Advanced Structural Concrete

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Advanced Structural Concrete

Objectives and content of the lecture

Overarching learning objectives

Within this course, the students are able to:

- deepen their understanding of structural concrete models and apply them to general design problems, including the assessment of existing structures.
- enhance their knowledge about the load-deformation response of reinforced and prestressed concrete structures.
- identify and assess the limits of applicability of limit analysis methods.
- recognise the assumptions of models suitable for computer-aided structural design and use in a critical way structural concrete design software.
- evaluate the long-term behaviour and the behaviour under fire conditions of concrete structures.
- assess the behaviour of fibre reinforced concrete structures.

Basics / additional documents

[1] Kaufmann, W., *Stahlbeton I/II*, Lecture notes, ETH Zurich, 2016/17
(Basics of the lecture) → available online

[2] Marti, P., *Theory of Structures*, Wilhelm Ernst & Sohn, Berlin, 2011

[3] Swiss society of engineers and architects (SIA), standards:
- SIA 262 *Concrete Structures*, Zürich, 2003 (Partial rev. 2013)
- SIA 260 *Basis of Structural Design*, 2003 (Partial rev. 2013)
- SIA 261 *Actions on Structures*, 2003 (Partial rev. 2014)

[4] Marti, P., Alvarez, M., Kaufmann, W., Sigrist, V., *Tragverhalten von Stahlbeton*, IBK, ETH Zurich, 1999 → available online

[5] Muttoni, A., Schwartz, J., Thürlimann, B., "Design of Concrete Structures with Stress Fields“, Birkhäuser, Basel, 1997

[6] Marti, P., *Stahlbeton I/II*, Lecture notes, ETH Zurich, 2009/10 → available online

[7] Nielsen, M.P., Hoang, L.C., “Limit Analysis and Concrete Plasticity”, CRC Press, 2010

[8] Kaufmann W., Mata-Falcón J., Weber M., Galkovski T., Tran D.T., Kabelac J., Konecny, M. et al., *Compatible Stress Field Design of Structural Concrete: Principles and Validation*, ISBN 978-3-906916-95-8, ETH Zurich & IDEA StatiCa, 2020.
→ available as an E-Book and at the ETH Store

[9] *fib* Bulletin 100, “Design and assessment with strut-and-tie models and stress fields: from simple calculations to detailed numerical analysis”, 2021

→ Technical terms and designations shall be used in accordance with SIA 262 (Clause 1).

→ Translation and calculation aids → available online

Additional literature

Kaufmann W., Mata-Falcón J., Weber M., Galkovski T., Tran D.T., Kabelac J., Konecny, M. et al., *Compatible Stress Field Design of Structural Concrete: Principles and Validation*, ISBN 978-3-906916-95-8, ETH Zurich & IDEA StatiCa, 2020.

- Paper copy available directly from the Chair – contact TA

  85 CHF regular price / 25 CHF student price

- E-Book available at https://payhip.com/b/DP6N

  60 € regular price / 18 € student price

  70% student discount voucher by request

Content

1. **Introduction**

2. **In-plane loading** (Enhancement of understanding and additional remarks to Stahlbeton I)

- Walls and beams
  - Stress fields
  - Stress fields with prestressing
  - Compatibility and deformation capacity
- Membrane elements
  - Equilibrium, yield conditions
  - Compatibility and deformation capacity
- Numerical modelling

3. **Fire behaviour**

4. **Long term effects**
- Basics (material properties, superposition principle of Boltzmann)
- Application (General approaches and simplified calculation of structures subjected to creep and shrinkage)

5. **Slabs** (Enhancement of understanding and additional remarks to Stahlbeton II)
- Equilibrium, yield conditions
- Shear and punching shear
- Numerical modelling

6. **Steel fibre reinforced concrete**

Organisation Advanced Structural Concrete

Lecture

- Thursday, 09:45-11:30, HIL E 7. No streaming available
  Detailed semester program and lecture materials available online at http://www.concrete.ethz.ch/asc

Exercises

- Enhancement of the understanding of the topics discussed in the lecture
- Introduction to the exercises in the lecture: 10.10., 24.10., 28.11., 12.12.
- Submission optional, questions can be discussed during the consultation hours

Consultation hours

- Every Wednesday, 13:00 – 14:00, HIL E10.2
- Assistant: Paul Merz
- For questions concerning the lecture or exercises, sign-up via paul.merz@ibk.baug.ethz.ch

Workshop “Compatible Stress Fields” (optional)

