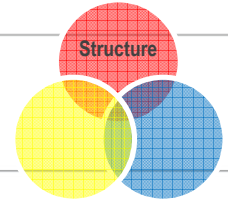
- Lay track in numerical order
- Straighten and line up correctly
- Screw into foundation





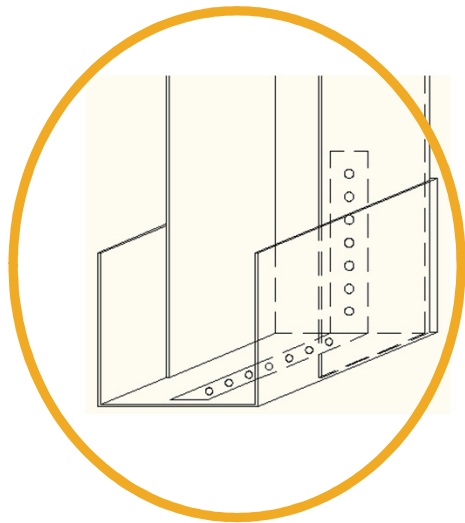
Bottom Track Connections





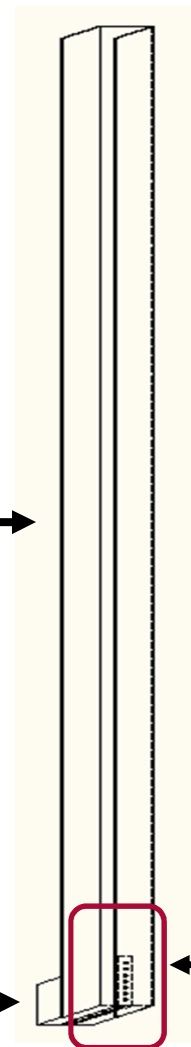
Panel Connector to Track

- Screw strap to bottom track

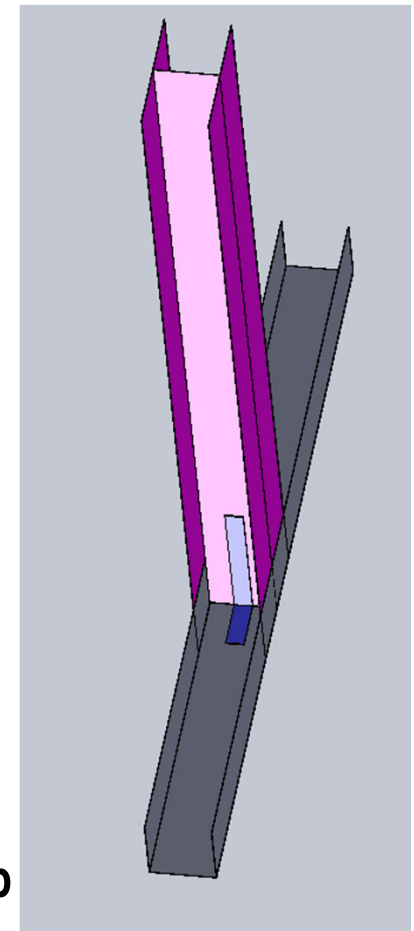


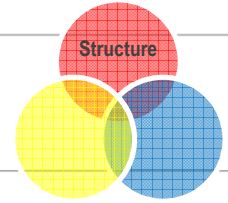
Panel Connector →

Bottom Track →



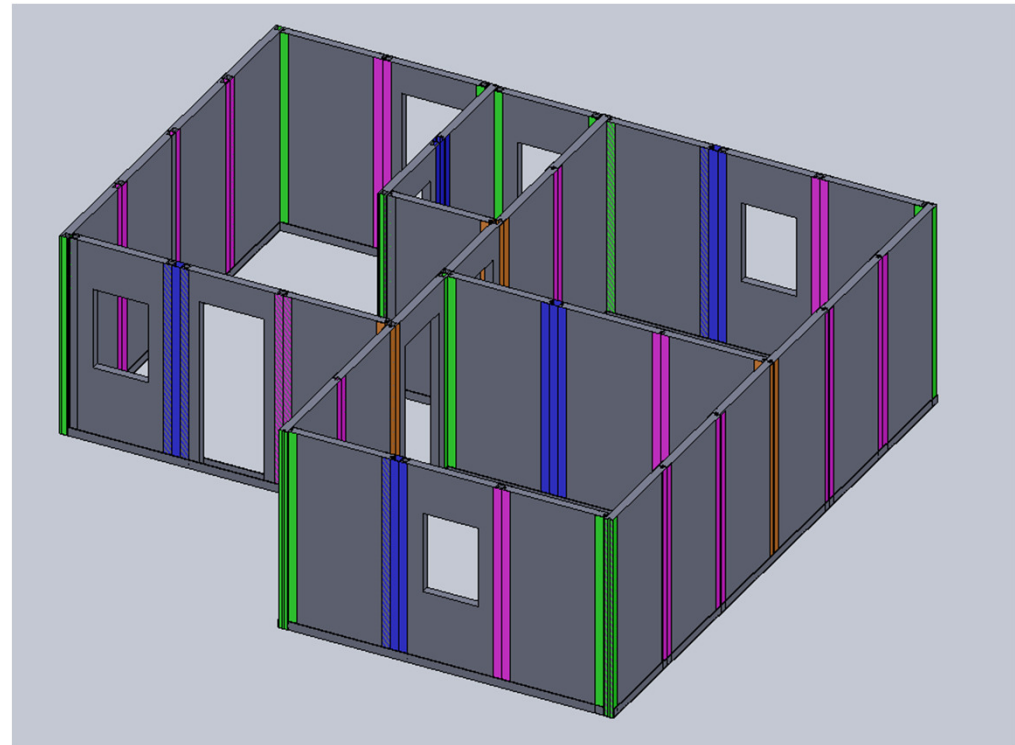
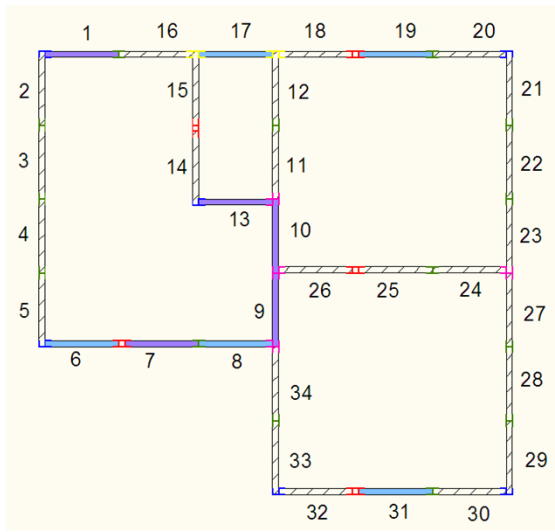
← Strap

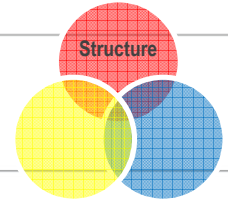




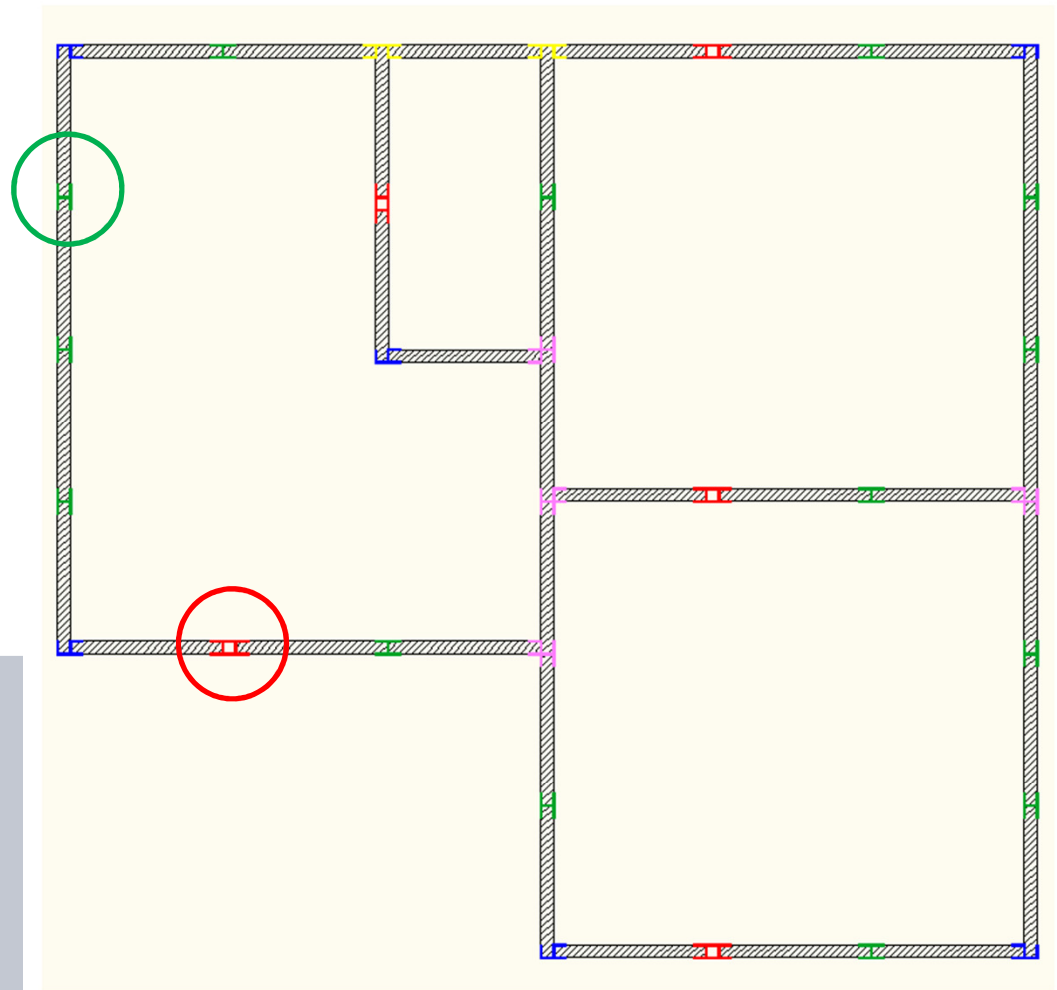
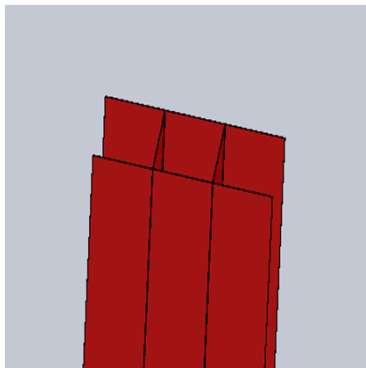
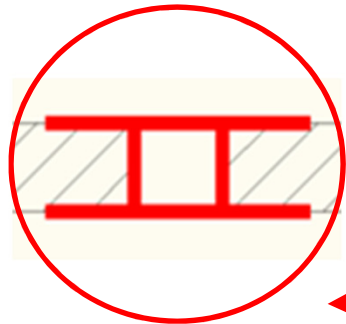
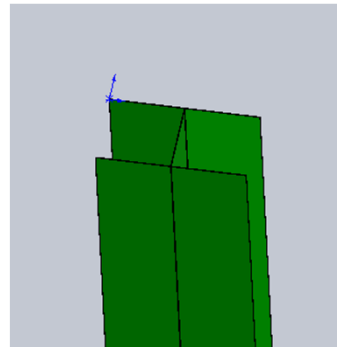
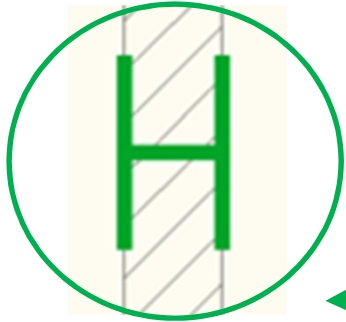
Walls

