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Development of CFT Column Seismic Reinforcement Method to Secure Safety of School Facilities

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Abstract

Seismic technology has emerged as a future technology that can create high added value in the overseas construction market as the damage caused by earthquakes has increased due to population growth and urbanization worldwide. In particular, domestic school facilities are the residence space for students who lack self-protection ability, and large-scale damage is expected in the event of an earthquake due to the uncertain seismic performance of the school building used as a shelter during a disaster. Therefore, in this paper, we intend to study the method development to secure the structure safety through the performance enhancement using the CFT column for seismic reinforcement of existing school facilities. To prove the mechanism various experiments were actually applied by making four test specimens (PRBA, TRBA, PRBN, TRBN Destructive form), and the performance of the development method could be compared and reviewed through cracks and mutations occurring in the structure.

Keywords: *CFT column, Seismic reinforcement, Safety, School facilities, Strengthen*

1. Introduction

Since the largest earthquake in Korea's seismic history occurred in Gyeongju in September 2016, it has been argued that Korea is not a safe zone for earthquakes, especially as the recent Sichuan earthquake has increased the frequency of earthquakes inside the earthquake plate, which has led to the potential for a large earthquake. Amid the growing anxiety over earthquakes, the government is continuously strengthening its anti-seismic design regulations as one of its measures to prevent earthquakes, and the domestic earthquake-related construction market is expected to continue to grow as it is pushing for measures to strengthen the anti-seismic level of existing public facilities [1][2]. As global population growth and urbanization have caused massive damage caused by earthquakes, earthquake-resistant technology is emerging as a future technology that can create high value-added products in overseas construction markets [3].

In order for domestic construction companies to secure technological competitiveness in the global construction market and dominate the market, they should expand investment in earthquake-resistant technology development from a long-term perspective and strengthen their capabilities in advanced seismic technologies [4][5]. In particular, domestic school facilities are residential spaces for students with insufficient self-protection capabilities, and due to the uncertain seismic performance of school buildings used as shelters in case of

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disasters, massive damage is expected in the event of an earthquake [6]. Therefore, in this paper, we would like to study the development of construction methods to secure the safety of structures through performance reinforcement using CFT column of existing school facilities.

2. Subject

2.1. Status of related technologies at home and abroad

Seismic remodeling of the school building of the Unreinforced Masonry structure can cause the following problems. In the case of a non-reinforced masonry structure of a regular concrete block, which is a structural system that divides the interior of most aged school structures, it can cause serious damage, such as conduction of members, since there is little lateral resistance capability in the direction outside of the surface when an earthquake occurs [7]. Column is the most important central structure of the structure. In low-rise buildings, the pillars are very weak compared to beams due to their small axial forces, so the columns are more likely to be destroyed than beams [8].

The destruction of these pillars is a factor in the sudden collapse of the structure, which takes a very short time to collapse than the destruction of beams. In the case of exposed columns between openings, there is a risk of shear failure. In most school structures, windows often end up in the middle of the floor height at the bottom of the window frame. In this case, the column located on the upper part of the masonry wall is changed to a single-weekly behavior pattern, which increases the probability of shear failure compared to the ordinary column, causing the structure to be subjected to deliberate destruction [9][10]. The types of structural risk occurrence of the Non-ductivity RC Structure are as follows. For low structures built before 1988 when seismic design was not mandatory, the sectional rebar ratio of columns and beams is often not satisfied with the current seismic design requirements.

As a result, major structural members lack ductivity in response to the action of external lateral forces, which is more likely to be destroyed early as it is similar to simple concrete movement rather than rebar concrete movement.

2.2. Development of seismic retrofit technology using CFT columns

After the development of the seismic reinforcement method using CFT columns, the prototype production should be developed in the following three ways. The first is to develop a construction method that makes full use of the strengths of steel pipes and concrete. The second is the development of a construction method that can be reinforced while using the interior of the classroom and finally, a construction method with excellent reinforcement effect must be developed with members of the same size as the general expansion method.

2.3. Experimental overview

Four prototypes were manufactured to check and verify the results of the product's resistance to lateral loads. The criteria for the test object were the exterior columns of the first floor of the school, and the gravity load was applied to the upper part of the column at 590KN, and the force was applied repeatedly to 0.11mm/sec by the displacement control method according to the displacement amount of the load applied by the actuator.

In addition, an inclinometer was installed at the top of the column during the lateral load test and measured at intervals of two minutes through wireless remote measurement [11].

The members are 1,800mm long, the column sizes are 300mm long and the main iron bars are 8EA-HD22, and the HOOP ends are 100mm apart and the center is 300mm apart. The size of the CFT Square Hollow Section Steel Tube is 300×200×9 (width×length×length×thickness).

(1) Material properties of the materials used

Strength and testing methods of the materials used, and the results are as shown in [Table 1-5] below. The effect of the development method on the building can be grasped through the results of the research test [12][13].

