BUCKET OVERLOADING RATIO OF MINING SIZE WHEEL LOADERS & LOAD DISTRIBUTION CURVES - A CASE STUDY

Metin Özdoğan[1], Hakkı Özdoğan[2]

ABSTRACT

It is extremely important to monitor bucket payload of mining wheel loader in terms of evaluating both performance of the operator and the equipment. Both underloading and overloading should be avoided. It is better sticking to the optimum payload recommended by the Original Equipment Manufacturer (OEM) which represents the optimum load for the equipment. Neither overloading nor underloading of wheel loader (WL) is recommended. Underloading is not good from productivity point of view; whereas, overloading will be shortening the life expectancy of the machine in the long run and lower the Mean Time Between Failures, (MTBF).

A LeTourneau L-1350 model (21m3) Electric Wheel Loader (EWL) operating in a gold mine in Uşak, Aegean Turkey, was monitored via onboard device for five cases. The payloads, overloads and critical overloads; load distribution curves of shifts with respect to overloads investigated. The overload and critical payload counts are given and ratios in total bucket counts are calculated and illustrated for the cases reviewed.

Keywords: Electrical Wheel Loader, Bucket Payload, Target Payload, Bucket Overload, Bucket Critical Overload, Payload Distribution.

ÖZET

Elektrik tekerli yükleyicinin kepçe yükünü izlemek, hem operatörün hem de ekipmanın başarımını değerlendirmek bakımından olağanüstü önemlidir. Kepçeyi makina üreticisi tarafından önerilen hedef yükten az ya da çok yüklemekten kaçınmalıdır. Optimum yükten az doldurmak araç üretkenliği bakımından, çok doldurmak ise araç ömrü ve sağlığı açısından önerilmez. Kepçenin aşırı yüklenmesi makinadan beklenen ömrün ve arızalar arası sürenin kısalmasına neden olur.

Ege Bölgesinde, Uşak’da bir altın madeninde çalışan bir LeTourneau L-1350 model (21m3) elektrik tekerlekli yükleyicinin başarımı özellikle kepçe yükü ve aşıurı kepçe yükleri yönünden izlenen beş vaka verilmiştir. Vardiya ve günlük kepçe yükü dağılım eğrileri, aşırı ve kritik aşırı yük sayıları ve yüzdeleri irdelenmiştir.

Anahtar Kelimeler: Elektrik Tekerli Yükleyici, Kepçe Yükü, Hedef Kepçe Yükü, Kepçe Aşırı Yükü, Kritik Kepçe Aşırı Yükü, Kepçe Yük Dağılımı.

[1] Dr. Maden Yüksek Mühendisi, Çayyolu Mahallesi, 2706. Sokak, Havadar Sitesi No:44 Çankaya, 06810 ANKARA e-mail: metinozdogan@gmail.com

[2] Elektrik-Elektronik Mühendisi, Çayyolu Mahallesi, 2706. Sokak, Havadar Sitesi No:44 Çankaya, 06810 ANKARA e-mail: hakki@idealph.com

1. INTRODUCTION

1.1 Overview

Surface Mining Equipment mainly comprise of wheel loaders, hydraulic shovels, hydraulic backhoes, electric rope shovels and electric walking draglines. Large wheel loaders (electric or mechanic) have grown in size to match large off-highway mining size trucks developed. If the prevailing conditions of the mine favours, it is a low capital cost alternative as a loading tool. Where mobility is paramount (selective mining, multiple loading faces etc.) the mining class wheel loaders are primary loading tools. Mining size wheel loaders are available in 15m3, 20 m3, 25 m3, 30 m3, 40 m3 bucket ranges;and capable of loading to 150 tonnes, 200 tonnes, 250 tonnes, 350 tonnes and 400+ tonnes range off -highway trucks (OHT). Wheel loaders need wider benches to manoeuvre, eventhough they are articulated 40º degrees [1].

Firm level, dry, smooth and wide bench floors, drained wet sections to minimize tire damage, well-blasted materials for minimizing penetrating time, especially in the toe-area of the face, multiple faces, frequent moving, lower bench heights are favourable conditions for wheel loader applications. Whereas, soft, wet and weak bench floors, poor blasting, loading areas with limited spaces are unfavourable conditions for wheel loader applications [11].

Productivity of the loading equipment affected by several factors: Muckpile characteristics, loader type and design, loading geometry and practice and operating conditions [10].

