Executive Summary

One of the problems currently present on the Sears Centre project is the relatively light building weight. The current system is a complex envelope system composed of (1) 8' x 8' Architectural Pre-cast Panels, (2) 8" x 16" x 12" Split Face CMU(s) and (3) Type 1, 2, 3 CIM panels. CIM panels have an average weight distribution of 4.9036 lb/ ft^3.

Panel Designation	Panel Density lb/ft^3
Type (1) CIM Panel (2" thickness)	4.7147
Type (2) CIM Panel (4-1/2" thickness)	5.2814
Type (3) CIM Panel (2" thickness)	4.7147

Since the member distribution of CIM panels accounts for nearly 50% of the buildings cladding envelope, and analysis of a heavier alternative envelope member will be conducted in an effort to reduce over-turning in the strip footing, will at the same time reducing over sizing of footing weight by redistributing envelope loads to enclosure material.

Selection Criteria for Alternative Envelope Member(s):

1. ***Option #1***
   - ❖ Use pre-manufactured masonry panels in lieu of
     Pre-cast Form Liner
     Type (1) – Type (3) Metal Panels
     Type (1) – Type (3) Architectural CMU(s)
   - ❖ Alternative System Option # 1 – 100 % Pre-finished masonry
2. ***Option #2***
   - ❖ Use pre-manufactured masonry panels in lieu of
     Type (1) – Type (3) Metal Panels
     Type (1) – Type (3) Architectural CMU(s)
   - ❖ Alternative System Option # 2 – Pre-finished masonry w/ Pre-cast Form Liner
3. ***Option #3***
   - ❖ Use pre-manufactured masonry panels in lieu of
     Type (1) – Type (3) Metal Panels
   - ❖ Alternative System Option # 3 – Pre-finished masonry or Pre-cast panels with Brick Veneer w/ Pre-cast Form Liner & Arch CMU units

4. ***Option #4***
   - ❖ Use EZ-Wall System with thin briquettes in lieu of
     Type (1) – Type (3) Metal Panels
   - ❖ Alternative System Option # 3 – Pre-finished masonry or Pre-cast panels with Brick Veneer w/ Pre-cast Form Liner & Arch CMU units

Analysis of Footing Size Reduction (via) Remediation of the Complex Envelope System

Purpose for Analysis:

- The purpose of this structural pre-analysis is to determine if an overturning condition can be reduced by footing redesign or apply an additional klf loading to exterior strip footings and kips to column footings

The Sears Centre is a 240,000 SF sports facility with a complex envelope system composed of (8' x 8') Architectural Pre-cast Panels, 8" x 18" x 12" Split faced CMU(s), (2) Types of 2"- 4" thick CIM-*(Cored Insulated Metal Panels)* VersaWall Panels and (1) Type of 2" thick CIM-*(Cored Insulated Metal Panels)* Foam Wall Panel. Although the system is extremely affective in supplying insulation for large square foot areas, an inherent problem exist for relatively light weight envelope components.

As a result, strip and column footings have been oversized to limit the over turning condition. Additional loading will be utilized to add weight to the composite envelope.
The goals of the analysis:

