ARCHITECTURAL RESEARCH, Vol. 11, No. 2(December 2009), pp.27-34

Evaluation of Injection Property on the Crack Repair Method by Installing the Packer with Right Angle Drill Type in RC Structure

Jinsoo Ko, Sungbok Lee, Byungyun Kim and Cheho Seo
Ph. D, President of Meeram I.F, Seoul, Korea
Ph. D, Principal Researcher of Housing & Urban Research Institute, Korea National Housing Corporation
Ph. D, Senior Researcher of Korea Concrete Institute(KCI) Research Center
Professor, Department of Architecture, Konkuk University, Seoul, Korea

Abstract

The purpose of this study is to investigate the problem of crack repair materials and methods in existing concrete structure and to propose the effective injection method on crack repair by packer type. The result of this study is as follows. It is investigated that the crack width in the inner matrix of concrete structure is decreased about 30-40% than that in the surface of the concrete structure. Also it is showed that the possibility which could be monolithic with injection part became higher if the injection part is installed near to surface of concrete on the punching method to vertical direction against crack area. The injection of repair material can be poured smoothly under about 10N/㎟ pressure on the condition that cracks are monolithic with injection part without dust by drill. The method which is effective injection for a repair material is the punching method in compliance with coredrill. But, the research continuously is necessary about minimum injection pressure.

Keywords : Crack, Repair Method, Right Angle Drill Method, Packer, Injection, Punching

1. INTRODUCTION

1.1 Research background and aim

Concrete cast in the field experiences cracks due to various causes such as change of volume and temperature in the process of curing. The cracks occurred in concrete can reduce the longevity of a building by damaging inner structure of concrete or corroding reinforcing bars if ignoring the cracks even though the cracks are as slight as they do not damage the strength of the structure. Thus, the cracks are required to be repaired at a proper point so that problems occurred during the life time of the building can be minimized. The success of repairing cracks depends on not only selection of optimum materials by considering characteristics of cracks but also methods to inject the selected materials densely to the inside of the cracks. That is what method is chosen for the repair is important[1].

If materials are not injected densely into the inside of cracks, the same problem may occur again or the bigger problem may occur, and therefore, a following check up on the condition of injection of repairing materials is required after completing the reconstruction.

Extraction of core is the way to check the condition of injection of repairing materials after completion of reconstructing cracks, but it can damage the structure, leading to being impossible to extract the core. In particular, in the case of a newly established building, since the situation is worse, the process for verification of crack repairs is not conducted normally.

Therefore, this study analyzes the types of cracks subject to existing buildings and examines the characteristics of injecting materials and injection methods, and finally it intends to present measures to inject materials densely into the inside of cracks.

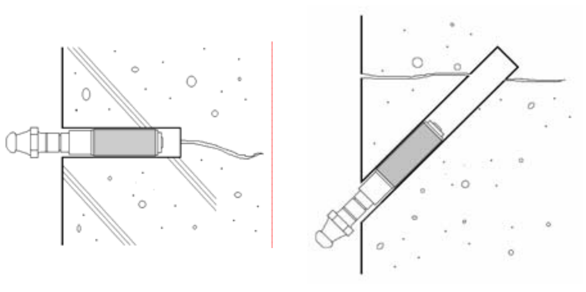
1.2 Research scope and methodology

Methods to repair cracks in concrete include progressive trenching, injection, and filling method as the following Table 1 and injection method is the most commonly used method in construction. Injection method is divided into two according to the methods of injecting repairing materials: syringe grouting method and packer grouting method, and double packer grouting method is used by drilling in a right angle or diagonal angle according to the types of problems or characteristics of materials as stated in Figure 1[2].

Right angle drill method is used for cracks in thin slabs or walls of wall column structure like apartments. This study examined characteristics of injecting repairing materials of a right angle drill repair method that is most commonly used in crack reconstruction of apartment houses.

Table 1. Crack repair methods and materials

Methods	Used materials	Ways of construction
Progressive trenching method	polymer-cement paste, cement filler, elastic waterproof acrylic or urethane coatings	Part application Whole application
Injection method	epoxy resins, urethane resins, polymer cement slurry	Syringe injection method Packer injection method
Filling method	epoxy resins, urethane resins, polymer cement slurry	V-cut way U-cut way



Right angle drill method (90˚) Diagonal angle drill method (45˚)

Figure 1. Installation methods of packers

Injection method to use packers is as the following order in Figure 2. Generally, it is proper to inject naturally at a low pressure when using packers. It is because if injecting concrete at a higher pressure than the pressure strength of concrete, it can damage the object. In order to inject repairing materials at a low pressure, cleaning the injection part, installing packers and injecting repairing materials among the processes of construction as seen in the Figure 2 are important variables. Therefore, by setting them as major factors, this study performs an investigation on patterns of causing cracks in existing buildings and characteristics of injection by applying right angle drill method and aims to present improvement measures to the problems occurred in the field.

