

Cadia East Project

By Stephen Duffield

The Cadia East Project is delivering what will become the largest underground mine in Australia and one of the largest underground gold mines in the world (Cadia East). Fiber-reinforced shotcrete has been essential for the safe development of this world-class project.

Cadia East is the latest mine to be developed at Newcrest Mining Limited's Cadia Valley Operations (CVO), situated approximately 160 miles (260 km) west of Sydney, in New South Wales, Australia. Newcrest Mining Limited (Newcrest) is the largest gold producer listed on the Australian Stock Exchange and one of the world's largest gold mining companies.

Cadia East has an approved mine life of 21 years and is forecast to increase CVO's annual production to 700,000 to 800,000 oz (20,000 to 23,000 kg) of gold and 99,000 tons (90,000 tonnes) of copper in the coming years. In the financial year ending June 2013, CVO produced 446,879 oz (12,669 kg) of gold and 59,440 tons (53,912 tonnes) of copper.

Caving at Cadia East

The massive underground gold and copper resource at Cadia East is suited to the low-cost, bulk underground mining method known as panel caving.

Panel caving is a natural caving method which uses ground stresses, rock structures, and gravity to break the rock and propagate mining vertically.

Cadia East is planned to have two panel caves with extraction levels situated at 4000 and 4600 ft (1200 and 1400 m) below the surface. Panel Cave 1 commenced commercial production in January 2013, and the development of Panel Cave 2 is underway. Cadia East is expected to ramp up to full production of 28.7 million U.S. tons per annum (26 MTPA) over the coming years.

These significant mining depths, along with induced stresses, the forecast deformation, and the blocky nature of the rock mass, are all factors that drive the need for high-quality and high-capacity shotcrete application at Cadia East.

The Cadia East Project commenced the main shotcreting segment of the underground development in June 2010 and has excavated 37 miles (59 km) of tunnels as of the end of November 2013. The majority of project development will be finalized by December 2014.

Cadia East Mine Development

A total of 37 miles (59 km) of underground tunnels have been excavated for the Cadia East

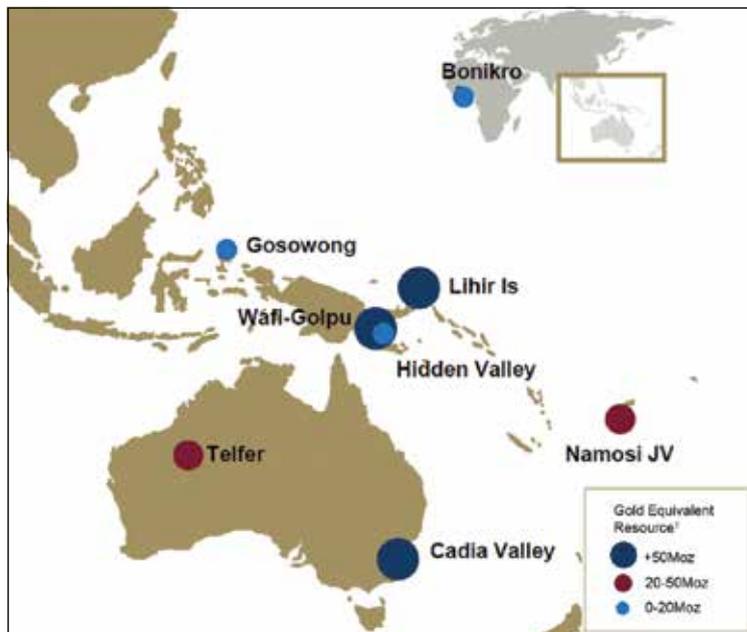


Fig. 1: Newcrest Mining Limited operating mines and advanced projects



Fig. 2: Jumbo drill rig installing rockbolts through shotcrete

Project since June 2010 to the end of November 2013. This includes the following major excavations:

- Main decline: Total linear distance of 5.6 miles (9.1 km) from surface at a gradient of 1 in 7;
- Conveyor decline: Comprising five legs of conveyor drive with a total length of 4.7 miles (7.6 km); mined at a gradient of 1 in 5.3 from surface;
- Crusher chambers: Three major underground excavations with approximate dimensions of 130 ft (40 m) in length by 85 ft (26 m) in height by 40 ft (12 m) in width, each;
- Undercut level: Over 1.9 miles (3 km) of tunnels;

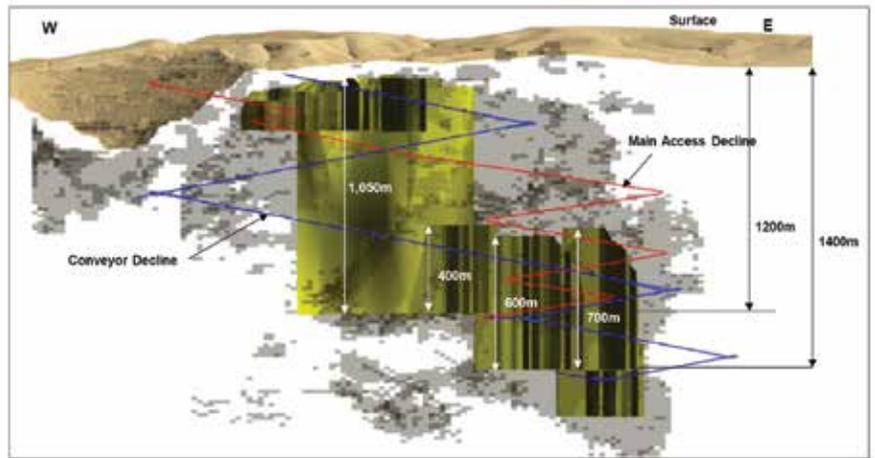


Fig. 3: Cadia East long section



Fig. 4: Shotcreted transfer chamber

- Extraction level: Over 5 miles (8 km) of extraction drives, draw points, and access drives; and
- Pump stations, electrical substations, workshops, lunch rooms, and amenities.

All development is excavated using drill and blast with a fleet of four boring jumbo drill rigs backed up by 10 rock bolting jumbos (Fig. 2). Every tunnel and chamber has been supported with fiber-reinforced shotcrete, with a total of 150,000 yd³ (115,000 m³) sprayed as of November 2013. The shotcrete is all supplied as fiber-reinforced wet mix and applied in-cycle before rock bolting.

The typical development cycle at Cadia East is:

- Drill;
- Charge and fire;
- Clearance and re-entry;
- Muck out;
- Scale/hydroscale;
- Shotcrete spraying;
- Rock bolt; and
- Survey markup for next round.

The minimum standard of ground support consists of 2 in. (50 mm) of fiber-reinforced shotcrete with 8 ft (2.4 m) long resin-grouted reinforcement bar rock bolts. Many headings also have additional ground support installed according to ground conditions, longevity, and projected stresses, such as:

- Steel mesh;
- Cable bolts;
- A second layer of fiber-reinforced shotcrete; and
- Steel sets.

Certain excavations have to stay safe and accessible for the life of the mine; hence, the quality of substrate preparation, shotcrete batching, application of shotcrete, and integration with other ground support elements is critical to ensure a safe and low-maintenance environment.

Mixture Design

Fiber-reinforced shotcrete is an integral part of ground reinforcement and support at Cadia East. It is considered essential for safe mining

development and has become the accepted standard for underground personnel when dealing with existing and induced stresses.

The main fiber-reinforced shotcrete mixture design used at Cadia East, Type B shotcrete, is specified at a compressive strength (UCS) of 5800 psi (40 MPa) at 28 days and a toughness of 500 joules (ASTM C1550).

The fiber-reinforced shotcrete mixture design has been developed over many years at CVO by Newcrest engineers with significant input from the concrete supplier, additive suppliers, and the shotcreting contractor.

The Type B shotcrete used underground at Cadia East is reinforced with 15.2 lb/yd³ (9 kg/m³) of Barchip Shogun polyolefin fibers, supplied by Elasto Plastic Concrete Pty Ltd (EPC).

