



The Leaning Tower of Pisa

Mike Bartusiewicz, Dong-Hyun Chung, Steve Cullen,
Kate Horlocker, Na Ning, & Bin Tong

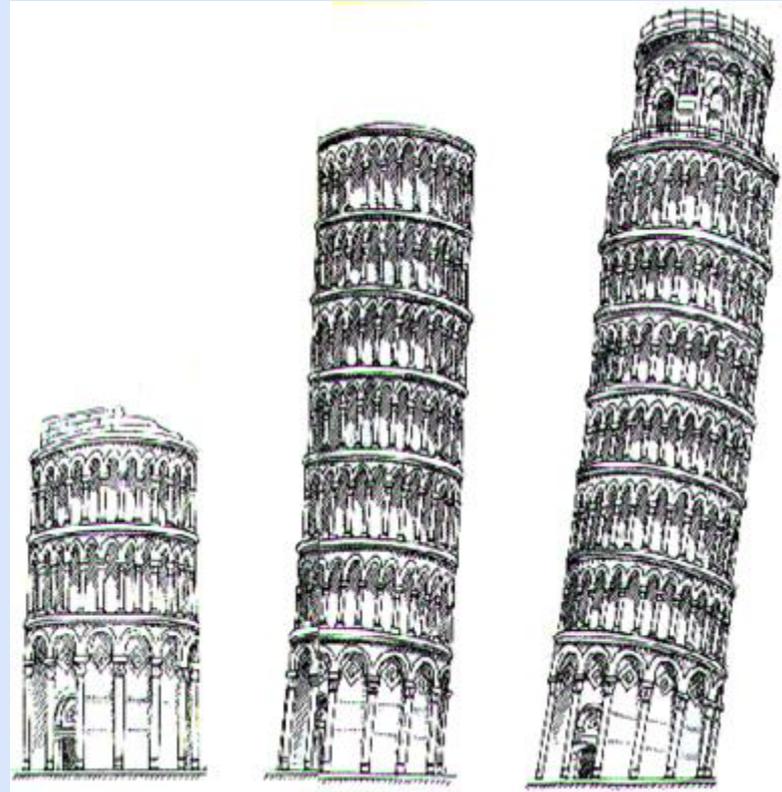
The Leaning Tower

- Construction of Tower began in 1173 under supervision of architect Bonanno Pisano
- Bell tower was built as manifestation of city's pride and was meant to reflect rich city of Pisa



Construction of The Tower

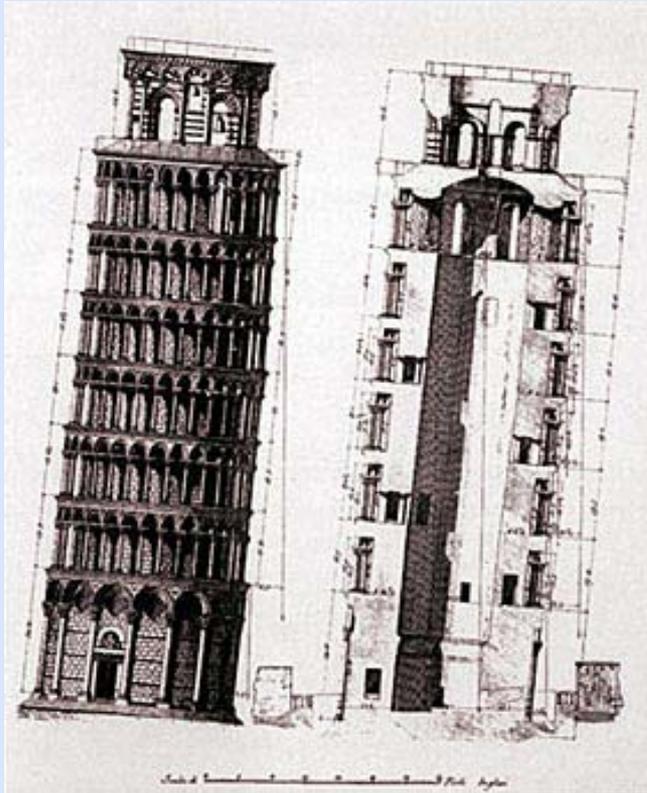
- Work on Tower ceased in 1178 for reasons unknown; studies have shown that soil on which Tower was built would not have been able to withstand more construction at that time
- Construction began again, but ceased in 1278
- Had Tower been completed at this time, would have collapsed because of the stress on soil



