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RADIANT HEAT WITH CONCRETE

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Efficiency often drives the evolution of our market places. Think back to the cars driven 20 years ago compared to those of today. Back then, bigger was better, and gas guzzling was not a concern. As fuel became more expensive and even scarce during certain periods, the auto industry was forced to create cars that were smaller and more efficient. A similar evolution is occurring in the heating industry. As a result, the efficiency of the residential furnace has risen dramatically over the last 15 years. As fuel costs continue to climb, the effectiveness of our heating systems must continue to improve.

One of the new stars on the heating market is radiant floor heating (see Fig. 1). Although North Americans are just starting to realize its benefits, radiant floor heating has been used successfully in Europe for over 50 years. The concept is simple: warm water circulates through tubing that is buried in the floor, keeping the heat where it is needed most. Building occupants are then comfortable at a lower thermostat setting (see Fig. 2), leading to a reduction in fuel costs of up to 40% (see first reference).

Comfort and efficiency are two reasons North Americans are turning to radiant heat. More conventional forms of heating address the heat loss of the structure, while radiant floor systems address the heat loss of the human body. Radiant floors take advantage of concrete's thermal mass: they absorb and store heat, then conduct it directly to the feet and to objects in the room that in turn re-radiate heat. Radiant heat warms objects, not just the air. Air quality is improved since there is no

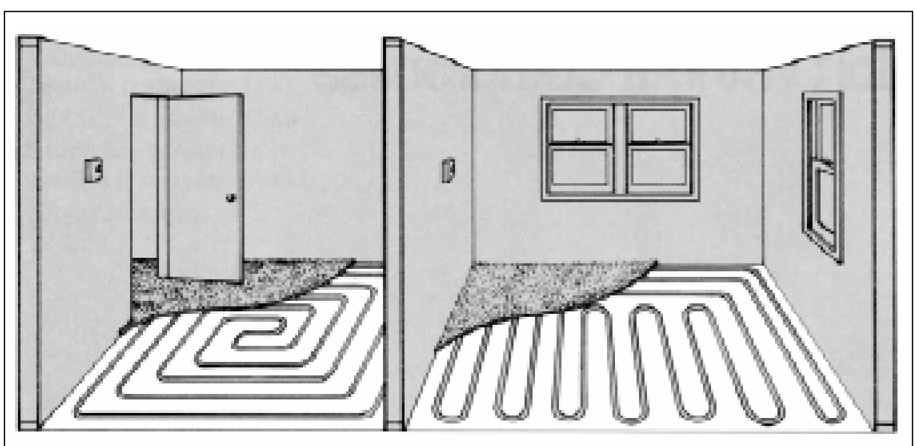

Fig. 1. Radiant heating is hidden within the floor, where it provides exceptional heating without the clutter of radiators or the drafts of forced air.

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hot air blowing dust and allergens throughout the building. Also, less air escapes each time windows or doors are opened.

A distinct advantage for both comfort and efficiency of radiant floor heating is the ability to zone the heat, placing it exactly where it is wanted and needed. Since the flexibility of these systems is increased due to zoning, they are especially well suited to retrofit or remodeling construction.

Tubing

Although steel, copper, and rubber have been used as tubing in radiant floor heating systems, one material is most compatible with concrete in the slab: cross-linked polyethylene or PEX. Unlike other plastic and metal tubing materials, PEX tubing cast in concrete is capable of lasting the life of the structure.

PEX tubing was introduced in Europe in the 1960s and offers properties not available with other plastics. PEX is extremely durable due to the strengthened molecular structure it acquires during cross-linking. Because of its flexible nature, it can be installed quickly and easily, and its creep-resistance reduces friction levels and the stress of linear expansion when embedded in concrete.

PEX tubing was first introduced in America in the early 1980s. Ideally suited to radiant floor heating and plumbing, PEX is gaining popularity in the U.S. as the material of choice for these applications. Just as not all metals are alike, not all forms of PEX are alike. Different manufacturing processes produce different products with varying degrees of quality. When specifying PEX products, engineers should check on the quality of the manufacturer and manufacturing process, history of producing PEX and type of PEX product. The specified material should conform to the applicable ASTM and other consensus standards (see references).