Table 1. Ingredients and testing methods

Ingredients and Strength	testing method
- Concrete : fck=24MPa	KS F 2405_concrete compressive strength test
Reinforcement: fy=400MPa	KS D 3504 (2011)_steel bar for iron concrete
- Steel Pipe : Fy=235MPa (SS400)	KS B 0802 (2003)_Metallic Material Tension Test
anchor bolt: Fu=400MPa (SS400)	Presented by the client

Table 2. Test results for compressive strength of concrete

Sample serial number	Destructive Load (N)	specimen cross-sectional area(mm2)	Compressive strength on 28th (MPa)	design basis strength (MPa)
1	268,500	7,854	34.2	24
2	287,600	7,854	36.6	24
3	265,000	7,854	33.7	24
Judgment result: design strength is higher than 24MPa				

Table 3. Test results for rebar yield strength

sample size	yield strength (MPa)		Tensile strength (MPa)		elongation rate (%)		note
	standard	Result	standard	Result	standard	Result	
13	400 +	522	560+	650	16+	19	SD400
22	400+	486	560+	627	16+	17	SD400
Judgment result: It is found to be higher than the SD400's strength.							

Table 4. Test results for steel plate yield strength

sample size	yield strength (MPa)		Tensile strength (MPa)		elongation rate (%)		note
	standard	Result	standard	Result	standard	Result	
9T	235+	351	400+	469	17+	39	SS400
Judgment result: It is found to be higher than the SD400’s strength.							

Table 5. Test results for tensile strength of anchor bolts

sample size	Destructive Load (N)	Tensile strength (MPa)		note
		standard	Result	
M16	99,800	400	496	SS400
Judgment result: It is found to be higher than the SD400’s strength.				

(2) Design drawings and experiments of prototypes

[Table 6] shows four types of column specimens to support the seismic load, and [Table 7] shows the results of compression and tensile in the specimen. Through the actual test object load displacement test, the optimum performance for earthquakes can be confirmed [14].

Table 6. Prototype classification

No.	Identification of experimental objects	CFT Reinforcement (O/X)	Beam installation (O/X)	Anchor installation (O/X)	direction of application of force (Parallel/ Right Angle)
1	PRBA	O	O	O	Parallel
2	TRBA	O	O	O	Right Angle
3	PRBN	O	O	×	Parallel
4	TRBN	O	O	×	Right Angle

Table 7. Test results

Test object type	Test results			
	Maximum load (kN)		Displacement at maximum load (mm)	
	+ direction (compression)	- Direction (tensile)	+ direction (compression)	- Direction (tensile)
(A) PRBA	291.0	-216.1	88.7	-88.6

(B) TRBA	225.5	-231.2	88.5	-88.4
(C) PRBN	281.4	-164.4	88.3	-58.6
(D) TRBN	178.5	-168.9	58.2	-59.1

(A) PRBA Destructive form

(B) TRBA Destructive form

(C) PRBN Destructive form

TRBN Destructive form

Figure 1. Destruction status by test object

Various experiments were actually applied by making four test specimens (PRBA, TRBA, PRBN, TRBN Destructive form), and the performance of the development method could be compared and reviewed through cracks and mutations occurring in the structure.

(3) Form and hysteresis characteristics of the test specimen

In the case of column specimens subjected to cyclic loads, it is difficult to determine the criteria for yield and ultimate failure but in this study, the intersection of the lateral force and load-displacement curve corresponding to 75% of the maximum load was defined as the yield displacement. In addition, the ultimate strength was defined as the time when the load decreased to 85% after the maximum load in order to apply the same to the reinforced fracture mode and the confined concrete fracture mode.

When the maximum load for each specimen was compressed (+), the specimen of PRBA was the largest with 291 kN, and the specimen of TRBA, PRBN, and TRBN was 225 kN, 281 kN, and 178 kN. The maximum load for each specimen was tensile (-), and TRBA specimens were the largest with 231 kN, and PRBA, PRBN, and TRBN specimens were 216 kN, 164 kN, and 169 kN [Table 6]. In addition, the picture of the test result for the test is shown in [Figure 1].

3. Conclusion

After this research, the company plans to maximize sales by establishing promotion and marketing strategies with differentiated technology and products by securing verification of seismic reinforcement performance. In the case of similar technologies, the existing finishing removal and restoration work is required for reinforcement, but in the case of the relevant development project, the removal of existing finishing materials is easy because there is no restoration work and there is no reinforcement work and the dismantling process of the formwork, so the construction period can be shortened.

Due to the development of earthquake-resistant construction methods that improve construction and economic feasibility, the location of reinforcement can be applied in various ways as needed and the size of reinforcement members can be adjusted according to the condition of lack of internal strength. Therefore, there are various fields of utilization. Interest in the design of earthquake-resistant steel for school buildings in Korea is expected to increase the market for development technology and increase market sales. The future research direction needs to improve the construction process to improve the efficiency of the construction part related to technical use and the economical efficiency of the overall construction cost. In order to improve the completeness of the research, we plan to discuss detailed research results by applying the demonstration site technology.

In addition, it is necessary to conduct repeated horizontal load tests and finite element analysis to collect experimental analysis data on the inelastic behavior of reinforcing members through additional experiments. The seismic performance of the reinforced column is verified through repeated horizontal load tests, and the inelastic behavior of the reinforced column can be predicted through finite element analysis.

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