

Stratablast™

A new
mining
method

T. GOSWAMI
G.F. BRENT

T. GOSWAMI*Principal Blasting Engineer*

Orica Australia

PO Box 196

Kurri Kurri NSW 2327

T 61 2 4939 5138

E tapan.goswami@orica.com**G.F. BRENT***Senior Consultant*

Orica Australia

PO Box 196

Kurri Kurri NSW 2327

T 61 2 4939 5290

E geoff.brent@orica.com

List of headings

03 Abstract

04 Introduction

06 Drawbacks of conventional mining practice

07 New method of multiple strata blasting

09 Application methodology

10 Current status and future directions

10 Acknowledgements

11 References



Abstract

The conventional practice in open cut coal strip mining has been to blast the overburden or coal layers in separate blast events. This is done in order to maximise the benefits from throw blasting and also to limit coal losses. Each blast event usually has a particular design of hole diameters, burdens and spacings, explosive charges and blast timing in order to achieve the required blast outcome for either the overburden or coal. This means that each blast has to be separately cleaned on the surface after excavation of the previous blast. Hole locations then have to be individually surveyed and marked, holes drilled, explosives and initiators loaded and the blast fired. Each of these actions takes considerable time and resources and therefore impacts on mine productivity. The mine has to be cleared for each blast event and every blast presents a new potential source for noise, dust or vibration disturbance to the neighbouring population. Exposed highwalls are also subjected to vibration and damage from each subsequent blast event.

Orica has recently developed a revolutionary new mining method that combines the separate blast events into a single blast through the innovative use of the i-kon™ electronic initiation system. Multiple overburden and coal strata can now be drilled, loaded with explosives and initiators and blasted in a single cycle. Each layer is blasted with a unique design and achieves its targeted blast result, which is different from that of the other layers. Designs in each layer generally differ in explosive type and powder factor, inter-hole and inter-row delays, direction of initiation and initiation time and position, making this method distinct from conventional through-seam blasting. High throw is achieved in the overburden while coal losses and pulverisation are reduced, leading to increased coal seam recoveries. Specialised blast models and blast design software are used in the design process.

The method has been proven in full-scale field trials in the Hunter Valley, NSW, Australia. It is being used commercially in production blasting in Australia and may be applicable at virtually all open cut coal strip mines around the world.

Introduction

The mining methods used in open cut coal strip mining in most major coal producing countries have been well established and fairly consistent over the past few decades. These general mining practices have been described by Kukla et al. (1993) and Aspinall et al. (1993) amongst others. **Figure 1** shows a schematic of typical coal strip mining operations. In most cases the overburden and coal cannot be excavated without prior blasting operations. Conventional drill and blast practices are used in both the overburden and coal, with each of these being mined in a separate cycle. Each layer is cleared and prepared, surveyed, drilled, loaded with explosives, initiators and stemming and blasted.

Australian coal mine productivity and overall production have shown a gradual increase over the years (Barnett, 2000) as these practices have been refined and as economies of scale, especially from the use of increasingly larger mining equipment, have steadily been introduced. Another factor driving mine productivity has been the use of “throw” or “cast” blasting, whereby a substantial proportion of the overburden material is thrown or cast directly into a final spoil position by the blast. This practice effectively utilises the explosive energy to perform two functions, namely fragmentation of the rock for subsequent excavation as well as the direct excavation of a proportion of the rock without the need for mechanical handling afterwards. Commonly around 30% of overburden material can be moved in this way, leading to a correspondingly reduced amount of waste to be moved by the mine fleet. Overviews of throw blasting practices and the effects of blast variables have been discussed by Sengstock and Kennedy (1995), Singh, Singh and Katkar (1996) and Workman (1998) amongst others. More recently, increases in throw blasting performance using the i-kon electronic initiation system have been described by Brent (2002). **Figure 2** (on next page) shows the general sequence of events in throw blasting of overburden and removal of the underlying coal seam.

