RESEARCH ON PRODUCTIVITY IMPROVEMENT AND QUALITY CONTROL SYSTEM DEVELOPMENT FOR AUTOMATIC LINE STRIPE REMOVAL SYSTEM USING DRY ICE BLASTER

Eun Soo Park[1], Byung Chul Chang[1], Won Bae Lee[2], and Tai Sik Lee[1]*

[1] *Department of Civil and Environmental Engineering, Hanyang University, Seoul, Korea*
[2] *The OD Company, Seoul, Korea*
** Corresponding author (cmtsl@hanyang.ac.kr)*

ABSTRACT: Recently, the construction industry beyond the traditional construction has increased automatic construction system because it is necessary to development for skilled labor shortage, productivity improvement, cost saving, quality improvement, safety concerns. However, current line stripe removing process both labor intensive and time consuming, employing a conventional grinding type manual machine. Out of manual tasks trigger various dangers either traffic accidents or explosion of harmful gas used for finalizing removing process. Therefore, the part of automatic system is that Automatic line stripe removing is necessary to improvement in construction field. This study develops the new concept of system using previously developed dry ice blaster to improve the productivity of line stripe removal system and includes the system development to remove residuals generated after removal processes perfectly. Also, a quality control system, for work efficiency after removing line stripe, will be developed by adding post-work quality control processes to improve the work efficiency through quality check by operator after work.

***Keywords**: Line Stripe Removal System, Quality Control System, Automatic System, Productivity Improvement, Dry Ice Blaster*

1. INTRODUCTION

1.1 Research Background

High-way, road, bike land, parking lot and airport are all introduced to a driver through line-stripes using paint. Such lanes have to be redisplayed due to diverse reasons such as expansion and change of lanes, and line-stripes must be removed in advanced to do so.

Methods and systems for manufacturing such line-stripes are being automatized, but the removing process is still being performed manually in a slow processing speed with risks.

Some of the methods used for removal do not completely remove the line-stripes, and thus incompletely removed line-stripes result in confusion with the new line-stripes to a driver, depending on change of lighting and weather. In addition, grinder and sand blaster, the two traditional methods for removing line-stripes, not only remove line-stripes in the removing process, but also cause failures such as damages to the road which can be applied as unexpected physical risks to a driver.

Moreover, the traditional line stripe removal is done by partially isolating roads, and thus vehicular traffic can be influenced. The workers involved are also directly exposed to the traffic flow, increasing the occurrence level of negligent accidents, and due to a simply-repeated, manual-based process, there are differences in productivity and work quality depending on the workers in charge.

To maximize productivity of such process to remove lanes, automated line stripe removal system previously researched was developed. Based on basic research stages, a possibility of the automated line stripe removal system was confirmed through previous researches [1].

The purpose of this research, as a research for improvement of previous researches, is to develop automated line stripe removal system with performances and features enhanced than that of the previous system, and to deduct the concept for such automated system to improve efficiency in line stripe removal.

1.2 Research Scope & Purpose

First of all, the fundamental purpose of this research is to maximize efficiency of traditional line stripe-removing process. The next purpose is to seek for measures to enhance the productivity of automatization through maximizing efficiency of automated line stripe removal system using the previous dry-ice blaster system.

To improve the preexisting system, the focus was concentrated on improving processing courses of the automated line stripe removal system which include parts for line stripe-removing and courses after removal.

1.3 Research Methods

As for the methods of research, the status of previous researches was analyzed to find limitations of these researches and improvements to be made. In addition, environmental matters were analyzed to find out if any addition should be made in actualizing the system.

Through such process, a method for development of system was deducted to increase the productivity of process, the most important part.

A new system module was designed to enhance efficiency of the lane-removing part from the preexisting system tested of its possibility for line stripe-removal, and a test was run to construct optimal environments for removal.

Based on such process, performance improvements differentiated from the preexisting system were deducted.

A concept for additional processing features to enhance a completion degree of automated line stripe removal system through considering the after-process of the line stripe-removing process was deducted from an environmental aspect.

