TEK 6-14: CONTROL OF INFILTRATION IN CONCRETE MASONRY WALLS

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Introduction

The U.S. Department of Energy, along with various State and independent energy investigators, have identified uncontrolled air-leakage or INFILTRATION as a key energy efficiency problem in today's buildings. Our response to the 1973 and 1979 fuel crisis was to construct "tighter" buildings, of relatively low cost lightweight materials using fiberous insulations to obtain high "R-values." But high R-values do not necessarily mean the occupant of a building is getting total thermal protection, or is cognizant of the differences in quality that may exist between types of construction. The R-value of a wall must not be confused with the "quality" of the wall.

Reduced air-leakage is one area where masonry walls excel compared to other typical walls if proper design criteria are applied. This TEK reviews available information on masonry wall infiltration versus competitive wall systems, and provides some guidance on further control of air-leakage in masonry walls.

Air-Infiltration

What is air infiltration? Technically, it consists of undesirable leakage of air from the environment into the conditioned spaces of buildings. Its direct result is an increase of energy consumption to maintain desired levels of human comfort. Ventilation differs from infiltration in that it is designed into the system for reasons of health, safety and often to reduce building energy use. Basically, infiltration comes from a myriad of cracks, gaps, poorly designed joints, flashings, utility penetrations, window and door frames and other convenient avenues of entry.

Obviously, it would not make sense from an economic standpoint to reduce infiltration to zero. The benefits versus costs would approach the point diminishing return. Adverse health effects could also result from too low an air exchange. In fact, infiltration reduction to minimum levels may carry with it a requirement for controlled air exchange to offset adverse indoor air quality effects.

Recent studies have shown that infiltration can be difficult to predict and measure accurately. [(1)] The prediction and measurements of air-leakage in walls has been the subject of recent study by both U.S. and international researchers. U.S. results have focused mainly upon wood stud wall construction and fiberous insulation approaches common to homebuilding. International research has looked at masonry walls as well as wood frame walls, since masonry is the traditional European construction mode.

The comparison of results from U.S. and International measurement on whole building infiltration show insulated masonry cavity wall buildings generally have lower air-leakage rates than wood stud construction of what would be considered similar overall insulative value. If frame walls indeed leak more air and have higher levels of conductance due to their lower thermal mass, these two factors can combine to reduce the ACTUAL thermal effectiveness paid for by the consumer. Frame wall air leakage can be reduced by the use of plastic film "vapor retarders" and polymeric paper "air-barriers," but these add cost, complexity and installation headaches.

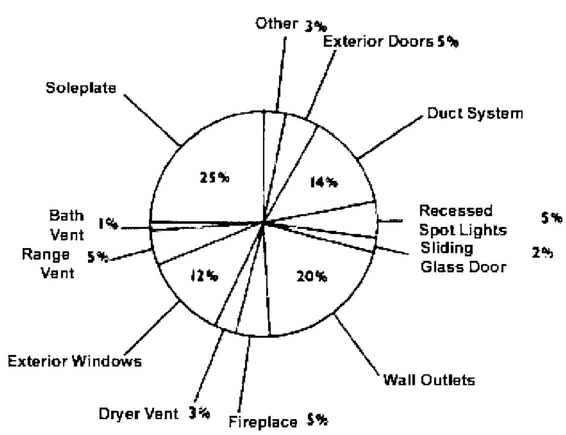
Data exists on actual building air infiltration and its reduction, but being highly technical, it is not widely available in a suitable form for most designers and builders. Also, while successful methods are known, their cost effectiveness is not clear. ASHRAE and ASTM are presently engaged in developing standards for estimating air-leakage in buildings that should be available for publication soon.

