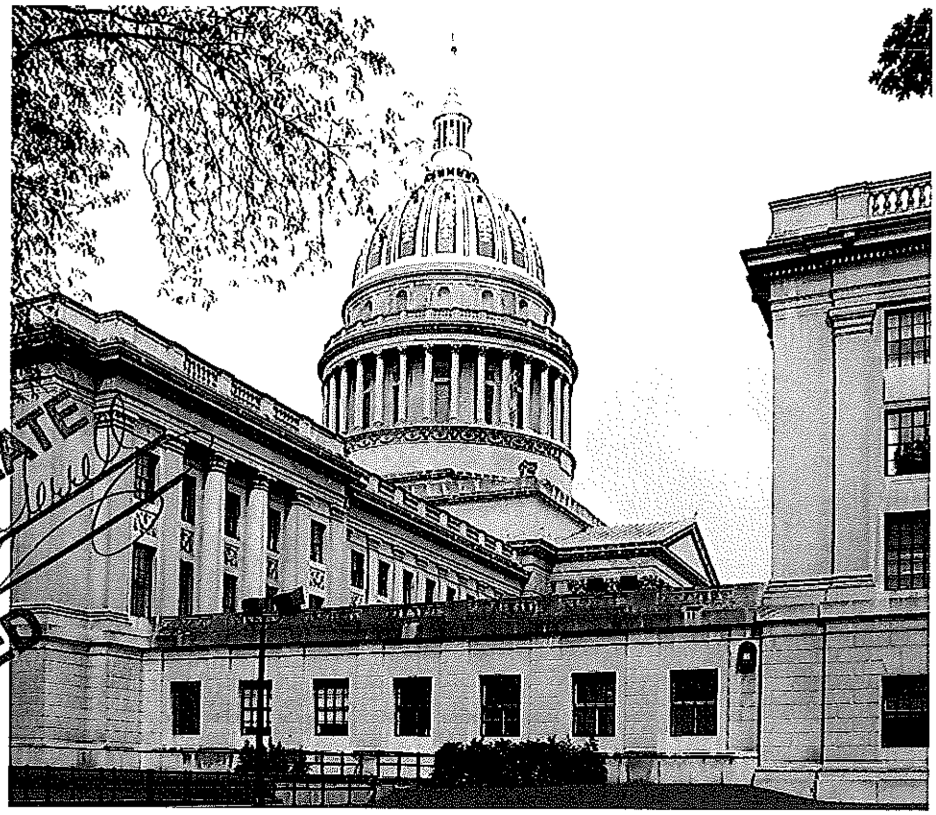
WJE

WEST VIRGINIA STATE CAPITOL
Request for Proposal for Roof Replacement
RFQ No. GSD 136423

West Virginia



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Request for Qualifications
January 14, 2013
WJE No. 2012.6389

Prepared for:
West Virginia State Capitol
Department of Procurement and Contracts
Department of Administration, Purchasing Division
2019 Washington Street East
Post Office Box 50130
Charleston, WV 25305-0130

Prepared by:
Wiss, Janney, Elstner Associates, Inc.
10 South LaSalle Street, Suite 2600
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax

WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

Wiss, Janney, Elstner Associates, Inc.
10 South LaSalle Street, Suite 2600
Chicago, Illinois 60603
312.372.0555 tel | 312.372.0873 fax
www.wje.com

Via: Federal Express

01/17/13 09:41:03 AM
West Virginia Purchasing Division

January 14, 2013

Department of Administration, Purchasing Division
2019 Washington Street East
Post Office Box 50130
Charleston, WV 25305-0130

Re: WJE Expression of Interest: West Virginia State Capitol Roof Replacement
RFQ No. GSD136423
WJE No. 2012.6389

To Whom It May Concern:

Wiss, Janney, Elstner Associates, Inc. (WJE) is pleased to respond to the Department of Administration, General Services of the State of West Virginia (Agency) request for qualifications for professional roofing consulting services including Addendums 1 and 2. We know we can make a positive contribution to the care and maintenance of the West Virginia State Capitol and appreciate your time in reviewing our team's qualifications. As we will demonstrate in our Expression of Interest we are uniquely qualified to provide professional services for projects of this technical detail, scope, size and on a building of such stature. The West Virginia State Capitol, constructed in 1924-1932, is an architectural gem. Designed by Cass Gilbert at the height of his career, it follows his Minnesota State Capital in 1905 and the Woolworth Building in 1912-13, which at the time of construction was the tallest building in the world. We are committed to the preservation of this "House of the People" and monument to Democracy.

3. Project and Goals

We understand the goal of the project is to provide a new roof system other than the river rock ballasted ethylene propylene diene monomer rubber (EPDM) roofing presently in place. The roof replacement will cover all flat roofs of the Capitol. Thus a complete tear off of existing roofing systems and insulation is anticipated. The project will include a new membrane, new insulation, new counterflashing at parapet terminations and other interruptions in the membrane, drainage and overflow. The roofing must be durable with a design life in excess of 25 years and be able to handle traffic and maintenance loads.

Part of the roof replacement project will be to upgrade the present access ramps that traverse the connector roofs to the east and west wings so that these ramps can be more durable and meet applicable safety requirements.

Finally gutter repairs and replacements are needed in selected locations. This is one part of the project that can affect the exterior appearance of this National Register property. Therefore these interventions will need to meet the criteria defined in the *Secretary of the Interior Standards* and match the historic appearance of the building.

5a. Concept

Starting decades ago our founder, Jack Janney, was known to say, "Ask the structure." This straightforward advice continues to guide WJE professionals. Our fundamental philosophy remains to develop the best solutions based on an accurate diagnosis of a structure's unique problems. Our considered concept to deliver this project is included in Appendix 5a.

5b Firm and Team Qualifications

WJE is an interdisciplinary group of architects, structural engineers, and material scientists specializing in investigation and design of repairs for distressed conditions in historic and contemporary buildings. With our extensive in house laboratories we could address all aspects of your project in-house. The firm's headquarters are in Northbrook, Illinois, with offices in nineteen other cities throughout the United States, including our branch offices in Washington DC and Cleveland, Ohio. We have been in business since 1956 and have successfully served thousands of clients on large projects and have the capacity to complete a project of such scope as the West Virginia State Capitol Roof Replacement.

The professionals at WJE have extensive experience in the evaluation of roofing and waterproofing system problems, are leaders in this field, and have worked on more than seven hundred roofing and waterproofing projects. Our extensive expertise in the investigation, evaluation, and repair design of roofing systems makes WJE uniquely qualified to perform the work required for the West Virginia State Capitol.

WJE are recognized experts in technical preservation. We have consulted on numerous state Capitols and are aware of the unique political pressures and territorial understandings of these projects.

A more complete description of our Firm Qualifications is included in Appendix 5b.

Team Leader: Stephen J. Kelley. AIA, SE, NCARB. Kelley is a Principal in the Chicago office. Mr. Kelley is an architect and structural engineer with extensive experience working on State Capitols and other Government buildings, is a nationally recognized preservation specialist, and has experience in the management of multi-disciplinary teams working on unique projects of all sizes. Mr. Kelley will be the point of contact for the WJE team. His contact information is as follows:

Mr. Stephen J. Kelley
Wiss, Janney, Elstner Associates, Inc.
10 South LaSalle Street, Suite 2600
Chicago, IL 60603
Office: (312) 325-0917
Mobil: (312) 560-0697
Email: skelley@wje.com

Roofing Specialist: Richard S. Koziol, AIA, NCARB. Mr. Koziol is a Principal in the Northbrook, Illinois office. Mr. Koziol has completed over 1,000 water leakage investigations since 1983 and is a nationally recognized authority on roofing system evaluation, repair, and replacement. Mr. Koziol has authored several articles and papers on roofing and plaza system technology.

Production: Clarissa Kenney, PE. Kenney is a Senior Associate in our Washington, DC office. Ms. Kenney has significant experience with consulting with the executive and legislative branches of the federal government and has delivered large projects on time and within budget.

Project Materials Scientist: Brad Shotwell. Mr. Shotwell is an Associate Principal in the Cleveland office. He is a petrographer with extensive experience studying building materials. Active in the field for over 35 years. Mr. Shotwell is a member of ASTM Committee C09.65 - Petrography.

The Resumes of Mr. Kelley, Mr. Koziol and Ms. Kenney along with the resumes of the project delivery team: Carole Ceja, RA in the Chicago office; Blake Kreuer, PE in the Cleveland office; Darin Rickert, RA in the Northbrook office; and Jason Sanchez, AIT in the Washington DC office and selected publications of Mr. Koziol are included in the attached Appendix 5b.

WJE understands that any and all work produced as a result of the contract will become property of the Agency and can be used and shared by the Agency as deemed appropriate.

5.c Project Organization

Team information and office location information has been provided above. The team organizational chart is included in Appendix 5c.

WJE has the expertise, experience and ability to provide professional services to successfully deliver the West Virginia State Capitol Building roof replacement project in its entirety.

5.d Demonstrated Experience

The following projects have been selected as being pertinent to the West Virginia State Capitol and are representative of similar projects that we have performed nationwide. Project Profiles of these projects are also included in Appendix 5d.

Nebraska State Capitol

- Replacement of extensive flat seam and standing seam copper roofs, protected membrane exterior promenades; waterproofing of four monumental entrances; and waterproofing of the tile dome of a National Register property.
- Project size: 100,000 square feet
- Name of owner including phone number and address: Robert Ripley; Office of the Capitol Commission; State Capitol 7th Floor; PO Box 94696; Lincoln, NE 68509-4696. Telephone: 402-471-0419
- Date of Completion or percentage of work completed: Roof Replacement completed 2010.

Eisenhower Executive Office Building

- Diagnosis and repair of a large flat seam copper roof and connection to surrounding standing seam copper, slate, and cast iron roofing systems on a National Register property over a three year period while the highly secure building remained operational.
- Project size: Classified, very large
- Name of owner including phone number and address: Executive Office of the President does not accept calls. Architect is AECOM, Greg Hall; 109 South Jefferson Street; Suite 1600; Roanoke, Virginia 24011. Telephone: 540-857-3223
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Fargo Dome

- Provided diagnosis, design and construction observation services on a large roofing replacement
- Project size: 200,000 square feet
- Name of owner including phone number and address: City of Fargo, 200 3Rd St. N. Fargo, ND. Telephone: 701-241-1310
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Kentucky State Capitol

- Dismantlement of the terra cotta dome on a National Register property to replace the water proofing membrane beneath and then reinstallation of dome with original and new terra cotta units.
- Project size: 5,000 square feet (area of dome)
- Name of owner including phone number and address: All State contacts have retired. Architect is KNBA; Steve Eggers; 611 West Main Street; Louisville, KY 40202. Telephone: (502) 582-2500
- Date of Completion or percentage of work completed: Dome repairs and master plan study completed in 2000.

McLean County Courthouse

- Investigation and replacement of sheet metal dome and restoration of limestone facade
- Dome covers about 5000 square feet
- Name of owner including phone number and address : Owner: Mclean County; Jack Moody; 104 W. Front Street; P.O. Box 2400; Bloomington, IL 61702-2400. Telephone: 309-888-5192
- Date of completion: 2009

Minneapolis Central Library

- Diagnoses of water leakage problems on new facility and repair design to address water leakage at the extensive gutter assemblies.
- Project size: 30,000 square feet
- Name of owner including phone number and address: Minneapolis Central Library, 300 Nicollet Mall, Minneapolis, MN. Telephone: 612-543-8000
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Candler Building

- Diagnosis and restoration recommendations terra cotta and marble facade elements on a National Register property.
- Project size: 50,000 square feet
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Soaring Eagle Lodge

- Peer review of building envelope prior to construction and water leakage during construction
- Project size: four-story hotel/condominium/restaurant facility
- Name of owner including phone number and address: Owner is Intrawest. However we were retained by Branch and Associates; Paul O'Keef; 5732 Airport Road NW; Roanoke, VA 24012. Telephone: 540-989-5215
- Date of Completion: 2008

Expedition Station

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Within the final tab of this proposal you will find Addenda 1 and 2 signed by the firm's contact person who will be responsible for the project.

Please contact us if you have any questions regarding our enclosed submittal. Thank you for considering our firm for this project.

Sincerely,

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Stephen J. Kelley
Principal

SJK:laa

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Sincerely,

WISS, JANNEY, ELSTNER ASSOCIATES, INC.

Stephen J. Kelley
Principal

SJK:laa

Enclosures

5a. Concept for Approach to Addressing Issues and Concerns with the West Virginia State Capitol Roof Replacement

Diagnosis

The focus of our diagnosis of the flat roofs of the State Capitol would be to gain a better understanding of concealed conditions and the structure and to develop the best details for roof replacement. Work would commence in late Winter or early Spring 2013, weather permitting. Our diagnostic plan would include the following elements:

- Meet with Agency representatives and maintenance staff in order to understand the specific concerns with the present roof and to establish collaboratively the specific needs, expectations and goals for the project.
- Review available archival documentation relative to the roof structure, present roofing systems and previous repairs and leakage problems.
- Perform an investigation to visually inspect the roof, drainage systems, scuppers and parapets. Parapets are particularly important and should be carefully considered in any roof rehabilitation project. We would also inspect the underside of the concrete roof decks, where possible, to determine their possible condition. In addition inspection openings would be created through the roof membrane to view the existing roof assembly composition and materials and examine the top surface of the roof deck.
- Determine the relative expected strength of the present concrete roof deck which may inform us on the appropriateness of potential roofing replacement systems.
- Check the building code requirements in IBC 2009 and the IECC 2003 and other pertinent West Virginia building codes in order to comply with the legal requirements of roofing system replacement.

Development of Appropriate Replacement Roof Systems

Once we have developed a diagnosis and preliminary recommendations for replacement we would prepare a summary PowerPoint report to present to the Agency in a "workshop type" setting. This would occur in Spring 2013. In the presentation we would discuss protected membrane assemblies (PMA) and exposed membrane configurations and would explore the advantages and disadvantages of the various roofing systems (cost, compatibility with existing substrates, ease of installation, durability, odors, scheduling and sequencing requirements and so on). In this workshop we would collaboratively select those systems that are best suited to the unique needs of the building and its use.

We would then prepare design development drawings and specifications for review by the representatives of the Agency which, when approved, would be further developed into construction documents. Construction would begin in Summer 2013 and would most likely be a multi-year project.

We would also be please to aid in project bidding and construction observation.

WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

5b. WJE General Qualifications

WJE is a professional firm providing practical, innovative, and technically sound solutions to structural, architectural, and materials problems. WJE is an interdisciplinary group of architects, structural engineers, and material scientists specializing in investigation, analysis, testing, and design of repairs for distressed conditions in historic and contemporary buildings and structures. We also provide specialized consulting services prior to construction to reduce the potential for the development of distress conditions in new buildings. The firm's headquarters are in Northbrook, Illinois, with offices in nineteen other cities throughout the United States, including our branch offices in Washington, DC and Cleveland, OH.

Since 1956, WJE has served more than thirty-five thousand clients, from individuals to large corporations and government agencies. Experience gained from investigation of thousands of distressed structures, together with extensive in-house laboratory testing capabilities, permits WJE to offer superior professional services in the evaluation of existing structures. For new or aging buildings and structures, WJE provides field and laboratory investigation, testing, analysis, and repair and rehabilitation design. Services include development of technical specifications, drawings, and construction observation for structural repairs, facades and roofs, fenestration and protection systems.

WJE's experience in building diagnostics is based on a sound understanding of the behavior and performance of materials and systems, which is supported by technical expertise in testing and instrumentation. The WJE in-house laboratory facilities offer state-of-the-art structural and materials test facilities and equipment for construction-related investigations, instrumentation, and research. WJE's experienced laboratory personnel are recognized leaders in performing analyses and evaluations of construction-related materials, including chemical analysis, petrographic studies, and other materials and structural laboratory evaluation techniques. These facilities and capabilities distinguish WJE from other engineering and architectural consultant firms and allow our experts to understand why materials and structures fail. The WJE laboratories support our consulting services with field and laboratory testing of construction materials using nondestructive testing, chemical analysis, microscopic examination, and physical testing.

WJE Roofing Experience

The professionals at WJE have extensive experience in the evaluation of roofing and waterproofing system problems, are leaders in this field, and have worked on more than seven hundred roofing and waterproofing projects. Our services for this type of work include the following:

- Visual inspections and condition surveys
- Roofing/waterproofing failure investigations
- Wind uplift testing
- Roof core analysis and testing
- Thermographic, capacitance, and high and low voltage moisture surveys
- Roofing/waterproofing peer design reviews
- Familiarity with various types of roofing/waterproofing products, systems, and installation procedures
- Preparation of drawings and specifications
- Field observation during construction
- Expert testimony

Our extensive expertise in the investigation, evaluation, and repair design of roofing systems makes WJE uniquely qualified to perform the work required for the West Virginia State Capitol. Through our broad range of consulting experience and our inspection of hundreds of buildings, WJE has become well versed in various types of roofing systems, and we are aware of both their strengths and weaknesses under specific installations.

WJE is a national leader in building envelope investigation and repair. WJE personnel have developed many testing and instrumentation methods for the evaluation of building roof components and have leadership roles in the American Society for Testing and Materials in standards development. Based on testing and investigations, WJE develops repair designs and construction documents to address distress conditions observed.

The WJE team has significant experience working in occupied, functioning buildings to minimize conflict between investigation and construction activities and the operational activities. Examples of issues addressed include noise control, mitigation of fumes during reroofing, developing methods for physical separation of construction activities from user activities, and establishment of schedules to avoid inconvenience to building occupants and users. In addition to these construction phase controls, the WJE team is familiar with organizing and implementing investigation phase tasks to avoid intrusion to building users and visitors. WJE and our consultant firms regularly work on projects within functioning buildings. WJE works almost exclusively on existing buildings rather than new design, and the majority of our projects involve buildings that are occupied during investigation and construction work. Our consultant firms also work extensively with existing buildings, many of which are occupied.

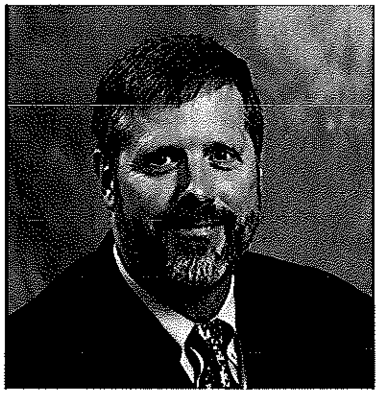
WJE Work on Historic Preservation and with State Government

WJE Architects and Engineers have significant experience with working on listed buildings and are recognized experts in technical preservation. We have been fortunate to consult on numerous state Capitols and are aware of the unique political pressures and territorial understandings that come to bear when performing work in buildings where there are powerful stakeholders representing the three branches of government. We are proud to have worked on the Colorado, Georgia, Idaho, Illinois, Kentucky, Minnesota, Nebraska, North Dakota, Virginia, Washington, and Wisconsin State Capitols.

WJE

PERSONNEL QUALIFICATIONS

Stephen J. Kelley | Principal



EDUCATION

- University of Illinois at Urbana-Champaign
  - Bachelor of Architecture, 1976
  - Master of Architecture, 1978

PRACTICE AREAS

- Brick, Stone, and Terra Cotta Deterioration
- Facade Cleaning
- Fire Damage Investigation
- Historic Preservation
- Historic Structures Reports
- Materials Conservation Analysis
- Repair and Rehabilitation Design
- Windows and Curtain Walls

REGISTRATIONS

- Architect in IL
- Structural Engineer in IL
- National Council of Architectural Registration Boards Certificate

PROFESSIONAL AFFILIATIONS

- American Institute of Architects (AIA)
- Association for Preservation Technology International (APT), fellow and past director
- International Council on Monuments and Sites (US/ICOMOS), fellow and past director

CONTACT

skelley@wje.com
312.372.0555
www.wje.com

EXPERIENCE

Since joining WJE in 1984, Stephen Kelley has developed expertise in the restoration of historic buildings and monuments. He has extensive experience in the area of skyscrapers; churches; facade cleaning; stone, brick, and terra cotta masonry; and curtain walls and windows. He has expertise in the analysis and conservation of historic building materials and systems including wood log buildings, plasters, and stained glass artwork. Mr. Kelley has investigated numerous historic churches that have been damaged by fire, wind, and floods.

Mr. Kelley's work in the area of preservation stretches from investigation, extensive use of laboratory techniques, coordination of all disciplines, document preparation, and construction observation. He has consulted on preservation projects in the former Soviet Union, Eastern Europe, and Asia. Mr. Kelley has lectured extensively in the United States, Europe, and Asia on aspects of technical preservation and has written numerous articles in journals and edited books on the topic.

REPRESENTATIVE PROJECTS

Facade Cleaning

- Georgia State Capitol - Atlanta, GA
- Tribune Tower - Chicago, IL
- Nebraska State Capitol - Lincoln, NE
- Holy Family Church - Chicago, IL: Structural stabilization and restoration of slate roofing
- Eisenhower Executive Office Building - Washington D.C.

Historic Preservation

- Nebraska State Capitol - Lincoln, NE: Restoration of facade and windows
- St. Cecilia's Cathedral - Omaha, NE: Restoration of tile roofing, facade, and interior sanctuary
- Basilica of St. Adalbert - Grand Rapids, MI: Restoration of tile roofing, facade, and stained glass
- Church of Our Savior of Berestove - Kyiv, Ukraine: Coordinator for development of restoration plan
- Eisenhower Executive Office Building, Washington, D.C.: Historic preservation specialist for 2004-2012 rehabilitation
- Gateway Arch - St Louis, MO : Technical study of corrosion
- Wood Log Church Survey - Eastern Slovakia: Development of master conservation for twenty-eight churches

Historic Structure Reports

- Kentucky State Capitol - Frankfort, KY
- Illinois State Capitol - Springfield, IL
- Gateway Arch - St. Louis, MO
- Old Courthouse - St. Louis, MO
- Central High School - Little Rock, AR

Repair and Rehabilitation Design

- Qasr al-Bint Temple Ruin - Petra, Jordan: Engineering feasibility study for seismic stabilization
- West Baden Springs Hotel - West Baden, IN: Structural stabilization after collapse
- Old St. Patrick's Church - Chicago, IL: Structural stabilization of wood truss system

Terra Cotta

- Reliance Building - Chicago, IL: Facade cleaning, restoration of facade and windows
- Carbide and Carbon Building - Chicago, IL: Facade cleaning, restoration of facade and windows
- Famous Barr Department Store - St. Louis, MO: Facade cleaning and restoration
- Midcontinent Tower - Tulsa, OK: Facade repair and maintenance

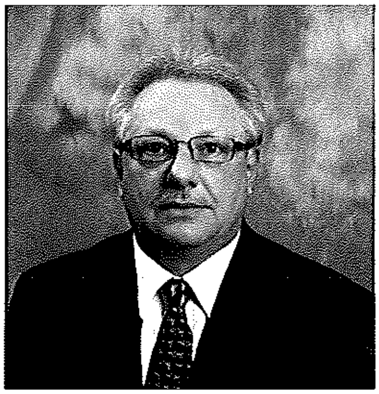
TECHNICAL COMMITTEES

- ASTM E06.24 - Building Preservation and Rehabilitation Technology (Chairman 1988 to 1998)
- International Science Committee on Analysis and Restoration Structures of Architectural Heritage (President 2008 - present)

WJE

PERSONNEL QUALIFICATIONS

Richard S. Koziol | Principal



EDUCATION
- University of Illinois, Chicago
  - Bachelor of Architecture, Architecture, 1980

PRACTICE AREAS
- Architectural Investigation
- Building Envelope Assessment
- Design Peer Review
- Plazas and Terraces
- Repair and Rehabilitation Design
- Roofing and Waterproofing and Condensation
- Water Penetration Testing

REGISTRATIONS
- Architect in FL, IL, MN, and NC
- NCARB Certified

PROFESSIONAL AFFILIATIONS
- American Institute of Architects (AIA)
- American Society for Testing and Materials (ASTM)
- Roof Consultants Institute (RCI)
- National Roofing Contractors Association (NRCA)
- Construction Specifications Institute (CSI)
- Chicago Roofing Contractors Association (CRCA)

CONTACT
rkoziol@wje.com
847.272.7400
www.wje.com

EXPERIENCE
Mr. Koziol joined WJE in 1983 and has since completed over a thousand investigations involving the evaluation of water infiltration problems in new and existing building envelopes. His experience includes a variety of roofs, plazas, foundations, masonry walls, EIFS, concrete, and window systems. He has developed designs and managed construction document preparation for repair of buildings experiencing deterioration, condensation, and/or water infiltration problems. His construction administration experience includes work on sensitive repair projects in occupied buildings that utilize a fast-track schedule. Field and laboratory testing experience includes durability and thermal movement studies for metal roofing systems, wind uplift testing of adhered roof systems and moisture surveys. He has provided expert testimony in over thirty cases involving a variety of roofing, wall and foundation waterproofing failures. He has served as consultant to architects, contractors, and owners in peer reviews of roofing and waterproofing systems. He has also investigated roof systems for wind and hail damage.

Mr. Koziol has authored several articles and papers on roofing systems, and made numerous technical presentations on roofing and plaza system technology to various groups.

REPRESENTATIVE PROJECTS
Building Envelope Assessment
- Peter B. Lewis Building at Case Western Reserve University - Cleveland, OH
- Arizona Science Center - Phoenix, AZ
- Bon Air Elementary School - Lower Burrell, PA
- Oakwood School - North Hollywood, CA
- Lake County Public Library - Merrillville, IN
- St. Chrysostom's Church - Chicago, IL

Repair and Rehabilitation Design
- FargoDome - Fargo, ND
- Park Hyatt Toronto - ON
- Myriad Convention Center - Oklahoma City, OK
- Jardine Water Purification Plant - Chicago, IL
- Oakwood School Math and Science Building - North Hollywood, CA
- Albion School - Albion, IL
- 116 South Michigan Avenue - Chicago, IL

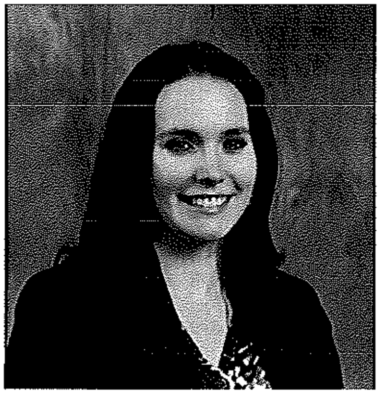
Roofing, Waterproofing, and Moisture Investigation
- One Financial Plaza - St. Louis, MO
- Hullston Hall, University of Missouri - Columbia, MO
- Wilson Trailer Plant - Yankton, SD
- Goldkist Foods Processing Plant - Boas, AL
- Franklin D. Roosevelt Drive - New York, NY
- Prairie State College - Chicago Heights, IL
- St. John's Health System - Springfield, MO
- Parkside Elementary School - Lawrenceville, IL
- Surf Club II and III Condominiums - Matanzas Shores, FL
- Central Middle School - Tinley Park, IL
- Sears Warehouse Building - Memphis, TN
- Depmeds Building at Hill Air Force Base - Ogden, UT
- Petsmart Distribution Center - Ottawa, IL
- Arizona Science Center - Phoenix, AZ
- Seminole County Sheriff's Office/Public Safety Building - Sanford, FL
- Alvin C. York VA Medical Center - Murfreesboro, TN

TECHNICAL COMMITTEES
- ASTM D08 - Roofing and Waterproofing
- ASTM E06 - Performance of Buildings

WJE

PERSONNEL QUALIFICATIONS

Clarissa S. Kenney | Senior Associate



EDUCATION

- The Catholic University of America
  - Bachelor of Science, Architecture, 2004
  - Bachelor of Civil Engineering, 2004

PRACTICE AREAS

- Condition Assessment
- Construction Administration and Observation
- Construction Documents and Specifications
- EIFS and Stucco Systems
- Facade Assessment and Recladding Design
- Failure Investigation
- Historic Preservation
- Leakage Investigation
- Masonry Structures
- Repair and Rehabilitation Design
- Roofing and Waterproofing
- Structural Evaluation
- Water Penetration Testing

REGISTRATIONS

- Professional Engineer in VA

PROFESSIONAL AFFILIATIONS

- Association for Preservation Technology International (APT)
- U.S. Green Building Council (USGBC)

CONTACT

ckenney@wje.com
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www.wje.com

EXPERIENCE

Since joining WJE in July 2004, Clarissa Kenney has completed condition surveys of multiunit residential and commercial building facades. Her focus lies in the area of existing structures, with an emphasis on historically significant buildings and structures. She has experience with a wide range of building materials, including clay brick and concrete masonry; granite, limestone; travertine; cast stone; cast-in-place concrete; exterior insulation and finish systems; architectural metal panels; terne-coated standing seam roofs; bituminous waterproofing; and glazed aluminum, wood and steel window units. She has been involved in the investigation and repair design of existing structures, including the development of repair drawings and specifications, as well as onsite construction observation and field testing services. She is currently gaining experience as a conservator and has had the opportunity to investigate and implement repairs on landmark structures listed on the National Register of Historic Places (NRHP).

