Dynamic Soil-Structure Interaction

With three case studies:

- Silo Building Zürich (118 Meter)
- Azadi Hotel Tehran (86 Meter)
- MIT Green Building (83 Meter)

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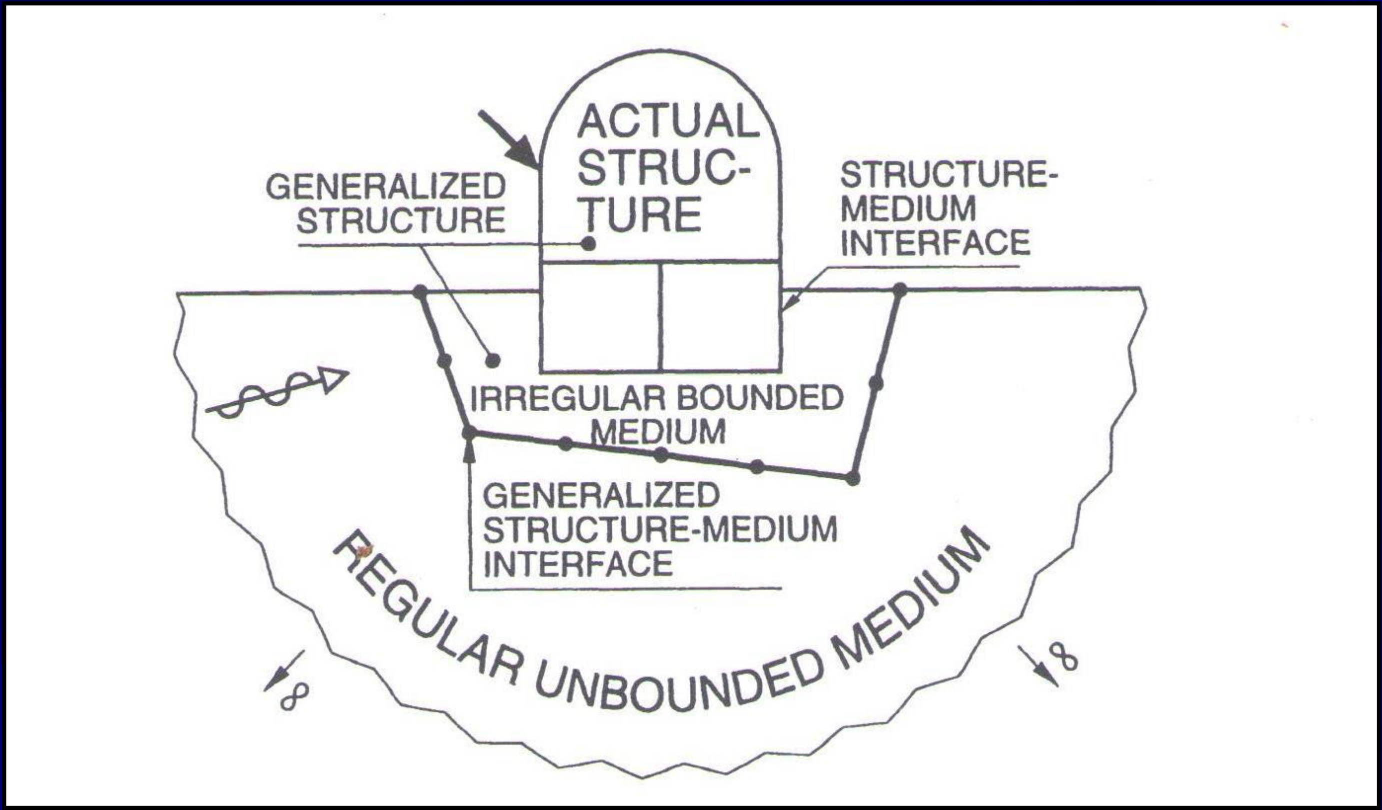
27th September 2015



