ASCE STANDARD

ASCE/SEI 30–14

Guideline for Condition Assessment of the Building Envelope

This document uses both the International System of Units (SI) and customary units

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SEI STRUCTURAL ENGINEERING INSTITUTE

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STANDARDS

In 2006, the Board of Direction approved the revision to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by the Society. All such standards are developed by a consensus standards process managed by the Society's Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee made up of Society members and nonmembers, balloting by the membership of the Society as a whole, and balloting by the public. All standards are updated or reaffirmed by the same process at intervals not exceeding five years.

The following standards have been issued:

ANSI/ASCE 1-82 N-725 Guideline for Design and Analysis of Nuclear Safety Related Earth Structures
ASCE/EWRI 2-06 Measurement of Oxygen Transfer in Clean Water
ANSI/ASCE 3-91 Standard for the Structural Design of Composite Slabs and ANSI/ASCE 9-91 Standard Practice for the Construction and Inspection of Composite Slabs
ASCE 4-98 Seismic Analysis of Safety-Related Nuclear Structures
Building Code Requirements for Masonry Structures (ACI 530-13/ASCE 5-13/TMS 402-13) and Specifications for Masonry Structures (ACI 530.1-13/ASCE 6-13/TMS 602-13)
ASCE/SEI 7-10 Minimum Design Loads for Buildings and Other Structures
SEI/ASCE 8-02 Standard Specification for the Design of Cold-Formed Stainless Steel Structural Members
ANSI/ASCE 9-91 listed with ASCE 3-91
ASCE 10-97 Design of Latticed Steel Transmission Structures
SEI/ASCE 11-99 Guideline for Structural Condition Assessment of Existing Buildings
ASCE/EWRI 12-13 Standard Guidelines for the Design of Urban Subsurface Drainage
ASCE/EWRI 13-13 Standard Guidelines for the Installation of Urban Subsurface Drainage
ASCE/EWRI 14-13 Standard Guidelines for the Operation and Maintenance of Urban Subsurface Drainage
ASCE 15-98 Standard Practice for Direct Design of Buried Precast Concrete Pipe Using Standard Installations (SIDD)
ASCE 16-95 Standard for Load Resistance Factor Design (LRFD) of Engineered Wood Construction
ASCE 17-96 Air-Supported Structures
ASCE 18-96 Standard Guidelines for In-Process Oxygen Transfer Testing
ASCE 19-10 Structural Applications of Steel Cables for Buildings
ASCE 20-96 Standard Guidelines for the Design and Installation of Pile Foundations
ANSI/ASCE/T&DI 21-13 Automated People Mover Standards
SEI/ASCE 23-97 Specification for Structural Steel Beams with Web Openings
ASCE/SEI 24-05 Flood Resistant Design and Construction
ASCE/SEI 25-06 Earthquake-Actuated Automatic Gas Shutoff Devices
ASCE 26-97 Standard Practice for Design of Buried Precast Concrete Box Sections
ASCE 27-00 Standard Practice for Direct Design of Precast Concrete Pipe for Jacking in Trenchless Construction
ASCE 28-00 Standard Practice for Direct Design of Precast Concrete Box Sections for Jacking in Trenchless Construction
ASCE/SEI/SFPE 29-05 Standard Calculation Methods for Structural Fire Protection
SEI/ASCE 30-14 Guideline for Condition Assessment of the Building Envelope
SEI/ASCE 31-03 Seismic Evaluation of Existing Buildings
SEI/ASCE 32-01 Design and Construction of Frost-Protected Shallow Foundations
EWRI/ASCE 33-09 Comprehensive Transboundary International Water Quality Management Agreement
EWRI/ASCE 34-01 Standard Guidelines for Artificial Recharge of Ground Water
EWRI/ASCE 35-01 Guidelines for Quality Assurance of Installed Fine-Pore Aeration Equipment
CI/ASCE 36-01 Standard Construction Guidelines for Microtunneling
SEI/ASCE 37-02 Design Loads on Structures during Construction
CI/ASCE 38-02 Standard Guideline for the Collection and Depiction of Existing Subsurface Utility Data
EWRI/ASCE 39-03 Standard Practice for the Design and Operation of Hail Suppression Projects
ASCE/EWRI 40-03 Regulated Riparian Model Water Code
ASCE/SEI 41-06 Seismic Rehabilitation of Existing Buildings
ASCE/EWRI 42-04 Standard Practice for the Design and Operation of Precipitation Enhancement Projects
ASCE/SEI 43-05 Seismic Design Criteria for Structures, Systems, and Components in Nuclear Facilities
ASCE/EWRI 44-05 Standard Practice for the Design and Operation of Supercooled Fog Dispersal Projects
ASCE/EWRI 45-05 Standard Guidelines for the Design of Urban Stormwater Systems
ASCE/EWRI 46-05 Standard Guidelines for the Installation of Urban Stormwater Systems
ASCE/EWRI 47-05 Standard Guidelines for the Operation and Maintenance of Urban Stormwater Systems
ASCE/SEI 48-11 Design of Steel Transmission Pole Structures
ASCE/SEI 49-12 Wind Tunnel Testing for Buildings and Other Structures
ASCE/EWRI 50-08 Standard Guideline for Fitting Saturated Hydraulic Conductivity Using Probability Density Functions
ASCE/EWRI 51-08 Standard Guideline for Calculating the Effective Saturated Hydraulic Conductivity
ASCE/SEI 52-10 Design of Fiberglass-Reinforced Plastic (FRP) Stacks
ASCE/G-I 53-10 Compaction Grouting Consensus Guide
ASCE/EWRI 54-10 Standard Guideline for Geostatistical Estimation and Block-Averaging of Homogeneous and Isotropic Saturated Hydraulic Conductivity
ASCE/SEI 55-10 Tensile Membrane Structures
ANSI/ASCE/EWRI 56-10 Guidelines for the Physical Security of Water Utilities
ANSI/ASCE/EWRI 57-10 Guidelines for the Physical Security of Wastewater/Stormwater Utilities
ASCE/T&DI/ICPI 58-10 Structural Design of Interlocking Concrete Pavement for Municipal Streets and Roadways
ASCE/SEI 59-11 Blast Protection of Buildings
ASCE/EWRI 60-12 Guidelines for Development of Effective Water Sharing Agreement

FOREWORD

The Board of Direction approved revisions to the ASCE Rules for Standards Committees to govern the writing and maintenance of standards developed by ASCE. All such standards are developed by a consensus standards process managed by the ASCE Codes and Standards Committee (CSC). The consensus process includes balloting by a balanced standards committee and reviewing during a public comment period. All standards are updated or reaffirmed by the same process at intervals of five years.

This standard has been prepared in accordance with recognized engineering principles and should not be used without the user's competent knowledge for a given application. The publication of this standard by ASCE is not intended to warrant that the information contained therein is suitable for any general or specific use, and ASCE takes no position respecting the validity of patent rights. The user is advised that the determination of patent rights or risk of infringement is entirely their own responsibility.

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This revision of the standard began in 2001 and incorporates information as described in the commentary.

This standard was prepared through the consensus standards process by balloting in compliance with procedures of ASCE's Codes and Standards Activities Committee. Those individuals who serve on the Standards Committee are the following:

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CONTENTS

CHAPTER 1
GENERAL

1.1 SCOPE AND INTENT

The intent of this standard is to provide a guideline and methodology for assessing the condition and performance of existing building envelope systems and components and identifying problematic and dysfunctional elements. It applies equally to a building's envelope or portion whose primary purpose may be to serve as the supporting structural system of the building. The reader may also wish to refer to ASCE Standard 11—*Guideline for Structural Condition Assessment of Existing Buildings*. This standard may be a source of comprehensive information for clients such as building owners, prospective purchasers, tenants, regulatory officials, and others.

This standard is primarily directed toward a consultant–client relationship; modifications may be made to the content for condition assessments performed by staff personnel of public agencies and multibuilding owners for management of facilities.

This standard establishes an assessment procedure including investigation, testing methods, and a form for the report of the condition assessment. It assists the investigator in developing a logical approach to the assessment of the building envelope to focus on fundamental defects rather than outward symptoms. The possibility of encountering hazardous materials, such as lead-based paint and asbestos-containing materials, should be considered.

Because any evaluation involves "professional judgment" and contains factors that cannot be readily defined and standardized, a section providing guidance is also included. This section must be used by the design professional as part of the evaluation.

1.2 PURPOSE OF ASSESSMENT

Condition assessment of an existing building envelope may be undertaken for a number of purposes. These purposes may include developing a performance report, establishing building serviceability, planning for maintenance or repair, code compliance, life safety, durability, historic preservation, or a number of special purposes based on the specific building and its current or proposed occupancy or function.

1.3 TYPES OF ASSESSMENT

1.3.1 Cursory Assessment. This is a visual overview of the general condition of the building envelope. It is often used for screening multiple buildings to establish priorities for maintenance and repair or further study.

1.3.2 Preliminary Assessment. A preliminary condition assessment is usually limited in scope. It consists of a site visit for familiarization and to identify problem areas, a review of available documents, an interview of involved parties, and a preliminary report of findings and recommendations.

1.3.3 Detailed Assessment. This is an expansion of the preliminary assessment. It includes a review of documentation, component classification, field investigation, testing, analysis, and report.

1.4 SAFETY

Numerous types of circumstances present a potential hazard to the safety of the personnel involved. Considerations regarding the fieldwork must also allow for the safety of the building occupants and the general public. The responsibility for safety falls upon those involved in the assessment. Structures being assessed may be dangerous and must be made stable to at least an extent to allow inspection access before conducting the assessment in accordance with OSHA and state and local requirements.

1.5 QUALIFICATIONS AND EQUIPMENT

1.5.1 Personnel Qualifications. All personnel involved in the assessment shall possess the technical qualifications, including practical experience, education, and professional judgment required to perform the individual technical tasks assigned. Interpretation of results and conclusions shall be performed by a design professional qualified in the appropriate discipline.

1.5.2 Equipment. Equipment shall be obtained as appropriate to accomplish or perform the various tests and inspection methods specified in the standard. Whenever necessary, equipment shall include items needed to provide a safe work environment for all those involved, building occupants, and the general public. All equipment shall be in good working order. For equipment that should be calibrated for proper use in the given application, reports of calibration shall be available and the results provided if requested.

1.6 AGREEMENTS

1.6.1 Services. The scope of services for the condition assessment, including any limitations, shall be defined by the design professional, and all conditions, applicable codes and standards, and services shall be mutually agreed upon by the client and design professional. Services may include one or more of the identified purposes of the assessment and may involve one or more specific building envelope components or systems covered in the subsections of this standard. A complete and thorough quantifiable understanding of the attributes of some building assemblies or components may not be possible during the assessment. The scope should be established and a written agreement obtained before commencing the condition assessment or increasing the scope because of discoveries during the initial part of the investigation (see Section 3.2).

1.6.2 Compensation. The client and the design professional shall mutually agree upon compensation for the services specified in Section 1.6.1. The agreement shall specify reimbursable expenses, such as testing laboratory costs. Compensation provisions shall consider that after the review of the preliminary data, additional investigations may be required, thereby changing the scope of the project.

1.6.3 Authority and Accessibility. The agreement shall clearly identify the agreed scope of work and authorize the design professional to perform the necessary investigation and tests and shall ensure access to the site, the building, the various portions of the building requiring investigation, and drawings and documents required to perform the condition assessment. Responsibility for removal and repairs to finishes and building elements that may result from the evaluation, test, or inspection procedures should be identified.

1.6.4 Liability. The extent of liability, if any, expressly accepted by the design professional shall be stated in the agreement. Scope limitations, physical constraints, and undisclosed conditions may still leave unknowns after the assessment of an existing building. Appropriate and carefully worded disclaimers are important to limit liability to the specific scope of the assessment. Requirements for liability insurance coverage shall be clearly documented.

1.6.5 Agreements or Contracts. Such arrangements with public agencies or multibuilding owners may be in their format. However, the scope and other considerations must still be addressed explicitly within the body of the document or as an exhibit.

1.6.6 Legal Obligations. The professional in responsible charge has legal and/or professional obligations under governing law regarding unsafe conditions that are discovered and a duty to notify specified parties when such conditions are encountered. These requirements vary among jurisdictions having authority. It is the professional's responsibility to know what type of notification is required and whom he or she is to notify as required by the jurisdiction where the building is located.

1.7 DEFINITIONS

The following definitions are provided to establish uniform understanding of some selected terms as they are used in this standard. Words not defined but used in this standard shall have the meanings given in *Webster's Third New International Dictionary* (Unabridged), Merriam-Webster, Springfield, MA, 1993.

ASSESSMENT—Systematic collection and analysis of data, documentation, evaluation, and recommendations regarding the various portions of an existing building envelope that are the subject of the investigation.

ATTRIBUTES—Building envelope performance features or characteristics such as integrity, serviceability, and aesthetic considerations.

BACKUP—That part of a wall system behind the exterior facing (elements).

BARRIER WALL—An exterior wall system designed to prevent penetration of moisture through the wall because of its mass or impermeable surface components.

BUILDING—An enclosed or partially enclosed structure for occupancy by personnel, animals, material, or equipment; any structure used or intended for supporting or sheltering any use or occupancy.

BUILDING ENVELOPE—That portion of a building separating its interior from the outside atmosphere and its exterior surroundings. Many systems are capable of transmitting external loads or forces to the building structure. The envelope may have aesthetic qualities. Appendages such as chimneys, porches, decks, balconies, porte cocheres, stairs, and fire escapes may be included in a broad definition of the building envelope.

BUILDING MATERIALS CONSERVATOR—A professional who specializes in protection and preservation of building materials. Usage herein would denote a person skilled in the assessment, evaluation, and remediation of building materials.

CAULK—To make watertight and/or airtight by filling or sealing.

CAVITY WALL—A multiwythe noncomposite masonry wall with a continuous air space within the wall (with or without insulation) that is tied together with metal ties.

CLADDING—Non-load-bearing exterior surface of a building. (See BUILDING ENVELOPE.)

CLIENT—The person or persons for whom the condition assessment of the building envelope is being performed. A government agency, corporation, association, or other group could be the client.

COMPONENT (NONSTRUCTURAL)—A portion of the building envelope able to resist applied lateral and/or vertical loads and its own weight. This portion includes elements such as parapets, ornamentation, cornices, overhangs, equipment, flagpoles, chimneys, panel walls, and windows.

COMPONENT (STRUCTURAL)—A portion of a building or envelope system designed to resist applied lateral and/or vertical loads, including those imposed by other structural or nonstructural components and its own weight. These components include roof decks, walls, exterior elevator cores and stair shafts, and foundation walls, for example.

COMPOSITE WALL—A wall built of a combination of two or more different materials bonded together, one forming the backup and the other the facing elements.

COMPUTATIONAL ANALYSIS—A quantitative evaluation of a building envelope component or system by or under the direction of a design professional.

CONNECTION—The fastening between components or other parts of the building envelope, which either by design or as a result of construction is capable of transferring loads or forces. A "connector" is a mechanical connecting device.

CONSULTANT—A person with special knowledge engaged to deal with specific aspects of the assessment and evaluation.

CURTAIN WALL—A nonbearing enclosure wall not necessarily supported at each story. (See PANEL WALL.)

DESIGN PROFESSIONAL—An architect or engineer licensed or registered to practice in the governmental jurisdiction in which the building is located.

DESTRUCTIVE TESTING—Testing properties of materials, components, or systems to a point at and beyond which the element, component, or system can no longer fulfill its function. Destructive testing of portions of a building envelope may be carried out on the building envelope in situ or on components removed and tested in the laboratory.

DRAINAGE PLANE—The building envelope assembly that provides a plane within the water drainage pathway to the exterior of the building or to a design collection point.

DRAINAGE WALL—Exterior wall system intended to intercept water in a drainage course or cavity between inner and outer surfaces and divert it to the outside. (See CAVITY WALL.)

ELEMENT—One of the constituent materials or parts of a component or subcomponent.

EVALUATION—The process of determining the adequacy of the building envelope system or component for its intended use. Evaluation by its nature implies the use of personal and subjective judgment by those functioning in the capacity of experts.

EXPERT—A person who, by education, training, and experience, has special knowledge and skill to deal with a particular problem.

EXTERIOR CLOSURE SYSTEM—The building envelope.

FACED WALL—A wall in which the masonry facing and backing are so bonded as to exert common action under load.

FACING (ELEMENTS)—Elements of some material applied to the outer face of buildings or other structures.

FENESTRATION SYSTEM—A non-load-bearing element that is installed within a wall.