REPRESENTATIVE PROJECTS

Facade Assessment

- Pocahontas Building (circa 1920s) - Richmond, VA: Evaluation of brick and limestone masonry building envelope and leakage investigation

Structural Evaluation

- Major Retail Chain - Various Locations Nationwide: Structural steel roof structure assessment and repairs
- Parking Garage No. 11 - Montgomery County, MD: Survey and evaluation of existing steel frame during restoration construction

Historic Preservation

- Eisenhower Executive Office Building (1888, NRHP) - Washington, D.C.: Historic investigation and documentation of interior and exterior historic building features
- Home Owners Loan Corporation (1928 / 1936, NRHP) - Washington, D.C.: Facade survey and investigation of historic metal window units, brick and limestone and granite panels; development of repair contract documents
- Navy Hill (1904 / 1932, NRHP) - Washington, D.C.: Facade survey and investigation of historic wood and metal window units, brick, and limestone panels
- Virginia Governor's Mansion and Cottage (1813, landmark designation on NRHP) - Richmond, VA: Investigation of water infiltration and evaluation of historic coatings and paint; development of restoration contract documents for chimney repairs and roof replacement and construction observation

Repair and Rehabilitation

- 2001 Pennsylvania Avenue - Washington, D.C.: Development of contract documents for brick, limestone, and cast stone repairs, and construction observation of facade repairs and cleaning
- Harbour Square Cooperative - Washington, D.C.: Design of expansion joint and waterproofing repairs and construction observation of repairs
- National Public Radio Building - Washington, D.C.: Investigation of travertine panel failure and existing anchorage conditions, supplemental anchorage design, development of repair contract documents, facade assessment, and construction observation of facade restoration
- Washington Tower - Arlington, VA: Evaluation of granite panel failure, redesign of granite panel anchorage system, development of repair contract documents, facade assessment, and construction observation of facade restoration

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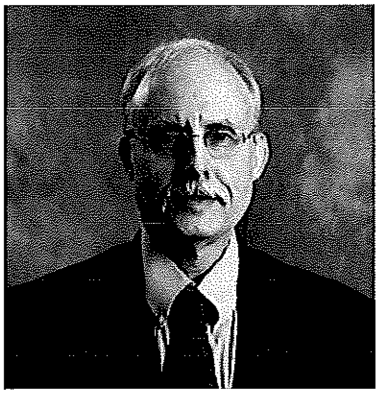
PERSONNEL QUALIFICATIONS

L. Brad Shotwell | Associate Principal



EDUCATION
- Kent State University
  - Bachelor of Science, Earth Science, 1971
  - Master of Science, Geology, 1973
  - Post-Graduate Training, Engineering Geology, Clay Mineralogy, and Groundwater Hydrology, 2004-2008

PRACTICE AREAS
- Petrographic Evaluation
- Microscopy
- Historic Preservation
- Facade Assessment
- Materials Evaluation and Research

REGISTRATIONS
- Professional Geologist in IL

PROFESSIONAL AFFILIATIONS
- American Concrete Institute (ACI)
- American Institute of Professional Geologists (AIPG)
- ASTM International (ASTM)
- Geological Society of America (GSA)

TECHNICAL COMMITTEES
- ASTM C09.65 - Petrography

CONTACT
bshotwell@wje.com
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www.wje.com

EXPERIENCE
Brad Shotwell provides materials testing and evaluation services. His current work includes petrography of concrete and concrete raw materials, mortars, plaster, dimension stone, and the application of petrographic techniques to solve materials problems. Mr. Shotwell has special expertise in petrography of early concrete structures for historic preservation. He has also developed a computer-assisted modified point-count apparatus used for air void system analysis of hardened concrete.

Prior to joining WJE, Mr. Shotwell performed numerous petrographic studies and managed petrographic laboratories for both a major construction materials manufacturer and a national materials testing laboratory. In this capacity, he performed failure analyses of concrete from a variety of structures and evaluations of aggregates for use in nuclear power plant construction, and approved raw materials for high-performance packaged grouts and mortars.

REPRESENTATIVE PROJECTS
Petrographic Evaluation of Concrete
- ASM International World Headquarters - Russell, OH: Petrographic evaluation of deteriorated concrete
- Cleveland Hopkins International Airport - OH: Petrographic evaluation of deteriorated concrete
- Kansas City International Airport - MO: Petrographic evaluation of distressed runway concrete

Petrographic Evaluation of Natural Stone
- Minnesota State Capitol - St. Paul: Field and laboratory evaluation of weathered marble cladding
- Swarthmore College - Swarthmore, PA: Evaluation of quarry in Switzerland proposed as a source for dimension stone
- Union Theological Seminary - New York, NY: Evaluation of dimension stone condition and of cast stone replacement material

Microscopy
- Bethany Village Center - Dayton, OH: Laboratory examination of distressed wood veneer panels

Historic Preservation
- Mississippi State Capitol, House and Senate Domes - Jackson: Field and laboratory studies of structural concrete elements of House and Senate domes
- New York Public Library, Main Branch: Field and laboratory petrographic evaluation of dimension stone and mortar repairs
- Perry's Victory and International Peace Memorial - South Bass Island, OH: Field examination and petrographic studies of historic concrete
- R.E. Lee Building - Jackson, MS: Field evaluation of pointing mortar deficiencies
- Perry's Victory and International Peace Memorial - South Bass Island, OH: Field examination and petrographic studies of historic concrete

Facade Assessment
- Nebraska State Capitol - Lincoln: Evaluation and documentation of various stone cleaning methods

AWARDS
- Association for Preservation Technology International, 2011 Oliver Torrey Fuller Award

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PERSONNEL QUALIFICATIONS

Carole M. Ceja | Associate III

EDUCATION

- University of Illinois at Urbana-Champaign
  - Bachelor of Science, Architectural Studies, 2004
  - Master of Architecture, Structures Option, 2006

PRACTICE AREAS

- Roofing and Waterproofing
- Leakage Investigation
- Repair and Rehabilitation Design
- Curtain Wall Systems
- Condition Assessment

REGISTRATIONS

- Architect in IL
- National Council of Architectural Registration Boards Certificate

PROFESSIONAL AFFILIATIONS

- ASTM International
- RCI, Inc.

CONTACT

cceja@wje.com
312.372.0555
www.wje.com

EXPERIENCE

Carole Ceja evaluates and repairs residential, commercial, and institutional buildings nationwide. Her practice areas include roofing and waterproofing, facade and curtain wall, water leakage and condensation, and structural components of these buildings. Ms. Ceja's projects focus on roofing and waterproofing systems–including single ply membranes, asphalt shingles, slate shingles, clay tiles, modified bitumen, sheet metal, and built-up roofing. She has expertise in nondestructive testing methods such as capacitance surveys, low-voltage and high-voltage integrity tests, infrared scanning, temperature and humidity monitoring, and water testing.

Based on evaluations she performs, Ms. Ceja develops repair designs and construction documents to correct building deficiencies. She also performs construction observation services of these projects to help assure that repairs are in compliance with plans and specifications.

REPRESENTATIVE PROJECTS

Roofing and Waterproofing

- Block Y - Chicago, IL: Low-slope roof evaluation, construction documents, and construction observation
- Duke University - Durham, NC: Tile roof evaluation, repair drawings, and construction observation
- Edward Don and Company - North Riverside, IL: Roofing condition survey and thermal scans
- Elmhurst Memorial Hospital - Elmhurst, IL: Slate roof evaluation and repair observation
- Renaissance Place - Highland Park, IL: Waterproofing repair drawings and construction observation
- Wisconsin Institutes for Discovery, University of Wisconsin-Madison: High voltage integrity testing roofing and waterproofing membranes

Leakage Investigation

- 900 Chicago Avenue - Evanston, IL: Residential water infiltration investigation
- University of Chicago Mitchell Pavilion - Chicago, IL: Curtain wall and plaza leakage investigation
- Veterans Park Elementary School - Lexington, KY: Condensation and leakage investigation

Repair and Rehabilitation Design

- Lord & Taylor - Schaumburg, IL: Expansion joint failure
- Pilgrim Baptist Church - Chicago, IL: Historic structure rebuild

Curtain Wall Systems

- 60 West Erie - Chicago, IL: Leakage investigation and repair design
- Hyatt Regency New Orleans - LA: Facade repair
- Ministry St. Clare's Hospital - Weston, WI: Condensation investigation and repair design

Condition Assessment

- St. Ita Parish - Chicago, IL: Exterior envelope Condition Assessment
- Stockyards Bank Building - Chicago, IL: Condition assessment

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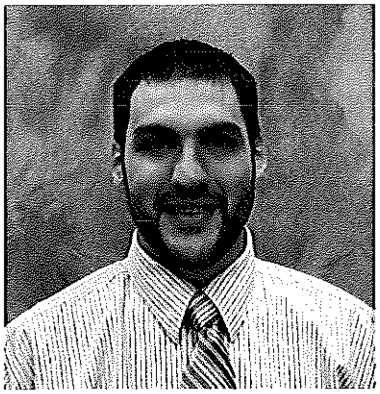
PERSONNEL QUALIFICATIONS

Blake R. Kreuer | Senior Associate



EDUCATION
- Cleveland State University
  - Bachelor of Science, Civil Engineering, 2004
  - Master of Science, Civil Engineering, 2006

PRACTICE AREAS
- Building Envelope Assessment
- Failure Investigation
- Roofing and Waterproofing
- Repair and Rehabilitation Design
- Nondestructive Evaluation

REGISTRATIONS
- Professional Engineer in OH
- Registered Roof Observer

CONTACT
bkreuer@wje.com
216.642.2300
www.wje.com

EXPERIENCE
Since joining WJE, Blake Kreuer has been involved in many structural and architectural investigations. These investigations include water leakage testing at windows and masonry walls; damage assessment of EIFS and stucco systems; existing roofing conditions; and evaluations of concrete, steel, and wood structures. Mr. Kreuer has also been involved in preparing construction documents and peer review of building enclosure systems.

Prior to joining WJE, Mr. Kreuer worked as a microscopist, identifying asbestos in roofing materials evaluating new and existing roofing systems. As a graduate student, Mr. Kreuer worked extensively on the research of specialty concretes including previous, internally cured and roller-compacted concrete and nondestructive evaluation techniques.

REPRESENTATIVE PROJECTS
Building Envelope Assessment
- Private Apartment Building - Cleveland, OH: Investigation of water leakage through windows and masonry wall
- West General Robinson Garage - Pittsburgh, PA: Investigation of grouted connections of precast wall panels

Roofing and Waterproofing
- National City Center - Cleveland, OH: Roof replacement and condition assessment
- Quicken Loans Arena - Cleveland, OH: Roof condition assessment
- Perry's Victory and International Peace Memorial - South Bass Island, OH: Roof replacement and condition assessment
- PNC Park at North Shore - Pittsburgh, PA: Repair of distressed sealant joints and expansion joints
- North Point - Cleveland, OH: Plaza and waterproofing renovation

Repair and Rehabilitation Design
- Canton Cultural Center Garage - Canton, OH: Structural condition assessment and repair design
- National Terminal Warehouse Apartments - Cleveland, OH: Structural condition assessment, repair design, construction phase services

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PERSONNEL QUALIFICATIONS

Darin C. Rickert | Senior Associate

EDUCATION
- University of Wisconsin-Milwaukee
  - Bachelor of Science, Architectural Studies, 2003

PRACTICE AREAS
- Building Enclosure Commissioning
- Peer Review
- Repair and Rehabilitation Design
- Facade Assessment
- Construction Observation Services
- Leakage Investigation
- Roofing and Waterproofing

REGISTRATIONS
- Architect in WI
- LEED Accredited Professional
- Registered Roof Consultant

PROFESSIONAL AFFILIATIONS
- American Institute of Architects (AIA) - Local Historic Resource Committee
- RCI, Incorporated
- Building Enclosure Council (BEC) - Wisconsin Chapter Planning Committee
- United States Green Building Council (USGBC)

CONTACT
drickert@wje.com
847.272.7400
www.wje.com

EXPERIENCE
Since joining WJE in 2007, Darin Rickert has performed building envelope assessments, leakage investigations, building envelope commissioning services, design peer reviews, and construction observation on a variety of new and existing structures. He has developed a number of repair and rehabilitation designs and has overseen construction administration for numerous commercial, residential, and industrial building assignments.

Prior to joining WJE, Mr. Rickert served as project manager with the firm of Inspec, Inc., where he specialized in all areas of exterior building envelopes and evaluated a variety of systems and materials, including precast concrete, exterior insulation and finish systems (EIFS), masonry, stone, glass, and various low-slope roofing systems. Mr. Rickert also served as project manager in support of facade ordinance inspections and historic restoration projects.

REPRESENTATIVE PROJECTS
Building Enclosure Commissioning
- Wisconsin Institutes for Discovery, University of Wisconsin-Madison: Terra cotta and metal panel open joint rain screen facade, aluminum and glass curtain wall, PVC roofing, and subgrade waterproofing

Peer Review
- 22 Washington Square North - New York, NY: Roofing, subgrade waterproofing, masonry, and windows
- 450 West Fourteenth Street - New York, NY: Roofing, subgrade waterproofing, masonry rehabilitation, and aluminum and glass window wall

Repair and Rehabilitation Design
- 98 Riverside Drive - New York, NY: Exterior wall masonry repairs and roof replacement
- 461 Park Avenue South - New York, NY: Exterior wall masonry repairs and roof replacement
- 670 West End Avenue - New York, NY: Exterior wall masonry repairs and roof replacement
- Northwestern Mutual - Milwaukee, WI: Precast concrete repairs and window replacement

Facade Assessment
- 10 West Seventy-fourth Street - New York, NY: Leakage investigation and facade assessment
- Beachwalk Landing Condominiums - Long Beach, NY: Facade, terraces, and parking garage assessment and leakage investigation
- University of Chicago: Multibuilding envelope assessments and repair recommendations
- Whitney Museum of American Art - New York, NY: Roof, facade, and plaza assessment

Construction Observation Services
- 200 East Sixty-second Street - New York, NY: Window and terrace door replacements
- Mitchell and Curtin Halls, University of Wisconsin-Milwaukee: Concrete facade restoration and exterior masonry stairway reconstruction
- Pierce Hall, University of Chicago: Brick and precast facade recladding
- Southside Hospital - Bayshore, NY: Masonry restoration and aluminum composite panel installation

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PERSONNEL QUALIFICATIONS

Jason A. Sanchez | Associate III

EDUCATION

- University of California, Berkeley
  - Bachelor of Arts, Architecture 2005

PRACTICE AREAS

- Architectural Field Investigation and Testing
- Building Design
- Building Envelope Assessment
- Construction Observation
- Litigation Support
- Repair and Rehabilitation Design
- Roofing and Waterproofing
- Windows and Curtain Walls

PROFESSIONAL AFFILIATIONS

- National Institute of Building Sciences (NIBS)

CONTACT

jsanchez@wje.com
703.641.4601
www.wje.com

EXPERIENCE

Since joining WJE in 2007, Jason Sanchez has contributed to a variety of projects, including architectural field investigations, roofing and waterproofing repair design, building façade repair and condition assessments, and construction observation and review.

Prior to joining WJE, Mr. Sanchez worked for the Architecture Department at the University of California, Berkeley. In that capacity, he worked for the dean's office on design-build improvement projects, which included the remodeling of the college's design studios. His duties included design, preparation of construction documents, construction review, and project management.

REPRESENTATIVE PROJECTS

Architectural Field Investigation and Testing

- Santana Row Condominiums - San Jose, CA: Investigation of water leakage of toilets in a new condominium complex
- Kaiser, Antioch - Antioch, CA: Water testing of newly installed windows in newly refurbished hospital
- Maxwell Elementary School and High School - Maxwell, CA: Leakage investigation and roof flood testing for newly installed HVAC units in three buildings

Building Design

- Church of Latter Day Saints - Modesto, CA: Aid in ADA compliant design retrofit for a church

Building Envelope Assessment

- MontBlue Casino and Resort - South Lake Tahoe, NV: Facade inspection of stucco and curtain wall and water testing of curtain wall and windows
- University of Texas Medical Building Galveston: Inspection of masonry facade, and onsite construction phase repair documentation and observation

Construction Observation

- Santana Row Condominiums - San Jose, CA: Rehabilitation of mold and black water damaged bathrooms in a new condominium complex
- Jamestown Condominiums - San Francisco, CA: Inspection of roofs, exterior facade, and retaining walls of a new condominium complex

Litigation support

- US Home Inspections - Sacramento, CA: Conducted multiple home inspections in a recently built subdivision for settlement purposes
- Sonoma County Junior College - Sonoma, CA: Review of construction documents for deposition preparation

Roofing and Waterproofing

- One Market Street - San Francisco, CA: Aided in the design and created all as-built and construction drawings for waterproofing of seventh floor patio's deck and planters
- West Hollywood Gateway Mall - West Hollywood, CA: Investigation of below-grade waterproofing and plaza waterproofing in a three story shopping mall

HISTORIC ROOF DECKS:

[ROOF DESIGN ISSUES AND CONSIDERATIONS]

By Richard S. Koziol, AIA, NCARB; and Christopher W. Giffin, AIA, NCARB

ABSTRACT

On many older buildings, frequent water leakage into the roof assembly over the years results in deterioration of the roofing system, structural deck, and exterior walls. Evaluation of the condition of the building components that interrelate with the membrane, especially flashings, is required for the successful installation of a new system. Simply replacing the membrane and disregarding direct or indirect issues such as deteriorated parapets, structural deck deficiencies, excessive deflection, drainage line corrosion, drainage system capacity, and conformance with current code requirements eventually results in poor stewardship of the assets that a historic property affords. It also supports short-term thinking that ultimately results in future performance problems and advanced and accelerated decay.

This paper focuses on problems and issues associated with substrate conditions that are hidden by materials and flashings and some of the pitfalls associated with them. Guidelines for evaluating the condition of masonry walls, lightweight concrete, and structural clay tile roof decks and their impact on performance are provided. Selection of the proper materials, given the condition of many older underlying substrates, is also discussed. In addition, the authors (based on their experiences) present suggested practices for obtaining a successful installation of a new roof system on an older, historic building.

WHY DO A THOROUGH INVESTIGATION?

Reroofing an historic structure should begin with a carefully thought-out plan so that a successful outcome will result for the building owner, designer, contractor, and general public. A thorough investigation should be the first step in developing a replacement program. The health, safety, and welfare of the building users are maintained if detailed and reliable information about as-built conditions is obtained, particularly for the roof deck. Reroofing specifications that are prepared based upon holistic interpretation and detailed knowledge of as-built conditions indicate to all concerned that the plan of action and approach to a project are professional, knowledgeable, and responsible. A prudent doctor would not proceed with surgery on a patient without running the necessary tests first to diagnose the problem. In fact, it may be considered professionally irresponsible for designers not to perform a thorough investigation of the interrelated roof system components to formulate a proper plan of action. The time invested in a detailed investigation is almost always recovered in more complete and accurate bids from contractors.

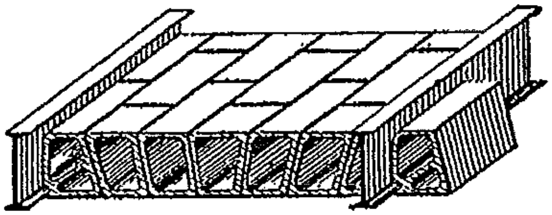
Through experience, the authors have found structural decks for historic structures to be relatively unique. When substrate conditions are properly assessed, a relatively small amount of unforeseen conditions will result in a construction project completed with relatively few change orders. Unpleasant surprises and cost extras are likely to occur if investigative activities are deferred to the construction phase.

Frequently, older structures have a history of prior leaks. The combination of deteriorated conditions at parapet walls and decks necessitates repair of these elements in conjunction with the roofing system replacement to achieve a successful project outcome. An inspection of interior spaces and attics will help to reveal areas of leakage. Water stains on wall and ceiling surfaces can be carefully recorded and superimposed with the relative position of specific areas of the roof. Focusing investigative attention on the areas of apparent deterioration increases the likelihood that worst-case scenarios will be revealed.

Inspection openings in the roofing system are necessary to identify the type and number of membrane layers, how the system is attached to the deck, whether insulation is present and what type was used, and the condition of the top surface of the structural deck. The openings should be relatively large so that a reasonable examination of the top surface of the deck can be made. Selecting an opening adjacent to a parapet wall has the benefit of revealing the condition of the wall below the flashing as well as the roof deck-to-wall interface. Conditions uncovered may substantially influence the new flashing design.

In many older buildings, the original architects designed the roof structure with liberal slope for drainage. Typically, low-slope decks employing masonry or cementitious materials were protected by built-up

Figure 1 – Typical assembly of flat and segmental clay tile arch systems.



View of 12½-in tile arch between 15-in I beams. Weight, 45 lbs per sq ft.

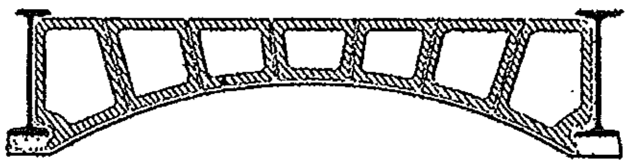
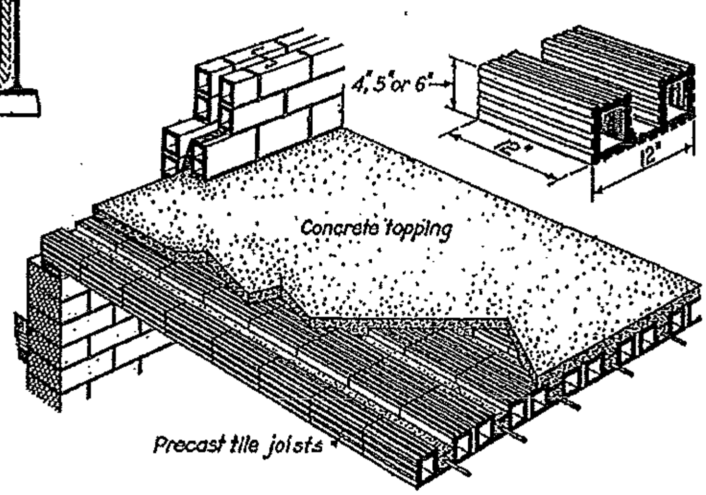


Figure 2 – Typical combination clay tile and integral concrete topping roof-deck system.



coverings or sheet metal. A common practice was to utilize an organic felt bituminous-membrane system adhered directly to the deck, without rigid insulation. In our experience – and depending on the age of the structure – it is not unusual to discover several membrane layers applied one over the other, sometimes with rigid insulation installed between some of the layers, as well. Also, older building designs often include attic spaces. Attic spaces have the benefit of accommodating access to mechanical, plumbing, and electrical services.

In our experience, roof drainage was given careful attention and consideration in many older buildings. The manner in which slope was achieved was either through sloping the structural system or by adding slope. Frequently, loose cinders were used as sloped fill over the structural deck, similar to today's factory-tapered insulation. Saddles and crickets were often made from wood and/or cementitious fills.

TYPICAL SUBSTRATES CIRCA 1900

Common materials used for roof substrates in older historic buildings included structural clay tile, lightweight concrete decks, precast gypsum planks, and masonry parapets. This paper focuses on structural clay tile and lightweight concrete decks and the interaction of these decks with masonry walls.

Structural clay tile is characterized by machine-made hollow units with parallel spaces. These units were available in a variety of shapes and sizes. Tiles were first manufactured around 1875. Several floor and roof designs were patented during this time. In 1903, the National Fireproofing Corporation of Pittsburgh published a handbook and catalogue illustrating products and presenting data for use in the design of segmental and flat-arch floors. The dead weight of structural clay tile systems often ranged from 35 to 45 lbs/sq ft. The main advantages provided by these floor and roof systems were ease and speed of erection (independent of temperature limitations), and fireproofing for structural steel framing. Structural clay tile may be classified into four groups:

- Flat arch
- Segmental arch
- Combination tile and concrete
- Book tile

Flat-arch and segmental-arch systems rely upon arch action for strength and rigidity. For these arches, tiles are placed between steel beams, forming a flat arch. *Figure 1* illustrates both of these.

Combination systems rely upon the composite interaction of clay tile units, concrete, and steel reinforcing bars to carry tensile and bending stresses, as shown in *Figure 2*. These decks often utilized a 2-in-thick plain or cinder concrete topping over the clay tile as a composite component of the roof-deck system. The combination system is analogous to a modern-day concrete pan joist or waffle slab structural system.

Book tiles are relatively large structural tile units that are supported by steel purlins with the sides held in place with steel T-bracing, as shown in *Figure 3*. Book tile was primarily intended for use on steep roofs, but they may be found on flat roofs, also. The name "book tile" refers to the shape of the tile, in that it resembles a closed book. The strength of the tile unit resists tensile and bending stresses.

On some structural clay tile roofs, a mortar or concrete topping, typically 1 to 2 in thick, was often field-applied over the tiles as a leveling and bedding layer. This was done to provide a smooth, uniform, and monolithic surface on which to install the roof membrane. During demolition of a roofing membrane from this deck, care needs to be taken during chipping or sawing to avoid potentially damaging the clay tile units and compromising the combined tile/arch integrity.

LIGHTWEIGHT CONCRETE

Lightweight concrete for roof decks can be characterized either by cast-in-place or precast material that can be classified into the following three groups:

- Cinder concrete
- Nailing concrete

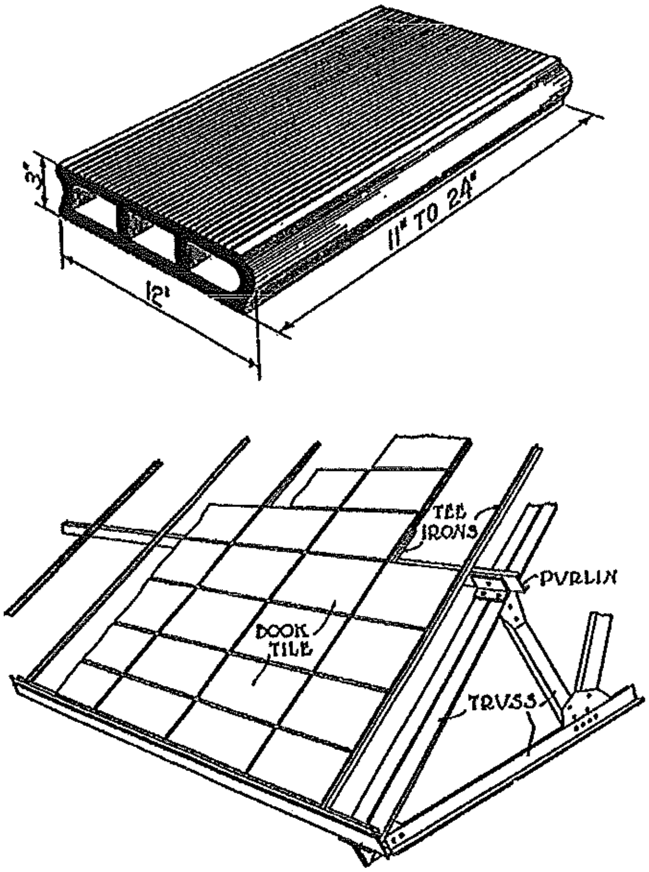


Figure 3 – Typical steep-slope application of clay book tiles.

- Sloped cinder fill and cementitious topping

Cinder concrete is a low-quality, lightweight, structural concrete that utilizes cinders as the primary aggregate. A commonly employed mix is one part cement, two parts sand, and five parts cinder. Cinder aggregate is a by-product of coal combustion and it is highly porous and cellular in nature. Cinder concretes have also been used as sloped fills over normal-weight concrete. Some cinder concretes have high sulfur contents, which are deleterious to steel. A nonstructural application for roofs utilizes loose cinders graded in a sloped configuration for drainage and then capped by a thin concrete or mortar topping, which provides a smooth surface for the roof membrane.