Examination on cracks
↓
Background procession
↓
Drilling injection parts
↓
Cleaning the injection parts
↓
Installing packer
↓
Sealing the cracked area
↓
Injecting repairing materials
↓
Finishing

Figure 2. Order of construction in injection method

2. INVESTIGATION ON CURRENT SITUATIONS

2.1 Investigation outline

Currently the crack repair of the concrete structure form of the crack which appears in the concrete surface according to work condition is selecting a repair method.

In particular, since the right angle drill method places the injection part in about 1 ~ 5 ㎝ inside of the concrete, the possibility of intersection point between a crack and the injecting track is different according to the types of the inner parts of cracks. If injection part does not meet with a crack, repairing materials can not be injected and therefore, a strong pressure is added to the inside of the injection part but this pressure can damage the structure when it is higher than the strength of concrete. As a result, packers should be installed by considering the characteristics of cracks sufficiently.

Hence, this investigation is conducted in order to examine characteristics of cracks in the inside of the structure in order to examine characteristics of injection when applying a right angle drill method.

2.2 Investigation items

The items of the investigation on characteristics of cracks inside the concrete structure for the examination on the correct installation methods of packers are as follows:

1) The direction of crack progression inside the structure.

In order to evaluate the possibility that the injection part of packers and cracks could join, an investigation on the inside shape of cracks in existing buildings was conducted.

2) Change of crack width inside of the structure.

Crack width appeared in the surface of the structure and the degree of changing the width inside the crack were measured.

2.3 Investigation method

The investigation for the characteristics of inside cracks includes a wall style structure building established in 2003 and a reinforced concrete apartment which was built in 1978 (about 30 years old) and is subject to demolition. With the two subjects, investigations on characteristics of inside cracks created in walls and slabs of the structures as well as on cracks appeared in the lower and upper parts of slabs and walls were performed, and the investigation on characteristics of inside cracks were examined after extracting the core. The order of the investigation is as follows:

1) Creating the whole map of cracks

A crack diagram illustrates cracks appeared in the upper and lower parts of slabs and bearing walls on a map of a whole plane by sketching and measures the length and width of each crack. (measurement of crack width and length)

2) Selecting the parts of investigation

The crack samples in the lower parts of slabs are extracted from Number six on fifth floor in a building of RC structure with 12~14 ㎝. In selecting cracks which have more than 1m of length and is close to 0.4±0.2 ㎜ of width in this building, 20 samples were extracted from them by having around 20 ㎝ drilling intervals.

Sampling extracted from cracks of upper parts of slabs are from Number 4 of Floor 15 in a wall style apartment and the thickness of the slabs are 18 ㎝. Eight samples were extracted from cracks with nearly 0.4±0.2 ㎜ that are similar to the width of the cracks in the upper parts of slabs in the building.

3) Drilling cracked areas

By drilling with Φ100 ㎜ of core in the selected area with 20 ㎝ intervals, a total of 18 samples were extracted.

4) Measuring cracks inside the structure

Samples drilled like Picture 1 is examined in terms of the possibility to intersect between the injection part and a crack after drawing the shape of cracks on a semitransparent paper by penetrating side of drilled area. Like Picture 1, an examination on the possibility to intersect between the inject port and a crack when installing a packer in a right angle.

5) Measuring widths of cracks inside the structures

The width of cracks inside the structure was measured every 5 ㎜ from the surface according to the depth. For measurement, optical microscope which can measure up to 0.01 ㎜ is used.

Picture 1. Section of drilled sample

2.4 The results of investigation

1) The direction of progression of crack inside the structure

In order to examine the possibility of junctioning between the injection part and cracks, the shapes of cracks on sections by drilling the area of cracks in the slabs and walls are illustrated in Figure 3～5.

In the figure, the tendency of crack progression from the surface of the structure to the centre of the crack is on a slant at maximum 45°, but when the changes are estimated on the basis of the whole length of a crack, it is shown that it tends to progress in a right angle within about 60°. The cracks which are not progressed on a straight line but curved are those which have changes in progression of direction because of the placement of aggregates, reinforcing bars and pipes laying, and there is a tendency that the angle of cracks are wider in slabs than walls.

