Detailing a Superinsulated Slab

A less-expensive and energy-efficient foundation for a house

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Photos: Steve Demetrick, except where noted

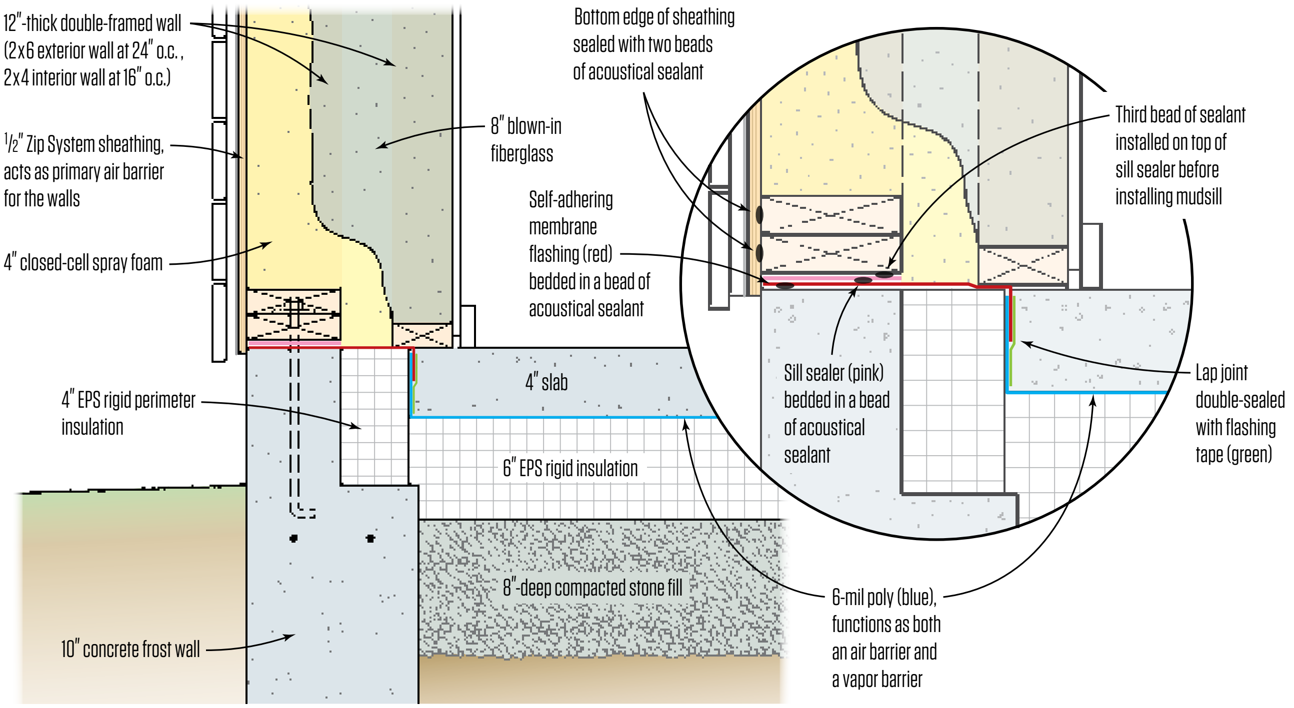
Every home can be thought of conceptually as a six-sided box, with a lid (the roof or topmost ceiling), four sides (the walls), and a bottom (the basement floor or the slab). From an insulation standpoint, people often assume that insulating the slab is a waste of time because it sits on the ground. But while the slab may generate less heat loss than the walls or the roof, it should definitely be included when addressing a home's overall insulation needs.

PROPORTIONAL INSULATION

But how much insulation is needed in the slab? The answer comes from looking at the house as a system—at the amount of insulation, along with level of airtightness and the energy requirements, for the whole house. The effectiveness of insulation tends to max out if it's not increased proportionally in all areas of the house. So if we insulated the lid and walls to high levels, an uninsulated slab would be a weak point in the insulation envelope—increasing R-values in the lid and walls would have little effect without increasing the insulation in the slab as well. For example, if we started with an R-100 roof assembly, increasing the roof to R-150 would have little impact on the home's performance unless we proportionally increased the insulation levels in the walls and the slab.

The good news is that the temperature delta (difference between highs and lows) in a slab is the lowest and most constant of any of

Airsealing Detail at Concrete Slab



the sides of the box. This is due primarily to the fact that the slab is coupled with the ground, which, for the most part, maintains a pretty steady temperature. Because of the ground coupling, the R-value requirement for the slab can be significantly less than that of the above-grade walls or the ceiling.

A proportional rule of thumb for a high-performance home design that uses a slab-on-grade foundation system is that the R-value of above-grade walls should typically be roughly half the R-value of the lid. Proportionally, the R-value of the sub-slab insulation should be half that of the above-grade walls, or roughly one-quarter the R-value of the lid.

For this project, we followed those proportions fairly closely. We calculated various insulating scenarios using Passive House planning software and decided on a roof R-value of about R-92, with the above-grade walls at roughly R-55, and the sub-slab insulation at around R-25.