2. STATUS OF PREVIOUS RESEARCHES & IMPROVEMENTS

2.1 Status of Previous Researches

The purpose of the previous research [1] was to find out rather the dry-ice blaster was appropriate enough in performing the function of the automated line stripe removal system, which is to remove the line-stripes.

This research presents the first results of a prototype automated line-stripe removal system using dry-ice pellet made of CO^2.

Based on the test result displayed in Fig. 1, it was confirmed that the dry-ice blaster can be applied to the line-stripe removal. The test results were used to detect appropriate values for nozzle shape, spraying angle and blaster compression. In addition, along with a proposal for a rough direction for system development, a possibility to decrease labor cost was confirmed as well.

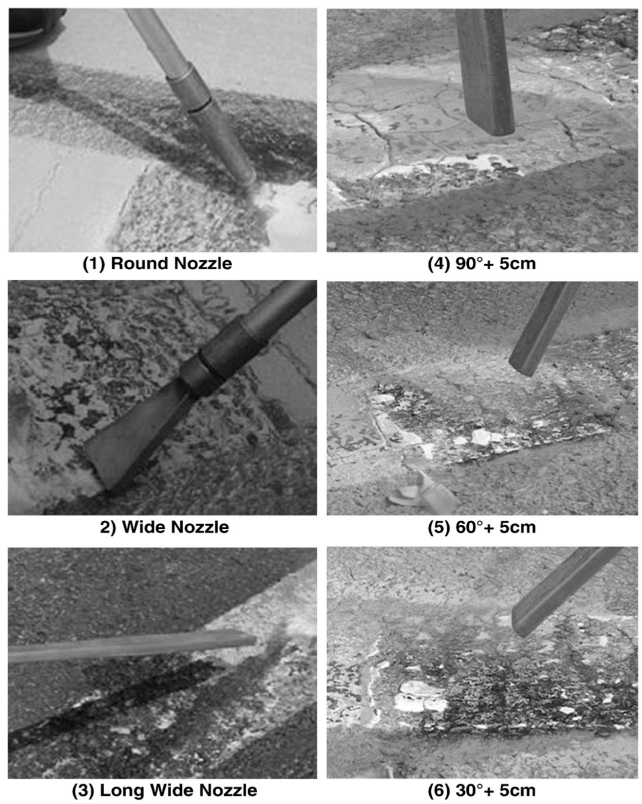


Fig. 1 Road test of blasting nozzles [1]

2.2 Limitations of Previous Researches & Improvements

Limitations of previous researches according to the courses of efficiency of removing process and process after removal were analyzed as follows.

(1) It is necessary to maximize process efficiency by enhancing efficiency of removing process.
There is a possibility that the productivity can be enhanced compared to that of the previous process.
However, it would be necessary to consider the damages to be caused to roads when the pressure is raised, to find an appropriate pressure, and to maximize efficiency of removing process through a new system.
(2) It is necessary to perform an optimal pressure adjustment through conducting a quantitative evaluation on efficiency of work after line stripe removal and on road damages.
It is difficult to make assessment on the level of line-stripes removal and of damages to line-stripes since accuracy on the level of line stripe removal is low.
Therefore, through a quantitative test data deduction for evaluation of efficiency after the line stripe removal, the system must be actualized based on an optimal pressure.
(3) It is necessary to come up with a method to practically process the residues originated after the line stripe removal is necessary.
From an environmental perspective, it is more important than any other matter to construct a treatment plant capable of processing residues. In addition, it is necessary to come up with an automated process synthetically connecting such series of courses.
(4) From a perspective of maintenance according to the removal rate after the line stripe removal, it is necessary to construct a quality-checking system.
In case the line stripe shouldn't be properly removed after the line stripe removal due to a number of environmental reasons, it is necessary to construct a quality-checking system to rerun a removal depending on the removal rate.