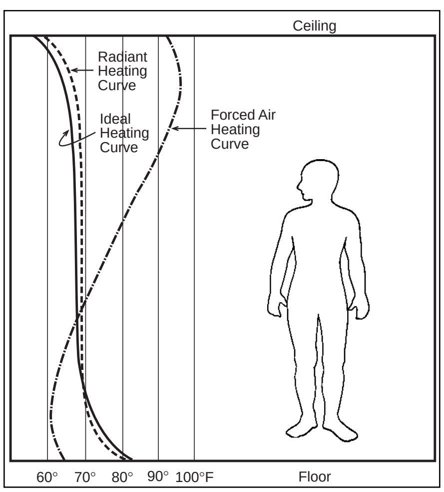

Fig. 2. Heat profiles from floor to ceiling show how radiant heat provides close to the ideal temperature, whereas conventional heating deviates from the ideal.

A Large Radiator

Engineers are discovering that concrete supplies a perfect complement to the benefits of radiant floor heating. Slab-on-grade applications provide an easy method of tube installation and concrete slabs are uniquely capable of recovering the thermostat setting after an influx of cold air. Open doors, large windows and even high air changes will not affect the building's temperature as much as with a forced air heating system. The heat is retained in the concrete, so the room stays warmer longer without extreme temperature fluctuations. This makes radiant floor heating in concrete slabs ideal for both commercial and residential applications. With the recommended high density insulation placed below the slab, the floor becomes a large, mild radiator.

Design and Construction

The key to designing a radiant floor system for a concrete slab is accurate heat loss calculations. The concrete slab acts as a giant radiator to heat the building, so it is important to reduce heat losses by using insulation. Most radiant floor heating manufacturers have computer programs that calculate the heat loss of particular concrete slabs. These programs are very thorough: they take into account everything from water table temperatures to slab depth to floor cover R-values to determine heat loss.

Once the design is complete, installation of a radiant floor system in a concrete slab is simple. Typically, the PEX tubing is either stapled to the insulation or tied to the wire mesh or rebar. The tubing is fastened to the substrate or reinforcement to hold it in its layout configuration and prevent it from floating to the surface during concrete placement (see Fig. 3). In commercial applications, tubing is often placed 300 mm (12 in.) on center. PEX tubing for radiant heating has an outside diameter of 13 to 19 mm (1/2 to 3/4 in.).

Fig. 3. Concrete is placed over tubing for a radiant floor.

PEX tubing is extremely durable and capable of handling the majority of activity on the job site. Normal care will provide adequate protection. If concrete buggies or pumping lines are being moved across the tubing, planking laid over key areas will protect the tubing. This will also protect the tubing layout pattern from being disturbed and causing delays during the concrete placement.

PEX tubing should have a minimum of 50 mm (2 in.) of concrete over the top of the tubing. Refer to the appropriate building codes for additional requirements.

Long-Term Performance

The benefits of radiant floor heating are well-documented and easily recognizable in the residential marketplace both in new construction and retrofit applications. As the radiant industry grows, it continues to expand into the commercial arena where its advantages in efficiency are quickly evident, particularly when heating spaces with large cubic volumes of air.

Radiant floor heat in concrete makes sense. Numerous applications over many years have shown that PEX tubing does not degrade when embedded in concrete, eliminating concerns about long-term durability. Well known for the superior comfort and efficiency it delivers, radiant floor

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heating increases the value of any structure in which it is placed. If you're placing a concrete floor, consider installing PEX tubing, because it can always be hooked up at a later date. Radiant heating can also be added to existing floors by embedding the tubing in a floor topping. See PCA's *Resurfacing Concrete Floors* (IS144) for information on overlaying concrete floors.

Two interesting case studies that follow illustrate the uses and benefits of radiant heat for both interior and exterior use.

The Casper, Wyoming, Service Center Warehouse

The city of Casper, Wyoming, saw firsthand the difference radiant floor heating made for comfort and energy efficiency. The city moved a maintenance and storage facility for utility equipment from the old 2300 m^2 (25,000 sq ft) site to a new 6500 m^2 (70,000 sq ft) building in 1987. The older building had 7.6 m (25 ft) ceilings and was heated with forced air while the new building has 12.2 m (40 ft) ceilings and is heated with a radiant floor in the concrete slab. The chart below shows the seasonal averages of energy consumption for the two buildings. The data for the old building was collected from December 1983 through February 1987. The data for the new building was collected from August 1987 through February 1991.

