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A COMMISSIONABLE AIR BARRIER SYSTEM FOR THE BUILDING ENVELOPE

REPORT

A Commissionable Air Barrier System For The Building Envelope

Presented to:

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INTRODUCTORY SUMMARY

Since the mid 70's, the construction industry has made significant advances in energy conservation and improved indoor conditions. These improvements, however, are shadowed by an increase in building envelope problems to include water penetration, condensation on and in roofs and exterior walls and cladding damages in many of our newer buildings. These problems have been attributed to uncontrolled air leakage.

A study of the causes of air leakage through the envelope has revealed that it is not just poor workmanship but a much broader problem, involving inadequate design, the lack of measurable performance indicators, ambiguous regulatory requirements and a general misunderstanding of air and vapour barriers.

This report proposes a method to obtain a commissionable air barrier system, by following the steps required to engineer its performance from concept (project brief), through design, construction and building operation. It also proposes a method of monitoring and maintenance for long term durability of the air barrier system.

Much of the information for this report was obtained from the ideas and suggestions of the group that participated in the CMHC Workshop on Commissioning the Air Barrier System.

Recommendations were made for further research and development work that could accelerate and solidify the process of improving air barrier systems.

INTRODUCTION

Depuis le milieu des années 1970, l'industrie de la construction a réalisé d'importants progrès en matière d'économie d'énergie et amélioré les conditions du milieu intérieur. Ces améliorations ont cependant été ombragées par une augmentation des problèmes de l'enveloppe des bâtiments causés par la pénétration d'eau, la condensation à la surface ou à l'intérieur des toits et des murs extérieurs, et les dommages au bardage de nombreux bâtiments de confection récente. Ces problèmes ont été attribués au manque de régulation des fuites d'air.

Une étude portant sur les causes des fuites d'air par l'enveloppe a révélé qu'il ne s'agit pas simplement de la piètre qualité d'exécution, mais bien d'un problème beaucoup plus vaste, faisant ressortir les règles de conception contre-indiquées, le manque d'indicateurs de performance mesurables, les règlements ambigus et l'incompréhension générale du rôle du pare-air et du pare-vapeur.

Le présent rapport propose un moyen d'obtenir un pare-air pouvant être mis en service, en suivant les étapes requises de l'étude technique de la performance à partir d'un concept (énoncé de projet) en passant par les étapes de la conception, de l'exécution et de l'exploitation du bâtiment. Il propose également un moyen de contrôler et d'entretenir le pare-air en vue d'assurer sa durabilité à long terme.

La majorité des renseignements contenus dans le présent rapport proviennent d'idées et de suggestions formulées par le groupe qui a participé à l'atelier de la SCHL sur la mise en service des pare-air.

Les recommandations visent l'approfondissement des travaux de recherche et de développement susceptibles d'accélérer et de raffermir le processus d'amélioration des pare-air.

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1. INTRODUCTION

The most prevalent problems with the performance and durability of the building envelopes of low-rise multis or high-rise apartments and condominiums are rain penetration, room temperature control, condensation on windows, frames, and in cavities and cladding damages. All four types of problems have been linked directly or indirectly to the leakage of air through the building envelope. In turn, the leakage of air has been found to occur because of the use of construction materials unsuitable to prevent air leakage, poor workmanship, design deficiencies built into the envelope, a poor understanding of the science of air leakage control and the absence of performance standards that provide a minimum level of measurable performance and durability. This situation is an industry wide problem and it will not be redressed easily or quickly.

To better understand the situation, we examine an air leakage problem and the type of damages it can cause. An 18 storey condominium, experiences a flooding problem on the ground floor suites every Spring for about four days. This has occurred repeatedly for five years since completion of the building. The building is clad with architectural precast over spandrels, beams and columns. A deep cavity is formed between the precast covers and the infil construction at the spandrels and columns. The spandrel walls consist of insulation, infill block, a polyethylene vapour retarder and interior gypsum board. The windows are sealed to the precast and the exterior of the precast joints are sealed at the face, except that the top of the precast cavity in front of the columns is open to outdoors but protected by a large overhanging roof.

The building is pressurized by a roof top ventilation system supplying air to corridors and the main floor lobby. This ventilation created a positive air pressure difference across the outside wall from the top of the building to the 2nd floor.

An investigation of the cause of flooding found that the water originated from the melting of frost and ice accumulated on the backside of the architectural precast. The source of the frost and ice was found to be condensation of the moisture in the air entering the construction cavities through the inside part of the walls and exiting through the top of the precast under the roof parapet. The leakage of air was induced through the walls and out by the ventilation system and also by stack effect pressure.

Typically, the responsibility for the problem and damage was directed to the builder. However, it was found that he had constructed the building essentially as per the architectural drawings and specifications. Further consideration of the drawing and specifications found that the materials chosen to construct the infil walls were unsuitable to reduce the leakage of air into the construction cavities. An examination of the design process found that there were no performance values or proven materials or components to guide the design and further there were no minimum standards of good practise or in the codes to govern the rate of air leakage as there is for diffusion control. Therefore, if the building envelope of our new building lacks sufficient air leakage control through wall, window or roof it would not be resolved by blaming poor construction quality. While the builder may be deemed responsible for failures, it is just as much the responsibility of the designer, material supplier, the regulatory agency and researcher.

Air leakage through the building envelope is not a new phenomenon. It was recognized as far back as 1960. However, because of our increased activities to reduce energy consumption (more insulation) and to improve indoor air quality and humidification (positive pressurization), the side effects of these changes became the symptoms of air leakage problems noted above.

Fortunately, there has been progress over the last ten years, on the research and development of air leakage control, and particularly from the Canada Mortgage and Housing Corporation (CMHC). Through its R & D activities it has investigated the type and severity of the problem, tested and categorized materials, tested various design details, determined performance requirements and it is now developing design guides to incorporate air barriers into the building envelope.

It has been suggested that commissioning the air barrier system could improve the performance and durability of the air barrier system. Commissioning is normally associated with mechanical and electrical systems in a building. It is the process of verifying the performance of HVAC systems to determine if the construction of the mechanical systems complies with the design documents and the specified performance ratings.

Undoubtedly, the concept of commissioning has appeal because it identifies the functional (measurable) attributes of a component system, information that is required to determined if the performance of the HVAC, or other system is within acceptable limits.

However, herein lies the complication for commissioning the air barrier system. There are no design measurable performance requirements for the air barrier system of a building envelope (except for metal and glass curtain walls and windows) for the maximum air leakage rates, structural support, material qualities, and guidelines to durability. Therefore while commissioning the air barriers may be interesting, the values obtained by field testing have no relationship to construction compliance and more important do not determine if the design of the air barrier was adequate. It will not solve any of the problems stated above, but it would be helpful in a broader approach where performance requirements are identified from the beginning of a project, the design of the air barrier system is engineering and tested if necessary and the construction is certified through compliance testing and review.. Then, with established performance criteria and proven design feasibility commissioning of the air barrier system may be applied.

