International Journal of Applied Engineering Research ISSN 0973-4562 Volume 12, Number 3 (2017) pp. 297-304

An Experimental Study on the Development of New Diamond Wire Saw Cutting System of Concrete Structure

Park Jong Hyup [1] and Lim Myung Kwan [2]*

[1] *Ok-Dang CO., LTD, Seoul City, Republic of Korea.*

[2] *Department of Architectural Engineering, Songwon University, Gwangju, Korea.*

[2]ORCID 0000-0002-0493-4439

Abstract

This article introduced the development process of the New Diamond Wire Saw Cutting System (NCC method) using a new diamond wire saw, developed independently in Korea, which solved both the environmental pollution issues caused by concrete sludge waste from the existing water-cooled concrete cutting method and the remaining dust on the section from the dry cutting method, introduced from Japan, and compared, and verified through an experimental study, the cutting performance between the developed NCC method and the existing water-cooled or dry cutting methods. The experimental verification study based on a model pier test showed that the proposed NCC method was superior to the dry cutting method in all aspects, including cutting performance and cooling effect. It is expected that the developed NCC system for cutting concrete structure will improve the demolition industry as it allows for environment-friendly demolition projects and minimize the project delay as it cuts down the cases of civil complaint.

Keywords: Concrete cutting, diamond wire saw, cooling performance, cutting time and temperature

INTRODUCTION

Amid the intense global competition among countries over eco-friendly construction technologies to cope with strict international environmental treaty that aims to save the earth, the demolition industry, which is often considered a main culprit to blame for environmental pollution due to its production of noise, dust scattering, and sludge, is recognizing the ever-growing demand on developing eco-friendly demolition technologies. While the existing water-cooled concrete cutting method shows relatively superior cutting performance to the other diamond wire saw (DWS) systems, it also produces serious environmental issues like soil or water pollution due to the production of slurry. Accordingly, advanced countries have developed alternative methods to the water-cooled concrete cutting method, including the dry cutting method or the liquid nitrogen cutting method. Meanwhile, the dry cutting method from Japan had been introduced and have been used in South Korea since 2005 as an alternative technology to the water-cooled cutting method. This dry cutting method imported from Japan solved the issues related to concrete sludge waste from the water-cooled concrete cutting method. However, it leaves dust on the section due to its limited dust collection capacity, and such remaining dust is scattered into the atmosphere or falls in the river as the cut structures are being transported, causing the secondary environmental damage. Furthermore, the remaining dust makes it difficult to clean the DWS, which results in degrading its cutting performance. Therefore, there has been consistent demand on developing an eco-friendly cutting technology in South Korea that completely substitutes for the water-cooled concrete cutting method, and at the same time, solves the issues of the dry concrete cutting method. Toward this end, this article introduced the development process of the New DWS Cutting System (NCC method), developed independently in South Korea, which solved both the environmental pollution issues caused by concrete sludge waste from the existing water-cooled concrete cutting method and the remaining dust on sections from the dry concrete cutting method, introduced from Japan, and compared, and verified through an experimental study, the cutting performance among the developed NCC method and the existing water-cooled or dry concrete cutting methods. The experimental comparison study was verified by a concrete model pier test.

PROBLEMS OF EXISTING TECHNOLOGIES AND ALTERNATIVES

Problem Analysis of the Existing Technologies

The existing water-cooled concrete cutting method uses about 2,000 liters of cooling water per hour to lower the heat generated by the DWS when it cuts concrete structure. As the cooling water mixes with concrete dust, created while concrete is cut, produces concrete sludge waste, which causes serious environmental damage like soil or water pollution.

Shown in Figure 1 is an example of such environmental pollution from a demolition project using the existing water-cooled concrete cutting method. To solve this issue, the dry concrete cutting method was imported from Japan in 2005.

As shown in Figure 2, instead of using cooling water, which is the cause of environmental pollution from the existing water-cooled cutting method, the dry cutting method uses forced cooling air at – 25 degree Celsius to cool the friction heat produced as the DWS cuts concrete structure.

