

A Comparative Analysis of the Construction Methods between Foreign and State-Owned Contractor Enterprises on the Jenelata Dam Project: The Case Study of Excavator Breaker and Blasting

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ABSTRACT

Determining the appropriate method and evaluating the work can have a significant impact on construction. Jenelata Dam is being constructed by both foreign and State-Owned Enterprise (SOE) contractors. Rock excavation is typically carried out using an excavator breaker or the blasting method. This study was conducted to compare the construction methods and to identify and evaluate the factors affecting the time performance of each method. This research uses descriptive, qualitative, and quantitative methods. A productivity analysis tool was utilized to compare the performance of the two contractors, and an analytical hierarchy process was deployed to determine the significance of the factors. Based on the evaluation results of the rock excavation work of the excavator breaker method at Concrete Face Rockfill Dam (CFRD) Works (left-bank), the daily productivity of SOE contractors is 729.10 m³/day for four units of equipment, and the completion time is 155 days. The daily productivity at the foreign contractor spillway is more effective using the blasting method of 875.95 m³/day for one unit of equipment, done in 73 days. According to both contractors, design is the most significant factor affecting construction time performance.

Keywords-dam; rock excavation; excavator breaker; blasting

I. INTRODUCTION

Water resource management is integral to infrastructure development that supports water, food, and energy security. In the Ministry of Public Works and Housing's (PWH) Strategic Plan 2020-2024, which aligns with the Minister of PWH Regulation Number 3 of 2024, the water resources sector remains the primary focus of infrastructure development. In 2015-2019, water resource infrastructure development produced 61 dams/reservoirs consisting of 16 advanced projects, 45 new dams, and 1,212 reservoirs and other water storage buildings. To address climate change challenges and

ensure long-term water security, the Ministry of PWH continues building dams in various regions through the Directorate General of Water Resources. One of the national strategic projects is the construction of Jenelata Dam in Gowa Regency, South Sulawesi, which began with signing the contract on June 29, 2022 [1].

Jenelata Dam is a CFRD type dam with an upright core height of 62.8 m and an adequate capacity of 223.6 million m³. The project is implemented by a joint contractor of foreign and state-owned companies. Construction includes the main structure of the dam, spillway, cofferdam, dodging channel, access road, and other auxiliary buildings [2, 3]. However,

during the construction process, there were differences in construction implementation methods, particularly in the rock excavation work, which was carried out using two primary methods: breaker and blasting. The choice of these methods significantly impacts the implementation time, quality of work, and cost efficiency of the project. The selection of appropriate construction methods is a key factor in the success of a dam project, especially in the main structures, such as the dam and spillway [4]. The method used must consider the type of rock, the volume of work, and the target implementation time. Authors in [5] compared two primary methods, hydraulic breaker and blasting, and found that the blasting method can save up to 18% time. However, strict vibration control is required due to the impact of this method on slope stability. These findings are relevant to the excavation work on the Jenelata Dam project, which has similar contours and geological conditions.

It has been indicated that one of the leading causes of delays is selecting construction methods without considering the local geotechnical conditions [6, 7]. It is important to adapt the work methods based on field survey data and geotechnical recommendations, while also providing technical training of local labor. This indicates that the project performance could be affected by the difference in the approach between foreign and SOE contractors when selecting implementation methods.

Other researchers compared the speed and risks of blasting and breaker methods. It was concluded that blasting provides faster results but requires additional mitigation of environmental hazards such as landslides and vibration [7, 8]. Breaker methods are safer for the environment but tend to be slower. This comparison is critical in the context of the Jenelata project, which requires time efficiency while maintaining safety and environmental sustainability.

Authors in [9] specifically compared stone quarrying methods on a dam project in South Sulawesi. They found that the breaker method is more suitable for sites with limited access and high landslide risk while blasting is more effective on open sites with large excavation volumes. The results of this study are highly relevant as they provide local data that can be compared directly with the conditions and methods used in the Jenelata project.