2.3 Additional Considerations in Working Conditions

(1) Variables based on the types of line stripe
The location and the shape of a line stripe are the variables to be considered initially in line stripe removal.
In this research, the range of line stripe is a basic research course, and a common centerline in which the width of line stripe not passing 20cm at maximum should be considered in working conditions [2].
Such range setting of a line stripe is will be the most definite section setting the range of automated system.
Depending on the recognition range of a line stripe, the length of nozzle and structure of system should be organized by considering location of system configuration and functionality.
(2) Variables based on Line stripe Painting & Construction Methods [3]
Diverse painting processes are being made to the Korea's roads depending on construction methods for line-stripes. To develop more accurate line stripe removal system, a test must be performed by considering environmental variables based on each construction method for line-stripes.
(3) Variables based on Surrounding Environments of Line stripe Removal
The line stripe removal must consider diverse environmental conditions. In particular, change of temperature and weather, road curves and cracks should be considered [2]. To do so, it is necessary to additionally consider system performance and separation distance to line-stripes.

3. INTRODUCTION OF NEW SYSTEM FOR MAXIMIZATION OF WORK EFFICIENCY

A new system was sought to maximize work efficiency. As for the new projection material to be inserted into the preexisting blaster system, a hammer was considered. However, considering the characteristics of line-stripes before the combination as a blaster system, needle scaler, a system projecting advance hit, was added. Generating output of two blaster systems in a row was initially considered, but the output pressure decreased and thus decreased the use of blaster into half. Using two blaster systems was practically inefficient cost-wise. Therefore, a new method was sought to use a new system.

3.1 Characteristics of Needle Scaler

Needle scaler is a hitting tool removing foreign matters from a location based on its impact delivered through the blow.
When the hydraulic type is used, it delivers power to each valve and cylinder through air compressor, and then the

impact is delivered to a certain location based on rotation and vibration of needles.

Generally, a needle scaler is frequently used on a metal surface, but it can be used on almost all sorts of surface including a surface treated with concrete. In particular, it is very useful for treating uneven surfaces. Therefore, it can be used on uneven and rough surfaces of the paved road, and it is very useful for treating road surfaces almost destroyed due to deterioration or abrasion

3.2 Test Outline

The purpose of this test is an application of a needle scaler for removal of stripes on the concrete/asphalt paved roads, the main subjects of this research. The Image J[1] was used to analyze the removal rate by initially removing the line-stripes through authorizing a blow in advance, and using dry-ice blaster for the second removal.

Giving consideration to the operating range(diameter: 4cm) of a single needle scaler, asphalt(fusion type) in width of 15*10cm was used.

After the initial blow, the removal rate per each spot was analyzed, and the optimal pressure of the needle scaler was selected. After the operation of identical needle scaler, efficiency of the blaster was measured and compared with the research data gained from the previous system test(Automated eco-friendly line stripe removal system) to find improvements. Then through an application of needle scaler according to nozzle, separation distance and the angle under identical conditions, a method to enhance improved productivity was deducted.

Variables applied for the test are as follows.

Table. 1 Status of test variables

Dependent Variable	Variable			
Nozzle Type	Round Nozzle (80/11mm)	Long Wide Nozzle (580/25mm)	Wide Nozzle (300/85mm)	-
Nozzle Angle	30°	45°	60°	90°
Nozzle Distance	1cm	3cm	5cm	7cm

[1]Image J is a public domain, Java-based image processing program developed at the National Institutes of Health. Image J was designed with an open architecture that provides extensibility via Java plugins and recordable macros.

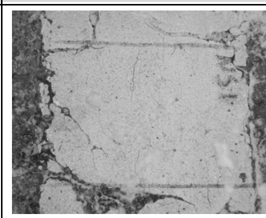
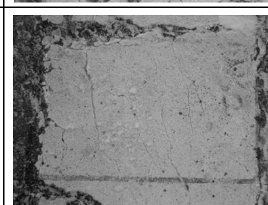
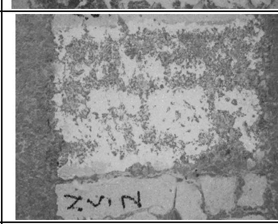
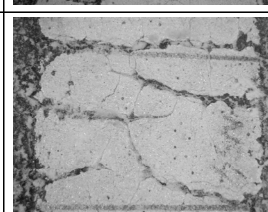
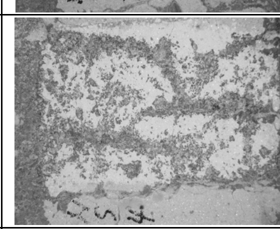
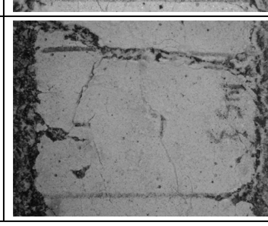
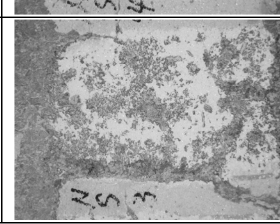
As for the pressure, 9bar, the maximum efficiency achievable by the test system, was used. However, giving consideration to the future damages to the road, up to 16 bar could've been used. In the future, an additional test should be performed to examine the damages to the road.

