The efficiency test of a rock excavator by use of a multistage edge excavation method

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Background

To reduce environmental loads was important to solve for rock mass excavation by rock blasting.

A construction machine such as a hydraulic breaker, having problems such as noise and vibration.

A need to develop a rock excavator achieving low noise and low vibration.
Purpose

To develop a rock excavator attached of a backhoe by use of a multistage edge excavation method.

Cost reduction possible by developing a backhoe attachment

Earlier studies have been proposed the edge excavation method is efficient.

We did experiments with the model excavator to find out efficiency and force acting on the rock excavator.
The edge excavation method

Since a rock **tensile strength** is smaller than **compression strength**, the edge excavation method is efficient.
The experimental apparatus

The specimen was W/C 50% mortar, 40N/mm² uniaxial compressive strength.
The model excavator

- Roller cutter bit
- Point attack bit
- Fish tail
- Maw
- Suction of excavated soil
The experimental method

In all 3 stages, 3 types of thrust set at each stage.

1st
7.5kN
8.5kN
10.0kN

2nd
20.0kN
22.5kN
25.0kN

3rd
30.0kN
35.0kN
40.0kN

Measured by thrust $F_z$, torque $T$, and digging depth $z$. 
Considered the thrust $F_z$ of this part as the average value.

Excavating proceeded with constant amplitude.

Considered the thrust $F_z$ of this part as the average value.
Excavating proceeded with almost constant amplitude.

Considered the torque $T$ of this part as the average value.
Results (Torque $T$)

Torque $T$ increased with increasing thrust $Fz$ at each stage.

Proportionate relationships between thrust $Fz$ and torque $T$ were observed when each dataset mixed together.
Excavating proceeded with constant speed.

Penetration speed $V$ is obtained by dividing the digging depth $z$ by the elapsed time $t$. 
Results (Penetration speed $V$)

Penetration speed $V$ increased with the increasing of thrust $F_z$ at each stage.

Gradient of penetration speed $V$ decreased with increasing number of stages.
Specific energy $E_s$

Specific energy $E_s (kN \cdot \text{cm/cm}^3) = \frac{\text{All power } P (kN \cdot \text{cm/s})}{\text{Excavated volume per unit time } V_E (\text{cm}^3/\text{s})}$

$P = \text{rotative power } P_T + \text{propulsive power } P_R$

The rotative power is proportional to torque $T$

The propulsive power is proportional to thrust $F_z$

$V_E$ are calculated from the excavated volume and the elapsed time at the end of excavation.

Smaller values of the specific energy $E_s$ are efficient.
The first stage was the lowest specific energy $E_s$.

Specific energy $E_s$ decreased with increasing the number of stages.

Combination of the fish tail and the point attack bit is effective to create the edge.

Efficient excavation
Conclusion

1. Force acting on the model excavator
   - Torque $T$
   - Penetration speed $V$
   - Proportional relation to Thrust $F_z$

2. Excavation efficiency
   - Specific energy $E_s$
   - Increasing the number of stages
   - Decreasing
Perspectives

Application

Measurement of thrust

Deducing

Torque

Penetration speed

Necessity

Further experiments increase the number of stages

Clarifying

Relationship between efficiency and the number of stages