The Productivity of Excavating Equipment Power Shovel (Earthmoving) in Construction Industry

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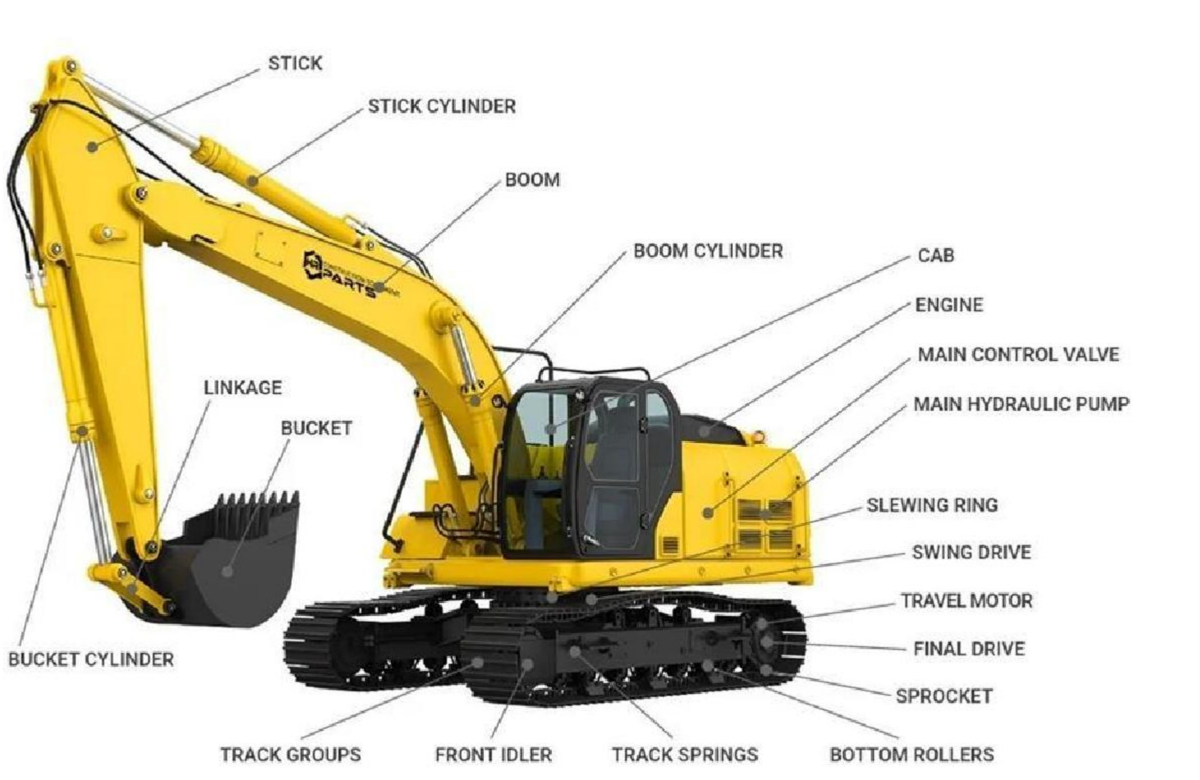
Abstract:
Construction equipment has long been recognized as a crucial factor in enhancing efficiency and productivity on construction sites, thus facilitating economic growth by reducing overall construction and operational costs. This study specifically examined the productivity of power shovels to provide a comprehensive analysis based on both theoretical and practical evaluations. The methodology involved an in-depth analysis of various factors affecting the productivity of power shovels. These factors include cycle time, bucket capacity, angle of swing, soil type, soil condition, and environmental influences. The productivity was assessed at six distinct construction sites, considering seasonal variations that could impact equipment performance. Data were collected during three different seasons: the rainy season, the winter season, and the summer season. Subsequently, we conducted a comparative analysis of the ideal productivity versus the theoretical productivity for the power shovels. In this investigation, we presented our findings using graphs to make them easier to understand. Our study showed that changes in cycle time and the surrounding environment had a notable impact on the excavating equipment's productivity. This analysis underscores the importance of considering these factors when evaluating and optimizing the use of power shovels in construction operations.
Keywords: Construction equipment, Efficiency, Productivity, Power shovels, Cycle time, Bucket capacity, Angle of swing, Soil type, Soil condition, Environmental influences, Comparative analysis, Seasonal variations, Excavating equipment, Theoretical productivity, Optimization

Introduction:
The construction industry has played a vital role in the country's economic and infrastructural development. Within this industry, new technologies and equipment significantly contribute to progress. Among these tools, the power shovel is particularly important for excavation and signifies the start of a project. The productivity of this equipment directly influences the overall efficiency and economic viability of projects. Productivity can be defined as the amount of material, typically measured in cubic meters, that the excavator can move within a specific time frame, usually expressed in hours. By studying the productivity of power shovels, we can identify the factors that influence the efficiency of the equipment so that we can adapt to those factors to increase productivity and reduce the cost of operations.