CHOOSING THE TYPE OF INSULATION

Once we had determined the target R-value, choosing the proper insulating material was next. Rigid foam insulation seemed to be the best choice, and we chose expanded polystyrene (EPS) IX foam for a number of reasons. This type of foam is engineered and rated for ground contact, unlike many off-the-shelf rigid foams. And it is treated with borates to guard against insect damage.

EPS foam also has less impact on the environment than other types of foam, because of the blowing agent it's manufactured with. The EPS we used was processed in Rhode Island fairly close to where the house was being built, again reducing the carbon footprint of the material.

On top of all that, EPS insulation was the least expensive among our choices based on R-value per inch, and it came in the full thickness we needed. It's rated at R-4.13 per inch, so we needed a thickness of 6 inches to meet our requirement of R-25—and the EPS insulation was readily and conveniently available in 6-inch-thick panels.

PAY ATTENTION TO THE EDGES

Besides the insulation between the ground and the slab, the most critical but often ignored component of the slab-insulation system is the perimeter insulation around the edge of the slab (see "Airsealing Detail at Concrete Slab," above). The perimeter insu-

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lation insulates the slab from direct contact with the foundation wall, which is most susceptible to heat loss because of its direct contact with the outside air. The perimeter slab insulation and the sub-slab insulation together wrap the slab on five sides and isolate it from any conductive heat loss through the foundation or the ground.

The house walls were to be 12 inches thick and double-framed with 2x6s 24 inches on-center for the exterior wall frame, and 2x4s 16 inches on-center for the interior wall frame. The foundation system consisted of 10-inch-thick concrete frost walls that extended 4 feet into the ground with a slab-on-grade inside the walls. The thickness of the frost walls gave us plenty of material to form a step in the top of the wall, creating a 6-inch-wide top surface to support and anchor the 2x6 exterior wall. The remaining thickness of the frost wall stepped down 8 inches to provide a 4-inch-wide shelf for the perimeter slab insulation **(1)**.

A 4-inch-thick by 8-inch-tall piece of EPS would then fit on the foundation shelf to be our perimeter insulation, and the 6-inch sub-slab insulation would butt into the perimeter insulation 4 inches down from the top. The concrete for the slab would fill the remaining 4 inches to the top of the perimeter insulation, creating a completely isolated and thermally broken slab.

SUB-INSULATION PREPARATION

Once we'd finalized the insulation strategy for the slab, we began preparing the ground below the insulation, also taking steps to deal with groundwater, water vapor, and radon management. The design decision to use the top surface of the slab as the finished floor made the detailing much easier because we didn't need to isolate the concrete slab from an additional layer of finish material.

The existing site conditions called for elevating the new slab and foundation above the existing grade. Technically, this arrangement is a "slab above-grade." We brought in fill and elevated the grade to put the slab at a height roughly 16 inches above the surrounding grade **(2)**. Raising the slab helped to minimize the risk of problems from groundwater.

For part of the fill under the sub-slab insulation, we compacted 8 inches of ¾-inch stone, which also acted as a capillary break between the compacted ground and the concrete slab. When the sub-slab bed was finished, the contractor who had brought in the stone

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told us that ½-inch pea stone would have been easier to screed and compact flat: Lesson learned.

The layer of ¾-inch stone provided a means to collect any sub-slab radon. We ran 4-inch-diameter perforated pipe horizontally in the stone bed and connected it to a riser that exits the home through the roof, for a passive radon-removal strategy **(3)**. If needed in the future, an in-line fan, installed in the riser where it passes through the attic, would make the system mechanically active.

LAYING DOWN THE INSULATION

The insulation installation began with the 4-inch by 8-inch perimeter pieces that sat on the foundation shelf. To cut the 6-inch EPS sheets, we sawed through from both sides using a Festool track saw **(4)** and finished the cut with a reciprocating saw **(5)**. This approach gave us square and accurate cuts for a tight-fitting, gap-free installation and eliminated the need for any glue or fasteners at the perimeter pieces.

As the pieces went in, we fine-tuned the crushed stone under each one so that it would be evenly supported. If more stone was needed, we added a little from a 5-gallon bucket. We raked the stone smooth **(6)** and then flattened it with a flat shovel **(7)**. To make sure the stone stayed at a consistent level, we checked it using a laser and a site-built "T" made of 2-by stock with the heights marked on it **(8)**. The "T" also helped us tamp the stone flat.

The foam sheets needed to be cut to fit around posts and the drain lines that had been stubbed in to fall inside an interior wall when the interior walls were framed. The plumber had left one of those pipes above the level of the stone, using temporary props to set the pitch of the pipe. When the foam panels went in, we replaced the props with solid foam and cut a channel around the pipe **(9)**. We sealed around the pipe with canned foam and then set the cap for the channel in place. We oversized the holes slightly around the other stubs to facilitate installation of the foam panels and filled any gaps with canned foam.

