

Experimental Study on Carbonation Resistance and Water Absorbing Property of Concrete Crack with repair

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Abstract. Existing RC Buildings have some cracks and the repairing service might last the buildings for long life. The durability of the RC component is evaluated by several ways as like as carbonation resistance test, permeability test, water penetration test, and so on. Therefore, it need to be measured how much advantage the concrete crack with repair have for the durability. The aim of this paper is to study on advantage of repairing a crack of concrete to the carbonation resistance and the water-absorbing property by the experimental way. The specimens were prepared in the following point. The finishing (direct finishing and mortal tile finishing), crack width (0, 0.05, 0.5, and 2mm), and choice repairing or not. All concrete specimens were formed 10 x 10 x 20cm and those W/C were 0.55. Then, the specimens were tested by the accelerated carbonation. After 4, 8 and 26weeks accelerated carbonation, the carbonation depth and the carbonation shape of the concretes were measured by 1% phenolphthalein reaction. Also, the amount of absorbed water from the bottom were measured at 1, 3, 6, 24, 48, 72 and 168h. From the results, the carbonation went rapidly located in 2cm around the crack in the case of the no-repair specimens, regardless of any finishing. But in the case of the specimens repaired, it went evenly from the exposure side. And water absorbing test results show a trend that water amount of the concrete with a crack more increase than one of the no-crack concrete.

Keywords: Concrete, Crack with Repair, Carbonation Resistance, Water Absorption.

1 Introduction

Existing RC buildings ordinary have some cracks. These expand air permeation and water penetration (D. Breysee *et al.*), which cause irregular carbonation (Xiao-Hui *et al.*, 2018), and rebar corrossions rapidly.

On the other hand, cracks of the reinforced concrete components sometimes have been repaired, and that might last the buildings for long life.

And now, the durability of the reinforced concrete components is evaluated by several way as like as the carbonation resistance test, the permeability test, the water penetration test, and so on. Therefore, it need to be measured how much advantage the concrete crack with repair have for the durability. The aim of this paper is to study on advantage of repairing a crack of the concrete to the carbonation resistance and the water-absorbing property by the experimental way.

2 Specimens

2.1 Specimens Type

Table 1 shows specimen type. 2piece of each type specimens were prepared. 10 x 10 x 20 cm rectangular column concretes were made. Many have a man-made crack at the center of oneself, and half of those were repaired.

Table 1. Specimen type.

No.	Finishing	crack (mm)	Repair material	No.	Finishing	crack (mm)	Repair material
1	Direct finishing	-	-	8	Mortal tile	0.5	-
2	Direct finishing	0.5	-	9	Mortal tile	0.5	Soft epoxy resin grouting
3	Direct finishing	0.5	Soft epoxy resin grouting	10	Mortal tile	0.5 ^{*1}	-
4	Direct finishing	2	-	11	Mortal tile	2	-
5	Direct finishing	2	U cut and filling with sealing agent	12	Mortal tile	2	U cut and filling with sealing agent
6	Direct finishing	0.05	-	13	Mortal tile	-	-
7	Direct finishing	0.05	Coating with flexible synthetic resin emulsion	*1 Mortal tile have no crack but concrete 0.5mm crack			

2.2 Mix Proportion of Concrete

Table 2. shows the mix proportion of the concrete. Portland cement was used, and form off 3days after cast. Then, 20°C RH 60 % air curing for not less than 28 days.

Table 2. Mix proportion.

SL (mm)	W/C (%)	s/a (%)	BVg (m ³ /m ³)	W	C	S	G
				(kg/m ³)			
18	55.0	45.8	0.59	180	327	793	961

2.3 Concrete Crack Width

The crack width of concrete were 0mm (no-crack), 0.05mm, 0.5mm, and 2mm. After air curing of the concrete, bending the concrete and put ones together carefully so as to being each crack wide. So, a man-made crack which pass through to another side was at the center of the specimens. Mortal tile also have a crack in response to each concrete crack, except No.10 in Table 1, which mortal tile have no-crack but concrete has a 0.5mm-wide-crack .

2.4 Finishing

Finishing type were direct finishing and mortal tile finishing. Making the mortal tile finishing, 2cm mortal were plastered after making concrete crack and cured for not less than 28days by oneself. Except some specimens, mortal tile finishing also have a crack. The crack of mortar bed were made by the way of putting a rubber in and remove it while mortar set. And, the tile were cut ahead and put on mortar bed adjusting a crack.

