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Radon Fundamentals and the Effectiveness of Coatings in Reducing Soil Gas Flow Through Block Basement Walls

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16. ABSTRACT The paper gives results of an evaluation of six different coatings in specially designed chambers built around 1.5 sq m concrete block wall sections. Data were collected over a pressure range of 1-12 Pa with flows from < 0.01 to 50 standard liters/minute (SLPM). The six coatings were a water-based catalyzed epoxy paint, an elastomeric paint, a cementaceous block filler, a surface bonding cement, a polysulfide vinyl acrylic paint, and a latex paint. A major preliminary finding is that all six coatings proved to be highly effective (98-plus %) when enough material is carefully applied. Considering both cost and effectiveness, a cementaceous block filler is highly effective, at lowest cost, in a single application. Among the paints, two coats of the water-based epoxy was most effective, although one coat may be adequate. Baseline (uncoated) flows varied by a factor of 2 (12.1 - 23.5 SLPM/sq m) between the two batches of block used for testing that came from a North Carolina manufacturer; these varied by an order of magnitude (1.8 SLPM/sq m) from blocks received later from a Minnesota manufacturer. This large variation in a small sampling of blocks is significant not only in the potential impact on coating performance, but also more significantly that specification of blocks with low air permeability for new construction substructures could greatly reduce soil gas entry, even if left uncoated.

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Radon Fundamentals and the Effectiveness of Coatings in Reducing Soil Gas Flow Through Block Basement Walls

John S. Ruppersberger
U. S. EPA, Air and Energy Engineering Research Laboratory
Research Triangle Park, NC 27711

ABSTRACT - Samples of six different coatings were evaluated in specially designed chambers built around 1.5 m^2 concrete block wall sections. Data were collected over a pressure range of 1 to 12 pascals with flows ranging from less than 0.01 standard liters per minute (SLPM) to 50 SLPM. A major preliminary finding is that all these coatings proved to be highly effective (98+%) when enough material was carefully applied. Baseline (uncoated) flows varied by a factor of two (12.1 to 23.5 SLPM/m^2) between the two batches of block used for coatings testing that came from a North Carolina manufacturer; these varied by an order of magnitude from blocks received later from a Minnesota manufacturer (1.8 SLPM/m^2). This large variation found in a small sampling of blocks is significant not only in the potential impact on coating performance, but more significantly that specification of blocks with low air permeability for new construction of substructures could greatly reduce soil gas entry, even if left uncoated.

INTRODUCTION - Pressure driven transport of soil gas carrying radon is believed to be the major entry mechanism for indoor radon. For houses with basements that have been mitigated as part of the EPA's research program, the perimeter crack where the floor slab meets the basement walls has often been considered the primary entry route. Generally, sound poured concrete has not been found to offer a significant entry route, even with typical hairline cracks. Therefore, coating poured concrete as part of a radon mitigation effort is not considered worthwhile when working toward a guideline of 4 pCi/L. Basement walls built of hollow concrete masonry units (CMUs) have always been suspect, and mitigation has sometimes included some work with this type of wall. The surfaces of these walls have been known to be an entry route, but given less treatment since other mitigation techniques such as active (fan driven) suction on the soil side of the substructure/soil interface have been developed to often be effective in achieving a 4 pCi/L guideline. Active systems are often powerful enough to extend their suction into the core of the CMU wall, effectively reversing the premitigation condition of the basement air, typically being the suction side of a slight pressure on the order of -3 to -5 Pa. Efforts to quantify the CMU wall source term is not commonly included in radon mitigation work to date. When quantified, it was found to contribute up to approximately 20% (1). Reports of the effectiveness of painting the surface of CMU walls have been mixed, with success credited to the treatment by some mitigators and no benefit even after thorough treatment with expensive paints by others. The recent development of the long term goal of ambient radon concentration supports more effort toward the more common houses, those with a premitigation level of 2 pCi/L or less. The relative significance of radon entry routes may be different for this large group of houses. Another major concern of active soil ventilation systems is the large volume of conditioned indoor air they draw through a typical uncoated CMU basement wall, producing inefficiency in the system and resulting in an energy penalty of conditioning the outside replacement air that is brought to the temperature of the house. Trace gas experiments indicated that 50% of the air exhausted from one active sub-slab mitigation system was from the basement. (1) Extension of the suction to all essential areas of the soil/substructure interface is made more difficult if CMU walls allow large flows of indoor air into the system.