3.3 Test Results

Initially, a test capable of minimizing damages to the road and possibility of using a needle scaler, was performed, applying the test results at the optimal pressure of 3 bar.

As shown in Table 2, it was confirmed that the work efficiency decreased due to pressure or even caused damages to partial roads. It was found that the 3 bar was the optimal pressure.

Table. 2 Before and after using scaler

Pressure	Before Using Scaler	After Using Scaler
2 Bar		
3 Bar		
4 Bar		
5 Bar		

In the second test, after operating the needle scaler under identical conditions, according to each test variable, the removal time was analyzed to compare such data with that of system from the previous research [4]. Table. 3 is comparing test result about Long Wide Nozzle 580mm of various test variable.

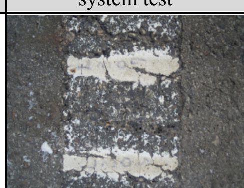
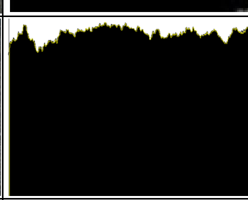
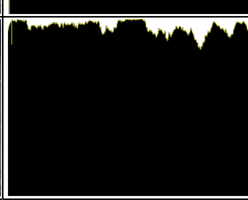
Table. 3 Comparative analysis by using Long Wide Nozzle

Angle	Previous Research (Not Using Needle Scaler)	Improved Research (Using Needle Scaler)	Efficiency Ratio (%)
30°	230 sec	116 sec	198%
60°	118 sec	73 sec	162%
90°	201 sec	75 sec	268%

Observing the test results, 90 angle test showed two-and-a half times more efficient than test result of previous research. And 30 angle test showed about two times more efficient than that, 60 angle test showed one-and-a half times more efficient than that.

Additionally, the removal rates after the first needle scaler test and the second blaster system test were deducted, using the Image J Program. The level of removal can be examined through table 4, and these figures can be applied to the basic concept of the quality checking system, for checking of efficiency of line stripe removal.

Table. 4 Removal rates analysis by Image J program

Angle	After the second blaster system test	Image J Analysis	Removal Rates
30			87.0%
60			90.2%
90			92.7%

3.4 Superiority of Test with Addition of Needle Scaler

It was confirmed through the above test results that an addition of a needle scaler system is effective for maximizing the work efficiency of line stripe removal compared to the work efficiency of previous dry-ice blaster. In addition, the process of using optimal pressure instead of unconditionally using the maximum pressure made contributions to resolving issues of damages to the road.

4. CONCEPT FOR ENHANCED COMBINED AUTOMATED LINE STRIPE REMOVAL SYSTEM

4.1 Loading Residue Processing System

The process of removing the residues created in the process of removing line stripe is just as important as the process of removing the line-stripes. As for the previous labor force for line stripe removal, the environment of work resulted in contamination due to road contamination and dust creation unless the residues were cleaned by such labor force.

Therefore, a residue processing system capable of effectively removing the residues with cyclone is to be loaded, in order to deduct a method to remove residues through vacuum suction.

The courses can be classified into processing of the first residues created after the needle scaler's blow, and the processing of the second residues created through the dry-ice blaster system.

4.2 Deducting A Quality Checking System Development

It is necessary to develop a quality managing system in order to check the residues still remaining on the road after residue processing, the final stage of the line stripe removal, is complete in order to transfer information regarding the quality of the line stripe removal, to the worker in real-time. Separately from automatization of line stripe recognition, an independent system monitoring the line stripe removal should be constructed.