To improve our industry's ability to predict the performance and durability of the air barrier system, we must look to providing better information for all, from the owner, through to the eventual user and a methodology to encourage designers and builders to advance air barrier system design and construction from an art to a science. In this respect, the Canada Mortgage and Housing Corporation, through various research and development projects, has made significant advances towards this objective. The results of this research forms the basis of a proposed methodology for the development of a commissionable air barrier system. The methodology proposed is dependent on certain assumptions. These are:

- that the performance requirements of the air barrier system be defined quantitatively in a project brief to include air leakage rates and structural loading,
- that the performance of the proposed design for the air barrier system be certifiable through evaluation, testing, manufacturer data or previously demonstrated performance,
- that the construction process incorporate adequate progress testing and field review to ensure compliance with construction documents,
- that remedial action can be undertaken during the design or construction process if the performance evaluation of any of its parts or the whole system fails to comply with the performance requirements of the project brief,
- that the work required to incorporated an engineered air barrier system is not within the normal scope of design services and therefore additional fees are justified, and
- that the work required to construct an engineered air barrier system is not within the normal scope of construction services and therefore an additional cost is justified in bid prices.

The information and methodology that follows explains and illustrates the steps to be taken to design, construct and commission the air barrier system of the building envelope of a residential project. It further discusses durability through operation maintenance and repair so that owners may benefit from improved technology.

The report is divided into five parts. These are;

- part 1, the Introduction, explains the cause and effect of uncontrolled leakage and the reasons some of the buildings do not perform as expected. It also proposes a conceptual approach for developing a commissionable air barrier system.
- part 2 Air Leakage Control, discusses performance requirements of air leakage control and proposes performance requirements for use in engineering the air barrier system.
- part 3, Design Construction and Performance. This part explains and illustrates the requirements of the Project Brief, a design procedure to account and certify the feasibility of the air barrier system design, a construction method to incorporate the air barrier system technology and progress review and testing, and a method of commissioning the air barrier system.
- part 4, Operation, Maintenance and Repair is intended for the owner. It is a conceptual plan for a manual that describes the system, explain direct/indirect monitoring and testing. It suggest maintenance where required, and how to service and repair the air barrier system.
- part 5, Conclusions and Recommendations reviews the current situation, how to attain a commissionable air barrier system and identifies areas of R & D to further improve our knowledge and skill in providing performing and durable air barrier systems.

2. AIR LEAKAGE CONTROL

2.1 Envelope Performance

The building envelope of any building must perform certain functions to provide adequate control of the indoor environment from the outdoor conditions. These functions were defined and explained in a National Research Council publication, Building Digest # 48, titled “Requirements for Exterior Walls” by N.B. Hutcheon. It is these requirements that form the basis of most building envelope design and construction in Canada. Among these requirements are seven control functions. These include:

- control of heat flow;
- control of air flow;
- control of water vapour flow;
- control of water penetration;
- control of light, solar and other radiation;
- control of noise; and
- control of fire.

While all the control functions listed above are important, this project focuses on the control of air flow, specifically the performance and durability of the air barrier system. What is most interesting, is that the control of air leakage directly affects five of the other control functions. For example, uncontrolled air leakage causes uncontrolled heat loss/gain, bypasses the vapour diffusion control to cause wetness (condensation) in cavities. It will disable a rainscreen and reduce it's ability to control rain penetration, it will disable noise resistance and it can severely impede smoke control measures.

The control of air leakage is important and the determination of the maximum allowable air leakage through the air barrier system of the building envelope is a complex issue. A comprehensive analysis is beyond the scope of this project but it would include:

a. analysis of the maximum moisture transport through different construction in different climates for varying indoor humidities,

b. analysis of the maximum heating and cooling energy losses by exfiltration,

c. analysis of the maximum rain water penetration through cladding materials and entrainment by infiltration,

d. analysis of the maximum allowable noise penetration duc to thc lcakage area of the air barrier, and

e. analysis of the maximum allowable air leakage to control smoke and heat propagation.

As each of these performance requirements is independent of the other, the analysis of each is necessary to determine the most stringent requirement. Then, the most stringent is selected to establish the performance criteria required of the air barrier system for the application in question. Before such criteria is selected it is most important to understand the conditions that cause air leakage and what can be done to control them.

2.2 Air Leakage Through The Building Envelope

The flow of air through the building envelope of a building is caused by a difference in air pressure across the components of the envelope and a direct or indirect path from one side to the other. It does not matter whether the air is clean or dirty or whether it is humid or dry, hot or cold, the air will leak through if there is an air pressure difference and a path (hole) leading through the envelope.

An air pressure difference is caused by one or more of the following three conditions;

1) by stack effect - an air pressure difference that is induced by a temperature difference between the inside of a building and the outside

2) by fan pressurization - a condition that occurs when ventilation air is either extracted from or pumped into the building and the imbalance causes an air pressure difference across the envelope.

3) by the effects of wind impinging on the exterior surfaces of the building envelopė, elevating the air pressure on windward side, and lowering it on the side and back walls and the roof.

Stack effect and wind conditions are loads caused by nature and cannot be controlled. The ventilation system, however, can be controlled and is sometimes used to offset the effects of stack pressure to reduce infiltration near entrance levels. However, when this is done, it also causes the air pressure difference at the roof augment and therefore induce greater exfiltration. Hence, if air pressure differences cannot be controlled then the holes (paths) must be reduced or eliminated.

Natural (including fan pressure induced) air leakage through buildings is quantified in different ways. It can be measured directly by tracer gas techniques or indirectly by fan pressurization and analysis. Thermographic studies are useful in determining the location of air leakage but are not effective at quantifying air leakage rates.

Another approach, is to measure the air leakage rate through materials, components and assemblies and to sum these into infiltration and exfiltration rates. The results are usually presented as air flow rate through a given envelope area in $l/s.m^2$ for given pressure difference and as l/s.m through joints also at a given pressure difference.

In a recent study, undertaken by the Canada Mortgage and Housing Corporation, a group of high-rise apartments in different geographic zones of Canada, were studied to determine the air leakage resistance of the building envelopes. These buildings varied from 6 storey up to about 20 storey and varied in age from 3 years old to about 30 years old. The findings, illustrated a wide variation in air leakage control. The spread of the results ranged from 1.0 $l/s.m^2$ to about 10 $l/s.m^2$ @ 75 pa.

In the EMR R-2000 program, a house is deemed to be air tight if it can be demonstrated that its forced air change rate under fan pressurization is less than 1.5 AC/hr @ 50 pa pressure difference in one direction only and that its normalized leakage area does not exceed 0.7 cm^2/m^2.

There are no standards or target values that determine what leakage rate is acceptable, however, an IRC/NRC publication "An Air Barrier for the Building Envelope", 1986, suggested that leakage rates should not exceed 0.15, 0.10, 0.05 $l/s.m^2$ at 75 pa for buildings having humidity greater than 50%, between 50 and 20%, and less than 20% respectively.

