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Performance evaluation of blasthole drilling equipment in a limestone quarry using overall equipment effectiveness

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Abstract. Blasthole drilling is a key operation in hard-rock quarrying, yet its operational effectiveness in African cement-production contexts remains insufficiently quantified. This study applies the Overall Equipment Effectiveness (OEE) framework to evaluate three Epiroc DM30 XC rotary blasthole drills at the Dangote Cement Plc limestone quarry in Obajana, Kogi State, Nigeria, and identify the principal sources of productivity loss. Field data were collected during fifteen day-shift observation sessions, comprising five sessions per machine over a three-month period. Scheduled operating time, planned and unplanned downtime, total holes drilled, actual cycle time, and hole quality were recorded using operator logbooks, maintenance records, and direct field observation. OEE was calculated from availability, performance efficiency, and quality rate, and daily values were averaged for each machine. DM30 No.1 achieved the highest mean OEE of 66.73%, with availability of 81.82% and performance efficiency of 81.56%, reaching a daily OEE of 84.83%. DM30 No.2 recorded a mean OEE of 58.27%, with availability of 83.27% and performance efficiency of 69.97%. Its maximum daily OEE of 87.27% indicated substantial variation between shifts. DM30 No.3 had the lowest mean OEE of 48.31%, with availability of 73.27% and performance efficiency of 65.93%; unplanned downtime exceeded 300 minutes in one observed shift. All recorded holes met the specified acceptance criteria, yielding a quality rate of 100% for each machine. Availability and performance losses therefore accounted for the observed reductions in OEE, with their relative contributions varying between machines. The findings support prioritising maintenance planning, operator performance monitoring, and standardised drilling procedures. These measures could improve equipment effectiveness and the reliability of limestone supply, although their benefits require verification through longer-term monitoring.

Keywords: *overall equipment effectiveness (OEE), blasthole drilling, limestone quarry, predictive maintenance, mining productivity, Nigeria.*

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1. Introduction

Drilling constitutes the foundational unit operation of surface quarrying, creating the blastholes through which explosives fragment rock for excavation [1]. In cement-grade limestone quarries, the operational continuity of drilling equipment is directly coupled to fragmentation quality, raw material supply rates, and ultimately plant-wide output [2, 3]. Dangote Cement Plc's Obajana Plant in Kogi State, Nigeria, is the largest cement facility in sub-Saharan Africa, with an annual production capacity exceeding 16 million tonnes [4]. The quarry supplying this facility depends on a fleet of heavy rotary blasthole drills, making their reliable performance a strategic imperative.

Despite this dependence, drilling operations in open-pit and quarry environments are routinely hampered by three converging challenges. First, unplanned mechanical failures interrupt scheduled production hours, reducing equipment availability. Second, operators frequently drill at speeds below the manufacturer-specified ideal, generating performance losses. Third, suboptimal drilling parameters can occasionally produce defective holes requiring rework, adding quality losses. The compounding effect of these three loss categories has been documented across multiple African and Asian mining case studies, where cumulative productivity shortfalls of 30 – 50% relative to design capacity are not uncommon [5-7].

Overall Equipment Effectiveness (OEE) is a structured, composite metric conceived within Seiichi Nakajima's Total Productive Maintenance (TPM) framework as a single index that captures all three categories of equipment loss simultaneously [8]. Computed as the product of Availability, Performance Efficiency, and Quality Rate, OEE condenses complex, multi-dimensional machine performance into a single percentage that can be tracked over time and benchmarked against the internationally recognised world-class standard of 85% [9, 10]. Its intuitive decomposition enables managers to isolate whether losses originate primarily from downtime, speed reductions, or quality failures, and to direct improvement efforts accordingly [11, 12].

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While OEE is extensively used in automotive and discrete manufacturing sectors, its application in mining and quarrying remains comparatively limited, particularly for drilling equipment [5, 13, 14]. In the Nigerian context, where cement demand continues to rise alongside infrastructure development, and where maintenance management practices often remain reactive rather than predictive, there is a compelling case for introducing such structured performance measurement tools. Existing Nigerian quarry studies have concentrated on load-haul equipment match factors [15], blasting optimisation [16-18], and socio-environmental impacts of quarry operations [19, 20], but empirical OEE assessments focused on blasthole drills at large-scale cement quarries have not been reported.