FOUNDATION WALL SYSTEM—That portion of the building envelope that is partially or completely in contact with the soil and must be capable of resisting the lateral loads applied by the soil. The foundation wall system, including waterproofing, can serve as a support for a wall, pier, column, or other structural part of a building and may or may not enclose habitable space. It may also have a subsurface drainage component.

HOLLOW WALL—A wall built of masonry units so arranged as to provide an air space within the wall, and in which the facing and backing of the wall are bonded together with masonry units.

INSPECTION—The activity of examining, measuring, testing, gauging, and using other procedures to ascertain the quality or state; detect errors, defects, or deterioration; and otherwise appraise materials, components, systems, or environments.

LOAD-BEARING WALL—A wall supporting any vertical load in addition to its own weight.

LOW SLOPE—A slope typically considered equal to or less than 3:12 (rise:run), or 25%.

MASONRY—A built-up construction or combination of building units or materials of clay, shale, concrete, glass, gypsum, stone, or other approved units bonded together with mortar.

MATERIALS SCIENTIST—One skilled in the science of one or more materials used in construction (e.g., chemist, geologist, metallurgist, or wood products pathologist) (See EXPERT.)

NONDESTRUCTIVE TESTING—A measured assessment of a material, component, or system performed without altering properties or impairing future service.

NON-LOAD-BEARING WALL—A wall that does not support vertical loads other than its own weight but is capable of transferring lateral forces to the building structure.

ON-SITE (IN SITU) LOAD TESTING—Testing carried out on building envelope systems or components on site to determine performance characteristics. It may include artificially applied loads intended to replicate service or ultimate load conditions.

ORNAMENTATION—Aesthetic nonessential components that could vary from subtle patterns to large appendages, consisting of natural or manufactured materials.

PANEL WALL—A nonbearing wall supported by each story on a skeleton frame.

PARAPET—That part of any wall entirely above the roof line.

PETROGRAPHER—Materials scientist dealing with the description and systematic classification of natural and artificial stone, concrete, and mortar.

PLAZA DECK—Horizontal deck at, above, or below grade designed to support traffic or landscaping. It consists of supported layers, drainage, waterproofing membrane, and the supporting structure.

PRINCIPAL INVESTIGATOR—The team leader; usually a licensed or registered architect or engineer.

PROFESSIONAL ARCHITECT OR ENGINEER—See DESIGN PROFESSIONAL.

QUALIFIED—Competent to perform the assigned task by reason of education, training, and experience.

RAIN SCREEN WALL—A water-resistant exterior face (rain screen) with a confined air space behind it that is vented to the outside for pressure equalization; it is also an interior air and weather barrier.

REGISTERED OR LICENSED ARCHITECT—See DESIGN PROFESSIONAL.

REGISTERED OR LICENSED ENGINEER—See DESIGN PROFESSIONAL.

ROOF ASSEMBLY—An assembly of interacting roof components (including the roof deck, vapor retarder [if present], insulation, and roof covering).

ROOF SYSTEM—A system of interacting roof components, generally consisting of membrane or primary roof covering and insulation (not including the roof deck), designed to weatherproof and, sometimes, to improve the building's thermal resistance.

SEALANT—A material used to seal a surface against the passage of liquid or gas.

SIDING—The finish covering of an exterior wall of a frame building.

STEEP SLOPE—Typically considered greater than 3:12 (rise:run), or 25%.

STRUCTURAL ENGINEER—See DESIGN PROFESSIONAL.

SURFACE-SEALED WALL—Exterior wall system designed to be impermeable to moisture and air at its exterior surface.

SYSTEM—An assemblage of components within a building envelope that function together to satisfy intended requirements.

TESTING LABORATORY—A facility in which the characteristics or performance of materials, products, and systems are measured, examined, tested, calibrated, or otherwise determined.

VENEER WALL—A masonry wythe or other weather-resistant material that provides the exterior finish of a wall system and transfers out-of-plane load directly to a backing but is not considered to add load-resisting capacity to the wall system.

WEATHERPROOF—The ability of an assembly or material to withstand exposure to weather without deterioration or loss of function to the structure.

WEEP, WEEP HOLE—A small opening in a wall or window member through which accumulated condensation or water may drain to the building exterior.

WINDOW WALL—A system of mullions, subframing, glazing, and opaque panels.

CHAPTER 2
BUILDING ENVELOPE SYSTEMS, COMPONENT FEATURES, AND MATERIALS

2.1 INTRODUCTION

A building envelope system can be defined as a set of components assembled to perform as a unit that is capable of separating or selectively filtering the exterior environment from the interior environment. Each system and its components are expected to have certain performance requirements to satisfy their functions as part of the building envelope. These performance requirements are diverse and may apply to all or only some of the components or systems.

The components are often made up of dissimilar materials that have dissimilar properties, which must be accommodated in the design and assembly of the system. On a broader scale, the properties of the envelope system must also be accommodated in its interface and interaction with other systems, such as the structural system or environmental control system of the building. An understanding of the properties of the individual materials, and of the system, is essential in the assessment of the performance of the building envelope. The physical condition of the elements and the performance of individual systems of the building envelope must be thoroughly evaluated.

Moisture and water penetration play a large role in the overall design of a system. Vapor and air migration (mass transport) are equally important to moisture and water penetration in many scenarios. There are several theories of design for the resistance and control of moisture and water penetration. An understanding of these theories is important in assessing particular problems with a given building envelope system. This understanding also affects the design of repairs to the envelope system.

2.2 BUILDING ENVELOPE SYSTEM CATEGORIES

The building envelope can be divided into seven general categories: roof systems, wall systems, fenestration systems, building appendages, foundation wall systems, deck waterproofing systems, and underground structures (see Fig. 2-1). Intersections and terminations of the various systems are often critical areas of concern.

2.3 ROOF SYSTEMS

A roof system can be defined as interacting roof components, generally consisting of a membrane or primary roof covering and insulation designed to weatherproof and, sometimes, improve the building's thermal resistance. The roof system does not include the roof deck. The components may include the following:

1. Weatherproofing membranes;
2. Water-shedding products;
3. Thermal insulation;
4. Fasteners;
5. Ballast (aggregate or pavers);
6. Vapor retarders;
7. Coatings;
8. Bituminous and other adhesives;
9. Edging, parapet caps, counterflashings, and other accessories; and
10. Flashing.

2.3.1 Low Slope Systems. The roof membrane is the roof system's weatherproofing component. All roof membranes comprise at least three elements—weatherproofing, reinforcement, and surfacing—and some materials within the membrane may perform more than one function.

1. Built-up roofing (BUR) membrane—The membrane consists of a continuous, semiflexible multi-ply roof membrane, consisting of plies or layers of saturated felts, coated felts, fabrics, or mats between which alternate layers of bitumen are applied. Generally, built-up roof membranes are surfaced with mineral aggregate and bitumen, a liquid applied coating, or a granule-surfaced cap sheet.
2. Single-ply roofing membrane—As applied in the field of the roof, the membrane consists of one layer of membrane material (either homogeneous or composite) rather than multiple layers. The manufacture of the single-ply sheeting may involve lamination of several layers of the same or different materials.
   a. Thermoset single-ply membrane—A sheet that solidifies or "sets" irreversibly when heated. Cross-linked polymers form the membrane, which can only be bonded to itself by the use of an adhesive because, once cured, new molecular linkages cannot be formed.
   b. Thermoplastic single-ply membrane—A sheet consisting of polymers that soften when heated and harden when cooled. This process is repetitive, provided that the material is not heated above the point at which decomposition occurs. This type of membrane differs from thermosets in that there is no cross-linking or vulcanization so that the membrane can be welded together with heat or solvent.
3. Polymer-modified bitumen membrane—Composite sheets consist of bitumen, modifiers, and reinforcement. The materials differ from one another with respect to the modifiers and reinforcements used. The sheets are sometimes surfaced with various types of mats, foils, and mineral granules. Current membranes commonly use multiple layers of polymer-modified bitumen sheets (or bituminous felts) and bitumen in addition to the polymer-modified bitumen sheets at the surface. In that configuration, the system function is more related to built-up roofing

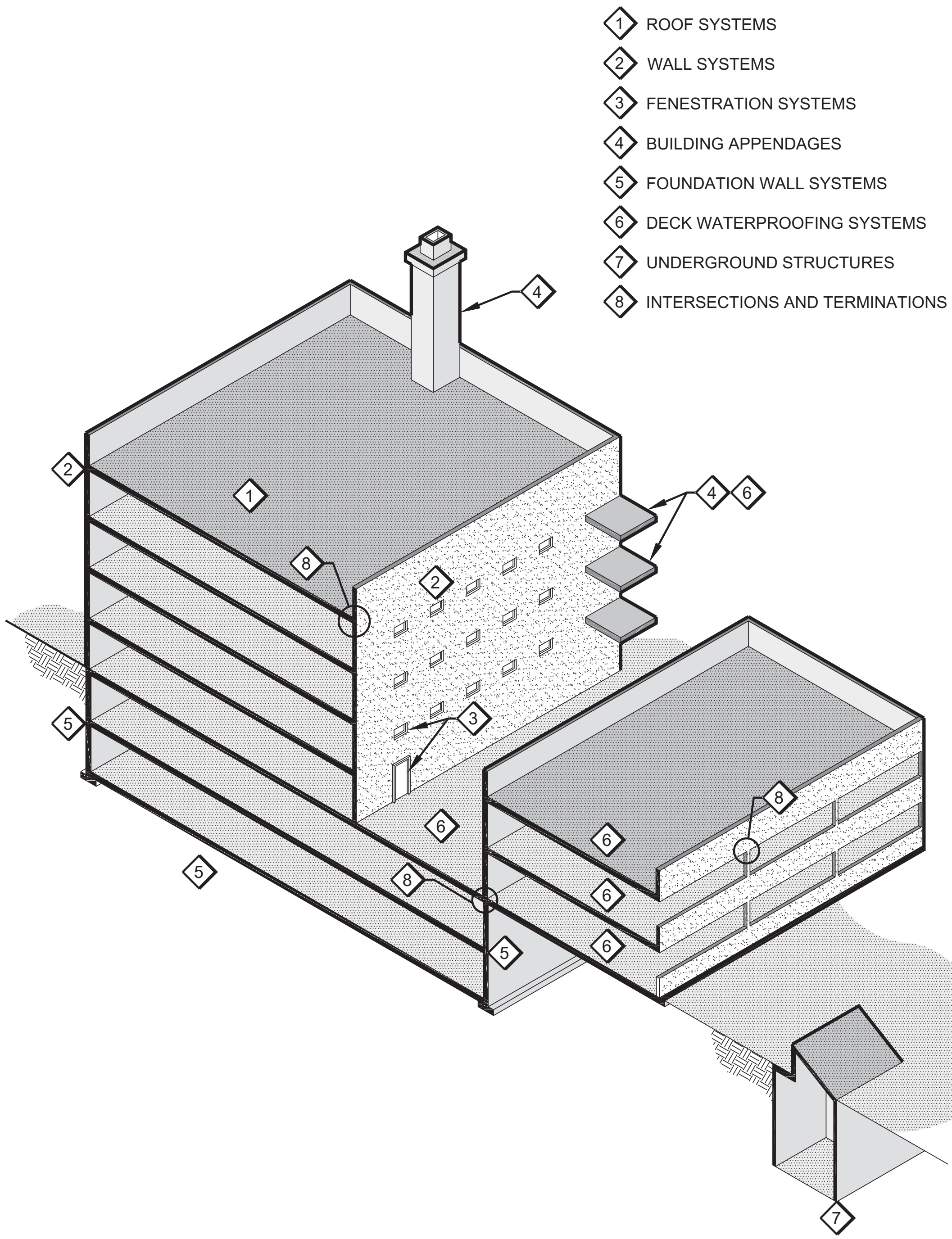

FIGURE 2-1 Building Envelope Systems

membranes. However, some installations are single-layer membranes.

4. Sprayed polyurethane foam membrane—The membrane consists of a seamless, sprayed-in-place polyurethane foam coated with one of a variety of coatings (materials may be acrylic, silicone, or polyurethane) to protect the foam from ultraviolet exposure. The foam is two components sprayed simultaneously to form a rigid, fully adhered, water-resistant, and insulating membrane.
5. Metal roofing—Low slope versions of metal roofing are generally standing seam structural panels, commonly with flat-lock or trapezoidal seams or on-site soldered flat-lock seam panels.

2.3.2 Steep Slope Systems. The roof slope combined with overlapping units of roofing panels controls water by shedding the water off the roof. Adequate slope to shed the water is essential. Underlayment is generally included for secondary protection. A weatherproof membrane may be necessary under certain roofing materials and/or with certain slopes in certain climatic regions.

1. Asphalt roofing materials—Asphalt roll roofing products and asphalt shingles are manufactured from a combination of refined asphalt and reinforcement felts or mats.
   a. Asphalt roll roofing materials—Roofing materials on a roll are normally 36 in. wide and are composed

of asphalt and smooth-surfaced or mineral-surfaced organic felts or fiberglass mats designed for overlapping installation on inclines as low as 8% (1 in./ft).

   b. Asphalt shingles—A shingle is a small unit of granular-surfaced asphalt roll roofing designed for installation with similar units in overlapping rows on inclines normally exceeding 25% (3 in./ft). There are two types of asphalt shingles:
      - Organic asphalt shingles—Organic felt composed of defibrated wood (cellulose matter) is saturated with soft flowing asphalt. The felts are then coated with harder, mineral-filled asphalts and surfaced with ceramic granules.
      - Fiberglass asphalt shingles—Fibrous glass mat is coated with mineral-filled asphalt and surfaced with ceramic granules.
2. Clay tile roofing—Clay roofing tile is produced by firing plates of molded clay into tile. The density of the tile is determined by the length of time it is heated and by the heating temperature used. Various surfacings may be included for improved weathering characteristics.
3. Concrete tile roofing—Concrete tile is composed of portland cement, sand, and water, mixed in varying proportions. These materials are extruded on individual molds under high pressure to form the tile product. Various surfacings may be included for improved weathering characteristics.
4. Slate roofing—Roofing slate is a dense, metamorphic rock material that is practically nonabsorbent. A principal property of slate is its natural cleavage, which permits it to be easily split in one direction. The surface texture of slate after it is split for commercial use depends on the characteristics of the rock from which it is quarried. Many slates split to a smooth, practically even uniform surface, and others split to a surface that is somewhat rough and uneven. Classification is according to surface texture and thickness.
5. Wood shingle and wood shake roofing—These types of wood roofing are described as follows:
   a. Wood shingles—A wood shingle is a sawed wood product usually manufactured in 16-in., 18-in., and 24-in. lengths, with a uniform butt thickness per individual length. As recommended by the Cedar Shake and Shingle Bureau, wood shingles are graded from No. 1 (premium) to No. 4 (utility) quality.
   b. Wood shakes—A wood shake is a wood roofing product that is split from a log and shaped by the manufacturer for commercial use. The three basic types of wood shakes are hand-split and resawn shakes; taper-split shakes; and straight-split shakes.
6. Metal tile—Sheet metal is formed into shingle units. The units are installed in a manner similar to that of shingles or tiles.
7. Architectural sheet metal—These roofs are supported by solid decking and use standing seams, batten seams, or Bermuda seams. Typically, the sheet metal is site fabricated. This type of system is designed for roofs with a minimum slope of 3 in 12. Various metal types are used. The most common are copper, galvanized steel, galvalume and aluminized steel, aluminum, terne metal (an alloy), stainless steel, and zinc.
8. Mineral fiber–cement tile—Thin shingle units are cast using cementitious materials reinforced with mineral fiber and installed in a manner similar to that of shingles or tiles.

2.4 WALL SYSTEMS

Wall systems can be considered either load bearing or nonload bearing. A load-bearing wall system is a wall supporting any superimposed vertical load in addition to its own weight. A wall that does not support vertical loads other than its own weight is a non-load-bearing wall. Load-bearing and non-load-bearing wall systems can often have similar or identical components.

A load-bearing or non-load-bearing wall system may serve as a shear wall, in which case it is required to resist in-plane lateral forces and transmit them into the foundation or ground as a part of the main lateral force resisting system (MLFRS) for the structure as a whole. All wall systems must be capable of resisting out-of-plane lateral forces between their supports and transferring them into the foundation or the ground or to the MLFRS. Some non-load-bearing systems, such as veneer walls, are only capable of transmitting lateral forces to the MLFRS.

Another important function of an exterior wall system, in addition to its structural functions, is to prevent water or moisture from entering the interior spaces in an uncontrolled or unacceptable manner. Following are various design methods used to address water penetration, with a brief description of the theory behind the method. These design methods are illustrated in Fig. 2-2. It is important to understand the manner in which the wall was intended to resist water penetration in performing an assessment of the wall system and in determining what the problems might be.

