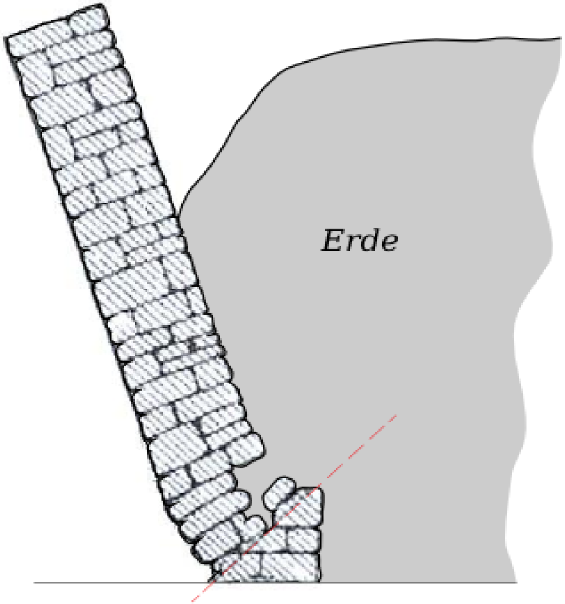
Workshop "Stability of Drystone Retaining Walls"

Purpose of this workshop:

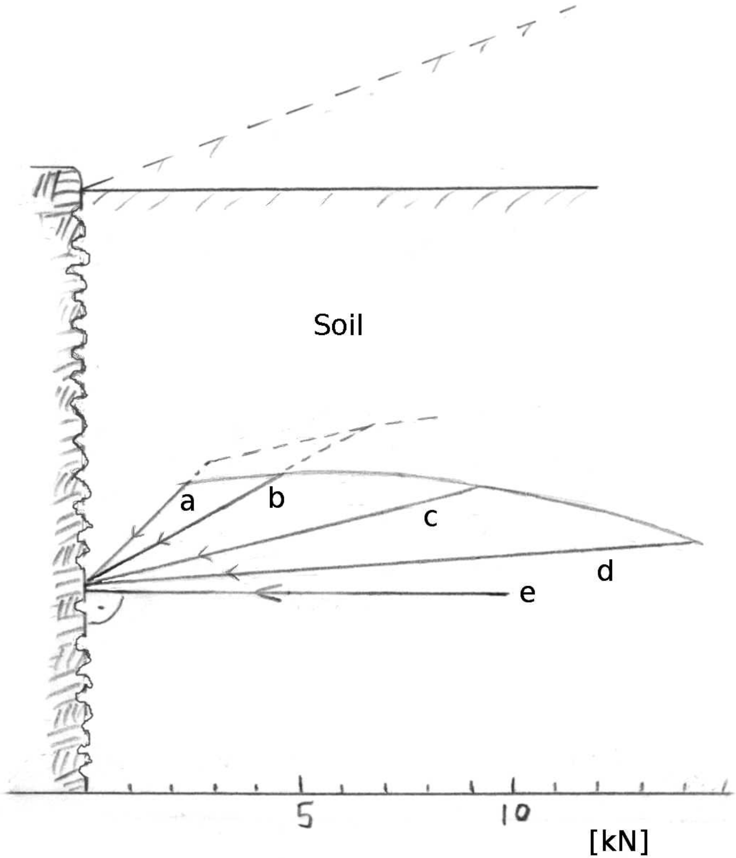
- Information for all interested persons
- Specific know-how for planners and builders
- Use of MurCalc retaining wall software.

First the soil!

The first task for calculating retaining walls is to determine the properties of the soil being retained, as the job of such a wall is to counteract with its weight the force of earth pressure.