This study addresses that gap. Three Epiroc DM30 XC rotary blasthole drilling machines operating at the Obajana limestone quarry were monitored over a three-month period to:

– quantify machine-level Availability, Performance Efficiency, and Quality Rate;

– compute and compare daily and average OEE values across all three units;

– (iii) identify the dominant loss categories and propose targeted, evidence-based strategies for productivity improvement.

The findings contribute to applied rock mechanics literature by validating OEE as a practical diagnostic tool for heavy drilling equipment in sub-Saharan African quarrying contexts.

2. Study area

The study was conducted at the limestone quarry of Dangote Cement Plc, Obajana Plant (Latitude 7°30'N, Longitude 6°06'E), Kogi State, Nigeria (Figure 1). Obajana Cement Project documented the geological setting as comprising thick-bedded Cretaceous limestone within the Bida Basin, providing an expansive reserve of cement-grade raw material. The quarry operates in three active pits (Pit 1, Pit 2 and Pit 3) as shown in Figure 1, where controlled bench blasting supplies the primary crusher. The Epiroc DM30 XC is the primary blasthole drilling platform deployed across the pits. Three machines, designated DM30 No.1, DM30 No.2, and DM30 No.3, were selected for evaluation based on their consistent, concurrent deployment throughout the observation window and the completeness of their maintenance documentation.

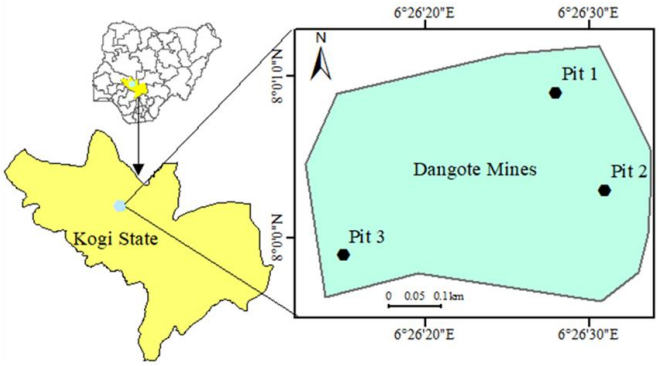


Figure 1. Location map of the study area showing the mines [17]

The DM30 XC is a heavy-duty rotary blasthole drill engineered for single-pass and multi-pass application in competent rock [21]. Key specifications relevant to this study include a single-pass depth of 8.5 m, a maximum blasthole depth of 45.1 m, and a maximum weight-on-bit of 20000 kg, with pulldown capacity rated at 0-176.4 kN. Under the site-specific drilling conditions at Obajana, each 8.5 m single-pass hole in competent limestone is completed in an ideal cycle time of 16 min, a figure derived from manufacturer performance data and validated against historical shift records by the quarry's drilling engineers.

3. Study area

3.1. Data collection protocol

Field data were gathered over a three-month period restricted exclusively to day-shift operations conducted under normal conditions, defined as the absence of rainfall, extreme ambient temperature anomalies, or scheduled major maintenance interventions. Five representative observation days were recorded for each machine, yielding 15 shift-level datasets in total. This five-point-per-machine structure reflects standard practice in industrial OEE field assessments, where the objective is to capture typical operational variance rather than continuous production monitoring [9, 22].

Data were extracted from three corroborating sources, namely operator shift logbooks, maintenance and downtime registers maintained by the quarry's mechanical department, and direct field observation by the researcher. Supervising engineers validated all entries for each observation session.

Scheduled Operating Time (SOT) was fixed at 720 min per shift, including a Planned Downtime (PD) allowance of 60 min for breaks. The net scheduled operating time was therefore calculated as SOT – PD = 660 min and used as the denominator for Availability. Unplanned Downtime (UD) included time lost to mechanical failures, hydraulic faults, bit changes, and unscheduled operational delays. Actual Operating Time (AOT) was calculated by subtracting UD from the net scheduled time of 660 min.

Total Holes Drilled (THD) represented the number of 8.5 m blastholes completed during each shift. Ideal Cycle Time (ICT) was set at 16 min per hole, based on manufacturer-validated performance for single-pass drilling in competent limestone. Actual Cycle Time (ACT) was calculated as AOT / THD and expressed in min/hole.

Hole quality was assessed using a binary classification. Holes with the required depth, diameter, and alignment that were ready for charging were classified as acceptable, whereas those requiring re-drilling were classified as defective.

