**NC Department of Insurance**
**Office of the State Fire Marshal - Engineering Division**
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**919-647-0000**

## Pre-Cast, Bolt-together Concrete Wall Classification (Superior Walls[i])

**Code:** 2018 Energy Conservation Code **Date:** 03/15/2021
**Section:** R402.1.3, R402.1.4
**Code:** 2018 Residential Code
**Section**: N1102.1.3, N1102.1.4

**Question:** *(there are 7 follow-up questions related to this topic in this document)*
Can thin-wall, high strength, bolt-together concrete panels use the WOOD FRAME WALL R-VALUE category to demonstrate compliance with the NC Energy Code?

**TABLE R402.1.2**
**INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]**

| CLIMATE ZONE | FENESTRATION U-FACTOR[b,i] | SKYLIGHT[b] U-FACTOR | GLAZED FENESTRATION SHGC[b,k] | CEILING R-VALUE[m] | WOOD FRAME WALL R-VALUE | MASS WALL R-VALUE[i] | FLOOR R-VALUE | BASEMENT[c,o] WALL R-VALUE | SLAB[d] R-VALUE & DEPTH | CRAWL SPACE[c] WALL R-VALUE |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 0.35 | 0.55 | 0.30 | 38 or 30ci[l] | 15 or 13+2.5[h] | 5/13 or 5/10ci | 19 | 5/13[f] | 0 | 5/13 |
| 4 | 0.35 | 0.55 | 0.30 | 38 or 30ci[l] | 15 or 13+2.5[h] | 5/13 or 5/10ci | 19 | 10 /15 | 10 | 10/15 |
| 5 | 0.35 | 0.55 | NR | 38 or 30ci[l] | 19[n] or 13+5[h] or 15+3[h] | 13/17 or 13/12.5ci | 30[g] | 10/15 | 10 | 10/19 |

h. The first value is cavity insulation, the second value is continuous insulation, so “13+5” means R-13 cavity insulation plus R-5 continuous insulation. If structural sheathing covers 25 percent or less of the exterior, insulating sheathing is not required where structural sheathing is used. If structural sheathing covers more than 25 percent of exterior, structural sheathing shall be supplemented with insulated sheathing of at least R-2.

i. The second *R*-value applies when more than half the insulation is on the interior of the mass wall.

**Answer:**
No.
That category is for, as titled, wood framed walls. Although the footnote “h” discusses cavity insulation and continuous insulation, these notes pertain to wood framed walls which have substantially different heat flow characteristics compared to concrete panel walls.

**Follow-up Question 1:**
Can these walls use the MASS WALL R-VALUE category in Table R402.1.2 to demonstrate compliance with the NC Energy Code?

**Answer:**
No.
Although they do meet the heat content (HC) of a Mass Wall (discussed later), the manufacturer’s literature does not show the insulation evenly covering the concrete panels at the minimum thickness called for in this category. Specifically, the concrete fins (studs), and header are provided with R-3.8 insulation, and the footers are uninsulated. The use of weighted average R-values is not accurate. Also, the R-13 and R-17 called for in the table correspond to wood

furring or a wood-stud wall on the interior with R-13 cavity insulation for Zones 3 and 4, and R-17[1] for Zone 5. Although the concrete panel walls do not prescriptively comply with these requirements in this category, we can use the U-factor table--see discussion further down.

**Follow-up Question 2:**
Can these walls use the BASEMENT WALL R-VALUE or the CRAWL SPACE WALL R-VALUE category to demonstrate compliance with the NC Energy Code?

**Answer:**
No.

The footnotes associated with these categories identify the insulation requirements as requiring continuous insulation or cavity insulation, and as discussed earlier, this cavity insulation is associated with wood-framed walls or furred out walls on the interior of CMU or other wall types. Footnote "o" is of interest, because it allows for a Mass Wall insulation level to be substituted for a Basement wall, but in this case the insulation level is not consistently maintained above the minimum required. This footnote is not carried over to the U-factor Table, whether by oversight or on purpose is not known.

c. "10/15" means R-10 continuous insulated sheathing on the interior or exterior of the home or R-15 cavity insulation at the interior of the basement wall or crawl space wall.

o. Basement wall meeting the minimum mass wall specific heat content requirement may use the mass wall *R*-value as the minimum requirement.

**Follow-up Question 3:**
Can these concrete panels be evaluated on a U-factor basis and compared to the values in Table R402.1.4?

