SAN096-2604C

Expanded Rock Blast Modeling Capabilities of DMC_BLAST, Including Buffer Blasting*

SAND--96-2604C
CONF-970253--2

Dale S. Preece
Sandia National Laboratories

J. Paul Tidman and Stephen H. Chung
ICI Explosives Canada

Abstract

A discrete element computer program named DMC_BLAST (Distinct Motion Code) has been under development since 1987 for modeling rock blasting (Preece & Taylor, 1989). This program employs explicit time integration and uses spherical or cylindrical elements that are represented as circles in 2-D. DMC_BLAST calculations compare favorably with data from actual bench blasts (Preece et al, 1993).

The blast modeling capabilities of DMC_BLAST have been expanded to include independently dipping geologic layers, top surface, bottom surface and pit floor. The pit can also now be defined using coordinates based on the toe of the bench. A method for modeling decked explosives has been developed which allows accurate treatment of the inert materials (stemming) in the explosive column and approximate treatment of different explosives in the same blasthole. A DMC_BLAST user can specify decking through a specific geologic layer with either inert material or a different explosive. Another new feature of DMC_BLAST is specification of an uplift angle which is the angle between the normal to the blasthole and a vector defining the direction of explosive loading on particles adjacent to the blasthole. A buffer (choke) blast capability has been added for situations where previously blasted material is adjacent to the free face of the bench preventing any significant lateral motion during the blast.

Modeling Dipping Geologic Layers

DMC_BLAST was originally developed to treat rock motion associated with blasting in U. S. surface coal mines which typically have flat lying sedimentary beds. Blasting in dipping layers of rock occurs in some parts of the world, particularly in surface coal mines in Western Canada. Modeling rock motion and muck pile formation is as important in dipping layers as in horizontal, requiring the geometrical definition in DMC_BLAST to be generalized. The two categories of layer dip in relation to bench blasting are, 1) layers dipping to the bench face, and 2) layers dipping away from the bench face. DMC_BLAST simulation for these two cases are illustrated in Figures 1 and 2, respectively. Figure 1 shows four time steps of a blast simulation in rock layers dipping to the bench face. Figure 2 shows a simulation with the layers

*This work performed at Sandia National Laboratories supported by the U.S. Department of Energy under contract no. DE-AC04-94AL85000 and also supported by ICI Explosives USA.

Published in the proceedings of the *13th Annual Symposium on Explosives and Blasting Research of the International Society of Explosives Engineers*, February 2-5, 1997, Las Vegas, NV.