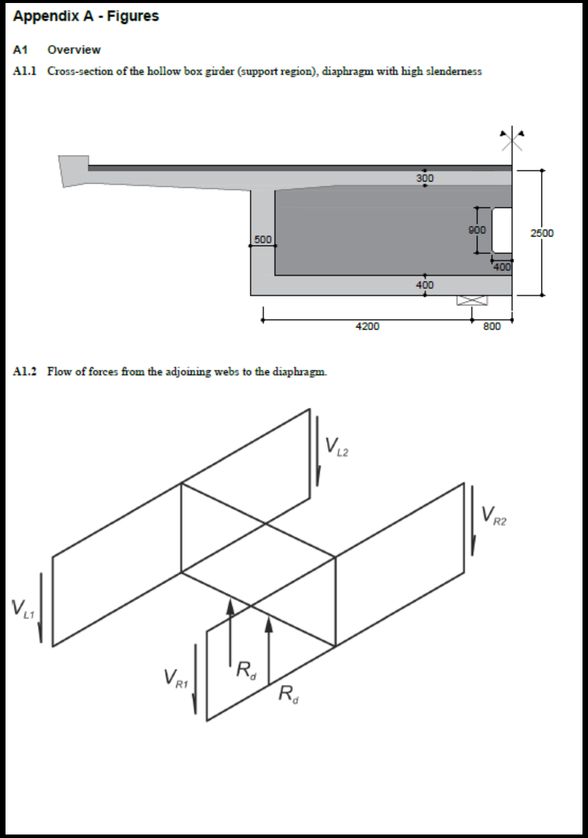
- Tuesday, 19.11., 16:00 – 18:00, in-person, room to be announced
- More information will follow

Exam

- 18’ task preparation, followed by 18’ oral examination (9’ task presentation + 9’ additional questions), language: English

Exercises

Exercise 1



Appendix A - Figures

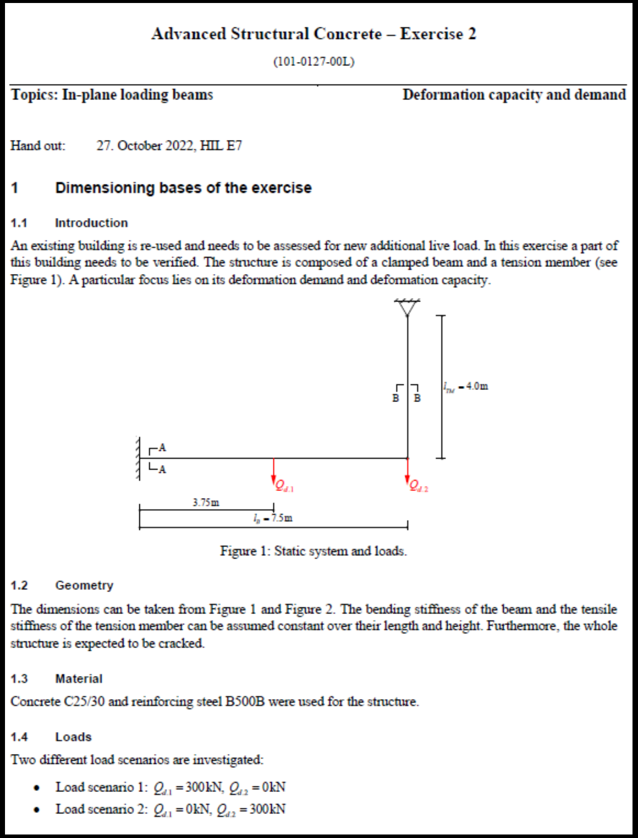
A1 Overview

A1.1 Cross-section of the hollow box girder (support region), diaphragm with high slenderness

A1.2 Flow of forces from the adjoining webs to the diaphragm.

Stress fields

Exercise 2



Advanced Structural Concrete – Exercise 2

(101-0127-00L)

Topics: In-plane loading beams — Deformation capacity and demand

Hand out: 27. October 2022, HIL E7

1 Dimensioning bases of the exercise

1.1 Introduction

An existing building is re-used and needs to be assessed for new additional live load. In this exercise a part of this building needs to be verified. The structure is composed of a clamped beam and a tension member (see Figure 1). A particular focus lies on its deformation demand and deformation capacity.

Figure 1: Static system and loads.

1.2 Geometry

The dimensions can be taken from Figure 1 and Figure 2. The bending stiffness of the beam and the tensile stiffness of the tension member can be assumed constant over their length and height. Furthermore, the whole structure is expected to be cracked.

1.3 Material

Concrete C25/30 and reinforcing steel B500B were used for the structure.