Figure 1. Problem of water-cooled concrete cutting method

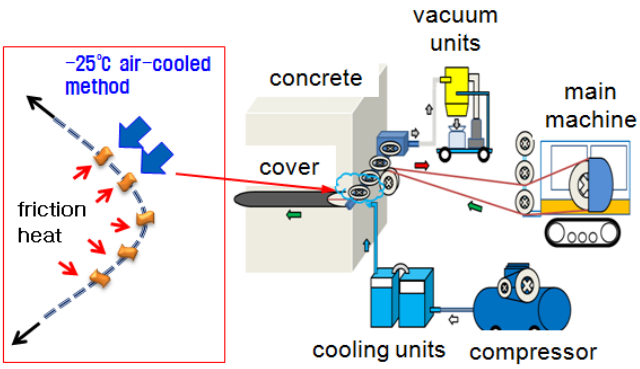


Figure 2. Schematic of -25℃ air-cooled concrete dry cutting method (Japan)

Not using water, this dry cutting method solved the environmental pollution from the water-cooled concrete cutting method. The dry cutting method uses a dust collection device to collect generated dust. However, its limited dust collection capacity causes dust to remain on the cut sections, and as discussed above, such remaining concrete dust makes it difficult to clean the DWS, resulting in degrading cut performance. (Figure 3) To solve the environmental pollution issues like the remaining dust on the cut section or the production of concrete sludge waste, the study aimed to develop a new concrete cutting technology for demolition.

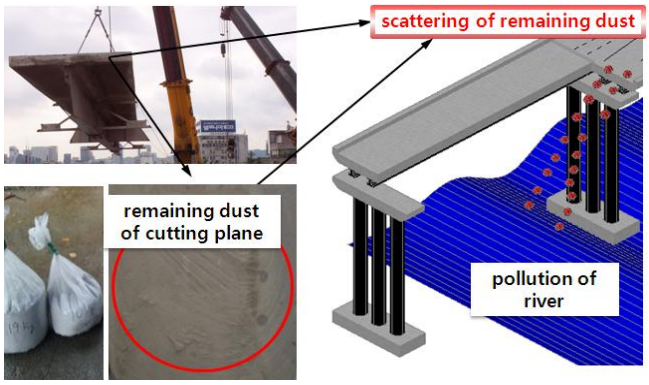


Figure 3. Problem of air-cooled concrete dry cutting method

Development Process of the NCC Method

Designing a cutting demolition technology :

As shown in Figure 4, the study first considered a new, "air+water" mist spray-based cooling method to develop a new DWS concrete cutting technology, which strived to solve the environmental pollution caused by the water-cooled concrete cutting method that uses about 2,000 liters of cooling water per hour, and at the same time, the poor cutting performance resulting from the remaining dust on the cut section by the dry concrete cutting method as the remaining dust makes it difficult to clean the DWS.