1.2 Bucket Payload

Payload (PYLD) is the net weight of the material in the bucket excluding the dead weight of the bucket and rigging. Payload limit (PYLD-L) is the recommended load limit by the OEM not to exceed the optimum bucket load. Exceeding this load limit implies wear and tear on the equipment and shorter economic life span [2].

Poor bucket fill factor (BFF) is generally an indicator of the loader operators' miss of some critical skills; and consequently implying loss of production. It is important to have a good match between the loader bucket sizes and haul truck capacity. If the operator cannot fill the bucket correctly, the expected BFF can not be achieved. The reason why may either be not digging right angle to the face or poor penetration into the bank [1][9]. Safe and quick training of operators is achieved by having realistic virtual training simulators, at the site. Operator training simulators secure less machine downtime, fewer accidents, more efficient and productive wheel loader operation [1].

Improved bucket fill factor results in less passes and better productivity. Poorly blasted material will result in partially filled buckets as well as having to work over toe and uneven floors. It is also important to make sure that the operator has the right tool for the job. A good bucket, matched to the application and machine is critical to achieve both short loading cycles with good bucket fill, resulting in high productivity [1][6].

Correct haul-truck positioning can make a tremendous difference to the safety and productivity of the load and haul operations [1][9].

2. FIELD INVESTIGATIONS

2.1 Equipment Specifications

The studied electric wheel loader (EWL) (21m3) is a high-lift electric wheel loader (LeTourneau L-1350) operating at Kisladag open pit gold mine (Figure-1); The data belongs to September 2016 and recorded by the onboard monitor of the equipment. It is a diesel electric drive loader and has four motorised electric wheels. Thus, the mechanical drive train is avoided and energy is transferred to the wheel motors via electric cables, only. By design, it has less number of moving parts so it requires less number of parts to maintain and replace. It consumes considerable less amount of fuel compared to mechanical mining loaders because of the design features. Some of the technical specifications are given in Table-1.

Table 1 Some technical specifications of L-1350 Electric Wheel Loader [1]

Specifications	Standard Lift Model	High Lift Model
Engine	1193 kW (1600HP)	1193 kW (1600HP)
Breakout Force	961 kN	987 kN
Operating Weight	184 tons	186 tons
Static Tipping Load	102 tons	95 tons
Bucket Capacity	23 m^3	21 m^3
Payload	--------	31 tons
Payload Limit	--------	34 tons
Overload Limit	--------	37.4 tons
Critical Overload Limit	--------	40.8 tons

Figure 1 L-1350 is loading to Hitachi HT-AC-5500 OHT at the gold mine in Uşak

The original equipment manufacturer (OEM) suggested payload (PYLD) is 31 t and payload limit (PYLD-L) of L-1350 high-lift loader is 34 tons. The overload limit (OVRLD-L) is 10% excess of PYLD-L which is 37.4 tons. Whereas, critical overload limit (C-OVRLD-L) is 20% excess of PYLD-L that is 40.8 tons [1][9]. When the bucket load reaches to critical overload limit, the hoist system stops working to protect the equipment; upon the excess material is dumped off, the hoist system starts functioning again[1] [11].

The target payload (T-PYLD) is taken 10% lighter than PYLD-L which is about 34 tons. The OEM recommends that the payload deviation of the target payload should not be greater or smaller than 5%.

Please note that bucket capacity is sized to material density. Standard rock bucket is based on a material density of 17,46 N/ m3 (1,78 kg/m3) by the manufacturer [2].

2.2 Electric Wheel Loader Bucket Payloads

Target payload (T-PYLD) is the optimum load suggested by the original equipment manufacturer; effort should be spent to reach the target payload and it is recommended that the deviation from this load should be in the range of ± 5%. See Table-2 for the EWL and OHT (Off-Highway Truck) payloads of the cases monitored in the gold mine.

Table 2 Average per shift bucket and truck payloads of the cases monitored.

