City of Vienna Court of Audit (StRH Wien)

STADTRECHNUNGSHOF WIEN

Group Safety Control,
Department V - Buildings, transport and energy
DI René Binder, Akad. PA[WU]

Requirements for public service buildings and critical infrastructure in connection with natural disasters

XII EURORAI CONGRESS AND GENERAL ASSEMBLY IN GENEVA
Exchange of experiences in the context of audits performed by regional public sector audit institutions on the management of natural disasters

2025 10 02

Version 1.10

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Source: StRH Wien;

i general information
T theory, basics
! Examples; **interesting information**

Audit environments of the City of Vienna Court of Audit

Audit environment of public-sector auditing	Audit environment of the ’Safety Control‘
Control of the **fiduciary management of public funds** in accordance with their intended purpose in conjunction with corresponding accountability and information obligations.	Monitoring compliance with **obligations and delegated powers with regard to human life and health** in connection with corresponding accountability and information obligations. !

Source: ISSAI 100:2019 para. 17 and para. 23 as well as para. 24; Binder;

Audited entities	’Safety Control‘*
Institutions of the • **municipality** • **federal state**	Performance • of official duties
Enterprises	Existence of • adequate, • appropriate, • proper security measures
Facilities and sites	

* Assessment with regard to the safety of human life or health

Source: § 73c Vienna City Statutes - WStV;

History of the 'Safety Control' in Vienna

Since 1923:

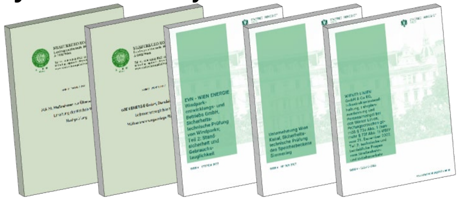
- **increased construction activity** in Vienna
- **StRH Wien** carried out **inspections** that also included **building aspects**
- **Examination mostly formal,** but in some cases also substantive technical examination

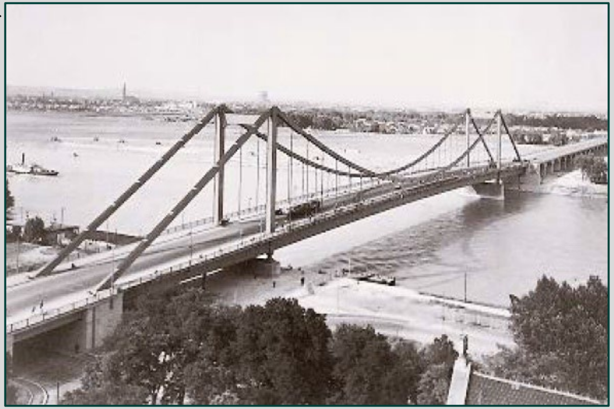
1 August 1976:

- **Collapse** of the **Reichsbrücke bridge** in Vienna
- **"hour of birth": 'Safety Control'** as an independent task
- now **technical audits**, too**!**

Since then:

- many '**Safety Controls**' by the StRH Wien





Source: MA 29;

Source: MA 29;

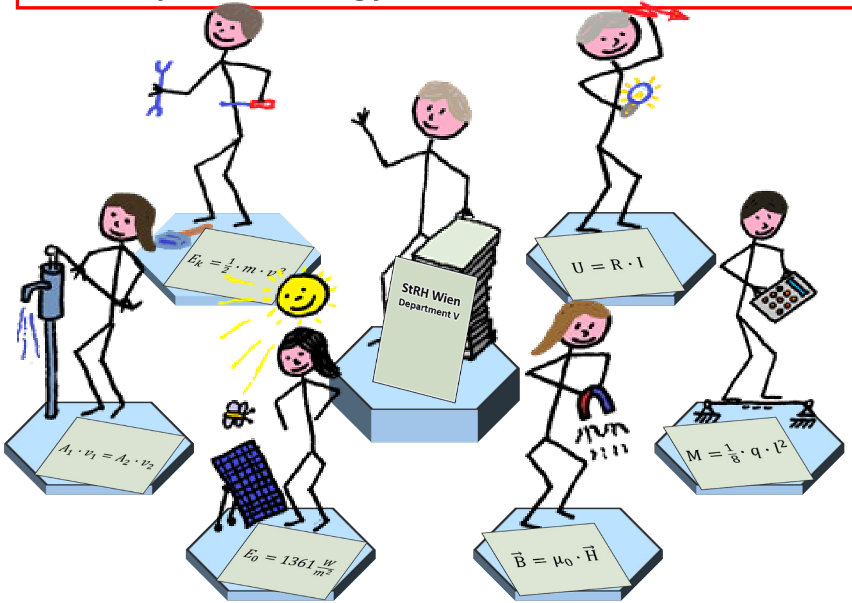
Organisational and personnel implementation