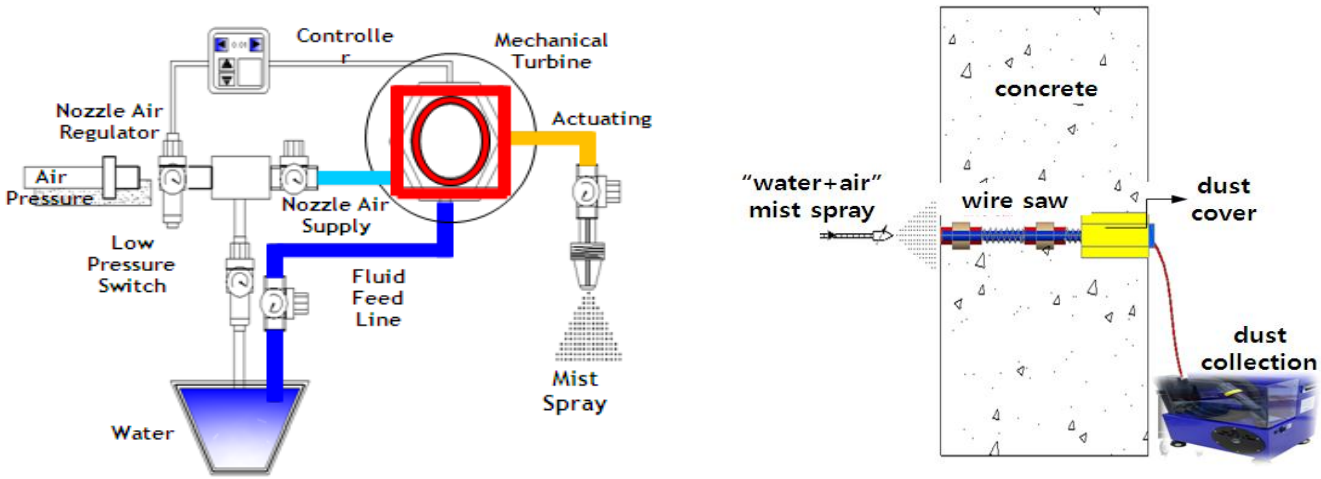


Figure 4. Schematic of "water + air" mist spray method for first idea

In the proposed "water+air" spray method, water is used to cool and to lubricate the contact surface that was cut, and air is used to clean the cut section and to facilitate the removal of remaining dust. With the water-cooled concrete cutting method that uses a considerable amount of water (about 2,000 liters per hour), water flows sufficiently into the cut contact surface in order to cool and lubricate it. With the mist spray method that uses only a small amount of water (3~20 liters per hour), hoping to tackle the water-cooled cutting method's environmental issue caused by its use of too much water, however, not enough water flows into the cut surface. Instead, it mixes cold air with water to cool and lubricate the surface. Moreover, the air used by mist spray method blasts out the remaining dust on the cut section, which is a problem of the dry concrete cutting method, to prevent the secondary environmental damage. As a part of the development process of proposed NCC method, the analysis on the DWS's cutting mechanism of concrete structures, as in Figure 5, shows that the DWS consists of beads, wire cables, lubber coating, a shank, and springs, and the beads consist of abrasive diamond grains, which play the crucial role in cutting concrete, and bonds.

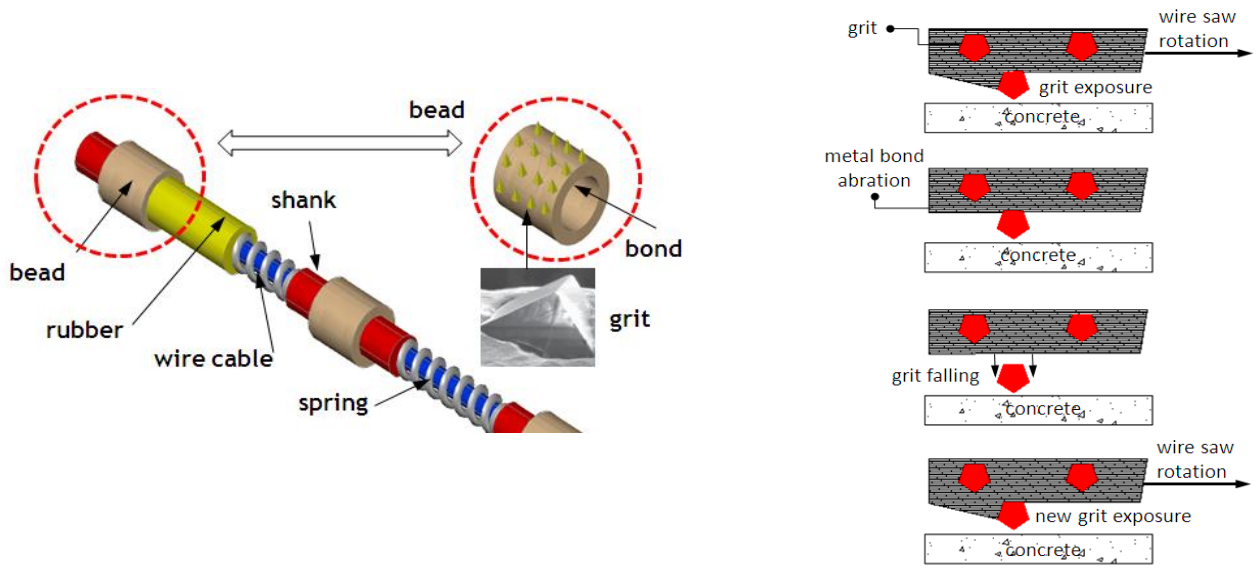


Figure 5. Diamond wire saw cutting mechanism

As in Figure 5, the exposed abrasive diamond grains in the first phase of the DWS's cutting mechanism are worn out as the bonds make contact with the concrete in the second phase, and in the third phase, as the old abrasive grains come off, new abrasive grains are exposed to continue the cutting mechanism.

