[TS1401_7019] Feasibility analysis of rock cutting-splitting method by scaled model tests

Chang-Heon Song, Joo-Young Oh, Sang-Min Lee, Dae-Ji Kim, Jung-Woo Cho#, and Sang-Hwa Yu

Corresponding Author: chojw1665@kitech.re.kr

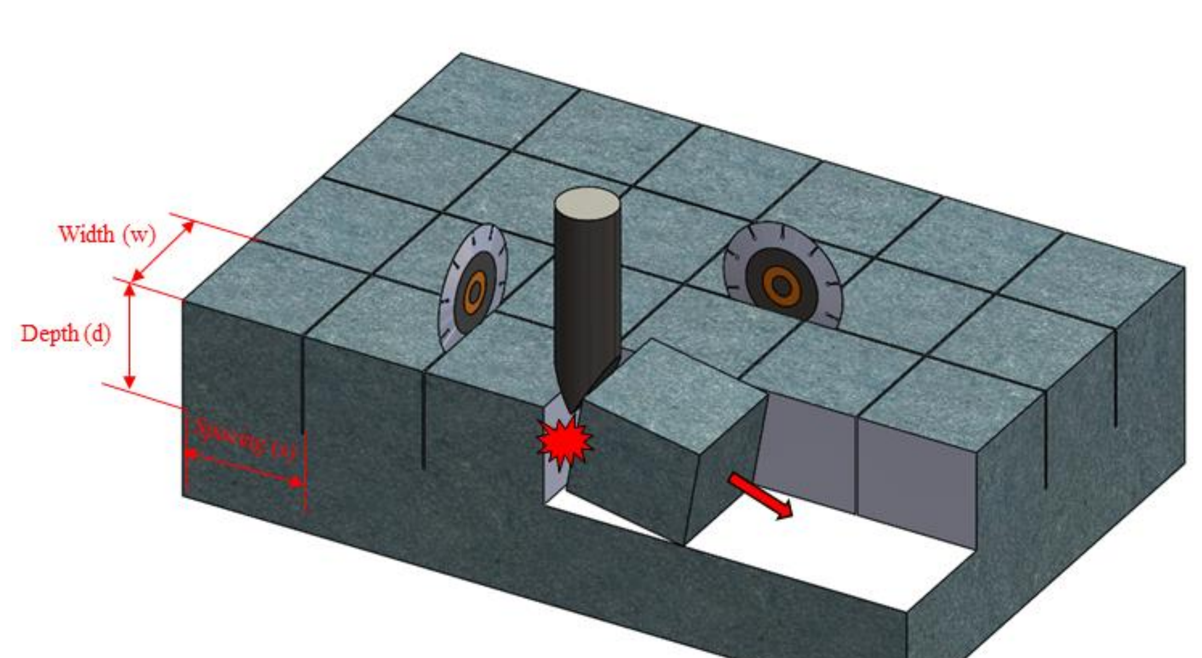
ABSTRACT

A rock cutting and splitting method is under developing to improve the rock excavation performance. The key mechanism of the method is fracturing on the base plane of rock blocks by indenting a chisel into the cutting lines. This method can improve the rock penetration rate during mechanized excavation process. A series of tests were designed and conducted to evaluate the advantageous geometry for the rock splitting process. The results showed that the maximum splitting spacing of rock blocks was 2 times of cutting depth. According the results, the excavation performance of current method was compared with the previous drilling and splitting method.

Introduction

- Recently, drilling and blasting method are not permitted in the urban area, many mechanized tunneling methods (e.g. hydraulic breakers, drilling-splitting method, and roadheaders, TBMs) are adopted in the tunneling sites in South Korea. Hydraulic breakers also incur noise and vibrations, and drilling-splitting method and roadheaders showed slow tunneling performance when encountering hard rocks. TBMs can show the high performance but the economic feasibility is satisfactory for the long tunneling site. Thus, previous methods has some limitations to alternate the drilling-blasting method.
- A new tunneling method having cutting-splitting procedure is under developing to improve the rock excavation performance. The key mechanism is tensile fracturing on the base plane of rock blocks by indenting a chisel into the cutting lines. The method can improve the excavation rate of rock excavation project. Because a large rock chips (i.e., split rock blocks) can be produced from the rock mass, this save the energy and time to break rocks into small particles.
- To guarantee the tensile fracturing of rock blocks, scaled model tests of cutting-splitting process were designed. Four kinds of strength model was selected for the tests. A series of tests were conducted to evaluate the advantageous geometry of rock splitting process. This method can show a high excavation rate for hard rocks because a large rock blocks can be extracted. Also, it is expected to significantly reduce the vibration comparing the blasting method.