Collaboration challenges in national strategic infrastructure projects implemented by joint operations between foreign contractors and SOEs have also been studied [10, 11]. One of the key findings was the difference in work culture and Standard Operating Procedures (SOPs), which impacted the construction implementation methods, labor effectiveness, and time target achievement [12, 13]. This research is highly relevant to the Jenelata Dam project, which was also undertaken by a joint operation between a foreign contractor and an SOE.

Multinational team coordination in large dam projects is essential [14]. The differences in work methods, technology used, and communication between teams can lead to time inefficiencies. In the context of Jenelata, the cooperation between two types of contractors demands harmonization of the implementation methods to avoid technical and

administrative conflicts. It has been shown that state-owned contractors tend to be more flexible in adapting to local conditions but less time efficient than foreign contractors, who apply international standard systems, highlighting the importance of integrating local wisdom and global efficiency, especially in joint operations, and prioritizing technical and managerial collaboration [15-18].

In addition to the implementation methods, the impact of technology on time efficiency is also an important aspect. Monitoring systems can reduce schedule deviations and speed up decision-making when field delays occur. This shows that integrating implementation methods with technology can be a strategic solution to keeping projects on schedule [19-24].

Despite the extensive research on dam construction methods and challenges, there is a lack of focused analysis on how the different approaches of foreign and state-owned contractors affect project performance—particularly in large-scale, joint-operation projects like Jenelata Dam. Given the critical role of dams in national infrastructure and the unique collaborative model of Jenelata's construction, this study is necessary to provide empirical insights into the effectiveness, quality, and efficiency of different implementation methods under real field conditions. Understanding these dynamics is crucial for improving the planning and execution of future national strategic projects, especially those involving multinational contractors.

This research provides a unique case study that contrasts the effectiveness, productivity, and completion time of the two methods under different contractors, offering valuable insights into how these factors vary between foreign and SOE contractors. Additionally, the study delves into the specific conditions of the Jenelata Dam project, which involves varying technical challenges, such as rock excavation at different elevations, making it a distinctive contribution to the field of construction management and methodology. By focusing on these two distinct methods and contractor types, the study fills a gap in the literature regarding the impact of contractor origin and method selection on large-scale infrastructure projects, particularly in the context of dam construction.

II. LITERATURE REVIEW

A. Dam Construction Project

According to the Regulation of the Minister of Public Works and Housing No. 7 of 2023 on Dams, a dam is a structure in the form of earth fill, stone fill, and concrete, which, in addition to retaining and storing water, can also be built to retain and store mining waste or mud. The construction of dams creates artificial reservoirs. The water stored there is mainly used to meet the needs of irrigation, raw water, electricity, fisheries, and tourism.

The construction of the Jenelata Dam, Gowa Regency, South Sulawesi, a type of CFRD, uses rock material as the central core with an impermeable upstream layer in the form of a reinforced concrete slab. The dam uses the strength of the rock to resist water pressure, while a reinforced concrete slab on the face acts as a barrier to water seepage. The scope of work for the Jenelata dam construction reviewed in this study

includes the CFRD dam and instrumentation, spillway, and water diversion works.

B. CFRD Works/Main Dam and Spillway Scope of Works

CFRD works is a type of dam that is widely used to meet various needs ranging from irrigation and mining to hydropower [10]. The flow chart of the CFRD works is shown in Figure 1.

