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THE ACTION OF WIND ON MOUNDS

by

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S U M M A R Y

A preliminary study of the action of wind on projections from a flat plane is made by means of a theoretical free-streamline model. A computer solution gives indications applicable, for instance, to the control of wind-blowing of stock-piles of granular materials. Limited experimental observations are adduced as confirmation of the model.

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Inviscid flow over mounds

Initially the two idealised 2-dimensional flow situations shown in Figure 1 are studied from

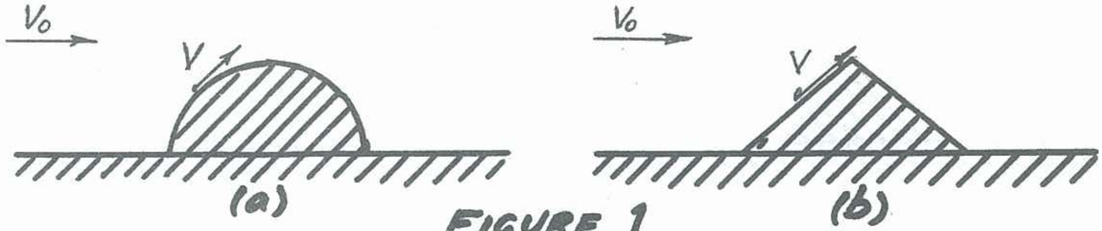

FIGURE 1

the point of view of surface velocity (expressed as $\frac{V}{V_o}$) and surface pressure (expressed as $C_p \equiv \frac{P-P_o}{\frac{1}{2}\rho V_o^2}$).

The ideal flow over the semi-cylinder in Figure 1(a) is well known and needs no elaboration here; the velocity ratio reaches a maximum value of 2 at the top, the pressure coefficient C_p goes down to -3 and two thirds of the surface is subjected to a velocity greater than the ambient velocity V_o.

The flow over the triangular section in Figure 1(b) is assumed to break away into a free streamline as shown in Figure 2.

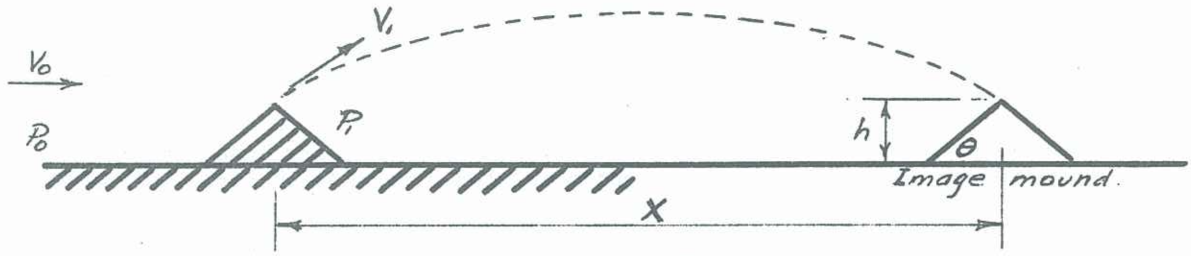

FIGURE 2

This has been analysed using the Schwarz-Christoffel transformation together with a computer and plotter to draw the free streamline profiles (see appendix A). The computation was carried out for values of θ = 30°, 35°, 40°, 45° and for values of P_1 corresponding approximately to C_p in the lee of the mound between -0.2 and-1.0. The values of parameters were chosen to be realistic for the usual run of stockpiles of granular materials, to which this study is primarily directed.

For this range of parameters $\frac{V_1}{V_o}$ ranges between 1.1 and 1.4. The computations show that the proportion of mound surface exposed to velocities higher than V_o does not vary from the value 0.22 by more than 10% for the whole range of parameters given. Also the value $\frac{X}{h}$ is never less than 10 and $\frac{H}{h}$ is never less than 2.5.

Real flow over mounds

The real flow is likely to differ from the foregoing idealised model for several reasons.

Firstly the approaching flow will not be uniform but will be part of the boundary layer between the wind and the ground, which clearly will behave somewhat differently from the simple model used. Nevertheless the model provides a useful first approach to the problem.

Secondly, in the case of the semi-cylindrical mound, the flow will of course separate on the downstream side; but this will not greatly affect the conclusions as to maximum velocity and minimum pressure.

Thirdly, in the case of the triangular mound, the free streamline fluid will begin life much as indicated by the computations, but as it progresses the shear between it and the semi-stagnant downstream fluid will result in a circulation like that shown in Figure 3. This pattern has been observed in the lee of actual stockpiles as well as in limited small-scale wind tunnel studies.

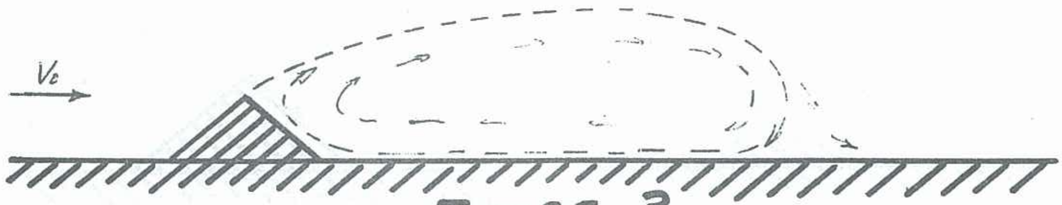

FIGURE 3

Fourthly, in the real situation the flow is never purely 2-dimensional but is likely to have 3-dimensional end effects.

All of the above indicates that there is still much more to be done on this problem, but in spite of this some useful findings are indicated by the work so far.

