Lecture 3:

FOUNDATIONS, COLUMNS
Foundations content:
   Introduction
   1. Basic design principles
   2. Classification of foundations
   3. Special design problems of shallow foundations
Strip foundations
Pad foundations
Slab foundations
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   5. Deep foundations
      a. Box and well foundations
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      c. Slurry wall foundations
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Introduction

„The structure stands on soil, which is not reinforced concrete!”
Improper design of the foundations may cause severe damages:
- uneven settlements
- swimming up
- sliding
- loss of stability due to tilting
Foundations transmit generally compression originated by vertical loads, but horizontal actions (wind, earthquake) may produce also tension in anchorage members (piles) of the foundation.
1. Basic design principles

To avoid uneven settlements (compression) stress distribution on foundation-soil contact surface should be near uniform.

Position of the foundation-soil contact surface (foundation depth):
- on load-bearing soil layer
- under freeze depth (at about 80 cm in Hungary)

The mode of foundation depends from:
- physical characteristics of the soil layers
- underground water conditions (max. level, aggressive behaviour)
- neighbour construction
- circumstances of the execution
2. Classification of foundations

According to foundation depth:

Shallow foundations
   Strip foundations
   Pad foundations
   Slab foundations

Deep foundations
   Box foundation
   Well foundation
   Pile foundations
   Slurry walls
3. Special design problems of shallow foundations

\[ \sigma = \frac{F}{A} \leq f_{soil,d} = \alpha f_{soil,u} \quad \alpha = 0.25 \text{ to } 0.75 \]

It is recommended that at least half of the contact area be working
(That is the eccentricity is smaller than \( B/4 \))
Stepping down to foundation level of the neighbouring building (or following the surface slope)

Strips arranged in perpendicular direction

Periodical underpinning of the neighbouring foundation
Danger of *swimming up* by high water table

Q: only self-weight

\[ Q \geq 1.3 \gamma_{\text{water}} m A_{\text{building}} \]

1.3: safety factor
DANGER OF TILTING AT SUPERPOSITION OF SOIL PRESSURE

Bodenspannung in der Tiefe $z$ – soil pressure in depth $z$
Setzungsmulde – settlement "basin,"

\[ \approx 45^\circ \]

\[ \sigma_a \quad \sigma_b \]

\[ s_a \quad s_b \]

\[ Setzungsmulde \]
3.1 Strip foundations

mass concrete

\[ \tan \alpha = \sqrt{\frac{3 f_{soil,d}}{f_{ct,d}}} \]

reinforced concrete

\[ A_s = \frac{\sigma_{soil,d} a^2}{2zf_{yd}} \]

transverse steel

longitudinal reinforcement to distribute uneven loading
Strip foundation along neighbouring building

or: combined footing in perpendicular direction

rc. wall strip footing
3.2 Pad foundations (Block foundation)

Calculation of $x_c$ by successive approximations
Pad foundations of prefabricated rc columns
Partially prefabricated pad foundation:
- prefabricated sleeve
- monolithic rc pad on
- mass concrete block

kiöntő beton – conrete filling
előregyártott kehely – prefab. sleeve
monolit talp – monolithic pad
központosító szerelvény – centering device
szerelőbeton – blinding
Reinforcement system of eccentrically loaded pad foundation

stair bars
Continuous transition from pad foundation to elastic badding
3.3 Slab foundations

- By high ground water level
- Danger of uneven settlements
- To reduce settlement by higher load intensities
  Characteristic settlements under a 10 storey building
  - strip foundation: 4 to 6 cm
  - pad foundation: 2 to 4 cm
  - slab foundation: 1 to 2 cm

Calculation of moment distribution as elastically supported slab

„Thumb rule“:

\[
\text{foundation slab thickness} = \text{number of floors supported} \times 10 \text{ cm}
\]

but min. 25 cm

Foundation slab above freeze depth

„Clasp“ light-weight structural system

in the 1980-ies:
4. Impermeable space limitations

a) White basin (Weisse Wanne)

GOK – ground level
BWS (Bemessungswasserstand) - Design water level

watertight construction
joint in watertight concrete
b) Black basin (Schwarze Wanne)

GOK – ground level
Bei bindigen Böden –
By cohesive soils
Bei nicht bindigen Böden – –
By cohesionsless soils
Abdichtung – water insulation
BWS – design water level
Foundation slab to wall joint by white basin (a, b) and black basin (c, d)

Faundation slab
Protective concrete layer
Insulation
Blinding

Perimeter heat insulation
Watertight concrete
Protective concrete
Sand bad or lean concrete

Back wall
Foundation slab
Protective concrete
Insulation
Blinding
Injection hose applied at dilatation joint
5. Deep foundations

5.1. Box and well foundations

Applied in bridge construction, for oil drilling towers
Well foundations

Bearing capacity: 1000 to 10000 kN

Sinking by excavation

Cutting edge
5.2 Pile foundations

Ways of force transfer between piles and the soil

End-bearing pile  Standing pile  Floating pile  Friction pile  Standing-friction pile  Tension pile