Problem definition of dynamic unbounded medium-structure-interaction analysis

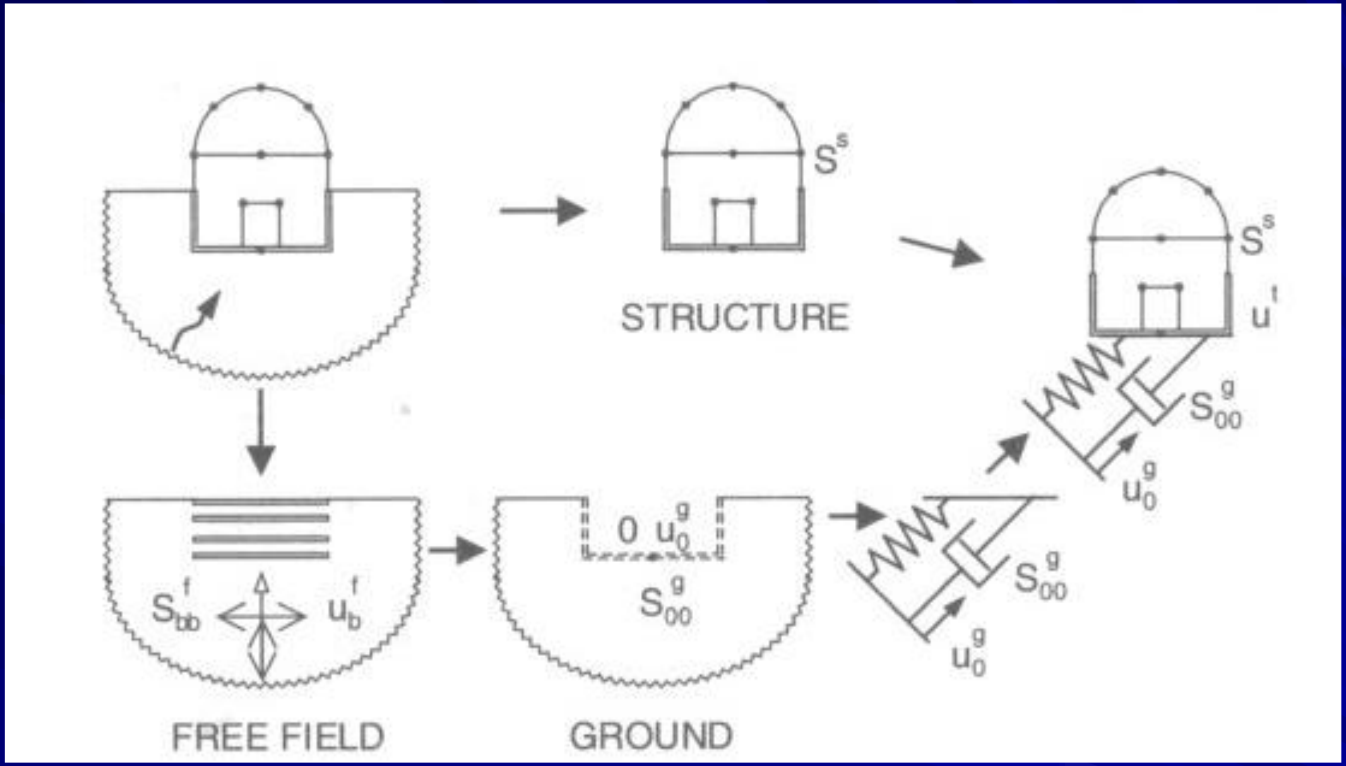
Wolf J. P., Ch. Song: Finite-Element Modelling of Unbounded Media, 1995