1. Barrier wall systems—This is a system that allows moisture to be absorbed within the material but not completely through the material. Concrete and certain masonry systems are examples of barrier systems. A barrier wall system can be load bearing or nonload bearing.
2. Drainage wall systems—In a drainage wall system, it is assumed that moisture infiltrates to some point within the system. This moisture is controlled and diverted back to the exterior through the use of cavities, flashings, and weep holes. As with the barrier wall system, there are load-bearing and non-load-bearing systems.
3. Surface-sealed systems—This system is a wall assembly that is impermeable to moisture and air at the exterior surface. Several types of curtain wall systems are surface-sealed systems.
4. Rain screen/pressure equalization wall systems—The rain screen principle and pressure equalization are used primarily in curtain wall design. Some aspects of the theories are used in masonry cavity wall and veneer wall systems. The general concept serves to prevent water and air infiltration separately by first addressing the various forces and conditions that promote water infiltration, leaving air infiltration to be controlled by a secondary system. In a general form, the exterior face of the wall construction has a "rain screen" intended to shield a secondary exterior face from water that may infiltrate by gravity, kinetic energy, surface tension, capillary action, air currents, and/or pressure difference. The space between the rain screen and the inner face of the wall construction is ventilated to the exterior to allow the air pressure within the space to equalize with the exterior air pressure. The water is controlled at the outer surface, and the inner face of the wall is designed to resist air infiltration. In an actual wall system design, the materials used in the wall construction, such as glass, aluminum extrusions, or concrete panels, are essentially impervious to water penetration so that the general concept is applied to joinery of various units or sections of the wall system.

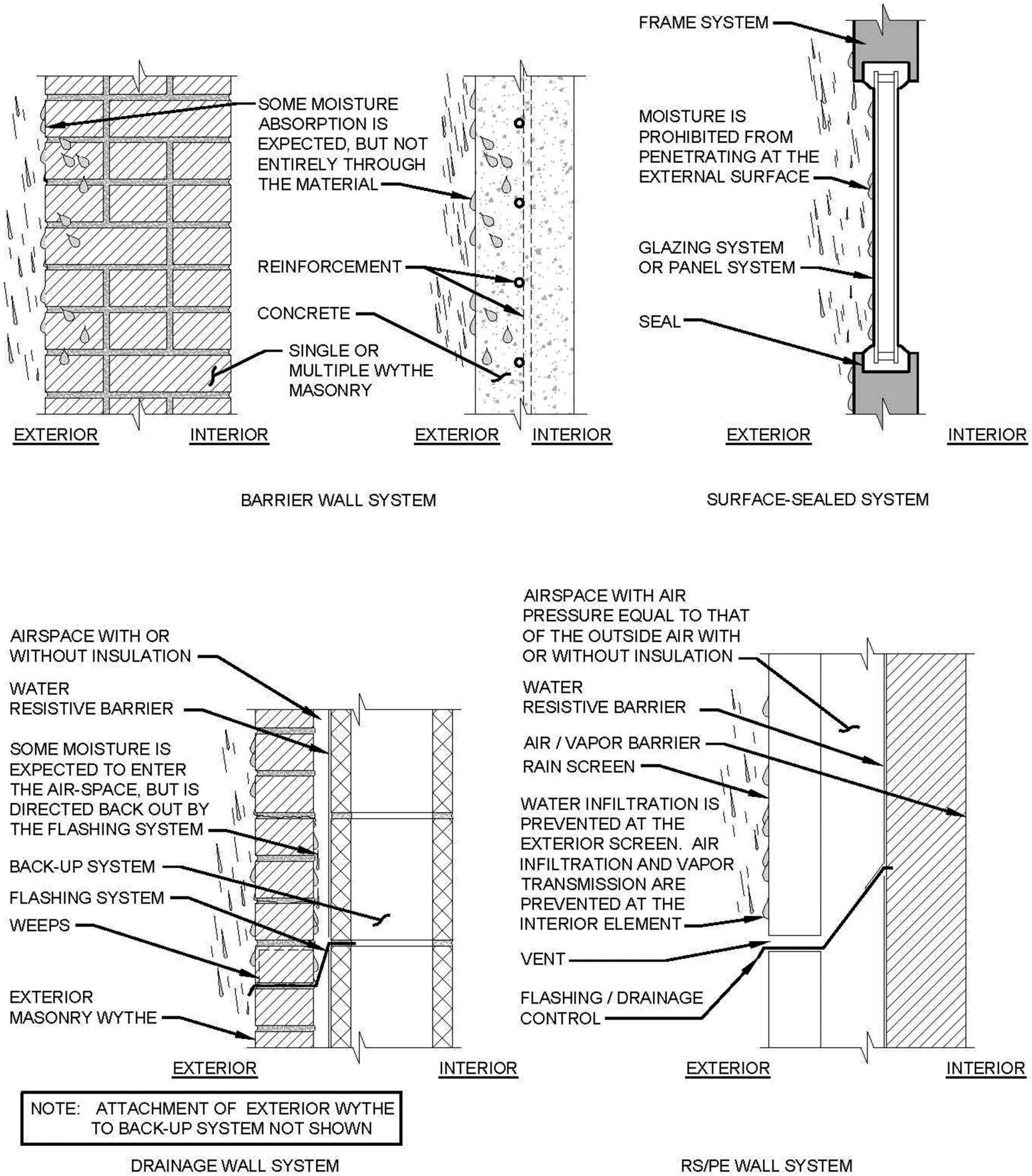

FIGURE 2-2 Exterior Wall Classifications

The following is a description of some of the wall systems that can be either load bearing or nonload bearing. These systems are generally capable of providing the resistance to lateral forces as a part of the MLFRS. The category of design theory to resist moisture penetration is also indicated. Table 2-1 shows which of the design methods listed can be used in the various wall systems listed in the rest of this section.

2.4.1 Unreinforced Concrete. Unreinforced concrete is normally limited to residential construction in the foundation systems, which may extend above grade. This system is considered a barrier-type wall system. The attributes and components are essentially similar to reinforced concrete, with the exception that steel reinforcement is less than the minimum required for reinforced concrete.

2.4.2 Reinforced Concrete. Reinforced concrete is considered a barrier-type wall system. In above-grade situations, concrete walls are capable of providing all the system component features listed below with the exception of condensation control. Condensation control is achieved through the use of a vapor retarder. Thermal resistance is improved by incorporating insulation. The components of this system may include the following:

1. Concrete;
2. Flexural, shear, thermal, and shrinkage reinforcement steel;
3. Insulation;
4. Vapor retarder;
5. Interior finish (e.g., wood or metal furring and gypsum wallboard or plaster); and
6. Exterior finish (e.g., molded formwork, exposed aggregate, or coating applications).

2.4.3 Precast Concrete. This system consists of prefabricated panels designed to provide dynamic and static serviceability

Table 2-1 Wall Systems

Wall Construction	Load Bearing Yes	Load Bearing No	Barrier Wall System	Drainage Wall System	Surface-Sealed System	Rain Screen–Pressure Equalization Wall System
2.4.1 Unreinforced concrete	x		x			
2.4.2 Reinforced concrete	x		x			
2.4.3 Precast concrete	x		x			x (at panel joints)
2.4.4 Unreinforced masonry	x		x			
2.4.5 Reinforced masonry	x		x			
2.4.6 Unreinforced masonry cavity wall	x			x		x
2.4.7 Reinforced masonry cavity wall	x			x		x
2.4.8 Masonry veneer with wood or steel stud backup	x			x		x
2.4.9 Siding systems with wood or steel stud backup	x		x		x	x
2.4.10 Architectural precast concrete	x	x	x			x (at panel joints)
2.4.11 Glass fiber reinforced concrete panel		x	x			x (at panel joints)
2.4.12 Aluminum frame curtain wall		x			x	x
2.4.13 Interlocking metal panel wall		x	x		x	x
2.4.14 Thin stone veneer panel		x	x		x	x
2.4.15 Prefabricated masonry panels		x	x	x		x

requirements that use conventional or prestressing reinforcement. The profile of the panels can be a single or double tee, or solid- or hollow-core slab panels. Their attributes are also similar to reinforced concrete, and they are considered a barrier system. Their components may include the following:

1. Concrete,
2. Conventional or prestressing reinforcement steel,
3. Embedded steel plates or shapes for connection purposes,
4. Insulation,
5. Vapor retarder,
6. Interior finish, and
7. Exterior finish.

2.4.4 Unreinforced Masonry. This system is defined as a wall that has one or more wythes of solid masonry units with collar joints (if there is more than one wythe) filled with mortar or grout. This system is considered a barrier system. Condensation control is achieved through the use of a vapor retarder. Thermal resistance is improved by incorporating insulation. The components of a solid masonry wall may include the following:

1. Clay brick, structural clay tile, terracotta, stone, or concrete masonry units;
2. Mortar;
3. Grout;
4. Metal ties;
5. Flashings, weeps, or lintels;
6 Insulation;
7. Vapor retarder;
8. Interior finish (e.g., wood or metal furring and gypsum wallboard or plaster); and
9. Exterior finish (e.g., detailed coursework, coating application, or stucco).

2.4.5 Reinforced Masonry. Component features of this system are similar to unreinforced masonry, but the use of reinforcement increases vertical and lateral load-resisting ability. Reinforcement is achieved by incorporating vertical steel reinforcing bars within the cells of hollow masonry units or between wythes of solid masonry units and by placing horizontal bars in specially shaped hollow masonry units or between wythes of solid masonry units. Bars are encapsulated in grout. Small horizontal bars or joint reinforcement may be placed in bed joints. This system is considered to be a barrier wall system. The components of this type of wall may include the following:

1. Interior and exterior masonry wythes (clay brick or concrete masonry units);
2. Metal wall ties or horizontal joint reinforcement;
3. Flashings, weeps, or lintels;
4. Insulation;
5. Steel reinforcement;
6. Grout;
7. Special concrete masonry shapes for such things as pilasters or bond beams;
8. Bar placement accessories;
9. Interior finishes; and
10. Exterior finish (e. g., detailed coursework, coating application, or stucco).

2.4.6 Unreinforced Masonry Cavity Wall. An unreinforced masonry cavity wall system can be defined as an exterior wythe and an interior wythe of masonry that is separated by a nominal 2-in. air space. Moisture is expected to infiltrate the exterior wythe and enter the cavity. The moisture flows down to the base of the wall or a lintel, where flashing directs the moisture back to the exterior. Weep holes placed on the horizontal leg of the flashing help to promote drainage. Components may include the following:

1. Interior and exterior masonry wythes (clay brick or concrete masonry units);
2. Metal wall ties or horizontal joint reinforcement;
3. Flashings, weeps, or lintels;
4. Waterproofing on backup;
5. Insulation;
6. Interior finishes;
7. Exterior finish (e.g., detailed coursework, coating application, or stucco); and
8. Mortar droppings collection device.

2.4.7 Reinforced Masonry Cavity Wall. This system is essentially the same as an unreinforced masonry cavity wall system that uses a concrete masonry interior wythe with spaced reinforcing steel that is grouted in the cells of the concrete masonry units.

Components in addition to those outlined in Section 2.4.6 include the following:

1. Steel reinforcement,
2. Grout,
3. Special concrete masonry shapes for such things as pilasters or bond beams, and
4. Bar placement accessories.

2.4.8 Masonry Veneer with Wood or Steel Stud Backup. This drainage wall system consists of a wood or steel stud wall with a single wythe of masonry that is laterally supported by the stud wall. The wall studs can be load bearing or nonload bearing. An air space is provided to allow drainage of moisture to the base of the wall or other flashing location. The components may include the following:

1. Clay brick, concrete, or stone masonry with or without coatings or sealers;
2. Building paper, air barrier, or water-resistive barrier;
3. Sheathing (e.g., plywood or gypsum);
4. Wood or steel studs;
5. Insulation;
6. Vapor retarder;
7. Interior finish;
8. Wall ties;
9. Flashings, weeps, or lintels; and
10. Drainage plane.

2.4.9 Siding Systems with Wood or Steel Stud Backup. There are several variations of this system type, which are used primarily in residential or light commercial construction. The quality of performance of the system depends on the quality of each component and on the details used in the construction of the system. These types of walls can be designed as barrier systems or surface-sealed systems. In general, the components include the following:

1. Exterior surface material (e.g., wood siding, manufactured wood products, metal and vinyl products, exterior insulation and finish systems [EIFS], or stucco);
2. Building paper, air barrier, or water-resistive barrier;
3. Thermal or structural sheathing (e.g., plywood or manufactured wood products);
4. Stud framing;
5. Insulation;
6. Vapor retarder;
7. Interior finish (e.g., gypsum wallboard or plaster);
8. Metal fasteners;
9. Flashings; and
10. Drainage plane.

The following wall systems are nonload bearing and are not designed to provide resistance to lateral forces as a part of the MLFRS. The systems must be able to resist lateral forces within themselves but are only capable of transmitting the lateral wind or inertial seismic forces to the MLFRS.

2.4.10 Architectural Precast Concrete. This panel system differs from the system described in Section 2.4.3 in that this system is designed only to be self-supporting and is conventionally reinforced. It is considered a barrier system. Insulation may be cast into the panel or applied to its interior surface. The components may include the following:

1. Concrete,
2. Reinforcement,
3. Insulation, and
4. Embedded steel lifting lugs and connectors.

2.4.11 Glass Fiber Reinforced Concrete Panel. This is a form of architectural precast concrete that consists of a metal framework that supports the glass fiber reinforced concrete (GFRC), which is commonly sprayed into a mold where the frame is partially embedded in the GFRC. The panel is then attached to the structural system. Another method is to use the GFRC as a backing material for tile or terracotta, which is also constructed in panel form and attached to the building. These panels are considered a barrier wall system. Components may include the following:

1. GFRC with or without an exterior facing material,
2. Metal framework or reinforcement,
3. Air infiltration retarder,
4. Connection accessories,
5. Vapor retarder, and
6. Interior finish.

2.4.12 Aluminum Frame Curtain Wall. Also known as a unitized-stick or unitized system, extruded aluminum shapes serve as mullions and muntins in which glass or insulated metal panels are installed. Normally, this system is designed to be a surface-sealed system, or it can incorporate rain screen/pressure equalization system elements. Components may include the following:

1. Aluminum extrusions;
2. Glass, metal, or thin stone panels;
3. Panel gaskets or sealants; and
4. Connection accessories.

2.4.13 Interlocking Metal Panel Wall. Interlocking metal panels can be cold-rolled sheets or a composite construction that is supported by a framework that is attached to the floor or roof edges, which transfer wind loads to the structural system. These types of panels are usually surface-sealed systems and may incorporate rain screen/pressure equalization elements. Generally, components may include the following:

1. Preformed or composite metal panels;
2. Girts, subgirts, or other framing devices;
3. Insulation;
4. Connection accessories;
5. Liner panels; and
6. Flashings or closure pieces.

2.4.14 Thin Stone Veneer Panel. Thin stone veneer is generally defined as stone panels that have a thickness of less than 2 in. (5.08 cm). Thin stone veneer panels consist of natural stone, such as granite, limestone, or marble, which are attached to the floor or roof edge. The stone panels can also be applied to a steel framework or a precast concrete panel that is attached as a unit to the structure. A third method is to attach the stone veneer to a masonry backup wythe. Depending on the type of backup construction, these panels can be designed as barrier walls, cavity walls, or veneer wall systems. Generally, components include the following:

1. Thin stone panels;
2. Stone anchorage accessories;
3. Backup structure (e.g., steel framework, steel studs, precast concrete, or masonry);
4. Vapor retarder; and
5. Interior finish.

2.4.15 Prefabricated Masonry Panels. Reinforced single-wythe masonry panels are fabricated in a shop and erected at the site. The panels are reinforced to resist wind or lateral in-plane loads and to withstand handling and erection loads. They are attached to the structural system by means of metal connectors that are built into the panels. These panels can be designed as barrier wall or cavity wall systems. The components may include the following:

1. Hollow clay masonry;
2. Reinforcement steel;
3. Embedded steel lifting lugs and connectors;
4. Mortar or grout;
5. Flashings or weeps;
6. Insulation;
7. Interior backup systems (e.g., metal studs or framework);
8. Vapor retarder; and
9. Interior finishes.

