Question: what is worth teaching to everyone from Soil Mechanics?
(civil engineering subject)

Answer:

What happens when soil compresses[1]

Part 3

[1] **compress**: to press or squeeze together, to undergo compression (Webster)

Goals of lesson in 3 parts + summary

- describe what happens when soil compresses
- link the description of soil settlement to the quantitative prediction of settlement (this is what civil engineers need to know)

Part 3

- WHEN SOIL COMPRESSES, EFFECTIVE STRESS INCREASES: EFFECTIVE STRESS IS THE STRESS CARRIED BY THE SOIL SKELETON
- WITH EFFECTIVE STRESS I CAN CALCULATE THE MAGNITUDE OF SETTLEMENT

Compression due to (a) loading, (b) pumping: same mechanism or not?

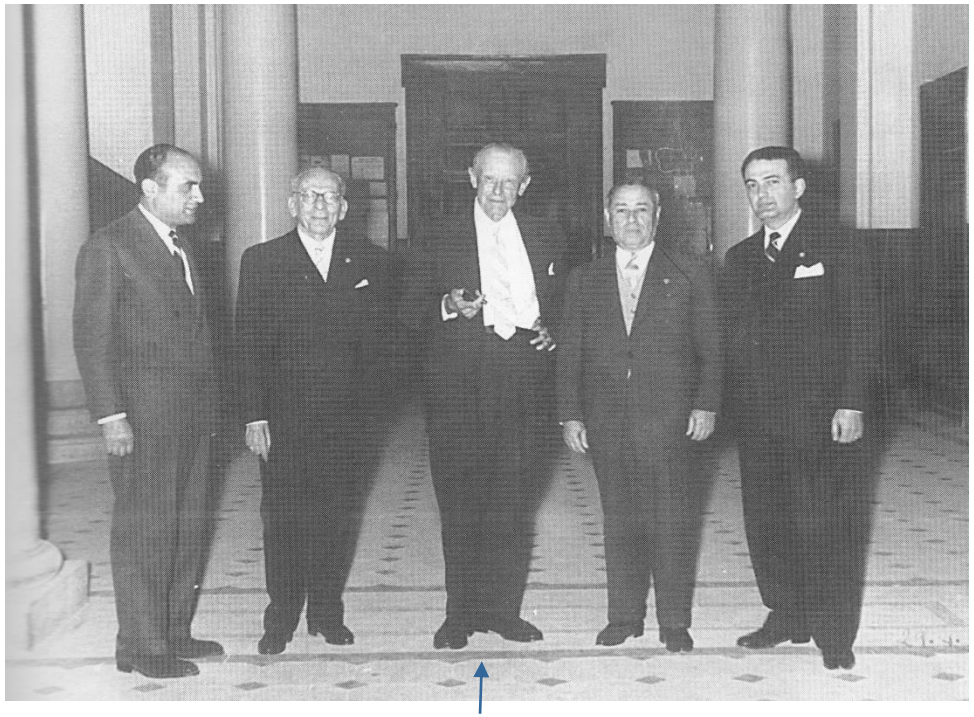
PHENOMENON:	BUILDING CONSTRUCTION	PUMPING
RESULT:	SETTLEMENT	SETTLEMENT
MECHANISM ?	 Loading like squeezing sponge ☑ 	Various ideas related to volume of water ☒

Common mechanism of compression for loading or pumping

SETTLEMENT

One possible vantage point: depends on loads placed on soil

Karl von Terzaghi, 1883-1963: adopts the vantage point of soil skeleton



Terzaghi at National Technical University of Athens in 1958

Soil Mechanics = “offspring” of Mechanics

Terzaghi

application of Mechanics
to a particulate material

relates stresses to deformations

(force) (changes of shape)