The Objective of Research:

- To analyse the productivity of excavating equipment Power Shovel(earthmoving) in the construction industry.
- Comparison of productivity between ideal and on-site conditions

Importance Of Research:

The productivity of excavating equipment, particularly power shovels, plays a crucial role in the construction industry for several reasons. Firstly, power shovels greatly enhance the efficiency of earthmoving operations, enabling faster excavation and material handling compared to manual methods or less advanced machinery. This increased efficiency results in shorter project timelines and reduced labour costs, essential for staying within budget constraints on construction projects. Moreover, understanding the productivity metrics of power shovels allows project managers to optimize resource allocation and scheduling, ensuring effective use of equipment throughout the project lifecycle. Given that construction projects often involve complex logistics and coordination among various teams, having reliable data on equipment productivity is crucial for planning and addressing potential delays due to equipment downtime or inefficiencies. Finally, with the growing emphasis on sustainability in construction practices, analyzing the productivity of excavating equipment can lead to more environmentally friendly approaches by minimizing waste and maximizing material reuse. Overall, this initiative not only enhances operational performance but also supports strategic decision-making that aligns with contemporary industry standards and environmental considerations.

Methodology:

The focus of the methodology is to calculate and analyze the productivity of the power shovel by considering different sites in both ideal and practical conditions.

Theoretical Calculation Considering Ideal Condition

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Site Selection and Site Observation

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Practical Calculation Considering Ground Condition

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Result and Analysis

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Comparison between Ideal and On-Site Conditions

Observation & Calculations:

Productivity of Power Shovel in various climatic conditions and models:

Shovels (Various Models):

Site Nos. & Model	Type	Bucket Capacity (m^3)	Angle Of Swing (Degree)	Cycle Time (Sec)	Maximum Digging Depth (Mm)
I	Crawler Mounted	0.26	45	100	4340
II	Crawler Mounted	0.9-1.0	90	220	6600
III	Crawler Mounted	0.9-1.02	45	140	5980
IV	Crawler Mounted	0.45	45	100	5090
V	Crawler Mounted	0.9-1.0	90	120	6600
VI	Crawler Mounted	0.95	90	120	6010

Site Details:

Site No.	Address	Season	Type Of Soil	Depth Of Excavation
I	Electronic Zone, Hingna Road, Nagpur	Rainy Season	Earth Rock Mixture	2m = 7ft
II	Jamdar School, Resambagh, Nagpur	Rainy Season	Sandy Soil + Black Cotton Soil	2m = 7ft
III	Subhmangal Vihar, Hingna Road, Near Lata Mangeshkar Hospital, Digdoh, Nagpur	Winter Season	Rock Well Blasted	2m =7ft
IV	Hingna Road, MIDC Naka, Indian Petrol Pump, Nagpur	Winter Season	Earth Rock Mixture	3.4m = 11ft
V	Trimurti Nagar, Near Gajanan Temple, Nagpur	Summer Season	Earth Rock Mixture	5.1m=17ft
VI	Rai Tower, Bharat Talkies, Tent Line, Mohan Nagar, Nagpur	Summer Season	Earth Rock Mixture	4.57m = 15ft

Productivity Observation:

Sr. No.	Site	Season	Ideal Productivity (m^3/hr)	Cycle Time (Sec)	Practical Productivity(m^3/hr)
1	**Site I:** Electronic Zone, Hingna Road, Nagpur	Rainy Season	16.92	100	5.07
	Site II: Jamdar School, Resambagh, Nagpur		39.74	220	5.41

2	**Site III:** Subhmangal Vihar, Hingna Road, Near Lata Mangeshkar Hospital, Digdoh, Nagpur	Winter Season	39.15	140	8.38
	Site IV: Hingna Road, MIDC Naka, Indian Petrol Pump, Nagpur		27.40	100	8.22
3	**Site V:** Trimurti Nagar, Near Gajanan Temple, Nagpur	Summer Season	40.63	120	10.15
	Site VI: Rai Tower, Bharat Talkies, Tent Line, Mohan Nagar, Nagpur		43.89	120	10.97

Data Sample Calculation:

1. Bucket Capacity (F):

$$F_{avg} = 0.26\ m^3$$

2. Bucket Filled Factor (Q):

Soil Type: Rock-Earth Mixture

Q=105-115%

$$Q_{avg} = 1.05$$

3. Cycle Time:

t = 100 Sec

4.(AS:D):

Depth = 2m = 7ft

Maximum Digging Depth= 4340 mm = 15 ft

Optimum Height=50% Of Maximum

=0.5×15

= 7.5 Ft

Percentage Optimum Height= $\frac{7}{7.5} \times 100$=93.33≈94%

Therefore, By Interpolation,

Since Ɵ = 45 degree

x_1=80	y_1=1.22
X= 94	y=?
x_2=100	y_2=1.26

$$y = y_1 + (x - x_1)\left(\frac{y_2 - y_1}{x_2 - x_1}\right)$$

$$y = 1.22 + (94-80)\left(\frac{1.26-1.22}{100-80}\right) = 1.24$$

(AS:D) =1.24

5. Efficiency Factor (E):

According to TRB (Transportation Research Board) information, the efficiency would be 30 to 45 working minutes per hour.