Proprietary lightweight concretes have been available under the trade names of "Federal nailing concrete," "Haydite concrete," and "Porete slabs." These systems were either poured in place or precast, with their chief benefits including speed of installation and nail-holding ability for attaching built-up membrane on low slopes and slate and clay tile on steep slopes. In precast systems, joints were grouted, and a thin cementitious topping may or may not have been installed, depending upon requirements. The precast systems were made in a channel configuration and had untopped thicknesses typically varying from 2¾ to 3½ inches.

Sloped cinder fill systems are nonstructural, field-made substrates for flat roofs that were placed over structural concrete slabs to provide slope for drainage. Cinders were loosely placed and graded to the required configurations and then topped by concrete or mortar, usually 1½ to 2 in thick. The topping would normally have a built-up membrane applied directly to its surface. A cinder-fill deck provides limited insulating capacity for the roof system. A drawback with sloped cinder fills is that water can collect within the cinder fill layer. When making an inspection opening, beware that the thin, poured concrete or mortar layer over the cinders may visually appear as though the deck is structural concrete. If a cementitious surface is observed at an inspection opening, it may or may not be the actual structural surface of the deck. Rather, it may be a nonstructural concrete or mortar topping. Chipping the cementitious surface should be done because it may help reveal if the surface onto which the membrane is applied is structural or nonstructural.

MASONRY PARAPETS AND WALLS

Parapet walls were often built as multiwythe masonry without cavities, frequently three to four brick wythes thick. Stone masonry and terra cotta were also used on parapets. Typically, the interior surfaces incorporated common brick masonry or rubble fill. Stone coping units or terra cotta tile were selected to cap the top of the parapet walls. The interface of the horizontal surface of the roof membrane with the vertical flashing surfaces of parapet walls often included a through-wall metal flashing system. This system is intended to prevent moisture within the wall system from entering the roof system or the building and is a good detail that is not utilized in today's construction as often as it should be.

Concealing or covering the through-wall flashing with roofing material is a common problem that leads to the early deterioration of both the roof system and masonry. In order to keep the roof system dry, the flashing terminations must be below the line of the through-wall flashing so that water within the wall does not drain into the roof system. Many older structures have the through-wall flashing positioned such that the minimum contemporary industry standard flashing clearance of eight inches cannot be achieved without terminating the flashing above the line of the existing through-wall flashing.

An evaluation of the condition of the parapet walls is critical when designing a roof-replacement project. Good roofing practice dictates that any reroof flashing should never be terminated above the line of a masonry through-wall flashing. A new through-wall flashing assembly could be installed at a higher position in the wall by reconstructing the wall. Another problem is encapsulating the entire inside surface of a tall parapet with roofing material. Covering the entire surface of the masonry with roof membrane flashing is contrary to good masonry practices and, in northern climates, can accelerate deterioration of the masonry. Over time, water infiltration, cyclic freeze-thaw damage, and efflorescence cause corrosion of embedded steel. (See *Figure 4.*)

Stair stepping the flashing along the parapet keeps the height within recommended industry standards, while allowing the masonry above the flashing to breathe. It may be necessary to locally remove sections of the masonry parapet and install a stair step design to maintain sufficient vertical height for membrane base flashings.

TYPICAL PROBLEMS ASSOCIATED WITH SUBSTRATES

Deterioration of the structural deck and parapet wall or corrosion of embedded steel components is usually attributable to moisture infiltration. Other causes may include building movement from either expansion/contraction or settling over time, or interior conditions that may contribute to

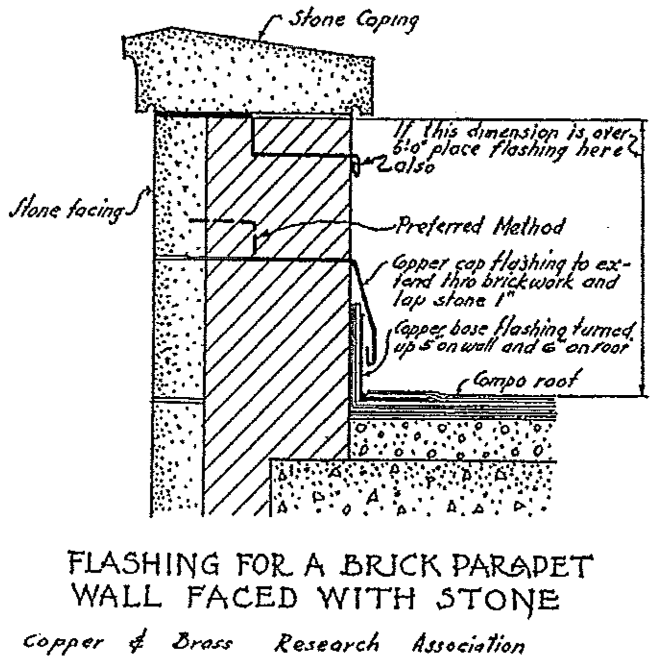


Figure 4 - A typical lightweight concrete topping course applied on a concrete structural slab.

condensation. Often, because of the type of construction, water leakage into the building may go unnoticed for an extended period of time. *Figure 5* highlights the many paths water can travel before it leaks into the interior spaces.

Deterioration of the mortar joints is a common problem in masonry parapets. Identifying the quantity and location where repointing work or brick replacement is needed will often avoid potentially costly change orders. If a through-wall flashing system is deteriorated or if flashing height is insufficient, some parapet repairs should be anticipated. Through-wall flashing in a two-piece configuration allows the counterflashing to be removed to allow maintenance of the membrane flashing, as well as future reuse of the counterflashing when reroofing occurs.

Stone parapet walls may be very porous. The porosity of the stone may allow water to travel through the wall, thus bypassing any surface-mounted roof flashings. A good detail is to provide a through-wall flashing to manage water that will eventually infiltrate the wall.

The bearing conditions of the structural framing members may be affected by moisture infiltration. This is a serious problem that should be examined thoroughly. Temporary shoring of the framing while masonry repairs are undertaken may be needed if deterioration is advanced.

Deterioration of the top shell in a clay tile unit within an arch system may reduce structural capacity and compromise the integrity of the arch. Similarly, concrete or mortar toppings may have delaminated and may conceal damaged top shells. A structural engineer familiar with clay-tile arch systems should be consulted to assess these issues.

Several attachment options must be evaluated to determine how the new roof system will be attached to the substrate. For flat roofs, the attachment options include fully or partially adhered, mechanically fastened, and ballasted systems. The condition of the deck will influence decisions for roof-replacement systems.

Wood saddles and cants should be inspected to determine their condition. Replacement should probably be anticipated unless their condition is exceptionally good. If the roof was re-covered in the past, perhaps new cants and saddles were installed, but no deck repairs were performed beneath the saddles.

During construction, damage can occur to the roof substrate from the equipment used to remove the old system. Storage of materials and construction traffic across the deck while removing the old roof and installing the new one may also weaken it and cause further damage. Stockpiling roofing material may overload already weakened areas of structural deck.

All of the above conditions and hypotheses should be evaluated prior to the start of the repair work to determine if the substrate for the new roof system is capable of providing continued safe performance.

DESIGN CONSIDERATIONS FOR MATCHING THE ROOF SYSTEM TO THE SUBSTRATE

Following are some of the design issues that should be considered and incorporated in a roof-replacement plan.

Consider Existing Conversions and Additions

Additions or conversions of space may have resulted in additional mechanical equipment on the roof and offsets between areas that create snowdrifting issues where none existed prior to the revision. A significant change in interior humidity and/or temperature may require a different amount and type of insulation as well as vapor retarder location. Expansion joints separating building additions need to be incorporated into the roof design. Removal and replacement of mechanical equipment may be necessary, which will add complexity to the overall renovation plan.

Provide Required Fire Protection

Clay tile provides an excellent source of fire protection for steel framing. *Figure 6* shows how the clay tile typically protected structural steel members. If there is significant deterioration of the existing clay tile deck and selected removal and replacement of tile units is necessary, the replacement materials need to provide the same or better fire protection of structural steel, should

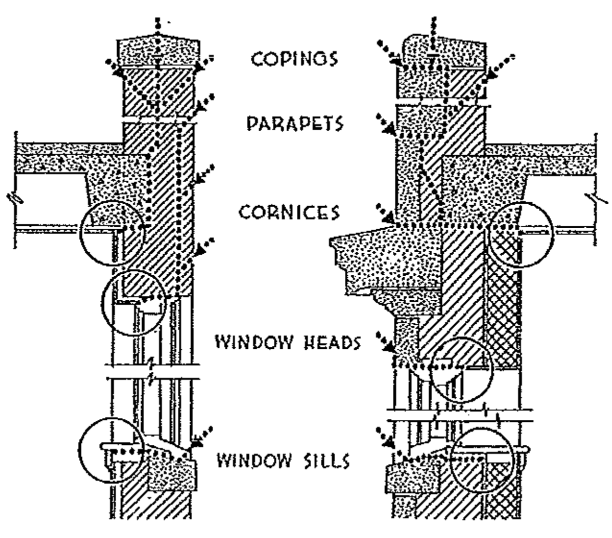


Figure 5 - Some of the paths water can follow before leakage is discovered in the interior spaces.

any be uncovered. The building code, local officials, and insurance company representatives should be consulted to make sure the repair design satisfies local fire-resistance protection requirements.

Consider Dead- and Live-Load Limitations, New Code Requirements, Uplift Design

New roofs should be designed to conform to the current building code requirements for dead, live, and wind loading. Particular attention should be paid to the condition of the structural slab for the load-carrying capacity and uplift resistance of the new roof covering. If the uplift resistance of the roof system over an historic deck substrate is not strong enough to overcome the imposed wind loading, the roof will not last long and can potentially blow off.

Achieve Proper Slope to Drain

Saddles built between drains may have been originally constructed of wood or mortar. The condition of these saddles needs to be evaluated, and they may need to be replaced or repaired. If a sloped cinder-fill system on sloped concrete topping exists and it is then removed, a new system should be provided that achieves adequate drainage slope.

Verify Plumbing Code Requirements

It is wise to add overflow drains or scuppers for roofs surrounded by parapet walls, and this is likely to be a building code requirement. Drains can become clogged and allow water to accumulate on the roof surface. Emergency overflows are designed and installed to prevent collapse from occurring. Often, the condition of the drainheads and drain leader lines is poor, necessitating replacement of a portion of the plumbing system itself. Existing drain lines may be potentially undersized and may require plumbing repairs in order to bring the drainage system up to current code.

Address Electrical Repairs

Electrical conduits may be buried in concrete toppings or insulation, and their existence can influence the repair approach to be taken. Conduits can be identified using a metal detector or by careful observation from the underside of the deck.

Structural Engineering

If the structural deck requires extensive repair, a qualified structural engineer should be consulted to evaluate the need for shoring and to recommend repair options.

Provide for Special Removal and Disposal Procedures for Asbestos Felts and Flashings

Testing of the existing roofing membrane and flashings should include a check to verify whether either of these materials contains asbestos. Special removal techniques and waste disposal procedures are regulated by government agencies.

Evaluate the Existing Bituminous Membrane if Well Adhered to the Structural Deck

If an existing bituminous membrane is present, is found to be tenaciously adhered to the deck, and is in good condition, one option may be to retain it rather than remove it. This membrane may provide a reasonable temporary protection, but it needs to be evaluated in terms of its interface with a new roof assembly. If a well-adhered bituminous membrane needs to be removed for any reason, major deck repair is almost certain to be required. In all likelihood, the condition of the bituminous membrane relates directly to the condition of the structural deck.

Consider Code and Insurance Requirements

Building code provisions for roofs need to be carefully reviewed on older buildings. The codes have established wind-resistance and fire-rating classifications. Applicable specifications should be followed based upon code- and insurance-prescribed ratings. Roof replacement normally deals with external fire exposure, but if the deck is included in the repairs, then the overall ceiling, deck, and membrane systems need to be considered together.

Consider Warranty Issues: What Is Not Warranted?

Roofing manufacturers will warranty the performance of products they manufacture and supply. However, they normally do not warranty the condition of the existing structural deck or how roofing materials are adhered to the deck. The design professional is required to verify the condition of the deck and method of attachment of the roof assembly.

Consider Insulation Requirements

The addition of insulation to the roof assembly may be desired but it may not be necessary if an attic space exists. Then, the choice to insulate the attic rather than the roof system is a more viable option in order to meet energy code requirements. Insulation can also be used in the roof assembly

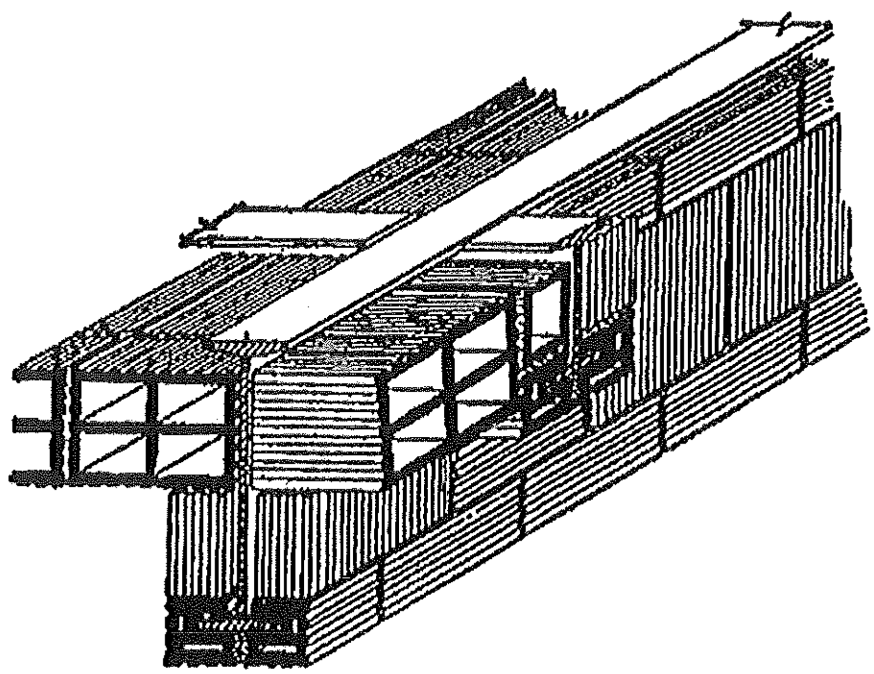


Figure 6 – How clay tile was used to cover structural steel members to provide fire protection.

where the substrate is uneven and irregular to provide a smooth, uniform surface for the roof membrane.

Perform a Dew Point Analysis of the Roof Assembly

A dew point and thermal analysis should be performed to determine if condensation would form within or on the underside of the structural deck, as is possible with a roof membrane in a cold climate.

Consider Mechanical Fastener Types Carefully

Withdrawal or pullout tests are useful to verify the holding strength and load capacity of mechanical fasteners. These tests assist in evaluating potential problems with anchorage of components such as wood blocking or prefabricated curbs to the substrate. Usually, conventional expansion anchors do not work well in cinder concrete or older lightweight concrete because of marginal concrete strength. Drilling into clay tile often results in spalling or cracking of the interior face of the top shell. The material the fastener is made from, along with the coating, if present, can greatly affect the long-term performance of the fastener. Including a fastener manufacturer early in the process is recommended to help identify which type of anchors will work. Not knowing in advance of construction whether special fasteners are needed can easily increase costs significantly.

CONCLUSIONS AND SUMMARY

The substrates of older structures need to be carefully examined in order to formulate a successful reroofing design. This plan will be significantly influenced by the type and condition of the roof deck and by the nature and condition of adjoining parapet wall systems. The roof of every building is unique, and a project-specific, holistic assessment of conditions is necessary to predict the manner in which to implement repairs as well as to make an informed selection of roofing system type.

Repair concepts on historic buildings often have structural performance implications. This necessitates involvement of a qualified structural engineer during the design phase to check the feasibility and constructability of those repairs. This step is important because the means and methods of repair are variable and are often limited by site and time constraints and by potential variability in workmanship. Trial repairs or mock-ups should be initiated, as this will help reveal problems and conditions that can only be identified during the physical act of construction and will also permit evaluation and refinement of proposed repair details.

The reroofing design plan should be guided by investigative findings and proper evaluation of all of the required design considerations. Economic constraints are often imposed on the designer. However, those constraints should not compromise professional opinions or technically appropriate decisions reached when proper analysis has been performed. The success of a new roofing system on an older historic building will ultimately be determined by the thoroughness of the investigation and care taken in selection and implementation of an appropriate repair or reroofing solution.

EDITOR'S NOTE: The original version of this article was published in the Roofing Handbook for Historic Buildings *(Washington, DC: Historic Preservation Education Foundation, 1999).*

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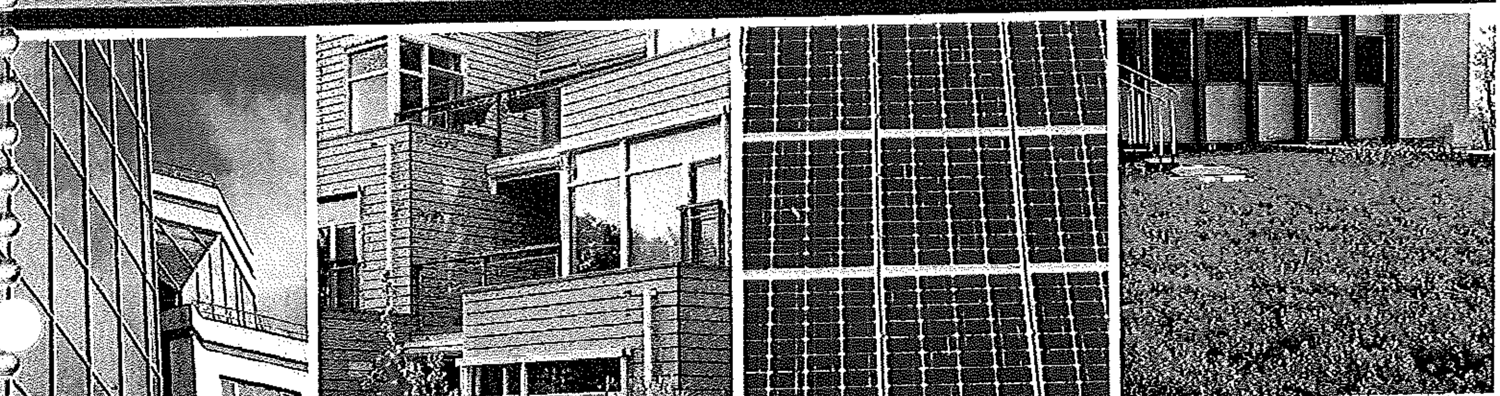

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EXPLORING the Sustainably Built Environment

Leaks, Drips, and Damage: Investigation and Repair of Widespread Building Envelope Problems In a New Community Center

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Leaks, Drips, and Damage: Investigation and Repair of Widespread Building Envelope Problems In a New Community Center

INTRODUCTION

A community center building in rural Minnesota experienced widespread water leakage and condensation-related problems shortly after its construction in 2000. This paper describes the investigative techniques that were employed to diagnose the causes of the problems, the repairs that were subsequently performed, and the lessons learned.

PROJECT

Building Description

The building had overall plan dimensions of approximately 200 ft x 200 ft and consisted of three primary sections: a natatorium, a gymnasium, and an office area. The office area contained administrative offices, meeting rooms, exercise rooms, a kitchen, and a walking track. The majority of the building was a one-level structure with a concrete slab-on-grade floor. An upper level mezzanine, which housed the building mechanical equipment, was located within the natatorium. The office and gymnasium sections of the building were steel-framed, consisting of pre-engineered, clear-span, steel rigid frames, and the natatorium was constructed of precast concrete. The floor of the mezzanine consisted of hollow-core precast concrete planks with a concrete topping. Refer to *Figures 1* and *2* for a plan view layout and partial view of the building. A section through the building is shown in *Figure 3.*

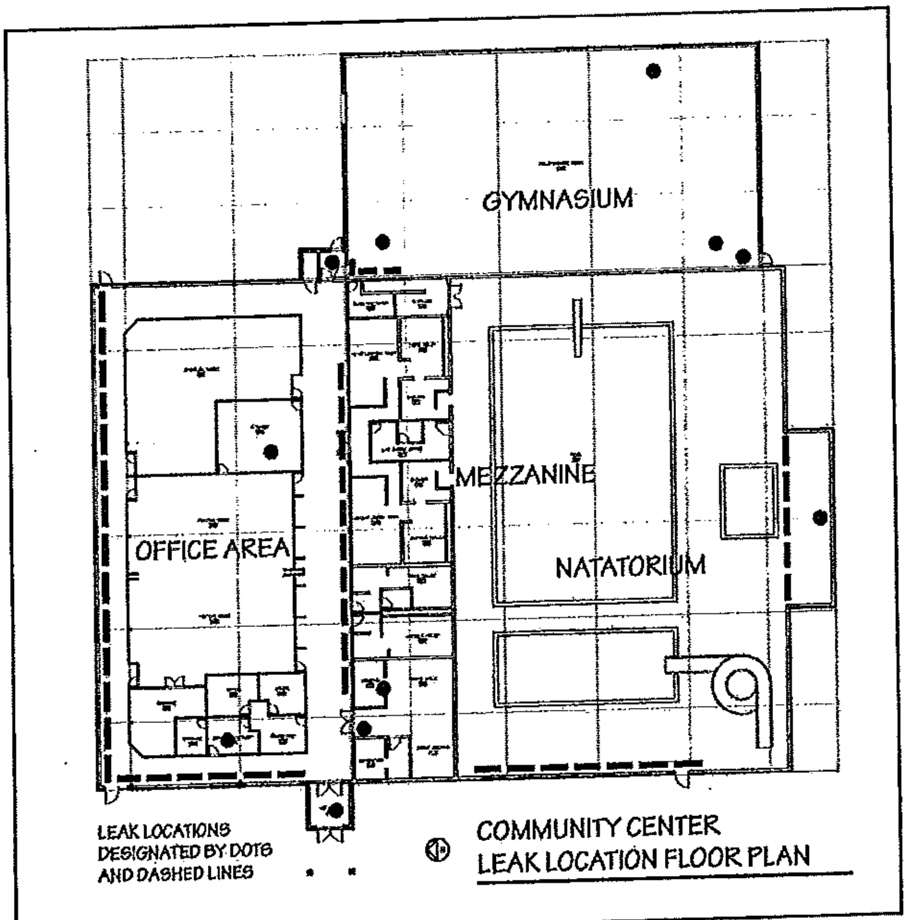


Figure 1– Plan view layout of building showing water leak locations.

Wall Construction

The exterior walls of the natatorium consisted of precast concrete hollow-core insulated wall panels with punched windows. The exterior walls of the office and gymnasium sections were framed with 6-in steel studs and finished with prefinished corrugated metal architectural wall panels and split-faced concrete masonry veneer. The metal panels were typically installed above the masonry. The typical backup construction behind the masonry veneer consisted of a 2-in air space, #15 felt paper, and paper-faced gypsum board sheathing installed directly on the exterior of the studs. In areas where metal panels were present, no felt paper or sheathing was installed and the panels were fastened to the studs. The remainder of the exterior wall construction included fiberglass batt insulation in the stud cavity, 4-mil polyethylene

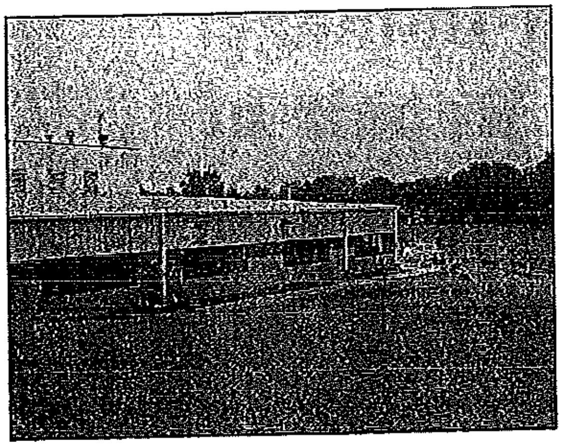


Figure 2 (left) – Partial view of building facing southwest, showing office area roof and air intake/exhaust louvers at mezzanine level (arrow).

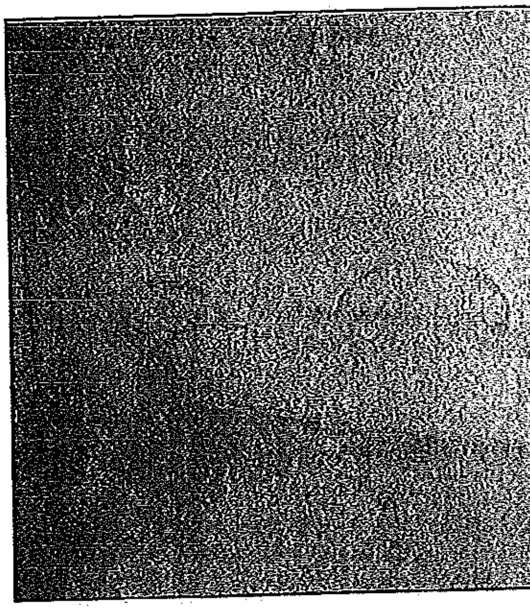


Figure 4 (right) – Stained ceiling tiles below roof-to-wall interface in office area.

vapor retarder, and interior gypsum wallboard.

The window system consisted of thermally improved aluminum storefront framing with 1-in-thick insulated glass units. All of the units were fixed frames without any operable units and were set into punched openings in the exterior wall system. A thermally improved subsill was specified beneath the window system.

Roof Construction

The typical roof construction (in all areas except the natatorium) consisted of 24-in-wide trapezoidal standing-seam metal roof panels that spanned between light gauge steel Z purlins with fiberglass batt insulation and a laminated vapor retarder beneath the roof panels. In the gymnasium, the underside of the ceiling and the interior and exterior surfaces of the exterior walls were finished with metal panels. In the office area, an acoustical lay-in ceiling system was suspended from the roof framing. The roof structure of the natatorium consisted of precast concrete double tees and the roof system consisted of a ballasted EPDM membrane over 6 inches of rigid insulation.

PROBLEMS

The predominant problems on this building were confined to the office area and natatorium and consisted of the following:

1. Roof water leakage and condensation-related moisture dripping. The most significant and frequent water leakage occurred over the length of an east/west corridor that was located in the office area, directly below a roof-to-wall interface, as shown previously in Figure 1. Water leakage was also noted below a rooftop exhaust vent, at air intake/exhaust louvers on the mezzanine wall, and at several locations in the field of the office area roof. Condensation-related moisture dripping was observed below the aforementioned roof-to-wall interface and at several locations in the field of the office area roof. The water leakage and condensation-related moisture dripping resulted in stained ceiling tiles and water accumulation on the vapor retarder beneath the roof panels. Refer to *Figure 4* for a view of typical staining observed on ceiling tiles along the length of the east/west corridor.

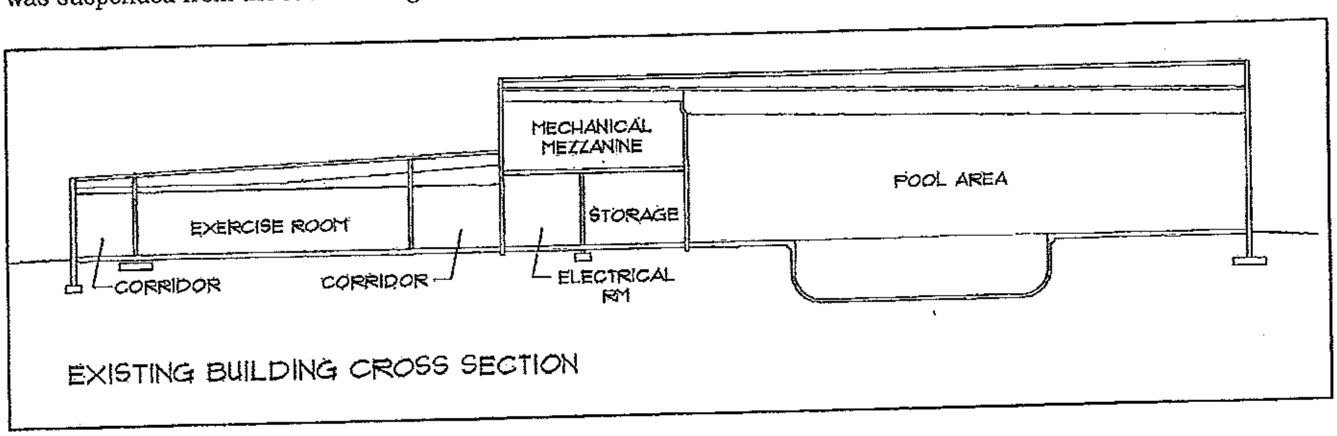
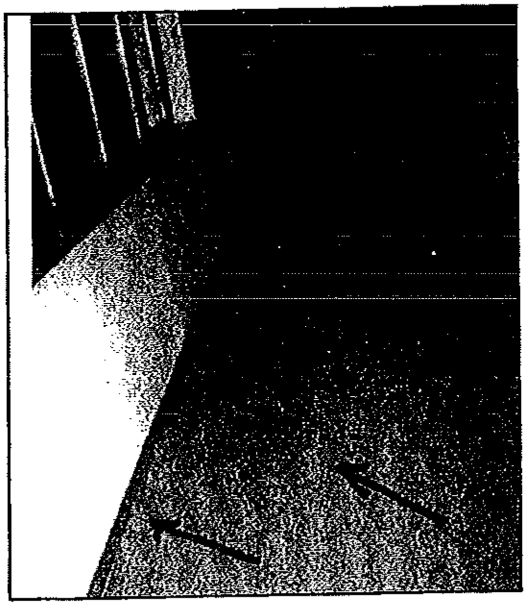


Figure 3 – Section through the building, facing east.