StRH Wien — 65 / 100% · 89 / 100%

Financial Control

'Safety Control' — 21 / 32.3% · 43 / 48.3%

- **Public Authorities and Municipal Technology**
- **Procurement and Construction**
- **Buildings, Transport and Energy**

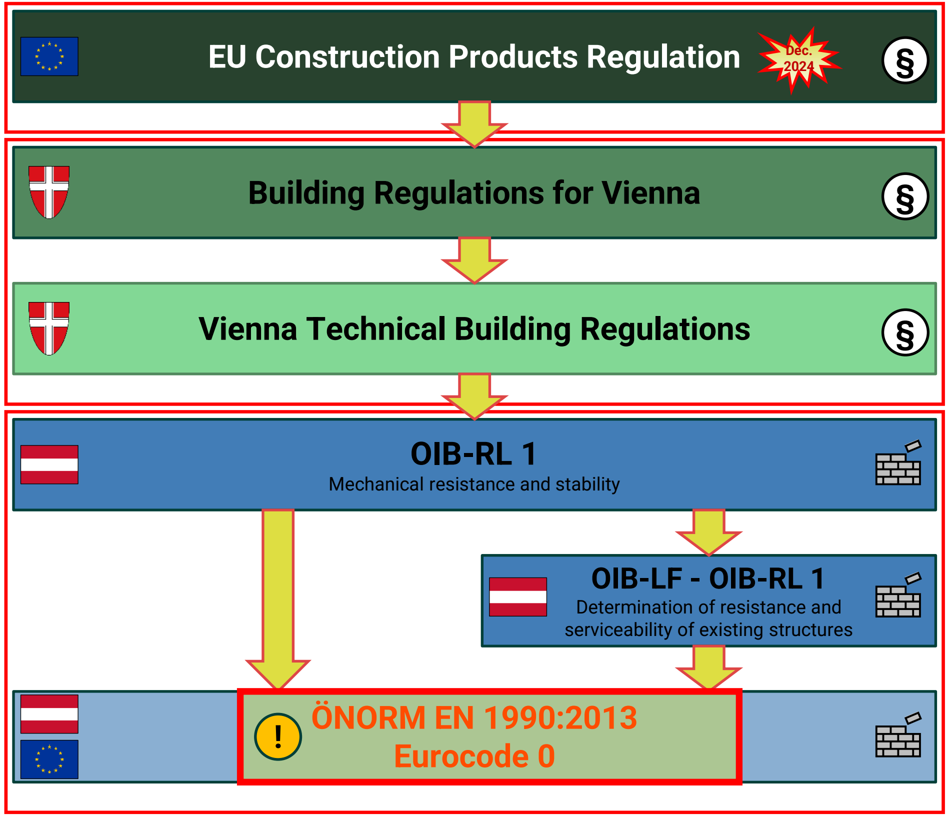


- **Mechanical engineering**
- **Electrical engineering**
- **Civil engineering:** Hydraulic engin.
- **Civil engineering:** Structural engin.
- **Civil engineering:** Environmental engin.
- **Technical Physics**

… and additionally:

- Chemical engineering
- Regional development
- Land and water management
- Legal science
- Veterinary medicine
- …

Legal and technical principles for buildings



Graphic: StRH Wien; coat of arms: Wikipedia;

Eurocodes: Basic structural design standards

Basis of structural design – EC 0 – EN 1990
- ÖNORM EN 1990 / ÖNORM B 1990-1
- ÖNORM EN 1990/A1 / ÖNORM B 1990-2