3.2. OEE computation methodology

The OEE framework of Nakajima [8], as operationalised for mining contexts by Waqas [9] and Elevli and Elevli [5], was applied. The three-component metrics and the composite OEE index were calculated using Eqs. (1)-(4).

Availability represents the ratio of actual operating time to net scheduled time, accounting for unplanned stoppage losses:

$$A = \frac{\text{AOT}}{\text{SOT-PD}} \times 100 = \frac{\text{AOT}}{660} \cdot 100 \,. \quad (1)$$

Performance efficiency represents the ratio of ideal to actual cycle time and quantifies speed losses during operating time:

$$P = \frac{\text{ICT}}{\text{ACT}} \times 100 \,. \quad (2)$$

Quality Rate represents the proportion of drilled holes meeting the acceptance criteria without rework:

$$Q = \frac{\text{THD} - N_d}{\text{THD}} \cdot 100 . \quad (3)$$

Here, N_d is the number of defective holes recorded during the shift.

Overall Equipment Effectiveness combines the three components into a single indicator:

$$\text{OEE} = \frac{A \cdot P \cdot Q}{10000} . \quad (4)$$

Here, A, P, Q, and OEE are expressed as percentages.

Performance values exceeding 100%, arising when the actual cycle time fell below the ideal (as observed on one shift of DM30 No.2), were capped at 100% before calculating OEE, following the convention [11] and [23]. Daily OEE values were computed for each machine, and five-day arithmetic means were derived as the representative performance indicators. All computations were executed in Google Sheets using custom templates, enabling reproducibility and auditability.

3.3. Limitations

This study carries four acknowledged constraints that should be considered when interpreting findings.

First, observations were confined to day shifts, excluding potential performance differences during night operations.

Second, data collection was restricted to climatically favourable conditions, which may not reflect year-round performance variation.

Third, five observation days per machine constitute a short panel; a longer, continuous monitoring programme would provide stronger statistical generalisability.

Fourth, operator logbooks occasionally contained minor inconsistencies, which were resolved through cross-validation with maintenance records and field observation.

Despite these constraints, the triangulation of three independent data sources substantially mitigates bias and supports confidence in the reported values.

4. Results and discussion

4.1. Field data summary

Raw field data for all three machines across the five observation days are presented in Table 1. Scheduled operating time was 720 min and planned downtime was 60 min for every shift, yielding a constant net scheduled time of 660 min per session. Unplanned downtime varied substantially between machines and between days, ranging from 36 min (DM30 No.1, Day 1) to 306 min (DM30 No.3, Day 4). The ideal cycle time of 16 min/hole was held constant, while actual cycle times ranged from 12.80 min/hole (DM30 No.2, Day 2, where performance exceeded ideal and was capped at 100%) to 34.88 min/hole (DM30 No.2, Day 1). No defective holes were recorded for any machine on any observation day.

The calculated indicators were compared across the three machines to identify differences in operating effectiveness. Availability and performance efficiency were examined separately to distinguish downtime losses from reduced drilling speed.

Table 1. Field data summary for all three DM30 XC drilling machines across five observation days

Machine	Day	SOT, min	PD, min	UD. min	AOT, min	THD	ICT, min	ACT, min/hole
DM30 No.1	1	720	60	36	624	25	16	24.96
DM30 No.1	2	720	60	168	492	24	16	20.5
DM30 No.1	3	720	60	54	606	35	16	17.31
DM30 No.1	4	720	60	162	498	28	16	17.79
DM30 No.1	5	720	60	180	480	25	16	19.2
DM30 No.2	1	720	60	102	558	16	16	34.88
DM30 No.2	2	720	60	84	576	45	16	12.8
DM30 No.2	3	720	60	192	468	18	16	26
DM30 No.2	4	720	60	96	564	26	16	21.69
DM30 No.2	5	720	60	78	582	25	16	23.28
DM30 No.3	1	720	60	222	438	19	16	23.05
DM30 No.3	2	720	60	108	552	23	16	24
DM30 No.3	3	720	60	150	510	22	16	23.18
DM30 No.3	4	720	60	306	354	15	16	23.6
DM30 No.3	5	720	60	98	564	20	16	28.2

SOT – Scheduled Operating Time; PD – Planned Downtime; UD – Unplanned Downtime; AOT – Actual Operating Time; THD – Total Holes Drilled; ICT – Ideal Cycle Time; ACT – Actual Cycle Time. All quality data: Defective Holes is equal to 0 for all sessions.

