Calculating Dragline Reach Requirements for Western Surface Mines

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The tremendous interest in development of surface-mineable coal throughout the western US will bring with it a requirement for many manhours spent in mine planning and equipment selection. One problem in particular that engineers face during the planning stage is that of selecting a dragline with the proper reach capability.

Reach, expressed in terms of operating radius and effective spoil radius, can be a major problem when mining deeper than originally planned, and aside from production requirements, the ability of a particular dragline to spoil across a strip is essential. Determination of dragline reach needed for a multiple-seam western coal operation can be simplified by use of an equation derived below that eliminates the need for tedious and repetitive calculations.

Earlier Equation Doesn't Apply to Western Conditions

The operating radius of a dragline is defined as the horizontal distance from the center line of the machine to the dump line under the boom point. Effective spoil radius is the operating radius less one-half the width over the shoes, minus an allowance for a safety berm at the edge of the highwall. The effective spoil radius necessary for any given mine is the horizontal distance from the crest of the highwall to the top of the spoil pile.

Rumfelt[1] simplified reach calculations during the 1960's by deriving an equation for effective spoil radius, using a typical single-seam mine and assuming a highwall slope of three to one (rise to run) and a spoil slope at the angle of repose of 0.8 to one—conditions typical of eastern strip mines.[2] The formula:

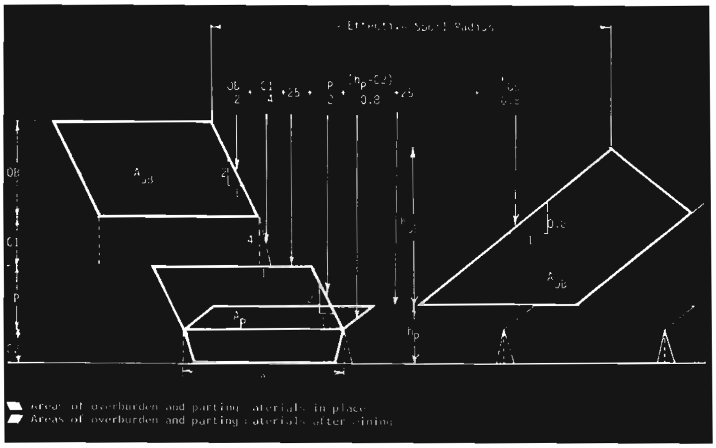
$$r = [0.33H - 3.3] + [1.25] \times [(1 + S/100)(H) - t + W/5]$$

where r = reach in feet
S = swell (in percent)
H = depth of overburden (in feet)
W = cut width (in feet)
t = deposit thickness (in feet)

unfortunately, does not apply to two- or three-seam mining operations or other surface-mine conditions typically found in the western US. There, the overburden and parting materials are weaker than in the East and the highwall will not stand as steep as three to one. Consequently, derivation of an equation for effective spoil radius at two- or three-seam mining operations in the West will be useful.

An equation for two seams is necessary to evaluate whether or not a given dragline can be used as a prime stripping machine with enough reach to allow stowing of parting material and mining of the lower coal seam. In a one-seam operation that has a lower seam not being mined, the dragline will have a given operating radius. Mining of the lower seam would be contingent upon whether this radius is large enough to reach across the additional pit width necessitated by the additional depth. This extra reach capability is frequently not available on stripping machines used presently in the West.

For operating mines, the two-seam effective spoil radius equation can indicate whether or not the present dragline has enough reach to allow mining of the second seam. For mines in the planning stage, the equation predicts the reach the dragline must have.



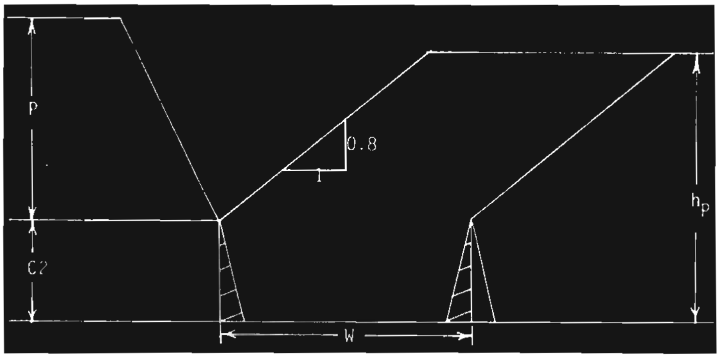


Fig. 1(top)—General geometry of a two-seam mining operation, using parting stowing methods. This case assumes: 200 ft $\geq h_p + h_{OB} \geq$ 100 ft.

