High Production Underwater Blasting Technique on the Pacific Post Panama Locks

HIGH PRODUCTION UNDERWATER BLASTING TECHNIQUE ON THE PACIFIC POST PANAMA LOCKS

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ABSTRACT
The excavation and construction of the south approach channel for the new Pacific Post-Panamax Locks was an important component of the Panama Canal expansion program. Underwater blasting works were required in order to remove approximately 1.0 million m³ of material, which demanded the use of 1.3 million kg of pumped explosive in less than 5 months. In order to perform this project in time, one of the biggest drilling vessels of its class was especially constructed and combined with MAXAM's special bulk pumped explosive technology. Thus, this paper summarizes the main challenges and solutions applied during the execution of this magnificent project.
Keywords: *underwater blasting, rock fragmentation, ground vibration*

Introduction

The Panama Canal has been playing a strategic position on economies of scale and international maritime trade since its inauguration. However, after almost a century of operations, forecasts predicted that the Panama Canal would soon reach its maximum sustainable capacity. Facing this scenario, the ACP (Panama Canal Authority) proposed a major expansion program which required the construction of a new set of locks to double the actual canal's capacity. Now, the final phase of that expansion program, the largest infrastructure works since its inauguration, is end. The expansion program has created a new lane of traffic along the Canal through the construction of a new set of locks – one in the Pacific and another in the Atlantic -, increasing the Canal's capacity and impacting the world's economy even more.

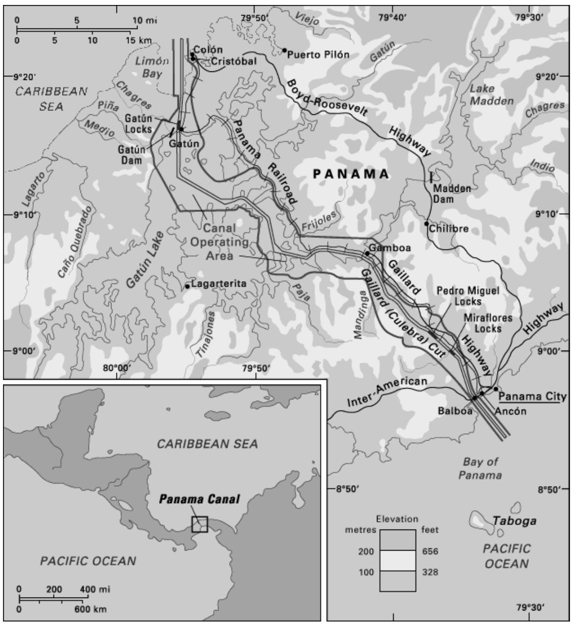

Figure 1: The Panama Canal.

The expansion program was composed by several individual projects, which includes the excavation and construction of the Pacific Post-Panamax locks South Access. This project was part of the Widening and Deepening of the Panama Canal Pacific Entrance Navigation Channel project. This contract was awarded on

April 1, 2008 to Belgian company Dredging International for a total of $177.5 million, starting blasting activities one year later, on April 2009. Around 8.7 million m^3 of material was removed, being 1.0 million from underwater blasting techniques.

Blasting works have consisted in removing a large layer of volcanic and sedimentary rock and was successfully executed in less than 5 months, after 144 shots. The combination of a huge underwater drilling capacity and MAXAM's product and technology have guaranteed high productivity rates, excellent fragmentation results, total control of vibration levels with no complains of neighborhoods and simple local logistic due to the classification of the main product used (Oxidizer 5.1). Thus, the South Access project milestones were:

Table 1: Project Milestones

Number of Blasts	Total Volume	Total of Explosive	Total of Holes	Total Drilled Meter
144	1,0 million m^3	1.3 million kg	11,8 thousand	74,6 thousand m

Project Challenges

Basically, there were four mains challenges to be overcome in order to successfully carry out the project:

(1) Ground vibrations should be kept under authorized levels due to nearby communities;
(2) Maximum fragmentation size should be P95% < 300mm, designed for a cutter section dredger;
(3) The explosive would be water resistant and perform well under high hydrostatic pressure;
(4) High productivity had to be achieved, to reach competitive costs.

