

Group 3: Michal Bartusiewicz, Steve Cullen, Dong-Hyun Chung, Kate Horlocker, Na Ning, and Bin Tong

The Leaning Tower of Pisa – Task 1

I. Introduction to the Leaning Tower of Pisa

- A. Construction of the Tower began in 1173 under the supervision of architect Bonnano Pisano. (<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)
 - 1. The bell tower was built as manifestation of the city's pride.
 - 2. The Tower was meant to reflect the rich city of Pisa.
- B. Work on the Tower ceased in 1178 for reasons unknown, but studies have shown that the soil on which the Tower was build would not be able to withstand more construction at that time.
- C. Construction began again, but this time, it ceased in 1278.
 - 1. The soil underneath the Tower was very unstable.
 - 2. Had the Tower been completed at this time, it would have collapsed because of the stress on the soil.
- D. During the actual construction of the Tower in the 1100's, the Tower originally leaned to the north (<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)
 - 1. Masonry blocks were placed on each level to correct the lean of the axis.
 - 2. By the end of its construction, the Tower leaned significantly to the South.
- E. The Tower was finally completed in 1370 and stands 53 meters above the ground.
- F. From early 1990 until December 2001, the Leaning Tower of Pisa was closed to the public because of safety issues.
 - 1. Italian engineers implemented a complex \$25 million rescue plan in order to stabilize the Tower.
 - 2. Although the tower looks as if it might collapse at any moment, in reality, it is more stable now than at any time in the past few centuries.

II. Alternatives of Restoration

- A. In 1838, an architect by the name of Alessendro della Gherardesca constructed a walkway around the base of the Tower.
 - 1. During construction, water filled the walkway area after the excavation extended below the water table.
 - 2. This plan increased the tilt of the Tower by over one quarter of a degree.
 - 3. Gherardesco placed 0.7 m thick ring of concrete around the walkway to help stabilize the Tower, but his excavation nearly caused its downfall.
- B. In 1934, engineers used grout injection to stabilize the foundation of the Tower. (<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)
 - 1. This process led to a displacement of the Tower.
 - 2. The tip of the tower tilted 10 mm more to the South

- C. In 1993, 600 Mg of lead weights were added to the north side of the Tower, attached by a removable concrete ring placed around the base of the Tower. (<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)
 - 1. This process reduced the leaning by nearly one minute of an arc, and it reduced the moment that pulled on the Tower by ten percent.
 - 2. The load was increased in 1995 to 900 Mg while the engineers attempted to replace the lead weights with ground anchors.
- D. One unique idea was to drill ten thousand holes in the tower to significantly reduce the weight of the Tower, and a replica was to be placed next to the tower leaning in the opposite direction to hold the original tower in place. (<http://news.bbc.co.uk/2/hi/europe/1391476.stm>)
- E. Many alternatives were available, but most of them harmed the foundation of the Tower or didn't preserve its original design.
 - 1. In 1996, a new idea was presented that would eliminate both of these problems
 - 2. Soil extraction became the leading restoration process that was considered, and it soon became the restoration process that would be used.

III. The Restoration of The Leaning Tower of Pisa

- A. A new restoration idea was presented in the 1990s. (<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)
 - 1. This idea was known as soil extraction, or soil subsidence.
 - 2. Its goal was to excavate the earth from beneath the Tower's foundation on its northern side so that the Tower would tilt back toward the perpendicular.
- B. The idea was put into motion after various tests on the Tower itself and on the soil underneath its foundation.
- C. Temporary cables were attached to the third level of the Tower.
 - 1. Cables were attached to support the Tower if anything went wrong during the soil extraction.
 - 2. Lead weights were attached to the ends of the cables to ensure that the Tower would remain steady.
- D. The first soil extraction occurred on February 9, 1999.
 - 1. The soil was extracted by means of corkscrew drills.
 - 2. At first, the Tower showed no sign of rotation, but then it began to rotate toward the North.
- E. The Tower had rotated seven seconds of an arc toward the North by February 23, 1999, but then it began to rotate back toward the South.
 - 1. Engineers found that the rotation to the South occurred as a result of strong, cold winds from the North.
 - 2. The Tower soon began to rotate back toward the North after the winds had diminished.
- F. The soil extraction was stopped after the Tower had rotated a total of eighty seconds of an arc by June 1999.