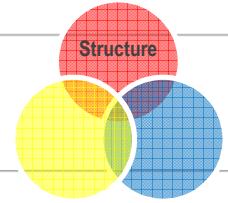
- Place wall panels in numerical order
- Color coded panel connectors
- Screw connector to panel



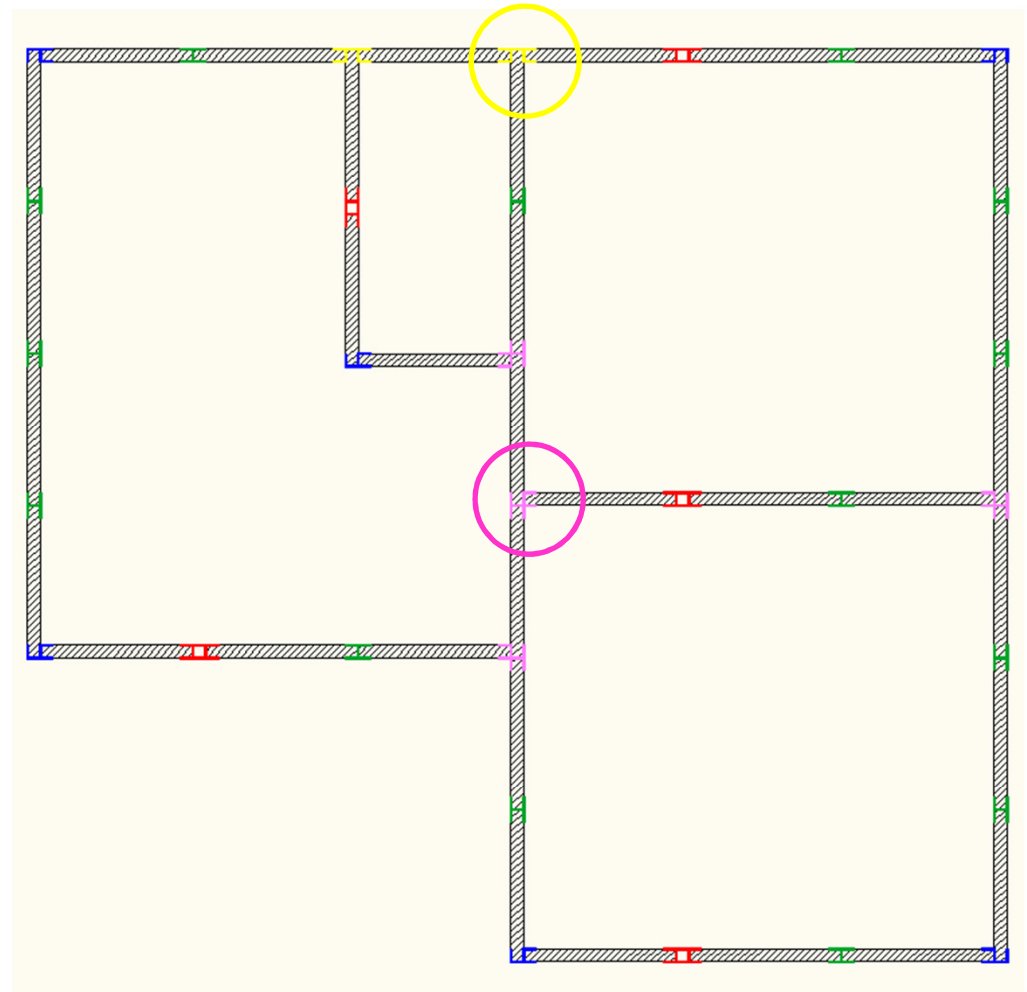
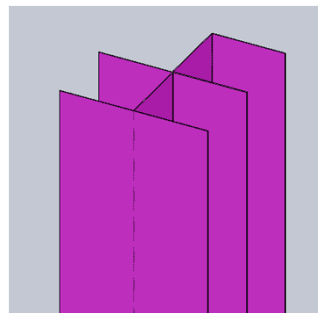
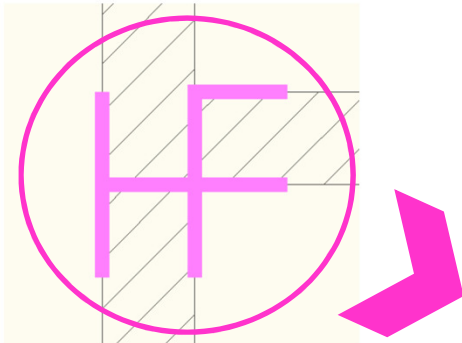
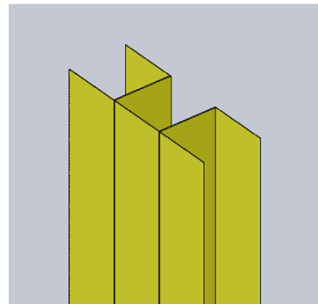
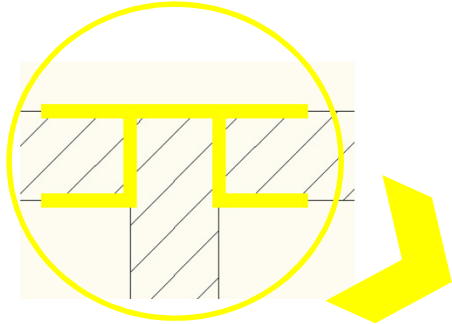


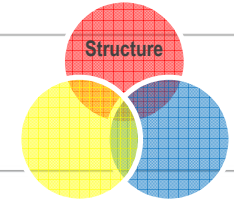
Wall Panel Connections



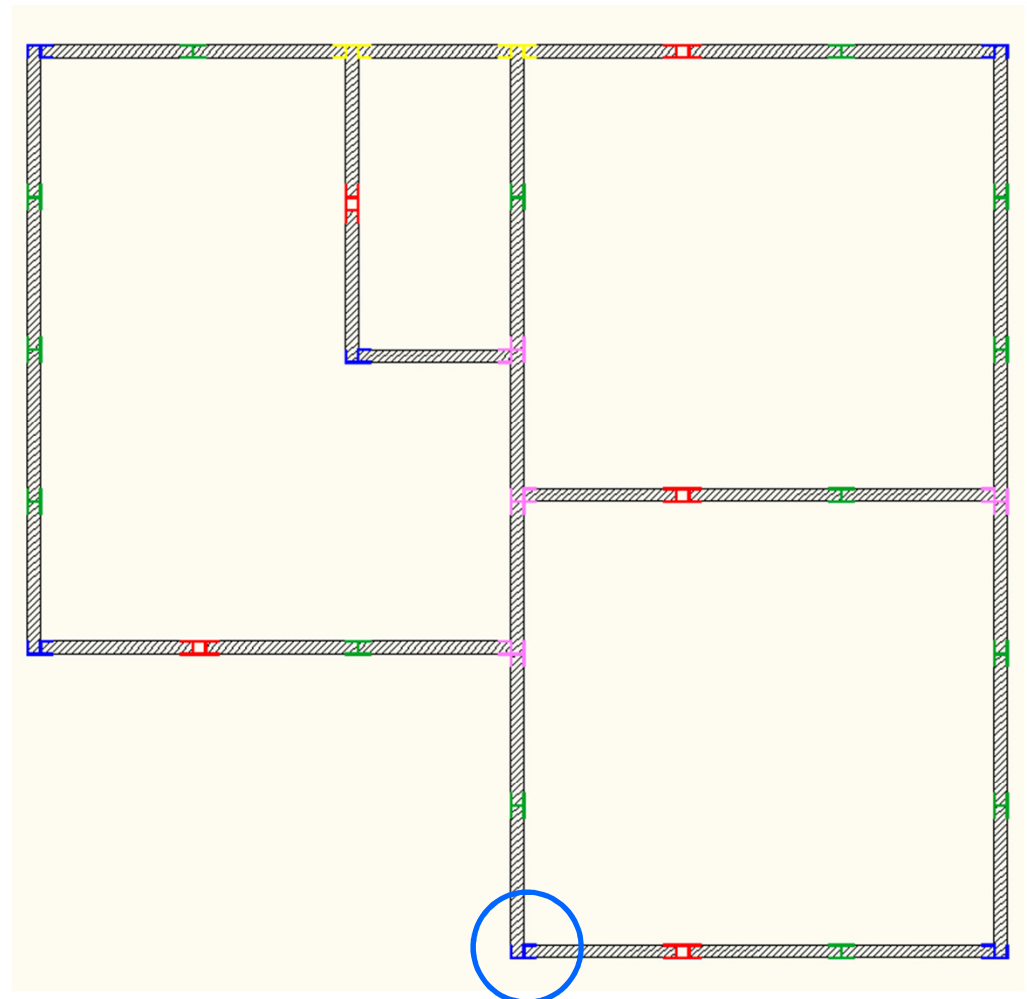
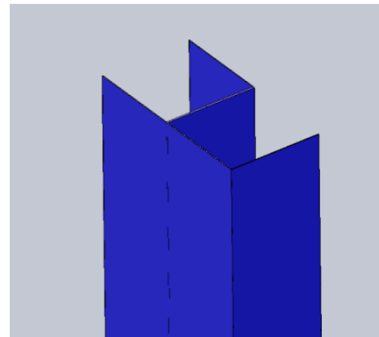
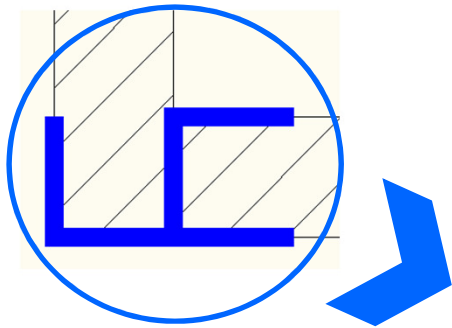


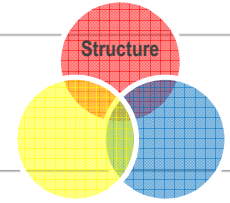
Wall Panel Connections





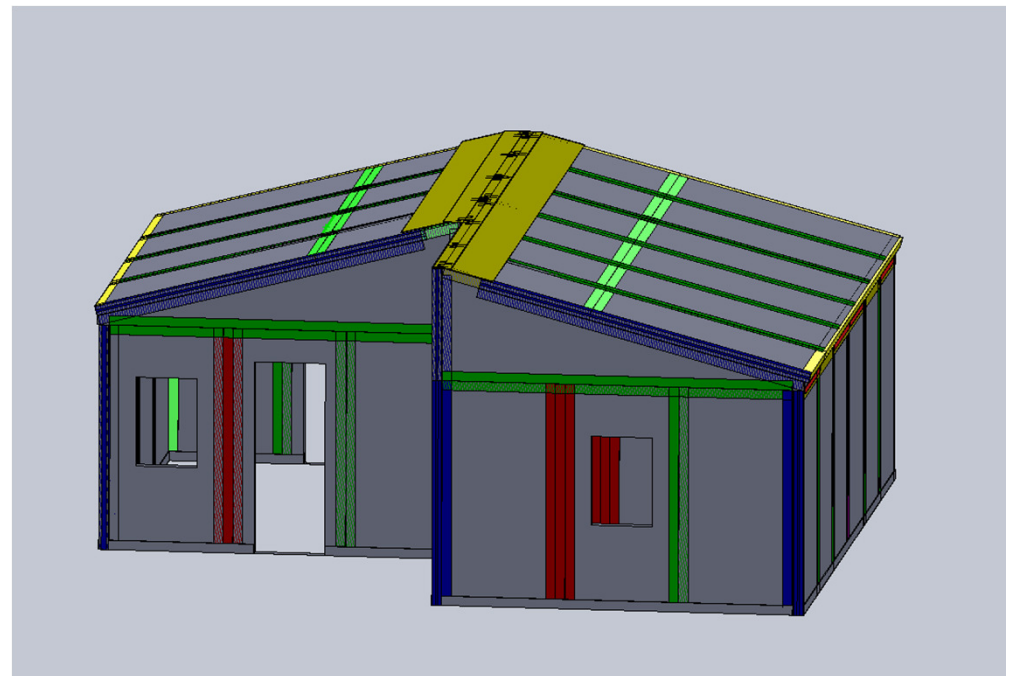
Wall Panel Connections





Roof Design Criteria

- Stay within panel dimensions used for walls
- Continue use of H-section connections
- Use connections already designed in the industry; however, change the dimensions to fit our house
- Provide natural ventilation