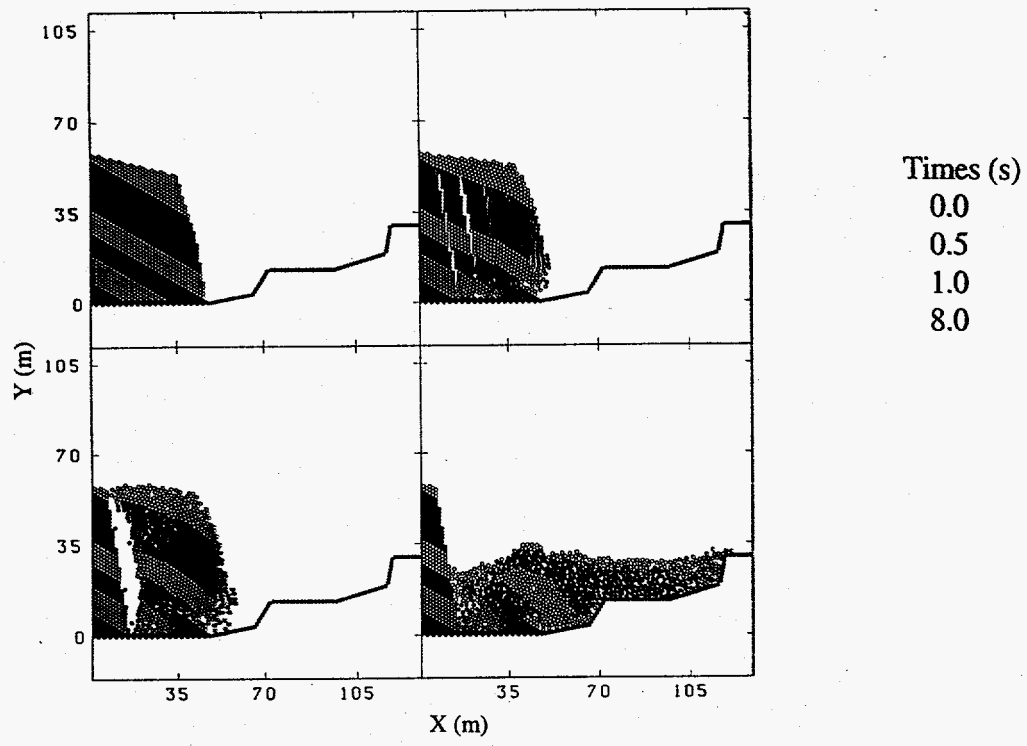

Figure 1: Bench blast simulation with geologic layers dipping to the face, differently dipping top surface with a flat bottom surface and a pit defined using coordinates.

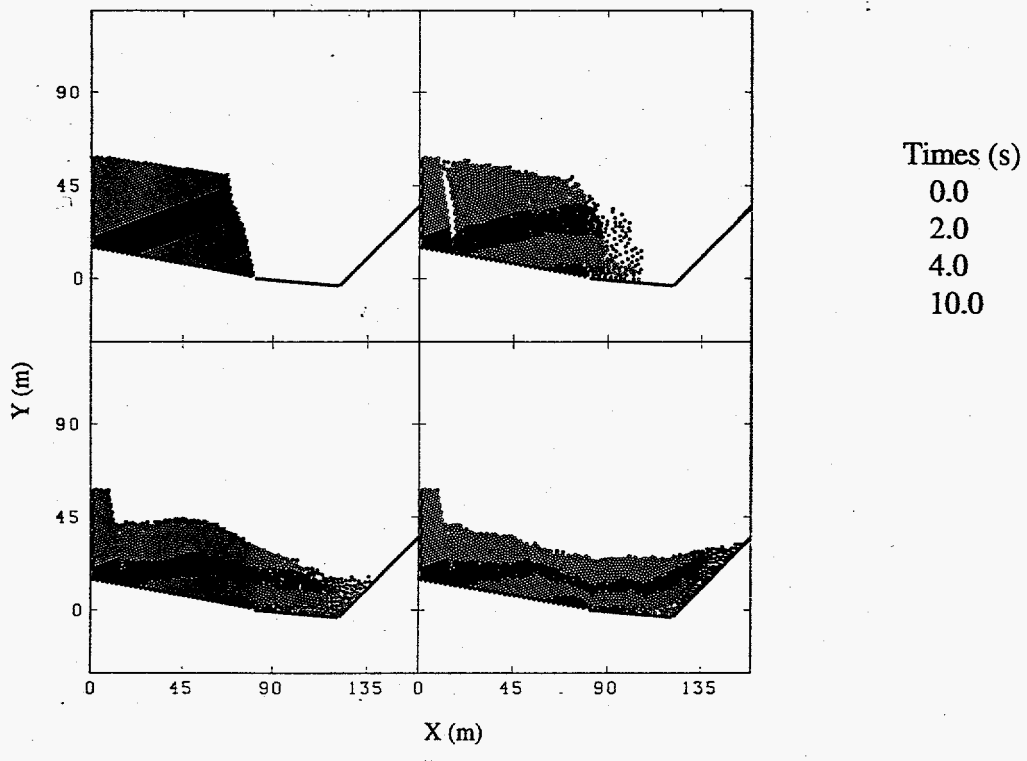

Figure 2: Bench blast simulation with geologic layers dipping from the face and a pit defined using pit width and pit dip. Top and bottom surfaces are parallel dipping to the face.

DISCLAIMER

dipping away from the bench face. These two simulations demonstrate significantly different behavior in the blast-induced movement and final location of the rock layers being blasted. Layers dipping away from the face are more likely to spread and be scattered than are layers dipping to the face though in each case the effect is amplified by the dip of the pit floor. Details for these two simulations as well as others presented in this paper are available in Table 1.

DMC_BLAST assumes that the explosive loading (powder factor) is high enough to totally fragment the rock, which is usually true for cast blasting. Complications to rock fragmentation can arise with relatively low powder factors and layers that dip to or from the face (Atlas Powder Company, 1987). Note that DMC_BLAST does not treat fragmentation and the attending behavior associated with bench blasting in dipping layers.

