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Mr. Thomas Tredgold

To cite this article: Mr. Thomas Tredgold (1818) LXVIII. On the pressure of the earth against revetements and retaining walls , Philosophical Magazine Series 1, 51:242, 401-404, DOI: [10.1080/14786441808637576](https://doi.org/10.1080/14786441808637576)

To link to this article: <http://dx.doi.org/10.1080/14786441808637576>

Published online: 27 Jul 2009.

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LXVIII. *On the Pressure of the Earth against Revetements and Retaining Walls.* By Mr. THOMAS TREDGOLD.

IT has been observed, in making experiments on the strength of revetements, that the pressure of the earth increases in a certain degree, the stability of the wall*. To account for this increase of stability, the writer of an article on the subject, in the *Encyclopædia Metropolitana*†, has adopted the method of resolving the force, resulting from the pressure of the earth, that appears to have been first practised by Rondelet‡: but this method is evidently inferior to the one used by Coulomb and Prony, as it does not indicate the angle of fracture; consequently does not give the maximum pressure of the earth; and when the cohesion is omitted, it is much inferior even in point of simplicity.

The cohesion of the earth, which is so strongly objected to by the writer above mentioned, is not a necessary appendage to Coulomb's Theory, and would, perhaps, be better left out; also, similar objections might be urged against introducing the cohesion of the mortar in calculating the strength of the wall.

But to return to the stability imparted to the wall by the pressure of the earth.—It appears to result partly from friction; as it must be evident no motion could take place without friction against the back of the wall. I will, therefore, attempt to include its effect in an investigation of the pressure of the earth. Let ABCD (Plate IV. fig. 12) represent a section of the wall; and BDE a section of the prism of earth that slides forward in the case of fracture, DE representing the plane of fracture, which we will suppose to be a plane surface.

Put W = the weight of the prism of earth acting against the wall.

R = the resistance of the wall, or the horizontal force that retains the sliding prism on the plane of fracture.

a = the angle which the plane of fracture makes with the horizon.

f = the friction when the pressure is unity.

h = the height of the wall = BD.

And, S = the weight of a cube of earth whose side is unity.

It is shown, by writers on mechanics, that when a body is sustained upon an inclined plane, and is in equilibrio, the whole

force in the direction ED is = $\frac{W (\sin. a - f \cos. a)}{\text{radius}}$. (A)

* Col. Pasley's "Course of Military Instruction," vol. iii. chap. xxv.

† Art. *Mechanics*, section xxv. part i.

‡ *L'Art de Bâti*, tome iii. p.128.

M^{rs} Ibbetson'sAnatomy of Vegetables. N^o 7

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This force is opposed by the resistance of the wall, which may be supposed to act in a horizontal direction; and when reduced to the direction DE it becomes $= \frac{R. (\cos a + f \sin a)}{\text{radius}}$. (B)

Also, the pressure against the back of the wall is equal to R; consequently the friction is $= Rf$; and when this force is reduced to the direction DE, it is $= \frac{R. (f \sin a - f^2 \cos a)}{\text{radius}}$. (C)

And, when the forces (A), (B), and (C) are in equilibrio, we have

$$R. (\cos a + 2f \sin a - f^2 \cos a) = W. (\sin a - f \cos a).$$

But, making the radius $= 1$, this equation may be put under a form better suited to the present purpose; that is

$$R = \frac{W (\tan a - f)}{1 + 2f \tan a - f^2}. \quad (D)$$

Or, because $W = \frac{1}{2} h^2 S \times \frac{1}{\tan a}$;

$$R = \frac{\frac{1}{2} h^2 S (\tan a - f)}{\tan a + 2f \tan^2 a - f^2 \tan a}. \quad (E)$$

The second part of this expression becomes a *maximum* when

$$\tan a = f + \sqrt{\left(\frac{1+f^2}{2}\right)}.$$

And if the angle which the plane of repose makes with the horizon be denoted by c ; then $f = \frac{\sin c}{\cos c}$; consequently

$$\tan a = \frac{\sin c + \sqrt{\frac{1}{2}}}{\cos c}. \quad (F)$$

If the friction against the back of the wall had been neglected, the expression for the $\tan a$ would have become equivalent to the simple and elegant one obtained by M. de Prony.