Project Geology

The rock domains in the Pacific side of the Panama Canal are dominated by Basalt rock, Pedro Miguel Agglomerates and La Boca Formation. However, the south approach access project site was strongly dominated by Basalt Formation, which could be classified in two subdivisions according to its heterogeneity, lithology and geomechanical characteristics: massive and columnar basalt, both with medium hard to very hard hardness, dense and tough.

Blast Design and Operation

The main product used was the RIOFLEX Marine. This blasting agent of great performance is a watergel gassing sensitized and cross-linked, which represents one of the greatest technologies on bulk explosives. As a result, some of its advantages were:

(1) Safety transport and storage (Oxidant Matrix);
(2) The product only becomes an explosive in situ;
(3) The product's transfer was faster and easier;
(4) Huge facility capacity to storage on board and;
(5) Faster and safer loading operation vs. cartridge loading.

The drill boat, the one of the biggest drilling platform ever build, was a self-propelled drilling boat equipped with bow thruster, six anchor winches, two working spuds and two auxiliary spuds, and ten hydraulic drilling rigs on top of mobile frames that enable the towers to move according to the designed drill pattern with great velocity and GPS precision. The drilling platform was anchored to six points to avoid the lateral movements and allow, when necessary, the change of position.

On the drilling platform's deck, three Mobile Sensitizing Units (Cassettes) were installed. These MSUs were developed to safely load underwater holes with pumped explosive. The Cassettes were also installed on mobile frames which enable the equipment to move behind of the drill towers, in order to attend to each drilled borehole, loading up to three holes in parallel. This system was projected to carry out the maximum number of blastholes in one work cycle.

Figure 2: YD007 drilling platform composed by 10 Drill Tower and 3 MSUs.

The blast design was strongly associated with desired fragmentation results. The most common pattern was 3.0x3.0m or 3.0x3.5m with an average powder factor of 1.63 kg/m^3. Higher powder factors were needed to guarantee the required fragmentation, having some peaks of 2.3 kg/m^3. Subdrilling was necessary to avoid possible toes. Furthermore, the Stemming played a very important role on low frequency ground vibrations [1].

Table 2: Blast Design Parameter for Underwater Blasting on the Pacific Entrance (south access channel)

Design Parameter	Range of Value	Average Value	Comments
Hole Diameter	140mm (5.5")	-	10 drill rigs installed on the drilling platform.
Hole Length	4.0 - 14m	6.3m	Depending of excavation design (slopes areas or channel)
Hole Inclination	0º	-	Vertical holes.
Burden	3.0 - 3.6m	3.1m	Bigger pattern was designed for Clamshell. Smaller pattern was adjusted in order to provide P95<300mm (CSD)
Spacing	3.0 - 4.2m	3.5m	
Stemming	0.0 - 4.3m	0.5m	Higher stemming in Test Blast (vibration study)
Subdrilling	0.0 - 6.6m	3.0m	Depending of excavation design (slopes areas or channel)
Stiffness Ratio	1.1 - 4.7	2.0	Taking into account all borehole length.
Powder Factor	0.74-2.3kg/m^3	1.63kg/m^3	Increased powder factor in order to provide P95<300mm.

In addition, the initiation system consisted of non-electrical detonators with 30m long dualdelay detonators of 300/42ms (as inter-hole delay), 6m long surface connectors of 25ms (as interrow delay) and 450g boosters. For safety reasons, a double prime (detonator and booster) was applied per borehole. The blast initiation was carried out by using a Lead in Line, 200m long, which allow shooting the blast from the drilling platform. The schematic priming configuration can be appreciated in Figure 3.

The operational sequence consisted in series of important task. After receiving the top of rock (and overburden) from the geotechnical/geological department, a blast plan is specially prepared by considering the expected ground vibration and desired fragmentation. The implementation of the plan is strictly followed during the drilling, priming and loading of the holes – adapting for any field deviation in terms of real top of rock, quality, etc. – and can be defined in eight steps: (1) Installation of Casing and Drill Tube; (2) Drilling Through Overburden; (3) Drilling; (4) Flushing; (5) Priming and Loading of bulk explosive/cartridge; (6) Stemming; (7) Retrieving casing and recovering of the line; and (8) Connection of detonators.