In Figure 3 that illustrates cracks in the lower parts of slabs, the angle of cracks transformed inside slabs is progressed bigger than the samples extracted from the upper parts and walls. This is because the angle is progressed bigger under the influence of slabs or load.

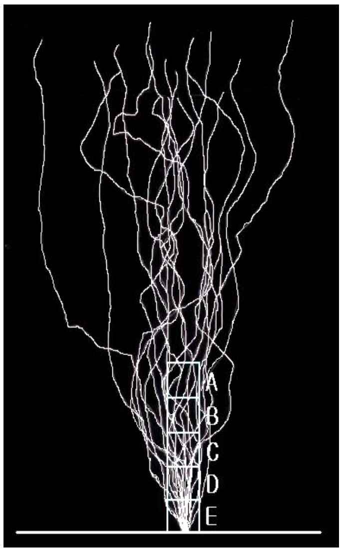


Figure 3. Section of the sample extracted from the cracks in the lower part of slabs

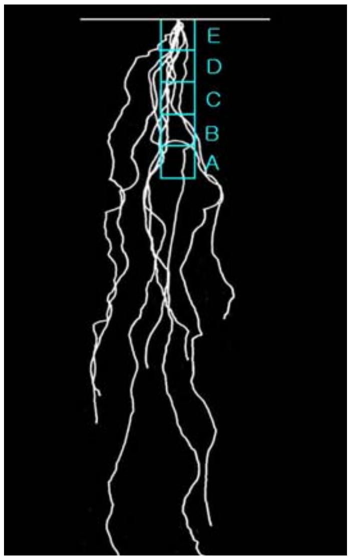


Figure 4. Section of the sample extracted cracks in the upper part of slabs

The Figure 4 illustrating cracks in the upper part of slabs contains more cracks that are progressed in a right angle and has relatively narrow transformative width compared to the cracks that appeared in the lower part of slabs. It is because most of the cracks are dry and contracted cracks occurred by rapidly evaporating water in the upper part of slabs. Generally, cracks that are occurred because of dryness and contraction are wider as it is close to the surface and narrow as it goes into the inside. This study also showed the similar tendency and cracks that tend to be curved on the surface of slabs. This result is assumed to be appeared as water in the upper parts of slabs are rapidly evaporated.

Figure 5 is a map of cracks on the outside of walls, which have more straight line cracks than other samples, and it is assumed that this is because most samples extracted were cracks that have progressed in a vertical way.

In the Figures from 3 to 5, A to D areas in the injection parts shows the places of injection part that repairing materials are injected and the possibility of intersection between the injection part and cracks are measured and shown in Table 2 and 3. It demonstrates that the possibility of intersection between cracks and injection part are more likely to be high as the place of injection part is close to the surface, and injection part in the area A that is placed 4～5 ㎝ in the injection part has a 50～63% of possibility that the injection part can intersect with the cracks, which is low probability. In other words, if packers are installed by drilling in a right angle in the area of cracks, about 37～50% are possible to intersect between injection part and cracks. In addition, samples that are extracted from walls are more likely to have higher probability of intersection between the injection part and cracks.

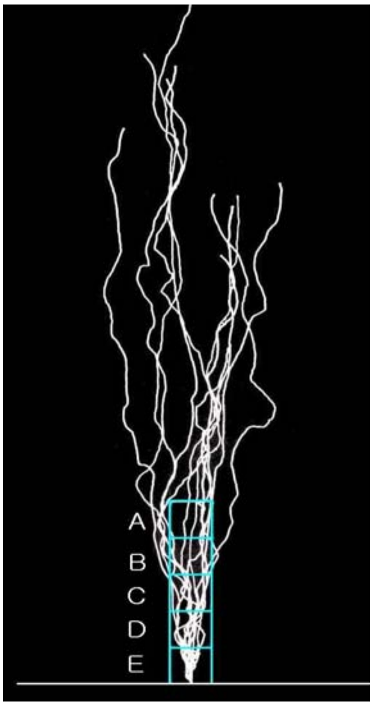


Figure 5. Section of samples extracted from cracks on the outside of walls

Table 2. Probability of intersection between cracks and injection part in slabs

The place of injection part	Cracks in lower parts		Cracks in upper part	
	Instances	Probability	Instances	Probability
A	10/20	50%	5/8	63%
B	12/20	60%	6/8	75%
C	17/20	85%	5/8	63%
D	18/20	90%	7/8	88%