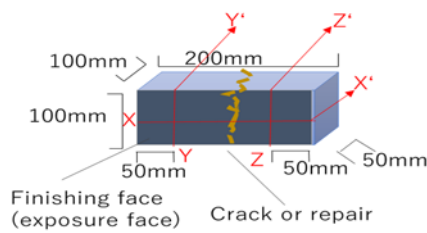


Figure 1. Cut directions after accelerated carbonation test.

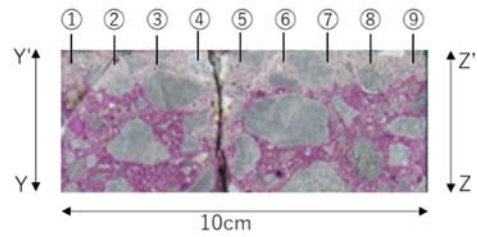


Figure 2. Measurement spots on x-x' cut side.

2.5 Repair Materials and Methods

Used repair materials and methods were shown in table 1. These repair material and method were select corresponding with the crack width. The soft epoxy resin grouting applied for 0.5mm crack, U cut and filling with the sealing agent applied for 2mm crack of either finishing. Also, coating with the flexible synthetic resin emulsion were applied for 0.05mm crack of direct finishing specimens.

3 Experiment

3.1 Accelerated Carbonation Test

The specimens were sealed with aluminium tape so that only the finishing face were exposure in 20°C, RH60%, and CO₂ 5% room. And, the term of accelerated carbonation were 4, 8 and 26 weeks.

3.2 Measurement Carbonation Depth

After the accelerated carbonation, specimens were cut along x-x', y-y' and z-z' directions as Figure 1. by diamond cutter, and then solution of 1% phenolphthalein in water were sprayed. Carbonation depths were measured at 5spots on y-y' and z-z' cut side. In case of x-x' cut side, 9spots located in 10cm around the crack were measured as shown in Figure 2.

3.3 Water Absorption Test

After the curing and sealing, specimens were set on the water and measured the amount of the absorbed water at 1, 3, 6h and 1, 2, 3, 7 days. Water were absorbed from the bottom of the specimens.

4 Results and Discussion

4.1 Carbonation Depth on y-y' and z-z' Cut Side

This paragraph shows the results of the carbonation depth from exposure side on y-y' and z-z' cut side. Averaged value of y-y' and z-z' are shown.

4.1.1 The results of the no-repair case

Figure 3. shows the carbonation depth on y-y' and z-z' cut side of the no-repair case. In case



Figure 3. The carbonation depth on y-y' and z-z' cut side of the no-repair case.



Figure 4. The carbonation depth on y-y' and z-z' cut side of the repair case.

of the direct finishing, the carbonation depth at 4, 8 and 26 weeks were 7~13mm, about 12mm, and 16~24mm respectively. Also, it were under 3mm, 4mm and 6mm respectively in case of the mortal tile finishing.

4.1.2 The results of the repair case

Figure 4. shows the carbonation depth on y-y' and z-z' cut side of the repair case. Except No.7, the carbonation depth at 4, 8 and 26 weeks were 10~12mm, 12~14mm and 18~23mm respectively in case of the direct finishing, that was close to the results of the no-repair case. Also, it were under 2mm, 3mm and 5mm respectively in case of the mortal tile finishing, that was also close to the results of the no-repair case. Note, No.7 were coated at all face with the flexible synthetic resin emulsion, so carbonation did not go.

4.1.3 Discussion

From the results in Figure 3. and Figure 4., the carbonation depth at each term were same, regardless of repair or not. That shows the process of carbonation located on 5cm away from a crack were not relate with a crack or repair.

Add to that, the mortal tile finishing have larger resistance for carbonation than the direct finishing have, as well as the previous studies on preventive effect of finishing materials against carbonation (Kono *et al.*, 2008).

4.2 Carbonation Depth on x-x' Cut Side

This paragraph shows the results of the carbonation depth from the exposure side on x-x' cut side. In the following figures, the symbol 'Max' means the maximum value in the 9 spots results on x-x' cut side as shown in Figure 2., the symbol 'ave. of 2cm around crack' means average of the results of the spots of ④, ⑤, ⑥ in Figure 2., and the symbol 'ave. of 10cm around crack' means average of 9 spots results.