2.5 FENESTRATION SYSTEMS

A fenestration system is defined as a non-load-bearing element that is installed within a wall. Fenestration systems include windows, louvers, doors, storefronts, and entrances. Many different materials make up the components of the various types of fenestration systems. The configurations of each system also vary greatly. Many types of fixed and operable window systems use the rain screen principle and pressure equalization to resist moisture and air infiltration in the same fashion that it is used in aluminum frame curtain wall systems. The application of pressure-equalized design to fenestration products is not material dependent. Because of the increased application of this design principle on high-rise buildings, the majority of these frames tend to be fabricated from aluminum extrusions. Many types of configurations fall into this category. The components include the following:

1. Extruded aluminum, PVC, wood, or fiberglass frames and sashes;
2. Single pane or insulated glass panels;
3. Setting blocks;
4. Glazing seals, air seals, sealants, and backer rods; and
5. Flashings and weeps.

2.6 BUILDING APPENDAGES

Ornamental or functional elements, such as balconies, chimneys, and porches, are often constructed of the same materials used to construct the wall or roof systems. These appendages generally do not provide a separation of the exterior from the interior of the building, nor do they serve as a structural element for the building, but they may be included in the condition assessment.

2.7 FOUNDATION WALL SYSTEMS

A foundation wall system is defined as that portion of the building envelope that is partially or completely in contact with the soil and must be capable of resisting superimposed loads, the lateral loads applied by the soil, and its own weight. Often these systems are required to resist and/or transmit lateral forces into the ground. In most situations, the foundation wall system consists of load-bearing walls constructed of materials that are not wholly impervious to water. A waterproof coating or membrane is often used to enhance the watertightness of the system. Insulation is sometimes added to the system to increase its resistance to thermal transmittance. To provide a habitable or otherwise usable space, a concrete floor slab is provided within the boundary of the foundation walls. There are several types of foundation wall systems and methods of preventing water infiltration.

2.7.1 Cast-in-Place Concrete. These walls can be reinforced or unreinforced.

2.7.2 Masonry. Masonry walls can be reinforced or unreinforced. The masonry units can be stone, clay brick, or concrete. Mortar is used to bond the units together.

2.7.3 Wood. Wood foundation walls are constructed of pressure-treated lumber using standard wood framing construction techniques. Pressure-treated plywood is used to provide lateral stability and distribute lateral pressures caused by the adjacent soil.

2.7.4 Waterproofing Systems. Waterproofing systems generally consist of a membrane or coating applied to the foundation wall system to serve as a barrier against moisture infiltration.

2.7.5 Drainage Systems. A drainage system is used to assist and enhance the waterproofing system, which directs water away from the foundation wall system. The drainage system is generally installed after or in conjunction with a waterproofing system.

2.8 DECK WATERPROOFING SYSTEMS

A deck waterproofing system is defined as a waterproof membrane applied to horizontal surfaces that are intended to receive pedestrian or vehicular traffic, such as a plaza or a rooftop parking deck. For nonvehicular use, such as on balconies, walkways, and landscaping planters, horizontal and vertical surfaces are covered by the membrane. These systems may be required at any level of a building and are generally based on the type of use and wear.

2.8.1 Exposed Membrane Systems.

1. A membrane, which is usually a coating, is applied to a concrete or a plywood substrate that serves as the barrier to moisture.
2. Drainage is provided by sloping the substrate to area drains or scuppers.
3. Because the membrane is exposed, it must be capable of withstanding traffic and direct exposure to the weather.

2.8.2 Protected Membrane Systems.

1. This system consists of a coating or sheet good applied to the substrate that is protected by a single-layer or multilayer protection material or system.
2. Drainage is usually provided by sloping the substrate to bi-level area drains. A drainage course directly above the membrane allows water that has infiltrated to the membrane to pass under the protective layers to the lower level of the area drains. The top surface of the protection layer is usually sloped to the upper level of the area drains.
3. The protection layer is designed to resist traffic wear and environmental degradation, or in the case of a planter, for example, it is designed to separate the soil from the membrane.

2.9 UNDERGROUND STRUCTURES

Common examples of covered underground structures are sidewalk vaults, service areas, equipment rooms, tunnels, and some parking garages. To be serviceable for occupancy by people or equipment, water intrusion must be prevented. This requirement is usually accomplished by applying a waterproofing system to all exterior surfaces of the structure and may include a drainage system (see Section 2.7).

2.10 FABRIC STRUCTURES

Permanent fabric or membrane structures consist of two types, air-supported structures (ASCE Standard 17-96) and tensile membrane structures. Tent structures and air-inflated dual-wall structures where the occupied space is not pressurized are considered temporary structures and are not included. Air-supported structures consist of a membrane that achieves or maintains shape and support by air pressure within its occupied space. Tensile membrane structures have a shape that is determined by tension in the membrane and the geometry of its support structure.

Membranes consist of flexible structural fabrics or films made most commonly of polyester, polyolefin, or fiberglass that are usually coated with vinyl, polytetrafluoroethylene, or silicone. The membrane supports imposed loads and transmits them to other components and/or the support structure. Most membranes are orthotropic, with a woven or knit substrate one lamina thick. Other composite membranes containing woven or laid fabric substrates may contain two or more laminae. These structures can be complex in their geometry and behavior and often have unique shapes that are not covered by ASCE 7. Therefore, the imposed wind and snow loading criteria cannot be easily established.

Membranes are primarily loaded in tension and have little or no bending or shear stiffness. The stress–strain relationship of these materials is nonlinear, which means that a significant nonlinear relationship exists between the loads and the stress and displacement of these structures. The geometric interaction of warp and fill yarns may result in Poisson values significantly different from most other materials. Modulus of elasticity (MOE) in these structures varies with stress. In addition, the Poisson ratio and MOE can vary in different directions. Therefore, practical and safe assumptions have to be made to "linearize" test data when analyzing these structures. As a result, unique load combinations and safety factors are used based on experience.

Unfortunately, computer software for analyzing these structures is mostly proprietary and not readily available. This software usually assumes that materials are linear but displacements are not. Because the fire performances of these structures are also unique and not easily or adequately accommodated by present building codes, they require special consideration by designers and building code officials.

The assessment of these structures is beyond the scope of this standard, and whenever possible or practical, they are assessed with extreme care or left to those with specialized experience and knowledge of these unique structures.

2.11 INTERSECTIONS AND TERMINATIONS

The interface of assemblies and individual materials and components can be the most critical areas of concern with regard to the overall performance of a building envelope. Most problems with air and water infiltration occur at intersections and terminations of components and assemblies.

As illustrated in Fig. 2-1, the intersection of roof and plaza decks with exterior walls is a potential problem area. Outside and reentrant corners, especially at parapets, often show evidence of movement. Expansion joints, both vertical and horizontal, can be problematic. Penetrations of roof and wall surfaces are likely points for water intrusion, as are changes in materials and wall surface planes. Responses of various materials and assemblies to thermal and moisture changes must also be considered at interfaces.

2.12 SYSTEM COMPONENT FEATURES

The envelope system and its components may be required to have certain features to achieve a desired effect. These features relate to the performance of the envelope system and must be taken into consideration in the assessment of the system or component. Most of the features required address environmental effects. Some of these effects are illustrated in Fig. 2-3.

2.12.1 Acoustical Resistance. A system may be required to limit sound transmission either from the exterior to the interior or vice versa. A school or library may require protection from the noise of a nearby airport. Interior noise resistance is also important. Standards for rating sound transmission loss of exterior walls in the frequency range normally generated by such sources as traffic, trains, and airplanes is known as outdoor/indoor transmission class (OITC). Structure-borne sound is created by impact noise. Its rating is known as impact insulation class (IIC) or impact noise rating (INR).

2.12.2 Aesthetic Treatment. The appearance of the system is often a requirement given high priority that can affect other requirements. The building shape is often dictated by the connotation of a trademark, image, or architectural statement.

2.12.3 Air Infiltration. A specified level of resistance to the passage of air through the system is a requirement normally used for window or curtain wall systems to limit the amount of heat loss within the space enclosed by the window or curtain wall and to prevent moisture-related problems resulting from moist air coming in contact with cool components of the building.

2.12.4 Condensation Control. A variance in temperature from the inside to the outside of the system combined with air containing some amount of moisture causes condensation. Because the water vapor cannot be eliminated, it must be controlled. Inadequate control of condensation can cause premature deterioration of the system and individual elements.

2.12.5 Durability. Durability is a property of the system and of its components to perform their required functions in their environment for a given period of time. Durability is an important factor in determining the remaining useful life of a system or materials.

2.12.6 Fire Resistance. Fire resistance is the ability of the system to withstand the propagation of fire or flames and to prevent the spread of fire for a given period of time. The system must be able to maintain an acceptable level of strength and stability during and after a fire to prevent collapse. The building location, size, occupancy, and usage, along with the type of construction, determine the requirements specified by the building codes. Smoke control is also an important consideration because most fire deaths result from smoke, not flame. Fire safing is defined as materials or systems that prevent the passage of smoke and flames through openings in walls and floors. With respect to the building envelope, fire safing is generally required at the intersections of walls and floors (see Section 2.11).

2.12.7 Historic Significance. A building, or in some situations, an element or individual system of a building may be an example of a style, design, method of construction, or material that is representative of a past era. Historical status can be assigned to

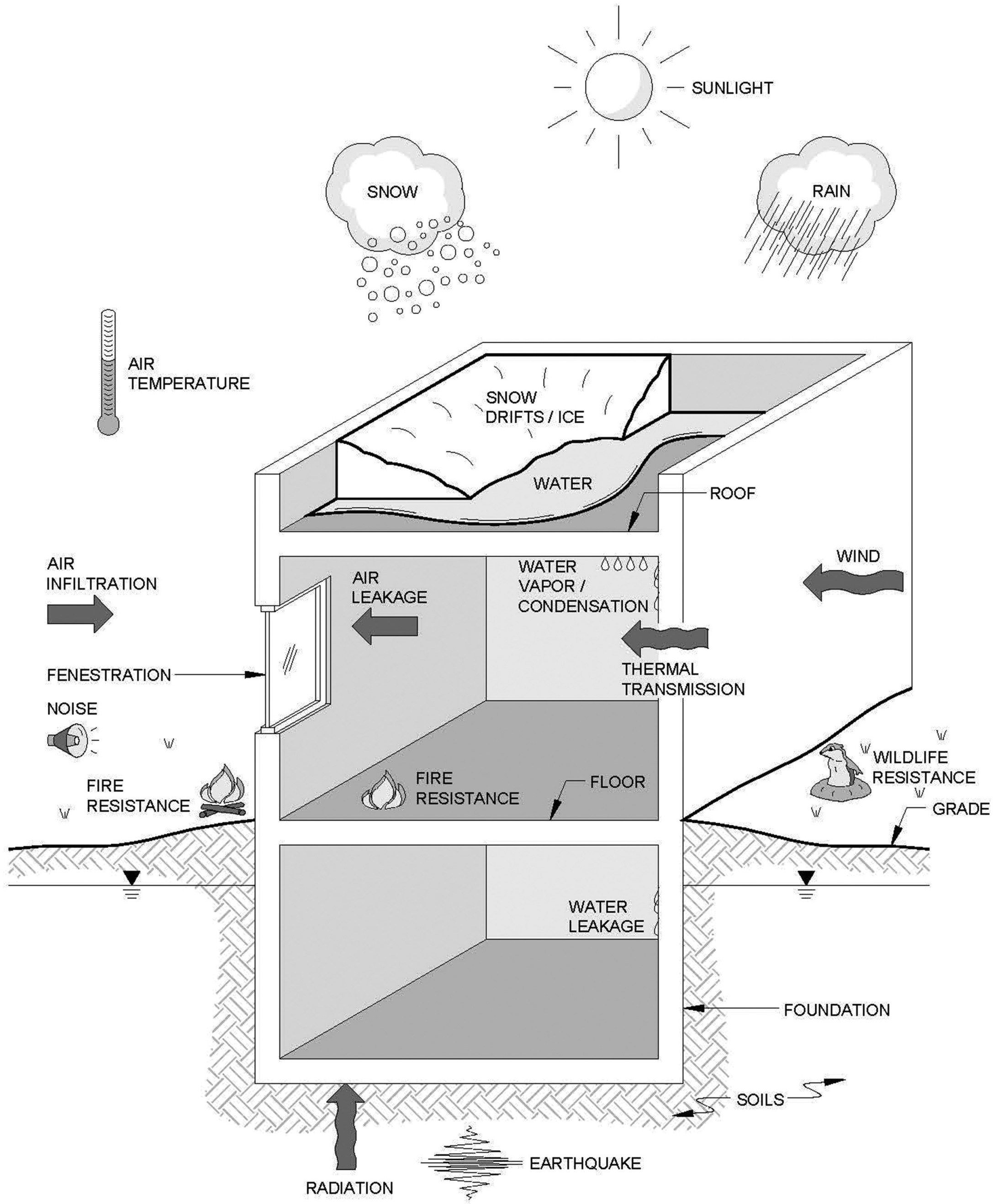

FIGURE 2-3 Effects on Envelope Systems

a building or area, which may impose limitations or restrictions on repair, replacement, or remodeling of the building or element given this status.

2.12.8 Interface Compatibility. Building envelope systems must be capable of being married to other systems that may or may not have similar materials. The performance of the interface system and materials is as important as the performance of the adjoining systems but can be more difficult to achieve.

2.12.9 Movement Control. The control of movement with respect to serviceability and watertightness of the systems is accomplished through the use of various types of interfacing materials forming a joint. The movement is not actually restrained or limited, but the distress caused by such movements in the adjacent materials is prevented or limited to certain locations.

1. Control joints—Movements caused by deflections, shrinkage, and creep normally result in cracking in undesirable locations. Control joints provide a desirable location for the anticipated crack to occur.
2. Expansion joints—Distress caused by loads and thermal and moisture movements is controlled by expansion joints, which provide the systems or materials room to expand or contract without interfering with adjacent materials or systems.

3. Isolation joints—Isolation joints are used in the design of systems and the building to accommodate movements caused by dynamic loads.

2.12.10 Natural Light and Ventilation. Minimum standards are normally required by model building codes for the provision of natural light and ventilation of habitable spaces.

2.12.11 Security. An envelope system can be required to provide safe separation between occupants and potentially dangerous persons or situations.

2.12.12 Serviceability. The building envelope systems must be capable of performing the function(s) for which they are designed and used, while resisting code-mandated loads, movements, or other effects inflicted on the system by either the building or outside sources. These systems are subjected to daily loading conditions (e.g., gravity and live loads or volume changes), which must be resisted without the loss of serviceability. The systems may also be required by the code to resist extreme loading conditions, such as earthquake, hurricane forces, and overpressures, with some acceptable loss of the system's serviceability. However, the envelope system should not create an unsafe condition to the public as a result of the extreme loads (see Section 2.12.14).

2.12.13 Solar Heat Gain. The development of heat inside the building and within the facade materials caused by absorption and transmission of the sun's rays into the system is called the solar heat gain. The system or a component may be required to accommodate this effect.

2.12.14 Strength. Building systems are required to safely resist static and impact loads, such as their own gravity loads, live loads, and possibly loads of adjacent systems. The systems are often required to resist other forces, such as earthquake, hurricane forces, hail damage, wind loads, overpressure, and periodic volume change. The minimum requirements for these loads depend on the building location and environment, and governing building codes.

2.12.15 Thermal Resistance. Envelope systems are required to act as thermal barriers between the interior and exterior environment. Thermal transmission by radiation, conduction, and convection must be resisted by the materials and by the design of the system. When the resistance to thermal transmission of the primary components of the system is low, insulation is incorporated into the system to improve the system's performance. Air and water infiltration also affect the overall thermal efficiency of a system.

2.12.16 Water Infiltration. One of the most important features of an envelope system is its resistance to moisture. The key areas susceptible to water infiltration are at interfaces with other systems or where systems terminate, turn a corner, or are perforated by an opening. Elements used to control water infiltration may include the following:

1. System field components,
2. Copings,
3. Flashings,
4. Joint treatment, and
5. Drainage plane.

2.12.17 Wildlife, Insect, and Organism Resistance. Birds, rodents, and various types of insects often seek shelter on or within an envelope system, which can be unhealthy or potentially dangerous to the occupants, to the building envelope and its component systems, or to the underlying structural system, as in the case of termites. Organisms such as decay and various forms of fungi can develop on or within certain materials when the conditions are appropriate. Such growth can also be unhealthy. An envelope system may be required to provide resistance to these types of threats.

CHAPTER 3
CONDITION ASSESSMENT PROCEDURE

This section describes the methods for conducting the condition assessment. This procedure is a generic sequence that can be applied to the entire envelope or to discrete component systems, such as roofing, wall cladding, or windows as described in Chapter 2 of this guideline.