Case#	Shift#1 (07-19hrs)			Shift#2 (19-07hrs)			Daily PYLD
	PYLD	# of Passes	T-PYLD	PYLD	# of Passes	T-PYLD	
1	30	4	131	32	5	171	31
2	30	6	169	30	4	116	30
3	31	6	160	30	4	127	30
4	35	4	130	35	4	124	35
5	30	4	124	31	4	122	30
Mean	31.2 ± 2.2	5 ± 1	143± 20	31.6 ± 2.1	4 ± 0.5	132 ± 22	31.2 ± 2.2

Not digging straight angle to the face results in poor bucket fill factors; it is also very hard on the loader, see Figure-2. It twists the loader frame, results in broken corner adapters on the bucket and causes unnecessary wear and tear on the machine [1]. The most common position for the truck to be placed at 45 degrees to the face and close into it, with the loader loading from driver's side. By placing the truck at this angle, the shortest possible loader travel distance is ensured guaranteeing productivity [6][8].

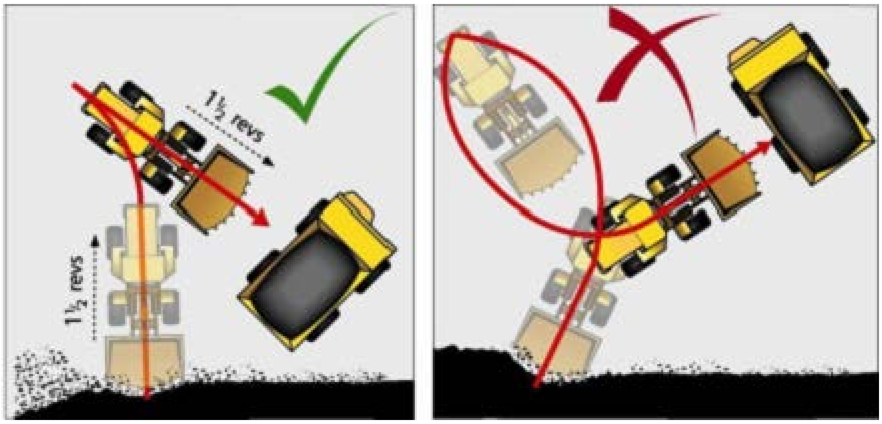

Figure 2 The position of wheel loader and truck with respect to the face [4]

It should be made sure that the loader operators dig at right angles to the face whenever possible, Figure-2. It should also be ensured that the back of the bucket is filled through good initial penetration. Bucket should be flicked before leaving the face in order to reduce the tyre damage [1][9].

Average bucket payloads shift 1 and 2 are depicted in Figure-3 for the five cases monitored. Case 2 have the highest bucket payloads in both shifts. This might be due to the style of the operator and/or density change of the face due to selective mining.

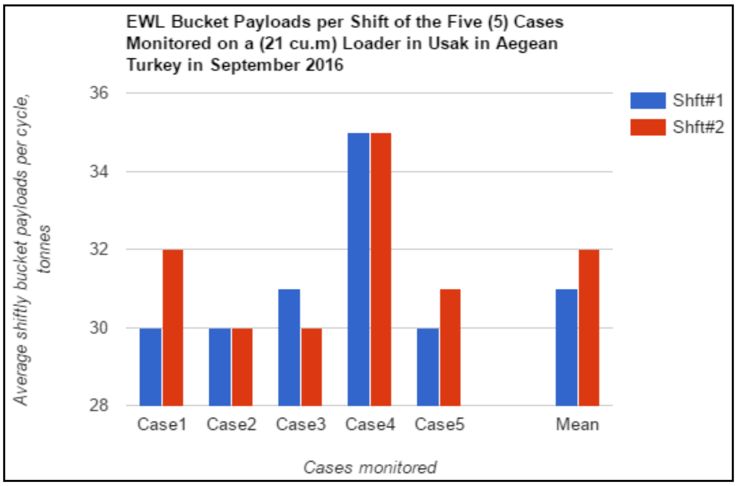

Figure 3 Average bucket payloads per shift of the cases

3. OVERLOADS AND CRITICAL OVERLOADS OF BUCKET

3.1 Bucket Overload and Critical Bucket Overload

Overload Limit (OVRLD-L) is the load which is 10 percent heavier than PYLD-L, whereas, Critical Overload Limit (C-OVRLD-L) is 20 percent heavier than PYLD-L by definition. If the weight of the load in the bucket gets closer to the critical overload limit, equipment enters into self-control mode and stop lifting the bucket. Upon reducing the load in the bucket by dumping some of the material to ground, and getting the bucket load below the critical overload limit, it starts lifting the bucket again.