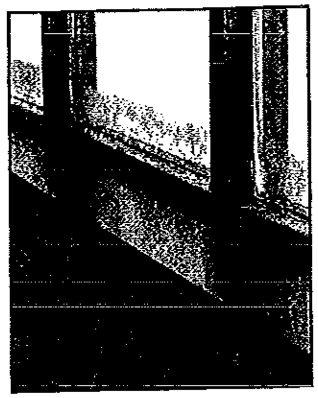


Figure 5 (left) – Water-stained walls and wet carpet below windows in office area. Figure 6 (above) – Frost build-up on window frames and insulating glass units.

2. Window water leakage and condensation. Water leakage in the vicinity of the windows resulted in stained wallboard and wet carpeting below the windows (*Figure 5*). In the winter months, frost buildup to an approximate thickness of one-eighth to one-fourth inch occurred on the window frames and insulating glass units (*Figure 6*). When this frost melted, water pooled on the windowsills and ran down the walls.

3. Snow accumulation in ductwork and HVAC units. In the winter, wind-driven snow entered air intake louvers and collected within the ductwork and air-handling units. Snow collected on air filters, causing them to distort and admit unfiltered air into the mechanical system. When the snow melted, the water dripped onto the mezzanine floor and stained the duct insulation. Occasionally, water leaked through the mezzanine floor to the finished spaces below.

4. Structural framing issues. During the original construction, the as-built steel framing was revised by the contractor from that shown on both the structural design and shop drawings. The principal variations occurred in the north wall of the office area and included the omission of six wide flange steel columns and accompanying steel beams, which were intended to provide lateral load resistance as well as significant revisions to the steel stud framing. The as-built conditions resulted in unresolved load paths through the wall structure and made the wall vulnerable to excessive deflections under wind loads.

Investigation Methods

The investigation was conducted over a nine-month period in order to evaluate summertime water leakage and wintertime moisture condensation. The investigation consisted of the following tasks:

1. Reviewing available documents, including design drawings and specifications, shop drawings, photographs of past leakage, and reports by others.
2. Interviewing building staff to pinpoint specific water leakage and condensation drip locations and to correlate weather conditions that accompanied these problems.
3. Observing waterstain patterns and locations.
4. Documenting as-built conditions and construction details at inspection openings cut in walls and roofs.
5. Water testing leak locations reported by the owner in walls and roofs.

Inspection Openings

Inspection openings were cut in the exterior walls to record as-built construction details and verify the extent of consequential damage due to past water leakage (i.e., mold growth, deteriorated gypsum wallboard, and corrosion). Openings were also cut in the laminated vapor retarder installed beneath the roof panels to look for breaches in the vapor retarder at roof-to-wall interfaces and to check for water accumulation within the batt insulation suspended beneath the standing-seam roof panels. In the winter season, openings were cut in the laminated vapor retarder to look for frost accumulation on the underside of the standing seam roof panels and water/moisture within the fiberglass batt insulation.

Water Penetration Testing

Water penetration testing of individual leak locations was performed in order to isolate the source(s) of infiltration. Interior spaces were carefully monitored during the water testing to record water entry points and establish leak paths. Water-testing methods used during the investigation included water spray rack tests, spray testing using a hand-held spray nozzle, and pond (flood) testing of window sills.

Spray Rack Test

Spray rack testing was performed in accordance with ASTM E1105, 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 to determine the resistance to water penetration of exterior window assemblies and sections of exterior wall assemblies. Water was applied to the exterior surface of the test area from a grid of water nozzles calibrated to deliver a uniform water spray equivalent to a minimum of 5.0 U.S. gallons per sq ft per hour. For the purpose of our testing, no static air-pressure difference was created across the test specimen. The water spray was maintained from five minutes to 45 minutes, depending on the location.

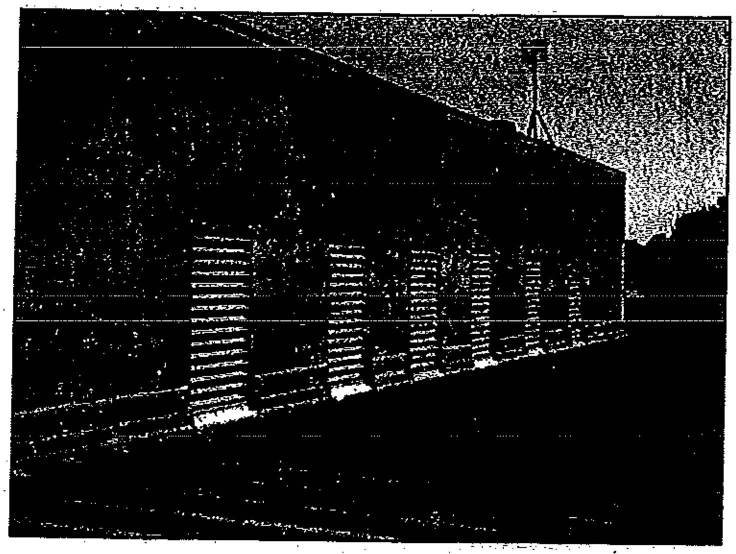


Figure 7 – Position of louvers on north exterior wall of mezzanine.

Spray Nozzle Test

Testing using a hand-held spray nozzle was performed in accordance with the requirements of American Architectural Manufacturers Association (AAMA) 501.2, Quality Assurance and Diagnostic Water Leakage Field Check of Metal Storefronts, Curtain Walls, and Sloped Glazing Systems for Water Leakage to pinpoint specific areas of water leakage. By utilizing a hand-held spray nozzle with a control valve and pressure gauge, various detail conditions were isolated and tested. Testing typically began at the lowest area and proceeded upward in approximately 5-ft increments. Water flow was adjusted to maintain a pressure of 30 to 35 psi. At selected test areas, a small diameter stream of water at pressures less than five psi was used.

Sill Flood Test

The window frame sill corners and metal flashing that extended beneath the window system were tested per the 2002 edition of AAMA 502, Voluntary Specification for Field Testing of Windows and Sliding Glass Doors and its Optional Sill Dam Test. This test was intended to determine the resistance to water penetration of the corner seals of the sill-framing members and metal sill flashing. The vulnerability of the window frames to leakage was evaluated by plugging the weep holes to hold a desired depth of water within the glazing pocket during the test.

INVESTIGATION RESULTS

Office Area Roof

The office area roof problems consisted of water leakage into the roof system and condensation on the underside of the metal roof panels. Both of these problems were widespread and had resulted in stained ceiling tiles and damaged interior finishes.

Leakage

The most visible and problematic water leakage occurred over the length of the east-west corridor in the office area, directly below a roof-to-wall interface along the north wall of the mezzanine. Leaks were also reported in the wintertime from melting snow and/or condensation at this same location.

The roof above the corridor was a prefinished standing-seam metal roof that terminated against precast, hollow-core insulated wall panels. The wall panels contained ten punched openings for air intake/exhaust louvers associated with mechanical units housed within the mezzanine space. The exterior face of the wall panels contained vertically oriented rustication grooves that functioned as an aesthetic feature that extended in a continuous band around the upper portion of the building. The grooves were ragged and closely spaced and extended into the concrete about one inch. At the base of this wall, the sills of the louvers were flashed integrally with the ridge termination for the standing-seam metal roof panels. The top of the metal roof flashing and counterflashing terminated into a reglet that was saw-cut across the rustication grooves and did not extend adequately into the concrete beyond the grooves. The sills of the louvers extended down past the upper edge of the roof counterflashing and were positioned approximately 4 inches above the roof panels (*Figure 7*).

Field water testing was performed and leakage was found occurring at a) the end cap for the counterflashing, which terminated against the jambs for the louvers; b) the reglet joint where the sheet-metal counterflashing terminated; c) the vertical rustication grooves at the reglet for the counterflashing; d) metal-to-metal joints between the louver jamb and the flashing trim that covered the edge of the precast concrete walls; and e) the sealant joint near the jambs at the interface of the louvers' sill extrusion and the sheet metal counterflashing that extended under the sill extrusion.

These as-built details were inadequate in three ways:

1. The irregularity of the concrete surface and the narrowness of the rustication grooves made sealing the grooves watertight problematic, even with the best workmanship;
2. No pan flashing was specified beneath the louvers to collect and drain water that penetrated through metal-to-metal joints in the louver frame; and
3. The louver sill flashing was specified to be positioned 4 inches above the roof surface instead of the 8 inches recommended by industry standards to avoid potential leak problems from snow accumulation and meltwater.

Condensation

Ceiling tiles were removed to examine the underside of the roof-to-wall interface above the east/west corridor in the office area for staining and visible condensation. The laminated vapor retarder and fiberglass batt insulation beneath the roof panels were removed to expose the underside of the metal roof panels. The underside of the uppermost edge of the flashing detail at the mezzanine wall was found to be uninsulated, and the vapor retarder along the corridor was discontinuous. Frost was observed in winter months and condensation meltwater dripped and stained the ceiling tiles below.

The vapor retarder that was installed in the north exterior wall of the office area was not sealed or otherwise integrated with the laminated vapor retarder facing on the roof insulation. The resulting breach and lack of continuity in the vapor retarder allowed moisture-laden indoor air to exfiltrate into the wall cavity and condense on the backside of the metal wall panels in the winter months. Condensation meltwater dripped out at the window heads below the roof-to-wall interface, as reported by facility personnel, and wet insulation and corroded metal-stud framing members were present within the stud cavity. Evidence of air exfiltration, in the form of frost on the exterior side of the north wall, was also observed in the winter months at a poorly detailed roof-to-wall interface.

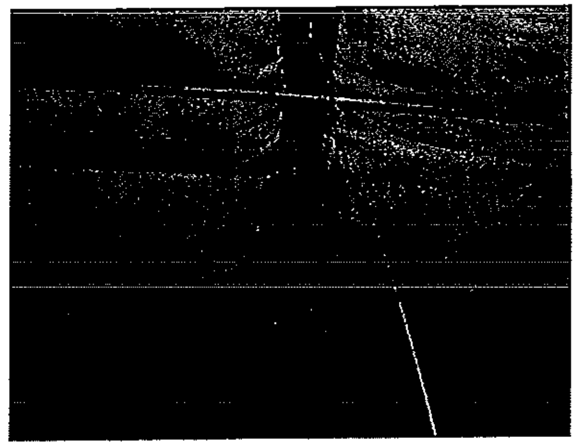


Figure 8 – Pillowed areas in the laminated vapor retarder/insulation.

Metal strapping supported the roof insulation and, when viewed from the underside of the roof, the laminated vapor retarder/insulation had a "pillowed" appearance (*Figure 8*). Approximately 580 pillowed areas were created by the roof purlins and metal strapping on the underside of the office area roof. When the outside air temperature was -10°F, 39 pillowed areas were inspected for evidence of past water intrusion and condensation. The inspection revealed frost accumulation on the underside of the metal roof panels at all locations, ranging from approximately one-eighth- to one-quarter-inch thick. Standing water from past water leakage and wet fiberglass insulation were also found in four pillowed areas. Water was drained from some pillowed areas and ranged from approximately one to four cups, with additional water remaining suspended in the fiberglass insulation. The pillowed areas that contained water were located below the end laps and the trapezoidal shaped ribs in the standing-seam metal roofing.

During the original construction of the building, the fiberglass batt roof insulation and accompanying laminated vapor retarder were installed as one component, dropped in between the roof purlins in narrow strips. Per the manufacturer's instructions, the lengthwise seams in the vapor retarder were to be sealed to the top flange of the Z purlins using two-sided tape. The seams at the ends were also to be lapped and sealed with tape. Inspection revealed visible

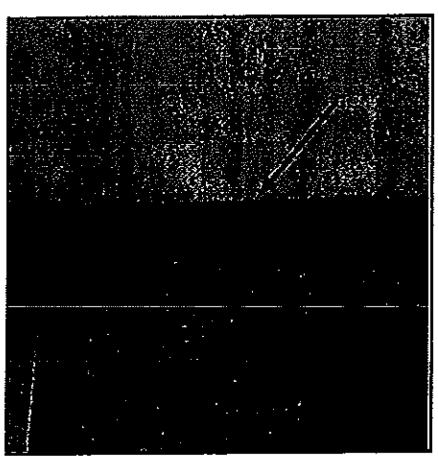


Figure 9 (left) – Flashing at top of walls and base of metal panel siding (arrow).

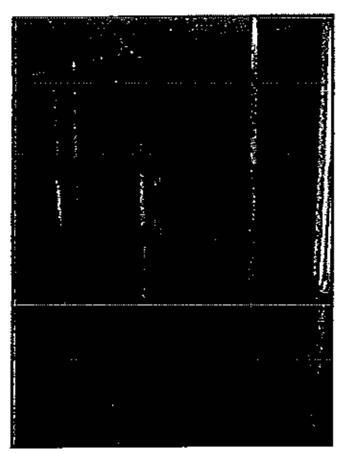


Figure 10 (right) – Mold growth on gypsum wallboard sheathing below the flashing shown in Figure 9.

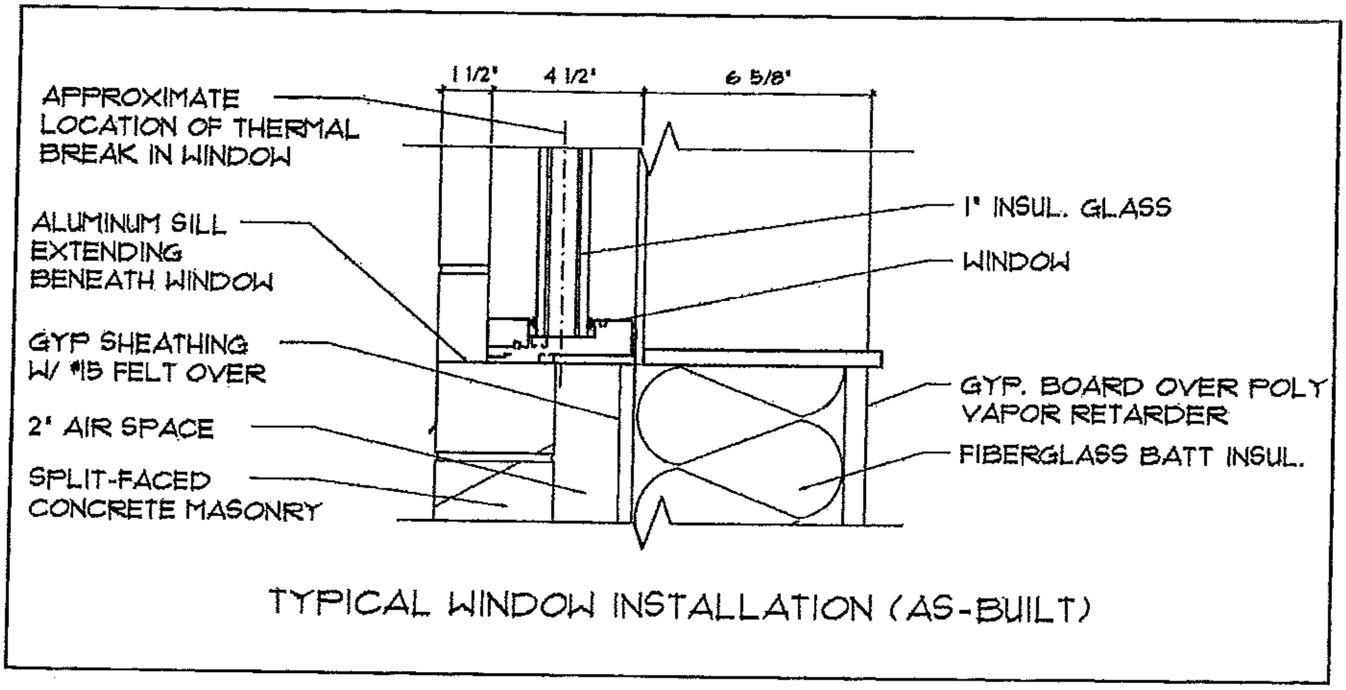


Figure 11 – As-built window installation.

openings in these seams at scattered locations throughout the roof.

Walls

Evidence of past water penetration was observed at the L-shaped horizontal metal flashing provided at the base of the corrugated metal panel siding above the split-faced concrete masonry at the north, east, and west exterior walls of the office area. Water spray testing produced leakage beneath the outboard edge of the flashing where it extended over the top surface of the masonry veneer, and at unsealed lap joints in the flashing. Past water leakage at these details resulted in deterioration of the exterior gypsum board sheathing and mold growth within the wall cavity (*Figures 9* and *10*).

As confirmed by visual inspection, water leakage had occurred through the east and west exterior walls at unsealed openings where pipes and roof-edge terminations penetrated the metal wall panels. At these locations, the watertightness of the penetrations was solely reliant on surface-applied sealant between the cut edges of the panels and the pipes or roof edges. The water leakage that occurred at these interfaces resulted in corrosion of metal stud framing members, deteriorated sheathing, and mold growth within the walls.

Windows

According to the manufacturer's literature, the windows in both areas of the building had a condensation resistance factor (CRF) rating of 53. This rating would be considered appropriate for the environmental conditions within the office area, but not for the elevated relative humidity conditions that were present within the natatorium. Inspections revealed stained interior wall and floor finishes in the vicinity of windows in the office area. In the natatorium, water intrusion through the windows ran down and stained painted walls and collected on the concrete floor.

Leakage

Both field-water spray testing and sill flood testing were conducted on windows installed on the west walls of the natatorium and office area. The testing revealed interior water penetration at two locations, with slightly different damage occurring at each location. Water flowed off the end of the metal flashing, which was installed beneath the windows and migrated into the wall. This resulted in water staining, mold growth, and deterioration of the exterior sheathing and interior wallboard; stained carpeting; and corroded metal stud framing members. Water also entered the interior beneath the window frames, through the joint between the window frame and the metal sill flashing. This water caused warping of the plastic laminate clad-wood sills, mold growth beneath the sills, and water intrusion into the wall.

The water penetration testing demonstrated the following: (1) The window units were not watertight; (2) water could readily penetrate the windows at unsealed frame joints and joints in glazing gaskets; and (3) the absence of the specified subsill drainage system with end dams allowed water to intrude into the wall and to the building interior.

Condensation

Observations made during the winter months revealed extensive condensation on window frames. Water from melting frost/ice was observed to collect on sills, run down

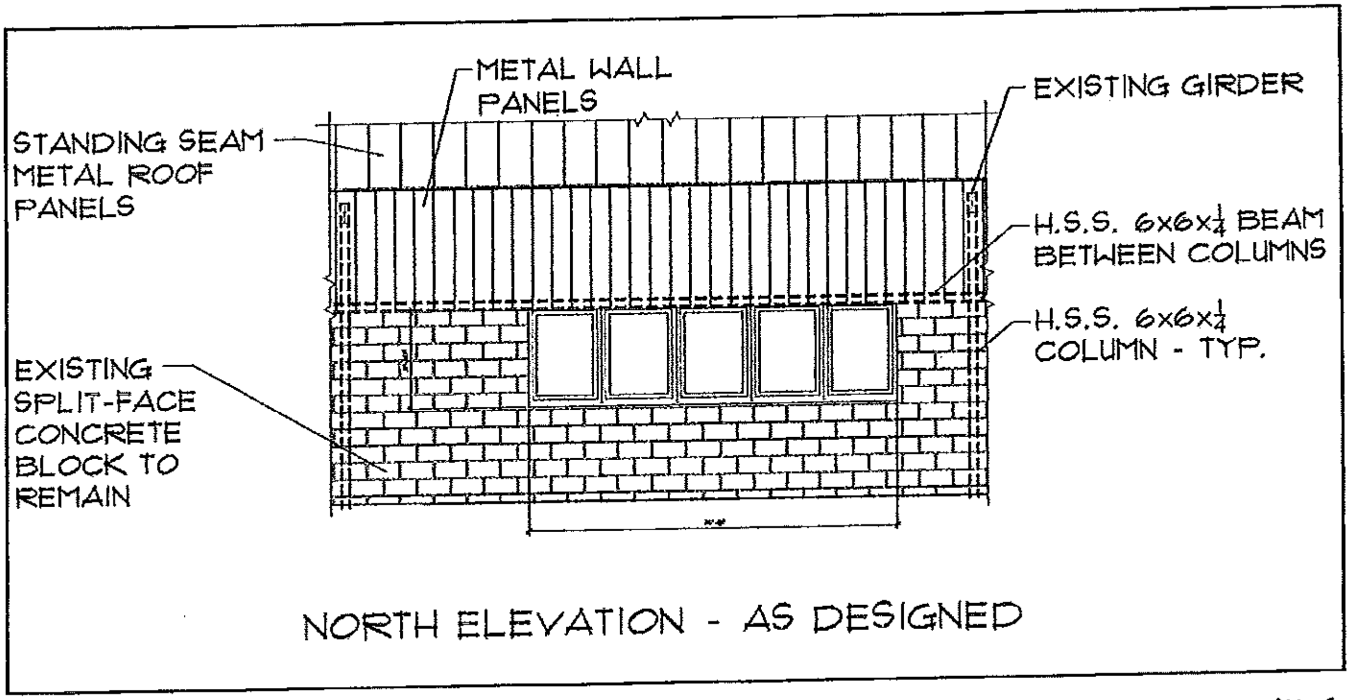


Figure 12 – View of north elevation showing beams and columns (dashed lines) that were omitted by the contractor.

painted walls, and spill onto the carpeted floor. Inspections revealed: (1) The specified thermally improved subsill was omitted and a nonthermally broken metal -ill flashing without end dams was substituted; (2) no cavity seals were installed within the masonry wall cavity to prevent air in the cavity from flowing to the interior portion of the window frame; and (3) the windows were set too far outboard in the exterior wall, exposing both sides of the thermally broken window frames to cold air (*Figure 11*).

Air Intake/Exhaust Louvers

Air intake and exhaust louvers were installed on the bottom of the north wall of the mezzanine. Because the louvers were not adequately designed to resist water penetration, and they were in a location where drifting snow could be expected (i.e., high roof / low roof area), unacceptable quantities of rain and snow entered the louvers. The quantity of rain penetration resulted in water flowing through the louver frame and spilling out of the ductwork and collecting on the mezzanine floor, with some water subsequently penetrating floor cracks and leaking to main level spaces below. Buckets were eventually used by the owner to catch water that leaked through the louvers. Snow entered the louvers in sufficient quantities to accumulate within the ductwork and air-handling units. This snow collected on air filters and caused them to bow out of plane. The resulting gaps created around the bowed filters permitted unfiltered air to enter the mechanical system and contributed to staining of the acoustical wall panels near diffusers in the natatorium. The snow that collected in the air-handling units was reportedly of sufficient volume to require removal by facility personnel, and melting snow within the ductwork wetted and stained the duct insulation.

Water testing with a spray rack (without applied pressure) demonstrated that water could easily enter the louver system and exit through joints in the duct behind the louvers to pool on the mezzanine floor.

Structural Framing

As the repair design was being formulated, inspections were made to compare as-built framing member locations and dimensions to those shown on the original design drawings and structural shop drawings. These inspections revealed steel columns and beams had inadvertently been omitted by the contractor along the north wall of the office area during the original construction (*Figure 12*). These omitted beams and columns were required to provide the necessary resistance to lateral loads (wind). In addition, significant modifications were found to have been made by the contractor to the steel stud wall framing. Subsequent structural analyses performed during the investigation showed the as-built framing of the north, east, and west walls of the office area to be deficient and lack the code-required resistance to lateral loads (wind).

REPAIR

The repair consisted of four basic steps: (1) relocating air intake/exhaust louvers from the north-facing wall of the mezzanine to the upper roof level, including over-cladding the wall to conceal abandoned louver openings and rustication groove detail; (2) removing and replacing the office area roof, including structural modifications; (3) removing and

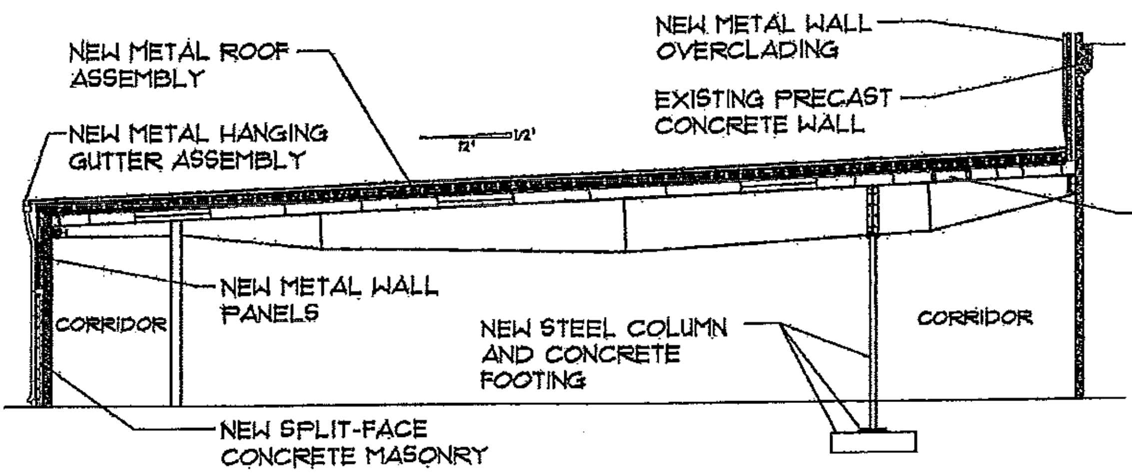


Figure 13 – North-south section through building, facing east, showing overall view of roof and wall repairs.

replacing the north, east, and west walls of the office area in their entirety; and (4) removing and replacing windows in the natatorium and office area. The repairs were completed in two summer construction seasons, one season for relocating the louvers, and the other for performing the remaining work. For the most part, the building was kept continuously occupied and was fully operational during the entire repair process.

Repair Sequence

The repair work progressed as follows:

1. Air intake/exhaust louvers were relocated to roof level and protective covers were installed on abandoned louver openings.
2. Pre-engineered steel frames of the office area were strengthened.
3. Office area roof was removed and replaced.
4. North wall of the mezzanine was over-clad to cover abandoned louver openings.
5. North, east, and west exterior walls of the office area were replaced.
6. Windows in office area and natatorium were replaced.

Air Intake/Exhaust Louvers

In order to prevent snow drifting against the louvers and improve the flashing detailing at the louver perimeter, the ten air intake/exhaust louvers located on the north wall of the mezzanine were abandoned and nine new gravity intake and relief hoods were installed in the upper roof, where the water and snow penetration resistance could be improved while still allowing adequate air flow. This work consisted of cutting holes in the precast concrete double-tee roof framing, installing new intake and exhaust hoods at the upper roof level, abandoning the existing louvers, and installing new ductwork. The new ductwork was sized to fit the space between the stems of the double-tee roof beams. The abandoned louver openings were covered with insulated, watertight panels that remained in place when the wall was over-clad with metal panels.

Office Area Roof

The new roof design was conceived in conjunction with structural strengthening necessitated by the missing columns on the north exterior wall, the increase in the applicable code-specified snow load, and the increase in dead load of the new roof design. The repair ultimately selected for the office area consisted of three steps:

(1) Structural strengthening of the existing steel frames and purlins (*Figure 13*);

(2) Removing the existing roof in its entirety and replacing it with an improved roof assembly; and

(3) Over-cladding the precast wall of the mezzanine from roofline to coping with corrugated metal siding panels similar to other wall areas to simplify the detailing at the roof-to-wall intersection.