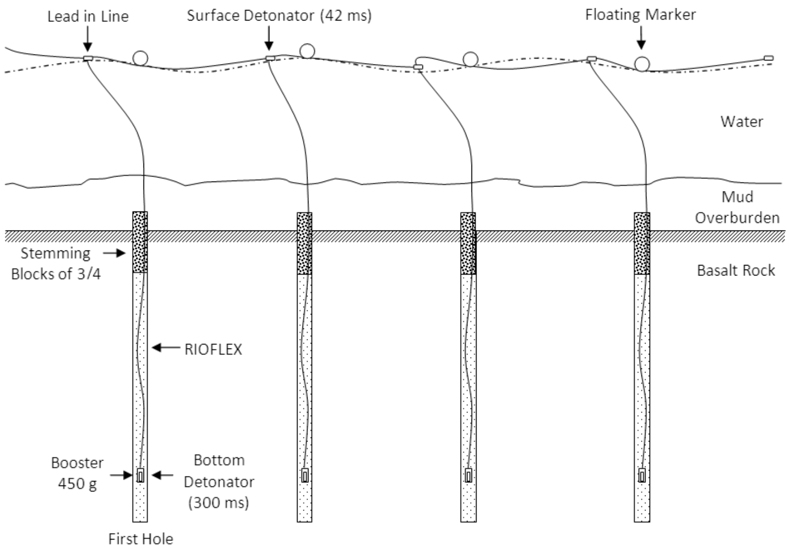

Figure 3: Scheme of priming configuration.

Fragmentation Results

The desired fragmentation size was defined according to the dredging equipment. In the beginning of the project, the initial dredger was a Clamshell, which required a maximum fragmentation size around 450mm-600mm. However, the productivity of this equipment was below expectation and the decision to change for the Cutter Suction Dredger (CSD) was taken. This important decision was based on the possibility to provide 300mm as maximum fragmentation size. Thus, in order to attend this requirement, the initial blast design was modified based on fragmentation analysis and prediction simulations, which indicates that the required fragmentation could be achievable.

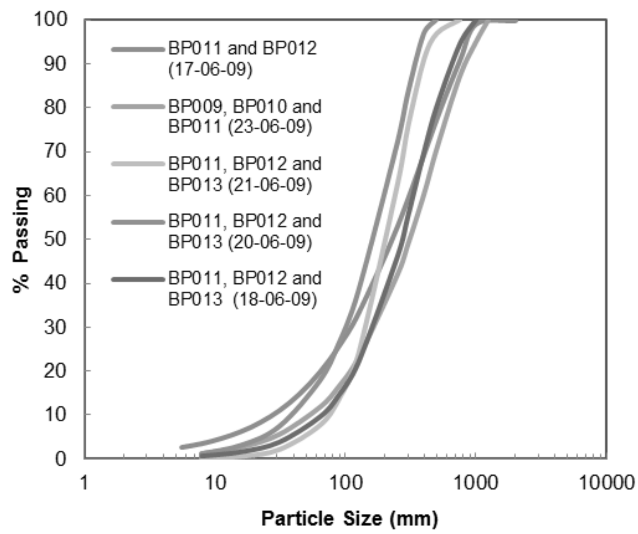

Figure 4: Fragmentation result from Blasts 11, 12 and 13, designed to Clamshell Dredger and used as reference to calculate the new patterns for P95% < 300mm.

The assessment of the actual fragmentation was a fundamental step to redesign the blast configuration. Thus, fragmentation analyses carried out by using the photometric analysis techniques were made on fragmentations resulted from initial shots. On the other hand, from the average field data of these blasts, a fragmentation curve prediction was developed and compered with the results obtained from the photometric analysis. The results have showed a very good agreement between the real and predicted fragmentation [1]. Consequently, the fragmentation model calibration allowed a better process to modify the drilling and blasting design in order to achieve the required fragmentation size to the Cutter Suction Dredger.

