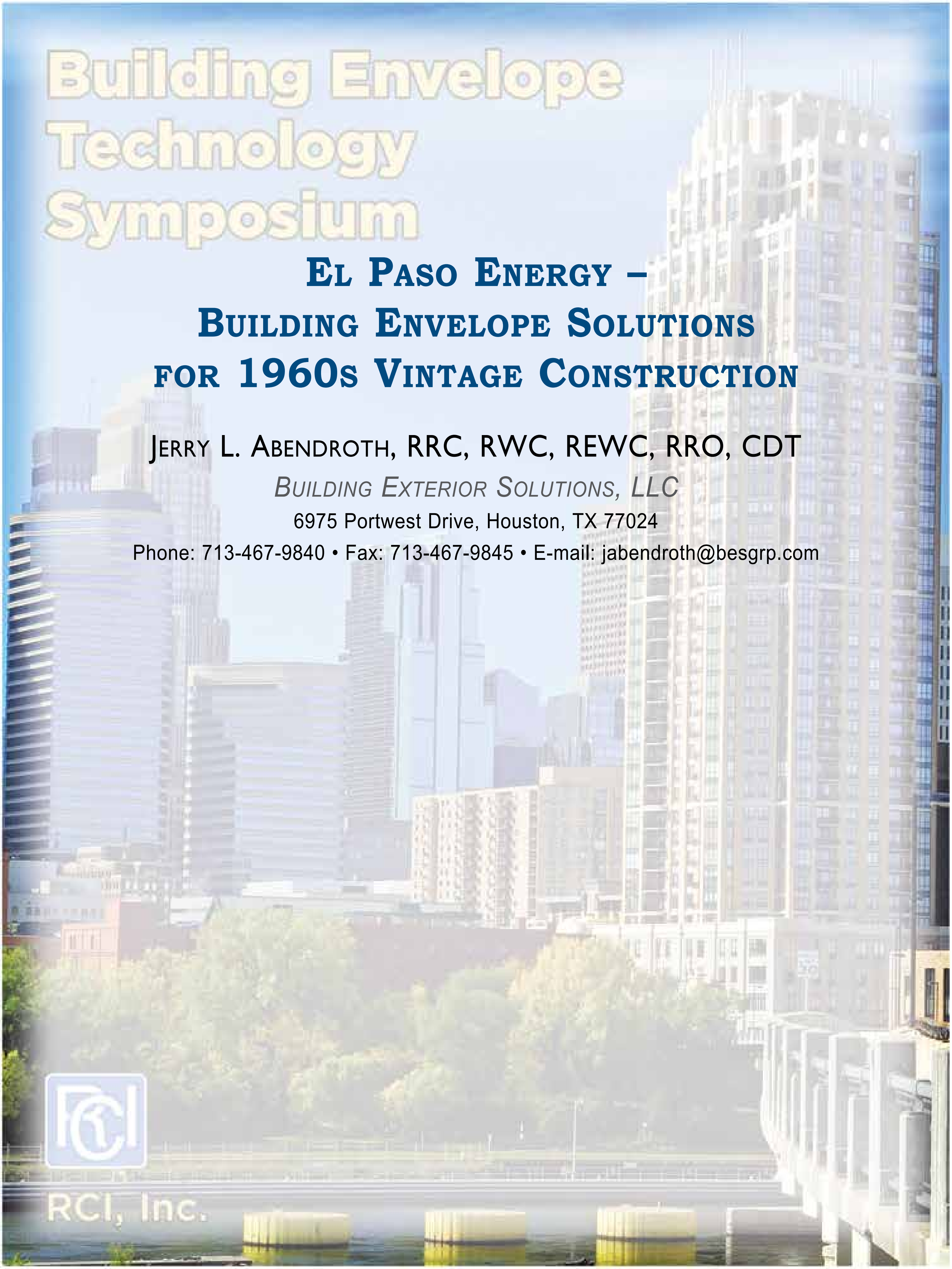

El Paso Energy – Building Envelope Solutions for 1960s Vintage Construction

Jerry L. Abendroth, RRC, RWC, REWC, RRO, CDT
Building Exterior Solutions, LLC
6975 Portwest Drive, Houston, TX 77024
Phone: 713-467-9840 • Fax: 713-467-9845 • E-mail: jabendroth@besgrp.com

ABSTRACT

In the 1960s, waterproofing and roofing of buildings were largely accomplished by the application of layers of felt set in asphalt, sometimes including components that are currently classified as hazardous materials. This seminar will focus on the necessary ingredients of successful integration of modern waterproofing systems with a 1960s-vintage building. Specific existing conditions and related waterproofing and roofing solutions of the building will be presented. Investigation techniques for plaza waterproofing, balcony waterproofing, and roof replacement will be discussed, with accompanying resolutions to critical issues that arose during construction. Finally, owner participation throughout construction will be highlighted as a critical component of a successful renovation project.

SPEAKER

Jerry L. Abendroth, RRC, RWC, REWC, RRO, CDT — Building Exterior Solutions, LLC

Throughout his 35-year career, JERRY ABENDROTH has managed waterproofing and roofing projects on a diverse portfolio of buildings in a variety of roles in the construction and consulting fields. He has performed design peer reviews of building envelopes, as well as building envelope commissioning for many commercial, medical, and industrial projects. In addition, he has performed evaluations of building envelope system failures on projects throughout the U.S. and provided associated repair recommendations and designs. His experience resolving design and construction-related issues has provided resolutions to unique problems encountered with building roofing and waterproofing systems.

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INTRODUCTION

Designers select building designs that enhance city landscapes with bold new looks, incorporating building envelope systems that are contemporary at a given point in time. In all eras, building technologies range between cutting-edge and tried-and-true systems with a proven track record over many years of service. Manufacturers continue to innovate and present products that provide protective envelopes for buildings for years into the future. Only with the benefit of time and experience can the team of owner/designer/consultant/contractor truly understand how these products performed through the test of time and exposure.