[Diagram showing various types of pile foundations, including end-bearing, standing, floating, friction, and standing-friction piles.]
CONSTRUCTION OF MONOLITHIC BORED PILES

Spiral drilled monolithic rc piles

Franki piles

- Punner
- Concreted during being backdrawn
- Length: max. 16 to 18 m
- Diameter max 60 cm (100 at bottom)
- Capacity: 1000 to 3000 kN
Micro piles (root piles)

Cement mortar – 600 kg/m$^3$ cement - injection into 8 to 25 cm diameter back-drawn steel tube, 4 to 20 m long, 1 piece of 16 to 20 mm diameter steel bar in the axis

Steel tube

Interior injection tube

Closing sack

Widespread use for posterior strengthening of existing foundations

Expanded injection body
5.3 SLURRY WALL FOUNDATIONS

40 to 80 cm thick, up to even 40 m deep underground rc walls, monolithic or prefabricated used for vertical and/or horizontal supporting: foundation walls or retaining walls-

The ditch excavated for the construction of slurry walls is provisory filled with a fluid heavier than the water- bentonite - to resist the pressure of soil and underground water

When the ditch is being filled with concrete, the bentonite is regained for the next use
a) Construction in pilgrim step using moulding tubes
b) Using prefabricated members for jointing
c) Using prefabricated rc wall units

Erdkerne – soil cores
Vor-Nachläuferlamellen – first and 2nd phase wall sections
Abschalrohr – moulding tube
Leitwand – guide wall
Schüttrohr – casting tube
Abpumpen der Stützflüssigkeit – pumping down of supporting fluid
TRENCH WALLS

Trench: the excavated underground space under buildings serving for the construction of the foundation and the underground levels of the building
PILE WALLS

Innenschale - internal shell
HDBV-Säule – jet-grouted column
Spritzbeton – shotcrete
Zwickelinjektion – jetgrouted micropile
SPECIAL MONOLITHIC PILE CONSTRUCTION TECHNOLOGY: SOIL STRENGTHENING BY JET-GROUTING
SOIL STRENGTHENING UNDER EXISTING FOUNDATIONS BY JET-GROUTING

Injektionslanzen – injection lance
Verfestigungskörper – strengthening bodies
ab 2,5 m Anker vorsehen – above 2,5 m back anchorage necessary
NATURAL AND INJECTED GROUND WATER BARRAGE

Naturlicher Grundwasserstauer – natural ground water barrage
Verbauwand – trench wall (slurry wall)
Baugrubensohle – trench bottom
Injections (HDBV) Sohle – jet grouted soil layer barrage
TRENCH LIMITING SLURRY WALL
a) integrated into the structure   b) separated from the structure by sliding joint
WAYS OF INTEGRATION OF THE TRENCH WALL INTO THE STRUCTURE OF THE BUILDING

a) Back anchored slurry wall with natural ground water barrege
b) Like a) with jetgrouted soil layer barage
c) Slurry wall supported provisorily by every second floor slab
d) Back anchored jetgrouted completion of the foundation of the neighbouring building
e) Slurry wall supports by floor slab cornice
f) Slurry wall support by soil embankment
BACK ANCHORES OF SLURRY WALLS

possible sliding plane

Távolságtartó – spacer
Gumiszelep – gummí walve
Befogési szakasz - restrained section
Zárózsák - closing sack
Injektáló cső – injection tube
Védőcső – protecton tube
Pfahl- bzw. Schlitzwand – pile or slurry wall respectively
Leitwand - guide wall
Ausgleichsschicht – equalizing layer
Abdichtungsrücklage – insulation back wall
Telleranker – Plate anchorage
Trenn- und Gleitschichte – Separating and sliding layers

DETAILS OF INTEGRATED TRENCH WALLS
a) White basin  b) Black basin with impeded relative settlement  c) Black basin with unavoidable relative settlement
INTEGRATED TRENCH WALL
BY HIGH DEMANDS ON
SURFACE AND WATERTIGHTNESS

a) Integrated trench wall as white basin

b) Mixed construction method with simultaneous extension upward and downward

Tertier natürlicher Grundwasserstauer – Natural ground water barrage
Abdichtungsrücklage – insulation back wall
Bohrschablone – drilling mould
Bohrpfahlwand mit Zwickeldichtung – Drilled pile wall with wedge insulation
Künstlicher GW-Stauer z.B. Hochdruckbodenvermörtelung – Artificial ground water barrage for example with soil jet-grouting
3.2 COLUMNS
S. Calatrava: Extension of the Milwaukee Art Museum
S. Calatrava: City of Arts and Sciences, Valencia
Calatrava: Saint Exupéry Airport Railway Station, Lyon
Calatrava: Saint Exupéry Airport Railway Station, Lyon
section A-A

6 17 Ø8/120,240 - 1,46

section B-B

7 2x17 Ø8/120,240 - 1,320 to 2,592 variable

315 to 951 variable

BME Department of Mechanics, Materials and Structures
Design of Reinforced Concrete Structures Foundations, columns