

**COMPARISON OF  
INSULATED CONCRETE FORMS  
AND  
WOOD FRAME CONSTRUCTION**

Submitted to: Mr. Larry Hatley, Department of  
Architectural Technology, Algonquin College

Submitted by: Adam Goulet  
Architectural Technology

In Partial Fulfillment of the Requirements for ARC 8425

November 22, 2002

## **Abstract**

This report will be discussing the differences between Insulated Concrete Forms and Wood Frame Construction. The method used to discuss the comparison is through the building matrix.

The topics that are covered in the report eight physical factors affecting the building envelope component of above grade walls. The eight factors are: heat, moisture, vapour, air, sound, fire, radiation and pollution. Other methods used to compare the two construction systems were the environmental impact and a brief cost analysis.

It is concluded that both wood frame and insulated concrete forms have their advantages and disadvantages. Following the conclusion are some of my recommendations on which system I believe to be better.

## Table of Contents

Table of Illustrations.....	v
Glossary.....	vi

<b>Chapters</b>	<b>Page</b>
-----------------	-------------

1. Introduction.....	1
2. Background.....	1
2.1 Plastic Foam Insulations.....	1
2.2 Conventional Wood Frame Construction.....	3
3. Strategy.....	4

<i>Four Major Physical Factors</i> .....	5
--	---

4. Heat.....	5
4.1 Heat Flow through Wood Frame Construction.....	5
4.2 Heat Flow through ICF's.....	6
5. Moisture.....	7
5.1 Moisture through Wood Frame Construction.....	8
5.2 Moisture through ICF's.....	8
6. Vapour.....	9
6.1 Vapour transmission in Wood Frame Construction.....	10
6.2 Vapour Transmission in ICF's.....	10
7. Air.....	11
7.1 Air leakage through Wood Frame Construction.....	12
7.2 Air Leakage through ICF's.....	13

Four Minor Physical Factors.....	13
----------------------------------	----

8. Sound.....	13
8.1 Sound Transmission through Wood Frame Construction.....	14
8.2 Sound Transmission through ICF's.....	15

9.	Fire.....	15
	9.1 <i>Fire in Wood Frame Construction</i> .....	15
	9.2 <i>Fire in ICF's</i> .....	16
10.	Radiation.....	17
11.	Pollution.....	17
12.	Environmental Impact.....	18
	12.1 <i>Environmental Impact in Wood Frame Construction</i> .....	18
	12.2 <i>Environmental Impact of ICF's</i> .....	19
13.	Cost.....	20
14.	Conclusions.....	22
15.	Recommendations.....	23
	 Bibliography.....	 25
	Appendix A: Interview.....	26
	Appendix B: Building Matrix.....	32
	Appendix C: Wood Frame Construction Detail.....	33
	Appendix D: Insulated Concrete Form Detail.....	34

## Table of Illustrations

<b>Figures</b>	<b>Page</b>
Figure 1: Consistency of Insulation.....	6
Figure 2: Thermal Mass.....	7
Figure 3: Air Infiltration.....	12
Figure 4: Sound Reduction.....	14
Figure 5: Fire Rating of Wood Frame walls vs. ICF walls.....	16
Figure 6: Flame Spread Indexes of Wood Frame Walls vs. ICF walls.....	17
Figure 7: Lumber vs. Concrete Producers Prices.....	20
Figure 8: Annual Estimated Heating Savings.....	21
Figure 9: Annual Estimated Cooling Savings.....	21

<b>Tables</b>	<b>Page</b>
Table 1: Typical Properties of Plastic Foams.....	2

## Glossary

- Center-of-Cavity R-value**..... R-value estimation at a point in the wall's cross-sectional R-value containing the most insulation
- Clear wall R-value**..... R-value estimation for the exterior wall area containing only insulation and necessary framing materials for a clear section with no openings, corners, or connections between other envelope elements such as roofs, foundations, and other walls
- Interface Details**..... A set of common structural connections between the exterior wall and other envelope components

## **1. Introduction**

Conventional Wood Frame Construction has been unchallenged for years. Now that there are alternatives for residential construction the challenge is to let the home buyers know what these alternatives are and how well they perform. One of the construction materials challenging Wood Frame Construction is Insulated Concrete Forms.

Contrary to popular belief insulated concrete forms originated in Canada and not Europe<sup>A</sup>. Werner Gregori was the man who was the first Canadian to submit for a patent. His expanded polystyrene form was called Foam Form. Insulated concrete forms (ICF's) are hollow blocks or panels made of plastic foam that construction crews stack into the shapes of the walls of a building. The center of the form is then filled with reinforced concrete to form the structure. ICF construction sandwiches a heavy, high-strength material (reinforced concrete) between two layers of light high-insulation foam. The combination of the foam insulation panels or blocks and reinforced concrete result in unusually good combinations of desirable properties: air-tightness, strength, low sound transmission, insulation and mass. Other benefits that the home owner will enjoy include: comfort, building strength, quietness, energy efficiency, and design flexibility.

## **2. Background**

### ***2.1 Plastic Foam Insulations***

The plastic foam insulations used in the ICF's can vary. The different types of insulation used are: extruded polystyrene (XPS), expanded polystyrene (EPS), polyurethane, or cement-foam composite.

---

<sup>A</sup> Permanent Buildings and Foundations

The following table titled Typical Properties of Plastic Foams will give a quick comparison of the different insulations used in ICF construction.

Table 1: Typical Properties of Plastic Foams

	EPS	XPS	Polyurethane	Composite
Density (lbs / cu ft)	1.35-1.80	1.60-1.80	2.00	21
R- value per inch	4.17-4.35	5.00	5.90	3.00
Compressive Strength (psi)	15-33	25-40	30	72
Tensile Strength (psi)	18-27	45-75	30	42
Water Absorption (%)	<3.0	<0.3	2.0	N/A
Retail Cost \$ / bd ft)	.17	.35	.70	N/A

EPS and XPS are made from the same plastic (polystyrene), but through different construction techniques. EPS is manufactured from expandable polystyrene beads containing a blowing agent and flame-retardant additive. Steam heat expands the blowing agent to produce moisture-resistant, multi-cellular particles, which increase up to 40 times their volume during the process. After a period of time the beads lose their moisture, and the blowing agent condenses out and air diffuses into the cellular structure. The EPS insulation is usually the least expensive. It also has very good performance properties such as, it insulates well, is resistant to air and moisture infiltration, and it is moderately strong. XPS is a continuous mass of molten material. Polyurethane foam is a result of two different ingredients, that when mixed together react with each other, (isocyanate, and polyol). The XPS insulation is usually more expensive than EPS but also provides about 25 % more insulative value is higher in strength and more water resistant. Polyurethane has a somewhat higher insulating value than the polystyrenes, but is comparable in strength. Cement-foam composites are a mixture of Portland cement and loose EPS beads. Because the composite materials contain cement they tend to be stronger and more durable but are more difficult to work with and have a lower insulating value.



All together each type of insulation has its advantages and disadvantages that need to be explored before deciding which type of ICF is right for the job.

## ***2.2 Conventional Wood Frame Construction***

Conventional wood frame construction on the other hand is a more complicated system. There are more materials involved in the construction of a wall opposed to constructing a wall from ICF's. Compared to ICF's, wood frame construction is more complex and requires more time and effort on the part of the contractor and sub contractor involved. A typical wood framed wall consists of an interior finish (paint), gypsum board, air and vapour barrier, glass fibre batt insulation, wood framing (studs), sheathing, sheathing membrane, and an exterior finish. Whereas, a typical ICF above grade wall consists of interior finish (paint), drywall, 2 ½ inches of foam plastic insulation (EPS, XPS, Polyurethane, or cement foam composite), reinforced concrete, another 2 ½ inches of foam plastic insulation, and any of the available exterior finishes. With the ICF's there is no need for an air or vapour barrier because the ICF itself acts as the barrier.