However, as indicated in Figure 6, if misty air is sprayed on the section, it mixes with concrete dust, generated by the DWS, causing concrete dust to become sticky. The analysis result showed that the sticky concrete dust then may fill in the gaps between the abrasive diamond grains, preventing smooth exposure of the abrasive grains in the DWS's cutting mechanism, shown in Figure 5, and potentially degrading the DWS's cutting performance. Accordingly, the study considered other cutting methods and concluded, based on the comprehensive analysis on the test results, that no water in any type, including mist spray, should be sprayed on sections.

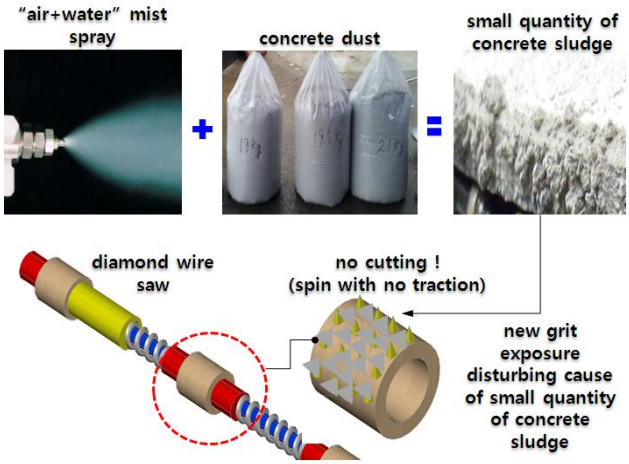


Figure 6. Problem of mist spray method

Consequently, as shown in Figure 7, the study designed a new concrete cutting method, which first implements a rotating air spray device that removes concrete dust inside the section with blasting air, and then a cleaning and cooling device located outside the section that cools the overheated DWS after cutting, and cleans a small amount of concrete dust left on the DWS. Shown in Figure 7 and Figure 8 are the overall conceptual diagrams.

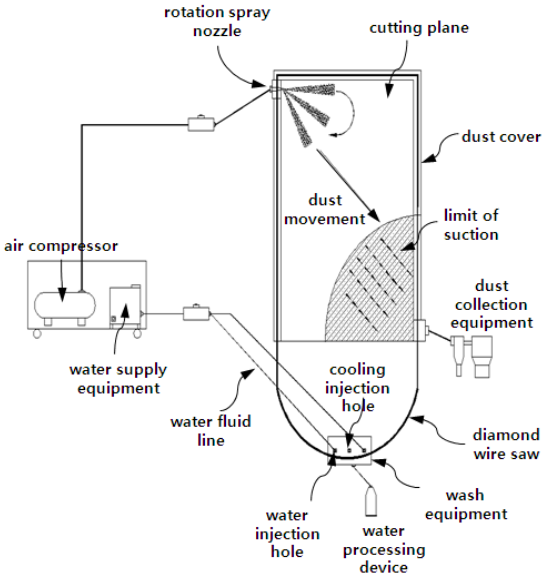


Figure 7. Schematic of new diamond wire saw concrete cutting system (2D concept)

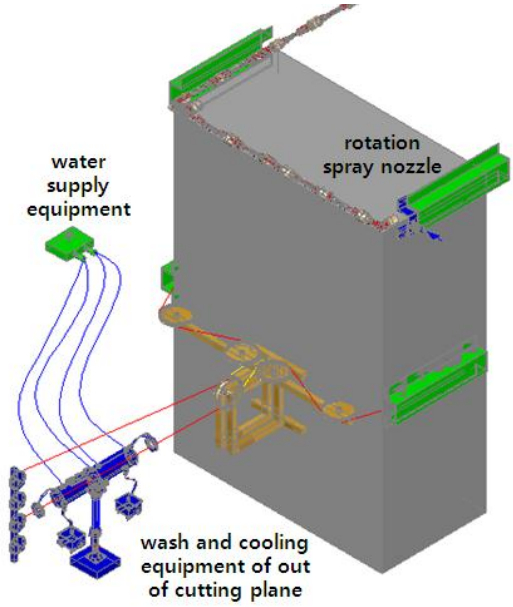


Figure 8. Schematic of new diamond wire saw concrete cutting system (3D concept)