The new roof assembly consisted of the following components, listed from top to bottom:

- 24-gauge prefinished standing-seam. metal roof panels with 2.5-in-high, narrow profile standing seams (sealed with inseam sealant)
- Self-adhering, high temperature-resistant membrane underlayment
- 5/8-in-thick CDX exterior plywood decking
- Two layers of 2.5-in-thick polyisocyanurate insulation with staggered joints (average R-value equal 28)
- 45-mil adhered EPDM temporary roof/vapor retarder/air barrier
- 5/8-in-thick Dens-Deck board (mechanically attached to decking)
- Corrugated metal decking

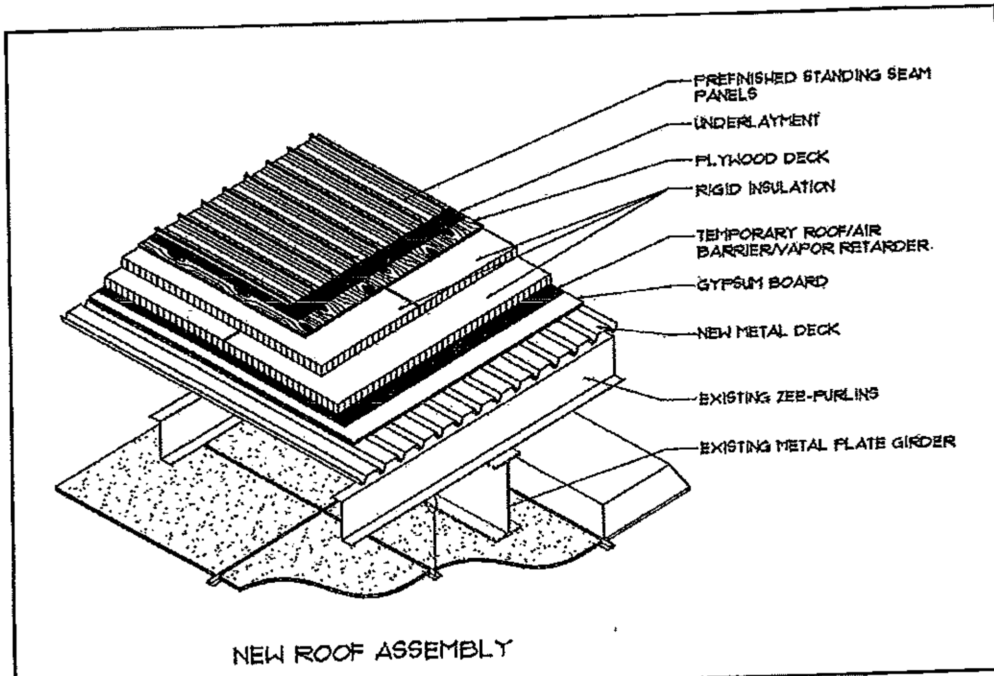


Figure 14 – Repair design of roof assembly.

An isometric view of the new roof assembly is shown in *Figure 14*. This repair design provided a practical and reasonable approach to keep the office area operational and protected from weather during the multiweek construction process (*Figure 15*). The new roof provided a comprehensive, redundant, and long-term repair that addressed both water leakage and condensation problems. The corrugated metal deck component was selected to function as a structural diaphragm, which enhanced the lateral-load resistance of the office wing, as well as a work platform and substrate for a temporary roof. The temporary roof served as the vapor retarder/air barrier of the new assembly. This assembly provided continuous rigid insulation of a uniform thickness and included an underlayment membrane beneath the new standing-seam panels to help manage any future moisture infiltration and to provide an added level of redundancy.

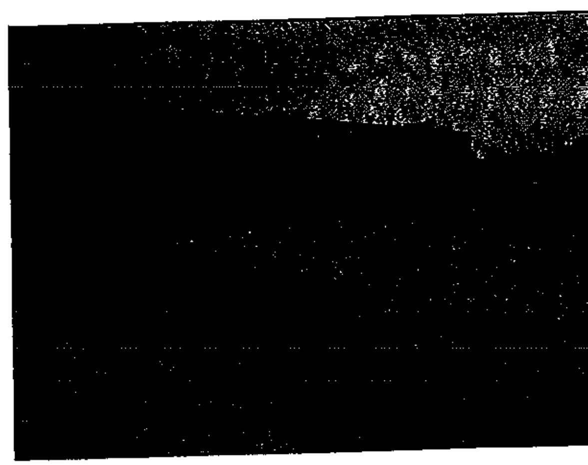


Figure 15 – Roof replacement in progress, with EPDM temporary roof/vapor retarder/air barrier in background.

Engineered buildings are typically designed to very tight standards with minimal, if any, surplus loading capacities. This was the case on the office area building, and strengthening of the preengineered steel roof frames was required to accommodate an increase in both the code-specified snow load and the increased dead load of the new roof assembly. The strengthening of the frames was accomplished by creating a two-span condition with the addition of steel columns on new concrete footings, and by adding web stiffeners and lateral bracing. The new steel columns consisted of 4x4 tubes that could be concealed within the interior partition walls. Existing purlins were reinforced, and bracing was added to accommodate the code-required increased snow load in certain roof areas.

During the design development stage of this project, several other roof repair alternatives were considered and analyzed, including: (1) performing spot repairs, (2) installing a new roof assembly over the existing roof, and (3) replacing the roof with a system similar to the original roof system. None of these repair alternatives was judged to be a viable option, and each was found to be deficient in its ability to provide a long-term solution to the water leakage and condensation problems and in its ability to provide adequate protection to building occupants and contents during construction. Installing a new roof assembly over the existing roof would have necessitated the strengthening of purlins in an already insulated roof. This was deemed to be an impractical repair option. Removing and replacing the roof with a similar roof system would have resulted in thermal insulation and vapor retarder continuity issues and challenges at the roof-to-wall interface at the mezzanine wall interface, similar to those experienced with the original design.

Full-time observations were performed by the design team over a major portion of the roof replacement work due to the uniqueness of the repair approach, the attention to detail in the repair, the potential for damage to interior contents, and the project location (i.e., 100 miles away from a major urban center, in rural Minnesota). These observations were critical to verify that materials were properly stored and protected from the weather prior to their installation, that work performed was in accordance with repair details, and that the vapor retarder in the roof was properly integrated with the vapor retarder in the walls.

Walls

The wall repairs consisted of removing the existing walls in their entirety (i.e., steel-stud framing, masonry veneer, metal panels, sheathing and insulation) at the office area; installing new steel-stud framing sized to accommodate the code-required lateral loads and address the omitted beams and columns; and installing a new masonry veneer and metal wall panels. The vapor retarder in the walls was integrated with the vapor retarder in the roof. Special design details were prepared to ensure continuity of the vapor retarder where the east and west walls met the sloped roof at eave and rake-edge conditions. The new masonry units were selected to match the rock-faced masonry units that were to remain on the unrepaired portions of the building. Diverter flashing was installed at roof-edge terminations and special details were prepared to ensure that a watertight connection was provided where piping penetrated the metal wall panels.

Windows

The window systems were replaced with new, thermally improved, high performance curtain-wall systems to achieve the required CRF for the natatorium and office area. Although the original window system could have met the thermal requirements at the office area, replacement was deemed practical in all areas due to the thermal bridge created by the sill flashing, the lack of a cavity seal and integration with the weather barrier behind the masonry veneer, and the water leakage through the system. The use of a curtain-wall system in the office area also provided additional condensation resistance in the event elevated interior dew-point temperatures occurred due to unanticipated airflow from the natatorium. Triple-glazed glass units were installed in the natatorium to improve the condensation resistance in that space. The curtain walls were shifted toward the interior to move the thermal breaks in the system closer to the insulation plane in the wall system. A cavity seal was installed in the masonry cavity to prevent airflow from the cavity from contacting the interior portions of the curtain-wall frames. This seal was created by extending a membrane from the sheathing into the curtain-wall system at the full perimeter. This membrane was integrated with the weather barrier system behind the cladding. The vapor retarder in the walls was wrapped into the opening and sealed to the curtain-wall frames to maintain the vapor retarder for the wall system and to form an interior air seal.

Other

Observations performed during the repair work found many workmanship defects that were not discovered during the investigation. These additional defects included missing anchor bolts at column base plates, a damaged steel frame member, missing end dams and unsealed lap joints in the through-wall flashing at the base of masonry walls, gaps in the felt paper that was installed behind the concrete masonry veneer, missing insulation, and 8-in concrete masonry units that had been sawed in half length-wise and substituted for 4-in units. The discovery of these additional defects shows why an owner should be alerted of the possibility of discovering hidden defects and why a contingency is needed to account for the additional repairs required.

LESSONS LEARNED

The lessons learned from the investigative design and construction process that may assist designers and contractors in avoiding similar problems in the future are as follows:

(1) Confirm as-built conditions before design of repairs. When evaluating an existing structure, it is necessary to verify that the framing layout and dimensions match those shown on the design and shop drawings. This step can avoid having a deficient structure after the repair is completed and/or costly delays during the construction process when deficiencies are discovered.

(2) Examine condensation issues in winter (as well as summer) seasons. When evaluating the cause and extent of condensation-related problems, it is important to evaluate the structure during the winter season, when the problems are apparent. This evaluation helped the investigators understand the condensation issues more thoroughly and thus address the full extent of the moisture problems at the building. It is also critical to determine the winter relative humidity and temperature

when evaluating existing window systems and designing replacement systems.

(3) Provide redundancy in the design and construction of roofs and walls. Proper integration, continuity, and redundancy of the roof-to-wall interface details should be scrutinized during all aspects of the design and construction process, and not be allowed to be functionally compromised by scheduling or cost-driven pressures. Roof and/or wall details that are solely reliant upon sealant for watertightness will leak eventually, and a secondary means of managing water infiltration should be incorporated into the detailing. The function and value of aesthetic features requiring integration with critical flashing details should be carefully considered by the designer to avoid interfaces that cannot practically be constructed.

(4) Consider snow drifting at high roof / low roof configurations. At high/low roofs, be aware of snow drifting that can impede airflow into low positioned louvers for mechanical equipment units and consequently lead to problems. Elevating the louvers above the snow drift plane and/or positioning air intake and exhaust hoods for mechanical units on the adjacent flat upper roof can be a better alternative, depending upon the building geometry and site orientation. Louvers should have drain pans that are watertight and drain to the exterior.

(5) Provide redundancy in window unit flashing details and position window units within punched openings in walls for optimal thermal performance. Window units are reliant upon sealant and gasket integrity for watertightness. These components will fail eventually or can experience problems during construction. A thermally broken subsill with fully sealed and mechanically fastened end dams beneath the window units, integrated with the wall components and geometry of the opening, provides a redundant means of managing water infiltration that occurs due to fenestration problems and irregularities. The position of window units within a punched opening configuration should be considered and selected primarily based on optimal thermal performance of the window unit.

(6) Observe roof and wall repairs during construction. Full-time observation during construction of a complex repair provides value to the building owner in several ways. Often the repair contractor does not have the benefit of the investigative findings or an appreciation for some of the seemingly small details involved in the repair design and their major impact on success or failure of the solution. Full-time observation by the design team also can guard against unwanted shortcuts, deviations, and product substitutions. In our opinion, full-time observation is a necessity to help avoid costly problems and nonconforming work when the repair contractor may not have executed a repair similar to the one that was required for this project.

LABORATORY TESTING FOR LOW-SLOPE STANDING SEAM METAL ROOF APPLICATION

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Laboratory testing was performed on a double locked standing seam roof design in a low-slope application. The test project included the design of the test mockups, construction of the test assembly, development of the test procedure, and evaluation of findings from the testing. The intent of the testing program was to assess the resistance of a low-slope standing seam metal roofing system to water leakage after being subjected to thermally induced and/or mechanical movements.

The test specimen or mockup was a 4.0 m x 2.9 m (13 ft 0 in. x 9 ft 7 in.) module of the standing seam metal roof construction, including transverse seams and davits, and incorporating recommendations of both the Sheet Metal and Air Conditioning Contractors National Association (SMACNA) publication and *Copper and Common Sense* regarding low-slope conditions, as well as other industry guidelines. The test apparatus was designed to mechanically cycle the roofing system to simulate the effects of thermal expansion and contraction at transverse and standing seams as required by the design and installation logistics. The mockup was ultimately tested to simulate a 20-year exposure to thermal cycling. Both water spray (in accordance with ASTM E 331) and flood testing were performed to determine the watertightness of the roofing system before and after testing. Based upon results of the different phases of testing, revisions and modifications were made to the system and subsequently evaluated. Design considerations based upon the testing were evaluated.

KEYWORDS

Flood testing, roofing mockup testing, standing seam metal roofing, thermal expansion/contraction, water leakage, water penetration testing.

INTRODUCTION

A design team for a long slender building located in a northern region of the United States had designed a standing seam metal roof to provide a durable, attractive enclosure for the structure. Due to the shape and size of the building, the metal roofing system design could not accommodate the industry-recommended guidelines for slope. This situation raised concerns about the watertightness of the roofing system design, especially because panels were to run the length of the building and multiple lengths of relatively long spans were needed. These long panel lengths were expected to undergo large movements during temperature changes and these movements could affect the durability and performance of the roof. In order to evaluate the resistance of the roofing system to water penetration, a testing program was undertaken to determine the effects of thermal movement and other conditions on the susceptibility of the design to water leakage.

DESCRIPTION OF ROOFING SYSTEM

The roof section under consideration measured approximately 107 m (350 ft.) long x 18 m (60 ft.) wide and its slope had a curvilinear profile with a radius of approximately 805 m (2,640 ft.). Two parallel rows of continuous skylights, 2.1 m (7 ft. 0 in.) wide and approximately 5.5 mm (18 ft.) apart, ran the entire length of the roof section. Davits supporting a track for an automated window washing system also interrupted the roof adjacent to the skylights. The proposed roofing system for the building (from interior to exterior) consisted of a metal decking system, 76-mm (3-in.) rigid foam insulation, 19-mm (¾-in.) fire-retardant-treated plywood, a self-adhering modified bitumen membrane (SAM) fully adhered to the plywood deck, rosin-sized paper, and 28-gauge terne-coated steel (TCS) standing seam roofing panels measuring 8 m (26 ft.) in length x 305 mm (12 in.) in width.

The plywood was attached to the metal deck with steel screws and plates anchored through the plywood and insulation. The SAM and the rosin-sized paper were continuous below the standing seam panels. The metal roof was attached to the plywood with 50-mm- (2-in.-) wide TCS cleats at 305 mm (12 in.) on center. The vertical standing seams of adjacent panels were coupled together in a double-lock folding process to create 25-mm- (1-in.-) high ribs with the direction of the standing seams or ribs parallel with the direction of the curvature and slope of the roof.

POTENTIAL ROOFING PROBLEMS AND CONCERNS

Because the radius of curvature for the roof was extremely large, the slope of this roof section was very shallow, especially adjacent to the peak of the roof structure. At the peak of this roof (midpoint of the chord, defining the shape of the building), the slope is zero, and as the roof continues downward, the slope increases to approximately 1:12 (8 percent) at each end of this section of the roof. In the SMACNA Architectural Sheet Metal Manual,1 standing seam metal roofs are only recommended for roof slopes greater than 3:12 (25 percent), unless special considerations are used for fabrication of the standing seams and lap joints.

Low-slope metal roofing systems can exhibit water leakage problems during heavy, short duration rains as a thick sheet of water develops on the surface of the panels. The thickness of this sheet will depend on the rate of rainfall as well as the surface characteristics and slope of the roof. The volume of water contributing to this sheet development depends not only on the surface area of the roofing panels, but also on adjacent components. As snow melts, water can also pond on the surface of the standing seams and transverse seams as ice blockage develops. Wind driven rain is an additional factor to be considered.

According to the SMACNA Manual, a standing seam roof that has a slope of 3:12 (25 percent) or less is deemed a low-pitched roof. Low-pitched roofs are unable to shed water quickly. For this reason, SMACNA recommends special detailing that includes applying sealant to the standing seams or increasing the standing seam height at low-pitch areas. When sealant is not used in these low-slope roofing conditions, SMACNA recommends that verification of the roof system design be made to ensure that water will not flood any seam or joint. These SMACNA recommendations primarily deal with the treatment of the vertical standing seams of the roof system, however, and not the transverse seams.

The Revere Copper Products, Inc. publication, *Copper and Common Sense*,[2] discusses other techniques for the prevention of water penetration through seams and joints in low-slope roof areas. This publication states that the transverse seam laps should be increased to 102 mm (4 in.) when the roof slope is between 3:12 and 6:12 (25 percent and 50 percent) to guard against water flowing under the lapped area. In addition to increasing the lap length to 102 mm (4 in.), it also recommends that a bead of sealant should be installed in the lock formed by the soldered locking strip. The lap of the vertical leg of the standing seam in the transverse seam lap should also be set in sealant. *Copper and Common Sense* further states that for standing-seam roofs with slopes that are less than 3:12 (25 percent), a high-grade butyl sealant tape, or alternately a bead of comparable sealant, should be applied to the top flange of the shorter standing-seam leg. This latter recommendation is similar to SMACNA's recommendation. The SMACNA manual does not state how to detail transverse seams in these cases.

Due to the 107-m (350-ft.) length of the structure, movement of the roofing panels due to thermal expansion and contraction was a concern. Many individual lengths of metal panels were required to complete the span due to the intended method of their field fabrication. The 8-m.- (26-ft.-) long metal panels were overlapped to form a series of shingled roof panels that extend the entire length of the roof and each overlap condition created a transverse seam lap joint. These transverse seams are also a potential source for water penetration when the slope is shallow (less than 1:12 [8 percent]) because large cyclical thermal movements can affect any applied seals. In addition, the geometry of the standing seams creates hydrostatic head conditions and sealant configurations that may not be durable. Large thermal expansion of the panels around davits also creates difficult waterproofing problems because the davits on the roof system remain stationary while the panels move around them. Finally, these panel movements can cause sealant problems at panel cleats that are folded into the double-lock folded vertical seams, as these cleats also remain stationary while the panels move over them.

In summary, the potential problems investigated in this study were as follows:

1. Potential water leakage through vertical seams, transverse seams, and davit flashings during heavy rains that create a sheet of water on the surface of the panels as water flows across them.
2. Potential water leakage through vertical seams and transverse seams and davit flashings during rains in combination with periodic wind uplift loads.
3. The effect of thermal movements on the resistance of vertical seams, transverse seams, and davit flashings on water leakage during heavy rains and rains with periodic wind uplift loads.

MODELING DRAINAGE FLOW OVER THE ROOF SURFACE

In order to determine the thickness of a water sheet that could develop during heavy short duration rains, weather data for the area was examined. Using rainfall data obtained from the United States Department of Commerce for the region, water accumulation was calculated for 2-, 5-, 10-, 25-, 50- and 100- year storm return periods having a 5- or 10-minute storm duration. For a 100-year storm of a 5-minute duration, the rate of water accumulation is about 248 mm (9.8 in.) per hour. For a storm of a 10-minute duration, the rate of water accumulation is about 191 mm (7.5 in.) per hour. The values for rates of water accumulation decrease as the storm return period is shortened. For a two-year storm of a 5-minute duration, the rate at which water will accumulate is about 131 mm (5.2 in.) per hour. For a storm of a 10-minute duration, the rate at which water will accumulate is 101 mm (4.0 in.) per hour.

Using the value obtained for a 100-year storm mean recurrence interval with a 10-minute duration, an analysis of the drainage flow characteristics in the low-slope areas was performed. Two roof conditions were analyzed. The first condition consisted of increasing the quantity of water on the curved roofing panel adjacent to the skylight where water runs off the skylights and onto this roofing panel. The second condition consisted of a single panel in the center of the roof, accommodating only storm water.

The analysis considered the drainage flow over the curved roof by dividing the roof into 20 sections of varying slope and using standard hydraulic flow formulas to evaluate the cumulative effects. Calculations revealed that the maximum amount of rainfall that would accumulate in the panel adjacent to the skylight would not exceed 17.5 mm (0.69 in.) of water flow. The maximum amount of rainfall that would accumulate on the typical field panel would not exceed 7.7 mm (0.30 in.) of water flow at the center of the roof.

The flood test portion of the test program was designed to simulate the effects of the sheet of water that develops during heavy, short duration rains. The mockup was flooded for a period of 24 hours to a height of 25 mm (1 in.) above the base of the pans. Though the height of 25 mm (1 in.) does exceed the calculated values previously discussed, this value was selected to offset erection tolerances existing on the actual mockup and still have at least 23 mm (0.90 in.) of water.

MODELING THE EFFECTS OF RAIN DURING PERIODIC WIND UPLIFT LOADS

In order to determine the design wind pressures, weather data from the regional airport near the project was examined, as well as data obtained from wind tunnel studies performed by Rowen, Williams, Davis, and Irwin, Inc. A negative uniform static air pressure difference of 814 Pa (17 psf) (in the uplift direction) is the one-year recurrence interval for the maximum wind gusts experienced at the regional airport and correlates with the wind tunnel studies. This analysis was performed to determine whether positive wind load conditions would ever exist for this roof. A positive wind load condition would drive water into the roofing system, whereas negative pressure would likely reduce penetration. The wind tunnel study revealed that a roof system would never be subjected to a positive wind load condition. The authors used a one-year recurrence interval to simulate a condition that would occur often during the life of the building.

To evaluate the capability of the roofing design to handle the thermal and uplift movements and drainage conditions, a mockup of the standing seam roofing system was designed and a test program was developed. In order to determine the mockup design, the appropriate tests had to be identified and the testing format developed.

The water spray testing portion of the test program was designed to simulate wind-driven rains. This was accomplished by utilizing the water spray rack specified by the American Society for Testing and Materials (ASTM) Standard E 331.[3] This test is similar to ASTM Standard E 1646[4] for water testing metal roofs, which was issued after the completion of this testing program. The water test was used to determine the resistance of the roof system to water penetration at room temperature. The roofing system was tested both with and without a uniform static air pressure difference to simulate the effects of wind. The test specimens were exposed to uniform static air pressure differentials of 0 Pa and -814 Pa (0 psf and -17 psf) (wind uplift) applied in a manner to simulate a gusting (fastest mile or minute) condition on the roof. Water was applied to the exterior surface of the roofing system by means of a grid of water nozzles set to deliver a uniform spray to the entire surface equivalent to a minimum of 5.25 mL/s (5.0 U.S. gallons/sq ft/hour) or an 203 mm (8 in.)/hour rainfall. The 10-minute storm duration rate for a 100-year storm return period is 191 mm (7.5 in.) per hour and compares closely to the rate of water application during the ASTM E 331 water spray test, thus not requiring any changes to this standard procedure. Also, considering the shape of the building, the roofing application, and the wind tunnel studies, the development of significant positive wind loadings on the roof during wind-driven rains was not expected and, therefore, the mockup was not exposed to these conditions. It was assumed that this cycle would only be encountered once per year. At the conclusion of the testing, the authors performed a static load test of -34 psf. This represents the maximum wind load in a 100-year reoccurrence interval. We observed no permanent deformation of the panels after this testing that would indicate that the waterproofing integrity of the system was not affected.

MODELING THERMAL MOVEMENTS ACROSS TRANSVERSE JOINTS

The effects of thermal cycling over a 20-year period were simulated to evaluate the adequacy and durability of the roofing system to resist water leakage after exposure to cyclic movement. A test apparatus was designed to mechanically simulate the effects of both thermal expansion and contraction at the transverse and standing seams by subjecting the mockup of the roofing system to longitudinal movement (parallel to the direction of the standing seams). It was assumed that approximately one-half of the days per year in the Midwest region receive sufficient solar radiation to subject the panels to a 27°C (80°F) temperature differential during the course of the day. It was assumed that the roof system is likely to experience 200 diurnal swings of this magnitude per year. The annual temperature extremes were based on temperature extremes of 71°C (160°F) for a bright summer day and -23°C (-10°F) for an overcast winter day.

The transverse seams were cycled to obtain a movement displacement of 4.8 mm (3/16 in.). This displacement represents one 27°C (80°F) diurnal temperature cycle. Because the diurnal temperature cycles occur over different temperature ranges during the various seasons of the year, the neutral position or center of translation of the test apparatus was changed to achieve a total lap joint displacement or a total transverse seam displacement of 9.5 mm (3/8 in.) (refer to Figure 1). The total displacement of 9.5 mm (3/8 in.) represents the amount of movement that would be experienced during one annual thermal cycle. Both displacement values were based on the following:

3/16 in. = 80°F (26 ft)(12 in./ft) (6.7 x 10-6 in./°F/ft)
4.8 mm = 44°C (8 m)(103 mm/m) (12.1 x 10-6 mm/°C/m)
3/8 in. = 170°F (26 ft)(12 in./ft) (6.7 x 10-6 in./°F/ft)
9.5 mm = 94°C (8 m)(103 mm/m) (12.1 x 10-6 mm/°C/m)

The mockup was also subjected to temperature extremes to expose the sealant in the various joints to elevated or lowered temperature conditions. Cooling was accomplished with a combination of refrigeration equipment and dry ice. Heating was accomplished with air heaters and heat lamps.

ROOFING SYSTEM MOCKUP

The mockup design simulated the roof design and included the same curb height limits, davits, gutters/drains and materials as the actual roofing system. The configuration also incorporated the refinements recommended in both the SMACNA publication and the *Copper and Common Sense* for low-slope conditions. Additional modifications, such as extending the transverse seam lap from 102 mm to 305 mm (4 in. to 12 in.), were incorporated into the mockup to further enhance the watertightness of the system.

Overall dimensions were 4.0 m x 2.9 m (13 ft 0 in. x 9 ft 7 in.). The mockup roof system was attached to a plywood deck over wood joists at approximately 305 mm (12 in.) on center. One side of the chamber deck was constructed with solid plywood, and the other side was constructed with

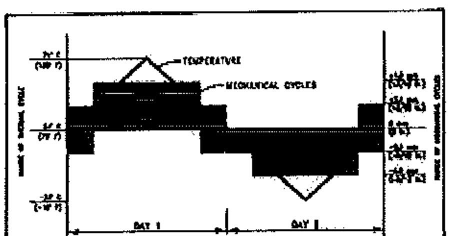


FIGURE 1 - Design Temperature Cycles (Seasonal) Compared to Induced Mechanical Cycles

Figure 1.

102-mm- (4-in.-) wide strips of plywood at 305 mm (12 in.) on center to allow for visual observation of the underside of the roof system. The window washing davits were constructed of steel tubes bolted to wood blocking between the roof joists. The side walls of the test chamber were constructed of wood studs and plywood (refer to Figure 2).

The top enclosure of the test chamber was constructed with wood framing members. Small plexiglass windows were placed in the walls of the enclosure to allow for visual observation of the roof system during the testing. The air pressurization equipment was connected to a 102-mm (4-in.) poly(vinyl) chloride tube located in the center of the enclosure, and a pressure tap was provided for connection of a water manometer, the device used to measure the pressure differences. The water spray grid was suspended from the inside ceiling of the top enclosure.

A steel reaction frame was designed to resist the load required to mechanically cycle the metal panels and induce differential movement at the transverse seams. The load was generated from an MTS dynamic machine, a servo-controlled hydraulic actuator capable of delivering either tension or compression with a maximum throw of 102 mm (4 in.) and adjusted to electronically monitor and control deflection. The load is applied to one side of the roof system via a lever arm that is connected to the MTS machine and a steel tube with four rectangular rods that are attached to a continuous plate secured to the underside of the roof panels. Small plates were placed on the top surface of the roof panels and secured to the continuous plate with two bolts through each standing seam panel. The bolts were tightened to create a friction connection allowing zero slippage of the standing seam roof at the connection. Three triangular steel trusses were constructed at the opposite end of the roof system to form the fixed connection of the reaction frame. The opposing end of the standing seam roof was attached to the trusses with a continuous plate in a similar manner. The entire test chamber and steel reaction frame were bolted into the concrete floor (refer to Figure 3).