### **3. Strategy**

There are other comparisons that can be drawn between the two forms of construction. The other ways in which to compare the two building systems is through a Building Envelope Design Matrix. An example of the Building Matrix prepared by Larry Hatley, Professor, Algonquin College (Construction Methods and Materials, and Working Drawings), is attached as Appendix B: Building Matrix. This matrix can be used as a design tool when designing a building envelope. It acts as a checklist against the eight (8) physical factors affecting the five (5) building components.

Both the Insulated Concrete Formwork and the Conventional Wood Frame Construction will be evaluated in depth using the eight (8) physical factors. The eight physical factors affecting the building envelope components can be further divided into the major and minor physical factors. The four (4) major physical factors affecting the building envelope components are:

- Heat
- Moisture
- Vapour
- Air

While the four (4) minor physical factors are:

- Sound
- Fire
- Radiation
- Pollution

After these eight (8) physical factors have been discussed, the following sections will explain the environmental impact of the two construction techniques, and an assessment of the costs of the two systems. The report will close with conclusions and recommendations on a preferred option.

## **Four Major Physical Factors**

The following sections will be discussing the four major physical factors affecting the walls in the building envelope design. The four factors are: Heat, Moisture, Vapour, and Air.

### **4. Heat**

The first of the four major physical factors affecting the building envelope component of walls is that of heat. Heat moves from hot to cold. The hot air from the summer wants to move to the cold air conditioning on the inside of the building envelope, better known as infiltration. Whereas, on the colder days of the year the hot air from the building wants to travel through the envelope and out into the cold of the outside, also known as exfiltration. Also because hot air is less dense than cold air it has the tendency to rise. There are three ways in which air travels around and through the walls in the envelope. They are via conduction, convection, and radiation.

#### ***4.1 Heat Flow through Wood Frame Construction***

The main way in which heat will flow through a wood frame constructed wall is through air infiltration and exfiltration. All exterior walls require some form of insulation and most of the time in residential wood frame construction this insulation is glass fibre batt insulation. The insulation is installed between the stud spaces of the wall. Usually the studs are 2" x 6" spaced at 16" centers, leaving enough space for a batt with an R-value of R-22. This R-value is a center of cavity insulation value meaning that the value is coming from the insulation only and not any of the framing members. Because the wood framed wall is penetrable by air, there is the chance of thermal drift that over time will cause the wall to lose its original R-value.

The other main thing about wood frame construction is the fact that for the system to be an effective envelope there needs to be continuity of the thermal barrier. Because the studs are attached to the sheathing which is the only protected by the air barrier and the exterior cladding there is a thermal bridge occurring at each stud. Thermal bridging

occurs when cold air is able to pass through the material and travel into the building through all of the other wall components.

#### 4.2 Heat Flow through ICF's

Heat can try to flow through the ICF's plastic foam insulation panels and concrete core, but it will not get very far. Some of the ICF's use Type 2 expanded polystyrene which provide typical permanent R-values. Thanks to the cellular structure of the EPS panels there is no possibility for air to travel through the EPS panel. These cells contain only stabilized entrapped air. Because of this the panels are equalized or moderated not allowing any air (heat) through the insulation panels. Another quality that the EPS panels possess is that aging has no effect on their thermal performance either. The other feature that aids in the performance of the ICF wall is the overall mass of the wall, (thermal mass). The ICF wall thickness varies and because of this varying thickness the wall can obtain R-values that are double that of a typical wood framed wall, depending on certain climatic conditions. The interlocking/ tongue and groove tops of the EPS blocks aids in the thermal performance as well. With these interlocking tops the insulation is one continuous wall on the two sides of the mass of concrete. With these two walls of insulation there is no chance for a cold bridge in the ICF system. Because the EPS insulation is providing continuous thermal barrier protection there is very little to no air penetrating the building envelope either by infiltration or exfiltration.

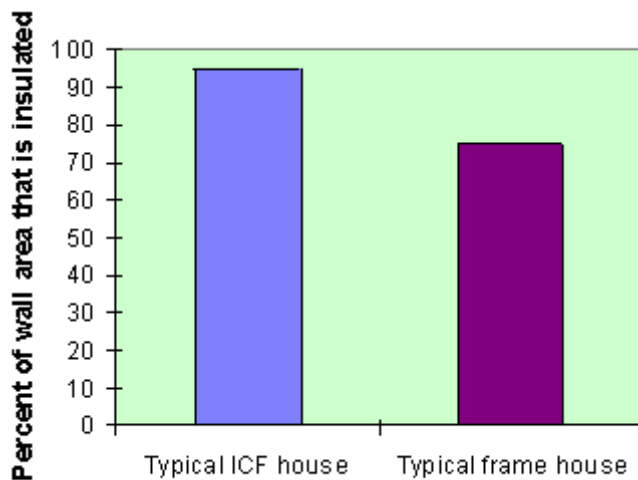


Figure 1: Consistency of Insulation

The disadvantage of a wood frame constructed wall compared to the ICF wall is that there is very little continuity of the thermal barrier. Without this continuity the building will always be transmitting air through the wall via infiltration and exfiltration. The transfer will happen where there is thermal bridging occurring. A solution to the problem

would be to place thermal gaskets at all studs or insulate the studs and then place the sheathing on top of the insulation. The ICF walls have the advantage because the insulation is part of the system; it is not something that needs to be placed with precision. Unlike glass fibre batt insulation that needs to be friction fit into the stud cavity and after time will suffer from settling and sagging and the wood framed wall will no longer be correctly insulated. It is possible to see from Figure 2: Thermal Mass that the ICF's have a greater thermal mass than that of wood frame construction. The advantage of this is that the higher thermal mass helps smooth out temperature swings.

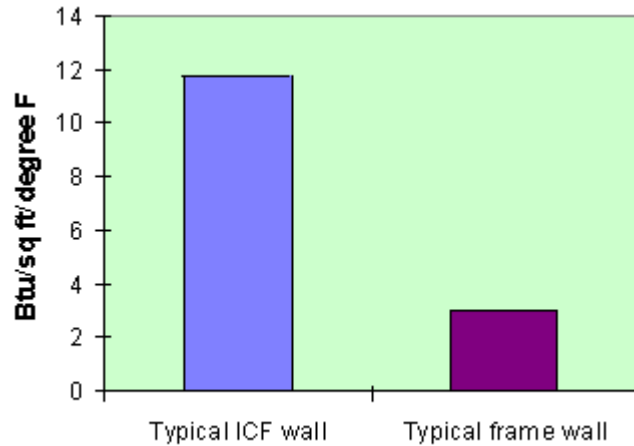


Figure 2: Thermal Mass

## 5. Moisture

A building envelope needs to prevent the movement of moisture in both directions between the interior and the exterior. In order for moisture penetration to occur three factors need to be present. The three factors are: there needs to be a source of moisture, there needs to be a hole or crack, and there needs to be a force that will move the moisture through the building envelope either by infiltration or exfiltration.

The way in which moisture moves occurs in three ways. Moisture can travel through the building envelope via diffusion, air leakage, and rain penetration. Diffusion occurs when moisture moves from an area of high humidity to an area of lower humidity through porous materials such as gypsum board and sheathing. It is a process which occurs over a large area and a vapour barrier must be provided in the building envelope to reduce moisture movement by diffusion. Air leakage is the movement of moisture as a result of humid air leaking through the building envelope. Air leakage takes places through gaps and discontinuities in the envelope and has the potential to deposit a large volume of

moisture in wall and roof cavities. An effective air barrier is required in the building envelope to prevent moisture movement by means of air leakage. Rain penetration is the entry of precipitation into the building envelope. A weather barrier, ideally a rainscreen, and other techniques are used to prevent infiltration.