4.2. Computed OEE components and composite index

Table 2 presents the computed daily and average Availability, Performance Efficiency, Quality Rate, and OEE for each machine.

Table 2. Daily and average OEE components and composite OEE (%) for the three DM30 XC drilling machines

Machine	Day	Availability, %	Performance, %	Quality, %	OEE, %	UD, min
DM30 No.1	1	94.55	64.1	100	60.48	36
DM30 No.1	2	74.55	78.05	100	58.18	168
DM30 No.1	3	91.82	92.39	100	84.83	54
DM30 No.1	4	75.45	89.95	100	67.87	162
DM30 No.1	5	72.73	83.33	100	60.61	180
DM30 No.1 Average	–	81.82	81.56	100	66.73	–
DM30 No.2	1	84.55	45.88	100	38.78	102
DM30 No.2	2	87.27	100.00*	100	87.27	84
DM30 No.2	3	70.91	61.54	100	43.64	192
DM30 No.2	4	85.45	73.77	100	63.03	96
DM30 No.2	5	88.18	68.68	100	60.55	78
DM30 No.2 Average	–	83.27	69.97	100	58.27	–
DM30 No.3	1	66.36	69.42	100	46.07	222
DM30 No.3	2	83.64	66.67	100	55.76	108
DM30 No.3	3	77.27	69.02	100	53.33	150
DM30 No.3	4	53.64	67.8	100	36.37	306
DM30 No.3	5	85.45	56.74	100	48.49	98
DM30 No.3 Average	–	73.27	65.93	100	48.31	–

*Performance capped at 100% where actual cycle time fell below the 16-min ideal (DM30 No.2, Day 2: ACT is equal to 12.80 min/hole). UD – Unplanned Downtime per shift.

4.3. Availability losses and their structural drivers

The availability results revealed markedly different maintenance profiles across the three machines as shown in Figure 2. DM30 No.1 averaged 81.82% availability, reflecting a pattern in which unplanned stoppages were present on every observation day, remained relatively brief (36-180 min.). DM30 No.2 achieved the highest mean availability at 83.27%, suggesting that its mechanical condition was generally adequate, though its narrow inter-day range (84-192 min. UD) masks a single session with 192 minutes of downtime that substantially reduced productivity. DM30 No.3 recorded the lowest mean availability (73.27%), with one session incurring 306 minutes of unplanned stoppage, equivalent to 46.4% of the net scheduled time being consumed by reactive repairs alone.

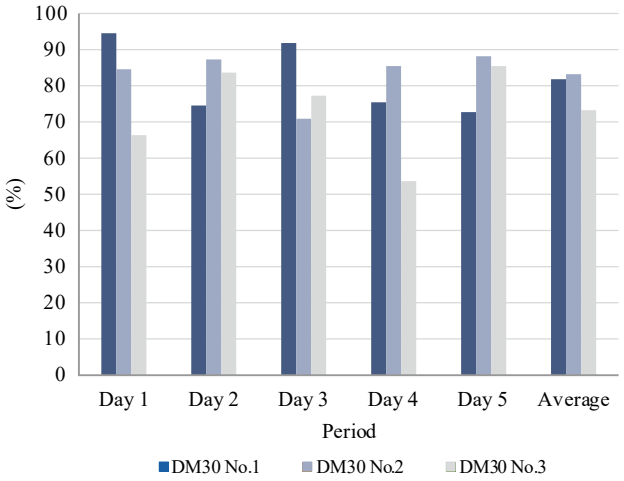


Figure 2. Availability of DM30 NO.1, DM30 NO.2 and DM30 NO.3

The graduated pattern of availability losses is consistent with what Deb and Islavath [24] described as the consequence of reactive, fault-driven maintenance regimes in open-pit mining, where minor mechanical faults are allowed to escalate into extended failures before intervention. Moubray [25] and Gupta and Vardhan [26] argued that transitioning from corrective to predictive maintenance, through condition monitoring of hydraulic systems, air compressors, and drill-string components, is the primary lever for improving availability in heavy mining equipment. For DM30 No.3 in particular, the extreme single-session loss suggests a recurring fault pattern rather than isolated incidents, warranting priority inclusion in any condition-based maintenance schedule.