Types of Air-Leakage

A key issue is the big difference between air-leakage at "sites" such as door and window openings, where the caulking and sealing of components in rough openings is at issue; versus the diffuse air-leakage that occurs through the insulated wall assemblies themselves. A difficulty is that under most types of infiltration testing it is nearly impossible to apportion the leakage between sites and diffuse types without expensive, detailed testing. The latest ASHRAE Fundamentals Handbook—Chapter 22, contains tables showing that the sealing of windows, doors and other assemblies in masonry wall rough openings provides greater opportunity for infiltration than for frame walls. Despite the use of estimates in the Handbook (not typical practice), the ASHRAE data implies that masonry wall openings can be 3 to 5 times as leaky as wood frame counterparts. The importance of caulking and sealing these locations cannot be over-emphasized. Materials that are Flyable and have long life expectancies over prolonged periods of exposure are to be used.

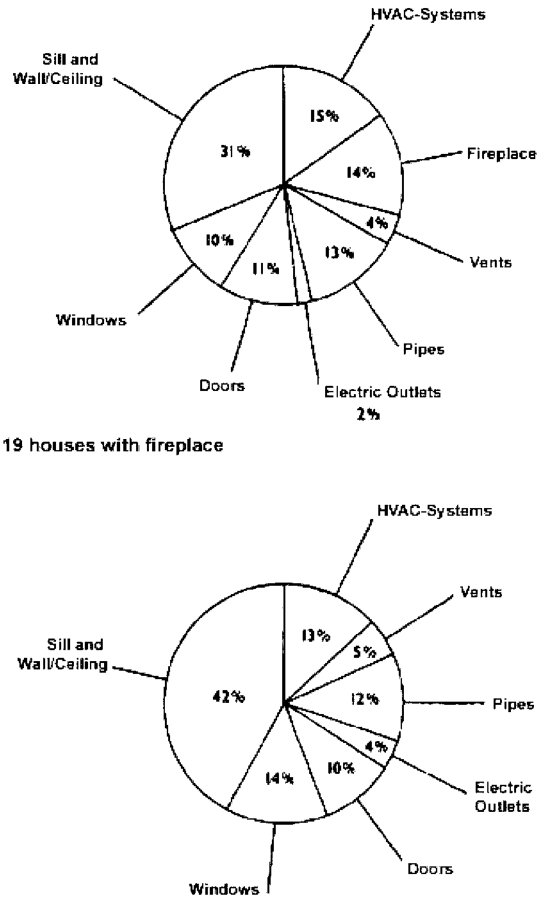
Builders have long known that infiltration is important from pioneering studies like the Texas Power and Light monitoring effort, conducted on 50 homes. (Figure 1). The role of soleplates, wall outlets, exterior windows and HVAC ducts in infiltration was clearly shown to be important. Later work by researchers at Lawrence Berkeley Lab (LBL)[2] indicated the distribution of infiltration losses was quite different between houses with and without fireplaces and chimneys, which had higher infiltration (Figure 2). If a builder does not add a fireplace, the role of the wall, ceiling and sill plate (in frame houses) becomes much more important, along with the windows and vents. The typical fireplace accounted for 14% of the total distribution of infiltration at 19 of 36 total houses studied by LBL.

FIGURE 1. Air leakage test results for average home of 1,780 sq. ft. (50 homes tested by Texas Power & Light Co.)



(Reprinted from "Energy Conservation for New Homes That Sell," National Association of Home Builders)

FIGURE 2. Distribution of Leakage Areas by Major Component Systems.



(a) 19 houses with fireplace

(b) 11 houses without fireplace

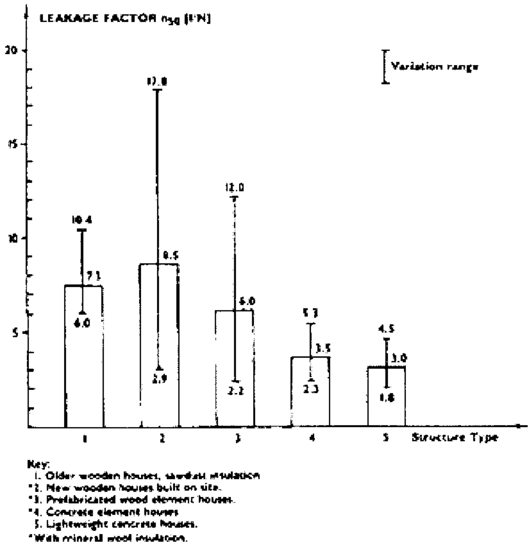
Builders have also become accustomed to rules of thumb such as those which state that "infiltration is about 40% of the total heating and cooling loads on a house," (1) and which are not necessarily correct. As further research and monitoring is conducted, we are learning that as buildings become better insulated, infiltration becomes a higher part of the total loads. There is quantitative evidence that quality of construction is directly related to infiltration, although direct numerical comparison is difficult.