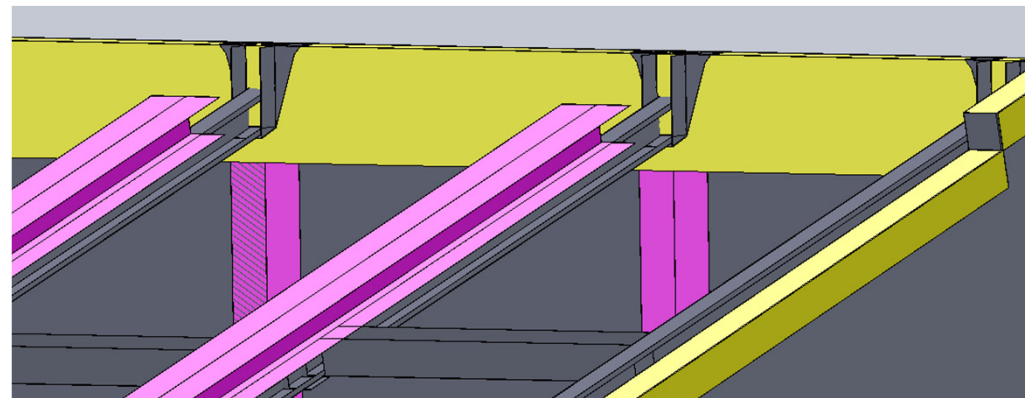
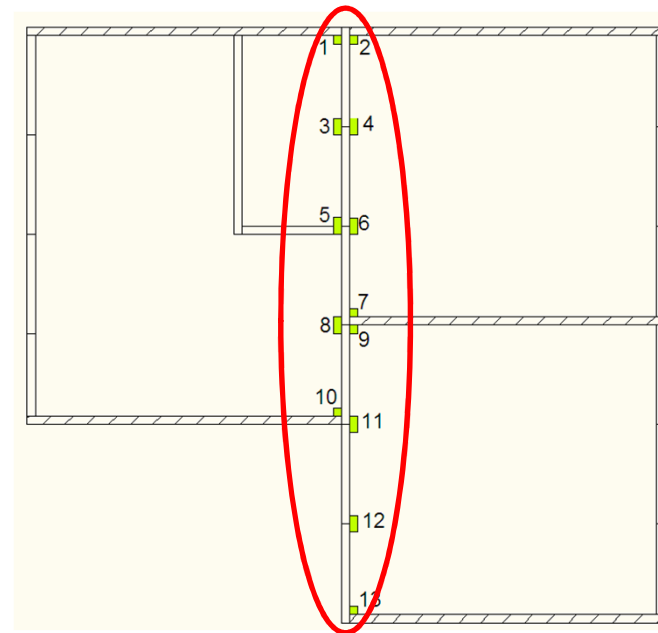
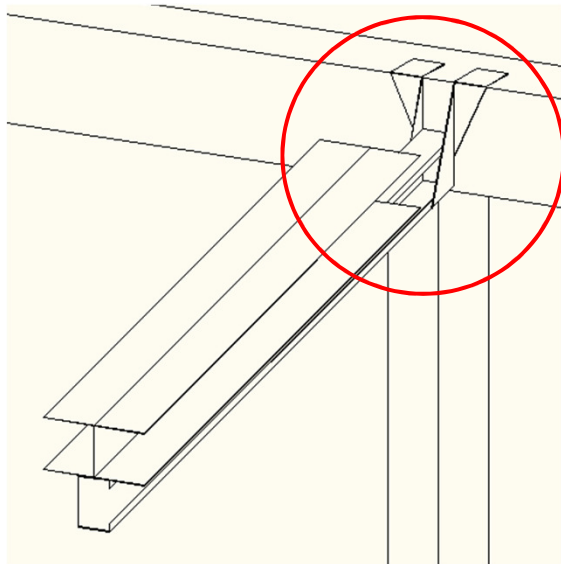


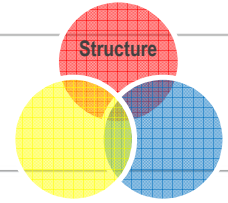


Roof Rafter Connections

- **Rafter to Ridge**

- Rafter sits in hanger screwed to center wall in line with H-Sections

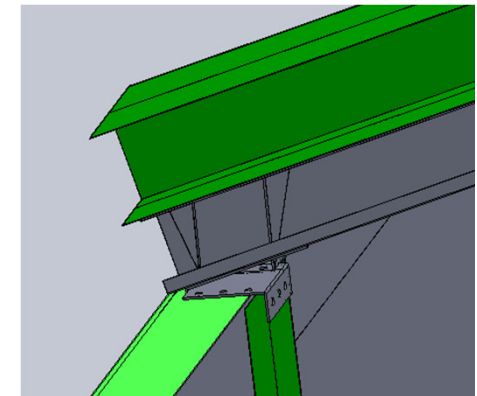
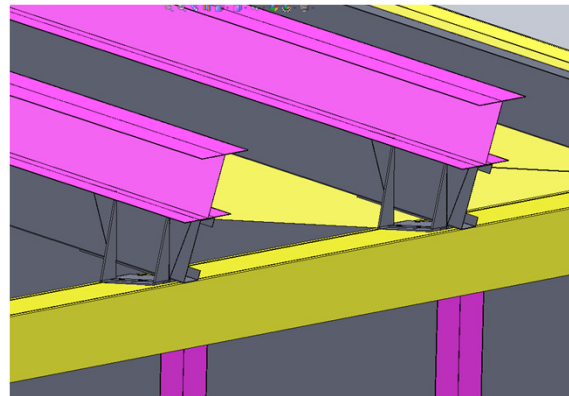
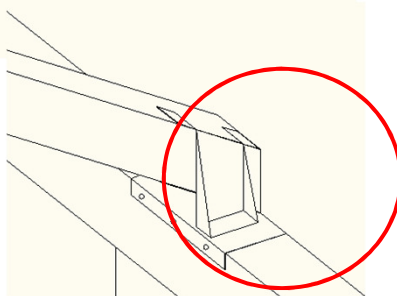
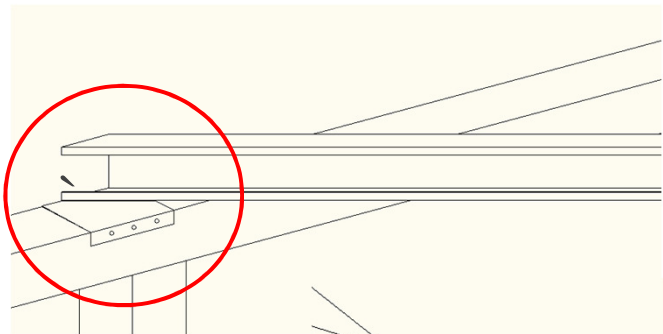
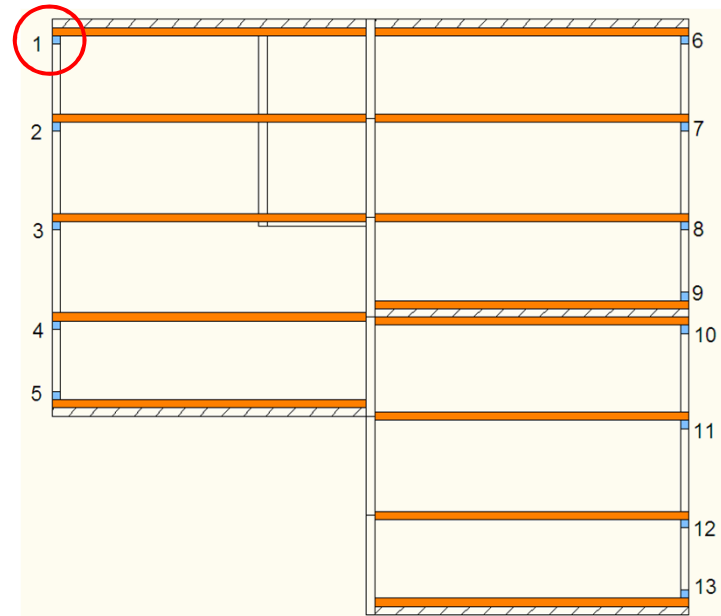


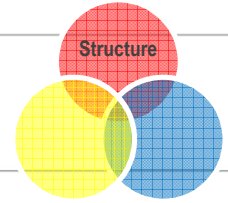


Roof Rafter Connections

● Rafter to Outside Wall

- Rafters sit on top of H-sections on outside walls
- Connected to outside wall through connection under rafter and hanger attached to side of rafter