2.3 Air Leakage Through Roof, Walls and Windows

Whole building air leakage rate is a commissionable attribute, but by itself it is too general to be of value to air barrier design because the average leakage rate determined may be acceptable for certain areas of the envelope and not for others. This whole number must be considered the average of air leakage rate limits defined separately for the roof, walls, windows below grade components and all joints in the air barrier system.

When considering air leakage control from this point of view, the performance requirements are reduced to two of the most important criteria, the control of condensation in cavities and excessive loss of heat/cool energy through the assemblies of the envelope. In this regard, CMHC commissioned a study on the maximum air leakage rate acceptable through exterior walls from a moisture accumulation standpoint, for various locations in Canada. The study :Criteria For The Air Leakage Characteristics of Building Envelopes, December 30, 1989 also provided a computer simulation model titled "EMPTIED". This computer program and its simulation results were used in combination with a preliminary energy study of air leakage rates to derive a tentative set of air leakage limits through the envelope. It is noted that some wall types are more forgiving than others in terms of moisture absorption and release, corrosion control, and potential cladding damages. The overall values obtained by this analysis were adjusted to 75 Pa pressure difference for easy comparison. This is because roofs are not forgiving as any moisture build-up will result in water damage. Note that the roof/ceiling values are five times less permeable than exterior walls.

The results of the study are presented as Table 1 below, as the maximum allowable air leakage through to roof and exterior walls for buildings up to twenty storeys, of average humidity and in different locations in Canada. For higher than normal humidities and for more unusual construction, it is best to undertake an engineering analysis of the specific condition, and to determine the performance and durability criteria applicable to this project.

Table 1

Maximum Air Leakage Rate l/s*m² through the Air Barrier System at 75 Pa for Roofs and Walls				
Location	**Up to 3 Storeys**		**Up to 20 Storeys**	
	Roofs	**Walls**	**Roofs**	**Walls**
St. John's Newfoundland	0.25	1.25	0.15	0.75
Halifax, Nova Scotia	0.25	1.25	0.15	0.75
Charlottetown, Prince Edward Island	0.25	1.25	0.15	0.75
Fredericton, New Brunswick	0.15	0.75	0.10	0.45
Quebec City, Quebec	0.15	0.75	0.10	0.45
Montreal, Quebec	0.15	1.25	0.15	0.75
Thunder Bay, Ontario	0.15	0.75	0.10	0.45
Winnipeg, Manitoba	0.15	0.75	0.10	0.45
Regina, Saskatchewan	0.15	0.75	0.10	0.45
Calgary, Alberta	0.15	0.75	0.10	0.45
Edmonton, Alberta	0.15	0.75	0.10	0.45
Vancouver, British Columbia	0.30	1.50	0.20	0.90
Victoria, British Columbia	0.30	1.50	0.20	0.90
Ottawa, Ontario	0.15	1.25	0.15	0.75
Toronto, Ontario	0.15	1.75	0.20	0.90

For wind load pressure distribution in exterior walls, Canada Mortgage and Housing Corporation has undertaken a study of the structural requirement of air barriers, and the application to air barrier system design for exterior walls. It is worth noting, that the exterior wall cladding must at this time be designed to support 100% of the design wind load for sustained and gust pressures. In face sealed wall system it is the face sealed cladding that supports and transfers wind load, while in rain screen wall systems it is a combination of the cladding and air barrier system that resist wind load pressures.

In the absence of adequate information it is noted that most testing for the structural characteristics of air barriers uses 1000 Pa as a minimu. The maximum must be determined by analysis and it must be understood that the resistance to air pressure must be designed for both directions.

2.4 Overview

To design and construct an air barrier systems with predictable performance, (a commissionable system) the process of developing the building envelope for a building must be partly changed and expanded.

The development of a commissionable air barrier system must begin with the owner. It is recommended that a specialist be involved to explain the process, the benefits and the costs of developing a commissionable air barrier system. The specialist, with the architect and the owner, chose the air barrier system performance criteria to suit the project being contemplated. The performance criteria may be developed fundamentally or they may be chosen from the recommended values developed in this chapter. These criteria become the quantitative attributes that must be met by the design and the construction of the air barrier system. They form an integral part of the project brief.

During the development of the envelope design, the specialist and architect develop an audit procedure to verify that all areas of the envelope will have an air barrier system and that the materials, components and assemblies are continuous, air impermeable and structurally supported. They develop the necessary supplementary instructions for the architectural documents to include a prescriptive description of the complete air barrier system. Specifications are developed in section 07195. The designer (architect) then certifies that the air barrier system design performance is attainable, that the air barrier design procedures were completed and that proof of design performance was obtained. At the end of this phase, the owner, designer and specialist review the design, the estimated supplementary costs and the benefits of providing a commissionable air barrier system.

At the construction phase, the specialist and builder review and schedule the required staff briefings, mock-up reviews as well as on-site and off-site tests that may be required. The builder is responsible for co-ordination, scheduling, construction and testing requirements and the specialist is made available to explain and demonstrate how the process is to be followed and how measurable performance will be obtained During this phase, progressive reviews and spot testing will ensure that the materials, components and assemblies meet the individual performance requirements as they are assembled into the air barrier system. This will ensure that the overall performance of the building envelope air leakage control will be attained without major surprises.

The last phase is the commissioning phase. It consists of performing an overall air leakage test of the building envelope and certification that all parts (from previous tests and observations) met the design and construction requirements for the air barrier system. At the end of the commissioning phase the specialist then issues a certificate of performance compliance for the construction of the air barrier system.

Post performance and monitoring of the air barrier system is a separate service that may be offered to the owner(s) of the building. It could involve visual reviews on a periodic basis for symptoms of non-performance to systematic measurements of building air change rates, exterior wall and roof air pressure difference. This service may be combined with a recommended maintenance schedule and repair techniques.

3. DESIGN, CONSTRUCTION AND COMMISSIONING

3.1 Project Brief

The project brief is a document that contains the character, the attributes and the constraints governing the design and construction of a new building project. It is developed by the designer (architect) and the owner(s) to document as clearly as possible the expectation and the constraints of the project. The project brief may be simple or intricate depending on the scale and complexity of the project. It may include architectural context, site conditions, zoning requirements, occupancy type and uses, spatial requirements, and exterior appearances.

Further, the project brief may describe the performances requirement of the envelope. It is at this time that the owner with the guidance of a designer (architect) declares his intention to commission the performance of the air barrier system. The general performance attributes of the air barrier system are chosen from Table 1, or developed from first principles and listed in the project brief. The project brief should describe briefly, the performance requirement of the air barrier system for the building as a whole and any limits that may apply to individual assemblies of the envelope, the roof area and exterior walls in particular.

For example, consider a new apartment building, 20 storeys in height, to be constructed in Ottawa. It will have a rectangular plan, balconies on two facades, and be constructed with a brick veneer, steel stud exterior wall system. The roof is flat and will comprise a protected membrane system. The building has an underground garage.