Case Studies

Silo Zürich 118 Meter

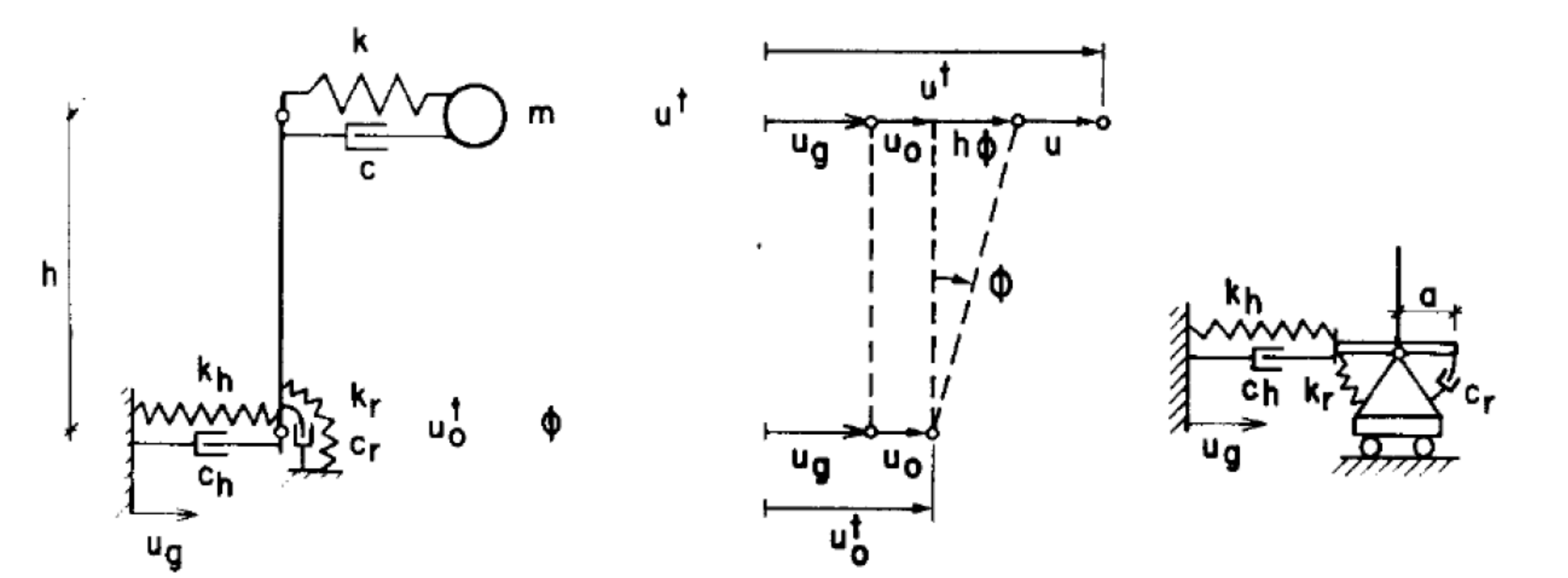
Azadi Hotel Tehran 86 Meter

MIT Green Building 83 Meter



Substructure method: Physical interpretation of basic equations of motion in total displacements with effective foundation input motion

Wolf J. P.: Dynamic Soil-Structure Interaction, 1985



Model with one dynamic degree of freedom

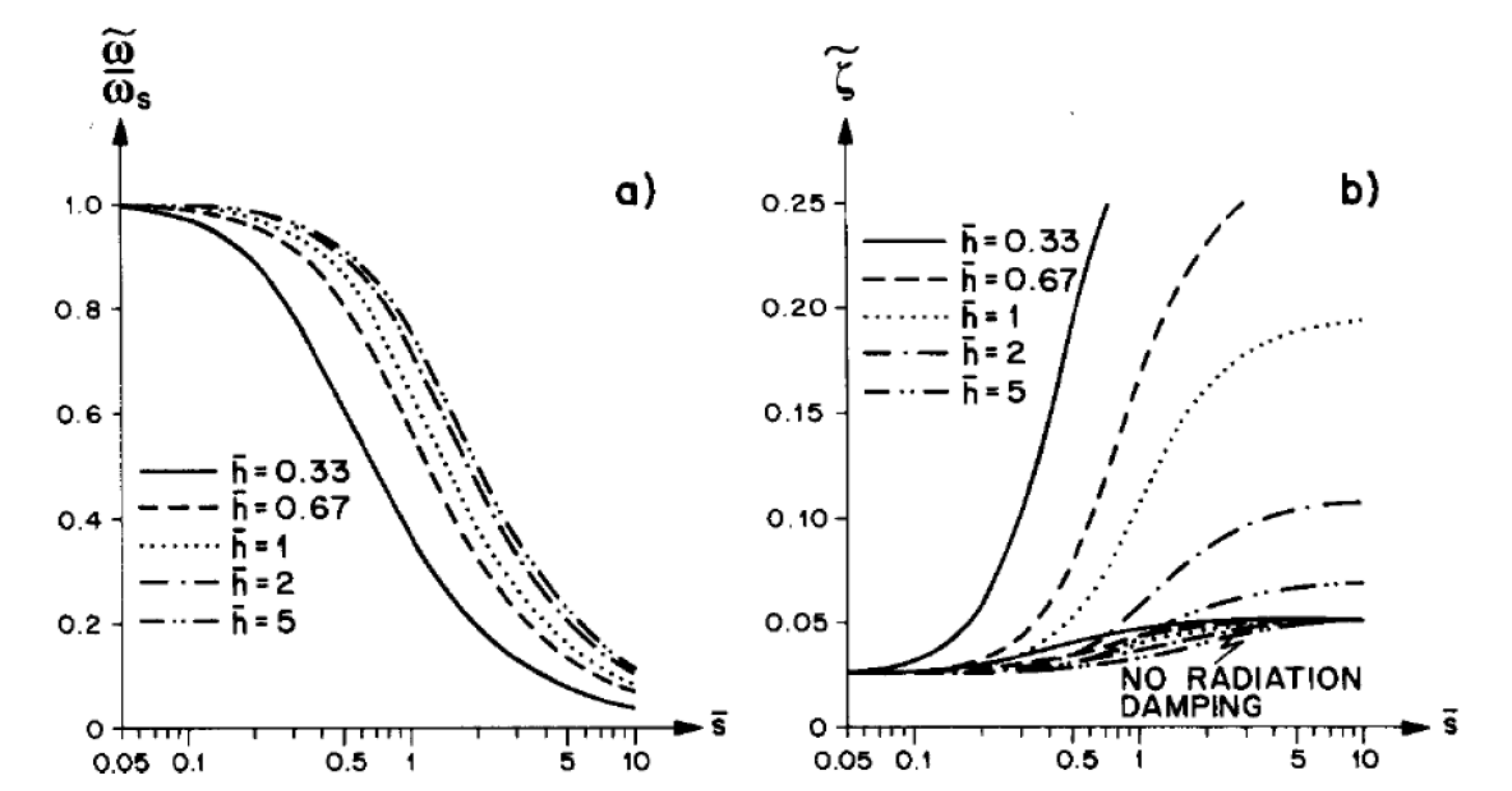
Wolf J. P.: Dynamic Soil-Structure Interaction, 1985