Fig. 2 (bottom)—The area of parting material (loose). This is an expansion of Fig. 1: The crosshatched area represents the area that must be subtracted from ($h_p \times W$) because of the ribs.

Adapting the equation to western mining conditions requires the following assumptions:

- Overburden and parting materials have two to one highwall slopes; upper and lower coal seams have highwall slopes of four to one; and spoiled material lies at a slope of 0.8 to one.
- There will be safety benches in the highwall at the base of the upper coal and in the spoil side if the total height of the spoil pile is more than 31 m (100 ft).
- Overburden and parting materials have similar swell factors.

The geometry of a two-seam mining operation utilizing a parting-stowing method is illustrated in Fig. 1. The overburden (A_{OB}) is initially placed across the cut, exposing the upper coal seam for removal. The parting material (A_p) is stowed in the bottom of the same cut from which the material is being removed. In this figure and in the equa-

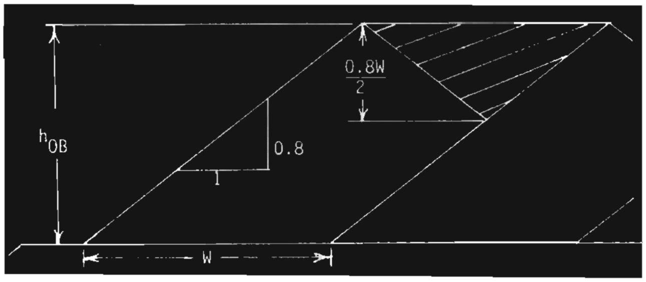


Fig. 3—The area of overburden material (loose). Also an expansion of Fig. 1, the crosshatched portion represents the area that must be subtracted from ($h_{OB} \times W$) because of the pointed spoil piles.

tion, the overburden, upper coal, parting, and lower coal thicknesses are represented by OB, $C1$, P, and $C2$ respectively. The height of the spoil due to parting material is h_p and the height of the spoil pile due to overburden material is h_{OB}.

For a unit thickness of material, equal volumes may be represented by equal areas per unit thickness. Therefore, the area of overburden material must equal the area of spoil due to the overburden with adjustment to the volume for swell.

The area of the parting material can be given by one of the following equations:

$$A_p = P \times W \quad \text{(In-place equation)} \quad (1)$$
$$A_p \times P \times W \times (1 + \text{swell}) \quad \text{(Loose equation)} \quad (2)$$
$$A_p = h_p \times W - C2^2/4 \quad \text{(Loose equation)} \quad (3)$$

where P = the parting thickness
W = the width of each succeeding cut
Swell = the parting material swell
h_p = the height of the spoiled parting material
$C2$ = the lower coal seam thickness

The geometry necessary for the derivation of the third equation is shown in Fig. 2. The area available for stowing the parting is equal to the total area ($h_p \times W$) less the area of half of the two ribs ($C2^2/4$). The area lost is two times the area of the right triangle that has $C2$ as its height and $C2/4$ as its base.

By taking Eq. 2 and 3 for the area of parting material and then solving for the height of parting material, the following equation is developed:

$$h_p = P(1 + \text{swell}) + C2^2/(4 \times W) \quad (4)$$

where P = the parting thickness
Swell = the parting material swell
$C2$ = the lower coal seam thickness
W = the width of each succeeding cut

The area of overburden material can be given by one of the following equations:

$$A_{OB} = OB \times W \quad \text{(In-place equation)} \quad (5)$$
$$A_{OB} = OB \times W \times (1 + \text{swell}) \quad \text{(Loose equation)} \quad (6)$$
$$A_{OB} = h_{OB} \times W \times 0.2W^2 \quad \text{(Loose equation)} \quad (7)$$

where
OB = the overburden thickness
W = the width of each succeeding cut
Swell = the overburden material swell
h_{OB} = the height of spoiled overburden material

Similarly, geometry governing derivation of Eq. 7 is represented in Fig. 3. The area available for piling the overburden material is the height of the overburden times the width of each cut less the amount represented by the crosshatched area created by the peaked spoil piles.