In the design brief, the instructions for the development of a commissionable air barrier system could read as follows.

The air barrier system of the building envelope of this building is to be designed, and constructed to provide a continuous, structurally supported plane of materials to contain the indoor air (exfiltration) and to prevent outdoor air from entering the building (infiltration) in accordance with the following requirements:

1) The envelope will incorporate a continuous air barrier system, as per the 1990 National Building Code, Article 5.3.1.

2) The maximum air leakage through the air barrier system within the roof area and associated penthouse envelope components is not to exceed 0.15 $l/s.m^2$ @ 75 pa.

3) The maximum air leakage through the air barrier system within the areas of the exterior walls in brick veneer steel stud back-up from the roof to grade (excluding windows, patio doors etc. is not to exceed 0.75 $l/s.m^2$ @ 75 pa.

4) The maximum air leakage through the fire floor between the parking garage and the main lobby of the apartment is not to exceed 0.10 $l/s.m^2$ @ 75 pa.

5) The maximum air leakage through the windows and patio doors are not to exceed the prescribed limits of CSA-A440 standard on windows.

6) The maximum air leakage between joints between the air barrier components of various assemblies is not to exceed 0.20 l/s.m @ 75 pa.

7) The air barrier system in all part of the envelope is to be designed to support maximum wind loads, 30 year return.

It is these requirements that form the basis of a commissionable air barrier system. The designer then proceedd with the development of the air barrier system in parallel with the project development. The essence of the next phase, is to demonstrate by audit, analysis, and test data, the performance attribute of the air barrier system for all parts of the project.

To develop the design brief requirements for the air barrier system and to implement these requirements in the design, it is recommended that the owner retain a specialist with this type of expertise to assist and guide the owner and designer (architect) through the design brief and the design process.

3.2 Design of the Air Barrier

The design process for the building envelope proceeds in the normal manner. Conceptual designs are developed to organize spaces, circulation, siting and general appearance. A conceptual structural system and method of construction are resolved for the building, followed by the development of systems for the roof, walls and windows. It is during this stage that consideration is given to the air barrier system. This includes locations within each assembly, types of materials and the performance attributes to be attained by the design.

For example, in our twenty storey apartment building, the roof will require an air barrier system. It may be a supplementary function of the waterproofing or it may be a completely different plane of materials. It must however be identified and then designed to the performance requirement of the project brief.

Similarly, the location of the plane of the air barrier of the exterior walls must be chosen, and materials identified having suitable attributes to meet the project brief performance requirements. As you can readily determine, the assemblies of the envelope of a twenty storey apartment, may be quite varied even if the plan of the building is a simple rectangle. The roof may have several types of roof waterproofing, including penetration details, penthouse walls, roof top ventilation equipment and parapet condition. The exterior walls may be masonry, architectural precast, metal and glass curtain wall, EIFS or others. Each type of wall will require an air barrier. The air barrier of the roof and wall must connect together and to other components that penetrate the envelope.

3.2.1 **Air Barrier Materials**

The control of air leakage through roofs, walls, windows and joints is for some the function of the whole building envelope. In other words in a brick veneer steel stud wall, the brick, sheathing, insulation, poly and gypsum provide the resistance to air leakage. To some extent this is true because all materials provide a measure of air leakage resistance (air impermeability) and they must be held in place by fastening or support. However, this view is confusing and it may become very costly to apply, particularly if all materials must be able to withstand the maximum structural wind loads.

The control of air leakage, requires that the construction materials intended for the air barrier system be air impermeable, continuous with other air impermeable material, and capable of transferring structural loads to the building structure and be durable. It is not necessary for every part of the roof or wall to exhibit these attributes. For example fibrous insulations are air permeable and flexible. They are not suited for air leakage control but they perform quite satisfactorily as thermal insulations. Bricks and mortar are reasonably air impermeable, but it is often required that the brick veneer be drained and vented. This means installing drain holes every third brick at the base of the wall and sometimes in the brick facade. This contradicts the requirements of air leakage control which requires continuity of airtightness so the brick is not the air barrier.

It is for these reasons, that envelope design and construction need only one plane of materials to perform the air leakage control function and it is termed the air barrier system.

The Canada Mortgage and Housing Corporation has undertaken several studies to determine the air permeability and strength of various construction materials, so that the design of the air barrier system is based on the predictable performance of materials, components and assemblies. A list of these materials and their properties will be found in Table 2 below.

Table 2

Air Permeability of Construction Materials

No.	Description	Air Permeability l/s * m^2 @ 75 Pa
1	2 mm, smooth surface roofing membrane	0.0
2	2.7 mm, modified asphalt membrane, torch-on-glass fiber ________, Aluminum V.B.	0.0
3	1.3 mm, modified asphalt, self adhesive membrane	0.0
4	2.7 mm, modified asphalt membrane, torch-on-polyester reinforced	0.0
5	9.5 mm plywood sheathing	0.0
6	38 mm, extruded polystyrene insulation	0.0
7	25.4 mm, foil back urethane insulation	0.0
8	24 mm, phenolic insulation board	0.0
9	42 mm, phenolic insulation board	0.0
10	12.7 mm, cement board	0.0
11	12.7 mm, foil backed gypsum board	0.0
12	8 mm, plywood sheathing	0.007
13	16 mm, flakewood sheathing	0.007
14	12.7 mm, moisture resistant gypsum board	0.009
15	11 mm, flakewood board	0.011
16	12.7 mm, particle board	0.016

Table 2 (Cont'd)

Air Permeability of Construction Materials

No.	Description	Air Permeability l/s * m² @ 75 Pa
17	Reinforced non-perforated polyolefin	0.020
18	12.7 gypsum board	0.020
19	15.9 mm, particle board	0.026
20	3.2 mm, tempered hardboard	0.027
21	Expanded polystyrene, Type 2, (thickness?)	0.119
22	30 lb roofing felt	0.187
23	15 lb non-perforated asphalt felt	0.271
24	15 lb perforated felt	0.396
25	Semi-rigid glass fibre insulation with olefin paper, one side	0.488
26	11 mm, fiberboard, plain	0.822
27	11 mm, fiberboard, asphalt impregnated	0.829
28	Spun bonded olefin film	0.960
29	Perforated polyethylene # 1	4.032
30	Perforated polyethylene # 2	3.231
31	Expanded polystyrene insulation (1)	12.237
32	Tongue and groove planks	19.117
33	Glass wool insulation	36.733
34	Vermiculite insulation	70.493
35	Cellulose fibre insulation (5 ply-on)	86.946

3.2.2 Areas and Continuity

The task of designing a commissionable air barrier is divided into two parts; an accounting part and a technical part.

The accounting part consist of a procedure to audit all areas of the envelope, all joints between the areas, the maximum air leakage rates for each, and the method of design validation to certify the limits of performance. In this way, the air barrier system is explicitly defined and its continuity is ensured.