Throw blasting generally employs high explosive powder factors and blast timing that favours forward displacement of the muckpile. The overburden is drilled with large diameter holes, typically 229 - 311 mm (9 - 12 1/4 inch), on a correspondingly large pattern. High-energy bulk explosives are used to maximise muckpile throw and fragmentation in the critical areas for excavation; usually the toe and key cut regions. Care is taken to provide an adequate standoff distance to the top of the underlying coal seams so as to minimise pulverisation, dilution and movement of the coal into the void. Restricting coal loss in throw blasting has been an area of active research for many years (see for example Kanchibotla, Cocker and Scott, 1999)

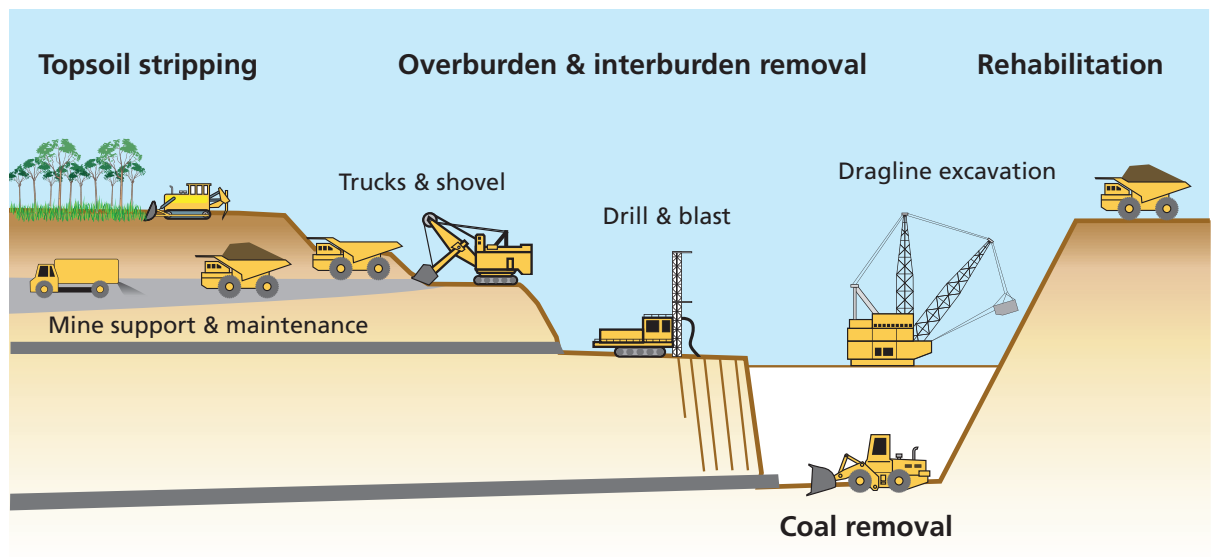


Figure 1. Schematic of typical coal strip mining operations.