- G. Three of the lead weights were removed in July 1999, and this resulted in a discontinuation of rotation.
- H. The main soil extraction began in the year 2000, after the preliminary extractions had showed vast improvement.
 - 1. The Tower had a tendency to rotate to the East throughout the process, so soil also had to be extracted from the foundation's west side.
 - 2. The Tower continued to move northward, and slowly the lead was removed from the structure.
- I. The concrete ring that was placed around the Tower in 1838 was attached to the Tower itself to increase the stability of the Tower's foundation.
- J. The restoration process was finished on June 6, 2001.
 - 1. The Tower had returned to the position it was in before 1838.
 - 2. The restoration process moved the Tower 1,830 seconds of an arc.

IV. Problems and Costs of Implementing

- A. The design process that was used cost the Italian taxpayers twenty-five million dollars. (<http://news.bbc.co.uk/2/hi/europe/1391476.stm>)
- B. The design process was complicated by a decree made by the Italian Government that needed to be approved regularly by the Italian Parliament. (<http://news.bbc.co.uk/2/hi/europe/793432.stm>)
 - 1. This delayed the design process.
 - 2. Work was halted for long periods of time.
- C. As stated previously, the restoration process was halted when harsh winds caused the Tower to rotate toward the South.
- D. Stabilization of the Leaning Tower provided difficulties of its own. (<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)
 - 1. The Tower was originally constructed on weak, compressible soil, which increased the instability of the Tower.
 - 2. The ground on the south side of the Tower had to be treated with delicacy because any disturbance could result in the falling of the Tower.
 - 3. The original design of the Tower had to be respected throughout the process to conserve the monument's character.
- E. Throughout the restoration process, the Tower had to be closed to tourists.
 - 1. Tourists had been able to pay a fee so they could climb the tower.
 - 2. Now, Pisa would lose this revenue (about two million dollars per year).

V. Other Items of Interest

- A. There are two hundred and ninety-four stairs to the top of the Tower. (<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)
- B. The Leaning Tower weights about 14,700 metric tons.
- C. About three million people visit the Tower annually.
- D. There are seven bells on the tower, the largest of which weighs three and a half tons (<http://www.endex.com/gf/buildings/ltpisa/ltpinfo.htm>).

VI. Conclusion

- A. The restoration process was very difficult to execute.
 - 1. The soil on which the Tower was built was very unstable.
 - 2. The Tower's original design had to be maintained.
- B. Soil extraction was a successful process that saved the Tower from collapse.
- C. There is speculation on whether the restoration process will be beneficial in the long-run.
 - 1. Professor Burland, who oversaw the restoration process, believes that the Tower may stay in the condition in which the Tower is in currently.
 - 2. Professor Burland also speculates that the Tower may begin rotating again, and in three hundred years, the Tower will be where it was in the 1990s.
- D. The Tower was reopened to the public on December 15, 2001.
(<http://www.pubs.asce.org/ceonline/ceonline02/0302feat.html>)

General Pictures:



<http://www.pubs.asce.org/ceonline/art/art02/0302feat1.jpg>



<http://archives.cnn.com/2000/TRAVEL/NEWS/06/17/pisa.open.01/italy.pisa.rome.lg.jpg>



Taken by Kate Horlocker



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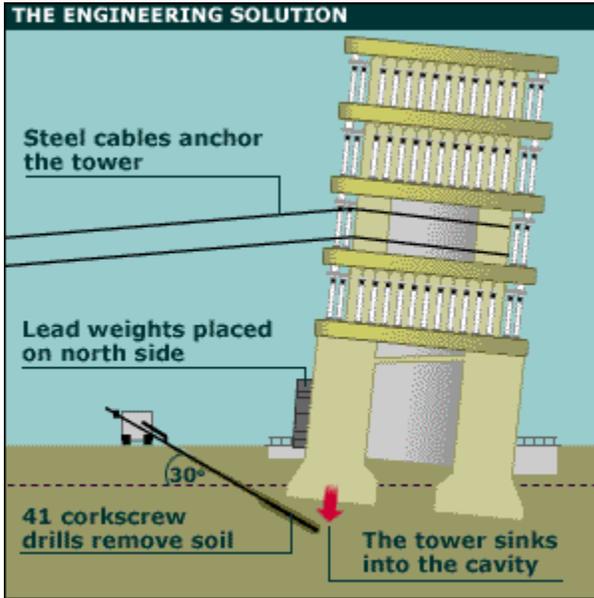