The technical part consists of developing, analyzing, testing the chosen details for the design of the air barrier system for each part of the envelope. Using information on materials, tested details, or other sources, the air barrier system is designed to comply with the requirements of the design brief. Further, the designer and specialist prepare additional instruction for the builder for site review, mock-up testing and eventual commissioning.

The first task of air barrier design is to audit and list all areas and joints, forming the continuous plane of the air barrier system. To facilitate this accounting, a table is devised to identify and to relate every area to every joint composing the building envelope. (Table 3 below). In this table, a matrix is presented in the form of a spread sheet separated by a diagonals. On this matrix, all primary envelope assemblies including the roof, the walls and window, the door and the below grade area, are listed along the top and down the left side.

Table 3

Certification Method	Maximum Air Leakage From.....(l/s)				
	Envelope	**Roof**	**North Wall**	**Windows North Wall**	⟶
Envelope	190 A				
Roof		12 B	6		
North Wall		E	36 C	10	
Window North Wall			E	5 D	
↓					

In Table 3 above, the maximum air leakage rates shown were computed from computed from the rates defined by the project brief and the areas of each envelope assembly. These values are shown in the diagonal row of squares while the remaining square(s) identify the joints between each area. Those squares that do not represent a joint are blanked out. Determine the maximum air leakage for each area and joint insert in the upper right side of the matrix. Design the air barrier system from a list of material and attributes provided in Appendix C and inscribe the rated performance in the lower left half of the matrix. This applies to areas and joints.

Sum all air leakage values for each area and joint and divide by the total area of the envelope. If the computed value is less than the average for the envelope, the air barrier system design has met the first requirement of design, the nominal values for performance.

The second part consist of documenting the sources of validation for the design detail in question to obtain validation of the performance of the air barrier system and its components.

The proof of design performance may take many forms but is likely to be one of the following:

A Building overall air leakage test.

B Certified by previous testing in another project.

C Certified performance as determined by CMHC, detail testing.

D To be certified by window test CSA A440.

E Certified by field mock-up test.

Similarly, the designer establishes the structural loads to be supported by the air barrier part of each area and each joint. A similar table is constructed, and the nominal loads are inserted in the table. The actual load resistance is determined by structural design or by testing. The certification must indicate which of these methods was used including any that would bc tested in a mock-up before or during construction.

3.2.3 Air Barrier Details

The technical part of the air barrier design will comprise the design of the section and details required to meet the performance requirements listed in the table above. To do so, the designer must establish the location of the air barrier system within the assembly and if it is a stand alone air barrier system or an inherent function of an existing plane of material.

To do either, the designer is directed to Table 3 and Table 4 below. In Table 3, the air permeability of various construction materials is presented. For the location in question, one or more of these materials may be chosen to be part of the air barrier system. The materials chosen must exhibit an air permeability that is less than the performance requirement listed in Table 3 above.

When materials are assembled into components and assemblies, their air leakage performance is not easily determined. There are, however, some tested (certified) detail designs that a designer can reference complete the design of the air barrier system. In Table 4 below, a sampling of details were tested in a laboratory and rated in terms of air permeability and structural adequacy.

Table 4

Certified Air Barrier Details

No.	Description	Air Leakage @ 75 Pa			Structural Loading
		l/s	l/s * m	l/s*m²	kPa
	CMHC Details I				
1	Header joist, traditional		0.22		±1.0
2	Header joist, poly		0.05		±1.0
3	Header joist, ADA		0.02		± 1.0
4	Header joist, EASE		0.04		± 1.0
5	Electric outlet, Traditional	0.09			± 1.0
6	Electric outlet, Poly	0.02			± 1.0
7	Electric outlet, ADA	0.38			± 1.0
8	Electric outlet, EASE	0.03			± 1.0
9	Window frame opening (Std)		0.60		± 1.0
10	Window frame, Poly Approach		0.07		± 1.0
11	Window frame, ADA		0.01		± 1.0
12	Window frame, EASE		0.06		± 1.0

The information noted in the above table was obtained from a CMHC study of the performance of wood framed construction details. The design of each will be found at the end of the report.

If such rated details do not exist, the details of the proposed method should be tested in a laboratory or by mock-ups on site. Regardless, no design detail for the air barrier should be specified unless proof of performance can be established.

As the design of the air barrier system progresses, the designer (architect) with the assistance of a specialist must also develop and prepare field verification procedures for inclusion into the tender documents. This is required so that the performance of the air barrier system assembly can be determined as early as possible, so that the air barrier system deficiencies may be corrected, before they are permanently built into the envelope. This means that a program of progressive testing and review will be undertaken to ensure that the performance of the air barrier system is fully determined by component assemblies before the final commissioning test of the building envelope as a whole.

Following a final verification of all plans, sections and details and specifications, to ensure that all areas of concern have been addressed, the designer (architect) includes the certification results for each type of air barrier system design and the system of joints with the tender documents.

3.3 Construction of the Air Barrier System

The construction of a high-rise apartment or condo is a complex challenge in scheduling and sequencing. Once the builder is selected, usually through the bid process the first activities on site are usually excavation and installation of below grade services followed by foundation and structure. The enclosure is then constructed from the ground up.

A typical building project may be directed by an engineer, but the majority of the builder's team members are skilled workers concerned with production, quality of assembly and scheduling. They are not trained to evaluate the function of the materials they install and much less the quality of the design they will assemble. For this reason, the process of assembling the air barrier system and of certifying it's performance, must be planned carefully, systematically and with the full knowledge of those involved.

For a small building such as a low-rise multi, the performance of the air barrier system may be determined progressively or all at once. If it is to be determined all at once, it is best to occur as soon as the construction of the air barrier system is complete but before it becomes inaccessible. It is common practice to use a door fan or two to determine the air leakage rates of houses and multiple unit housing. If the flow rate exceeds the specified limit, the location of the uncontrolled air leakage must be traced and repaired. If the flow rate is below the specified limit, the air barrier system is now commissioned for it's air permeability and need only be checked for it's structural attributes.

For a larger building, such as a twenty story apartment, the process is more involved and should be undertaken in a progressive manner. It may be necessary to construct on-site mock-up to test the quality of assembly for walls, windows and roofs. If the mock-up is found to pass as required, the quality of assembly is established, and construction of the envelope may proceed. As typical floors are enclosed but before all finishes are installed, it may also be necessary to test the wall area to verify that overall leakage rates do not exceed limits. If they do, then action may be undertaken to correct the higher than expected leakage rate. In this way, progressive testing provides progressive certification of performance and thereby avoid significant deficiencies of performance at the completion of the project.

For most construction projects the air barrier system is described in drawings and specifications. The sections and details show the type of materials and their respective position within each part of the envelope. The air barrier system is also described in the specification Section 07195. The type of materials, the preparatory work and installation procedure are presented and references to other sections. It is from this perspective that a construction quality compliance process is proposed for the air barrier system.