<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

<http://www.costruzioni.net/images/pisa.h4.jpg>

Construction of The Tower



- During actual construction of Tower in 1100's, Tower originally leaned north
 - Masonry blocks placed on each level to correct lean of axis
- By end of its construction, the Tower leaned significantly to the South
- Tower was finally completed in 1370; height is 53 m

The Leaning Tower Today



- From early 1990 until December 2001, Tower was closed to public because of safety issues
- Italian engineers implemented complex \$25 million rescue plan in order to stabilize Tower
- Although Tower looks as if it might collapse at any moment, in reality, it is more stable now than at any time in past few centuries

Alternatives to Restoration



- In 1838, architect Alessendo della Gherardesca constructed a walkway around Tower base
- Water filled the walkway area after the excavation extended below water table
- Plan increased tilt of Tower by over one quarter of a degree
- Gherardesco placed 0.7 meter thick ring of concrete around walkway to help stabilize Tower, but excavation nearly caused its downfall

Alternatives to Restoration

- In 1934, engineers used grout injection to stabilize the foundation of Tower
- This process led to a displacement of Tower
- The tip of Tower tilted 10 mm more to South



<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

http://www.intl.pdx.edu/EdAbroad/2006PhotoContest/Buildings%20&%20Architecture/Buildings%20&%20Arch%201/images/The%20Leaning%20Tower%20of%20Pisa_jpg.jpg

Alternatives to Restoration

- In 1993, 600 Mg of lead weights were added to north side of Tower, attached by a removable concrete ring placed around base of Tower
 - Reduced leaning by nearly one minute of an arc
 - Reduced moment that pulled on Tower by 10%
- Load was increased in 1995 to 900 Mg while engineers attempted to replace lead weights with ground anchors



Alternatives to Restoration



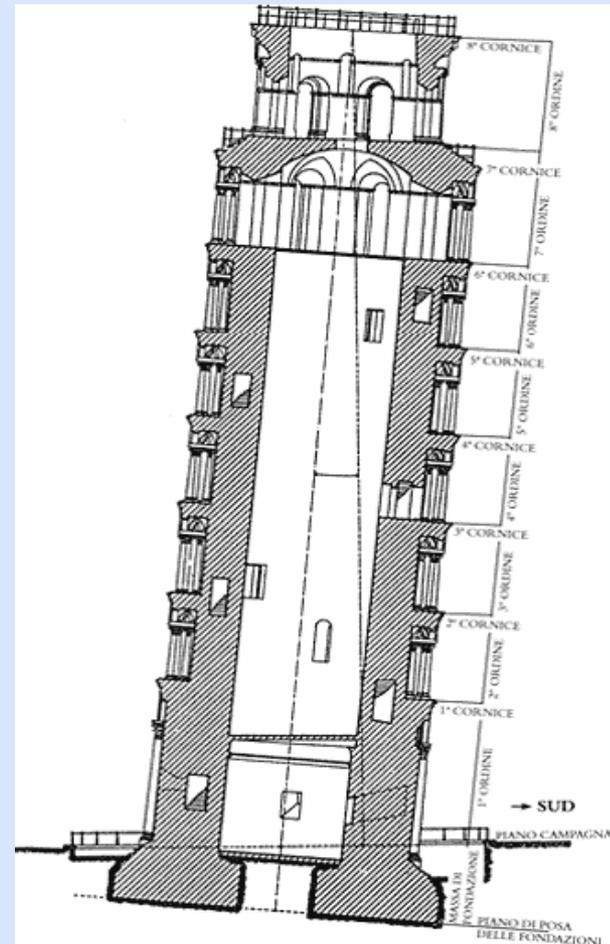
- One unique idea was to drill 10,000 holes in Tower to significantly reduce its weight
- Replica was to be placed next to Tower leaning in opposite direction to hold original tower in place