**TABLE R402.1.4**
**EQUIVALENT *U*-FACTORS[a]**

| CLIMATE ZONE | FENESTRATION *U*-FACTOR[d] | SKYLIGHT *U*-FACTOR | CEILING *U*-FACTOR | FRAME WALL *U*-FACTOR | MASS WALL *U*-FACTOR[b] | FLOOR *U*-FACTOR | BASEMENT WALL *U*-FACTOR | CRAWL SPACE WALL *U*-FACTOR |
|---|---|---|---|---|---|---|---|---|
| 3 | 0.35 | 0.55 | 0.030 | 0.077 | 0.141 | 0.047 | 0.091[c] | 0.136 |
| 4 | 0.35 | 0.55 | 0.030 | 0.077 | 0.141 | 0.047 | 0.059 | 0.065 |
| 5 | 0.35 | 0.55 | 0.030 | 0.061 | 0.082 | 0.033 | 0.059 | 0.065 |

**Answer:**
Yes.
This table is set up to allow the user to demonstrate compliance of different, or lesser-used wall construction that are perfectly good but have lesser-known thermal performance than the commonest wall types targeted in the R-value Table 402.1.2. It is incumbent on the manufacturer, designer, and contractor to perform the proper analysis to assign an accurate heat transfer value to the wall or other assembly in question, and then compare it to the values in the table to check for compliance.

[1]The R-17 is not a misprint, it is a nominal R-19 batt in a 5.5 inches stud cavity. This is in the model code language. ASHRAE 90.1 Appendix A identifies this as R-18, and this may be due to slightly different assumptions or manufacturer's data.

**Follow-up Question 4:**
Can the walls be compared to the CRAWL SPACE WALL, MASS WALL, or FRAME WALL Categories in Table R402.1.4?

**Answer:**
Yes.
Of course, the walls can be ordered with various insulation levels from the manufacturer and may be finished differently in the field, so the designer and contractor need to properly evaluate the U-factor of the purchased wall and compare it to the proper category and its respective U-factors. For instance, in the MASS WALL category, when more than half the insulation is on the interior of a mass wall, the footnote "b" requires the wall to meet the lower heat transfer value of 0.07 Btu/hr-ft$^2$-°F for Zones 3 and 4, as opposed to the 0.141 Btu/hr-ft$^2$-°F.

In Table R402.1.4, (U-factor Table) it would not be a violation to try and use the Frame Wall U-factor, unlike the Table R402.1.2 WOOD FRAME WALLS category, because if the U-factor of the concrete panel wall is equal to or lower than the values shown, the materials are not limited to only wood. Of course, the U-factor calculation for the concrete wall must be correctly done.

**Follow-up Question 5:**
What are some approximate U-factors for the commonest insulated concrete panels manufactured by Superior Walls?

**Answer:**
Table 1 tabulates the U-factors for three common panel models. Below the table are some of the assumptions used when determining the U-factors. Please note the final U-factors will vary depending upon what inside sheathing, finishing, or supplemental insulation is applied to the inside, and perhaps to the exterior.

**Table 1: U-factors for Selected Insulated Concrete Panels**

| Model | Height | Uo – w/o concrete footer | Uo – w/ concrete footer | Increased % heat transfer due to uninsulated footer |
|---|---|---|---|---|
| Xi | 4 ft | 0.09525 Btu/ft$^2$-°F | 0.1579 Btu/ft$^2$-°F | 66% |
| | 8 ft 2 in | 0.09189 | 0.1228 | 34% |
| | 9 ft | 0.09160 | 0.1196 | 31% |
| | 10 ft | 0.09151 | 0.1166 | 27% |
| Xi-15 | 4 ft | 0.08238 | 0.1458 | 77% |
| | 8 ft 2 in | 0.07870 | 0.1100 | 40% |

| | | | | |
|---|---|---|---|---|
| | 9 ft | 0.07837 | 0.1068 | 36% |
| | 10 ft | 0.07822 | 0.1036 | 32% |
| Xi Plus | 4 ft | 0.07008 | 0.15245 | 118% |
| | 8 ft 2 in | 0.06594 | 0.09713 | 47% |
| | 9 ft | 0.06558 | 0.09387 | 43% |
| | 10 ft | 0.06537 | 0.09067 | 39% |

**Assumptions:**

1. The walls were assumed to be basement walls, and only the interior air film of 0.68 was used. Since the outside would be covered with dirt, the nominal R-0.17 outdoor air film would not be applicable.
2. The basement will have a floor that covers or abuts the footing.
3. If these panels are used in a manner that has the footing exposed to the space, then use the higher U-factor column, since the uninsulated footers allow a considerable heat transfer.
4. No interior finishes or added insulation was included. In occupied spaces, it is likely that at least gypsum will be added, and that would contribute a modest R-0.45 – 0.50 value to the overall assembly.
5. The manufacturer has more information available for walls that are designed to be fully above grade. It is recommended the reader contact the manufacturer for finish and insulation options.