Actions on structures – EC 1 – EN 1991
- ÖNORM EN 1991-1-1 / ÖNORM B 1991-1-1
- ÖNORM EN 1991-1-2 / ÖNORM B 1991-1-2
- ÖNORM EN 1991-1-3 / ÖNORM B 1991-1-3
- ÖNORM EN 1991-1-4 / ÖNORM B 1991-1-4
- ÖNORM EN 1991-1-5 / ÖNORM B 1991-1-5
- ÖNORM EN 1991-1-6 / ÖNORM B 1991-1-6
- ÖNORM EN 1991-1-7 / ÖNORM B 1991-1-7
- ÖNORM EN 1991-2 / ÖNORM B 1991-2
- ÖNORM EN 1991-3 / ÖNORM B 1991-3
- ÖNORM EN 1991-4 / ÖNORM B 1991-4

Earthquake resistance – EC 8 – EN 1998
- ÖNORM EN 1998-1 / ÖNORM B 1998-1
- ÖNORM EN 1998-2 / ÖNORM B 1998-2
- ÖNORM EN 1998-3 / ÖNORM B 1998-3
- ÖNORM EN 1998-4 / ÖNORM B 1998-4
- ÖNORM EN 1998-5 / ÖNORM B 1998-5
- ÖNORM EN 1998-6 / ÖNORM B 1998-6

Design, calculation and dimensioning …

… for geotechnical design – EC 7 – EN 1997
- ÖNORM EN 1997-1 / ÖNORM B 1997-1-1, ÖNORM B 1997-1-2, ÖNORM B 1997-1-3, ÖNORM B 4434, ÖNORM B 1997-1-5, ÖNORM B 4431-2
- ÖNORM EN 1997-2 / ÖNORM B 1997-2

… of (reinforced) concrete structures – EC 2 – EN 1992
- ÖNORM EN 1992-1-1 / ÖNORM B 1992-1-1
- ÖNORM EN 1992-1-2 / ÖNORM B 1992-1-2
- ÖNORM EN 1992-2 / ÖNORM B 1992-2
- ÖNORM EN 1992-3 / ÖNORM B 1992-3
- ÖNORM EN 1992-4 / ÖNORM B 1992-4

… of steel structures – EC 3 – EN 1993
- ÖNORM EN 1993-1-1 / ÖNORM B 1993-1-1
- ÖNORM EN 1993-1-2 / ÖNORM B 1993-1-2
- ÖNORM EN 1993-1-3 / ÖNORM B 1993-1-3
- ÖNORM EN 1993-1-4 / ÖNORM B 1993-1-4
- ÖNORM EN 1993-1-5 / ÖNORM B 1993-1-5
- ÖNORM EN 1993-1-6 / ÖNORM B 1993-1-6
- ÖNORM EN 1993-1-7 / ÖNORM B 1993-1-7
- ÖNORM EN 1993-1-8 / ÖNORM B 1993-1-8
- ÖNORM EN 1993-1-9 / ÖNORM B 1993-1-9
- ÖNORM EN 1993-1-10 / ÖNORM B 1993-1-10
- ÖNORM EN 1993-1-11 / ÖNORM B 1993-1-11
- ÖNORM EN 1993-1-12 / ÖNORM B 1993-1-12
- ÖNORM EN 1993-2 / ÖNORM B 1993-2
- ÖNORM EN 1993-3-1 / ÖNORM B 1993-3-1
- ÖNORM EN 1993-3-2 / ÖNORM B 1993-3-2
- ÖNORM EN 1993-4-1 / ÖNORM B 1993-4-1
- ÖNORM EN 1993-4-2 / ÖNORM B 1993-4-1
- ÖNORM EN 1993-4-3 / ÖNORM B 1993-4-1
- ÖNORM EN 1993-5 / ÖNORM B 1993-5
- ÖNORM EN 1993-6 / ÖNORM B 1993-6

… of composite steel and concrete structures – EC 4 – EN 1994
- ÖNORM EN 1994-1-1 / ÖNORM B 1994-1-1
- ÖNORM EN 1994-1-2 / ÖNORM B 1994-1-2
- ÖNORM EN 1994-2 / ÖNORM B 1994-2

… of timber structures – EC 5 – EN 1995
- ÖNORM EN 1995-1-1 / ÖNORM B 1995-1-1
- ÖNORM EN 1995-1-2 / ÖNORM B 1995-1-2
- ÖNORM EN 1995-2 / ÖNORM B 1995-2

… of masonry structures – EC 6 – EN 1996
- ÖNORM EN 1996-1-1 / ÖNORM B 1996-1-1
- ÖNORM EN 1996-1-2 / ÖNORM B 1996-1-2
- ÖNORM EN 1996-2 / ÖNORM B 1996-2
- ÖNORM EN 1996-3 / ÖNORM B 1996-3

