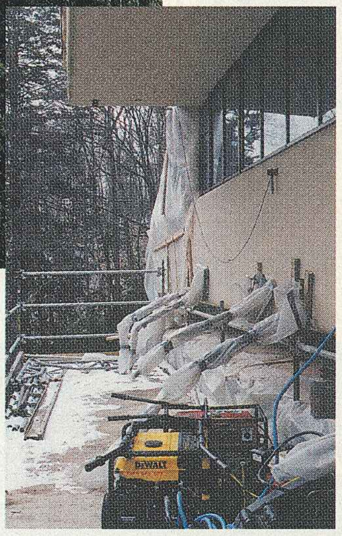
Structural Repair

'WRIGHTING' A FRAGILE LANDMARK SAGGING FOR NEARLY 65 YEARS



OVER WATER Fallingwater's cantilever, shored since 1997, gets fixed.

FIRST, THE LEANING TOWER OF PISA IS rescued. Then, Fallingwater—the sagging house of Pennsylvania. Workers are completing a post-tensioning procedure designed to put a stop to the historic sagging of the hallmark cantilevered portion of the 64-year-old Fallingwater, designed by Frank Lloyd Wright. The 15-ft cantilever, which perches the landmark over a waterfall, has been propped since 1997.

Insufficient reinforcement caused the 15 x 62-ft concrete slab to sag soon after the Mill Run house, about 70 miles southeast of Pittsburgh, was completed in 1937. The post-tensioning raised the cantilever about ½ to ¾ in., lifting it slightly above the shoring.

The process was not intended to restore the cantilever, which has sagged more than 7 in. in places, to its original position, say engineers. "It would be much more damaging to bring the original shape back," says Mario Suarez, senior consultant for South Norwalk, Conn.–based Schupack Suarez, the project's post-tensioning specialist.

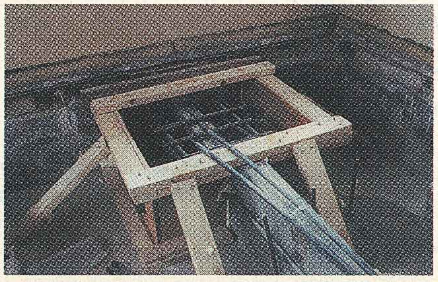
The delicate structural fix is part of a $11.5-million restoration of the house and grounds, slated for completion in 2005, that includes a new landscape plan and a wastewater treatment plant. About $3.5 million of the total, including other structural repairs, waterproofing and pointing, will be spent on the house. The work is funded by federal, state and private grants, says Lynda S. Waggoner, vice president of the Western Pennsylvania Conservancy, the Pittsburgh-based nonprofit organization that now owns and maintains Fallingwater.

Late last year, crews removed the stone floor in the living room to reveal the deteriorating existing structure below, which consists of four, 36 x 20-in. reinforced concrete beams running north-south, approximately every 12 ft on center. The inverted "T" beams have a 4-in.-thick slab acting as the flange. Joists that are 4 x 17 in. run between beams every 4 ft or so. The assembly projects from four large concrete "bolsters," or walls, built into a sandstone ledge.

Crews injected epoxy into cracks to repair members. This would limit the amount of upward movement associated with the post-tensioning and ensure even distribution of compression through the whole beam, says John Matteo, an associate in the Washington, D.C., office of Robert Silman and Associates, the job's structural engineer.

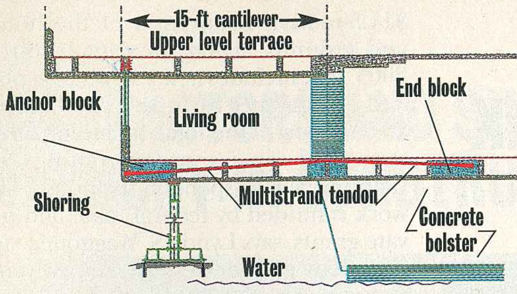
On either side of each beam, workers placed a tendon made up of seven, ½-in.-dia. strands housed in a plastic duct that is grouted after tensioning. On each side of the joists, crews placed a tendon made up of a single ½-in.-dia. strand, greased and housed in a plastic sheath.

The upper level terrace, which had also sagged, visually functions as an independent cantilever. However, it is structurally tied to the level below by mullions of living room windows. These had become highly overstressed. "We considered reinforcing the upper level with post-tensioning, but had a limited amount of backspan," says Matteo. Instead, the

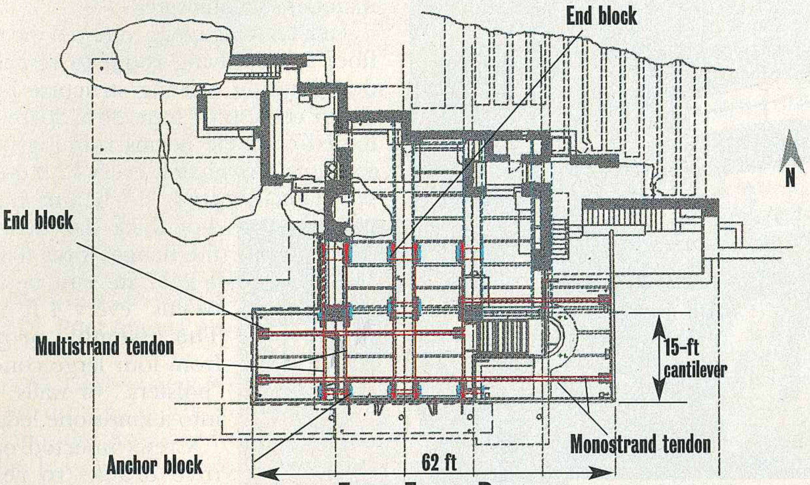


INSIDE JOB Post-tensioning of beams, to arrest up to 7 in. of sagging, raised cantilever less than 1 in.

PHOTOS BY JOANN GONCHAR FOR ENR



SECTION LOOKING WEST



FIRST FLOOR PLAN

ILLUSTRATIONS COURTESY OF ROBERT SILMAN ASSOCIATES PLLC

TIED TOGETHER Window mullions join upper terrace and living room level to function as one cantilever.

team decided to reinforce the mullions by welding a ⅜ x 2½-in. steel plate to each side.

Tensioning took several days. First, workers tensioned the monostrand tendons, bringing them to a force of some 43 kips. Next came the multistrand tendons, gradually bringing them to a force of about 390 kips each. "We gave the building time to respond slowly since it moved down over 60-plus years," says Matteo.

Multistrands were tensioned by attaching a hydraulic jack to the cables where they protrude from anchor blocks on the building's south face. Monostrands were tensioned from the interior using couplers, in order to avoid unnecessary penetrations in the building's skin, says Jim Loper, a structural engineer with VSL, Springfield, Va., the general contractor.

The process went smoothly. "We were actually expecting broken window panes and had none," Loper says.

The conservancy plans to begin modified visitor tours while Fallingwater's construction and maintenance crews reassemble the living room. This should be the last chance to see the innards of Fallingwater for a very long time. □

By Joann Gonchar in Mill Run, Pa.