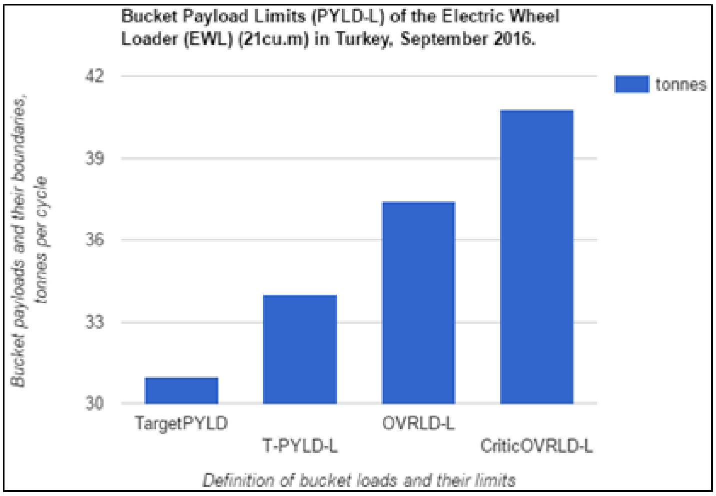

Figure 4 Bucket load boundaries of the electric loader examined.

The target payload and deviation ratios of the electric loader (21m3) investigated in this study are given in Table-3 and Figure-4. Based on the monitoring results of the week, average bucket payload is 31.2 ± 2.2 tons, target payload is 34 tons, and deviation from the target payload is minus (-) 8% (Table-3).

Table 3 Definition of bucket payload and boundaries

Loader Model	Bucket m^3	Payload, tonne	Target Load Limit, tonne	Overload Limit, tonne	Critic. Overload Limit, tonne
L-1350 High Lift	21	31	34	37.4	40.8

Table-4 depicts that overload and critical overload percentage of the cases monitored are acceptable with an exception of Case 2, night shift. Overloads and critical overloads may cause premature failures of the machine that is why they are better to be monitored shift by shift, operator by operator so that the operator's misuse may be improved by further hands on training.

3.2 Bucket Overload (OVRLD) and Critical Bucket Overload (C-OVRLD) Ratios of the Monitored Cases

Table 4 Overload and critical overload percentages in the total number of buckets

Case #	Shift#1 (07-19hrs)		Shift#2 (19-07hrs)		OVRLD Ratio in Total Bucket Counts, (%)	C-OVRLD Ratio in Total Bucket Counts (%)	Total Bucket Counts in Shift#2, Counts
	OVRLD Count	C-OVRLD Count	OVRLD Count	C-OVRLD Count			
1	0	0	22	12	3.45	1.88	637
2	0	0	5	5	0.98	0.98	510
3	0	0	3	7	0.69	1.62	431
4	0	0	97	28	16.30	4.71	595
5	0	0	17	11	2.64	1.71	643

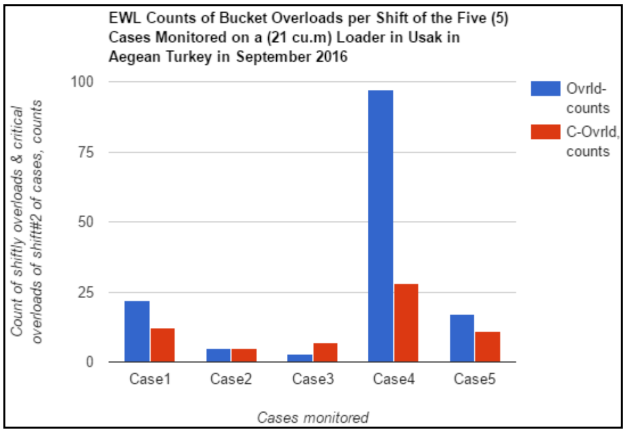

Figure 5 Number of overloads and critical overload counts of the cases studied.

Overloads and critical overloads of bucket may be detrimental to the equipment in the long run, (Figure-5) and have negative effect on the expected economic life of the loader [2][5][7].

4. DISCUSSION

4.1. Bucket Load Distribution Curves

Interpretation of shift and/or daily bucket load distribution curves give hint about the operator; one can differentiate the good operator from the shift's load distribution curve qualitatively.

The higher the bucket fill factor is the higher bucket payload, consequently the higher the production is. However, an optimum payload has to be found which is termed as target payload. Overloads may be considered favourable from productivity of the equipment perspective, but overloads to be avoided because of the fact that they may adversely affect the availability of the electric wheel loader in the long run.

