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An Ultramodern Building Shows Signs of Age

By CATESBY LEIGH

Washington

In the summer of 2005, National Gallery of Art personnel and a consulting engineer were chasing down a leak on a roof terrace atop the gallery's marble-clad, I.M. Pei-designed East Building. Suddenly the beginnings of what would turn out to be a far more serious problem caught someone's eye. One or two of the 2-by-5, 438-pound marble panels on the building's main air shaft were tilting out.

At first, gallery officials believed the problem was localized, caused by the freezing of water lodged on the shaft's deteriorated asphalt lining. But tilted panels soon started cropping up on different parts of the building. To date, the displacement of some 400 of the East Building's 16,200 exterior panels—about 2.5% of the total—has been observed. That may seem a small amount. But because this is a public venue, and because "we can't model or predict the rate of failure," says Susan Wertheim, the gallery's deputy administrator for capital projects, National Gallery officials decided in 2008 to reinstall all of the panels. They plan on hiring a contractor to oversee the project next year.


Dennis Brack/Black Star

The National Gallery's East Building

Mellon money—the equivalent of about half a billion dollars today—built the National Gallery, both John Russell Pope's 1941 West Building and Mr. Pei's 1978 addition. But taxpayers will be footing the bill for the cladding reinstallation on the latter. The project is scheduled for completion in 2013 at an estimated cost of $85 million. A *cordon sanitaire* has been discreetly established by means of wooden entrance pavilions, roped-off entrance steps, and temporary fencing around the building. But visitors can't identify the problem because newly tilting panels are swiftly wedged back into place with leaden shims.

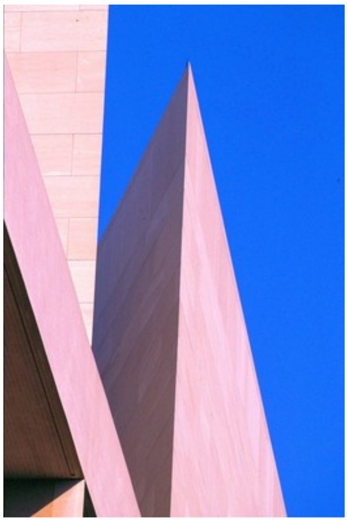
Despite the stylistic divide between Pope's spare but refined classicism and Mr. Pei's prismatic, sculptural modernism, the two buildings' exterior marble walls appear to have been constructed in the same way—in a coursed ashlar pattern of Tennessee pink marble cut to the same dimensions.

They weren't. In the West Building, stones ranging from 4 to 8 inches thick were laid up with mortar joints and mortared to a back-up of concrete or brick. Mr. Pei considered adapting Pope's massive wall construction to the East Building. But the necessary quantity of Tennessee pink marble was not obtainable within a reasonable time frame, and "it would have cost very, very much," he said in a 1993 interview with a gallery archivist. (Mr. Pei declined to comment for this article.)

Instead, Mr. Pei opted for a curtain wall, a standard construction technique in postwar architecture in which a veneer consisting of thin panels of glass, stone, metal or concrete is supported by a structural frame. While Mr. Pei's stone echoes the dimensions of Pope's, the East Building veneer is just three inches thick—still considerably thicker than typical marble curtain-wall cladding. And rather than being mortared to their back-up, Mr.

Pei's panels hang two inches out from the brick infill within the East Building's load-bearing concrete frame. (The two-inch air gap helps prevent moisture from getting inside the building.) The bottom corners of adjacent panels rest on stainless-steel, J-shaped "gravity clips" that are 8 inches wide and fitted into slots in the bottom of each panel. "Lateral anchors," stainless-steel pegs whose hooked ends are fitted into holes on top of the panels, hold them in. Contrary to appearances, these marble panels are not intended to bear the weight of the stone above. The gravity clips and lateral anchors transfer that load back to the frame.

The standard minimum joint width for curtain-wall stone cladding is a quarter-inch, but for the sake of uniformity Mr. Pei retained Pope's narrow, 1/8-inch joints. (He noted during the 1993 interview that such fine joints were "very rare.") Instead of the caulking materials usually employed with stone cladding, Mr. Pei opted for soft, tubular gaskets made of neoprene, a synthetic rubber. The flexible gaskets would allow the marble panels to expand in hot weather and contract in the cold while "floating" on their stainless-steel supports. The gaskets also would spare the East Building the need for wide, visually disruptive expansion joints—a standard feature of curtain wall veneer, running horizontally and vertically at regular intervals to accommodate thermal movement. And while caulk can deteriorate after just a few years, the East Building gaskets were supposed to provide a weatherproof seal for half a century or more.



National Gallery of Art, Washington/Dennis Brack/Black Star

A detail of the marble paneling.

According to the minutes of a July 1971 meeting with the National Gallery's Building Committee, shortly after ground was broken for the addition, Mr. Pei advocated his curtain-wall approach as "a technological breakthrough for the construction of masonry walls." How, then, could lateral anchors have started working loose, allowing panels to tilt out, less than 30 years after the building's completion?

