Optimized Design of Combined Disciplines:

STEEP-SLOPE ROOFING AND EXTERIOR-WALL CLADDING

By Don Kilpatrick

The University of Chicago, chartered July 1, 1890, is located in the heart of the historic Hyde Park neighborhood on the South Side. The inventory of buildings on the campus includes an eclectic mix of Gothic forms with ages varying from 70- to 100-plus years to new facilities constructed within the past four to six years and the ever-present groundbreaking to accommodate continued expansion.

A common thread in the university's past and present is the master plan developed by Henry Ives Cobb, the architect hired by John D. Rockefeller to fulfill his vision for the design of the campus. Central to the vision (beyond academia), was the requirement that the campus core be represented by its connection to the surrounding community, a design standard that the continued expansion of facilities must acknowledge. The Gothic theme of the first 40 years of construction is characterized as an immediate reference to the past but, perhaps more importantly, as evidenced by the grandeur and scale of the buildings, a commitment to the future.

As grand and pleasing to the eye as the inclusions of the master plan were, notably absent was any discussion specific to the standard of care and maintenance. This is not entirely surprising, as the older, established buildings on the campus were built to last, of solid wall construction with multiple brick wythe back-up walls, clad with flat ashlar and carved limestone. Craftsmen and building stewards of the era fully expected to achieve robust returns in terms of life cycle. Steep-slope roofs were covered with clay tile and copper accessory flashings and gutters. This type of construction could easily deliver years of service in the absence of regular maintenance, a truism that up until the past 20 - 30 years held strong.

The performance history of those buildings in the inventory that are now approaching 70 - 100 years in age would do Cobb proud as they remain largely intact, vibrant, and functional components of the master plan. However, according to Barry O'Quinn, senior manager of building envelope, sheet metal, and masonry, "We find ourselves faced with a large inventory of historically significant buildings, all coming of age at the same time in terms of much-needed and well-deserved large-scale maintenance, most notably on the building envelope, roofs, and exterior walls." The current condition indices of these buildings, when comparing and contrasting service life to capital expense and maintenance costs, would establish a very gradual curve over the first 50 - 60 years of service. Beyond the 50 - 60 year point in their respective life cycles, the component assemblies are nearing the end of their service lives and are subject to replacement (reroofing) and maintenance (tuckpointing, selective removal and replacement of stone cladding).

The majority of the steep-slope, tile roof assemblies on the vintage buildings in the inventory are representative of original construction, combined with cut and carved limestone façades (barrier walls) establishing the building envelope. At and above the roofline, the clay tiles transition to carved copings at parapets and limestone-clad sheer walls of higher, interior, partial elevations. It is at these interfaces, where the work scope becomes interdisciplinary, that the discriminating eye turns toward the overall condition of cladding features adjacent to and above the roofline. These combined elements of roofing and cut limestone cladding result in complex geometries of converging slopes and changes-in-plane, with demanding needs specific to flashing. The true success of the building envelope in this instance is measured by the combined performance characteristics and present-day condition indices of the individual components for the roof and exterior walls.

The current standard of care for the vintage buildings continues to evolve, as evidenced by expenditures in the tens of millions of dollars over the past five years to address deferred maintenance as identified in response to the initial round of 2001 City of Chicago Façade Ordinance inspections. According to O'Quinn, "Compliance with the ordinance on the older buildings has resulted in the commitment of a significant amount of money over the past five to six years. Lessons learned through the development of repair strategies specific to each building and its particular nuances have been helpful in establishing priorities and the standard of care for the remaining buildings on the campus that, by virtue of height, may not necessarily fall under the provisions of the code."

The majority of the current capital projects are focused on stewardship of the building envelope for the vintage buildings on campus, for these represent the past, present, and future identity of the campus. Provisions for maintenance and repair were notably missing from Cobb's master plan. Arguably, there would be no need for a structured maintenance and repair program, as the projected life cycle for the steep-sloped tile roofs and walls of cut limestone would predictably exceed the tenure of anyone involved in facilities management.

Photo 1 – Original construction of Burton Judson Courts, circa 1931.

Photo 2 – Aerial photo of the Burton Judson facility.

