The Recovery of a Dozer from a Highwall Using Blasting

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Abstract

A dozer operator at a surface gold mine accidentally drove a D10 off the side of a highwall. The blade of the dozer caught on the lip of a catch bench 60 ft. (18.3 m), down stopping its descent. The operator scrambled to safety in fear that the dozer would not hold.

Engineering and management looked at multiple dozer recovery options, with safety the overriding consideration. The initial plan was to rent a crane to lift the dozer out. However, Caterpillar would not sanction tying off on the tool bar. This meant that personnel would have to remove the tool bar on the highwall, which was deemed unsafe. For work to be done at the dozer level an access bench was necessary. Mechanical excavation was initially attempted, but only had success several feet down before the rock was no longer diggable. The only option other than abandoning the dozer was blasting the access bench down to the elevation of the dozer blade.

The drill and blast team had discussed blasting solutions and came up with a sound approach that was presented when mechanical excavation failed. Normal mine production blasts use 7 7/8th in.(200 mm) holes drilled 23 ft. (7.0 m) and loaded with 7 ft. (2.1 m) of powder, with 30 to 40% hole utilization and a PF of 0.4 lbs\ton (0.2 kg/tonne). Down the hole detcord and surface delays are used and blasts can be violent. The problem was three fold: damaging the dozer with flying rock, knocking the dozer down the highwall, and vibrations causing cascading material to bury and damage the dozer. Fortunately the ground was mostly waste rock, which meant there were few constraints on blasting. The plan involved increasing both powder factor and hole utilization to send more of the energy into breaking the rock and casting it away from the dozer whilst eliminating flyrock and minimizing ground vibrations. Blasts as near as 80 ft (24 m) away from the dozer were designed using one of the highest powder factors ever used at the mine of 0.8lbs/ton (0.4 kg/tonne) or 1.6lbs/cyd (0.9 kg/m^3) and a 63% hole utilization using the timing precision of electronic detonators with the process, philosophy and designs described in detail in the paper. The process was documented using video, seismograph and laser profiling movement monitoring.

The D10 dozer was successfully extracted with none of the windows damaged and no damage from the blasting. It was back in operation at the mine after a thorough inspection and maintenance.

Introduction

A dozer operator during night shift drove a D10 dozer up a berm and off the edge of the highwall. The dozer fell down the highwall 60 ft(18.3 m) before the front blade dug into a catch bench. The dozer operator high tailed it out of the dozer and climbed to safety after the dozer came to a stop on the catch bench. The highwall the dozer drove off was at a 65 degree angle but the dozer sat on the catch bench at a 40 degree angle. Figure 1 shows a photograph of the dozer caught on the catch bench.

At first hooking onto the dozer's tool bar and dragging it out was suggested, but this was deemed unsafe and damaging to the dozer. Bringing in a crane to lift the dozer was also suggested but in order to access a sufficient tie off point the tool bar would have to be removed. It was deemed unsafe for personnel to do any work on the dozer in the middle of the highwall. The decision was made to excavate down to the bench elevation in order for personnel to be able to work on the dozer from the safety of bench elevation.

At first they tried to free dig the material but it soon turned too hard to dig. The blast tech team knew that blasting would be an option if we changed our normal blast design. When excavation was no longer possible the idea of specialized blasting was casted out and management took the bait.

Figure 1. Day After the Dozer Drove off the Highwall

Methodology

The whole idea of the design was to put as much of the explosive energy into breaking and casting the rock as possible to reduce the amount of vibrations escaping the blast pattern. Explosive energy likes to take the path of least resistant. The less contained a blast is the more energy goes into breaking and casting the rock in the direction of the free face than goes into the material behind the blast. The bigger the bench height to burden ratio is the more tensile stress is exerted onto the rock. Rock tends to break the best under tensile stress. This is like trying to break a tall skinny pencil in half and a short fat pencil in half. The tall skinny pencil is a lot easier to break. The plan was to increase the powder factor by decreasing burden and spacing and increasing face height. This in theory would increase movement of the material, increase fragmentation, and decrease ground vibrations.