### ***5.1 Moisture through Wood Frame Construction***

Once again the way in which moisture passes through a wall is through diffusion, air leakage and rain penetration. In order to insure that the moisture will not damage the wall when and if moisture does get into the envelope there are a few things to consider. The need for drainage layers and/or weeps at the bottom of walls will provide a way for the moisture to leave the envelope. The primary moisture barrier is the exterior cladding. There is secondary moisture barriers also called air barriers that will help stop the moisture from entering the building. Problem areas in homes occur at wall to wall and wall to ceiling intersections. These may be areas where condensation will occur, due to thermal bridging through framed members, discontinuous air seals, and insufficient insulation. Adequate insulation and air barrier installations will prevent this problem. The disadvantage to the wood frame wall is that if the moisture barrier like the thermal, air and vapour barriers are not continuous throughout the envelope then the moisture will penetrate the sheathing and sit in the insulation and studs of building. When this happens the moisture will stay in the envelope and the studs will develop mold, mildew and begin to rot.

### ***5.2 Moisture through ICF's***

Using ICF's as the construction of the wall assembly provides a complete building envelope system. The advantages to the ICF's are that the foam plastic insulation blocks or panels located on either side of the reinforced concrete act as all of the necessary barriers. Again the primary moisture barrier like wood frame construction is the exterior finish placed on the ICF's. The next line of defense is the EPS blocks or panels. EPS has the ability to be an air, moisture, and thermal barrier all in one product. Although EPS's water vapour transmission properties are moderately low. It is EPS's uniform closed-cell structure that allows the diffusion of moisture / water. Because EPS will not trap water

within the exterior walls, there is no need for costly venting as in wood frame construction. The advantage to using ICF's is that they are considered a complete system. Compared to wood frame construction there is little to worry about when it comes to wall to wall intersections. Because the exterior walls are constructed of reinforced concrete in a monolithic pour, there is no worry of thermal bridging, with the result of condensation build up. The one area that there is a possibility of thermal bridging is in the wall and ceiling intersection of the top floor. At this intersection the ICF's are meeting a wood framed roof. Some moisture may still be in the wood causing slight condensation. To prevent this from happening a vapour barrier is used around these areas to reduce the chances of condensation.

## **6. Vapour**

Vapour is a major contributor to building envelope failure. The way in which to stop the movement of vapour through the building envelope is through the means of a vapour barrier. A vapour barrier is a membrane that restricts the migration of moisture by diffusion from an area of high humidity.

The location of the vapour barrier is very important. It must be located near the warm side of walls and ceilings so that condensation in the cold areas of the assembly does not occur. Vapour barriers are usually placed on the warm side of the insulation to keep water vapour from cooling and condensing within the wall assembly, and within the insulation, which will cause sagging of the insulation resulting in a loss of R-value.

Condensation will not usually occur as long as two-thirds of the insulating value of the wall is located outside the vapour barrier. "Materials such as asphalt impregnated kraft paper, polyethylene, aluminum foil, and paint (two coats of alkyd applied to gypsum wallboard) deter water vapour from penetrating into and through the building envelope by diffusion"<sup>B</sup>.

Because diffusion takes place slowly over a large area, small openings in the vapour barrier do not greatly affect moisture movement by diffusion. However, such openings

---

<sup>B</sup> [www.cwc.ca](http://www.cwc.ca)

do increase air movement and the mass transport of moisture-laden air through small openings, and are potentially a greater hazard for moisture deposition than diffusion.

### ***6.1 Vapour transmission in Wood Frame Construction***

With wood frame construction there needs to be a vapour barrier present in order to stop the transmission of water vapour through the building envelope. Because the diffusion of vapour is slow and uniform there is less deterioration caused by vapour diffusion than there is of the diffusion of air. The 6 mil (0.15mm) polyethylene is the most commonly used vapour barrier in wood frame construction today. The problems associated with the failure of the vapour barrier are increased levels of vapour diffusing and moving through the building envelope. If the vapour does not have a way out of the envelope it will remain in the stud cavity, resulting in rot, mold, mildew and deterioration of the studs and wall overtime. Also the insulation will become saturated with water and lose some of its R-value. As well the insulation will begin to sag in the stud cavity resulting in no insulation in the top half of the wall assembly.

### ***6.2 Vapour Transmission in ICF's***

Insulated concrete forms are unique in the way they use the foam plastic insulation as the environmental barriers. Although EPS is not a vapour barrier it still has the ability because of the closed-cell structure to allow the diffusion of moisture / water. The ICF's that use EPS insulation are required to use "Type 2 EPS that has a water vapour transmission rate of 3.50 perms/inch maximum (200 max. Ng/Pa.s.m<sup>2</sup>) in accordance with CANULC 5701"<sup>C</sup>. Another advantage to the ICF's is that the reinforced concrete becomes a monolithic structure. The poured concrete also aids in stopping vapour transmission as another function of poured concrete is also an air and vapour barrier.

---

<sup>C</sup> IntegraSpec Installation / Technical Manual



## 7. Air

Air leakage is the major factor in the deterioration of the building envelope. Air leakage in a building occurs wherever there is an opening, hole or puncture in the building envelope. There are three main forces driving the movement of air. They are stack effect, wind effect and mechanical pressure. Stack effect is where warm air rises in a building causing outward air pressure in the upper storeys and inward air pressure at the base of the building. Wind effect is the positive pressure on the windward side of a building and the negative pressure on the leeward side of a building caused by wind. Mechanical pressure is the negative air pressure in a building caused by the emission of air by ventilation fans without a supply of replacement air. Three ways in which air moves through the building envelope are; diffuse flow, orifice flow, and channel flow. “Diffuse flow occurs when the air diffuses through the building materials that make up the building envelope. This is not only happening at a specific point but all over the entire building envelope. Orifice flow on the other hand picks a specific point in the wall and moves through the envelope. The orifice flow is usually in a straight direction through the envelope. Channel flow takes a much longer and slower route to damage the envelope. The air flows through cores and holes in concrete blocks and other materials seeking out voids in the envelope taking the path of least resistance. When the channel flow enters the envelope it takes a long time for the flow to stop and in turn causes major problems in the building envelope design”<sup>D</sup>.

Openings such as plumbing vents or stacks, framing and windows and doors, etc. allow air to exfiltrate or infiltrate, and must be properly sealed to reduce drafts, reduce heating costs, and to avoid warranty repairs after construction has been completed.

In order for an air barrier system to function properly there are five basic requirements used in installing the air barrier. The five requirements are as follows:

- The air barrier must be continuous
- Must be impermeable to air leakage, (glass and galvanized metal)

---

<sup>D</sup> Methods and Material lecture September 24, 2002

- Rigid, solid, stable, no movement, ability to transfer wind loads, stop infiltration and exfiltration
- Must be durable, last the life of the building
- Must be repairable

### 7.1 Air leakage through Wood Frame Construction

When 6 mil (0.15mm) polyethylene is completely sealed with caulking at all joints supported by framing members and held tight with the application of gypsum board, the membrane is considered to be capable of withstanding negative air pressure, and is considered to be an air/vapour barrier.