Therefore, **assume E = 30 min**

6. Swell Factor:

Since the soil is Rock Earth Mixture

Swell factor=20%=0.2

$$\frac{1}{\text{Volume correction}} = \frac{1}{1+\text{Swell factor}}$$

PRACTICAL CALCULATION:

$$\textbf{Productivity} = \frac{3600\text{ sec} \times Q \times F \times (AS{:}D)}{t} \times \frac{E}{60\text{ min}-\text{hr}} \times \frac{1}{\text{volume correction}}$$

$$= \frac{3600\text{ sec} \times Q \times F \times (AS{:}D)}{t} \times \frac{E}{60\text{ min}-\text{hr}} \times \frac{1}{1+\text{Swell factor}}$$

$$= \frac{3600 \times 0.26 \times 1.05 \times 1.24}{100} \times \frac{30}{60} \times \frac{1}{1+0.2}$$

Productivity =5.07 m^3/hr

IDEAL CALCULATION:

$$\textbf{Productivity} = \frac{3600\text{ sec} \times Q \times F \times (AS{:}D)}{t} \times \frac{E}{60\text{ min}-\text{hr}} \times \frac{1}{\text{volume correction}}$$

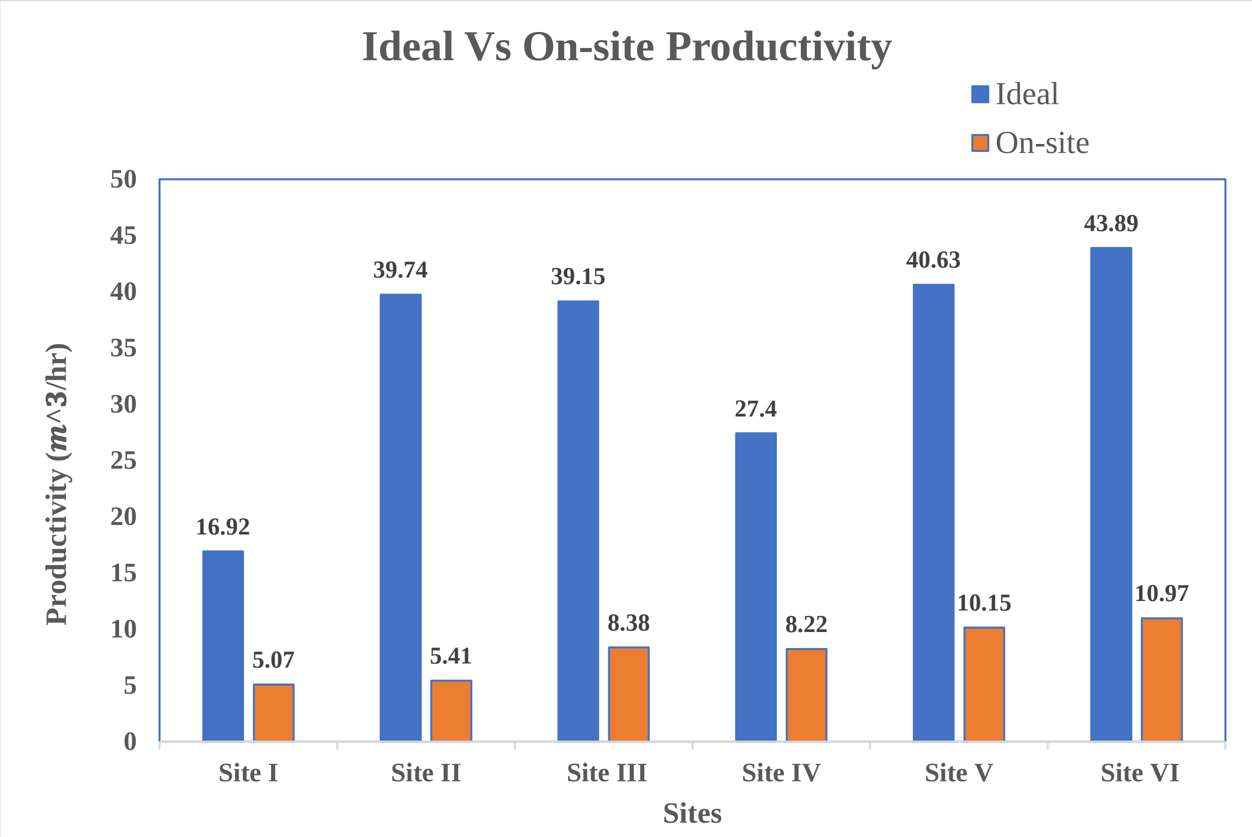
$$= \frac{3600\text{ sec} \times Q \times F \times (AS{:}D)}{t} \times \frac{E}{60\text{ min}-\text{hr}} \times \frac{1}{1+\text{Swell factor}}$$

