



CTU in Prague  
Faculty of Civil Engineering  
Department of Building Structures

# Restoration of foundations

## Leaning Tower of Pisa

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# Description of the object

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- ▶ tower based on clay with seashells and with layers of sand
- ▶ tower height of 56.4 m, weight of 14,453 tons
- ▶ diameter of 14.54 m, 48.6 m circumference
- ▶ 296 steps
- ▶ wall thickness
  - ▶ at the foot 4.09 m, in the top 2.48 m
  - ▶ deviation: in 1272 to 90 cm,  
in 1992 to 447 cm
- ▶ originally inclination to one side after the additional load tower flips to the other side
- ▶ settlement of tower - almost 2 m



# Description of the object





# History of the object

- ▶ construction works started in 1173, shortly after the beginning began to tilt. (setting from 30 to 40 cm, tilt 5cm)
  - ▶ based shallow foundations in soft ground (1 kg / m)
- ▶ attempt to compensate tilt - into the foundations thrown stones and branches
- ▶ the tower, formed up and later began leaning to the other side
- ▶ 1185 three-story height - apparent tilt - construction stopped
- ▶ 1275 built another floor slightly tilted to the other side = change in center of gravity, an attempt to stop further tilt
- ▶ compared to the original plan to build the highest bell tower of its time in 1350 ended the sixth floor of belfry for hanging bells



# History of the object

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- ▶ in 20 century tower top deflection increased to more than 5 meters
- ▶ 1990 Tower closed to the public, conservation work



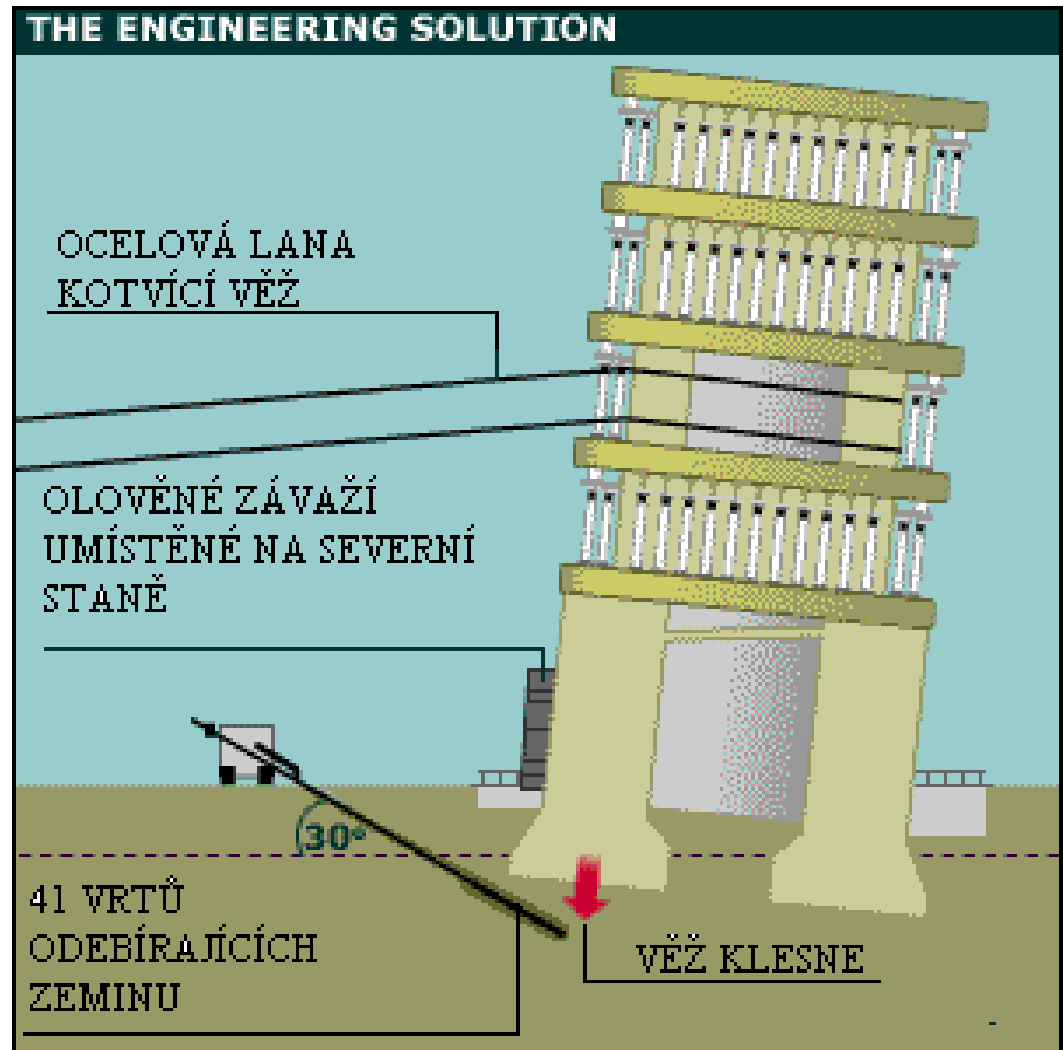
# Analysis of defects

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- ▶ unstable subsoil
- ▶ tower based on low bearing capacity soils (clay with seashells and with layers of sand)

# Restoration of defects

- ▶ designed restoration
  - ▶ 4 cables around the 3rd floor transmit power from the load and the hydraulic piston stabilizes the tower during the drilling





# Restoration of defects

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# Restoration of defects

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- ▶ restoration process
  - ▶ an iron ropes was let into the ground to consolidate the foundations
  - ▶ part of the unstable subsoil under the foundations of the tower was take out
  - ▶ inclination of the tower began to gradually decrease, now is the deviation of the tower only about 3 meters
  
- ▶ prevention of failure
  - ▶ making a detailed geological survey
  - ▶ subsurface drainage of ground (reducing soil moisture)
  - ▶ prevent waterlogging or drying soil at footing bottom
  - ▶ supporting system suit to the way of foundation