2020

Fibre reinforcement shotcrete in coal

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FIBRE REINFORCEMENT SHOTCRETE IN COAL

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ABSTRACT: Fibrecrete Reinforced Shotcrete (FRS), a cement-based mixture pneumatically applied at a high velocity onto coal surfaces. The material component of shotcrete is essentially cement and fly ash blend in a mixed powder form combined with sand, gravel and water. This wet process of shotcrete application is unique to coal, but has been used in the civil industry and hard rock mines for many years. This process allows a good compaction of applied ground support liner that allows penetration into the strata giving a bonded liner with stability, compared to cast-in-place concrete. The advantages of the shotcrete process are related to the reduction of the installation time for ground support, compared with the traditional mesh and bolts system, with the added advantage being a reduction of labour required to place the same work load. The logistics are advanced with a better safety factor, environmental conditions, improved ventilation and reduction of roadway gases. FRS is considered as a primary and secondary support material particularly suitable and used in underground coal mining. The current use of FRS wet mix, which has significant resistance to segregation and benefits as a ground support system as implemented in Queensland mines particularly within the Bowen Basin.

FIBRECRETE REINFORCED SHOTCRETE (FRS) UNDERGROUND COAL

This paper discusses the development of the FRS and the introduction of a Flameproof Shotcrete Rig (FSR), shown in Figure 1, with improved performance into underground coal mine. Over the past seven years FRS has been considered as the primary and secondary support material particularly suitable in underground coal mining. The current use of FRS wet mix, which has significant resistance to segregation and benefits as a ground support system has been implemented primarily in coal mines in the Bowen Basin area of Queensland. It allows a significant reduction in manual handling and resources in this application as it is applied by robotic spraying. Key benefits associated with FRS ground support systems and the development of the FRS to be used in all areas of the mine as listed below:

- Secondary support to development roadways
- Rehabilitation works
- Ventilation control devices
- Gas Mitigation to strata in old workings
- Underground roadways which interlock into the walls
- Drainage sumps
- M and M drift repair
- Overcasts and underpasses
- Conveyor drifts rehabilitation by hand spraying from a movable conveyor platform
- Works completed via robotic and hand spraying using the FSR

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Figure 1: Flameproof Shotcrete Rig (FSR)

Figure 2 demonstrates FRS used as a wall and intersection support system for ground fretting and sustaining damage from trailing cables and machinery bumping the walls. The FSR is the first custom built underground self-propelled FSR. A stand-alone Diesel-powered unit that is mining compliant to be driven around the mine pumping and effectively placing FRS to the desired result with the robotic and hand held spraying diversity. The FSR is operated remotely, from a hand held control box connected to the FSR by a 10 metre (M) cable with an extendable 9.5 M boom. This ensures operators safety and mining compliance allowing the operator to be safe under supported ground during the FRS placement process. The rig can spray and place 15 cubic metres of FRS per hour depending on the delivery cycles and/or mining environmental variables and factors. This paper explores the current Fibrecreting innovative technology and methodology in addition to the FSR; pumping technology and Drop Hole Technology to allow the shotcrete mix to be dropped from the surface into receiving kettles then into a kibble and transported to shotcrete rig.

Figure 2: Underground Intersection rib support with FRS

SHOTCRETING FRS INNOVATIVE AND PRACTICAL WAYS

The industry is yet again facing difficult times with the pressure of low coal prices and reduced tolerances to cost exposures to operations. Yet to survive in this industry it is well known over the years that such cycles do happen and will continue to happen. Mine operators and contractors need to adapt and maintain control to deliver safe coal production and financial returns back to stakeholders and ensure corporate families continue to have confidence with the company. To achieve this, many successful companies have turned to innovation to assist in finding ways to get critical activities done in a safe, effective low cost method. This requires vision of key decision makers to recognise such things. These decision makers understand every aspect of current costs and future projections for the success for the innovation. As well as understanding the process of risk management in all areas of business and have the ability to articulate the vision of what the innovation will produce. Innovation does not have to be seen as an additional cost, but if done right, a cost reduction system by working collaboratively with clients with such innovation and vision. To recognize all of the above factors and with the expertise and the commitment of the project team and the proactive vendors heavily involved in our projects. One true testament of such innovation being successful is presented in the excellent safety results reported despite the hard financial times, thereby proving that the innovation is real and effective. This then should be used as a good example for the industry, if done right; the FRS innovation must be a priority for any business, particularly in the hard times faced today, while keeping all personnel safe.