EXPERIMENTAL VERIFICAIOTN OF THE PROPOSED NCC METHOD

Fabrication of a Cutting Model Specimen

The modelling and experimental verification aimed to verify the technical superiority of proposed NCC method over the water-cooled concrete cutting method and the dry concrete

cutting method by using a pier specimen, which is widely used in cutting demolition projects. The test strived to evaluate the cutting time, the most important performance parameter in DWS cutting, and the generated heat temperature to compare the cooling effect of the proposed method and the existing methods. The fabrication of a specimen was modelled after an actual pier cutting situation, and by considering its rectangular shape of a pier, the test produced a life-size specimen in 1.5m x 1.5m in cross section and 2m in height. The axial steel used for the specimen was D25-40EA, and the concrete strength was 24MPa. Shown in Table 1 are the properties of the specimen. Figure 9 shows the fabrication process of the specimen, and the curing took 28 days. Figure 10 shows the developed cooling device for the cut section, an installation of the device on actual specimen, and an installation of rotating air spray device that effectively removes remaining concrete dust on the section surface. While a model cutting test could consider several variables, the test performed in this study verified concrete cutting performance, which is the most important variable in the test, and the generated maximum temperature, which is linked to cooling effect. The results of the verification test are discussed below.

Table 1. Mock up specimen properties

Gmax (mm)	slump (mm)	W/B (%)	S/a (%)	Unit quantity (kg/m^3)						
				W	C	BS slag	Fly ash	Fine agg.	Coarse agg.	Admixture
25	120	47.2	46.6	122	238	63	70	414	954	2.6

Figure 9. Mock up specimen manufacturing

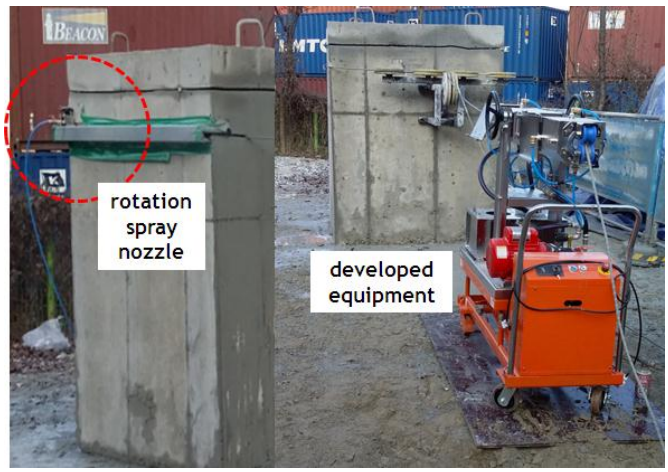


Figure 10. Test scene of concrete pier specimen

Evaluation of cutting performance

To evaluate the construction (cutting) speed among the developed NCC method and the two existing methods, the water-cooled concrete cutting method and the dry concrete cutting method, the study applied identical running speed and wire saw tension to the identical pier model specimen and conducted the cutting test. The results are shown in Table 2 and Figure 11. Cutting the identical cutting area of 1.5m x 1.5m took 28 minutes with the water-cooled concrete cutting method, 35 minutes with the dry concrete cutting method, and 30 minutes with the NCC method, showing that there was no significant difference between the developed NCC method and the water-cooled concrete cutting method. However, it showed about a 15% increase in cutting performance compared to the dry concrete cutting method. It is believed that this is because the sufficient concrete dust cleaning action by the rotating air spray has led to the smooth operation of the exposure of the abrasive diamond grains.