Structural displacement	**8 cm**
Soil displacement	2 cm
Displacement due to rocking	11
Total displacements	21 cm

Silo Zürich, roof displacements in cm, Swiss SIA earthquake

Structural displacement	20 cm
Soil horizontal displacement	2 cm
Displacement due to rocking	8
Total displacements	30 cm

MIT-Building 54, roof displacement in cm, Boston earthquake



Properties of eqivalent one-degree-of-freedom system, varying slenderness ratio

Wolf J. P.: Dynamic Soil-Structure Interaction, 1985

Example: Determination of equivalent frequency for MIT Green Building

$$\bar{s}=\frac{\omega_S h}{c_S}=\frac{\frac{2\pi}{1.3978}\times\left(2/3\times 83.7\right)}{207.85}=1.2$$

$$\bar{h}=\frac{h}{a}=\frac{h}{\sqrt{\frac{2L\times 2B}{\pi}}}=\frac{2/3\times 83.7}{\sqrt{\frac{34\times 20.5}{\pi}}}=3.74$$

$$\bar{m}=\frac{m}{\rho a^3}=\frac{12238\times 1000}{2034\times\left(\sqrt{\frac{34\times 20.5}{\pi}}\right)^3}=1.82$$

$$\frac{\tilde{\omega}^2}{\omega_s^2}=\frac{1}{1+\frac{\bar{m}\bar{s}^2}{8}\left[\frac{2-\nu}{\bar{h}^2}+3(1-\nu)\right]}=0.589\Rightarrow\tilde{\omega}=\sqrt{0.589}\times\frac{2\pi}{1.3978}=3.45Hz$$

$$\tilde{\xi}=\frac{\tilde{\omega}^2}{\omega_s^2}\xi+\left(1-\frac{\tilde{\omega}^2}{\omega_s^2}\right)\xi_g+\frac{\tilde{\omega}^3}{\omega_s^3}\frac{\bar{s}^3\bar{m}}{\bar{h}}\left[0.036\frac{2-\nu}{\bar{h}^2}+0.028(1-\nu)\right]\approx 0.055$$

