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# Pillar recovery using new wireless blasting technology: a case study in Vazante mine, Brazil.

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ABSTRACT: The application of explosives has never been considered as a major influencing factor during either the designing of a mine or the selection of the mining method. However, this has changed with the launch of WebGenTM wireless blasting system, which allowed underground mines to exploit their orebody applying methods previously not possible due to limitations imposed by the use of wired detonators. The wireless blasting system is based on magnetic induction communication, and its signal is capable of overcoming hundreds of meters through rock, water, and air, to reach individual primers in the blastholes without any physical connection.

A noble application of wireless detonators is being used in Vazante mine, Brazil, an underground zinc mine where ore pillars are left in the mined stope to secure stability and minimize dilution by limiting the hydraulic radius. The recovery of these pillars is financially desirable but involves extra time and costs associated with scaling, backfilling, reinstalling infrastructure, accessing areas previously blasted (less stable), drilling, charging with explosives, and subsequently, firing and mucking out the blasted material with expected high dilution. Applying 100% wireless detonators made it possible to safely preload the pillar together with production blasts before losing access to the area, a method named Temporary Rib Pillar (TRP). After all the stope is mined and the pillar accomplished its objectives, the primers are initiated without neither the need for the extra cycles described previously, nor the need to re-enter the area. Thus, it was possible to reduce the exposure of people and equipment, reduce operational cycles, and increase ore recovery, directly contributing to anticipate the ore production while guaranteeing the safety of the teams involved.

**KEYWORDS**: wireless booster, pillar recovery, WebGen$^{TM}$, safety, production increase

## 1 INTRODUCTION

Commercial explosives are designed to be relatively stable for safe usage, transport, and manufacture. A powerful localized shock or detonation is required to initiate commercial explosives. This is achieved by use of an initiating device such as a detonator (Bhandari, 1997)

Bender (1999) defines a detonator as a device, either electric, non-electric or electronic, that is inserted in the explosives and used to detonate them. Additionally, he defines the initiation system as being the entire structure for initiating the blast, including the blast machine (blaster) or specialized hardware, detonators, delay devices and their interconnecting parts.

The correct selection and use of the initiation system are among the most important considerations in a blast design. It controls the correct blast sequence, influence vibration levels, flyrock and airblast, as well as contribute for adequate fragmentation, wall control and many other evaluation attributes of a blast (Konya & Albarrán, 1998).

The evolution of the various initiation systems developed by Orica - the world's largest provider of commercial explosives and innovative blasting systems - begun back in the nineteenth century with the use of safety fuses and has seen a rapidly acceleration over the last two decades, culminating in the world's first Wireless Initiating System, WebGen™.


Figure 1 – Evolution of initiation systems for commercial blasting

Bhandari (1997) states that an initiation system consists of three basic parts:

1- An initial energy source;
2- An energy distribution network that conveys energy into the individual blastholes;
3- An in-the-hole component that uses energy from the distribution network to initiate a cap-sensitive explosive.

This classification was indeed true and valid for all available initiation systems at the time, but the technology advanced quickly and applied R&D brought to light a new initiation system that allowed the elimination of the *(2) energy distribution network* through the removal of all down wires and surface connecting wires.

This system includes wireless in-hole primers which are initiated by a firing command that communicates through rock, water, and air.

The Wireless Primer is the source of the blast initiation and consists of three components:

- i-kon™ Plugin: Accurate and fully programmable detonator with millisecond timing accuracy which can be assigned delays up to 30 seconds.
- DRX™: The i-kon™ electronic detonator plugs into a receiver comprising a multi directional antenna, and a battery which serves as the in-hole power source.
- Pentex™ W Booster: Securely locks onto the unit at the time of charging a blast hole.


Figure 2 – WebGenTM 100 consumable components

Unlike traditional wired blasting systems where a firing command travels from the blast box through harness wire and into the detonator, the WebGen™ system communicates with the in-hole primer via ultra-low frequency signals through magnetic induction. The blasting sequence and encrypted 'arm' and 'fire' code is stored in the primer during encoding which is performed when charging the blast.