Proposed method



The proposed method is cutting-splitting method which is consisted of two processes: cutting and splitting. First step is rock cutting by a rock saw according to the predesigned dimensions Then, a sharp chisel is percussed into the cutting slot to propagate the tensile crack on the bottom surface of rock mass.

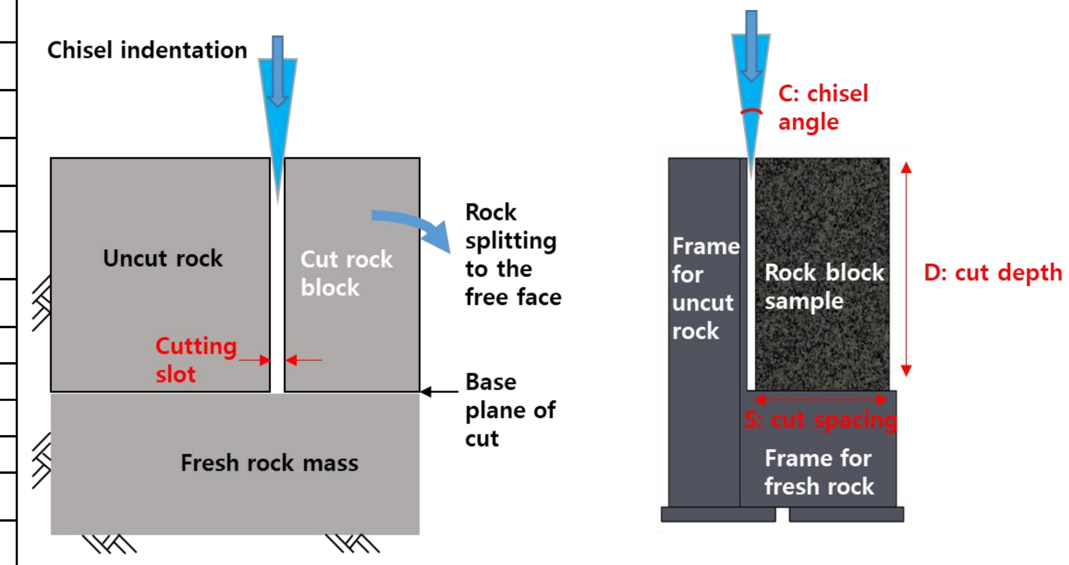
Contribution rate of design factors

Design factor		Contribution rate		
No.	Name	Max. Force	Max. Displacement	Complete/Fail
A	Rock strength	19.8%	4.3%	4.8%
B	Cut spacing	53.5%	70.8%	81.0%
C	Chisel angle	8.9%	15.5%	4.8%
-	Error	17.8%	9.4%	9.5%

The cut spacing was a significant factor for the completion of method, because the contribution rate of this for the complete decision was 81%. This means that the cutting geometry (i.e., cut spacing and depth) is the most important factor to design the rock excavation work.