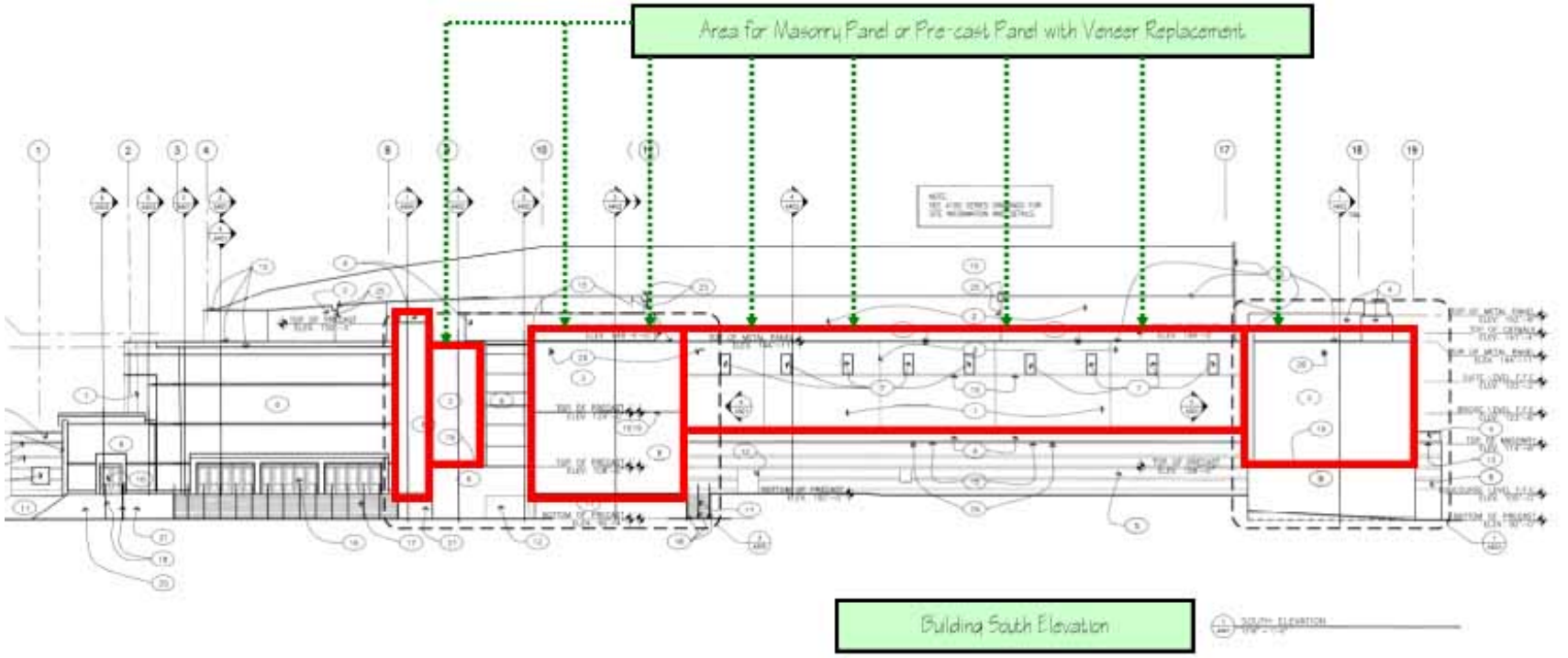
- Identify the region on the current envelope system for new member installation
- Identify the affected foundation areas
- Selecting an appropriate alternative for current envelope system of equal aesthetic *(Important for Arena appearance)*
- Determine a klf load which will safely reduce overturning occurrence
- Check current footings designs via redesign in an effort to reduce material, time and money associated with foundation installation costs. (Basic equation used/ Assumptions -Pleased see appendix for full hand calculations)

Identify complex envelope system elements

System Component	***Weight per linear foot (klf)***	***Percentage of Envelope***
8' x 8' Arch. Pre-cast Panels	*4.3291 klf*	*26 %*
8" x 16" x 12" Split CMU(s)	*0.0847 klf*	*24 %*
Type (1) 2"thick CIM panels	*0.0132 klf*	*13 %*
Type (2) 4-1/2"thick CIM panels	*0.0251 klf*	*15 %*
Type (3) 2"thick CIM panels	*0.0140 klf*	*22 %*
Total	***4.4661 klf***	***100 %***

