Review of Test Methods for Selected Building Enclosure Component Types

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ABSTACT

Building enclosure physically separates the interior from the exterior of a building. It consists of walls, windows, doors, roofing and foundations, insulation, barriers, membranes and other components aimed at controlling heat, air and moisture that can flow through the building enclosure. Today's global environmental crisis has significantly drawn attention to green building design and construction. Since building enclosure and its performance seriously impacts the energy consumption of a building, and because there are great variety of material and system types that can be used in the enclosure, validation testing of building enclosure components is vital to ensure the energy-efficiency and durability of a building. There is a need for more widespread awareness of the test methods for different components of building enclosure as such understanding helps design appreciate the basis upon which they will be prescribing or specifying various product types. This paper provides a review of most relevant test methods for several residential building enclosure components types. The test methods discussed provide a means to evaluate performance of these components when subjected to various physical and environmental conditions. The review is introductory and can be useful to those without prior knowledge of such test methods.

The paper presents summary results of a review of several building enclosure component types including vapor barriers/ retarders, waterproofing membranes, air barriers/retarders and insulations along with relevant test methods. The paper includes a brief introduction of each building enclosure component type made by a selected number of manufacturers, including their uses, features and application approach. The main focus of the paper, however, is on the ASTM test methods for evaluating their important mechanical properties. For each particular ASTM test method, the paper summarizes test objective, apparatus, procedure and analysis of the results. The paper offers a quick overview of the tests each product goes through as per manufacturer website and introduces appropriate references for each test for follow-up reading.

1.0 INTRODUCTION

Today's global environmental crisis has drawn increasing attention to design of energy-efficient buildings. Among all building components, building enclosure has the greatest impact on the energy consumption of a building and because there are great variety of material and system types that can be used in the enclosure, testing for performance validation of building enclosure components is vital to improve and enhance the energy-efficiency and durability of a building. There is a need for more widespread awareness of the test methods for different components of building enclosure as such understanding helps design professionals appreciate the basis upon which they will be prescribing or specifying various product types.

The objective of this paper is to review standard test methods for building enclosure components and to provide a summary of most commonly used methods. Testing of enclosure components will improve the quality of systems that protect the building with respect to heat, air and moisture transfer and help energy performance. It is introductory and can be useful to those without prior knowledge of such test methods.

There are three different physical states of moisture: solid (ice), liquid (water) and gas (vapor). Water vapor primarily moves with air or by diffusion. Air movement accounts for most of the water vapor migration through a building, while diffusion through materials is a much smaller and a very slow process. Once air reaches its dew point, the moisture that the air can no longer hold will condense. This can happen in attics, foundations, and walls, and the result is wet framing and insulation with potential for mold grow. Moreover, the building will become less comfortable, and costly to heat and cool and less energy-efficient. Thus, a variety of building enclosure products have been developed to control moisture: Vapor barriers/retarders retard the diffusive water vapor migration; Waterproofing membranes are designed to prevent water penetration through the membrane; Air barriers control air movement through the envelope; Insulation reduces heat transfer or flow and helps avoid condensation. Among these products, vapor barriers/retarders and waterproofing membranes are both functioned to control moisture but with a difference: Vapor barriers/retarders prevent or retard vapor increment due to diffusion; Waterproofing membranes prevent penetration of water in its liquid state.

The paper introduces a selected number of products and ASTM test methods related vapor barriers/ retarders, waterproof membranes, air barriers and insulations.

2.0 VAPOR BARRIERS/ RETARDERS

As an important part of building enclosure, vapor barriers/retarders help reduce water vapor related problem in enclosure performance. Vapor barriers/retarders are generally applied on walls, roofs or under slabs. In this section, four representative vapor barrier/retarder products are introduced with corresponding technical data sheets included to help a better understanding of the test methods.

2.1 Introduction of Selected Vapor Barrier/ Retarders

AIR-SHIELD ™ Self-Adhering Air/Vapor and Liquid Moisture Barrier AIR-SHIELD is a roll-type air/vapor and liquid moisture barrier product. It will adhere to surfaces of precast concrete, cast-in-place concrete, masonry (concrete block), interior and exterior gypsum board, styrofoam, primed steel, aluminum mill finish, anodized aluminum, primed galvanized metal, drywall, and plywood (Figures 1 and 2).

Figure 1 AIR-SHIELD ™ barrier product (Courtesy of W. R. Meadows, Inc.)

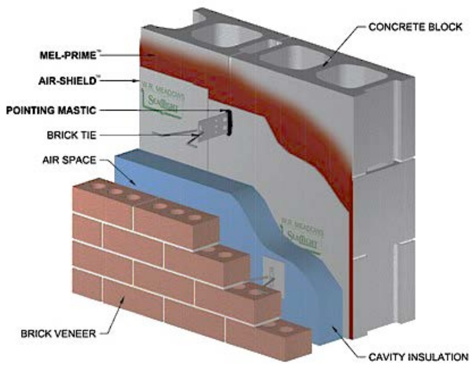

Figure 2 AIR-SHIELD ™ barrier in wall assembly (Courtesy of W. R. Meadows, Inc.)

DuPont™ Tyvek® DrainWrap™ Moisture Barrier DuPont™ Tyvek® DrainWrap™ has a vertically-grooved surface that can provide protection against water on the wall assembly and facilitate drainage. The material fabric structure can help drying in the wall system and keep bulk water out but to allow water vapor to pass through it. (Figure 3).

Figure 3 Application of DuPont™ barrier (Courtesy of Professional Remodeler magazine/Photo: Erika Taylor)

Figure 4 Application of 3M™ barrier (Courtesy of Panthereast)

3M™ Air and Vapor Barrier 3015 3M™ Air and Vapor Barrier 3015 is an air and vapor barrier membrane designed to allow application in temperature range between 0°F to 150°F. The membrane has self-sealing property against nail fasteners and penetrations. It can be installed onto wall with a rubber roller (Figure 4).

Stego® Wrap Vapor Barrier Stego® Wrap Vapor Barrier is a low permeance under-slab vapor barrier membrane. Stego® Wrap is installed over the area where the concrete slab is to be placed. Permeance, puncture resistance and tensile strength tests as well as other conditioning tests are conducted for Stego® Wrap Vapor Barrier.

Table 1 summarizes various ASTM tests the manufacturers have reported in their test data sheets. The test methods are explained in the next section.

Table 1 Summary of ASTM Test Methods for Vapor Barriers/ Retarders Products.