Gypsum board is a rigid material capable of withstanding negative wind pressure. When the gypsum board is sealed around outlets and openings, and when gaskets are applied between floor and ceiling horizontal framing members, an air barrier system called the airtight drywall approach (ADA) results. The advantage of the above mention airtight drywall approach is that the building is considered to be air tight. Because the building is

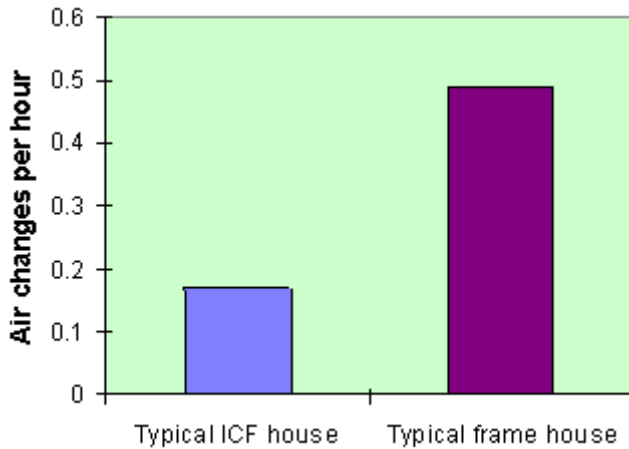


Figure 3: Air Infiltration

air tight no infiltration or exfiltration of moisture laden air will occur. This is a definite advantage, where the problem lies is insuring that all of these gaskets and seals are installed properly. The other disadvantage to the ADA is the increased cost of the wall when factoring in the gaskets and seals, and also the labour needed to install them. Yes the cost will be recuperated through energy

efficiency or so it is said to be. There needs to be honesty coming from the contractors where the ADA is being used and this system needs to be installed properly. The location of the air barrier can be either on the inside or outside of the thermal barrier (insulation); basically speaking there is no rule on where the air barrier needs to go in the

building envelope. Figure 3: Air infiltration demonstrates that the interlocking foam faces, sealed with continuous concrete in the center make ICF walls exceptionally air tight.

## **7.2 *Air Leakage through ICF's***

“Air infiltration in an ICF home is minimal due to the continuous air barriers provided by the foam insulation and the concrete. Likewise, there are no convection currents within wall cavities. Because the ICF's have no cavities there is no chance for the moisture laden air that passes if any passes through the plastic foam to sit and cause rot, mold, mildew and deterioration. The concrete walls of an ICF home have high thermal mass, which buffers the interior of a home from the extremes of outdoor temperature during every 24-hour cycle. This reduces both peak and total heating and cooling loads.

This combination of high R-values, low air infiltration, and high thermal mass is believed to account for the amazing 25% to 50% energy savings of ICF versus wood or steel-framed homes”<sup>E</sup>.

Once again the ICF's are a superior building envelope compared to the conventional wood frame constructed home because of the moisture, vapour, and air tightness of the system.

## **Four Minor Physical Factors**

The following sections will be discussing the four minor physical factors affecting the walls in the building envelope design. The four factors are: Sound, Fire, Radiation, and Pollution.

## **8. Sound**

Sound transmission through walls is something that has been study for many years and keeps getting better. Sound is heard by the ear detecting fluctuations in atmospheric pressure caused by the vibration of air particles.

---

<sup>E</sup> [www.forms.org](http://www.forms.org)

Sound can travel through solid materials as well as air in the form of vibrations. When a sound pressure wave impacts a surface vibrations occur and these vibrations are carried through the source on which they hit. This is how sound is transmitted through a building. The best way to reduce sound transmission is to use construction techniques that dampen vibration and convert sound energy into heat of friction. The other method in which sound travels is through impact. Sound can be categorized into two main types; airborne sound, and mechanical contact (impact) sound.

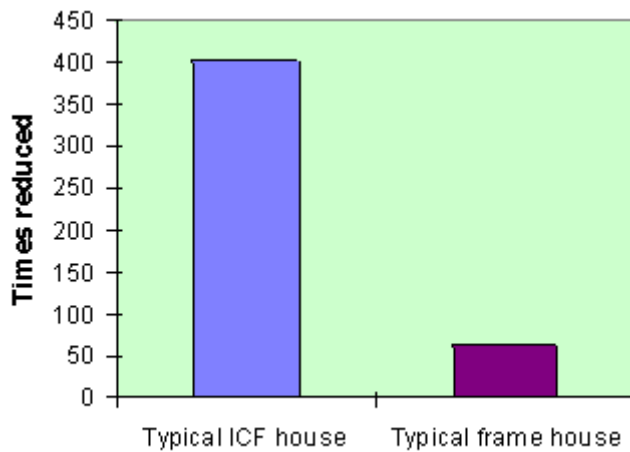


Figure 4: Sound Reduction

For the purpose of this comparison sound is the same as unwanted noise. Neither of the two construction techniques wants the home owners to be disrupted by the sounds of the outside world. It is for this reason that there is a standard in determining the sound transmission

classification (STC) of walls. Figure

Sound Reduction shows that the ICF walls reduced the sound transmission about 400 times whereas the wood framed wall only reduced the sound transmission about 50 times.

### 8.1 Sound Transmission through Wood Frame Construction

Most wood frame constructed exterior walls will be able to give the home owner an STC rating of approximately 36. This is not a bad rating but there is still the ability to improve this rating to be even better. With an STC 36 wall the home owner will be able to hear the outside noise, of the construction workers and the street traffic. Architects and designers want to be able to give the home owners peace and quiet and it just is not possible using the conventional wood frame construction.

## **8.2 *Sound Transmission through ICF's***

Concrete walls built with insulating concrete forms effectively buffer a house's interior from the outdoors. The thick ICF walls made of plastic foam and reinforced concrete sharply cut fluctuations in temperature, air infiltration, and noise. ICF's keep the inside of a house more comfortable and quiet than ordinary wood frame walls. Using ICF's for the construction of the exterior walls will provide the home owner with an STC rating of 50. This rating will render the building envelope virtually sound-resistant. The occupants of the home will never be disrupted by any of the unwanted outside noise.

## **9. *Fire***

Fire is a destructive force that has troubled humans through the ages. Even with modern construction technology and fire detection and suppression systems, building occupants' highest risk comes from heat and smoke inhalation. The resistance to fire is something that is difficult to achieve. There are not too many homes that will stand up against a fire. Once the fire hits a residential dwelling unit there is nothing that will save it so that the occupants can just come back to live in the house that they once knew. The smoke and heat generated during a fire cause about 90% of deaths. Only 0.2% of deaths in homes were attributable to structural collapse

### **9.1 *Fire in Wood Frame Construction***

Wood is a material that does burn, but like steel and concrete, can meet and exceed the fire safety provisions of building codes for use in walls, floors and roofs. Wood can retain its strength during a fire because of the char that forms, providing protection to the unburned portion. In wood frame construction not only is the frame of the structure burning and being destroyed but at the same time the materials around the frame are also burning. All of these materials are giving off some kind of gas that is toxic to the environment. Any of the fibreboard or OSB sheathings that are made with glues and resins when burned will give off toxic gases that harm the environment.

## 9.2 Fire in ICF's

Of all construction materials concrete is one of the most resistant to heat and fire. That fire resistance gives houses built with ICF's certain safety advantages. Experience shows that concrete structures will remain standing over structures made of other materials.

Unlike wood concrete does not burn and unlike steel concrete does not bend and lose its strength. Concrete does however break down and begin spalling when exposed to thousands of degrees Fahrenheit. This has been confirmed through fire wall tests. In these tests the ICF walls were subjected to continuous gas flames and temperatures of up to 2000° F for as long as four hours. None of the ICF walls ever failed structurally<sup>F</sup>. In the same test wood frame walls typically collapse in an hour or less. When looking at the ICF walls as flame spreading resistant, in the same test the wall did not allow enough heat through the wall to start a fire on the other side for anywhere between two to four hours. In contrast wood frame walls typically allow both flame and fire-starting heat through in an hour or less.

The following two figures show the Fire Ratings of wood frame walls compared to ICF walls, and Flame Spread between wood frame walls and ICF walls.