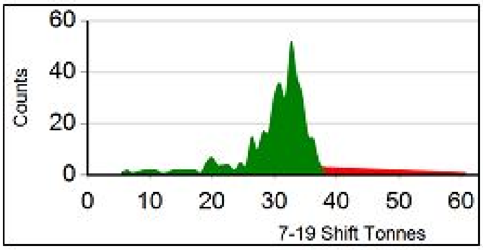

Figure 6a Day shift bucket distribution curve of Case 2 [3].

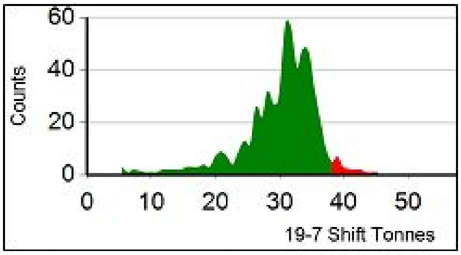

Figure 6b Night shift bucket distribution curve of Case 2 [3].

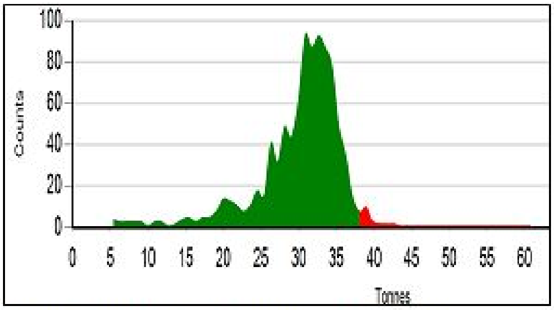

Figure 6c Daily load distribution of Case 2 [3].

There exist no overloads of Case 2 day shift in September 2016, Figure-6a, and night shift's counts of bucket overloads are negligible i.e five counts of overloads and five counts of critical overloads. Bucket loads have to be monitored regularly whether the deviations from the original equipment manufacturer's recommended target loads are in acceptable limits. As a rule of thumb, the deviation should be in the range of ± 5%.

There exist 5 counts of overload and 5 counts of critical overload in shift 2 of Case 2, which is a good distribution curve in terms of bucket overloading see Figure-6a, Figure-6b, Figure 6-c and Figure-7. It is interesting to note that day shifts of the monitored five days have no overloading, at all. All the overloading cases happened during night shifts.

4.2. Analysis of Bucket Load Distribution Curves

Figure-7 illustrated a normal bucket load distribution curve with acceptable number of overloads. Whereas, the situation seen in Figure-8 is not so good; overloading limits of the equipment is violated frequently.

Beyond 37.5 tons line of the curve indicates over-loadings. The number of overloads seems to be acceptable; which are 7 counts bucket critical overload and 3 counts bucket overload (Figure-7). However, there are some under-loaded bucket counts as well. In general, average payload is in the range of the target bucket payload, as it is recommended.

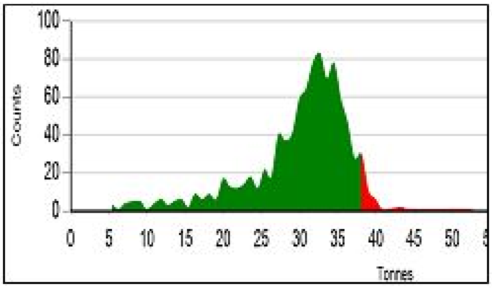

Figure 7 Daily load distribution curve of Case 3 [3]

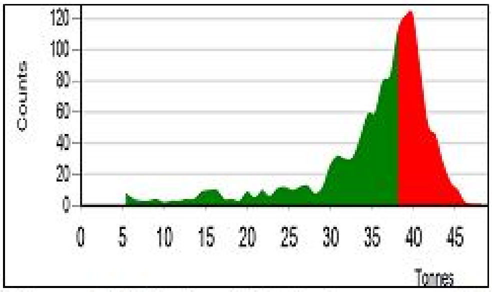

Figure 8 Daily load distribution curve of Case 4 [3]

The curve's section beyond 37.5 tonnes line indicates overloading area, Figure-7 and Figure-8. It is a normal (bell shaped) distribution curve. Daily load-weight records indicate that there exist 28 counts of bucket critical overloads and 97counts of bucket overloads in Case 4 of September 2016.

