Useful numbers for geotechnical Engineers

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1 Introduction

This document contains some typical mechanical, thermal and hydraulical parameters of rock and soil material. In addition also a few parameters for construction materials typically used in civil engineering are given. If not otherwise mentioned the numbers refer to intact and dry rock or soil samples tested in the lab under room temperature.

Please note:

- **The given date are obtained by literature review and own test results.**
- **The data refer to undisturbed (undamaged) material.**
- **The data cover the typical range, exceptions are possible.**
- **Use of these data will never replace individual parameter determination.**
- **Note, that results (obtained parmeters) depend to some extent on test procedure and applied standards.**

There are specific data base available (open access) for rockmechanical / petrophyiscal data, like the P^3-data base (Bär et al. 2020), Weinert et al. (2020) or EMI (Kim & Hunt, 2017).

Older standard books or publications might also be helpful, like those published by Schön (1983, 1996), Lama & Vutukuri (1978) or Waples & Waples (2004). They show also correlations between parameters and dependence on stress and environmental conditions.

2 Useful numbers

2.1 Density and porosity

Density (dry)		
Material	**Density [kg/m^3]**	**Remark**
Sandy soil	1800	
Gravel soil	2000	
Silty soil	2100	
Clay soil	1900	
Igneous rocks	2700 - 3000	
Metamorphic rocks	2700	
Sedimentary rocks	2600	
Rock salt	2500 - 2600	
Coal	1100 - 1400	
Steel	7850 - 8050	
Glas	2400 - 2600	
Wood	200 - 1000	
Concrete	1750 - 2400	

Porosity (mainly open porosity)		
Material	**Porosity [%]**	**Remark**
Sand	20 - 35	
Gravel	30 - 40	
Silt	35 – 50	
Clay	30 - 60	
Stiff clay	0.1 – 0.4	
Very stiff clay	0.4 – 0.8	
Hard clay	0.8 – 2.0	
Silt	0.05 – 0.1	
Sandstone	5 – 30	
Limestone	5 – 30	
Shale	10 - 30	
Slate	0.1 – 0.5	
Marble	0.5 – 2	
Granite	0.5 – 1.5	
Gabbro	0.1 – 0.2	
Diabase	0.1 – 0.5	
Gneiss	0.5 – 1.5	
Basalt	0.1 - 1.0	
Quartzite	0.1 – 0.5	
Salt	0.5 - 5	
Steel	1 - 10	only part is accessible by water
Concrete	1 - 50	only part is accessible by water

2.2 Elastic constants

Young's moduls (= elastic modulus)		
Material	**Young's modulus [GPa]**	**Remark**
Loose sand	0.01 – 0.03	
Dense sand	0.03 – 0.07	
Soft clay	0.001 – 0.003	
Hard clay	0.006 – 0.014	
Sandstone	5 – 50	
Shale	5 – 70	
Limestone	15 – 70	
Marble	30 – 70	
Granite	20 - 70	
Quartzite	50 - 90	
Gneiss	30 – 80	
Basalt	40 - 80	
Steel	~ 200	Note plastic behavior
Glass	~ 70	
Wood	6 - 15	
Concrete	15 - 30	

Poisson ratio		
Material	**Poisson ratio [/]**	**Remark**
Sand	0.2 – 0.4	
Sandstone	0.2 – 0.4	
Shale	0.2 – 0.4	
Limestone	0.2 – 0.35	
Marble	0.1 – 0.3	
Granite	0.1 – 0.2	
Basalt	0.1 – 0.2	
Shale	0.1 – 0.2	
Dolomite	0.1 – 0.2	
Gabbro	0.2 – 0.35	
Schist	0.15 - 0.25	
Steel	0.26 – 0.3	Note plastic behavior
Glass	0.2 – 0.3	
Wood	6 - 15	
Concrete	0.1 – 0.2	

2.3 Strength parameters

Friction angle = angel of internal friction = arctan(friction coefficient) = peak friction angle		
Material	**Friction angle [°]**	**Remark**
Sand	30 - 40	
Loose sand	30 – 35	
Medium sand	40	
Dense sand	35 – 45	
Gravel	35	
Silt	26 - 35	
Clay	20	
Shale	18 - 25	
Slate	25 - 30	
Granite	40 - 55	
Limestone	27 - 37	
Gneis	25 - 30	
Sandstone	30 - 35	
Basalt	30 - 40	
Fault / fracture	20 - 35	Interface/contact friction
Fracture / fault fillings	5 - 30	Interface/contact friction
Glass on glass	~ 22	Interface/contact friction
Rubber on concrete	~ 37	Interface/contact friction
Steel on steel	17 - 30	Interface/contact friction
Sand on steel	20 - 40	Interface/contact friction