In this table, instances = cracks penetrated injection part / the number of the whole cracks
probability = cracks penetrated injection part / the total number of total cracks *100

Table 3. Probability of intersection between cracks and injection part on walls

The place of injection part	Instances	Probability
A	7/12	58%
B	11/12	92%
C	12/12	100%
D	12/12	100%

Table 4. The widths of cracks inside of the structure (Unit ㎜)

Depth \ Width	Samples extracted from the lower parts of cracks						Samples extracted from the upper parts of cracks						Samples extracted from walls					
170											0.2							
165											0.1							
160										0.3	0.2		0.4		0.2			
155								0.5		0.3	0.2		0.6	0.2	0.3			
150								0.2		0	0.3		0.4	0.2	0.4	0.2		
145								0.1		0.5	0.2		0.5	0.2	0.3	0.3		
140	0.4							0.5		0.3	0.2		0.4	0.2	0.2	0.4		
135	0.4							0.6		0.2	0		0.3	0.2	0.4	0.3		
130	0.5							0.5		0.6	0.2	0.2	0.4	0.4	0.1	0.3	0.8	
125	0.5						0.1	0.3		0.6	0.2	0.2	0	0.6	0.2	0.4	0.8	
120	0.4						0.2	0.7	0.4	0.6	0.2	0.3	0	1.2	0.3	0.4	1.0	
115	0.4						0.3	0.9	0.3	0.7	0.2	0.3	0.3	0.6	0.3	0.5	1.2	0.2
110	0.1						0.2	0.6	0.4	0.7	0.2	0.6	0.3	0.4	0.3	0.3	0.8	0.2
105	0						0.2	0.6	0.4	0.8	0.2	0.5	0.3	0.2	0.4	0.4	0.8	0.2
100	0						0.2	0.6	0.4	0.9	0	0.45	0.4	0.2	0.3	0.4	0.6	0.2
95	0	0.1		0.2			0.3	0.7	0.5	0.7	0.1	0.7	0.4	0.2	0.3	0.5	1.6	0.2
90	0	0.1		0.2	0.2		0.2	0.6	0.5	1.0	0.2	0.7	0.4	0.2	0.5	0.5	1.0	0.4
85	0.1	0.3		0.4	0.5		0.3	0.7	0.5	1.2	0.2	0.6	0.5	0.2	0.4	0.4	0.8	0.2
80	0	0.2		0.4	0.4		Reinforcing bars	0.8	0.4	0.9	0.2	0.6	0.6	0.4	0.4	0.4	0.8	1.0
75	0.1	0.2		0.2	1.2		Reinforcing bars	0.7	0.4	1.2	0.2	1.2	0.5	0.4	0.4	0.4	0.8	0.4
70	0.2	0.8		0.1	0.4		Reinforcing bars	0.9	0.3	0.9	0.2	1.0	0.5	0.4	0.3	0.3	1.4	0.8
65	0	0.1		0.6	0.5		0.2	0.5	0.3	0.3	0.2	1.0	0.4	0.4	0.3	0.4	1.4	1.0
60	0.3	0.2		1	0.2	0.5	0.2	0.5	0.3	0.3	0.2	1.0	0.5	0.6	0.4	0.5	1.2	1.2
55	0.3	0.6	0.4	0.2	0.1	0.6	0.1	0.5	0.5	0	0.4	1.0	0.5	0.4	0.4	0.3	1.4	0.8
50	0.2	0.3	0	0.1	0.2	0.5	0.1	0.6	0.5	0.4	0.4	0.9	0.4	0.4	0.5	0.3	1.6	2.0
45	0.2	0.3	0.5	0	0.1	0.5	0.3	0	0.4	0.5	0.4	1.0	0	0.4	0.4	0.3	0.8	1.2
40	0	0.1	0.4	0.4	0.1	0.4	0.2	0.4	0.4	0.5	0.3	0.8	0	0.4	0.4	0.4	0.4	0.8
35	0.3	0.3	0.3	0.6	0.3	0.1	0.1	0	0.5	0.8	0.3	1.2	0	0.4	0.4	0.4	1.2	1.2
30	0.1	0.2	0	0.8	0.3	0.5	0.1	0	0.5	0.9	0.4	1.2	0.2	0.6	0.5	0.3	1.0	0.8
25	0	0	0.4	0.4	0.2	0.5	0.3	0.2	0.4	0.5	0.4	1.0	0.1	0.6	0.4	0.4	0.6	1.2
20	0	0.1	0.2	0.6	2.2	0.3	0.3	0.5	0.4	0.3	0.5	1.0	0.2	0.4	0.4	0.4	0.8	1.6
15	0	0.1	0.4	0.6	0.3	0.5	0.5	0.4	0.4	0.3	0.6	1.3	0.3	0.4	0.5	0.5	0.8	1.8
10	0	0.3	0.3	0.6	0.2	0.4	0.4	0.9	0.4	0.5	0.5	1.4	0.4	0.6	0.3	0.4	1.2	1.8
5	0.1	0.2	0.3	0.6	0.2	0.4	0.4	1.2	0.4	0.3	0.5	0.8	0.4	0.4	0.3	0.4.	0.6	1.6
Depth	0.3	0.4	0.4	0.6	0.6	0.7	0.3	0.3	0.4	0.7	0.6	0.9	0.3	0.4	0.4	0.6	0.8	1.4