Properties	**AIR-SHIELD ™ Self-Adhering and Air/Vapor Liquid Moisture Barrier**	**DuPont™ Tyvek® DrainWrap™ Moisture Barrier**	**3M™ Air and Vapor Barrier 3015**	**Stego® Wrap Vapor Barrier**	**GRIFFOLYN® Vapor Wall Retarders & Barriers**
Water Vapor Permeance	E 96 (B)	E 96(A, B)	E 96	F 1249 E 154	E 96
Water Absorption	D 1970 D 570-81				
Air leakage/ Air Penetration	E 2178 E 283 E 2357	E 2178	E 2178		
Tensile Strength Film	D 412 D 882	D 882	D 882		D 882
Elongation Film	D 412 D 882	D 882	D 882		
Puncture Resistance	E 154			D1709	D 4833
Lap Peel Strength	D 903				
Lap Adhesion			D 3330		
Pull Adhesion			D 4541		
Tear Resistance		D 1117			
Surface Burning Characteristics		E 84	E 84		
Low Temperature Flexibility			D 1970		
Dart / Cold Impact Strength					D 1709
Nail Sealability			D 1970 E 331/547		

2.2 Test Methods for Vapor Barriers/Retarders

The major property of vapor barriers/retarders that need to be tested is water vapor transmission and its rate in that the performance of vapor barriers/retarders depends on this property of the material. Other properties include tensile strength, elongation and low temperature flexibility. Standards ASTM E96 and ASTM F1249 describe the test methods for water vapor transmission property.

ASTM E96: ***Standard Test Methods for Water Vapor Transmission of Materials***

The purpose of this test is to obtain values of water vapor transfer through permeable and semipermeable materials expressed in term of Water Vapor Transmission (WVT). It is applicable for specimens that are not over 1¼ in. (32 mm) in thickness. Two methods with different test procedures are introduced: the Desiccant

Method and the Water Method. The test procedure is explained in Figure 5.

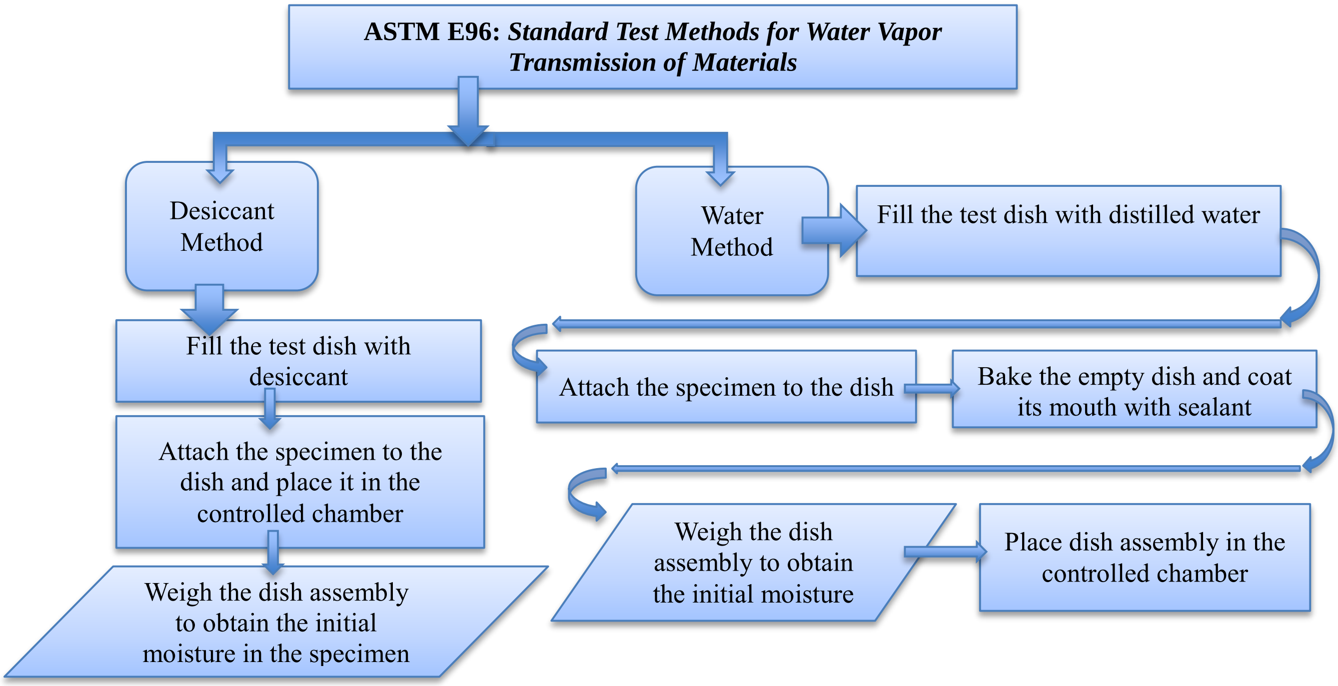

Figure 5 Flow chart of ASTM E96 Test Procedure

There are two ways of analyzing the results to obtain the Water Vapor Permeance:

- Graphic Analysis: Plot the weight against elapsed time (modified by the dummy specimen if used). Then inscribe a curve that tends to become straight. In this case, a nominally steady state is assumed, and the slope of the straight line is the rate of water vapor transmission.
- Numerical Analysis: A mathematical least squares regression analysis of the weight as a function of time will give the rate of water vapor transmission.

ASTM F 1249: ***Standard Test Method for Water Vapor Transmission Rate through Plastic Film and Sheeting Using a Modulated Infrared Sensor***

This test is to obtain values for the water vapor transmission rate (WVTR) through barrier material. Also, permeance of the film to water vapor, and for homogeneous materials, water vapor permeability coefficient can be determined in this test. It is applicable for flexible material specimens up to 3 mm (0.1 in.) in thickness.

The barrier material to be tested separates dry chamber from a wet chamber of known temperature and humidity, which make up a diffusion cell where the test film is sealed. The pressure-modulated infrared sensor measures the fraction of infrared energy absorbed by the water vapor and produces an electrical signal. Comparing the signal to the one produced by measurement of a calibration film of known water vapor transmission rate, the rate at which moisture is transmitted through the test material can be calculated.

