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Effect of standoff distance and abrasive flow rate on the removal volume for AWJ rock drilling

Hyun-Joong Hwang[1)], Yohan Cha[2)], Tae-Min Oh[3)], and *Gye-Chun Cho[4)]

[1), 2), 4)] Department of Civil and Environmental Engineering, KAIST, Daejeon 34141, Republic of Korea
[3)] Department of Civil Engineering, Pusan National University, Busan 46241, Republic of Korea
[4)] gyechun@kaist.ac.kr

ABSTRACT

This study aimed to understand how standoff distance and abrasive flow rate affect material removal when using abrasive waterjet drilling. At the same exposure time of 60 seconds, the experiment was carried out. The change of abrasive flow rate in the same standoff distance, the trend of removal volume shows different tendency depending on standoff distance. In terms of drilling depth and width, we analyzed the efficiency of unit mass of abrasive as the abrasive flow rate increases. In this study, the standoff distance is more sensitive than the abrasive flow rate in terms of removal volume of rock.

1. INTRODUCTION

Recently, the necessity of underground space development is growing. Creation of new living space by undergrounding of commercial and residential facilities as well as social infrastructures. Rock excavation projects are currently underway due to the exhaustion of urban space. Currently, there are various methods for rock excavation. Among them, an abrasive waterjet can be used to cut and drill rock by itself or in combination with conventional mechanical rock excavation methods (Summers 1992, Kim 2012). Using waterjet makes up for the disadvantage of the conventional rock excavation methods (e.g. reduction of vibration and noise).

For charging, drilling hole width of 8 ~ 10 cm and drilling hole depth of 1 m or more are required. In other words, more than a certain amount of removal volume is required. Rock removal performance using waterjet is determined by several parameters (Momber 1997, Karakurt 2012, Oh 2014). They are water pressure,

[1)] Graduate Student
[2)] Graduate Student
[3)] Assistant Professor
[4)] Professor

abrasive characteristics, water flow rate, abrasive flow rate, standoff distance, and traverse speed.

In this study, We have observed at the possibility of rock removing volume by using abrasive waterjet. By setting standoff distance (SOD) and abrasive flow rate (AFR) as variables, rock drilling performance (i.e. depth, width, and volume) were measured and analyzed. According to this observation, the effect of abrasive flow rate on the removal volume was analyzed.

2. EXPERIMENTAL PROGRAM

Abrasive waterjet drilling tests were performed on rock specimens using intensifier types of pumps while changing standoff distance, and abrasive flow rate. Rock specimen was used granite which can be seen frequently in the construction site. Abrasive was used garnet [$Fe_2O_3Al_2(SiO_4)_3$] which has tiny particles (80 mesh) and a high degree of hardness (7.5 ~ 8.5 on the Mohs scale).

The intensifier waterjet system had the sapphire orifice diameter of 0.254 mm, focusing tube diameter of 0.762 mm and produced a water flow rate of 28.5 ml/sec with water pressure of 320 MPa (Table 1). Maximum water pressure and Maximum water flow rate of pump are 412 MPa and 100 ml/sec, respectively.

Table 1 Specifications for the waterjet system

Pump type	Power [HP]	Water pressure [MPa]	Water flow rate [ml/sec]	Orifice diameter [mm]	Focusing tube diameter [mm]	Focusing tube length [mm]
Intensifier	50	320	28.5	0.254	0.76	76.2

The generated high-pressure water and abrasive are mixed in mixing chamber and jetted down onto the target material through the focusing tube (Fig. 1).

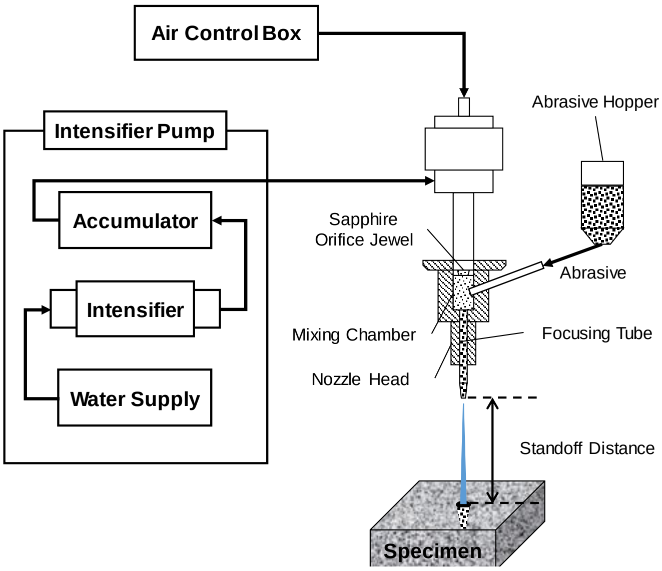

Fig. 1 Abrasive waterjet system

Drilling tests were performed by changing standoff distance (SOD), and abrasive flow rate (AFR) in the same granite specimen. Experimental conditions consisted of 5 cases of abrasive flow rate (i.e. 5.6, 7.5, 11.1, 15.0, and 18.0 g/sec) and 4 cases of standoff distance (i.e. 10, 50, 100, and 200 mm) combination (Table 2). It was total 20 cases. In all cases, the exposure time was set to 60 seconds. After drilling was completed, the depth, width, and removal volume of each hole were measured.