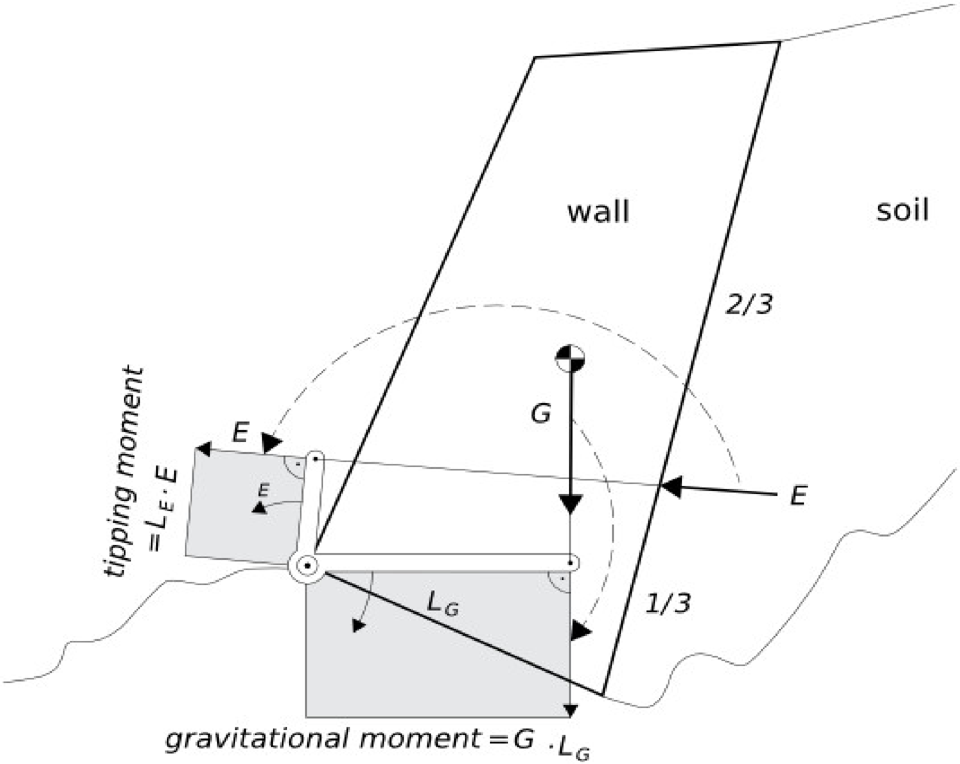


Drawing of one of Sir John Burgoyne's famous research walls at the moment it is tipping over due to increasing earth pressure.



Coulomb earth pressure force in kilonewton per meter wall length and for 1.414 m wall height.

The vectors a,b,c,d,and e are for soil with 18 kN/m³ bulk weight and friction angles (δ = φ) of 45° (sharp gravel), 30° (loose sand), 15° (very unstable earth), 5° (highly liquified mud), and 0° (water, 10 kN/m³).



A retaining wall on hard ground can be represented as a (L-shaped) balance between two moments or torques around the pivot formed by the toe.

Rule of thumb

The simplest method is a rule of thumb as used for free-standing walls: in average conditions, make the base width half the height and use some batter, e.g. 10-20%.

Such rules suffice for walls where a failure would not cause injury and small projects where the amount of stone use is not of major importance.

ENTPE-CAPEB

The book "Pierre sèche: guide de bonnes pratiques" (2008) published by CAPEB (Confédération de l'Artisanat et des Petites Enterprises du Bâtiment) is based on work by the ENTPE (École Nationale des Travaux Publics de l’État) near Lyon. Its diagrams allow:

- upright rectangles and trapezoids,
- two values of batter,
- two stone types,
- two terrace slopes in addition to horizontal,
- single soil weight,
- $\varphi = \delta = 0°$ to $50°$,
- no surcharge,
- safety values of 1.2 and 1.5 for sliding and tipping.

FLL

The publication "Empfehlungen für Planung, Bau und Instandhaltung von Trockenmauern" (2012) by the German organisation FLL (Forschungsgesellschaft Landschaftsentwicklung Landschaftsbau) also provides easy-to-use diagrams:

- upright or tiltable rectangular and trapeziodal profiles,
- two stone weights,
- two terrace slopes in addition to horizontal,
- single soil weight,
- φ 25° to 40°,
- $\delta = 2/3\ \varphi$,
- surcharge of 5 kN/m^2 ,
- safety values of 1.5 and up to about 3, for sliding and tipping.

MurCalc

Powerful and universal, written in the form of a spreadsheet:

- four profiles: rectangles, CAPEB-type trapezoids, FLL-type trapezoids and chordal quadrilateral.
- three modes: monolithic, CAPEB-type, FLL-type
- any batter
- any stone weight
- any soil weight
- any φ
- any δ
- any μ (friction coeffficent between layers)
- any terrace slope
- any safety factors
- profile schematic
- fully documented free/libre open source

Spreadsheet for calculating earth pressure force, sliding and tipping values of retaining wall profiles.

	Enter variables here						
profile type =	2	---->	1, 2, 3, or 4: means:	**chordal quadrilateral**	definitions see Info		
height =	1.50	m	definition see info	1.66	retaining height		
width =	0.80	m	definition see info	0.80	width at toe (m)	0.50	cope width (m)
batter =	20	%	batter of front face	0.30	absolute batter (m)		
β =	0	°	slope of retained terrace				
φ soil =	30	°	factor δ / φ = 0.99	29.70	δ (angle in ° from Eag to right angle on α)		
φ foundation =	30	°	angle of friction of foundation to soil	0.58	coefficient of friction μ of foundation to soil		
γ wall =	20	kN/m³	wall porosity = 25 %	26.67	specific gravity γ of stone (kN/m³)		
γ soil =	18	kN/m³	specific gravity of soil	1.11	ratio γ wall / γ soil		
p =	5	kN/m²	assumed load on terrace (actual or e.g. 5 kN/m² for people, 10 kN/m² for vehicles).				

