Weathering effects on engineering properties of Schist of Menderes Massif, West of Turkey

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Abstract

Schist is a metamorphic rock type that is widely exposed in the Western Anatolia. Schist of Menderes Massif is located in different locations and geological levels. The rock is mainly used as a filling and building material in the present and in foreseeable future. Usage of schist as filling materials in dams is related with their weathering degree which affects their geomechanical properties. To determinate the petrographic, chemical, index and engineering properties of the schist used as filler material in the dams/small dam crest, fresh and weathered samples of rock material were collected from quarries. The relationship between the weathering degree index and engineering properties were determined by simple regression analyses'. The results show that the studied parameters of physical and mechanical properties of the studied schist have a positive correction with weathering grade. Thus, increasing weathering grade affects the durability of the schist thereby compromising its applicability.

Full Text

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Tables

Table 1 Summary of weathering indices evaluated in this study

Weathering Index	Symbol	Formula	Value in the Unweath. Rock	Value in the Weath. Rock	Reference
Weathering Index of Parker	WIP	$CIA = 100 \times (Al_2O_3 / (Al_2O_3 + CaO + Na_2O + K_2O))$	>100	0	[23]
Chemical Alteration Index	CIA	$CIA = 100 \times (Al_2O_3 / (Al_2O_3 + CaO + Na_2O + K_2O))$	≤50	100	[24]
Chemical Index of Weathering	CIW	$CIW = 100 \times (Al_2O_3 / ((Al_2O_3 + CaO + Na_2O)))$	≤50	100	[22]
Alteration Index of Plagioclase	PIA	$PIA = 100 \times ((Al_2O_3 - K_2O) / (Al_2O_3 + CaO + Na_2O - K_2O))$	≤50	100	[25]
Weathering Index	WI	$WI = 100 \times (LOI / (CaO + MgO + MnO))$			[17]
Ruxtion Ratio	RR	$RR = 100 \times (SiO_2 / (Al_2O_3))$	<2.9	>2.9	[18]
Silica-Titania Index	STI	$STI = 100 \times [SiO_2 / ((TiO_2)) / [SiO_2 / (TiO_2) + SiO_2 / (Al_2O_3) + (Al_2O_3) / (TiO_2)]]$	>90	0	[26]

Table 2 Mineral contents of rocks observed in the study areas

	Rock Material	Minerals						
		Quartz %	Calcite %	Musquovite %	Graphite %	Feldspar %	Garnet %	Chlorite+Biotite %
BURG AZ DAM	Musquovite Calcschist	10	60	30	-	-	-	-
	Graphite Calcschist	-	60	10	30	-	-	-
	Quartz Calcschist	20	50	10	10	-	-	-
ARSLANLAR SMALL DAM	Musquovite Calcschist	50	20	30	-	-	-	-
	Musquovite Schist with Garnet	40	-	30	-	10	10	10
	Biotite-Musquovite Schist with Garnet	30	-	10	-	10	20	30
	Musquovite Quartzschist	80	-	20	-	-	-	-
	Musquovite Quartzschist	80	-	20	-	-	-	-
TİRE-YENİŞEHİR SMALL DAM	Biotite-Musquovite Schist with Garnet	40	-	20	-	-	20	20
	Garnet Biotite Schist	40	-	-	-	-	20	40
	Biotite-Musquovite Schist with Garnet	30	-	20	-	-	20	30
	Chlorite Biotiteschist	20	20	-	-	-	-	60
	Quartz-Musquoviteschist	40	-	60	-	-	-	-
	Garnet Biotite Schist	30	-	-	-	-	20	50