… of aluminum structures – EC 9 – EN 1999
- ÖNORM EN 1999-1-1 / ÖNORM B 1999-1-1
- ÖNORM EN 1999-1-2
- ÖNORM EN 1999-1-3
- ÖNORM EN 1999-1-4
- ÖNORM EN 1999-1-5

Products in general:

ETAGs European Technical Approval Guideline;
ETAs European Technical Approval;

Execution …
(Excerpt from the most important standards)

… of (reinforced) concrete structures
ÖNORM EN 13670; ÖNORM B 4704;

… of composite steel and concrete structures
ÖNORM EN 13670; ÖNORM B 4704;
ÖNORM EN 1090-x;

… of steel structures
ÖNORM EN 1090-x;

… of aluminum structures
ÖNORM EN 1090-x;

Graphic: StRH Wien;
Source, Graphic: Eurocodes - Austrian Standards; Eurocodes: Building the future;

Eurocodes: Levels of reliability

Consequence class	Sub-class	! Indicative qualification of consequences		1-year reference period			50-year reference period		
		! Loss of human life or personal injury	Economic, social or environmental consequences	β_1	$P_{f,1}$	$1: P_{f,1}$	β_{50}	$P_{f,50}$	$1: P_{f,50}$
CC4 (new) Highest Consequences	- -	Extreme	Huge						
CC3 Higher Consequences	B A	High	Very great	5,2	0,000 000 100	10.035.701	4,3	0,000 008 540	117.097
CC2 Normal Consequences	B A	Medium	Considerable	4,7	0,000 001 301	768.753	3,8	0,000 072 348	13.822
CC1 Lower Consequences	- -	Low	Small	4,2	0,000 013 346	74.930	3,3	0,000 483 424	2.069
CC0 (new) Lowest Consequences	- -	Very low	Insignificant						

Source: ÖNORM prEN 1990:2021 Table 4.1 (NDP) and Table C.3 (NDP);

β Reliability index

P_f Probability of failure

$P_f = \Phi(-\beta)$ bzw. $\beta = -\Phi^{-1}(P_f)$

ÖNORM prEN 1990:2021 Formula (C.5)

Note: Decimal separators in tables and calculations used according to conventions in the english version of Eurocode 0!

Eurocodes: Actions on structures

EC 1 EN 1991	• Densities, self-weight, imposed loads for buildings	• **Wind actions** !	• **Traffic loads on bridges** !
	• **Exposition to fire**	• **Thermal actions** !	• Actions induced by cranes and machinery
	• **Snow loads**	• Actions during execution	• Actions on silos and tanks
		• **Accidental actions**	
EC 8 EN 1998	• **Earthquake resistance** for (high-rise) buildings	• **Earthquake resistance** for retrofitting of buildings	• **Earthquake resistance** for Foundations, retaining structures
	• **Earthquake resistance** for bridges	• **Earthquake resistance** for silos, tanks and pipelines	• **Earthquake resistance for towers, masts and chimneys** !

Graphic: StRH Wien;

Wind turbines – Flood

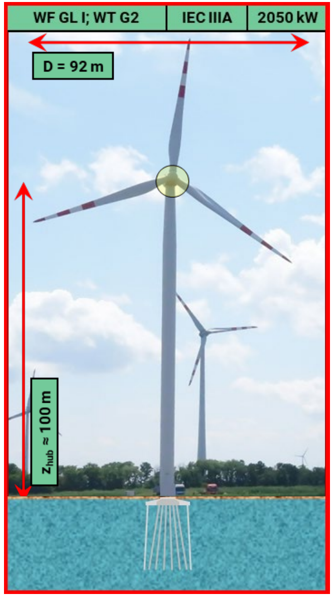
Wind turbines (WT) consist of:

- Tower; height z_{hub}
- Nacelle, machine room
- Rotor; diameter D
- Foundation

The **foundation must absorb forces** (e.g. from its self-weight, wind, etc.) **and transfer them** to the load-bearing subsoil.

In addition to the **ground type**, the influence of **water** is also important:

- Water influences the geotechnical soil parameters.
- Loss of equilibrium due hydraulic uplift by water pressure (buoyancy).