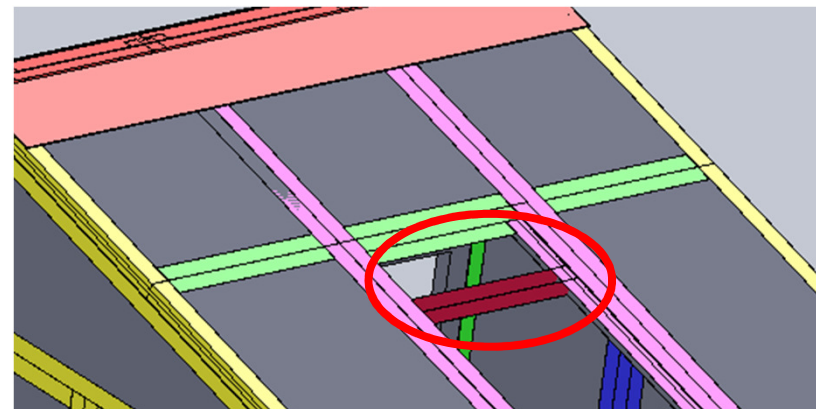
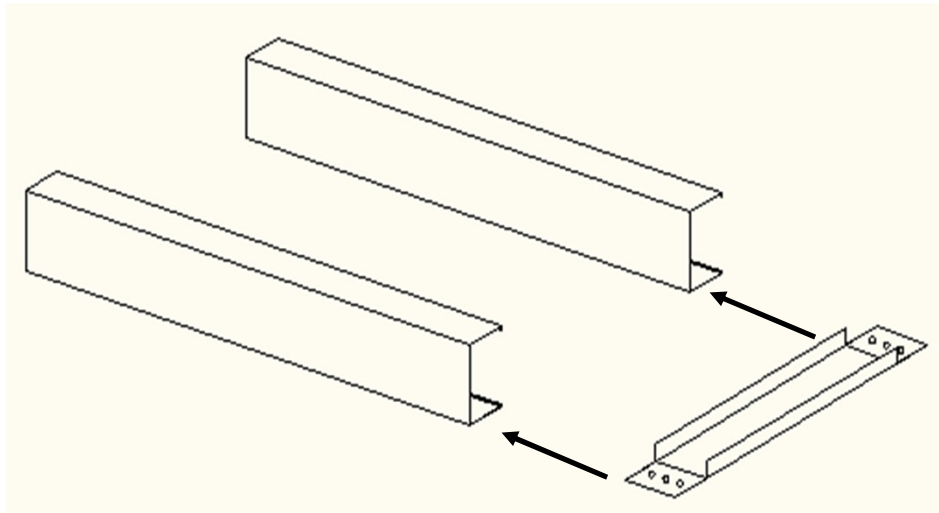
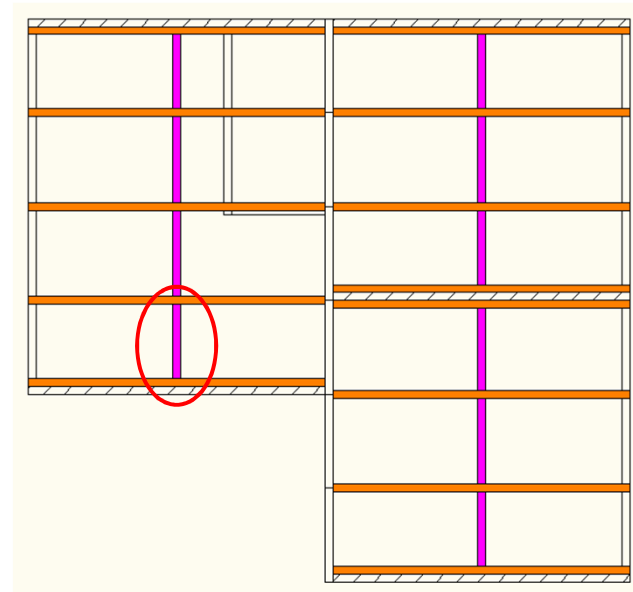


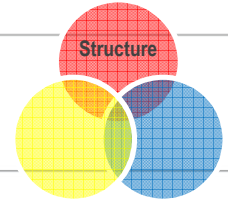


Roof Mechanical Bracing

- **Mechanical Bracing**

- Bracing is placed at mid-span between all rafters
- Shortens unbraced length of the rafters

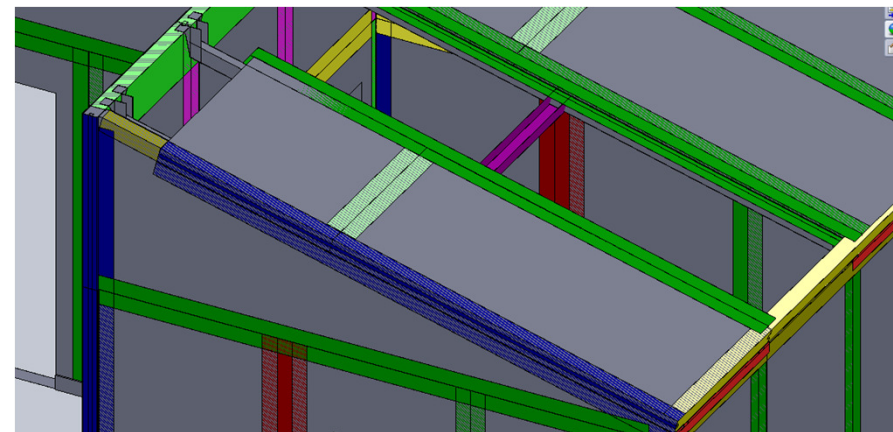
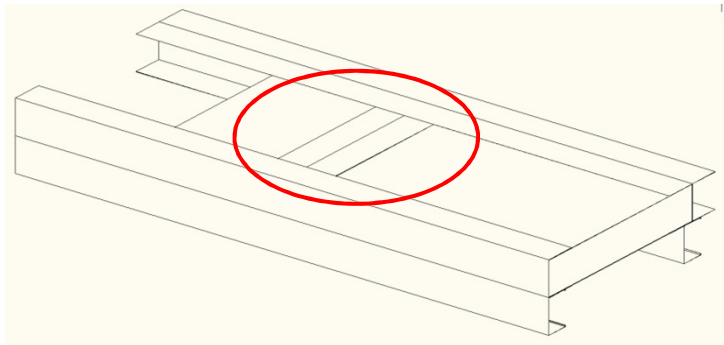
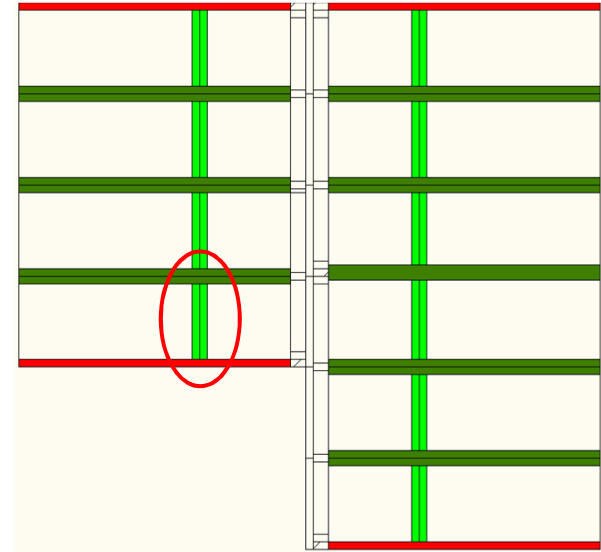


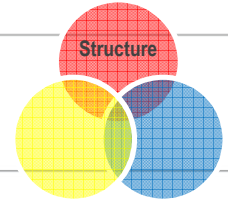


Roof Panel Connections

● Panels

- Panels can easily slide into H-sections already connected to rafters
- An H-section is placed between panels for connection

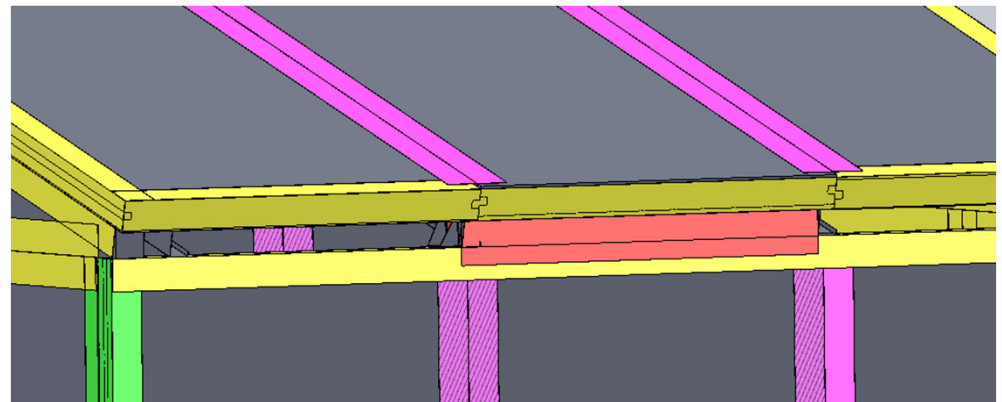
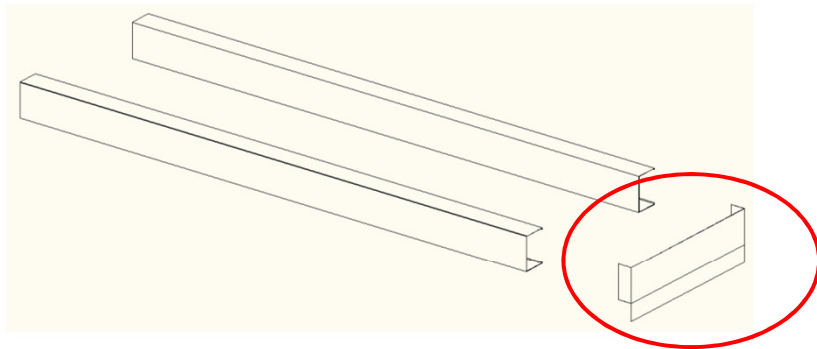
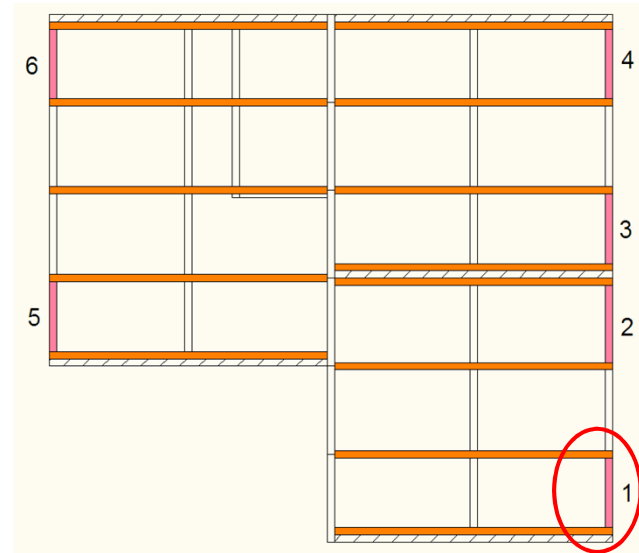




Roof Natural Ventilation

● Natural Ventilation Blocking

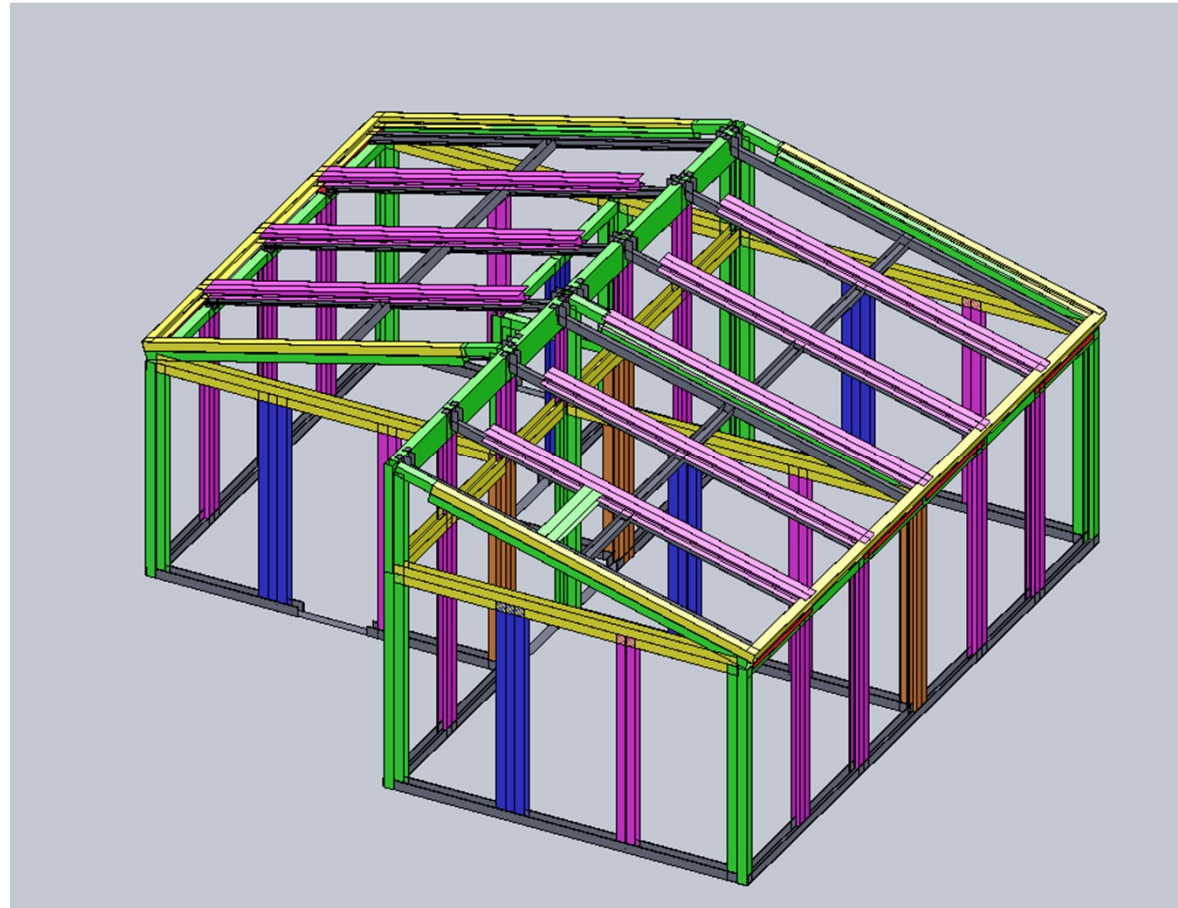
- Blocking is placed at outer wall between every other rafter to create natural ventilation openings