for solid materials

BIG IDEA of Soil Mechanics

❶ Terzaghi distinguishes → stress* due to all applied loads, σ

σ = total stress

stress felt by the soil skeleton, σ′

σ′ = effective stress

❷ Discovers their relationship: $\sigma' = \sigma - u$

u = pressure of water in soil pores

* stress = force/area

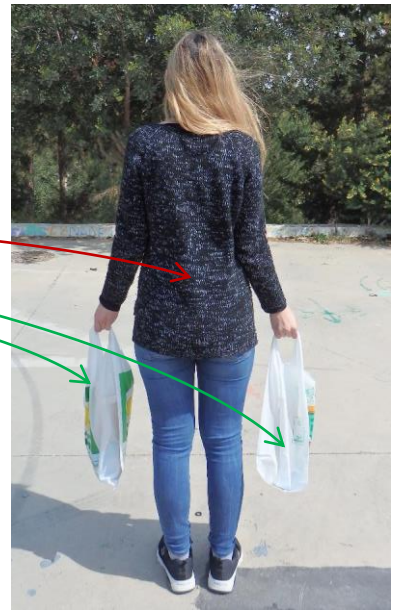
BIG IDEA of Soil Mechanics, continued

$$\sigma' = \sigma - u$$

σ = stress due to soil weight[1] (W_1) + stress due to loads from buildings[2] (W_2)