All fiber-reinforced shotcrete is batched on the surface by Boral Concrete & Quarries Ltd. Boral supplies all aggregates, sand, and cement and also coordinates concrete additives. The batch plant operates 24 hours per day, all year. In winter, nighttime temperatures can reach 23°F (-5°C), so heating of batch water is important.

Cadia East has the benefit of a local basalt quarry 12 miles (20 km) from the mine site. This quarry is operated by Boral and supplies high-quality crushed basalt aggregate to the on-site batch plant.

All shotcrete additives are supplied through BASF Australia Ltd, including:

- Hydration stabilizer;
- High-range water-reducing admixture;
- Liquid silica;
- Low-range water reducer; and
- Set accelerator.

Shotcrete Application

The average rate of shotcrete application has been 3800 yd³ (2900 m³) per month. This rate has been consistent and will remain so over the 4-year construction period of the project. This is a massive amount to batch, supply, and spray each month, which has presented many logistical challenges.

All fiber-reinforced shotcrete was sprayed using robotic spraying rigs by shotcreting contractor Stratacrete Pty Ltd. At the peak of project development, five to six Jacon Roboshot Maxijet spray rigs were used at any one time. Stratacrete Pty Ltd is a mining and civil shotcrete contractor specializing in robotic placement for both underground and surface operations throughout Australia and selected international markets.

All shotcrete is batched on surface by Boral Ltd and transported to the headings by a fleet of underground agitator trucks via the main decline to depths of up to 4600 ft (1400 m) below surface. This can result in a one-way trip of over 6.2 miles (10 km) to the spraying site and can take up to 2 hours

Table 1: Mixture design for Type B shotcrete

Ingredient	Quantity, lb/yd ³	Quantity, kg/m ³
River sand	1795	1065
10/7 mm Basalt aggregate	960	570
SL cement	675	400
Fly ash	95	55
High-range water-reducing admixture	50 fl.oz/yd ³	2000 mL/m ³
Liquid silica	180 fl.oz/yd ³	7000 mL/m ³
Low-range water reducer	30 fl.oz/yd ³	1200 mL/m ³

depending on mine traffic. Retarding of the shotcrete mixture is essential to avoid hydration, and hydration stabilizer is added at the rate of 50 fl. oz/yd³ (2 L/m³) at the batch plant.

Boral operated a fleet of agitator trucks, all equipped for underground operation:

- Five CAT 730 trucks, capacity 10.4 yd³ (8 m³);
- Four Mercedes-Benz trucks, capacity 6.5 yd³ (5 m³); and
- Two Atlas Copco 5010 trucks, 10.4 yd³ (8 m³).

Agitator truck operators carry an additional supply of hydration stabilizer and are permitted to add a specified amount with supervisor approval in the case of excessive delays underground.

During the peak of project construction, coordination of traffic in the main decline was critical as this was the only way in and out of the mine for heavy vehicles. The second egress from the mine, the conveyor decline, was not available for concrete truck travel, as the 4.7 miles (7.6 km) of conveyor system with an ultimate capacity of 4850 tons per hour was being installed.

The agitator trucks did not have sole access in the main decline, sharing the route with construction traffic and truck haulage of mine rock. These factors made shift-by-shift planning of shotcrete deliveries, major concrete placements, and timing of nonreversible construction loads all the more important.

Slickline delivery of shotcrete was trialed in a lined borehole from surface with the objective of reducing the number of concrete trucks from surface. However, the excellent coordination of main decline traffic and the good working relationship between all parties meant that the slickline was not required.

Throughout the Cadia East Project, there were 25 to 30 headings to be sprayed each week spread over the huge extent of the mine. It has only been the well-managed daily planning and willingness of all parties involved to work together—both client and contractors—that made achievement of the high rate of shotcrete application possible.

Quality Assurance

Regular testing of materials and batched shotcrete is undertaken by Boral as part of their internal quality assurance standards and results are made available to CVO.

