

The famed Leaning Tower of Pisa is no doubt one of Italy's most iconic monuments. It is also one of its most endangered buildings, having teetered on the brink of collapse until recently, when conservators and engineers carried out an ingenious plan to reduce the tower's lean by a mere .5°, buying it several centuries of relief. Sixty meters tall and 20 meters wide, the bell tower was constructed over a 200-year period—interrupted by long periods of inactivity—that began in August 9, 1173. The eight-story, cylindrical structure is essentially hollow, each level accessed via an interior spiral staircase.

The tower's instability surfaced early on, coming to light during construction of its second story in 1272. At that time, masons believed they could correct, if not completely reverse, the tower's lean by simply adjusting the position of subsequent courses of marble and lightening the weight of building materials and fill. When these efforts failed, further measures were taken to straighten the tower by adding courses of masonry to the south and subtracting them to the north, evident in the construction of the belfry, which has six steps to the south and only four to the north. Today, these "corrections" are noticeable in the tower's obvious banana shape when viewed from the east or west.

None of these measures, however, were able to straighten the tower or reduce the ever-increasing strain

Still Leaning After All These Years

**EIGHT CENTURIES AFTER ITS CONSTRUCTION,
PISA'S FABLED TOWER IS GRANTED A 300-YEAR REPRIEVE**

on the structure caused by differential settling. Analysis of the subsoil around the tower revealed that in antiquity, a river ran across the landscape, right through the Pisa church square. The tower's instability is the result of differential composition of the riverine deposits and surrounding soils.

Over the centuries, the whole tower has subsided vertically by about 2.8 meters as a result of the unstable nature of the underlying ground. The differential subsidence, however, is 1.89 meters—the extreme north and south having subsided by 1.86 meters and 3.75 meters, respectively. This extreme inclination has caused severe vertical compression of the building materials on the tower's south side, evident in cracking and separation of the marble masonry and fill. Over the centuries, 175 of the tower's 269 original columns have been replaced



THE TOWER IS SECURED WITH STEEL CABLES AND 1,000 TONS OF LEAD COUNTERWEIGHTS, ABOVE, TO PREVENT IT FROM TOPPLING DURING CONSERVATION AND STABILIZATION WORK. SOILS BENEATH THE NORTH SIDE OF THE TOWER, LEFT, ARE TREATED WITH LIQUID NITROGEN PRIOR TO REMOVAL.

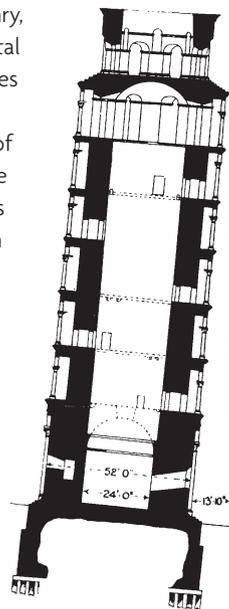




after breaking under the strain. In addition to replacing masonry, efforts to preserve the tower are evident in the numerous metal supports—rings, brackets, and chains, some applied centuries ago—that can be found throughout the building.

In 1911, the first accurate measurements were made of the tower's inclination, which at that time was $5^{\circ}14'46''$ —the seventh story projecting over the first by some 4.22 meters on the south side. In 1992, an electronic monitoring station was installed in the tower to record its constantly changing inclination as well as erratic structural deformation caused by winds and seismic activity. An analysis of these measurements revealed that the rotation speed of the tower had accelerated from 4" (seconds of arc) per year in the 1930s to 6" per year at the end of the 1980s.

In 1993, the commune of Pisa embarked on a radical plan to reduce the tower's lean, and hence the vertical load on the structure. A counterweight composed of lead ingots weighing 1,000 tons was placed on the north side of the tower's base in order to arrest its southward rotation and secure the



building during restoration. The tower was further anchored with steel cables and a series of subsurface stays. Once the tower was stabilized, engineers embarked on the task of boring into the ground and removing soils from beneath the north side of the tower, causing it to further subside.

"While the interventions are not permanent," says Michele Jamiolkowski, head of the International Committee for Safeguarding the Tower, "we believe that a century from now, true solutions will exist to permanently stabilize the tower." In the meantime, a conservation team has returned to the tower to carry out work on its stone masonry.

The Leaning Tower of Pisa: Ten Years of Restoration, which chronicles the history of the bell tower and the extraordinary efforts to preserve it, will be on view in the lobby of the United Nations in New York from July 21 to August 29, 2003. From there, the exhibition will travel to UNESCO in Paris and the Italian Cultural Centers in San Francisco, Washington, D.C., and Buenos Aires. ■

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