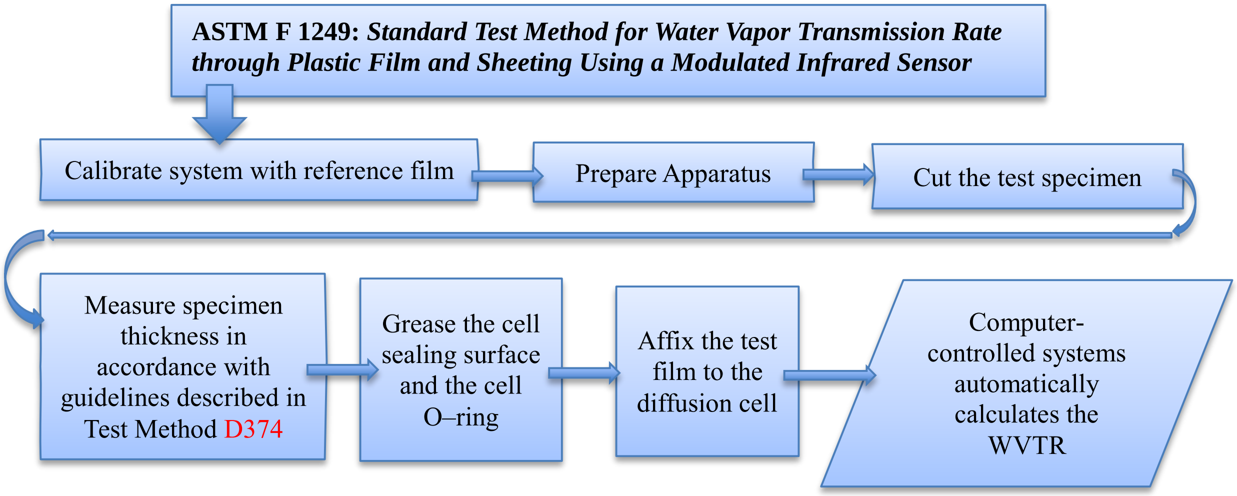

Figure 6 Flow chart of ASTM F 1249 Test Procedure

Summary of Test Methods for Water Vapor Transmission:
The methods are intended to allow approaching the actual conditions of use of vapor barriers/ retarders with test temperature and relative humidity conditions clearly stated.
Roof and wall vapor barriers/ retarders are generally tested with the method introduced in ASTM E96 Standard Test Methods for Water Vapor Transmission of Materials, while under-slab options are usually tested according to ASTM F 1249 Standard Test Method for Water Vapor Transmission Rate Through Plastic Film and Sheeting Using a Modulated Infrared Sensor.

Tensile Strength The test methods applied to test tensile strength of vapor barriers/ retarders are described in standards ASTM D 412 *Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension* and ASTM D 882 *Tensile Properties of Thin Plastic Sheeting*.
The purpose of ASTM D 412 test is to evaluate the tensile properties of vulcanized thermoset rubbers and thermoplastic elastomers. Two types of test specimen are used corresponding to two different test methods.
1) Dumbbell and Straight Section Specimens— Test Method A Figure 7 explains the test procedure

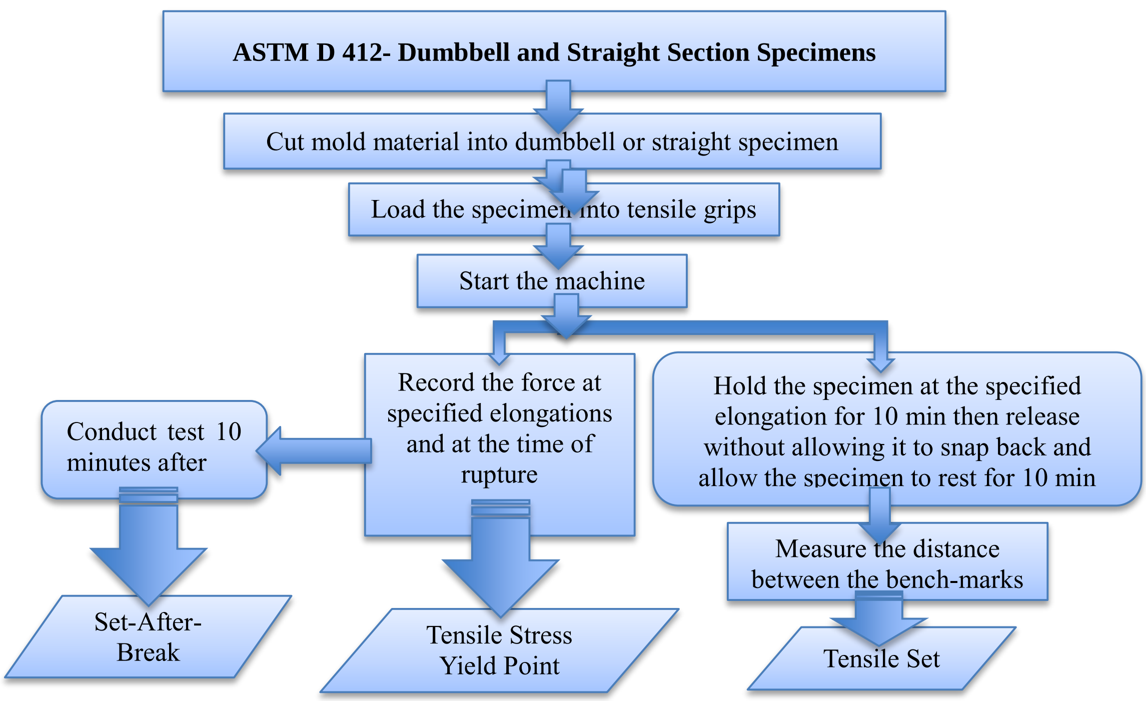

Figure 7 Flow chart of ASTTM D 412 Method A Test Procedure

2) Cut Ring Specimens— Test Method B One important characteristic for stress-strain properties of ring specimen is that the inside strain (or stress) is greater than the outside strain (or stress) because extending the ring generates a non-uniform stress (or strain) field, which is different from the dumbbell and straight specimens. But the stress-strain properties of ring specimens are calculated in the same manner for dumbbell and straight specimens. The test procedure is explained in Figure 8.

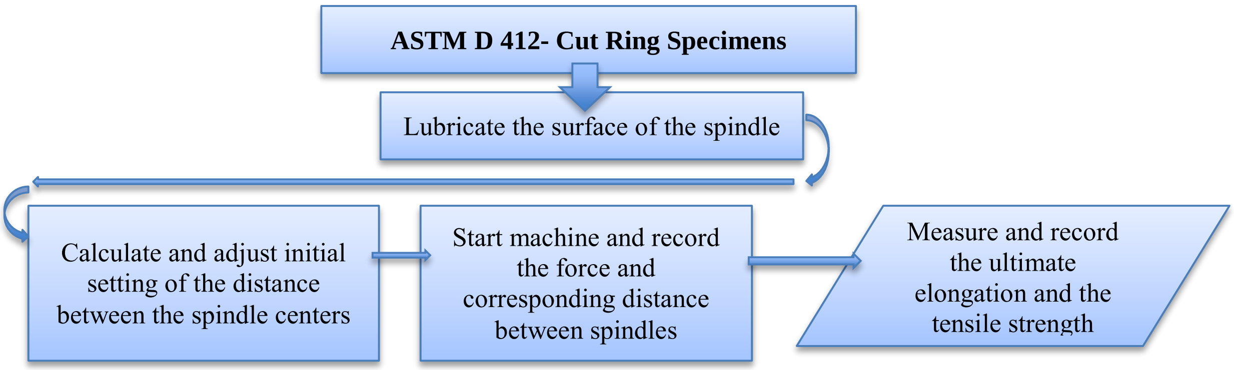

Figure 8 Flow chart of ASTTM D 412 Method A Test Procedure

ASTM D 882
The ASTM D 882 test is to determine tensile properties of thin plastic sheeting and films, with thickness less than 1.0 mm (0.04 in.). Figure 9 explains the procedure for this test method.

