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# RADON REDUCTION IN NEW CONSTRUCTION: DOUBLE-BARRIER APPROACH

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## ABSTRACT

A double-barrier design with the space between the barriers having little resistance to gas flow is described for those parts of homes and buildings that interface with the soil or surficial rock to reduce soil-gas (radon) entry into structures. The outside or soil-side barrier interfaces with the soil. A barrier placed on the soil under the subslab aggregate is an important element in this design. This forms the outer barrier for the floor. The subslab aggregate forms a permeable layer, while a plastic membrane above the aggregate, the slab, and caulking form the inner barrier. If hollow block are used, barrier coatings can be placed on both the soil side and interior wall of the blocks, while the hollow space in the blocks forms the permeable space. The hollow-block walls are connected to the subslab aggregate to form a small interconnected permeable volume that can be managed in the following ways to reduce soil-gas entry into the structure.

1. Sealed.
2. Passively vented to outdoor air.
3. Passively depressurized using an internal stack.
4. Actively depressurized.
5. Actively pressurized.

In addition to basements with hollow-block walls, the double-barrier technique can be adapted to solid wall, crawl space and slab-on-grade construction including various combinations.

## INTRODUCTION

In the long term, substantial reduction in radon exposure can result from improved new home and building construction techniques that reduce radon entry. In addressing this approach to reducing radon exposure, the EPA has published a report "Radon-Resistant Residential New Construction" (1) in which construction techniques to minimize radon entry in new structures and to facilitate its removal after construction are described. This report is the first edition of technical guidance for constructing radon-resistant structures to be issued by the EPA, and they anticipate future editions as additional experience and approaches become available. The EPA report includes a section on barriers to reduce radon entry including wall coatings, sub-slab membranes, caulking, sealing and prevention of slab cracking. Another section discusses designs for post-construction active or passive sub-slab ventilation. A primary element in these designs is a minimum of 4 in. of aggregate under the slab. The preferred material is crushed aggregate with a minimum of 80% of the aggregate at least 3/4 in. in diameter. This highly permeable bed under the slab is necessary for good communication in the event that sub-slab ventilation is needed. The aggregate is placed directly on the soil and represents a large permeable volume into which radon can diffuse or flow from the soil and rock under and around the foundation. The radon that accumulates in the permeable aggregate can then flow with little resistance to any penetrations in the barriers above the aggregate. These barriers include the membrane placed over the aggregate, the slab and any caulking and sealing of the wall floor joint, cracks and penetrations. Having a permeable volume between the soil and the barriers reduces the effectiveness of the barriers. Barriers are most effective when interfacing with the soil. A similar situation occurs when hollow blocks are used to construct the foundation walls. Radon that infiltrates through the outer wall and into the hollow cavity of the block walls can then flow with little resistance to any penetrations of the inside wall barriers. Again, barriers to radon entry are most effective on the outside or soil-side of the wall.

An indication that aggregate under the slab increases radon entry into structures was obtained in a survey of over 6,000 homes in New Jersey (2). The data collected in this study show a definite relationship between age and radon concentration. On average, houses built since World War II tend to have higher indoor radon concentrations than houses built between 1900 and about 1945. Initially, it was suspected that newer houses had higher indoor radon concentrations because newer houses tend to be tighter and have lower air exchange rates. However, closer examination of the data indicated that the differences in radon concentrations associated with tightness did not fully account for the decline in radon concentration with increasing age in 20th-century houses. The authors speculated that the use of sub-slab aggregate, which increased in the post-World War II era, could also contribute to the higher indoor radon observed in newer homes.

It is difficult to determine the effectiveness of the barriers to radon entry suggested by the EPA, when used in the passive mode, since it is not possible to know what the indoor radon concentrations would be for a house if the radon-resistant techniques were not employed. The initial results, however, have led the EPA to conclude "that in the presence of a moderate-to-high radon source, radon prevention techniques that are passive only may not produce indoor radon levels consistently below 4 pCi/l." In a study of 15 full-basement homes in New York State which were built employing radon-resistant techniques in an area with above-average levels of indoor radon, most of the homes required active sub-slab ventilation systems (3). The results from the New Jersey survey and the initial results of the homes built with radon-resistant construction indicate that sub-slab aggregate interfacing directly with the soil or rock under a home can increase radon entry into the home and decrease the effectiveness of barriers placed above the aggregate.