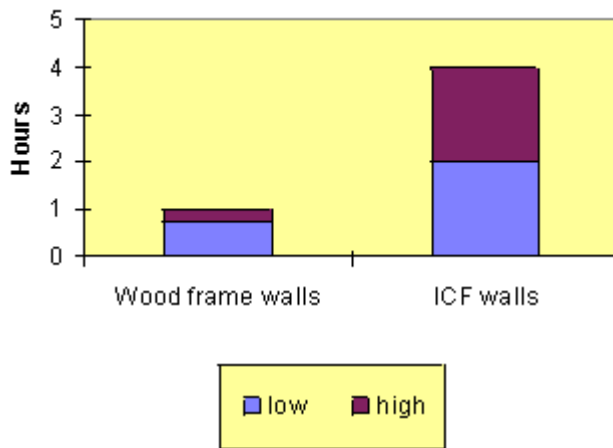


Figure 5: Fire Ratings of Wood Frame walls vs. to ICF walls

---

<sup>F</sup> [www.forms.org](http://www.forms.org)

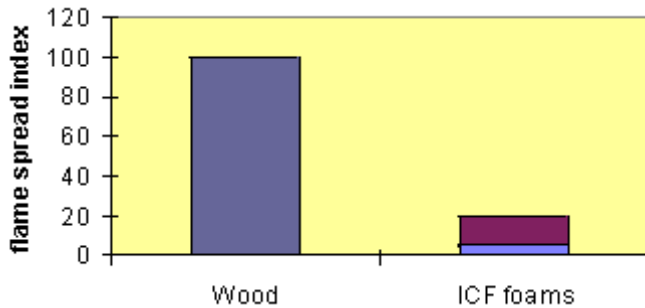


Figure 6: Flame Spread Indexes of Wood Frame walls vs. to ICF walls

## 10. Radiation

Radiation is the cause of material deterioration in the building envelope, during installation processes. Until the exterior cladding is placed on the building all of the materials undergo some kind of deterioration. If this deterioration occurs the building envelope will suffer major consequences. One specific material that is affected by UV radiation is XPS insulation. The sun begins to break down the cellular structure of the XPS, leaving the material with a lower R- value than what the material originally started with. The exterior cladding is the radiation barrier in a building envelope.

UV radiation affects both wood frame construction and ICF construction in pretty much the same matter. All of the building materials used in both of the construction methods need to be sealed / covered as soon as possible to prevent UV radiation deterioration.

## 11. Pollution

The pollution barrier in the building envelope is taken care of by the air barrier system already present in both of the construction methods. For the wood frame construction the air barrier is a 6 mil (0.15 mm) polyethylene barrier that needs to be continuous to keep the infiltration and exfiltration of air and moisture out of the building. With the ICF wall the air barrier system is provided through the continuity of the plastic foam insulation. This foam insulation runs the height of the building providing continuity from the footing all the way up to the roof of the structure.

## **12. Environmental Impact**

Environmental impact is a hot topic in the building envelope design field these days. Why? Well it is because the Architects, Engineers, Technicians and Technologist are all trying to design buildings that are more environmentally friendly. The biggest challenge is to design an environmentally friendly building while at the same time keeping the cost down. All of the building materials in new buildings today are supposedly able to be recycled and renewed. But how much of these materials can actually be reused? No one really knows for sure. Most building materials harm the environment, whether it is in the way they are manufactured or the way they are being destroyed. For example when a building burns, toxic gases are being emitted from the building regardless of the materials inside.

### ***12.1 Environmental Impact in Wood Frame Construction***

People do not look at wood frame construction as an environmental impact. How can it be, the house / buildings are made of a natural resource. Well the answer is that there is an environmental impact in wood frame construction. Look at the manufacturing process of engineered lumber and sheathing such as plywood, or oriented strand board (OSB). These “better” building materials are being made from strands of wood and recycled wood, really good, but the problem lies in the adhesion of the different layers. They are being glued together with formaldehyde or other toxic resins that give off gas just like some of the other materials found in residences today.

The other environmental impact is the waste of construction materials. Yes the wood can be taken and reused somewhere else but why not cut down on the amount of waste. Recycling takes energy and energy means the use of fossil fuels; these fuels give off gases which in turn will harm the environment.

Looking at the environmental impact of the wood frame house as it burns is another concern. All materials produce smoke and that smoke is harmful to the environment no matter what it is.



## ***12.2 Environmental Impact of ICF's***

Most people look at ICF's as environmental hazards because they are made of plastic foam insulation. Well this is not true as the manufacturing process of some of these foams requires only steam to expand the air inside the small beads. EPS is manufactured from expandable polystyrene beads containing a blowing agent and flame-retardant additive. Steam heat expands the blowing agent to produce moisture-resistant, multi-cellular particles, which increase up to 40 times their volume during the process. After a period of time the beads lose their moisture, and the blowing agent condenses out and air diffuses into the cellular structure.

The EPS insulation used in the ICF's has the ability to be recycled if the need ever arises. Methods in which the EPS panels or blocks are recycled are through grinding, melting, and incineration. Grinding of the used foam plastic produces additional brand products such as Styromull. Styromull is a soil additive that is used to improve substrates and soil as a composting additive, as a filter material in pipe drainage and as a filler material in slot drainage. The EPS insulation has the ability to be melted into its original compact starting product of polystyrene. When the EPS insulation panel scraps are incinerated there are no measurable changes in the composition of the fumes. The toxicity of the gas from the burning and low temperature carbonization is lower than, for example, that of the same amount of wood or cardboard. The other ways to discard of the EPS panels are through dumping. There are no problems in depositing the scrap at properly organized refuse dumps. The only restriction is that the panels be reduced in size to avoid air pockets and allow for compaction. The foam scraps improve the airing of the dump and contribute the decay of the organic substances dumped with it.

Other impacts that the ICF's have on the environment are that when the building is on fire the EPS insulation panels will emit toxic gases into the atmosphere. People think that the EPS is more harmful during a fire than wood studs and all the sheathings and other materials used in wood frame construction, but the truth is that all of the materials in any building will produce smoke that contains some kind of toxic gases.

Here is what Ed Lage had to say about the environmental impact of the two construction methods. “Environmental impact, walk through a conventionally constructed subdivision. Now that is environmental impact. I see two issues:

1. The production of the product.
2. The disposal of the product.

In using an ICF block no trees were cut. No shipping of the materials. No manufacturing of the materials and less energy is being consumed. Less fossil fuel needed means less environmental impact. Less expense to the home owner. ICF is simplification.”

### 13. Cost

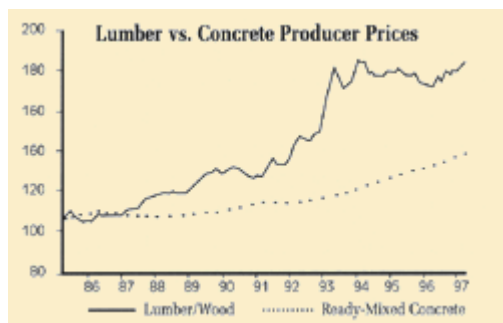


Figure 7: Lumber vs. Concrete Producer Prices

Cost competitive, over the last ten years, concrete prices have been remarkably stable. Recent price increases in other materials have generated interest in concrete building systems as never before. Labour savings and readily available materials make ICF's, feature for feature, one of the most cost competitive wall systems in U.S. and Canadian housing markets.

Comparing both the wood frame wall and the

ICF wall the cost from what has been researched from many different sources appears to be roughly 20-30% more to construct a building out of ICF's. Although through an interview conducted with Ed Lage a contractor he was able to prove that the cost of the ICF system was substantially lower. Almost 50-60% less than conventional wood frame construction with virtually no waste material onsite. If the research is correct that the ICF homes cost 20-30% more then the factors to look at are those of the energy savings.

From the following figures it is possible to see that the ICF homes will save the home owner money when it comes to looking at heating and cooling costs. The way in which the owner will recuperate his or her cost will be through energy efficiency.