3.1 GENERAL APPROACH

The assessment procedure is intended to aid the investigator in understanding the functional behavior of the building envelope, analyzing its current performance, and identifying any discrepancies between the intended behavior and performance. This assessment is achieved through a two-phase approach that includes the following:

Phase 1: Preliminary condition assessment to identify user concerns, key components, typical problem areas, and the required scope for further investigation.

Phase 2: Detailed condition assessment to review background information and to assess the function, condition, and adequacy of selected envelope systems and components.

Neither phase should be initiated without clearly defining the scope of work and obtaining an agreement from the client in writing. The investigator should not proceed with a detailed condition assessment before analyzing the cost/benefit based on the preliminary findings.

Each phase should be terminated with a verbal or written report to the client detailing the findings, providing conclusions, and outlining recommendations consistent with the assignment. All verbal reports must be summarized in writing by the investigator and included as part of the project file.

In general, the procedures herein describe the condition assessment of a single building envelope, as schematically outlined in Fig. 3-1. However, the principles of condition assessment can easily be extrapolated to incorporate an entire facility, which may include many buildings. Phase I could be periodically repeated for each similar type of building or envelope system within the complex. Once the condition of the individual building or system falls below a previously defined baseline, a more intensive condition assessment can be initiated. Fig. 3-2 illustrates an approach for such a facility-level condition assessment program.

3.2 CURSORY CONDITION ASSESSMENT

A cursory condition assessment is generally used for screening multiple buildings for an owner or agency to establish relative priorities for unit assessment and to develop a facility assessment plan. A checklist with a numerical rating system may be provided by the owner or agency for the overview assessment and subsequent ranking of the buildings.

The reports of the cursory assessments may be used for planning and budgeting of maintenance and repair. When performed periodically, new deterioration becomes evident when reports are compared with past reports.

An estimation of the rate of deterioration and remaining service life may be triggered by these reports but will require a more thorough investigation and analysis.

3.3 DEFINITION OF SCOPE

More often than not, the client engaged the investigator because of one or more recurrent problems with the building envelope. Before beginning the investigation, obtain a clear definition from the client of all specific problems to be addressed during the condition assessment. If the building user is different from the client, involve the users in the problem definition.

The scope of the assessment may vary from a general assessment, including all component systems of the building envelope down to evaluation of individual or selected subsets of component systems. Base the definition of scope on the client needs and directives but provide sufficient breadth to adequately assess problem areas. As such, it is often necessary to increase the scope of a narrowly defined assessment if the investigation indicates problems with systems and/or components beyond the initial scope. Whenever possible, endeavor to identify other potential problem areas and make sure that the client is aware of these issues before accepting a narrowly defined project.

The investigator must make the client aware that he or she will not be looking for structural, health, safety, or other issues that are not within the defined scope. For example, the client should not interpret as an endorsement the fact that the investigator walked by a handrail that is a few inches below the code-required height limitation while examining the exterior stone facade.

Often, the scope is not determined initially but is developed during the preliminary evaluation based on the investigator's observations. Experienced investigators can often determine, based on the presence or absence of visual damage, if envelope defects exist and whether they indicate general or localized problems. However, latent defects are often not readily apparent during the preliminary investigation that may require increases in scope during the final phase of the assessment. This circumstance is particularly true for existing buildings, whose concealed components may not be accurately portrayed in the background documentation. From the onset, the investigator must clearly communicate to the client that unforeseen problem areas may arise during the investigation and that these problems may warrant further investigation as part of the detailed assessment. As modifications in scope become necessary, immediately

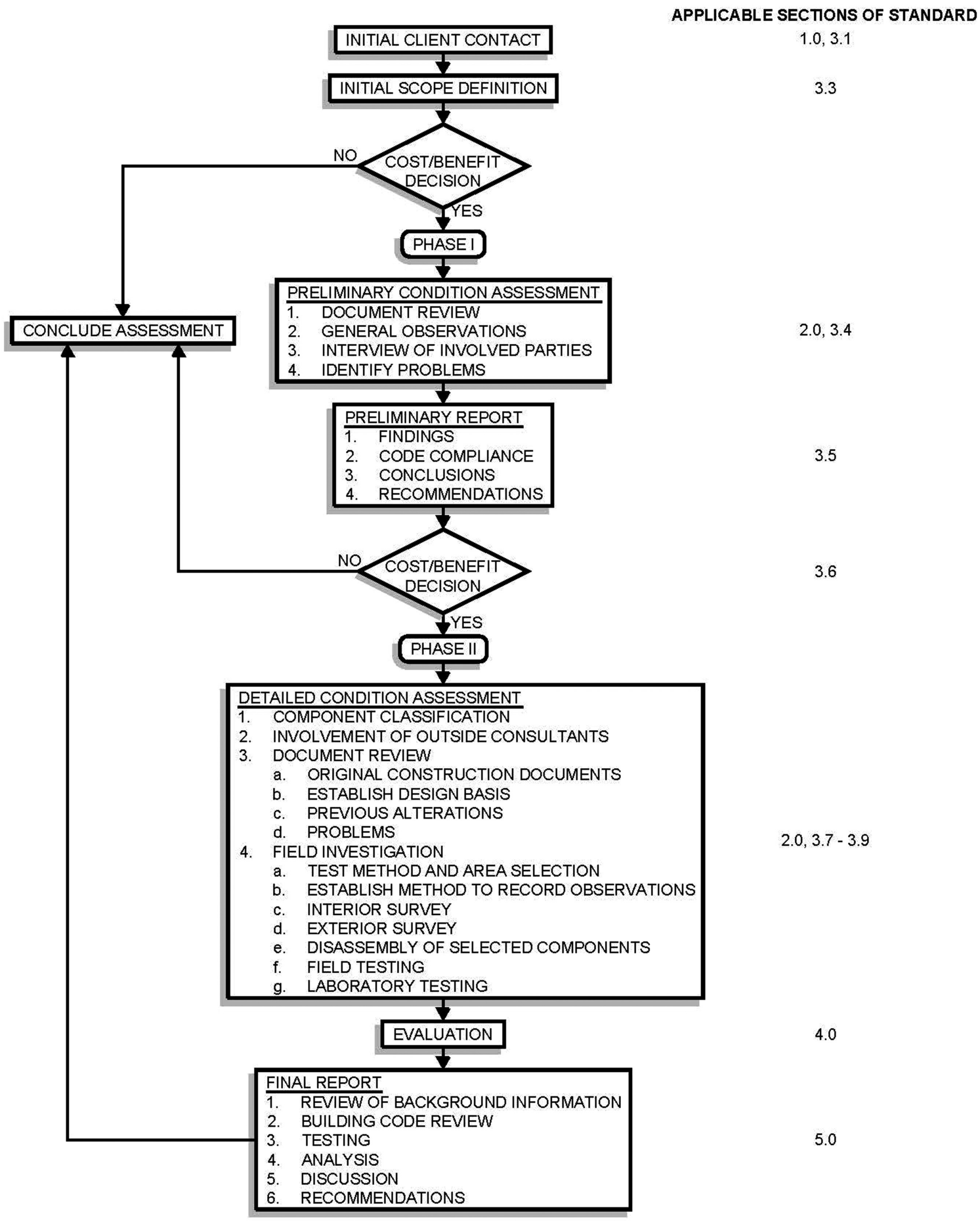

FIGURE 3-1 Condition Assessment, Single Building Envelope

discuss them with the client. Obtain a written confirmation from the client before commencing the additional work.

3.4 PRELIMINARY CONDITION ASSESSMENT

The initial condition assessment is limited. The amount of time available for a site visit usually governs the scope of the preliminary assessment, not the size or complexity of the building envelope systems to be addressed. The initial assessment typically does not involve testing or disassembly of envelope components. It provides the investigator with an opportunity to familiarize himself or herself with the envelope materials and details, to understand the exposure conditions of the various materials and systems, to identify obvious defects, and to establish a scope for the detailed assessment, if necessary. If the preliminary condition assessment is to be successful, the investigator must be free to exercise comprehensive professional judgment, must have free access to the entire building or facilities, and must not be confined to a prearranged routine that might omit potential problem areas or unnecessarily emphasize or deemphasize a particular problem.

3.4.1 Document Review. Often, the nature of this phase limits the document review to a brief review of plans, elevations, and a few details. Use this opportunity to determine what documents are available.

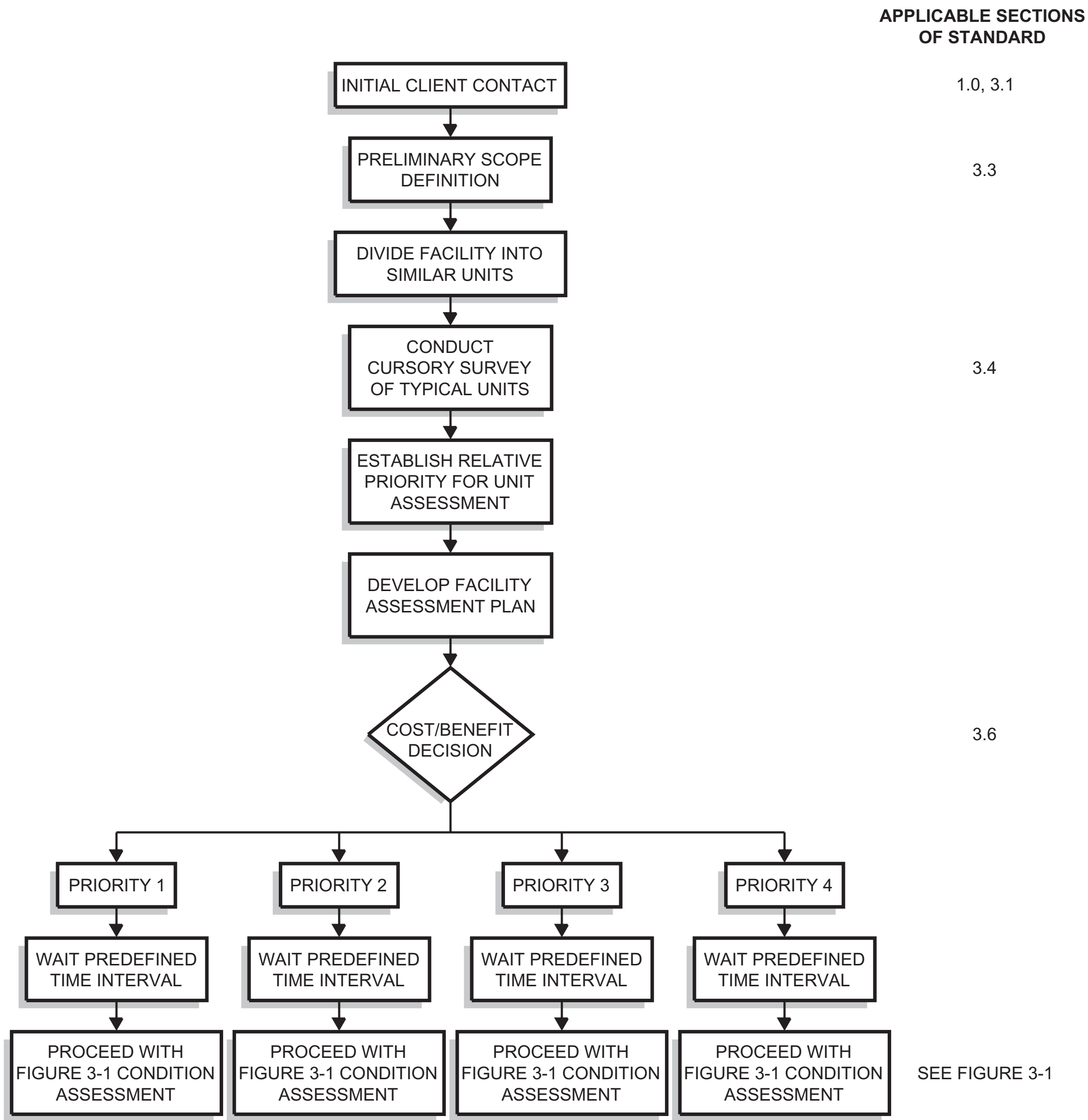

FIGURE 3-2 Condition Assessment, Facility Level Program

3.4.2 General Observations. The goal of the general observations is for the investigator to make a rapid evaluation of which, if any, envelope components require a more detailed evaluation during future phases of work. The required depth and time for this procedure depend on the experience of the investigator with similar systems and condition assessment procedures. Because these observations are primarily visual, be careful not to judge systems as acceptable that may have underlying distress or deterioration. Conversely, do not indicate a component failure without understanding other system components. The general observations typically include the following:

1. Walk-around survey of the exterior and typical roof areas. Take general photos (or video tape) of each elevation and roof area visible along the inspection route. Record observations of systems and materials observed at each area and note any obvious defects or potential defects. Obvious defects include cracks, bulges, displacement, staining, open or deteriorated sealants, missing components, sponginess of roofs, or other forms of distress readily visible to the unaided eye.
2. Tour accessible interior spaces and areas and report specific problems. Record and visually document the location of stains, peeling paint, corrosion, exfoliating plaster, and similar signs of moisture-related damage and cracks, displacement, bulges, or other evidence of potential structural distress.
3. If significant damage is noted at a specific interior area, make additional exterior observations proximate to the damage. Note the systems and details potentially responsible for the damage. Record and visually document observations.
4. Identify any components that appear to pose an immediate safety risk. Notify the owner and, if so required by local law, the appropriate governmental authorities immediately of any such hazards and recommend appropriate action to mitigate the temporary life safety hazard.

3.4.3 Interviews with Involved Parties. Whenever possible, use the initial site visit as an opportunity to interview the client, building management, building maintenance personnel, and any other involved parties about the performance of the building envelope systems to be assessed. Often, these parties can provide a rough history of the building's problems and repairs. This information helps to identify areas for further study during the detailed assessment and document review.

If possible, use the interviews to determine weather conditions and time periods when the building envelope problems were most severe. This information can often be correlated with statistical weather data to provide insight to the environmental conditions that have proven to be the most problematic for the building envelope.

When applicable, ask the involved parties about the history of alterations and repairs that have affected the building envelope. Try to determine if the changes brought about by previous repairs and alterations have been effective.

3.4.4 Identification of Typical Problem Areas. Use the document review, general observations, and interviews conducted during the initial site visit to identify potential problems with the existing building envelope. Careful attention paid to locating typical problem areas at this stage helps to determine an appropriate scope of work and to streamline the detailed condition assessment.

3.5 PRELIMINARY REPORT

The goal of this phase is to convey the initial findings and the importance of conducting future investigations back to the client. Issue a preliminary report, which outlines the preliminary findings, conclusions, and recommendations from the initial condition assessment. As a minimum, include the following in the preliminary report.

3.5.1 Preliminary Findings. Outline the condition and configuration of the typical building envelope components observed during the preliminary condition assessment. Clearly identify and present in the preliminary report all observed problem areas, including all concerns raised by the client and those interviewed. Present each observed problem area and its potential for building envelope distress. Clearly differentiate in the preliminary report the various classes of problems, including water infiltration, structural distress, air infiltration, water vapor migration, and other relevant concerns.

In addition to presenting the findings, emphasize in the preliminary report that all findings are subject to modification based on the results of the detailed assessment. To the extent possible, communicate which findings are most likely to be modified and the potential outcomes of those modifications.

3.5.2 Identification of Legal and/or Code Compliance Issues. All major building codes, and many local building codes, include provisions that directly affect the building envelope. Codes often mandate standards for structural integrity, fire performance, water permeance, and air infiltration. Review all applicable legal and code requirements for the building envelope in question. Present in the preliminary report the relevant legal and code requirements reviewed and how they relate to the building.

Clearly present and discuss any retroactive code requirements that affect the building. If the building doesn't meet these requirements, identify the problem areas and address the reasoning behind the code requirement in the preliminary report. In addition, present code requirements that become effective only in the event of a renovation.

In the case of code-related safety concerns, whether an issue is retroactive or not must never supplant the investigator's judgment that a component should be upgraded. Include in the report a discussion of any safety concern and clearly address why the problem should be corrected, even if it is not specifically mandated by the code.

3.5.3 Preliminary Conclusions. After a complete discussion of the observed problem areas and legal and code requirements, address the significance of each item and how it relates to the overall performance of the building envelope. If expected defects were not observed in the preliminary site visit, include in the report the likelihood of their existence and the potential effect upon performance.

Whenever possible, estimate the severity of each problem and compare it with others observed in the building. It is often useful to develop a rank ordering, which outlines each building envelope problem area in the order of building envelope distress severity based upon the investigator's judgment.

Whenever relevant, compare the building envelope distress of the subject building with others of similar construction in the region. Present persistent problems with a particular type or method of construction, even if they were not specifically observed in the preliminary site visit. If the building envelope class is popular, but only in regions other than that of the subject building, include in the report a discussion of why the building envelope component may or may not be suited for its current use.