Modeling Dipping Top Surface, Bottom Surface and Defining the Pit Floor

Other new capabilities of DMC_BLAST for treating bench blasting are 1) dipping top surface, 2) dipping bottom surface, and 3) pit floor definition. These are illustrated in Figures 1 and 2. The discrete element model in Figure 1 has a top surface that dips to the face and a flat bottom surface. The model in Figure 1 also has the pit defined with coordinates based on the toe of the bench. Figure 2 illustrates top and bottom surfaces dipping to the face as well as a pit defined by a width and dip angle along with a spoil angle.

Burden Movement

Figures 3 and 4 present a simulation that is identical those in Figures 1 and 2 except that the burdens are represented by different colors (gray shades) as is common practice in the blast modeling program SABREX (Kirby et al, 1987). Display of the burdens in this fashion provides a visual check on the blast design entered into the simulation and also allows an assessment of the movement and final location of the material associated with each row of blastholes.

A challenge associated with bench blasting is the difficulty of moving the material in the toe (bottom) of the blast as shown in Figures 3 and 4. This problem can be alleviated by placing decks of higher energy explosive in the bottoms of the blastholes. This type of modeling can now be done in an approximate manner in DMC_BLAST by increasing the *explosive loading factor* from 1.0 to a maximum of approximately 1.5. The *explosive loading factor* is a multiplier applied to the calculated gas force on spheres adjacent to the blasthole.

Decking Through Layers

Inert decking through layers can be important when blasting dipping coal seams along with the material above and below the seam. It is desirable to fragment the material surrounding the coal without fragmenting (chilling) the coal itself. This is commonly done by placing an inert deck (stemming material) through the layer, with some stand-off from the layer, to prevent explosive loading of the coal. DMC_BLAST allows the user to define decking-through a specific layer since manual definition can be tedious for dipping layers. This capability is illustrated in Figure 5 which shows the same simulation as

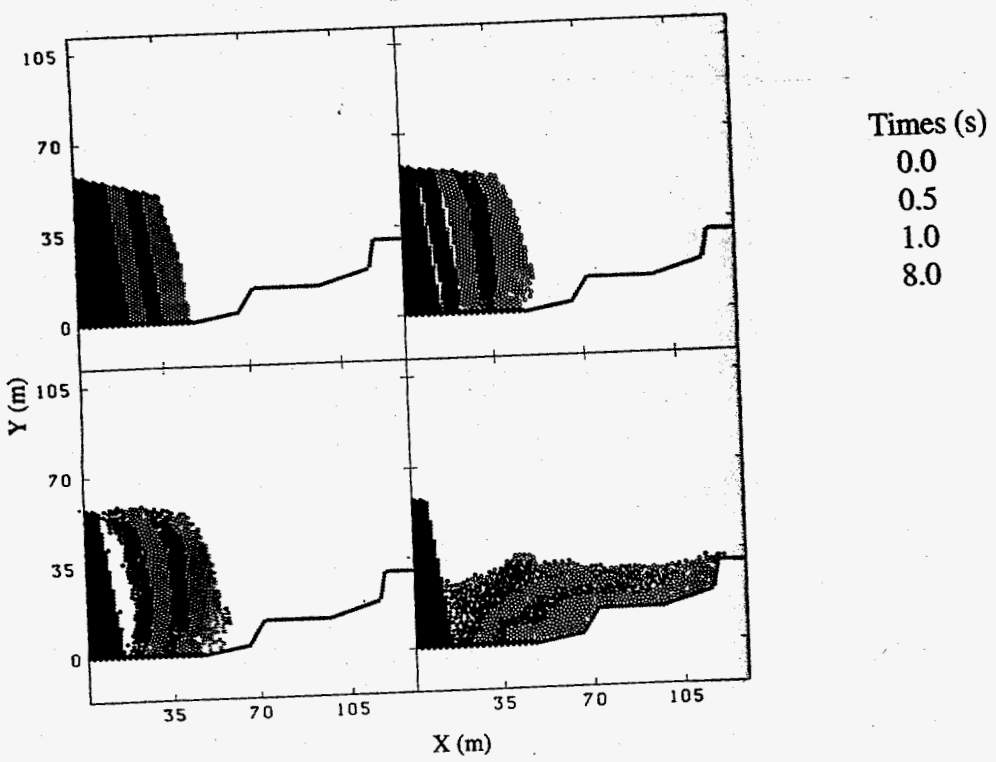

Figure 3: Bench blast simulation as in Figure 1 but with differentiated burdens.