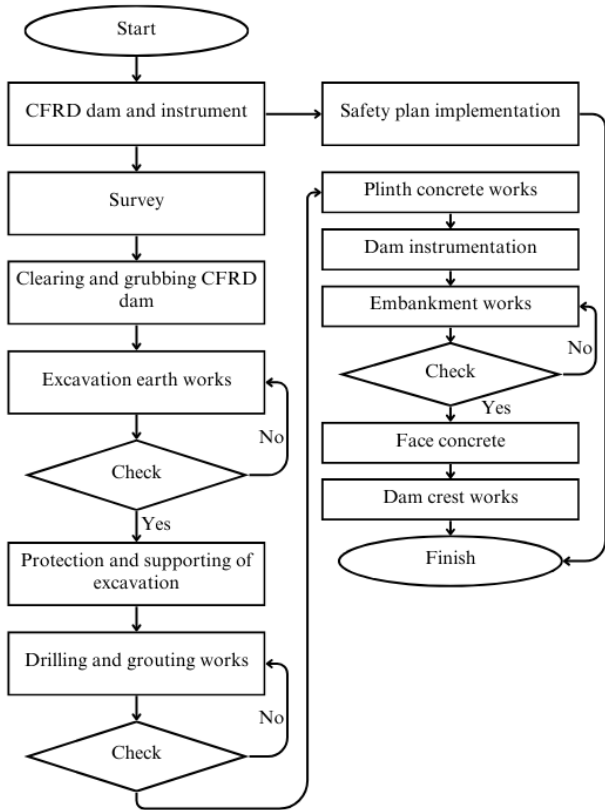


Fig. 1. Flowchart of CFRD and instrument.

A spillway is a structure used to provide a controlled flow from a dam to downstream areas. It discharges flood water entering the reservoir so that the safety of the dam body is not compromised [11]. The process of spillway construction is displayed in Figure 2.

C. Construction Methods for CFRD Works/Main Dam and Spillway

Each contractor uses two excavation methods to construct the CFRD and the spillway. An excavator breaker was utilized in both the left and right cliff areas for rock excavation work of the CFRD, whereas both the excavator breaker method and the blasting method were employed in the case of the spillway.

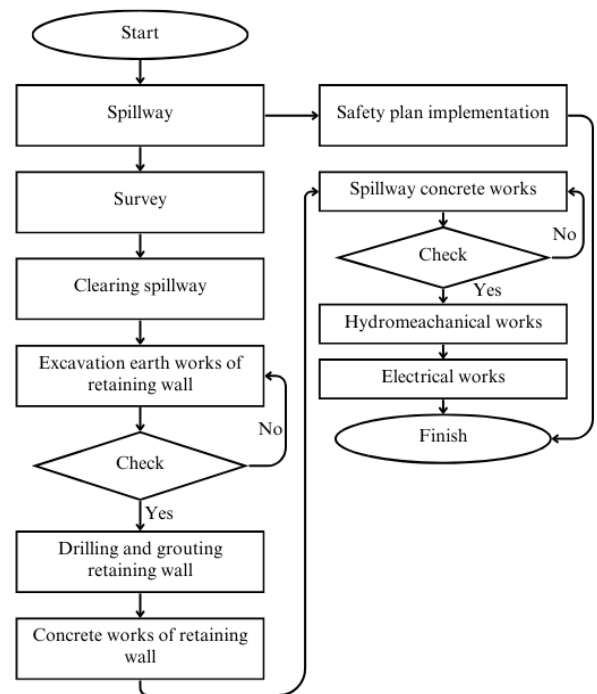


Fig. 2. Flowchart of spillway.

III. METHODOLOGY

This study employs a comparative case study approach. The methodology is structured to ensure systematic data collection, objective analysis, and valid conclusions regarding the time performance and productivity of each method.

A. Research Strategy

The research strategy is designed to ensure that the data collected are accurate, support a comparative analysis, and help identify the factors that significantly influence time performance in rock excavation works. The operational research framework involves several key stages:

- **Problem Identification:** Delineating the need to assess the time performance of different excavation methods used by different contractor types.
- **Data Collection and Processing:** Gathering primary and secondary data from the project and transforming them into a structured dataset suitable for analysis.
- **Quantitative and Qualitative Analysis:** Calculating productivity, comparing durations, and interpreting implementation practices.
- **Decision Analysis:** Applying multi-criteria analysis to evaluate the relative effectiveness of each method.

B. Data Collection

The data used in this study were obtained from the Jenelata Dam construction project and include both primary and secondary sources.