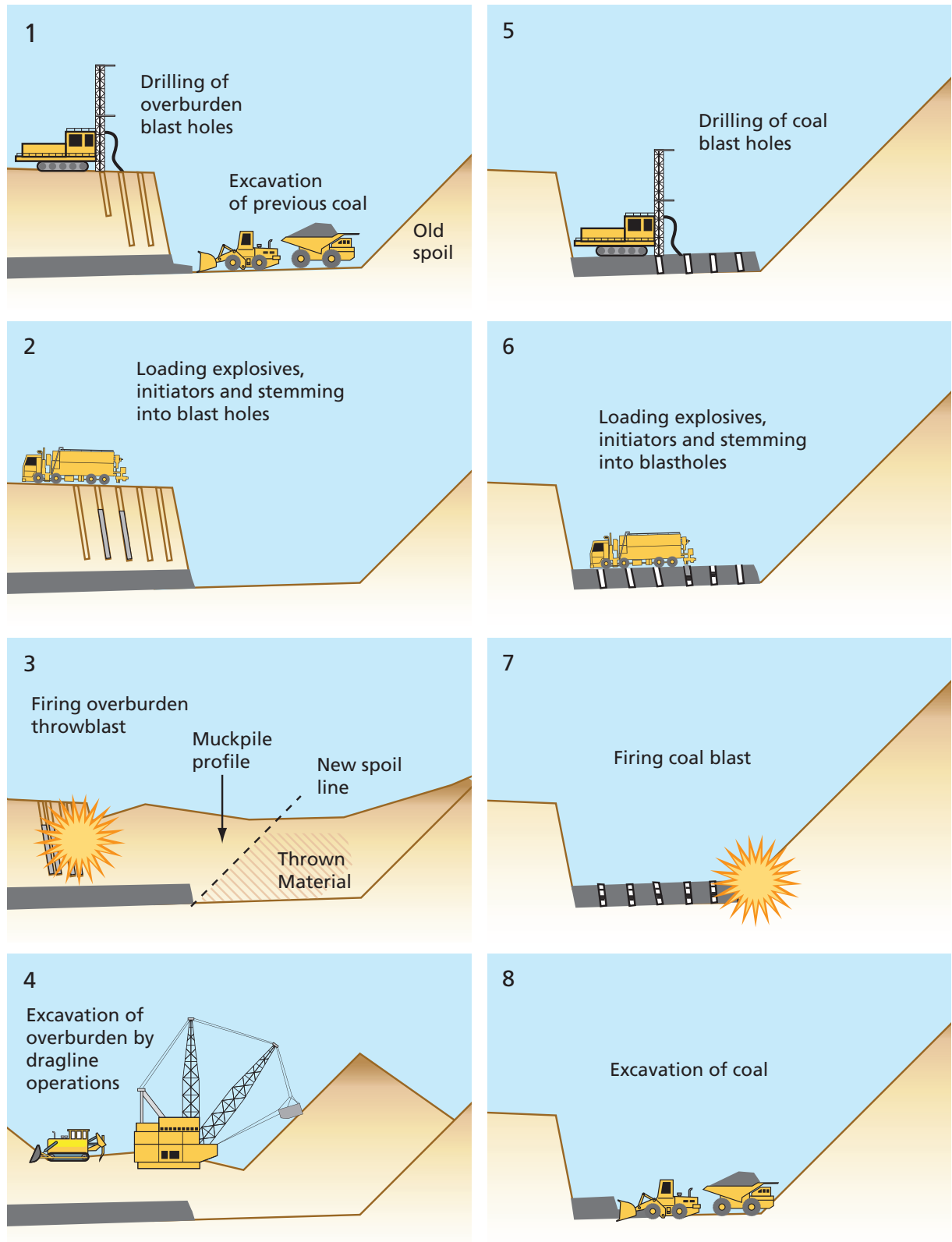


Figure 2. General mining sequence for throw blasting and coal extraction.

Introduction (continued)

since these losses translate directly into lost revenue and profit. Techniques such as providing a buffer of imported waste material in front of the coal seam, as well as several modified drilling and explosive loading methods have been trialled over the years with mixed success.

By contrast, coal blasting generally has lower powder factors and blast timing that limits any displacement of the coal. This mode of blasting is often termed “stand-up” blasting. The blast patterns used in blasting the coal are smaller with smaller diameter holes generally being used. Hole diameters for coal blasting may range from 127 - 254 mm (5 - 10 inch). Often, a separate dedicated drill rig is used for coal blasting. The coal blast blocks are often smaller than the overlying overburden throw blast block. This may be done for several reasons, including problems with keeping the coal blastholes open for a sufficient period of time and complications from water ingress into the blastholes and explosive over fairly short periods of time. This means that two or three separate coal blasts are performed to excavate the coal from one throw blast block. Overall, it is thus not unusual to have four separate blast events to mine the coal from a single throw blast block.

Drawbacks of conventional mining practice

While throw blasting has undoubtedly increased coal mine productivity by moving much of the overburden into final spoil, there are still a number of drawbacks with the conventional practice. The major problem of coal dilution and loss has already been mentioned above. Furthermore, each separate blast cycle includes the steps of blast surface and face preparation, surveying and marking hole collar locations, drill rig location at each blasthole collar, drilling, hole depth measurement, explosive charge and initiator determination and loading, stemming, pit clearance and firing followed by post-blast clearance and cleanup operations. Each of these steps requires considerable resources and time to perform.

The penalties associated with each additional drill and blast cycle in conventional practice include:

- The direct costs in resources and time to perform the chain of steps listed above for each drill and blast cycle of an individual layer.
- Direct downtime for the entire pit as it is cleared for each additional blast event.
- Each additional blast may be a source of dust, fume, noise and vibration disturbance, or even non-compliance with environmental standards.
- Separate coal blasts occur at the foot of new highwalls. The freestanding highwalls are thus subjected to considerable vibration from the coal blast and have the potential to lose stability due to resonant vibrational motion, or they may release material from the face onto the coal, requiring subsequent cleanup. Large coal blasts such as those typical of the Powder River Basin in the USA produce considerable levels of blast vibration that may contribute to highwall instability.
- The operations involved in the coal blast cycle incur additional risks as they involve working under the highwall for extended periods.
- Additional inadvertent backfill may occur as the drill withdraws from each new blasthole and moves into position to drill subsequent holes. This equates to lost drilling expenditure on each newly drilled blast pattern.