4.4. Performance efficiency and speed loss mechanisms

Performance efficiency captures the degree to which a machine utilises its available time productively, specifically by drilling holes at or near the ideal 16 minutes cycle time. Figure 3 shows that DM30 No.1 achieved the most consistent performance at 81.56%, with daily values ranging narrowly between 64.10% and 92.39%. The comparatively low performance on Day 1 (64.10%), despite the highest availability of any single session (94.55%), implies that speed losses on that day were driven by operational factors rather than mechanical ones. Possible explanations include a less experienced drill crew, suboptimal feed pressure settings, or increased inter-hole repositioning time due to the bench geometry.

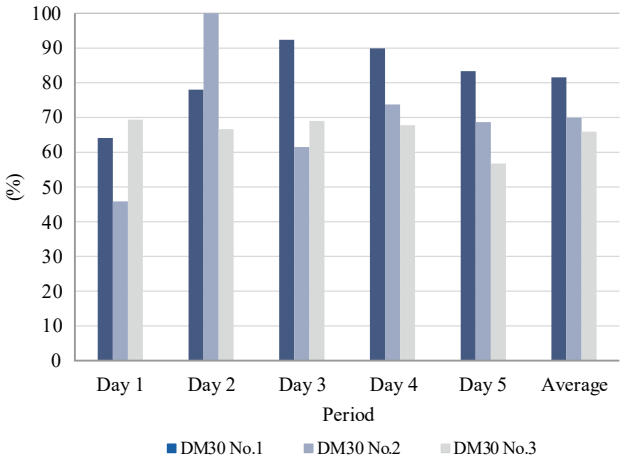


Figure 3. Performance Efficiency of DM30 NO.1, DM30 NO.2 and DM30 NO.3

DM30 No.2 presents the most analytically interesting performance profile: an average of only 69.97% despite a single exceptional session where actual cycle time (12.8 min./hole) fell below the ideal, yielding a capped performance score of 100% and an OEE of 87.27% [27]. This exceptional day demonstrates the machine's mechanical potential but also highlights the degree to which that potential is routinely underrealized on other shifts. The cause of such inter-day variance, which is too large to attribute to rock mass variability given that all machines operated in the same limestone formation [28], most plausibly relates to inconsistencies in operator technique, bit wear state [29], or weight-on-bit management [30]. This is precisely the type of loss that standardised operating procedures and real-time performance dashboards could address [9, 31].

DM30 No.3 sustained the lowest average performance at 65.93%, with daily values concentrated in a narrow range (56.74-69.42%). Unlike DM30 No.2, whose performance variance suggests intermittent factors, DM30 No.3's constrained range points to a chronic, structural speed loss possibly attributable to advanced wear in the rotary head, deteriorating air-compressor output, or operator habituation to a slower drilling pace. Elevli and Elevli [5] noted precisely this phenomenon in OEE assessments of South-East European open-pit mines, where reduced speed losses became institutionalised through operator adaptation to machine limitations.

4.5. Quality rate: precision as an operational strength

The uniformly perfect Quality Rate of 100% across all fifteen observation sessions as shown in Figure 4, with zero defective holes requiring re-drill, is a notable and substantively significant finding. In blasthole drilling, hole quality directly governs downstream blasting outcomes: incorrect depth, diameter, or alignment produces irregular fragmentation [32], adversely affects burden and spacing geometry, and can generate flyrock or misfires, all of which escalate operational costs and safety risks [2, 6, 16, 17, 33, 34].

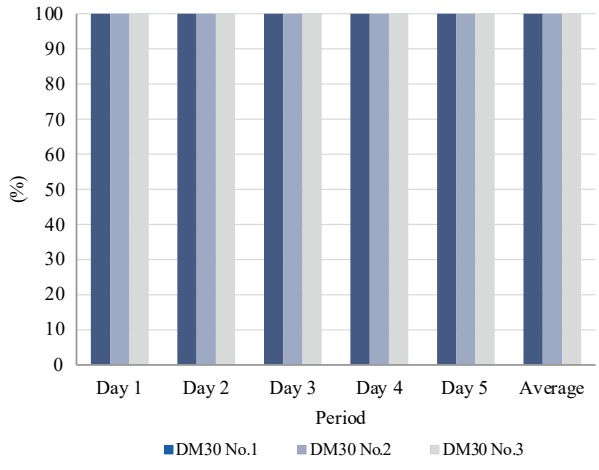


Figure 4. Quality rate of DM30 NO.1, DM30 NO.2 and DM30 NO.3

The consistent zero-defect outcome indicates that despite availability and performance shortfalls, the Obajana drilling crews maintained rigorous adherence to hole specifications, a positive reflection of operator training and the effectiveness of supervisory oversight by the quarry's drilling engineers.