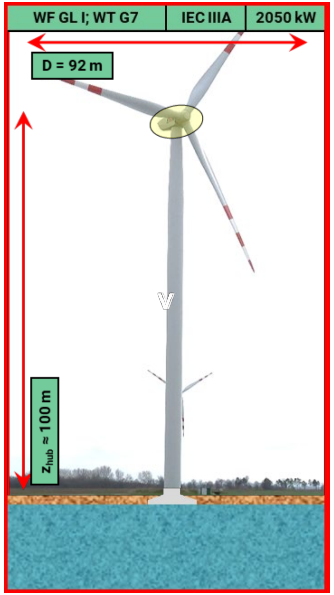


Graphic: StRH Wien;

Pile foundation

- Cross-shaped plate
- 24 Piles
- Buoyancy-proof

Problem: ❗
Only 20 piles (instead of 24 piles)



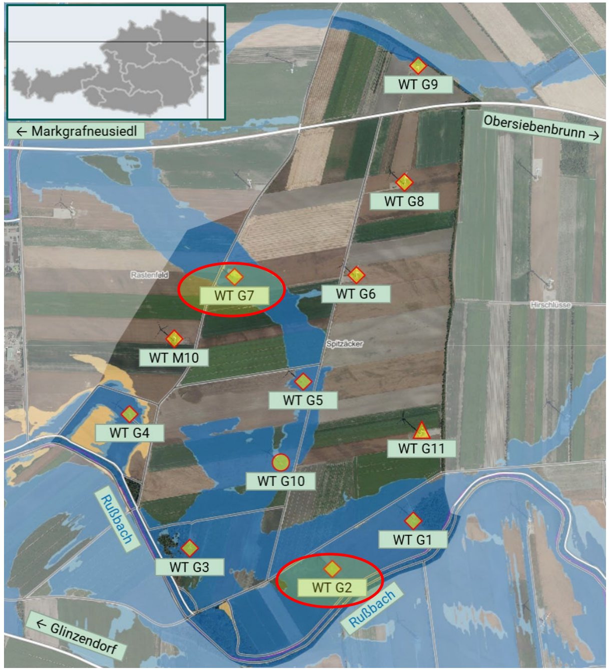
Graphic: StRH Wien;

Spread foundation

- Circular plate
- Buoyancy not taken into account

Problem: ❗
Flood zone

Wind farm (WF) **Glinzendorf** (Lower Austria)



Source: StRH Wien; HORA;

Medium risk:
Flooding possible during a **100-year flood event.**

High risk:
Flooding possible during a **30-year flood event.**

Wind turbines – Wind

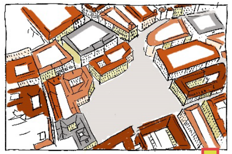
Wind turbines are classified into WT Classes:

WT Class			I	II	III
	V_{ref}	[m/s]	50,0	42,5	37,5
A+	I_{ref}	[1]	0,18		
A	I_{ref}	[1]	0,16		
B	I_{ref}	[1]	0,14		
C	I_{ref}	[1]	0,12		

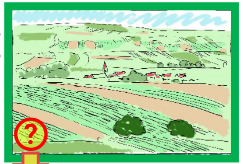
Source: OVE EN IEC 61400-1:2020-01-01;

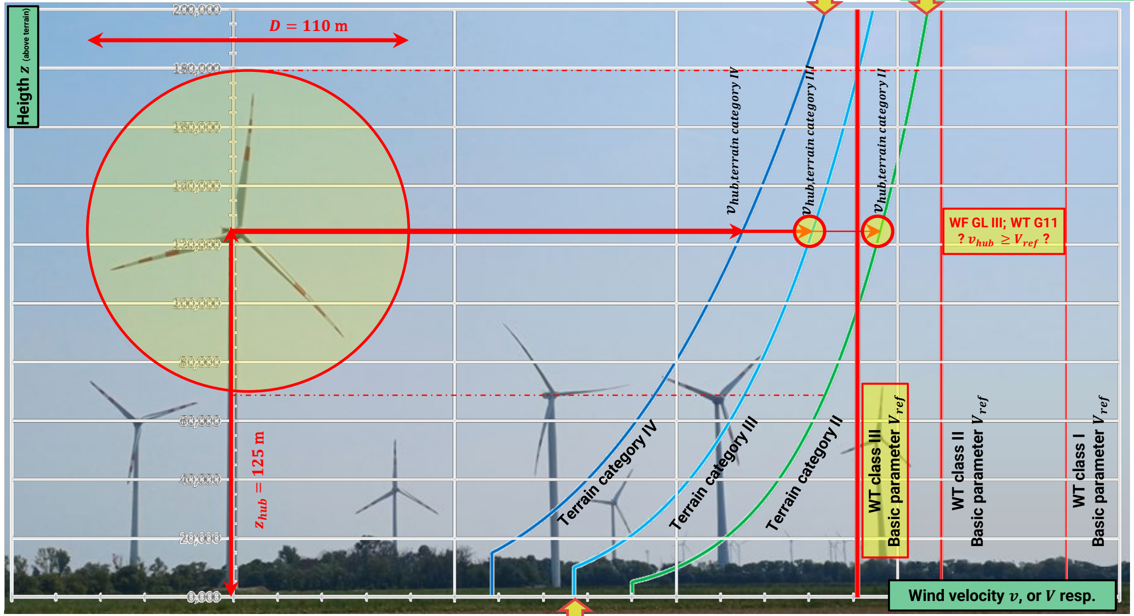
The **wind velocity at the height of the rotor hub** is (among other things) essential for the classification (v_{hub}).