- Primary data include interviews with field engineers and site observations.

- Secondary data entail s-curve project progress reports, technical specifications, equipment lists, and rock excavation work volume and durations.

The focus of the data is on the volume of work (in m³) and the duration of execution (in days) for each work item performed using either the excavator breaker or the blasting method by both contractor types.

C. General Project Overview

Table I summarizes the key excavation work items analyzed in the study.

TABLE I. DETAILS AND SCHEDULE OF THE WORK ITEM

Work item	Contractor	Volume (m ³)	Duration (days)
CFRD Dam and Instrument			
Left-bank CFRD (breaker method)	State-owned	113,005.45	509
Right-bank CFRD (breaker method)	Foreign	47,006.02	153
Spillway and Water Diversion Work			
Open Excavation of rocks	Foreign	64,030.44	122
Open Excavation of rocks	State-owned	2,145.74	151
Open excavation with breaker	Foreign	34,782.83	122
Open excavation with breaker	State-owned	19,311.66	212

D. Data Analysis

The analysis integrates descriptive quantitative, descriptive qualitative, and multi-criteria decision-making methods.

1) Quantitative Productivity Analysis

The productivity in rock excavation is calculated based on equipment characteristics, working time, and operational efficiency. The formulas used are:

- Breaker Method

$$Q = \frac{V \times F_b \times F_a \times 60}{T_s} \tag{1}$$

Description:

Q = Productivity (m³/hours)

V = Equipment capacity

F_b = Tool factors

F_a = Equipment efficiency factor

T_s = Cycle time (minutes)

- Blasting Method

$$V = B \times S \times H \times n$$

or

$$V = \text{The area} \times H \tag{2}$$

Description:

V = Blasting capacity (m³)

B = Burden (m)

S = Spacing (m)

H = Average Depth (m)

n = Number of blastholes

2) Qualitative Descriptive Analysis

Qualitative interpretation is performed by examining non-numerical influencing factors, such as:

- Soil and rock conditions in each work zone
- Type and brand of equipment used
- Operator efficiency and shift patterns
- Site accessibility and working environment

The use of both analytical approaches allows for a comprehensive evaluation of each method's effectiveness, enabling a realistic comparison that accounts for both measurable output and contextual field conditions.

3) Software Tools Used

The software tools utilized in this study include Microsoft Excel, which was employed to calculate equipment productivity, process excavation volumes and construction durations, and generate visual comparisons such as charts and tables. This tool facilitated a systematic and accurate analysis of quantitative data. Additionally, various project documentation sources—such as technical specifications, progress reports, and construction schedules—served as the primary references. These documents were essential for validating the field data, understanding the equipment usage, and ensuring that the analysis accurately reflected the real project conditions.

The diagram in Figure 3 illustrates the operational framework of the research methodology used to compare the construction methods for rock excavation. It begins with the research question and then in the input stage, it utilizes various data sources to support an accurate and contextual understanding of each contractor's excavation process. The process stage involves both qualitative and quantitative analysis, focusing on three main components.

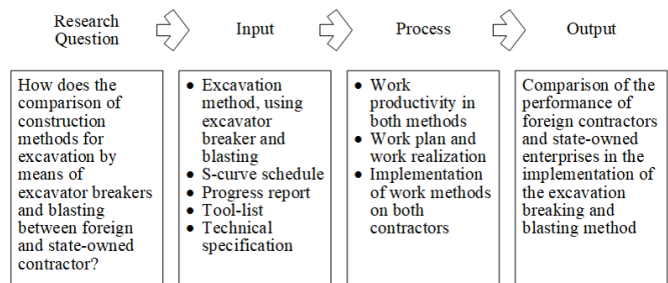


Fig. 3. Operational framework.