Design

The bench elevation that the dozer drove off was on the 5740 ft (1750 m) elevation. The front dozer blade caught on the 5680 ft (1731 m) catch bench below. This meant the blast would have to fragment 60 ft (18.3 m) of material to be excavated to create a pad to work on the dozer. Two types of blasting were designed for creating the pad, one being for the initial drop and the other for removing the material closest to the dozer.

Since we had to drop down 60 ft (18.3 m), the drop cut was made by shooting two levels. The first level was drilled to 5697 ft (1736 m) and the second was drilled to the 5677 (1730 m). This was because we used normal production design for the drop because it was far enough away to not be as concerned with moving or hurting the dozer. This helped out the speed of the mining cycle.

Signature hole analysis was done on a 40 ft (12.2 m) bench using normal production practice of down hole cord and on a 60 ft bench using a down hole electronic detonator. An explosives supplier was used to analyze the signature hole data and they came up with 33 ms hole to hole and 62 ms row to row for the 40 ft (12.2 m) bench and 25 ms hole to hole and 53 ms row to row for the 60 ft bench. These situations simulated well at 100 ft (30.5 m) and 200 ft (61.0 m) locations from the blast hole.

Normal production patterns used at the mine site are 16 ft x 18 ft x 23 ft (4.9 m x 5.5 m x 7.0 m) (Burden x Spacing x Depth) in ore and 18 ft x 18 ft x 44 ft (5.5 m x 5.5 m x 13.4 m) in overburden. The average powder factor on site is around 0.4 lbs of explosives per ton of material (0.2 kg/tonne). The decision was made to double the powder factor to 0.8 lbs/ton (0.4 kg/tonne) for the special panel shots by decreasing the burden and spacing to 13 ft x 15 ft (4 m x 4.6 m) and increasing depth to 63 ft (19.2 m). The pounds of explosives were limited in the 63 ft (19.2 m) face by using a 6.75 in. (171 mm) hole instead of normal 7.875 in. (200 mm) hole. A buffered blend with a density of 1.15 g/cc was used due to reactive ground potential. Unfortunately getting nice crushed stone wasn’t an option for stemming so drill cuttings were used for stemming the holes. The quality of the drill cuttings for stemming was decent due to the damp conditions of winter and stemming ejection was minimal.

The panel shots were limited to three rows to minimize constipation of the shot. After three rows, relief caused by the row timing and material moving, starts to decrease. This causes an increase in vibrations going back into the wall. The pattern designs of the drop cuts and panel shots are shown in Table 1. Figures 2 and 3 show a plane view of the pattern designs.

Table 1. Pattern Designs

Shot type	Burden (ft)	spacing (ft)	hole depth (ft)	Hole diameter (in)	bench height (ft)	PF lbs/ton	PF lbs/cyd	Stemming (ft)	lbs/hole	Blend (% emulsion)
40 ft drop	17	18	43	7.875	40	0.54	1.10	24	500	15
20 ft drop	16	18	23	7.875	20	0.34	0.84	16	180	15
60 ft panel	13	15	63	6.75	60	0.8	1.62	23	700	15
Metric	(m)	(m)	(m)	(mm)	(m)	Kg/tonne	Kg/m^3	(m)	Kg/hole	%
40 ft drop	5.2	5.5	13.1	200	12.2	0.27	0.61	7.3	227	15
20 ft drop	4.9	5.5	7.0	200	6	0.17	0.43	4.9	82	15
60 ft panel	4	4.6	19.2	171	18.3	0.4	0.90	7.0	318	15