Terrain category IV



Terrain category II



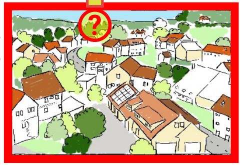


Graphic: RENATENTWURF (2025 09 00): https://www.renatentwurf.at/; StRH Wien;

Source: StRH Wien;

The **wind velocity** depends heavily on the **roughness of the terrain** (i.e. the terrain category).

Terrain category III



Problem:

- WT classified as IEC S(IIIA) …
- … Terrain category III used

Source: StRH Wien;

Waste incineration plant – Earthquakes

Waste incineration plant Flötzersteig

(Austria's oldest thermal waste-to-energy incineration plant; WTE plant)

Characteristic values WTE plant:

- Waste incineration: 200,000 to/a
- Thermal output : 51 MW (district heating)

History (excerpt):

- Built between 1959 and 1963
- …
- Renovated between 1991 and 1993
- Old reinforced concrete chimney replaced by **steel chimney** in 1993
- ...

Chimney specifications:

Height: 100 m
External tube: structural shell (windshield)
Internal tube: lining system (for exhaust gases)

Structural analysis for chimney :

- Calculations by the manufacturer
  General static verification of the chimney
- Calculation by a civil engineer
  Location-specific static verification for the chimney

Source: StRH Wien;

Problem:

- **Static analyses** took only wind loads into account, but **not earthquake loads**.
- Vibration behaviour is essential for earthquake analyses. **Chimneys** are **susceptible to vibration**.

Standards applicable at the **time of construction** of the chimney (1993):

- ÖNORM B 4015-1:1979
  'Load assumptions in construction, earthquake forces on structures not susceptible to vibration'
- ~~ÖNORM B 4015-2:19xx –~~
- ~~'Load assumptions in construction, earthquake forces on structures susceptible to vibration'~~

! The standard was never published !

Source: Lanz Gerald (2007): 'Force-based design of masonry structures subject to seismic loads based on Eurocode 8': Chapter 2.2.1

It was **not until 1999** that a corresponding **earthquake standard** was published: ÖNORM B 4015-2:1999
Design loads in building - Accidental actions - Seismic actions - Methods of calculation

Waste incineration plant – Post failure

How does the structure behave after damage has occurred?

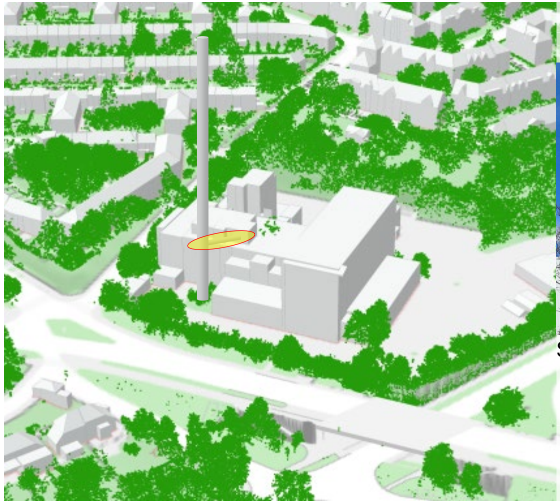
e.g.: important for vital infrastructure, disaster control, etc.