Table 3 Major element composition of Menderes Massif Schist

	Na ₂ O	K ₂ O	Σ Fe ₂ O ₃	MnO	SiO ₂	Al ₂ O ₃	CaO	MgO	TiO ₂	LOI	Mean value of LOI	TOTAL
Arslanlar Run 1	2.44	3.14	7.72	0.08	63.29	16.45	1.16	2.70	0.22	2.79	0.72 ±0.12	99.98
Arslanlar Run 2	2.14	3.45	7.14	0.09	63.97	16.10	1.25	2.28	0.36	2.73		99.52
Arslanlar Run 3	2.73	3.26	7.07	0.03	63.96	16.62	1.17	2.66	0.07	2.77		100.34
Arslanlar Run 4	2.00	3.27	7.64	0.09	63.36	16.55	1.21	2.87	0.88	2.11		100.40
Arslanlar Run 5	3.42	2.90	7.44	0.17	58.92	18.78	2.40	2.47	1.25	1.86		100.30
Arslanlar Fun 1	0.37	0.52	1.40	0.04	92.09	3.48	0.91	0.27	0.19	0.70	2.45 ±0.44	99.96
Arslanlar Fun 2	0.33	0.50	1.35	0.03	92.19	3.43	0.94	0.24	0.17	0.60		99.78
Arslanlar Fun 3	0.34	0.55	1.32	0.04	92.35	3.55	0.88	0.21	0.15	0.62		99.99
Arslanlar Fun 4	0.43	0.51	1.34	0.03	93.15	3.10	0.09	0.21	0.36	0.69		99.96
Arslanlar Fun 5	0.51	0.59	1.11	0.06	90.26	3.89	0.80	0.15	0.96	0.91		99.23
Arslanlar Fun 6	0.52	0.58	1.19	0.06	90.23	3.88	0.74	0.11	0.98	0.73		99.02
Arslanlar Fun 7	0.51	0.59	1.18	0.06	90.75	3.82	0.72	0.12	0.97	0.88		99.60
Arslanlar Fun 8	0.50	0.57	1.65	0.03	91.78	3.33	0.07	0.21	0.38	0.65		99.29
Burgaz 1	2.83	2.14	5.87	0.12	68.60	14.24	1.89	1.73	0.29	1.87	2.06 ±0.26	99.57
Burgaz 2	3.00	2.71	5.81	0.12	68.01	14.40	1.88	1.73	0.27	1.82		99.74
Burgaz 3	2.53	2.43	5.91	0.12	68.59	14.34	1.90	1.71	0.47	1.89		99.89
Burgaz 4	2.80	2.14	5.62	0.11	67.51	14.44	1.84	1.75	0.85	1.86		99.42
Burgaz 5	2.53	2.58	7.54	0.06	65.50	15.03	1.16	2.51	0.27	2.30		99.48
Burgaz 6	2.97	3.00	7.74	0.08	63.89	15.50	1.25	2.53	0.47	2.57		100.00
Burgaz 7	2.53	2.45	7.64	0.06	65.38	15.42	1.17	2.13	0.20	2.13		99.11
Burgaz 8	2.51	3.60	7.88	0.07	62.10	15.29	1.67	2.94	1.07	2.04		99.25
Yenişehir 1	1.51	3.64	6.95	0.10	63.76	17.56	0.50	0.57	0.41	4.32	4.08 ±0.25	99.33
Yenişehir 2	1.59	3.62	6.91	0.11	63.81	17.40	0.44	0.53	0.41	4.38		99.20
Yenişehir 3	1.56	3.61	6.98	0.12	63.81	17.39	0.42	0.51	0.45	4.36		99.21
Yenişehir 4	1.43	3.74	6.85	0.08	63.75	17.66	0.46	0.57	0.85	4.11		99.84
Yenişehir 5	1.43	3.20	7.73	0.09	63.65	17.66	0.39	0.76	0.43	3.86		99.18
Yenişehir 6	1.45	3.12	7.85	0.10	63.62	17.93	0.18	0.70	0.41	3.75		99.12
Yenişehir 7	1.38	3.04	7.63	0.10	63.61	17.99	0.70	0.65	0.45	3.86		99.41
Yenişehir 8	1.60	3.65	7.17	0.07	63.34	17.65	0.49	0.68	0.84	3.99		99.81

Table 4 Results of the weathering grades of the analyzed samples

Dam/Small Dam	Water Content (%) (Min-Max)	Weathering Grade
Arslanlar Small Dam - Fun Rock Material Quarry <i>Quartzschist</i>	0.51-0.90	W1
Arslanlar Small Dam - Run Rock Material Quarry <i>Musquoviteschist</i>	1.89-2.80	W3
Burgaz Dam - Rock Material Quarry <i>Calcschist</i>	2.11-2.77	W3
Yenişehir Small Dam - Rock Material Quarry <i>Biotiteschist</i>	1.20-4.41	W4