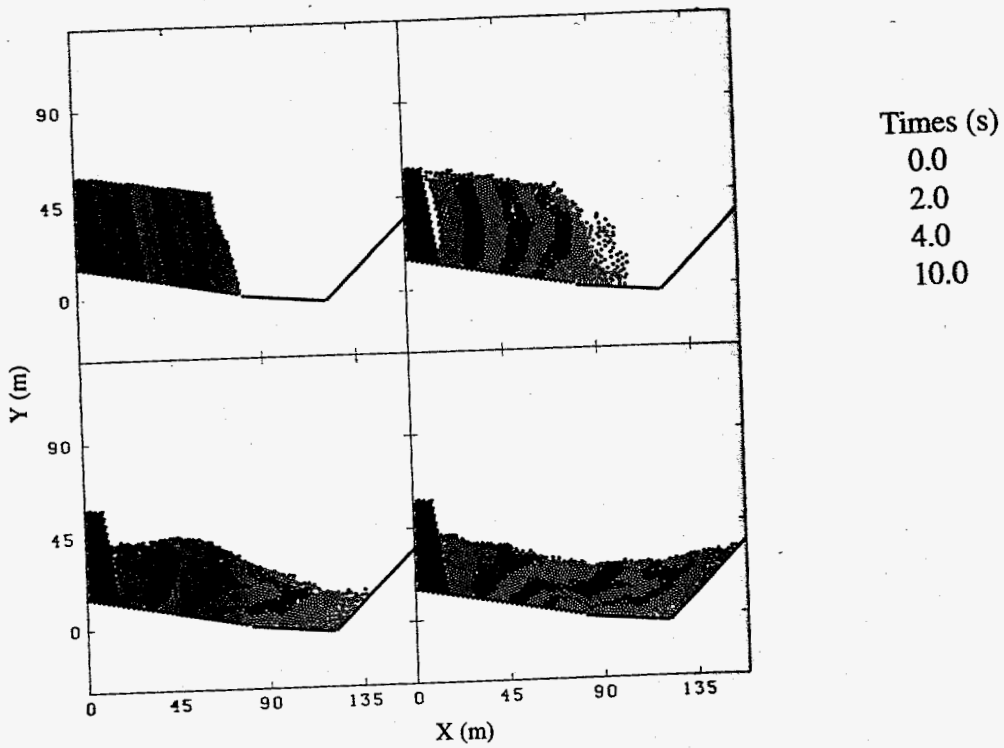

Figure 4: Bench blast simulation as in Figure 2 but with differentiated burdens.