Depending on the scale of the project, the builder may be required to follow one of the following progressively more stringent options:

1. The air barrier system of the envelope will be tested after substantial completion to determine its air leakage rate. If it is found to leak more than the prescribed limit, it must be investigated by the builder and repaired at his cost.

2. In option 2, the air barrier system of the envelope will be progressively tested to determine the air leakage rate of the individual areas as they are constructed. This may include the roof air barrier, the wall air barrier including windows and other assemblies. Once an air barrier assembly type has been tested it need not be tested everywhere, so long as construction reviews certify that the other areas are constructed to the same quality. The structural performance of the air barrier must be tested selectively or certified by a structural engineer. Following substantial completion, the whole building will be tested/commissioned to determine compliance with the overall building envelope leakage rates.

3. In option 3, parts of the air barrier system will be tested progressively as described in 2 above and the structural performance will be certified by test or engineering design. Further, the air barrier system assembly will be tested by on site mock-ups prior to the construction of the building envelope. The mock-ups are described in the architectural documents and will include a representative section of the roof, the exterior wall, the windows, the soffits and other unique conditions. The mock-up will be constructed only to the extent that the air barrier system is complete and that selective testing can be undertaken. If the air leakage rate and the structural attributes comply with the performance requirements, the construction of the envelope may proceed so long as construction of the air barrier is identical to the mock-ups. If the performance is not as per requirement, the construction quality must be revised until the requisite performance is attained. The process then proceeds in a progressive manner with certified performance for the material, the components, the assemblies and finally the building enclosure as a whole.

4. Option 4 includes the prescriptions of options 2 and 3 but in addition, includes a series of site briefings to be organized during the construction, to explain the design objective to the construction team responsible for its assembly. These

briefings would include the purpose, function and performance requirements, what test will be undertaken to verify performance, what qualities will be accepted and what qualities will be rejected and why. In addition, a pre-tender meeting will be held for all bidders, so that new requirements can be explained, allowances explained and the role and responsibilities of the specialist during construction and following substantial completion.

3.4 Commissioning The Air Barrier

As the building nears completion the overall performance of the air barrier system may now be commissioned. Commissioning the air barrier system consists of testing it's performance attributes. The final performance tests to be undertaken must determine the maximum air leakage rate through the envelope as a whole and the ability of the air barrier system to withstand a structural load also prescribed by the tender documents.

This procedure is achieved by an overall test of the building envelope using a portable fan or the ventilation system of the building. The procedure to be followed is described in ASTM E-1157, "Air Leakage Measurements For Buildings".

In addition to the overall air leakage test, the structural attributes of the air barrier system must also be certified. This requires that a high air pressure difference be applied across the building envelope but, as this is not practical on the building as a whole, it must be done on small areas, at the appropriate time during construction, or be certified by a structural engineer as to it's structural capabilities. It is the specialist's responsibility to collect these proofs of structural performance during the construction and to submit these with the final certification of the air barrier system. The procedure to be followed is described in ASTM E-1233-88, "Standard Test Method For Structural Performance of Exterior Windows, Curtain Walls and Doors by Cyclic Static Pressure Difference".

In addition to the overall air leakage requirements, there may be limits of air leakage for individual assemblies within the building envelope. Where this is applicable, for example, the roof may not be allowed to leak more than 6 litres per second, the designer must specify a procedure to test and verify the assembly during construction that is, separate from the building test as a whole. This would not be required for most buildings but it may be required in larger projects.

Should the building envelope not pass the final test, the specialist is empowered to investigate and find the location(s) of the extraneous leakage and to direct the builder to undertake the necessary repairs. It is understood through the owner/builder contract that the costs of any repeat testing will be paid by the builder or contractor. It is for this reason that progressive evaluation and certification of various areas, components, systems and assemblies become important to the builder to avoid any major surprises.

In the event that a dispute arises out of a claim that the error or cause of failure is due to design, the specialist will review the documents to assure himself that the proof of concept is valid for the area in question and submit his findings and opinions to the builder, designer and owner.

Following all testing, the specialist will accept the builder's certificate of compliance for the air barrier system and commissioning certificate. It certifies that the design, construction and performance of the air barrier system in it's entirety, to include materials and workmanship, were tested and found to perform within the performance envelope limits prescribed by the owner project brief.

3.5 Durability of the Air Barrier

The performance of the air barrier system is specified by the design brief. The process followed in design and during construction should ensure compliance, but it does not guarantee how long it will last. This is quite another matter. The specialist, the designer and builder, at the request of the owner can develop an operation, maintenance and repair manual for the air barrier system of the building. It is this document that will explain the probable long term performance or durability of the air barrier system.

For projects such as apartments and condos, it is wise to ensure long term performance as the eventual owners tend to keep their building a long time if the operation and maintenance is small with respect to investment and return.

Condo owners by contrast would insist on quality; if such authority could be placed in their hands before they bought the unit.

Durability is *not* a property of materials, it is the result of the interaction of materials, their intended use and the environment they are placed in. For the air barrier, the conditions to consider are pressure loads, temperature, fatigue and physical abuse. If materials are selected to withstand these loads are applied in a workmanlike manner, the system will perform a long time without the need for maintenance or repairs.

4. OPERATION, MAINTENANCE AND REPAIR

4.1 Description

The monitoring of the air barrier system can be undertaken at various levels but each level entrains it's own cost category to the operation and maintenance of the building. Before entering into a monitoring program it is important to have an accurate description of the air barrier system of the building envelope for the building in question. The description should focus on the types of materials, their location within each assembly and the continuity by which they are linked together at various joints throughout the building envelope plane.

For example, a roof system may be a conventional BUR, however, it may have a 2-ply 15 lb. asphalted paper over a gypsum board sheathing as the air and vapour barrier component of the roof assembly. Thus, it would be expected that a 2-ply system would carry the air pressure loads from stack effect and wind uplift as well as separate the moisture conditions of the outdoor and indoor at that plane.

Also, the exterior walls may be constructed of brick veneer steel stud. In this part of the building envelope, several components may have been chosen to compose the air barrier system. If the air barrier system used the air drywall approach, then the inside gypsum board is to provide the function of the air barrier and must therefore be air impermeable, continuous with itself and with other components, to make a continuous plane within the wall system from grade up to the roof.

Alternately, the air barrier system may be on the exterior of the steel stud but behind a brick veneer. In this case the system is inaccessible and must be inspected and tested prior to closing with the brick veneer.

Most important in the description is a clear understanding of the various joint designs. The most important joints will be the roof/wall connection, usually at a parapet. This joint design may be made of various types of material to include sheet steel, asphaltic membranes, plastic or rubber membranes but in most instances it is likely to be hidden and not easily serviced.

Connections to grade are also important as well as connections of wall systems to other types of wall systems. For example, a brick veneer steel stud wall system may be connected to a portion of metal and glass curtain wall. The connection between the two may be an important service point.

