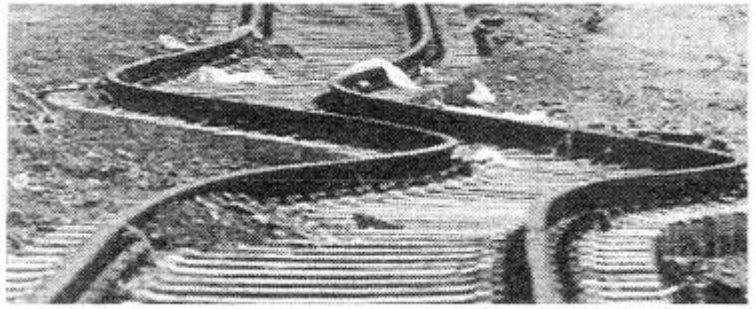
CIV-E4100 Stability of Structures
Opening Lecture
26.2.2024

D.Sc. Joonas Jaaranen, University Teacher

Motivation





To avoid failures…

…we need to analyse properly…

…and design accordingly.

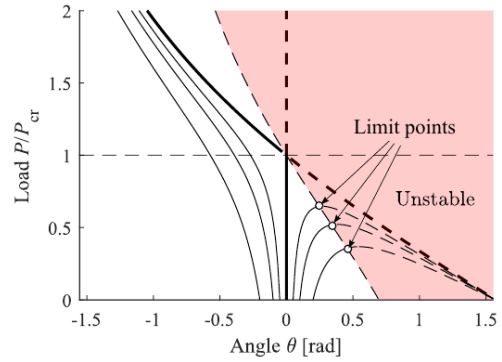
Learning objectives

After finishing the course, the student:

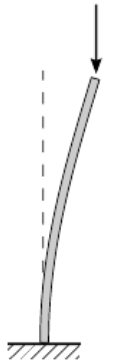
- can apply the theory and concepts of elastic stability to the problems in structural engineering
- can formulate stability problems mathematically
- can apply exact or approximate solution methods and FE-software to solve stability problems
- can utilize literature to extend the skills and knowledge gained during the course

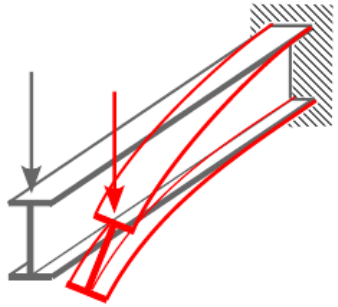
Course content

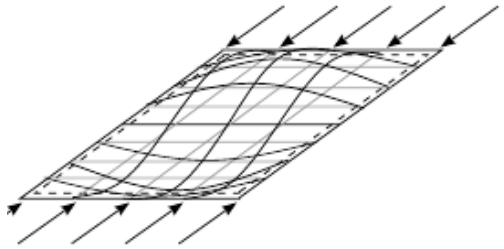
- Theory and concepts of stability of structures: equilibrium, stability, bifurcation, imperfection sensitivity, critical load, post-critical behaviour.
- Governing equations of structural stability problems.
- Exact and approximate solution methods.
- Numerical solutions using finite element methods.
- Flexural buckling.
- Torsional and lateral-torsional buckling.
- Plate buckling.
- Shell buckling basics.



$$\delta\left(\Delta\Pi\right) = \int_0^L EIv''\delta v''\mathrm{d}x - \int_0^L Pv'\delta v'\mathrm{d}x = 0$$







Workload

- Lectures 4 x 6 = 24 h
- Exercise sessions 6 x 6 = 36 h
- Independent work 56 h
- Exam (incl. preparation) 16 + 3 = 19 h

Course overview

Lectures **6 x (2 + 2) h**	**Exercise sessions** **6 x (2 + 2 + 2) h**	**Homework assignments** **1 / week**	**Exams**
Weekly lectures • Monday 10.15-12.00 • Tuesday 10.15-12.00	Weekly exercise sessions • Wednesday 8.15-10.00 • Wednesday/Thursday 16.15-18.00* • Friday 14.15-16.00 • Guidance to homework assignments / examples	Homework assignments • Published each week on previous Sunday • Submission to MyCourses next week Wednesday 23.59 (latest) • Graded 0-20…25 points Homework grade limits • Right to take part in the course exam: total points ≥ 50 % max. total points • Total points ≥ 75%: exam grade upgraded by (+1) for the course grade. Applicable within 2024-2025.	• Course exam 18.4.2024 13.00-16.00 (R1) • Make-up exam 5.6.2024 13.00-16.00 (R1) [Sign-up via sisu.aalto.fi]