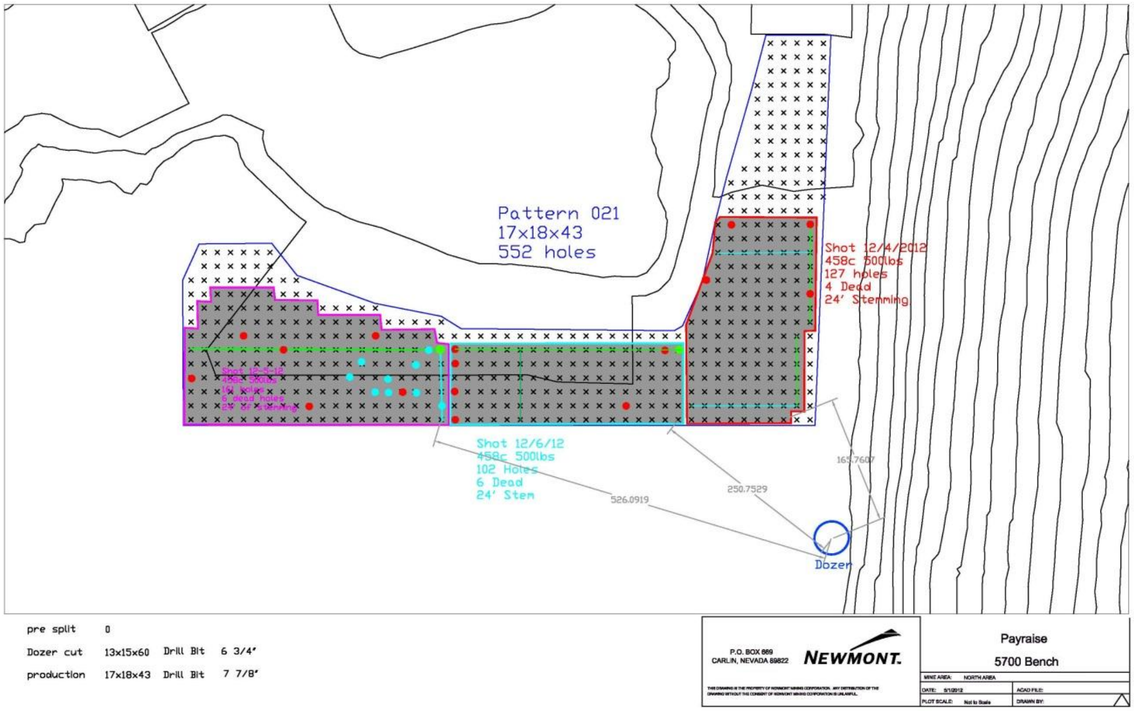

Figure 2. 5700 Bench Shot Map

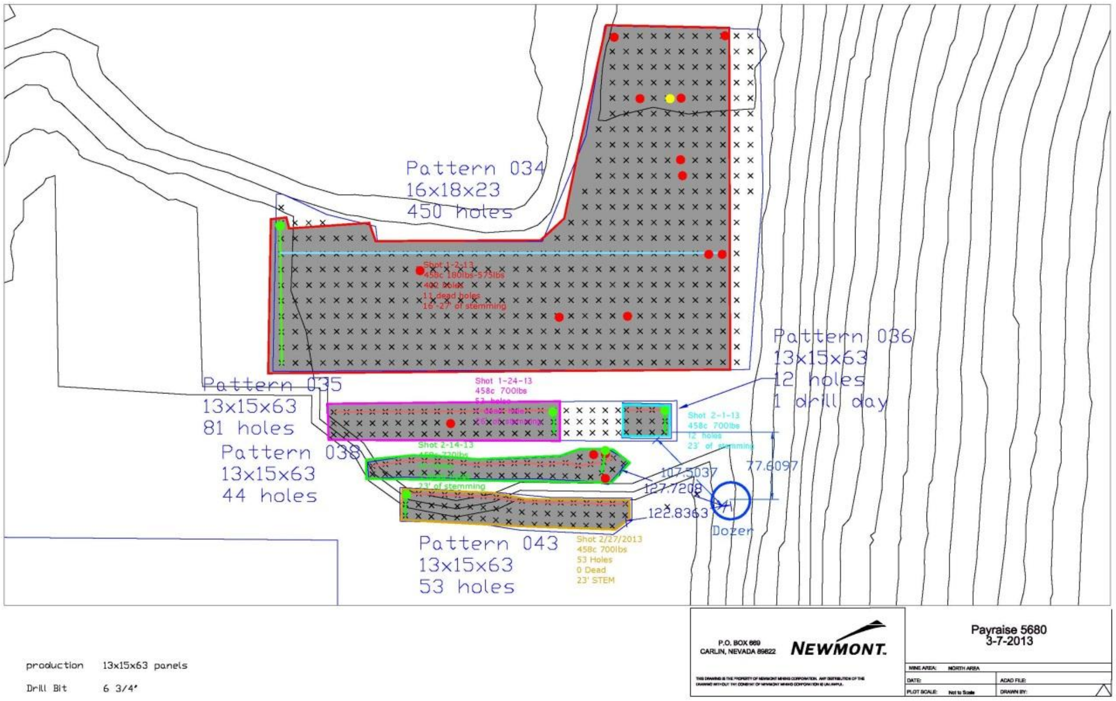

Figure 3. 5680 Shot Map

Results

Unfortunately there are no regulations on the maximum vibrations for a D10 dozer sitting on the edge of a high wall. The engineers had no starting place besides trial and error. Since the material with the dozer didn't fail due to weather conditions changing, it was assumed that the dozer could take quite a bit more than the regulation for structures of 2 in/s (50.8 mm/s). Table 2 shows the distances away from the blast of the seismographs and seismograph data. Notice that the last three blasts had significantly more ground vibrations. This was due to the proximity of the blasts. From data collected vs. what was estimated, vibrations near the dozer were significantly reduced by using signature hole data and increasing powder factor by decreasing burden and spacing and increasing hole length. Now in a perfect world the hole diameter would of have been drastically reduced. This would have decreased pounds per hole to be less than production and still doubled the powder factor. With this operation going lower than 6.75 in (171 mm) diameter was not an option.

Table 2. Seismograph Distance from Blast & Data

Blast	Seis distance (ft)	Seis Distance (m)	PPV (ips)	PPV (mm/s)	Frequency (Hz)	calculated PPV (ips) (k factor of 1140)	Calculated PPV (mm/s)
1st (12-4-12)	157	48	2.12	53.85	26.9	47.23	1199.64
2nd(12-5-12)	493	150	0.21	5.33	9.3	7.57	192.28
3rd(12-6-12)	220	67	1.36	35.54	17	27.53	699.26
4th(1-2-13)	153	47	1.52	38.61	22.2	22.14	562.36
5th(1-24-13)	170	52	1.88	47.75	13.4	58.95	1483.23
6th(2-1-13)	72	22	ips>5	mm/3>127	N/A	233.05	5919.47
7th(2-14-13)	92	28	N/A	N/A	N/A	157.44	3998.98
8th(2-27-13)	84	26	8.8	223.52	28.4	182.11	4625.59