※ Parts indicated as the width 0 means that they are small cracks with 0.1 ㎜ although there are traces of cracks.

※ The thickness of slabs of samples extracted from the lower part is 120 ㎜ and the thickness of samples extracted from the upper parts of cracks on walls is 150 ㎜.

2) Change of the width of cracks inside the structure

In order to examine the tendency of change of crack width inside of the structure, the width of cracks in slabs and walls extracted from samples was measured and is shown in Table 4 and Figure 6 to 8.

As a result of cracks with width of about 0.3～1.4 ㎜, if the crack width appeared on the surface of the object is 0.3 ㎜, average cracks width inside of the object is 0.2 ㎜, 0.4 ㎜ about 0.2~0.3 ㎜, 0.6 ㎜ about 0.4 ㎜ and 0.7 ㎜ about 0.4 ㎜, which show that the width of the inner parts of cracks is reduced about 30~50% more than the surface.

In particular, cracks below 0.6 ㎜ checked the parts that are blocked inside. Partly blocked cracks in the inside of the object mainly appeared where many aggregates are condensed or where reinforcing bars or pipes are. It is because of the effect of blocking the progression of cracks as the amount of drying and contracting reduces in the area that many aggregates are condensed because aggregates have relatively lower dryness and contraction compared to cement paste. Cracks in the lower part of slabs are occurred because of dryness and contraction, sagging, and shear load, and dryness and contraction make the object experience cracks and because of shear load on the splited parts, they cross each other.

Thus, the parts that cracks are blocked become a bottleneck situation by disturbing injected materials flowing through inside cracks, so when injecting repairing materials, they should be injected with higher pressure than estimated pressure for cracks on the surface.

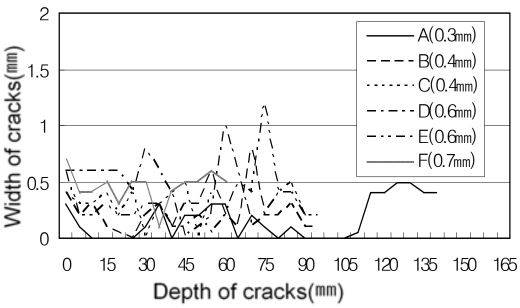


Figure 6. Depth and width of cracks in the lower part of slabs

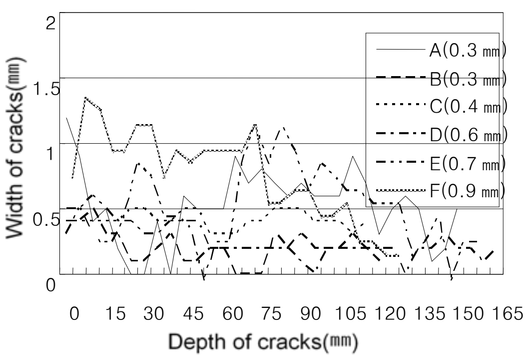


Figure 7. Depth and width of cracks in the upper part of slabs

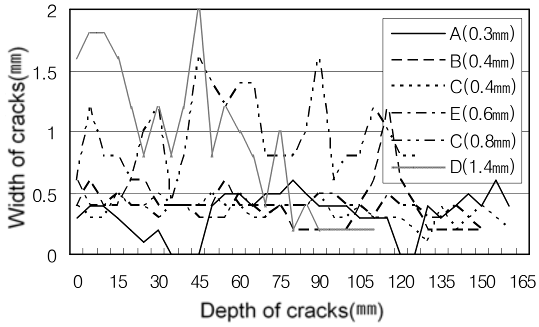


Figure 8. Depth and width of cracks in walls

3. FIELD EXPERIMENTS

3.1 Experiment outline

Methods to inject repairing materials in the part of cracks can be divided into two: syringe method and packer method. This experiment focuses on investigating characteristics of using packers among the methods.

