ITRC Technology Information Sheet

Vapor Intrusion Mitigation Team | December 2020

Sub-slab Ventilation (SSV)
Active Mitigation Systems (uses electric fan)

This ITRC Technology Information Sheet provides basic information when using a fan to ventilate the sub-slab environment to prevent and/or reduce sub-slab vapor concentrations and mitigate the potential for vapor intrusion at a given building. Any system that draws gas from below a floor slab for the purpose of sub-slab depressurization (SSD) will also result in some degree of sub-slab ventilation (SSV). SSV can be installed in buildings, at or near vapor intrusion sites, where the permeability of the material below the floor is high, such that ventilation reduces sub-slab concentrations to levels too low to pose a potential indoor air quality concern. Ventilation will occur at these properties even in areas where the sub-slab vacuum is too low to be reliably measured considering instrument sensitivity and baseline fluctuations. The key differences between SSD and SSV are the performance goals and metrics, and the importance of the relative permeability of the floor slab and the material below the slab.

Overview

SSV is an active engineering control employed to mitigate potential vapor intrusion (VI) for volatile organic compounds (VOCs) into buildings. The difference between SSV and sub-slab depressurization (SSD) is that the design objective for SSV is to reduce vapor concentrations below a structure's slab to levels that are low enough to maintain acceptable indoor air concentrations above the slab, regardless of whether there is a consistent or measurable vacuum below the floor. Generally, this is practical where the material below the slab has a high permeability (e.g., coarse-textured, granular fill materials, drainage mats, aerated floors) that allows high air flow rates to be induced below the slab with minimal applied vacuum. SSV is best suited to cases where sub-slab vapor concentrations are relatively low to begin with, and reduction to concentrations less than levels of concern can be readily achieved.

SSV occurs to some extent during the operation of an SSD system and vice versa. The ITRC ***SSD Technology Information Sheet*** should also be reviewed for additional information that may apply to SSV systems. SSV performance may not be quantified if performance monitoring only involves measurements of vent-pipe vacuum or cross-slab differential pressures. If the ventilation rate (i.e., flow rate) below the slab is sufficient to reduce the VOC concentrations to very low levels, then an occasional reversal of the cross-slab pressure gradient will not result in substantial VOC transport into the building. As such, continuously maintaining the more conventional minimum sub-slab vacuum pressure differentials may not be necessary to prevent unacceptable exposures due to VI.

SSV systems can be used in both existing and new construction. For existing buildings, SSV is most suitable where the sub-slab fill material is highly permeable to allow for appreciable air exchange rates (AERs) below the slab and where there are minimal constraints to sub-slab ventilation, such as grade beams or wall footings that may restrict horizontal vapor flow below the floor slab. In a new construction scenario, SSV systems include many similar components of SSD systems, including gas-permeable layers (or aerated floors), horizontal perforated pipes, and/or vapor barriers. New construction SSV systems are designed similarly to SSD systems, although an SSV system may include the addition of air inlets to allow dilution air to enter below the slab if leakage across discontinuities in the floor slab is inadequate for air supply. Sufficient dilution air is needed to reduce sub-slab VOC concentrations to levels less than mitigation criteria (e.g., building-specific sub-slab screening levels). In many cases, SSV is also capable of reducing sub-slab vapors to concentrations less than generic sub-slab screening levels published by states or other regulatory entities.

Selection of a membrane for new construction SSV is similar to that process discussed for new construction in the ***SSD Technology Information Sheet***. The addition of a properly installed membrane should reduce cross-slab leakage and expand the radius of influence of each SSV suction point. For existing buildings, it is valuable to consider sealing the floor, particularly at expansion joints, floor drains, and obvious stress fractures.

Components

SSV system components are essentially the same as SSD system components (a fan or blower connected to piping that is engineered to evacuate air from the sub-slab area). The main difference between SSD and SSV is in the performance objectives (reducing concentrations below the slab instead of reducing pressure) and associated monitoring (concentrations and mass emissions rather than static vacuum). The electric fan or blower can be installed on either the outside or inside of a building, depending on access to available locations. Typically, fans are installed on the outside of the building to facilitate access during both system installation and ongoing operations, maintenance, and monitoring (OM&M). Fans installed on the outside of a building are subject to changing weather conditions that, depending on the geographic region, may result in condensate issues and additional wear on the fan. Fans installed in interior spaces (e.g., attics) need to be to fully excluded from occupied and/or insulated interior spaces (i.e., outside the occupiable building envelope) to mitigate the potential for leaks in the fan's vent from entering the occupied space. Fans installed in protected spaces, such as attics, have a longer and more consistent operating life because they are protected from extreme weather conditions, but also require permission from the property owner to obtain access for each OM&M visit.

When the subfloor materials are not very permeable, it will be easier to impose a vacuum. Conversely, appreciable flow can be achieved at vacuum levels that may be too low to measure when subfloor materials are highly permeable. An SSV system can also be integrated with other technologies, such as an aerated floor, to reduce air flow resistance in the sub-slab zone.