In a Canadian study, external coatings were evaluated for their ability to form an airtight membrane that would remain intact even if cracks occurred in the substrate subsequent to their application. Coatings were applied to two adjacent concrete blocks, which were then moved apart to simulate opening of a crack. (2)

Recent work performed at Princeton University found that block wall air permeability was reduced by 99.5+% with two coats of a special rubberized paint, a polysulfide copolymer. One coat was 91% effective. Two coats of ordinary latex and oil base paints reduced wall permeabilities by 95%. Air permeabilities were determined from flow versus pressure data. (3)

A "standard test method of rate for air leakage through exterior windows, curtain walls, and doors" has been established by ASTM. (4) This test method covers the determination of resistance of curtain walls to pressure driven air infiltration. The EPA test apparatus complies with the ASTM test method in every major aspect, and differs only in the use of instrumentation exceeding the ASTM accuracy requirements, and data collected at lower pressure differentials in the range of 1 to 12 Pa.

MATERIALS AND PROCEDURES - Concrete masonry units of the type used in this test are covered by an ASTM "standard specification for hollow load-bearing masonry units." (5) This specification covers hollow load-bearing concrete masonry units made from portland cement, water, and mineral aggregates with or without the inclusion of other materials. The three weight classifications are normal, medium, and lightweight.

Coatings selected for evaluation include a two part catalyzed water based epoxy paint, an elastomeric paint, a cementaceous block filler, a fiber reinforced surface bonding cement, a polysulfide vinyl acrylic paint, and a latex paint. Selection criteria included an attempt to sample various types of coatings that might be used on CMU basement walls under various conditions. Some coatings are not well suited, or even recommended by the producers for negative side (inside) basement walls, but were evaluated because they may already exist on some walls of basements needing mitigation, or might be better suited for application to walls under certain conditions than other coatings. Coatings were applied separately to bare wall specimens even though the desired result of a continuous gas flow resistant film might better be achieved by a combination, such as a block filler and a coat of paint. This was done to collect data on each coating separately - - performance of various combinations may be estimated from the data, but to be more precise, and perhaps more realistic in some instances, reasonable recommended combinations could be subjected to further evaluations. The effectiveness of a single coat of the two part water based epoxy argues against a strong need for further such tests. Freshness of samples and adherence to application directions were emphasized. No two coatings were produced by the same manufacturer.

The test stand was designed for a 16 ft^2 (1.5 m^2) CMU wall. The wall assembly is made by pouring a concrete footing (48 in. x 16 in. x 6 in.) on which a block wall of

15 standard blocks and 6 half blocks is carefully built. Mortar construction techniques vary; these walls were built with two fairly generous strips of mortar on which the base course of blocks are laid. Mortar is applied to all horizontal surfaces of the previous course and to the end of the next block that will butt up against the last block on a course in progress. After the wall has set up for over a week it is caulked generously and, while wet, the side and top panels are assembled then fitted with covers to encapsulate the wall with a plenum on either side. Closed cell rubber gasket material is sandwiched between all mating metal surfaces, and between the metal and acrylic plastic covers.

The completed assembly is leak tested by pressurizing to between 2.5 and 3.0 in. H_2O (500 to 750 Pa) using helium gas, and tested for leaks using a halogen gas leak detector. Leak testing is also conducted on the pressure side of the air delivery equipment. The control panel is composed primarily of computer controlled mass flow controllers, a pressure transducer, a pump, and a by-pass valve that provide precise control of flows from less than 0.01 SLPM to 50 SLPM over a pressure range of 1 to 12 Pa. The acrylic plastic cover over the side of the wall to be painted is then removed. After baseline data are collected, the coating is carefully applied. Care is taken to quantify material used. Additional coats were applied a day after the previous coat except when data collection needs dictated longer periods or when it might be reasonable to stop application of that paint with that coat. It is important to note that the coatings were applied by brush, carefully working material into the block surface and leaving as much material on the wall as possible without runs. Primary consideration was sealing the porous block surface, not the amount of material used. Exceptions are the elastomeric paint which was applied at the maximum recommended rate and the surface bonding cement which was applied using a steel trowel.