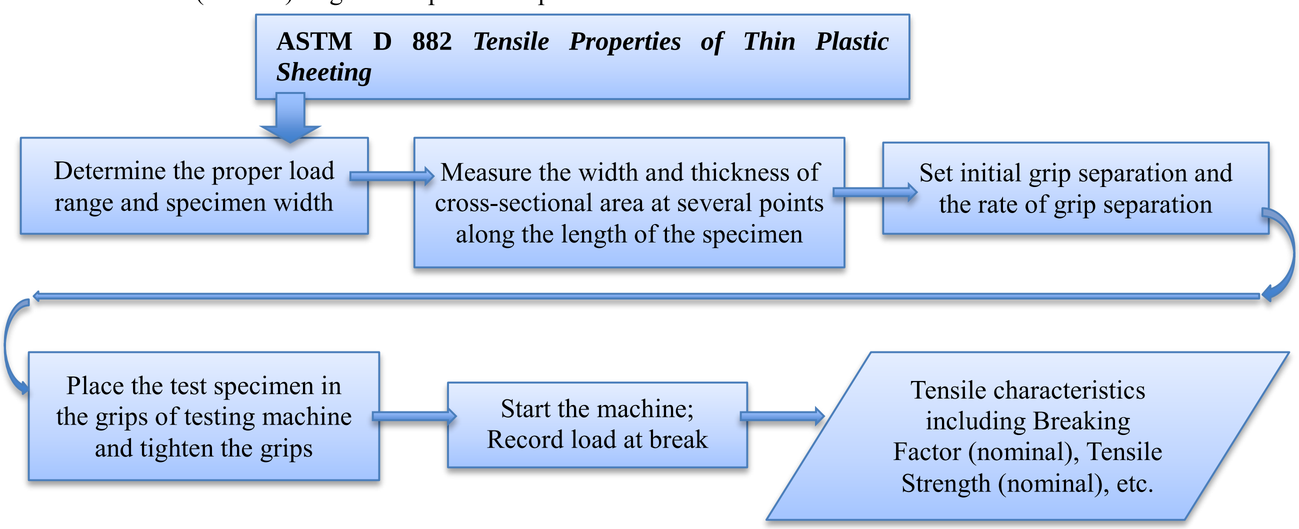

Figure 9 Flow chart of ASTM D882 Test Procedure

Low Temperature Flexibility
ASTM D 1970 ***Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection*** This test method is to determine the low temperature flexibility of the underlayment sheets. This standard is for polymer modified bituminous sheet materials used as underlayment to prevent leakage from water back-up due to ice dams. The procedure is shown in the following flow chart in Figure 10:

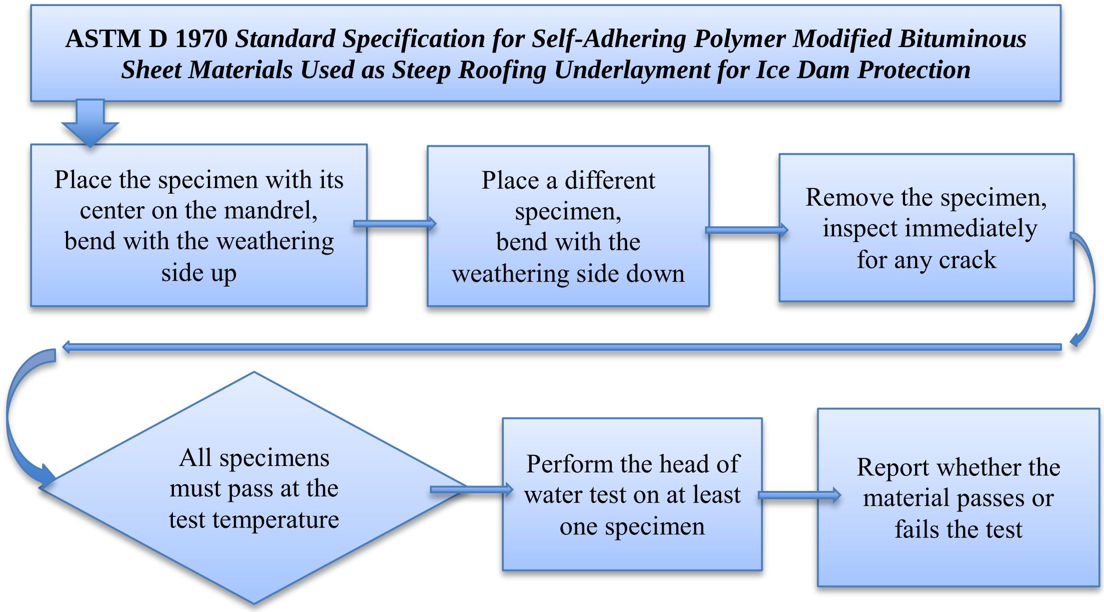

Figure 105 Flow chart of ASTM D 1970 Test Procedure

3.0 WATERPROOFING MEMBRANES

Waterproofing is used to prevent water intrusion into the structural elements of a building or its finished spaces. Building envelope systems including roof, siding, foundations, walls, basements, and all of the various penetrations through these surfaces need to have waterproofing material applied. Waterproofing membrane can either be applied to the interior, the exterior, or in places inaccessible by people. Types of waterproof membranes include applied or liquid membrane, film or sheet membrane, built-up or laminate membrane and injectable waterproofing.

3.1 Introduction of Selected Waterproofing Membranes

TAMKO®TW-60 Sheet Waterproofing Membrane TAMKO® TW-60 is a self-adhering rubberized asphalt sheet membrane with a polymer film on the surface. It can be applied as below-grade waterproofing of foundation walls, tunnels, earth shelters, ICF forms and similar structures (Figure 11-12).

Figure 11 TAMKO®TW-60 Sheet (Courtesy of TAMKO)

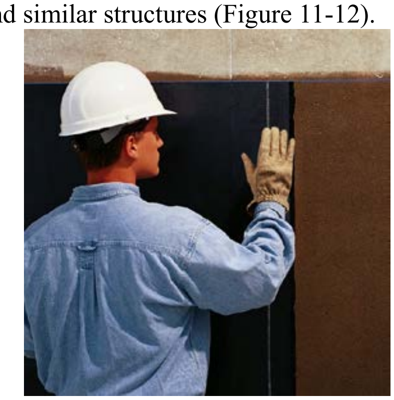

Figure 12 Application of TAMKO®TW-60 Sheet (Courtesy of TAMKO)

W. R. MEADOWS MEL-ROL Waterproofing Membrane MEL-ROL is a rolled and self-adhering waterproofing membrane composed of thick layer of polymeric waterproofing membrane on a cross-laminated polyethylene carrier film. It can be applied to waterproof foundations, vertical walls, and below-grade floors (Figure 13-14).