3.5.4 Preliminary Recommendations. Include in the report at least one recommended action for each conclusion presented, even if it is to do nothing. Clearly identify and present problems that require immediate action prioritized in order of importance (see Chapter 4). List safety concerns and their recommended remedial repair in the strongest possible terms.

Recommend further study during the detailed condition assessment for every potential problem that could not be clearly defined and addressed by the preliminary investigation.

3.6 REFINEMENT OF SCOPE FOR THE DETAILED ASSESSMENT

After the preliminary walk-through and report, work with the client to adjust the original scope of work to reflect the preliminary findings and recommendations. Include a proposal in the revised scope of work for every item recommended for further study in the preliminary report. Remove items from the initial scope for the preliminary investigation if they were not found to be problematic during the preliminary investigation.

After defining a scope of potential work, determine with the client whether further study is economically justified. It may not be justified if the apparent problems are far less intrusive and expensive than the proposed investigation. However, the problem may be so severe that replacement is inevitable and an investigation would not be economically rewarding. Incorporate in this analysis the relative costs that might be associated with the various destructive and nondestructive testing possibilities that might be used, as well as an opinion of the probable cost of rehabilitation.

3.7 DETAILED CONDITION ASSESSMENT

Think of the detailed condition assessment as an opportunity to gain an up-close, magnified view of the building envelope's problems and distress. Use the detailed condition assessment to answer all questions raised by the preliminary investigation and those that might arise once the building's problems begin to unfold. Use all testing and observation opportunities in a clear, consistent, and detailed manner.

3.7.1 Component Classification. Develop a list of all systems comprising the exterior envelope areas to be included in the detailed condition assessment. For each of these systems, identify all component materials, along with their expected exposure conditions. For example, the polyvinyl chloride flashings incorporated in the roof system are exposed to direct sunlight, wind, snow, rain, and salt spray for the beach-side condominium to be evaluated.

In addition to the expected exposure, identify the criticality of each component to the overall performance of the envelope system. Mark for careful observation during the detailed condition assessment all nonredundant components with a critical effect on safety and building performance.

3.7.2 Use and Coordination of Consultants. Issues often arise within a detailed condition assessment that fall outside the investigator's range of expertise. Retain other consultants, with the written approval of the client, to address those problems. In concert with the other consultants, establish a well defined scope of work and method of presentation as soon as the consultant is retained. Clearly identify the benchmark for work product review and coordination for all of the other contractors.

In the course of a building envelope condition assessment, other consultants may be required for related issues, including but not limited to the following:

1. HVAC—Mechanical consultants might be used to help evaluate the adequacy of the existing HVAC system and its effects on the performance of the building envelope. Air infiltration, thermal performance, and vapor migration studies must be coordinated with the efficiency of the existing HVAC system.
2. Architectural—Among other things, architectural consultants are often retained to assist with the development of repair options that will affect the appearance of the existing building envelope. The architectural consultant can assist the client in the evaluation of the aesthetic characteristic of a remedial repair.
3. Industrial hygienist—Building envelope failures can result in biological and chemical contamination of the interior air quality. Industrial hygienists can help to determine the severity, effect, and remediation of this contamination. Often, the work of the industrial hygienist needs to be closely coordinated with that of the HVAC specialist.
4. Historic preservationist—Historic preservation consultants may be required for studies of buildings with historic significance. Remedial repairs to these buildings need to be carefully coordinated with federal, state, and local restrictions. These criteria should be presented as part of any detailed condition assessment.
5. Materials scientists—Metallurgists, masonry specialists, wood technologists, and other material scientists might be required to evaluate some components of the building facade, including material degradation, coating failures, material compatibility, suitability, and complex material failures.

3.8 DOCUMENT REVIEW

In concert with the field investigation, include a careful review of the available documentation for the building. In addition to familiarizing the investigator with the building components and configurations, this review helps to indicate potential problem areas before the detailed field assessment. As a minimum, include the steps in the following sections in the detailed document review.

3.8.1 Original Design and Construction Documents. When available, documentation from the original design and construction can prove to be an invaluable source of information. Carefully review this documentation for all building envelope components to be included in the condition assessment. The original construction documentation may also provide insight to other related problem areas that may not necessarily have been included in the scope of the original assessment. It also helps to identify concealed details and materials that may have been common at the time of construction but have since proven to be problematic or obsolete. Verify that the building was constructed according to the original drawings. In general, study all details and documentation that address the components and configurations within the building envelope that are of concern to the condition assessment, including the following:

1. Construction drawings and specifications, architectural, structural, and others if circumstances require;
2. Shop drawings and submittals;
3. As-built drawings;
4. Manufacturers' material data;
5. Applicable building codes and standards; and
6. Pertinent correspondence from construction.

3.8.2 Design Basis. After reviewing the documentation from the original construction, determine how the original designer intended the building facades and roof systems to function. Establish the intent of the designer with regard to the architectural, structural, waterproofing, thermal, vapor migration, air infiltration, and other relevant aspects of the building envelope components of concern. For example, was an existing exterior facade designed to perform as a barrier wall or a cavity wall? A curtain wall or panelized wall? Which components were intended to be wet and which were intended to remain dry?

Use the construction documentation to verify that the constructed systems are consistent with the original design intent. Trace the path of the structural loads, water infiltration, energy flows, and other criteria of concern through the entire building envelope. Pay particular attention to continuity at locations where different envelope systems connect and where the work of different trades coincides. Roof-to-wall, wall-to-balcony, plaza deck-to-wall, and other similar system interfaces are often the sources for many building envelope problems.

After the construction documentation and design intent have been analyzed, identify critical aspects of the design for detailed review in the field.

3.8.3 Records of Previous Alterations and Repairs. Obtain and analyze any written documentation for alterations or repairs that affect the building envelope systems. Carefully review sealant maintenance, coating applications, drainage alterations, and material repairs. Identify the scope and type of repairs undertaken and determine if they are consistent with the intent of the original design. Establish if the repairs were undertaken because of a problem with the original design and construction or for an unrelated reason. Determine if previous repairs and alterations have been effective.

Identify architectural, HVAC, structural, electrical, or other repairs that may have affected the exterior building envelope. Alterations or repairs to these areas can breach or otherwise affect the performance of the building envelope without due consideration. Determine whether the use or operation of the building has changed since it was originally constructed and what effect these changes may have on the building envelope.

3.8.4 Documentation of Problems. Review any available documentation that might help to ascertain previous and current problem areas. For many larger buildings, it is often possible to obtain valuable information from the following:

1. Water leakage records (or records from related interior repairs),
2. Energy usage records,
3. Observed distress, and
4. Findings of previous investigators.

3.9 FIELD INVESTIGATION FOR DETAILED CONDITION ASSESSMENT

Before beginning the field work for the detailed condition assessment, carefully outline the work to be conducted. Incorporate the information gathered during the preliminary assessment and document review process into the design of a detailed field program. As a minimum, include the steps from the following sections.

3.9.1 Test Method and Area Selection. Determine what types of testing would be the most appropriate for the systems and materials to be covered by the detailed assessment. Outline the relevant structural, water infiltration, vapor migration, air infiltration, or other test procedures and their requirements for material and labor. Identify the components of the building envelope that should be carefully inspected during the detailed interior and exterior observations.

Select areas of the building for further study that would be most appropriate for detailed observations, building envelope system tests, and component material tests. Be sure to select areas representative of the building's problems. It is always advisable to choose testing and sampling locations that encompass a variety of distress and exposure conditions. Determine what scaffolding, swing stage, or other means of access is required for each of the proposed test areas.

Outline with the client the effect of each of the proposed testing methods. Whenever possible, show a preference for nondestructive techniques. When destructive tests are necessary, determine what effect they will have on the building envelope and what will be required to return the envelope to its original condition. Work with the client to address the cost and effect of the testing upon normal building operations.

3.9.2 Method for Recording Observations. As part of the establishment of scope for the field investigation, determine the most appropriate and efficient method for recording field observations and encounters. Time spent before the investigation determining the most effective notation methods helps to ensure their completeness and usefulness back in the office. Though this often overlooked step might be skipped for small buildings or projects of limited scope, it becomes essential for large-scale and complex projects.

Ensure clear and methodical documentation from the field investigation. Whenever feasible, create video documentation for the field investigation. Video records often capture sample openings, water tests, damaged areas, and other aspects of the investigation from different angles and perspectives. Still photography, although useful, does not typically provide as much information and does not allow for the close coordination between field notes and video images. After the investigation, the video can often be used to go back and answer questions not necessarily considered during the early parts of the condition assessment.

It is often useful to develop simple floor plans and/or interior elevations for the purpose of recording interior survey notes and photos. For example, interior elevations and floor plans are useful for recording interior water damage. Similarly, small exterior elevations can be produced for the purpose of recording cracks, deterioration, defects, stains, and other noteworthy conditions on the exterior of the building. For both interior and exterior observations, it may be useful to include video documentation of some crucial areas, especially if the building is, or may be, the subject of litigation.

By considering the most efficient means of documentation ahead of time, it is possible to include provisions for additional drafting and video documentation. If these factors are not considered until immediately before the field investigation, it is often too late or expensive to include them within the project budget.

3.9.3 Detailed Interior Observations. A detailed interior survey can be one of the most useful means of pinpointing the problem areas of a building envelope. Conduct a thorough examination of the interior of a building envelope before beginning any testing. The interior survey should be used to do the following:

1. Record damage,
2. Identify the presence of moisture,
3. Record the interior and exterior temperature and relative humidity, and
4. Look for pressure differences and air movement across the envelope.

Careful study of the patterns of building distress from the interior survey helps to locate windows, flashings, construction joints, drains, panel connections, roof details, environmental conditions, and other items to be emphasized during the remainder of the assessment. When analyzing the results, remember that significant building envelope distress can be concealed within the wall cavity that might go undetected during the interior investigation.

Whenever possible, inspect all interior surfaces of the building envelope during the interior survey. On large-scale or residential structures, a 100% survey might not be feasible. In such instances, view a random selection of interior surfaces for each building exposure. Provide as large a sample size as possible.

3.9.4 Detailed Exterior Observations. Conduct a detailed exterior survey of the building envelope to record the visible condition of the exposed components. Notes, photographs, and video documentation of the exterior observations are referenced to the building elevations. During the detailed exterior survey,

1. Record cracks, stains, material failures, and other damage;
2. Identify breaches in the building envelope;
3. Assess the condition of the exposed materials;
4. Study the configuration and integration of the exterior components;
5. Verify that the existing construction is consistent with the contract documents; and
6. Measure environmental conditions.

As with the interior survey, document the condition of the entire exterior building envelope. When that's not feasible, observe representative portions of each building exposure. Emphasize areas found to be problematic during the interior survey.

After the exterior envelope survey, correlate the results with those of the interior survey. It is often possible to link areas of internal distress with specific conditions observed during the exterior observations. Link poor flashing details, sealant joint failures, cracks, and other distress locations with the resultant damage.

3.9.5 Disassembly of Selected Building Elements. After the document review and detailed building observations, disassemble portions of the building envelope with the aid of a qualified contractor to reveal the concealed as-built conditions and building distress. Potentially hazardous materials encountered should be identified and tested; mitigation may be required. Break down and compare with the building's documentation and the original design intent representative details, including windows, doors, prefabricated panels, flashing details, sealant joints, wall cavities, construction joints, roofing membranes, shingles, crickets, and other typical systems. Verify the condition and configuration of each system and component. Check for poorly terminated flashings, inconsistent insulation, discontinuous air and water barriers, or other concealed conditions that might affect the building envelope performance. Be especially observant for recurrent damage to hidden building elements that might be a result of water infiltration at other locations or through seemingly unaffected building components.

3.9.6 Field Testing. Once the interior and exterior surveys are complete, conduct in situ testing to verify suspected building envelope behavior. For example, the investigator may believe that water stains on the interior finishes at one location are the direct result of a faulty roof flashing, or that the cracking of the exterior tile veneer is caused by a mortar bed with substandard strength. Carefully selected and implemented field tests can validate these hypotheses or implicate another, unsuspected cause. In addition, field tests often provide quantifiable information that may be required for remedial design or for comparison with established building performance benchmarks.

It is often prudent to conduct some field testing before disassembling selected building elements. Disassembly at a test location immediately after a test helps to create a direct correlation between the test results and concealed conditions at a particular location.

The sections herein briefly summarize some test classes that can be conducted to study a particular problem. These classes typically involve an entire system, rather than a specific material. For example, air infiltration tests described here may be geared for an entire wall or window assembly, not just the glass, aluminum, or other individual components.

Various test procedures can be applied to assess the condition of an exterior building envelope. Many of these tests are intended for laboratory use but can be applied in situ with appropriate modification. In all cases, good engineering judgment is necessary when designing the tests and interpreting results. In particular, it is critical to identify the degree to which the tests reasonably recreate actual service conditions.

3.9.6.1 Structural Testing. Often, it is necessary to evaluate the structural adequacy of an envelope assembly. This evaluation may be required to compare portions of the envelope with established benchmarks, to compare with applicable building code requirements, or to quantify as-built systems to be incorporated within a remedial design. For example, pullout tests for an exterior insulation and finish system veneer can determine if the wall is capable of meeting the code-mandated wind load requirements. Load testing of a steel stud wall system might determine if the as-built conditions are stiff enough to support a contemplated veneer switch from aluminum panels to brick.

Not many standard test procedures directly address in situ testing for the building envelope condition assessment. Always use careful engineering judgment when applying a standard test procedure or developing a new procedure.

3.9.6.2 Corrosion-Related Testing. Corrosion-related testing and evaluation are important aspects of the condition survey and are needed for understanding the condition of the building envelope system. This type of evaluation is needed to select the most cost-effective repair and corrosion mitigation strategy. The actual scope of the work is project specific, depending on the type of construction (i.e., reinforced concrete or steel frame, or reinforced concrete or masonry wall panels). A typical testing program could consist of the following:

1. Visual observations to note cracks, spalls, stains, out-of-plane elements, and exposure conditions;
2. Delamination survey to locate existing defects;
3. Chloride profile samples to identify the depth of contamination;
4. pH testing to determine depth of carbonation;
5. Depth of concrete cover to steel reinforcing or steel frame elements;
6. Material resistivity;
7. Half-cell potential testing;
8. Corrosion rate determination; and
9. Limited destructive testing, such as partial removal of finishes or veneers, or installation of probes.

After completion of field testing, a summary and preparation of survey results, including findings, conclusions, and recommendations, should be prepared.

Corrosion is one of the major causes of damage to the building envelope and if left unchecked can lead to structural damage and safety concerns. Strategies for mitigating corrosion can include using coatings, membranes, galvanic or impressed current cathodic protection systems, and electrochemical treatments, such as chloride removal or re-alkalization. Corrosion monitoring devices can be installed and used to ensure the longevity of the final repairs.

3.9.6.3 Water Leakage Testing. A carefully designed and implemented water testing program may be the only way to evaluate the waterproofing capabilities of a building envelope. Avoid assessment conclusions and recommendations for waterproofing based on speculated leakage paths. Persistent water leakage can often only be defined by a carefully coordinated program of in situ testing.

A typical program of water testing for a particular building envelope system consists of five steps, including four basic tests:

1. Identification of potential problem areas during the document review, interior survey, and exterior survey;
2. General testing of the trouble spots with a broad coverage spray rack under calm climatic conditions;
3. General testing of the same areas with a broad coverage spray rack and an applied pressure difference across the building envelope;
4. Testing with a calibrated nozzle to isolate suspected leakage paths; and
5. Flood testing of roofs.

As with structural testing, use good engineering judgment when including standard water test procedures as part of a condition assessment. Standard test criteria may not be reasonable for some field conditions. For example, the short duration of water spray provided in a standard specification may have been developed for glass and metal curtain wall applications. When using a general water test for masonry, it may be necessary to apply water for hours, or maybe even days, to represent actual climatic exposure conditions that may lead to masonry leakage. A second example would be the amount of pressure differential to apply across the building envelope during water testing. Published standards often correspond to benchmarks for new construction. They may not necessarily apply to existing buildings exposed to unique climatic conditions.

Flood testing of roofs, when used for water leakage, is not the same as structural load testing and normally occurs in limited areas and at limited depths so as not to overload the structure.