Nineteen-sixties vintage construction waterproofing and roofing systems were primarily built-up asphalt or coal tar-based systems applied in layers utilizing integrated felts or carrier products that were designed to stabilize the asphalt-based system for long-term durability. Typically, these systems had poor elastic capabilities, and building movements were difficult to accommodate. Very often, hazardous materials such as asbestos were utilized to provide a fire barrier or as a protection layer for the asphalt-based waterproofing systems. These materials, once covered under plaza-cladding materials, typically remained undisturbed for long lengths of time.

BACKGROUND

The El Paso Energy Building, completed in 1963, is a 502-ft.-tall skyscraper at 1001 Louisiana Street in the downtown district of Houston, Texas. The building was designed by Edward C. Bassett of the national architecture firm of Skidmore, Owings and Merrill. The firm was recognized with an Honor Award and the Bartlett Award for Handicapped Access from the American Institute of Architects in 1969. The 33-story structure has a 50-ft. colonnade at the base of its tower; a dark gray, metallic-aluminum exterior; and pink Texas granite cladding. It was originally known as the Tenneco Building, and when Tenneco owned the building, the letters T-E-N-N-E-C-O outlined the top of the building on each of the four sides (*Figure 1*).

The building has two tunnels that connect it to adjoining buildings in the Houston tunnel system. As originally designed, an elevator or escalator was required to access the main lobby of the building. One of the original tenants of the Tenneco Building was a bank with a number of drive-through kiosks along Louisiana Street. In 1984, the kiosks were replaced with fountains designed by Richard C. Keating of the Houston branch of Skidmore, Owings, and Merrill (*Figure 2*).

Tenneco owned the building from its construction until 1996, when the company was purchased for $4 billion by El Paso Energy Corporation. In 2001, the fountains were refurbished, replacing water-delivery systems and improving waterproofing systems.

Figure 1 – Tenneco Building.

Figure 2 – Fountains.

Figure 3 – Granite paving at original plaza.

In 2008, Gilbane Construction began renovation of the building's interior and limited exterior with designs by Gensler Architects (Gensler) in 2008. The renovations were completed in 2012. The main lobby is now located on Level 1 with entrances on Louisiana Street and Travis Street. Level 2 contains conference rooms. Levels 3 through 29 are office space, and Levels 30, 31, and 32 are the executive offices. The executive offices boast a three-story grand stairway, boardroom, many conference rooms, and spacious offices and meeting areas.

At the end of the 2008-12 renovation, Kinder Morgan purchased the building as part of its acquisition of El Paso Corporation in 2012. Kinder Morgan moved its headquarters to this building. EP Energy (formerly El Paso E&P Company) leases floors 18-27 from Kinder Morgan.

PLAZA INVESTIGATION AND RENOVATION

The plaza of the El Paso building is clad with Texas pink granite and sweeping curved stones at horizontal/vertical transitions to the walls of the building (*Figure 3*). There are two ramps in the plaza—a down ramp and an up ramp, which provide access to and from the basement for delivery vehicles. An active fountain system was included in the revamped design in 1984. With the exoskeleton design, the plaza area is partially covered by the overhang of the building. As part of the renovation of the building, the owner authorized limited investigation of the plaza waterproofing and cladding elements for a redesign of the lower floors, planters, and fountain areas.

Relative Construction Documents

Whenever possible, original construction sets of documents should be reviewed prior to conducting site investigations. Gensler, the architect of record for the project, conducted research into the building's history. The plans, "The Tennessee Gas Building Corporation," were issued by Skidmore, Owings & Merrill and dated March 31, 1961. Early in the 2008 renovation design, the architect provided selected original drawings from this set for the applicable consultants for review. Although original submittals were not available, the drawings and specifications provided a valuable trove of information from which to begin. As listed above, several major renovations to the plaza area (e.g., fountains, drives) had been completed prior to major renovation design; however, the basic waterproofing and paving systems had remained virtually unchanged since installation in the early 1960s.

Building Personnel Interviews

Building personnel typically have extensive, undocumented knowledge of a building's systems and of the numerous renovations and repairs that have been performed throughout the years. The building engineer at the El Paso Energy Building managed the building systems for over 20 years. He also managed several of the adjoining buildings and the connecting tunnels. From this interview, it was discovered that a comprehensive survey had been completed on the building several times. The most recent survey, which had been conducted several years prior to renovation design, included a section concerning testing of the plaza materials. Several of the waterproofing and protection board materials were found to contain asbestos. The design team gleaned from the discussions with El Paso Building management personnel that limited removal of asbestos had been completed; however, all asbestos-containing materials in the plaza waterproofing system remained.

There are three governing agencies that regulate the production and removal of asbestos in the U.S.: the Environmental Protection Agency (EPA), the Occupational Safety and Health Administration (OSHA), and the Consumer Product Safety Commission (CPSC). The EPA estimates that hundreds of thousands of buildings still standing have asbestos-containing materials within them. Laws limiting the use of asbestos in the U.S. were not enacted until the 1980s.

Site Investigation

In the case of the El Paso Building, a construction manager had been selected to complete the work; however, because of the sensitivity of the plaza area, the owner preferred not to open any asbestos-containing areas prior to demolition and construction. In addition, there were several openings in the plaza (e.g., penetrations, hatches, etc.) where metal closures could be removed to obtain a view of the "cross section" of the plaza cladding materials without disruption of asbestos-containing materials.

The site investigation began with a walk-through of plaza and basement areas. The objective of the walk-through was twofold—first to verify the plaza deck and waterproofing construction as shown on the plans, and secondly to observe and record leak areas. Access to the underside of the plaza deck provided opportunities to observe exposed areas of the original plaza deck and waterproofing construction. There were also several areas at the street level where covers could be removed for observation and easily replaced.