As shown in Table 1, for NC, the Xi Plus panel has the ability to meet several of the categories, because the U-factor is less than 0.070 Btu/ft2-F. The Xi and Xi-15 would not be able to meet many categories unless additional insulation were added.

The general procedure followed for calculating the U-factors is similar to an example shown in ASHRAE 90.1-2016 User's Manual, Example 5-G.

Another example in ASHRAE 90.1-2016 User's Manual, is located on page 414, Figure G-A. **Modeling Uninsulated Wall Conditions**, is similar to this wall, in that the studs and headers of the wall are projecting beyond the plane of the concrete face, and have a lesser level of insulation. The example recommends "cutting" the projection off flush, and using it as an uninsulated wall section. In the case of the concrete panels, the studs are cut off, and the lower level of insulation is used over the stud area affected. The images of this are as shown next:

**Figure 1: Top View of Wall (Step 1)**

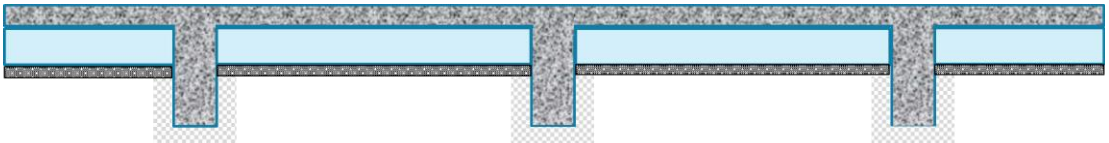


**Figure 2: Top View - Cutting off concrete fins/studs (Step 2)**

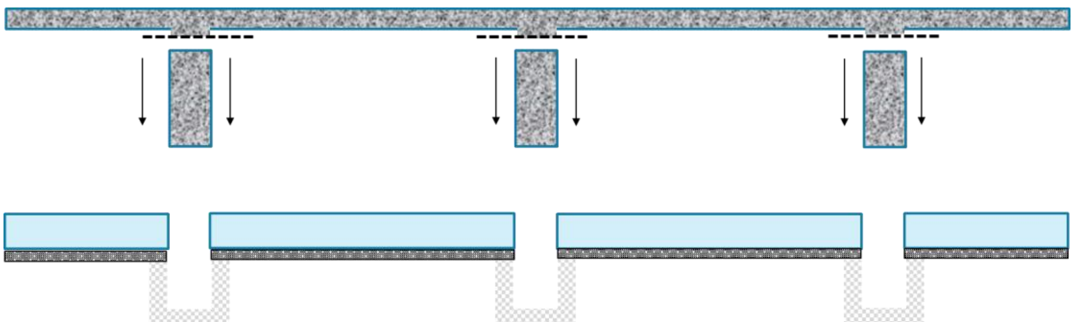


**Figure 3: Top View - Resultant wall to be evaluated (Step 3)**

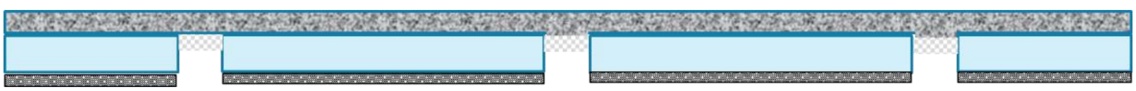
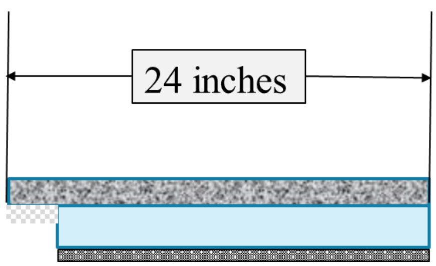


**Figure 4: Top View - Representative Panel Section (Step 4)**




Figures 1 – 4 diagrammatically illustrate the steps taken to put the wall into a format that is a representative 24-inch section that can be evaluated for heat transfer. When dealing with wood walls, the heat transfer is simplified as being just straight through, but with concrete being so conductive, the heat can travel easily into any portion of the concrete face, including the fins, or concrete studs; therefore, the heat can escape at a right angle to the R-3.8 insulation, and does not have to travel to the insulation in straight lines. Therefore, cutting off the fins is a realistic representation of the assembly.