<http://news.bbc.co.uk/2/hi/europe/1391476.stm>

<http://www.stilepisano.it/immagini13/>

Restoration of The Tower

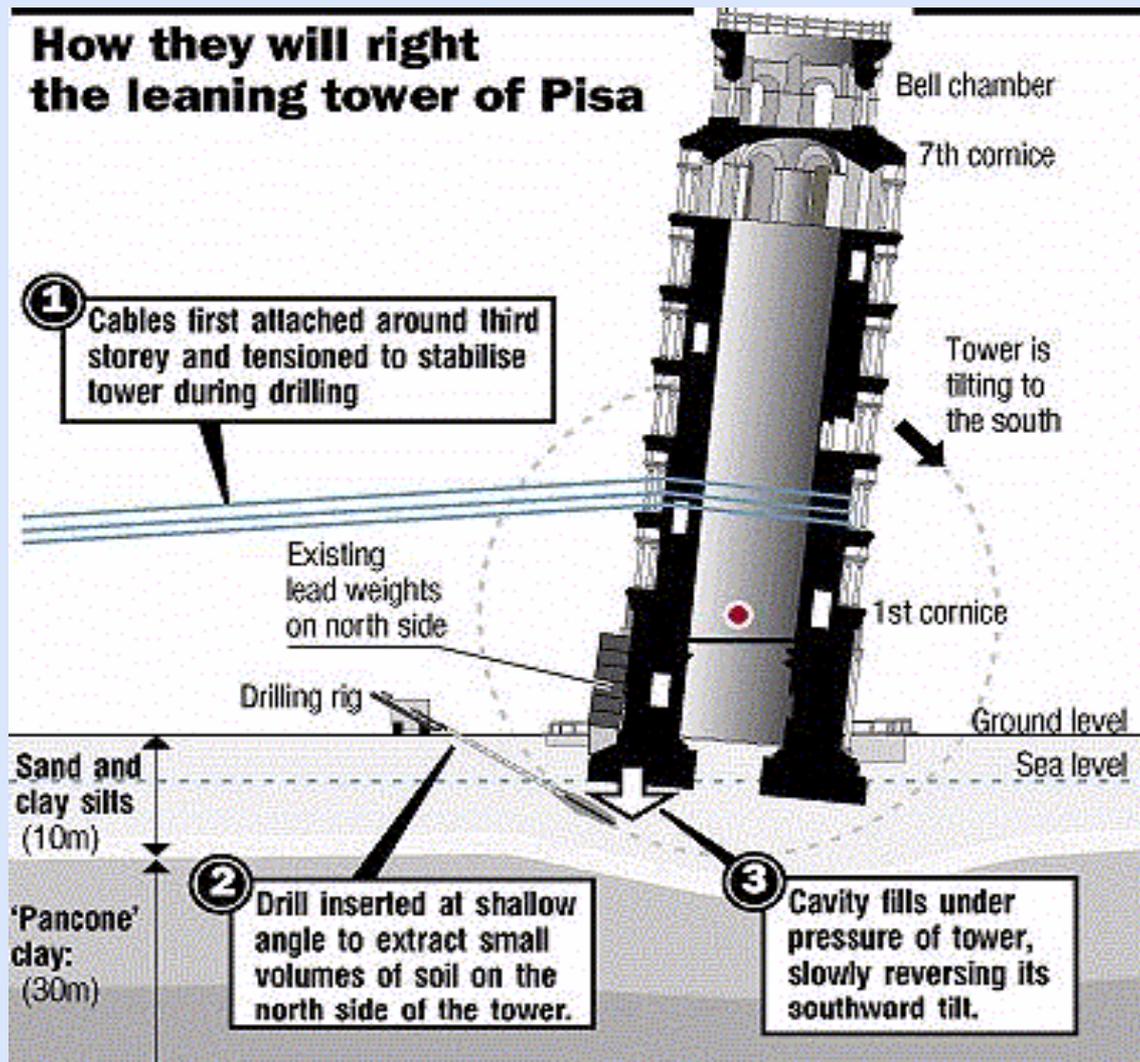
- A new restoration idea was presented in the 1990s
 - Known as soil extraction, or soil subsidence
 - Its goal was to excavate earth from beneath Tower's foundation on its northern side so that Tower would tilt back toward perpendicular
- Idea was put into motion after various tests on Tower itself and on soil underneath its foundation