Observations revealed the plaza deck construction, waterproofing, protection layer, insulation, and paving materials matched what was shown on the plans from the 1960s. The initial installation included a three-ply asphalt and felt waterproofing system, asbestos protection layer, cellular glass insulation, concrete topping, and paving materials. There were several areas where leaking had occurred over a length of time, as evidenced by the substantial staining and from reports of building personnel who conducted the walk-through. During the walk-through, cracking of the deck that would require repair during renovation activities was observed in several areas. Although the entire underside of the deck was not open for observation, enough area was open to once again verify that the plaza drains were located and sized as shown on the original plans. Sufficient information from these observations was gathered to continue with basic design.

A limited number of drains had been installed at the structural concrete deck level. As was typical of 1960s construction, a substantial portion of the drainage was designed by sloping the plaza deck toward the street. Some of the drainage water was designed to be funneled to concrete "catch basins," which eventually were drained into the soil beneath the street (*Figure 4*). Most of the drainage was simply designed to travel over the waterproofing layer of the plaza deck, over the edge of the building, and down the basement walls.

Preliminary Design

When performing consulting services for the architect, the building envelope consultant should endeavor to gain as much information as possible to provide a complete design. Existing buildings always prove to be more of a challenge, because no matter how extensive the scope of the investigations and observations, there will always be unknowns that cannot be accurately represented in renovation design documents. In the case of the El Paso building, destructive testing was very limited, and substantial openings of the plaza area would not occur until the construction phase of the project began. To properly manage the unknowns, the architect/consultant team had to provide excellent communication and contingency within the construction documents to properly prepare the contractor and subcontractors for the potential scope of work.

Figure 4 – Concrete "catch basins" at street.

A 215-mil hot-fluid-applied waterproofing system was selected as the basis of design for the plaza area. This system is similar in lifespan to the original system, with the added benefit of providing limited accommodation for movement in the plaza deck. The existing plaza had been in service for over 40 years. Repair of the concrete substrate, pretreatment of existing cracks, and provision for movement at critical areas were incorporated into the new system. The elements of the system were similar to those of the existing system. A protection layer was followed by drainage mat, extruded polystyrene insulation, and concrete topping layers.

A new paving cladding system was selected to be set in a mortar bed over the waterproofing and concrete layers. At several locations, existing cladding was to be integrated into the new design. After lengthy discussions about waterproofing tie-ins, it was decided that the existing cladding would be removed and reused at selected areas. The final design was not chosen until demolition was significantly in progress in order to determine what, if any, existing cladding materials could be salvaged and reinstalled.

From observations and from electronic level readings made during the several plaza and basement walk-throughs, a drainage plan was developed that added effective drainage to the plaza by locating new plaza drains in strategic areas that had previous evidence of deck deflection and ponding water. Several areas of the basement were included in the renovation design, and this facilitated installation of supplemental drainage lines to critical areas. For instance, the new plaza design included large planter areas with lengthy trench drains. Draining an area this large to the street would have overwhelmed the

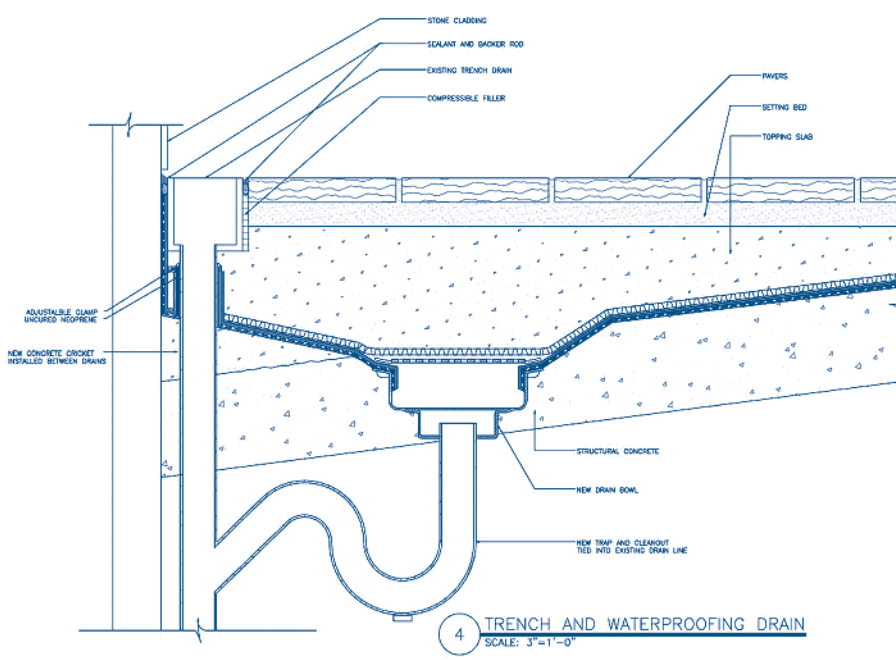

Figure 5 – Drain configuration at planter walls.

drainage mat for the waterproofing system. Additional drains were installed on both sides of the new planter walls to evacuate drainage water more efficiently (*Figure 5*).

The representatives from El Paso Energy were very knowledgeable concerning construction practices and building envelope systems. Their participation during the design-build process was critical to its success. As was discussed earlier in the building interview portion of this paper, building personnel can be the most important source of information during design development. Building envelope consultants should listen carefully to the "building's story" to fully understand the requirements for new designs.