Methods to install packer shapes injection part inside of the object and when the injection part intersects with cracks, repairing materials can be injected. Therefore, by examining characteristics of cracks inside of the structure, packers should be installed.

In addition, the process to install packer, namely drilling injection part, installation of packer and injecting repairing materials, can be the factors that disturb injection of repairing materials when they are not processed properly for the construction. Therefore, in order to quantitatively examine whether those factors affect actual injection of repairing materials, this study conducted field experiments.

3.2 Experiment items

Items for experiments in order to examine characteristics of right angle drill methods are as follows:

1) Effective (maximum) pressure of packer

When injecting repairing materials after installation of packers in the parts of cracks, it is common that the repairing material liquid is not injected but flew backward or the packer comes out of the injection part by being pushed. Thus, in the process of injecting repairing materials, in order to examine the possibility that damages the structure with addition of high pressure into the injection part without the repairing materials being injected, effective (maximum) pressure of packer was measured.

2) Pressure of injection according to intersection between cracks and packers

Method installing packers can face the possibility of unintersected cracks and injection part according to the direction of cracks inside of the structure because injection part is placed deep inside cracks. Thus, in the condition that injection part is intersected with cracks or they are not intersected each other inside the structure, pressure of injection was compared.

3) Injection pressure according to the way of cleaning injection part

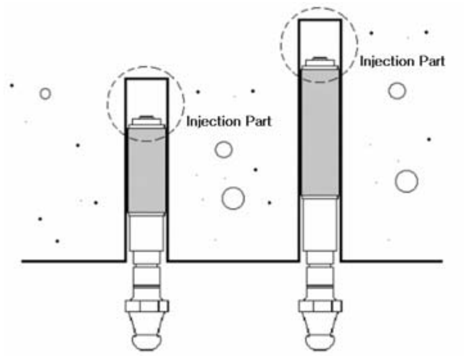
In order to install packers, after drilling injection part, there are several ways to clean inside of the injection part such as removing dust with air pressure, cleaning with water, removing dust with brush and drilling with core drill,a and amon them, this study conducted an examination on the method using air pressure to remove dust which is most commonly used in order to confirm the minimum measure that is necessary to inject repairing materials into the part of cracks.

3.3 Experiment method

The structure and resources used for this experiment is as seen in Figure 9 and Table 5. By drilling the part that has cracks in a right angle, they are divided into A-type and B-type according to the depth of drill and characteristics of each injection were examined. In addition, repairing materials used in this experiment includes main materials with 230(cP) of viscosity and hardner with epoxy of 50(cP) low viscosity, presented in Table 6.

1) Effective pressure of packers

Effective pressure of packers was measured at the point where the injection part reached the maximum pressure by adding each A-type and B-type packer with manual injection machine. Pulling power of packers was calculated as the maximum load that a packer pulled by using attachment strength measurement machine. Equipment with measuring pressure ranging from zero to 50 N/㎟ normally and accuracy within ±1.5% is used. The injecting area for A-type and B-type packer is illustrated as the place of injection in Figure 3 to 5 and the place of injection of A-type packer is area B and the place of injection of B-type area A.



A-type packer B-type packer

Figure 9. Structure of packer

Table 5. Resources of packers

Classification	Depth of injection (㎜)	Outside mirror of packer (㎜)	Inside mirror of packer (㎜)	Materials used
A-type packer	32	8	2	iron material /rubber
B-type packer	38	10	2	iron material /rubber

Table 6. Properties of injected epoxy

Viscosity (cP)		Specific gravity		pH		Time of working
Main materials	Hardner	Main materials	Hardner	Main materials	Hardner	20 minutes
230	50	1.11	0.99	6.5	7.5	

2) Injection pressure according to intersection between cracks and a packer

When injection part is intersected with cracks, there is not a problem but when they are not intersected each other, the object can be damaged because of high pressure from inside the injection part when injecting repairing materials. Therefore, this study measured injection pressure in each condition, namely intersected or un-intersected between cracks and injection part. Injection pressures are measured in the same way as the method to measure maximum attachment power and packer effective pressure in Clause 1).