Despite the fact that the floor space nearly tripled and the ceiling height almost doubled, the fuel consumption only doubled. Radiant floor heating makes the best use of the large slab

Annual Usage	Old	New	Change, %
Total CCF_{gas}	26,340.000	57,684.000	+119
CCF_{gas}/SF_{space}	1.050	0.820	-22
CCF_{gas}/CF_{space}	0.042	0.021	-51
$\$/CF_{space}$	$0.016	$0.008	-51
Total Cost	$10,273.00	$22,497.00	+119

area used in warehouse-type structures. Comfort levels also remain consistent as large volumes of warmed air are not escaping to the outside each time loading dock doors are opened. Since radiant heat primarily warms objects, not air, the recovery time is fast when the doors close.

The Holland, Michigan Snow & Ice Melt Project

Flexibility refers not only to the property of the tubing but also to the many applications of radiant slab heating. Its efficiency and comfort extend to another area—snow and ice melting.

Fig. 4. Clear streets and sidewalks are safer for walking and driving and attract business to the area.

In the summer of 1988, the city of Holland, Michigan began planning a renovation project for their downtown area. The intent of the city fathers and local businesses was to beautify the downtown area with pavers, planters, and other landscaping to add to the area's historic features. The problem was that Holland receives between 2.0 and 2.5 m (75 and 100 in.) of snow each winter. In a relatively short period of time, the new improvements might look old and beaten from the salt and snow removal equipment.

The local electric power utility was also faced with the task of reducing their water temperature prior to releasing the water back into the river. Working together, the two parties found a mutually beneficial solution.

Today, five city blocks of street, adjacent sidewalks, and two parking lots are free of ice and snow all winter (see Fig. 4). The system operates with water at a temperature of 26°C to 32°C (80°F to 90°F). The water is heated through an exchanger from the power plant. The water is then cooled as it circulates through the streets, returning back to the river at about 13°C (55°F). In essence, the city gets free heat and the streets have become the cooling tower for the power plant.

This has proven to be an economic boon for the area. People can park and walk without slipping or having to climb over mounds of piled snow. Locals bring visiting friends and relatives downtown to see the system. Much of their time is spent walking the city streets, shopping and stopping for a bite to eat. Because the system is under constant circulation, the streets and sidewalks remain clear and never experience the stresses caused by freeze-thaw cycles. This, and the elimination of snow removal equipment and deicing chemicals, contributes to reduced maintenance costs and a longer pavement life.

References

A Comparative Energy Efficiency Analysis of Wirsbo Hydronic Floor Radiant Heating Systems: Final Report, Londe-Parker, Inc., (Ballwin, Missouri), September 1991.

ASTM F 876, *Specification for Crosslinked Polyethylene (PEX) Tubing*

ASTM F 877, *Specification for Crosslinked Polyethylene (PEX) Plastic Hot- and Cold-Water Distribution Systems*

CAN/CSA Standard B137.5M-96, *Standard for PEX Tubing*

ANSI/NSF Certification 14 (Ingredients, materials, products, quality assurance, and marking for thermoplastic and thermoset piping systems)

ANSI/NSF Certification 61 (Toxicity for plumbing materials)

ICBO Evaluation Report No. 4407 (Piping with oxygen diffusion barrier)

ICBO Evaluation Report No. 5142 (Piping with no oxygen diffusion barrier)

Partial list of items to consider when specifying and constructing radiant heated concrete floors:

- Perform heat loss calculations
- Specify minimum length of tubing per square floor area
- Plan spacing (typically 300 mm or 12 in.) and layout of tubing (zig-zag, looped, or other configuration)
- Use extruded polystyrene for subfloor insulation, specify minimum thickness
- Staple tubing to subfloor/insulation or tie to wire mesh or steel reinforcement
- Prevent crushing of tubing
- Maintain minimum 50-mm (2-in.) cover over tubing
- Use a conventional concrete mix, 20 MPa (3000 psi) minimum
- Specify ASTM F 876 and F 877
- Consult local building code

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