Project Profile — Phased Steep-Slope Roof/Exterior Wall Rehabilitation

Burton Judson Courts, completed in 1931, was built to house a burgeoning student population. Construction of the steel-reinforced, concrete, and wood-framed housing unit began in the late 1920s, providing work for skilled Depression-era craftsmen on what was, at the time, one of the largest private construction projects in all of Chicago (*Photo 1* [Jean F. Block, *The Uses of Gothic Planning and Building on the Campus of the University of Chicago, 1892-1932*]). The building, clad with cut and carved limestone with roof slopes of clay tile exceeding 16:12, consumes an area equivalent to a quarter of a city block (*Photo 2*).

By The Numbers

The magnitude of the combined steep roof/exterior wall rehabilitation, with a total cost in excess of $10 million, justified an initial bid package centered on a projected five-year, phased construction period. Summer 2008 represented the start of Phase III as identified in the original solicitation of bids (*Photo 3*). The abbreviated annual construction window of June through September has presented a challenge during Phases I and II (*Photo 4*). The university is currently giving consideration to adding a sixth-year phase to provide reasonable assurance that the construction will be completed within the time constraints established by the annual scheduling parameters. With year-round occupancy by resident heads and the increased student traffic for spring departures and fall arrivals, the schedule, beyond the work itself, may be considered a determining factor in establishing the overall success of the project (*Table 1*).

Existing Conditions

During the summer of 2004, facilities personnel reported that the individual clay roof tiles were failing to the extent that pieces were falling to grade at random locations without apparent cause. In response to the reports of falling tiles, a roof survey was performed to determine why the tiles were

Areas by Phase (Sq Ft) – Steep-Sloped Clay Tile, Flat-Lock Seam, Modified Bitumen, and Exterior		
	Roofs	**Walls**
Phase I	11,114	17,210
Phase II	11,367	10,415
Phase III	20,504	21,806
Phase IV	13,208	14,502
Phase V	11,008	15,088
Totals	67,201	79,021

Table 1

Photo 4 – Phase I, south exposure.

Photo 3 – Overall view of pending Phases III and IV.

Photo 5 – Typical condition of the tile in the field of the roof.

exhibiting distress. Through a visual examination, it became apparent that the tiles were exhibiting severe cracking in sections, across the full dimension or thickness of the tiles (*Photo 5*). There was no apparent pattern to the cracking or evidence to suggest that it was induced by any impact.

Tiles were removed, and an initial rate-of-absorption test was performed. Interestingly, the results, when compared and contrasted to tile from other buildings in excess of 100 years of age, indicated the absorption rate for the failing tiles was, by volume, 30 to 40 times greater than that of the older materials that were not exhibiting distress or cracking. The findings supported the theory that the performance issues related to the tile were the result of water retention and subsequent freeze/thaw cycles. Understanding that the continued free-fall of fragmented clay tile to pedestrian areas below presented an unacceptable risk, the owner opted to install nets to catch the projectiles over the short term until funding for design and construction could be secured (*Photo 6*).

In an effort to add value, the roof survey included a cursory inspection of the building's exterior walls, in part due to the readily discernable wall distress conditions in exterior-wall features (parapets) adjacent to and extending above rooflines. The roof side of the parapet and stone copings had been subjected to liberal applications of mastic-based repairs over the 75-year life cycle of the installation (*Photo 7*). Removed from the above-roofline features, it was noted that much of the stone cladding in close proximity to window heads was exhibiting out-of-plane movement and localized distress in the form of cracked, spalled stone.

The aforementioned wall distress conditions were serious enough to warrant further review through selective removals in areas of interest to develop an improved understanding of the as-built conditions, most notably at the gabled roof features present at regular intervals across the primary N/S- and E/W-orientated wings of the facility. As suspected, concealed steel imbeds (loose steel lintels at the window heads) had been subjected to moisture, resulting in corrosion (*Photos 8* and *9*). The

Photo 6 – Netting installed as emergency response to falling tile.

Photo 7 – Repeated applications of cold-process repairs at rakes with adjacent stone coping.

volumetric expansion of the steel had shifted the surrounding stone from its original setting. The above-described rust jacking (expansion of steel in sections due to corrosion) of the loose-set steel lintels established conditions warranting a complete rebuild of the backup materials with new steel and concrete-reinforced CMU wall sections. At several locations, it was noted that the overall length of the loose steel lintels fell short of the full span established by the window opening, with the ends not bearing of the jamb stones as would be prescribed by current engineering conventions (*Photo 10*). The presence of corrosion and the questionable integrity of the condition established by the incorrectly sized lintels provided justification for the complete rebuild of the stone-clad gables.