3.9.6.4 Air Infiltration Testing. A comprehensive air infiltration testing program can determine the relative tightness of the exterior envelope. This information has direct bearing on HVAC performance, water vapor and thermal migration, and overall indoor air quality. Quantified values can be compared with published design standards as a performance benchmark. A typical air infiltration testing program might consist of the following:

1. General air leakage testing through the entire envelope (For small buildings it is often feasible to test the performance of the entire envelope. For larger structures, it may be necessary to limit testing to convenient internal zones.);
2. Isolation testing of individual components, such as HVAC units, windows, doors, and wall panel assemblies; and
3. Specific testing of cracks and openings within a given assembly to determine the major air infiltration contributors.

3.9.6.5 Condensation and Thermal Performance Testing. Field testing can help to evaluate the overall condition and thermal performance of the building envelope for comparison with published standards. This comparison is particularly important when a change in use is expected for the building.

In general, most recognized standard test methods involve controlled laboratory conditions. However, surface temperature surveys, dew point surveys, interior climate surveys, infrared thermography, nuclear hydrogen detection, and other qualitative measurements may isolate thermal bridges and system deficiencies. They can also help to verify a calculation-based analysis of the envelope.

3.9.6.6 Long-Term Testing. In some instances, it may not be possible to accurately assess a given building envelope problem within the confines of a relatively short field visit. In those instances, develop a program of periodic or continuous monitoring and measurement.

Long-term monitoring might be required to evaluate the building exposure. External building sensors can develop information to quantify wind and climatic conditions for specific envelope components. In some areas, the nearest meteorological station with recorded data may not directly apply. For example, the data recorded at an airport 20 miles inland might not be sufficient for a high-rise building on the beach.

Internal building sensors can monitor wind effects, temperature, relative humidity, air pressure differences, and other conditions over a number of seasonal changes. For some buildings, this monitoring may provide useful information for comparison with published standards or for design when published standards do not provide sufficient information.

Long-term testing provides insight to envelope movement. For example, the settling, displacement, and crack growth of a limestone facade can generally be evaluated by periodic measurement. Measurement over a range of conditions can also help to determine if cyclical movements correlate directly with building use or climatic conditions.

Before initiating any long-term testing, determine the most cost-effective method of monitoring that provides the required information. Work with the client to limit the intrusion of the testing on normal building operations.

3.9.7 Laboratory Testing. In many instances, it may be necessary to evaluate individual components of a building envelope to check for suspected problems related to strength and durability or to provide for a quantified comparison with an established benchmark. For example, samples of a roofing membrane might be removed to evaluate the residual strength or to determine the chemical composition. Samples of masonry or mortar might be extracted to determine their compressive strength and to determine how that strength compares with accepted design values. Remove samples from areas that are typical of the envelope's exposure and condition. In instances with severe budget constraints, it may be useful to remove samples from the most deteriorated portions of a given system to evaluate a worst-case scenario.

Testing for specific material components can often be accomplished with the aid of recognized test methods.

CHAPTER 4
EVALUATION

4.1 GENERAL

Evaluation, as used herein, is the process of determining the adequacy of the building envelope or components for their intended use. This process considers compiled data, field condition assessment, results of testing, and acceptance criteria.

Evaluation by its nature implies the use of personal judgment by those qualified as experts. Because these experts must ultimately take the professional responsibility for the evaluation, the requirements for evaluation cannot be standardized.

4.2 METHODS

Recognized reliable methods should be used for all evaluation procedures. However, the use of new methods for evaluation procedures is encouraged, provided that there are reliable and sufficient checks of the new methods by the use of recognized methods.

4.3 ACCEPTANCE CRITERIA

The client and design professional should agree on the criteria for acceptance. Code-related issues include fire and life safety, structural safety, health and hygiene, and accident prevention. Owner-related issues include envelope integrity, energy conservation, security, and appearance.

4.4 PERFORMANCE ATTRIBUTES

The emphasis of the evaluation is directed by the purpose of the investigation. In many cases, the performance of the envelope as a system for protection from the weather, water, or other intrusive forces is of prime importance; in others, the performance of the materials and components of the envelope itself is the major consideration.

4.5 OBJECTIVES

The order of priorities is always life safety on the exterior and health and welfare of the occupants on the interior; mitigation of any hazards disclosed by the investigation; integrity of the building envelope and its potential effect on the structure, finishes, and operation of the building; and, lastly, aesthetic or cosmetic considerations.

4.6 ANALYSIS

Any necessary analyses should be conducted in close coordination with the document review, field investigation, on-site and laboratory testing programs, and projected use. The following analyses may be required for a detailed condition assessment, not excluding others needed for a specific evaluation.

1. Identification of dysfunctional materials and/or components;
2. Patterns of distress or failure;
3. Compilation and analysis of information accumulated during the interior and exterior surveys;
4. Correlation between information accumulated during the field investigation with that disclosed during the document review;
5. Results of exploratory openings and disassembly of components;
6. Compilation and analysis of air infiltration testing information;
7. Statistical correlation between interior damage and defects uncovered during water testing;
8. Statistical analysis of historical meteorological information to determine actual building exposure conditions;
9. Evaluation of thermal and vapor migration characteristics of the envelope;
10. Structural and/or material analysis of selected systems and components;
11. Review of serviceability (e.g., earthquake, hurricane, tornado, or terrorism) as defined in Section 2.12.12;
12. Evaluation of repair methods and materials;
13. Remedial repair recommendations for deficiencies with associated service life estimates and cost–benefit analyses; and
14. Service life estimates and cost–benefit analysis for selected systems and components.

4.7 FORENSICS

Evaluation for forensic application is a specialized field that is not included in this guideline.

4.8 REFERENCES

Building exterior performance references are given in Appendix B. The list is not all-inclusive, and other references may be used as applicable. Additional information is available from ASTM Committees D8 on roofing, waterproofing, and bituminous materials and E6 on performance of buildings.

CHAPTER 5
REPORT OF THE CONDITION ASSESSMENT

The content of the report should be, at a minimum, consistent with the scope of the assignment. Unanticipated conditions disclosed during the assessment should be reported to the appropriate entities and included in the report. A simple checklist may suffice for a cursory assessment and a letter report for a preliminary assessment. A full report would be appropriate for a detailed assessment.

This chapter is a guide, because the order and content may vary with the scope of the engagement, the methods and techniques used by the design professional, and for specific investigations. It provides a description of the various parts of the preliminary and detailed assessments that may be used. This chapter presents a form for a typical client–consultant relationship, but it does not preclude a different format. Appendix A is an example outline for such a report.

In the case of public agencies or multibuilding owners where routine or special condition assessments are performed by staff personnel for the management of facilities, the form of the report may be established by that agency or owner. Similarly, such a client may require a specific format when the condition assessment is performed by a consulting design professional.

It must be recognized that any report could be used in future litigation. Hence, the depth of the investigation and analysis should be stated explicitly. Conclusions and recommendations should be carefully worded, and the possible consequences of not following recommendations should be stated. A carefully worded disclaimer may be included in the report.

5.1 EXECUTIVE SUMMARY

An executive summary at the beginning of the report is discretionary. It contains brief statements of the purpose, scope, procedure, findings, conclusions, and recommendations.

5.2 INTRODUCTION

5.2.1 Purpose of Assessment. This introductory section should be a concise statement describing the reasons for the condition assessment. Background information, if pertinent, may be related in this part and includes any applicable government, owner, or user reporting requirements (see Section 1.2).

5.2.2 Scope of Investigation. The scope of the investigative work performed for the assessment varies with the assignment. An explicit scope and any limitations must be stated specifically and clearly (see Section 3.3). Assumptions, governing codes, and standards should be indicated in this portion. Any unusual conditions affecting life safety or health should be given special consideration.

5.2.2.1 Cursory Condition Assessment. This is a visual overview of the general condition of the building envelope and may use a checklist with a numerical rating system provided by the owner or agency. It is often used for screening multiple buildings to establish priorities for immediate, short-term, or long-term attention. The report should identify problem areas and indicate the need for a more thorough condition assessment where applicable. Priorities and needs recommended in the report may be used as a planning and budgeting tool for maintenance and/or repair.

5.2.2.2 Preliminary Condition Assessment. An initial walk-through visit for orientation and general impressions is common to most assessments. Review of available documents, planning for further site inspections, preliminary analysis, and preliminary evaluation and recommendations may be part of this work (see Section 3.4). Results may indicate the need for an increase in the scope of the investigation.

5.2.2.3 Detailed Condition Assessment. This is an expansion of the preliminary assessment if needed. It includes a review of documentation, building inspection, materials and systems assessment, detailed analysis, cost impact study, detailed evaluation, and recommendations (see Section 3.7).

- *Commentary*—Write a detailed, self-contained report to clearly convey the results of the detailed condition assessment. In general, consider the report for the detailed assessment an intensified version of the preliminary report. The goal of the report is to present all background review, data collection, testing, analyses, conclusions, and recommendations in a format that can be readily reviewed and understood by the client. In addition, any building envelope consultant must be able to review the report and continue any investigation or remedial work without having to duplicate any work included within the scope of the detailed assessment. Incorporate the work performed by any other retained consultant into the report.

5.2.2.4 Testing. The range and types of testing used should be outlined in this section.

5.2.3 Methods and Techniques. Methods and techniques used in the survey, investigation, and testing should be covered in more detail in this part.

5.2.3.1 Data Collection and Documentation. Visual observations, photographs, oral and video tapes, measurements, drawings and sketches, and methods of investigation should be explained herein.

5.2.3.2 Testing. On-site and laboratory testing should be described.

5.2.4 Meetings. A summary of meetings during the investigative phase should be included.

5.3 DESCRIPTION OF BUILDING ENVELOPE SYSTEMS

5.3.1 General. A general description of the building envelope systems to be assessed should be given at this point. This description includes the type of architecture, component systems, and materials comprising the building envelope. For every component included within the scope of work for the detailed condition assessment, present all relevant background information. Include any information discovered during the preliminary assessment and detailed document review. Clearly indicate the source for all information presented.

5.3.2 Dates of Construction, Alteration, and Repair. Any information available should be given in this section.

5.3.3 History. The past performance of the building envelope throughout its life, maintenance procedures, environmental conditions, and any unusual behavior or other factors should be discussed.

5.3.4 Input from Other Disciplines. The results of the survey and evaluation by other disciplines as they affect the building envelope should be given here, or the report can refer to reports of others.

5.3.5 Collected Data. Information accumulated during the survey, investigation, and assessment should be listed. This information may include such things as original drawings, insurance data, alterations, photographs and tapes, measured drawings, interviews, or design calculations.

5.4 DISCUSSION OF FIELD INVESTIGATION

5.4.1 Overview. This is a report of the initial site visit for orientation and general impressions. On a limited assignment, this may comprise the entire engagement.

5.4.2 Survey. A more thorough survey should consider component materials and systems, dimensions, deflections and distortions, identification of problem areas, sample locations, and a record of data obtained. Usually, plans, details, and photographs are included to show this information.

5.4.3 Observations and Their Significance. This part should be a summary of observations made and how they affect the assessment.

5.5 BUILDING CODE REVIEW

Present the applicable, relevant building code requirements for each item included within the scope of work. Review applicable codes currently in effect and those in effect at the time of original construction. Clearly indicate which items in the current code may be retroactive, even those retroactive only in the event of a major renovation.

5.6 TESTING PROGRAM

Testing methods used shall be reviewed. Nondestructive, destructive, and special tests may be used. Provide a description of all the field and laboratory tests conducted as part of the detailed assessment. Define the goal of each test, identify the applicable item within the scope of work, and reference any standard test procedures. State any assumptions incorporated within the testing program. Results of testing may be given here, or you may refer to test results in the appendix of the report.

5.7 ANALYSIS

Describe all analyses conducted during the assessment, state applicable items within the scope of work, and briefly summarize the results. Clearly indicate any general assumptions made during the analysis and provide reference standards and sources for published information when applicable.

5.8 DISCUSSION

Provide a detailed, concise discussion for every item included within the scope of work. Establish the design basis for each item and discuss the implications of all the information presented in the background review and code review portions of the report. Interpret the results of all of the analyses and tests conducted.

Discuss any changes or modifications to the preliminary findings, conclusions, or recommendations from the preliminary condition assessment report. Be sure to present the reason for each variation.

Whenever possible, estimate the severity of each problem and compare it with others observed in the building. It is often useful to develop a rank ordering to outline each building envelope problem area in order of distress severity.

5.9 SUMMARY OF STUDY

Field and office work directed toward the condition assessment should be summarized. Compliance with building codes, life safety requirements, and special owner or user criteria should be discussed for the initial construction, alterations, present condition, and potential future use (if applicable). An executive summary, including conclusions and recommendations, may be placed at the beginning of the report.

5.10 CONCLUSIONS

Based upon the information developed in the previous sections of the report, provide a conclusion for each item included within the scope of work for the detailed assessment.

5.11 RECOMMENDATIONS

Present at least one recommendation for each item outlined within the original scope of work, even if it is to do nothing. When applicable, provide schematic repair recommendations for each of the envelope's problems. Include the results of any life-cycle cost analysis. Clearly indicate problems that require immediate action and identify life safety concerns. Prepare a recommended program if appropriate for maintaining the continuing adequacy of the building envelope.

- *Commentary*—Conclusions and recommendations are based upon the survey, investigation, testing, and evaluation. These steps require experience and professional judgment. As such, they are not considered to be part of the standard, although they are the most important part of the report.

5.12 APPENDIXES

The appendixes should include all supporting data, such as survey information, record drawings, photographs, test data and reports, computations, and references.

APPENDIX A
REPORT OF THE CONDITION ASSESSMENT

(Not part of Standard)

1. EXECUTIVE SUMMARY (OPTIONAL)
2. INTRODUCTION
   - 2.1 PURPOSE OF ASSESSMENT
     - 2.1.1 Determine current conditions or deficiencies
       - (a) Life safety
       - (b) Performance
       - (c) Serviceability
       - (d) Durability
     - 2.1.2 Planning
       - (a) Maintenance
       - (b) Repairs
       - (c) Budgeting
     - 2.1.3 Change of owner
     - 2.1.4 Change of occupancy
     - 2.1.5 Refinancing
     - 2.1.6 Alterations or additions
     - 2.1.7 Code compliance
       - (a) Life safety
       - (b) Fire safety
       - (c) Strengthening for lateral and/or vertical forces
     - 2.1.8 Adaptive reuse, rehabilitation, or restoration
     - 2.1.9 Historic preservation
     - 2.1.10 Distress or failure—local or major
       - (a) System or material failure or damage
       - (b) Cracking, bulging
       - (c) Water intrusion: rot, freeze–thaw damage, ice, corrosion
       - (d) Fire
       - (e) Flood
       - (f) Wind: storm, tornado, hurricane
       - (g) Blast, impact, vibration
       - (h) Seismic event
       - (i) Subsidence, differential settlement, sinkhole, heaving, swelling soils
       - (j) Connection failure
       - (k) Deterioration, erosion, weathering
       - (l) Insect, rodent, or bird infestation
       - (m) Others
     - 2.1.11 Aesthetic concerns
       - (a) Weathering
       - (b) Staining
   - 2.2 SCOPE OF INVESTIGATION AND ASSESSMENT
     - 2.2.1 Types of assessment
       - (a) Cursory assessment or screening
       - (b) Preliminary assessment
       - (c) Detailed assessment
     - 2.2.2 Survey
       - (a) Corroboration of existing drawings
       - (b) Measured drawings or measurement of components
       - (c) Field evaluation of conditions (e.g., visual or probing)
       - (d) Identification of problem areas
       - (e) Record of observations (e.g., prints, matrix, photos, or tapes)
     - 2.2.3 Testing
       - (a) Nondestructive
       - (b) Destructive
       - (c) Special tests
   - 2.3 METHODS AND TECHNIQUES
     - 2.3.1 Visual—including binoculars, magnifying glass, borescope, and fiber optics
     - 2.3.2 Photography, X-ray, infrared thermography, ultrasonic, impulse-echo, impulse-radar
     - 2.3.3 Tapes—audio, video
     - 2.3.4 Drawings and sketches
     - 2.3.5 Measurement
     - 2.3.6 Investigation procedure and tests used
   - 2.4 MEETINGS
3. DESCRIPTION OF BUILDING ENVELOPE SYSTEMS
   - 3.1 GENERAL
     - 3.1.1 Type of architecture and facade
     - 3.1.2 Component systems
     - 3.1.3 Component materials
   - 3.2 HISTORY
     - 3.2.1 Dates of construction, alteration, and repair
     - 3.2.2 Past performance, maintenance procedures
     - 3.2.3 Environmental conditions
     - 3.2.4 Unusual behavior
   - 3.3 INPUT FROM OTHER DISCIPLINES
   - 3.4 COLLECTED DATA
     - 3.4.1 Available drawings, specifications, reports
     - 3.4.2 Newspaper and magazine articles
     - 3.4.3 Alteration documentation
     - 3.4.4 Photographs and tapes
     - 3.4.5 Measured drawings from survey
     - 3.4.6 Interviews of people familiar with building
4. DISCUSSION OF FIELD INVESTIGATION
   - 4.1 OVERVIEW—may be overview of entire engagement
   - 4.2 SURVEY
     - 4.2.1 Component systems
     - 4.2.2 Component materials
     - 4.2.3 Dimensions
     - 4.2.4 Deflections, distortions, deterioration
     - 4.2.5 Identification of problem areas

4.2.6 Record of data
  (a) Sketches and drawings
  (b) Notes
  (c) Photographs, X-rays, infrared scans
  (d) Tapes—audio, video
4.3 OBSERVATIONS AND THEIR SIGNIFICANCE
  4.3.1 General
  4.3.2 Limitations and qualifications
  4.3.3 Need for immediate repairs

5. TESTING PROGRAM
  5.1 NONDESTRUCTIVE METHODS
  5.2 DESTRUCTIVE METHODS
  5.3 SPECIAL TESTS
    5.3.1 System or component
    5.3.2 Methods
    5.3.3 Instrumentation

6. OFFICE OR LABORATORY ANALYSIS

7. SUMMARY OF STUDY
  7.1 FIELD
  7.2 OFFICE
  7.3 CODE CONFORMANCE (PAST AND PRESENT)

8. CONCLUSIONS

9. RECOMMENDATIONS

10. APPENDIXES
  10.1 ORIGINAL DRAWINGS AND SPECIFICATIONS
  10.2 SURVEY INFORMATION
  10.3 RECORD DRAWINGS
  10.4 PHOTOGRAPHS
  10.5 TEST DATA AND REPORTS
  10.6 COMPUTATIONS
  10.7 REPORT FROM OTHER DISCIPLINES
  10.8 REFERENCES

APPENDIX B
BUILDING EXTERIORS PERFORMANCE REFERENCES

The list of references given herein is not all-inclusive. Other references may be used as applicable.