In Figure 4, the overall U-factor was determined by taking the overall U-factor of the insulation layers, and then converting that to an effective R-value (not an average, or weighted average, but an effective R-value), and then adding this effective R-value to the R-value of the concrete, and then during an overall U-factor for the assembly.

In Figure 5, the elevation view of a 24-inch wide by 4-foot-tall panel is shown with its relative dimensions for the header, stud, footer, and the panel. The insulation level over the header and studs is R-3.8, and the insulation level over the panel varies by model, and the footers are uninsulated. Average R-values cannot be used, but the overall U-factor can be determined first, and then turned into an effective R-factor for the entire assembly. If ordering walls for above-grade installation, the manufacturer's website instructs the reader to call for variations.

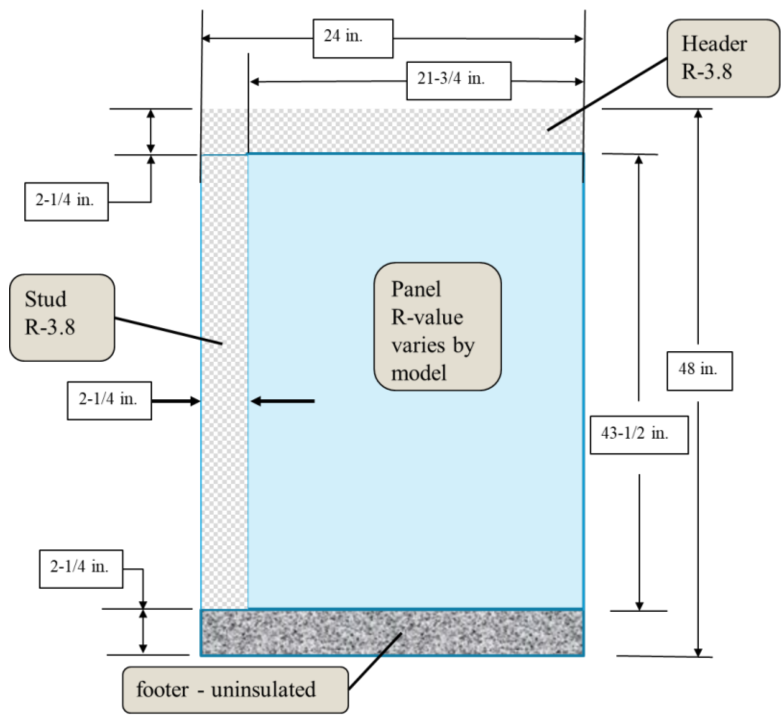



**Figure 5: Elevation view of 4-foot-panel**

**Follow up Question #6:**
Can pre-cast lightweight concrete walls be classified as Mass walls?

**Answer:**
Yes, if they meet the criteria in the code.
The published weight per square foot manufacturer (Superior) qualifies as a mass wall. The weight of the panel face alone, at 1.75 inches is not adequate by itself, but when the weighted average of the concrete studs and headers and footers are added in, they do qualify. There is not enough technical data to determine if mass walls are required to be uniform in mass, but they meet the minimum criteria of weight and as a double-check the Heat Content was calculated for the published data, and they appear to be above the minimum of 6 Btu/ft$^2$-°F.

**Follow up Question #7:**
Can the soil R-values be added to the wall to obtain the overall R-value or U-factors?

**Answer:**
No.
In the 2012 NC Energy Code, there was a footnote "d" that was sometimes misunderstood as allowing, or even requiring the soil R-values to be added to show compliance. That is not the case. The U-factor table values are for the wall itself, which includes an interior air film. The soil resistivity is not included, but they are basement walls, so the code-prescribed U-factor is already assuming they will be below grade. However, in order to compare two walls with different U-factors, the proper way to account for it is to do the heat transfer across each wall, which may vary for each foot of depth, and then compare the overall heat loss from one wall to the other wall. So, the code is not allowing the soil R-values to be added to only a single wall, but is instructing you to account for it when you are going to do a trade off between two walls or the overall building by adding the soil resisitivity to both the prescriptive code wall and the proposed wall, and doing the heat transfer analysis across both, and then comparing it to each other, which may also include the rest of the building. If trade offs are not being done, this step is not requried.