## DOUBLE-BARRIER CONSTRUCTION

It is the purpose of this paper to suggest a design for new home construction that is more effective in reducing radon entry in the passive mode but one that can be readily adapted to active mitigation systems if needed. The design proposes to reduce soil-gas entry by using double-barrier construction for the sub-grade structure of homes and buildings. A primary element in this approach is to have a radon barrier under the subslab aggregate at the soil interface.

The double-barrier approach is illustrated in Figure 1 for a basement with block walls and a sump. The hollow space in the block walls is connected to the subslab aggregate via weeping holes or some other low resistance pathway for air flow, to form an interconnected permeable space that surrounds the entire subgrade structure. Barriers to radon transport such as membranes, coatings, caulking, sealing, etc., are placed on both the soil side and inside of the permeable space. Since radon barriers are most effective at the soil interface, most of the barrier effort should be concentrated on the sub-aggregate and outside wall barriers. The barrier below the aggregate may be a composite of materials such as cement, tar, plastic film, fine sand, and clay. Barriers at the soil interface should be resistant to both diffusive and convective flow. A special effort should be made to seal the outside wall barrier at the wall-footing joint and the barrier below the aggregate at the footing-aggregate and aggregate-sump joints.

The double-barrier subgrade construction creates a reasonably small volume between the inside and outside barriers that can be managed in several ways to reduce radon entry. Without a barrier below the aggregate, the soil and rock under and around the house will be directly connected to any mitigation system used to reduce radon entry. The double-barrier approach works toward decoupling this direct connection. For the double-barrier system shown in Figure 1, passively venting the hollow-block walls to outdoor air will allow outdoor air to flow with little resistance into the permeable space. As gas from the permeable space is drawn through any penetrations in the interior or upper barriers into the basement by indoor-outdoor pressure differentials, outdoor air can flow into the permeable space with little resistance. The outside air flow reduces the draw on soil-gas at any penetration in the outer or below barriers and thereby reduces the flow of soil-gas radon into the permeable space. Alternatively, the permeable space could be treated by depressurization (passive or active) or pressurization (active). For these approaches it would be best to not vent the block walls to outside air. Radon entry reduction can then be accomplished by creating either a reduced pressure or increased pressure in the permeable space. Having created a reasonably small interconnected permeable space with sealing