All WebGen™ units require the correct unique signal to 'wake up' and the correct signal to fire. These signals are generated by the WebGen™ Transmitter and sent to the surroundings by a specific antenna, which are then received and interpreted by each DRX™ in the blastholes. All communications are intrinsically secure, and its reliability is attested by the achievement of SIL3 (Safety Integrity Level 3) Certification for the DRX™.

The safety integrity level is defined as the relative level of risk-reduction provided by a safety function, which is a globally accepted certification issued by the IEC (International Electrotechnical Commission).

WebGen™ represents a significant step in the evolution of blast initiation, and the base for the automation of drill & blast processes in mining. It allows the development of new mining methods for underground mines, for instance, the Temporary Rib Pillar (TRP) technique presented in this paper, while providing a safer and more productive ore extraction.

## 2 GEOLOGY AND MINE OPERATION

Vazante is a zinc/lead mine located in the northwest of the state of Minas Gerais, Brazil, and owned by Nexa Resources, a company formed from the merger between the Brazilian

Votorantim Metais and Peruvian Milpo. The mine currently stands for 28% of the company's equivalent zinc production, delivering and beneficiating 374 and 35kt in Zn and Pb concentrate, respectively. All the ore production is concentrated at the mine site and transported to Três Marias, where the metallurgical concentration takes place in a smelter.

Vazante is inserted in a karstic context associated with high rates of hydric circulation and its connection to the terrain's morphology (high outflow rates associated with geological structures, presence of sinkholes and caves), which leads to extra concerns to the mine's operation. Operations started in 1969 as an open pit mine and developed to an underground operation in 1982, with Vertical Retreat Mining (VRM) and Long Hole Open Stope being used as main methods for ore extraction. The method of choice is dictated by the ore block geometry, as well as continuity and angle.

The VRM is a variant of Sub-Level Stoping, consisting of opening two parallel galleries (drifts) at the base of the ore panel, the first being developed in the orebody and the second in waste, which is used for access and transport. Both lower galleries are connected by a crosscut approximately every 60m. On top of the orebody panel, another tunnel is developed. The deposit is controlled by a large shear zone, from which the Willemite mineral (zinc silicate) is extracted from hydrothermal veins embedded in a breccia main body. The shear zone has a main NE / SW direction, with dips ranging from 30 to 85° to NW and veins width of approximately 4.5m.

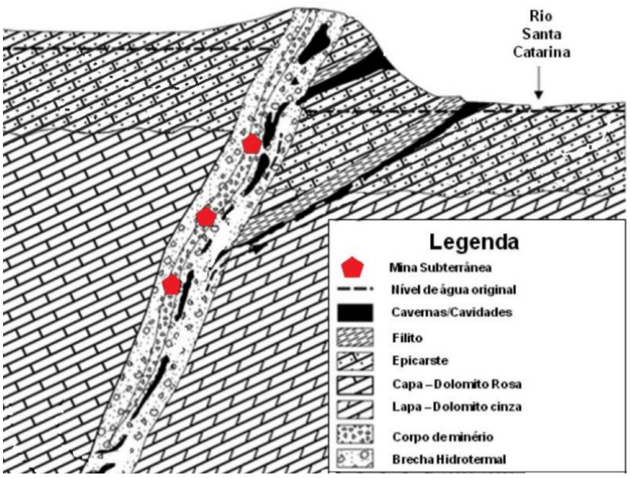

Figure 3 – Vazante orebody representation (Bittencourt & Reis, 2012)

## 3 PILLAR RECOVERY

Where the VRM method is used, roughly 15m wide pillar is kept between each designed stope to enhance the stability of the rock mass and maintain operational dilution at a controllable level. The recovery of the ore contained in these pillars depends on several discrete operations that are required after the entire stope is blasted and mined out, which involves resources and time that could have been used for primary production. Most importantly, it requires exposure of people to areas that have already suffered great damage due to very close blast cycles performed during the mining of the stope. The re-entry for blasting the pillar is accomplished by implementing several roof-supporting steps, such as shotcrete, rock bolting and cable bolting after completing the backfill.