The initial wall was constructed as part of prototype development and was used for the polysulfide vinyl acrylic paint evaluation. Its baseline flow was as shown in Figure 1, Line a, 35 SLPM at 3 Pa, or about 2 SLPM per full block. The remaining five coatings were evaluated from walls built later, from a different batch of blocks. Although from the same local North Carolina manufacturer, meeting the same ASTM specifications for CMUs and with no noticeable difference in appearance, the baseline flows were approximately half of that of the prototype wall, as shown in Figure 1, Line b, 18 SLPM at 3 Pa, or about 1 SLPM per full block. Then an opportunity developed to evaluate blocks received from a Minnesota manufacturer. The baseline flow for these blocks is on average approximately an order of magnitude lower than the local blocks, as shown in Figure 1, Line c, 2.7 SLPM at 3 Pa or about 0.15 SLPM per full block. Blocks from both manufacturers are typical of those used in their geographical regions for residential construction. The more air permeable North Carolina block is a lighter block, 12.1 kg, that has become common in the southeast. It contains expanded light weight aggregate, filled with numerous discrete voids that do not appear to be interconnected. The less air-permeable Minnesota block weighed 16.9 kg, uses natural aggregates, and has a smoother, less porous surface appearance.

WATER BASED EPOXY PAINT - This is a water based catalyzed (two part) epoxy resin paint. Its analysis by weight, as supplied by the manufacturer, is 16.5% titanium dioxide pigment and 83.5% vehicle (7.7% epoxy resin, 6.6% ethylene glycol and alcohol, 20.7% acrylic resin, 46.5% water, and 2.0% additives). The data for this paint are summarized with other coatings in Table 1. Even with a slightly higher baseline flow of 19.8 SLPM, a single coat of this epoxy paint resulted in the lowest airflow of any paint evaluated, 0.75 SLPM at 1 day drying time, and was the lowest for any two coats of paint evaluated, at 0.01 SLPM. The paint film is very smooth, and dried specimens exhibited unexpected elongation and strength upon being pulled apart, although these observations were not quantified by any standard testing techniques. Application was considered easier than average to provide a continuous film for both the first and second coats.

ELASTOMERIC PAINT - The analysis of this elastomeric acrylic emulsion paint was not given. Application rate for concrete block was specified as 50 to 125 ft^2/gal. The first coat was applied at 50 ft^2/gal. Based on the performance of the first coat, a second coat was also evaluated. About a third of the quantity of paint used for the first coat was used for the second coat. The data for this paint are summarized with other coatings in Table 1. The measured effectiveness of the elastomeric paint was second only to the epoxy: 1.36 SLPM for one coat, and 0.025 SLPM for two coats. Application by brush was considered the easiest of any paint evaluated.

CEMENTACEOUS BLOCK FILLER - This is a portland cement plaster that can be troweled, sprayed, or brushed. There was no information concerning composition on the container (a bag holding 50 lbs) or sales literature, other than references to portland cement. In keeping with the general trend of brush application, this product was applied with a "masonry brush" purchased from the dealer. It required a different technique than typical paints, but application progressed satisfactorily after a brief time. Application was considered more difficult than average to provide a continuous coating with reasonable surface appearance. Experience would probably improve both application rate and appearance. The other cementaceous product evaluated was troweled on, but that product specified a 1/8-in. thick coating; this cementaceous block filler (also called a "finish coat" by the manufacturer) was applied at a thinner consistency and thinner than 1/8-in. by brush. The data for this coating are summarized with other coatings in Table 1. The single thick coating resulted in an air flow of only 0.06 SLPM; only about half of the flow through the fiber reinforced surface bonding cement, and over an order of magnitude less than one coat of the most effective paint.