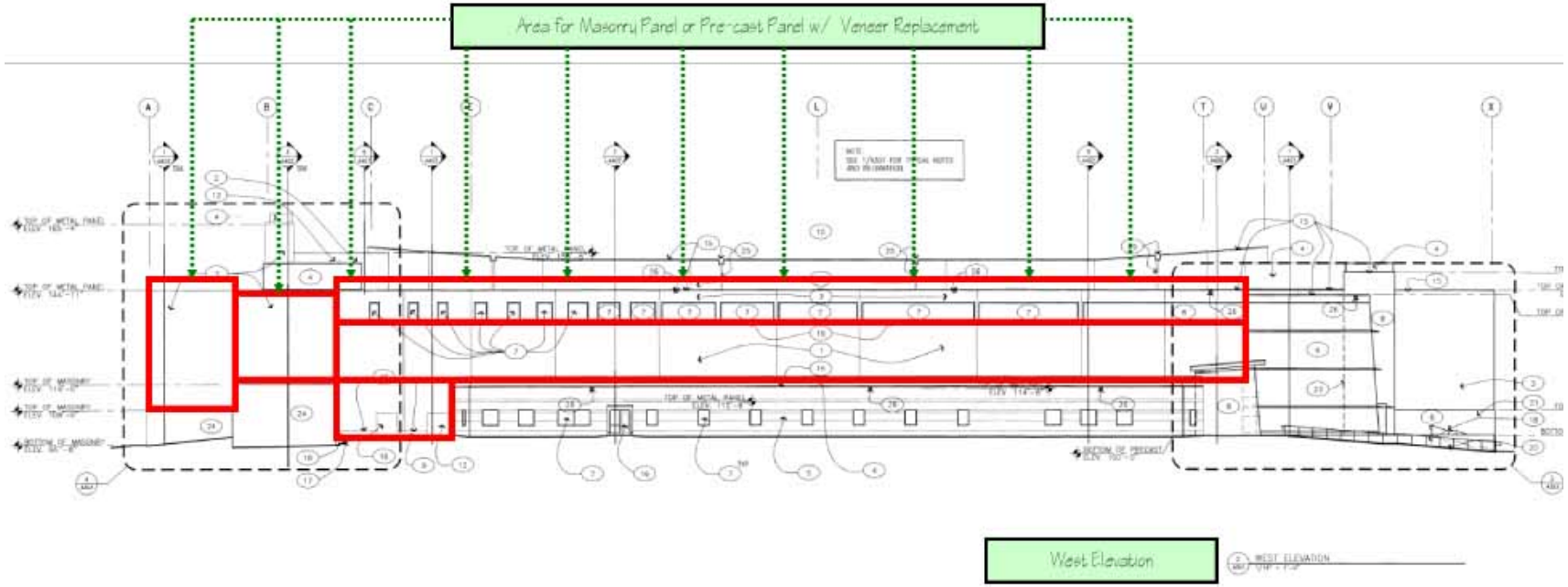
Identified Building Envelope Regions for Alternative Element Placement