Figure 13 Installations of MEL-ROL Membranes (Courtesy of W. R. Meadows, Inc.)

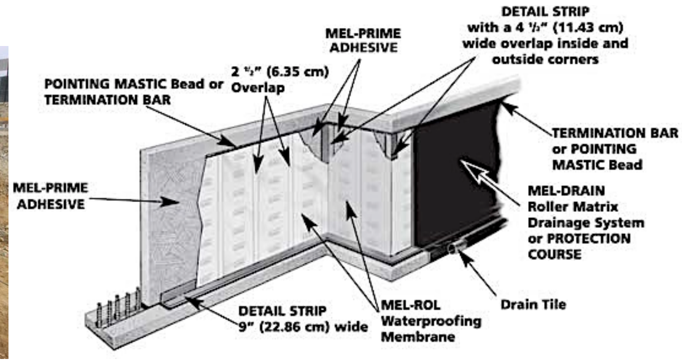

Figure 14 MEL-ROL Membrane Assembly (Courtesy of W. R. Meadows, Inc.)

GRACE Bituthene System 4000 Bituthene 4000 is a pre-formed below-grade waterproofing membrane comprised of a cross-laminated HDPE carrier film with a self-adhesive rubberized asphalt compound.

Polyguard 650 Waterproofing Membrane Polyguard's 650 Waterproofing Membrane is a below grade waterproofing sheet membrane material for both foundation walls and plaza deck applications. 650 Waterproofing Membrane for Foundation Walls contains a layer of polymerized asphalt formulation with a backing layer of polyethylene film.

REDGARD® Crack Prevention and Waterproofing Membrane RedGard® Crack Prevention Waterproof membrane is an elastomeric liquid product. It works by creating waterproofing barrier on interior or exterior substrates.

Table 2 summarizes various ASTM tests the manufacturers have reported in their test data sheets. The test methods are explained in the next section.

Table 2 Summary of ASTM Test Methods for Waterproofing Membrane Products

Properties	TAMKO®TW-60 Sheet Waterproofing Membrane	W. R. MEADOWS MEL-ROL Waterproofing	GRACE Bituthene System 4000	Polyguard 650 Waterproofing Membrane	REDGARD® Crack Prevention and Waterproofing Membrane
Tensile, Membrane	D 412 (C)	D 412	D 412	D 412 Modified Die C	ASTM D638
Tensile, Film	D 882	D 412	D 882	D 882	
Elongation	D 412 (C)	D 412	D 412	D 412	
Water Vapor Absorption		E 96, B		D 570	
Water Vapor permeability	E 96	D 1970	E 96 (Water Method)	E 96 Method B	
Flexibility	D 1970		D1970		
Low Temp. Crack		C 836			
Crack Cycling	C 836		C 836	C 836	
Peel Strength	D 903	D 903	D 903	D 903 D 1000	
Lap Adhesion	D 1876	D 1876	D1876		
Puncture Resistance	E 154	E 154		E 154 Blunt Instrument	
Hydrostatic Head	D 5385	D 5385	D 5385	D 5385-93	

3.2 Test Methods for Waterproofing Membranes

The most important property of the waterproofing is the water absorption rate. Also important is the thickness of the material and resistance to hydrostatic head. Others include tensile strength of membrane and film, flexibility, puncture resistance, crack cycling, peel adhesion and lap adhesion.

Water Absorption

ASTM D 570: *Standard Test Method for Water Absorption of Plastics* This test is to determine the relative water vapor absorption rate of all types of materials when immersed. The test procedures for different types of immersion methods are listed in Table 3 below:

Table 3 Summary of ASTM D 570 Test Procedures for Different Types of Immersion

	Procedure
Twenty-Four Hour Immersion	• Place conditioned specimen in distilled water maintained, entirely immersed • Remove the specimen one at a time at 24+1⁄2, −0 h, wipe off with dry cloth • Immediately weigh specimens to the nearest 0.001g
Two-Hour Immersion	• Tested as described in Twenty-Four Hour Immersion • time of immersion: 120 ± 4 min
Repeated Immersion	• 2-h immersion • Weigh specimen to the nearest 0.001 g • Replaced in the water • Weighed again after 24 h
Long-Term Immersion	• Tested as described in Twenty-Four Hour Immersion • Repeat weighing at the end of the first week and every two weeks until the increase in weight per two-week period averages less than 1 % of the total increase in weight or 5 mg
Two-Hour Boiling Water Immersion	• Place conditioned specimen in boiling distilled water, entirely immersed • Remove the specimens from the water and cool in distilled water maintained at room temperature at the end of 120 ± 4 min • Remove the specimen one at a time after 15 ± 1 min, wiped off with dry cloth • Immediately weigh specimens to the nearest 0.001 g
One-Half-Hour Boiling Water Immersion*	• Tested as described in Two-Hour Boiling Water Immersion • time of immersion: 30 ± 1 min
Immersion at 50°C	• Tested as described in Two-Hour Boiling Water Immersion • time of immersion: 48 ± 1 h • temperature of immersion: 50 ± 1°C • Omit cooling in water before weighing

Resistance to Hydrostatic Head

ASTM D 5385 : *Standard Test Method for Hydrostatic Pressure Resistance of Waterproofing Membranes* The objective of this test is to determine the hydrostatic resistance of a waterproofing membrane under certain laboratory condition. This test method is not applicable to systems that rely on confinement of the seams. The test procedure is explained in Figure 15. The head of water from the pressure the sample withstood and the mean and standard deviation of the head of water withstood can be obtained from the test.

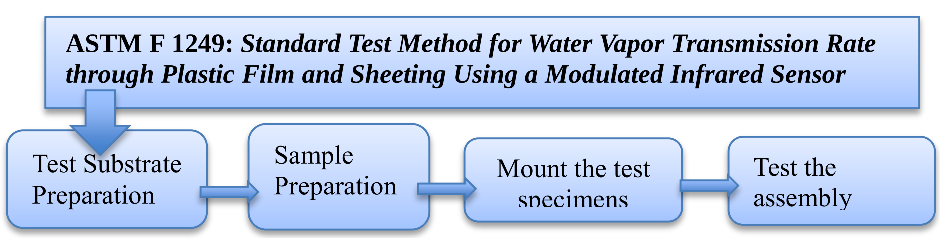

Figure 15 Flow chart of ASTM F1249 Test Procedure

Crack Cycling

ASTM C836: ***Standard Specification for High Solids Content, Cold Liquid-Applied Elastomeric Waterproofing Membrane for Use with Separate Wearing Course*** Required properties and test methods for cold liquid-applied elastomeric-type membrane are presented in this specification including: 1) Hardness; 2) Weight Loss; 3) Low-Temperature Crack Bridging; 4) Film Thickness on Vertical Surface; 5) Adhesion-in-Peel After Water Immersion; 6) Extensibility After Heat Aging; 6) Stability. The Low-Temperature Crack Bridging Test is in compliance with the requirements of Test Method C1305.