3) Injection pressure experiment according to drilling methods for injection part

Injection part for installation of packers are drilled with a hammer drill and in order to remove dust that created when drilling, air pressure is used. This study compares injection pressure of a condition that injection part is drilled with hammer drill with that of the condition that the injection part is cleaned with air pressure after drilling in order to examine whether these ways to clean injection part is effective. Installation of experimental object that is packers is as seen in Figure 10 to select similar cracks between each condition and each injection pressure was measured.

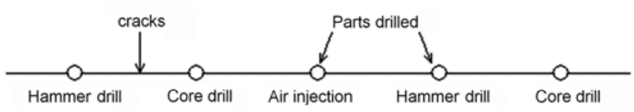


Figure 10. Installation method of experimental objects for pressure measurement according to drilling method of injection part

3.4 Results

1) An experiment on effective pressure of packers

The results of measured effective pressures of packers are illustrated in Figure 11. The injection parts of A-type and B-type packers are placed about 3 ㎝ or more into inside of the object, so when adding pressure, endurable pulling power and the maximum value of injection pressure showed about 40 (MPa) or close to it or above, which is high value. Given the fact that pressure strength of concrete applied to public houses is about 30 to 40 (MPa), it secures sufficient effective pressure.

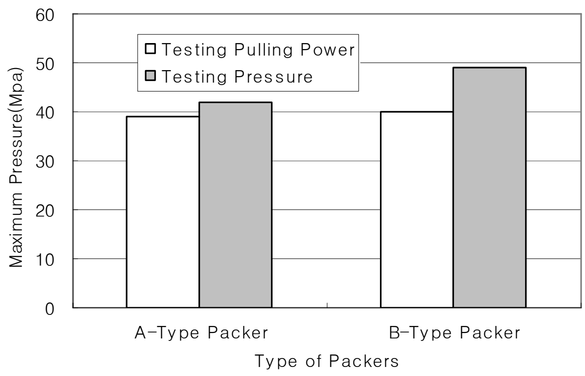


Figure 11. Maximum pulling power and injection pressure of packers

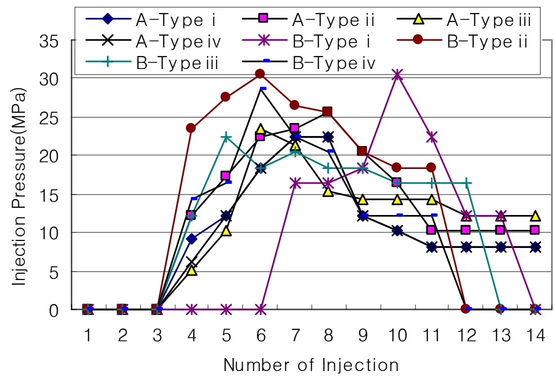


Figure 13. Injection pressures when injection part is not intersected with cracks

2) Injection pressure according to intersection between cracks and a packer

This study conducted an experiment on measuring injection pressure when injecting repairing materials under the conditions that cracks are intersected with injection part and vise versa.

In Figure 12 illustrating injection pressure when cracks are intersected with injection part, it is confirmed that injection pressure of A-type packer and B-type packer is a range of about 8 to 16 (MPa). On the other hand, in Figure 13 demonstrating the results when cracks are not intersected with injection part, it is found that the maximum pressures of A-type packer and B-type packer is a range of about 15 to 30 (N/㎟) and in the range objects were broken or packers were leaking repairing liquid.

In particular, when the pressure reached maximum 30 (N/㎟), second cracks were occurred near injection part and repairing materials flew out of the cracks. This phenomenon occurred in a similar pressure to the pressure strength of concrete so it can be colse to the strength of the object or the pressure above can damage the object and therefore, materials should be injected with lower pressure than the strength of the object so that it can be stable injection condition that does not damage the object.