South Elevation with proposed area of remediation highlighted



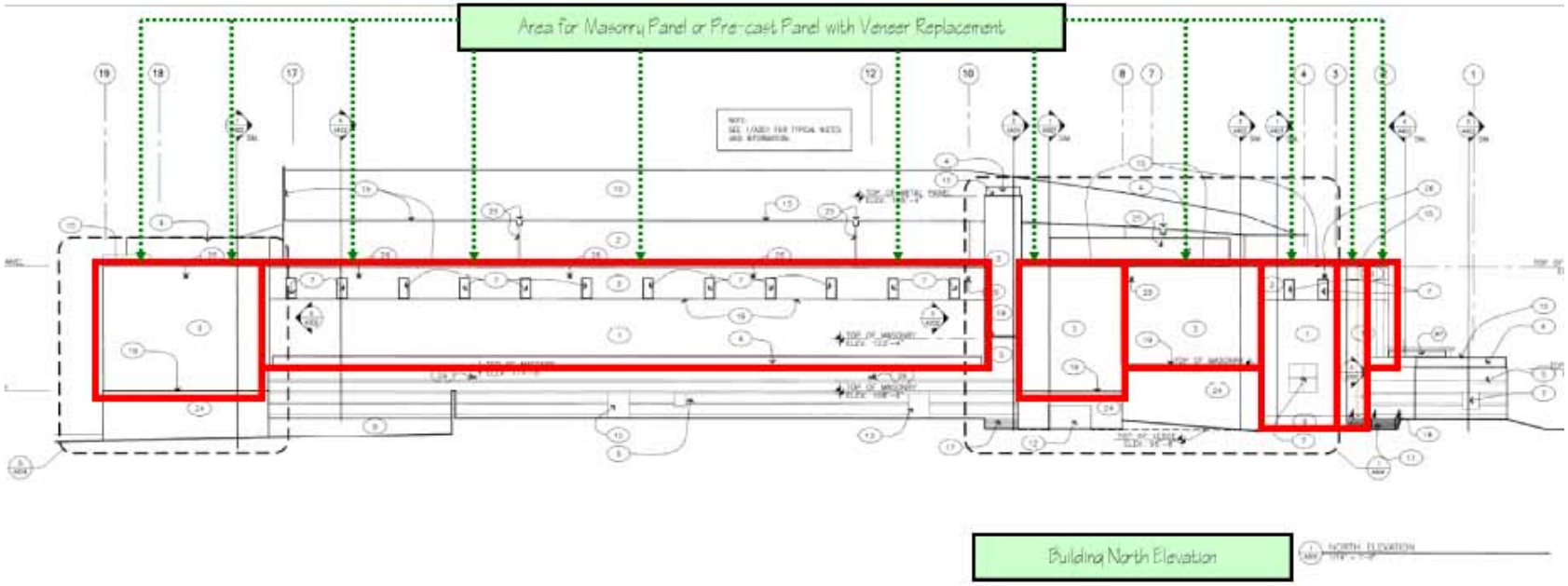
Current Assessment:
Proposed Change to: (South Elevation)
7,092 lbs → 7.092^{k} @ 8,743 SF

West Elevation with proposed area of remediation highlighted



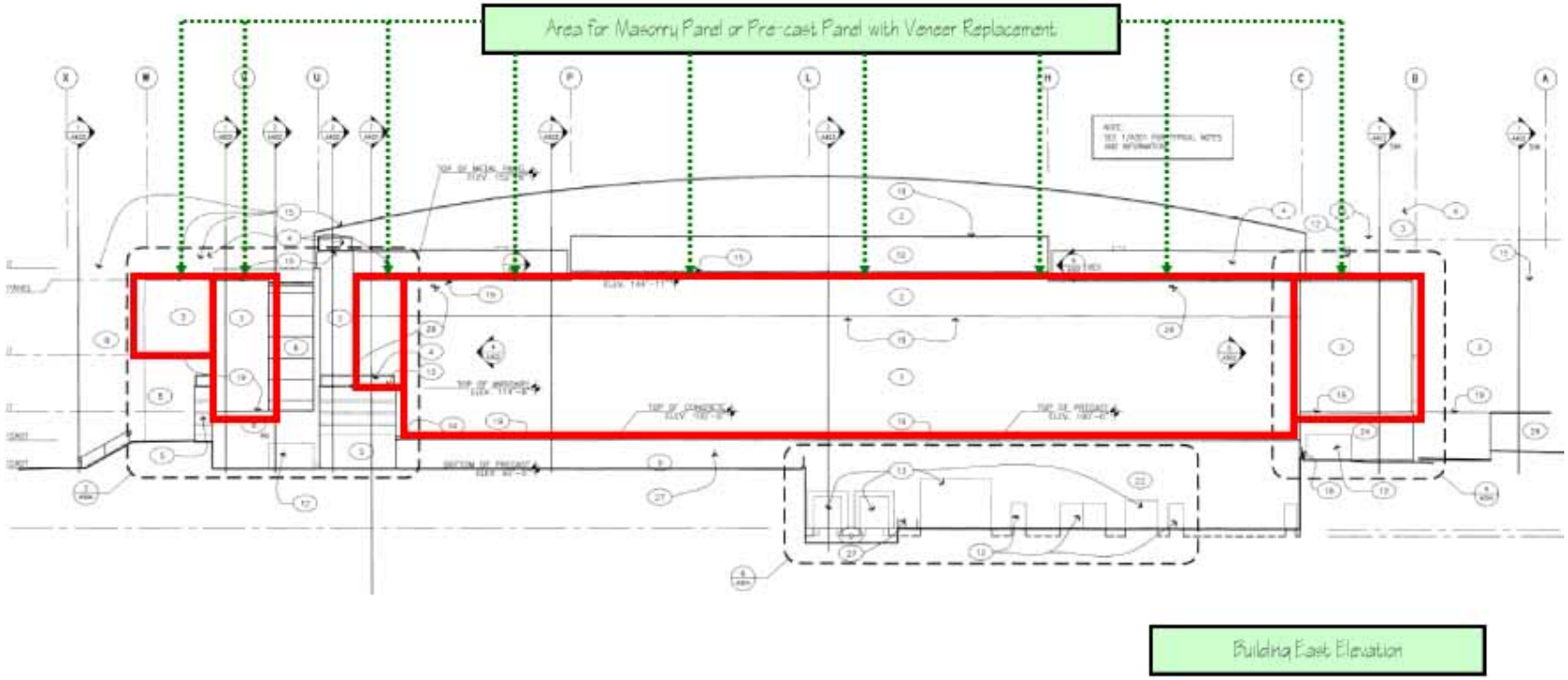
Current Assessment:
Proposed Change to: (West Elevation)
10,050 lbs → 10.050^{k} @ 13,112 SF

