Development of CFT Method and IT Sensing for Seismic Reinforcement of Structures

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Abstract

This study proposed a CFT (Concrete Filled Tube Column) seismic construction method and a real-time safety maintenance system. It is the latest structural type that increases strength and ductility and secures economic efficiency by pouring concrete inside the steel pipe. The method developed in this study was compared with the general section increase method, and the rebar installation process, formwork installation, and dismantling process were omitted, so the experiment was conducted with a method that reduced schedule and reduced construction costs to verify the performance. In this paper, the effect of seismic reinforcement was analyzed through experiments on the bolt-assembled CFT seismic reinforcement methods, one of the seismic reinforcement methods by strength and stiffness reinforcement. Therefore, it is a method that shortens the construction period and reduces the construction cost. A bolt-assembled CFT seismic reinforcement methods is a technique developed to easily reinforce existing buildings using bolts by applying the excellence of the CFT method.

Keywords: CFT, Seismic construction, Real-time, Safety maintenance system, Ductility

1. Introduction

1.1. Current status and problems of existing construction methods

Concrete-filled steel tube structure (CFT) has high ductility and is very effective in buckling and strength due to the external steel pipe structure and the internal concrete filling. However, it takes a lot of time for the site to move the steel pipe frame to join it by welding and to erect the member [1]. In addition, quality problems also arise due to poor concrete filling in the lower part of the structure even in field construction. Existing seismic reinforcement technology has a problem that the construction period is prolonged due to the complicated construction process. Due to this, labor and construction costs have been an economic burden [2]. Therefore, the purpose of this study is to simplify the construction procedure to secure safety and economics.

1.2. Background and purpose of research

In response to the problems that emerged during the last Po-hang earthquake of Korea, The Ministry of Public Administration and Security announced measures to improve earthquake prevention in May 2018. The purpose of the project is to improve the contents of emergency disaster messages and to prepare measures to resolve non-receipt messages, and to continuously strengthen the earthquake warning system [1][2].

Based on this, the government is expanding investment and support to improve the seismic rate of domestic buildings, strengthening safety regulations and shortening the period of nationwide fault survey [3]. The government has come up with a series of measures to improve the safety inspection system of facilities and strengthen the nation's ability to respond to earthquakes through nationwide earthquake evacuation drills and supplement public action guidelines.

Therefore, in this study, we would like to analyze the weaknesses of the existing seismic reinforcement method, study the countermeasures, and finally present the optimal seismic reinforcement method to be applied to the building.

2. Main subject

2.1. Necessity

As major projects in Busan are being invested and developed in the coastal areas of Busan, local residents are feeling uneasy about safety.

Liquefaction was cited as one of the types of earthquake damage in the 2017 Po-hang earthquake, and Busan also raised the possibility of liquefaction due to earthquakes in vulnerable areas such as floodplains and landfills.

The seismic wave characteristics depend on the interaction with the ground when there is a structure on the soft ground, the structure built on the soft ground receives greater seismic behavior than the structure built on the rock. As a result of analyzing vibration damage with the thickness of the ground and maximum ground acceleration, West Busan Distribution District, Sasang-gu, Dongnae-gu, Busan Port, Suyeong River areas were classified as dangerous [Figure 1].
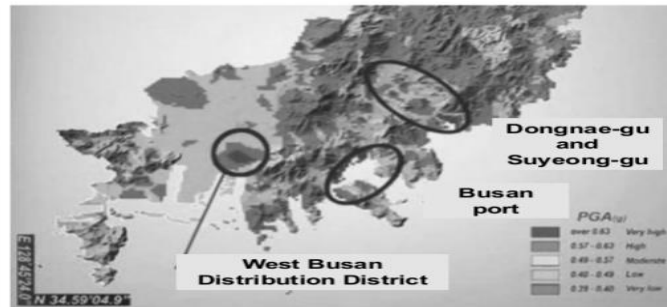

Figure 1. Liquefaction and Busan earthquake disaster map (Busan development institute)

The redevelopment of Busan Port and the development of Eco Delta Smart City are one of the core projects of Busan Metropolitan City, and Busan's largest 33km2 "International Free Logistics City" is being promoted in Gangseo-gu and Gimhae. Busan Port's redevelopment project is a large-scale project that consumes a total of 8.519 trillion won (2.388 trillion won in infrastructure and 6.48 trillion won in upper facilities) [Figure 2].