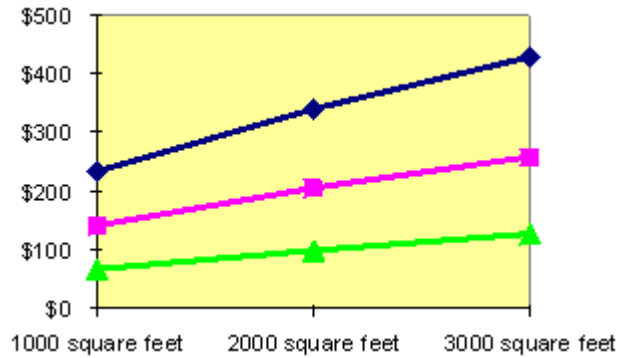


Figure 8 : Annual Estimated Heating Savings

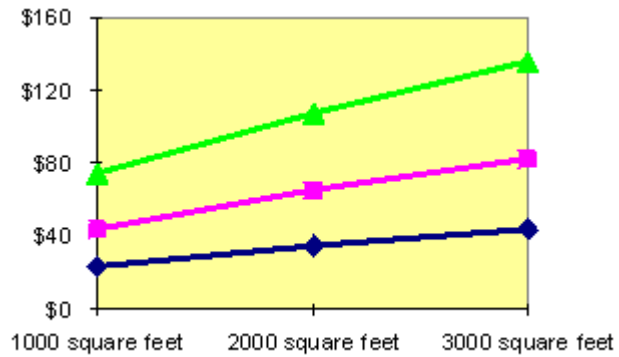
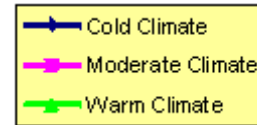


Figure 9 : Annual Estimated Cooling Savings

#### **14. Conclusions**

Looking at all the information presented in this report it is evident that only the customer can decide on which construction materials he or she decides to use. Both Wood Frame construction and ICF construction have their advantages and disadvantages. When designing a building envelope a very good tool to use is the building matrix. The building matrix is a quick check list to insure that the detail being designed will be able to withstand the eight physical factors that affect the building envelope components. Once again the eight physical factors to test the building envelope components by are: heat, moisture, vapour, air, sound, fire, radiation, and pollution.

The other main property that should be looked at in any construction project is that of the environmental impact. Environmental concerns are nothing new, it is just that the building industry has neglected to look at the materials being used in construction and see what they have done to the environment. People also need to be told the truth about the environmental impact of certain building materials. There are rumours circulating that some building materials are very harmful to the environment when in actual fact after enough research has been performed, it is found that these materials have been harmful in the past but know with the technological advancement they are actually helping the environment more than they are hurting it.

Both wood frame construction and ICF's are excellent building envelopes but one will eventually out weigh the other. The only thing that needs to happen is to let the customers know the truth about both of the construction materials and techniques used in constructing the different buildings.

Refer to Appendix C: Wood Frame Construction Details to see a sample of a sill detail in wood frame construction. Refer to Appendix D: Insulated Concrete Form Detail to see a sample of the exterior insulated concrete form wall meeting a wooden floor joist in ICF construction.

## **15. Recommendations**

After performing research for this paper I am now able to make a conscience decision on which building envelope I will be choosing when it comes to building my home and which system I will recommend and try to spread the word about in my travels. To me insulated concrete forms are the only way to go. There is so many advantages and little disadvantages that I have found to this system. Some of the advantages include: greater comfort, lower energy bills, peace and quiet, solid and lasting security, less repair and maintenance, a healthier home and environment. And the most important thing I have learned about the ICF system is that it is 50-60% less expensive than any other building system on the market today.

Also I have only heard bad things about the environmental impact that the EPS panels produce, but after researching this report I have found out that the EPS panels are used for more applications than just in the ICF building system. There are three positive aspects in the handling of the EPS panels and scraps. They include things such as:

- The conversion of used foamed articles into Styromull or recycled polystyrene produces new, saleable products from scrap.
- The high heating energy of the materials can be used cost effectively in refuse incinerators or special combustion chambers.
- If disposed of properly, no environmental pollution is likely.

In the environmental impact section of the report I mentioned that the foam scraps improve the decay of the inorganic substances dumped with it. To me that is pretty impressive, again since I have only ever heard that EPS is hard to get rid of and it is harmful to the environment. Unless the information I have received is false I find that the ICF's are as environmentally friendly if not more friendly than other building materials on the market today.

Wood frame construction has its advantages as well. First of all it has been around in the market for as long as time can tell. It is a widely used and known building envelope. Where the wood frame construction loses to me is in the complexity of the envelope. It is very amazing that all the different materials work together, but at the same time when one

of the materials fail then most likely the entire envelope will fail as well. There has been extensive studies conducting on ways of improving the building envelope but tell me why someone would want to build a house out of wood when they can have all the advantages of a solid monolithic reinforced concrete structure for less.

One thing that I have learned from this report and from the interview I conducted with Ed Lage is that the world is corrupt. As Ed says “Published prices are values which are benchmarked by the people selling them. As explained previously, supply and demand affect the prices of new products on the market. It is people who ultimately control the price of goods in the industry. Not the product”. Also according to Ed Lage who has worked with both wood frame construction and ICF’s “You can not compare this technology with conventional construction. The Ontario Building Code is the minimum standard allowable. Why would anyone wish to build a structure to the minimum allowable standards?”<sup>G</sup>

In closing I have also found out that our major home builders in the Ottawa region live in ICF homes. This seems to be the norm with these developers. Give what you do not want for yourself (with a heavy price to the customer) and live in an ICF home.

For the complete interview with Ed Lage refer to Appendix A: Interview

---

<sup>G</sup> Interview with Ed Lage, November 17<sup>th</sup> 2002

## Bibliography

Eco-Block Installation Manual, May 12, 2000

HUD, "Alternatives to Lumber and Plywood in Home Construction," prepared by  
NAHB Research Center, Upper Marlboro, Maryland, April 1993.

Kesik, Ted J., Canadian Wood Frame House Construction, CMHC, 1998

Kosny, J. and Desjarlais, A.O., "Influence of Architectural Details on the Overall Thermal  
Performance of Residential Wall System," Journal of Thermal Insulation and  
Building Envelopes, Vol. 18, July 1994

Lage, Ed. Contractor, interview with person. November 17, 2002

Phil-Insul Corporation, Integraspec, Installation/Technical Manual, 1999, 2000

[www.arxxbuild.com](http://www.arxxbuild.com), Arxx Building Products, September 30, 2002

[www.forms.org](http://www.forms.org), Insulating Concrete Form Association, November 15, 2002

[www.formtechsys.com](http://www.formtechsys.com), Formtech International Corporation, November 1, 2002

[www.cwc.ca](http://www.cwc.ca), Canadian Wood Council, October 30, 2002

I received a number of pamphlets from different manufacturers of the insulated concrete forms. They were very helpful and quick in sending me information, when I requested some literature on their product. I also attended the Ottawa Home Show on September 29, 2002 where I received more pamphlets from various ICF manufacturers again. At the Ottawa Home Show I was also able to talk with a number of representatives about their products. Some of the manufacturers included Eco-Block, and Arxx Building Products.

## Appendix A: Interview

with Ed Lage (Contractor)

1. Why did you decide to build with Eco-Block opposed to other ICF's?

**Ed Lage:** All ICFs are made the same. What I mean by this is at the end of the day Insulated concrete is insulated is still insulated concrete. To say that one system is better than another would be incredibly misleading. Each system has its own variation of locking mechanism and its general appearance is slightly different from one product to another. At the end of the day it is still concrete sandwiched between two pieces of the Expanded Insulation. It is what we choose to believe that makes each of the many ICF's different from one to another.

There are many reasons why eco was chosen as the ICF Supplier used on this project. Simplistically answered, Service!!! Always is Buyer beware.