Finally, in the output stage, the results of the evaluation provide insights into the effectiveness of each excavation method, highlight the comparative performance between foreign and state-owned contractors, and identify the strengths and weaknesses of both methods. This systematic framework allows for a structured and comprehensive comparison that supports objective conclusions about the efficiency and suitability of excavation practices in dam construction projects.

IV. RESULTS AND DISCUSSION

Field observations at the Jenelata Dam Project in Gowa Regency, South Sulawesi, focused on the CFRD works and spillway works, with particular emphasis on rock excavation works carried out by foreign and state-owned contractors. Each contractor employed different implementation methods, reflecting variations in technology, management, and approaches to efficiency and safety. Foreign contractors emphasized the use of advanced technology and modern heavy machinery to ensure high quality and fast execution, while state-owned contractors focused on optimizing the use of local labor and adapting their methods to the existing field conditions, aiming to minimize costs and maximize the involvement of local human resources.

A. CFRD Work

The implementation of the CFRD work consists of the left bank (state-owned contractor) and the right bank (foreign contractor). The stages of implementation of the CFRD work for excavation work are depicted in Table II.

TABLE II. ROCK EXCAVATION USING BREAKER METHOD

Activity description	Equipment/material
Survey and stacking out	Total station and level
Joint inspection and mobilization of tools, material, and manpower (clearing)	Bulldozer
Open excavation of earth	Excavator PC200, Dumptruck
Open excavation of rock with excavator breaker	Excavator + breaker
Geological inspection of rock layers/classification and planned elevation, transport of excavated material for disposal	Geological hammer, dumptruck and excavator

Each activity utilizes specific equipment and materials to carry out the tasks efficiently, and proper documentation, such as survey reports, inspection results, and logs of equipment usage, is essential to track progress and maintain project accuracy.

The rock classification and the elevation plan need to be considered in this rock excavation work. Figure 4 shows a cross-section of a CFRD, indicating key components such as the dam crest elevation, embankment works, face concrete, plinth, and open excavation area. These elements represent the structural and excavation aspects essential for dam construction. Table III accompanies the image, categorizing rock outcrops into three classes. This classification helps determine the appropriate excavation methods and equipment based on field conditions.

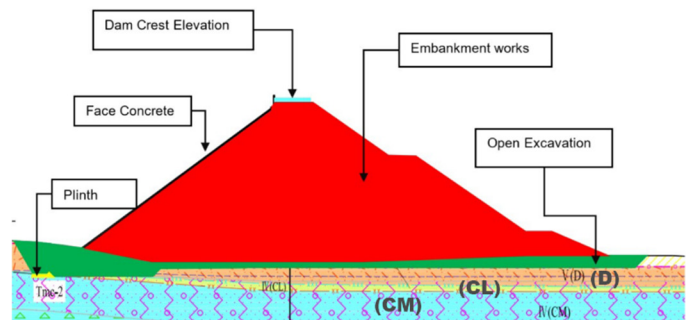


Fig. 4. Rock class position.

TABLE III. ROCK CLASSIFICATION

Class	Outcrop condition
D (decomposer)	Very soft rock
CL (class low)	Soft rock
CM (class medium)	Hard rock

Table IV presents the productivity comparison of the excavator breakers used by foreign contractors and SOE contractors. The parameters include: V (bucket volume), Fb (bucket fill factor), Fa (attachment efficiency factor), Ts (cycle time in min), and Q (productivity in m³/h). Both contractor types operate with similar technical specifications: a bucket volume of 0.70 m³, a fill factor of 1.00, and an attachment efficiency of 0.83. The slight difference lies in the cycle time, with foreign contractors operating at 1.56 min and SOE contractors at 1.53 min per cycle. As a result, the calculated productivity (Q) is 22.35 m³/h for foreign contractors and slightly higher at 22.78 m³/h for SOE contractors. This indicates that, despite using similar equipment, SOE contractors achieve marginally higher productivity due to a slightly faster operating cycle.