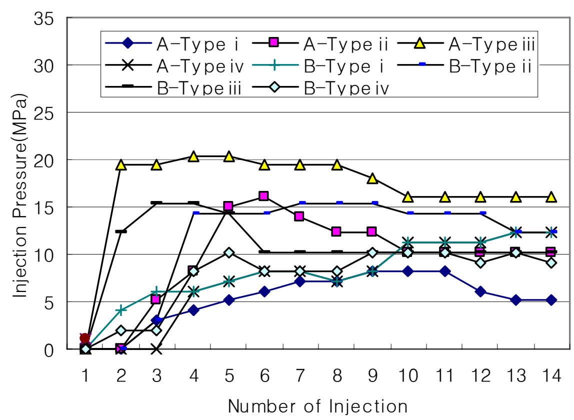


Figure 12. Injection pressures when injection part is intersected with cracks

3) Injection pressure experiment according to the ways of drilling in the injection part

Figure 14 shows the results of measuring injection pressure according to drilling methods. As results of examining injection pressure according to drilling methods of injection part subject to similar sizes of cracks, when drilling with a hammer drill with injection part, dusts from drilling blocked the cracks, the materials were injected with about 12～21 (MPa) of high pressure.

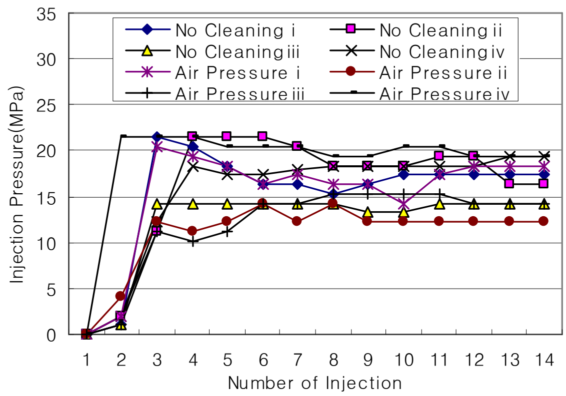


Figure 14. Pressure according to cleaning condition of injection part

It is found that the most commonly used method which is removing dusts with air pressure is not effective to remove the dust inside injection part as it was measured as similar injection pressure when the inside was not cleaned.

In order to repair cracks effectively by using packers, cracks and injection part should be intersected correctly. In the intersected cracks, injection part should not be blocked with dusts from drilling and this study found that the most commonly used way of cleaning the dust did not satisfy the requirement sufficiently.

4. CONCLUSION

As a result of examination on injection performance of repairing method installing packers by drilling in a right angle, this study reached conclusions as follows:

1) The results of examination on characteristics of cracks inside the structure by extracting core in concrete with cracks showed that the width of cracks were about 30～40% smaller than that of the width of the surface of the structure, especially it was confirmed that some parts of cracks below 0.6 ㎜ were blocked. Therefore, when selecting injection method, it is appropriate to choose a method by considering characteristics of cracks inside the object.

2) The method that installs packers by drilling in a right angle on the area that have cracks showed high possibility of intersection with cracks as the place of injection part is close to the surface. In the case of slabs, as the place of injection is 3 ㎝ or above deeper from the surface, approximately 25% and above of cracks were not congruent with the injection part.

3) As a result of experiment on injection pressure according to injection condition of injection part, it was found that when cracks were intersected with injection part, the repairing materials were injected with around 8 to 16 (MPa) pressure but when the cracks were not intersected with the injection part, they were injected with about 15 to 30 (N/㎟) pressure, causing damage of the object or leakage of repairing liquid from packers.

4) Improving measure should be taken for the method to clean the injection part since the air pump was not effective in order to remove the dusts from drilling inside the injection part.

REFERENCES

Korean Concrete Institute, Repair of concrete structures. Reinforced guidelines (Draft) 1997. 3

Korea Construction and Technology Institute, Repair of RC structures. Examination on reinforcement materials, 1997. 12

Ministry of Construction and Transport, Structure planning skills and design for improvement of structural performance of elderly common houses. Construction manual development, Korean Housing Public corporation et al., 2001. 11

Korean Concrete Institute, Cracks in concrete structures, 2000

Ministry of Construction and Transport, Structure planning skills and design for improvement of structural performance of elderly common houses. Construction manual development, Korea Housing Public corporation et al., 2000. 11

Taekwanselim, Plastic materials class [2] Polyurethane-methly methacrylate, Translated by Kim, Hong Jae, 1979. 11

Korean Concrete Institute, Check, reinforcement and maintenance of concrete structures, 1995. 3

Architectural Institute of Japan, Durable investigation, diagnosis and repair guideline of reinforced concrete (draft), 1997

Japan Painting Contractors Association, Repair manual o f a concrete structure, 1994

Repair Handbook of Concrete structure, 1995

Ko Jin Soo, Evaluation of Injection Property on the Crack Repair Method by installing the packer with Right Angle Drill Type in RC Structure. The Korea Institute of Building Construction, 2006. 6

(Data of Submission : 2009.8.14)