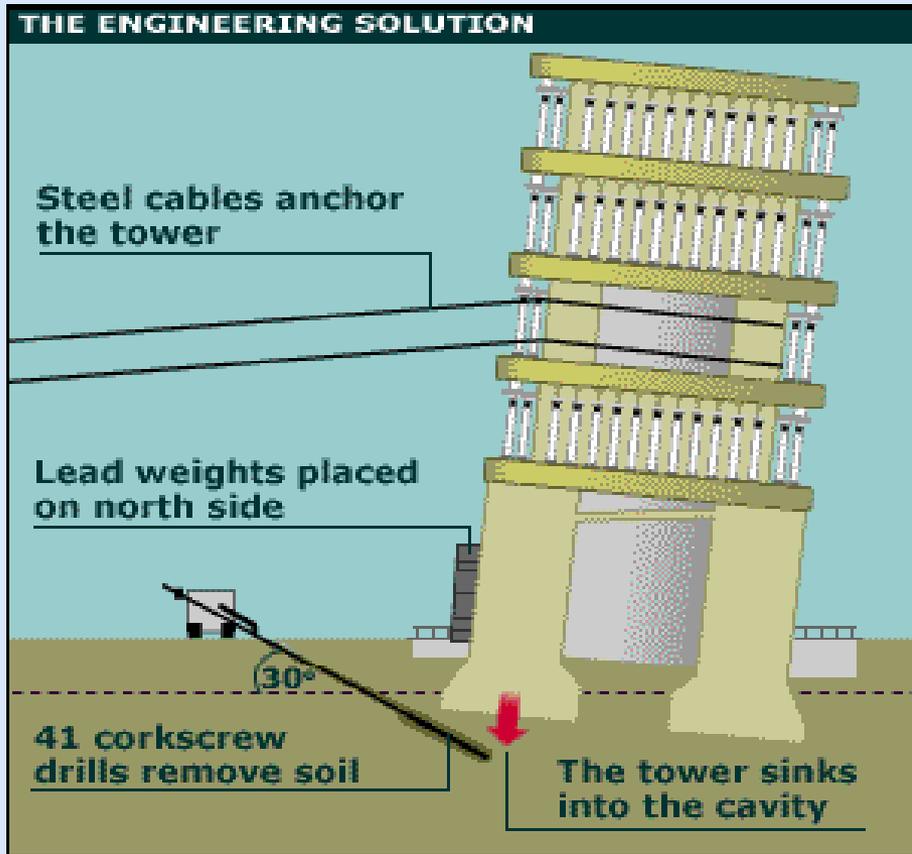
<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

