Construction and Energy Costs for Radiant System in California Bay Area

Symposium: Optimizing Radiant Systems

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Agenda

• Project overview
• Case study building
• Cost data
• How to reduce construction costs
• Energy performance
• How to reduce energy costs
Project Overview

Objectives
- Provide cost data for radiant systems in California Bay Area
- **Suggest opportunities to reduce cost and improve energy efficiency**

Approach
- Provide baseline and alternative design options
- Cost estimation by contractors
- Energy performance evaluation by EnergyPlus
Background

Status of VAV

- Predominant HVAC approach
  - Optimized construction process
  - Competitive market
- Design guidelines
  - Advanced VAV System Design Guide
  - ASHRAE Guideline 36

Status of radiant

- Small market share, mostly in low-energy and ZNE projects
- Limited design guidelines and tools
- Lack of familiarity by building construction industry
Case study building

Real building with radiant design

Simplified floor plan

- Open office with meeting rooms
- Total floor area 112,000 ft²

Building features

- Solar load control
  - Window-wall ratio 40%
  - Glazing U-value 0.4 and SHGC 0.28
  - Exterior overhang
- LED lights and daylight control
- Advanced plug load control

Image: EnergyPlus model of the case building
Radiant slab design

- High thermal mass radiant system with tubes in every ceiling slab
- 10 radiant zones per typical floor
- 13 DOAS VAV zones per typical floor
  - Demand controlled ventilation in large conference rooms

Radiant slab zoning plan (part of typical floor)

DOAS zoning plan (part of typical floor)
Radiant system design

Dedicated outdoor air system (DOAS)
- Design air flowrate: 19,400 cfm
- Changeover heating/cooling coil

Central plant
- Four-pipe air source heat pump
- Serves both DOAS and radiant slabs to reduce cost

Radiant design schematic
Construction costs

HVAC and controls only

Common mechanical elements NOT included

San Mateo labor rate

- Sheet metal: $123/hr
- Piping: $118/hr

Results

Average: $38.9/ft²
Construction cost breakdown

- Equipment: $8.1 (Contractor A), $6.9 (Contractor B)
- Sheet Metal: $0.3 (Contractor A), $0.4 (Contractor B)
- Labor: $4.0 (Contractor A), $4.3 (Contractor B)
- Material: $1.4 (Contractor A), $1.6 (Contractor B)
- Piping: $14.3 (Contractor A), $14.2 (Contractor B)
- Subs/Misc: $5.7 (Contractor A), $4.7 (Contractor B)
- Services/Markup: $5.6 (Contractor A), $6.1 (Contractor B)

20% of total cost: Equipment and Sheet Metal

44% of total cost: Labor
Piping labor breakdown

Radiant slab: $6.6/ ft$^2$
Floor distribution + risers: $2.9/ ft$^2$
Equipment Cost

Radiant equipment: $2.82/ ft²
DOAS AHU: $0.79/ ft²
ASHP: $2.71/ ft²
Impact of labor rate

- National average labor rate: $85/hr
How to reduce radiant system cost?
Facilitate the use of radiant mat

Costs

- Mats: \(~$4 - 6 /\text{ft}^2\)
- Loops*: \(~$6 - 8 /\text{ft}^2\)

Limitations for mats

- Maybe limited by shape and size of radiant zones
- May not be cost effective for smaller jobs (assembled on a made-to-order basis)

* For 6-inch tube spacing
Hydronic distribution layout: Multiple risers vs. single riser

- Strategically locate risers to minimize piping: 30% piping reduction
- Cost savings: $2.5/ft²
Use larger radiant tube spacing: 9” vs. 6 in”

- Loop design: ~$1.7/ft² of labor cost savings
- Mat design: 5-15% cost savings and 5% labor savings
- Thermal capacity: initial evaluation shows similar dynamic performance
Other approaches to reduce radiant costs

- Large vs. small radiant zones
- Consider no radiant tubes in ground or roof slab
- Use passive supplemental system strategically (For example, ceiling fans)
- Hydronic system type: 4-pipe vs. 2-pipe vs. mixed 4 and 2-pipes
- Reduce central plant equipment size with load shifting
- More details in the report*

HVAC annual site electricity

Total: 2.9 kBtu/ft²

- Cooling is 41% of total energy
- Fan energy is 34% of total energy
Central plant cooling and heating load

- Cooling energy use in winter months
- DOAS uses significant energy
How to reduce radiant system energy cost?
Potential for economizer to reduce cooling energy

Potential full airside economizer hours

Plant Cooling Load (kBtu/hr)

Temperature (°F)

06/15 24:00:00
06/16 12:00:00
06/16 24:00:00
06/17 12:00:00
06/17 24:00:00
06/18 12:00:00
06/18 24:00:00

Radiant_DOAS  Radiant_Slab  OADB  DOAS SAT
Implement load shifting strategy to reduce demand

Radiant slab operates 6 am - 6 pm

Radiant slab operates 0 am-12 pm
Implement load shifting strategy to reduce demand

- Whole building electricity cost
- High performance design to minimize heat gain is key
Optimize DOAS supply air temperature control

- Neutral SAT
- OA reset
- Large deadband

Neutral Supply Air Temperature

Single Setpoint (OA Based Reset)

Deadband_CC OA Reset
Optimize DOAS supply air temperature control

- Use large heating/cooling setpoint deadband
- Reset supply air temperature higher with space humidity feedback
Approaches to reduce energy cost

- Take advantage of free cooling with waterside economizer (mild weather in particular)
- Implement load shifting strategy to reduce demand charge and equipment size
- DOAS design and control are critical
  - DOAS supply air temperature control is IMPORTANT
  - Avoid unnecessary oversizing of DOAS by strategically distributing the ventilation air
  - Decouple cooling source for radiant slab and DOAS in humid climates
- More details in the report*

There are opportunities for improving current practice!

Questions?
Thank You

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