SHOTCRETING INNOVATIVE SYSTEM (FOUR MOST IMPORTANT STEPS)

Shotcreting involves four important steps: Raw Materials/ Mix Design/ Batching and testing; delivery/ placement mix and human resources. Shotcrete has the potential to be an easy and pleasurable operation and very cost effective to mine operators, giving long term results if all of the steps are followed.

MIX DESIGNS

Shotcrete mix design relies on raw materials, their shape and ability to pack, and a good ongoing supply of a constant gradings. The quality of the cement blend and clinker needs to be of a general purpose fly ash blend. To reduce the risk of flotation, potable water must be utilised in conjunction with the correct use of prescribed chemicals and dose rates as directed by the chemical providers. Batching plants are required to meet all of the Australian standards and have a full computerised recording system in conjunction with multi weight bins. Each and every load must meet the required slump, be checked at the batch plant, and leave the batch plant fully mixed.

BATCHING

The mix needs to be of a high standard following quality assurance and quality control procedures to meet with the Australian Standards. Batching can be altered to meet the individual needs of mine manager's dependant on mix design rules.

DELIVERY MIX

FRS is delivered by a mixing agitator road truck from a local concrete batch plant to the drop off point in the mine. It needs to be well mixed before the delivery is slumped and dispatched. The mix needs to meets the required slump design, then dispatched into a drop hole or waiting kibble slump retention. It is vital that additional water not be added on site as this will reduce the mix design strength. As shotcrete is used as a ground support system, strength is of high importance in conjunction with flexible-strength and toughness of the FRS mix. Therefore using the drop hole system which does not impact on the mix, design testing is carried out on a weekly basis checking strength on the surface at the batch plant and sampling the FRS at the receiving point in the underground from the same load. Demonstrated results from tests carried out by National Association of testing Australia (NATA) are shown in Tables 1-3.

DELIVERY AND PLACEMENT OF THE FRS UNDERGROUND

The FRS is delivered to the spray machine via kibble. Depending on the location of the drop hole it may take up to 60 minutes to get into the application area. All loads have been retarded for four hours, giving time for the product to be transported from the batch plant and out to the onsite location. Once the FRS enters the machine, the pumping commences and a hydration activator chemical is injected into the mix whilst spraying. Spraying coverage is managed utilising placement pins arranged in diamond patterns.

FRS SYSTEM DEVELOPMENT

The system for coal was developed in the 1990's overseas where it was tested to withstand the constant movement and fretting associated with coal mines before being introduced to Australia in 2012. The catalyst for FRS was due to mines experiencing drift and strata failure. It was imperative that a permanent low risk solution be found to mitigate the risk of reoccurrence. With this in mind a full design was completed and evaluated by multiple experts, both internal and external to the company. The implementation and objectives of the project was to increase the safety factor of the support in drifts and life mine system. Figure 3 demonstrates the Round Determined Panel (RDP) size and design sprayed with the same FRS as placed in the underground.

Figure 3: Sprayed RDP

Table 1: RDP testing results (tested by NATA - Mackay)

Sample Date	Concrete Class	Report No.	Location	Joules – Energy at 40mm	
				Joules	Age (days)
25/04/2018	32Fibrecrete - 6kg/m3 fibre	102544	49-52CT D-F Hdg Mains	570.0	28.0
25/04/2018	32Fibrecrete - 6kg/m3 fibre	102545	49-52CT D-F Hdg Mains	448.0	28.0
25/04/2018	32Fibrecrete - 6kg/m3 fibre	102546	49-52CT D-F Hdg Mains	424.0	28.0
25/04/2018	32Fibrecrete - 6kg/m3 fibre	102547	49-52CT D-F Hdg Mains	554.0	28.0
2/05/2018	32Fibrecrete - 6kg/m3 fibre	102976	67-69CT D-F Hdg Mains	373.0	28.0