Masonry Buildings

The masonry wall infiltration issue has been researched more widely in Europe by such groups as the Air Infiltration Center in England, (3) than in the U.S. due to the dominance of wood frame construction here.

Results from detailed air infiltration work done in Finland show that concrete block and lightweight concrete (panelized) walled homes had much lower infiltration rates than wood frame structures. (4) Figure 3 illustrates these differences comparing older wood frame houses averaging 7.3 air changes (ACM) at 50 Rascals, a common measurement pressure. Newer site-built wood frame houses showed even higher infiltration rates averaging 8.5 ACH, with a very wide range of values. Prefabricated wood "element" (panelized) houses were better at 6.0 ACH. However, both concrete "element" (block) and lightweight concrete houses had roughly ½the air-changes as the average panelized wood frame homes.

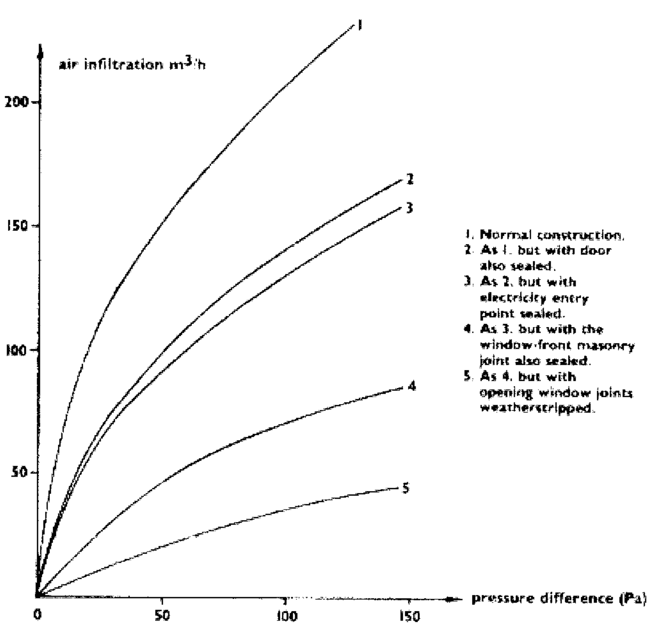
FIGURE 3. Leakage factors at 50 Pa for detached houses



Belgian researchers used a sequential technique in masonry walled homes to examine how incremental infiltration measures worked. Figure 4 shows the progression of air change rates at 50 Rascals from "normal construction," which evidently assumes no infiltration reduction measures, through to a fully weatherproofed masonry wall. The fully protected wall shows about an 87% decline in infiltration by the combined measures. The largest improvements are the sealing of the door and window frames to their respective rough openings, in agreement with the data in ASHRAE. The Belgian findings also agree with a statement in a compendium of European air infiltration results [(5)] which states:

“The critical details from the point of view of air-tightness are associated with the (quality of) formation of openings in masonry walls…"

FIGURE 4. Field results showing infiltration through various elements of a masonry-constructed room under varying imposed pressure differences across the external walls.



