For the intermediate value of ϕ we have $\frac{O + 90}{2} = 45^\circ$,

when $\phi = 45^\circ$, $E = \frac{h^2\gamma}{2}(1 - \sin\phi) = \frac{h^2\gamma}{2}(1 - \sin 45^\circ)$

$= \frac{h^2\gamma}{2}(1 - .707) = \frac{h^2\gamma}{2}.293.$ In other words, the inter-

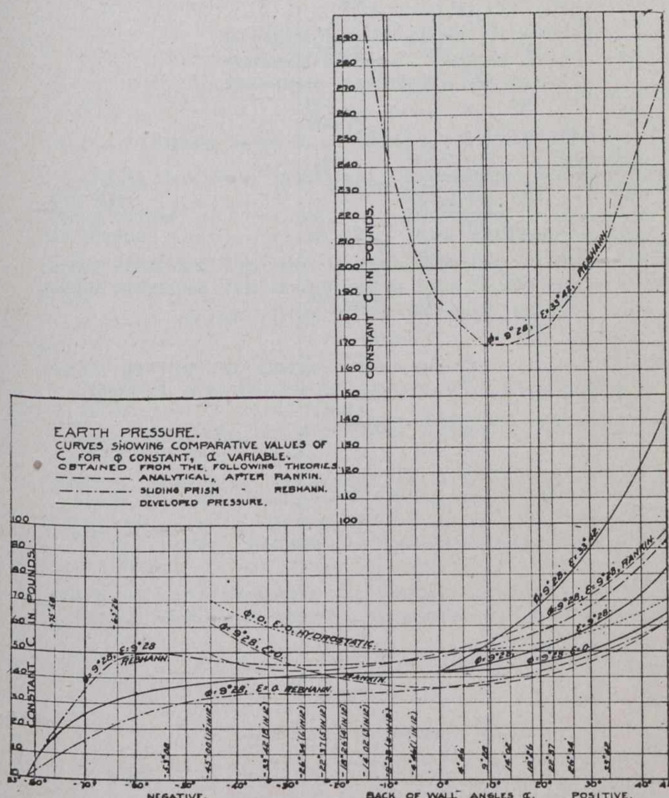

Fig. 6.—Platted Values for $\phi = 9^\circ\ 28'$, $\epsilon = O$, $9^\circ\ 28'$ and $33^\circ\ 42'$.

mediate value of ϕ gives a value for E which is a little over one-quarter that given for $\phi = O^\circ$ making E the maximum. The increase in the value of E (= C) is almost inversely proportional to the square of decrease of ϕ from the value (90°), giving the lower limit, as by the above formulae.

For back of wall batter α positive (sloping away from the fill), and $\epsilon = O^\circ$, the formulae becomes:

$$E = \sqrt{\left(\frac{\gamma}{2}(1 - \sin\phi)\right)^2 + W^2e}. \qquad We = \frac{h^2 \tan\alpha\,\gamma}{2}$$

= the weight of the earth wedge carried on the vertical projection of the back batter of the wall.

In Fig. 7 is given the dimensions by which the area of the earth wedge carried over the back of wall batter may be determined. The larger diagram was originally drawn to scale with the height h as unity, and the results checked with trigonometrical formula. Referring to the sketch at top of the diagram the formula for obtaining the area of the earth wedges A B L or A B S are as follows:

$BL = AL \tan\alpha = h \tan\alpha.$

$$\text{Area } ABL = \frac{BL \times h}{2} = \frac{h \tan\alpha\, h}{2} = \frac{h^2 \tan\alpha}{2}$$

$SL = BL \tan\epsilon = h \tan\alpha \tan\epsilon.$

$SA = h + SL = h + h \tan\alpha \tan\epsilon = h\,(1 \div \tan\alpha \tan\epsilon)$

$$\text{Area } ABS = \frac{BL \times SA}{2} = \frac{h \tan\alpha\, h\,(1 + \tan\alpha \tan\epsilon)}{2}$$

$$= \frac{h^2(\tan\alpha + \tan^2\alpha \tan\epsilon)}{2}$$

$$\text{Weight of } ASB = We = \frac{\gamma h^2(\tan\alpha + \tan^2\alpha \tan\epsilon)}{2}$$

The horizontal earth pressure P_ϵ is taken for the full height S A, and equals $\frac{\gamma}{2}(h\,[1 + \tan\alpha \tan\epsilon])^2\,(1 - \sin\phi)$.

With surcharge and back of wall batter away from the fill,

$$E = \sqrt{P^2_\epsilon + W^2_\epsilon} =$$

$$\sqrt{\left[\frac{\gamma(h\,[1+\tan\alpha \tan\epsilon])^2(1-\sin\phi)}{2}\right]^2 + \left[\frac{\gamma h^2(\tan\alpha + \tan^2\alpha \tan\epsilon)}{2}\right]^2}$$

The assumed point of application of P_ϵ is at ⅓ S A = $\frac{1}{3}h_\epsilon$ from the bottom.

DIRECTION OF EARTH PRESSURES.

The direction of the resultant earth pressure E with the horizontal equals the angle δ, and tang $\delta = \frac{W_\epsilon}{P}$

The earth pressure P is considered as acting only in a horizontal direction whether the wall carries a surcharge or not. When a mass of earth is either confined in a bin or surrounded by a mass of the same material, and indefinite in extent, the developed pressure producing squeeze, to be in equilibrium, must act and react on the particles within the mass. Consequently the net resultant of the squeeze will be at right angles to the force of gravity.

The case of material simply confined in a bin should not be confused, however, with the case in which material is withdrawn from the bottom. In the latter case, as soon as material is withdrawn from the bottom, friction is developed against the sides of the bin and the whole case is thereby modified.

Where Surcharge Gives no Added Pressure.

For a negative back of wall batter as well as for vertical back, a surcharge fill is not considered as giving any more pressure than if it ran off level or even sloped down away from the back of the wall. To illustrate, take Fig. 8, which represents a bin 40 ft. deep and 10 ft. square. For hydrostatic pressure the amount is the same, whether the fluid pressing against the side of the bin extends back from the face one foot or is of indefinite extent. The same should hold true within certain limits for granular and semiplastic substances. With a bin of the size shown and filled with a granular mass possessing little or no cohesion and incompressible, but having sufficient friction between the particles to stand at an angle of repose of 45°, there is little reason to believe there would be any more pressure on the side A B with a surcharge slope than with a level top. In the upper right-hand corner of Fig. 8 is sketched what we will term a pile of cylinders, marked 1A — 1E, 1A — 9A, etc. A common example is the piling of barrels. When piled as shown they will stand with a natural slope of 60°, and are held in this position by friction alone, as there is manifestly no cohesion. If the cylinders and the plane a c, on which they rest, were to lose all friction they would sink to the level of 1A, 1B, etc. As long as the angle of friction between cylinders in contact is greater than 30° the cylinders will remain in equilibrium. (The angle which the tangent passing through the points of contact of the cylinders makes with the horizontal is 30°.)