*) Day varies, check the weekly schedules

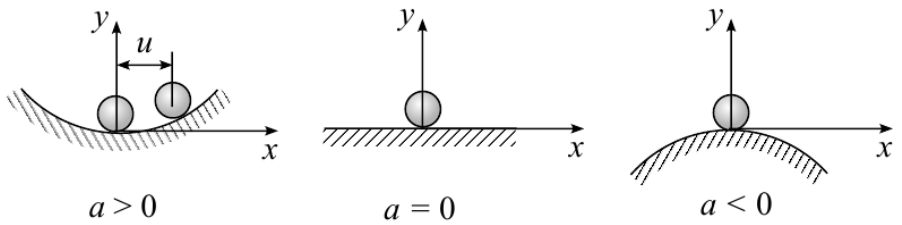
Schedule - overview

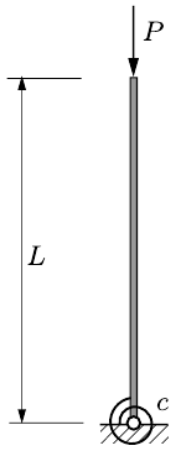
	Week 9 26.2.-3.3.	Week 10 4.3.-10.3.	Week 11 11.3.-17.3.	Week 12 18.3.-24.3.	Week 13-14* 25.3.-7.4.	Week 15 8.4.-14.4.	Week 16 8.4.-14.4.
Lectures (Monday 10-12) (Tuesday 10-12)	- Opening - Concepts - Discrete systems	- Flexural buckling	- Approximate methods - Torsional buckling	- Lateral-torsional buckling	- Plate buckling	- Shell buckling - Recap	Final exam Thu 18.4. 13.00-16.00 R1
Exercise sessions	Guidance HW1 + examples	Guidance HW2 + examples	Guidance HW3 + examples	Guidance HW4 + examples	Guidance HW5 + examples	Guidance HW6 + examples	
Assignment/ **Due date!**	Homework 1 Wed 6.3. 23:59	Homework 2 Wed 13.3. 23:59	Homework 3 Wed 20.3. 23:59	Homework 4 Wed 27.3. 23:59	Homework 5 Wed 10.4. 23:59	Homework 6 Wed 17.4. 23:59	

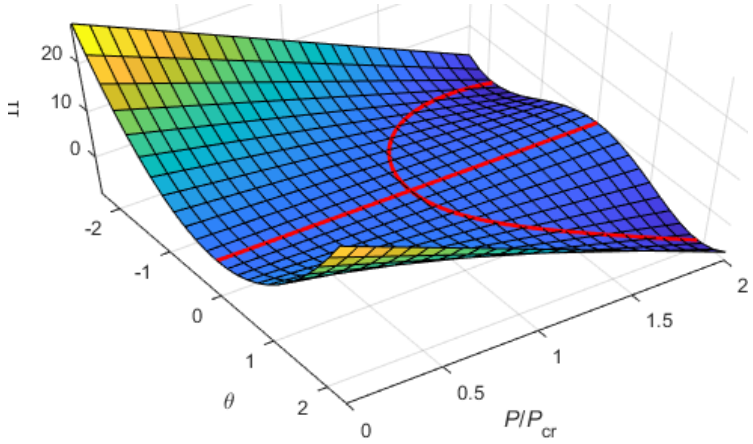
*) Weeks 13-14: Easter holiday break

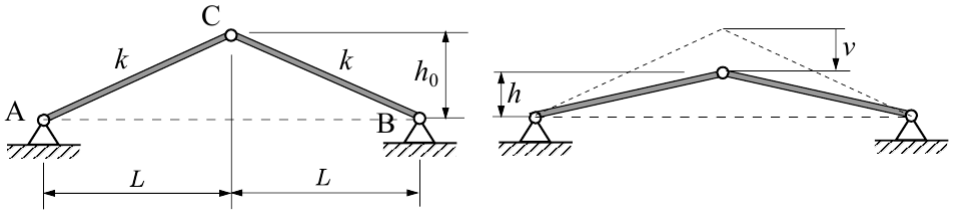
Course content

- Week 1
- Basic concepts of stability analysis of mechanical systems
- Energy approach for stability analysis: concepts, calculus of variations, stationarity condition, stability conditions
- Analysis of discrete systems:
  - Perfect system
  - Imperfect system
  - Linearization
  - Multi-degree-of-freedom system
- Bifurcation and limit point, critical load, imperfection sensitivity





