Fundamental Properties of Some Norwegian Magmatic and Metamorphic Rocks

Propriétés fondamentales de quelques roches magmatiques et métamorphiques de Norvège

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SUMMARY

To obtain a better knowledge of some fundamental properties of Norwegian rocks, various types of building stones have been examined. The results of these studies to determine permeability, static modulus, dynamic modulus, tensile splitting strength, density, porosity, and swelling are presented in a table.

SOMMAIRE

On a examiné des types différents de pierres de construction pour obtenir une meilleure connaissance de quelques propriétés fondamentales des roches de Norvège. On présente les résultats des essais suivants sous forme de tableau: perméabilité, module statique, module dynamique, résistance à la fente, densité, porosité et gonflement.

IN A PAPER presented at the 1963 Europäische Baugrundtagung (Wiesbaden) Kjærnsli and Sande (1963) have shown that the unconfined compression strengths of some samples of syenite gave higher values than the same rocks when saturated with water, and still higher values than when the saturated sample is submerged. Several investigations as to the elastic properties of rocks have shown an influence upon the elastic moduli as a function of water content (e.g., Judd, 1958).

On the other hand, it is known that the elastic properties depend very much upon the method of measurement. In order to get a picture of some fundamental properties of Norwegian rocks, samples of various types of building stones from some of the best known representatives of the Norwegian quarrying industry have been examined. Normally four selected samples from various parts of each quarry have been examined. Every sample had been carefully examined to avoid cracks and zones of apparent weakness.

The following data have been determined (Table I):

Permeability, k, measured by Geonor apparatus

Static modulus of deformation in dry state, E_{sd}, measured by compression at stress 217 kg/sq.cm.

Dynamic modulus in dry and wet state, E_{Dd} and E_{Dw}, measured by Amber high frequency pulsator

Tensile splitting strength, T, according to ASTM (1962)

Density, porosity, and swelling from dry to saturated state.

Compression strength data of some of the rocks have been

TABLE I. DATA ON FUNDAMENTAL PROPERTIES OF SOME NORWEGIAN ROCKS

Trade name, Locality, Petrographic name		k, permeability, cm/sec $\times 10^{10}$	E_{Sd} Mp/sq.cm.	E_{Dd} Mp/sq.cm.	E_{Dw} Mp/sq.cm.	Crushing strength kp/sq.cm.	T, splitting tensile strength kp/sq.cm.	γ20 C gram/cu cm	Swelling per cent vol.	n, porosity per cent vol.	Mineral composition	Texture
Iddefjord granite	i-I	115									microcline, quartz, plagio-	Hypauto-
Bakke, Østfold	i-II	160	94.7	154	167		109.0	2.642	0.64	0.86	clase, biotite, muscovite	morph
Granite	i-III	170	66.8				87.8	2.646	0.61	0.90	(rather rare), garnet,	granular
	i-IV	120	112.3				94.3	2.643	0.70	0.97	apatite, zircon, magnetite, titanite	
Iddefjord granite	3-I	120				1970/13					microcline, quartz, plagio-	Hypauto-
Skriverøen,	3-II	210	154.2	246	246		93.0	2.642	0.39	0.61	clase, biotite, muscovite	morph
Østfold	3-III	188	159.4	200	192		71.8	2.642	0.46	0.82	(very rare), magnetite,	granular
Granite	3-IV	167	174.0				75.2	2.643	0.17	0.62	garnet, apatite, zircon, epidote, titanite, (kaoline?), sericite, calcite (very rare), chlorite, leukoxene	
Støren granite	S-I	13.7	129.3	281	331		106.8	2.692	0.30	0.76	plagioclase, quartz, micro-	Hypauto-
Støren, South	S-II	21.5	128.3	356	322	2097/3	132.6	2.689	0.23	0.63	cline, biotite, amphi-	morph
Trøndelag	S-III	19.5	156.4	146	131.5		123.8	2.693	0.38	0.76	bole, titanite, zircon,	granular
Tonalite (quartz diorite)	S-IV	16.4	147.7	253	259		127.0	2.690	0.28	0.65	apatite, magnetite, epidote, sericite	
Tolga granite	T-I	45	90.0				91.1	2.672	0.37	0.74	plagioclase, quartz, micro-	Hypauto-
Tolga, Hedmark	T-II	42.6	106.4	185	200		82.4	2.670	0.30	0.67	cline (rare), biotite,	morph
Quartz diorite	T-III	42.2	114.0	179	179		79.8	2.672	0.60	0.96	amphibole, apatite,	granular
(tonalite)	T-IV	47.7	126.4		210		84.4	2.672	0.46	0.67	zircon, magnetite, titanite, zoicite	

TABLE I (*continued*)