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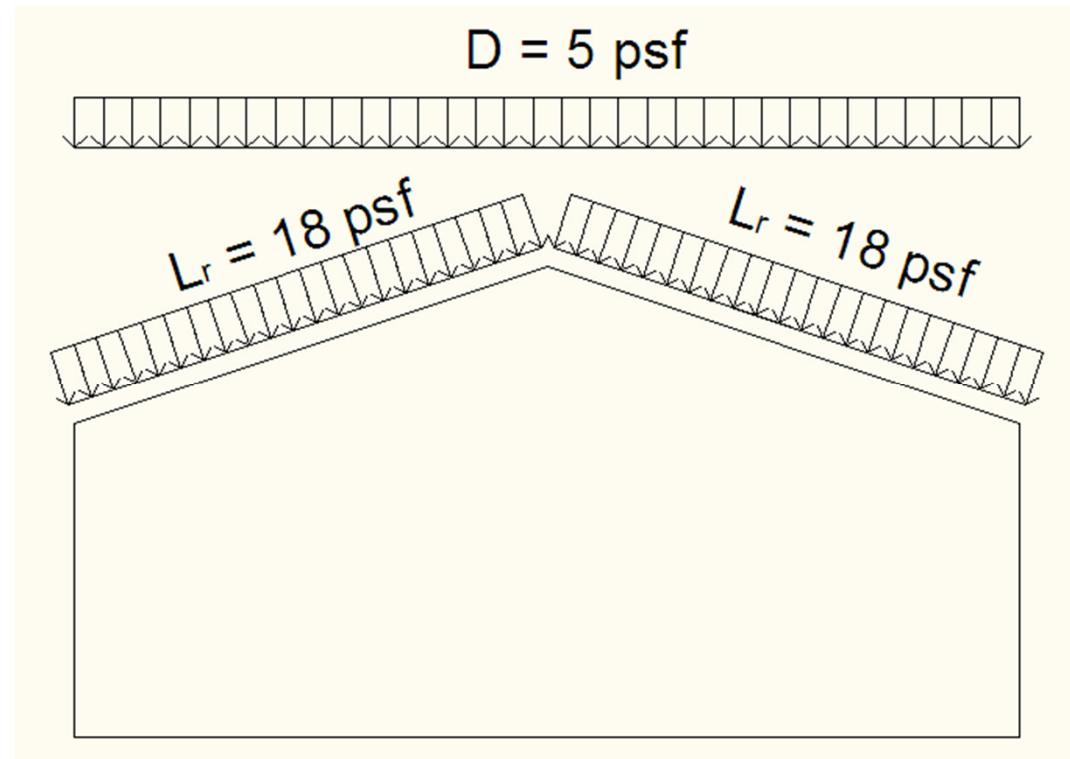
Gravity Load Resisting System





Gravity Loads

- **Roof Dead**
- 5 psf
- **Roof Live**
- 18 psf (along length of rafter)
- **Floor Dead and Live**
- None (single story house)

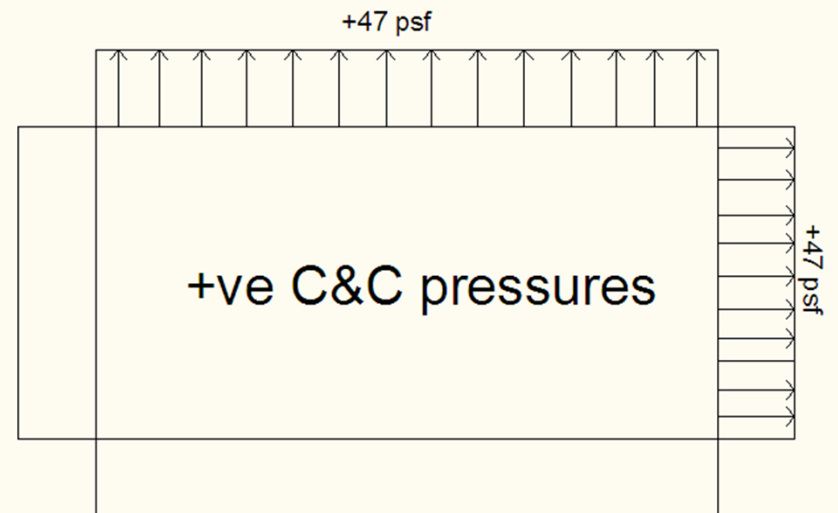
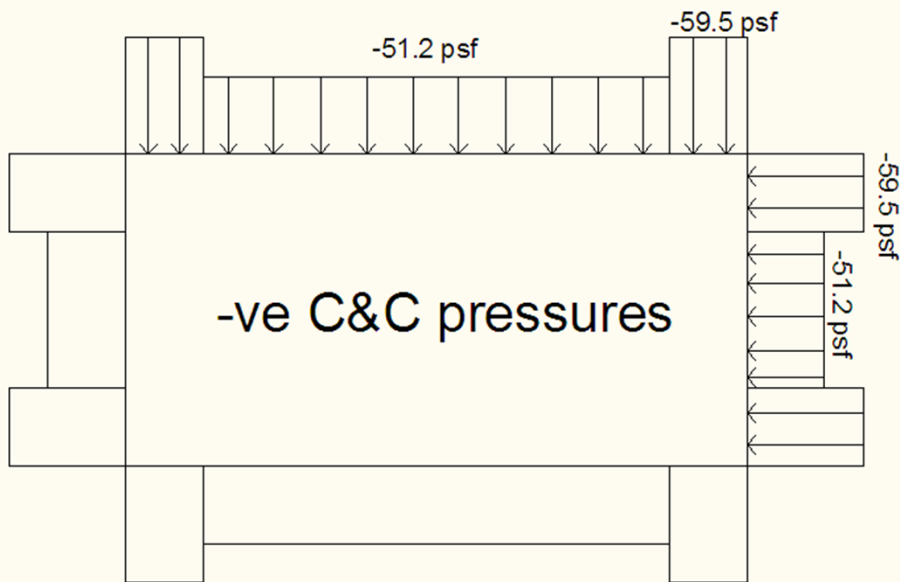




Design Loads

Component and Cladding

Walls

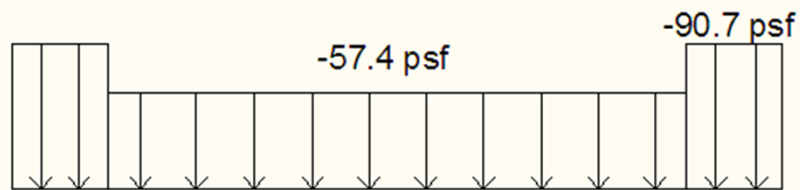




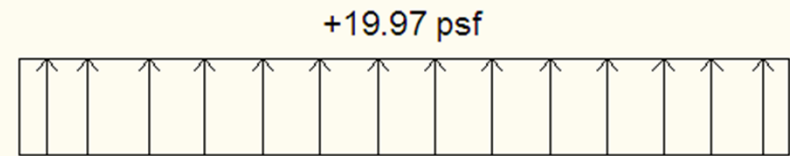
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Design Loads Component and Cladding

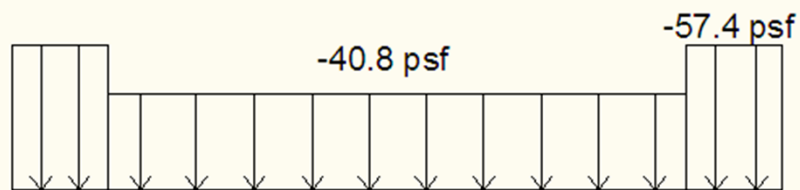
Roof Joists



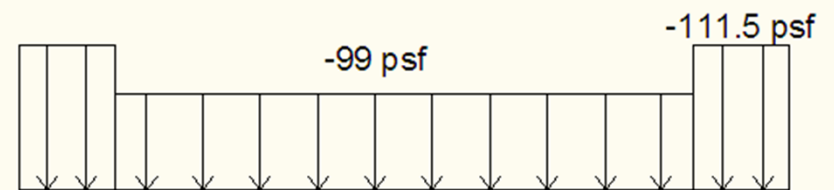
within 3 feet of wall



inward



> 3 feet from wall



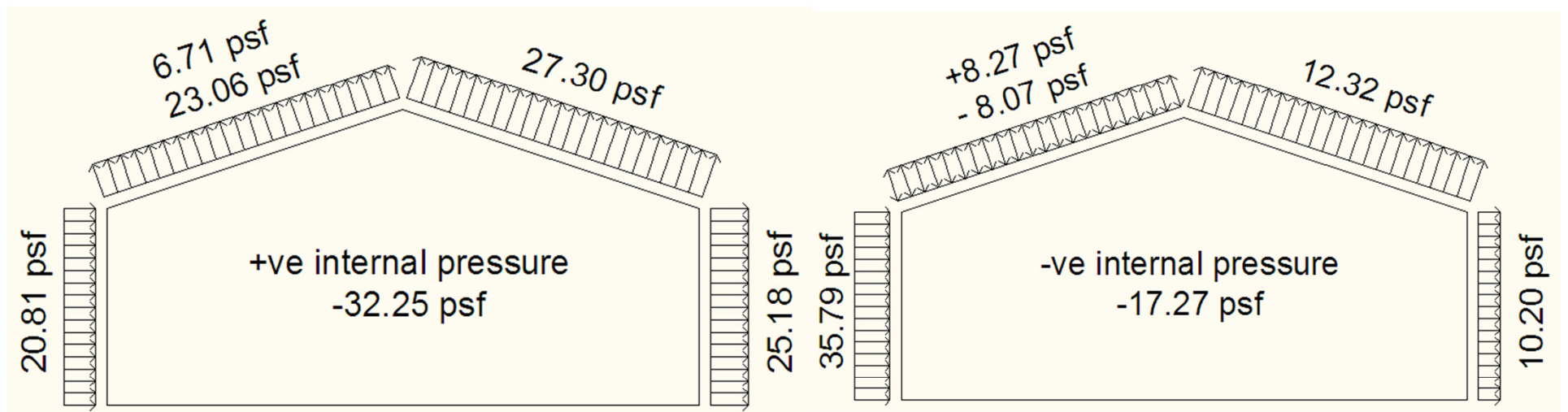
overhang



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Design Loads Wind Load – MWFRS