Components of SSV include:

- High-permeability materials below the floor slab, to allow for high vapor flow velocity and AERs below the floor, which can be measured using pneumatic and tracer tests (McAlary et al., 2018).
- System piping, including a sampling port for conducting system diagnostic testing (i.e., vacuum and air velocity/flow) and for collecting samples to measure VOC concentrations in the effluent to support mass removal rate calculations.
- Fan(s) or blower(s) capable of high flow rates.
- Air inlet pipes if the rate of air leakage across the floor slab is too low to achieve adequate sub-slab AERs.
- Permanent u-tube manometer, vacuum gauge, or pressure sensor on the system piping to monitor system vacuum where and if appropriate.
- Balancing valves on the system piping, which provide an efficient way to adjust the system flow from multiple areas and/or reconfigure the system footprint over time if needed. Blowers that have variable speeds may also be used to balance or rebalance a system over its operational life.
- Qualified personnel to conduct design, installation, and OM&M of control systems.

Advantages

SSV as an active mitigation technology has the following advantages:

- SSV is an easily deployable engineering control.
- In higher permeable sub-slab soils, small, low-vacuum, high-flow fans or blowers can be used.
- Many different types of fans and blowers are available, making system applications widespread.
- Energy cost for operation are usually low because the highly permeable material below the floor imposes minimal resistance to flow.
- Performance monitoring devices can easily be connected to remote telemetry technologies.
- SSV can readily be installed with other engineering controls on or around the building.
- If sub-slab concentrations are reduced to levels that pose no risk to indoor air quality, it may not be necessary to collect indoor air samples for performance monitoring, which avoids potential forensic analysis of background sources and disruption to occupants.

Limitations

SSV as an active mitigation technology has the following limitations:

- Installation of an SSV system impacts the occupants of the building in that coordination with and cooperation of the building occupants is needed during system installation (for existing buildings) and ongoing OM&M (both new construction and existing buildings).
- Low permeability soils below the slab will limit ventilation rates and radius of influence. SSD is a more appropriate technology in these cases.
- Sub-slab differential pressure measurements may not be useful for direct measurement of system performance (i.e., air flow and/or sub-slab ventilation rates are required). Additional communication may be needed with the local agency if they are expecting differential pressure readings because SSVs need to be evaluated with other performance criteria.
- Poor concrete slab construction, excessive cracks in the slab, or utility penetrations/floor drains/pipes may create short circuiting of air flow and potentially have a high energy penalty through loss of conditioned indoor air to the sub-slab. A substantial amount of sealing to limit indoor air from being drawn into the system and to enable overall system effectiveness may therefore be needed.
- SSV may not be continuously effective during high water table conditions if water is in contact with or within a few inches of the slab.
- SSV systems may not meet performance requirements if required design and construction practices are not followed. There are important differences in mitigation design and practitioner qualifications for VOC and radon VI mitigation that should be recognized.
- For some properties, it may be difficult to prevent property owners from tampering with and possibly damaging system components.
- SSV systems will not necessarily prevent diffusion of VOCs across slabs and some vapor barriers if very high concentrations (e.g., millions of $\mu g/m^3$) are present immediately below the slab.

Cost Considerations

The approximate costs for installation of this technology range from $2 to $4 per square foot. These costs are typically for installation only and do not necessarily include the costs of predesign testing; preparation of a work plan, design and specifications; installation monitoring; regulatory agency and stakeholder liaising; post-installation verification testing; and reporting.

Factors affecting cost include but are not limited to the following:

- sub-slab permeability and floor leakage rates
- building size
- the number of suction points and the type and number and size of fans or blowers
- ducted fresh air supply to the sub-slab (if needed)
- electrical power requirements and local utility rates
- building construction features
- aesthetic considerations
- exhaust filtration (if needed)
- monitoring and reporting requirements
- permitting, regulatory, and legal oversight

A large building with an aerated floor, engineered plenum (e.g., continuous void space under the slab), or highly permeable sub-slab fill material, and a high-integrity concrete slab would be on the lower end of the per square foot cost range. A residential home with moderately permeable sub-slab fill material would be on the upper end of the per square foot cost range.

Special Circumstances

Special circumstances for construction of an SSV include:

- In new construction, SSV systems can be designed using engineered plenums or aerated floors to facilitate air flow.
- In existing construction, the permeability of the material below the floor is fixed, and may or may not be adequate for SSV, in which case it may be necessary to design an active SSD system instead of SSV.
- It may be challenging to gain regulatory acceptance and approval of SSV systems because performance is documented using metrics that may be different than standard acceptable SSD system performance metrics. The use and acceptance of SSV systems appears to be increasing.
- Precautions should be taken to ensure that new tenants and/or construction activities (e.g., accessing sub-slab utilities, service pits) do not damage the SSV system.
- Precautions to understand and monitor changes in building use/building modifications should also be taken.

Occupant, Community, and Stakeholder Considerations

It is essential to develop and implement a site-specific community involvement plan that addresses, among other things, how to win trust and gain access to properties, communicate risk to potentially exposed individuals, and minimize the disruption of people's lives and businesses. For more details see ITRC's fact sheet on ***Public Outreach During Vapor Intrusion Mitigation***.

References

- McAlary, Todd, W. Wertz, and D. Mali. 2018. Demonstration/Validation of more cost-effective methods for mitigating Radon and VOC subsurface Vapor Intrusion to Indoor air, Environmental Security Technology Certification Program (ESTCP). Project ER-201322, July 2018. https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Emerging-Issues/ER-201322
- ITRC Technical and Regulatory Guidance Document, Vapor Intrusion – A Practical Guideline, 2007.
- ITRC Petroleum Vapor Intrusion, Fundamentals of Screening, Investigation and Management, 2014.

Resources

For more information and useful links about VI pathways and mitigation technologies, go to http://www.itrcweb.org .

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