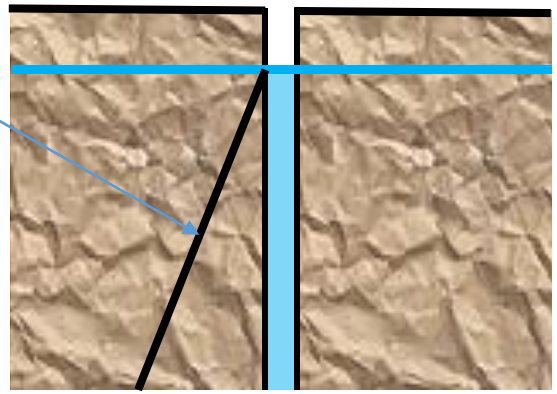
u = water pressure, often hydrostatic

Effective stress σ′ describes soil behavior

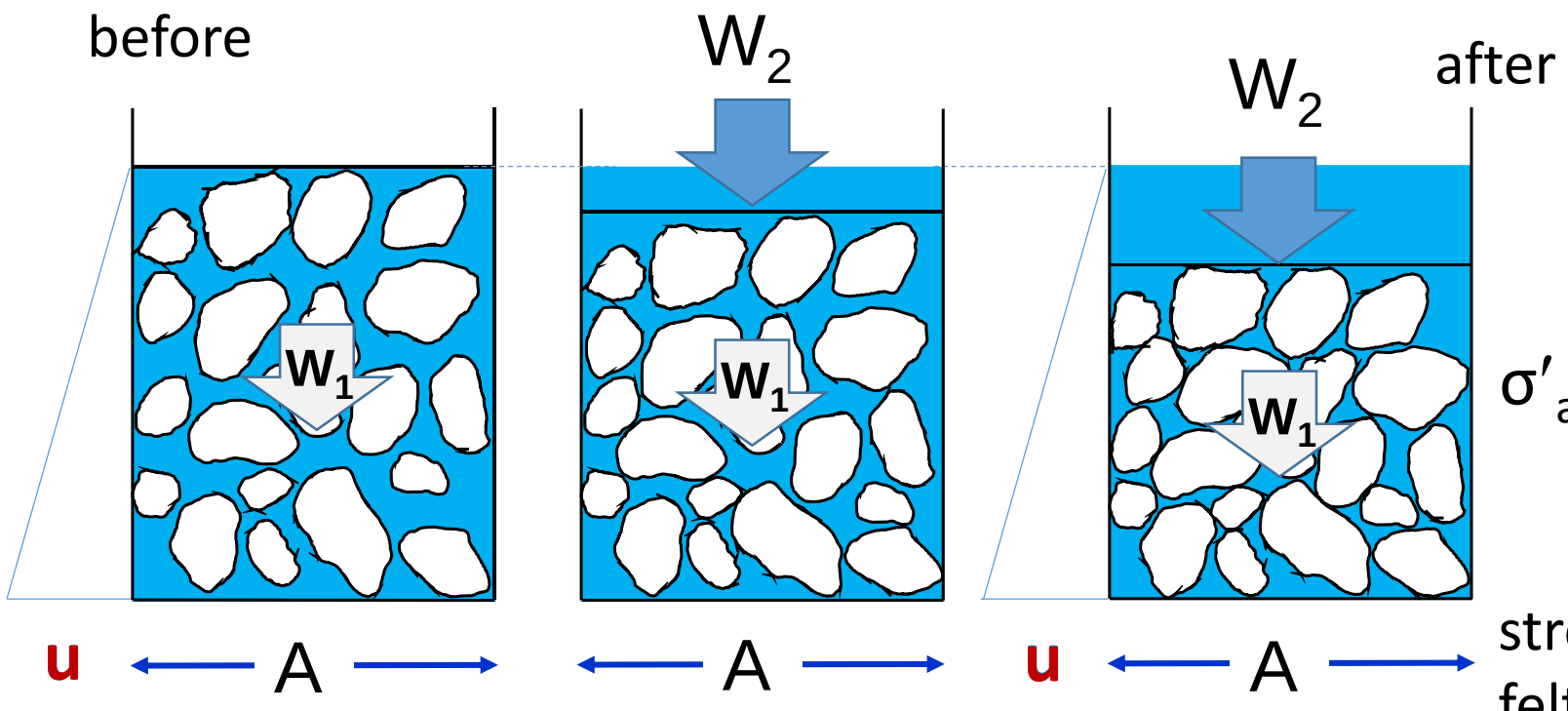


[1] like our body weight, which we always carry

[2] like the extra weight of shopping bags



Construction of building <u>increases load</u> → <u>increases effective stress</u> → soil compresses



$$\sigma'_{bef.} = \sigma_{bef.} - u$$

$$\sigma'_{after} = \sigma_{after} - u$$

$$\sigma'_{after} - \sigma'_{bef.} = \sigma_{after} - \sigma_{bef.} > 0$$

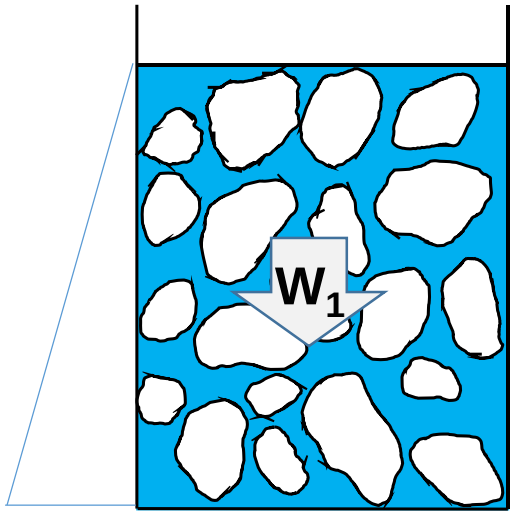
Same water pressure **u** **after excess water escapes**

stress increase felt by soil skeleton, **after excess water leaves**

Stress increase due to building construction

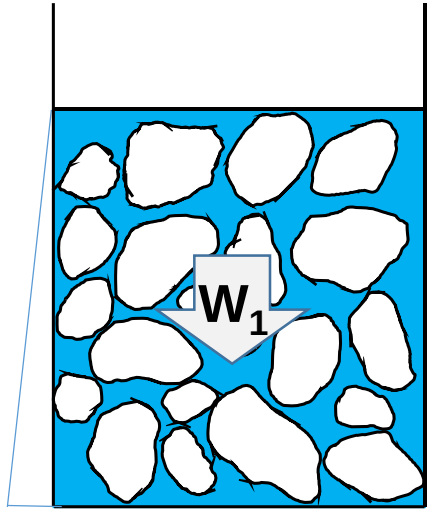
Pumping reduces water pressure → increases effective stress → soil compresses

before



u_{before}

after



u_{after}

Pressure decrease!

pumping

$$\sigma'_{bef.} = \sigma - u_{bef.}$$

$$\sigma'_{after} = \sigma - u_{after}$$

$$\underbrace{\sigma'_{after} - \sigma'_{bef.}}_{\text{increase of effective stress} \rightarrow \text{compression}} = \underbrace{u_{bef.} - u_{after}}_{\text{difference in pore water pressure}} > 0$$

Check understanding & quantitative prediction

How much soils 1 and 2 will compress?
Same or different settlement?