Proper sealing of components into masonry rough openings may be as important as reductions of air leakage through the porosity of masonry assemblies. Dr. Hiroshi Yoshino of Japan's Tohoku University investigated Japanese housing air infiltration [6] in a broad comparison with data from other nations. He ranked data points from his own research and other investigators into air tightness categories. He observed during the course of his work that some concrete multi-family housing was so air-tight that indoor air quality and condensation problems resulted, and ventilation was required. Concrete block houses of "air-tight" construction ranked among the best in Japan for air infiltration prevention. Several of the other Japanese reports he cited also showed concrete and concrete block houses to have lower air leakage than typical Japanese frame houses. Historically, the Japanese house has not been thermally efficient, but new government regulations are reversing this trend.

Masonry Walls

The National Research Council of Canada performed interesting research in 1968, comparing parametric air leakage across the block and brick walls using different surface treatments and core fills. [7] Test huts of 6 by 6 foot floor plan areas were constructed to compare block and brick walls. The rest of the hut's construction was held constant, and two locations were used: Ottawa and Saskatoon.

Results are shown in Figure 5, and Table 1, for the wall types and variety of surface treatments applied to reduce infiltration. Infiltration was much higher through untreated lightweight block walls than through denser concrete block walls according to the data. But lightweight block walls responded more greatly to applications of surface treatments and became fairly air-tight.

FIGURE 5.

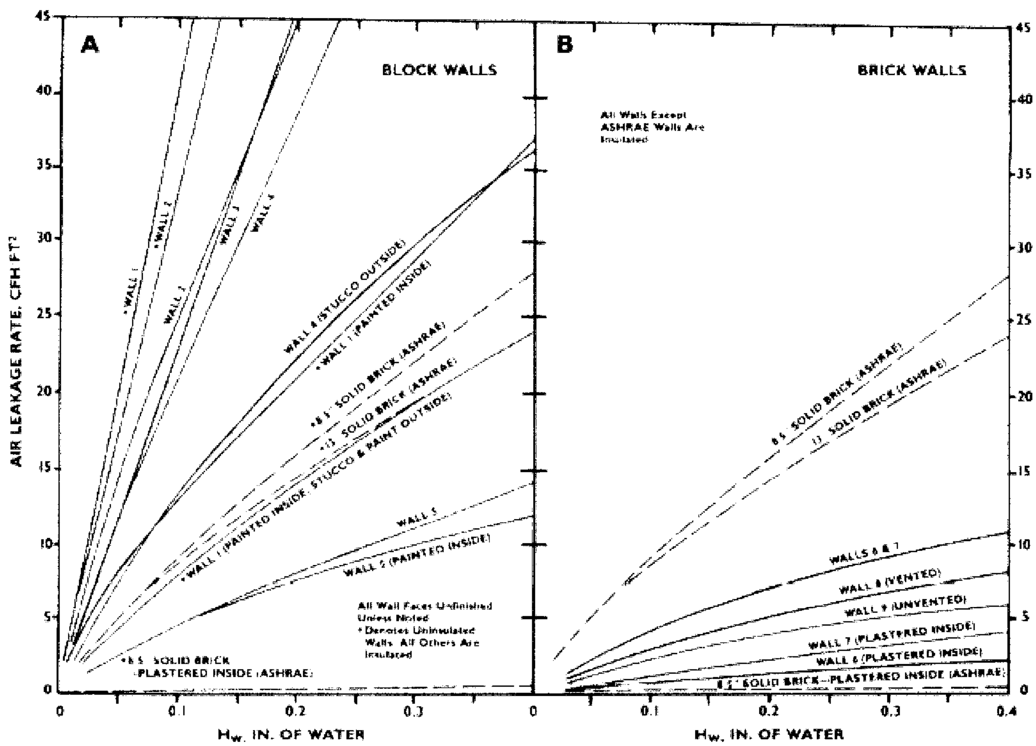


TABLE I
Wall Air Leakage Characteristics
Cu Ft of Air/(Hr) (Sq Ft of Wall Area) (Average of 4 Walls)