The first blast went well. Laser profile scans were taken before and after the blast and showed minimal movement. Figure 4 shows a picture of the blast. Notice the dozer in the lower right hand corner. The dozer was 166 ft (50.6 m) away from the blast. We did not decide to bring the next pattern back from the crest edge because the scans didn't show any movement in the material between the dozer and the blast. The blast had 127, 43-ft (13.1-m) holes, and 500 lbs (227 kg) of explosives per hole. The seismograph reading next to the dozer had a peak reading of 2.120 in/s (53.848 mm/s) at 26.9 Hz with the lowest frequency of 21.3 Hz at 1.840 ips (46.736 mm/s). It was noted that normal blasting practices did send quite a bit of material down the high wall. If this design was shot by the dozer it would have covered the dozer with material and potentially dislodged the dozer. See Figure 2. for the location of the blast on 12-4-2012. It is the blast bordered in red.

Figure 4. First Dozer Shot

The next two blasts were on the same bench as the first with the same design and timing. These blasts are outlined in pink (12-5-2013) and teal (12-6-2012) in Figure 2. The second shot had 161 holes (8 dead) and was 529 ft (161 m) away from the dozer. This shot had a peak particle velocity of 0.210 ips (5.334 mm/s) at 9.3 Hz with the lowest frequency being 8.9 Hz at 0.180 ips (4.572 mm/s). Little to no movement was reported from the scans for the material around the dozer and the dozer itself. In Figure 5 the blast shows a little stemming ejection. This is very common when using detcord down the hole as an initiator. The stemming ejection causes quite a bit of fly material that is unwanted once we get closer to the dozer. The third shot had 102 holes (6 dead) and was 251 ft (77 m) away from the dozer. This shot had a PPV of 1.360 ips (34.544 mm/s) at 17.0 Hz with the lowest frequency being 10.2 Hz at 1.360

ips (34.544 mm/s). The scans reported little to no movement of the dozer from before the blast. In Figure 6 the blast shows a little more violent stemming ejection.

