Water management in urban areas
Design, Soil & Elaboration

Dr. ir. Frans H.M. van de Ven
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Content

• Introduction
• Accessibility and bearing capacity
• Permeability
• Consolidation
• Filling methods
• Selection of a filling method
• Elaborating on the water assignment
Introduction

- Building site preparation evaluation based on:
  - Development strategy
  - Investment costs
  - Maintenance costs
  - Groundwater management
  - Physical conditions of the site
    - Accessibility and bearing capacity
    - Permeability
    - Consolidation
Accessibility and bearing capacity

Definition

- **Accessibility**
  Possibility to drive or walk on a terrain
  - Supply and processing of construction material
  - Transport of heavy equipment

- **Bearing capacity**
  Capacity to absorb loads
  - Foundation pressure of structures, sewer pipes, etc.
  - Bearing of roads
  - Storage of construction material
Accessibility and bearing capacity

Responsibility

- Municipality
  - Only accessibility is required

- Contractor
  - Total quality of the construction site

- Scientific approach
  - Overall quality and cost evaluation

In practice, benefits and costs have different actors
Accessibility and bearing capacity

Requirements

- Accessibility by motorised traffic
  Dependent on equipment type and engine power
  - Tractor 200 – 300 kN/m²
  - Mobile crane on tyres 2000 kN/m²
  - Mobile crane on rails with wooden sleepers 2000 – 5000 kN/m²

- Storage of materials
  Dependent on accessibility of the site, the kind of material and the need to keep the material clean
  - Near the construction roads
  - Bricks, sand, cement 400 kN/m²
  - Proper cover

- Earth foundation of roads
  - Consolidation
  - Drainage
Accessibility and bearing capacity

Bearing capacity

Dependent on degree of saturation and organic content

<table>
<thead>
<tr>
<th>Type of soil</th>
<th>Wet</th>
<th>Dry</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slurry-sand</td>
<td>200-600 kN/m²</td>
<td>400kN/m²</td>
<td>Dependent of the density (compaction)</td>
</tr>
<tr>
<td>Sandy clay (mature)</td>
<td>50 kN/m²</td>
<td>400kN/m²</td>
<td></td>
</tr>
<tr>
<td>Sandy clay (immature)</td>
<td>50 kN/m²</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>
Permeability

- Ability to transfer water through the soil
- Strong influence on building site preparation phase
- Can decrease drastically during the construction phase
- Requires extra attention at slurry filled sites
Consolidation

- Subsidence caused by increased loads
  - Raising of the terrain
  - Lowering of the groundwater
  - Enhancing soil characteristics (‘grondverbetering’)
- Development of the subsidence (Terzaghi)
  - Consolidation is a slow process (> 30 years)
  - Residual subsidence has to be accepted (± 0.1 m)
- Consolidation can be enhanced by vertical drainage
  (very costly)
Filling methods

Variety’s

- Integral raise
  - Complete raise of the site with > 0.7 m sand

- Excavation method
  - Filling of sand below pavement and crawlspace

- Other methods
  - Partial filling
  - Filling with EPS
Filling methods

Integral raise

- Sand layer on the entire site
- > 0.5 m sand realises sufficient bearing capacity
- Due to tracks > 0.7 m is applied
- Extra raise to maintain sufficient freeboard and drainage depth
- Minimal soil and sand movement (soil balance)
Filling methods

Excavation method (cunettenmethode)

- Soil is excavated out of the road profile and crawlspaces
- Sewer trenches and ditches often filled as well
- Raising of new ground level depends on freeboard
- No consensus on thickness and quality of the fill

<table>
<thead>
<tr>
<th></th>
<th>Sandy soils</th>
<th>Clay on firm Underground</th>
<th>Clay on weak Underground</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major roads</td>
<td>0.50</td>
<td>0.60</td>
<td>&gt; 1.00</td>
</tr>
<tr>
<td>Residential streets</td>
<td>0.30</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>Parking lots</td>
<td>0.20</td>
<td>0.40</td>
<td>0.60</td>
</tr>
<tr>
<td>Bicycle- and pedestrian paths</td>
<td>0.15</td>
<td>0.20</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Filling methods

Excavation method (cunettenmethode)

Tertiary roads

- Excavation method (cunettenmethode)
- Tertiary roads
- Secondary roads
- Sewer trenches in sand
- Sewer trenches in clay
- Sewer trenches in peat

- Filling methods
| 14.0 Water management in urban areas – Design, Soil & Elaboration | 14 | 33 |
Filling methods

Other methods

• Combinations of integral raising and excavating based on soil characteristics

• Filling with other materials
  - EPS
Selection of a method

Evaluation aspects

- Development strategy
- Use of sand and topsoil
- Initial conditions
- Construction requirements
- Preparation for habitation
- Maintenance
- Environmental aspects

Multi-criteria analysis
Selection of a method

Direct costs

- Percentage of pavement
- Percentage of open water
- Percentage of vegetation (concentrated in lots)
Selection of a method

Indirect costs

- Integral raise
  - Interest loss over the invested capital for building site preparation
  - Interest loss over the acquisition cost of the entire building site
  - Maintenance due to extra subsidence

- Excavation method
  - Limited production during rain
  - Extra transport facilities (steel plates)
  - Extra construction costs of cables and pipes
  - Extra costs of drainage system
  - Maintenance due to unequal subsidence
## Selection of a method

### Summary

<table>
<thead>
<tr>
<th></th>
<th>Integral fill</th>
<th>Cunette method</th>
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</thead>
<tbody>
<tr>
<td>Planning</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Sand consumption</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Subsidence</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Preparation for construction, earthworks</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Preparation for construction, other work</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Construction of houses</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Preparation for habitation</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Loss of interests</td>
<td>-</td>
<td>+</td>
</tr>
<tr>
<td>Saving existing vegetation</td>
<td>-</td>
<td>+/-</td>
</tr>
</tbody>
</table>
Elaborating on the water assignment

- Step 1: Surface water
- Step 2: Water quality
- Step 3: Groundwater
1.d. Determine required storage

Storage
1.d. Determine required storage
Hydrological model (sobek)
3.b. Type of drainage system

Public

Road-excavation drainage

Pavement

Sand

Drain in trench

Discharge drain

Canal
3.b. Type of drainage system

Public
3.b. Type of drainage system
3.b. Type of drainage system

Private
3.c. Lay-out of system
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3.c. Lay-out of system

Maintenance
3.d. Type of drainage tubes

Threats

• During construction

• Maintenance during habitation
3.d. Type of drainage tubes

Reducing risks

- Drains in coarse aggregate profile
- Soil characteristics enhancement with coarse aggregate
- Stiff PE drains instead of flexible PVC drains

Computation according to the top of the profile!
3.d. Type of drainage tubes

Dimensioning of the drains

1. Available pipe diameters
2. Minimum diameter (>50 mm)
3. Hydraulic capacity

- Flexible corrugated PVC drains

  Maximum area to be drained (Dekker and Ven)

  \[ A = l \cdot L = 2.27 \cdot 10^7 q_d^{-1} d_e^3 \left( \frac{h}{L} \right)^{2/3} \]

  - \( l \) drain distance [m]
  - \( L \) drain length [m]
  - \( q_d \) design discharge [m/d]
  - \( h \) available pressure head [m]
  - \( d_e \) effective diameter [m] = 1.04 \( D_i \) – 0.008
  - \( D_i \) inside diameter

- PE drains of IT sewer

  Energy losses (Colebrook)