TABLE IV. PRODUCTIVITY OF EXCAVATOR BREAKER

	V	Fb	Fa	Ts	Q (m ³ /h)
Foreign contractors	0.70	1.00	0.83	1.56	22.35
SOE contractors	0.70	1.00	0.83	1.53	22.78

Table V shows the productivity evaluation of the excavator breakers used by the two types of contractors based on the work volume and production duration. For foreign contractors, the total excavation volume was 47,006.02 m³, with an equipment productivity-based duration of 178.77 days, and a total project completion time of 263 days, which includes factors such as mobilization, delays, and non-productive time. On the other hand, SOE contractors handled a significantly larger excavation volume of 113,006.45 m³. Despite the higher workload, their equipment productivity allowed them to complete the excavation in 182.27 days, and the overall project duration was only 155 days, indicating more efficient time management and possibly better coordination or resource allocation. This comparison highlights that SOE contractors achieved faster completion with higher volume due to greater overall efficiency.

TABLE V. PRODUCTIVITY EVALUATION OF EXCAVATOR BREAKER

Parameter	Volume	Day produc.	Equip. produc.	Total (days)
Foreign contractors	47,006.02	178.77	178.77	263
SOE contractors	113,006.45	182.27	729.10	155

B. Spillway Work

Based on field observations, two rock excavation methods are used in the spillway area: the excavator breaker method and the blasting method. Table VI displays the stages of blasting in the spillway area carried out by foreign contractors.

TABLE VI. ROCK BLASTING IN SPILLWAY

Stages of work	Activity description	Materials
Preparation	Licensing (warehouse and production permit), and construction of explosive warehouse	Permit document, explosive warehouse, manpower
	Mobilization of equipment and blasting	1 set drilling equipment
Determination of blasting plan points	Design the points to be blasted	Blasting design documents
Drilling	Drill according to the points in the previous plan, then clean the hole.	
Charging and connecting system initiation	Conducting explosive charging of holes	Explosive and cables for initiation systems
Blasting	Prior to blasting, the safety team conducted a safety induction to notify the evacuation and security distance of 300-500m.	
Loading and hauling	Carry out the transportation of blasted materials, then dispose of them to disposal for unusable materials.	Excavator and dump-truck

Table VII presents the productivity of the excavator breakers in the spillway area, comparing the performance of foreign contractors and SOE contractors. For the foreign contractors, the excavation volume reached 34,782.83 m³, with an equipment productivity duration of 178.77 days, which matches the number of productive days. The total completion time for the spillway excavation was 195 days, accounting for additional factors such as idle time, mobilization, or delays.

In contrast, the SOE contractors handled a smaller volume of 19,311.66 m³, but their equipment productivity was significantly higher, completing the excavation in just 182.27 productive days, with a much shorter total duration of 53 days. This suggests that the SOE contractors demonstrated greater operational efficiency and better project scheduling in the spillway area, managing to complete their portion in far less time despite the slightly longer equipment operation durations.

TABLE VII. PRODUCTIVITY EVALUATION OF BREAKER IN SPILLWAY AREA

Parameter	Volume	Day produc.	Equip. produc.	Total (days)
Foreign contractors	34,782.83	178.77	178.77	195
SOE contractors	19,311.66	182.27	364.55	53

Table VIII presents the productivity evaluation of the blasting method used by foreign contractors. The total excavation volume achieved through blasting was 64,030.44 m³. The equipment productivity and the number of productive working days were both recorded at 875.95 days, indicating that the blasting operation required sustained equipment use over a long duration. However, despite the high equipment usage, the total project duration was only 73 days, suggesting that multiple units of equipment operated simultaneously or that the work was conducted in parallel processes, resulting in high efficiency and a relatively short overall completion time. This reflects effective planning, resource allocation, and coordination in the implementation of the blasting method.