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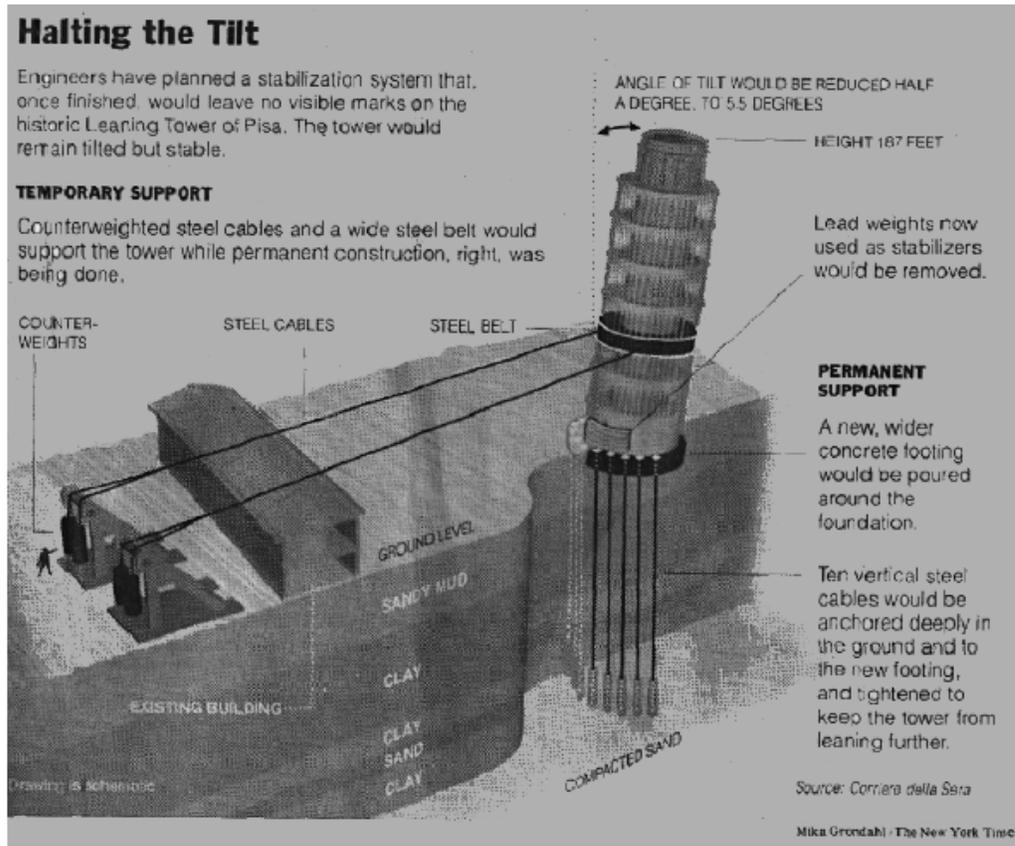


[http://www.stilepisano.it/immagini13/thumbnails/Leaning_tower_Pisa%20\(26\)_jpg.jpg](http://www.stilepisano.it/immagini13/thumbnails/Leaning_tower_Pisa%20(26)_jpg.jpg)