On a more localized area, penetrations through the roof, such as ventilation equipment, plumbing equipment, hatches, electrical equipment, etc. are all important and must be checked from time to time. Similarly, in exterior walls various penetrations will occur. These include windows, patio doors, ventilation ducts and these should all be carefully sealed to the equipment or apparatus which penetrates the exterior wall.

The location of the air barrier is equally important. If it is on the inside and is accessible, then it is serviceable. But it is also subject to damage, which may go undetected for some time, even though it is easily repaired. Air barriers hidden in the construction which are not accessible, but may require access, should be evaluated first from the design documents. In some instances it is easier to remove brick and to repair an air barrier system that it is to move the tenant and remove the inside finishes of the wall. It should be clearly understood what is the air barrier system and it's materials, components and location.

4.2 Operating Parameters

The purpose of the air barrier system is to contain the air within the building. Its operation may not be perfect, however, it should provide enough resistance to air flow to provide adequate control over the various functions of the exterior walls and roof and window elements of the building. The functions which it must provide include limiting infiltration and exfiltration. This is important to prevent the loss of control of temperature and humidity in a room or a floor and it is also important to prevent the build-up of interstitial condensation in construction cavities and less of excessive heat/cool energy.

It is equally important that the air barrier system operate adequately so as to protect the cladding from damage of interior moisture that may build up behind the cladding elements, a condition for which most claddings were not designed. Another function of the air barrier system may be to control rain penetration. Rain penetration control involves four specific requirements. These include direct blockage of rain path, adequate gravity drainage by way of suitable flashings on the exterior as well as the interior of cavities, appropriate capillary breaks to prevent the surface water run-off from penetrating deep in thc construction, and finally, by controlling the air pressure difference occurring across a cladding elements. This method of controlling rain penetration is termed the rainscreen system and it requires a functional air barrier system in order that the pressure within the cavity behind the cladding be contained and allowed to track with the pressures induced by the wind on the surface of the rainscreen system.

The control of air leakage is also important for energy conservation. Indiscriminate loss of air through exfiltration causes unnecessary loss of heating and cooling energy. This can be significant if allowed unchecked and adds significant burden to the cost of the operation of the building.

The air barrier system is also important for the control of air quality. While it is understood that tightening up the envelope has given rise to concern over air quality, it is also known that large buildings such as high-rise apartments that are connected to outside garages are sometimes subject to increased CO and CO_2 because of infiltration air coming from these local sources. For these reasons the air barrier system becomes extremely important, especially to the safety and quality of the indoor air.

The function of the air barrier system is also to control noise and fire propagation. A good quality air barrier system will reduce noise penetration from the outside and it would also limit the propagation of fire and smoke. The air barrier system is important to the performance of the building envelope of any building. It has a significant impact on most functional requirements of the building envelope. It is therefore prudent to consider monitoring the performance of the air barrier system during its lifetime.

4.3 Monitoring and Maintenance

To ensure that the air barrier system performs it's functions adequately and for a long period of time, a program of monitoring and testing may ensure durability.

Monitoring means to inspect, observe, and verify that the performance of the system continues to meet the attributes that were originally measured during the commissioning process. This is not easy and it is difficult to decide as to what locations and how the overall and select locations combine to provide the performance expected. Let us consider different methods of monitoring and testing that may be used for air barrier systems in an apartment building.

4.3.1 Indirect Monitoring

Indirect monitoring may be undertaken through visual observations of the roof and facades for symptoms that relate to increased air leakage or by examining locally damaged areas. These symptoms include efflorescence on bricks, icicles below window sills and from the weepholes in masonry, there may be rust stains appearing at various locations which are not related to the direct surface water runoff of rain but rather to the continuous condensation of moisture exiting to the outside, expansion of masonry products would suggest an increase in moisture content, stains in exterior finishes, melting of snow and ice, or just simply the appearance of hoar frost or steam from locations where there should be none.

A second method of indirect monitoring involves the energy usage for space heating within the building. If all the energy bills for space heating of a building are noted and recorded when the building is new, a base level of energy use may be determined. It can then be used for comparison purposes in monitoring the performance of the air barrier system. It the air barrier system is subject to damage or degradation and increased air leakage occurs, especially during the winter, there will be a corresponding increase in energy use which would appear in the comparison monitoring of the energy bills. However, consideration must be given to changes in lifestyle of occupant but it is unlikely that one or two families using more energy will alter the balance. If significant changes take place to the quality of the air barrier, there will be a corresponding change in energy use patterns.

4.3.2 **Direct Monitoring**

Direct monitoring is more expensive than indirect monitoring. It involves the use of instrumentation and equipment installed at strategic locations to monitor the factors that govern the performance of the air barrier system. Typically, these are air pressure differences, temperature and humidity in cavities with respect to outdoor and indoor conditions. This would include placing pressure taps, thermocouples and humidity sensors in roof cavities, in two or three locations and monitoring these by way of electronic equipment. Monitoring may be periodic or continuous.

By examining the air pressure difference across the air barrier with respect to the wind conditions across the roof or wall, a pressure difference index may be determined initially and used for direct comparison purposes from time to time to determine the performance of the air barrier during the life of the building. Similarly, by monitoring the temperature and humidity in construction cavities, a relation can be drawn between the air pressure difference, the temperature and humidity and the amount of air leakage increase taking place.

Such instrumentation can be installed in the roof, in the exterior walls, and at critical locations at grade and in other areas, but should leakage occur in areas not being monitored, these would be undetected and would show up as symptoms and damages at some later date. To complement this method, it is suggested that other methods of direct testing be used. This would include tracer gas techniques and fan pressurization.

Another method of monitoring the overall performance of the air barrier system is to perform a thermographic scan of the building. This scan would examine the exterior walls and roof, during a time when exfiltration is most prevalent or in winter. Air leaks usually show up in a pronounced manner and the location of leakage.

4.3.3 Testing

If and when an area of the roof or wall is suspected of increased air leakage, it may be necessary to undertake testing to localize the problem and to determine the repair required to reinstate it's performance. The most usual test methods include the pressurization of an area in combination with the use of smoke, smoke pencil, and sometimes thermography. This method will induce air leakage and with the use of smoke or thermography, the locations of leaks can be traced to the most probable cause. This is usually followed by test openings and inspection. Test openings and inspections are usually expensive. They may be undertaken from the inside, or from the outside. From the outside they often require swing stage equipment and contractors to demolish or take apart parts of the exterior cladding. From the inside it is usually disruptive to the tenants and may require that they be moved temporarily while inspection and repairs are undertaken.

4.4 Diagnosis and Repairs

When a symptom or damage indicates that excessive air leakage is the cause, there are a few important operating conditions to verify before embarking on a program of construction repair. First, has there been a significant change in the operating pressure of the building? This means that the ventilation to the building may have changed and it may have been increased substantially because of installation of new equipment or adjustments to old equipment. The air pressures must be restored to former levels before embarking on envelope repairs.