Wind Pressure - E/W Direction

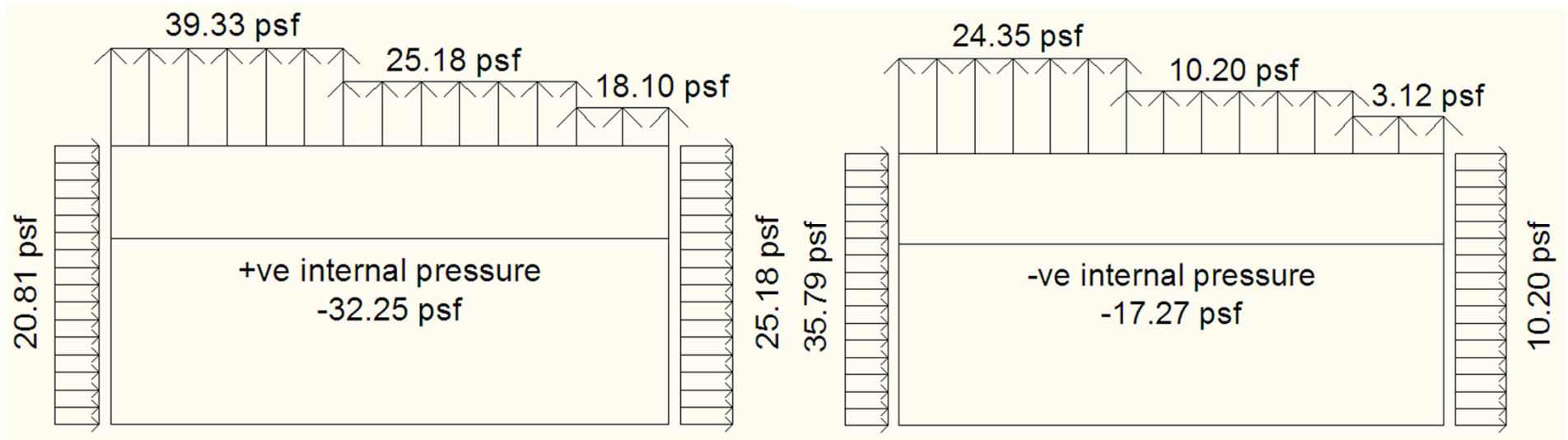




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Design Loads Wind Load – MWFRS