The TCS standing seam panels were installed according to proposed details by highly skilled workmen employed by a nationally recognized roofing contractor. The mockup was constructed with eight full-width standing seam panels, each containing a complete transverse seam detail. On both sides of the mockup, small half panels were constructed with a transverse seam that folded up the curb on each side. The

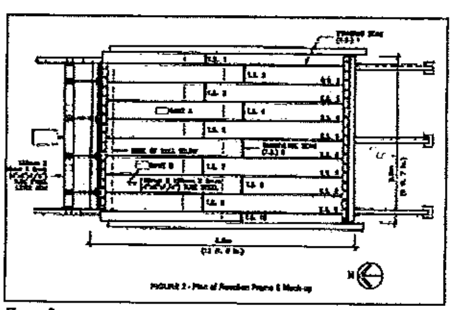


Figure 2.

sequence for installation of the TCS panels was as follows:

1. SAM was placed over the entire surface of plywood deck including the 102-mm- (4-in.-) wide plywood strips used for inspection openings. The window washing davits were also flashed with SAM.
2. Water-indicating paper strips were installed at approximately 152 mm (6 in.) on center to detect any water penetration through the metal roof.
3. Rosin-sized paper was installed in 305-mm- (12-in.-) wide strips between the panel cleats.
4. TCS panels 305 mm (12 in.) wide were laid over the rosin paper. The panels were held down with cleats at 305 mm (12 in.) on center. Each cleat was set on the SAM in a bed of liquid membrane (trowel grade modified asphalt compatible with SAM and nailed to the deck with two nails. The nail holes were covered with butyl sealant and the bottom leg of the cleat folded over the sealed nail heads (refer to Figure 4).
5. To simulate field installation of the panels around the davits, the standing seam panel on the mockup was cut oversized to fit around the davit. A prefabricated metal flashing assembly with upturned legs was placed over the davit and soldered to the standing seam panels. The davits are fixed in place. Panel movement around the davits was

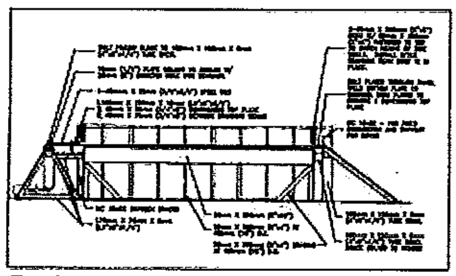


Figure 3.

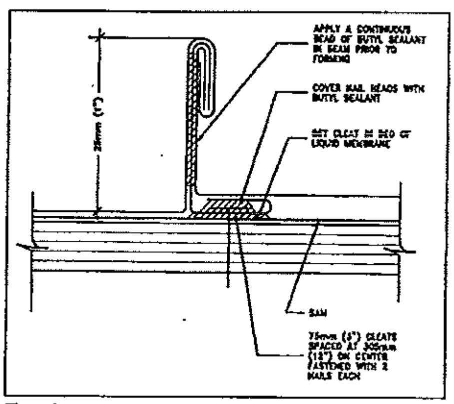


Figure 4

accommodated by the oversized opening in the panel and the flexibility of a lead boot flashing.

6. A specially designed two-piece lead boot davit flashing was soldered to the horizontal portion of the TCS panel. A metal drawband strap was used to attach the flashing to the davit. A bead of butyl sealant was placed over the top edge of the lead flashing to seal the joint.
7. A continuous bead of butyl sealant was placed inside the vertical legs before the fold of the standing seam was formed.
8. A bead of sealant was placed inside the 19-mm (¾ in.) hemmed edge used to attach the panels to the continuous transverse seam cleat.
9. Once all the panels were installed, the seams were folded together in a double-lock standing seam by hand or by the use of a mechanical seam roller. Amounts of the butyl sealant applied inside the standing seam extruded from the folds during forming and was cleaned from the surface of the metal.
10. The exposed transverse seams were sealed using a 19-mm (¾ in.) bond breaker tape over the seam joints and applying a 6-mm x 50-mm (¼ in. x 2-in.) bead of silicone sealant over the bond breaker tape (refer to Figure 5).

OVERVIEW OF TESTING PROGRAM

The testing program evolved into three phases. Observations regarding each of these phases are described in detail in the following section. In the first phase, the apparatus for mechanical cycling and the equipment for evaluating the roof system response to water were refined. Initially, this mockup was to be used to conduct the complete testing program; however, leaks developed during the first set of cycles.

In the second phase, several smaller mockups were developed and additional methods of water leakage testing were performed to investigate the causes of the water leakage. These involved some tests where dams were created to pond water in isolated areas.

In the third phase, a new mockup was built that incorporated many of the modifications to the testing apparatus and to the roofing system design that were developed during Phases 1 and 2.

Phase 1

The Phase 1 testing consisted of the following:

1. Perform 1,000 mechanical cycles between 71°C and -23°C (160°F and -10°F).
2. Perform 15-minute water spray test per ASTM E 331 with five air pressure spikes for 0 Pa and -814 Pa (0 to -17 psf).

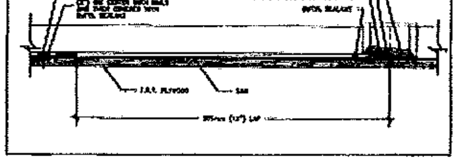


Figure 5.

3. Perform 24-hour flood test at 25-mm (1-in.) level.

Phase 2

The Phase 2 testing consisted of the following:

1. Flood test transverse seams by using water stops to isolate them. The isolated locations were filled with water to the top of the transverse seam sealant.
2. Flood test north half of mockup with 13 mm (½ in.) water after isolating the north half of mockup from south half, and also isolating the davits and transverse seams.
3. Flood test isolated north half of mockup to 25 mm (1 in.) water.
4. Flood test isolated regions around davits to 25 mm (1 in.) water.
5. Flood test south half of mockup with 25 mm (1 in.) water.
6. Unfold standing seams and inspect cleats. Install butyl sealant directly under the panel cleat and refold the standing seams.
7. Flood test mockup after refolding seams to 25 mm (1 in.) water.
8. Concurrently with the flood test in Item No. 7, build a separate mockup, the same size, but with no transverse seams included in the construction. Seal all of the standing seams with butyl sealant.
9. Flood test mockup with no transverse seams to 25 mm (1 in.) water for a three-day period.

Phase 3

The Phase 3 testing consisted of the following:

1. Remove original mockup as described for Phases 1 and 2 and construct a new mockup incorporating modified davit flashing and butyl sealant beneath standing seam panel cleats.
2. Flood test new revised mockup to 25 mm (1 in.) water.
3. Perform 1,000 mechanical cycles.
4. Perform 15-minute water spray test per ASTM E 331 with 5 air pressure spikes from 0 Pa and -814 Pa (0 to -17 psf).
5. Flood test entire mockup to 25 mm (1 in.) water.
6. Perform 3,000 mechanical cycles.
7. Perform 15-minute water spray test per ASTM E 331 with five air pressure spikes from 0 Pa and -814 Pa (0 to -17 psf).
8. Flood test mockup in increments of 3 mm, 19 mm and 25 mm (⅛ in., ¾ in. and 1 in.) water.

OBSERVATIONS DURING TESTING

Observations During Phase 1 Testing

Phase 1 testing began by mechanically cycling the panels. After 1,000 mechanical cycles were completed, the roof mockup was visually examined for evidence of distress caused by the cycling. Two small splits, ranging in size from 3 mm to 6 mm (⅛ in. to ¼ in.), were observed in the transverse seam silicone sealant at one location. The splits occurred on the vertical upturn portion of the sealant along the uppermost edge of the standing seam. However, no water leakage was observed during the ASTM E 331 water spray test when the roof mockup was subjected to water spray in conjunction with static air pressure difference or when the roof was subjected to water spray with and without the application of a static air pressure difference. The testing continued by flooding the roof mockup to the height of the top of the standing seams. Extensive leakage was observed inside beneath the standing seams when the water was ponded on the surface of the metal roofing panels. These leak locations are shown in Figure 6. The total amount of water that penetrated through the roofing system was not measured due to the volume of leakage. Water entered the roof system through all of the standing seams except one. This seam had been modified by installing silicone sealant along the length of the vertical seam prior to the start of the testing to evaluate its effectiveness in accommodating movement.

Observations During Phase 2 Testing

Upon completion of the Phase 1 test, when the roof system was flooded, a relationship was observed between the level of water on the roof and the amount of water leakage that occurred. If the water level was maintained below the top of the standing seam, the roof system leaked only slightly and at isolated locations. To identify the leak source in the roof system and to study this relationship, the transverse seams and the davit locations were isolated from the remainder of the roof system with small plexiglass dams and butyl sealant to evaluate specific joints for watertightness.

When the water on the sectioned-off north half of the mockup was flooded to the top of the standing seams, leakage occurred through the metal dam where the metal roof terminates.

Sources of water leakage were attributed to conditions at or around the davit flashings and leakage through the standing seams. Leakage through the standing seams occurred either through the vertical (upturned) portions of the transverse sealant or at panel cleats. Along the standing seam where the panel cleats were fastened, the butyl sealant application in the standing seam was interrupted. The cleats were initially installed dry on the metal panel, and the next panel was installed with butyl sealant placed in the fold. When the panel was laid down over the cleats, the butyl sealant covered only the top of the cleats, leaving the area under the cleats without sealant. Neither the SMACNA publication nor *Copper and Common Sense* discusses sealing of cleats in low-slope roof areas.

Because water penetration through the area around the unsealed cleats could not be eliminated, the mockup was disassembled and modified. Trial repairs to seal the panel cleats were implemented by locating the panel cleats, opening the standing seam folds, placing butyl sealant in the joint under the panel cleat, and folding the seams back into their double-folded position without resulting in any visual distortions.

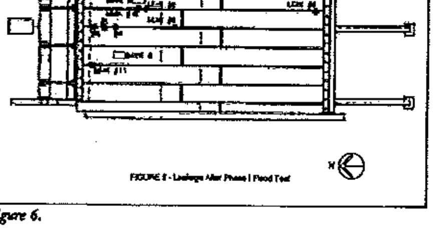


Figure 6.

The roof panels were then flooded again to determine if these trial repairs were effective. With these modifications, water leakage occurred through the metal roof system at approximately the same volume and rate as observed during the previous flood tests of Phase 1, indicating that either the repairs were not effective or that leakage through the transverse seams was significant.

A second trial mockup panel, composed of several continuous metal panels with no transverse seams or davits, was then constructed to evaluate whether the panel cleats could be effectively sealed. The panel cleats were sealed by applying butyl sealant beneath each cleat in addition to the butyl sealant placed within the standing seams. This trial mockup was then flooded with water to the height of the top of the standing seams for three days, with no signs of any leakage through the standing seams. However, no thermal cycling was performed on this system to assess degradation associated with movement.

Observations During Phase 3 Testing

The original mockup that was installed in Phase 2 was completely rebuilt and included two different davit flashing details. Davit A was fitted with an "L"-shaped water stop 25 mm (1 in.) high soldered to the horizontal portion of the panel around the davit. The two-piece lead boot was then placed over the water stop and installed in the same manner as before. The water stop was installed so that any water that penetrated the solder joints around the lead boot would not penetrate the opening cut in the standing seams for fitting around the davit. At Davit B, a bead of butyl sealant was placed on the inside of the flange of the lead flashing boot. This davit did not contain a water stop. The lead boot was then soldered and installed in the same manner as before. The sealant was intended to act as a water stop to restrict water from entering the opening cut in the panel, should the solder joints around the lead boot fail.

The leak occurred at the west side of Davit A. At this location, the panel was cut through the standing seam to facilitate the installation of the panel around the davit. A TCS "L" water stop had been soldered around the davit before the lead boot was soldered to the panel; however, the leakage appeared to be coming from the standing seam area.

The test procedure continued as planned to determine if any new leaks became apparent after testing. Phase 3 Part 2, testing of the revised mockup roof system began with the in-phase simulated five-year exposure consisting of 1,000 mechanical cycles. No noticeable leakage occurred during this first phase of testing. Additionally, no water leakage was observed during the Phase 3, Part 3-ASTM E 331 water spray test, and no leakage was observed when the mockup roof system was subjected to both zero pressure and negative pressure.

Testing proceeded with Phase 3, Part 4-flood test, during which the roof mockup was flooded to the height of the top of the standing seams. Considerable leakage occurred through the roof system during this portion of the test. Leakage occurred at the two initial leak locations and three new leak locations.

The source of the initial two leaks and the three new leaks that developed after the first 1,000 cycles of the revised test program was investigated. (Leak locations are shown in Figure 7.) Leak No. 1 was attributed to either a sealant void in the standing seam or leakage at the top portion of the transverse sealant. The leakage occurred along the seam and water migrated along the seam and out the end of the test chamber.

Leak No. 2 occurred at Davit A. This area was repeatedly tested by creating small dams of butyl sealant and testing selected areas. The rate of leakage resulting from testing at these smaller isolated areas never equalled the rate observed during the full-scale flood test. Two plexiglass dams were created on either side of the davit between the standing seams. Once the entire area around the davit was flooded, the rate of leakage was approximately the same as that recorded during the flood test. The source of this leak could not be definitively identified without completely dismantling the roof system. However, it appeared to be associated with the standing seam in this area. The solder joints around the cut portion of the roof panel that fit around the davits were damaged when the standing seams were folded.

Leaks No. 3 and 4 were the result of water entering the transverse seam at the point where the transverse seam sealant turned up the standing seam fold. At this location, a shearing action took place in the sealant, resulting in the sealant becoming debonded from the surface of the metal. Water penetrated the sealant at this location and filled the transverse seam lap joint.

Sealant at the vertical upturn was inspected at the remaining transverse seams. Hand pressure applied to the horizontal portion of the transverse seam and to the 305-mm (12-in.) lap resulted in water being pumped out at the bottom edge of the standing seam fold adjacent to the vertical upturn of the sealant. Water flowed out from six of the eight transverse seams at the vertical upturn of the sealant. Water that entered the other transverse seams did not leak since water needed to build up over the height of the back hemmed edge before it could be observed below the mockup.

Leak No. 5 was located at Davit B. The same procedure was utilized for isolating the leak at Davit A. As the leak was being isolated, cracks were observed in the solder joints around the lead flashing boot. These cracks were soldered tight, the area was flood tested again, and no leakage occurred. The cracks in the solder joints were likely the result of fatigue from the mechanical cycling.

Four thousand additional mechanical cycles were performed for a total of 5,000 cycles at room temperature. The additional 4,000 mechanical cycles were performed to evaluate the durability of the system to accommodate movement for an expected twenty-year period. The amount of movement at the transverse seam was approximately 5 mm (3/16 in.). The center point of the cycle was shifted similar to the hot and cold temperature shifts after 2,000, 3,000, and 4,000 cycles to maintain the total overall movement of 10 mm (3/8 in.) during annual cycles.

As the system was mechanically cycled, the butyl sealant placed in the standing seams extruded out of the folds of the seams at the location where the panels were staggered. At this location, one panel moved relative to the fixed adjacent panel, causing the butyl sealant to be pushed out the folds of the standing seam. This resulted in voids in the butyl sealant, creating a situation where water could enter the standing seam. During the mechanical cycles, the flashings at both davits appeared to slide back and forth with the movement of the panels, resulting in an opening in the butyl sealant around the top of the lead flashing. The metal drawband used to fasten the lead boot to the davit was not a snug fit, allowing the flashing to slide back and forth. The davit flashing rocked back and forth in a pendulum-type motion rather than side to side.

Only flood tests were performed on the mockup in conjunction with this series of cycles because the gaps at the davits would have likely produced a leak under water spray testing. A flood test was performed at the end of 2,000 cycles and 5,000 cycles.

The flood test after the completion of 2,000 mechanical cycles (Phase 3) resulted in eight leaks in the roof system. (Leak locations are indicated in Figure 8.) Leaks No. 1, 2, and 4 occurred at the same locations as noted during the previous test. Leak No. 3 was located at the inspection opening from the previous test made in the first full transverse seam, indicating that leakage occurred through the transverse seam sealant at the vertical upturn.

Intense leakage occurred immediately at Davit B (Leak No. 5) when the mockup was flooded. Water leakage, at a rate of approximately 1.05 mL/s (1 gallon per hour), was collected at the 102-mm- (4-in.-) diameter inspection hole near the davit. The source of the leakage was the hairline fractures in the solder joints.

Leak No. 6 was only a slight drip and occurred either at the fixed edge of the transverse seam lap or a panel cleat that was located in the area. Leak No. 7 was associated with a cleat directly over the slight drip. Leak No. 8 occurred at the far west inspection hole drilled into the solid portion of the deck. The source of this leak was not definitively determined, but was most likely the result of excess water on the roof deck.

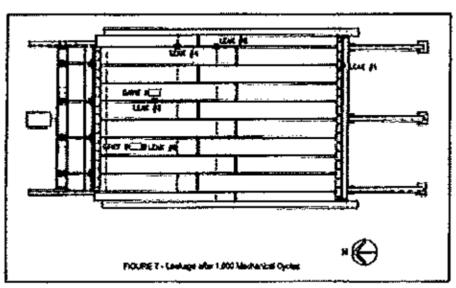


FIGURE 7 - Leakage after 1,000 Mechanical Cycles

Figure 7.

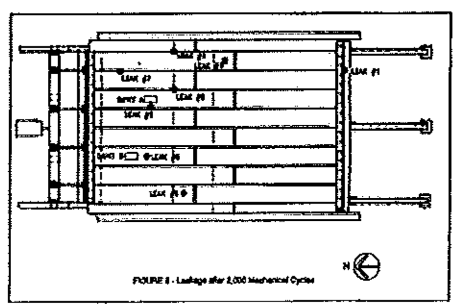


FIGURE 8 - Leakage after 2,000 Mechanical Cycles

Figure 8.

The roof system was flood tested after the completion of the 5,000 mechanical cycles (Phase 3) in three steps. The leak locations from this test are shown in Figure 9. The davits were isolated from the roof with small plexiglass dams to determine the height of water at which leakage occurred. Water was filled to one-half the height of the standing seam with no signs of leakage through the davit areas. The water level was raised to three-quarters the seam height with no leakage observed around the Davit A; however, there was significant leakage at Davit B (Leak No. 5). Fractures occurred in the solder joints around the davit, resulting from the rocking motion. These fractures were covered with butyl sealant and the areas around both davits were filled with water to the top of the standing seam. No further leakage was observed at Davit B; however, a small leak developed at Davit A (Leak No. 2). Although this leak occurred at the same location as noted previously, the rate of leakage was significantly less. Based upon these leaks, it was concluded that standing seams were contributing to leakage.

The remainder of the roof mockup was then flooded to approximately one-half the standing-seam height. No new leakage was observed. Additionally, there was no evidence of new water leakage when the mockup was flooded with approximately 19 mm (¾ in.) of water. However, once the roof mockup was flooded to the top of the standing seams at approximately 25 mm (1 in.), six new leaks developed. A few of the leaks (Nos. 1, 2, 3, 5, 6 and 8) occurred at the same location as previously noted under Phase 2; some previous leaks (Nos. 4 and 7) had disappeared; and some new leak locations (now identified as Nos. 4 and 7) developed.

Leak No. 8 occurred at a transverse seam. Since the roof deck was previously dry and the Davit B flashing leak did not cause water to flow across the deck, this leak was attributed to water leaking through the vertical upturn of the transverse seam sealant. A new leak (Leak No. 7) developed at the side of Davit A, resulting from a cleat directly over the leak. The source of Leak No. 4 was most likely the vertical upturn in the transverse seam sealant similar to Leak No. 8 described above.

The leak previously identified as Leak No. 4 under the Phase 1 and Phase 3, Part 2 testing disappeared. This leak had been attributed to a vertical upturn of the transverse seam sealant. However, the source of this leak was likely the result of a cleat in the nearby area. The butyl sealant located within the folds of the standing seam probably separated from the adjacent metal, resulting in the earlier leakage.

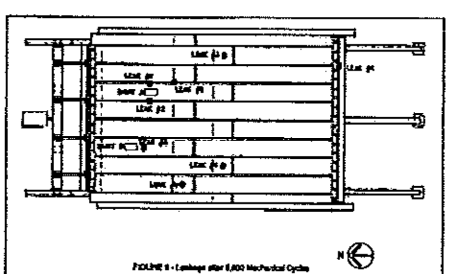


Figure 9.

With the additional mechanical cycles and the nature of butyl sealant to remain gummy, the sealant most likely healed itself, thus closing off the source of the leakage.

Three modes of failure were identified in the Phase 3 tests: leakage at davits, leakage through standing seams, and leakage through the vertical upturn of the transverse seam. Leakage occurred at both davit locations, either through the panel splice or from the davit flashing itself. Three leaks could be attributed to the vertical upturn of the transverse seam. Three leaks were also attributed to butyl sealant failing at the panel cleats. Finally, two leaks were attributed to either the vertical upturn of the transverse seam or to a panel cleat (refer to Figure 10).

SUMMARY OF TEST RESULTS

Observations made during the testing program and an analysis of the conditions encountered revealed the following results of the testing program:

1. The horizontal portion of the transverse seam sealant performed satisfactorily during all testing phases.
2. No leakage was observed through the SAM membrane during the testing.
3. Three leaks were observed at panel cleats when ponded with 25 mm (1 in.) of water indicating that water can penetrate the seam, travel longitudinally in the fold of the standing seam, and leak outside the test frame. Movement of the standing seam panels relative to the cleats can cause a wearing action such that the butyl sealant is pushed from the surface of the metal creating a small void in the sealant.
4. Butyl sealant within the standing seam was extruded from the seam when the folds were formed and during the mechanical cycling, resulting in isolated voids in the sealant.
5. Sealant must be placed below the cleats to prevent leakage through this metal-to-metal joint.
6. The vertical portion of the transverse seam sealant joint failed to resist water penetration when water was ponded on the mockup to a level greater than 19 mm (¾ in.). Shearing action of the bridge seal applied at this location caused voids to develop and the sealant to fail along the bottom edge of the standing seam at the folded side during the mechanical movement. Failure of the sealant may also be attributed to the incompatibility of the silicone and butyl sealant within the seam. Debonding of the silicone sealant at the upturn panel edge created a void for

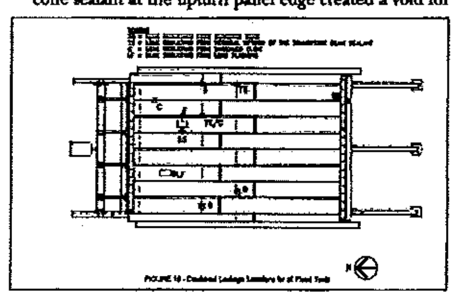


Figure 10.

water to infiltrate at transverse seam locations.

7. The flashing surrounding the davits was a two-piece lead boot that was soldered to the TCS panels, clamped to the top of the steel davit with a drawband, and sealed with butyl sealant. Mechanical cycling caused small cracks to develop in the lead sheet and solder from metal fatigue, allowing water infiltration. Additionally, the butyl sealant and drawband at the top of the lead flashing separated from one of the davits after 3,000 mechanical cycles.
8. With the exception of leakage at the both davit locations, leakage in the original mockup did not occur at any time during the ASTM E 331 water spray testing and wind uplift tests. The height of the water allowed to pond on the panels had a direct correlation to leakage. Water ponded to a height of approximately 19 mm (¾ in.) did not result in leakage, excluding the davit locations. Leakage did occur, however, when water was ponded above 19 mm (¾ in.). The center of the folded edge of the standing seam is the critical height for leakage to occur, excluding wind driven rain.
9. Calculations taking into account drainage flow on a curved roof indicated that the height of the water resulting from a 100-year rainfall intensity for a duration of 10 minutes would reach a maximum of 17.5 mm (0.69 in.). The level of water during these rains will be from 7.4 mm to 17.5 mm (0.3 to 0.69 in.) plus the thickness of the sealant at the transverse seam, or approximately 22 mm to 29 mm (⅞ to 1⅛ in.). Raising the standing seam above 25 mm (1 in.) will significantly improve the watertightness of the metal at the transverse joints because the bottom of the folded portion of the seam will be elevated above anticipated design rainfall levels.

RECOMMENDATIONS TO IMPROVE WATERTIGHTNESS

As a result of the testing program performed on the mockup of the roofing system, the following recommendations would improve the watertightness and performance aspects of the design:

1. Installation of the SAM is critical to provide a second line of defense against leakage. Special care must be taken when forming the membrane at laps and corners around davits. These details should include the use of a liquid membrane to seal and enhance the watertight performance of the laps in the membrane.
2. Openings cut in the standing-seam panels for the davits should be made through the flat portion of the pan only and not through the standing seams.
3. Davit boot flashing should include a flexible connection to the steel davits using an elastomeric sheet membrane.
4. The height of the standing seam should be raised so that the maximum water flow above the sealant at transverse seams will be below the bottom edge of the double lock seams.
5. Stainless steel expansion cleats should be installed on the entire roof system in lieu of friction cleats to reduce the shearing action of the seam sealant. Set the expansion cleat in sealant onto the panel to avoid a metal-to-metal joint.
6. Install pre-formed silicone sealant "bridge seal" type seals at all transverse seams in the low-slope regions up to 3:12 (25 percent) slope.

REFERENCES

1. *Architectural Sheet Metal Manual*, fourth edition, Sheet Metal and Air Conditioning Contractors National Association, Inc., Tysons Corner, Virginia, 1987. The fifth edition was issued in 1993, subsequent to the test program described in this paper.
2. *Copper and Common Sense*, seventh edition, Revere Copper Products, Inc., Rome, New York, 1982.
3. American Society for Testing and Materials E 331: "Standard Test Method for Water Penetration of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference," West Conshohocken, Pennsylvania, American Society for Testing and Materials.
4. American Society for Testing and Materials E 1646: "Standard Test Method for Water Penetration of Exterior Metal Roof Panel Systems by Uniform Static Air Pressure Difference," West Conshohocken, Pennsylvania, American Society for Testing and Materials.

LITIGATION/LEGAL PROCEEDINGS HISTORY

for Wiss, Janney, Elstner Associates, Inc.

Litigation History

WJE is involved in over 7,000 contracts per year. As a consequence of these contracts, WJE is brought into a variety of lawsuits. Nevertheless, during the past ten years, WJE's Professional Liability carrier has not paid a single professional liability claim on behalf of WJE. Summary status of professional legal claims/disputes over the last five years are provided below.

Over the last ten years, WJE has NOT been involved in any litigation or legal proceedings involving allegations against the firm for false claims or fraud.

WJE has NOT been fined or convicted in any other state or federal litigation or legal proceeding relating to the procurement or performance of any public or private construction project over the last five years.