Table 2 Drilling test cases for the abrasive waterjet system

Case	AFR (g/sec)	SOD (mm)			
A	5.6	10	50	100	200
B	7.5	10	50	100	200
C	11.1	10	50	100	200
D	15.0	10	50	100	200
E	18.0	10	50	100	200

3. RESULTS AND DISCUSSIONS

3.1 Experimental Results

In previous studies, generally, more increase standoff distance (SOD), the drilling width increases and depth decreases because of high jet dispersion. Also the drilling hole has a cylindrical shape when standoff distance is 10 mm, and a conical shape when standoff distance is more than 10 mm (Ahn 2018). When the shape of the drilling hole is conical, calculating the removal volume results in the square of the drilling width and is applied the drilling depth value itself.

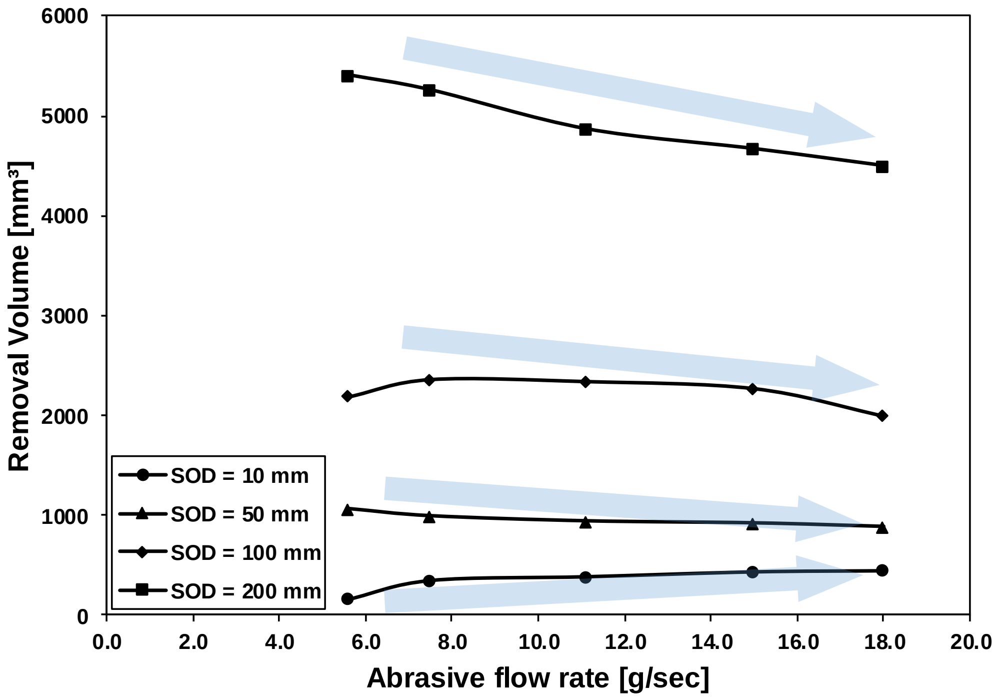

Fig. 2 Effect of abrasive flow rate on the removal volume

In this study, also, the greater standoff distance, the wider drilling width, the higher removal volume. Therefore the removal volume in the same abrasive flow rate is dominant in drilling width. However the removal volume in the same standoff distance had different trends. Abrasive flow rate increases, removal volume increases in 10 mm of standoff distance. And abrasive flow rate increases, removal volume decreases in more than 10 mm of standoff distance. (Fig. 2).

3.1 In Terms of Drilling Depth

In certain standoff distance ranges (i.e. 10 ~ 100 mm), they show different trends from the usual drilling depth results. The drilling depth decreases and then increases in the ranges. When the standoff distance exceeds 10 mm, the drilling form is made into a conical shape. The interference effect between the launched abrasive waterjet and the bounced slurry increased at SOD of 10 ~ 50 mm which was not ensured in the conical shaped hole. But the drilling width in SOD of 50 ~ 100 mm was started to be secured and the interference effect was decreased and then the drilling performance was increased (Ahn 2018).