All the above drawbacks can now be eliminated with the new mining method of multiple strata blasting.

New method of multiple strata blasting

A new method for concurrently drilling, loading and blasting separate multiple layers of overburden and coal seams has recently been developed and tested. The method allows for full exploitation of the benefits of throw blasting while improving the ability to limit coal damage, dilution and loss. Effectively, in its simplest form, this method combines the first three steps from each of the overburden and coal sequences shown in **Figure 2** into single steps combining both layers.

Furthermore, the method may be extended beyond a single layer of overburden and coal to multiple layers of waste and coal. The method incorporates the use of the i-kon electronic initiation system which has been described elsewhere (for example Brent, 2002). Precise electronic initiation systems like the i-kon system are required to provide the necessary timing ranges, flexibility and accuracy to achieve the complex blast timing within the multiple strata blasts. **Figure 3** shows a schematic representation of the case of a multiple strata blast to achieve throw blasting in a single overburden layer combined with fragmentation of a single underlying coal seam in a “stand-up” mode of blasting.

In this multiple blast, the overburden is thrown first and once it is in front of the coal seam to provide a buffer, the coal blast is fired some time later, usually several seconds later. The blast design in the overburden is such that throw is maximised subject to environmental constraints such as airblast. By contrast, the blast design in the coal is such that sufficient fragmentation is obtained with very little vertical or lateral disruption of the coal seam. This requires vastly different powder factors and blast timing in each layer. Not only are the inter-hole delays in the coal blast completely different to those used in the overburden, the initiation position and direction of the blast are also completely different. It should be noted that a presplit row may form part of the throw blast phase of the multiple blast; being fired ahead of the main throw blast holes.

Figure 4 (on next page) shows a more complex multiple blast with several strata. In this case, two coal seams, an interburden layer and an overburden layer are all concurrently drilled and blasted in a single cycle. The uppermost overburden is subjected to a throw blast while the interburden and bottom coal seams are blasted in “stand-up” mode. In this example the upper thin coal seam is not directly loaded with explosives.

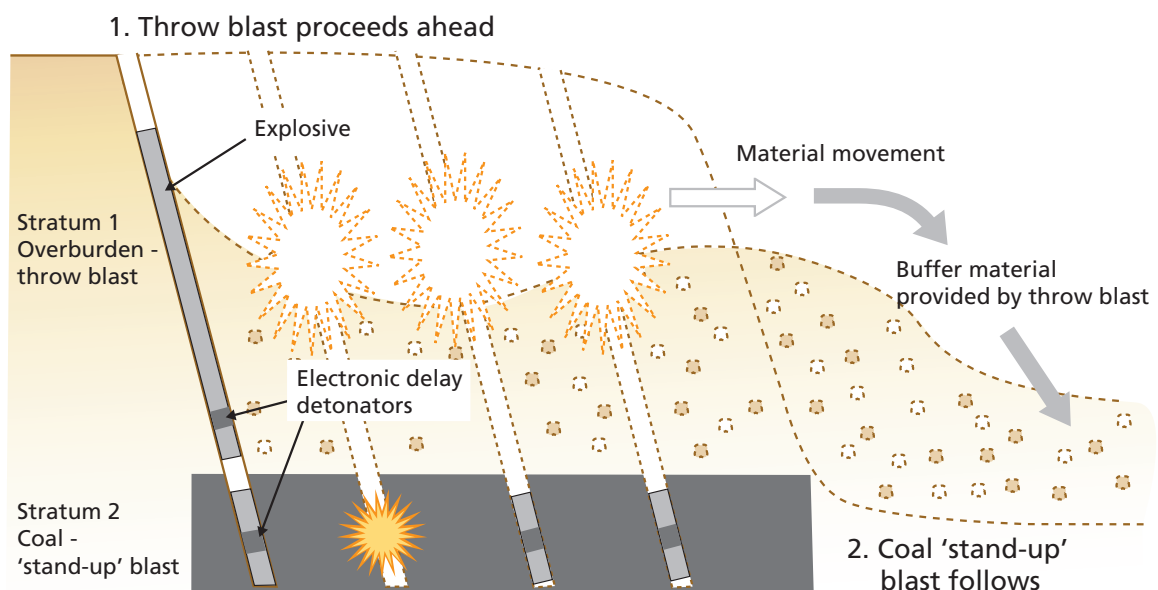


Figure 3. New multiple strata blasting method for combined throw blasting and coal blasting - single coal seam.