Cohesion (according to MC law) = peak cohesion		
Material	**Cohesion [MPa]**	**Remark**
Silt	0.075	
Very soft clay	0 – 0.05	
Soft clay	0.05 – 0.1	
Medium clay	0.1 – 0.2	
Stiff clay	0.1 – 0.4	
Very stiff clay	0.4 – 0.8	
Hard clay	0.8 – 2.0	
Silt	0.05 – 0.1	
Granite	20 - 50	
Sandstone	20 - 35	
Fault / fracture fillings	0 – 0.3	
Steel	~ 250	Note plastic behavior

Uniaxial compressive strength (= UCS)		
Material	**UCS [MPa]**	**Remark**
Soft soil	0.01 – 0.1	
Hard soil	0.2 – 1.0	
Sand	0	
Sandstone	20 - 170	
Shale	50 - 200	
Limestone	30 - 250	
Marble	35 – 60	
Granite	50 - 250	
Basalt	100 - 300	
Quartzite	150 - 300	
Steel	400 - 900	Note plastic behavior
Glass	~ 1000	
Wood	~ 5	
Concrete	15 - 70	

Uniaxial tensile strength (= UTS)		
Material	**UTS [MPa]**	**Remark**
Soft soil	0.0001	
Hard soil	0.01	
Sand	0	
Sandstone	1 - 15	
Shale	5 - 20	
Limestone	10 - 20	
Marble	5 - 10	
Granite	6 - 15	
Basalt	15 - 25	
Steel	400 – 900	Note plastic behavior
Glass	40 - 200	
Wood	1.5 – 6.5	
Concrete	1.5 – 5	

Fracture toughness K_{IC} (Mode-I)		
Material	**K_{IC} [MPa·m$^{0.5}$]**	**Remark**
Granite	1.5 – 2.5	
Limestone	1	
Tuff	1 – 2	
Sandstone	1 - 2	
Gabbro	2.5 – 3.3	
Marble	1.5 – 2.5	
Basalt	1.5 - 3	
Diorite	3 - 3.5	
Concrete	1 - 2	depending of concrete type

Fracture toughness K_{IIC} (Mode-II)		
Material	**K_{IC} [MPa·m$^{0.5}$]**	**Remark**
Granite	4 – 5	
Marbel	3	
Limestone	2 – 3	
Sandstone	2 - 3	
Diorite	4 - 5	
Concrete	3 - 5	depending of concrete type

2.4 Elastic wave velocities

Compressional wave velocity (= P-wave velocity)		
Material	**P-wave velocity [m/s]**	**Remark**
Sand	200 - 1000	
Clay	600 - 1800	
Sandstone	3000 - 6000	
Shale	1400 - 3000	
Limestone	3500 - 6000	
Marble	3500 - 6000	
Salt	4500 - 5000	
Granite	3000 - 6000	
Basalt	4500 - 6500	
Quartzite	5000 - 6500	
Gabbro	6500 - 7000	
Coal	2200 - 2700	
Steel/Iron	5800 - 6200	
Glass	4600 - 5200	
Concrete	3000 - 3900	
Ice	3000 - 4000	
Air	320 - 340	
Water	1450 - 1500	
Oil	~ 1300	

Shear wave velocity (= S-wave velocity)		
Material	**S-wave velocity [m/s]**	**Remark**
Sand	100 - 200	
Clay	150 - 500	
Sandstone	1500 - 4000	
Shale	1000 - 2600	
Limestone	3000 -3500	
Marble	2000 - 4000	
Salt	2500 - 3100	
Granite	3400 - 3600	
Basalt	2000 - 4000	
Quartzite	3500 - 5000	
Coal	1000 - 1400	
Steel/Iron	3100 - 3300	
Glass	2100 - 2300	
Concrete	1800 - 2300	
Ice	3000 - 4000	
Air	320 - 340	
Water	0	Not existing: shear strength zero
Oil	0	Not existing: shear strength zero