Footnote "d" from 2012 NC Energy Conservation Code, Table 402.1.3:

> d. Foundation U-factor requirements shown in Table 402.1.3 include wall construction and interior air films, but exclude soil conductivity and exterior air films. U-factors for determining code compliance in accordance with Section 402.1.4 (total UA alternative) of Section 405 (Simulated Performance Alternative) shall be modified to include soil conductivity and exterior air films.

Similarly, paragraph A.4.2 of the ComCheck Technical manual (Figure 10) describes a similar process that is used by ComCheck. ResCheck uses similar logic.

**A.4.2 Required UA Calculation**

The MEC does not consider the surrounding soil in determining the basement wall $U_o$-factor requirements (Table 502.2.1, Footnote 5 in the 1992 and 1993 MEC [CABO 1992, 1993]; Table 502.2.1a, Footnote 5 in the 1995 MEC [CABO 1995]; Table 502.2, Footnote 'e' in the 1998 and 2000 IECC [ICC 1998 and 1999]. To directly compare the required $U_o$-factor specified by the code (which does not include soil) to the proposed building $U_o$-factor (which does include soil), the code requirement is adjusted to include the impact of the soil.

**Figure 6: Methodology from ResCheck Technical Guide**

This further describes the process for doing the UA comparision of a code-prescribed wall with a proposed wall, which adds soil impact to both walls to compare apples-to-apples but it is not allowing the user to simply add the soil R-values to a non-prescriptive wall in order to increase the actual R-value of the wall itself.

## Background Manufacturer's Information

The following figures are provided for reference. The user can contact the manufacturer[ii] for specific details.

**Figure 7: Top View from Superior Walls Literature**

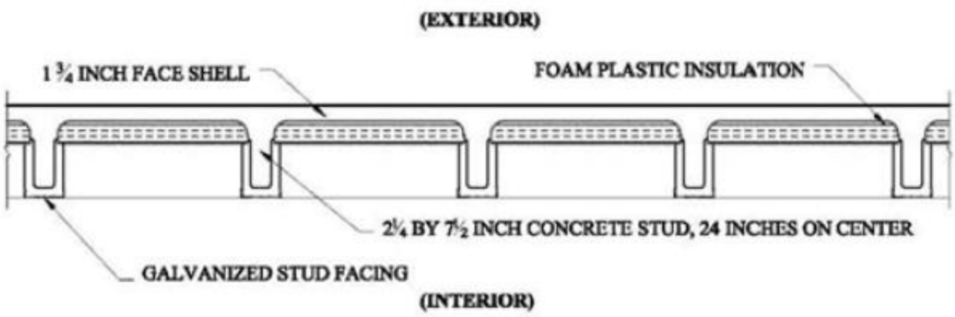
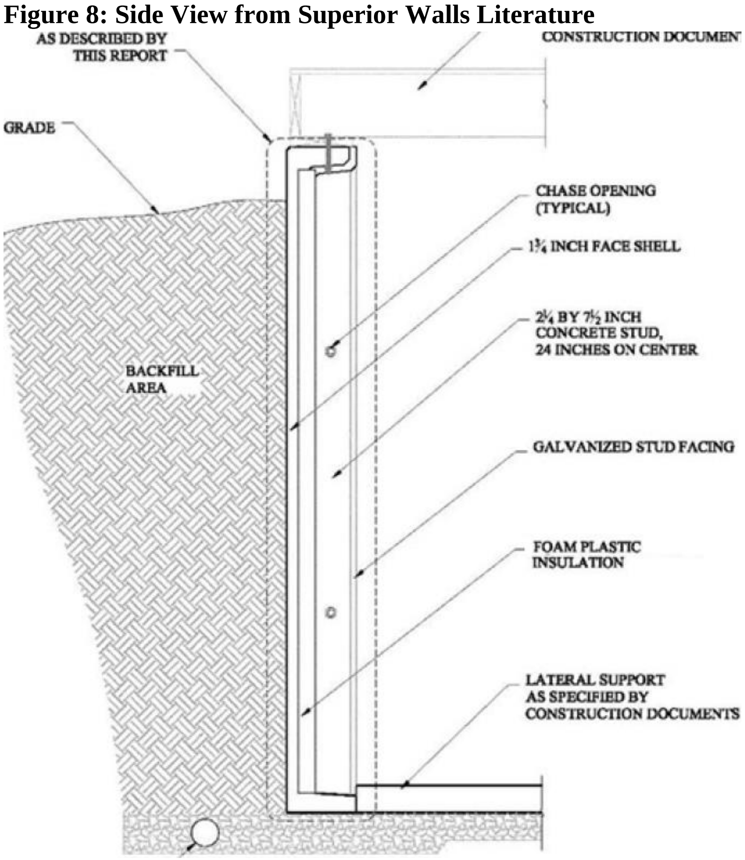