Trade name, Locality, Petrographic name		*k*, permeability, cm/sec × 10^{10}	E_{Sd} Mp/sq.cm.	E_{Dd} Mp/sq.cm.	E_{Dw} Mp/sq.cm.	Crushing strength kg/sq.cm.	*T*, splitting tensile strength kg/sq.cm.	γ20 C gram/cu cm	Swelling per cent vol.	*n*, porosity per cent vol.	Mineral composition	Texture
Sognefjord granite	4-I	21.6	179.1	158	156		149.5	2.643	0.44	0.76	plagioclase, quartz, micro-	Hypauto-
Kinsedal	4-II	27.3	157.0	206	207	2772/2	161.8	2.643	0.61	0.92	cline, biotite, muscovite	morph
Granodiorite	4-III	25.0	134.6	124	92		151.0	2.642	0.50	0.79	(very rare), titanite,	granular
	4-IV	21.5	139.3	195	189		119.5	2.640	0.36	0.84	zircon, magnetite,	
											allanite, apatite,	
											secondary sericite and	
											leukoxene	
Blue Pearl,	1-I	11.1	158.0	394	349		85.3	2.737	0.10	0.10	feldspar, augite, biotite,	Coarse-
Light Labrador	1-II	10.8	258.0	277	230	1848/12	134.7	2.739	0.00	0.12	apatite, ilmenite,	grained
Tvedalsbruddet	1-III	11.0	184.0	398	386		89.5	2.734	0.08	0.08	titanite, zircon,	
Heia, Brunlanes	1-IV	12.7	194.0	434	419		86.7	2.720	0.03	0.07	fluspate	
Larvikite												
Emerald Pearl,	2-I	33.7	152.8	415	403		109.5	2.712	0.00	0.42	feldspar, augite, biotite,	Coarse-
Dark Labrador	2-II	14.6	107.5	296	289	1202/13	94.4	2.713	0.17	0.40	apatite, magnetite,	grained
Haslebruddet	2-III	19.8	193.0	129	161		97.8	2.711	0.12	0.53	titanite, zircon,	
Tjølling, Vestfold	2-IV	18.8	177.3				99.0	2.706	0.15	0.53	fluspate	
Larvikite												
	F-I	3.06	83.0				183.5	2.710	0.41	0.72		
	F-II	1.63	102.8				151.0	2.698	0.44	0.77		
	F-III	3.41										
	F-IV	1.63	151.5	296	212		141.5	2.691	0.26	0.49		
Flammegneiss	F-V	7.93	235.0				194.4	2.732	0.41	0.75	quartz, plagioclase, micro-	Lepido-
Skjeberg, Ise	F-VI	2.41	161.0			(1130)	138.2	2.733	0.26	0.43	cline, biotite, muscovite,	blastic
near Sarpsborg	F-VII	1.77	177.3		189	Hvaler	177.0	2.730	0.19	0.40	chlorite, titanite,	(gneissy)
Østfold	F-VIII	2.46	133.5		307		127.7	2.724	0.32	0.50	apatite, zircon,	
Biotite-musco-											magnetite, pyrites	
vite gneiss	FT-V	20.2	185.5				197.5	2.708	0.43	0.59		
	FT-VI	9.26										
	FT-VII	4.47	148.8	242	230		147.5	2.716	0.33	0.40		
	FT-VIII	9.27	89.4				230.5	2.707	0.41	0.63		
Tjøtta marble	TØ-I	172	125.0	192	281	681/1	44.2	2.717	0.83	0.94	calcite (quartz, pyrite)	Granular,
Tjøtta, Nordland	TØ-II	128	163.6				21.1	2.708	0.71	0.97	rare	anhedric,
Marble	TØ-III	175	166.9	264	244		55.3	2.708	0.57	0.73		grain size
	TØ-IV	150	110.0				3.1	2.703	0.99	1.40		from
												0.1 × 0.1
												mm up to
												1 × 0.8
												mm
Hove marble	H-I	6.34	89.0	219	261	(1152)	80.7	2.738	0.48	0.63	different types of car-	Micro-
Marble (breccia)	H-II	10.6	73.9		222		73.0	2.733	0.53	0.86	bonate particles vary-	brecciated
	H-III	11.5	83.5		112		12.5	2.734	0.24	0.52	ing in texture and	(recrystal-
	H-IV	29.2	70.9		199		14.35	2.724	0.36	0.47	size	lized)
Otta-schist	O-I	1.70	73.2	362	310		265.5	2.840	0.47	0.77	quartz, biotite, muscovite,	
Brudd Dam-	O-II	13.4	57.4				226.0	2.811	0.63	0.84	magnetite, pyrites,	Schistous
dokken	O-III	1.30	173.3				343.5	2.826	0.23	0.55	turmaline, titanite,	porphyro-
Bekkesten	O-IV	11.2	235.0				348.5	2.821	0.66	0.72	apatite, zircon.	blastic
Navnløsberg											Porphyrblasts of	
Quartz-biotite-											actinolitic amphibole	
muscovite-phyllite											and garnet	
(mica schist)												
Opdal quartzite	Op-I	11.8									quartz, albite, epidote,	Granular
Opdal, Sør-	Op-II	7.8									microcline, hematite,	lepido-
Trøndelag	Op-III	13.3									muscovite, rutile	blastic
Quartzite	Op-IV	5.9										
	Op-V	5.95										
	Op-VI	26.0										
	Op-VII	29.8										
	Op-VIII	21.7										
Alta quartzite	A-I	2.11									quartz, oligoclase, micro-	Lepido-
Alta, Finnmark	A-II	1.46									cline, epidote, titanite,	blastic
Quartzite	A-III	0.38									dolomite, magnetite	

compiled from the literature (Vogt, 1949) and added for comparison. All rocks have been microscopically investigated.

The following conclusions may be drawn:

1. The permeability of seemingly dense rocks free from visible cracks may vary by a factor of 100 or more.

2. The elastic properties of the rocks do not seem to correspond to the Hook model, but are closer to a Kelvin Voigt body.

3. The saturated samples have lower elastic moduli than the dry ones.

4. Swelling or shrinkage may be considerable and seem to be somewhat related to the porosity.

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