Depends on how "soft" or "hard" is each soil

Soil sample → Test in soil laboratory

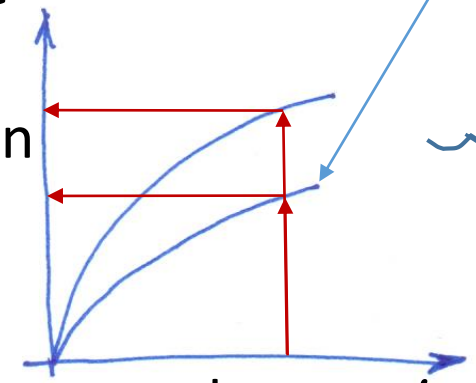
$\sigma_{soil1} = \sigma_{soil2}$

same reduction u due to pumping

$\sigma'_{soil1} = \sigma'_{soil2}$

"harder"
(less compressible)

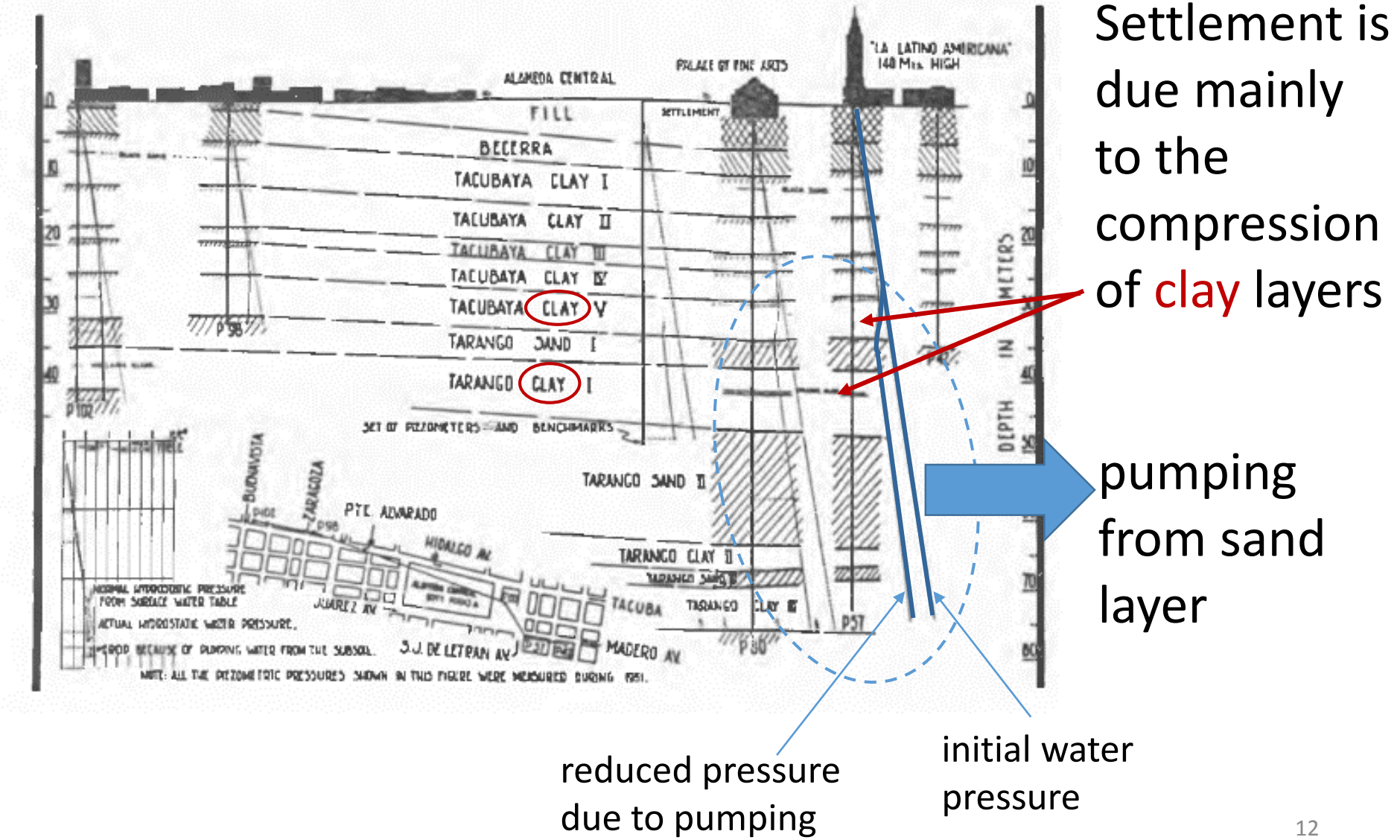
sample height reduction



quantitative prediction of settlement

Venice: mildly compressible soil, 13 centimeters settlement

Mexico City: very compressible soil, 7-10 meters settlement



Settlement is due mainly to the compression of clay layers

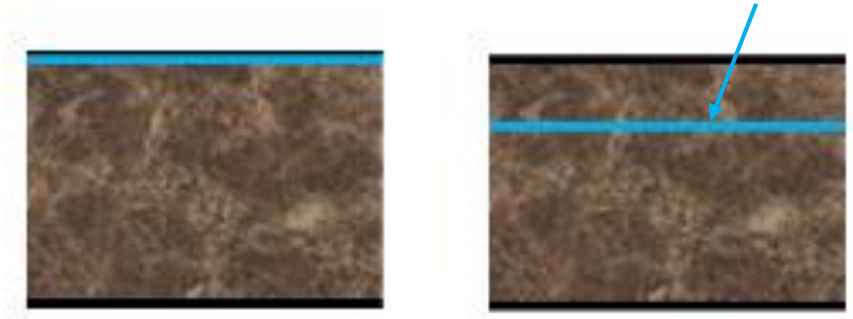
pumping from sand layer

reduced pressure due to pumping

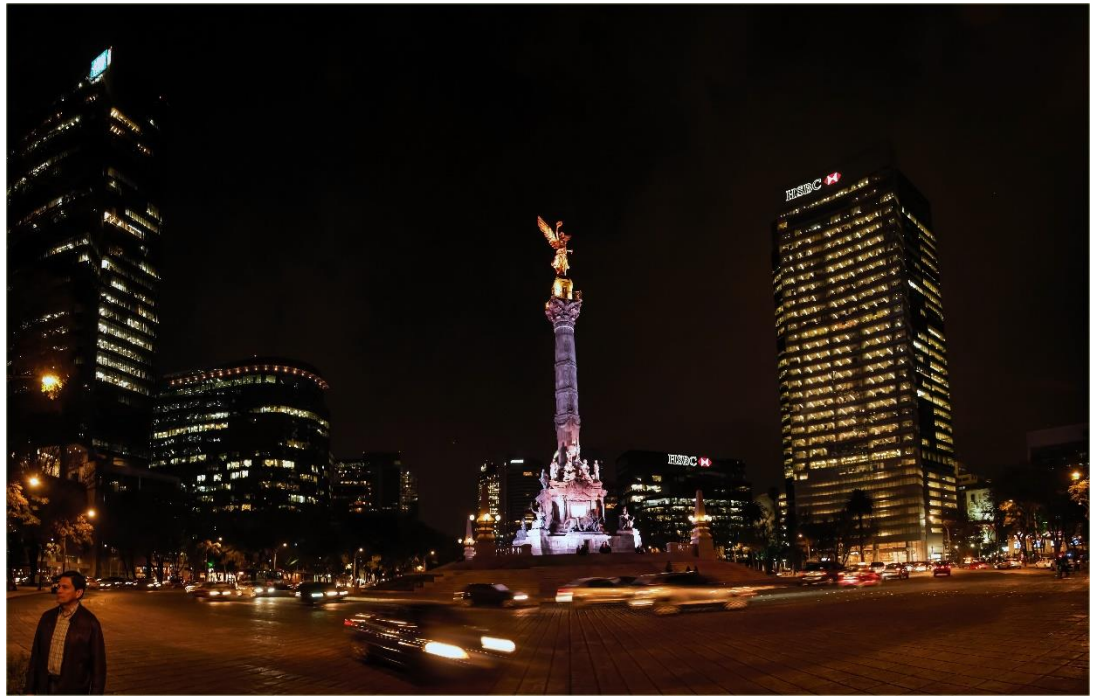
initial water pressure

Holland: “same” phenomenon, same result, different mechanism

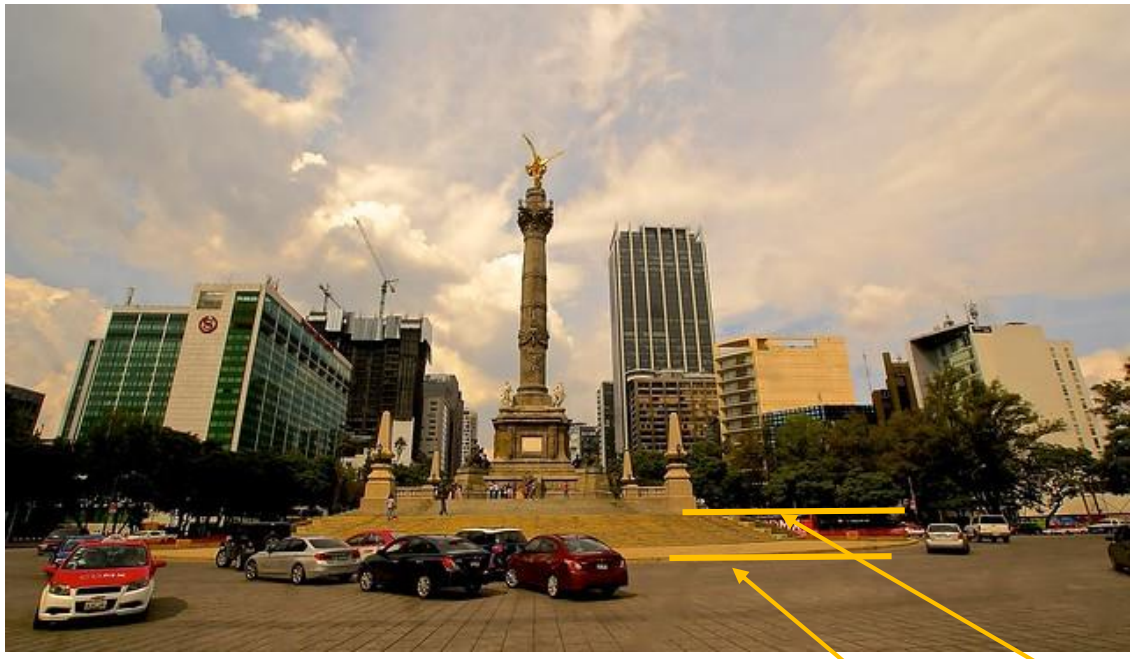