Figure 2. Location characteristics and status of Busan port and view of neighborhood area (Busan City Hall, BPA Busan Port Authority)

2.2. Development of seismic reinforcement method using CFT columns

The seismic reinforcement technique of CFT column improves the seismic performance of existing concrete by installing CFT joint on the surface of the existing reinforced concrete member and then welding and unifying the CFT column to the junction and injecting high performance mortar [4][5]. As steel pipes act as formwork, formwork construction is unnecessary, and the construction period is shortened, the deformation capacity is large and the seismic performance is also displayed for the action of repeated loads [6][7].

In addition, it is strong against torsion as a member of a closed section, and has the advantage of mitigating the limit of thickness ratio of plate width compared to pure steel pipe, which is advantageous for local buckling [8]. The existing method of reinforcement of seismic reinforcement of column augmentation was difficult to install rebar next to existing columns, difficult to install formwork, and limited height due to concrete side pressure [Figure 3]. However, the construction of the CFT seismic reinforcement method is carried out from outside without the demolition work inside, so reinforcement work is possible during internal use.

In addition, the existing column-increasing seismic reinforcement method had disadvantages such as rebar installation process, formwork installation process, height limit of concrete placement, separation of formwork dismantling process, and increase of construction cost. However, the CFT seismic reinforcement method has the advantage of reducing time and structure dismantling process being omitted.
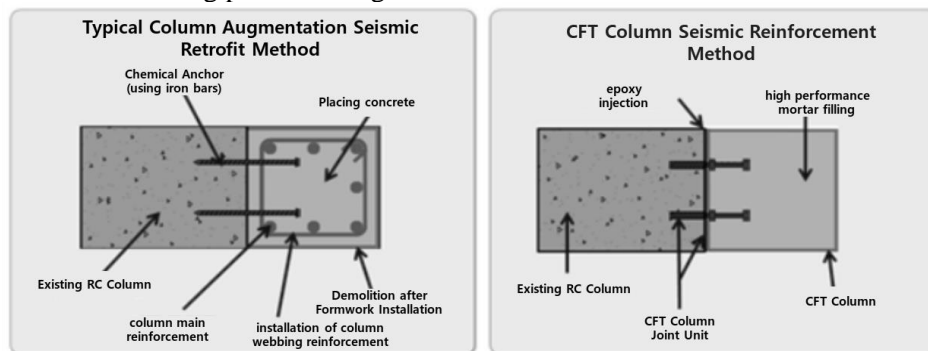

Figure 3. Comparison between the normal column-increasing seismic reinforcement method and the corresponding technology development method

2.3. Development of real-time remote safety management system for seismic reinforcement structures

Users can set the required level of control values, and the program provides a step-by-step notification service to users when they detect data that exceeds the user's set control values. In addition, the program is developed to prevent unexpected accidents in advance through the function of sending automatic messages to mobile phones when users are absent. This is applied to IoT-based real-time wireless remote safety management system that can check the safety status of structures in real time after seismic reinforcement [9][10].

Through this, it is possible to secure the reliability of the application of the seismic reinforcement construction method, as well as to secure the safety of emergency situations from the inspection and response system to the preemptive response system [11]

2.4. Performance experiment

2.4.1. Detailed development review of construction of CFT seismic columns

Through detailed development of CFT column joints for seismic design of high-rise buildings, detailed diagrams and specifications for CFT diaphragm joints are prepared, and based on this, construction of PC-CFT column joints for logistics facilities is developed.

2.4.2. Experimental plan

The experimental plan of two-story frame full-size for actual application of the site, such as coastal ground and landfill, is carried out, and based on this, the behavior of CFT seismic-resistant columns and existing columns, including the resistance and displacement, is analyzed [Figure 4].