2.5 Hydraulic parameters

Hydraulic conductivity (laminar Darcy flow, water)		
Material	**Hydraulic conductivity [m/s]**	**Remark**
Sand	1e-5 – 1e-2	
Gravel	1e-2 – 1e-1	
Clay	1e-11 – 1e-8	
Silt	1e-10 - 1e-5	
Sandstone	1e-9 – 1e-6	
Limestone	1e-10 – 5e-7	
Anhydrite	1e-13 – 1e-8	
Shale	1e-14 - 1e-12	
Slate	1e-13 – 1e-10	
Granite	~ 3e-10	
Gabbro	1e-11 – 1e-7	
Gneiss	~ 2e-9	
Basalt	1e-11 - 1e-7	
Quartzite	1e-12 – 1e-9	
Rock salt	1e-14 - 1e-8	
Concrete	1e-14 – 1e-8	

Permeability		
Material	**Permeability [m^2]**	**Remark**
Sand	1e-13 – 1e-9	
Gravel	1e-10 – 1e-7	
Clay	1e-20 – 1e-15	
Sandstone	1e-17 – 1e-13	
Limestone	1e-16 – 5e-13	
Basalt	1e-18 - 1e-10	
Granite	1e-20 – 1e-17	
Gneiss	1e-20 – 1e-16	
Rock salt	1e-24 _ 1e-18	
Concrete	1e-18 – 1e-15	

Porosity		
Material	**Porosity [%]**	**Remark**
Sand	30 - 50	
Gravel	30 – 50	
Clay	33 – 60	
Silt	35 - 50	
Sandstone	10 - 25	Intact rock matrix
Limestone	2 – 20	Intact rock matrix
Anhydrite	1 - 15	Intact rock matrix
Shale	1 - 10	Intact rock matrix
Slate	0.1 - 2	Intact rock matrix
Granite	1 - 3	Intact rock matrix
Gabbro	1 - 4	Intact rock matrix
Gneiss	0.5 – 2	Intact rock matrix
Basalt	0.5 - 3	Intact rock matrix
Quartzite	0.5 – 5	Intact rock matrix
Salt	1 - 4	Intact rock matrix
Concrete	3 - 70	Intact matrix

2.6 Thermal parameters

Volumetric thermal expansion coefficient		
Material	**Expansion coefficient [/K]**	**Remark**
Sand	(8 – 12) e-6	
Sandstone	(8 - 12) e-6	
Limestone	(3 - 10) e-6	
Slate	(8 – 10) e-6	
Granite	(6 – 10) e-6	
Gneiss	(8 – 10) e-6	
Basalt	(4 – 6) e-6	
Quartzite	(10 – 30) e-6	
Salt	(1000 – 1200) e-6	
Concrete	(8 – 12) e-6	
Ice	51e-6	at 0°C
Water	200e-6	at 20°C
Air	3400e-6	at 20°C
Steel	(3 – 4) e-5	at 20°C

Specific heat		
Material	**Specific heat [J/(kg·K)]**	**Remark**
Sand	1000 – 2000	
Sandstone	200 - 1000	
Limestone	800 – 1000	
Shale	600 – 700	
Slate	700 - 1200	
Granite	600 - 1200	
Gabbro	700 - 1000	
Gneiss	700 - 1200	
Basalt	800 - 1000	
Quartzite	700 - 1000	
Coal	1000 - 1400	
Salt	800 - 900	
Concrete	1000 - 2700	at 20°C
Ice	2040	at 0°C
Water	4200	at 20°C
Air	1000	at 20°C
Steel	500	at 20°C

Thermal conductivity		
Material	**Thermal conductivity [W/(m·K)]**	**Remark**
Sand	0.2 – 2	
Clay	1.5 - 2	
Sandstone	1 - 2	
Limestone	1 – 1.5	
Shale	1 – 2	
Slate	1 - 2	
Granite	1.5 - 4	
Basalt	1.7 - 2	
Coal	0.5 - 1	
Gneiss	2 – 3.5	
Quartzite	5 - 8	
Salt	5 - 6	
Coal	0.15 - 0.2	
Concrete	0.2 - 5	
Ice	2.2	at 0°C
Water	0.6	at 20°C
Air	0.024	at 20°C
Steel	20 - 50	at 20°C

3 Literature

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