# Rock Tunneling

Ben-Gurion University of the Negev
Dept. of Geological and Environmental Sciences

**Instructor:** **Prof. Yossi Hatzor**
Course no.: 206-2-3861
Class Room: Bldg. C-58, Room 018
Day and Time: Wednesday, 12:00 – 14:00
Office hours: C-58, Room 019, Tuesday 14:00 – 15:00 (please coordinate before you come).
TA's: Doron Morad, Bldg. 60, Room 009
Yair Gordin, Bldg. 60, Room 008

## Course Outline

**Lecture No. 1, Oct. 30, 2019: Basic Concepts**

- Ground Reaction Curve
- Principles of the New Austrian Tunneling Method (NATM)
- Terzaghi's Rock Load Classification
- Lauffer's Stand Up Time Classification
- Case study – Numerical determination of minimum rock cover for stability in tunnels through horizontally layered and vertically jointed rock masses.

**Lecture No. 2, Nov. 6, 2019: Significance of Rock Discontinuities**

- Scales of rock discontinuities
- Relationship between project scale and scales of discontinuities
- Examples of structural failures dictated by rock discontinuities
- Sources of rock discontinuities
- Surface conditions of rock discontinuities and influence on shear strength – basic concepts only

**Lecture No. 3, Nov. 13, 2019: Geological Engineering Description of Rock Masses**

- Mean spacing
- Rock bridge
- Mean block size
- Number of joint sets
- Orientation of joint sets
- Performance of a joint survey in the field
- Case study – Numerical analysis of the stability of Ayalon cave, Nesher quarry, Ramleh.

**Special Lecture –Tuesday Nov. 19, 2019, 14:00 – 16:00: Main challenges of TBM excavation under high water pressure. Guest Lecturer by Dr. Roberto Scuerch, PINI Swiss.**
*The goal of the lecture is to give an overview of the main challenges related to TBM excavation under high water pressure. After a theoretical introduction about the origin and the assessment of the hazards, the lecture will focus on two case studies: the construction of the Lake Mead Intake tunnel No. 3 and the construction of the 3RPORT Tunnel, both projects located in the USA.*

**Lecture No. 4, Nov. 20, 2019: Empirical Rock Mass Classifications**

- Deer's rock strength and deformability classification
- Deer's Rock quality designation - RQD
- Bianiawski's Rock mass rating - RMR
- Barton's Q rating method
- Case study – Lessons from the Giloh tunnels, Jerusalem

⇒ Computer class C-58, Room 122, Nov. 20, 2019 14:00 – 15:00. Training on program "RocData 5.0" for homework assignments 1-3.

⇒ Homework assignment no. 1 – Empirical Rock Mass Classifications

**Lecture No. 5, Nov. 27, 2019: Strength of intact rock**

- Griffith's failure criterion
- Coulomb – Mohr failure criterion
- Bianiawski's failure criterion for intact rocks
- Hoek and Brown's failure criterion for intact rocks

⇒ Homework assignment no. 2 – Strength of Intact Rock

**Lecture No. 6, Dec. 4, 2019: Strength and deformability of rock masses**

- Hoek and Brown's criterion for rock masses
- Hoek and Brown's Geological Strength Index – GSI
- Empirical correlations for rock mass elastic parameters
- Field determination of rock mass elastic parameters
- Determining elastic parameters of the rock mass by inversion using numerical methods
- Case study – Strength and deformability of principal rock units in Israel

⇒ Homework assignment no. 3 – Strength and deformability of rock masses

**Lecture No. 7, Dec. 11, 2019: Relevant analytical solutions from theory of elasticity**

- Quick review of stress, strain, plane strain, plane stress
- Stress distribution around thick walled cylinders
- Stress distribution around circular opening – Kirsch solution
- Zone of influence between adjacent tunnels
- Case study – Stability of the bell shaped caverns at Bet Guvrin
- Case study – Stress inversion from displacement monitoring at the 2500 m deep tunnels of Jinping hydroelectric project in Sichuan, China.

⇒ Computer class C-58, Room 122, Dec. 11, 2019 14:00 – 15:00. Training on program "RS2 9.0" for homework assignment 4.