(A) CONCRETE BLOCK WALLS	Hw—in. of water					
	.05	.10	.15	.20	.30	.40
NO. 1— Light-weight concrete block wall (no insulation)						
—bare surfaces	20	40				
—two coats of paint added on inside surface	8	13	17	21	29	37
—two coats of stucco and one coat of paint added on outside surface	4	8	11	14	19	24
NO. 2— Light-weight concrete block wall						
—with no insulation	17	34				
—with fill insulation (volcanic dust)	14	25	35	45		
NO. 3— Light-weight concrete block wall, with fill insulation (expanded mica)	12	23	34	46		
NO. 4— Light-weight concrete block wall, with fill-insulation (expanded mica)	11	21	30	39	55	71
—three coats of stucco added on outside surface	7	13	18	22	39	36
NO. 5— Concrete block wall, with fill-insulation (expanded mica)	2	4	6	8	11	14
—one coat of paint added on inside surface	2	4	6	7	10	12

(B) BRICK WALLS	Hw—in. of water					
	.05	.10	.15	.20	.30	.40
ASHRAE Values—						
13" Solid brick, bare	5	8	11	14	20	24
—8½" Solid brick, bare	5	9	13	16	24	28
—8½" Solid brick, two coats of plaster added on inside surface	.	08	..	.14	20	.27
NO. 6— Clay-brick cavity wall (unvented), with fill-insulation (expanded mica)	2	4	6	7	9	11
—three coats of plaster added on inside surface	—	.5	—	1 0	1.6	2 2
NO. 7— Clay-brick cavity wall (unvented) with fill-insulation (granulated mineral wool)	2	4	6	7	9	11
—three coats of plaster added on inside surface	--	1	--	2	3	4
NO. 8— SCR brick wall with interior finish, vented air space	1.5	3	4	5	7	8
NO. 9— SCR brick wall with interior finish, unvented air space	1	2	3	4	5	6

The heavy weight block had lower air leakage rates than the ASHRAE Handbook curves for brick walls. Inside treatments of plaster reduced the brick wall infiltration to a minimum. Thus, interior surface parged CBS walls may produce generally lower infiltration rates than CMU wails using exterior treatments. The exception to this is stucco treatments on the exterior, which performed better than the tested paint options, but not as well as interior applications of plaster (parging) or paints. The addition of loose fill insulation to the block cores reduced infiltration, but not as dramatically as combinations of measures.

Of the CBS walls tested, the heavy weight wall with loose fill insulation and the interior painted surface performed best. Not only does the loose fill reduce the air-leakage but it adds significantly to the overall R-value. Foam systems with controlled shrinkage can be expected to perform similarly. It is also logical to assume that a block wall with 3 coats of interior plaster would have low air leakage similar to the plastered brick wall.

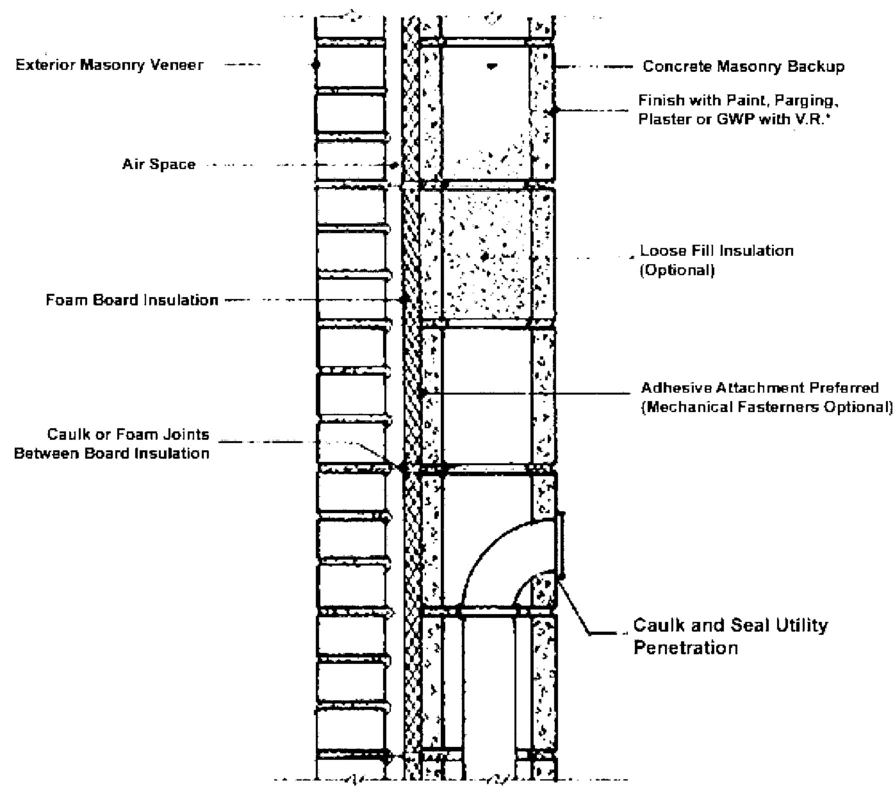
The Canadian Building Digest (8) bulletin #23 recommended that for masonry walls "porous construction must be eliminated on the warm side of the structure (wall)." This guideline is similar to use of vapor retarders as air-barriers on the warm wall side in cold climates. This suggests the air-tightness of the inner part of the structure must always be greater than the outer cladding. These recommendations are not valid for block walls in hot, humid climates like Florida, where the "warm" side of the wall is facing outdoors for seven months and indoors for three months, and experience diurnal reversals for the other two months. This confused pattern of heat and moisture flow into and out of masonry walls in hot, humid climates must be studied further.