If the indoor humidity has changed significantly because of new equipment or lifestyle, then these conditions must also be restored to their former level or the roof/wall system may require upgrading to support the new conditions.

When air barrier systems fail it is usually a local condition. For example, a poly sheet may have been intended as the air barrier material of choice, but a sudden gust of wind pressure has ripped the material from its attachments because it was unsupported. When this happens, it is pointless to repair the poly as it may happen again at any time. It is best to re-examine the wall section design and to correct the deficiency with a new approach using more robust materials and better attachments.

At times, failures will occur because of creep loading. This is a condition of low air pressure difference, caused by stack effect or fan pressurization and the eventual detachment of a joint material such as a tape, sealant or membrane. when this occurs, and the connections are deep within the construction, the most cost effective solution is to dismantle and repair. No other treatment is known to improve this situation except to alter operating conditions of indoor temperature, pressure and humidity to the dismay and comfort of the occupancy.

It is beyond the scope of this report to prepare a manual of repair for all types of air barrier systems. However, the most important questions are: what type of air barrier system was designed for this particular building? what part of the building is in need of repair? and, what is the simplest procedure to repair the air barrier system?

For roofs, the air barrier system may be the roof membrane, which in the case of the BUR is on thc outsidc of thc insulation and in the case of a protectcd mcmbrane system is below the insulation. If repairs are necessary to the roof air barrier system it usually involves the removal of several layers of exterior materials to access the roof membrane. Repairs over large areas are usually unnecessary, as most repairs will be at intersections, junctions or penetrations.

In exterior walls there are several types of air barrier systems to include:

1. Interior or warm side air barrier systems such as the polyethylene air/vapour barrier, and the air drywall approach
2. There are air barrier systems which are hidden in the construction. These would be located on the outside of the insulation but behind the exterior cladding; and finally
3. There are face sealed buildings in which the air barrier system is the exterior cladding and it's various joints and components.

The inside and outside air barrier systems are relatively easy to service and not necessarily expensive to repair. However, they are vulnerable to damage from the occupancy and the exterior environment loads. The air barrier systems that are within the construction are usually inaccessible and may require substantial effort to repair. But, if installed and tested correctly before they are closed in may never require servicing as they are not vulnerable to abuse or to environmental conditions.

5. DEVELOPMENT COSTS

The cost of developing a commissionable air barrier are difficult to define precisely because it is a new concept, there is no experience and the principal factors that govern the quality and success of the process are widely variable. The cost, however, can be divided into two parts: consulting fees and technical upgrade costs.

The consulting fees would include a specialist to work with the owner, designer, builder and eventual property manager (or owner again). His tasks would involve development of the design brief with the owner and designer; assist the design team to develop and validate the design of the air barrier system from concept to construction documents. He is further required to work with the builder during assembly and testing and finally to lead the commissioning process during completion of the project. He may also be required to start up and initiate a monitoring program for the air barrier system.

In addition to a specialist, the designer (architect) would be entitled to an increase in fee for the extra work required to develop and validate his air barrier design to specific performance requirements. There would undoubtedly be a cost for additional documentation of construction details and supplementary specifications as well as instruction to the builder concerning the field verification of workmanship and the commissioning tests.

Similarly, the construction process (builder) is entitled to an increase in bid price to include the necessary briefings, mock-ups, testing and field reviews required of the validation process. His price should include the final commissioning costs, and a contingency allowance for unforseen requirements.

The construction costs of the air barrier system can vary significantly. Simply identifying the components of an air barrier system on the plans and specifications does not justify the cost. Unless an air barrier system is known to be air impermeable, structurally supported, continuous and durable its value is questionable at any price.

It has been estimated that the cost of an air barrier system adds between 5% and 10% of the building envelope costs. When the construction costs and the consulting fees for development and review are combined, it is estimated that the development of a commissionable air barrier system would increase the cost of the building between 1% and 2%, depending on the scale, complexity, geographic location and occupancy type.

6. CONCLUSIONS AND RECOMMENDATIONS

The concept of a commissionable air barrier system is attractive and definitely needed by our industry. Current design and construction of building envelopes is efficient but they are not performing as effectively as they should in some projects and we are only marginally capable of predicting better air leakage performance.

Current thinking that field testing of the building envelope for airtightness performance will improve the quality of performance of the air barrier is not realistic. This is because test results, although needed for research and development, are not enforceable consequences. Builders are not required, by drawings and specifications, to build envelopes and air barriers in particular, to measurable performance. More importantly, the technology of design for an air barrier system and its details is not developed so designers can predict their performance to meet even modest air permeability and air pressure loads. But, in fairness to the design community, it must be conceded that there are no minimum performance requirements by code and the state of the art practice does not require it.

Owners, on their part, do not generally understand this technology, although there are more and more owners recognizing the need for better than minimum standards and certainly are willing to consider improved technology.

To develop, design and build a commissionable air barrier system for the building envelope, the process must begin with the owner through a project brief that specifies the quantifiable performance requirements for all parts of the air barrier system. Without these criteria, there can not be a commissionable air barrier system.

The designer (architect) must then develop the project and the air barrier system in particular, to meet the performance objective of the design (project) brief. The design and its detail must be validated through testing, previous experience analysis or some other method. The designer must demonstrate continuity, air impermeability, structural support and quality of the system. He must also develop the necessary construction documents to allow builders to understand the new challenge and to aware sufficient funds to pay for the new technology.

Most designers (architects) are not skilled with the engineering of an air barrier system. It is recommended that the owner engage a specialist to assist and guide if necessary, the designer through this process.

Builders are used to being instructed on what to do, when and how. They are prepared and poised to sequence and assemble a higher quality product, but it must be recognized that builders are not designers and they may never understand fully why a particular design was developed in a particular manner. However, through briefings and progressive testing and reviews, it is believed that builders will be able to construct functional and performing air barrier systems, and they will adapt to the new requirement of pre-commissioning activities and the purpose of the commissioning tests.

Successful commissioning of the air barrier system depends on all parties to the project, and in particular, the designer (architect) and the construction process (builder).

To further advance the application of air barrier technology to building envelopes and to attain commissionable systems, it is recommended that:

1. A project be initiated to apply the process described above to a hypothetical medium rise apartment in Ottawa. It should be done with an architectural firm and reviewed by an owner and builder.
2. A performance standard for the air barrier system should be developed, possibly through CSA or the National Building Envelope Council.
3. Development and testing of generic air barrier systems and details so that designers (architects) can select sections and details from proven performance rather than require lab testing every time.
4. Development of better and simpler methods of field testing for continuity, air permeability and structural qualities of the air barrier component, assemblies and systems.
5. Develop and demonstrate construction assembly techniques to illustrate strength and weakness of workmanship.
6. Study the consequences of indoor humidity, air pressure differences and outdoor temperatures to establish the maximum air leakage rates that can be tolerated without affecting moisture and energy performance significantly.
7. Study the cost and benefits of better air leakage control for various types of occupancies and building durability.

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