From an OEE optimisation standpoint, the perfect quality record clarifies the strategic priority: the entire productivity gap between current performance and the 85% world-class

benchmark resides in the Availability and Performance dimensions. No resource should be directed toward quality improvement interventions; instead, maintenance investment and training effort should be concentrated wholly on reducing unplanned downtime and closing the gap between actual and ideal drilling speeds.

4.6. Composite OEE and benchmarking

The aggregate OEE values of 66.73%, 58.27%, and 48.31% for DM30 No.1, No.2, and No.3, respectively as shown in Figure 5, place all the three machines below the 85% world-class threshold and, in the case of DM30 No.3, below even the commonly cited 50% acceptable lower bound for capital-intensive equipment [8, 9]. When compared with OEE values reported in analogous studies, these figures align with the range of 40-70% documented in [5] for open-pit mining drills and excavators in Eastern European mines, and with the 55-68% range reported in [6][6] for rotary drills in Indian open-pit coal mines. The comparability of findings across geographically and operationally distinct sites reinforces the universality of the availability and performance loss categories in heavy mining equipment.

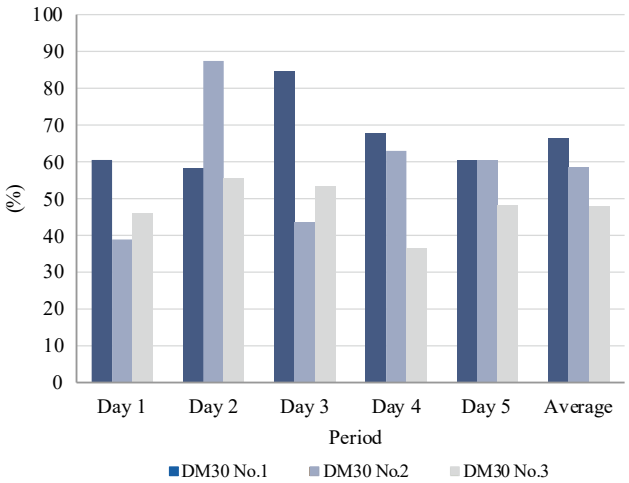


Figure 5. Overall OEE of DM30 NO.1, DM30 NO.2 and DM30 NO.3

DM30 No.1's single-session peak OEE of 84.83%, nearly reaching the world-class threshold, provides an empirically grounded near-term target for all three machines. The fact that this performance was achieved under actual operating conditions in a Nigerian quarry environment, rather than in controlled testing, demonstrates that the target is physically achievable with existing equipment. Reaching it consistently requires eliminating the structural causes of availability and performance losses identified above, rather than capital replacement of the drilling fleet.

4.7. Strategic recommendations

Based on the foregoing analysis, three targeted interventions are recommended in order of expected impact:

1. Transition from corrective to predictive maintenance. Equipping the DM30 XC fleet with condition-monitoring sensors on hydraulic circuits, air-compressor bearings, and rotary head components would enable fault detection prior to unplanned stoppage. The literature on IoT-enabled OEE tracking suggests availability improvements of up to 20% in comparable applications [35, 36] For DM30 No.3 specifically, where availability losses are most severe and consistent, this intervention would yield the largest absolute OEE gain.

2. Implement standardised drilling operating procedures and performance tracking. The high intra-machine performance variance observed in DM30 No.2, and the chronic speed losses in DM30 No.3, are consistent with the operator-skill and operating-parameter explanations documented [9] and [31]. Shift-level performance feedback dashboards displaying real-time cycle time against the 16 minutes ideal, combined with a crew-level performance review protocol, would create accountability for speed losses that currently go untracked.