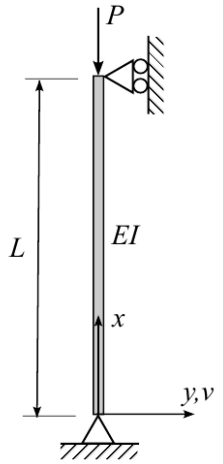


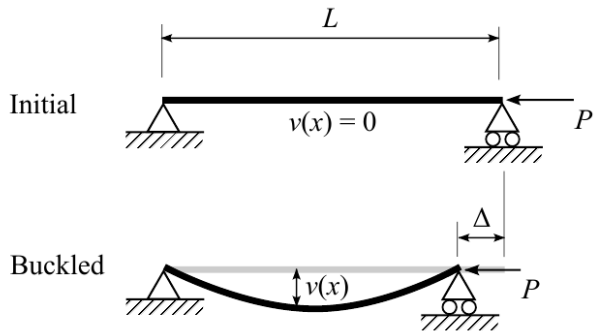


Course content

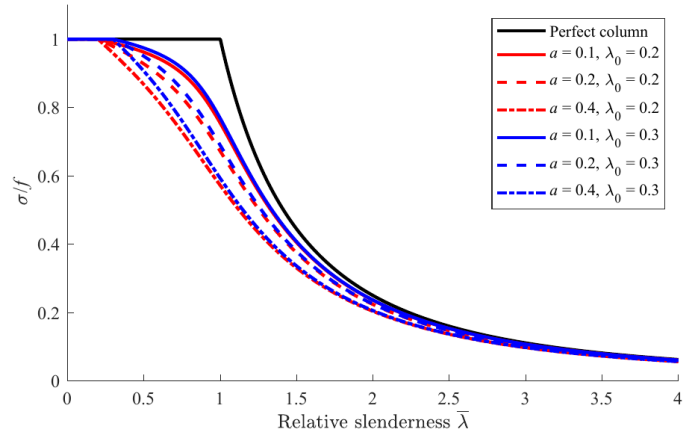
Week 2

- Governing differential equations for columns
- Critical load and mode shapes (perfect Euler columns)
- Effect of imperfections
- Columns on elastic foundation or with elastic supports
- Post-critical behaviour





$$P_{\mathrm{cr}} = \frac{\pi^2 EI}{L^2}$$

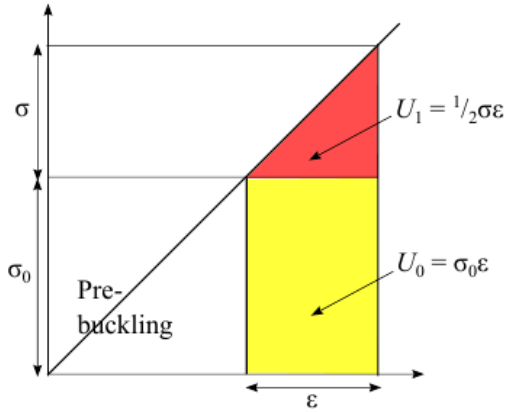


Course content

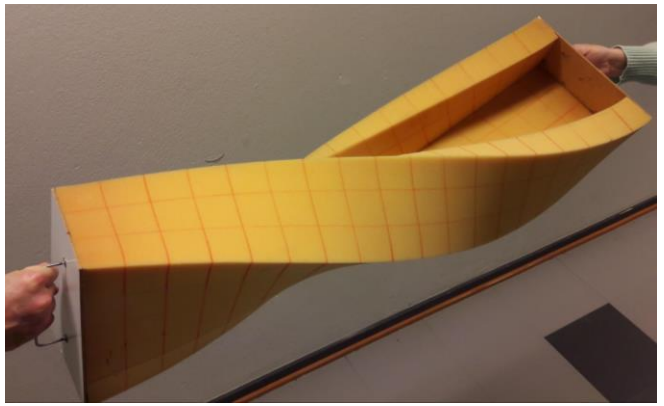
Week 3

- Approximate solution methods; Rayleigh-Ritz method
- Different forms of energy criteria