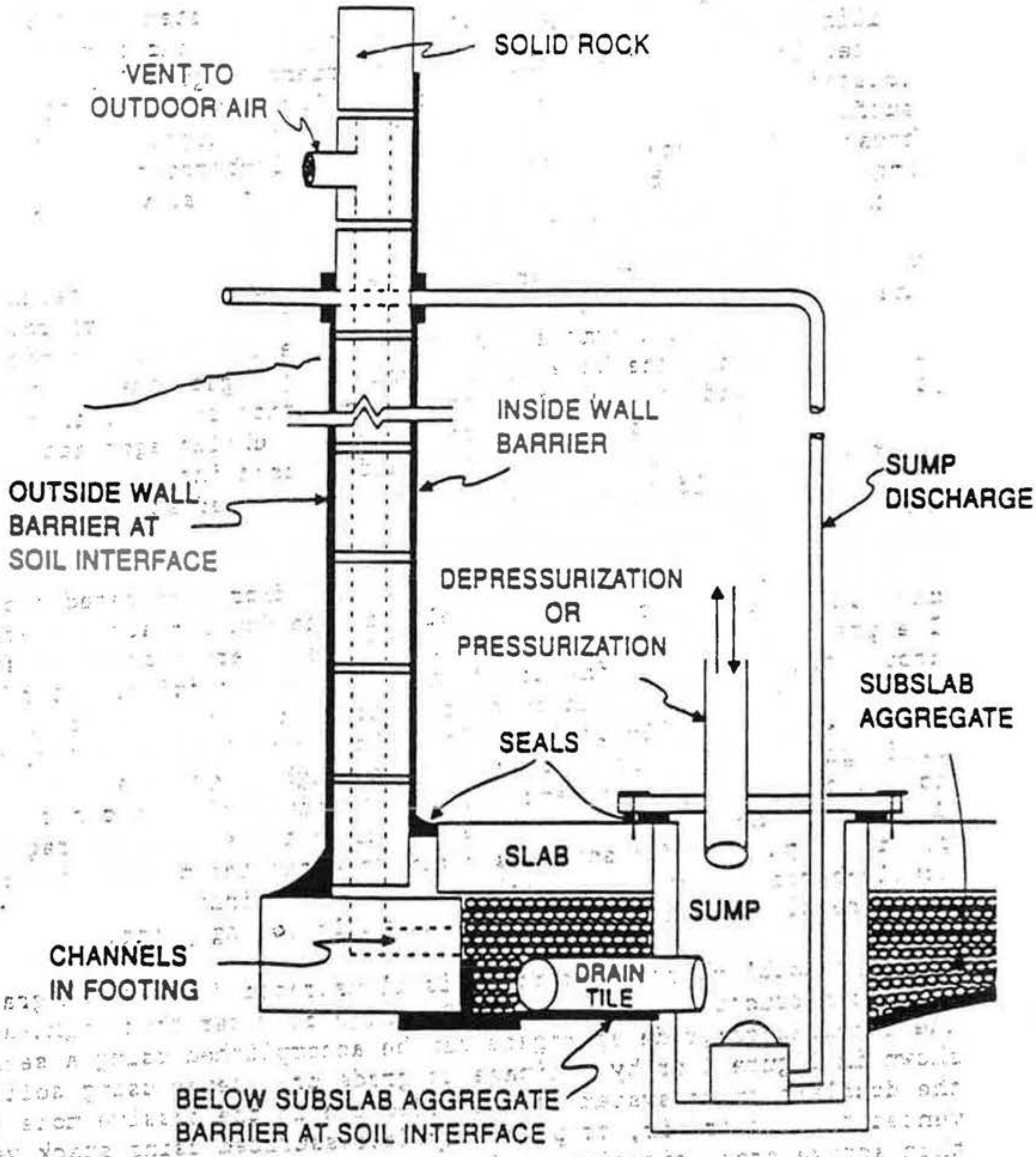


**Figure 1. Double-barrier construction for a basement with sump.**

on both the soil side and inside, it is expected that, if passive venting (using a stack through the house interior), active suction, or positive pressure flow is necessary to reduce indoor radon to acceptable concentrations, then relatively low flow rates would be successful.

An example for an active pressurization system would be to draw air from ceiling vents in the highest level of the house and blow this air into the permeable space between the double barriers (Figure 2). The fan could be located in the basement and relatively low flow rates (~20 cfm) should suffice. In this manner, heated air from the highest interior level of the house would be used to pressurize the double-barrier system heating the floor and walls of the basement while reducing heat loss via exfiltration from the higher levels of the house.

It is of primary importance to ensure that water effectively drains from the permeable substructure space between the double barriers. This can be accomplished with a sump as shown in Figure 1. It may be necessary to grade the soil forming the base of the subslab aggregate toward the drain tiles and the sump to aid in preventing the accumulation of water in the subslab aggregate. If it is possible to drain the subslab aggregate to grade or to a sewer, then this drainage option could be used instead of or with a sump. Solid pipe should be used and it should be sealed at the outside or soil-side barrier.

Exterior footing drainage of gravel and/or perforated piping is used by many builders and presents a problem to the double-barrier design approach. The gravel and/or perforated piping of the exterior drainage system runs around the outside perimeter of the wall-footing joint. It represents a permeable volume in which radon can accumulate and flow to any penetrations in the wall and wall-footing joint. To minimize radon entry, the exterior drainage system should be drained to daylight or to a sewer and not connected to the subslab aggregate and sump via weeping holes or other methods. Connecting the exterior drainage system to the subslab aggregate would provide a pathway for soil-gas radon to enter the permeable zone of the double-barrier system. Exterior perimeter drainage systems increase the need for careful sealing at the exterior wall-footing joint.

The double-barrier approach is illustrated for slab-on-grade and crawl space construction in Figure 3. Drainage of water that might accumulate in the sub-slab-on-grade aggregate can be accomplished using a sealed sump as shown in Figure 1 or by drainage to grade or a sewer using solid pipe. If the double-barrier system is not effective in the passive mode (sealed, vented to outdoor air, or passively depressurized using stack ventilation), then active pressurization or depressurization can be employed. When a barrier is placed directly on the soil of a crawl space and the floor of the house is sealed, one obtains a double-barrier system with the space between the soil barrier and the floor being the permeable space. The crawl space can then be vented to outdoor air or the crawl space can be sealed and passively depressurized, or actively pressurized or depressurized. To reduce the volume of air to be pressurized or depressurized, a permeable layer of aggregate or other construction to form a permeable space with barriers on both the soil side and house side can be used as shown in Figure 3. Sealing the floor and using a double barrier at the soil surface results in a triple-barrier system where the two permeable spaces could be treated independently.