Most established "Good" ICF manufactures or suppliers will offer a number of different moulds to facilitate the ease and time required to construct an ICF Building. Onsite fabrication of 90, 45, 22.5 degree corners increases the cost of the structure as it becomes more "corner complicated". I would recommend a manufacture that is structured this way. It makes for painless installation. The Bracing Systems for wall alignment during the concrete pour was another reason for my choice. The Eco Bracing systems comes with all the parasitic certifications that are mandated by our Government. An Expensive added cost that really is not required. An Engineer was already paid to develop them. However, they are a must. Other companies may make there own braces out of wood on site at your expense. Eco's Bracing system is manufactured from steel.

2. What are some of the advantages and disadvantages to building with ICF's?

**Ed Lage:** One would say that using this type of construction technology would be most beneficial when assessing the Big Picture in any building envelope. In my case a few mistakes in the planning were made that logistically changed the evolution of my project. In some areas of the building because of design restrictions we sized the building to the block. It is most advantageous to size the block to the building if at all possible. Less waste will result. Make sure you let your designer know this. This is not common practice in the industry. The opposite has been my observation.

If we look at the system as a whole, it is untouchable. It offers the consumer a structure that has air penetration values through the ICF wall system of less than half of a percent. The system is ready to accept any finishing system to its exterior face. Conventionally constructed a house wrap is still required before a finishing system can be applied required. In my case stucco was chosen as the finishing system to the outside of the building. This negates the necessity to hire a SUB



CONTRACTOR to install the (in my case) 5800square ft of expanded insulation. The expanded insulation is already there.

From an interior perspective, once the bracing system is removed and electrical wiring installed you are ready to install drywall. Again the product has negated the use of another SUB CONTRACTOR. No wall insulation required. Furthermore, these structure and there inhabitants have reportedly (The Learning Channel & Ottawa Citizen) survived the worst of hurricanes. As they are steel re-enforced they have incredible strength. One of the engineers working on site has referred to these systems as "Over Kill" That is what you want to hear. Combustibility is nominal in a structure like this. It utilizes the same materials and engineering principles as those found in commercially constructed structures. Think of the Engineered Safety Factors negotiated into all of our skyscraper structures. Engineering Firms pay close attention to these details. If you hire the Correctly Motivated Contractor, he/she will ensure that materials chosen for the interior construction keep with the idea of non-combustibility. At virtually no extra cost, probably less. The roof structure in this building is of conventional construction. In my opinion, the weak link. A light steel roof system, not Structural steel, as CURRENTLY used in commercial construction projects would be my choice. Due to the high performance caricaturists of this construction technology, another disadvantage arises. The house holds moisture. If not controlled, inner air quality suffers and mold begins to form. A Heat Recovery Ventilator is required to make the house breath correctly

3. Ed these systems are made of either two types of insulation, either expanded or extruded polystyrene? There must be some kind of disadvantage to using these insulations? There must also be some dangers with the way the insulation is made? For example chemicals and blowing agents?

**Ed Lage:** To answer your question I was not entirely sure myself. How this answer generated itself I am not sure. Regarding the Technical Data on the expansion of the insulation, I am still unclear. As a future technologist how about you find out for me. You'll probably need it in your studies. I will however say I am curious to find out if it is a chemical agent or a steaming process as it has been explained to me. It did not answer all of my questions based on passed experience in manufacturing.

With regards to water it is still unclear. I did not like the variations in answers which I received from various parties. The advice was from one end of the spectrum. Good time to exercise caution. If you noticed in the pictures and the visit to the site. A membrane (\$862.50 42"x 423') was used to completely seal the foundation from possible moisture. The back fill material is of pure sand, Excellent for drainage. Do I worry about this foundation absorbing water? NO. It is an idea that I have that prolonged expose would cause "sponging", possibly. That is also based on passed experience.

Environmental Impact. Walk through a conventionally constructed sub-division. Now that is environmental Impact. I see two issues. 1. The production of the product. 2. The disposal of the product.

In using an ICF block no trees were cut. No shipping of that material. No manufacturing of those materials. Less energy consumed. Less fossil fuel needed, less environmental impact. Less expense to the home owner. ICF is simplification.

You can not compare this technology with conventional construction. The Ontario Building Code is the minimum standard allowable. Why would anyone wish to build a structure to the minimum allowable standard?

4. How much more is it to build with ICF's over Wood Frame Construction?

**Ed Lage:** There was a special in the news paper regarding airline tickets a few months ago. It was rather interesting in what WEST JET was advertising. They proposed flying you at cost. It actually made the papers a second without WEST JET paying any ADVERTISING. What they did was offended the fares with full discloser. Six bucks! I Kid you not. To the consumers surprise however, when you add up the Tax, plus the sure charge, debt repayment charge, the airport development charge, additional security charge, airport administration fee, and whatever else they can think of. The consumer gets the bill for 187.60. How is that possible from six bucks!!!!!!

It is not what it's worth, It what you did to earn the money. Have they stopped teaching these values in school?

5. How many years will it take to recover the initial cost output?

**Ed Lage:** As explained in my last transmission with you, the costs are no more than a conventionally built home. If anything it is significantly cheaper. Published prices are values which are benchmarked by the people selling them. As explained previously, supply and demand affect the prices of new products on the market. It is people who ultimately control the price of goods in the industry. Not the product.

Let us use the current situation in our high tech markets to try and explain the current pricing of this product. Let us take the computer in which I have used to communicate with you. I paid three thousand dollars for it. In the span of 8 months it was worthless. That appears to be a silly investment for the gross expenditure. Do you think that the industry changes that rapidly or is it good marketing? Why would any money generating entity give you all the technology up front? A one time purchase negates future business. Is it possible that if you release the technology in small sprints, significantly more money can be made from it. A 286 MHz computer was used for the first moon landing re-entry. That

was thirty years ago. The internet has been around for 20 years or so. You do the math. Is it possible that the Capitalist approach could be the culprit?

Try this one for size. A Mazda Protégé as explained to me costs 4000.00 to manufacture. Why does the consumer get hit with over 20 000.00 or more for it? Because that is what people are prepared to pay for it.

Let us try this. Currently the Provincial Government has this formula in how it regulates the installation of Septic systems and their associated sizes. Let's use a Tap Count in your home to make the point.

The current GOVERNMENT legislation states that based on the size of your dwelling your septic system grows with its size. What does mean. If you have a 1000 sq ft dwelling with 5 bathrooms vs. a 9000 sq ft dwelling with the IDENTICAL 5 bathrooms or total tap count, and the same inhabitants the dwelling that is 9000 sq ft has a septic system 9 times bigger. Why is that? Well, that sounds like the rich can afford to pay a little more for it. Try getting an answer from the local regulatory office. The answer you will get is "We are not prepared to comment on behalf of the provincial gov't". Sounds fishy to me. Sounds like bureaucrats are at it again. Sounds like entitlement is happening again. Capitalism at it's best

6. How do you find the methods construction with ICF's compared to the construction of wood frame construction?

**Ed Lage:** Construction Logistics.

It is a simplistic system. Adult Lego. The difficulty comes with ensuring that the work is PLUMB, SQUARE, and LEVEL. As with any structure the only difference is mistakes can not be fixed. Due Diligence is required. It is all in the planning. Failing to plan is planning to fail. Failure in this capacity exaggerates the final pricing of a given project. Perhaps this is where some of the extra costs are being justified. The overall lack of knowledge or awareness usually drives the price up. Our industry budgets extra to counter act money lost in the learning curve. That is again how people affect the overall price of any new system price.

7. Are the people and materials readily available to build with ICF's?

**Ed Lage:** As with every industry there is a learning curve. However most of us have logged thousands of hours playing with Lego as children. IF A CHILD UNDERSTANDS THE LOGISTICS OF LEGO, why can't adults grip the concept? Something else is possibly fueling the exaggerated price. Remember, IT IS LEGO. ICF's are incredibly simplistic when compared to conventional construction methods. Fewer materials are needed negating unnecessary material management. Yet another cost saving value when using ICF's.