974	α_L	11.31	°	inclination of foundation and stone layers
	α	0.00	°	angle of inner surface to vertical
	A	**1.04**	m²	area of profile
	G	**20.78**	kN/m	weight per m length

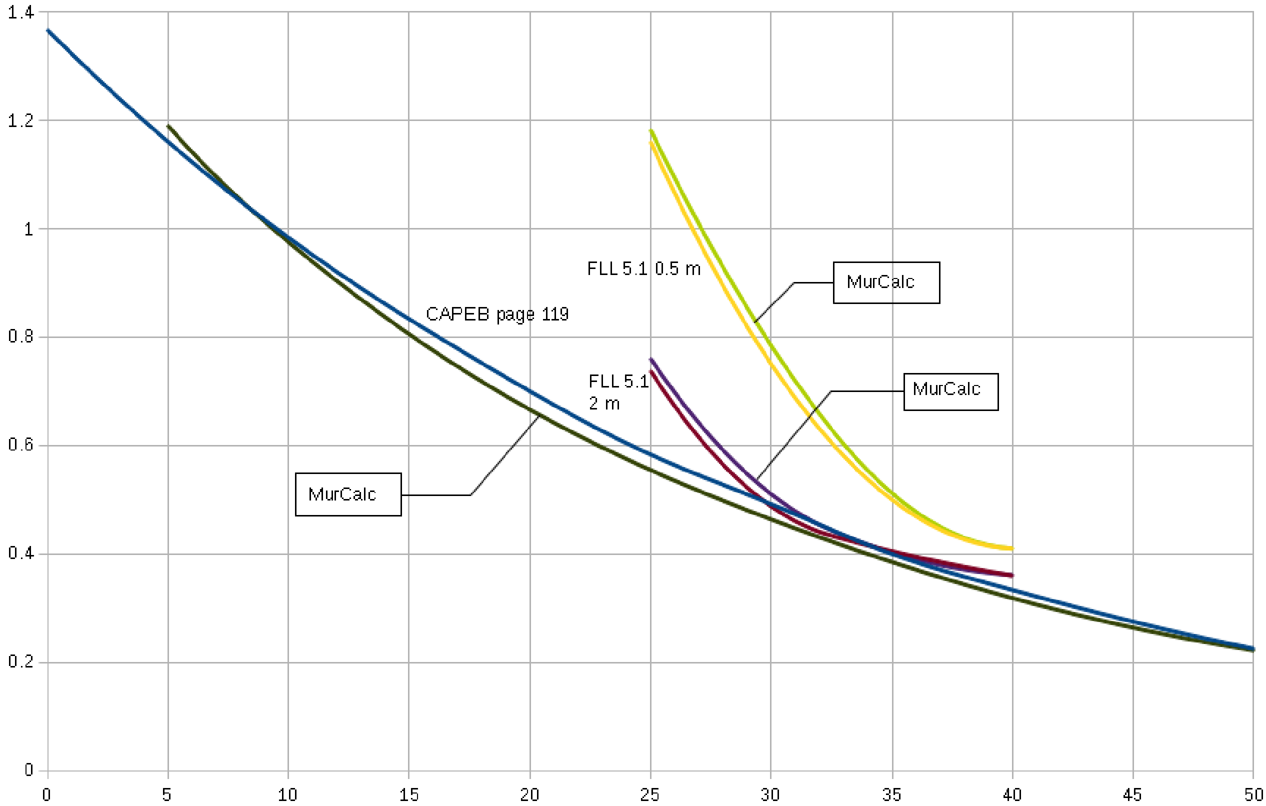
lever (m)	moment (kNm)	
0.469	9.75	stabilising moment (approximation with very small error)

active earth pressure coeff.	
Ka	**0.297**
Kah	**0.258**

earth pressure (kN/m²)	
eagh	7.71
eagv	4.40
eaph	1.29
eapv	0.74

earth pressure force (kN/m)		lever (m)	moment (kNm)			
		0.891	(Ld)			
Eag	**-7.37**	-0.055	0.40			
Eap	**-2.47**	0.264	-0.65	dist. toe (m)		
		sum g	10.15	**0.416**		
		sum g+p	9.50	**0.370**		
Eagh	-6.40	0.393	-2.52			
Eagv	3.65	0.800	2.92	eccentricity e (m)		
Eaph	-2.14	0.670	-1.43		DIN	SIA
Eapv	1.22	0.800	0.98	actual	max. allowed	
sum g	24.43		10.15	**-0.016**	0.133	0.267
sum g+p	25.65		9.70	**0.022**	0.267	0.267

safety factor	safety factor
SF tipping	SF sliding
24.20	**9.813**
39.42	**4.632**



Width to height ratio as a function of soil friction angle

Disclaimer

All the tools described come with no guarantee for correctness and have no legal standing e.g. instead of building codes. Walls of appreciable size, where a failure could lead to injury, should therefore be checked by qualified persons. These might however use the same tools. In particular MurCalc is completely open and documented: http://data.umwelteinsatz.ch/T/ (in German language, translation expected in 2017).

Profiles calculated with these tools will only perform as expected if the walls are crafted to the normal standards of professional wallers or given in drystone walling literature or by drystone walling associations.