AAMA: AMERICAN ARCHITECTURAL MANUFACTURERS ASSOCIATION, SCHAUMBURG, IL

AAMA 101/IS 2-97 (AAMA/NWWDA). *Voluntary Specifications for Aluminum, Vinyl (PVC), and Wood Windows and Glass Doors*.
AAMA 101/IS 2/NAFS-02 (ANSI/AAMA/WDMA). *Voluntary Performance Specification for Windows, Skylights, and Glass Doors—A North American Fenestration Standard*.
AAMA 307-05. *Voluntary Performance Requirements and Test Procedures for Laminates Intended for Use on AAMA Certified Plastic Profiles*.
AAMA 450-10. *Voluntary Performance Rating Method for Mulled Fenestration Assemblies*.
AAMA 501-05. *Methods of Test for Exterior Walls*.
AAMA 502-02. *Voluntary Specification for Field Testing of Windows and Sliding Glass Doors*.
AAMA 503-03. *Voluntary Specification for Field Testing of Storefronts, Curtain Walls, and Sloped Glazing Systems*.
AAMA 506-06. *Voluntary Specifications for Hurricane Impact and Cycle Testing of Fenestration Products*.
AAMA 507-12. *Standard Practice for Determining the Thermal Performance Characteristics of Fenestration Systems Installed in Commercial Buildings*.
AAMA 851-09. *Fenestration Sealants Guide for Windows, Window Walls, and Curtain Walls*.
AAMA 1503-09. *Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors, and Glazed Wall Sections*.
AAMA 1504-97. *Voluntary Standard for Thermal Performance of Windows, Doors, and Glazed Wall Sections*.
AAMA CW-RS-1-12. *The Rain Screen Principle and Pressure-Equalized Wall Design*, AAMA Aluminum Curtain Wall Series.
AAMA CW-DG-1-96. *Aluminum Curtain Wall Design Guide Manual*.
AAMA CW-10-12. *Care and Handling of Architectural Aluminum from Shop to Site*.
AAMA CW-13-85. *Structural Sealant Glazing Systems*.
AAMA CWG-1-89. *Installation of Aluminum Curtain Walls*.
AAMA GDSG-1-87. *Glass Design for Sloped Glazing*.
AAMA MCWM-1-89. *Metal Curtain Wall Manual*.
AAMA TIR A9-91. *Metal Curtain Wall Fasteners*.
AAMA WSG.1-95. *Window Selection Guide*.

ACI: AMERICAN CONCRETE INSTITUTE, FARMINGTON HILLS, MI

ACI 201.1R-08. *Guide for Conducting a Visual Inspection of Concrete in Service*.
ACI 222R-01 (Reapproved 2010). *Protection of Metals in Concrete against Corrosion*.
ACI 224R-01 (Reapproved 2008). *Control of Cracking in Concrete Structures*.
ACI 224.1R-07. *Causes, Evaluation, and Repair of Cracks in Concrete Structures*.
ACI 437R-03. *Strength Evaluation of Existing Concrete Buildings*.
ACI 504R-90. *Guide to Sealing Joints in Concrete Structures*.
ACI 515.1R-85 (withdrawn, discontinued by ACI and is available for informational purposes only). *Guide to the Use of Waterproofing, Dampproofing, Protective, and Decorative Barrier Systems for Concrete*.
ACI 523.1R-06. *Guide for Cast-in-Place Low-Density Cellular Concrete*.
ACI 523.2R-96. *Guide for Precast Cellular Concrete Floor, Roof, and Wall Units*.
ACI 530/530.1-13. *Building Code Requirements and Specification for Masonry Structures and Companion Commentaries*, TMS 402-13/ACI 530.1-13/ASCE 5-13.
ACI 544.1R-96 (Reapproved 2009). *Report on Fiber Reinforced Concrete*.
ACI 544.2R-89 (Reapproved 2009). *Measurement of Properties of Fiber Reinforced Concrete*.
ACI 544.3R-08. *Guide for Specifying, Proportioning, and Production of Fiber-Reinforced Concrete*.
ACI 544.4R-88 (Reapproved 2009). *Design Considerations for Steel Fiber Reinforced Concrete*.
ACI Compilation No. C10. *Repair and Rehabilitation of Concrete Structures*.

AF&PA: AMERICAN FOREST AND PAPER ASSOCIATION, WASHINGTON, DC

ANSI/AF&PA NDS-2012. *2012 National Design Specification (NDS) for Wood Construction*, American Wood Council.
ANSI/AF&PA SDPWS-2008. *Special Design Provisions for Wind and Seismic (SDPWS) with Commentary*, American Wood Council.
ASD/LRFD (2005). *Manual for Engineered Wood Construction*, 2005 Ed.

AISC: AMERICAN INSTITUTE OF STEEL CONSTRUCTION, CHICAGO, IL

Steel Construction Manual (2011). 14th Ed.

AISI: AMERICAN IRON AND STEEL INSTITUTE, WASHINGTON, DC

AISI S100-12. *North American Specification for the Design of Cold-Formed Steel Structural Members*.

AISI S202-11. *Code of Standard Practice for Cold-Formed Steel Structural Framing*.

ASCE: AMERICAN SOCIETY OF CIVIL ENGINEERS, RESTON, VA

ASCE 5-13. *Building Code Requirements for Masonry Structures*.

ASCE 6-13. *Specification for Masonry Structures*.

ASCE/SEI 7-10. *Minimum Design Loads for Buildings and Other Structures*.

SEI/ASCE 11-99. *Guideline for Structural Condition Assessment of Existing Buildings*.

ASCE 17-96. *Air-Supported Structures*.

ASCE (1982). *Evaluation, Maintenance, and Upgrading of Wood Structures*.

ASCE (1986). *Evaluation and Upgrading of Wood Structures: Case Studies*.

ASCE (1989). *Guidelines for Failure Investigation*. Task Committee on Guidelines for Failure Investigation.

ASTM: AMERICAN SOCIETY FOR TESTING AND MATERIALS, WEST CONSHOHOCKEN, PA

ASTM C42/C42M-13. *Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete*.

ASTM C67-13a. *Standard Test Methods for Sampling and Testing Brick and Structural Clay Tile*.

ASTM C509-06 (2011). *Standard Specification for Elastomeric Cellular Preformed Gasket and Sealing Material*.

ASTM C597-09. *Standard Test Method for Pulse Velocity through Concrete*.

ASTM C823/C823M-12. *Standard Practice for Examination and Sampling of Hardened Concrete in Constructions*.

ASTM C856-13. *Standard Practice for Petrographic Examination of Hardened Concrete*.

ASTM C864-05 (2011). *Standard Specification for Dense Elastomeric Compression Seal Gaskets, Setting Blocks, and Spacers*.

ASTM C876-09. *Standard Test Method for Corrosion Potentials of Uncoated Reinforcing Steel in Concrete*.

ASTM C920-11. *Standard Specification for Elastomeric Joint Sealants*.

ASTM C952-12. *Standard Test Method for Bond Strength of Mortar to Masonry Units*.

ASTM C1036-11e1. *Standard Specification for Flat Glass*.

ASTM C1072-13. *Standard Test Methods for Measurement of Masonry Flexural Bond Strength*.

ASTM C1389-90e1 (withdrawn, replaced by E514), *Standard Test Method for Water Penetration and Leakage through Masonry*.

ASTM C1601-11. *Standard Test Method for Field Determination of Water Penetration of Masonry Wall Surfaces*.

ASTM D4580-12. *Standard Practice for Measuring Delaminations in Concrete Bridge Decks by Sounding*.

ASTM E105-10. *Standard Practice for Probability Sampling of Materials*.

ASTM E122-09e1. *Standard Practice for Calculating Sample Size to Estimate, with Specified Precision, the Average for a Characteristic of a Lot or Process*.

ASTM E283-04 (2012). *Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors under Specified Pressure Differences across the Specimen*.

ASTM E330-02 (2010). *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights, and Curtain Walls by Uniform Static Air Pressure Difference*.

ASTM E331-00 (2009). *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform Static Air Pressure Difference*.

ASTM E514-11. *Standard Test Method for Water Penetration and Leakage through Masonry*.

ASTM E518-10. *Standard Test Methods for Flexural Bond Strength of Masonry*.

ASTM E547-00 (2009). *Standard Test Method for Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls by Cyclic Static Air Pressure Difference*.

ASTM E774-97 (withdrawn 2006, no replacement). *Standard Specification for the Classification of the Durability of Sealed Insulating Glass Units*.

ASTM E783-02 (2010). *Standard Test Method for Field Measurement of Air Leakage through Installed Exterior Windows and Doors*.

ASTM E987-88 (2009). *Standard Test Methods for Deglazing Force of Fenestration Products*.

ASTM E1105-00 (2008). *Standard Test Method for Field Determination of Water Penetration of Installed Exterior Windows, Skylights, Doors, and Curtain Walls by Uniform or Cyclic Static Air Pressure Difference*.

ASTM E2112-07. *Standard Practice for Installation of Exterior Windows, Doors, and Skylights*.

ASTM E2128-12. *Standard Guide for Evaluating Water Leakage of Building Walls*.

ASTM E2270-13. *Standard Practice for Periodic Inspection of Building Facades for Unsafe Conditions*.

ASTM F588-07. *Standard Test Methods for Measuring the Forced Entry Resistance of Window Assemblies, Excluding Glazing Impact*.

ASTM F842-13. *Standard Test Methods for Measuring the Forced Entry Resistance of Sliding Door Assemblies, Excluding Glazing Impact*.

ATC: APPLIED TECHNOLOGY COUNCIL, REDWOOD CITY, CA

ATC-21 Report, FEMA 154 (2002). *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Handbook*, 2nd Ed.

ATC-21-1 Report, FEMA 155 (2002). *Rapid Visual Screening of Buildings for Potential Seismic Hazards: Supporting Documentation*, 2nd Ed.

AWPA: AMERICAN WOOD PROTECTION ASSOCIATION, BIRMINGHAM, AL

AWPA Book of Standards (2013).

AWS: AMERICAN WELDING SOCIETY, DORAL, FL

ANSI/AWS D1.1/D1.1M (2010). *Structural Welding Code-Steel*, 22nd Ed.

ANSI/AWS D1.4/D1.4M (2011). *Structural Welding Code-Reinforcing Steel*.

BIA: BRICK INDUSTRY ASSOCIATION, RESTON, VA

Technical Notes on Brick Construction. http://www.gobrick.com/TechnicalNotes/LinkstoTechnicalNotes/tabid/11294/Default.aspx

CSSB: CEDAR SHAKE AND SHINGLE BUREAU, SUMAS, WA

Exterior and Interior Wall Manual (2011). http://www.cedarbureau.org/cms-assets/documents/37201-764816.wallmanual-2011.pdf.

New Roof Construction Manual (2011). http://www.cedarbureau.org/cms-assets/documents/30985-306719.roof-manual-011.pdf.

FMG: FM GLOBAL, JOHNSTON, RI

Approval Guide: A Guide to Equipment, Materials & Services Approved by Factory Mutual Research Corporation for Property Conservations (2006). CD-ROM.

ANSI FM 4474-2004 (R2010). *Evaluating the Simulated Wind Uplift Resistance of Roof Assemblies Using Static Positive and/or Negative Differential Pressures*.

ANSI FM 4880-2001 (R2007). *Evaluating Insulated Wall or Wall and Roof/Ceiling Assemblies, Plastic Interior Finish Materials, Plastic Exterior Building Panels, Wall/Ceiling Coating Systems, Interior and Exterior Finish Systems*.

GA: GYPSUM ASSOCIATION, HYATTSVILLE, MD

GA-231-06 (2006). *Assessing Water Damage to Gypsum Board*.

GA-235-10 (2010). *Gypsum Board Typical Mechanical and Physical Properties*.

GA-600-12 (2012). *Fire Resistance Design Manual*, 20th Ed.

HUD: U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT, WASHINGTON, DC

Rehabilitation Guidelines

Guideline 8 (2000). *Guideline on Fire Ratings of Archaic Materials and Assemblies*.

Guideline 9 (1983). *Guideline for Structural Assessment*.

Guideline 10 (1983). *Guideline on the Rehabilitation of Walls, Windows, and Roofs*.

Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing (1995).

Residential Rehabilitation Inspection Guide (2000).

ICC: INTERNATIONAL CODE COUNCIL, WASHINGTON, DC

International Building Code (2012).

International Existing Building Code (2012).

International Property Maintenance Code (2012).

International Residential Code for One- and Two-Family Dwellings (2012).

NCMA: NATIONAL CONCRETE MASONRY ASSOCIATION, HERNDON, VA

TEK Manual for Concrete Masonry Design and Construction (2012). CD-ROM.

NFPA: NATIONAL FIRE PROTECTION ASSOCIATION, QUINCY, MA

NFPA 101 (2012). *Life Safety Code*.

NFPA 101 (2012). *Life Safety Code Handbook*.

NRCA: NATIONAL ROOFING CONTRACTORS ASSOCIATION, ROSEMONT, IL

The NRCA Building Codes Manual, 3rd Ed. (2006).

The NRCA Roofing Manual: Architectural Metal Flashing, Condensation and Air Leakage Control, and Reroofing-2010.

The NRCA Roofing Manual: *Membrane Roof Systems-2011*.

The NRCA Roofing Manual: *Metal Panel and SPF Roof Systems-2012*.

The NRCA Roofing Manual: *Steep-Slope Roof Systems-2013*.

The NRCA Waterproofing Manual (2005).

Repair Manual for Low-Slope Membrane Roof Systems (1997).

PCI: PRECAST/PRESTRESSED CONCRETE INSTITUTE, CHICAGO, IL

Architectural Precast Concrete, 3rd Ed. (2007).

PCI Committee on Glass Fiber Reinforced Concrete Panels (1981). "Recommended Practice for Glass Fiber Reinforced Concrete Panels," *Journal of Prestressed Concrete Institute*, Vol. 26, No. 1, Jan–Feb, 25–93.

PCI Design Handbook, Precast and Prestressed Concrete, 7th Ed. (2010).

SPRI: SINGLE PLY ROOFING INDUSTRY, WALTHAM, MA

ANSI/SPRI RP-4 (2008). *Wind Design Standard for Ballasted Single-Ply Roofing Systems*.

ANSI/SPRI WD-1 (2012). *ANSI/SPRI Wind Design Standard Practice for Roofing Assemblies*.

SPRI/NRCA (1992). *Manual of Roof Inspection, Maintenance, and Emergency Repair for Existing Single-Ply Roofing Systems*.

TMS: THE MASONRY SOCIETY, BOULDER, CO

MGD-6 (2010). *Masonry Designers' Guide*, 6th Ed.

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