North Elevation with proposed area of remediation highlighted



Current Assessment:
Proposed Change to: (North Elevation)
13,240 lbs → 13.240^{k} @ 16,670 SF

East Elevation with proposed area of remediation highlighted



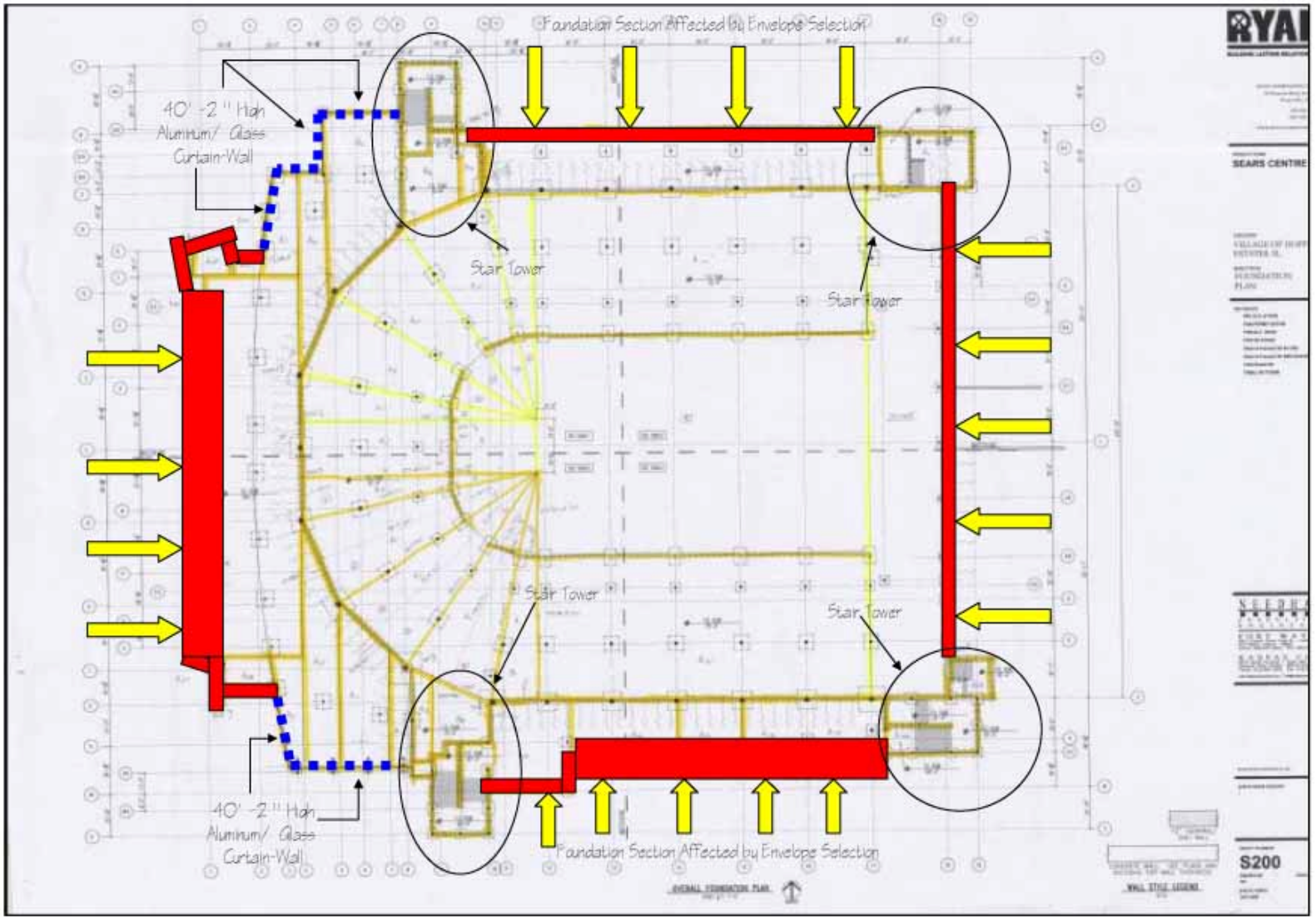
Current Assessment:

