KHH Green Paper:

The Bottom of the Envelope:

Foundations, Slabs on Grade, and Sustainability

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Continuity of the insulated thermal envelope below grade is critical to a building's efficient energy usage in most parts of the United States. Foundation walls are most commonly insulated with vertical insulation on their inside face from the top of the footing (or four feet below grade) up to the slab. Frequently, a horizontal stretch of rigid insulation is placed along a two to four foot wide stretch under the perimeter of the slab on grade. However, this is not always sufficient.

In both heating and cooling climates, the perimeter edge of concrete slabs on grade should be insulated from exterior temperatures. In most cases this is a prescriptive requirement of ANSI 92.1-2005. Insulation at this location is critical, since otherwise the thermal mass of the interior slab (within the conditioned space) is thermally coupled with the exterior temperatures. Heat loss through this perimeter edge can be a significant source of wasted energy, as illustrated in infrared thermal images of building exteriors with no perimeter slab insulation.

Unfortunately, this can be a difficult detail to implement. For foundations with rigid insulation located vertically along the interior face of the foundation wall, a reasonably effective compromise is to cut a 45-degree bevel at the top of the insulation, with the acute top edge of the insulation at the intersection of the top of the slab and the inside face of the foundation wall. This cut can be either field cut or hot-wire factory cut. The appropriate thickness of insulation varies with the climate and type of insulation, but is frequently 2 to 2½ inches thick to achieve the required R-value. Despite its awkward appearance, the detail has been successfully used in a number of buildings, and achieves its purpose of providing thermal separation to prevent heat loss through the slab edge for the entire service life of the building.

Alternatively, foundation insulation could be located on the exterior face of the foundation wall. Although any exposed insulation surfaces need to be protected from degradation and damage, no additional insulation is needed at the slab edge.

The most challenging condition of thermally insulating slab edges is at exterior doors. In some cases, whether the foundation insulation is along the inside or the outside face of the foundation, the top of the insulation can be detailed to jog over to a vertical section directly under the door threshold, which itself is ideally thermally broken and designed to attach to concrete on either side of the insulation. Overhead door openings with no floor thresholds and loading docks are particularly problematic in achieving complete thermal separation.

When the perimeter building wall includes an exterior wythe of masonry, such as brick, with a cavity space, the foundation wall can become quite thick, compared to the structural strength requirement of the wall. In addition, the placement of vertical insulation on either the inside or the outside face of the foundation wall results in a significant thermal bridge across the top of the wall, since the foundation insulation plane is away from the plane of the superstructure insulation. An alternative is to reduce the thickness of the concrete foundation wall to the thickness of the backup wall only (whether it be stud or masonry), extend the rigid insulation down the outside face of the foundation wall to the footing (aligning with the superstructure wall's cavity and exterior insulation plane, if there is one), and building support for the exterior masonry wythe up from the footing with concrete masonry units. This "sandwiching" of the foundation insulation reduces the thickness of the foundation wall and provides a much more continuous insulation plane, while providing the structural support required of the foundation. As with any change to traditional construction methods, the details of such a scheme must be carefully worked out for each project condition.

One way to minimize the material usage in a building foundation is to reduce the depth of bearing from traditional frost depths, and implement a designed frost-protected shallow foundation system. These systems incorporate insulation that extends either vertically along the exterior face of a foundation, horizontally under the footing or out from the face of the footing, or both. A properly designed and detailed shallow frost-protected foundation system can reduce the environmental impact and cost of excavation, backfilling, and concrete usage, as well as be a part of an effective thermal building envelope. There are also strategies for shallow frost-protected foundation designs for unheated buildings. Design guides are available and should be carefully followed, primarily SEI/ASCE 32-01 *Design and Construction of Frost-Protected Shallow Foundations*.

Another scheme that can save material and money on a project's foundations is the use of flowable fill as a substitute for deeper walls and/or footings. One such system that, when applicable, can be very material efficient and economical is to excavate a trench or bearing pad area below frost elevation (or to the required depth of a frost-protected shallow foundation), fill the excavation with flowable fill to a level elevation (such as two feet below grade), and form and place the foundation walls and insulation directly on top of the flowable fill. The flowable fill can be proportioned to achieve a strength anywhere from the equivalent of hardpan earth (100 psi, which is 14.4 kips/square foot), to conventional concrete strength. If the foundations are designed around the lower strength flowable fill, then they are removable in the future with a backhoe, and the mix design requires only about 50 lbs. of Portland cement per cubic yard, while performing the same support for the building as a conventionally formed and placed footing and foundation wall.

Finally, back to foundation wall insulation - Colder climates warrant, and many building codes in these areas require, a four-foot width of insulation of a certain R-value (generally 8 to 12) around the perimeter of a building, down from the slab on grade, a total of four feet - either vertically or horizontally. This serves to arrest the flow of heat between the conditioned building space and the exterior. This interface - the insulated building envelope - can be thought of as wrapping around underneath the building as well. If the average temperature of the earth is 55 degrees, and a building's slab on grade is in direct thermal contact with the earth, then heat is lost down into the earth's thermal mass whenever the buildings are heated to a temperature greater than 55 degrees. Designers of buildings in warmer climates may want this thermal differential to remain, since this helps the spaces remain cool. But for colder climates, it may make economic and energy performance sense to install insulation under the slab on grade - perhaps one or two inches of rigid insulation or spray-applied foam insulation. If the spray foam is closed cell, it will serve as an air and vapor barrier, possibly eliminating the need for an additional vapor barrier sheet product.