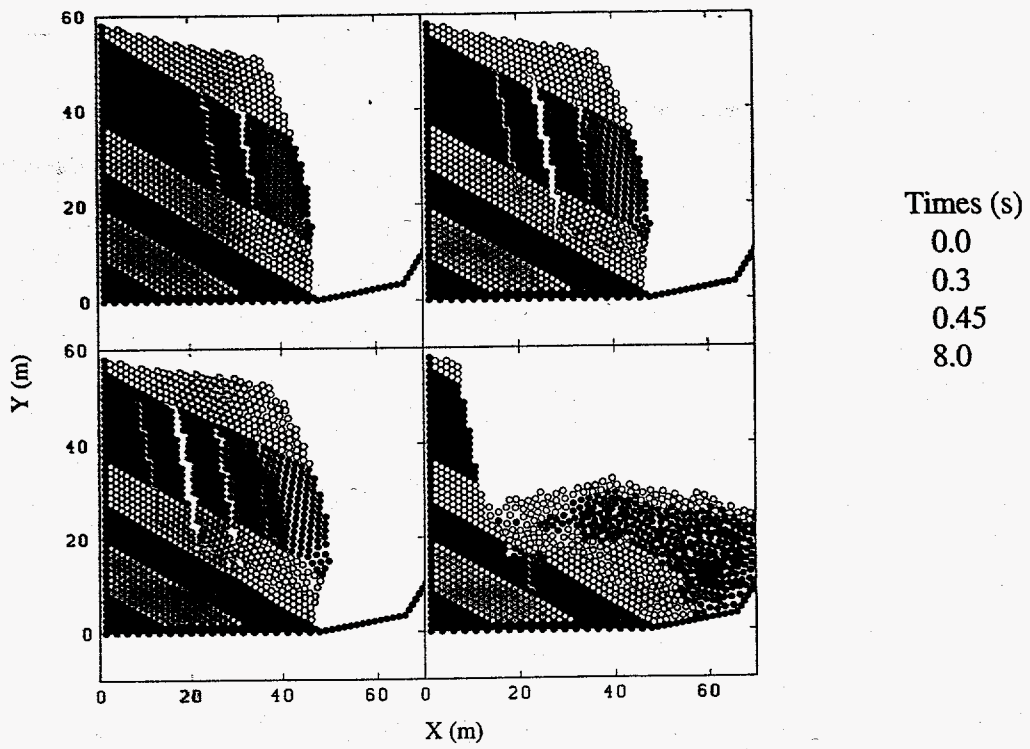

Figure 5: Bench blast simulation as in Figure 1 but with the fourth layer from the top decked-through with inert to prevent explosive loading.

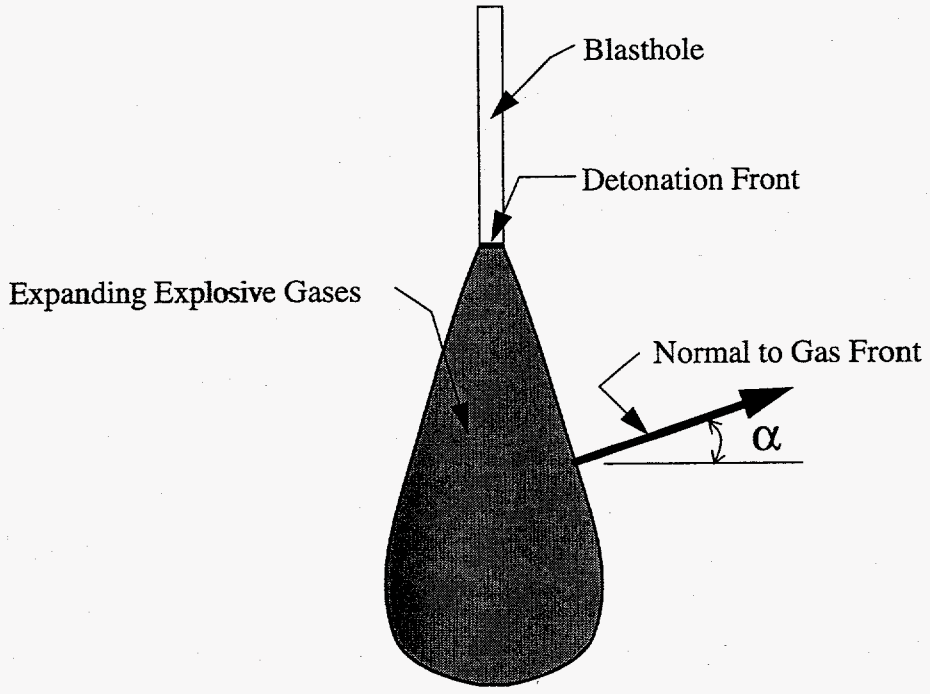

Figure 6: Definition of uplift angle, α.

that of Figure 1 but with the fourth layer from the top decked-through with inert material. A stand-off of 2 m from the layer was also specified. Close observation of Figure 5 indicates explosive loading above and below the layer, but no loading of the layer itself. Drag forces exerted by the surrounding explosively loaded material cause some movement of the layer but it is minimal compared to that seen in Figure 5.

Uplift Angle

The concept of uplift angle is defined as the angle between horizontal and the normal to the expanding gas bubble as illustrated in Figure 6. An estimate of the uplift angle, α, can be obtained from the detonation velocity, V_d, and the gas expansion velocity, V_e, using the following the equation

$$\alpha = \text{atan}\frac{V_e}{V_d}$$

The detonation velocity, V_d, is published for all commercial explosives and is therefore easy to obtain. The gas expansion velocity, V_e, is much more difficult to determine and is the subject of current research. A estimated uplift angle of 20° has been used in the example simulations presented in this paper. Figure 7 shows the loading direction for spheres adjacent to a vertical blasthole with the uplift angle set at 20°.