Average bucket pass counts of the five cases are 4.5±0.7 passes. Day shift's (07AM-07PM) counts of bucket passes per haul-truck are 5±1, and that of night shift (07PM-07AM) passes are 4±0.5 per truck.

Case 4 has the highest overloading and critical overloading number of counts among the five cases examined. The overloaded section of the curve is beyond 37.5 tons boundary (Case 4), as seen in Figure-9 and Figure-10. It happened again in night shift.

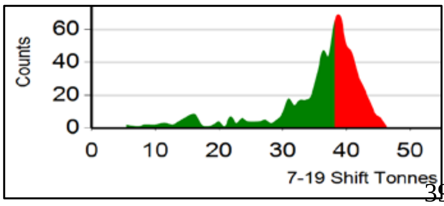

Figure 9 Bucket load distribution curve of case 4 in day shift [3]

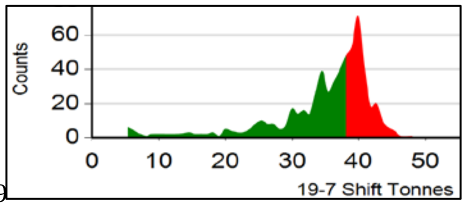

Figure 10 Bucket load distribution curve of case 4 in night shift [3]

CONCLUSIONS

- The higher the bucket fill factor, the higher bucket payload, and the higher the production. However, an optimum payload has to be found which is termed as target payload. Overloads may be considered favourable from productivity of the equipment perspective, but overloads to be avoided because of the fact that they may adversely affect the availability of the electric wheel loader in the long run.

- On the other hand, under-loading is as unfavourable as overloading; it implies that the mine site does not making use the full capacity of the equipment; thus losing money.

- The operator has a key role in proper performance of loader and truck system of excavation. Therefore, performance of the operators should be monitored shift by shift. They have to be trained properly and periodically. Hands on trained either on the real equipment and/or on realistic virtual training simulators.

- The performance of the operator may be distinguished from the load distribution curves, qualitatively. The load distribution curve of a good operator's shift has a smaller red section that implies less number of overloads and critical overloads happened. If the distribution curve has a wider red area, it depicts the bigger violation of overload limits of the equipment. Having smoother bell shaped distribution curve indicates a smoother operation.

- As far as the cases monitored are concerned, it is interesting to note that all overloading violations happened in the second shifts (night shifts) (19-07 hrs) of the cases and mostly in 5 to 6 AM hours. In this sense, the worst cases are Shift 2 of Case 4, Shift 2 of Case1, and Shift 2 of Case 5 in sequence.

- Loading the loader bucket and haul-truck tray to target load specified, ensure the operation gets the highest optimum productivity, possible. In the past, mine sites often put as much on the bucket and truck tray as possible. In other words, overloading was seen as a good practice. The original equipment manufacturer certainly did not see it that way. For this reason, equipment have on-board load weighing systems to ensure that loaders and haulers are not overloaded and prematurely worn-out and can be operated in a safe manner.

REFERENCES

[1] Anon a, 2016 ; "Wheel Loaders", www.joyglobal.com/surface-mining/wheel-loaders.

[2] Anon b, 2016 ; "P&H PreVail System Centre", U.K.

[3] Anon c, 2016 ; "P&H Prevail System Daily Monitoring Reports", U.K.

[4] Anon d, 2016 ; "Loader Manual Sample" North Pacific Training &Performance, Inc., B.C., Canada

[5] Franklin, S., 2016 a; "Fill the loader bucket", www.cemagg.com/fill-the-loader-bucket.

[6] Franklin, S., 2016b; “Position the haultruck correctly”, www.cemagg.com/position-the-haultruck-correctly.

[7] Franklin, S., 2016c; “Establish the correct haultruck payload”, www.cemagg.com/establish-the-correct-haultruck-payload.

[8] Franklin, S., 2016d; “Provide sufficient working room”, www.cemagg.com/provide-sufficient-working-room.

[9] Franklin, S., 2016 e; “Don’t work in water”, www.cemagg.com/don’t-work-in-water.

[10] Singh, S and Narendrula, R. 2007; “Performance monitoring of loading equipment” Aggregates International, 01/2007, pp.16-21, Nederlands

[11] Wood, A., 2014; “Personal communication”, Joy Global Surface Mining Equipment Division”, Bolton, England.