Testing

Because access to the structural plaza deck was limited for the consultant, the general contractor, and their subcontractors, provisions for deck preparation had to be included in the design documents based on limited information. Meetings were conducted with the hazardous material abatement contractor to determine the method of removal for the asphalt waterproofing, asbestos protection material, and insulation systems. Although asbestos was limited to the protection material, removal of all waterproofing and protection materials was placed under one subcontract to reduce potential liability and reduce costs. After several meetings, a plan was developed to efficiently remove the materials in a progressive manner while preparing the deck to receive the new waterproofing system. Representatives of the waterproofing system manufacturer also attended these meetings to assist with product information and testing.

The waterproofing membrane manufacturer included the following language in the testing portion of the waterproofing specification section:

> "Final check to determine if concrete has been properly cleaned is to apply a test patch of Monolithic Membrane 6125® to the surface and check its adhesion."

Because of the potential of deck contamination, a section was added to provide for additional testing of the hot-fluid-applied system at regular intervals throughout demolition and construction. In most instances, this testing and follow-up between the building envelope consultant and contractor occurred throughout construction to ensure quality installation procedures were followed. In several deck areas, because of demolition activities, extensive deck repairs had to be executed prior to installation of the waterproofing system. These areas were also tested for proper adhesion.

There are two types of testing for field quality control of the installed waterproofing system—flood testing and electronic field vector mapping. Because only small areas of the plaza could be completed at any given time, flood testing of the installed system proved to be the most efficient, cost-effective method to verify the integrity of the installed system. The following instruction was placed in the "Field Quality Control" portion of the specification section.

> Flood Testing: Flood-test each deck area for leaks according to recommendations in ASTM D5957, after completing waterproofing but before overlying construction is placed. Install temporary containment assemblies, plug or dam drains, and flood with potable water.
>
> 1. Flood to average depth of 2½ inches with minimum depth of 1 inch and not exceeding depth of 4 inches. Maintain 2 inches of clearance from top of flashings.
> 2. Flood each area for 48 hours.
> 3. If leaks occur, drain water completely, remove protection sheet, and repair waterproofing. Replace protection sheet and retest.
> 4. Repeat flood testing process and repairs until no leaks occur.

There are two electrical/telecommunication vaults located beneath the El Paso Building Plaza that are critical to the operations of the building. During sequencing of construction operations, it was determined that the schedule had to be modified regarding work over the vault areas. Special precautions were taken to work over these areas, including verification of weather windows (less than 20% chance of precipitation over two-day periods) and provision of temporary covering to ensure the vaults would not be exposed during rain events. Electronic vector mapping was utilized at these two areas to remove the threat of test water entering the basement areas.

Construction Challenges

During construction activities, the designer worked closely with the contractor/subcontractor team to resolve issues that arose due to original construction detail changes and from problems encountered from integration of new plaza systems into the existing plaza construction. During initial demolition operations, the contractor/subcontractor team experienced difficulty with proper tie-ins of the new hot fluid-applied waterproofing system to the existing asphalt-based system. Tie-in difficulties were resulting in leaks into the basement area.

Leaks during construction activities can cause problems with destruction of finishes and disruption of building activities. During the first several rain events, leaks caused primarily by tie-ins from old systems to new waterproofing did not occur over sensitive areas, and leak remediation efforts were moderately successful. However, demolition/installation operations would later be performed over highly critical areas, and a plan had to be made to further mitigate the possibility of leaks over these areas. Meetings were conducted with the demolition/hazardous waste subcontractor to discuss removing the paving materials and overburden approximately one foot past the demolition area while leaving the asphalt waterproofing system as originally installed to the greatest extent possible. Significant coordination was required to ensure the workers performed exactly what was required to provide a base for a sound tie-in. Because hazardous waste was present, the best way to approach the tie-in issue was through trial and error. After several attempts, the team arrived at a two-fold approach. Torch-applied modified bitumen was installed at difficult transitions to provide a tough tie-in that could withstand construction traffic. Secondly, self-adhered membrane was used to make the transitions from waterproofing to existing paving materials where demolition activities could not provide the needed tie-in base. In these areas, the waterproofing subcontractor utilized mastic and liquid membrane to produce an effective tie-in. As these areas were much more susceptible to damage by other trades, the general contractor installed

Figure 6 – Redesigned plaza incorporating old and new cladding.

a hard protection layer constructed of a framework and plywood to protect the critical tie-ins from damage.

Results

The final result of many meetings, additional preparation, and careful planning was an integrated plaza system with a bold new look that incorporated the original theme of the building. Beneath it all is an innovative waterproofing system that will perform for decades to come (*Figure 6*).

TUNNEL WATER MANAGEMENT

Houston's tunnel network is a framework of tunnels approximately 20 feet below Houston's downtown streets and between six and seven miles long. The tunnel concept began years ago as a tunnel between two downtown movie theaters. Houston's tunnel system today is a series of underground passageways that, with aboveground skywalks, link office towers to hotels, banks, corporate and government offices, restaurants, retail stores, and the Theater District. Only Wells Fargo Plaza and McKinney Garage on Main offer direct access from the street to the tunnel; otherwise, entry points are from street-level stairs, escalators, and elevators located inside office buildings that are connected to the tunnel. Most of the tunnel system is located in the western half of downtown Houston.

The Challenge

The El Paso Building has two connecting tunnels that connect the building to the Wells Fargo Plaza under Louisiana Street and the Travis Place Garage under Milam Street. The tunnels were constructed in the 1960s of cast-in-place concrete with similar asphalt-based waterproofing systems as the El Paso Building plaza. Both tunnels had leaked for many years, and building personnel were still managing several leaks during the first few walk-throughs of the building. Some crystalline waterproofing had been added in limited areas, and injections had been performed at concrete cracks in the tunnel's ceilings and walls. Catch pans had been installed in ceiling areas to catch water during rain events and from other unknown water sources.