Further study showed cyclical exposure to moisture as the catalyst for the accelerated corrosion of the concealed steel imbeds (loose lintels) at this location. As originally constructed, a through-wall flashing was installed as a supplement to the stone coping, replete with an extended downward or vertical break on the roof side to provide coverage for the accessory flashings for the tile roof assembly. As previously stated, liberal applications of mastic were present through this change in plane from the roof to the stone copings. Removal of the stone coping at the transition of the sloped-rake roof edge to the short, horizontally oriented coping at the base of the gables was very instructive. At this location, it was determined that the through-wall flashing was not continuous through the complex geometry of differing planes as established by the stone coping assemblies (*Photo 11*). The ultimate demise of wall cladding at this location can be attributed to this "disconnect" of the drainage plane as witnessed in the through-wall flashings below the stone coping.

Photo 8 – Inspection opening at area of localized distress at gables.

Photo 9 – Typical corrosion of loose steel lintels at window head of gable features.

The required selective removals of wall cladding materials to facilitate the removal and replacement of the damaged loose steel lintels typically stopped at the window heads (*Photo 12*). All stone copings and masonry backup materials were removed, exposing the timber framing of the roof deck (*Photo 13*). This accommodated the necessary modifications to the wood roof deck (cutting back flush with the timber frame) and the installation of "J" hooks that would be integrated with the new steel-reinforced CMU back-up wall as it was built up (*Photo 14*).

Subsequent to the complete reconstruction of the gables, new through-wall flashing was provided over the top of the underlying stone cladding and fully grouted CMU

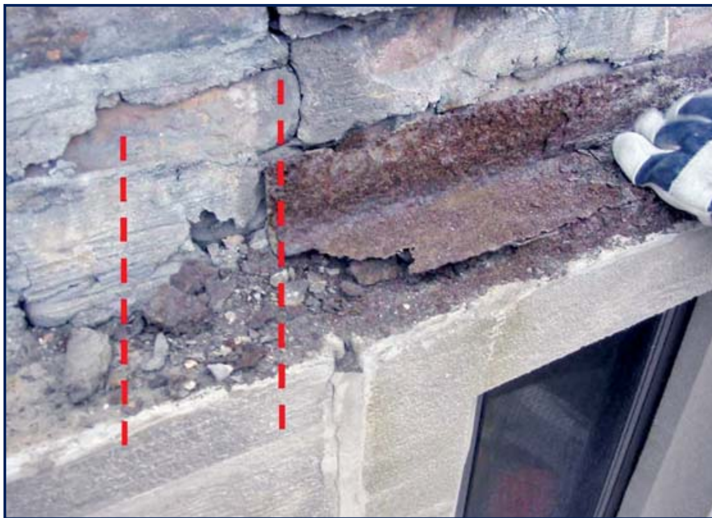
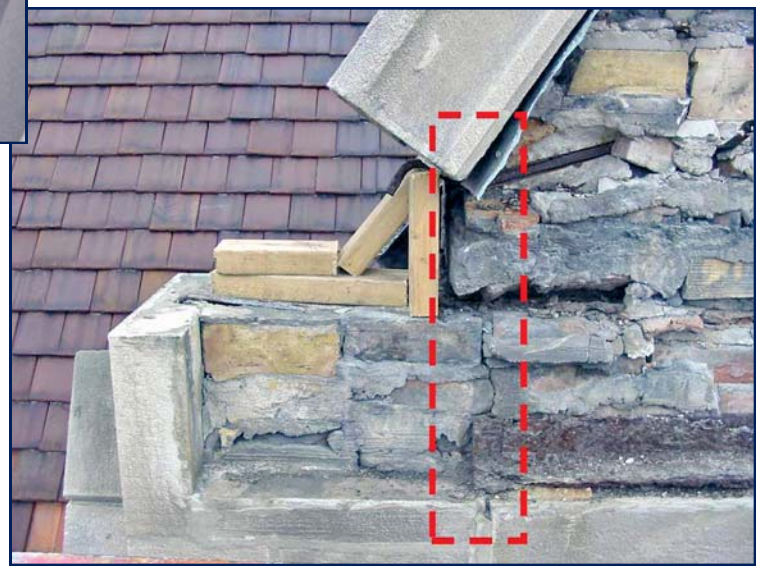


Photo 10 – Loose steel lintels did not provide adequate span across the full dimension of the window opening. The area between the lines indicates approximate revised bearing limits of new steel window head lintel.