Modeling of Choke/Buffer Blasting

Choke or buffer blasting refers to a blast initiation pattern that does not run parallel to a bench free face. A choke blast is a series of relatively shallow crater blasts that are typically initiated in an echelon pattern, the object of which is to fragment the rock and dilate it enough to make it diggable. This type of blasting is used extensively in the U. S. surface gold mines in Nevada where fragmentation and diggability are desired with minimum rock movement. Uneven distribution of high grade ore requires preblast assaying of blastholes during drilling. Assay data are used to plan the excavation of ore and waste. Since all planning is done preblast, significant blasting-induced movement can result in ore dilution. Rock movement during choke blasting has been monitored and the displacement has been found to be significant (Zhang et al, 1994, Taylor et al, 1996). Based on measured displacement of the rock, ore dilution is estimated to be large enough to have an economic effect on the mine.

An example choke-blast simulation with rock layers differentiated is illustrated in Figures 8. Details of the blast design employed in this simulation are available in Table 1. The information of most interest from this simulation is the lateral movement of rock from its initial position. Figure 9 displays the burdens, giving an indication of the spatial distribution of the calculated horizontal movement. The final horizontal displacement of spheres adjacent to four of the eight rows of blastholes are shown in Figure 10. Lateral motion during choke blasting, as measured by Zhang et al, 1994, varies from 0 to 7m. Displacements predicted by DMC_BLAST (Figures 9 &10) have an interesting pattern with rock in the bottom of the blast moving laterally a maximum of approximately 8 m. The lateral movement increases with row number. However, rock at the top of the final few rows detonated rolls backward after landing and has a small or sometimes negative final lateral displacement. This behavior is evident from row 7 of Figure 10.

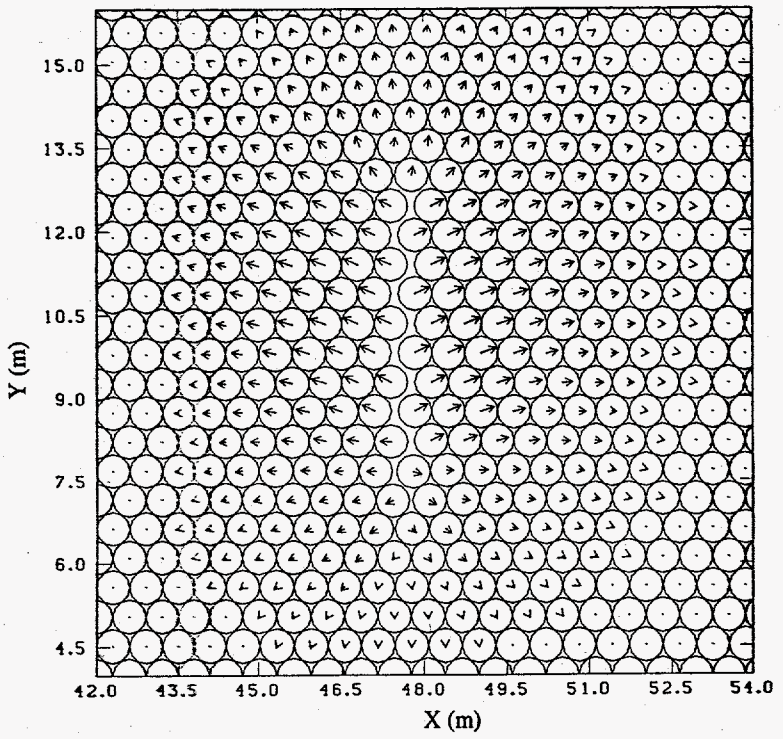

Figure 7: Loading vectors on spheres adjacent to a vertical blasthole. Uplift angle = 20°.