Water Management Design

Because of the presence of major streets above both tunnels, access to repair or replace the existing waterproofing from the outside was not possible, and a plan had to be developed to eliminate leaks as much as possible and to provide water management for expected water intrusion into the tunnel space. It was important for all parties involved to understand that a comprehensive leak-prevention strategy for the tunnel was virtually impossible; however, a water management strategy could be designed that would make the tunnel areas safer and more functional. After lengthy discussions and many ideas from the owner/designer/contractor team, the building envelope consultant—with considerable input from building management personnel—designed a threefold approach to managing the expected water intrusion.

First, a thermoplastic-lined gutter system was designed to be installed at the base of the wall that ran the entire length of the tunnel. The gutter was specifically designed to accept incidental water that seeped through the tunnel's walls (*Figure 7*). At the lowest end of the gutter system, workers installed a drain that was routed to an open stormwater drain. The existing construction of the tunnel provided for slight slope; however, there were areas of ponding water in the drain area during testing of the system. Water was added to determine the extent of ponding water throughout the length of the gutter drain.

As noted earlier, crystalline waterproofing had previously been installed on some areas of the perimeter wall. In one area, an unknown elastomeric system that was peeling and delaminating from the wall

Figure 7 – Tunnel gutter.

Figure 8 – Drain pan system.

had been installed on localized wall areas. A decision was made to prepare the entire wall by removing all waterproofing and sealant materials for a proper installation of crystalline waterproofing to prevent as much water migration through the wall as possible. A specification was prepared for crack remediation and limited repairs to the concrete walls. The manufacturer of the crystalline waterproofing system was engaged throughout the process to ensure the best final installed system possible.

Traffic approximately 20 feet above the tunnel would continue to cause almost constant vibration over the roof of the tunnel. Pans had been installed above the suspended ceiling to catch water seeping through the roof of the tunnel (*Figure 8*). During periods of substantial water infiltration, the pans would have to be emptied several times per week. In the past, building management had several waterproofing subcontracting firms install injection repairs in these areas; however, after many attempts and limited success, a new system had to be developed. A repair protocol was created to provide for the larger crack repairs in the roof deck of the tunnel to stabilize these areas. After injection repairs, a kerf drip edge was cut around the crack area to prevent migration of leak water to other areas. Enlarged stainless-steel pans were installed under the leak areas, and each pan was fitted with a drain. The drain was plumbed with copper fittings to route leaking water from the roof of the tunnel to the thermoplastic gutter system.

Construction Concerns

Because the Houston tunnel system is heavily used each day, waterproofing installation was scheduled to commence on a Friday night, with workers scheduled to work around the clock until Monday morning. Coordination meetings were conducted with building management personnel, the contractor/subcontractor team, and building personnel from the adjoining buildings. During these meetings, construction phasing was presented to all parties. The construction team had removed all tunnel wall finishes during the week and had erected a barrier between the wall and the pedestrian traffic. Preparation and repair of wall surfaces had been accomplished during the evening and early morning hours to prepare for application of the waterproofing system on the weekend. The following instructions, listed in the manufacturer's specifications, was distributed to the team:

3.04 CURING

A. **General:** Begin curing as soon as Xypex coating has hardened sufficiently so as not to be damaged by a fine spray. Cure Xypex treatment with a mist fog spray of clean water three times a day for two to three days, or cover treated surfaces with damp burlap for the prescribed period.

B. **Air Circulation:** Do not lay plastic sheeting directly on the waterproofing coating, as air contact is required for proper curing. If poor circulation exists in treated areas, it may be necessary to provide fans or blown air to aid in curing of waterproofing treatment.

We noted that because of the curing process, humidity levels in the tunnels' spaces would rise significantly during installation and curing. All team members were alerted to the possibility that additional air movement, venting, etc. might be needed if humidity levels became a problem. At one end of one tunnel, a set of double doors exited to a parking garage. The contractor suggested that if needed, humid tunnel air could be vented into the unconditioned garage space. The preparations listed above provided for a successful installation of the water management system with little disruption to building operations.

The second phase of the water management system included installation of stainless-steel pans and related piping. The installation of this system and electrical and telecommunication lines, HVAC equipment, etc. could be accomplished during the evening after hours of daily operation. Finally, the removable cladding panels were installed at the walls of the tunnel.

Results

The walls of the tunnel have been designed with removable wall panels and a cavity area that allows for cleanup of leak water that does not migrate to the gutter drain. This cavity also provides for maintenance of the drainage system. The revised tunnel water management system has been in service for approximately two years, and the tunnel has remained operational ever since, with no need for orange cones or "wet floor" area signs.

BALCONIES

As noted previously, the El Paso Building is located in the harsh environment of south Texas. Because of the building's diagonal orientation, all four sides of the building are exposed to sunlight on longer summer days. Skidmore, Owings, and Merrill, the original architect of record, included a window system in the design that is recessed from the frame to control heat and glare from the sun. This places the windows approximately four feet back from the exterior columns of the building and creates a balcony deck at each of the upper floors (*Figure 9*). Although all balconies on the building are exposed to sunlight, the balconies on two sides of the building (plan south and plan west) are exposed to sunlight for extended periods of daylight hours. The balcony areas were not designed for access by building patrons; however, the original design incorporated two "swing" window openings at each floor level to provide access for maintenance personnel.

The original design of the balcony decks included minor slope only (in most instances approximately 1/16 to 1/8 in. per ft.), resulting in many areas of ponding water. The original system was a layered asphalt roof system installed directly onto the concrete balcony deck. In the past, these areas had been reroofed with asphalt-based granulated modified-bitumen (mod-bit) roof systems to provide a proper walking surface for window-washing and maintenance personnel. Because of prolonged exposure to sunlight and ponding water, they would often fail prematurely. The deck drains for the balconies had been routed through columns, as was typical of construction during the 1960s. Many of the cast-iron drains had corroded, allowing stormwater to deteriorate the concrete around the drain leader pipe.