The value of the $\tan a$ (F) being introduced in the equation (E), it becomes

$$R = \frac{\frac{1}{2} h^2 S}{\sin c \sqrt{2} + 1 + \frac{\sin^3 c \sqrt{2} + \sin^2 c}{\cos^2 c} + \frac{\sqrt{2}}{2 \cos c}}. \quad (G)$$

But the numeral value of the denominator will be constant for the same kind of earth; and let this value be $= t$;

$$\text{then } R = \frac{h^2 S}{2t}. \quad (H)$$

And as the wall may either slide on its base, or turn on the point C as a centre of motion; it may be shown, that in the latter case, the leverage $Dp = \frac{1}{3}h$.

The preceding inquiry extends only to retaining walls, counterscarp revetements, terrepleins without parapets, &c. But a simple

simple case of partial scarp revetements presents itself, which it would be as well to consider.

Suppose the revetement (fig. 13) to have a berm AB equal to the breadth of the top of the wall, and that the plane of fracture produced would intersect the earthen scarp at G; also let h' be the height of this point above the top of the wall = FB; h being the height of the wall as before. It is obvious that the equation (D) still expresses the conditions of equilibrium; that is,

$$R = \frac{W \cdot (\tan. a - f)}{1 + 2f \tan. a - f^2}$$

But if b be the angle which the front of the scarp BG makes with the horizon; then by supposition $\frac{h + h'}{\tan. a} = \frac{h'}{\tan. b}$; therefore

$W = \frac{1}{2} h S \frac{h + h'}{\tan. a}$. And as this change in the value of W will not affect that of the angle of fracture in any considerable degree, it may be neglected; in which case

$$R = h S \frac{h + h'}{2l}. \quad (I)$$

Hence the leverage becomes $Dp = h \frac{2h + 3h'}{6(h + h')}$, and the value of h' is $= \frac{h \tan. b}{\tan. a - \tan. b}$.

But in the actual construction of revetements the angle b is generally 45° , and in that case $h' = \frac{h}{\tan. a - 1}$; consequently

$$R = h^2 S \frac{\tan. a}{2l(\tan. a - 1)}. \quad (K)$$

$$\text{And, } Dp = h \frac{2 \tan. a + 1}{6 \tan. a}.$$

The equation (K) might be applied to demirevetements, and to partial revetements in general, where it would be accurate enough for practical purposes: and it must be remembered that the old methods fail completely when applied to these revetements.

According to the principles I have endeavoured to point out, it appears, that when the earthen scarp exceeds the height h' , it might be raised to any height without increasing the pressure against the wall; as is indicated by the experiments of Col. Pasley*. But if we suppose (with Belidor, Rondelet, &c. &c.) that the angle of fracture coincides with the natural slope of the earth; and also that the inclination of the earthen scarp BG (fig. 13) is the same as the natural slope (which is generally taken at 45°); it is obvious that the pressure ought to increase with the height of the earthen scarp, without limit.

* "Course of Military Instruction," vol. iii, chap. xxv.

This, however, is directly contrary to the results of the experiments above quoted, and to the experience of every practical man, who has been guided by the intuitive suggestions of his own feelings in preference to the rules of mechanical writers.

20, Bentinck-street, May 25, 1818.

LXIX. *On the Seeds of Plants.* By Mrs. AGNES IBBETSON.

To Mr. Tillock.

SIR, — MY object, it is well known, is to simplify my subject, render the real knowledge of the form and nature of plants easy; to furnish the means of comparing together the analysis of their resemblance and their differences; and by these means assign to each part a name, that may recall not only an appellation, but the idea of their *properties* and *qualities*, and what situation each part should hold in their general character in the vegetable world, when compared with the animal creation.

To show the formation of a plant by taking plants up *progressively* from the ground, and then *dissecting them in their increase*, must appear (I should suppose) of all means the *most exact and conclusive*; since one specimen becomes inevitably the correction of the preceding ones.

It is certainly the most *exact method* of understanding the formation of a plant, though it was never before known that a vegetable could be so taken: but common sense shows, that if the last part can be examined *progressively* and outwardly, the first should be sought in the same manner, in its *regular process in the interior*; and if every part of a plant assimilates with the animal creation in so exact a manner *interiorly*, is it likely it should differ in so essential a point as to form its *progeny or seed between the skins*? Is there a single instance in nature of such a formation, either animal, reptile, or insect tribe? the latter of which so much resembles plants. In my last letter I again brought forward that curious circumstance of which each dissection confirms the *truth*, and which forms a most beautiful and simple *delineation* of the construction of *vegetable nature*; I mean the fact "that the corculum of the seed is protruded in the root." It has been said that I assert "that the seed is formed there." I appeal to my various letters in this work and in Nicholson's Journal, for the refutation of this charge; proving there positively, that I never advanced such a proposition. No two things can be more different than the corculum of the seed and the seed itself; the first being inserted within the second in the way