http://torre.duomo.pisa.it/towersposters/english_version/2/sezione.gif

How they will right the leaning tower of Pisa



Restoration of The Tower

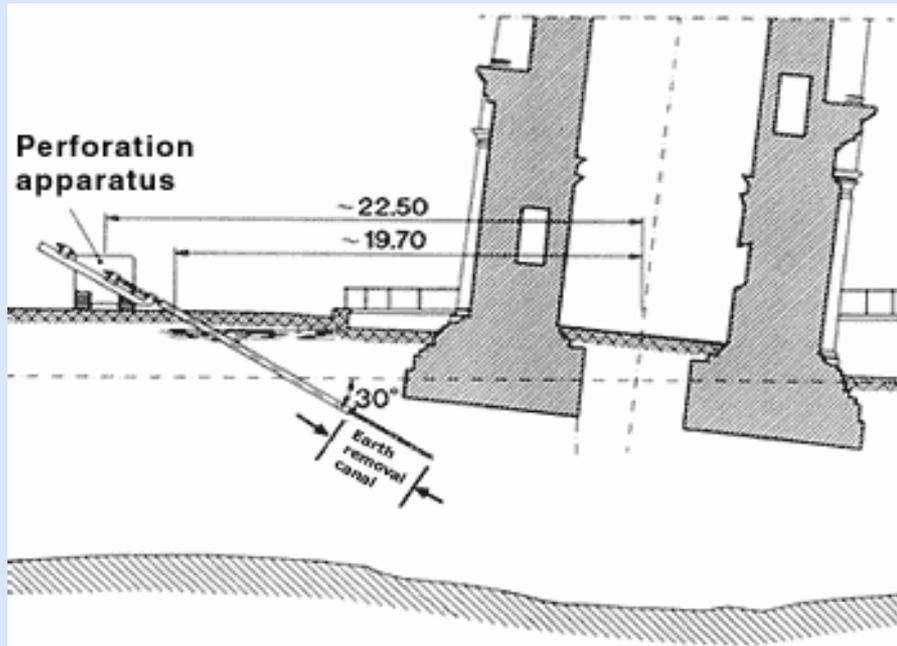


- Temporary cables attached to 3rd level of Tower
 - Would support Tower if anything went wrong during soil extraction
- Lead weights were attached to ends of cables to ensure that Tower would remain steady

<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

http://news.bbc.co.uk/olmedia/790000/images/_793432_pisa2_300gra.gif

Restoration of The Tower



- First soil extraction occurred on February 9, 1999
 - Extracted by means of corkscrew drills
- At first, Tower showed no sign of rotation, but then rotated toward the North

Restoration of The Tower



- Tower had rotated seven seconds of an arc toward the North by February 23, 1999, but then it rotated back toward the South
 - Occurred as a result of strong, cold winds from the North
 - Tower soon began to rotate back toward the North after winds had diminished

Restoration of The Tower



- Soil extraction was stopped after Tower had rotated a total of eighty seconds of an arc by June 1999
- Three of the lead weights were removed in July 1999, and this resulted in a discontinuation of rotation