During a recent interview, Robert A.M. Stern, dean of the Yale School of Architecture, observed that the new technologies employed in modernist architecture after World War II sometimes proved problematic. (Mr. Stern declined to speak about the East Building in particular.) He cited the example of Lever House in midtown Manhattan, an early glass-walled office building. In the decades following its completion in 1951, many of its glass panels fractured while its carbon-steel curtain-wall frame rusted. A 1990s renovation substituted an improved aluminum frame and glass panels, while remaining faithful to the original design. "It took years of research—and also the technology of glass kept evolving—making it more and more likely they could do the job they actually ended up doing," Mr. Stern says.

But the East Building cladding problem does not boil down to a simple matter of design getting out in front of technology. It's more complicated—and unusual. "I've never seen a cladding failure on a job with three-inch panels," says Brian Dyer, a third-generation architectural stone salesman based in Fredericksburg, Va. The National Gallery quietly called in four building forensics firms to examine the panel tilting as it spread. "Nobody looked at this and said, 'Yeah, I know what the problem is,'" Ms. Wertheim notes. The structural investigation report subsequently prepared by Robert Silman Associates, which is responsible for designing the panel reinstallation, is confidential due to contracting guidelines and security considerations.

Ms. Wertheim portrays the failure as the calamitous result of the "confluence" of three different and interdependent phenomena or "events." One event is the shrinkage of the concrete frame. Most of this shrinkage should have occurred within a couple of years of the East Building's completion. But it has contributed to "compression in the cladding and reduction of the 1/8-inch joint," Ms. Wertheim says.

A second event is the hardening of the joints. During construction, mortar laid in the gravity clips to more firmly attach the marble panels to them spilled out and at some point started binding panels together. Also, stone setters placed pairs of 1/8-inch-high lead spacers, or "setting buttons," beside the anchors and clips to maintain joint width. They should have been cleared away as construction progressed, but an unknown number weren't. To make matters worse, gaskets have lost their elasticity, like soft sponges that have dried out, Ms. Wertheim says.

The third event, and the "driving factor" in the panel displacement, according to Ms. Wertheim, is the continuous seasonal and daily thermal movement—expansion and contraction—of the panels. These cyclical micromovements trigger a downward load transfer through the panels and their constricted, hardened joints that compromises the intended transfer of the panels' weight back to the concrete frame. As a result, some of the panels are no longer "floating," but are instead "stacking" on top of one another. At the same time, the thermal movement is inducing fatigue in the lateral anchors, causing some to work loose. Ms. Wertheim likens the thermal cycles' effect on the anchors to wiggling a loose tooth.

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The prevalence of the East Building's tilting panels in locations most exposed to the sun—on the southern and western facades, and at higher elevations—is typical of a degenerative syndrome, hysteresis, to which marble is more vulnerable than other stones. Hysteresis operates through a combination of temperature and moisture variation, which produces granular decohesion that causes loss of strength and permanent expansion in the stone, which in the case of marble veneers often involves warping. Hysteresis has plagued numerous postwar structures, such as Chicago's Amoco Building (now the Aon Center). In the early 1990s, its 44,000 Carrara marble panels—1¼ to 1½ inches thick, with many of them warped or cracked—had to be replaced with thicker granite cladding.

A common manifestation of hysteresis is a minute but permanent expansion of the stone resulting from cyclical, otherwise-reversible thermal movement. According to Bent Grelk, a Danish building-materials expert who had a prominent role in a five-year, $5 million study of marble cladding problems that was partly funded by the European Community, such a permanent expansion of the East Building's panels, with no warping, may have had a critical role in the failure of the lateral anchors. Acknowledging that he was speaking without firsthand knowledge of the East Building problem, he said the panels' attachment to the supporting wall, including the narrow joint width, may not have adequately compensated for such expansion.

Charles Muehlbauer, technical director of the Marble Institute of America, a Cleveland-based trade association, shares Ms. Wertheim's view that permanent expansion of the East Building panels is a "minor" and "hypothetical" factor. But like Mr. Grelk he questions the wisdom of Mr. Pei's 1/8-inch joints. "That's not something I would have recommended," he says. "There's little forgiveness there, just taking into account any slight imprecision in the cutting of the stone, shrinkage of the building frame and thermal movement." He said he could not think of another curtain-walled building with masonry joints that narrow, and that the East Building's problems come as no surprise. The West Building's 1/8-inch joints do not raise experts' eyebrows because its massive walls are bound to restrain thermal movement—and thus any permanent expansion—to a far greater degree than the East Building's veneer.

By contrast, the 1964 National Museum of American History is clad with Tennessee pink marble panels of the same 3-inch thickness as the nearby East Building, but with 3/16 inch joints. It has had no major cladding problems, though the fact that it is framed in steel, not concrete, could also be a reason.

Ms. Wertheim says wider East Building joints would have hardened as a result of the spilled mortar, unremoved setting buttons, and problematic gaskets. But given Mr. Pei's narrow joints, panels might have wound up tilting out even in the absence of those snafus. It seems pretty clear that the architect's "technological breakthrough in the construction of masonry walls" was more of an experiment than he realized.

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