

Uniaxial compressive strength ( $\sigma_c$ ) and deformation modulus of rocks

Average values from tests of intact rock samples		Tests of rocks world-wide				Scandinavian rocks tested at SINTEF				
		$\sigma_c$ MPa	E GPa	E / $\sigma_c$	Number of tests	$\sigma_c$ MPa	E GPa	E / $\sigma_c$	Number of tests	
ROCK										
Crystalline texture	Dolomite	86	38	443	8	110	49	443	2	
	Limestone	107	47	441	81	74	71	961	25	
	Marble	133	63	474	20	66	71	1074	4	
	Greenschist	-	-	-	-	93	44	472	3	
	Clay schist / -stone	68	38	563	2	40	21	537	6	
	Micaschist	104	39	374	16	71	30	422	21	
	Gneiss	130	53	406	27	130	50	385	107	
	Micagneiss	-	-	-	-	89	29	330	5	
	Granitic gneiss	-	-	-	-	89	29	330	5	
	Granulite	90	41	451	4	-	-	-	-	
	Amphibolite	212	101	474	7	107	70	660	16	
	Greenstone	281	101	359	1	105	53	503	7	
	Quartzite	209	58	276	28	172	56	328	7	
	Anorthosite	228	90	395	2	157	86	545	2	
	Diorite	173	64	368	6	130	52	403	6	
	Gneissgranite	-	-	-	-	117	42	354	5	
	Granite	154	48	313	71	169	42	250	20	
	Granodiorite	160	51	319	2	171	20	118	2	
	Gabbro	228	106	466	5	248	76	306	1	
	Norite	229	82	356	8	-	-	-	-	
	Olivinestone	-	-	-	-	87	113	1307	5	
	Peridotite	197	55	280	1	109	164	1502	1	
	Monzonite	110	28	256	8	106	61	580	4	
Andesite	152	31	206	6	-	-	-	-		
Basalt	145	50	347	25	207	82	395	3		
Diabase, dolerite	229	88	384	13	152	81	537	5		
Hyperite	-	-	-	-	245	108	441	2		
Clastic texture	Graywacke	81	25	310	12	-	-	-	-	
	Sandstone	109	28	257	95	147	28	189	5	
	Siltstone	89	31	350	14	-	-	-	-	
Very fine-grained rocks	Hornfels	111	74	668	3	-	-	-	-	
	Claystone	5	2	301	2	-	-	-	-	
	Phyllite	39	26	672	4	61	46	756	12	
	Chalk	1	2	1606	2	-	-	-	-	
	Marl, marlstone	17	2	133	9	-	-	-	-	
	Mudstone	11	1	106	4	-	-	-	-	
	Claystone	5	2	301	2	-	-	-	-	
<b>Organic rocks - coal</b>		30	3	107	14	-	-	-	-	
Sum of tests =					502	Sum of tests =				281

Uniaxial compressive strength ( $\sigma_c$ ), E-modulus and the factor  $m_i$  in the Hoek-Brown failure criterion for rock masses

Average values from tests of intact rock samples		Tests of rocks world-wide*				Scandinavian rocks tested at SINTEF / NTNU ***				Rating of the factor $m_i$ **
		$\sigma_c$ MPa	E GPa	E / $\sigma_c$	Number of tests	$\sigma_c$ MPa	E GPa	E / $\sigma_c$	Number of tests	
ROCK										
Crystalline texture	Dolomite	86	38	443	8	110	49	443	2	10.1
	Limestone	107	47	441	81	74	71	961	25	8.4
	Marble	133	63	474	20	66	71	1074	4	9.3
	Greenschist	-	-	-	-	93	44	472	3	
	Clay schist / -stone	68	38	563	2	40	21	537	6	
	Micaschist	104	39	374	16	71	30	422	21	15?
	Gneiss	130	53	406	27	130	50	385	107	29.2
	Micagneiss	-	-	-	-	89	29	330	5	30?
	Granitic gneiss	-	-	-	-	89	29	330	5	30?
	Granulite	90	41	451	4	-	-	-	-	
	Amphibolite	212	101	474	7	107	70	660	16	31.2
	Greenstone	281	101	359	1	105	53	503	7	20?
	Quartzite	209	58	276	28	172	56	328	7	23.7
	Anorthosite	228	90	395	2	157	86	545	2	
	Diorite	173	64	368	6	130	52	403	6	27?
	Gneissgranite	-	-	-	-	117	42	354	5	30?
	Granite	154	48	313	71	169	42	250	20	32.7
	Granodiorite	160	51	319	2	171	20	118	2	30?
	Gabbro	228	106	466	5	248	76	306	1	25.8
	Norite	229	82	356	8	-	-	-	-	21.7
	Olivinestone	-	-	-	-	87	113	1307	5	
	Peridotite	197	55	280	1	109	164	1502	1	
	Monzonite	110	28	256	8	106	61	580	4	30?
Andesite	152	31	206	6	-	-	-	-	18.9	
Basalt	145	50	347	25	207	82	395	3	(17)	
Diabase, dolerite	229	88	384	13	152	81	537	5	15.2	
Hyperite	-	-	-	-	245	108	441	2		
Clastic texture	Graywacke	81	25	310	12	-	-	-	-	
	Sandstone	109	28	257	95	147	28	189	5	18.8
	Siltstone	89	31	350	14	-	-	-	-	9.6
Very fine-grained rocks	Hornfels	111	74	668	3	-	-	-	-	
	Claystone	5	2	301	2	-	-	-	-	3.4
	Phyllite	39	26	672	4	61	46	756	12	13?
	Chalk	1	2	1606	2	-	-	-	-	
	Marl, marlstone	17	2	133	9	-	-	-	-	
	Mudstone	11	1	106	4	-	-	-	-	
Organic rocks - coal		30	3	107	14	-	-	-	-	
Sum of tests =					500	Sum of tests =			281	
<b>Soil materials</b> (from ISRM (1978):										
Very soft clay		$\sigma_c = 0.025$ MPa			Stiff clay		$\sigma_c = 0.1 - 0.25$ MPa			
Soft clay		$\sigma_c = 0.025 - 0.05$ MPa			Very stiff clay		$\sigma_c = 0.25 - 0.5$ MPa			
Firm clay		$\sigma_c = 0.05 - 0.1$ MPa			Hard clay		$\sigma_c = 0.5 - 1$ MPa			
Silt, sand (assumed)		$\sigma_c = 0.0001 - 0.001$ MPa								
* Test results mainly from "Handbook of physical properties of rocks and minerals" by R.S. Carmichael (1989); some test results also from Lama and Vutukuri (1978).										
** $m_i$ is the factor for intact rock in the Hoek Brown failure criterion for rock masses. Values in brackets have been estimated by Hoek et al. (1992); values with question mark are assumed by Palmström (1995).										
*** NTNU = Norwegian University of Science and Technology. SINTEF = The Foundation of Scientific and Industrial Research at NTNU.										