Table 2 Cutting performance test results

division	cutting start time	cutting end time	cutting time (minute)	cutting performance (min/m^2)
water-cooled cutting method (WCCM)	PM 14:30	PM 14:58	28	12.4
air-cooled cutting method (ACCM)	PM 16:00	PM 16:30	30	13.3
NCC method	PM 17:00	PM 17:35	35	15.5

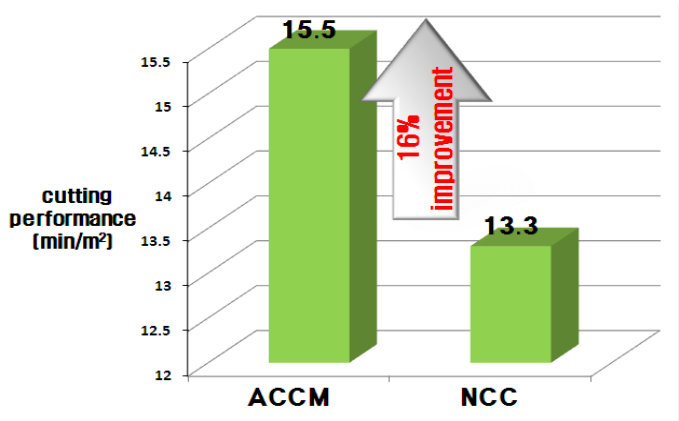
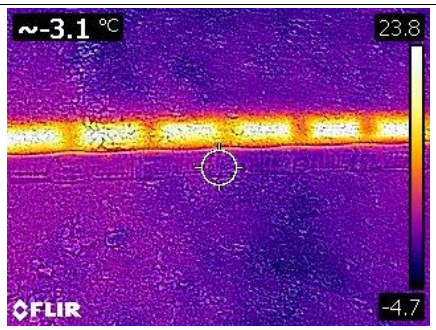
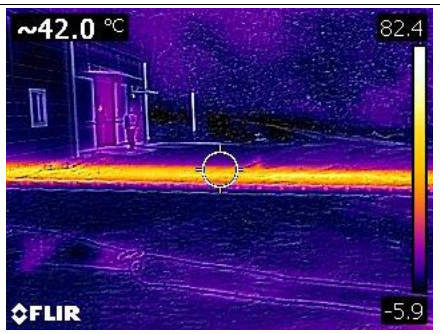


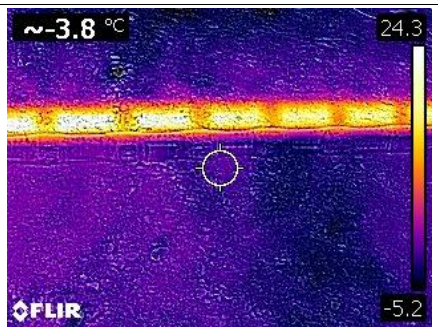
Figure 11. Comparison of cutting performance

Temperature evaluation of the generated heat

The present study compared the temperature generated by the developed NCC method, the water-cooled concrete cutting method, and the dry concrete cutting method, and images for the heat generation analysis were taken by a thermos-graphic camera at the starting point, the mid point, and the end point of the cutting process. Shown in Table 3 are minimum and maximum temperatures of DWS during the test. The upper right bar in Table 3 shows a maximum temperature of DWS, whereas the lower right bar shows a surrounding temperature. The maximum temperature of DWS generated during the cutting process based on the developed NCC method, the water-cooled concrete cutting method, and the dry concrete cutting method was 23.8 degrees Celsius, 82.4 degrees Celsius, and 24.3 degrees Celsius, respectively. The result shows that both water-cooled concrete cutting method and proposed NCC method had a similar temperature increase, whereas dry concrete cutting method resulted in a considerable increase in temperature. As shown in Figure 12, compared to dry concrete cutting method, NCC method improved temperature by about 2.5 times. Meanwhile, all three methods generated the heat below 100 degrees Celsius, which was considerably lower than 800 degrees Celsius, the melting point of abrasive diamond grains. However, it is close to 120 degrees Celsius, the melting point of lubber, which covers the gap between beads on the DWS, and it is expected that lubber will become deteriorated by heat, resulting in reducing the durability life of DWS. Although this test cut the specimen only one time and measured the result, it is determined that further research would be required to evaluate the durability life of DWS in more detail by cutting several sections and conducting a comprehensive analysis of the temperature characteristics.