- Phenomenon: pumping (started 1000 years ago!)
- Result: settlement
- Mechanism?
- Pumping to dry up shallow rich organic soil (peat) and make it arable, not from deep layers for water supply
  → water level drops



- Peat gets in contact with air → oxidizes → shrinks → compresses
- Compression → shallow soil wet again → more pumping is needed (windmills employed) → more compression is caused and so on…



"Homework": explain to a friend why we care for the compression of soil in Mexico City, in Holland, in Venice.



- Related to the “homework”: the monument in this picture from Mexico City has very deep foundation (piles), which extend to hard soil that compresses very little. Hence the monument “stays put” (like the borehole casing in Part 2), while the surrounding soil subsides.
- The base of the monument corresponds to the street level in 1910, when the monument was built. It was necessary to add steps to make up for the difference of 2.5 m from the new street level.

Attribution of sources

- Slides 9, 11, 12, 13, 14, 15: photographs from Creative Commons, https://www.flickr.com/creativecommons/
- Slide 10, left photograph: DeJong, J. and Boulanger, R. W., 2000, An introduction to drilling and sampling in geotechnical practice -- 2nd Edition (online), right photograph: Mark Jaksa, 2015, Interactive learning modules for Geotechnical Engineering (online).
- Slide 12: Zeevaert, L., 1953, Pore pressure measurements to investigate the main source of subsurface subsidence in Mexico City, Proceedings of the III International Conference on Soil Mechanics, Zurich, ISSMGE online library.