SURFACE BONDING CEMENT - This is a mixture of portland cement, fiberglass reinforcement fibers, and unspecified (proprietary) ingredients. Application is specified as a minimum of 1/8-in. thick with coverage per 50 lb bag of approximately 50 ft^2. Trowel or spray application options are in the product literature supplied by the producer. Application was with a steel trowel by an experienced mason to a thickness of slightly over 1/8-in. The data for this coating are summarized with other coatings in Table 1. The single application resulted in an air flow of only 0.10 SLPM.

This is more than the other portland cement coating evaluated in this study, but still is highly effective at 99.5% flow reduction in one application, allowing less than 14% the flow of one coat of the most effective paint.

POLYSULFIDE VINYL ACRYLIC PAINT - This coating is not yet (May 1989) available commercially. The supplier described it as polysulfide/vinyl acrylic dispersion without giving any further specifics on composition. It was offered at the time the program was started and was used for the original prototype test stand and equipment testing. Since it was accepted for those first developmental tests, it was decided to evaluate it as the first coating using the equipment after it was fully calibrated to QA/QC specifications. Application was considered average to provide a continuous film for both the first and second coats, although pinholes were observed soon after application and their apparent number and size increased with drying time. The data for this paint are summarized with other coatings in Table 1. Specifically, the baseline flow was much higher than for the walls built later from another batch of blocks. The measured effectiveness of one coat of this paint was approximately 80%; many pinholes were apparent in one coat. The second coat reduced air flow at 3 Pa substantially, with an effectiveness of 99.4%: 0.20 SLPM of the baseline flow of 35 SLPM. The observed time dependence on measured effectiveness resulted in reconsideration of a standard condition of 2 weeks drying time since data collected at different drying times exhibited different slopes and a consistent trend of increasing flows with increasing drying time. Performance deteriorated further between 2 weeks and 2 months with visual pinholes becoming more numerous and larger.

LATEX PAINT - This is a latex semi-gloss paint. It is commonly sale priced at retail and might be considered the type of latex paint homeowners would often buy; there are both less and more expensive latex paints available. Its analysis did not list ingredients by weight, merely as pigment; titanium dioxide and hydrous aluminum silicate, and vehicle; polystyrene resin, acrylic latex, vinyl acrylic resin, 1, 2 propanediol, additives and water. Application information on the label stated 400 ft^2/gal. or less, and that textured surfaces may require more paint. Actual application rate on the test wall was approximately 100 ft^2/gal. That first coat took as much paint as the next two coats combined, resulting in a coverage after the three coats of approximately 50 ft^2/gal. Application of the paint by brush was considered slightly more difficult and time consuming than the average of the paints evaluated. The data for this paint are summarized with other coatings in Table 1. The measured effectiveness of this latex paint was less than any of the other three paints evaluated for either one or two coats. One coat was not very effective, about an order of magnitude less effective than the epoxy or elastomeric paints, allowing 11 of the baseline 19 SLPM to pass at 3 Pa after 1 day drying time. It was the only paint applied with three coats, but that third coat greatly increased the effectiveness, from 84.2% with two coats up to 98.1% (0.37 SLPM) at three coats.

DISCUSSION - Reduction of air entry is the primary concern that motivated this work and all aspects of the test program. Several observations are especially noteworthy. The first is that of these coatings, everything works well in reducing air flow across these test walls (initially at least, under these ideal conditions) if sufficient material and care are used in their application. A major finding, and a surprising one after discussions with several paint chemists working to formulate especially effective radon flow resistant paints, and seeing fairly expensive specialty paints being advertised specifically as radon resistant, is that all these coatings, when carefully applied with sufficient quantity and coats, demonstrated that they can be highly effective in reducing gas flow across the face of concrete masonry units. Another is the interesting observation that the data for any particular set of flow vs pressure plots is a straight line on arithmetic paper. Apparently, flow through these small openings at low pressure differentials is laminar.