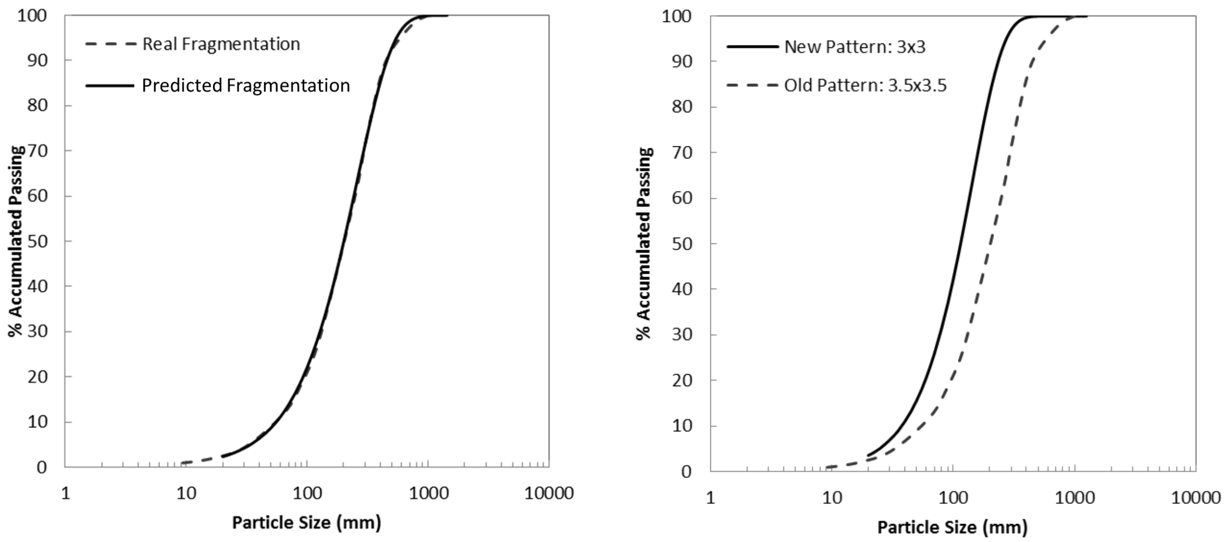

Figure 5: Fragmentation curves from a prediction and Photo Analysis from the blasts 11, 12 and 13. Improvements of fragmentation and uniformity proposed after applying the model.

Ground Vibration

In order to affront the challenge of keeping ground vibration levels under control, a site-specific Test Blast Program was specially designed and carried out prior to the production blasting phase in order to establish the local attenuation law and, then, be able to define the maximum admissible instantaneous charge (MIC) for each blast. Diablo and Diablo Dock communities were more exposed to ground vibrations generated by underwater blasting due to their proximity to the excavations zones as well as the Customer offices on the west side of the Channel. In order to control the effects of the ground vibration over these areas, a daily vibration monitoring, with seven seismographs located in different positions of interest, were carried out.