4.0 AIR BARRIERS

Air barriers are significant to the energy-efficiency of buildings as air leakage directly influences the energy consumption of the HAVC systems. Thus, air barrier testing methods are vital to establishing installation guidelines for real practice. Based on the application methods, air barrier materials can be defined as fluid-applied, sheet-applied or self-adhesive membranes.

4.1 Introduction of Selected Air Barriers

GRACE Perm-A-Barrier VPL Perm-A-Barrier® VPL is a fluid applied, one component air barrier membrane as shown in Figure 30. It is vapor permeable but impermeable to liquid water.

DuPont™ Tyvek® Fluid Applied WB System DuPont™ Tyvek® Fluid Applied WB is a water and fluid applied air barrier as shown in Figure 16. It is based on silyl terminated polyether polymer technology to achieve low shrinkage during curing and elasticity. However, Tyvek® Fluid Applied WB is not approved for use on residential single family homes.

Figure 16 Application of DuPont™ Tyvek® Fluid Applied WB
(Courtesy of DuPont)

Henry® Non-Permeable Air Barrier Air-Bloc 06 WB Henry® Air-Bloc 06 WB is an elastomeric asphalt emulsion for use as air and vapor barrier membrane. It can be used for either above grade on construction surface to provide air barriers or below grade on foundation or footings as waterproofing membranes.

AIR-SHIELD TM Self-Adhering Air/Vapor and Liquid Moisture Barrier AIR-SHIELD TM is a sheet-applied air barrier product introduced in Section 2, which provides resistance to both vapor and air penetration. Refer to the previous part for detailed information.

3M™ Air and Vapor Barrier 3015 3M™ is also a sheet-applied product introduced earlier and functions as an air and vapor barrier. Refer to the previous part for detailed information.

Table 4 summarizes various ASTM tests the manufacturers have reported in their test data sheets. The test methods are explained in the next section.

Table 4 Summary of ASTM Test Methods for Air Barrier Products

Properties	GRACE Perm-A-Barrier VPL	DuPont™ Tyvek® Fluid Applied WB System	Henry® Non-Permeable Air Barrier Air-Bloc 06 WB	AIR-SHIELD TM Self-Adhering Air/Vapor and Liquid Moisture Barrier	3M™ Air and Vapor Barrier 3015
Air Permeance	E2178	E2178	E2178	E 2178-01	E 2178
Assembly Air Permeance	E2357	E2357 E283		E 2357 E 283	E 2357
Water Resistance	E331		D466		
Water vapor Transmission	E96 Method B	E96	E96		
Tensile Strength	D412				
Elongation	D412				
Low Temperature Flexibility	D1970				
Nail Sealability	D1970				
Adhesion Strength		D4541			
Tensile Strength		D412	D412		
Surface Burning Characteristics		E84			

4.2 Test Methods for Air Permeance Property of Air Barriers

Test methods for properties of air barriers including Tensile Strength, Elongation, and Low Temperature Flexibility have already been included in previous sections. The most important property that needs testing for products functioning as air barriers is air leakage resistance.

From the technical data of products introduced, the air leakage property of air barrier material, assembly and whole building all need to be tested, because testing of material property is not enough and actual installation and workmanship in the field are also critical to control air leakage of the building enclosure. Corresponding ASTM test methods are shown in Table 5.

Table 5 Summary of ASTM Test Methods of Air Leakage Property of all Levels

Air Leakage	ASTM Test Methods
Material	ASTM E 2178 Standard Test Method for Air Permeance of Building Materials
Assemblies	ASTM E 1677 Standard Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls
	ASTM E 2357 Standard Test Method for Determining Air Leakage of Air Barrier Assemblies (2011)
	ASTM E 283 Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
Whole building	ASTM E 779 Standard Test Method for Determining Air Leakage Rate by Fan Pressurization

4.2.1 Air barrier materials

Air leakage property on the material level is defined by air permeance, which is the rate of air flow per unit area and per unit static pressure differential. The standard test method used is ASTM E2178, *Standard Test Method for Air Permeance of Building Materials*.

ASTM E 2178: ***Standard Test Method for Air Permeance of Building Materials*** The purpose of the test is to measure the air permeance of flexible sheet or rigid panel-type building materials. Test procedure is explained in Figure 17.

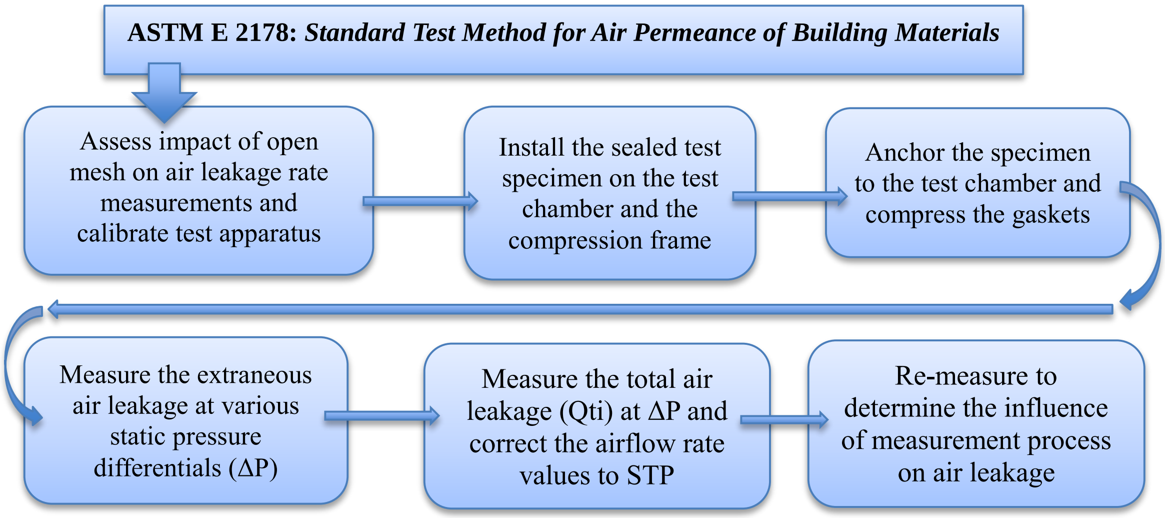

Figure 17 Flow chart of ASTM E2178 Test Procedure

4.2.2 Air barrier assemblies

Air barrier assembly is defined as the air barrier materials with air barrier accessories that provide a continuous designated plane. Test methods are intended to simulate the performance of various air barrier materials/accessories when combined into an assembly. For both accepted test methods ASTM E2357 and ASTM E1677 for air barrier assemblies, focus is given on ASTM E2357 since it is more stringent than ASTM E1677 and assemblies tested under its conditions can significantly outperform requirements under ASTM E1677 according to research results by Maria Spinu, 2009.