Determination of soil dynamic stiffness: dampers, springs

a) Rigorous Models

- FEM
- Boundary Element Method, BEM
- SBFEM

b) Approximate Models

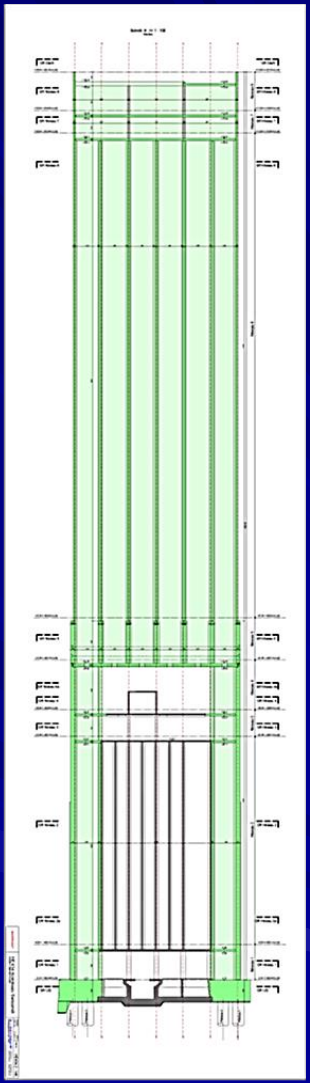
- Cone
- Lumped Mass Model

Overview of Zürich City

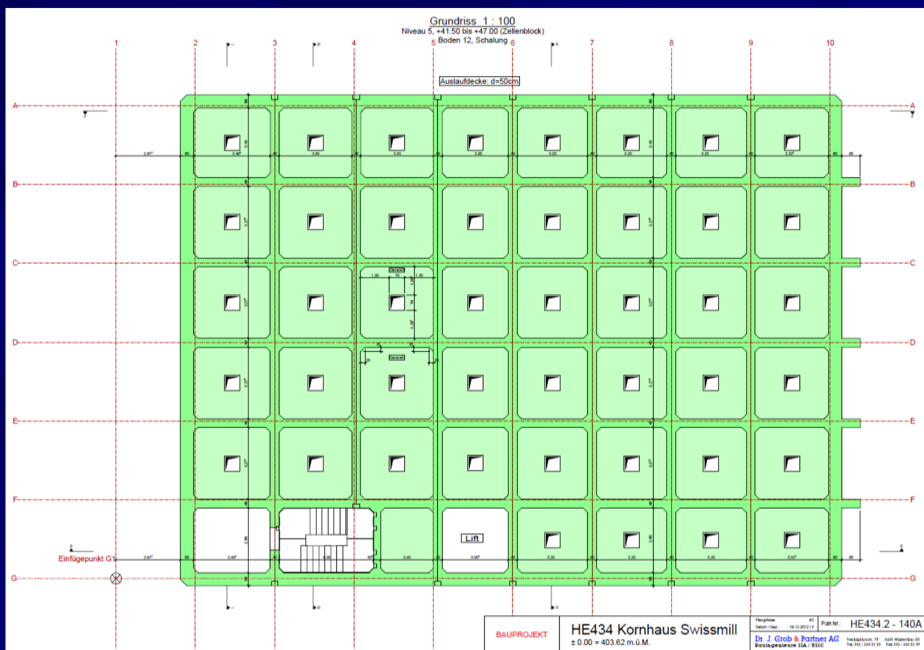
Height	118 m		
Floorplan dimensions	22.40 m x 30.0 0m		
Cubic	81'430 m^3		
Roof displacement	direction west – east direction north – south	± 17 cm ± 21 cm	
First eigenfrequency		0.32 HZ	
Excavation volume	with piles	5'000 m^3	
Piles	49	diameter 1.50 m	length 40 – 45 m
Beton volume		18'000 m^3	
Steel volume		2'700'000 kg	

Technical data of Silo in Zürich

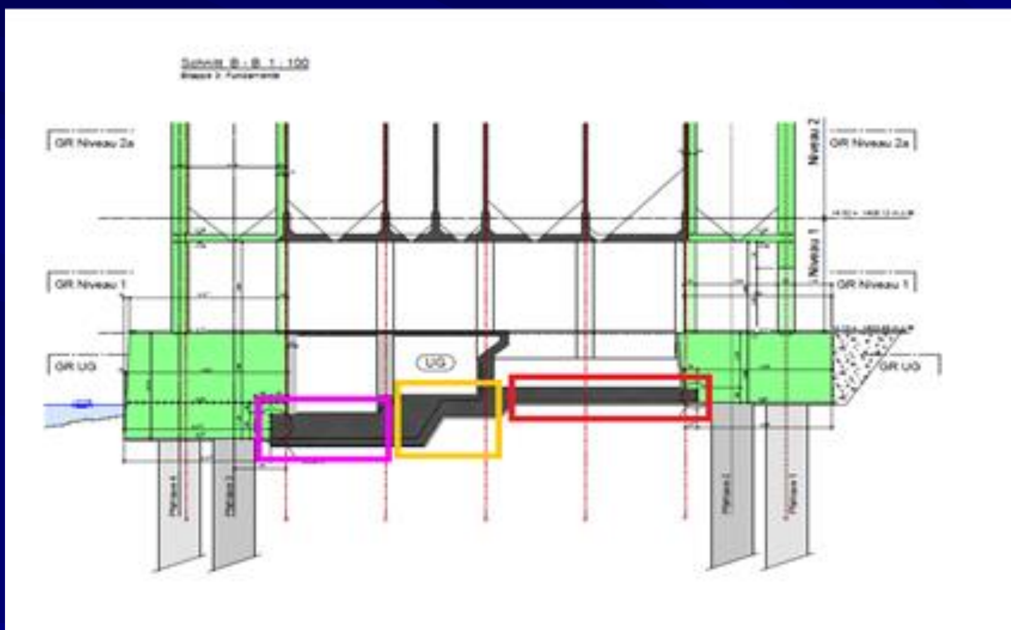
Existing silo: 38 meter high
50 years old