Air-Leakage Reductions

Masonry walls do not have sole plates (sills) like wood or steel frame walls, since the wall is a continuous assembly from the footing up. An uncaulked wood frame sill creates a sizeable leakage area. The top of masonry walls is typically a "tie-beam" or bond beam. The trusses or rafters are often set to a plate which is attached to the top course. The ceiling finish edge details are a potentially troublesome area for reducing air leaks, as are attic access ways. These details are critical and good caulking and sealing is especially important. Window air-leakage data shows casement type windows are best, and double hung windows are worst for infiltration.

In cavity wall construction, the insulation in the air gap must be attached to the outer face shell of the backup scythe with adhesives and if possible, mechanical fasteners to eliminate air leaks behind the board insulation. Mechanical fasteners should be kept to a minimum, using existing reinforcing or wall ties where possible. This will keep thermal bridges to a minimum. Care should be taken to caulk between the board insulation as the wall is erected, to ensure both good R-values as specified and to reduce air leakage from the venting cavity to the backup wythe. (Figure 6)

FIGURE 6. Cavity Wall



*Indoor Vapor Retarder Cold Climates
Delete in Hot, Humid Climates

Discussion

Data indicates concrete masonry walls may have better "natural" resistance to air infiltration than typical wood frame construction. It is also clear that their infiltration problems may be corrected at lower cost than for frame walls. Quality construction of concrete masonry walls requires a similar commitment by the builder as do quality frame walls. However, the C/M system is simpler in that it has integral joints of similar material, and the wall surfaces themselves can be treated to manage air and moisture vapor, as opposed to frame walls which require extra materials such as polymer papers or plastic films to achieve similar results.

Retrofits for infiltration reduction with C/M construction seem to be simpler also since fewer dissimilar joints are involved. Also stucco, paints and mastics are cheaper than new sheathing, polymer papers, etc. Infiltration retrofits to C/M walls may also be less objectionable to the occupants since they are frequently done outside the wall, thereby not reducing the usable floor area.

Guidelines

1. CBS walls sealed on the interior with plaster, paint, mastic or parging seem to perform better than when having the exterior sealed.
2. Integral or loose fill insulation in the block cores reduces infiltration, as well as increasing system R-values. Loose fill insulated block walls should also be used in conjunction with other sealing methods for best results, because porosity of the concrete face shells must also be reduced.
3. Caulking around window, door, and ceiling to wall joints is also very important, once porosity has been reduced to a minimum. Continuous penetrations through both shells of blocks must be sealed, such as utility cables, plumbing, etc.

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