TABLE VIII. PRODUCTIVITY EVALUATION OF BLASTING METHOD

Parameter	Volume	Day produc.	Equip. produc.	Total (days)
Foreign contractors	64,030.44	875.95	875.95	73

The evaluation results show that state-owned contractors achieved higher productivity than foreign contractors. In the excavator breaker method, state-owned contractors reached a productivity rate of 22.78 m³/h, with a daily production of 729.10 m³/day using four or more units of equipment—exceeding the number used by foreign contractors. As a result, rock excavation in the CFRD area (left bank) was completed in 155 days, significantly faster than the planned 509 days. In comparison, foreign contractors working on the CFRD (right bank) achieved a lower productivity of 22.35 m³/h and 178.77 m³/day using only one unit of equipment (Figure 5).

A similar pattern is observed in the spillway area, where state-owned contractors again outperformed foreign contractors with a daily production of 364.55 m³/day using two units of equipment. In contrast, foreign contractors managed 178.77 m³/day with only one unit (Figure 6).

When comparing the excavator breaker method and the blasting method, the blasting method proved to be more effective in terms of productivity, achieving 875.95 m³/day (Figure 7). This method is especially advantageous for rock excavation in larger volumes and is suitable for reaching the required CL and CM elevations needed for subsequent structural work.

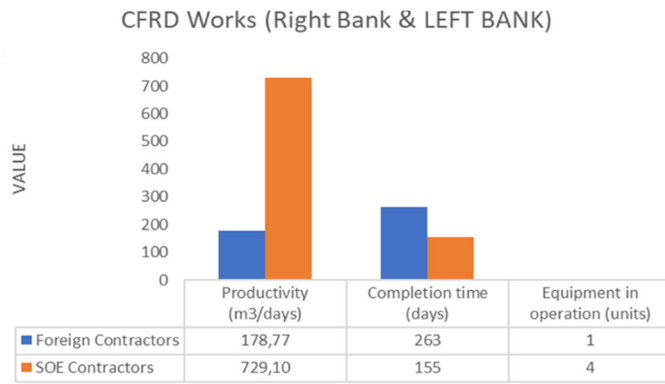


Fig. 5. Comparison of excavator breaker productivity in CFRD.

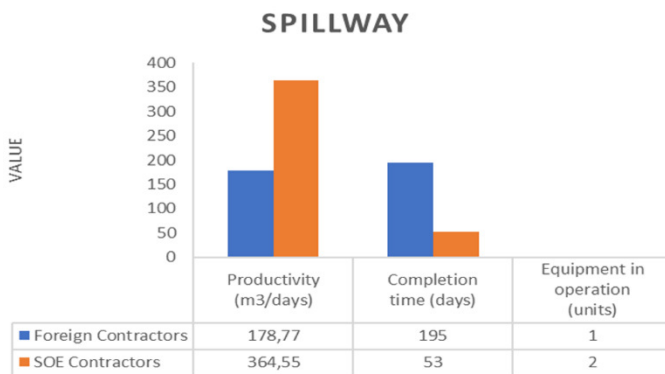


Fig. 6. Comparison of excavator breaker productivity in the spillway.

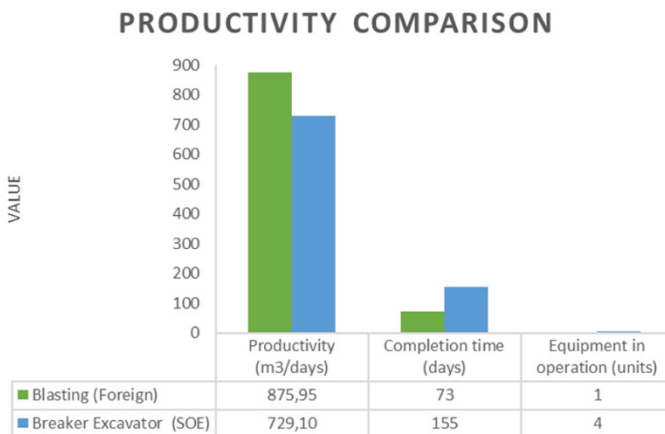


Fig. 7. Comparison of blasting productivity in the spillway.