Existing silo (gray)
New silo (green)



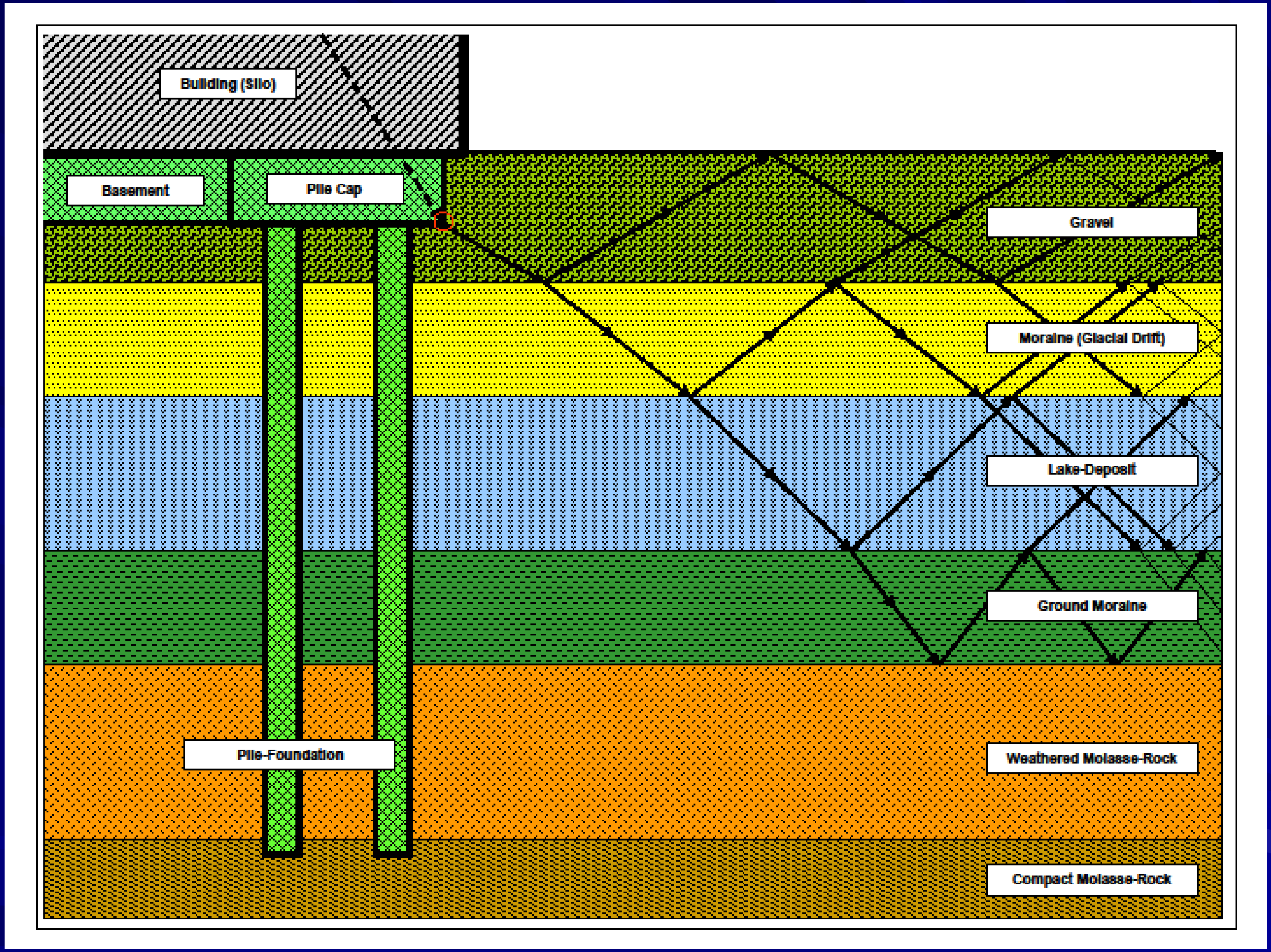
Typical floor plan view



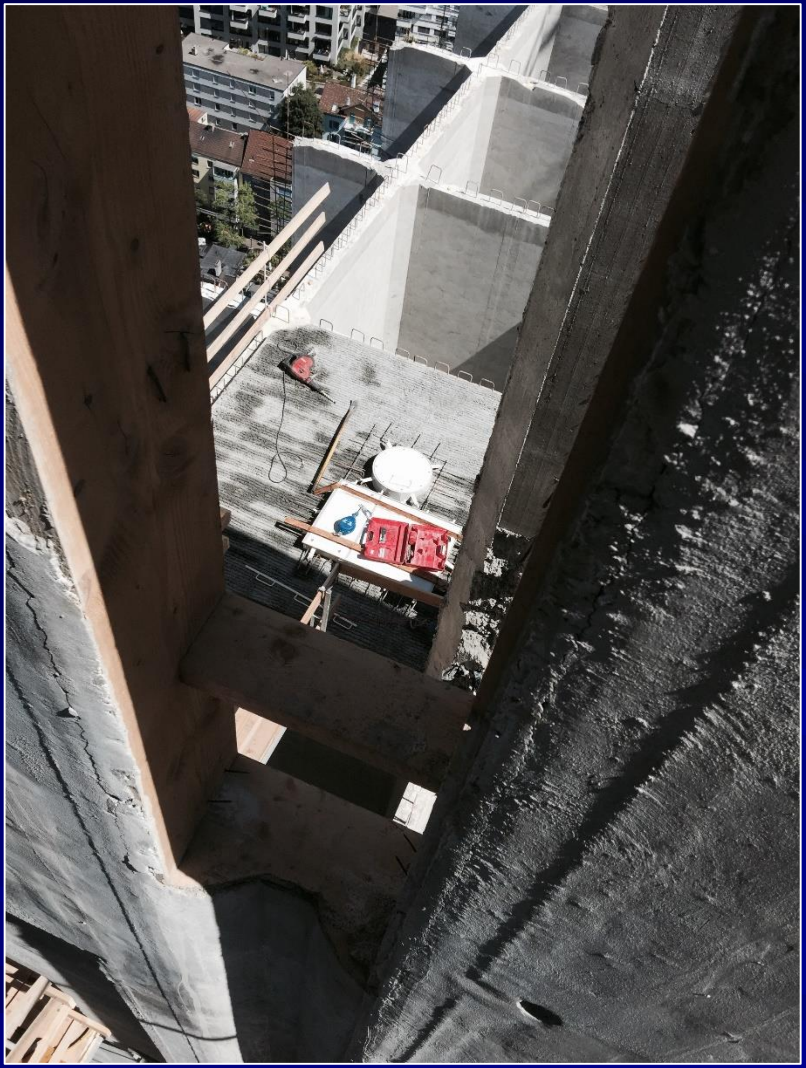
Foundation of the existing and of the new silo

Existing silo: Mat foundation

New silo: Pile foundation with 49 piles and two pile cops 4.2 Meter



Site layers and the wave pattern



- Sight from top of silo to the ground
- Distribution of silo cells, 118 Meter
- Construction stage, August 2015
- Construction work at severe conditions, safety net and ropes

Zürich Riverbank, August 2015

- Reinforcement
- Placing the reinforcement at 110 Meter
- 24 hours work (3 shifts, 8 hours)
- 81 Meter at in-situ concrete in 21 days
- 4.1 Meter per 24 hours