$$\sum_{j=1}^{N}\left(\int_0^L EI\phi_i''\phi_j''\mathrm{d}x - P\int_0^L \phi_i'\phi_j'\mathrm{d}x\right)c_j = 0$$



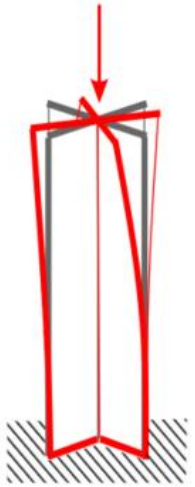
- Torsion of beams
  - St. Venant torsion and Vlasov torsion
  - Kinematics, internal forces, cross-section properties, notation



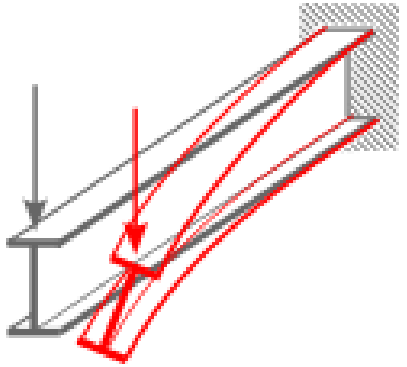
Course content

Week 4

- Torsional buckling
  - Differential equations and boundary conditions
  - Solution methods



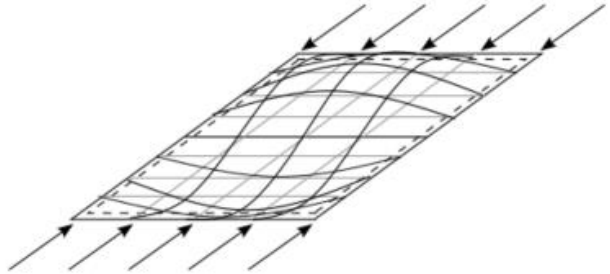
- Lateral torsional buckling
  - Differential equations and boundary conditions
  - Solutions methods