New method of multiple strata blasting (continued)

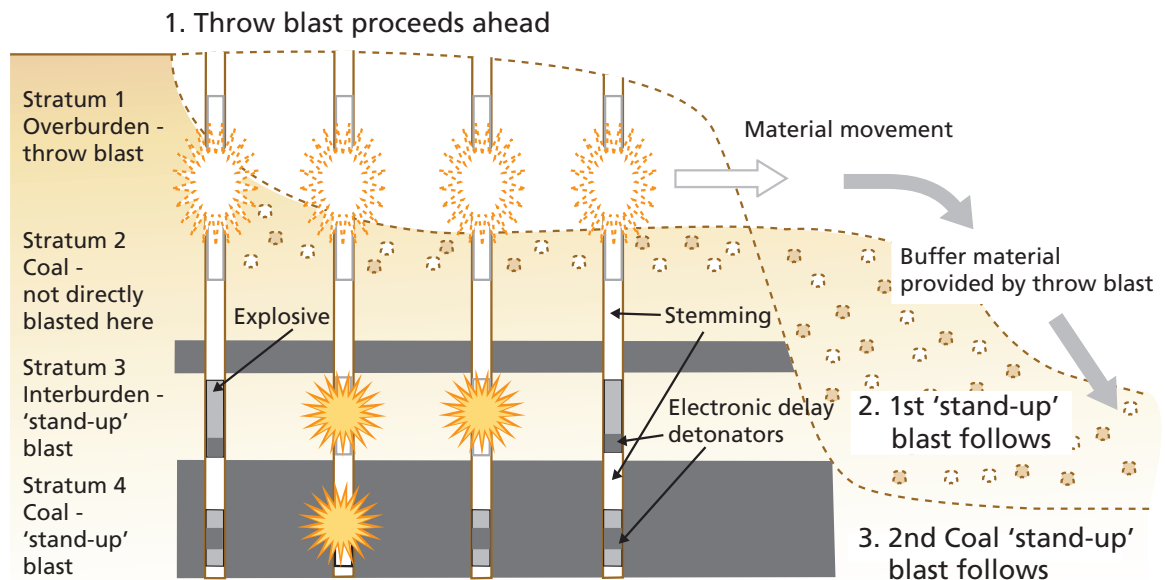


Figure 4. Multiple strata blast for overburden, interburden and two coal seams.

Instead, sufficient fragmentation for its subsequent excavation is achieved via the indirect explosive stress wave action both from the blasts above and below this layer. Once again, in this multiple blast the overburden is thrown first and is in position above and in front of the bottom coal seam to provide a buffer before the coal is fired. Again, the blast design in the overburden maximises the throw subject to environmental constraints. The blast designs in the interburden and the bottom coal seam are different to the throw blast and to each other. The goals in the coal and interburden are to provide sufficient fragmentation while minimising pulverisation, dilution and disruption of both coal seams. Quite different powder factors and blast initiation timing are again applied in each layer. As for the two-layer example the inter-hole and inter-row delays in the various strata are completely different from other strata and the initiation positions and directions of progression of the blasts in each of the strata also differ. Furthermore, the order of firing the various strata is not limited to top-down sequencing as modified orders have also been used. Once again, a presplit may form part of such a multiple blast to facilitate highwall quality.

It must be noted that this method, named Stratablast™, is quite distinct from so-called "through-seam blasting", which has been successfully adopted for many years in some operations, particularly where seams are steeply dipping or undulating. Through-seam blasting has been described by Chung and Jorgenson (1985), Burrell (1990) and Kukla et al. (1993) amongst others. In conventional through-seam blasting the overburden and interburden are drilled and blasted in a single blast cycle, thus blasting through intermediate coal seams. However, through-seam blasting is different from throw blasting as through-seam blasts are specifically designed to minimise lateral movement of all of the material in order to avoid any disruption of the coal seams, except possibly in a vertical sense. Explosive powder factors in through-seam blasts are thus generally low. Furthermore, through-seam blasting does not use blast initiation timing that may promote forward or sideways movement of the material, such as that used in throw blasting. Another major distinction is that in conventional through-seam blasting the delays between adjacent holes and the direction of blast initiation are designed to be the same for each layer blasted. Non-electric detonators are therefore often adequate for this type of blasting, with a surface detonator providing the inter-hole delays and downhole detonators providing any inter-deck delays. Often, through-seam blasting is used where the coal seams are relatively thin, allowing the subsequent mining of the seams without the need to blast the coal.

