FRICTION ANGLE OF SOIL AND ROCK

Dragan Lukić[1]
UDK: 624.131
DOI: 10.14415/konferencijaGFS2018.034

Summary: *By examining the soil and the rock mass is one of the main parameters to be determined is the angle of internal friction. Soil friction angle is a shear strength parameter of soils. Its definition is derived from the Mohr-Coulomb failure criterion and it is used to describe the friction shear resistance of soils together with the normal effective stress. In the stress plane of Shear stress-effective normal stress, the soil friction angle is the angle of inclination with respect to the horizontal axis of the Mohr-Coulomb shear resistance line.*
This paper presents the values of the angle of internal friction obtained on the basis of research and testing in situ and which are a big help to designers.

Keywords: *soil, rock mass, friction angle,*

1. INTRODUCTION

Soils generally fail in shear where the soil grains slide over each other along the failure surface, and not by crushing of soil grains. Shear strength τ_f of soils can be described by Mohr-Coulomb failure criterion which relates the shear stress τ_f on the failure plane (i.e., shear strength) with the normal stress σ on the same plane and two soil constants: friction angle ϕ, and cohesion c.
The cohesion (c) and friction angle (ϕ) of soil are important soil parameters required for evaluating stability and deformation of geotechnical structures. It is well known that there is cross-correlation between c and ϕ of soil and that this cross-correlation affects reliability analysis of geotechnical structures. Ignoring the cross-correlation between c and ϕ may lead to a biased estimation of failure probability. It is therefore important to properly quantify the cross-correlation between c and ϕ of soil for geotechnical analysis and design.
For developers it is important that a test they know about the value of strength parameters, and tests confirm it. This paper aims to show the values of the parameters of strength from various literature, based on the obtained results of the test.
The results of soil and rock research from domestic and foreign literature are presented.
The results of the survey are given in the form of a table.

[1]Prof. dr Dragan Lukić, dipl.inž. građ., University of Novi Sad, Faculty of Civil Engineering Subotica, Kozaračka 2a, Subotica, Serbia, tel: ++381 24 554 300, e – mail: drlukic.lukic@gmail.com

2. THE PARAMETERS OF THE SOIL STRENGTH

In the studies that were performed for the needs of the army in the construction of military roads are given values of strength parameters of the soil:

Table 1. Strength parameters of the soil [1]

Description	USCS	Soil friction angle [°]		Cohesion [KN/m²]	
		min	max	min	max
Gravel well granulated	GW	40	50	0	
Gravel is well granulated with clay binder	GC	45	50	0	
Gravel of uniform composition	GU	35	40	0	
Gravel poorly granulated	GP	30	40	0	
Gravel with a lot of fine particles	GF	30	35	0	
Sand well granulated	SW	30	35	0	
Sand is well granulated with clay binder	SC	35	40	4,90	9,81
Sand of uniform composition	SU	30	35	0	
Sand poorly granulated	SP	25	30	0	
Sand with a lot of fine particles	SF	15	25	4,90	9,81
Dust (silt) of low plasticity	ML	10	22	9,81	14,71
Clay of low plasticity	CL	8	20	14,71	29,42
Organic clay of low plasticity	OL	5	15	19,61	49,03
Dust (silt) of medium plasticity	MI	5	15	19,61	49,03
Clay of medium plasticity	CI	3	14	29,42	68,65
Organic clay of medium plasticity	OI	2	10	39,23	78,45
Dust (silt) of high plasticity	MH	0	8	39,23	78,45
Clay of high plasticity	CH	0	8	49,03	98,07
Organic clay of high plasticity	OH	0	5	44,13	98,07
Peat	Pt				

The following table gives the results of the study of soil from foreign literature.Some typical values of soil friction angle are given below for different USCS soil types at normally consolidated condition unless otherwise stated. These values should be used only as guidline for geotechnical problems; however, specific conition of each engineering problem often needs to be considered for an appropriate choice of geotechnical parameters.

Table 2. Strength parameters of the soil [2]

Description	USCS	Soil friction angle [°]			Cohesion [KN/m^2]	
		min	max	Specific value	min	max
Well graded gravel, sandy gravel, with little or no fines	GW	33	40		0	
Poorly graded gravel, sandy gravel, with little or no fines	GP	32	44		0	
Sandy gravels - Loose	(GW, GP)			35	0	
Sandy gravels - Dense	(GW, GP)			50	0	
Silty gravels, silty sandy gravels	GM	30	40		0	
Clayey gravels, clayey sandy gravels	GC	28	35			20
Well graded sands, gravelly sands, with little or no fines	SW	33	43		0	
Well-graded clean sand, gravelly sands - Compacted	SW	-	-	38	0	
Well-graded sand, angular grains - Loose	(SW)			33	0	
Well-graded sand, angular grains - Dense	(SW)			45	0	
Poorly graded sands, gravelly sands, with little or no fines	SP	30	39		0	
Poorly-garded clean sand - Compacted	SP	-	-	37	0	
Uniform sand, round grains - Loose	(SP)			27	0	
Uniform sand, round grains - Dense	(SP)			34	0	