Table 3 Temperature test results

div.	Max. Temperature
water-cooled method	
air-cooled method	

NCC method	

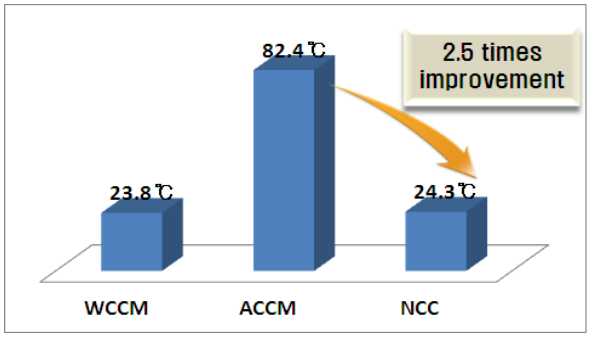


Figure 12. Comparison of temperature

CONCLUSIONS

This experimental study compared the cutting performance between the two existing methods, the water-cooled concrete cutting method and the dry concrete cutting method, and the NCC method, which was developed based on the needs of a new eco-friendly cutting demolition technology. The conclusions of this study are as follows.

1) It is known that the water-cooled concrete cutting method uses about 2,000 liters of water per hour, and a process of six hours would then use as much as 16,000 liters of water. Once mixed with remaining concrete dust on concrete cutting sections, it produces significant amount of concrete sludge waste. Not using cooling water on cutting sections, the NCC method produces no concrete sludge waste as shown in the Figure 13 below.

Figure 13 Comparison between NCC construction method and wet cutting method

2) Shown in Table 4 are the results of performance evaluation among the NCC method, the water-cooled concrete cutting method, and the dry concrete cutting method.

Table 4 Results Test

division	cutting performance (min/m^2)	Max. temperature (℃)
water-cooled cutting method	12.4	23.8
air-cooled cutting method(ACCM)	15.5	82.4
NCC method	13.3	24.3

3) As shown in Table 4, cutting performance was the highest with water-cooled concrete cutting method, and compared to dry concrete cutting method, NCC method showed an about 16% increase in cutting performance. The generated temperature was also shown to be the lowest with water-cooled concrete cutting method, and compared to dry concrete cutting method, NCC method improved the temperature characteristics by about 2.5 times.

4) According to the test results, the water-cooled concrete cutting method was shown to be more superior to the other two methods in terms of cutting performance. However, considering 2,000 liters of concrete sludge waste per hour it will generate and the resulting environmental damage, it is determined that NCC method will be a new alternative in concrete structure cutting technologies using DWS; and finally.

5) It is believed that further research would be required to evaluate the durability life of DWS in more detail by cutting several sections and conducting a comprehensive analysis of the temperature characteristics, and that the measurement test on the amount of generated dust should be conducted at the same time.

ACKNOWLEDGMENTS

This study was conducted with the research grant funded by the construction technology research project (13 construction technology A 01) by the Ministry of Land, Infrastructure and Transport/Korea Agency for Infrastructure Technology Advancement.

REFERENCES

[1] Ministry of Land, Infrastructure, and Transport (MOLIT), "*Planning Report on Intelligent and Eco-friendly Pier Technology Development*", August 2012.

[2] Han, J. S., "*Case Studies on Structure Demolition Work Personally Experienced at the Site of Cheonggyecheon Elevated Structures*", Seoul City Headquarters of Cheonggyecheon Restoration Promotion, 2006.

[3] Korea Institute of Civil Engineering and Building Technology (KICT), "*A Comparative Study on Structure Demolition Methods*", KICT 88-AD-2, 1988.

[4] Ministry of Land, Transport and Maritime Affairs, *Demolition Work Safety Guidelines*, 2012

[5] Yoo, B. I., *Demolition Methods and Construction*, Kimundang, 1980.

[6] Korean Institute of Construction and Transporting Technology Evaluation and Planning (KICTEP), "*Advanced Demolition Technologies for Eco-friendly Urban Regeneration"*, Korea Land and Housing Corporation Research Report, February 2005.

[7] Bai, Y., and W. Burkett., "*Rapid Bridge Replacement: Processes, Techniques, and Needs for Improvements*," ASCE Journal of Construction Engineering and Management, Vol. 132, No. 11, pp. 1139-1147, 2006.