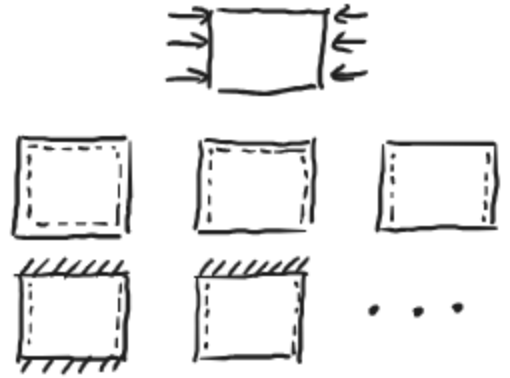


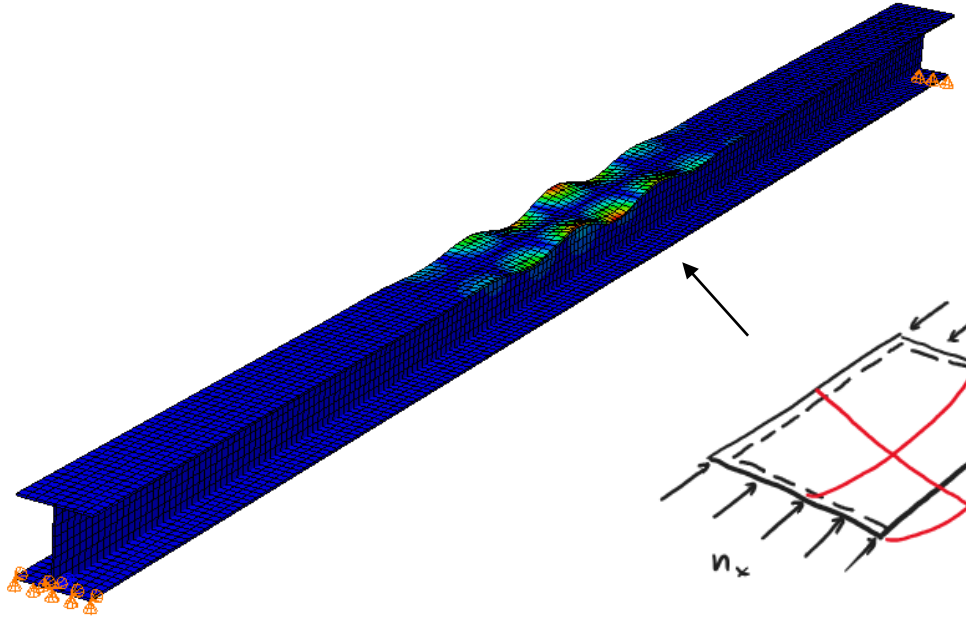
Course content

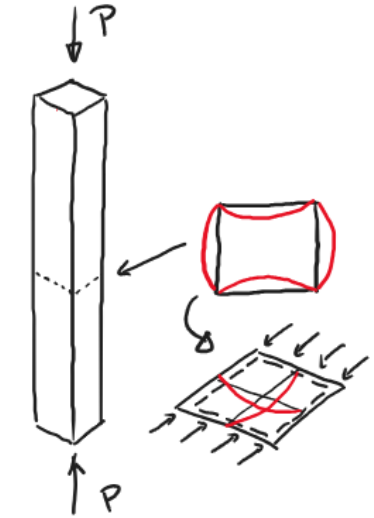
Week 5

- Governing equations of plate buckling
- Solutions for basic cases
- Approximate solutions
- Local buckling in structural members





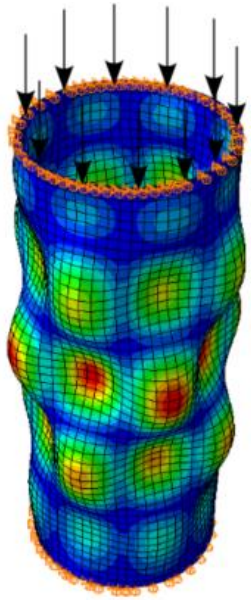




Course content*
Week 6

- Buckling of cylindrical shells
- Critical load
- Post-critical behaviour
- Imperfection sensitivity
- Other aspects

Buckled wine tanks.
https://shellbuckling.com



Buckling of a soda can. https://www.youtube.com/watch?v=AXSG3q1Jqp0

- Preparation for the exam

Literature

- Yoo, Chai Hong, and Sung Chil Lee. Stability of Structures: Principles and Applications. Amsterdam; Butterworth-Heinemann, 2011. **[Course book]** E-version available in Aalto Library: https://primo.aalto.fi/permalink/358AALTO_INST/ha1cg5/alma999087064406526
- Timoshenko, Stephen, and James M. Gere. Theory of Elastic Stability. 2nd ed., Dover ed. Mineola, N.Y: Dover Publications, 2009. E-version available in Aalto Library: https://primo.aalto.fi/permalink/358AALTO_INST/ha1cg5/alma999103404406526
- Galambos, T. V. (Theodore V.), and Andrea Eden Surovek. Structural Stability of Steel: Concepts and Applications for Structural Engineers. Hoboken, N.J: John Wiley & Sons, 2008. E-version available in Aalto Library: https://primo.aalto.fi/permalink/358AALTO_INST/ha1cg5/alma999069624406526
- Eslami, M. Reza (Mohamad Reza). Buckling and Postbuckling of Beams, Plates, and Shells. Cham: Springer, 2018. E-version available in Aalto Library: https://primo.aalto.fi/permalink/358AALTO_INST/ha1cg5/alma999162354406526
- Markku Tuomala. Rakenteiden stabiilisuusteoria, luentomoniste. [In Finnish] http://rmseura.tkk.fi/opetusmonisteita/Tuomala_Rakenteiden_stabiilius_luentomoniste.pdf
- Zdenek P. Bazant and Luigi Cedolin. Stability of structures: Elastic, inelastic, fracture and damage theories. World Scientific, 2010.
- N. A. Alfutov. Stability of Elastic Structures. Springer, 2000