The height of the spoil pile due to overburden is given by:

$$h_{OB} = OB(1 + \text{swell}) + W/5 \quad (8)$$

where
OB = the overburden thickness
Swell = the overburden material swell
W = the width of each succeeding cut

The effective spoil radius for the case presented in Fig. 1 can now be derived. Using the geometry of this typical cut, including 8-m (25-ft) safety benches, the following equation can be written for the effective spoil radius:

$$\text{ESR} = \frac{OB}{2} + \frac{C1}{4} + 25 + \frac{P}{2} + \frac{h_p - C2}{0.8} + 25 + \frac{h_{OB}}{0.8} \quad (9)$$

where h_p = value given by Eq. 4
h_{OB} = value given by Eq. 8

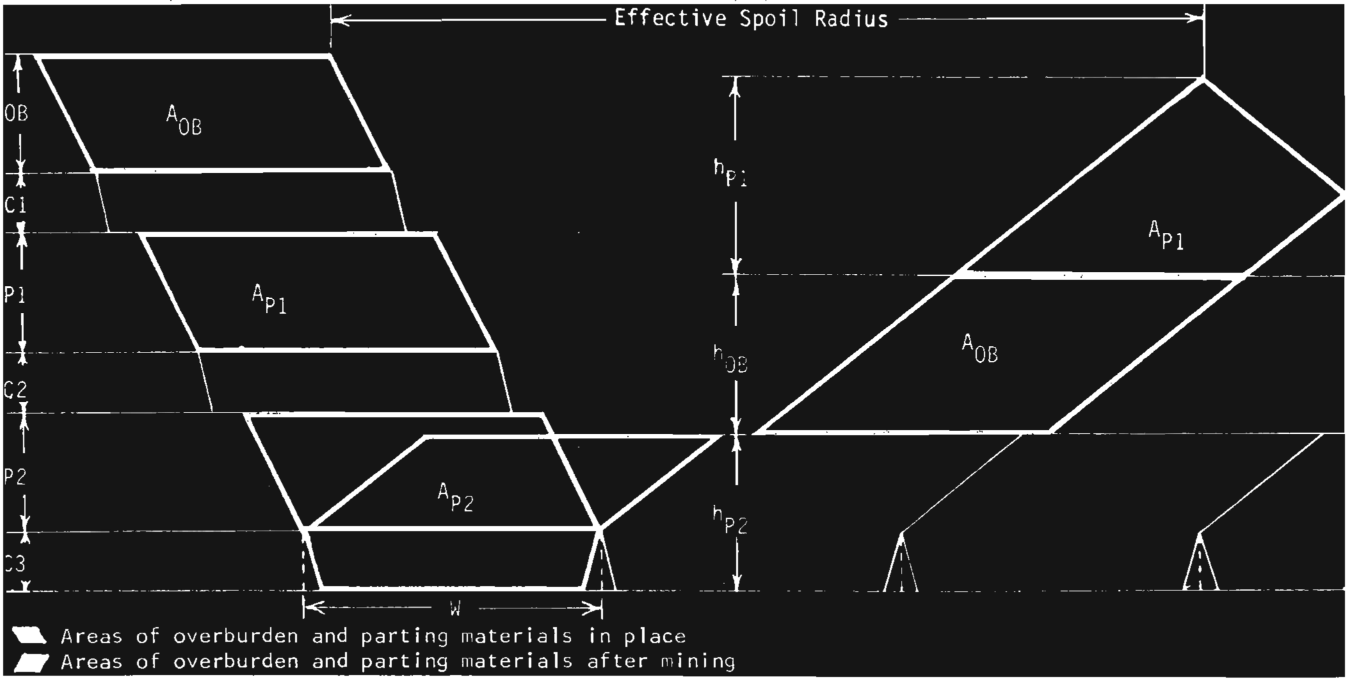


Fig. 4—The general geometry of a three-seam mining operation. This case assumes: 200 ft $\geq h_{OB} + h_{P1} + h_{P2} \geq$ 100 ft.