Photo 11 – Lack of continuity in through-wall flashing resulting in corrosion of loose steel lintel below.



backup wall. Final roof system accessory flashings were integrated with the new through-wall flashing below the stone copings (*Photo 15*). With all masonry and new through-wall flashing components in place, the work area was turned over to the roofing contractor, and tile installation began (*Photo 16*).

In an effort to expedite the remaining portions of the project, each phase was reviewed during the winter months for the express intent of establishing unit quantities of stone and loose steel lintel replacement. While initial quantities were published in the bid set documents, it has been noted that over the term of the project, additional distressed stones (beyond those catalogued in the initial inventory) will be presented in increased numbers, primarily at window heads and mullions. Steel, stone, and roof tile are ordered in advance of the phase start-up to minimize the possibility of delays attributed to lead time. The masonry restoration service provider fulfills the role of general contractor, assuming all responsibility for establishing shared work platforms (scaffolding) as necessary for both trades.

As a result of the project approach on the Burton Judson facility, the university has saved approximately $400,000 - $500,000 in scaffolding costs over that which would have been required if the project had been solicited separately, by discipline. In addition, added value is derived from having the two trades work concurrently on building features removed from one another by trade yet related by function in the combined assembly of the building envelope. The repair of the walls and above-roofline cladding features established a sound substrate for the termination of accessory roof flashings and continuity of through- wall flashing conditions that previously proved to be the apparent cause of significant wall distress conditions.

Beyond the readily discernable cost savings specific to scaffolding,

Photo 12 – Cataloguing of stone cladding ahead of required selective removals for the gable, backup wall rebuild.

Photo 13 – General limits of demolition at gables with temporary roof covering established.

Photo 14 – Gable end rebuild with new bond beam and "J" hooks that will interface with fully grouted, steel-reinforced CMU backup wall.

the optimized building envelope management protocols bring added value through:

- Minimized facilities disruption with targeted, manageable work scopes.
- Matching site-specific building features and trades to a well-defined annual construction period at which time all building envelope distress conditions were given equal consideration.
- Early in the planning stages, proactively addressing at the face of the work condition indices of building features that are categorized as supplemental to one another in the component assembly.
- The new roof and accessory flashings are integrated with restored, adjacent, and above-roofline wall sections, establishing baseline total systems performance that will result in a projected life cycle rivaling that of the original installation.

Photo 15 – Completely reinstalled stone coping with integrated through-wall and accessory counterflashing assembly ready for the installation of clay tile.

Photo 16 – Installation of clay tile subsequent to the completion of adjacent cladding repairs.

Closing Thoughts

Beyond the obvious challenges relative to access are the ever-present needs specific to the balance of the building envelope. In summary, steep-slope roof assemblies present a set of challenges unique from the perspective of design routinely not given consideration in the low-slope arena. Steep roofing components of building envelopes are dynamic in form and function as defined by their simple but demanding needs related to the critical placement and integrity of accessory flashings. The continuum of a functional drainage plane through complex geometries of dissimilar materials must be acknowledged in the design process.

If the present roof system, with an industry-accepted standard service life in the range of 60 to 80 years, is in a condition warranting replacement, then it is reasonable to assume that everything around it should be given equal consideration during the design phase of the project. By some measure, all above-roofline features on vintage buildings should be considered extensions of the roof assembly. In the absence of due diligence centered on the understanding that a roof represents only a portion of the building envelope, economies in volume may be overlooked, and the integrity of a significant investment in the roof component of the assembly will predictably be compromised.

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Donald Kilpatrick has been with INSPEC, Inc., since 1985. Don has performed numerous building envelope investigations on a variety of new and vintage structures. Information derived from the investigations has been used successfully in the development of design and repair strategies. Kilpatrick received the Horowitz Award for outstanding contribution to *Interface* journal in 2004.