Application methodology

The overall methodology for multiple strata blasting comprises several steps, including:

- Determining major blast objectives, including overburden throw goals and environmental constraints.
- Ascertaining the locations of various strata, using techniques such as blasthole logging with gamma ray equipment.
- Modelling of the blast using blast models, such as SOH (Minchinton and Dare-Bryan, 2005). An output from this model for determining the muckpile throw profile and the coal seam movement for a multiple strata blast in the Hunter Valley is shown in Figure 5. The modelling is used to guide the blast design process.
- Determination of appropriate blast design parameters, including burdens and spacings, explosive loading, stand-off distances and importantly, the sequence, direction and timing of the blast initiation; with each explosive charge within the entire multiple blast generally having a unique firing time. Usually the various blast layers will have different inter-hole and inter-row delays, as well as a different the direction of initiation to other blast layers.
- Where environmental constraints are imposed, further models such as statistical vibration models (see Blair, 1999) are required to refine blast design, particularly the complex blast initiation timing.
- Blast design implementation in the field, with accurate explosive charge and inert deck location being of paramount importance.
- Measurement of blast performance, including environmental performance and blast throw.
- Measurement of mining productivity, especially coal recovery and excavator performance, as well as reductions in lost time and resources.

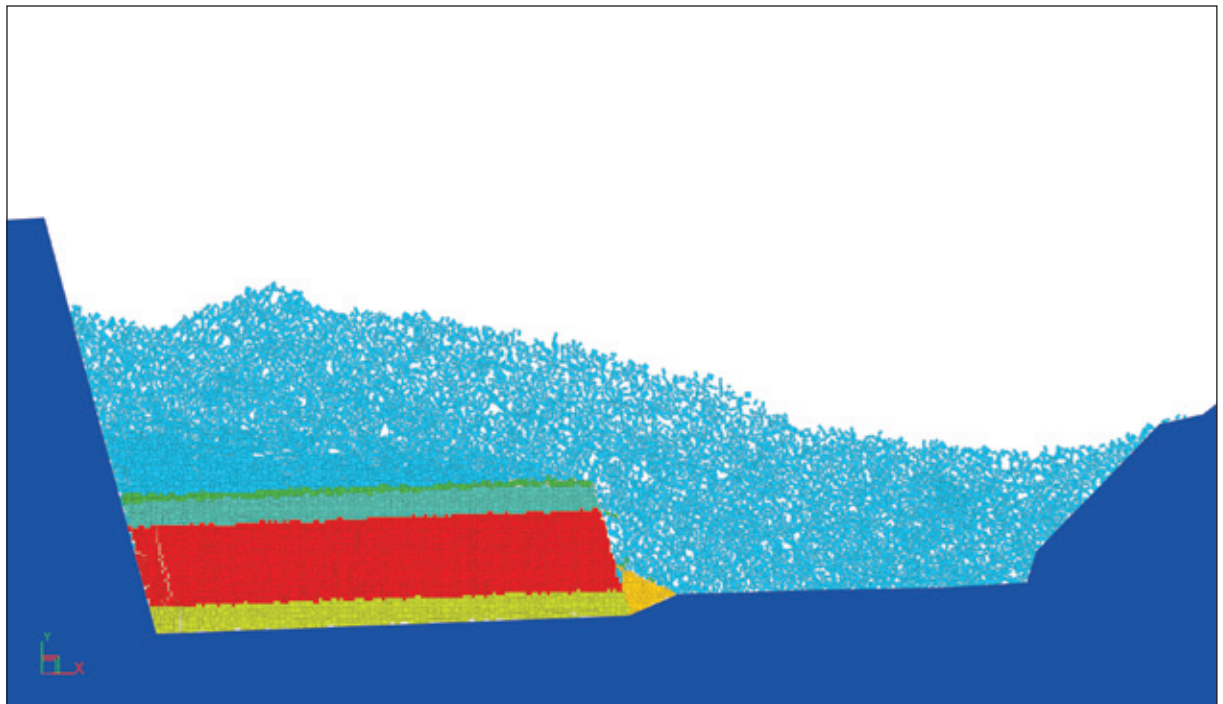


Figure 5. Blast model output for a multiple strata blast - combined throw blast, interburden and dual coal seam blast.