Wind Pressure - N/S Direction

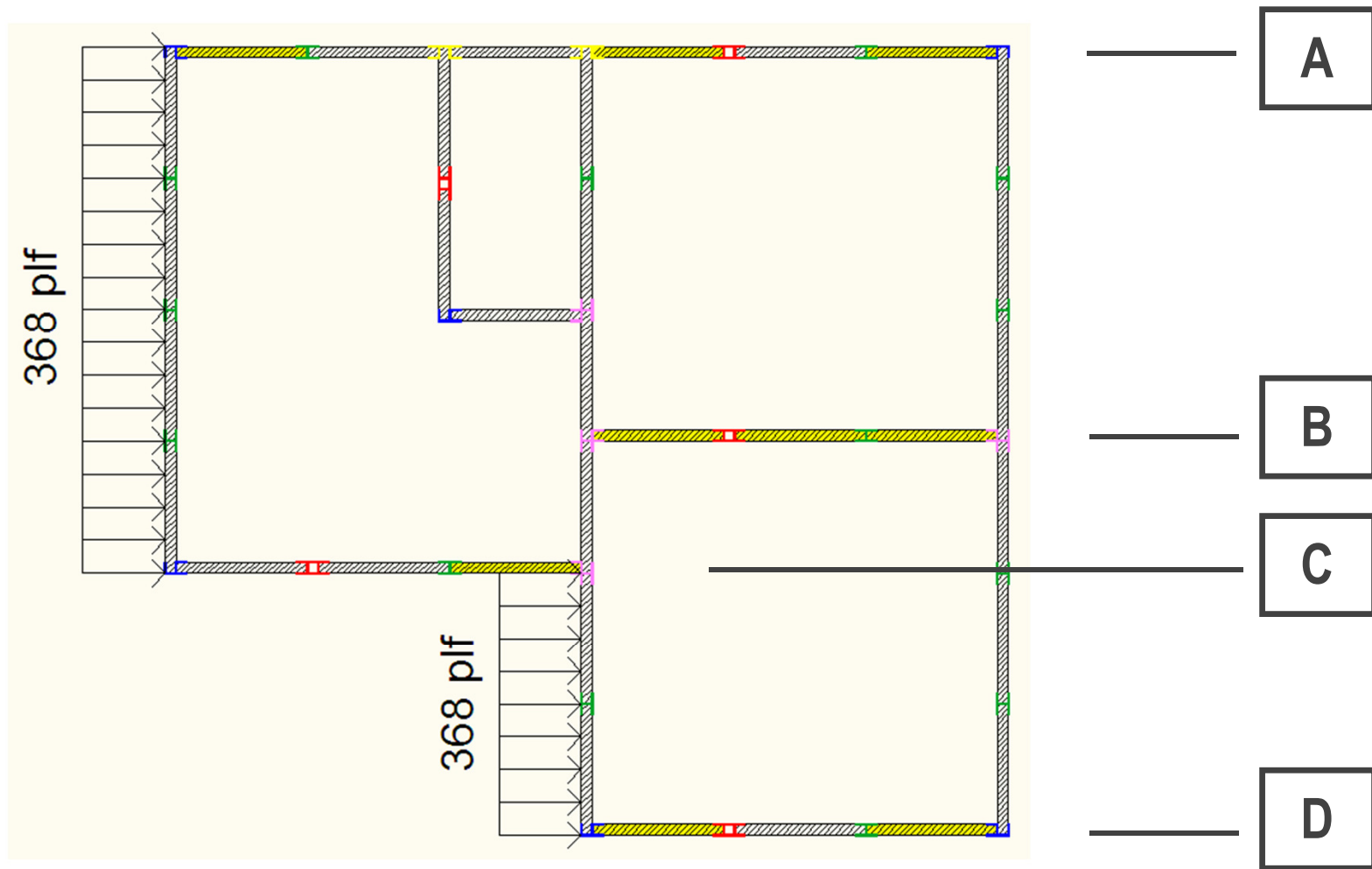




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Shear Walls

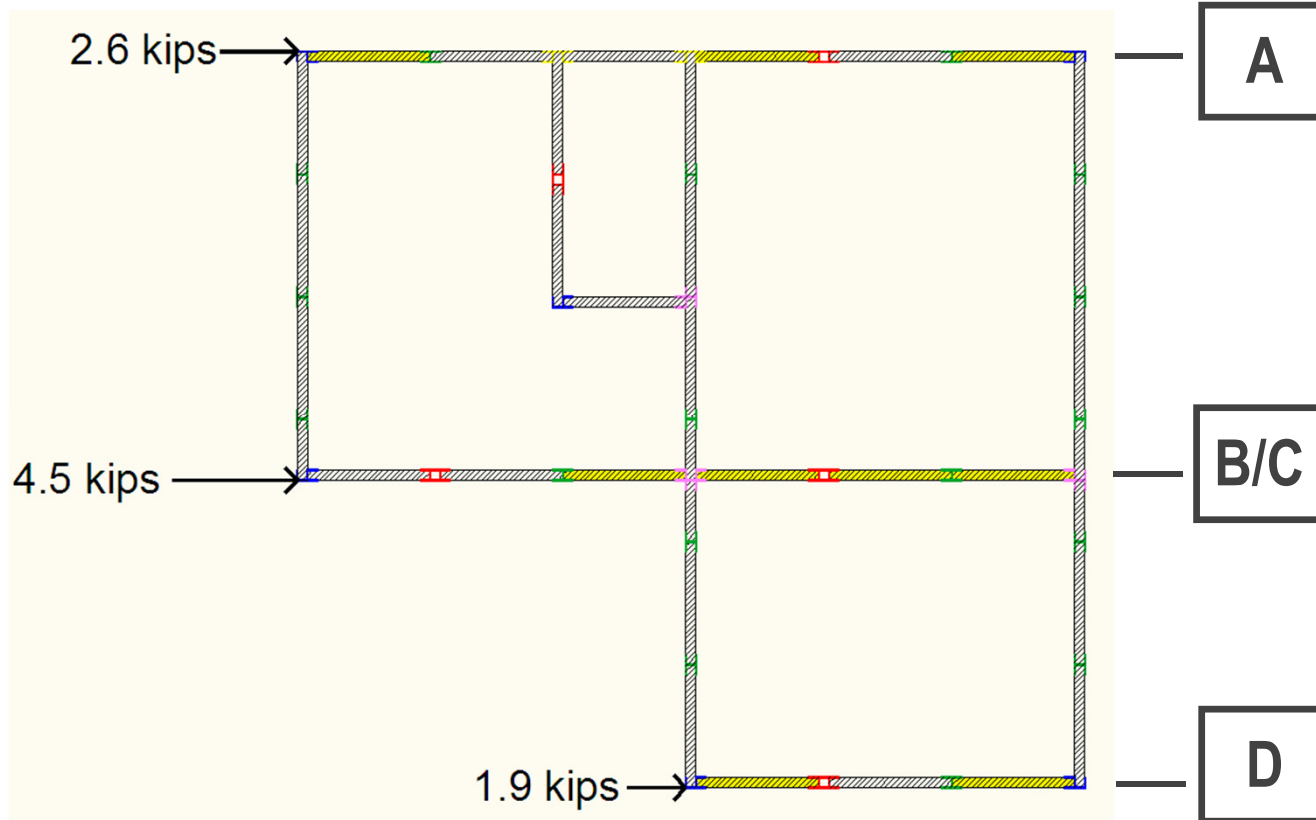
Wind Pressure – E/W Direction





Shear Walls

Wind Pressure – E/W Direction



- Wall lines B&C were assumed to be aligned

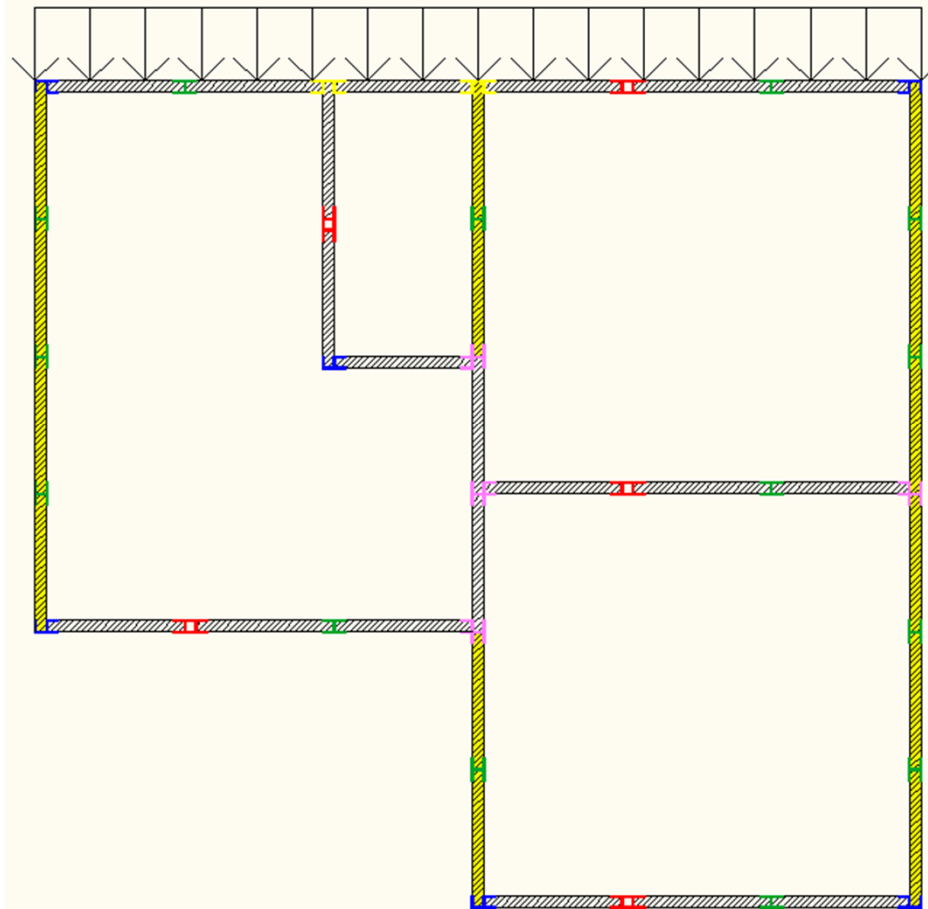


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Shear Walls

Wind Pressure – N/S Direction

368 plf

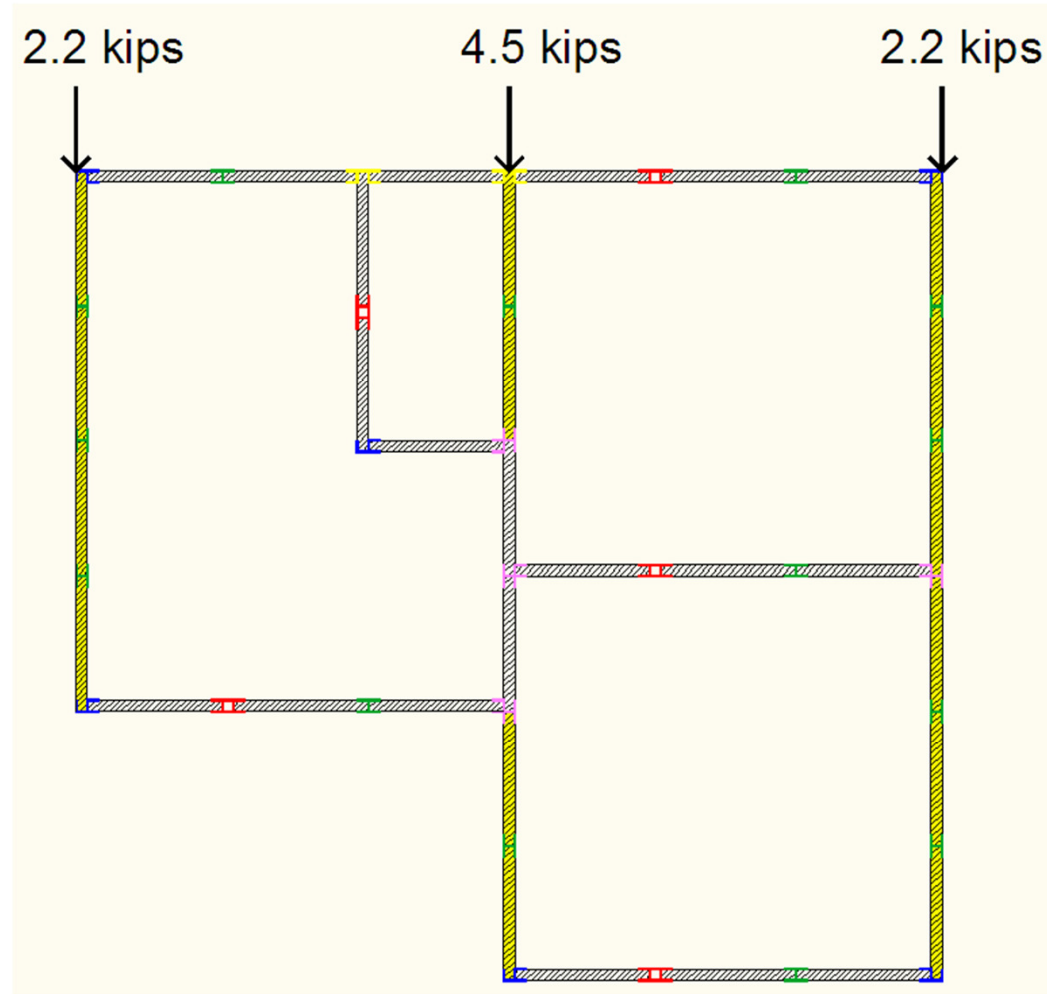




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Shear Walls

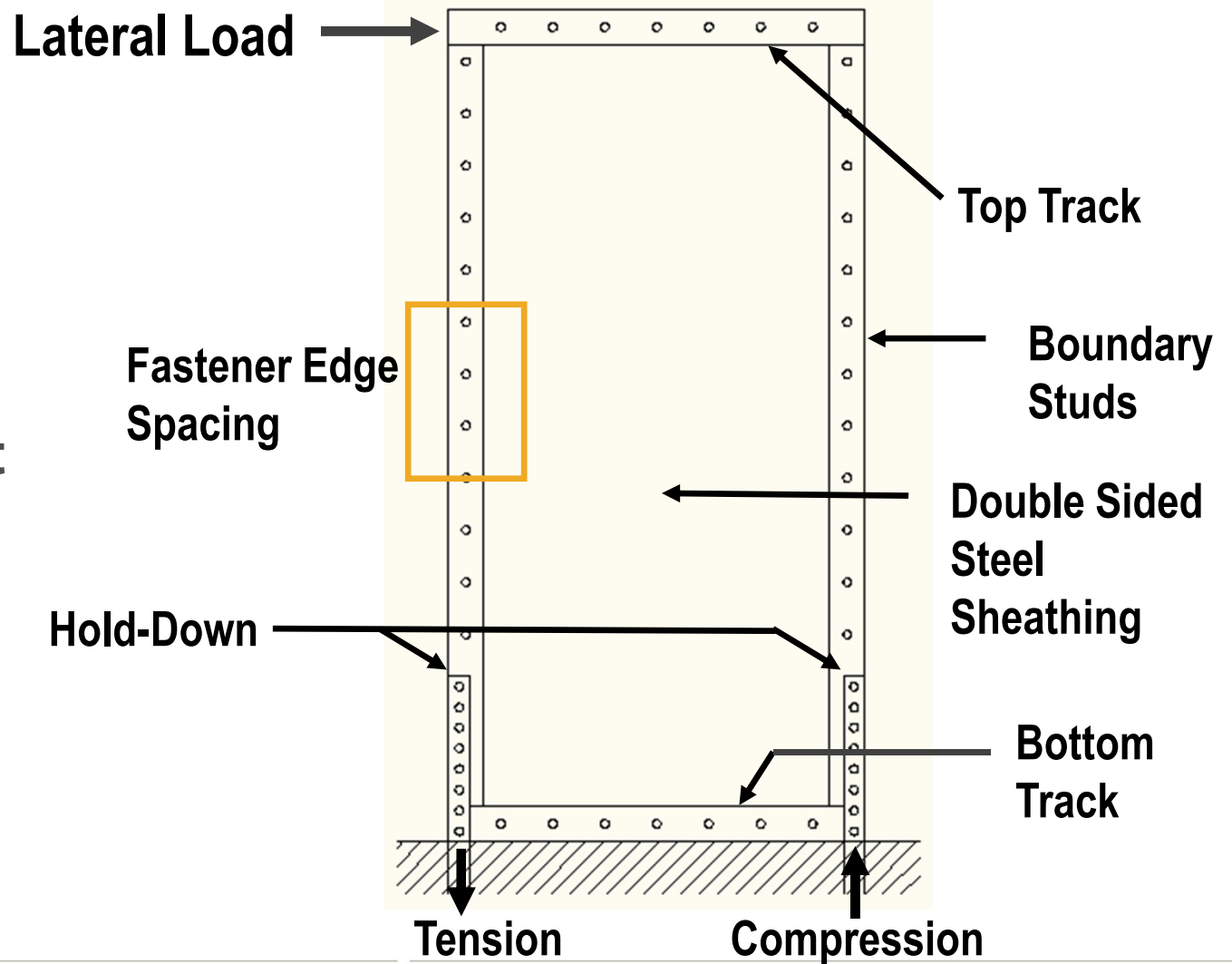
Wind Pressure – N/S Direction





Shear Walls

- All full panels used as shear walls
 - Not doors
 - No windows
- Shear testing not completed yet
 - Min 280 plf capacity per wall needed

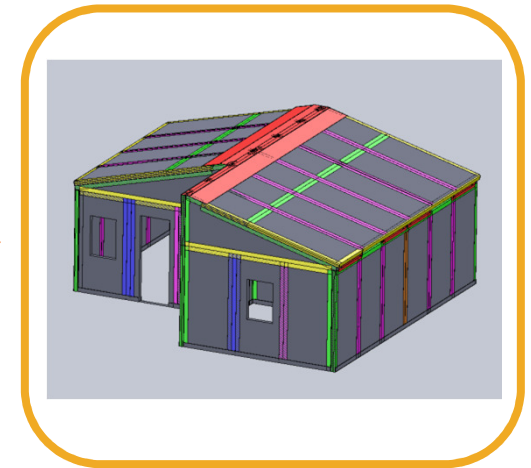




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Cost Estimate

| | |
|-----------------|---------------------|
| Foam | \$ 8,340.00 |
| Steel Materials | \$ 2,998.90 |
| Labor | \$ 6,000.00 |
| TOTAL | \$ 17,338.90 |
| Cost/Sq Ft | \$ 36.12 |



| | |
|-----------------|--------------------|
| Foam | \$ 1,112.60 |
| Steel Materials | \$ 1,145.40 |
| Labor | \$ 2,000.00 |
| TOTAL | \$ 4,258.00 |
| Cost/Sq Ft | \$ 29.57 |



Next Generation Design

- **First Generation Design**
 - Element enhancement
 - Hollow horizontal section
 - Central roof drainage
 - Water Filtration materials
 - Shear Wall Testing
 - Coding system
 - Roof rafter aesthetics





“L’Union Fait La Force” Conclusion

- **Modular housing system**
 - addresses quality control
 - inexpensive
 - simple fabrication
 - quick construction
 - structurally stable
 - multiple application locations
 - potential for a new industry
 - flexible structure design





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We would like to thank everyone who helped to make our project possible...

- Professor Reynaud Serrette – Advisor
- Professor David deCosse – Ethics Advisor
- Georgi Hall – Director of Engineering at CEMCO
- Jerry Jensen – Atlas EPS
- Tal Barnea – WeCutFoam
- All construction workers – Tim Quan, Justin Chow, Nick Robertson, Quinn Peck, Johnette Besseling



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QUESTIONS?



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Foam R value

-70 F = 4.4/inch

- 40 F= 4.7/inch

- 25 F= 5.0/inch

Compressive strength

-@ 1% = 15 psi

- @5% = 40 psi

Shear Strength

-38 psi

Flexural Strength

- 75 psi

NO degradation of Thermal Resistance, Dimensional Stability, or Strength after ASTM C1512 Moisture / Temperature Cycling Test for Insulation

NO growth of mold as tested via ASTM G21, D3273, and C1338

US via E84 = Flame Spread 20, Smoke Developed 400

Canada via CAN/ULC S102.2 = Flame Spread 290, Smoke Developed > 500

NO degradation of Thermal Resistance, Dimensional Stability, or Physical Strength after 15 year foundation exposure test.