Depending on the moving direction of system, the movement is progressed toward the direction of the line stripe. However, for an accurate control, It is necessary to construct a system monitoring the distinction of removal rate in real-time such as the Image J Program to allow the worker in charge to receive the status of work progress in real-time

4.3 Concept for Development of Enhanced System & Process

Configuration of a work system which can be considered in the course of research, except for attachment of work system and transportation vehicle, can be classified into two fields of sensor/control and control system. Configuration of main modules per R&D system is as follows.

Table. 5 Main modules for R&D system

Div.	Module	Configuration
Vehicle	Vehicle Module	Vehicle
Sensor/ Control	Line stripe Sensor Module	Vision Sensor System Monitoring Module
	Location Control Power Module	Location Control System Monitoring Module
	Quality Check Sensor Module	I/R Sensor Monitoring Module Quality Signal Transfer System
Removal System	Hitting System Module	Nozzle(Needle Scaler) Air Compressor
	Blaster System Module	Nozzle/Blaster Dryice Pellet Air Compressor
	Pneumatic Process Module	Pneumatic Inhaler Pneumatic Storage Cyclone/Vacuum System

The basic process of concept for combined automated line stripe removing system including needle scaler, an improved advance blow system, pneumatic processing system, and quality checking system is as follows.

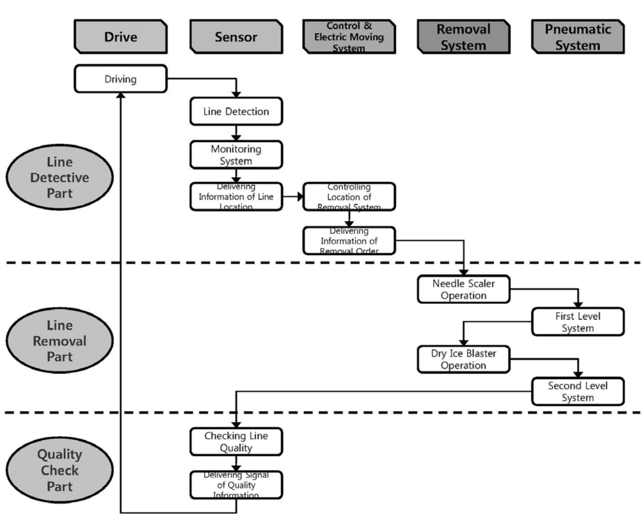


Fig. 2 Process of main concept for combined automated line stripe removal system

5. CONCLUSION

The purpose of this research is to maximize productivity of the previous line stripe removal system, and to improve its work process.

To do so, an additional attachment of needle scaler, a new blow system, was proposed and possibility of enhancing productivity was confirmed through comparing it with the previous system. In addition, by deducting concepts for residue processing module, an additional function, and quality checking system to improve detailed processing of the combined automated line stripe removal module, a contribution was made to enhancing the performance of the combined automated system.

In the future, a research is to be performed to supplement and improve problems which may additionally occur through constructing and demonstrating a system in which these system functions are combined.

ACKNOWLEDGEMENT

This work was supported by Korea Expressway Corporation, and by the 2nd Brain Korea 21 funded by the Ministry of Education and Human Resources Development.

REFERENCES

[1] Leonhard E. Bernold, Tai Sik Lee, Ja Kyung Koo, Deuk Soo Moon, “Automated eco-friendly line stripe removal system”, *Automation in Construction*, 19, pp. 694-701, 2010.

[2] Korea Road & Transportation Association, “Special Specifications about Road Construction - Ministry of Land, Transport and Maritime Affairs”, *MLTM*, 2009.

[3] National Police Agency, “Manual for Install and Maintenance of Traffic Road Stripe”, Basic Manual 2 Vol. 41, Traffic 2-2, 2005.

[4] Ja Kyung Koo, Deuk Soo Moon, Leonhard E. Bernold, Tai Sik Lee, “Study on the Application Dry-Ice Blaster for Development of Automatic Stripe-Line Removal”, *The Magazine of Korean Society of Civil Engineers*, Vol. 29, No.2D, pp. 252, 2009.