Appendix V - Rock Mass Properties

AAI indicated in a written response to the investigation team that the rock mass modulus was modified from $1x10^6$ psi used in their calibrated EXPAREA model to $2x10^6$ psi to account for the reduced stiffness introduced by the laminated rock mass used in LaModel. However, the engineer who conducted the work subsequently indicated that he had used the default elastic modulus in LamPre (i.e. $3x10^6$ psi) and evaluated the response of their model to lamination thicknesses of 25 and 50 feet. He noted no difference between the two thickness values and opted to use 25 feet thereafter.

In his dissertation, Heasley[5] provides equations that represent the relationship between convergence in the laminated overburden used in LaModel and homogeneous elastic rock masses used in other boundary element models. First, he notes that the seam convergence across a two-dimensional slot for the laminated model (s_l) as a function of the distance from the panel centerline (x) can be determined as:

$$s_l(x) = \frac{\sqrt{12(1-\nu^{2)}}}{t}\frac{q}{E}(L^2 - x^2) \qquad \text{Equation 1}$$

where: s = seam convergence,
- x = distance from the panel centerline,
- υ = rock mass Poisson's ratio,
- t = layer or lamination thickness,
- q = overburden stress,
- E = rock mass elastic modulus, and
- L = half width of longwall panel.

A comparable equation for convergence in a homogeneous, isotropic, elastic overburden (s_h) is provided by Jaeger and Cook[27]:

$$s_h(x) = 4(1-\nu^2)\frac{q}{E}\sqrt{(L^2 - x^2)} \qquad \text{Equation 2}$$

Heasley equates these relationships and solves for the lamination thickness (t) corresponding to the convergence at the center of the panel (x=0):

$$s_l(0) = \frac{\sqrt{12(1-\nu^{2)}}}{t}\frac{q}{E}L^2 = 4(1-\nu^2)\frac{q}{E}L = s_h(0) \qquad \text{Equation 3}$$

Assuming that the elastic modulus in both cases is constant, the result is:

$$t = \sqrt{\frac{3}{4}}\frac{L}{\sqrt{1-\nu^2}} \qquad \text{Equation 4}$$

However, in the present case, AAI increased the modulus threefold. To account for dissimilar moduli, equations 1 and 2 can be solved in a similar manner to yield the following relationship:

$$t = \sqrt{\frac{3}{4}}\frac{E_{HOMOGENEOUS}}{E_{LAMINATED}}\frac{L}{\sqrt{1-\nu^2}} \qquad \text{Equation 5}$$

Equation 5 indicates that the required thickness is reduced by a factor of three as a result of increasing the rock mass modulus for the laminated model. However, if we assume a panel half-width of 117 meters (385 feet or half the width of an average 770-foot wide longwall panel), the estimated lamination thickness is 35 meters (115 feet) which is more than four times greater than the 25-foot thickness that AAI used. The effect of thin laminations is that stress will be concentrated more at the edges of openings rather than be distributed farther away.