**Figure 8: Side View from Superior Walls Literature**



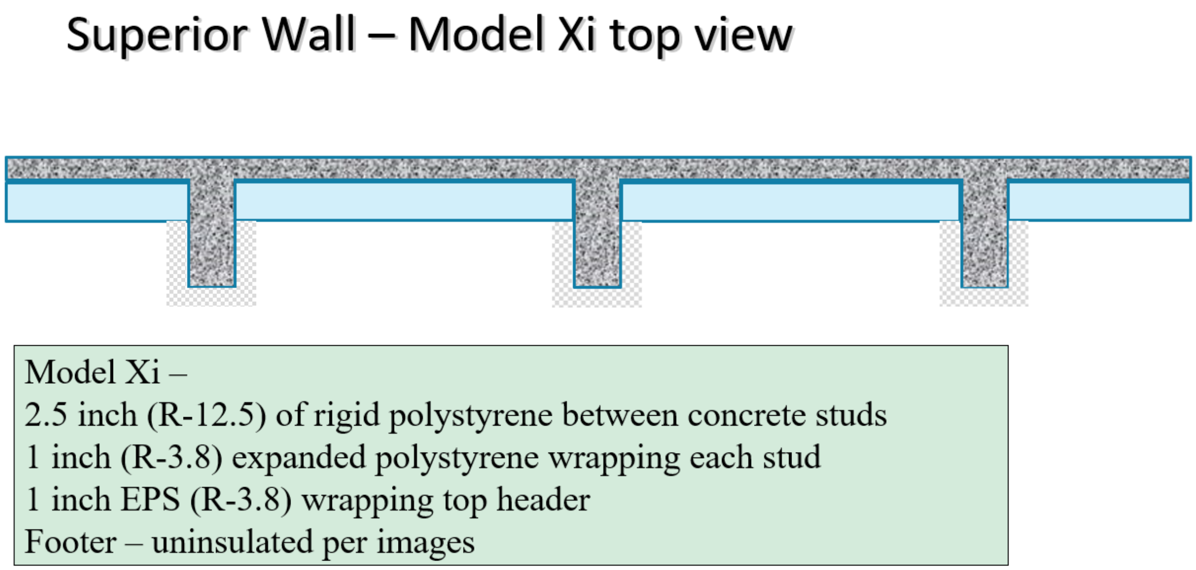



**Figure 9: Superior Walls Model Xi Insulation Summary**

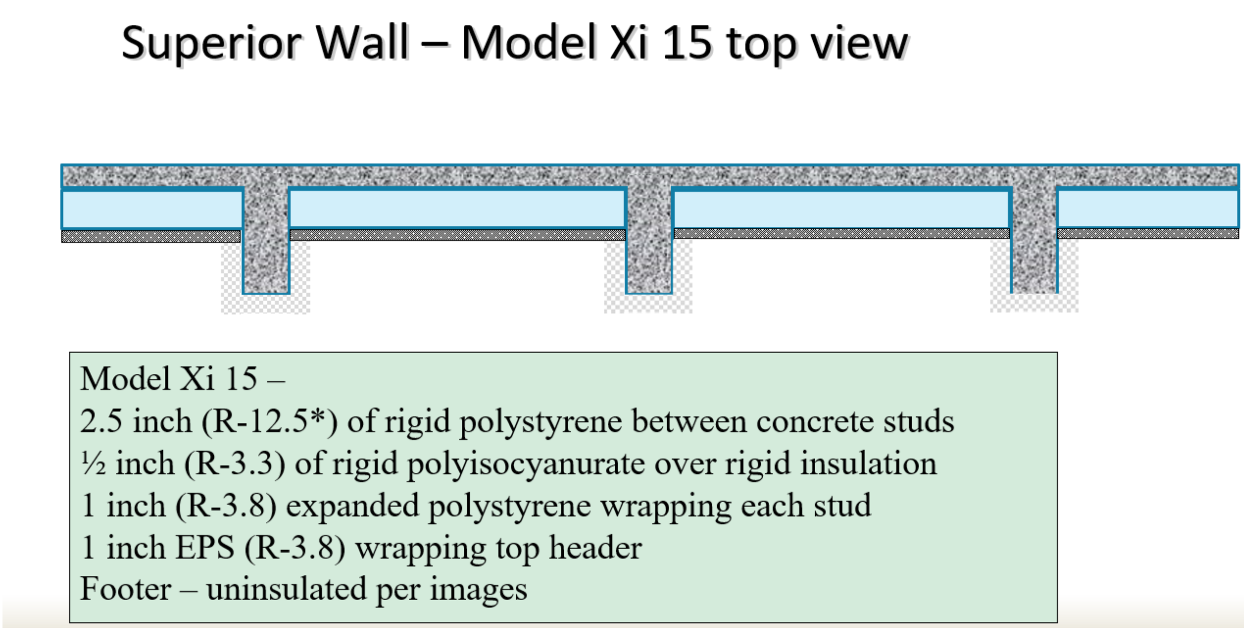



**Figure 10: Superior Walls Model Xi 15 Insulation Summary**

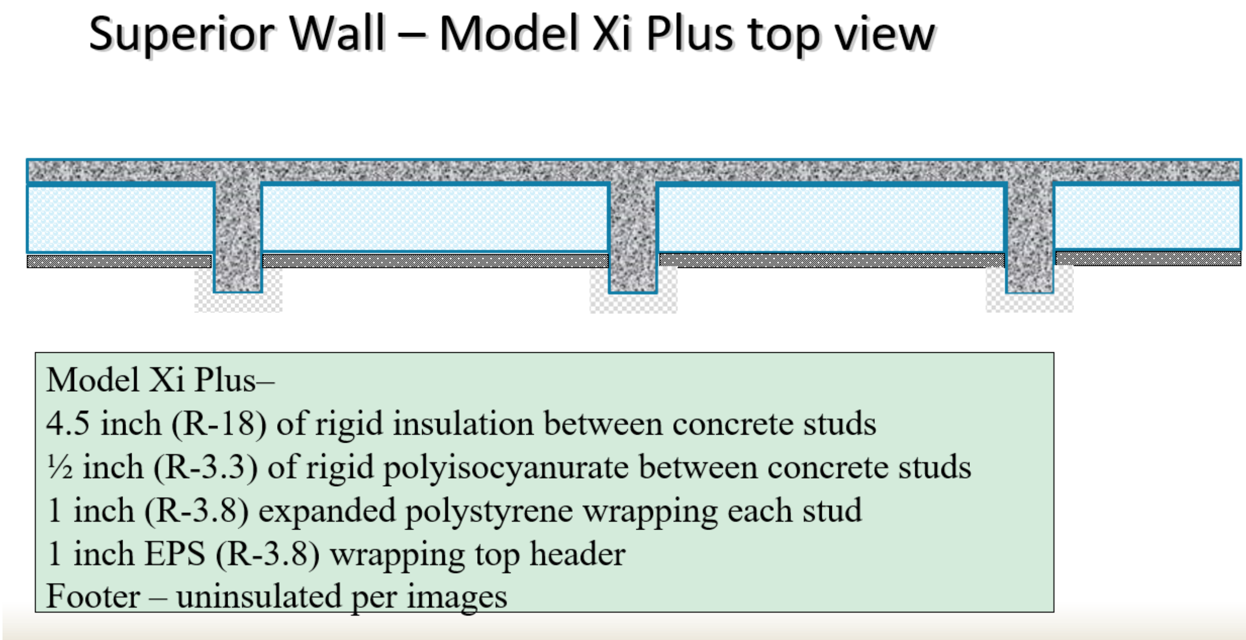



**Figure 11: Superior Walls Model Xi Plus Insulation Summary**

Key Words:
None

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[i]The most common manufacturer in NC is Superior Walls, but the analysis would be similar for like-products

[ii] https://www.superiorwalls.com/