MULTITASKING PLASTIC SHEET

After we finished fitting the insulation, we covered it with a sheet of 6-mil polyethylene that serves a number of functions. It acts as a backup to prevent capillary water movement from the ground to the slab, and it also serves as our vapor barrier in the

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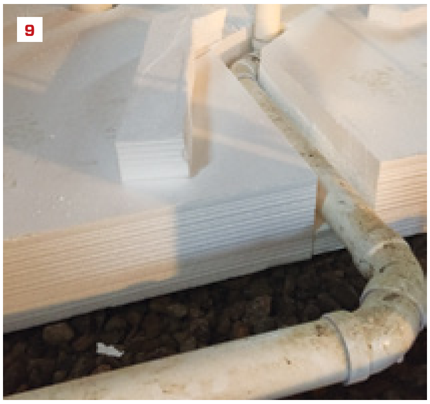

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system, preventing any moisture from rising through the assembly and making the slab damp. Another reason for using the polyethylene sheet on top of the rigid insulation was to keep the wet concrete from seeping between—and under—the insulation panels during the installation. We had heard horror stories and seen scary pictures of wet concrete getting under insulation and causing the panels to "iceberg" or float up through the wet mix before it hardened.

But the most important function of the 6-mil polyethylene sheet in this assembly was to provide an air barrier for the slab. The challenge was finding a way to connect the poly sheet to the air barrier around the rest of the house.

Usually the slab is poured before the framing starts. In that case, we would simply drape the poly sheet over the foundation wall and integrate it into the mudsill assembly, which is part of the wall air barrier. But we were building this house in the winter in New England, when pouring an exposed slab would be difficult. In addition, the slab surface was to be the finished floor, and the winter snow and weather would have destroyed it. So we opted to frame the exterior walls of the house first, which meant we had to devise a strategy for connecting the air barriers after the walls were framed.

We relied on Zip System wall sheathing for the primary air barrier for the above-grade exterior walls—a detail that we've used successfully numerous times. With the slab pour delayed, we decided to install a 10-inch-wide piece of adhered-membrane flashing on top of the foundation before we started framing. We bedded the flashing in a bead of acoustical sealant and applied a second bead of sealant on top of the flashing before installing the sill seal and the mudsill **(10)**. A strip of flashing about 5 inches wide was left inside the 2x6 frame. Later, we peeled the backing from the flashing and adhered it to the edge of 6-mil poly to connect the air barriers **(11)**.

At all electrical and plumbing penetrations through the slab, we securely taped the poly sheet to the pipe or conduit using an all-weather flashing tape **(12)**. We also used flashing tape to reinforce and double-seal the seam between the flashing membrane and the poly. Two support posts in the house sit on concrete footings that are roughly level with the top of the foam panels. We wrapped the post bases with membrane flashing, extending it well over the level of the concrete, and then secured the poly to the membrane with flashing tape. We double-checked all the taped

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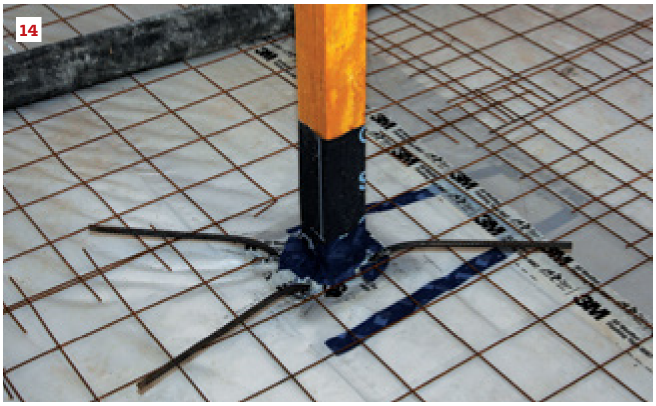

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connections to ensure the continuity of the air barrier after the slab was poured.

THE POUR

Before ordering the concrete, we placed 6-inch by 6-inch steel reinforcement mesh over the entire slab area, cutting it where needed to fit around pipes or posts **(13)**. To integrate the post footings with the slab, we included four lengths of rebar at the corners of each footing and bent these over the wire mesh **(14)**.

The lot was fairly tight and access for the concrete trucks was limited, so the concrete contractor opted to pump the mix in through the front door. The contractor set up a laser level—in an area that was formed off to stay dry—to check the slab level as the mix was distributed and screeded **(15)**. The height of the finished slab followed the top of the perimeter insulation pretty closely.

Because the slab surface was to be the finished floor of the house, the contractor created a smooth, polished surface using a power trowel **(16)**. Within a few days we were able to begin framing the inside 2x4 wall of the double exterior walls. This inside wall rests primarily on the thermally-broken insulated slab.

As a postscript to this particular project: We did a blower-door test when the air barriers for the walls and ceiling were completed, but before the slab insulation and poly were installed. We did a second test after the slab was poured with the completed sub-slab air barrier. The numbers from the two tests were very similar—enough so to conclude that the slab and the poly-sheet air barrier do not play a significant role in the airtightness of this house. Nevertheless, we still think it's worth taking these measures for the long-term integrity of the air barrier and will continue the practice. Different soil conditions in a different location might test differently.

In the end, we achieved our primary goals: creating a well-insulated slab that proportionally matched the insulation levels of the rest of the house, and ensuring that the home would meet a high level of thermal performance.

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Photos on this page: Roe Osborn