Sand	SW, SP	37	38		0
Loose sand	(SW, SP)	29	30		0
Medium sand	(SW, SP)	30	36		0
Dense sand	(SW, SP)	36	41		0
Silty sands	SM	32	35		22
Silty clays, sand-silt mix - Compacted	SM	-	-	34	20
Silty sand - Loose	SM	27	33		20
Silty sand - Dense	SM	30	34		50
Clayey sands	SC	30	40		5
Calyey sands, sandy-clay mix - compacted	SC			31	11
Loamy sand, sandy clay Loam	SM, SC	31	34		10 20
Inorganic silts, silty or clayey fine sands, with slight plasticity	ML	27	41		7
Inorganic silt - Loose	ML	27	30		9
Inorganic silt - Dense	ML	30	35		67
Inorganic clays, silty clays, sandy clays of low plasticity	CL	27	35		4
Clays of low plasticity - compacted	CL			28	86
Organic silts and organic silty clays of low plasticity	OL	22	32		5
Inorganic silts of high plasticity	MH	23	33		20
Clayey silts - compacted	MH			25	10
Silts and clayey silts - compacted	ML			32	67
Inorganic clays of high plasticity	CH	17	31		25
Clays of high plasticity - compacted	CH			19	103
Organic clays of high plasticity	OH	17	35		10
Loam	ML, OL,	28	32		60 90

	MH, OH				
Silt Loam	ML, OL, MH, OH	25	32		60 90
Clay Loam, Silty Clay Loam	ML, OL, CL, MH, OH, CH	18	32		10 20
Silty clay	OL, CL, OH, CH	18	32		10 20
Clay	CL, CH, OH, OL	18	28		90 105
Peat and other highly organic soils	Pt	0	10		

Table 3. Typical cohesion and angle of internal friction values[3]

Mn/DOT Triangular Textural Classification	Cohesion, kPa (psf) Compacted	Saturated	Angle of Internal Friction (degrees)
Gravel	0	0	> 37
Sand	0	0	37 – 38
	50 – 75	10- 20	
Loamy Sand	(1,000 - 1,500)	(200 – 400)	31 – 34
	50 – 75	10 - 20	
Sandy Loam	(1,000 - 1,500)	(200 – 400)	31 – 34
	60 – 90	10 - 20	
Loam	(1,300 - 1,800)	(200 – 400)	28 – 32
	60 – 90	10 - 20	
Silt Loam	(1,300 - 1,800)	(200 – 400)	25 – 32
	50 – 75	10 – 20	
Sandy Clay Loam	(1,000 - 1,500)	(200 – 400)	31 – 34
	60 – 105	10 -20	
Clay Loam	(1,300 - 2,200)	(200 – 400)	18 – 32
	60 – 105	10 - 20	
Silty Clay Loam	(1,300 - 2,200)	(200 – 400)	18 – 32
	50 – 75	10 - 20	
Sandy Clay	(1,000 - 1,500)	(200 – 400)	31 – 34
	90 – 105	10 -20	

Silty Clay	(1,800 - 2,200)	(200 – 400)	18 – 32
	90 – 105	10 - 20	
Clay	(1,800 - 2,200)	(200 – 400)	18 - 28

3. STRENGTH PARAMETERS OF THE ROCK MASS

The paper shows the in situ studies, which were performed by a professor Kujundzic. Studies have been done for different rock mass.

Table 4. The parameters of the shear strength of rock masses (c and φ) B. Kujundžić [4]

serial number	Rock mass	c (KN/m^2)	φ (˚)
1	Paleozoic sandblasting argilloscope with slopes and clays	128,47	41
2	Paleozoic argillosist, poor slim and cracked	93,16	32
3	Paleozoic solid sandy argilloscope with the sands of the sands, quite cracking	686,47	42
4	Paleozoic heavy slit argillosist, badly cracked	88,26	39
5	Paleozoic argilloscope with quartz wires and lenses, very slim and soft	29,42	41
6	Paleozoic healthy argillosist, protruded by the sands of the sands	176,52	34
7	Paleozoic black graphite argillosist, with sands of the sands	54,92	33
8	Paleozoic black graphite argillosist, with sands of the sands	147,10	33
9	Paleozoic clay black graphite slate with quartz and calcite wires and lenses	73,55	24
10	Paleozoic clay black graphite slate with quartz and calcite wires and lenses, wired	78,45	18
11	Paleozoic black graphite agrilosist with clay deposits and quartz wires. Decomposes in contact with water and air	49,03	30
12	Paleozoic black graphite argillosist with clay deposits and quartz wires. Decomposes in contact with water and air	49,03	41
13	Paleozoic biotite gneiss with closed cracks and soft gneiss	706,08	44
14	Fractured granognes, biotite gnays. The whole mass has been homogenously cracked and has a breechy appearance	568,79	68
15	Tektonized biotite gnays, cataclase with lenses and intercalations of granognes	0	30