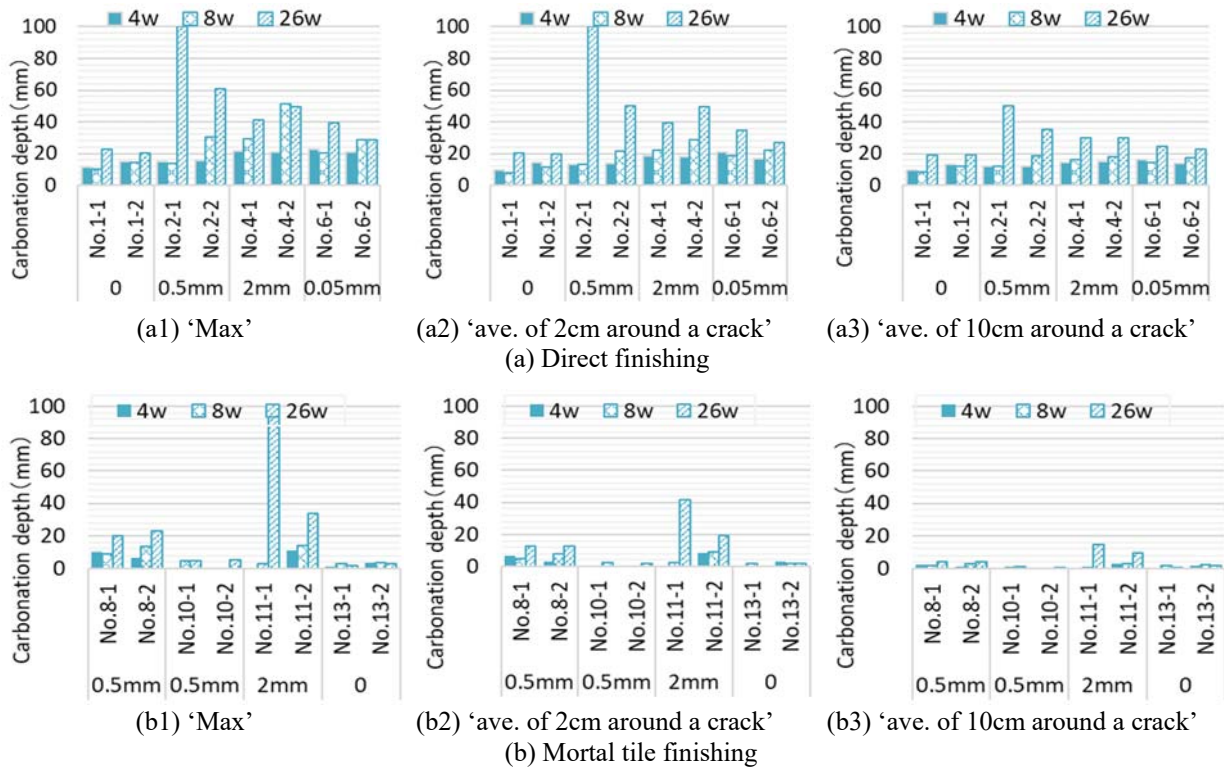


Figure 5. The carbonation depth on x-x' cut side of the no-repair case.

4.2.1 The results of the no-repair case

Figure 5. shows the carbonation depth on x-x' cut side of the no-repair case. From the results of 'max' of No.4 and No.6, the carbonation depth were about 20mm at 4weeks, that was twice of the result of y-y' and z-z' cut side at Figure 3 (a). And the results at 8 and 26weeks were so large as 30mm and 50mm. Also, the results of 'ave. of 2cm around a crack' of No.2, No.4, and No.6 were about 15~20mm at 4weeks, that was about half time of the result of y-y' and z-z' cut side. And No.2 at 26weeks were 100mm. Meanwhile, the result of No.1, which don't have cracks, at 4, 8 and 26weeks were about 10mm, 10mm and 20mm each, regardless of 'Max', 'ave. of 2cm around crack', and 'ave. of 10cm around crack', that was close to the results of y-y' and z-z' cut side.

And then, focused on the mortal tile finishing specimens, the carbonation depth of No.8 'Max' at 4, 8 and 26 weeks were about 9mm, 12mm and 20mm, also that of No.8 'ave. of 2cm around a crack' were 5mm, 7mm and 13mm, and also that of No.8 'ave. of 10cm around a crack' were 3mm, 3mm and 4mm respectively. Likewise, that of No.11-2 'Max' at 4, 8 and 26 weeks were about 11mm, 14mm and 34mm, also that of No.11-2 'ave. of 2cm around a crack' were 9mm, 9mm and 20mm, and also that of No.11-2 'ave. of 10cm around a crack' were 3mm, 3mm and 10mm respectively.

Both 'Max' and 'ave. of 2cm around a crack' results were more than double for that of y-y' and z-z' cut side as showed in Figure 3. So, these 'Max' and 'ave. of 2cm around a crack' results of x-x' cut side were so larger than that of y-y' and z-z' cut side.