Conclusions

1. A sharp edged mound (Figure 1(b)) by causing a break-away of the flow into a free streamline, has much less of its surface exposed to velocities greater than ambient than has a rounded mound.

2. Likewise the sharp-edged mound has smaller maximum value of surface velocity and less pressure drop than the rounded mound.

3. This implies that (for instance) a sharp-edged stockpile of granular material is less liable to wind-blowing than a rounded one. Furthermore it suggests that economies may be effected in the common practice of protection by surface spraying, by limiting the spraying to strategic areas.

4. There is a considerable sheltered region downstream of the sharp edge, in which the velocity nowhere reaches more than a fraction of the ambient velocity. The values of $\frac{X}{h}$ and $\frac{H}{h}$ are indicative of the extent of the region. This means that one sharp edge can protect stockpiles of material in its lee as shown in Figure 4. In a

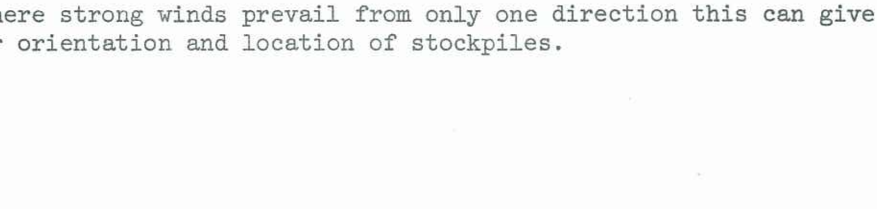

FIGURE 4

situation where strong winds prevail from only one direction this can give useful guidance for orientation and location of stockpiles.

APPENDIX A

FREE-STREAMLINE DEVELOPMENT

Refer to Figure 5. By three transformations the flow in the z plane is transformed to the uniform flow of the w plane, as follows :

(i) z plane to ζ (hodograph) plane -

$$\zeta = \frac{dz}{dw} = \left| \frac{1}{V} \right| e^{i\alpha}$$

where V is magnitude of velocity and α is its direction.

(ii) ζ plane to ζ' plane -

$$\zeta' = \ln \zeta = \ln \left| \frac{1}{V} \right| + i\alpha$$

(iii) ζ' plane to w plane (Schwarz - Christoffel transformation)

$$\zeta' = A \int \frac{dw}{(w^2 - a^2)\,(w^2 - 1)^{\frac{1}{2}}} + B$$

This may be further developed using elliptic integrals, but it turns out to be less convenient than direct numerical integration using the computer. Hence the computer was used to produce the results quoted.

The boundary $I_{-\infty}CDEFI_{\infty}$ is the main interest (or ultimately the free streamline DE). This transforms as shown.

The constants A, B, a are evaluated for chosen values of θ by taking known corresponding values of ζ' and w for the points

$$I \;\left(\zeta' = \ln\frac{V_1}{V_0}\,,\quad w = \pm\,\infty\right)$$

$$D\;(\zeta' = \theta i\,,\quad w = -1),\qquad E\;(\zeta' = -\theta i,\quad w = +1)$$

The values of z are then computed thus determining the shape of the free streamline and any other information required.

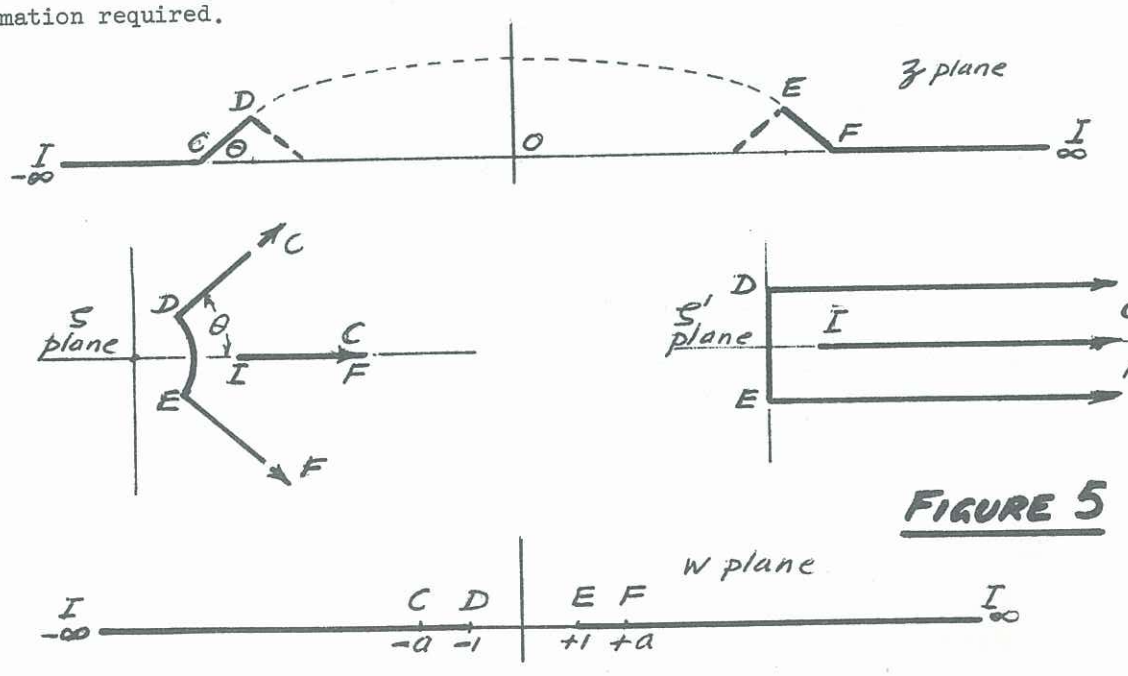

FIGURE 5