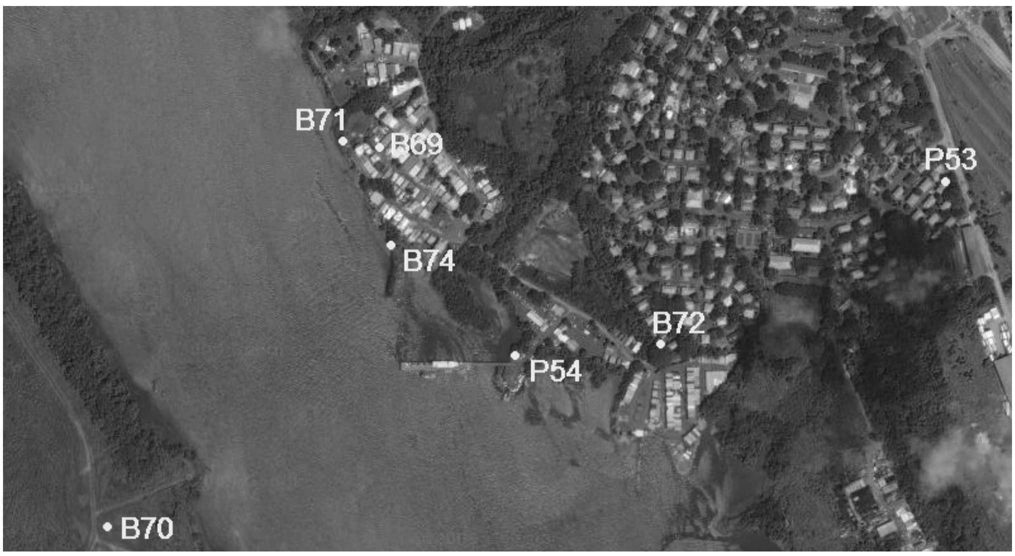

Figure 6: The positioning of the seven seismographs over the Diablo Community.

The levels of peak particle velocity are controlled and ground vibrations have never surpassed the limits of USBM RI8507 and OSMRE (Figure 7(a)) [1]. Environmental effects related with underwater blasting are more noticeable because of ground vibrations are often accompanied by low frequency components and hydrodynamic shock waves present a very large radius of action. Low frequency phenomena were recurrent in ground vibrations recorded along of the Diablo Community as can be observed in Figure 7(b) [2].

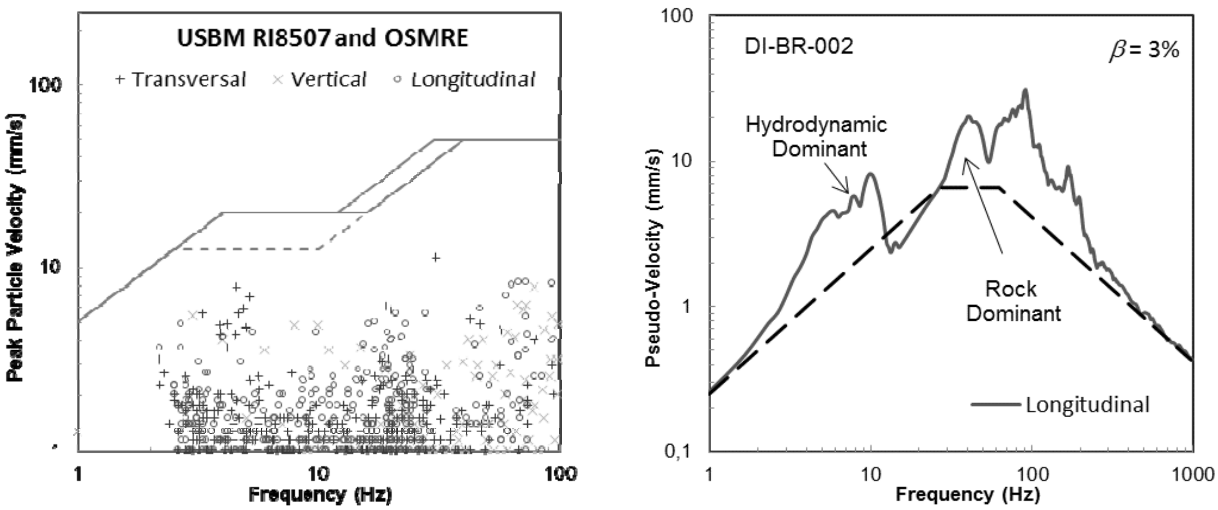

Figure 7: (a) Historical vibration levels from 144 shots compared with the local regulation limits. (b) Response Spectra of Ground Vibration generated by underwater blasting in Panama Project [2]

Conclusions

The underwater drilling and blasting operation has been successfully completed with the use of high production and specialized blast techniques and solutions. More than 140 blasts have been safely carried out in order to shape the South Access Channel of the Pacific Post Panama Locks, by excavating 1,0 million m^3 of material in 5 months of works. Undesirable environment impact effects have been controlled as a result of a conscientious and comprehensive ground vibration monitoring and studying program. Finally, the final fragmentation was perfectly suitable to the cutter suction dredger.

References

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