Figure 4 the 400 mm x 400 mm sprayed sample it is cored where four sample get removed and tested at 7 days 14 days 21 days 28 days

Figure 42: 400 mm x 400 mm core panel

Table 2: Core panel testing results carried out by Nata of Mackay

Sample Date	Concrete Class	Report No.	Location	Compressive Strength (MPa)				
				7	14	21	28	56
11/06/2019	32 Fibrecrete - 6kg/m3 fibre	5676/R/51996-1	20-21CT C HDG 2nd North Mains	19.5	26.0	29.0	32.5	-
18/06/2019	32Fibrecrete - 6kg/m3 fibre	5676/R/52194-1	22-23CT C Hdg 2nd North Mains	24.5	26.5	28.0	30.5	-
25/06/2019	32Fibrecrete - 6kg/m3 fibre	5676/R/51948-1	TG604 X Drive	23.5	26.5	26.0	28.5	-
4/07/2019	32Fibrecrete - 6kg/m3 fibre	5676/R/52672-1	2-9CT B HDG East Mains	20.5	22.5	26.0	30.0	-
9/07/2019	32Fibrecrete - 6kg/m3 fibre	5676/R/52823-1	14-18CT HDG East Mains	19.5	21.5	22.5	24.5	-

Table 3: Record of concrete compressive strength reports (Tested by Nata of Mackay)

Sample Date	Concrete Class	Report No.	Location	Compressive Strength (Mpa)				
				7	14	21	28	56
19/03/2019	32Fibrecrete - 6kg/m3 fibre	14892/R/20997-2	66-67CT E Hdg Mains	17.5	23.0		32.5	-
26/03/2019	32Fibrecrete - 6kg/m3 fibre	14892/R/21032-1	66-67CT E Hdg Mains	25.0	30.5		36.0	-
2/04/2019	32Fibrecrete - 6kg/m3 fibre	14892/R/21037-2	81CT D-E Hdg Mains	20.0	25.0		30.3	-
9/04/2019	32Fibrecrete - 6kg/m3 fibre	14892/R/21199-1	14-15CT HDG 2nd N/Mains	16.5	25.0		33.3	-
24/04/2019	32Fibrecrete - 6kg/m3 fibre	14892/R/21284-1	17-20CT C HDG 2nd N/Mains	26.5	29.5		36.5	-

Figure 5 shows the 400 x 400mm steel core box where the FRS is sprayed into the test box for sampling.

Figure 43: 400mm x 400mm Core Panel Box

PEOPLE

In order to achieve quality application, the collaboration of a skilled project team with the commitment of stakeholders with a shared vision of the project outcome is required. Additionally, the operating team members in charge of placing the FRS need to be fully trained in placing FRS on to the coal strata as this differs from hard rock spraying.

The support team helping with the placement FRS needs to be of a high standard in delivering the FRS to the FSR they need to understand the QA-QC requirements as well as being very confidant with the pumping process of the FSR

SUMMARY

The innovation of the FRS system was more than just a shotcreting machine and spraying shotcrete for different purposes. There were various additional innovations to support the differing system uses, which have been found for this new innovative material in coal. This system has been heavily used in Hard Rock mining for the past 40 years, initiating in the Mount Isa region before expanding to other areas. Examples of its use include several mines in the Mount Isa Mining District Mine (A) Deep Copper Mine used daily in conjunction with the in cycle mining system Mine (B) development of life of mine roadways Today the Hard Rock mines located in all parts of Australia use FRS on a daily basis as permanent ground support this has allowed them the ability to reduce the bolting patterns and numbers of bolts.Civil Industry use FRS as a ground support under the exposed segments it is used as a sealing process and permeant support within the tunnel system Tunnel (A) located in Queensland going under the Brisbane river is a prime example of the versatility FRS tunnels located in New South wales and Victoria all use FRS as their secondary and primary support. Even the construction industry, use FRS in Dam construction and roadway bank surfacing on major highways (Dam (A) Roller Compacted Concrete (RCC) dam wall RCC is one of the first to be constructed in Australia using the FRS to enhance the wall surfacing and supporting the RCC process compaction significant advances have been made with this work.