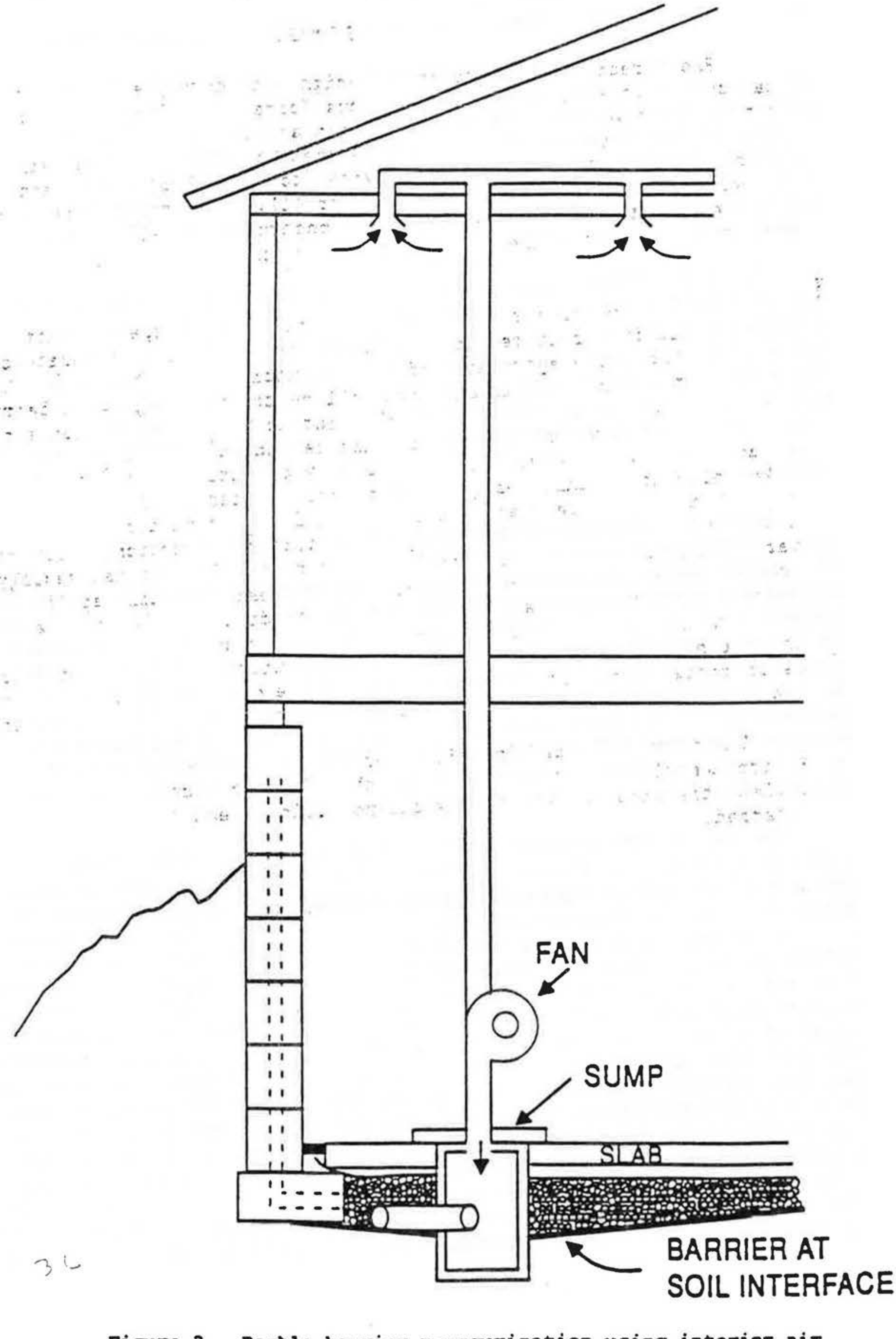


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Figure 2. Double-barrier pressurization using interior air.

For example, the aggregate could be passively depressurized and the space below the floor could be vented to outdoor air.

## SUMMARY

Radon-resistant construction designed to decouple houses from the soil has been suggested and used in various forms. The EPA refers to constructing a pressure break between the foundation and the soil. Brennan and Osborne (4) suggested that a drainage mat be used to form an air curtain around the foundation. A Denver builder excavates to a depth of 10 ft. and constructs a crawl space under a wood basement floor (1). The crawl space is then actively ventilated. Walkinshaw (5) constructs a shell inside the basement and then ventilates the space between the interior shell and the basement floor and walls.