Figure 9 – Typical balcony, original condition.

The top floor of the El Paso Building had a wider balcony with a guardrail and access for building patrons. This balcony construction was similar to that of the plaza deck, with an asphalt-based waterproofing system with concrete topping and tile surfacing. This area had also experienced leaking throughout the service life of the building; however, because it was for the most part a water-shedding walk surface, the leaks were kept to a minimum. In most cases, those leaks were manageable with little disruption to building tenants.

The Challenge

Building management personnel indicated that the roofs of the balconies had been an ongoing problem during the service life of the building. The owners expressed concern regarding a reroofing plan that would include "another typical roof system." Another concern voiced during these meetings was the fact that when previous asphalt-based systems began to deteriorate because of ponding water, the surfaces of the balconies became slippery, causing a hazard to maintenance workers.

During the interview process, the design team reviewed several options to provide for a long-term roof system that would last at least 20 years. The new system would have to incorporate long-term resistance to ponding water and resistance to premature weathering from prolonged exposure to direct and reflected sunlight.

In the case of the top-floor balcony, a new sandwich-style balcony would be designed with a waterproofing and drainage mat system followed by concrete topping and new paving materials to match the building's renovation design.

Site Investigation

The original schedule called for other work to be performed on the balconies before removal and replacement of the existing roofs. The contractor/subcontractor team was well-established when site investigations of the balconies began. The contractor provided assistance to access the balconies and to repair any testcut areas that were required. Several floors were selected for test cuts to provide a representative condition assessment of the roofing and deck components. The test cuts were consistent throughout and affirmed the system information provided by building personnel.

The test cuts revealed some areas of the concrete balcony deck where previous deck repair attempts had been made. Some of this material delaminated during removal of the mod-bit roof system. Other areas of the decks were wet due to prolonged exposure to ponding water. The adhesion of the roof system to the deck was adequate in areas without water contamination and damage. The test cuts indicated that because of many reroofs over the years and because of the poor condition of the existing roof system, the repair specifications would have to include provision for deck repairs and for drying of the decks at some locations.

The counterflashing for the balcony system was a steel receiver incorporated into the base of the window wall system. The counterflashing was designed to create a totally closed steel counterflashing to receive the base flashing of the balcony roof system. The steel had been repainted several times and, even after many years of service, was in good condition to act as a receiver for the new system.

Design

To meet the 20-year service life requirements and to provide a strong wear-resistant, slip-resistant surface, a poly(methyl methacrylate) (PMMA) liquid waterproofing system was specified for installation on the balcony decks. The system is a seamless, fully reinforced waterproofing system that can be used in conjunction with mod-bit base ply membranes. As stated earlier, the balcony roofs had been replaced several times during the life of the building. The deck was in relatively good condition, but some repair and drying of the concrete surface would be required during construction. It was determined that installing a mod-bit base sheet would provide a suitable substrate for the PMMA liquid system. The fire code for the City of Houston requires the following requirements for installation of torch-applied components:

> **11.5.4 Standby Personnel.**
> Standby Personnel shall be required for roofing operations conducted on the roof of a building classified as a High-rise Building, and any other building containing parapets as described in Section 11.3.4.2 of this Standard, or as deemed necessary by the Fire Marshal.

This requirement basically entails the contractor hiring a City of Houston fire code inspector to be present at all times during installation of the torch-applied membrane (approximate cost of $500/day. This would have not only have been cost-prohibitive, but it would also have been a scheduling nightmare. A self-adhered, mod-bit base sheet was specified to provide for a proper base sheet and to work within the construction scheduling for each floor.

Finally, a wearing surface had to be designed to provide a long-term, slip-resistant finish. After discussions with the manufacturer and owner, the following instruction was added to the specification.

> Provide verification that the finished surface meets the requirements as set forth in ASTM C1028 - 07 (*Standard Test Method for Determining the Static Coefficient of Friction of Ceramic Tile and Other Like Surfaces by the Horizontal Dynamometer Pull-Meter Method*). Recoat all nonconforming areas to meet specifications.

It is important to note that the manufacturer had valuable experience and knowledge to assist the designer/contractor team in this area. The manufacturer provided examples of similar applications over a period of years. This information provided a baseline for the product specification.

Construction

A preconstruction meeting was conducted with the consultant and the applicable subcontractors to coordinate sequencing of the construction and to clarify installation methods and recordkeeping. There were two major concerns addressed at this meeting:

- Prior to demolition and replacement of the balcony waterproofing system, all drains were inspected and replaced as required. The drain repairs/replacements were scheduled approximately two floors ahead of the installation of the waterproofing systems.
- Several mock-up areas were chosen to install the self-adhered base sheet to test for proper adhesion. In most instances, this installation was successful with few problems. The consultant worked closely with the subcontractor on the first two floors to ensure all deck anomalies were properly addressed. The manufacturer also conducted site visits during the first two weeks of work to ensure proper installation of the waterproofing system. The subcontractor understood the importance of the installation and also that informational resources available from the design team and the manufacturer were available should the need arise.

Figure 10 – Renovated balcony.