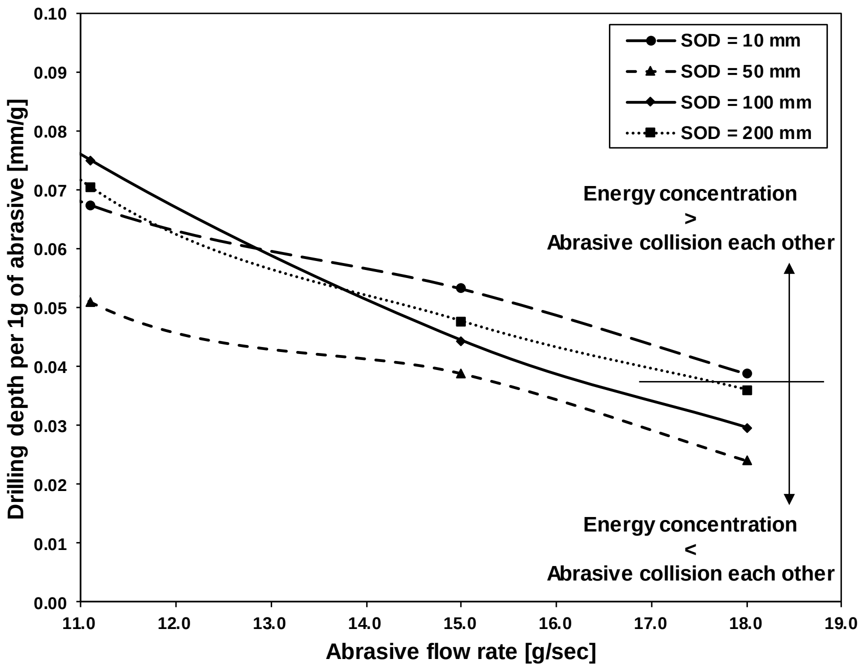

Fig. 3 Unit mass of abrasive effect on the drilling depth

In terms of unit mass of abrasive, when standoff distance is 10 mm, energy concentration is bigger than the abrasive collision each other. But when standoff distance is more than 10 mm, energy concentration is smaller than the abrasive collision each other. Therefore the efficiency of unit mass of abrasive is the largest at 10 mm of standoff distance in the same abrasive flow rate (Fig. 3). The results were the same as those in the previous studies due to the interference effect of the abrasive.

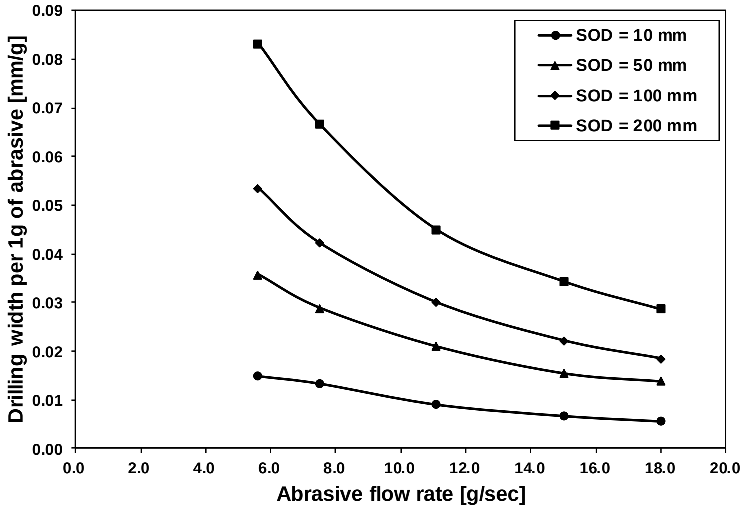

Fig. 4 Unit mass of abrasive effect on the drilling width

3.3 In Terms of Drilling Width

In all cases, abrasive flow rate increases, the efficiency of unit mass of abrasive on the width decreases (Fig. 4).

In terms of unit mass of abrasive efficiency, both drilling depth and drilling width decreases as the abrasive flow rate increases. So the removal volume also should decrease. However when standoff distance was 10 mm, the removal volume increased due to increase in width (Fig. 2). This means that standoff distance parameter is more sensitive to the changing of removal volume than abrasive flow rate parameter.

In other words, the removal volume decreases as the abrasive flow rate increases in large standoff distance (i.e. 50, 100, 200 mm) and the removal volume increases as the abrasive flow rate increases in small standoff distance (i.e. 10 mm). So, in large standoff distance, the removal volume is large but the efficiency is low. In small standoff distance, the removal volume is small but the efficiency is high. Therefore depending on the purpose of abrasive waterjet drilling, proper standoff distance and abrasive flow rate need to be set.

4. CONCLUSIONS

In this study, the effects of standoff distance (SOD) and abrasive flow rate (AFR) were analyzed in abrasive waterjet rock drilling. The results obtained through experiments are summarized as follows.

- The removal volume in the same abrasive flow rate is dominant in drilling width.
- In terms of drilling depth, the efficiency of unit mass of abrasive is the largest at standoff distance of 10 mm due to comparison between energy concentration and abrasive collision, although it decreases overall.
- In terms of drilling width, the efficiency of unit mass of abrasive decreases in all cases.
- In large standoff distance, the removal volume is large but the efficiency is low as the abrasive flow rate increases. In small standoff distance, the removal

volume is small but the efficiency is high as the abrasive flow rate increases.

- Standoff distance parameter is more sensitive to the changing of removal volume than abrasive flow rate parameter.

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