Claimant	Year	Project Site	Description	Disposition/Status
Dr. Morgan Reynolds	2007	New York	Twin whistle blower lawsuits claiming World Trade Center destruction caused by US Govt.	WJE dismissed
Dr. Judy Wood	2007	New York		
Stevenson Lumber	2007	Connecticut	Claim of roof truss repair design.	Closed
Asbury Tower	2007	New Jersey	WJE mediation claim for unpaid fees.	WJE dismissed
State Farm/Hedstrom	2008	Chicago	Claim over loss of material sample held by WJE.	Closed
McGurran Residence	2008	Minnesota	Claim that water damage report did not address code violations or construction defects.	Closed
Herrington Spa	2008	Chicago	Claim that WJE report on water damage failed to include cause was clogged city sewer.	Closed
Arrabelle at Vail Square	2008	Colorado	Water Damage.	Pending
Cristo Rey High School	2009	Illinois	Water Damage Caused by Line Breakage.	WJE dismissed
Lakeview Estates	2009	Colorado	Construction defects.	Conditionally released

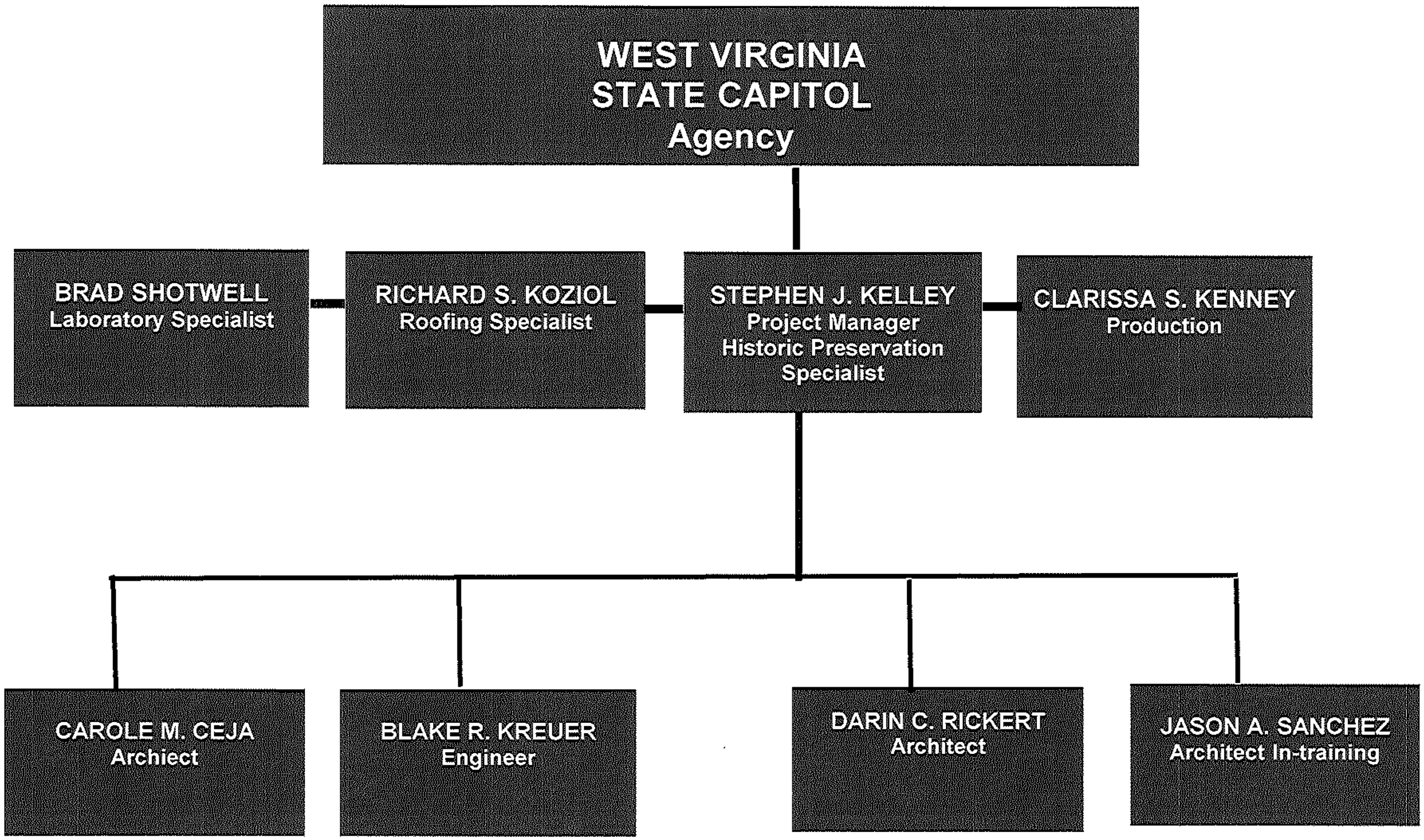
Soul Circus	2009	Maryland	Claim based upon clown on stilts falling on person in audience.	WJE dismissed
First Ascent	2009	California	Construction defects to Condominiums in Squaw Valley.	Pending
Twelve Oaks Medistar	2009	Texas	WJE alleged to have conspired with insurance company to deny recovery to owner.	WJE dismissed
Sandpiper Condominiums	2009	Florida	WJE alleged to have conspired with client to make subcontractor do more work.	WJE dismissed
Recreational Design & Construction, Inc.	2010	Florida	WJE alleged to have breached its duty when informing client that plaintiff installed defective slide.	WJE dismissed
Anderson v. Commodore/ Green Brier	2010	Illinois	WJE alleged to have contributed to drunk person falling through railing.	WJE dismissed
1999 McKinney Condominium Association	2010	Texas	WJE alleged to have failed to oversee repairs at condominium.	Pending
Federal Insurance	2011	Illinois	WJE alleged to have wrongfully approved plans for City of Evanston.	Closed
Downtown Lofts	2012	Colorado	WJE provided statutory notice that building on which WJE worked has problems.	Pending
Residences at Little Nell	2012	Colorado	WJE provided statutory notice that building on which WJE worked has problems.	Pending

Suspension or Debarment

WJE is not presently, nor has it ever been, debarred, suspended, proposed for debarment, or declared ineligible for the award of contracts or any state or federal agency.

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

5c. WJE Team Organization for the West Virginia State Capitol Roof Replacement Project

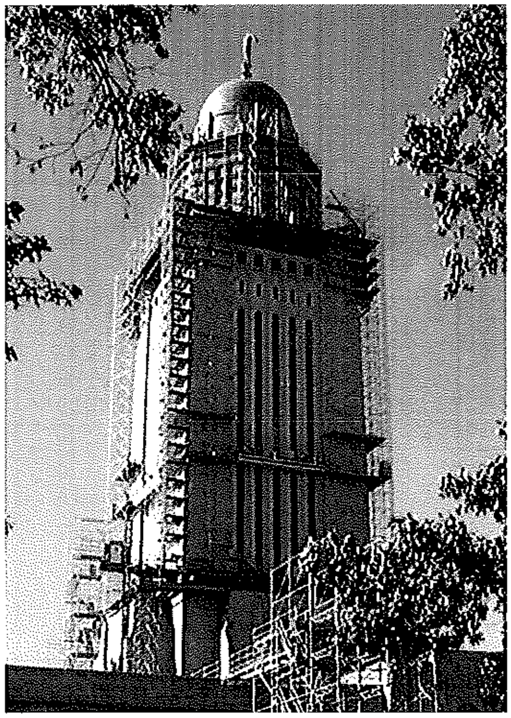


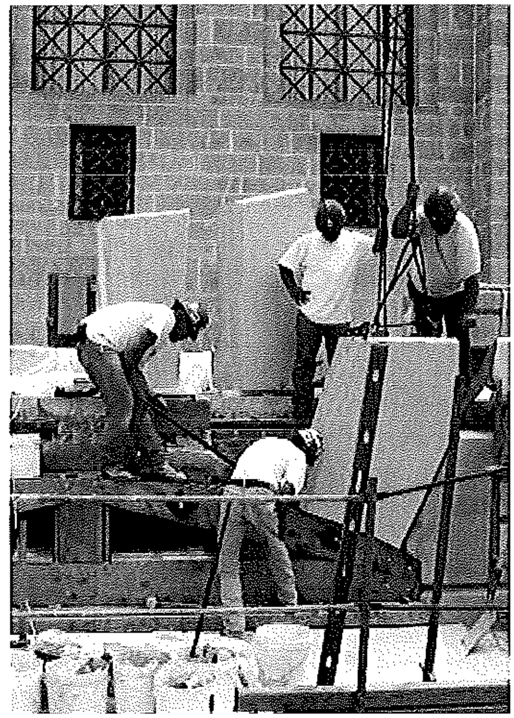
Wiss, Janney, Elstner Associates, Inc.

PROJECT PROFILE

Nebraska State Capitol

Exterior Facade Investigation and Restoration Design | Lincoln, NE

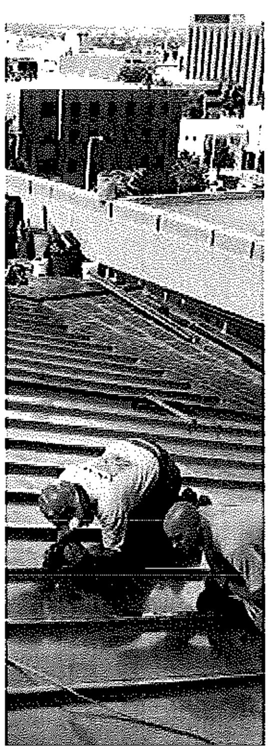




CLIENT
State of Nebraska

BACKGROUND
The historic Nebraska State Capitol is a 400-foot-tall monument design by Bertram Grosvenor Goodhue and constructed between 1922 and 1932. A result of a national design competition, the building follows the Beaux-Arts design tenets and melds the traditional domed state capitol building with a post-World War I skyscraper.

WJE provided specialized architectural and conservator services for the restoration of the building facade, including limestone masonry, ceramic tile dome, clay tile arches, sculptural elements, windows, roofing, and related structural systems.



SOLUTION
WJE engineers and architects performed a comprehensive investigation of the exterior building systems including the dome, facades, promenades, windows, and copper roofing system. The team utilized rappelling techniques for inspection of the dome and other difficult access areas. Petrographic analysis of the limestone masonry was performed as well as an evaluation of cleaning and biocide treatments.

In cooperation with Bahr, Vermeer & Haecker, WJE developed restoration drawings and specifications for the restoration of the historic structure. All work was performed in strict accordance with the *Secretary of the Interior Standards* following a "conservative philosophy," salvaging and respecting the historic building fabric whenever possible. WJE also redesigned inconsistencies in the original design and construction to give the building fabric increased durability.

WJE provided observation services and continuing laboratory analysis on an as-needed basis throughout the multiphase project.

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WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

Eisenhower Executive Office Building

Washington, DC

CLIENT

AECOM

STRUCTURE

The Eisenhower Executive Office Building, constructed between 1871 and 1888, was originally designated the State, War, and Navy Building. It was constructed in phases in the French Empire Style according to the design of Alfred B. Mullet. The design of the building reflects its role as a hierarchically organized workplace for clerical, administrative, and executive personnel. This aspect of its nature can be seen in structural, organizational, and decorative systems, which signify, clarify, and enhance distinctions among those personnel. The EEOB currently provides office space for White House Staff and Members of the Executive Office of the President.

CHALLENGE

The building is presently undergoing a remodeling, which includes making the facility able to withstand blast and ballistic attack, and modernizing the Mechanical, Electrical, and other service systems. This all needs to be accomplished while retaining major exterior and interior historic features.

SCOPE

- Perform condition survey of roof, cast iron trim, roofing systems and interior spaces.
- Develop strategies to protect historic fabric of the building
- Design repair of exterior façade, cast iron trim and leaking copper roof
- Develop restoration strategies for various interior spaces.
- Inspect work that is being performed.

SOLUTION

- Serve as Historic Preservation Consultant to Design Build team
- Develop strategies for protection, conservation, or sensitive replacement of interior finishes.
- Consultation the replacement of wood window and exterior door systems with new blast and ballistic enhanced window systems that match original window.
- Perform HABS documentation on interior and courtyard spaces.
- Clean façade and replace flat seam copper roofs.

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

FargoDome Multipurpose Sports and Exposition Facility

Roof Leakage Investigation and Reroof/Canopy Design
Fargo, North Dakota

CLIENT

City of Fargo

CHALLENGE

Shortly after construction of this large multipurpose stadium, the standing seam sheet metal roof at the perimeter of the building began leaking and several large sections of the roof were blown off. In addition, snow and ice sliding from the sloped portions of the roof created a serious safety hazard around building entrances during winter months.

STRUCTURE

The FargoDome was completed in 1992 and is located just north of the North Dakota State University (NDSU) campus. The venue is home to the NDSU Bison football team and hosts a variety of concerts, trade shows, and other large-scale exhibitions throughout the year. The roof comprises sloping areas around the perimeter that are clad with standing seam metal panels and a low-slope roof with a membrane roofing system at the interior.

SOLUTION

WJE first performed a detailed investigation to determine the causes and extent of the observed roofing problems. Since the original standing seam portions of the roof lacked adequate wind uplift resistance, these components were replaced along with a new plywood deck covered with a self-adhered waterproofing underlayment for enhanced protection against moisture penetration. We also designed canopies to be added along entryways around the perimeter of the building to provide protection against falling ice. The canopies were constructed of concrete and faced with brick and an exterior insulation and finish system to complement the architectural design of the original building exterior. In addition to developing all associated contract documents, we also provided construction period services for the owner.

WJE

PROJECT PROFILE

Virginia Governor's Mansion

Condition Assessment and Restoration Plans | Richmond, VA

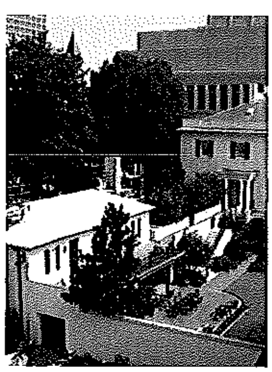
CLIENT

Commonwealth of Virginia Department of General Services

BACKGROUND

Built in 1813, the Virginia governor's mansion is the oldest continuously occupied governor's mansion in the United States. Architect Alexander Parris designed the structure, which is now a national historic landmark. A cottage/guest house and a carriage house are also part of the executive mansion's complex.

Portions of this historic mansion and two adjacent structures were in need of restoration. Problem conditions included warping wood and mold growth, cracking and spalling in the exterior masonry walls, and deterioration of the standing seam metal roof and brick chimneys. A detailed restoration plan was required to address these problems. The plan had to comply with The Secretary of the Interior's Standards for the Treatment of Historic Properties.



SOLUTION

WJE's investigation of the facility's problems included visual documentation of deterioration and distress and localized water testing. Together with the owner, WJE prepared a phased restoration plan in conformance with the applicable historic standards. Repairs included recoating of the mansion walls to address water leakage, tuckpointing and other retrofit work on the cottage/guest house chimneys, and replacement of the entire cottage/guest house metal roof and underlayment systems. To confirm that the repairs were implemented in conformance with the plans and specifications, we assisted the owner during the construction phase by providing periodic observation of the work.

WJE | ENGINEERS
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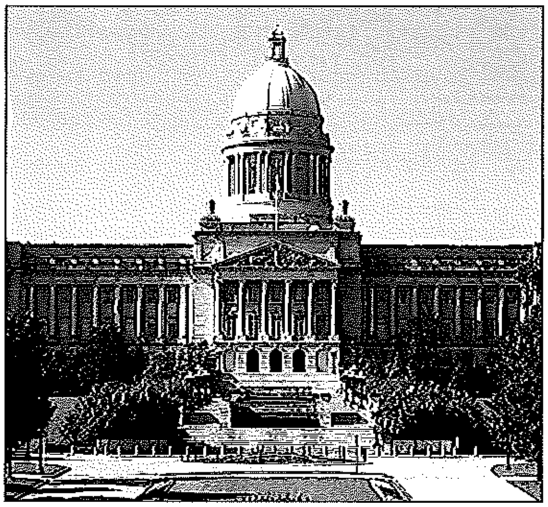
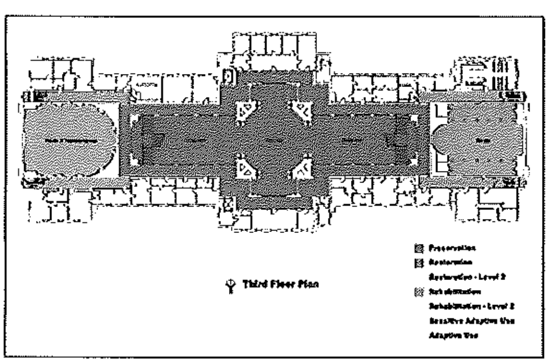
MATERIALS SCIENTISTS

Kentucky State Capitol

Historic Conservator for Restoration Master Plan
Frankfort, Kentucky





CLIENT

K. Norman Berry Architects

STRUCTURE

The Kentucky State Capitol, constructed in 1906, was designed in the Beaux Arts Style by Ohio architect Frank Mills Andrews. With visual links to the Parisian Hôtel des Invalides and Opera, the Capitol develops the classical Beaux Arts motif surmounted by a dome. While the exterior is clad with limestone with a dome of terra cotta, the interior is festooned with various types of granite and marble, exotic woods, and "scagliola" plaster surfaces. The public and legislative spaces are finished with a high degree of craftsmanship that is indicative of the era in which it was completed.

CHALLENGE

The Commonwealth of Kentucky made specific recommendations for outlining a strategy for the restoration and preservation of the Kentucky State Capitol. The breadth of the Master Plan included the Capitol Building, Capitol Annex, Parking Structure, Site Improvements and a new Executive Office Building. The intent of the work was to preserve the Capitol and to allow it to serve the people of Kentucky through the next millennium. The Louisville firm of K. Norman Berry Architects was awarded the contract to prepare a Master Plan for the Capitol complex. WJE served as the Project Conservator to the team.

SCOPE OF SERVICE

- Conduct all historical research
- Perform condition assessment of all exterior and interior building systems and materials
- Prepare an Historic Structures Report on findings

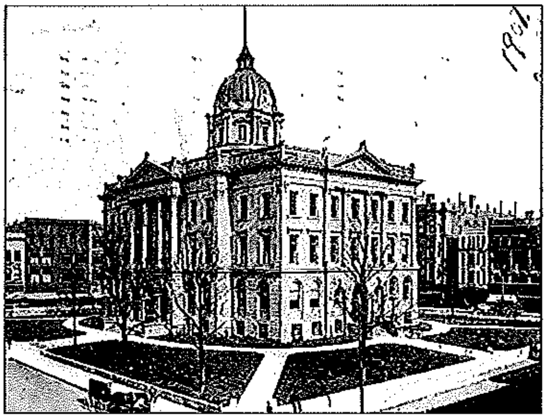
SOLUTION

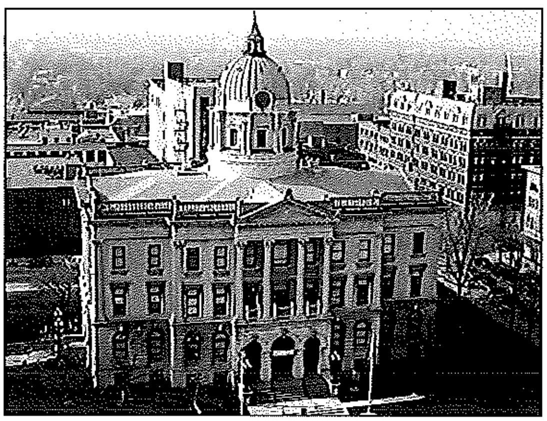
- Multi-disciplinary, in-house WJE team incorporated difficult access techniques to perform an in-depth condition assessment of roofing, facade, and windows
- Managed subconsultants for interior condition survey of MEP, wood, metals, plaster, and paint finishes
- Performed field and laboratory studies
  - Accelerated weathering testing was used to evaluate the terra cotta
  - Biological treatment studies were performed on the building exterior
- Served as the Preservation component of the team

WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

McLean County Courthouse

Conservation Assessment Program, Investigation, and Repair Documents
Bloomington, Illinois





CLIENT

McLean County

STRUCTURE

Designed by the Peoria firm of Reeves and Baillie, architects of several buildings that are now listed on the National Register of Historic Places, the McLean County Courthouse was completed in 1903. Despite almost 90 years of continuous service as a public facility, the former courthouse retains many of its exterior and interior architectural elements. Following the completion of a new county courthouse in 1989, the McLean County Historical Society moved into the old courthouse. The building currently houses the offices, exhibits, and collections of the society.

CHALLENGE

WJE, in cooperation with Vinci/Hamp Architects and a consulting conservator, was retained to conduct a Conservation Assessment Program (CAP) survey, and to provide a report evaluating both the building and its collections. At the request of McLean County government, WJE is also performing an additional investigation to determine the causes of observable distress conditions and to develop preliminary design documents for the repair and restoration of the building.

SCOPE OF SERVICE

- Conservation Assessment Program (CAP) Survey
- Close-up inspection
- Recommendations for restoration and repair
- Cost estimation
- Construction documents

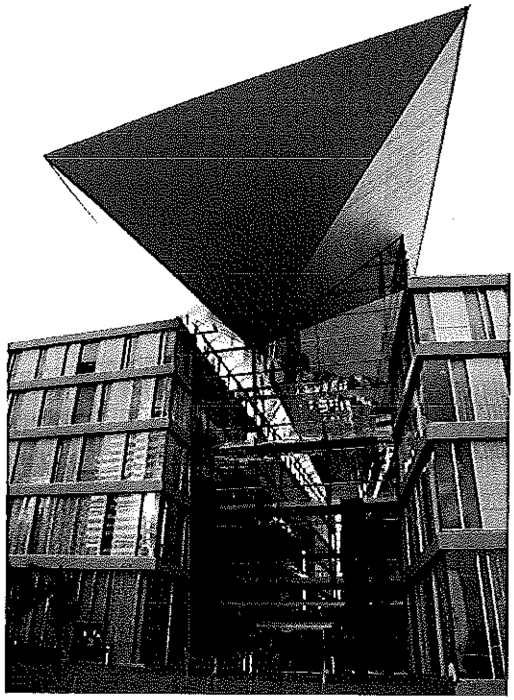
SOLUTION

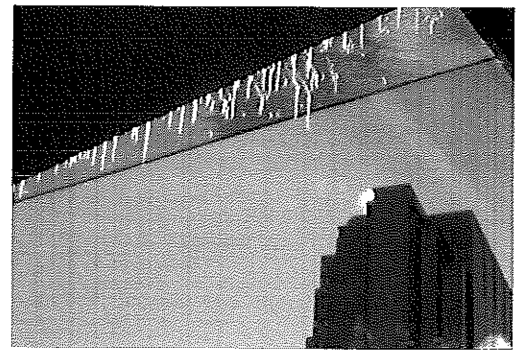
- Performed CAP study that included narrative history, observations of the existing conditions of the building materials, and inventory of the Museum collections
- The survey report addressed recommendations for restoration and repair
- WJE conducted a secondary survey focusing on observed distress conditions and prepared preliminary cost estimation
- Conducted a close-up inspection of the exterior facade from a personnel lift
- Developed scope for repair and restoration work
- Submitted survey, scope of repair work, and preliminary cost estimates to the county for review
- Construction documents will be prepared and implemented based on priorities of repair

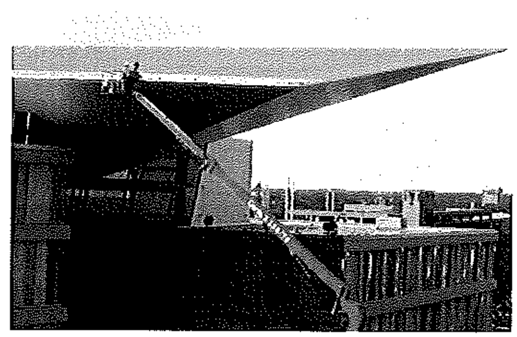
PROJECT PROFILE

Minneapolis Central Library

Icicle Formation Investigation | Minneapolis, MN







CLIENT
Hennepin County

BACKGROUND
The Minneapolis Central Library is a five-story, 350,000-square-foot, glass-enclosed building containing geometrically designed shapes that fuse urban culture motifs with design elements reflecting Minnesota's natural features. Completed in 2006, the building was designed by Pelli Clarke Pelli Architects. The structure boasts a beautiful canopy roof with metal downward sloping "wings" clad with standing seam metal panels that projects over the south and east entrances of the building. Equally impressive is the 18,500-square-foot "green" roof, which contains low-growing, sun- and drought-resistant ground cover.

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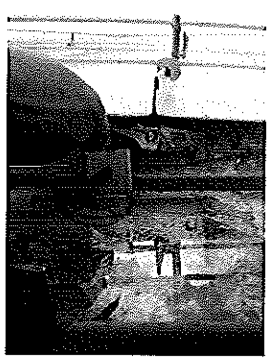
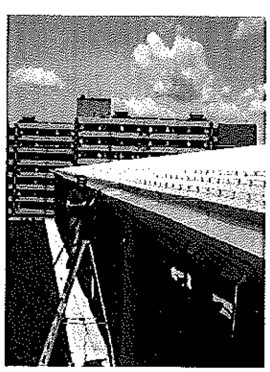
Hennepin County Property Services of the State of Minnesota contacted WJE after large icicles reportedly fell from the cantilevered metal roofs onto the entrance plazas. The client sought to identify the cause(s) of the icicle formation and to receive recommendations concerning the repair design proposed by the design architect.





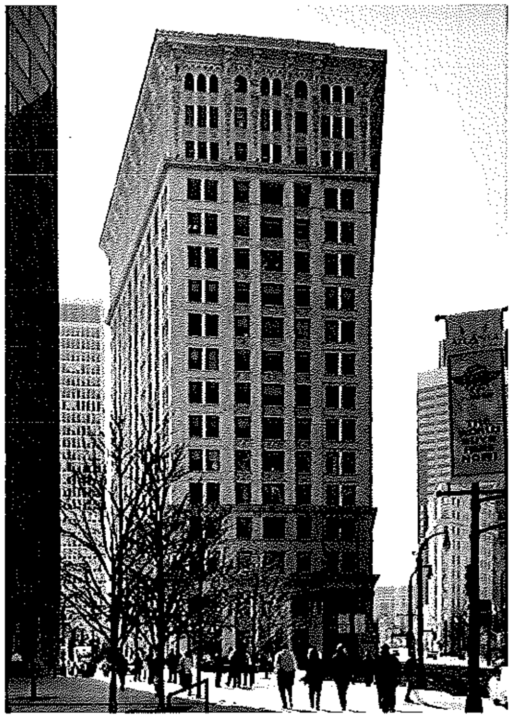
SOLUTION
WJE completed field work and water testing to evaluate the water tightness of the existing gutter assembly. WJE's water testing isolated suspect details including cracked soldered gutter seams and joints not designed to withstand a submerged condition during ice damming or standing water. Water leakage testing induced leakage at multiple test locations within minutes and produced water seepage in quantities and at locations in accordance with the reported icicle formation.

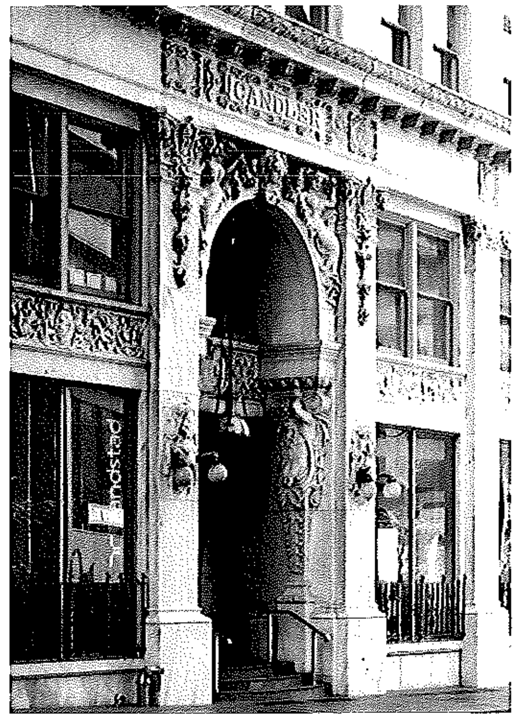
The proposed repair design focused on the built-in gutters constructed along the south edge of the wing roofs. The proposed repair included building up the outboard edge of the gutters to prevent the snow and ice from reaching the roof edge where it would melt, run over the edge, and refreeze on the soffit.

PROJECT PROFILE

Candler Building

Marble and Terra Cotta Facade Investigation | Atlanta, GA





CLIENT
Alpha & Omega Group

BACKGROUND
The 17-story steel-framed office/commercial structure was constructed in 1906 by Asa Candler, the founder of Coca Cola. Listed on the National Historic Register, the building's first three floors are clad in white marble with white architectural terra cotta above. It features projecting water tables at three floors, a large projecting roof cornice, and numerous sculpted terra cotta decorations. The facade contains both wood and steel windows. Steel framing at the building exterior is encased by cast-in-place concrete and infilled by brick walls, forming the backup support for the terra cotta and marble veneer. Steel shelf angles at each floor line help support the terra cotta but no relief joints for masonry expansion were built into the facade.

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

Problems with the terra cotta portion of the building facade included cracking and spalling of the terra cotta veneer at various locations due to moisture expansion of the masonry and the corrosion of the supporting structural steel shelf angles and other elements. Additional problems in the facade included surface granulation of the marble at some locations, deterioration of the wood windows, and failed joint sealants. The Candler Building Management retained WJE to perform an intensive facade investigation, and recommend repairs.

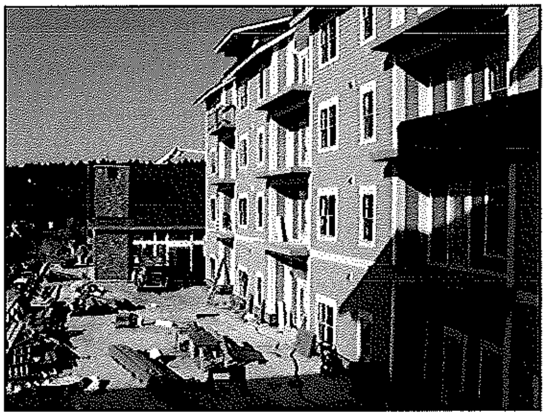
SOLUTION
WJE performed a full close-up visual, sounding and probe survey of the masonry facade and windows with exploratory openings. Contract documents for the repairs were developed and construction administration services were provided during the repairs.

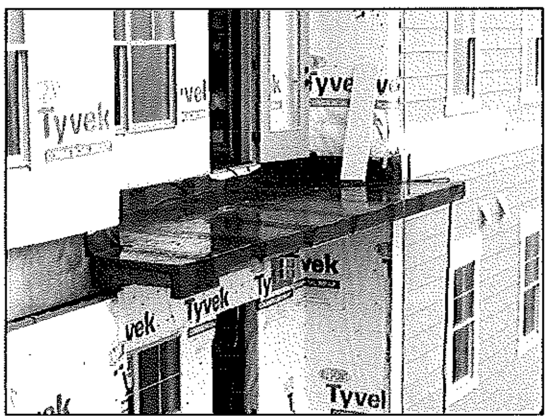
WJE architects repaired the terra cotta by spot pinning, patching, coating, and tuckpointing. These same techniques, as well as spot application of a consolidant, were used to restore the marble. WJE addressed the problem of rotted wood through the use of consolidant, patch, Dutchman, and replacement repairs, as well as the application of new paint and sealants.