During initial demolition and installation activities, the manufacturer worked with the contractor to ensure a proper method was utilized to meet the slip-resistant standard in the specification. Each balcony deck was to have a final walkthrough after installation was complete; however, the subcontractor wanted to have a verification method in place to confirm that the proper amount of aggregate was installed to provide the proper surface. The manufac-

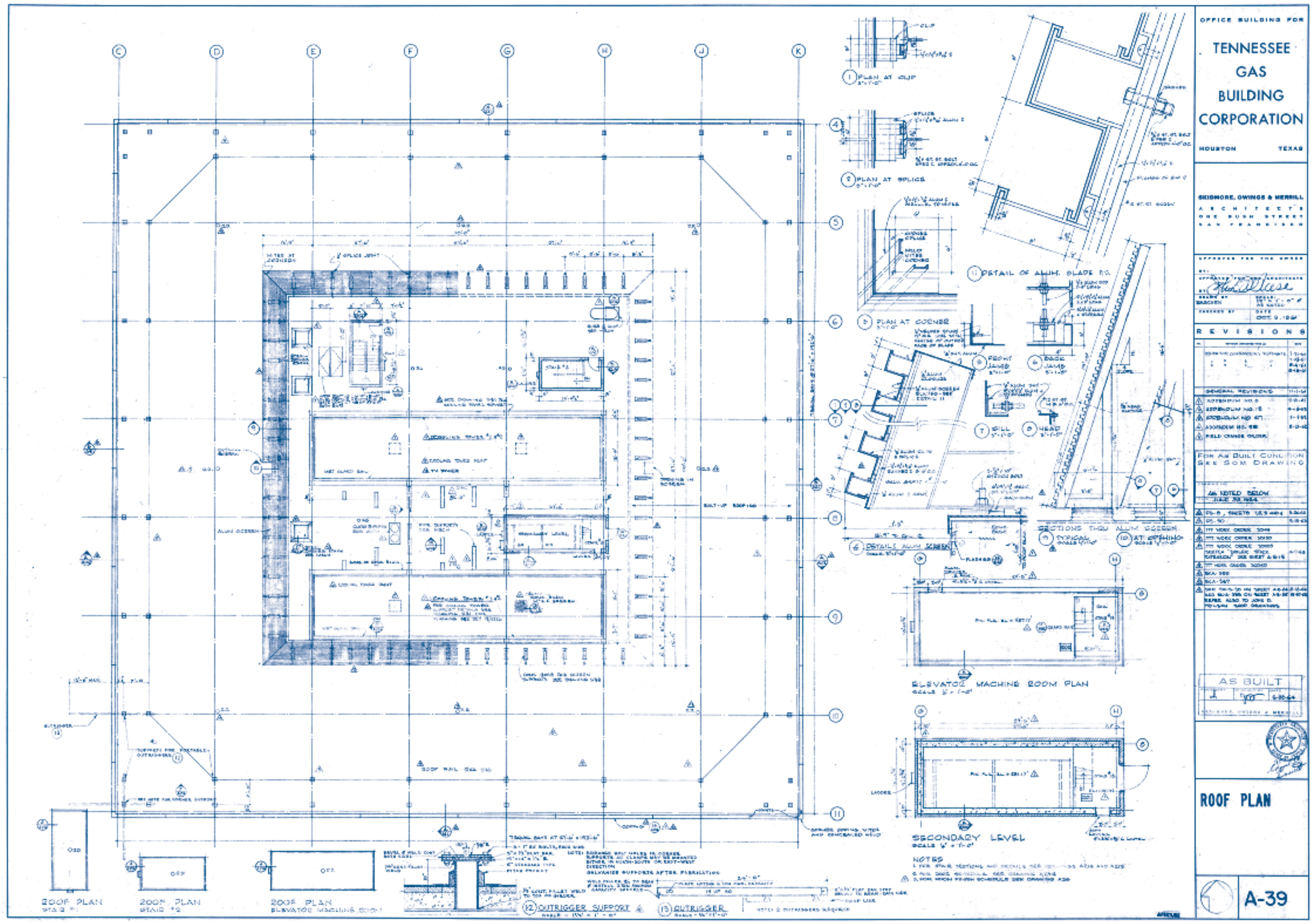

Figure 11 – Original roof plan.

turer, consultant, and subcontractor agreed to track the delivery and installation of aggregate for each floor level and for each elevation of the floor.

Results

The finished product was a consistent waterproofing installation meeting the needs of the owner for years to come with a minimal amount of maintenance. The waterproofing system at the balconies provides a slip-resistant base for maintenance operations, with minimal cleaning required (*Figure 10*).

ROOF REPLACEMENT AND UPGRADE

The original roof system specified for the building was an asphalt built-up roof system with fiberglass insulation, three-ply organic felts, and a flood coat with gravel surfacing (*Figure 11*). This system was typical for the U.S. for 1960s-vintage construction. Numerous studies of posthurricane damage specifically cite roof gravel as a significant source of destructive debris. Both low-rise and high-rise gravel roof systems with and without significant parapets have been documented as a primary source of window breakage, subsequent water penetration, and roof system loss from overpressurization of the buildings. In the late 1990s and early 2000s, many of the building code groups began instituting changes to the code to restrict or eliminate the use of gravel surfacing in high-density downtown areas. The following is a section of the Houston Building Code, which clarifies the use of gravel surfacing in the city of Houston.

> **(In general)**
> **1504.8 Gravel and crushed stone.**
> Gravel or crushed stone shall not be used on the roof of a building.
>
> **Interpretation:**
> This Section was added to prohibit the use of common, built-up roofing aggregate that is generally less than 1½ inches in diameter. It does not restrict the use of ballast rock (1½ in. nominal and greater) used on single-ply roofing systems installed in accordance with Sections 1504.12 and 1504.13.

Insurance companies have also carefully monitored these changes to limit liability to themselves and their clients. In most instances, even when a roof replacement utilizing gravel surfacing of a high-rise building would be allowed, it is rarely specified.