Figure 5. Second Dozer Shot

Figure 6. Third Dozer Shot

Blast number four next to the dozer was a 20ft (6 m) drop pattern to get the 5700 ft (1737 m) down to the 5680 ft (1731 m) elevation to fully free face the panel shot. Since this shot had less than half the explosives per hole than the 40 ft (12 m) drop it was decided to shoot all 402 holes (11 dead) in one shot. This is the blast shot on 1-2-13 outlined in red in Figure 3. The closest hole to the dozer was 158 ft (48 m) and gave a seismic reading of 1.520 ips (38.608 mm/s) max at 22.2 Hz and the lowest frequency 13.0 Hz at 1.280 ips (32.512 mm/s). The dozer scans did not show any significant movement near or around the dozer. This blast (1-2-13) is outlined in red in Figure 3. This blast had less ground vibrations than the first shot that was similar in distance but this shot had less than half the lbs per delay. This blast had a lot of stemming ejection and was also quite violent as can be seen in Figure 7. Quite a bit of material was cascaded down the side of the highwall and there was some fly material that could have hit the dozer if it had been closer. There was a little bit of snow that fell down the high wall in front of the dozer but no actual material fell.

Figure 7. Fourth Dozer Shot

Shot number five next to the dozer was the first panel shot. There was a failure in the wall that split the pattern up into two shots. In Figure 3 there is a gap in-between the pink and teal shots that was the area that failed. The pink pattern (1-24-13) was the panel shot we shot first. The blast had 53, 63 ft (19 m) holes, and 700 lbs (318 kg) of explosives per hole. The closest hole to the dozer was 219 ft (67 m). This shot gave a PPV of 1.880 ips (47.752 mm/s) at 13.4 Hz which was the lowest frequency. The before and after dozer scans came back negative for significant movement. Figure 8 shows a picture of what the before and after scans looked like. All of the scans looked very similar except for one so only two scans will be shown in the paper. In the scan anything that is in blue is up to 1 ft (0.3 m) of material gain, gray is zero movement, and orange is up to 1 ft (0.3 m) of lost material. The green color means it went out of the range of -1 ft (-0.3 m) to 1 ft (0.3 m). The scan shows that the material near the dozer was basically unaffected. The material that is right next to the free face shows a little bit of loss but it was right in front of blast and it was expected to see a little bit of movement in front of the blast. One thing to note from this scan is that the material next to where the blast was located is unaffected. This means that this is a safe distance (140 ft/43 m) from the high wall to put the blast once we get to patterns directly behind the dozer. Figure 9 shows a photograph of the blast. This blast had the least amount of fly material and only one stemming ejection that was from a hole plugging during stemming.