Independent testing of shotcrete and concrete is carried out for CVO by K&H Geotechnical Services Pty Ltd, one of the major private testing facilities in Eastern Australia. K&H are accredited by the National Association of Testing Authorities (NATA) for Public Testing Services—Construction Materials and conduct the following tests at Cadia East:

- Shotcrete sampling and testing of cored panels for compressive strength and round determinate panel to ASTM C1550 for flexural strengths;
- On-site slump testing;
- Casting of concrete cylinders;
- Concrete coring, sampling, and testing services; and
- Aggregate size, shape, and strength testing.

Research and Innovation

Newcrest excavates many miles of underground tunnels annually and as a result uses tens of thousands of cubic yards of shotcrete across its mines and development projects. Based on the significant volume of shotcrete and associated costs, Newcrest has allocated funding to research areas that will result in improvements in shotcrete design, quality, and economics.



Fig. 5: Nozzleman spraying heading with robotic spray rig



Fig. 6: Shotcreting in progress in undercut drill drive



Fig. 7: Agitator truck reversing up to shotcrete spray rig



Fig. 8: ASTM C1550 toughness panels being sprayed at underground site



Fig. 9: Large-scale shotcrete capacity test



Fig. 10: Shotcrete rig and agitator truck in one of the many underground chambers

As part of the program of research to develop high-performance economical shotcrete, several trials were undertaken by Newcrest and shotcrete consultant Technologies in Structural Engineering Pty Ltd (TSE), including:

- Investigating the influence of air-entraining agent, microfibers, and silica additives on the wet properties and early-age strength characteristics of fiber-reinforced shotcrete¹;
- In-place testing of fiber-reinforced shotcrete load capacity and failure modes²; and
- Testing of mine waste rock as shotcrete aggregate.

As an independent laboratory accredited by NATA for public testing services, TSE have also carried out specialized testing for Cadia East.

The Cadia East Project has also offered the opportunity to trial photogrammetry to measure applied shotcrete thickness. A heading is digitally captured post-scaling and post-shotcreting and measurement of shotcrete thickness and coverage is undertaken with the photogrammetry software. Cross-referencing of thickness measurements from drill holes showed an accuracy of ± 0.2 in. (± 5 mm).³

Further innovation has taken place with the bulk delivery of set accelerator. An 8000 gal. (30,000 L) bulk storage tank and delivery system supplied by BASF was commissioned in May 2013. This reduces the need for multiple 260 gal. (1000 L) intermediate bulk containers or “pallecons,” which can be damaged in the underground environment. This innovation has reduced the frequency of deliveries to site and given the added benefit of improved costs.

Summary

The sheer size and complexity of the Cadia East Project have made the application of fiber-reinforced shotcrete a significant challenge. The combination of depths of up to 4600 ft (1400 m) underground, distances from surface batch plant to spraying sites of over 6.2 miles (10 km), the need to spray multiple headings in-cycle, and the interaction with mining and construction mobile equipment accessing through one main decline, has been an incredible test of design, logistics, and resource organization.

At Cadia East, fiber-reinforced shotcrete is essential for the safe development of a world-class mining project—without the application of consistent, high-capacity shotcrete on time and in the right locations, the project would stop. A key factor in the successful application of shotcrete has been the willingness of all teams involved, whether contractors, suppliers, consultants, or the client, to work together, seek high performance, and value innovation. These values have ensured

the application of high-quality shotcrete with no disruptions to the successful production ramp-up of the Cadia East Project.

References

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management from the University of Sydney, Sydney, Australia, in 2003. Duffield has worked in underground mining, construction, and tunnelling on both the contractor and client sides. He holds an NSW Underground Mine Manager’s Certificate. Duffield has been involved with shotcrete on deep mining projects since 1992 and has published six shotcrete-related papers. He is a committee member of the Australian Shotcrete Society.

The Outstanding International Project

Project Name
Cadia East Project

Project Location
Orange, NSW, Australia

Shotcrete Contractor
Stratacrete Pty Ltd

Architect/Engineer
Cadia Valley Operations (Newcrest Mining Ltd)

Material Supplier/Manufacturer
Boral Concrete & Quarries Pty Ltd
Elasto Plastic Concrete Pty Ltd
BASF Australia Ltd

Project Owner
Newcrest Mining Ltd