ASTM E 2357: ***Standard Test Method for Determining Air Leakage of Air Barrier Assemblies***

This laboratory test is to determine the air leakage rate of air barrier assemblies of building enclosure before and after exposure to specific conditioning cycles, which may be applied on site mockup.

The initial leakage test shall be conducted with 7 measurements across the sample in accordance with Test Method E283: *Standard Test Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen*. Results shall be curve fit using a least squares procedure to establish the relationship between pressure difference and leakage. The reported air leakage rate of the specimen for both positive and negative cases, shall be the rate of the specimen after the structural (wind) loading conditioning.

4.2.3 Whole building air leakage

ASTM E779: ***Standard Test Method for Determining Air Leakage Rate by Fan Pressurization***

Fan-pressurization method qualifies the air tightness by measuring the air-leakage rates of the whole building under mechanical pressurization and depressurization. By measuring the airflow rate and the pressure differences at each pressure increment and collecting data for both pressurization and de-pressurization cases, the air leakage can be determined using the equations suggested in the standards.

5.0 INSULATION

Insulation is an important product for use in buildings applied in attic, ceilings, walls, roofs and sometimes basements to enhance thermal, acoustic, and sometimes fire-resistant property of these building components or spaces. There are essentially three types of insulation: loose insulation, rigid insulation and spray foam insulation.

5.1 Introduction of Selected Insulation Products
5.1.1 Loose insulation
Cellulose Cellulose insulation is a loose fill product manufactured from recycled wood products, newspaper, for use in blown-in applications such as attics and wall cavities.
ULTRATOUCH™ CELLULOSE UltraTouch Nature Blend Cellulose is a loose-fill insulating product for attic applications. (Figure 18)

Figure 18 Application of UltraTouch ™ Cellulose

Figure 19 Application of UltraTherm™ Fiber Glass (Courtesy of Cerntainteed)

Fiber-glass Fiberglass (also called glass wool) is a commonly used insulation material made from fibers of glass and arranged in the texture similar to wool.
UltraTherm™ S&R Loose Fill Fiber Glass Insulation UltraTherm™ S&R Loose Fill Fiber Glass Insulation is designed for use in attic as shown in Figure 19.

Rock-wool Rock-wool insulation is made from actual rocks and minerals with extraordinary ability to block heat and sound. It is a mass of fine intertwined fibers, bound together with starch.
Rockwool Premium Plus™ Rockwool Premium Plus™ Insulation is a mineral fiber insulation manufactured in a granular form. The wall assembly section is shown in Figure 20.

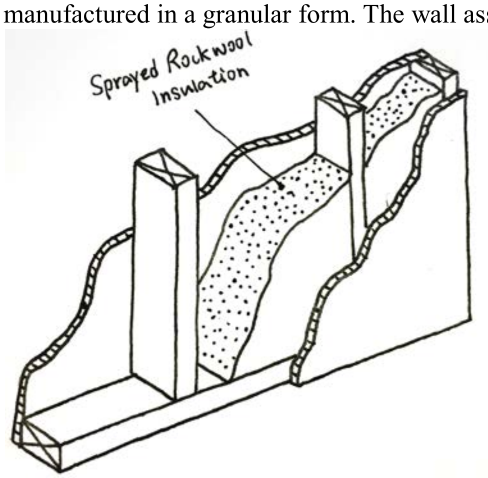

Figure 20 Section of Rock-wool Insulation

Figure 21 Installation of ThermalStar® X-Grade (Courtesy of Altas EPS)

5.1.2 Rigid insulation
Expanded Polystyrene (EPS)
ThermalStar® X-Grade® ThermalStar® X-Grade is an Expanded Polystyrene material insulation product for below grade applications as shown in Figure 21. It can provide thermal insulation and protection against backfilling for foundation walls.

Extruded Polystyrene (XPS)
FOAMULAR® 150 Rigid Extruded Polystyrene (XPS) Foam Insulation FOAMULAR® 150 is a rigid XPS foam insulation. The densely packed air cells within the foam insulation provide thermal insulating

performance. It can be applied in attics, floors and walls, basement and crawlspaces, etc.

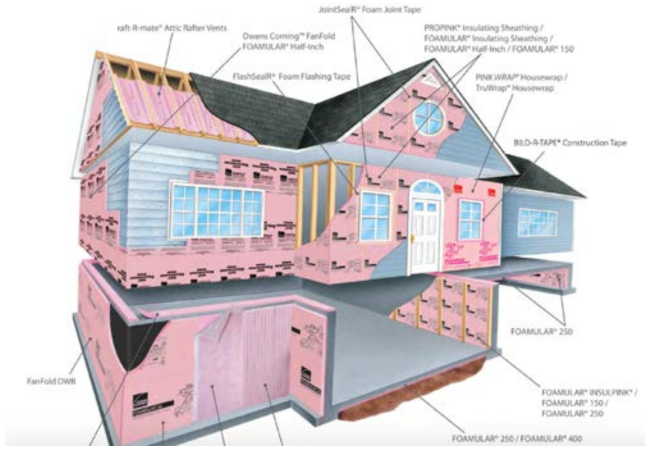

Figure 22 Section of Application of XPS Insulation
(Photo courtesy of Owens Corning)

Polyisocyanurate (ISO)
THERMAX™ Sheathing It is a rigid board insulation consisting of a glass-fiber-reinforced polyisocyanurate foam core and aluminum foil facers on both sides.

Figure 23 THERMAX™ Sheathing Product
(Courtesy of the Dow Chemical Company)

Figure 24 Section of THERMAX™ Sheathing
(Courtesy of the Dow Chemical Company)

5.1.2 Spray foam
STYROFOAM™ Brand Spray Polyurethane Foam (SPF) Insulation STYROFOAM™ Brand Spray Polyurethane Foam (SPF) insulation is a closed-cell, two-component spray foam barrier on the interior of steel stud walls. It can block air infiltration by filling gaps, cracks and penetrations. It needs to be applied by a trained SPF insulation applicator only as shown it Figure 25.

Figure 25 Application of STYROFOAM™ Brand Spray Polyurethane Foam
(Courtesy of The Dow Chemical Company |dowbuildingsolutions.com)

Table 6 summarizes various ASTM tests the manufacturers have reported in their test data sheets. The test methods are explained in the next section.