In general, an underground mine discretizes its rock mass into smaller "blocks", for which its characteristics can be estimated with a certain level of reliability through specific laboratory and field tests. Nonetheless, the mechanic behavior of the rock mass due to stope opening and interaction between blocks is difficult to predict. This is why Palkanis et al. (2002) suggest an empirical or probabilistic approach for this propose.

The influencing factors to determinate the dimensions of an open stope are complex. Therefore, the methodology used to design the stope has to be of easy comprehension and application, and allow for onsite modifications when necessary (BRADY et al. 2005).

To control dilution, Vazante performs individual stope stability analysis under the methodology introduced by Potvin (1988) and ELOS (equivalent linear overbreak/slough). The results of the analysis indicated the necessity of introducing an island pillar into the mine sequence to reduce stopes hydraulic radius and standup time.

The figure below shows the layout and mine sequence from the stopes 255 BL1 12300 and 255 BL1 12400 (numbers 1 to 4) and the island [rib] pillar (number 5). Numbers 1 to 4 were mined using the current blasting technology onsite (Bulk emulsion and i-kon™ III electronic detonators), whereas number 5 was mined using WebGen™ 100.

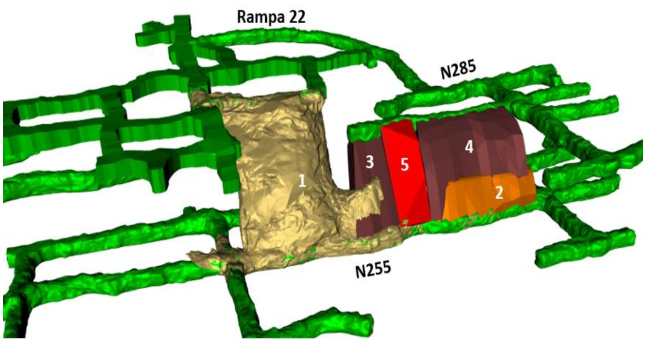


Figure 4 - layout and mine sequence from the stopes

255 BL1 12300 island [rib] pillar recovery using wired detonators would be dependent on rock filling the adjacent open stope, reinstalling ground control where needed, scaling, and managing the risks associated with personnel exposure to previously blasted rock mass. This generates additional costs and time delays. All these operations aim to allow the safe re-entry to the upper level in order to load 110mm downholes, program the electronic detonators, and fire the shot. The ore is then extracted from the lower level with 60% expected recovery, as well as dilution caused by the contact with the backfill material.

## 4 TECHNICAL SOLUTION

Using WebGen™ 100 wireless technology, Orica presented the possibility of recovering 255 BL1 12300 island [rib] pillar minimizing people's exposure and allowing the mine to improve operational productivity safely and efficiently by keeping two mucking accesses to the main stope.

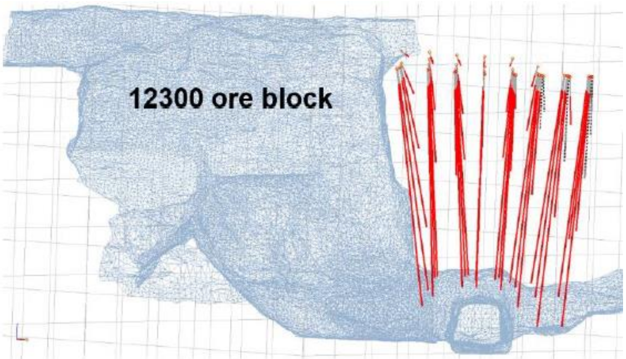


Figure 5 – BL1 12300 pillar loaded with WebGenTM 100 wireless detonators and CMS (Cavity Monitoring System) from 12300 stope

The pillar was preloaded with WebGen$^{TM}$ 100 wireless detonators before losing access to the upper level due to the blast events on the main 255 BL1 12300 ore stope. After the ore from the block was extracted and the pillar had completed its requirement to provide regional stability and dilution control, the island [rib] pillar was remotely initiated.