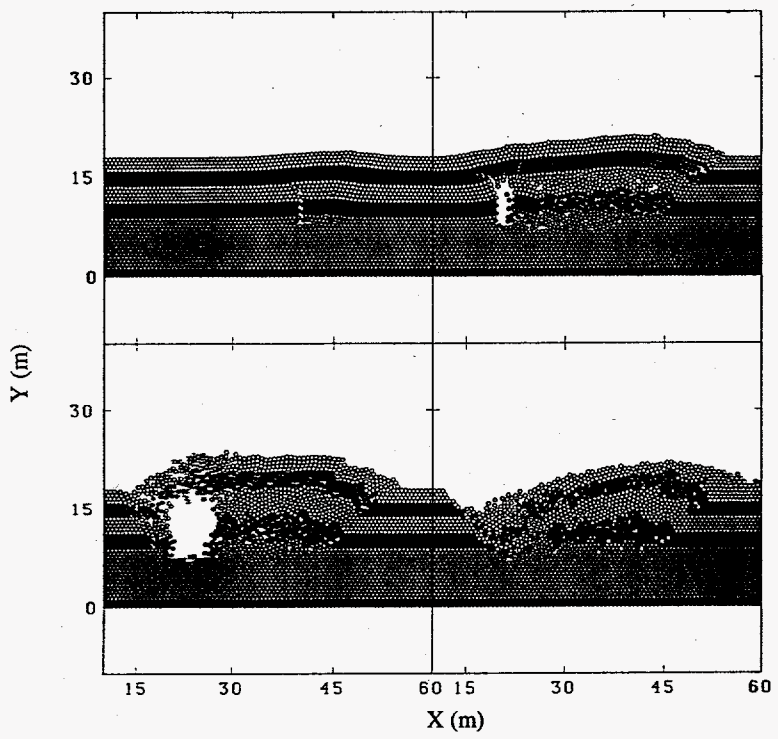

Figure 8: Choke blast simulation with geologic layers differentiated.