OB = the overburden thickness
$C1$ = the upper coal seam thickness
P = the parting thickness
$C2$ = the lower coal seam thickness

Substituting Eq. 4 and 8 into this equation yields the following equation for the effective strip ratio, in terms readily available to anyone working on a particular operation:

$$ESR = \frac{OB}{2} + \frac{C1}{4} + \frac{P}{2} + \frac{5P(1 + \text{swell})}{4} + \frac{5(C2)^2}{16W} - \frac{5(C2)}{4} + \frac{5OB(1 + \text{swell})}{4} + \frac{W}{4} + 50 \quad (10)$$

where
OB = the overburden thickness
$C1$ = the upper coal seam thickness
P = the parting thickness
$C2$ = the lower coal seam thickness
Swell = the swell of overburden and parting material
W = the width of each succeeding cut

This final equation will be useful to engineers working in two-seam coal mining operations, and, using a parting-stowing technique, maximum mining depths can be computed for a known machine reach and effective spoil radius. For a given mine geometry the necessary effective spoil radius may be computed, and a dragline ordered which will have sufficient reach.

Reach limitations are of primary importance when ordering a dragline; of secondary importance is the limited dumping height of such machines. The latter can be evaluated by comparing the total height of the spoil pile ($h_{OB} + h_p$) against the total depth of the cut plus the maximum dumping height of the dragline.

Derivation of Three-Seam Equation

The geometry of a conventional three-seam mining scheme is presented in Fig. 4 for the purpose of deriving an effective spoil radius equation for this case. It is assumed that the overburden and the upper parting will both be moved from the highwall side of the mine and the lower parting material will be moved using some method of parting stowing. Parting and overburden material slopes are two to one, coal seam slopes are four to one, and the spoil pile slope is 0.8 to one. For this particular case safety berms of 3 m (10 ft) are assumed at the base of each of the upper coal seams and only one 10-ft berm in the spoil pile. The following equation will produce the effective spoil radius needed:

$$ESR = \frac{OB}{2} + \frac{C1}{4} + \frac{P1}{2} + \frac{C2}{4} + \frac{P2}{2} + \frac{(h_{P2} - C3)}{0.8} + \frac{h_{OB}}{0.8} + \frac{h_{P2}}{0.8} + 30 \quad (11)$$

where $h_{P2} = P2\,(1 + \text{swell}) + C3^2/(4 \times W)$
$h_{OB} = OB\,(1 + \text{swell})$
$h_{P1} = P1\,(1 + \text{swell}) + W/5$
OB = the overburden thickness
$C1$ = the upper coal seam thickness
$P1$ = the upper parting thickness
$C2$ = the middle coal seam thickness
$P2$ = the lower parting thickness
$C3$ = the lower coal seam thickness
Swell = the overburden and parting material swell
W = the width of each succeeding cut.

Substituting h_{P2}, h_{OB}, and h_{P1} into Eq. 11 will produce an equation in terms familiar and readily available to any design engineer or equipment specifier. If the highwall or spoil slopes or the mining sequence differ, the equation must vary accordingly.

Use on a Case-by-Case Basis Only

Dragline reach equations are an important way of solving certain problems encountered in mine planning or operation. Each equation is derived using the slope stability characteristics of the particular area or mine in question, and each equation must take into account the mining scheme being used.

Since the reach requirements are calculated from a single equation using few variables, the technique is easily adaptable to a programmable pocket calculator or a desk-top unit. Reach requirements and boom lengths are immediately available without tedious calculations or time-consuming range diagrams. Utilization of this method can increase planning output and reduce the time involved in examining multiple mining options. □

References

[1] Rumfelt, H., "Stripping Machinery Mass, Overburden Volumes Relationships," SME-AIME Fall Meeting, St. Louis, 1960.
[2] Woodruff, S. D., "Methods of Working Coal and Metal Mines. *Planning and Operations*, Pergamon Press, New York, 1966, p. 421.

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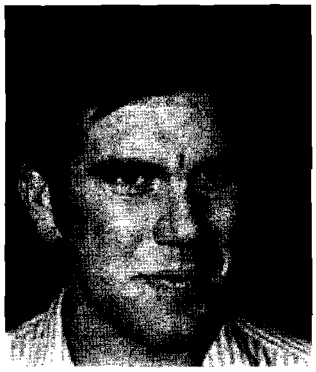

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