- **Eurocode 0** recognises **limit states**:
  A state beyond which the structure no longer satisfies the relevant design criteria.
  Source: ÖNORM prEN 1990:2021 Section 3.1.2.14;

  For example, there are limit states for:
  - **Resistance (ULS)** *(en.: Ultimate Limit State)*
  - **Serviceability (SLS)** *(en.: Serviceabillity Limit State)*

- **Limit states** and associated **seismic action** according to Eurocode 8:
  - **Near Collapse (NC)** *(en.: near collapse)*
    Building heavily damaged (ULS);
  - **Significant Damage (SD)** *(en.: significant damage)*
    Building significantly damaged (ULS);
    Repair possible, but uneconomical;
  - **Damage Limitation (DL)** *(en.: damage limitation)*
    Building only slightly damaged (SLS);
    Repair economically feasible;
  - **Fully Operational (OP)** ! *(en.: fully operational)* **new**
    Building only slightly damaged (SLS);
    Repair economically feasible;
    Continuous operation possible; **Adapt to 'operation'**

  Source: ÖNORM prEN 1998-1-1:2022 Section 4.3 Paragraph (1);



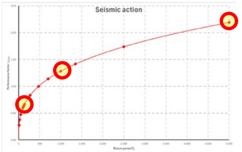
Source: MA41 – City Surveying; Sketch: StRH Wien;

Connecting flue pipe (to chimney): "Compensator":

Source: StRH Wien;

- Connecting flue pipe between:
  - 'rigid' boiler house and ...
  - ... 'flexible' chimney
- possibly already **OP decisive**

(Magnitude of) **Seismic action: NC > SD > DL > OP**



In Austria, usually **'only' SD** is **veryfied.**

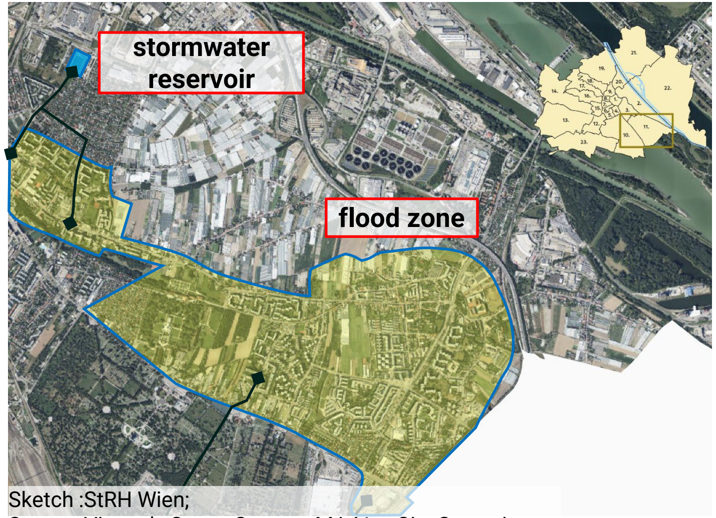
Source: ÖNORM EN 1998-3:2013 Section 2.1 i.c.w.
ÖNORM B 1998-3:2018 Section 6.1.1;

CC3-b					DL					SD			NC
CC3-a				DL					SD			NC	
CC2			DL				SD				NC		
CC1		DL				SD		NC					
T_R	[a]	100	115	125	140	275	475	500	700	1.000	1.350	2.500	5.000
$\gamma_{LS,CC}$	[1]	0,60	0,60	0,65	0,65	0,85	1,00	1,00	1,15	1,30	1,40	1,70	2,20
p für t_l	[%]	39,35	35,26	32,97	30,03	16,62	9,99	9,52	6,89	4,88	3,64	1,98	1,00

Source: ÖNORM prEN 1998-1-2:2023 Section 4.2 Table 4.3 (NDP) and Table 4.4 (NDP); t_l=50a;

Stormwater reservoir “Simmering“ – intense rainfall

- **After intense rainfall:**
- often **floodings** in “Simmering“ (11th Viennese district)



Sketch :StRH Wien;
Source: Vienna’s Sewer System; MA41 – City Surveying;

Source: StRH Wien;

Stormwater reservoir:

- Reservoir: subterranean, watertight
- Dimensions: 91 m x 46 m
- Material: reinforced concrete
- Capacity: 28.500 m³ (+ 6.000 m³ storm water sewer)
- Pumps: 3 x 600 l/s (expansion stage: 3 x 1.800 l/s)

