Coefficient of Friction on Sub-base.

The conditions affecting the Sliding Safety Factor will be the nature of the bed of stream and material used in the structure. As has been explained in a previous article, the depth of the water should be taken into account also, but this has evidently been neglected in all existing structures:

	Trautwine.	Rankin.	Turneaure.
Soft limestone well dressed on same	.64		
Soft limestone on hard limestone.	.65		
Hard limestone on hard limestone, both well dressed	.38		.38
Hard limestone on soft limestone, both well dressed	.67		
Hard limestone, dressed (medium) on brickwork			.60
Masonry and brickwork, dry	.65	.6 to .7	
Masonry and brickwork, with wet mortar	.47		
Masonry and brickwork, with slightly damp mortar	.74	.74	
Masonry on dry clay	.51	.51	.510
" " moist clay	.33	.33	.325
Concrete on clay, dry			
" " " wet			
" " soft stone			
" " hard stone			
Beton blocks on like blocks			.66
Masonry on clayey gravel			.577
Granite (roughly worked) on dry sand			.65
Granite (roughly worked) on wet sand			.47
Granite (roughly worked) on gravel and sand			.41
Fine cut granite (medium) on like granite			.58
Point dressed granite (medium) on like granite			.70
Point dressed granite (medium) on c. brick			.63
Point dressed granite (medium) on s. concrete			.62
Common bricks on common bricks.			.64
Common bricks on hard-dressed limestone			.60

The above table gives the coefficient of friction for different materials as quoted by the authors named.

With a coefficient of .65, and allowing a safety-factor (S.S.F.) of 1.3, the working coefficient would require to be taken at .500; for S.S.F. = 1.5 we would use .433.

For S.S.F. = 2.0, we would use .325. By reference to plate on page 15, giving S.S.F. of various existing structures, it will be seen how rare is a coefficient of friction of .325, and how frequent is a coefficient of .5; the Assuan, New Croton, San Mateo, Vyrnwy and Gileppe being the only ones in that long list of dams built since the introduction of the Theoretical Profile which have a coefficient approaching .325.

Water Flowing Over Crest of Dam.

It may be interesting to investigate the effect upon the safety-factor of water flowing over the crests of dams of various heights:

S.S.F. of 1.3. Ultimate coefficient of friction.... .65
Working coefficient of friction... .50

Height of dam in feet	10	20	40	60	80	100
Depth of flood in feet over crest required to eliminate S.S.F. of 1.3	1.4	2.8	5.6	8.41	11.21	14.01
Coefficient of .50 would increase to.	.65	.65	.65	.65	.65	.65

S.S.F. of 1.5. Ultimate coefficient of friction.. .65
Working coefficient of friction.. .433

Depth of flood in ft.	2.2	4.5	9.0	13.4	17.9	22.4
Coefficient of .433 would increase to.	.65	.65	.65	.65	.65	.65

S.S.F. of 2. Ultimate coefficient of friction... .65
Working coefficient of friction... .325

Depth of flood in feet	4.14	8.28	16.5	24.85	33.13
Coefficient of .325 would increase to.	.65	.65	.65	.65	.65

With a safety factor of 2 against overturning, any of the above dams would, with the depth of flood given in each case, have this factor of 2 reduced to 1.19.

With a safety factor of 2½, it would be reduced to 1.42; or with 3, to 1.70.

If the O.S.F. had been only 1½, any of the dams would have overturned before reaching the height of flood given in tables, the O.S.F. being reduced to .85.

Safety Margins.

When we say that a structure has a factor of safety of two, we mean that the strength divided by the pressure will give a quotient of 2; i.e., for sliding safety factor

$$\frac{w}{p} = 2, \text{ or } \frac{W}{P} = 2.$$

w = weight of dam per lineal foot.
p = pressure on dam per lineal foot.
W = total weight of dam.
P = total pressure on dam.

For overturning safety-factor we would mean the stability moment divided by the overturning moment, i.e.,

$$\frac{wz}{pz'} = 2, \text{ or } \frac{WZ}{PZ'} = 2.$$

$z = \frac{1}{3}$ height of dam.

Z' = distance from centre of gravity to toe.

A safety-factor of 2 does not mean, however, a surplus strength of 2, but only a surplus strength of 1.

A safety-factor of 1.5 does not mean a surplus strength of 1.5, but only a surplus strength of .5.

Some authorities claim that 1.5 is a sufficiently large safety-factor, but if we bear in mind that the total surplus strength is only .5 of the pressure, it will be seen how precarious is the life of such a structure.

The great majority of engineers seem content with a sliding safety-factor of 2, and since this equals a surplus strength of P × 1 only, and this surplus strength has to make up any deficit in stability, or increase in pressure, that may occur, it is easily seen how precarious is the life of this structure also.

The following may be termed as actual forces tending to prevent the structure from having the full strength intended to be contained by it:—

1. Defects in sub-base, i.e., bed of stream.
2. " in material composing the structure.
3. " in material composing the joints of structure.
4. " in method of building.
5. " in workmanship.
6. " through action of rain during construction.
7. " through action of frost during construction.
8. " through action of the sun during construction.
9. Wrong assumption as to value of coefficient of friction.
10. Wrong assumption as to specific gravity of material.
11. Change in value of coefficient of friction due to pressure from head of water affecting condition of the mass.