3. Implement systematic OEE monitoring as a standing operational practice. The fifteen-session dataset employed here is sufficient for a diagnostic study but insufficient for ongoing operational management. Installing a permanent, digital OEE tracking system, recording downtime causes, hole counts, and cycle times at shift level for every machine, would generate the longitudinal dataset required to detect deterioration trends, schedule predictive maintenance interventions, and objectively evaluate the impact of any improvement initiative [11, 37, 38].

5. Conclusions

This study applied the Overall Equipment Effectiveness framework to evaluate three Epiroc DM30 XC rotary blasthole drilling machines at the Dangote Cement Plc limestone quarry, Obajana, Nigeria. The principal conclusions are:

1. Average OEE values of 66.73%, 58.27%, and 48.31% for DM30 No.1, No.2, and No.3, respectively, confirm that no machine achieved the world-class 85% benchmark, and that DM30 No.3 operates in a range classified as unacceptable in the OEE literature.

2. All productivity shortfalls reside in the Availability and Performance dimensions. The uniformly perfect Quality Rate of 100% across all observation sessions demonstrates that hole quality is not a constraint, and corroborates that the drilling crew's technical competence is not in question.

3. Unplanned downtime is the dominant loss category for DM30 No.3, where a single 306 minutes stoppage reduced one session's availability to 53.64%. Reactive maintenance practices are the structural cause, and predictive condition monitoring is the appropriate remedy.

4. DM30 No.2's single-session OEE of 87.27% demonstrates that world-class performance is mechanically achievable with the existing equipment under current site conditions. Closing the gap between this peak and the machine's average requires addressing the performance inconsistency attributable to operator and operating-parameter variability.

5. OEE provides a practical, field-deployable framework for quarry drilling performance management in sub-Saharan Africa. Its adoption as a standing operational metric, rather than an episodic research tool, would support data-driven maintenance decision-making and underpin the continuous improvement culture necessary to sustain productivity gains at large-scale cement quarries.

Author contributions

Conceptualization: KAI, EBS; Data curation: EBS; Formal analysis: KAI, EBS; Funding acquisition: KAI, EBS; Investigation: KAI, EBS; Methodology: KAI, EBS; Project administration: KAI, EBS; Resources: KAI, EBS; EIO, NA, FOB; Supervision: KAI; Validation: KAI; Visualization: EBS; Writing – original draft: KAI, EBS; Writing – review & editing: KAI, EBS, EIO, NA, FOB. All authors have read and agreed to the published version of the manuscript.

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Conflicts of interest

The authors declare no conflict of interest.

Data availability statement

The original contributions presented in this study are included in the article. Further inquiries can be directed to the corresponding author.

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Жабдықтың жалпы тиімділік көрсеткішін пайдалана отырып, әктас карьерінде жарылғыш ұңғымаларды бұрғылауға арналған жабдықтың тиімділігін бағалау

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Аңдатпа. Жарылғыш ұңғымаларды бұрғылау тау жыныстарын ашық игерудегі негізгі операция болып табылады, алайда Африкадағы цемент өндірісі жағдайында бұрғылаудың пайдалану тиімділігі сандық тұрғыдан жеткілікті зерттелмеген күйінде қалып отыр. Осы зерттеуде жабдықтың жалпы тиімділігінің көрсеткішіне негізделген тәсіл (overall Equipment Effectiveness, OEE) Обаджандағы, Коги штатындағы Dangote Cement Plc компаниясының әктас карьеріндегі epiroc dm30 XC үш жарылғыш ұңғымаларды айналмалы бұрғылау станоктарының жұмысын бағалау және өнімділікті жоғалтудың негізгі көздерін анықтау үшін қолданылады. Далалық деректер үш ай ішінде күндізгі ауысымда жабдықтың жұмысын он бес бақылау барысында жиналды-әр станок үшін бес. Операторлардың журналдары, техникалық қызмет көрсету жазбалары және тікелей далалық бақылаулар негізінде жоспарланған жұмыс уақыты, жоспарлы және жоспардан тыс тоқтап қалу, бұрғыланған ұңғымалардың жалпы саны, нақты цикл уақыты және ұңғымалардың сапасы тіркелді. OEE көрсеткіші қол жетімділік, өнімділік және сапа коэффициенттері негізінде есептелді, содан кейін күнделікті мәндер әр машина үшін орташа болды. 66.73% құрайтын ең үлкен OEE орташа мәніне 81.82% қол жетімділік және 81.56% өнімділік коэффициенттері бар №1 dm30 машинасы қол жеткізді. OEE максималды тәуліктік мәні 84.83% жетті. №2 dm30 машинасы үшін OEE орташа мәні 58.27% құрады, қол жетімділік коэффициенттері 83.27% және өнімділік 69.97%. OEE максималды тәуліктік мәні 87.27%-ға тең, ауысымдар арасындағы айтарлықтай айырмашылықтарды көрсетті. №3 dm30 машинасы 73.27% қол жетімділік коэффициенттері және 65.93% өнімділігі бойынша OEE - 48.31% ең төменгі орташа мәнге ие болды. Байқалған ауысымдардың бірінде жоспардан тыс тоқтап қалу ұзақтығы 300 минутты құрады. Барлық тіркелген ұңғымалар белгіленген қабылдау критерийлеріне сәйкес келді, сондықтан әр машина үшін сапа коэффициенті 100% құрады. Осылайша, OEE-нің байқалған төмендеуі қол жетімділік пен өнімділіктің жоғалуына байланысты болды, олардың салыстырмалы үлестері машиналар арасында әр түрлі болды. Алынған нәтижелер техникалық қызмет көрсетуді жоспарлаудың, операторлардың тиімділігін бақылаудың және бұрғылау процедураларын стандарттаудың басымдылығын негіздейді. Мұндай шаралар жабдықтың тиімділігін және әктас жеткізілімінің сенімділігін арттыруы мүмкін, бірақ олардың тиімділігі ұзақ бақылау арқылы растауды қажет етеді.