Top of silo, August 2015

Professor Ahmed Ghoniem MIT, Dr. Sassan Mohasseb, Zürich 2015

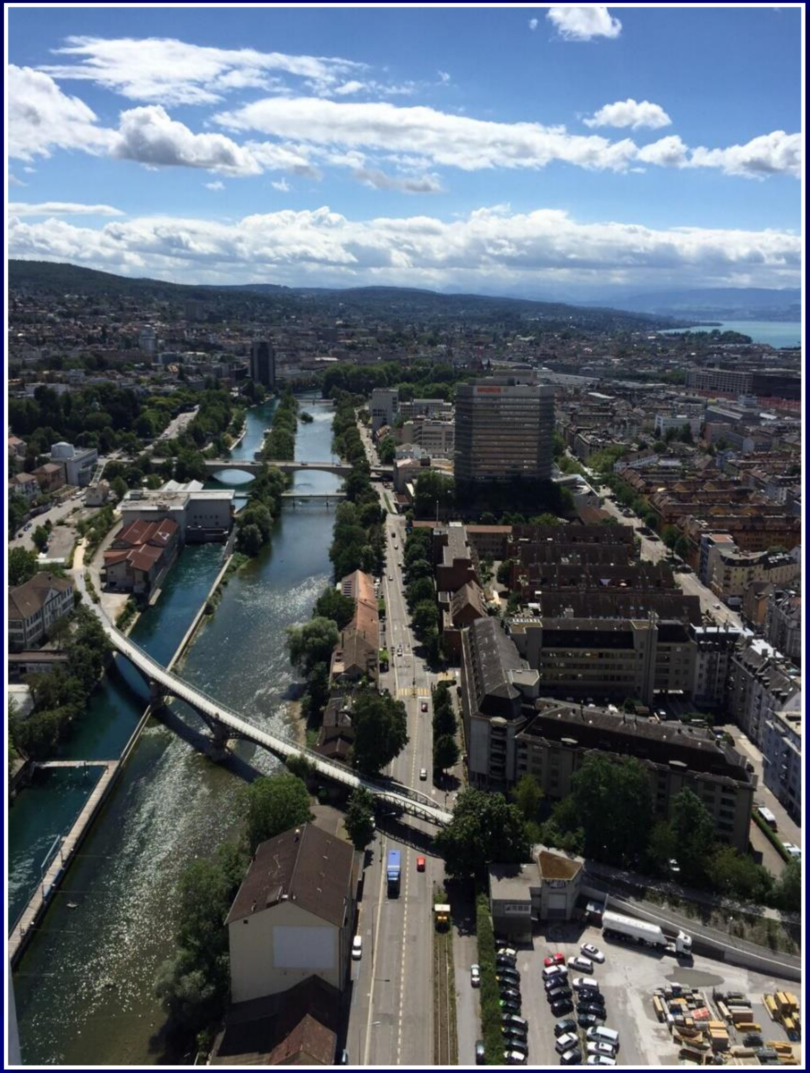
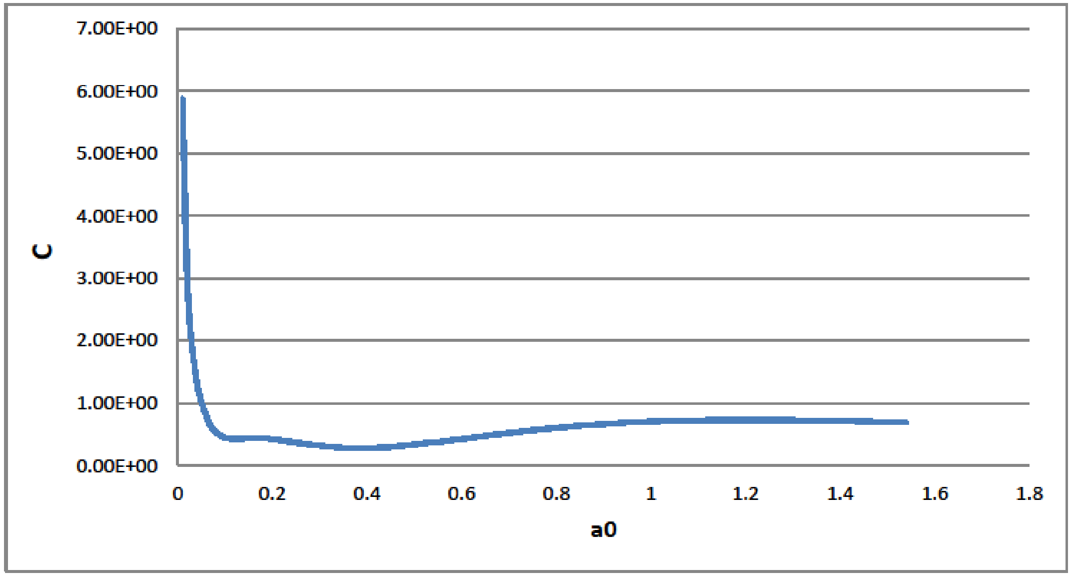


Photo from top of silo:

River with train viadukt



Soil Damping calculated with CONAN using Cone Models (Wolf, ETH)

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