A comparison of percent effectiveness in reducing the baseline flow and estimated cost associated with do-it-yourself (approximated by the material cost) and professional application total cost is summarized in Table 1. Among the four paints, the polysulfide vinyl acrylic offered as specifically formulated for radon control performed much less effectively (78.6%) than either the epoxy (96.2%) or elastomeric (92.1%) with only one coat. It is interesting to note that material cost of the polysulfide vinyl acrylic paint is as estimated by the supplier and for two coats is considerably lower than other paints of approximately similar effectiveness. However, since this paint is not commercially available, cost should be considered subject to change. Of commercially available paints, the latex is the least expensive material for three coats. However, a do-it-yourselfer would have to be strongly motivated to save a few pennies per square foot and get about 2% more effectiveness, to go to the trouble of applying three coats of a slightly more difficult to apply paint, than one coat of the epoxy that provided almost equivalent effectiveness. The better appearance and other desirable properties of this epoxy over the latex paint might also influence a final decision. Considering just the paints, one coat of an equivalent water based epoxy might be a reasonable choice since the trouble and expense of a second coat produce only a little over 3% increase in effectiveness.

From these data, the clear performance value leader is the cementaceous block filler. This product contains portland cement, but no fiberglass. The product evaluated was white; if a natural grey color similar to the original block wall is acceptable, it would be approximately a penny less per square foot material cost. This type of coating, highly effective at the lowest cost, and with the effect of significantly changing the block wall appearance to a much smoother plastered look, is an apparent first choice unless conditions in the basement do not favor its application. Such adverse conditions would also produce problems with paints in general. The surface bonding cement is only slightly more expensive. It has added advantages of its fibers providing added tensile strength that may be helpful for walls experiencing problems with minor cracking, and also has a higher portland cement content that imparts improved waterproofing performance -- although this and most others are recommended for exterior application.

In summary, considering both cost and effectiveness, a cementaceous product such as the cementaceous block filler is apparently the first choice. If a paint is desired, the choice is more complicated based on these results, but one coat of a similar performing water based epoxy would be good if about 96% effectiveness is acceptable. If top effectiveness is the only criterion, two coats of the water based epoxy is found to be the most effective of the coatings evaluated.

PRELIMINARY CONCLUSIONS AND RECOMMENDATIONS:

1) All of the six coatings selected for evaluation can provide highly effective reductions in air flow under the conditions of the tests when sufficient quantity is carefully applied.

2) Considering both cost and effectiveness, a cementaceous product such as the cementaceous block filler offers highly effective flow reductions in a single application at low cost. Among paints, two coats of the water based catalyzed epoxy was found to be most effective in these tests, although one coat may be adequate for some situations.

3) The variation in air flow characteristics between similar looking blocks is large; in this limited sampling of only two batches of blocks from a North Carolina

manufacturer, it was found to vary by about a factor of two (12.1 to 23.5 SLPM/m^2), and when blocks from Minnesota were included, the variation increased to an order of magnitude (1.8 SLPM/m^2). This large variation found in a small sampling of blocks is significant not only in the potential impact on coating performance, but more significantly that specification of blocks with low air permeability for new construction of substructures could greatly reduce soil gas entry, even if left uncoated.

4) Flow vs pressure data collected for these carefully constructed test walls and at this very low pressure range were found to be linear.

REFERENCES:

1. Hubbard, L.M., et al. Research on Radon Movement in Buildings in Pursuit of Optimal Mitigation. Proceedings of American Council for an Energy Efficient Economy 1988 Summer Study, Vol. 2, Asilomar, California, August 1988.
2. DSMA ATCON LTD. Atomic Energy Control Board Development Program for Radon Reduction, Report 9, "Laboratory Tests External Coatings," August 1979.
3. Maryonowski, J.M. "Measurement and Reduction Methods of Cinder Block Wall Permeabilities," Center for Energy and Environmental Studies, Princeton University, Working Paper No. 99, 1988.
4. ASTM E 283-84, "Standard Test Method for Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors," September 1984.
5. ASTM C 90-85, "Standard Specification for Hollow Load-Bearing Concrete Masonry Units," July 1985.