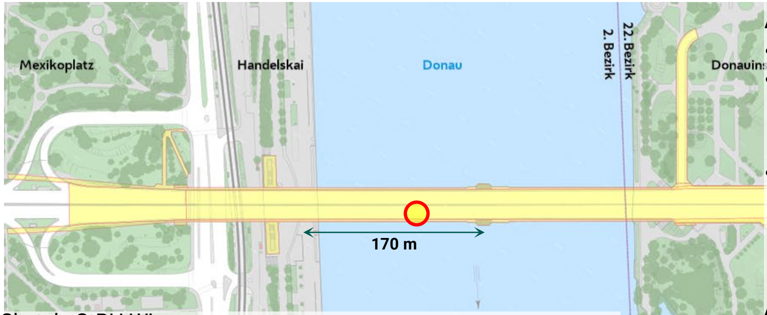
Intense rainfall event:

- Reference period: 10 years
- Rainfall duration: 60 minutes

Problem: !

- (too) **low resistance vs. buoyancy**
- **Reinforcement** of **beams** (too) **low**

Bridge “Reichsbrücke“ – Temperature



Sketch: StRH Wien;
Source: MA29 – Bridge construction and foundation engineering;

Bridge “Reichsbrücke“:

- Construction: 1978 until 1980
- Cross-section: two (symmetric) box girder sections
- two levels of use:
  Underground transport; road traffic; pedestrian traffic; infrastructure lines;
- Prestressed concrete bridge (with multiple sections)
  längste Spannweite 170 m

Prestrain (with tendons):

- The **prestressing forces** ensure that only **compression forces** are present **in the concrete**.
- If the prestrain is lost, **tensile forces** arise in the concrete, **causing cracks**. The **resistance** may **decrease**.

Audit StRH Wien (2016):

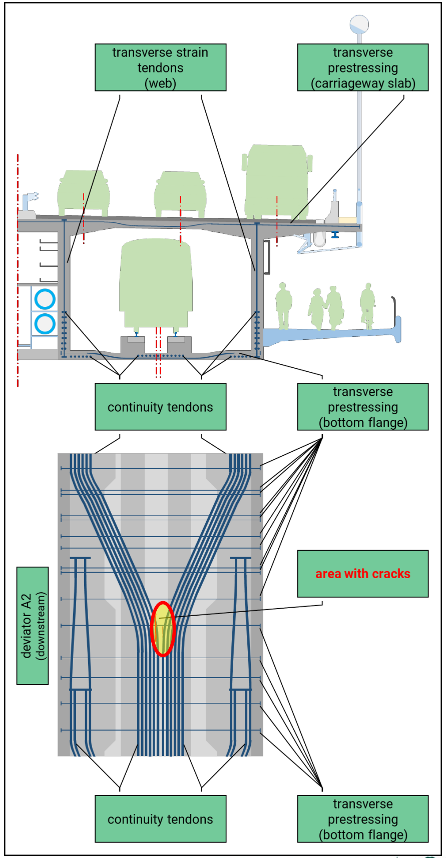
- **Prestrain** was addressed
- *MA29 – Bridge construction:*
  As long as there are **no cracks, full prestressing** is given.
- *StRH Wien:*
  Recommended to **clarify** whether **resistance** is **still given in the event of cracks** (in the concrete tension zone).

After the audit:

- *Expert opinion 2016:*
  Resistance: OK (announcement before failure)
- **2019: MA29 detects cracks** !
- *Expert opinion 2021 about cracks:*
  Cause of the cracks was that originally (in 1980), **no temperature differences** have been **taken into account** for the verification of the box girder sections construction.

Follow-up audit StRH Wien (2022):

- *StRH Wien:* !
  The verifications **did not take crowd loading** (crowds of people on the bridge) **into account** (according to Eurocode 1).
- ***Vienna City Marathon:***
  Start in front of the bridge with over **35,000 participants** (annually since 1984).



Sketch: StRH Wien; Source: MA29 – Bridge construction and foundation engineering;

Thank you for your attention ...

DI René Binder, Akad. PA[WU]
Auditor, Department V - Buildings, transport and energy
1082 Wien, Landesgerichtsstraße 10
E-Mail: rene.binder@wien.gv.at
www.stadtrechnungshof.wien.at

Source: StRH Wien;