Proposed Change to: (East Elevation)

11,160 lbs → 11.160^{k} @ 13,938 SF

SEARS CENTRE

Footing Analysis via Redesign



Decide alternative envelope scheme:

Scheme Selection Summary

1. ***Option #1***
   - ❖ Use pre-manufactured masonry panels in lieu of
     Pre-cast Form Liner
     Type (1) – Type (3) Metal Panels
     Type (1) – Type (3) Architectural CMU(s)
   - ❖ Alternative System Option # 1 – 100 % Pre-finished masonry

   Reason for Rejection: Cost per cubic foot well beyond budget scope
   Reason for Rejection: Imposed Panel Weight per Area via 8' x 8' Panel or 8' x 30' could increase the size and costs of strip footing

2. ***Option #2***
   - ❖ Use pre-manufactured masonry panels in lieu of
     Type (1) – Type (3) Metal Panels
     Type (1) – Type (3) Architectural CMU(s)
   - ❖ Alternative System Option # 2 – Pre-finished masonry w/ Pre-cast Form Liner

   Reason for Rejection: Depended on size of unit a full sized masonry unit may also increase the size and bearing capacity of strip footing

3. ***Option #3***
   - ❖ Use pre-manufactured masonry panels in lieu of
     Type (1) – Type (3) Metal Panels
   - ❖ Alternative System Option # 3 – Pre-finished masonry or Pre-cast panels with Brick Veneer w/ Pre-cast Form Liner & Arch CMU units

   Reason for Rejection: Mentioned in previous option

4. ***Option #4 [Probable System to be used]***
   - ❖ Use EZ-Wall System with thin brackets in lieu of
     Type (1) – Type (3) Metal Panels
   - ❖ Alternative System Option # 3 – Pre-finished masonry or Pre-cast panels with Brick Veneer w/ Pre-cast Form Liner & Arch CMU units

   1. *Reason for Selection: To stay on the safe side this method was chosen do to reasonable load increase per linear foot, in addition to the relatively short installation time similar to the current CIM system.*
   2. *Reason for Selection: Similar to the overall selection criteria this method provides all season, installation method independent on outdoor temperature.*
   3. *Reason for Selection: Comparable Panel Sizes*

System selected: *Summitville Thin Brick / Installed in EZ-Wall Stud System*

- The proposed system to be used for the replacement of Type (1) & Type (3) CIM panels is the Summitville Thin Brick / Installed in an EZ-Wall Stud System.