The design of the El Paso Building includes the placement of two large cooling towers on the main roof area, with a large screen wall around the central equipment area. The slope of the cast-in-place concrete roof deck was minimal (1/8 in. per ft.), with ponding water in several large areas. The last reroof of the tower had been completed in 1996 with the installation of the mod-bit roof system. This system, much the same as the balconies, provided a granular-surfaced cap sheet for slip resistance for

Figure 12 – Roof test cuts.

maintenance workers. With the low slope, the ponding areas accumulated water and dirt, causing areas of the roof to become "spongy" and deteriorated. This problem was exacerbated by the constant "wetting" of the roof surface from the mist of the cooling towers, which were operational almost year-round. To provide a walking surface for the workers, wood walkways were constructed around mechanical units and the chiller towers. These walkways then became a second maintenance problem because of Houston's humid environment and from the continual water spray from the two chillers.

Relevant Construction Documents

The building maintenance personnel kept an excellent record of roof replacement and roof repair/modification documents, and a log of vendors accessing the roof documents for various activities. The roof system had last been replaced in 1996. At the time of the initial site visits, the ten-year roof warranty had been expired for approximately two years.

Building Personnel Interviews

Building maintenance personnel stated that some leaks had occurred; however, they had not been problematic and were easily manageable without interrupting building operations. The roof was performing adequately and had been maintained on a periodic basis since installation.

Site Investigation

The construction manager coordinated the roofing subcontractor and safety personnel during the site investigation to assist with test cuts and repairs. At the initial site visit, the owner was still uncertain whether the scope would include a full roof replacement or selected roof repairs. Because of this uncertainty, we took the approach of engaging the original roof manufacturer and the original roofing contractor who had completed the installation in 1996 and had completed interim repairs.

We scheduled representative test cuts at the central equipment area and at the roof perimeter. The test cuts revealed areas of the mod-bit roof system that evidenced significant water infiltration (*Figure 12*). Some of the wet areas were at the base of the cooling towers, which could be expected. However, several areas were considerably far from the equipment on the roof, and all wet areas would require extensive drying of the deck prior to reroof operations.

Representative moisture readings utilizing hand-held and walk-behind capacitance roof scanners were also taken during site visits to assist the team in determining the magnitude of water infiltration. The site visits were conducted in February (when the cooler load was lowest). However, water mist from the coolers was still present during this period. Surface moisture from the mist skews the results from the moisture-metering devices. When elevated levels of moisture were discovered, the roofing subcontractor provided test cuts at these areas to verify the results. Test cuts were also taken at the building perimeter to enable our team to record the components of the existing parapet construction.

Design

Although all leaks can cause operational problems, for the first 40 years of its existence, the floor directly below the roof deck was a mechanical floor with equipment and building maintenance personnel. One of the possible design changes within the renovation scope of the El Paso Building was to reduce the area on the top floor that was devoted to mechanical equipment and utilize this area for penthouse offices. Leaks that were originally classified as minimal would not be tolerated in a sensitive executive penthouse area. After considering the new use of this area, the expired term of the existing warranty, and the findings during site observations, the owner/designer team decided that roof replacement would make the most practical sense for renovation design.

Many of the same considerations that were applicable to the balcony waterproofing were applied to the selection of the roof system for the main roof of the building. The slopes of the roof decks were minimal, and adding significant slope for the new roof system would prove to be difficult. Building personnel would often use the roof surface for routine maintenance, and the surface of the roof would have to provide a solid walking surface, even in the case of slight ponding of water. In addition, the owner did not want to reroof the building for at least 20 years. The new design also had to include a provision to increase the wind resistance of the roof system to meet applicable code changes. For all of these reasons, a PMMA liquid-applied roof system similar to that utilized for the balconies was chosen for the main roof of the building.


Figure 13 – The El Paso Energy Building today.

Because we were aware of wet areas of roofing and roof deck, the design team added several modifications to the typical roof replacement specification. After the site investigation, we knew the condition of the decking was questionable. After discussions with the owner regarding exposure to potential rain events, we determined that it would be prudent to specify a temporary roof system applied directly to the roof deck. Because wet areas of the deck would have to be dried out prior to installation of this system, a venting base sheet was specified for installation over the deck to provide for water vapor relief from potential wet areas. The base sheet temporary roof system and PMMA system both had to meet the high wind uplift requirement for the building.

Construction

Periodic site visits were conducted during the reroofing process. Demolition of the existing roof system was conducted during daylight hours, with debris removal accomplished by complete bagging of the debris, which was taken down the elevator system to a dumpster at the loading dock. During demolition of the roof system, several deck areas with concrete deterioration were discovered. A repair mortar was specified for these areas, which provided a suitable substrate. The screen wall supports were set on concrete bases approximately 3-ft. square by 1-ft. high. Demolition of the roof flashing system exposed many deteriorated areas of the bases.

The structural engineer for the renovation project inspected the condition of the bases and designed a "wrap repair" to be integrated into the roof replacement scope. Because of proper site investigations and relevant preconstruction meetings, the roofing contractor was prepared to provide repairs and temporary coverings during the demolition/roof replacement cycle. Several roof areas, as previously noted, were very wet; and efforts had to be made to temporarily cover these areas so drying efforts could be completed. Representatives of the roofing manufacturer were present throughout construction to provide guidance for the preparation of the roof deck to accept installation of the system.

Results

The roof system with associated accessories will provide a low-maintenance, wind-resistant, long-lasting roof covering for years to come. The roof system includes a 120-mph wind rider to the warranty to provide excellent resistance to expected hurricane-force winds. The edge metal coping system includes a warranty to resist a Category 5 hurricane. The PMMA system with proper aggregate eliminates the need for most walkways and provides a slip-resistant walking surface for maintenance of the building systems.

CONCLUSION

In summary, we have covered the challenges in upgrading a 1960s vintage building to performance standards for the 21st century. Utilization of the knowledge of experienced building maintenance personnel, and coordination of the designers, contractors, and subcontractors was critical to the effective design installation of replacement building envelope systems. This integrative approach ensured participation and ownership of all parties in the successful renovation of the El Paso Energy Building (*Figure 13*).