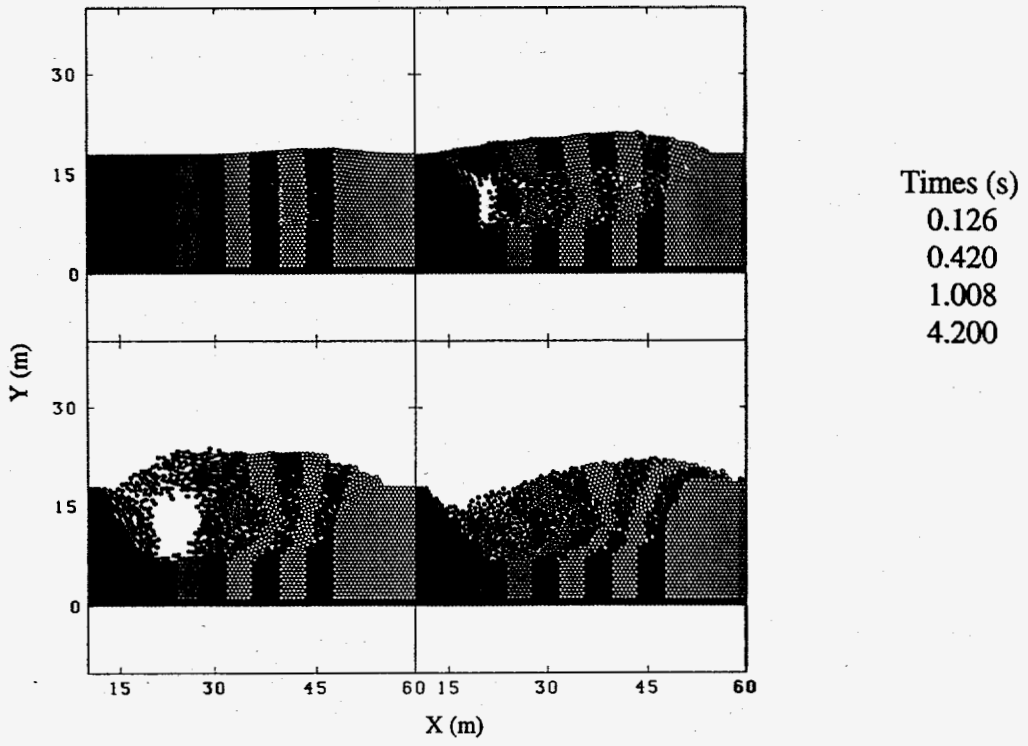

Figure 9: Choke blast simulation with burdens differentiated

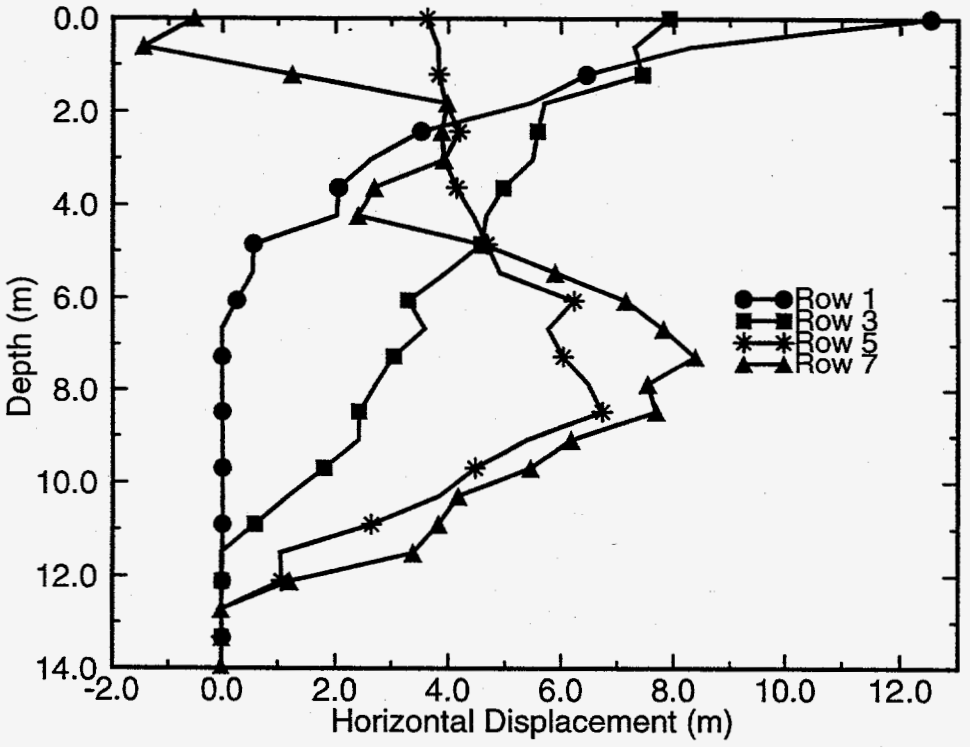

Figure 10: Horizontal displacement versus depth for spheres adjacent to four of the blastholes from the blast shown in Figures 8 and 9.

Close study of Figures 9 and 10 indicates that the lateral movement of material during one of these blasts varies spacially and can be quite complex.

Conclusions

An expanded geometrical blast definition capability for DMC_BLAST has been documented. DMC_BLAST is now qualified to treat a wider variety of bench blasting problems than ever before and can also now treat choke/buffer blasting. Simulations of choke/buffer blasting show a spacial variation of horizontal displacement that increases with increasing row number and that also varies vertically, depending on the position of the row in the blast.

Table 1: Blast Design Parameters

Description	Figure No's	Explosive	No. of Rows	Burden (m)	Spacing (m)	Hole Dia (mm)	Hole depth (m)	Stemming Height (m)
6 Layers dipping to face. Dipping top surface. Face defined with coord. Pit defined with coord.	1,3,5	Emulsion	4	7	12	311	Variable ~52	8
4 Layers dipping from face. Dipping top and bot. surf. Face defined with coord. Pit width and dip defined. Spoil angle defined.	2,4	Emulsion	7	7.5	12	254	Variable ~44	6
Buffer blast with 5 horizontal layers of rock.	7,8,9, 10	Heavy ANFO 30/70	8	3.96	4.57	165	10	5.18

References

Atlas Powder Company, 1987, *Explosives and Rock Blasting*, pp 316-318.

Kirby, I.J., Harries, G. H., and Tidman, J. P.,1987, *ICI's Computer Blasting Model SABREX - Blast Principles and Capabilities*, Proceedings of the Thirteenth Conference on Explosives and Blasting Technique, Society of Explosives Engineers, Miami, Florida,

Preece, D. S. and Taylor, L. M., 1989, *Complete Computer Simulation of Crater Blasting Including Fragmentation and Rock Motion*, Proceedings of the Fifth Annual Symposium on Explosives and Blasting Research, Society of Explosives Engineers, New Orleans, LA.

Preece, D. S., Burchell, S. L., and Scovira, D. S., 1993, *Coupled Explosive Gas Flow and Rock Motion Modeling With Comparison to Bench Blast Field Data*, Proceedings of the Fourth International Symposium on Rock Fragmentation by Blasting, Technical University, Vienna, Austria.

Taylor, S. L., Gilbride, L. J., Daemen, J. J. K., and Moussett-Jones, P., 1996, *The Impact of Blast-Induced Movement on Grade Dilution in Nevada's Precious Metal Mines*, Proceedings of the 5th International Symposium on Rock Fragmentation by Blasting, Montreal, Canada

Zhang, S, Hurley, J, Mousset-Jones, P. and Daemen, J., 1994, *Blast Rock Movement and It's Impact on Ore Grade Control at the Coeur Rochester Mine*, Proceedings of the 20th Annual Conference on Explosives and Blasting Technique, pp 215-226, Austin, TX.