The double-barrier approach described in this paper attempts to modify normal building practices to be more radon-resistant at moderate cost. Barriers under the aggregate and on the outside of hollow-block walls interfacing with the soil and rock will be the most effective barriers in reducing radon entry. The double-barrier construction creates a relatively small permeable volume between the inside and outside barriers that can be managed in several ways, either passively or actively, to reduce radon entry. A key element in this design is to maintain water drainage from the permeable space between the barriers and from around the foundation. There are many types and variations of house and foundation construction. Very often these variations are dictated by the local and regional surficial geology. It is not possible to describe a radon-resistant design readily applicable to all types of construction and water drainage conditions. However, a better understanding of how water drainage systems around foundations can increase the potential for radon entry will enable builders to make water drainage and radon-resistant construction more compatible. Double-barrier construction is such an attempt to make water drainage and radon resistance work together.

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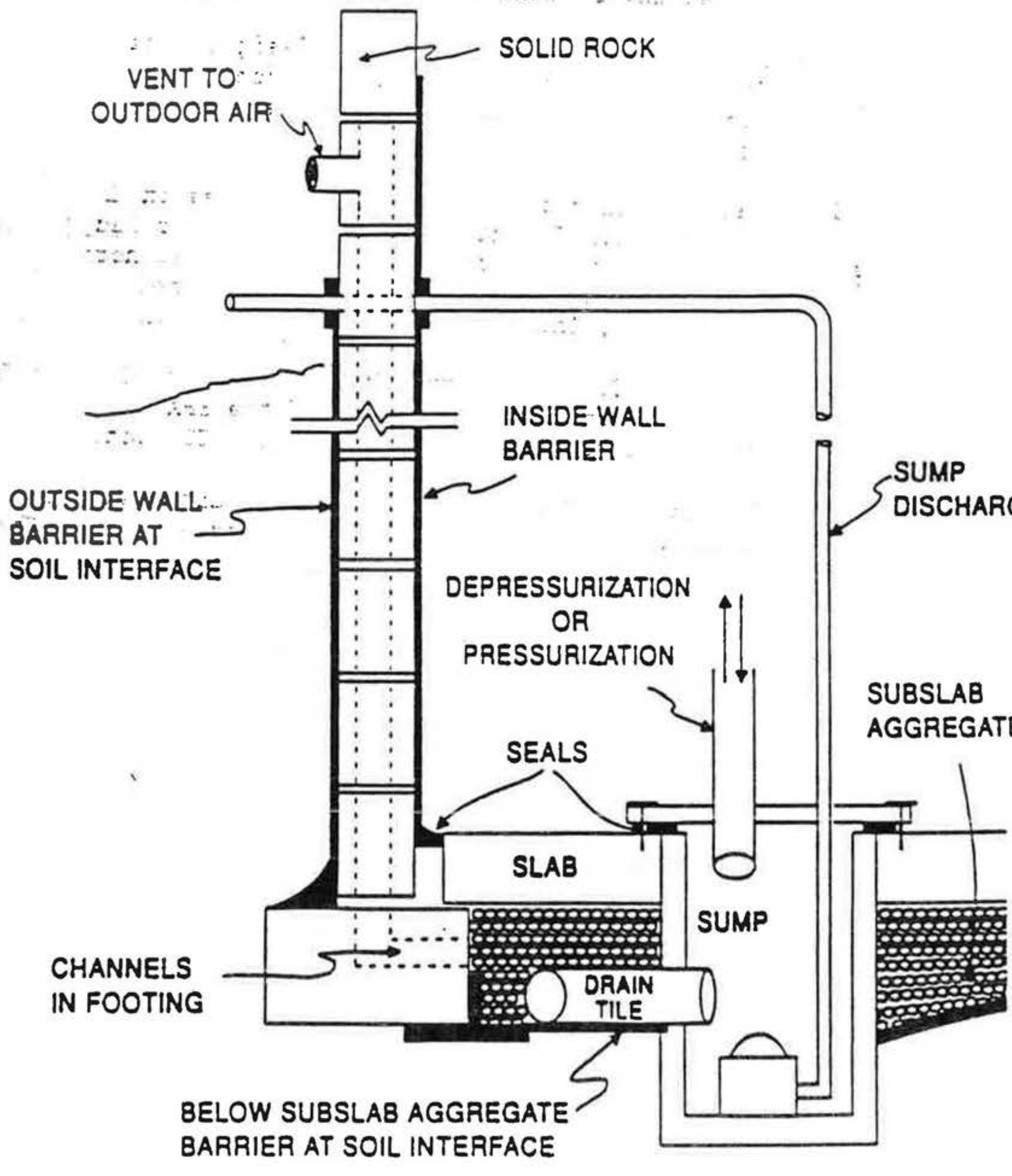


Figure 1. Double-barrier construction for a basement with sump.

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