Current status and future directions

The method of multiple strata blasting has now been developed and technically refined by the authors over the past two years. Full-scale trials in the Hunter were successfully implemented from late 2004. The cases of two layers (overburden and coal) and four layers (overburden, coal, interburden and coal) have been successfully tested. Blast outcomes and mine productivity results from these trials have been exceptional. Coal recoveries, in particular, have far exceeded those usually obtained in the conventional separate blasting of the strata. Orica holds an international patent for this technique, covering amongst other features the use of throw blasts above stand-up blasts as well as the use of different inter-hole and inter-row delays within various layers of a blast. The methodology may also be applied to conventional throw blasts by creating a second blast layer within the overburden to eliminate coal loss. The method is now being used in production blasting and is believed to be applicable in most open cut coal situations.

The method offers new flexibility to open cut coal operations where new ways of combining multiple layers into single drill and blast cycles may be considered. For example, while this paper has focussed on overburden and coal, the application of this technique to prestripping operations may also be readily achieved. The future development of deeper drilling capabilities may extend the benefits of this new mining method even more.

Acknowledgements

The authors thank personnel and Orica Limited for their co-operation and assistance during this work. In particular Peter Dare-Bryan is thanked for the blast model runs and output including **Figure 5**.



References

- Aspinall, TO, Isles, PT, Davidson, CW, Davies, AL, Hagan, TN, McManus, DA and Smith, GH, 1993. Strip Mining, in *Australasian Coal Mining Practice*, (eds: Hargraves AJ and Martin CH), pp 203-224 (AusIMM: Illawarra, Australia).
- Barnett DW, 2000. Competitiveness in the Coal Mining Industry, in *Proc. After 2000 The Future of Mining - The Impact of New Technology and Changing Demands on the Mining Industry*, AusIMM Publication Series No.2/2000 (AusIMM: Carlton, Victoria, Australia).
- Brent, GF, 2002. Blasting into the Future, *World Coal 11 No. 8*, pp 39-41 (Palladian Publications: Surrey, U.K).
- Blair DP, 1999. Statistical models for ground vibration and airblast, *FRAGBLAST-Int. J. Blasting and Fragmentation 3*, pp 335-364.
- Burrell MJ, 1990. Innovative Blasting Practice at Sands Hill Coal Company, in *Proc. 16th Annual Conference on Explosives and Blasting Technique*, pp 401-408 (International Society of Explosives Engineers: Orlando, Florida, USA).
- Chung SH and Jorgenson, GK, 1985. Computer Design and Field Application of Sub-Seam and Multi-Seam Blasts in Steeply Dipping Coal Seams, in *Proc. 11th Conference on Explosives and Blasting Technique*, pp 42-48 (International Society of Explosives Engineers: San Diego, California, USA).
- Kanchibotla, S, Cocker, A and Scott, A, 1999. Understanding and Controlling Coal Damage during Cast Blasting - Final Report, ACARP Project C5005, ACARP.
- Kukla, GT, Buffier, MJ, Balks, RJ and Farnell, GK, 1993. Open Pit Operation, in *Australasian Coal Mining Practice*, (eds: Hargraves AJ and Martin CH) pp 225-237 (AusIMM: Illawarra, Australia).
- Minchinton, A and Dare-Bryan, P, 2005. On the application of computer modelling for blasting and flow in sublevel caving operations, in *Proc. 9th Underground Operators' Conference*, Perth, WA 7-9 March 2005 (AusIMM).
- Sengstock GW and Kennedy BJ, 1995. Australian Open Cut Coal Mine Blasting Practices and Trends, in *Proc. 21st Ann. Conf. on Explosives and Blasting Technique* pp136-152 (International Society of Explosives Engineers: Nashville, USA).
- Singh DP, Singh MM and Katkar A, 1996. Blast Casting in Surface Excavations-A Global Scenario, *Mining Technology (78) No.894*, pp55-59.
- Workman JL, 1998. An Economic Analysis of Cast Blasting compared to other Stripping Alternatives, in *Proc. 24th Ann. Conf. on Explosives and Blasting Technique*, pp587-604, (International Society of Explosives Engineers: New Orleans, USA).



Stratablast™

Orica Blast Based Services

For more information visit www.oricamining services.com/stratablast