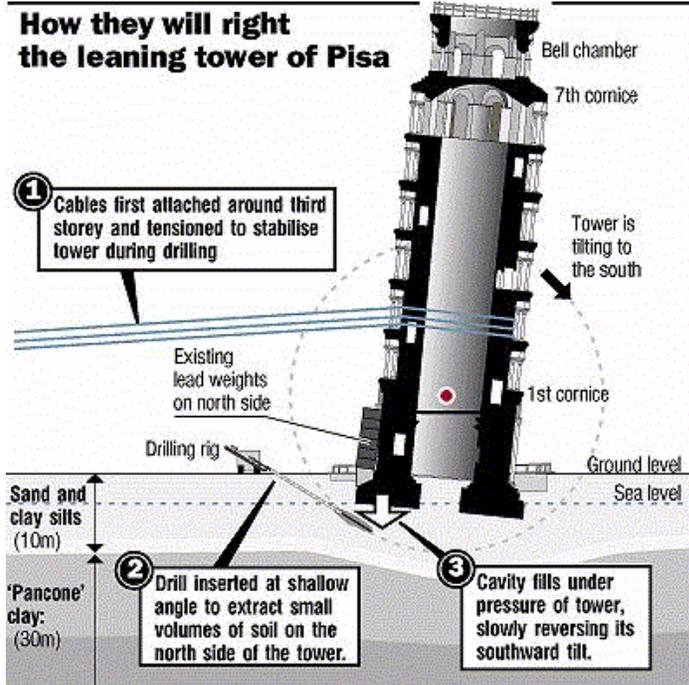
Pictures of Construction/Process of Restoration:



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



<http://www.endex.com/gf/buildings/ltpisa/ltpnews/ltpnyttx.gif?x=69&y=44>

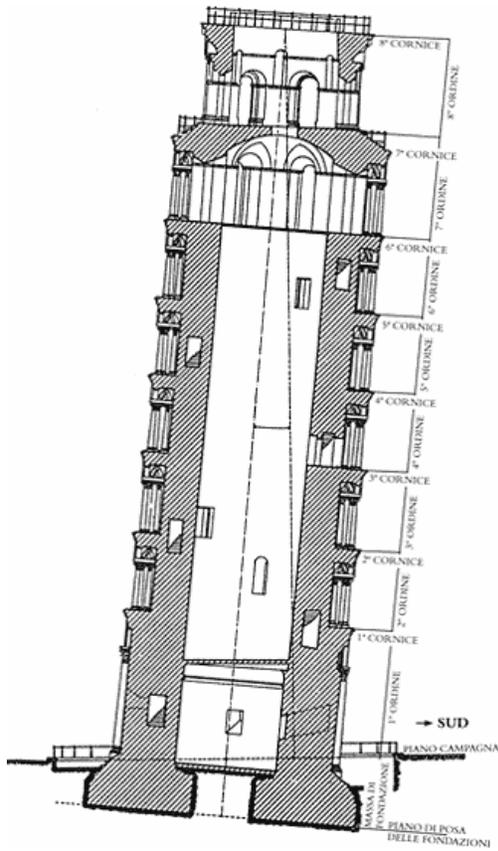


<http://www.endex.com/gf/buildings/ltpisa/ltpgallery/telwpis20.gif?x=89&y=55>

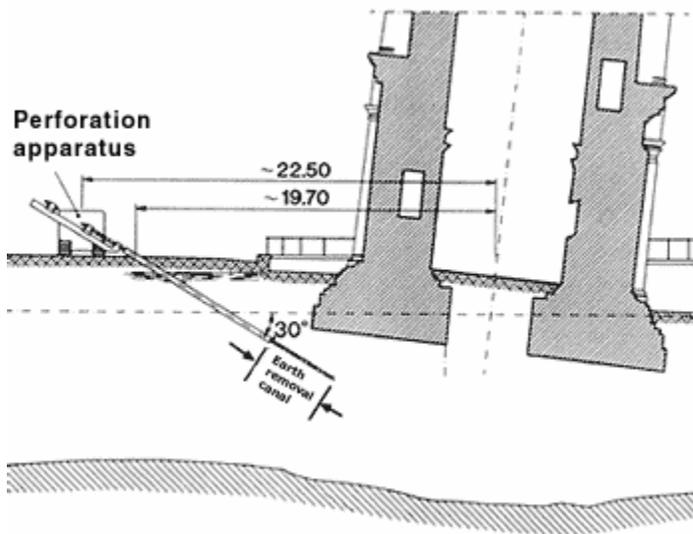


Lead weights:

<http://www.endex.com/gf/buildings/ltpisa/ltpgallery/freepix/pisaa6y.jpg?x=41&y=49>



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



http://torre.duomo.pisa.it/towersposters/english_version/10/perforazioni.gif