8. What are the systems specifications? i.e. size, dimensions, r-value, exterior cladding etc.

**Ed Lage:** Product specifications will be listed in the technical information which you have in your possession. Residential values should be used as the commercial values are different. You might ask yourself how this can be the standard. An ICF is an ICF. At the end of the day it is still concrete sandwiched between two layers of expanded insulation. So what is the difference? With regards to CMHC and additional coverage due to construction methodology. It is my understanding that ICF's are a preferred choice. You might want to ask them yourself.

9. Because concrete is fire resistant are the insurance companies giving premium rebates / discounts when ICF's are used?

**Ed Lage:** There is no such thing as a premium or rebate. Where one concession is made another source of capitalist income must prevail. My fear is if we begin to produce homes that carry none of the established utilities, where does our wasteful get government get its tax dollars. Well, sorry to say, it will take from you stating that you live above the norm and that is slated as a luxury. For example. Let us assume that you Adam have a home in which you diligently take care of. Let's take the windows in the dwelling and say that they are original equipment installed when the home was constructed. You decide that you would like to make an upgrade and change all of the windows. Not only have you creating a better home that is more energy aware, you have also placed yourself in a position with our current government to hit you with more property tax. What sense does that make. You will be assessed by Revenue Canada, as they see this as a luxury. And to make sure you can not trick them, they the government has mandated that date of manufacture is stamped within the panes of glass. Kind of hard to remove. Again we show that it is not the product that sets the pace, but the people around it.

10. Staying with the fire resistance of ICF's, because the system is made of expanded or extruded polystyrene, is there an environmental concern with the insulation melting and giving off toxic gases?

**Ed Lage:** When using a correctly motivated contractor, it should be a collective goal to construct dwellings that offer the minimum traditional impact to the environment and to those who choose to reside in them. The choice of construction materials has a direct relationship in how a structure will perform. The markets are saturated with materials that offer exceptional prolonged performance. Why build a structure knowing that the materials are limited. If it burns, look for an alternative. If it off gases toxic material, why would you use it. There is always an option. All you have to do is look for them. Our major home builders in the Ottawa region live in these homes. Contractors who have worked on these sites have sworn to secrecy. I actually tried to visit a site in Rockcliffe Park. An ICF project. I was not allowed to step on site. Why is that? Why would

any builder build something and state it is the best, and not live in his or her own creation. Sounds like Capitalism and a little bit of Deception are at play. I will tell you, the home in Rockcliffe Park belongs to our biggest home builder in the region. Perhaps you may want to ask him why this is. Believe you me. It is not like I have not tried. That seems to be the norm with these developers. Give what you do not want for yourself (with a heavy price to the consumer) and live in an ICF home without sharing that with your current client base. I would say that is quite deceptive and lacks Integrity.

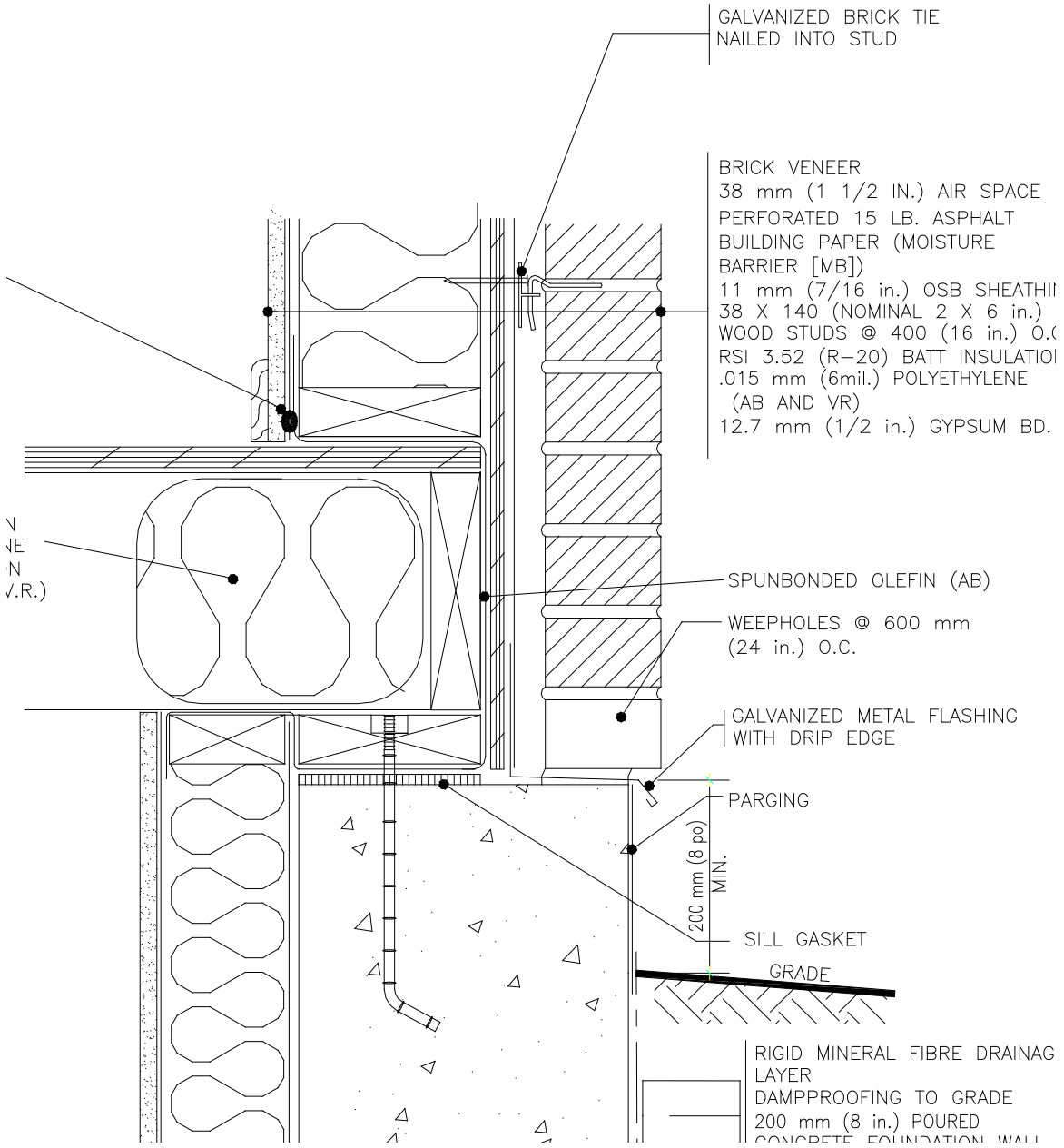
Most of what is build lacks the builders' integrity. You're making a living to pay bills. It should be the endeavor of each and every one of us to create a home for the client. Not how much I can make from this project. Honesty, Integrity, is the keys to the success of any endeavor. It is the people who surround a product that control how it is to be used.

In closing Adam, I hope that you can convey this message to your colleges. The truth is paradigm. The best approach into any endeavor is that of education. Pass on what you have learned.

Through general conversation with Ed Lage, I learned that the owners of RichCraft and Minto homes have left there wood frame constructed houses to move into homes constructed ICF's. If these systems are bad for the environment and cost so much more then tradition wood framed homes why are the two predominate builders in Ottawa living in ICF homes? I also became educated with what is really happening in the industry. I realized that the contractors are taking the clients for a ride for every penny they can squeeze out of them. Buildings and pretty much everything in life are subject to people and not the products. You just need to find the right person who will work for the client and not for himself.

## **Appendix B:** Building Matrix

# Appendix C: Wood Frame Construction Detail



## Appendix D: Insulated Concrete Form Detail