Apart from the productivity parameters, the comparison between the excavator breaker method and the blasting method also involves several other important aspects, including work quality, safety risks, environmental impact, and a balanced evaluation of the advantages and disadvantages of each method. In terms of quality, the excavator breaker method generally provides more controlled excavation results with minimal overbreak, making it suitable for areas requiring precision. However, it is relatively slower. On the other hand, the blasting method enables rapid excavation, especially for large rock volumes, but may result in irregular excavation surfaces and requires careful planning to maintain precision

and limit overbreak. From a safety perspective, the excavator breaker method poses lower immediate risk to workers as it involves mechanical operation with predictable movements. In contrast, blasting involves higher safety risks due to the handling and detonation of explosives, requiring strict adherence to safety protocols and specialized personnel. Environmentally, the breaker method generates less vibration, dust, and noise, making it more suitable for areas near populated or sensitive zones. Meanwhile, blasting can cause significant environmental disturbance, including ground vibration, noise, and fly rock, which may affect the nearby structures or ecosystems if not properly managed. Each method also presents its own set of advantages and disadvantages. Therefore, for the method selection, not only productivity should be considered, but also the overall project requirements, site conditions, and risk management priorities.

TABLE IX. COMPARISON OF OTHER PARAMETERS OF THE TWO ROCK EXCAVATION METHODS

Parameters	Excavator breaker	Blasting
Quality	-Fewer cracks in the rock. -Small/medium volume for excavation with a certain elevation, easier to control.	-Possible damage to surrounding rock. -Larger volume and faster completion, but not suitable for small volume work and excavation of certain elevations. -The excavation elevation was uneven, and required the use of breakers to reach the design elevation.
Safety risk	Low; tool operator is inside the machine, safe from direct injury.	High; if the safety induction is not well understood by all personnel involved, or if the safe radius is not maintained, there is a risk of accident. It is necessary to induct and sterilise the area prior to blasting and to ensure that all blasting charges and initiation systems are in accordance with procedures.
Environmental impact	-Low noise, vibration and dust levels. -Minimal cracking potential. -Landslide potential.	-High noise, vibration, and dust levels. -Vibrations from blasting caused cracks in neighboring structures near the site. -Potential for flooding if there is a prolonged rainy season.
Strengths and weaknesses	-It is more expensive, but more efficient in smaller volumes. -No special licence required. -Longer working time if equipment is not planned.	-Cost is lower for large volumes, not effective for small volumes. -Need to go through many special expert approvals before blasting. -Faster working time.

V. CONCLUSION

There is a significant difference between state-owned and foreign contractors in the application of the two methods used in the Concrete Face Rockfill Dam (CFRD) Works project. The state-owned contractor employed the excavator breaker method with a daily productivity of 729.10 m³/day, using four units of equipment, and completed the work in 155 days. This method proved to be more effective for rock excavation at specific elevations, requiring precision in equipment selection. On the other hand, the foreign contractor used the blasting method, achieving a higher daily productivity of 875.95 m³/day, utilizing only one unit of equipment, and completed the work in a much shorter period of 73 days. The blasting method proved more effective for large-volume work requiring fast completion. This comparison indicates that the foreign contractor excels in productivity for large-scale projects, while the state-owned contractor is more efficient for projects with specific technical requirements, such as rock excavation at particular elevations. Thus, although the foreign contractor completed the work faster, the state-owned contractor was able to save significant time compared to the original schedule.

Based on the results, it is proposed that for projects involving large volumes of work, the blasting method should be considered, as it offers higher productivity and faster completion times. However, for projects with specific technical requirements, such as rock excavation at certain elevations, the excavator breaker method would be more suitable. It is also proposed that future projects evaluate both methods and their respective strengths in relation to the specific conditions and requirements of the work area to optimize both time and cost efficiency. Additionally, collaboration between a State-owned enterprise (SOE) and foreign contractors could be explored to combine the strengths of both methods for an even more effective project execution.

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