This way it was possible to recover the ore contained in 255 BL1 12300 island pillar without the need to complete all cycles needed in a standard pillar recover, thus minimizing crew exposure, and improving mine productivity.

## 5 RESULTS

While there was still access to the top of the island pillar, Orica and Nexa conducted extensive site signal surveying and followed best practices to ensure all the drill pattern in the pillar was correctly loaded and all 88 WebGen$^{TM}$ 100 units were encoded and positioned as planned. This blast was kept loaded with WebGen detonators in stand by mode for 33 days. In the meantime, several ore blasts took place beside the preloaded pillar in order to release ore to be mucked from the main 255 BL1 12300 stope. The lower level had shotcrete applied to eliminate the risk of slumping blastholes interacting with bogging operations, as well as an additional safety precaution for all operations and people working under the sleeping shot. Without this safe spot, the tele-remote operated mucking process would have to be done over 90m due to the size of the open stope, resulting in significantly lower productivity. However, this can be avoided by using WebGen™. After all the ore material from 255 BL1 12300 main stope was mined, the wireless primers were safely fired using a magnetic inducted signal travelling through the rock.

A special blast sequence was also used for this specific application with the intent to lower blast vibration levels. A seismograph was installed to verify the initiation of the charges.

The preloaded pillar had dimensions of approximately 25x30x6m, generating 18.8kt of ore accounting for 12% of zinc production for the month, achieving an overall average Zn content of 9.19%.

Applying WebGen™ 100 enhanced pillar recovery enabled the mine to improve its productivity without exposing people to areas previously damaged due to prior blast cycles. The process was completed with no misfires, adequate fragmentation, allowing 88% recovery of the pillar, with operational dilution kept under desired levels, and resulting in a net benefit of US$1.59M for Nexa Resources Vazante.


Figure 6 – Post bast results showing good fragmentation.

The following outcomes were achieved using WebGen™ 100 for pillar extraction:

- Increased expected ore recovery from 80% to 88% for the pillar
- Cycle time reduction of approximately 70% for the extraction of the pillar (from 90 to 20 days)
- Reduced dilution of 255 BL1 12300 main stope from 27% to 20% due to hydraulic radius reduction and less standup time.

A second application currently being studied will allow to preload an entire stope, which will reduce operational risk and the number of cycles, resulting in further increases in ore production and therefore profitability.

## 6 CONCLUSION

The search for automation of process and safer working environments with minimum exposure of people is a current reality in the industry, and drill & blast is a part of the productive mining chain where many important enhancements can be accomplished.

Following this trend, we have seen extensive investment in research and development put into initiation systems over the last 2 decades. The advent of electronic detonators provided a much more accurate timing and eliminated risks for unplanned initiation because of the absence of explosives in the down wires. Nonetheless, they still rely on physical connection between surface and primers inside the blastholes, what makes massive preloading impracticable and holds the need to tie up and test circuits for a possible leakage/voltage drop after the blast has been loaded, implying unproductive hours of work and exposure of blast crew to hazards.

The use of 100% wireless detonators enables underground operations to preload massive areas safely and efficiently while having access to blastholes and then manage the size of blasts as they wish, without having to go back in to tie or test the detonators, expose people or develop extra unproductive work. The range of possibilities enabled by this feature was unimaginable until now and gives important flexibility to mine planning as it enables miners to better manage their stock of broken rock, substituting small unproductive loads and tie up cycles by just one, which can be performed before starting to blast in the stope.

WebGen™ adoption rates are increasing rapidly through all mining markets, driven by positive results shown from solid value propositions, for instance, the presented case study from Vazante mine. This will drive production costs further down and allow an increasing number of mines to take advantage of this technology, which will ultimately benefit the industry and the mine community as a whole.

## ACKNOWLEDGEMENTS

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