Restoration of The Tower

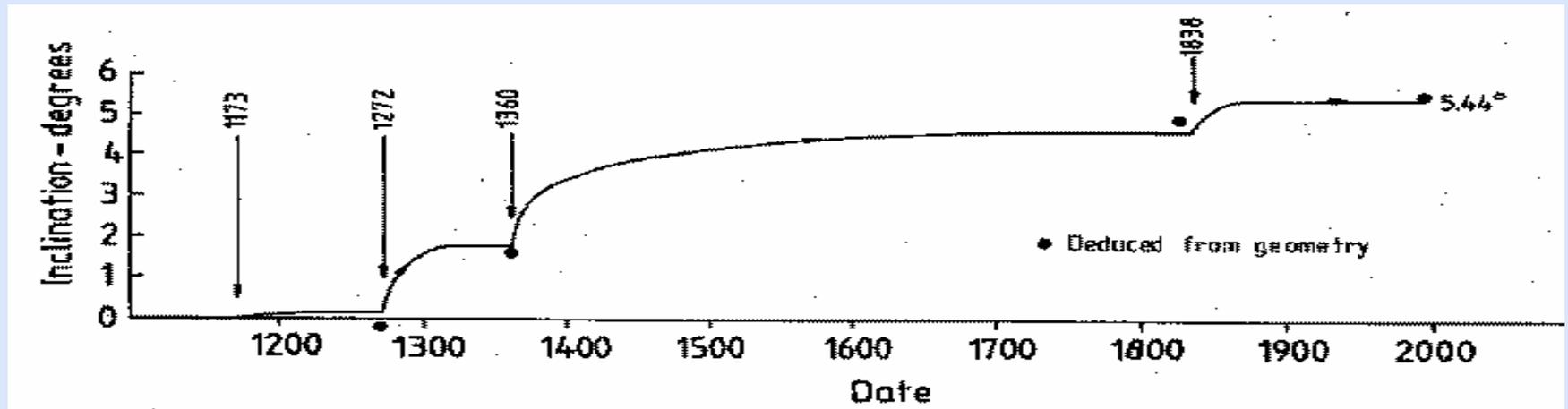


- Main soil extraction began in the year 2000, after preliminary extractions had shown vast improvement
- Tower had a tendency to rotate to the East throughout the process, so soil also had to be extracted from foundation's west side
- Tower continued to move northward, and slowly the lead was removed from the structure

<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

<http://www.endex.com/gf/buildings/ltpisa/ltpgallery/lavori/ltpreud1498gc.jpg?x=52&y=59>

Restoration of The Tower



- Restoration process was finished on June 6, 2001
- Tower had returned to position it was in before 1838
- Restoration process moved Tower 1,830 seconds of an arc

<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

<http://www.rod.beavon.clara.net/pisa.htm>

Problems and Costs of Implementing

- Design process cost the Italian taxpayers \$25 million
- Design process was complicated by decree made by Italian Government that needed to be approved regularly by Italian Parliament
 - Delayed restoration process
 - Work was halted for long periods of time



<http://news.bbc.co.uk/2/hi/europe/1391476.stm>

<http://news.bbc.co.uk/2/hi/europe/793432.stm>

<http://www.answers.com/topic/leaning-tower-of-pisa>

Problems and Costs of Implementing

- Restoration process was halted when harsh winds caused Tower to rotate toward the South
- Throughout restoration process, Tower had to be closed to tourists
 - Tourists had been able to pay a fee so they could climb Tower
 - Now, Pisa would lose revenue (about \$2 million/yr)



Problems and Costs of Implementing



- Stabilization of Leaning Tower provided difficulties of its own
 - Tower was originally constructed on weak, compressible soil, which increased instability of Tower
 - Ground on south side of Tower had to be treated with delicacy because any disturbance could result in falling of Tower
 - Original design of Tower had to be respected throughout the process to conserve monument's character

<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

<http://www.endex.com/gf/buildings/ltpisa/ltpgallery/22nov02/ltp3064rx.jpg>

Other Items of Interest



- There are 294 stairs to top of Tower
- Leaning Tower weighs about 14,700 metric tons
- About three million people visit Tower annually
- There are seven bells on Tower, largest of which weighs 3.5 tons

<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

<http://www.endex.com/gf/buildings/ltpisa/ltpinfo.htm>

<http://www.endex.com/gf/buildings/ltpisa/ltpgallery/22nov02/ltp3096rx.jpg>

Conclusion



- Restoration process was very difficult to execute
 - Soil on which Tower was built was very unstable
 - Tower's original design had to be maintained
- Soil extraction was a successful process that saved Tower from collapse

The Future of The Leaning Tower



- Speculation on whether restoration process will be beneficial in future
 - Professor Burland, who oversaw the restoration process, believes Tower may stay in its current condition
 - Professor Burland speculates that Tower may begin rotating again, and in 300 years, Tower will be where it was in 1990s
- Leaning Tower was reopened to public on December 15, 2001

<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>

http://www.funniestpictures.net.au/userimages/user1680_1165895778.JPG

Works Cited

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