Table 6 Summary of ASTM Test Methods for Insulation Products

Properties	Loose insulation			Rigid insulation			Spray foam
	Cellulose	Fiber-glass	Rock-wool	Expanded Polystyrene (EPS)	Extruded Polystyrene (XPS)	Polyisoc-yanurate (ISO)	
	ULTRATOUCH™ CELLULOSE	UltraTherm™ S&R Loose Fill Fiber Glass Insulation	Rockwool Premium Plus™	ThermalStar® X-Grade®	FOAMULAR® 150 Rigid Extruded Polystyrene (XPS) Foam Insulation	THERMAX™ Sheathing	STYROFOAM™ Brand Spray Polyurethane Foam (SPF)
Density	C 739		E 605				D 1622
Thermal Resistance	C 518	C 518 C 687		C 518	C 518		C 518
Acoustical Performance		E 90 E 413					
Surface Burning Characteristics/ Fire Resistance	E 84	E 84	E 119 E136 E84	E 84	E 84		
Water Vapor Sorption	C 739	C 1104					
Water Absorption			C 553	C 272	C 272	C 209	
Water Vapor Permeance				E96	E 96	E 96	E 96
Odor emission		C 1304					
Fungi resistance		C 1338	C 1338				
Corrosiveness		C 764	C 665				
Compressive Strength				D 1621	D 1621	D 1621	
Flexural Strength				C 203	C 203	C 203	
Dimensional Stability					D 2126		

5.2 Test Methods for Insulations

The major properties of insulation products are its thermal resistance and acoustical performance. Other material properties including water vapor absorption, water vapor permeance, air permeance, and surface burning characteristics have been introduced in the previous sections.

Thermal Resistance

ASTM C 518: ***Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus*** This test method can measure the steady state thermal transmission properties through thermal insulation specimen with high accuracy. The test procedure is explained in Figure 26.

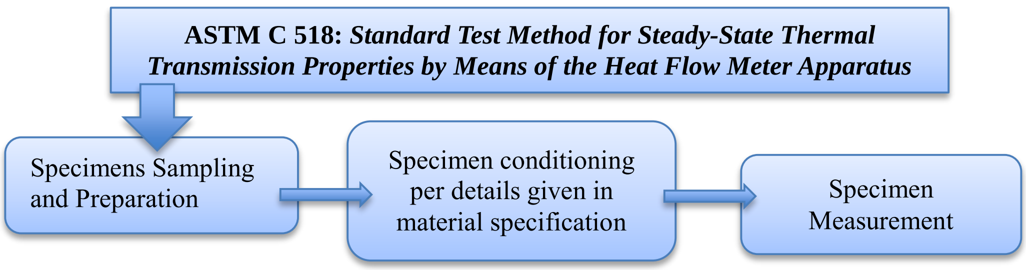

Figure 26 Flow chart of ASTM C518 Test Procedure

Acoustical Performance

ASTM E 413: ***Classification for Rating Sound Insulation***

This test method calculates single-number acoustical ratings based on the reference sound insulation contour provided in the standard, which can be used to evaluate sound insulating performance of building insulation products. The test procedure is explained in Figure 27.

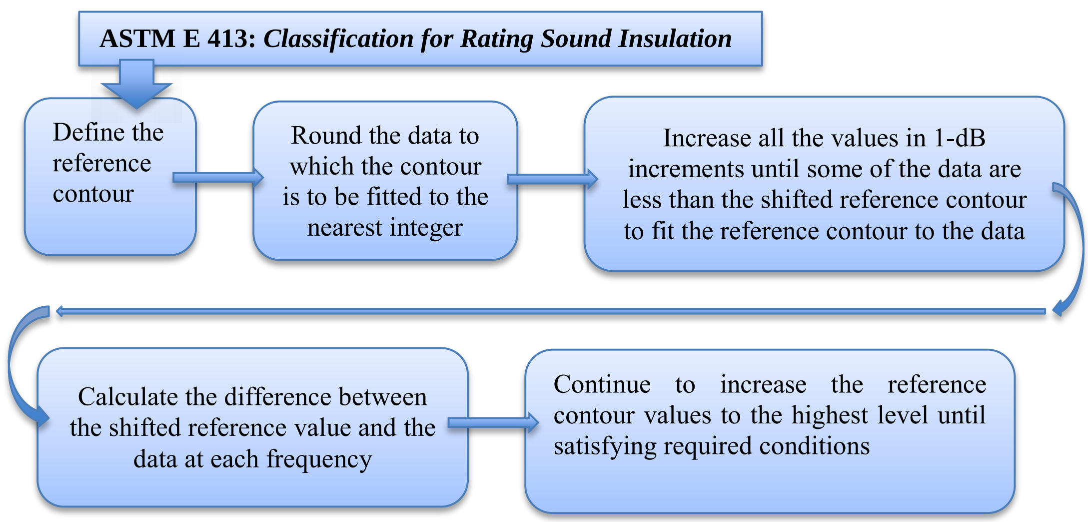

Figure 27 Flow chart of ASTM C518 Test Procedure

6.0 CONCLUDING REMARKS

The paper has presents a review of the most important components of a building enclosure: vapor barriers/ retarders, waterproof membranes, air barriers and insulation. Starting from the basics of a component, general ideas of what they are and how they function are explained. The review shows that some components have multiple functions, for example, vapor barrier and air barrier are sometimes the same layer as they can both prevent flow of vapor and air through the material. Multiple function property is also true for insulation, as it has to enhance not only thermal but also acoustic, and sometimes fire-resistance property. Through exploring the building enclosure component products in the market, the commonly used standard test methods can be generalized. Besides, information on where to apply in a wall assembly and how to apply the product is also provided by manufacturers. Test methods for a typical property can vary with different materials of the products and are stated in detail in ASTM Standards. Test methods are vital to establish installation guidelines in real practice. If the building enclosure components products are wisely selected and properly installed, they can work together to achieve low energy consumption and long-term durability. The performance of a building can be improved by measuring it. That is the meaning of studying test methods for building components. Many institutes and organizations are devoting their efforts into improving test methods for building enclosure components. In this paper, some articles and research papers on state of art studies and testing projects are also referenced for further reading.

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[4] ASTM D1970/D1970M−13a, Standard Specification for Self-Adhering Polymer Modified Bituminous Sheet Materials Used as Steep Roofing Underlayment for Ice Dam Protection.
[5] ASTM E84-14, Standard Test Method for Surface Burning Characteristics of Building Materials.
[6] ASTM E96/E96M−13, Standard Test Methods for Water Vapor Transmission of Materials.
[7] ASTM E154/E154M−08a, Standard Test Methods for Water Vapor Retarders Used in Contact with Earth Under Concrete Slabs, on Walls, or as Ground Cover.
[8] ASTM C386-93, Standard Practice for Use of Chemical-Resistant Sulfur Mortar.
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[15] ASTM E779 – 10, Standard Test Method for Determining Air Leakage Rate by Fan Pressurization.
[16] ASTM E1677 – 11, Standard Specification for Air Barrier (AB) Material or System for Low-Rise Framed Building Walls.
[17] ASTM E2178−13, Standard Test Method for Air Permeance of Building Materials.
[18] ASTM E2357 – 11, Standard Test Method for Determining Air Leakage of Air Barrier Assemblies.
[19] ASTM C518−10, Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus.
[20] ASTM E84−14, Standard Test Method for Surface Burning Characteristics of Building Materials.
[21] ASTM E413−10, Classification for Rating Sound Insulation.