To check the performance of the CFT seismic reinforcement technique, experiments were conducted on non-reinforced subjects(A) and on the test subjects(B) reinforced with concrete filled steel tubing. The details and reinforcement types of the subject are as follows.
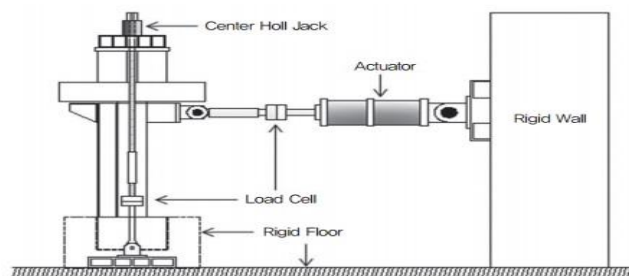

Figure 4. Conceptual diagram of CFT column experiment

2.4.3. Experiment result

In the case of (A), most cracks occurred within 150mm of the end of the column, and crushing occurred at the corner of the column. In $6\triangle y$ the cladding concrete was completely eliminated up to 300 mm below the column.

(B) produced minor cracks at the end of the tensile side in $2\triangle y$. Even on the same column surface, no cracks were found near the concrete filled steel pipe (CFT). In $4\triangle y$'s 2-Cycle, a diagonal-shaped crack occurred at a 150mm height point at the bottom of the existing column

toward the end of the reinforced column. As the repetitive load progressed, the width of the crack increased and the clad concrete below the diagonal was eliminated.

Looking at the load-displacement hysteresis curve for (A) and (B), (B) has a maximum load of 1.8 times greater than (A) and a displacement of 6mm less at the time of peak load, so the strength and stiffness are significant and the seismic reinforcement effect is considered to be excellent [Table 1].

Table 1. Summary of experimental results

Specimens	Yield Load(kN)		Max. Load(kN)		Ultimate Load(kN)	
	Displacement(mm)		Displacement(mm)		Displacement(mm)	
	Push(+)	Pull(-)	Push(+)	Pull(-)	Push(+)	Pull(-)
(A)	71.91	64.73	95.89	86.31	81.50	73.37
	26.2	19.40	45.88	39.05	92.54	81.36
(B)	130.97	188.85	174.60	158.40	148.43	134.70
	24.12	32.98	39.10	62.55	107.43	133.50

2.4.4. Establishment of a combined platform for measurement, analysis, and evaluation for regional IoT-based disaster response

The automation platform for all processes of measurement, seismic performance evaluation and verification of CFT seismic column is established and the database base is built based on the analysis results for frame behavior, determination of the performance level of building and seismic performance evaluation [Figure 5].
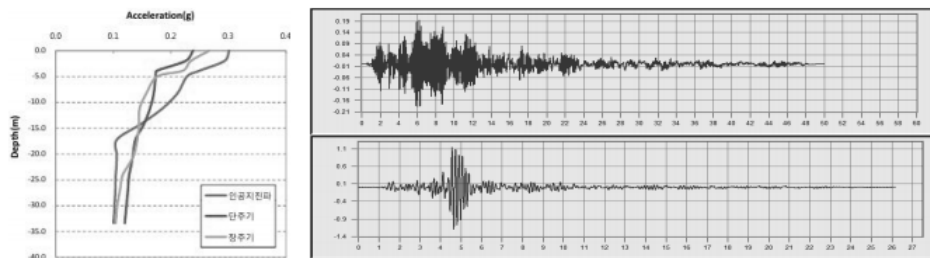

Figure 5. Seismic wave calculation by ground response

3. Conclusion

This study presented the CFT column seismic method and real-time safety maintenance system, and it is a state-of-the-art structure that increases strength, ductility, and economy by placing concrete inside the steel pipe and it can be used as a seismic method to solve the factors that occur in the existing construction method.

The construction method developed in this study is a method in which the construction period is shortened and the construction cost is reduced because there is no need to install or dismantle the rebar and formwork compared to the general cross-sectional expansion method. In addition, it is possible to prevent secondary accidents against disasters by developing disaster response processes through real-time remote management safety systems to enable emergency evacuation and rapid recovery of damage.

Through future experiments, the problems and solutions of application for improving seismic performance will be analyzed and applied to future research and development.

Acknowledgements

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