Негізгі сөздер: *жабдықтың жалпы тиімділігі, жарылғыш ұңғымаларды бұрғылау, әктас карьері, болжамды техникалық қызмет көрсету, тау-кен өнімділігі, Нигерия.*

Оценка эффективности оборудования для бурения взрывных скважин на известняковом карьере с использованием показателя общей эффективности оборудования

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Аннотация. Бурение взрывных скважин является основной операцией при открытой разработке скальных пород, однако эксплуатационная эффективность бурения в условиях цементного производства в Африке остается недостаточно изученной в количественном отношении. В настоящем исследовании подход на основе показателя общей эффективности оборудования (Overall Equipment Effectiveness, OEE) применяется для оценки работы трех станков вращательного бурения взрывных скважин Epiroc DM30 XC на известняковом карьере компании Dangote Cement Plc в Обаджане, штат Коги, Нигерия, и выявления основных источников потерь производительности. Полевые данные собирались в течение трех месяцев в ходе пятнадцати наблюдений за работой оборудования в дневную смену – по пять для каждого

станка. На основании журналов операторов, записей о техническом обслуживании и непосредственных полевых наблюдений регистрировались запланированное время работы, плановые и внеплановые простои, общее количество пробуренных скважин, фактическое время цикла и качество скважин. Показатель OEE рассчитывался на основе коэффициентов доступности, производительности и качества, после чего суточные значения усреднялись для каждого станка. Наибольшее среднее значение OEE, составившее 66.73%, было достигнуто станком DM30 №1 при коэффициентах доступности 81.82% и производительности 81.56%. Максимальное суточное значение OEE достигло 84.83%. Для станка DM30 №2 среднее значение OEE составило 58.27% при коэффициентах доступности 83.27% и производительности 69.97%. Максимальное суточное значение OEE, равное 87.27%, указывало на существенные различия между сменами. Станок DM30 №3 имел наименьшее среднее значение OEE – 48.31% при коэффициентах доступности 73.27% и производительности 65.93%. В одну из наблюдаемых смен продолжительность внеплановых простоев превысила 300 минут. Все зарегистрированные скважины соответствовали установленным критериям приемки, поэтому коэффициент качества для каждого станка составил 100%. Таким образом, наблюдаемое снижение OEE было обусловлено потерями доступности и производительности, относительный вклад которых различался между станками. Полученные результаты обосновывают приоритетность планирования технического обслуживания, мониторинга эффективности работы операторов и стандартизации процедур бурения. Такие меры могут повысить эффективность оборудования и надежность поставок известняка, однако их результативность требует подтверждения посредством более длительного мониторинга.

Ключевые слова: *общая эффективность оборудования, бурение взрывных скважин известняковый карьер, предиктивное техническое обслуживание, производительность горных работ, Нигерия.*

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