⇒ Homework assignment no. 4 – Kirsch solution

**Lecture No. 8, Dec. 18, 2019: Influence of discontinuities on stress distribution**

**Lecture No. 9, Dec. 25, 2019: Arching mechanisms in the roof (Voussoir Beam Analogue)**

- Main structural elements around underground openings
- Rock mass response to tunneling, difference between thinly and thickly bedded strata
- Deformation mechanisms in the roof – lab experiments and physical models
- Statics of the bending of a horizonal layer in the roof – the Voussoir analogue
- Factors of safety against shear along abutments, axial crushing, and buckling
- Case study – Roof stability in Tel Beer Sheva underground cambers
- Case study – Roof stability in Zedekyah underground quarries, Jerusalem.

⇒ Homework assignment no. 6: The Voussoir beam

**Lecture No. 10, Jan. 1, 2020: Introduction to Block Theory**

- Brief review of the stereographic projection
- The whole stereographic projection
- Upper and lower half spaces of an infinite plane
- Lines of intersection between planes
- The joint pyramid
- Shi's theorem of removability

**Lecture No. 11, Jan. 8, 2020: Hands-on computer lab on Block Theory (C-58, Room 122)**

⇒ Homework assignment no. 7 – Block Theory

**Lecture No. 12, Jan. 15, 2020: Principals of rock bolting**

- T. A. Lang's design criteria for rock bolting
- Laboratory verifications of Lang's approach
- Lang and Bishop solution for layered rocks
- Types and characteristics of rock bolts
- Rock anchors
- Case study – Rock bolting through columnar basalts: the case of Baihetam hydropower station, Sichuan/Yunnan provinces, China.

○ Computer class C-58, Room 122, January 15, 2020 14:00 – 15:00. Program "RocSupport 4.0" for homework assignments 4.

⇒ Homework assignment no. 8: Rock bolt design for underground openings in horizontally layered rock masses

**Field Trip: Thursday January 16, 2020. Kokhav Hayarden Pumped Storage Station.**

**Midterm Exam: 22, January 2019. In Class (C-58, Room 018) 12:00 – 14:00.**

**Rules of the Game:**

- Class attendance is highly recommended
- All homework assignments must be submitted by the published due date
- HW assignments can be submitted in groups of two students.
- Attendance in field trip is mandatory – it is not possible to gain credit for this class without attending the field trip and submitting the field report.
- Submission of field report is mandatory, it can be submitted in groups of two.
- Grading:
    - HW Assignments 60%
    - Field trip report 20%
    - Midterm exam 20%

**Recommended texts:**


Brady, B. H. G. and Brown, E. T., 2004. *Rock Mechanics For Underground Mining*, 3rd ed.,Klumer Academic Publications. 628p.

Goodman, R. E., 1989. *Introduction to Rock Mechanics*, 2nd ed., John Wiley & Sons, New York, 562 p.

Hoek, E. and Brown, E. T., 1980. *Underground Excavation in Rock*. The Institution of Mining and Metallurgy, London, 527 p.

Hoek, E., Kaiser, P. K., and Bawden, W. F., 1995. *Support of Underground Excavation in Hard Rock*. A. A. Balkema, Rotterdam, 215p.

Hudson, J. A. and Harrison, J. P. 1997. *Engineering rock mechanics, an introduction to the principles*. Pergamon, Elsevier Sciences Ltd. Oxford.

Jaeger, J. C., and Cook, N. G. W. Fundamentals of Rock Mechanics. Chapman and Hall, London, 3rd Ed., 1979.

Mahtab, M. A. and Grasso, P. 1992. *Geomechanics Principles in the Design of Tunnels and Caverns in Rock*. Elsevier, Amsterdam, 250p.

Obert, L. and Duvall, W. I. 1967. *Rock Mechanics and the Design of Structures in Rock*. John Wiley and Sons Inc. New York, 650p.

Wittke, W., 1990. *Rock Mechanics: Theory and Applications with Case Studies*. Springer-Verlag, Berlin, 1075 p.


Enjoy!