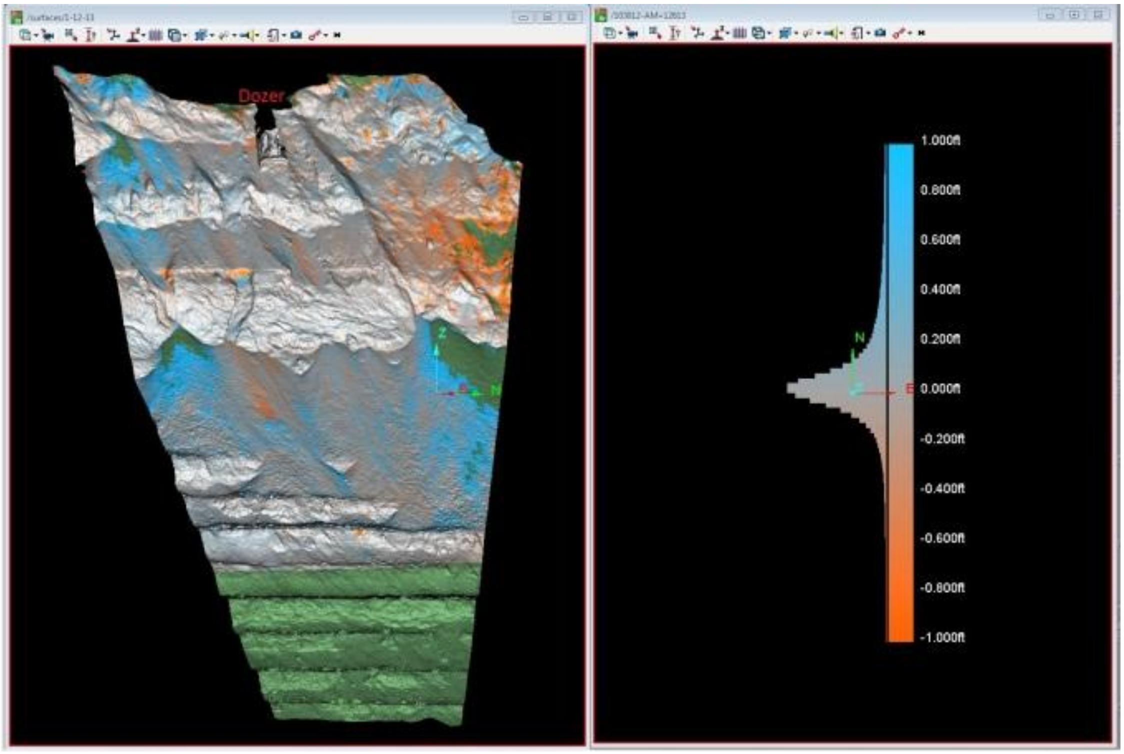

Figure 8. Before and After scan of the First Panel shot

Figure 9. Fifth Dozer Shot

Shot number six was the second panel shot next to the dozer. The blast had 12, 63 ft (19 m) holes (0 dead), and 700 lbs (318 kg) of explosives per hole. The teal pattern (2-1-13) in Figure 3 shows shot number six. This pattern was only 108 ft (33 m) away from the dozer and had more burden than designed due to the failure. This pattern also had some short holes in the middle of the pattern. This shot gave a PPV greater than 5 ips. Unfortunately the seismograph was set to a max of 5 ips so data was not received. The scan showed little to no movement on and around the dozer. This was a good sign that the dozer was pretty well set in the catch bench and as long as the material in the catch bench did not get casted the dozer would be fine. One thing from this blast that was noticed was the material in-between the dozer and the blast did show a little bit of movement, as seen in Figure 10 below. It was then decided to pull the rest of the panels 50 ft back. Figure 11 shows a photo of the shot. This shot had no fly material and no stemming ejection.