Design of experiment

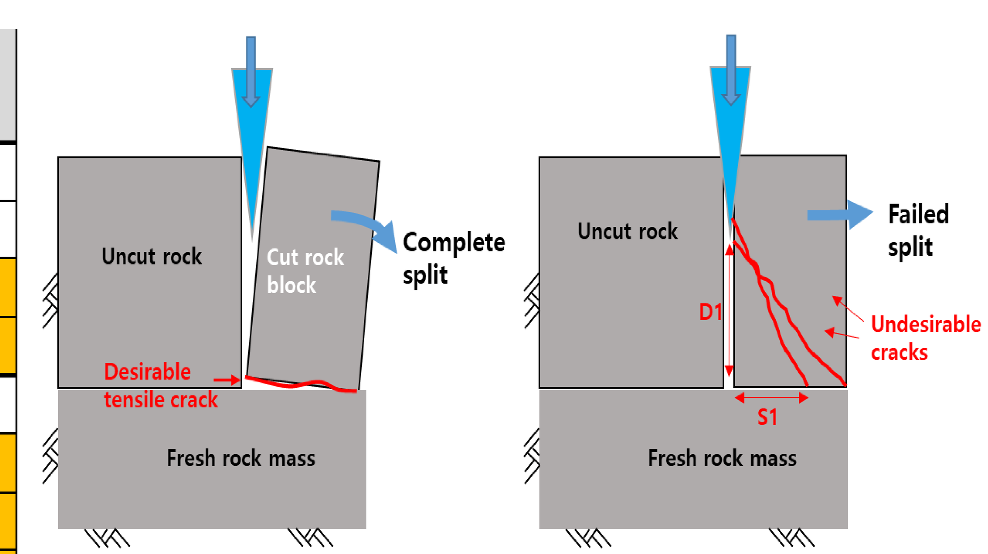
Exp. No.	A	B	C
1	Moderate strength	160	2
2	Moderate strength	320	3.5
3	Moderate strength	480	7
4	Moderate strength	800	10
5	Medium strength	160	3.5
6	Medium strength	320	2
7	Medium strength	480	10
8	Medium strength	800	7
9	High strength	160	7
10	High strength	320	10
11	High strength	480	2
12	High strength	800	3.5
13	Extremely High strength	160	10
14	Extremely High strength	320	7
15	Extremely High strength	480	3.5
16	Extremely High strength	800	2



- The three main design factors are selected as strength, cut spacing, and chisel angle. The cut depth was fixed to 160 and the cut spacing/depth was in the range of 1.0~4.0.
- The main purpose of the test is evaluation of optimum cutting condition for the cutting-splitting method. Thus, the cutting slots for each block were pre-cut before the scaled splitting experiments.

Testing results

Rock class	Case No.	S_{scaled}	D_{scaled}	W_{scaled}	Chisel angle	Max. force	Max. displaceme	S1	D1	Decision
		(mm)	(mm)	(mm)	(deg)	(kN)	(mm)	(mm)	(mm)	
Moderate strength	1	160	160	160	2	4.05	47.43	-	-	Complete
	2	320	160	160	3.5	4.90	85.82	-	-	Complete
	3	480	160	160	7	31.7	158.9	401	115	Failed
	4	800	160	160	10	42.45	82.74	716	40	Failed
Medium strength	1	160	160	160	3.5	6.10	43.19	-	-	Complete
	2	320	160	160	2	22.85	155.78	255	0	Failed
	3	480	160	160	10	57.05	91.92	390	60	Failed
	4	800	160	160	7	55.20	113.96	570	10	Failed
High strength	1	160	160	160	7	3.45	20.11	-	-	Complete
	2	320	160	160	10	7.94	106.98	-	-	Complete
	3	480	160	160	2	15.44	153.62	380	0	Failed
	4	800	160	160	3.5	36.00	152.46	735	0	Failed
Extremely High strength	1	160	160	160	10	12.95	22.21	-	-	Complete
	2	320	160	160	7	44.90	162.78	-	-	Complete
	3	480	160	160	3.5	18.39	138.32	405	0	Failed
	4	800	160	160	2	110.55	165.32	621	0	Failed



- All the cases of ratio cut spacing (S) to depth (D) =1.0 were completed and one case of S/D=2/1 at medium strength was failed. All the cases of S/D=3.0-4.0 were failed. The output means the case of S/D=1.0 can be successfully cut and split by the method.
- The scaled model ratio to real scale was 1/5, so the desirable geometry is 800 mm of cut spacing when the cut depth is 800 as well. In other words, the real dimension of 800*800*800 mm rock block is suitable for the cutting-splitting method

CONCLUSION

- The paper introduced a new method with cutting and splitting process as anti-vibration method for tunnel excavation. The mechanism was briefly explained and the feasibility was evaluated by the scaled model tests. The testing results conclude as follows.
- 1) The cutting geometry (i.e., cut spacing and depth) is the most important factors to design the rock excavation work.
- 2) The desirable ratio of cut spacing to depth was 1/1 for excavation the moderate and intermediate rocks, that ratio was possible up to 2/1 for the hard and extremely hard rocks.
- 3) According the 1/1 ratio value, working time for a specific tunnel face was calculated and the new method proposed in the study can increase the excavating rate up to 41% compared to the previous method.
- For the exact validation, a series of real scale model tests should be carried out in the future.

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