16	Paleozoic gneiss with a lot of biotite, altered, cracks filled with clay	245,17	24
17	Biotic gneiss with pronounced hazards, moist	264,78	41
18	Biotic - quartz gneiss with soft pasteles	519,75	43
19	Biotytic gneiss, altered	353,04	37
20	Biotic gneiss with soft shaved batches	46,09	56
21	Paleozoic strongly altered gneiss with a lot of biotite, cracks filled with clay. Decomposes in contact with air .	166,71	45
22	Paleozoic strongly altered gneiss with a lot of biotite, cracks filled with clay. Decomposes in contact with air	196,13	42
23	Filithic cracked slate Filithic cracked slate	29,42 78,45	40 35
24	The clay shavings of the fleece series are decomposed in the air	245,17	35
25	Coated gray marls, clays and limestones, marls (flysch), very cracked, wet. Decomposes in contact with air	568,79	34
26	Massive shortened limestone with rare passes of marlstone limestone	392,27	70
27	Massive shortened limestone with rare passes of marlstone limestone	392,27	56
28	Very kaolinizated andesite, very cracked	196,13-294,20	37
29	Very kaolinizated andesite with wires plaster	49,03-98,07	30-50
30	Kaolinizated, silicified andesite and low pyritizated	245,17-392,27	59-66
31	Kaolinizated andesite	98,07	55
32	Gray marls	196,13	54
33	Fine-grained conglomerates	392,27	70
34	Piroclastic walls are sprinkled with numerous cracks as well as calcite cells	294,20	60
35	Modified gray marls	68,65	20
36	Bright - brown marls	58,84	15
37	Amfibolitski slate crystalline structures of various degrees of decomposition	98,07	62
38	Decomposes layered sandstone	245,17	44
39	Layered to leafy sandstone	68,65	54
40	Paleozoic argilošist with layers of sandstone	98,07	55
41	Paleozoic argilošist with layers of sandstone	127,49	32
42	Paleozoic graphite argilloscope with quartz wires and lenses	0	45
43	Paleozoic black and gray argillosist, picked, with quartz wires. In contact with water is	49,03	41

	falling apart		
44	Paleozoic quartz conglomerate with predominantly silicon binder, cracks and crevices clenched	392,27	67
45	Paleozoic crustal sandstone with rare quartz lenses. Binder limonit- carbonate. Cracks filled with clay.	1225,83	40
46	Palaeozoic strong slate sandstone, partly clayey. Cracks with a yawn to 2 cm filled with clay.	294,20	26
47	Tectonic damaged serpentine with a lot of cracks and fissures that are filled with asbestos, basic solid monoliths	98,07	72
48	Serpentine, tectonically damaged, basic monoliths solid	490.33-1078,73	50
49	Paleozoic altered biotite chlorite gneiss	588,40	71
50	Paleozoic altered gneiss. Cracks with a yawn to 1.5 cm.	539,37	37
51	Fractured granoganys, biotite gnays, homogeneous crack, breccia-like appearance.	196,13	68
52	Biotite gnais cataclase with lenses and intercalations granognajsa	0	52

4. CONCLUSION

In this paper we show the parameters of the soil and rock mass parameters. Research is presented in the tables. The aim of this paper is that the project designers have at one place the values of the parameters of soil and rock mass strength. These results are important for designers to compare the results of geotechnical research for the object being built with research.

Acknowledgements
The authors gratefully acknowledge the support of the Ministry of Education, Science, and Technological Development of the Republic of Serbia in the framework of the scientific research project TR 36043 (2011-2018).

REFERENCES

[1] *Inžinjerijski priručnik*, Državni sekretarijat za narodnu odbranu, Beograd, **1971**
[2] www.geotechdata.info/parameter/angle-of-friction.html download 01.03.2018.
[3] *Pavement Manual*, Minnesota Department of Transportation, Minnesota, **2010**,
[4] Kujundžić, B. Mehanika stena, *Gradjevinski priručnik*, Tehnička knjiga, Beograd,

1974.
[5] Wang, Y., Akeju, V.O.: Quantifying thecross-correlation between effective cohesion and friction angle of soil from limited site-specific data, *Soils and Foundations*, **2016**, 56(6), p.p. 1055–1070.
[6] Jay Ameratunga, J., Sivakugan, N., Das M.B.: *Correlations of Soil and Rock Properties in Geotechnical Engineering*, Springer, New Delhi, **2016.**

УГАО УНУТРАШЊЕГ ТРЕЊА ТЛА И СТЕНА

Резиме: *При истраживању тла и стенске масе један од основних параметара који се одређују је угао унутрашњег трења. Угао трења земљишта је параметар јачине чврстоће земљишта. Његова дефиниција је изведена из критеријума лома. Mohr-Coulomb-а и користи се за описивање отпора смицања смицања тла уз нормалан ефективни напон. У равни напона смицања-ефективног нормалног напрезања, угао трења земљишта је угао нагиба у односу на хоризонталну осу линије отпорности на смицање Mohr-Coulomb.*
У овом раду се приказују вредности угла унутрашњег трења које су добијене на основу истраживања и испитивања ин ситу и које представљају велику помоћ пројектантима.

Кључне речи*: тло, стенска маса, угао унутрашњег трења*