Brick Veneer Panel Support System:

- 18 ga. Architectural Grade steel
- Hot dip Galvanized G-90
- Adjusted to support a 16" x 48" veneer/ insulated composite panel
- (Comparable to 1/3 size of the standard 48" x 48" Panel used for system)
- *** Custom Sizes interchangeable with system ***
- Maximum Wall Stud framing 24" o.c. / Sears Centre requirement 16" metal stud spacing for veneer construction
- Maximum Stud spacing from Girts 30" o.c

Thin Brick Unit Dimensions/ Adhesive Strength (etc):

- 7-5/8" x 2-1/4" x 3-5/8" with thickness = 9/16" Briquette
- *Comparable to the EZ-Wall supplied Ambrico, Inc. economy masonry unit of same type and size*
- Veneer Bonding adhesive rate for 150 psi
- Gypsum board classification

Determine impact on structural systems (Resultant Load in klf)

System Component	*Weight per linear foot (klf)*	*Percentage of Envelope*
8' x 8' Arch. Pre-cast Panels	*4.3291 klf*	*26 %*
8" x 16" x 12" Split CMU(s)	*0.0847 klf*	*24 %*
Type (2) 4-1/2"thick CIM panels	*0.0251 klf*	*15 %*
7-5/8" x 2-1/4"x 3-5/8" Thickness = 9/16" Thin Brick Assembly	*0.1267 klf*	*36 %*
Total	***4.5656 klf***	***100 %***
Loading Increase (klf) = 0.0995 klf		

Elevation	Load Increase (k)	Revised Envelop Load (k)
South Elevation	58.67^{k}	$2{,}163.60^{k}$
West Elevation	88.60^{k}	882.99^{k}
North Elevation	112.11^{k}	672.86^{k}
East Elevation	93.67^{k}	734.25^{k}

Total Envelope Load Increase (∑) = 353.05^{k}
Total Revised Envelope Load (∑) = 4,453.70^{k}

Structural Summary:

Condition:

- ❖ Strip Footing Re-design
- ❖ Column Size Verification via Re-design checks

(Full Hand calculations can be referenced in thesis appendix)
(Summitville Panelized Brick system data can be referenced in thesis appendix)

A composite wall composed of 8" x 16" x 12" Split Face/ Burnished Finish concrete masonry units, 8' x 8' Architectural Pre-cast panels, 4-1/2" thick 'CIM' panels and 4-3/4" and 7-5/8" x 2-1/4" x 3-5/8" thin brick/ EZ Wall Panelized system imposes a load of 4,565.60 kips per linear foot to a concrete strip footing.

Elevation		Effected Length
South	→	167.59 ft
West	→	303.65 ft
North	→	220.78 ft
East	→	253.55 ft

Note: The following assumptions where made when completing structural calculations for this student breadth:

1. Allowable soil bearing pressure 4 ksf
2. Concrete Strength f'(c) = 4,000 psi
3. Typical column sized used for analysis was an 18" x 18" pre-cast column
4. Strip footing analysis was completed based on pre-determined envelope weights with calculated additions
5. Frame loading on individual beams where held as constants in this scenario due to time constraint for area of focus (Please note that any proposed changes will need to reference analysis of individual beams and column members before any changes can occur in envelope system)
6. Column footings sized for typical condition at 165 columns per building to have equal axial load distribution
7. Costs savings/ overruns for typical columns can only be analyzed for (34) pre-cast columns on project
8. Column Footing sized checked against 12' x 12' existing square footing

Note: Inherent conditions on the project have oversized footings considerably; an additional purpose of this analysis is to re-size the footing, if possible for cost reduction, will providing the required loading.