$$= \frac{3600 \times 0.26 \times 1.05 \times 1.24}{30} \times \frac{30}{60} \times \frac{1}{1+0.2}$$

Productivity =16.92 m^3/hr

Results & Discussion:

Under ideal conditions, the cycle time is 30 seconds, and on the basis of on-site time taken by the power shovel, the following results were obtained from calculations performed at different sites.



Based on the results factors that significantly affected productivity are as follows:

1. Bucket Capacity:

Bucket capacity refers to the volume of material that a bucket can hold when it is filled to the brim. As bucket capacity increases, productivity also increases; conversely, a decrease in bucket capacity leads to a reduction in productivity. For example, at Site I in the electronic zone, the bucket capacity is 0.26 cubic meters, resulting in decreased productivity under ideal conditions compared to On-site conditions. Therefore, we can conclude that bucket capacity is directly proportional to productivity.

2. Angle of Swing:

The angle of swing refers to the horizontal angle measured between the position of an excavator's digging bucket while it is actively excavating material and the position when it is rotated to dump the load. This angle represents the degree of rotation the excavator's upper body makes when moving from the digging spot to the dumping location during a single excavation cycle, and it is typically expressed in degrees. Productivity is maximized when the angle of swing is optimal, which is generally considered to be 90 degrees. For example, at Site I, the angle of swing is 45 degrees, while at Site II, it is 90 degrees. The difference in productivity is significant, with Site II demonstrating maximum productivity due to the optimal swing angle of 90 degrees. Therefore, we can conclude that productivity is directly proportional to the optimal angle of swing, which is 90 degrees.

3. Cycle Time:

Cycle time refers to the total duration required to complete a single digging operation, starting from when the excavator bucket begins to penetrate the ground until it fully dumps the excavated material at the designated location. This duration includes the time spent bending, moving, loading, and unloading the bucket. Productivity increases as cycle time decreases. When comparing ideal conditions to onsite conditions, we see that when cycle time is minimized, productivity is maximized. Thus, we can conclude that productivity is inversely proportional to cycle time.

4. Seasonal variations:

Seasonal variations significantly affect productivity, particularly soil conditions, which can influence cycle times. For instance, during the rainy season, the moisture content in the soil is high, leading to a greater risk of the excavator skidding. As a result, operators must exercise caution, which increases cycle times and decreases productivity. Conversely, in the summer months, the soil typically has less moisture, providing a better grip for the equipment. This allows for smoother operations and maximizes productivity. Therefore, we can conclude that seasonal variation plays a significant role in influencing the productivity of excavators.

Conclusion:

The study on the productivity of power shovels in construction offers a comprehensive analysis of various factors that influence excavation operations' performance and efficiency. The key factors identified include bucket capacity, swing angle, cycle time, and seasonal variations. The research found that bucket capacity is directly proportional to productivity; larger bucket sizes result in higher productivity because more material can be excavated in each cycle. Additionally, the swing angle significantly impacts productivity, with an optimal swing angle of 90 degrees yielding the best results. This angle minimizes the time spent rotating between excavation and dumping positions. Cycle time, which refers to the total time taken for digging and dumping, is inversely related to productivity: shorter cycle times lead to greater efficiency. The study also revealed that seasonal variations significantly affect productivity levels. During the rainy season, increased soil moisture and instability lead to longer cycle times and decreased productivity, primarily due to the challenges in maintaining equipment stability. Conversely, summer brings drier soil conditions, which provide better grip and allow for faster and more efficient excavation, resulting in higher productivity. When comparing practical conditions to ideal ones, the study noted that real-world factors, such as soil type and environmental conditions, cause productivity to be much lower on-site than in theoretical scenarios. Operational delays, equipment performance limitations, and challenging soil conditions often contribute to this reduced productivity. These findings underscore the importance for construction managers to consider these various factors when planning excavation operations. By optimizing equipment use and adapting to environmental conditions, they can significantly improve productivity, reduce downtime, and lower overall operational costs.

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