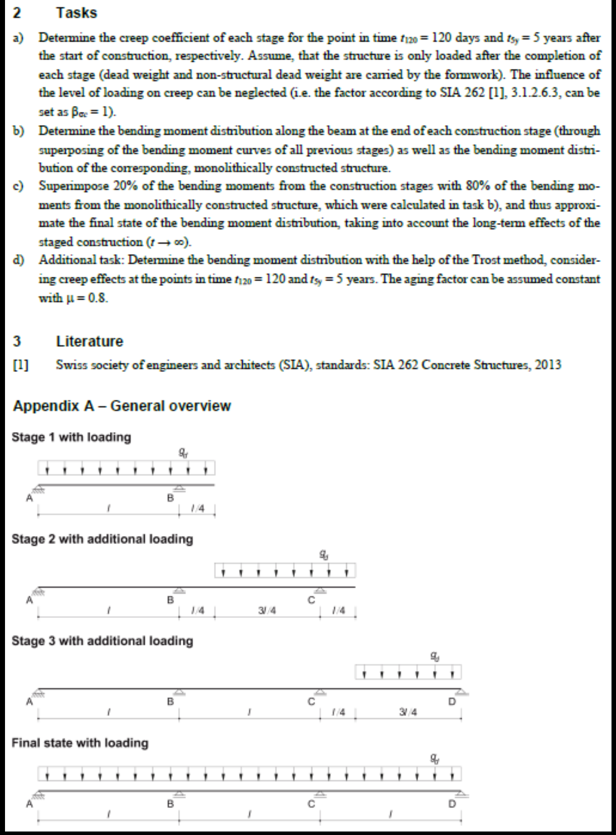
1.4 Loads

Two different load scenarios are investigated:

- Load scenario 1: $Q_{d,1} = 300$kN, $Q_{d,2} = 0$kN
- Load scenario 2: $Q_{d,1} = 0$kN, $Q_{d,2} = 300$kN

Deformation capacity

Exercise 3



2 Tasks

a) Determine the creep coefficient of each stage for the point in time $t_{120} = 120$ days and $t_{5y} = 5$ years after the start of construction, respectively. Assume, that the structure is only loaded after the completion of each stage (dead weight and non-structural dead weight are carried by the formwork). The influence of the level of loading on creep can be neglected (i.e. the factor according to SIA 262 [1], 3.1.2.6.3, can be set as $\beta_{\sigma c} = 1$).

b) Determine the bending moment distribution along the beam at the end of each construction stage (through superposing of the bending moment curves of all previous stages) as well as the bending moment distribution of the corresponding, monolithically constructed structure.

c) Superimpose 20% of the bending moments from the construction stages with 80% of the bending moments from the monolithically constructed structure, which were calculated in task b), and thus approximate the final state of the bending moment distribution, taking into account the long-term effects of the staged construction ($t \rightarrow \infty$).

d) Additional task: Determine the bending moment distribution with the help of the Trost method, considering creep effects at the points in time $t_{120} = 120$ and $t_{5y} = 5$ years. The aging factor can be assumed constant with $\mu = 0.8$.

3 Literature

[1] Swiss society of engineers and architects (SIA), standards: SIA 262 Concrete Structures, 2013

Appendix A – General overview

Stage 1 with loading

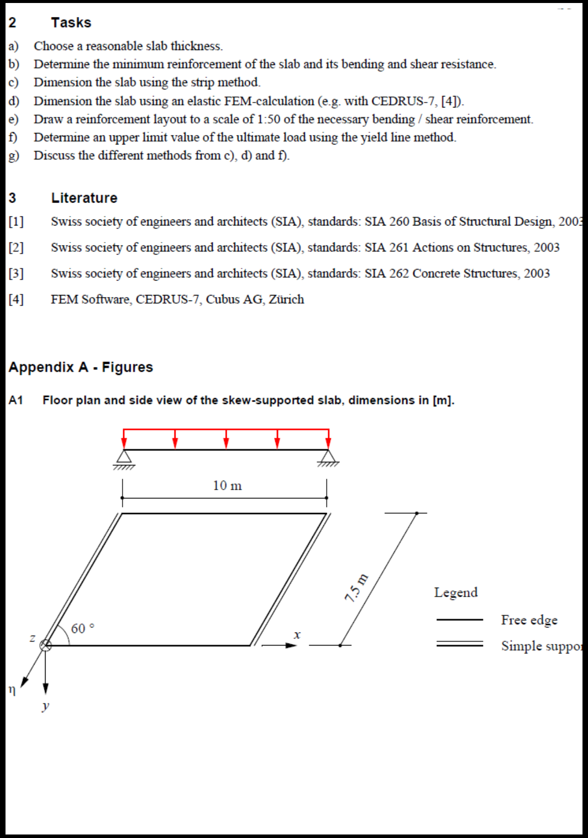
Stage 2 with additional loading

Stage 3 with additional loading

Final state with loading

Long term effects

Exercise 4



2 Tasks

a) Choose a reasonable slab thickness.
b) Determine the minimum reinforcement of the slab and its bending and shear resistance.
c) Dimension the slab using the strip method.
d) Dimension the slab using an elastic FEM-calculation (e.g. with CEDRUS-7, [4]).
e) Draw a reinforcement layout to a scale of 1:50 of the necessary bending / shear reinforcement.
f) Determine an upper limit value of the ultimate load using the yield line method.
g) Discuss the different methods from c), d) and f).

3 Literature

[1] Swiss society of engineers and architects (SIA), standards: SIA 260 Basis of Structural Design, 2003
[2] Swiss society of engineers and architects (SIA), standards: SIA 261 Actions on Structures, 2003
[3] Swiss society of engineers and architects (SIA), standards: SIA 262 Concrete Structures, 2003
[4] FEM Software, CEDRUS-7, Cubus AG, Zürich

Appendix A - Figures

A1 Floor plan and side view of the skew-supported slab, dimensions in [m].

Slabs