General Calculations used for analysis:

Strip footing & Column Footing Analysis:

1. $P_{(total\ load)} = P_{(dead\ load)} + P_{(live\ load)}$
2. $q_{(allowable)} = P_{(total\ load)} / A_{(ftg)}$
3. $P_u = 1.2P_{(dead\ load)} + 1.6P_{(live\ load)}$
4. $q_{(factored)} = P_u / A_{(ftg)}$
5. $ØV_c = Ø2\sqrt{f'(c)} * bd$
6. $V_u = [(B_{(ftg\ width)} - \text{largest width of wall}) / 2]*(\text{unit strip})$
7. $d_{(ftg\ depth)} = V_u / P_u$
8. $h = d + 3"(\text{cover}) + 0.25"$ *strip footing only*
9. $h = d + 3"(\text{cover}) + 0.625"$ *column footing only*
   (a) $= [(A_s)(F_y)]/[(\beta)(\sqrt{f'(c)})(\text{unit strip})]$
   (a) $= [(A_s)(Fy)]/[(\beta)(\sqrt{f'(c)})(\text{square column dimension})]$
10. $Mu = ØMn = ØA_sf_y*[d-(a/2)]$
11. $\rho = A_s/[(b)(d)] \geq 0.0018\ in^2/in^2$
12. $c = a/\beta_1$
13. $\varepsilon = [(0.003)/c][(d - c)] > 0.005$ in/in
14. $A_{smin} = 0.0018bh$ *strip footing only*
15. $ØB_n > P_u$ *column footing only*

Calculation Results:

Strip Footing Scenario	*Dimensions*	*C.Y / linear foot (unit length)*
Current Footing	*1'- 4" x 12"x length*	*0.0493 CY/ LF*
Proposed # 1	*1'- 4" x 6"x length*	*0.0246 CY/ LF*
Proposed # 2	*1'- 4" x 8" x length*	*0.0330 CY/ LF*

Square Footing Scenario	*Dimensions*	*C.Y*
Current Footing	*12'-0" x 12' -0"x 2'-8"*	*14.24 CY*
Proposed # 1	*11'-4" x 11' x 4"x 2'-4"*	*11.08 CY*
Proposed # 2	*8'-0" x 8'-0" x 2'-0"*	*4.74 CY*

Cost/ Benefit Analysis:

Strip Footings:

Elevation		CY Strip Footing Reduction
South	@ 8" Depth	2.73 CY
West	@ 8" Depth	4.95 CY
North	@ 8" Depth	3.60 CY
East	@ 8" Depth	4.13 CY
Total	**@ 8" Depth**	**15.41 CY**

Elevation		CY Strip Footing Reduction
South	@ 6" Depth	4.14 CY
West	@ 6" Depth	7.50 CY
North	@ 6" Depth	5.45 CY
East	@ 6" Depth	6.26 CY
Total	**@ 6" Depth**	**23.35 CY**

Square Footings : (Sized for reduction of current condition, then analyzed for added loading)

Columns		CY
12'-0" x 12' -0"x 2'-8"	@ 34 columns	484.16 CY
11'-4" x 11' x 4"x 2'-4"	@ 34 columns	376.64 CY
8'-0" x 8'-0" x 2'-0"	@ 34 columns	161.19 CY

Proposed Reduction	
11'-4" x 11' x 4"x 2'-4"	484.16 CY (less) 376.64 = 107.52 CY
8'-0" x 8'-0" x 2'-0"	484.16 CY (less) 161.19 = 322.97 CY

Determine cost of selected alternative:

Envelope Remediation
$ 559,750 (less) $ 540,708 = $ 19,042 Saved

Cubic Yard Reduction (STR. FTG @ 8" Depth w/ 11'-4" x 11"-4" SQ. FTG)
(15.41 CY + 107.52 CY = 122.93 CY)($ 80.14) = $ 9,851 Saved

Cubic Yard Reduction (STR. FTG @ 6" Depth w/ 8'-0" x 8"-0" SQ. FTG)
(23.35 CY + 322.97 CY = 346.32 CY)($ 80.14) = $ 27,754 Saved

Time Savings (Assuming Panel Placement is the same) = 2 days; 5 days
Total Savings Respectively = $ 28,893 (2 days); $ 46,796 (5 days)!