Schedule

Week 9

	Mon 26.2.	Tue 27.2.	Wed 28.2.	Thu 29.2.	Fri 1.3.
8-10			Exercise (R2)		
10-12	Lecture (266)	Lecture (R266)			
12-14					
14-16					Exercise (R2)
16-18			Exercise (266)		
18-20					

Schedule

Week 10

	Mon 4.3.	Tue 5.3.	Wed 6.3.	Thu 7.3.	Fri 8.3.
8-10			Exercise (R2)		
10-12	Lecture (266)	Lecture (266)			
12-14					
14-16					Exercise (R2)
16-18			Exercise (TBA)		
18-20					

Schedule

Week 11

	Mon 11.3.	**Tue 12.3.**	**Wed 13.3.**	**Thu 14.3.**	**Fri 15.3.**
8-10			Exercise (R2)		
10-12	Lecture (266)	Lecture (266)			
12-14					
14-16					Exercise (R2)
16-18				Exercise (266)	
18-20					

Schedule

Week 12

	Mon 18.3.	Tue 19.3.	Wed 20.3.	Thu 21.3.	Fri 22.3.
8-10			Exercise (R2)		
10-12	Lecture (266)	Lecture (266)			
12-14					
14-16					Exercise (R2)
16-18				Exercise (266)	
18-20					

Schedule

Week 13

	Mon 25.3.	Tue 26.3.	Wed 27.3.	Thu 28.3.	Fri 29.3.
8-10			Exercise (R2)	No teaching	Easter
10-12	Lecture (266)	Lecture (266)			
12-14					
14-16					
16-18					
18-20					

Schedule

Week 14

	Mon 1.4.	Tue 2.4.	Wed 3.4.	Thu 4.4.	Fri 5.4.
8-10	Easter	No teaching			
10-12					
12-14					
14-16					Exercise (R2)
16-18				Exercise (TBA)	
18-20					

Schedule

Week 15

	Mon 8.4.	Tue 9.4.	Wed 10.4.	Thu 11.4.	Fri 12.4.
8-10			Exercise (R2)		
10-12	Lecture (266)	Lecture (266)			
12-14					
14-16					Exercise (R2)
16-18			Exercise (266)		
18-20					

Schedule

Week 16

	Mon 15.4.	Tue 16.4.	Wed 17.4.	Thu 18.4.	Fri 19.4.
8-10					
10-12					
12-13					
13-14				Exam 13-16 (R1)	
14-16					
16-18					
18-20					

Course staff

- **Lectures, responsible teacher**
  - Joonas Jaaranen, joonas.jaaranen@aalto.fi, room 229 (CIV department)
- **Exercise sessions, grading**
  - Ahmad Shahgordi, shahgordi@hotmail.com
  - Gabriel Da Silva Reis, gabriel.dasilvareis@aalto.fi

Requirements

- **Mandatory homework assignments**: ≥ 50% of the max. points grants right to the exam
- **Submision deadlines**: submit each week's homework to MyCourses latest on Wednesday 23:59 during the following week
- **Course grading: 0-5**
  - Final exam graded 0-5
  - Grade upgrade to course grade (+1), if total homework points ≥ 75% of the max. total points

Assignments

- Must be submitted **Wednesday 23:59 next week (latest)** in MyCourses
- Homework tasks for each assignment in MyCourses, published latest in the beginning of the week (Monday morning)
- Submit **a single pdf-file, paper size A4**
- Make the answers clear, ambiguous answers do not score points
- Write clearly, illustrate by drawings when needed
- **There is lot to do: start early, do not leave close to submission deadline!**
- **Participate the exercise sessions; assistants are there to support you**

Software [Computer exercises]

Computer exercises: RFEM 6 (or your own preferred software)

Access options:

1. Access in the computer classes. Check available at campus:
   https://wiki.aalto.fi/pages/viewpage.action?spaceKey=AaltoWin&title=Aalto+IT+Windows+Classroom+Software+list

2. Remote use of classroom computers, instructions: MyCourses → RFEM instructions

3. Installation on a personal computer, instructions: MyCourses → RFEM instructions

End of opening lecture

Questions?