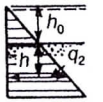
Properties of granular materials

Retained cohesionless soils etc.	Angle of internal friction θ	Weight kN/m³ In bulk D	Weight kN/m³ Moist (drained) D_3	Weight lb/ft³ In bulk D	Weight lb/ft³ Moist (drained) D_3
Gravel: common ($\mu = 30°$)	35° to 45°	17.3 to 22.0	—	110 to 140	—
Shingle: loose	40°	18.1	—	115	—
sandy: compact	40° to 45°	20.4	—	130	—
loose	35° to 40°	18.9	—	120	—
Sand ($\mu = 30°$)					
fine: dry	30° to 35°	15.7	—	100	—
wet	0° to 30°	18.1 to 18.9	—	115 to 120	—
well graded: compact	40° to 45°	17.3 to 18.9	18.9 to 22.0	110 to 120	120 to 140
loose	35° to 40°	15.7 to 17.3	17.3 to 18.9	100 to 110	110 to 120
uniform:					
fine or silty: compact	35° to 40°	15.7 to 17.3	17.3 to 21.2	100 to 110	110 to 135
loose	30° to 35°	14.1 to 15.7	15.7 to 17.3	90 to 100	100 to 110
coarse or medium: compact	35° to 40°	15.7 to 17.3	18.9 to 20.4	100 to 110	120 to 130
loose	30° to 35°	14.1 to 15.7	16.5 to 18.9	90 to 100	105 to 120
Crushed rock:					
granite	35° to 45°	15.7 to 20.4	—	100 to 130	—
basalt, dolerites		17.3 to 22.0	—	110 to 140	—
limestone, sandstone		12.5 to 18.9	—	80 to 120	—
Broken chalk		9.4 to 12.5	—	60 to 80	—

Contained granular materials	θ	Pressure calculations D kN/m³	D lb/ft³	Capacity calculations Angle of repose	D kN/m³	D lb/ft³
Coal: dry unwashed ($\mu = 35°$)	40°	9.1	58	45°	7.1	45
washed	40°	9.0	56	45°	7.1	45
wet (15% moisture)	25°	9.0	56	45°	7.1	45
fine	20°	9.0	56	40°	7.1	45
slurry	0° to 20°	9.8	62.5	40°	7.9	50
anthracite	27°	8.2	52	40°	7.1	45
Coke, breeze etc.	40°	5.5	35	45°	4.7	30
Shale: broken	30°	20.4	130	35°	15.7	100
colliery dirt	35°	11.0	70	45°	9.4	60
Grain: wheat ($\mu = 24°$)	25°	7.9	50	25°	7.9	50
maize ($\mu = 23°$)	27.5°	7.1	45	25°	7.1	45
barley ($\mu = 24.5°$)	27°	6.3	40	25°	6.3	40
oats ($\mu = 25°$)	28°	4.7	30	25°	4.7	30
Cement: static fine ($\mu = 30°$)	10°	14.1	90	15°	13.2	84
coarse ($\mu = 30°$)	18°	14.1	90	20°	14.1	90
air-agitated	0°	11.8	75	—	11.8	75
Ashes ($\mu = 40°$)	35°	9.4	60	45°	6.3	40
Broken brick	35°	15.7	100	45°	11.0	70

Values of $D_l\alpha = D_l\left\{1 + k_2\left[\frac{D_m}{D_l} - (1 - \beta)\right]\right\}$

Horizontal pressure of granular materials submerged in water	θ approximately when submerged	$D_l = 9.81$ kN/m³: D_m (solid) kN/m³	Percentage of voids (= 100β) 30%	40%	50%	$D_l = 62.4$ lb/ft³: D_m (solid) lb/ft³	Percentage of voids 30%	40%	50%
Coal (crushed)	35°	12.5	11.30	11.60	11.87	80	72	74	76
Stone (crushed)	35°	25.0	14.72	15.00	15.25	160	94	96	97
Sand	0°	25.0	27.94	28.92	29.90	160	179	185	191



$q_2 = D_l h_0 + (D_l\alpha)h$

For k_2 see *Table 18*

$\alpha = 1 + k_2\left[\frac{D_m}{D_l} - (1 - \beta)\right]$

Properties of cohesive soils

Type of soil	Saturated unit weight D kN/m³	Saturated unit weight D lb/ft³	Angle of internal friction θ	Cohesion C kN/m²	Cohesion C lb/ft²
Clay: very stiff boulder	19 to 22	120 to 140	16°	170	3600
hard shaly			—	> 140	> 3000
stiff			7°	70 to 140	1500 to 3000
firm	17.5 to 20.5	110 to 130	6°	35 to 70	750 to 1500
moderately firm	17.5 to 19	110 to 120	5°	50	1100
soft			4°	18 to 35	375 to 750
very soft	15.5 to 19	100 to 120	3°	< 18	< 375
Puddle clay: soft			3°	32	675
very soft			0°	21	450
				70 to 140	1500 to 3000
Sandy clay: stiff	15.5	100		35 to 70	750 to 1500
firm					

Type of soil	Bulk unit weight D kN/m³	Bulk unit weight D lb/ft³	Angle of internal friction θ	Cohesion
Clay: dry	17.3	110	30°	Determine by test
damp (well drained)	18.1	115	45°	
wet	18.9	120	15°	
gravelly	19.6	125	35°	
Earth: top soil	13.4	85	(35°)	In absence of test results, apply formulae for saturated clay with $\theta = 0°$
common	15.7	100	(35°)	
dry	14.2	90	30°	
moist	15.7	100	45° to 50°	
very wet	16.5	105	17°	
punned	15.7	100	65° to 75°	
Peat: dry	4.7	30	15° to 45°	
wet	9.4	60		