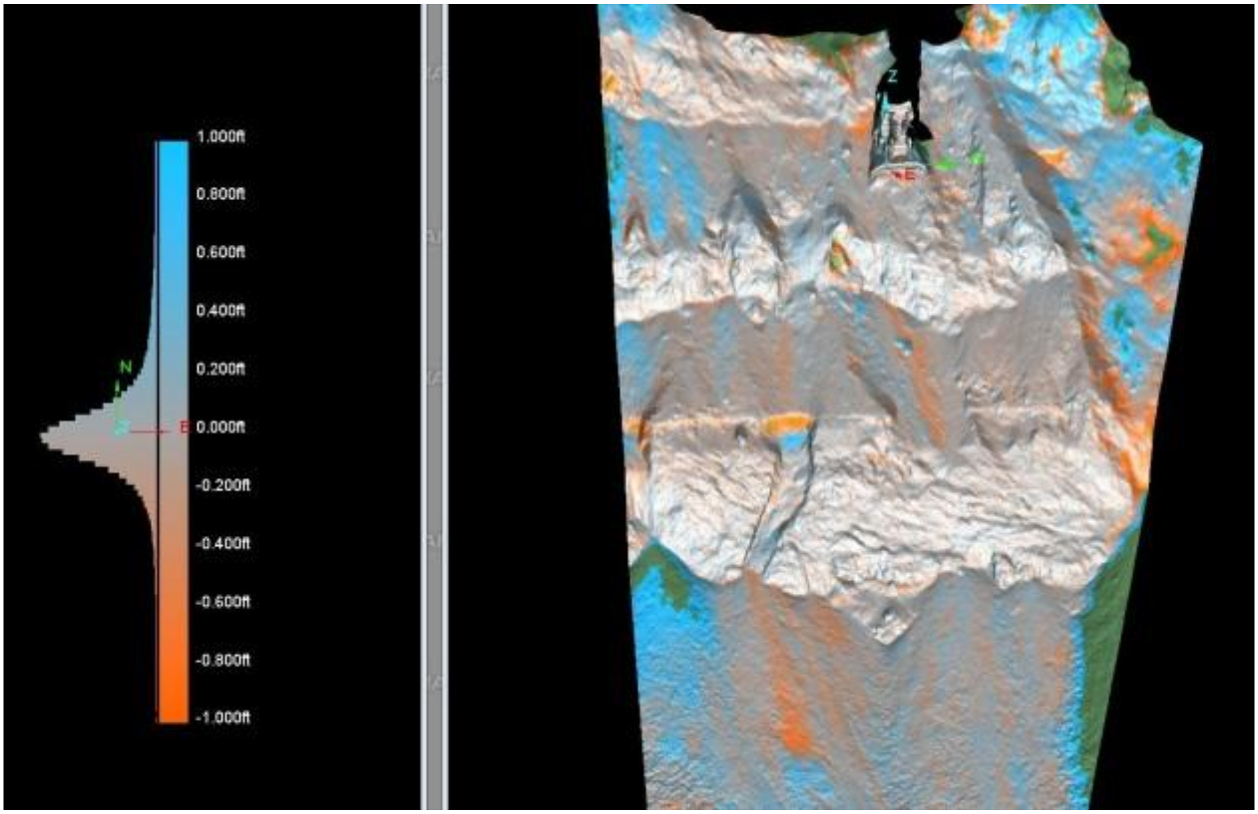

Figure 10. Dozer Scan of the Sixth Shot

Figure 11. Sixth Dozer Shot

Shots 7 (2-14-13) and 8 (2-27-13) were similar in design to the first panel shot and can be seen in Figure 3 in green and yellow respectively. Shot 7 was 128 ft (39 m) away from the dozer. This blast was done while the blasting engineers were at the 2012 ISEE conference and the seismograph monitors were improperly set up and a valid reading was not obtained. The video was also missed, but the before and after dozer scans showed little to no movement of the dozer and the surrounding material. This shot was slightly north of being behind the dozer. Shot 8 was the last dozer shoot needed for equipment space to retrieve the dozer and was slightly south of being behind the dozer. This shot had 53, 63 ft (19 m) holes (0 dead), and 700 lbs (318 kg) of explosives. This shot gave a PPV of 8.80 ips (223.52 mm/s) at 28.4 Hz with the lowest frequency of 4.7 Hz at 6.00 ips (152.4 mm/s). The scans showed little to no movement of the dozer or the material around it. Figure12 shows a photograph of the eighth dozer blast. This shot had some stemming ejection that was caused by using drill cuttings and holes plugging.

Figure 12. Eighth Dozer Shot

After the eighth shot the bench was down to the dozer blade elevation and there was enough room for equipment to operate. The 50 ft (15 m) buffer zone ended up being easy to dig. This was due to the shock wave from the blast creating micro fractures in the rock. This was expected, but was not expected to work as well as it did. Figure 13 shows the dozer after final excavation of the buffer zone. The removal of the dozer was done by strapping onto the tool bar with the shovel and digging the material out from under it with a backhoe then dragging it to more stable ground. The dozer had no blast damage and all of the glass was intact. Once the fluids were changed this dozer was out in the pit again working.

Figure 13. Dozer after Final Excavation

Conclusion

The dozer rescue using blasting to excavate the bench to the level of the dozer was a success. Although vibrations were significantly more at the dozer with the panel shots than the drop cuts, using regular production blasting design would of caused even more vibrations in the same location and would of casted material onto the dozer and disturbed the catch bench material that the dozer was sitting on, resulting in dozer lose. No vibration limit was established due to only being able to measure up to 10 in/s (254 mm/s) and the use of laser profiles to track movement. The accuracy of the laser profiles was around 2 inches (50 mm) so if the laser profile showed a movement of 3 inches (80 mm) or more a design change for the next shot would have been implemented. Using the technique of increasing powder factor by decreasing burden and spacing and increasing face height and casting the rock away from the dozer did significantly reduce the impact of blasting near the dozer.

References

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