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ASCE 7-05

- $R = 2$
- $\Omega_o = 2.5$
- $C_d = 2$

TABLE 12.2-1 DESIGN COEFFICIENTS AND FACTORS FOR SEISMIC FORCE-RESISTING SYSTEMS

| Seismic Force-Resisting System | ASCE 7 Section where Detailing Requirements are Specified | Response Modification Coefficient, R^a | System Overstrength Factor, Ω_o^b | Deflection Amplification Factor, C_d^c | Structural System Limitations and Building Height (h) Limit ^d | | | | |
|--|---|--|--|--|--|-----|-----------------|-----------------|-----------------|
| | | | | | Seismic Design Category | | | | |
| | | | | | B | C | D ^e | E ^f | F ^g |
| A. BEARING WALL SYSTEMS | | | | | | | | | |
| 1. Special reinforced concrete shear walls | 14.2 and 14.2.3.6 | 5 | $2\frac{1}{2}$ | 5 | NL | NL | 160 | 160 | 100 |
| 2. Ordinary reinforced concrete shear walls | 14.2 and 14.2.3.4 | 4 | $2\frac{1}{2}$ | 4 | NL | NL | NP | NP | NP |
| 3. Detailed plain concrete shear walls | 14.2 and 14.2.3.2 | 2 | $2\frac{1}{2}$ | 2 | NL | NP | NP | NP | NP |
| 4. Ordinary plain concrete shear walls | 14.2 and 14.2.3.1 | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{1}{2}$ | NL | NP | NP | NP | NP |
| 5. Intermediate precast shear walls | 14.2 and 14.2.3.5 | 4 | $2\frac{1}{2}$ | 4 | NL | NL | 40 ^f | 40 ^f | 40 ^f |
| 6. Ordinary precast shear walls | 14.2 and 14.2.3.3 | 3 | $2\frac{1}{2}$ | 3 | NL | NP | NP | NP | NP |
| 7. Special reinforced masonry shear walls | 14.4 and 14.4.3 | 5 | $2\frac{1}{2}$ | $3\frac{1}{2}$ | NL | NL | 160 | 160 | 100 |
| 8. Intermediate reinforced masonry shear walls | 14.4 and 14.4.3 | $3\frac{1}{2}$ | $2\frac{1}{2}$ | $2\frac{1}{2}$ | NL | NL | NP | NP | NP |
| 9. Ordinary reinforced masonry shear walls | 14.4 | 2 | $2\frac{1}{2}$ | $1\frac{3}{4}$ | NL | 160 | NP | NP | NP |
| 10. Detailed plain masonry shear walls | 14.4 | 2 | $2\frac{1}{2}$ | $1\frac{3}{4}$ | NL | NP | NP | NP | NP |
| 11. Ordinary plain masonry shear walls | 14.4 | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{1}{4}$ | NL | NP | NP | NP | NP |
| 12. Prestressed masonry shear walls | 14.4 | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{3}{4}$ | NL | NP | NP | NP | NP |
| 13. Light-framed walls sheathed with wood structural panels rated for shear resistance or steel sheets | 14.1, 14.1.4.2, and 14.5 | $6\frac{1}{2}$ | 3 | 4 | NL | NL | 65 | 65 | 65 |
| 14. Light-framed walls with shear panels of all other materials | 14.1, 14.1.4.2, and 14.5 | 2 | $2\frac{1}{2}$ | 2 | NL | NL | 35 | NP | NP |
| 15. Light-framed wall systems using flat strap bracing | 14.1, 14.1.4.2, and 14.5 | 4 | 2 | $3\frac{1}{2}$ | NL | NL | 65 | 65 | 65 |
| B. BUILDING FRAME SYSTEMS | | | | | | | | | |
| 1. Steel eccentrically braced frames, moment-resisting connections at columns away from links | 14.1 | 8 | 2 | 4 | NL | NL | 160 | 160 | 100 |
| 2. Steel eccentrically braced frames, non-moment-resisting connections at columns away from links | 14.1 | 7 | 2 | 4 | NL | NL | 160 | 160 | 100 |
| 3. Special steel concentrically braced frames | 14.1 | 6 | 2 | 5 | NL | NL | 160 | 160 | 100 |
| 4. Ordinary steel concentrically braced frames | 14.1 | $3\frac{1}{4}$ | 2 | $3\frac{1}{4}$ | NL | NL | 35 ⁱ | 35 ⁱ | NP ^j |
| 5. Special reinforced concrete shear walls | 14.2 and 14.2.3.6 | 6 | $2\frac{1}{2}$ | 5 | NL | NL | 160 | 160 | 100 |
| 6. Ordinary reinforced concrete shear walls | 14.2 and 14.2.3.4 | 5 | $2\frac{1}{2}$ | 4 $\frac{1}{2}$ | NL | NL | NP | NP | NP |
| 7. Detailed plain concrete shear walls | 14.2 and 14.2.3.2 | 2 | $2\frac{1}{2}$ | 2 | NL | NP | NP | NP | NP |
| 8. Ordinary plain concrete shear walls | 14.2 and 14.2.3.1 | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{1}{2}$ | NL | NP | NP | NP | NP |
| 9. Intermediate precast shear walls | 14.2 and 14.2.3.5 | 5 | $2\frac{1}{2}$ | 4 $\frac{1}{2}$ | NL | NL | 40 ^f | 40 ^f | 40 ^f |
| 10. Ordinary precast shear walls | 14.2 and 14.2.3.3 | 4 | $2\frac{1}{2}$ | 4 | NL | NP | NP | NP | NP |
| 11. Composite steel and concrete eccentrically braced frames | 14.3 | 8 | 2 | 4 | NL | NL | 160 | 160 | 100 |
| 12. Composite steel and concrete concentrically braced frames | 14.3 | 5 | 2 | 4 $\frac{1}{2}$ | NL | NL | 160 | 160 | 100 |
| 13. Ordinary composite steel and concrete braced frames | 14.3 | 3 | 2 | 3 | NL | NL | NP | NP | NP |
| 14. Light-framed walls with shear panels of all other materials | 14.1, 14.1.4.2, and 14.5 | 2 | $2\frac{1}{2}$ | 2 | NL | NL | 35 | NP | NP |
| 19. Ordinary reinforced masonry shear walls | 14.4 | 2 | $2\frac{1}{2}$ | 2 | NL | 160 | NP | NP | NP |
| 20. Detailed plain masonry shear walls | 14.4 | 2 | $2\frac{1}{2}$ | 2 | NL | NP | NP | NP | NP |
| 21. Ordinary plain masonry shear walls | 14.4 | $1\frac{1}{2}$ | $2\frac{1}{2}$ | $1\frac{1}{4}$ | NL | NP | NP | NP | NP |

| | | | | |
|---|--------------------------|---|-------|---|
| 14. Light-framed walls with shear panels of all other materials | 14.1, 14.1.4.2, and 14.5 | 2 | 2 1/2 | 2 |
|---|--------------------------|---|-------|---|



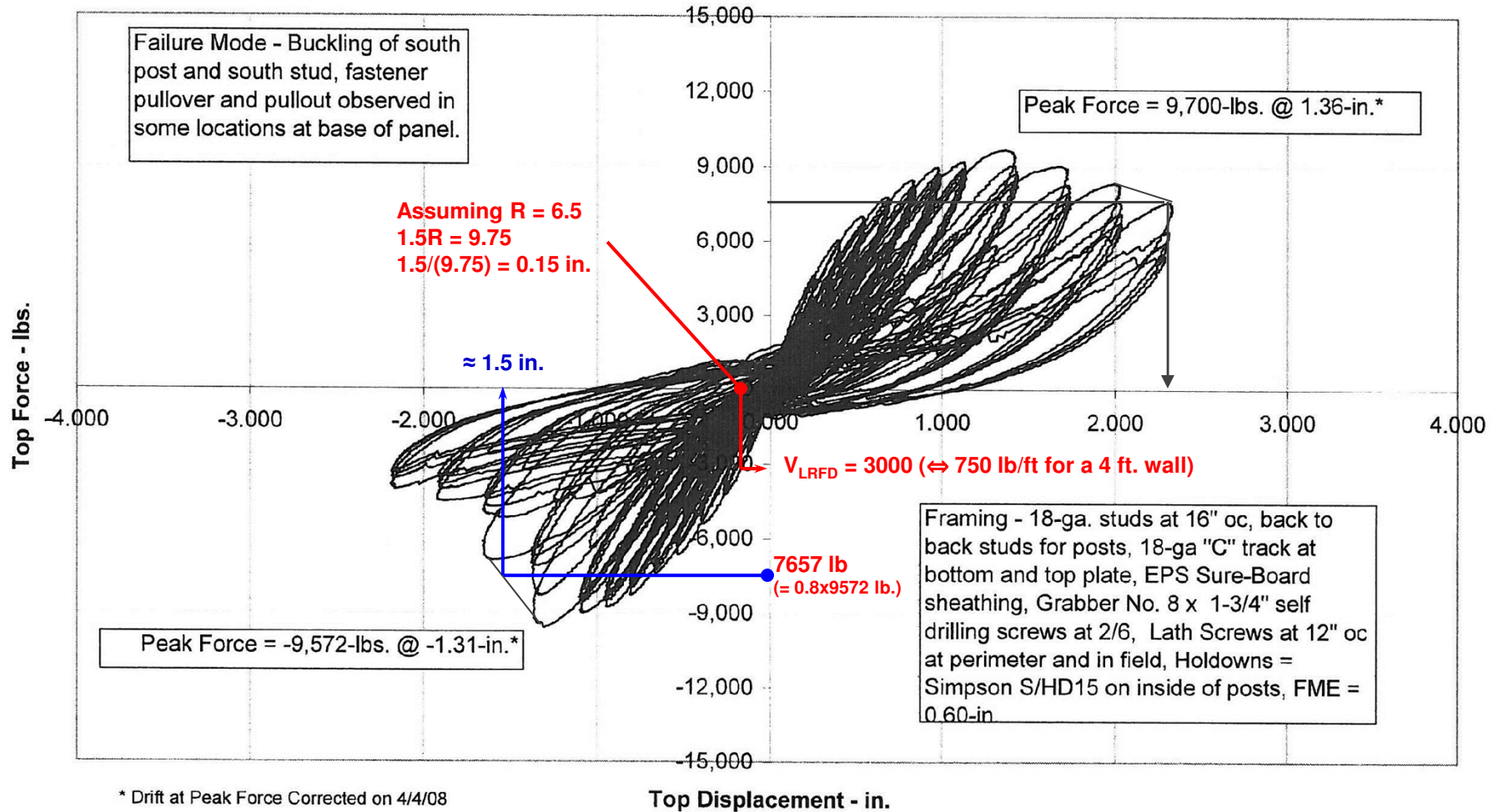
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CEMCO - Racking Shear Test

Phase 29 - Test No. 1 - 4-ft. x 8-ft. Shear Wall w/ 18-ga. Steel Framing @ 16-in. oc and EPS Sure-Board

Sheathing EPS = 2-in. White Foam

3/31/2008



$V_{ASD} = 0.7 \times 3000 = 2100 \text{ lb}$ (\Leftrightarrow 525 lb/ft for a 4 ft. wall)
 $\Omega = 9572/2100 = 4.55$