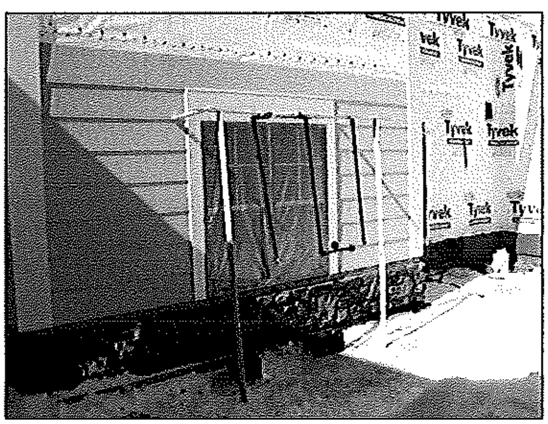
WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

Soaring Eagle Lodge

Building Envelope Consulting during Construction
Snowshoe, West Virginia







CLIENT

Branch & Associates, Inc.

CHALLENGE

Constructed atop a ridge in the Appalachian Mountains, the newest lodge at Snowshoe Mountain Resort would be exposed to harsh winter weather, including recurring hurricane-force winds. Being concerned about the lodge's ability to withstand such extremes and not suffer air and water infiltration, the design and construction team retained WJE subsequent to the development of design drawings but prior to construction of the facade elements to aid in improving air and water management details.

STRUCTURE

The four-story wood-frame building is clad with fiber-cement siding and trim, vinyl double-hung windows, and thin cultured stone veneer. Balconies floor-framing members cantilevering beyond the facade penetrate the building envelope with regularity. Numerous balconies occur over occupied space, necessitating a membrane waterproofing on the balcony deck.

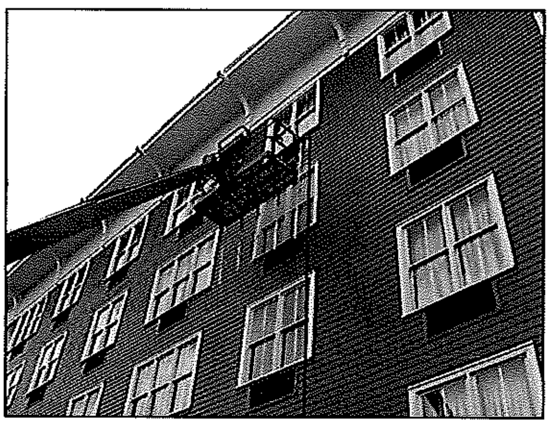
SOLUTION

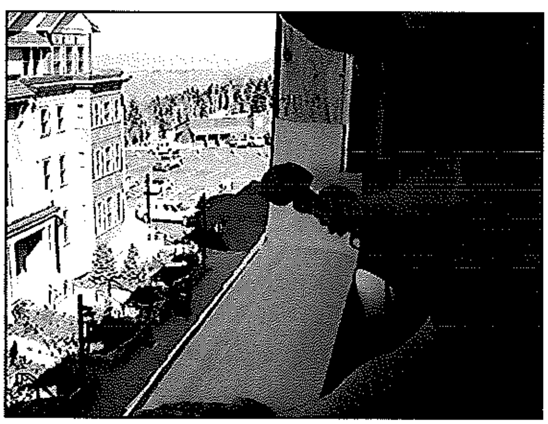
After reviewing the design documents to gain familiarity with the design intent for the building envelope, WJE made regular site visits to evaluate and make recommendations to improve as-built facade details. WJE also performed water and air infiltration performance testing of an early-stage window and facade mock-up installation. WJE's services, as a supplement to the customary role of the design and construction team, resulted in a building free of systemic facade performance issues despite its exposure to harsh weather conditions.

WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

Expedition Station

Investigation of Water Infiltration through Windows and Cladding
Snowshoe, West Virginia





CLIENT

Branch & Associates, Inc.

STRUCTURE

Expedition Station is a residential condominium located in an extreme mountain top environment. It was constructed from wood framed premanufactured modules stacked on top of a steel and concrete base. It is clad with fiber cement siding nailed over a weather-resistant barrier on oriented strand board (OSB) sheathing. The building's windows are vinyl double-hung units which are often ganged into double or triple configurations.

CHALLENGE

The contractor initially asked WJE to investigate buckled trim and deteriorated siding that was perceived as evidence of structural distress. WJE determined that the cause was not structural in nature, but rather a combination of moisture infiltration and wood swelling and shrinkage. The client retained WJE to determine the source of water leakage in windows, consult on the required performance level of replacement windows, and aid the contractor in detailing the weather-resistive barrier and sill flashings at window openings.

SCOPE OF SERVICE

- Document review
- Conducted infrared thermal scanning of walls to locate wet areas and water leakage testing of windows and the surrounding cladding
- Inspected and documented as-built conditions at probe openings
- Construction period services

SOLUTION

- Determined, through water leakage testing, that the vinyl windows were not thermally welded where the jamb meets the sill, providing a water pathway into the building
- Found that the lack of end dams in the flashing contributed to deterioration of fiber cement siding
- Replaced all double-hung windows in the building
- Assisted the contractor in coordinating window installation, siding replacement, insertion of new end dams, sill flashings, and weather-resistant barrier tapes with the extant wall system
- Added end dams in metal siding trim to prevent deterioration of adjacent fiber cement siding

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

REPRESENTATIVE STATE CAPITOL PROJECT EXPERIENCE

California State Capitol Building
Sacramento, California
- Repair and rehabilitation design, waterproofing consulting
- Coating and sealant investigation

Capitol Center Building
Honolulu, Hawaii
- Facade testing
- Aluminum, curtain wall, glass investigation

Colorado State Capitol
Denver, Colorado
- Historic preservation surveys
- Steel, stone, wood investigation
- Dome condition survey

Georgia State Capitol
Atlanta, Georgia
- Roof repairs, historic preservation
- Investigation of historic limestone and cleaning studies
- Petrographic examination, facade testing

Idaho State Capitol
Boise, Idaho
- Terra cotta facade assessment
- Water leakage investigation
- Repair and rehabilitation design

Illinois State Capitol
Springfield, Illinois
- Exterior finish analysis, plaster investigation
- Historic preservation services
- Restoration of chamber skylight

Kentucky State Capitol
Frankfort, Kentucky
- Restoration and historic preservation services

Louisiana State Capitol
Baton Rouge, Louisiana
- Investigation of cast in place concrete
- Corrosion investigation, physical testing of materials, nondestructive testing
- Historic preservation

Michigan State Capitol
Lansing, Michigan
- Roofing investigation, air and water leakage investigation
- Repair and rehabilitation design

Minnesota State Capitol
St. Paul, Minnesota
- Comprehensive facade inspection
- Marble assessment
- Petrographic evaluations
- Repair and rehabilitation design

Nebraska State Capitol
Lincoln, Nebraska
- Restoration of clay tile arches and windows
- Limestone investigation, historic preservation
- Roofing replacement, exterior facade restoration

New Jersey State Capitol
Trenton, New Jersey
- Failure investigation of interior masonry walls
- Ceiling plaster cracking investigation
- Peer review services for restoration and rehabilitation services

North Dakota State Capitol
Bismarck, North Dakota
- Granite, limestone investigation, metal panel repairs
- Repair and rehabilitation design

Oregon State Capitol
Salem, Oregon
- Repair and rehabilitation design
- Air and water leakage investigation

Pennsylvania State Capitol
Harrisburg, Pennsylvania
- Granite cracking investigation

Rhode Island State House
Providence, Rhode Island
- Water leakage investigation
- Repair design

US Capitol Visitor Center
Washington, D.C.
- Stone paver cracking investigation
- Physical testing of stone materials

Virginia State Capitol
Richmond, Virginia
- Skylight leakage investigation
- Development of cleaning manual

Wisconsin State Capitol
Madison, Wisconsin
- Restoration of exterior granite
- Repair and rehabilitation design

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

REPRESENTATIVE ROOFING AND WATERPROOFING PROJECT EXPERIENCE

186 Riverside Drive
New York, New York
- Terrace waterproofing

470 Park Avenue
New York, New York
- Facade and roofing investigation

Admiral Thomas Condominium
Honolulu, Hawaii
- Waterproofing system investigation

Aiea Shopping Center
Aiea, Hawaii
- Investigation of waterproofing membrane failure

American Museum of Natural History
New York, New York
- Condition investigation of the historic facades and repair recommendations

Archbold Hall Building
Wallingford, Connecticut
- Construction period services and envelope investigation

Atascadero City Hall
Atascadero, California
- Historic materials conservation, waterproofing consulting

Atlanta Marriott Marquis
Atlanta, Georgia
- Facade waterproofing repair observation

Austin Convention Center
Austin, Texas
- Reroofing and reinstallation of seven air handling units

Baruch Academic Complex
New York, New York
- Litigation support

Beach Villas at Ko Olina
Kapolei, Hawaii
- Peer review of building envelope designs

Behavioral Science Building
Chicago, Illinois
- Construction documents for renovation of plaza

Building One
Philadelphia, Pennsylvania
- Design development

Buyer's Flea Market
Chicago, Illinois
- Inspection of waterproofing system

Calvin Court
Atlanta, Georgia
- Engineering services for exterior restoration and waterproofing

Carl Sandburg Jr. College
Galesburg, Illinois
- Structural and waterproofing investigation

Campbell Square
Kapolei, Hawaii
- Drawings and specifications for partial waterproofing

Candler Building
Atlanta, Georgia
- Roofing design and construction administration

Carleton Hotel
Aspen, Colorado
- Waterproofing consultation

C.O.R.E Plaza Rehabilitation
Evanston, Illinois
- Design repair of plaza

Dallas Arts District
Dallas, Texas
- Parking garage waterproofing specifications and systems

Duke University
Durham, North Carolina
- Roofing tile evaluation of selected buildings on campus

Elks Veterans Memorial
Chicago, Illinois
- Waterproofing repair design

FBI Academy
Quantico, Virginia
- Construction consulting services

WJE | ENGINEERS
ARCHITECTS
MATERIALS SCIENTISTS

REPRESENTATIVE ROOFING AND WATERPROOFING PROJECT EXPERIENCE

Fountain Square
Cincinnati, Ohio
- Evaluation of plaza water infiltration

Grove Terrace Condominium
Buffalo Grove, Illinois
- Investigation of terrace water leakage

Hillsboro-Ocean Club Condominium
Hillsboro Beach, Florida
- Investigation of waterproofing construction problems

Indian Hill Office Park
Auburn, California
- Waterproofing consulting services

Jackson Tower
San Francisco, California
- Spall repair and waterproofing

JC Penney Garage
Plano, Texas
- Construction administration for waterproofing

Kakaako Elderly Housing
Honolulu, Hawaii
- Roofing and waterproofing design

Keola La'i Residential Tower
Honolulu, Hawaii
- Consulting for roofing and waterproofing at new high-rise condominium building

Kimpton Philadelphia Palomar
Philadelphia, Pennsylvania
- Construction documents for exterior envelope repairs

Lady Bird Johnson High School
San Antonio, Texas
- Roofing design and construction administration

Lakewood Orthopedic Clinic
Lakewood, Colorado
- Waterproofing design for plaza

Lions Square Lodge
Vail, Colorado
- Design of roof and plaza waterproofing system

Lincoln at LaVillita
Irving, Texas
- Construction period consultation and observations of building envelope to prevent future water infiltration

Lincoln Nell Plaza
Aspen, Colorado
- Plaza repair construction services

Marina City
Chicago, Illinois
- Exterior concrete and waterproofing investigation

Maroon Creek Townhomes
Aspen, Colorado
- Design of waterproofing system

Mauna Kea Beach Hotel
Honolulu, Hawaii
- Roofing and waterproofing system consulting

Methodist Hospital
Houston, Texas
- Roofing survey

Metro Lofts
Denver, Colorado
- Consulting services for design of waterproofing for exterior plaza

Miriam Osborn Memorial Home
Rye, New York
- Litigation support for exterior building envelope

NASA Building 2 and 15
Clear Lake, Texas
- Roofing evaluation and design

NBD Bank of Skokie
Skokie, Illinois
- Facade waterproofing repair design

North Church Condominiums
Evanston, Illinois
- Recommendation for repair of terrace waterproofing

North Point Plaza
Cleveland, Ohio
- Plaza rehabilitation bidding assistance

REPRESENTATIVE ROOFING AND WATERPROOFING PROJECT EXPERIENCE

Oakland Museum
Oakland, California
- Waterproofing and structural analysis

One California Building Plaza
San Francisco, California
- Waterproofing construction observation

One Cherry Center Plaza
Denver, Colorado
- Plaza schematic design

One Sutter Street
San Francisco, California
- Waterproofing investigation

Owl Creek Townhomes
Snowmass, Colorado
- Design of waterproofing and roofing for new residential building

Pacific Gas & Electric Company
San Francisco, California
- Waterproofing consulting services

Petro Lewis Plaza
Denver, Colorado
- Waterproofing consultation

Plaza Tower One Garage
Englewood, Colorado
- Waterproofing design for concrete parking deck

Philadelphia Zoo
Philadelphia, Pennsylvania
- Performed comprehensive evaluation of the roofing, planter waterproofing, skylights, masonry walls, and concrete canopy roof decks

Point Apartments
Silver Springs, Maryland
- Design services for garage repairs, waterproofing and asphalt overlay

Pompano Fashion Square
Pompano Beach, Florida
- Investigation of roof waterproofing system

Presidents Plaza and Plaza Deck
Chicago, Illinois
- Design services for garage repair, waterproofing, and asphalt overlay

Preston Plaza Tower
Dallas, Texas
- Garage waterproofing and repair design

Roosevelt Square
Seattle, Washington
- Observed membrane waterproofing installation for conformance to construction documents
- Observed water testing of installed waterproofing membrane system

River Front & River Colony Apartment
San Diego, California
- Inspection of plaza structure and waterproofing membrane

Seattle Kingdome
Seattle, Washington
- Roofing and waterproofing system repair design

Sheraton Maui
Honolulu, Hawaii
- Peer review of roofing and waterproofing construction documents

Sky Harbor Airport
International Concourse, Terminal 4
Phoenix, Arizona
- Design of repairs for terminal waterproofing
- Field inspection of waterproofing installation

State of Hawaii
Honolulu, Hawaii
- Construction observation services during roofing and waterproofing of new state office tower

Tribune Building - Nathan Hale Court
Chicago, Illinois
- Consulting services for design of new granite paving and waterproofing system

Ultimate Sports Dome
Aurora, Illinois
- Laboratory studies and strength tests of fabric samples
- Structural design review

University of Colorado, Boulder Geology Building
Boulder, Colorado
- Design review and construction observation for roofing/waterproofing system

REPRESENTATIVE ROOFING PROJECT EXPERIENCE

Adolf Coors Company Cold Storage Building
Golden, Colorado
- Failure investigation and analysis

Albion Grade School
Albion, Illinois
- Roof leakage and condensation investigation, structural review, and roof replacement design

Amoco Building
Chicago, Illinois
- Condition investigation, reroofing design, and construction observation

Appletree Condominiums
Englewood, Colorado
- Condition investigation, reroof design, and construction observation

Asbury School
Denver, Colorado
- Condition investigation, reroof design, and construction observation

Ash Grove School
Denver, Colorado
- Condition investigation, reroof design, and construction observation

Barnett Bank Plaza
Tampa, Florida
- Condition investigation

Bayshore on the Boulevard
Tampa, Florida
- Condition investigation and repair recommendations

Beachside I Condominiums
Destin, Florida
- Condition investigation

Browning Apartment Building
Denver, Colorado
- Condition investigation, reroof design, and construction observation

Café Brauer
Chicago, Illinois
- Tile investigation and restoration design

Carson, Pirie, Scott
Chicago, Illinois
- Condition investigation

Catherine Hall Gymnasium Milton Hershey School
Hershey, Pennsylvania
- Copper condition investigation and repair design

Center for Development in Ministry
Mundelein, Illinois
- Repair design for copper gutter and roof

Cherry Hills Medical Building
Englewood, Colorado
- Condition investigation, reroof design, and construction observation

Christ Church Cathedral
Indianapolis, Indiana
- Investigation, laboratory studies, and restoration of historic slate roof

Columbia University
New York, New York
- Condition investigation of copper cornice

Conoco Oil World Headquarters
Houston, Texas
- Investigation/consulting for standing seam roof

Cook House Lincoln Home National Historic Site
Springfield, Illinois
- Investigation and repair design for preservation project, including reconstruction of wood shingle roof on historic wood building

Cumberland Mall
Cumberland, New Jersey
- Specifications for standing seam roof

Del Pueble School
Denver, Colorado
- Condition investigation, reroof design, and construction observation

Delta Memorial Hospital
Delta, Colorado
- Condition investigation, reroof design, and construction observation

WJE | ENGINEERS ARCHITECTS MATERIALS SCIENTISTS

REPRESENTATIVE ROOFING PROJECT EXPERIENCE

Bathhouse Row National Historic District
Hot Springs, Arkansas
- Condition investigation, stabilization, and restoration design

Harold Washington Library Center
Chicago, Illinois
- Peer review and consulting on design of new building including standing seam roof

Headquarters Plaza
Morristown, New Jersey
- Condition investigation

Rodef Shalom Synagogue
Pittsburgh, Pennsylvania
- Condition investigation, structural analysis of dome, and materials studies of glazed clay tile roofing system

Rookery Building
Chicago, Illinois
- Structural evaluation of roof system

Sabin School
Denver, Colorado
- Condition investigation, reroof design, and construction observation

Service Center Buildings No. 1 & 3
Lakewood, Colorado
- Condition investigation, reroof design, and construction observation

Sheridan High School
Sheridan, Wyoming
- Failure investigation and analysis

Slavens School
Denver, Colorado
- Condition investigation, reroof design, and construction observation

St. Bride's School
Chicago, Illinois
- Condition investigation of copper roof

St. Charles Police Department
St. Charles, Illinois
- Condition survey and repair recommendations of wind damaged copper roof

St. Clements Church
Chicago, Illinois
- Condition investigation of copper roof

State House and Annex
Trenton, New Jersey
- Condition investigation, instrumentation, repair recommendations, and peer review for restoration

Steele School
Denver, Colorado
- Condition investigation, reroof design, and construction observation

Talisman Building
Vail, Colorado
- Condition investigation, reroof design, and construction observation

Three East Sixty-Ninth Street
New York, New York
- Investigation of water leakage

Traylor School
Denver, Colorado
- Condition investigation, reroof design, and construction observation

U.S. Postal Service Facility
Norman, Oklahoma
- Design of new roof

United Engineering Company
Pevely, Missouri
- Investigation and analysis of standing seam metal roof

University of Colorado-Denver Tivoli Student Center Building
Denver, Colorado
- Construction observation on four large roofs

University of Illinois, Chicago Physical Education Building
Chicago, Illinois
- Roof replacement and construction observation services

West Park Office Roof
New Orleans, Louisiana
- Building envelope, roofing, and condition survey

SOLICITATION NUMBER: GSD136423
Addendum Number: No. 01

The purpose of this addendum is to modify the solicitation identified as ("Solicitation") to reflect the change(s) identified and described below.

Applicable Addendum Category:

[✓] Modify bid opening date and time

[ ] Modify specifications of product or service being sought

[ ] Attachment of vendor questions and responses

[ ] Attachment of pre-bid sign-in sheet

[ ] Correction of error

[✓] Other

Description of Modification to Solicitation:

Addendum issued to redistribute the EOI information in its entirety.

Bid Opening date has been changed from: 01/09/2013 at 1:30 PM.
To: 01/16/2013 at 1:30 PM.

Additional Documentation: Documentation related to this Addendum (if any) has been included herewith as Attachment A and is specifically incorporated herein by reference.

Terms and Conditions:

1. All provisions of the Solicitation and other addenda not modified herein shall remain in full force and effect.

2. Vendor should acknowledge receipt of all addenda issued for this Solicitation by completing an Addendum Acknowledgment, a copy of which is included herewith. Failure to acknowledge addenda may result in bid disqualification. The addendum acknowledgement should be submitted with the bid to expedite document processing.

CERTIFICATION AND SIGNATURE PAGE

By signing below, I certify that I have reviewed this Solicitation in its entirety; understand the requirements, terms and conditions, and other information contained herein; that I am submitting this bid or proposal for review and consideration; that I am authorized by the bidder to execute this bid or any documents related thereto on bidder's behalf; that I am authorized to bind the bidder in a contractual relationship; and that to the best of my knowledge, the bidder has properly registered with any State agency that may require registration.

Wiss, Janney, Elstner Associates, Inc.
(Company)

(Authorized Signature)

Stephen J. Kelley, Project Manager
(Representative Name, Title)

312/325-0917 312/372-0873
(Phone Number) (Fax Number)

1-14-13
(Date)

RFQ No. GSD136423

STATE OF WEST VIRGINIA
Purchasing Division

PURCHASING AFFIDAVIT

MANDATE: Under W. Va. Code §5A-3-10a, no contract or renewal of any contract may be awarded by the state or any of its political subdivisions to any vendor or prospective vendor when the vendor or prospective vendor or a related party to the vendor or prospective vendor is a debtor and: (1) the debt owed is an amount greater than one thousand dollars in the aggregate; or (2) the debtor is in employer default.

EXCEPTION: The prohibition listed above does not apply where a vendor has contested any tax administered pursuant to chapter eleven of the W. Va. Code, workers' compensation premium, permit fee or environmental fee or assessment and the matter has not become final or where the vendor has entered into a payment plan or agreement and the vendor is not in default of any of the provisions of such plan or agreement.

DEFINITIONS:

"Debt" means any assessment, premium, penalty, fine, tax or other amount of money owed to the state or any of its political subdivisions because of a judgment, fine, permit violation, license assessment, defaulted workers' compensation premium, penalty or other assessment presently delinquent or due and required to be paid to the state or any of its political subdivisions, including any interest or additional penalties accrued thereon.

"Employer default" means having an outstanding balance or liability to the old fund or to the uninsured employers' fund or being in policy default, as defined in W. Va. Code § 23-2c-2, failure to maintain mandatory workers' compensation coverage, or failure to fully meet its obligations as a workers' compensation self-insured employer. An employer is not in employer default if it has entered into a repayment agreement with the Insurance Commissioner and remains in compliance with the obligations under the repayment agreement.

"Related party" means a party, whether an individual, corporation, partnership, association, limited liability company or any other form or business association or other entity whatsoever, related to any vendor by blood, marriage, ownership or contract through which the party has a relationship of ownership or other interest with the vendor so that the party will actually or by effect receive or control a portion of the benefit, profit or other consideration from performance of a vendor contract with the party receiving an amount that meets or exceed five percent of the total contract amount.

AFFIRMATION: By signing this form, the vendor's authorized signer affirms and acknowledges under penalty of law for false swearing (*W. Va. Code* §61-5-3) that neither vendor nor any related party owe a debt as defined above and that neither vendor nor any related party are in employer default as defined above, unless the debt or employer default is permitted under the exception above.

WITNESS THE FOLLOWING SIGNATURE:

Vendor's Name: Wiss, Janney, Elstner Associates, Inc.

Authorized Signature: [signature] Date: 1-14-13

State of Illinois

County of Cook, to-wit:

Taken, subscribed, and sworn to before me this 14 day of January, 2013.

My Commission expires February 1, 2016.

AFFIX SEAL HERE **NOTARY PUBLIC** [signature]

Purchasing Affidavit (Revised 07/01/2012)

OFFICIAL SEAL
LAURA A ALTMAN
NOTARY PUBLIC - STATE OF ILLINOIS
MY COMMISSION EXPIRES:02/01/16

ADDENDUM ACKNOWLEDGEMENT FORM
SOLICITATION NO.: GSD136423

Instructions: Please acknowledge receipt of all addenda issued with this solicitation by completing this addendum acknowledgment form. Check the box next to each addendum received and sign below. Failure to acknowledge addenda may result in bid disqualification.

Acknowledgment: I hereby acknowledge receipt of the following addenda and have made the necessary revisions to my proposal, plans and/or specification, etc.

Addendum Numbers Received:
(Check the box next to each addendum received)

[x] Addendum No. 1	[ ] Addendum No. 6
[ ] Addendum No. 2	[ ] Addendum No. 7
[ ] Addendum No. 3	[ ] Addendum No. 8
[ ] Addendum No. 4	[ ] Addendum No. 9
[ ] Addendum No. 5	[ ] Addendum No. 10

I understand that failure to confirm the receipt of addenda may be cause for rejection of this bid. I further understand that any verbal representation made or assumed to be made during any oral discussion held between Vendor's representatives and any state personnel is not binding. Only the information issued in writing and added to the specifications by an official addendum is binding.

Wiss, Janney, Elstner Associates, Inc.
Company

Authorized Signature

1-14-13
Date

NOTE: This addendum acknowledgement should be submitted with the bid to expedite document processing.

SOLICITATION NUMBER: GSD136423
Addendum Number: 2

The purpose of this addendum is to modify the solicitation identified as ("Solicitation") to reflect the change(s) identified and described below.

Applicable Addendum Category:

[ ] Modify bid opening date and time

[ ] Modify specifications of product or service being sought

[✓] Attachment of vendor questions and responses

[ ] Attachment of pre-bid sign-in sheet

[ ] Correction of error

[ ] Other

Description of Modification to Solicitation:

To provide technical questions and answers

Additional Documentation: Documentation related to this Addendum (if any) has been included herewith as Attachment A and is specifically incorporated herein by reference.

Terms and Conditions:

1. All provisions of the Solicitation and other addenda not modified herein shall remain in full force and effect.

2. Vendor should acknowledge receipt of all addenda issued for this Solicitation by completing an Addendum Acknowledgment, a copy of which is included herewith. Failure to acknowledge addenda may result in bid disqualification. The addendum acknowledgement should be submitted with the bid to expedite document processing.

ADDENDUM ACKNOWLEDGEMENT FORM
SOLICITATION NO.: GSD136423

Instructions: Please acknowledge receipt of all addenda issued with this solicitation by completing this addendum acknowledgment form. Check the box next to each addendum received and sign below. Failure to acknowledge addenda may result in bid disqualification.

Acknowledgment: I hereby acknowledge receipt of the following addenda and have made the necessary revisions to my proposal, plans and/or specification, etc.

Addendum Numbers Received:
(Check the box next to each addendum received)

[ ] Addendum No. 1	[ ] Addendum No. 6
[x] Addendum No. 2	[ ] Addendum No. 7
[ ] Addendum No. 3	[ ] Addendum No. 8
[ ] Addendum No. 4	[ ] Addendum No. 9
[ ] Addendum No. 5	[ ] Addendum No. 10

I understand that failure to confirm the receipt of addenda may be cause for rejection of this bid. I further understand that any verbal representation made or assumed to be made during any oral discussion held between Vendor's representatives and any state personnel is not binding. Only the information issued in writing and added to the specifications by an official addendum is binding.

Wiss, Janney, Elstner Associates, Inc.
Company

Authorized Signature

1-14-13
Date

NOTE: This addendum acknowledgement should be submitted with the bid to expedite document processing.
Revised 6/8/2012

From: (312) 372-0555
WJE-Chicago Administration
Wiss, Janney, Elstner Assoc
10 S. LaSalle St.
Ste. 2600
Chicago, IL 60603

Origin ID: CHIA

FedEx Express

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Ship Date: 15JAN13
ActWgt: 2.0 LB
CAD: 4609518/INET3300

Delivery Address Bar Code

SHIP TO: (304) 558-2596 BILL SENDER

Purchasing Division
Department of Administration
2019 Washington Street East
P.O. Box 50130
CHARLESTON, WV 25305

Ref # 2012.6389-SJK
Invoice #
PO #
Dept #

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Use of this system constitutes your agreement to the service conditions in the current FedEx Service Guide, available on fedex.com.FedEx will not be responsible for any claim in excess of $100 per package, whether the result of loss, damage, delay, non-delivery,misdelivery,or misinformation, unless you declare a higher value, pay an additional charge, document your actual loss and file a timely claim.Limitations found in the current FedEx Service Guide apply. Your right to recover from FedEx for any loss, including intrinsic value of the package, loss of sales, income interest, profit, attorney's fees, costs, and other forms of damage whether direct, incidental,consequential, or special is limited to the greater of $100 or the authorized declared value. Recovery cannot exceed actual documented loss.Maximum for items of extraordinary value is $1,000, e.g. jewelry, precious metals, negotiable instruments and other items listed in our ServiceGuide. Written claims must be filed within strict time limits, see current FedEx Service Guide.