Table 5 Physical and mechanical properties of studied schists at various degree of weathering

Dam	Rock Type	WG	γ_d (g/cm ³)	n (%)	Vp (m/sn)	Na ₂ SO ₄ freeze- thaw durability (%)	Los Angeles test (LA, %)	Slake Durability (SD, %)	Uniaxial Comp. Strength (UCS, MPa)	Point Load Strength (Is ₅₀ , MPa)	Brazilian Tensile Strength (TS,MPa)
			TS EN 1097-6	ISRM 1981	ISRM 1981	ASTM C33	TS EN-1097- 2	ISRM 1981	ISRM 1981	ISRM 1985	ISRM 1981
Arslanlar Small Dam Fun Arslanlar Small Dam Run Burgaz Dam Yenişehir Small Dam	Quartzschist	W1	2.71±0.3	0.75±0.2	4500±300	1.85±0.1	27.60±0.1	98.90±0.1	47.04±10.06	6.20±1.10	3.50±0.40
	Musquoviteschist	W3	2.67±0.1	2.35±0.5	2709±248	3.14±0.1	46.34±0.1	97.20±0.1	23.66±6.60	4.80±0.10	1.50±0.80
	Calcshist	W3	2.61±0.2	2.44±0.3	3455±1902	4.72±0.1	47.50±0.1	97.78±0.1	32.80±9.12	2.45±0.80	2.08±0.77
	Biotiteschist	W4	2.56±0.8	2.81±1.6	2824±1430	5.36±1.78	49.88±26.41	97.97±0.1	21.30±1.20	1.50±0.30	1.42±0.30

WG: Weathering Grade; n:Porosity; γ_d : Dry density; Vp: Ultrasonic velocity

Table 6 The best correlations between loss on ignition and mechanical and physical properties of the studied schist

Variables	Formula	r
UCS vs. LOI	UCS= -15.553 Ln(LOI)+41.696	0.97
n(%) vs. LOI	n = 1.2233 LN(LOI) + 1.2619	0.97
Vp(m/sn) vs LOI	Vp= -1053.8 Ln(LOI) + 4083.2	0.93
Na ₂ SO ₄ (%) vs LOI	Na ₂ SO ₄ = 2.3349 (LOI) ^{0.5921}	0.89
SD (%) vs LOI	SD= 98.432 LOI ^{-0.0071}	0.72
LA (%) vs. LOI	LA= 13.48 Ln(LOI) + 33.733	0.97
Is ₅₀ (MPa) vs LOI	Is ₅₀ = -2.4731 Ln(LOI) + 5.4065	0.84
TS (MPa) vs LOI	TS = -1.2804 Ln(LOI) + 2.9891	0.97

Declarations

The academic conflict of interest lists is given below.

Atiye Tuğrul Prof., Istanbul Universitesi tugrul@istanbul.edu.tr She has researched in a similar topic

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Figures

Figure 1

Locations of the quarries where samples were taken within the scope of the research (From left to right Aslanlar dam, Burgaz Dam and Yenişehir Dam, respectively)

Figure 2

Sampling areas a-) Arslanlar small dam-quarry run rockfill material b-) Arslanlar small damquarry fun rockfill material c-) Burgaz dam- rock material quarry d-)Yenişehir small dam- rock material

Figure 3

Thin section images of a-) Burgaz dam b-) and c-) Arslanlar small dam fun and run rock material quarry, respectively d-) Yenişehir small dam rock material quarry

Figure 4

The relationship between LOI and weathering indices

Figure 5

Relationship between mean value of LOI and physical and mechanical properties of tested schists a-) UCS vs LOI; b-) SD vs. LOI; c-) n vs LOI; d-) LA vs. LOI; e-) V_p vs LOI; f-) Is50 vs LOI; g-) Na_2SO_4 vs. LOI; h-) TS vs LOI