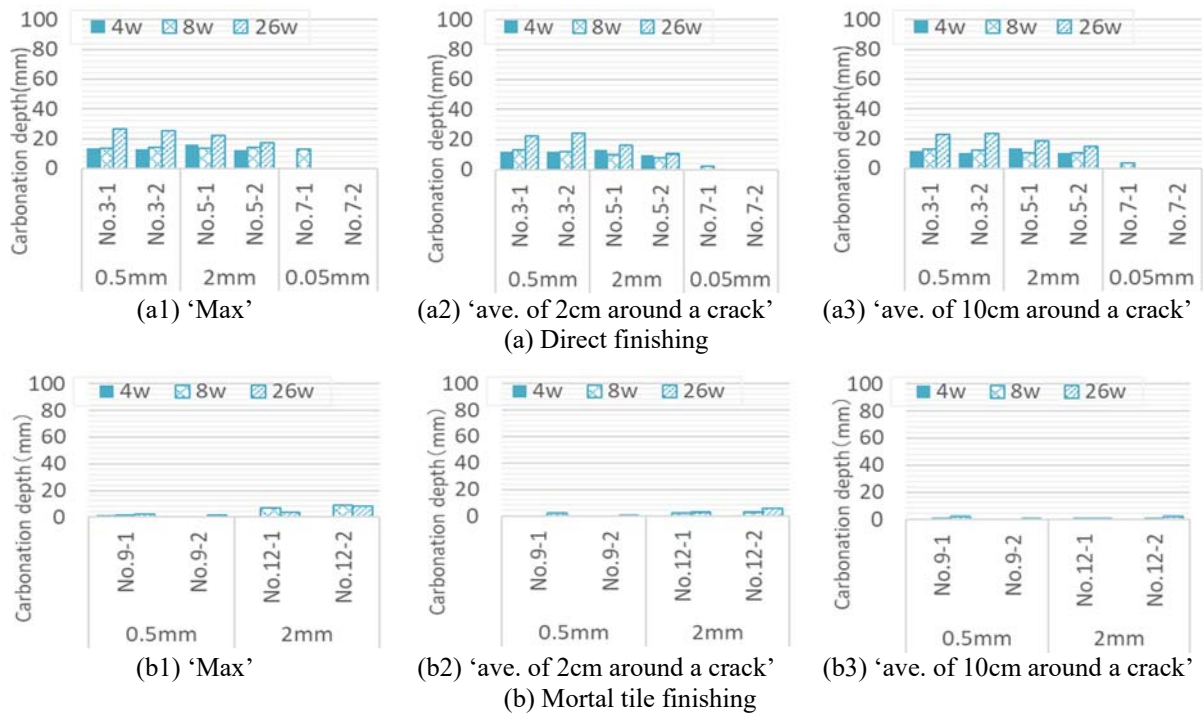


Figure 6. The carbonation depth on x-x' cut side of the repair case.

And, results of 'ave. of 10cm around a crack' of x-x' cut side were not differ greatly from that of No.13 which have no crack as showed in Figure 3 (b). By the way, No.10 results show that carbonation didn't go at all as 0mm at 8weeks and 5mm at 26weeks, because this specimen have a concrete crack but no crack of tile.

4.2.2 The results of the repair case

Figure 6. shows the carbonation depth on x-x' cut side of the repair case. The 'Max' of No.3 and No.5 at 4, 8 and 26 weeks were about 13mm, 13mm and 23mm, also that of 'ave. of 2cm around a crack' were about 11mm, 11mm and 18mm, and also that of 'ave. of 10cm around a crack' were 11mm, 11mm and 20mm respectively. So, these have no difference in measurement field. Add to that, these results were close to the results of No.1 (no-crack case) as well as y-y' and z-z' cut side showed at Figure 4.

And, No.7 were coated at all face with the flexible synthetic resin emulsion, so carbonation have not gone.

As an exception case, the results of No.11 which have 2mm-wide crack shows the carbonation depth were small until 8weeks but it were large at 26weeks. Because of the repair method that block up by buried only surface layer but the filling didn't reach to deep part, the carbonation went rapid where the filling didn't reach.

And then, focused on the mortal tile finishing, the 'Max' of No.12 at 4, 8 and 26 weeks were about 0mm, 8mm and 6mm, also that of 'ave. of 2cm around a crack' were 0mm, 3mm and 4mm, and also, that of 'ave. of 10cm around a crack' were 0mm, 1mm and 2mm respectively. And the carbonation depth of No.9 at 4, 8 and 26 weeks were under 2mm regardless of the symbol. These were close to the results of the no-crack case as well as the results of y-y' and z-z' cut side.

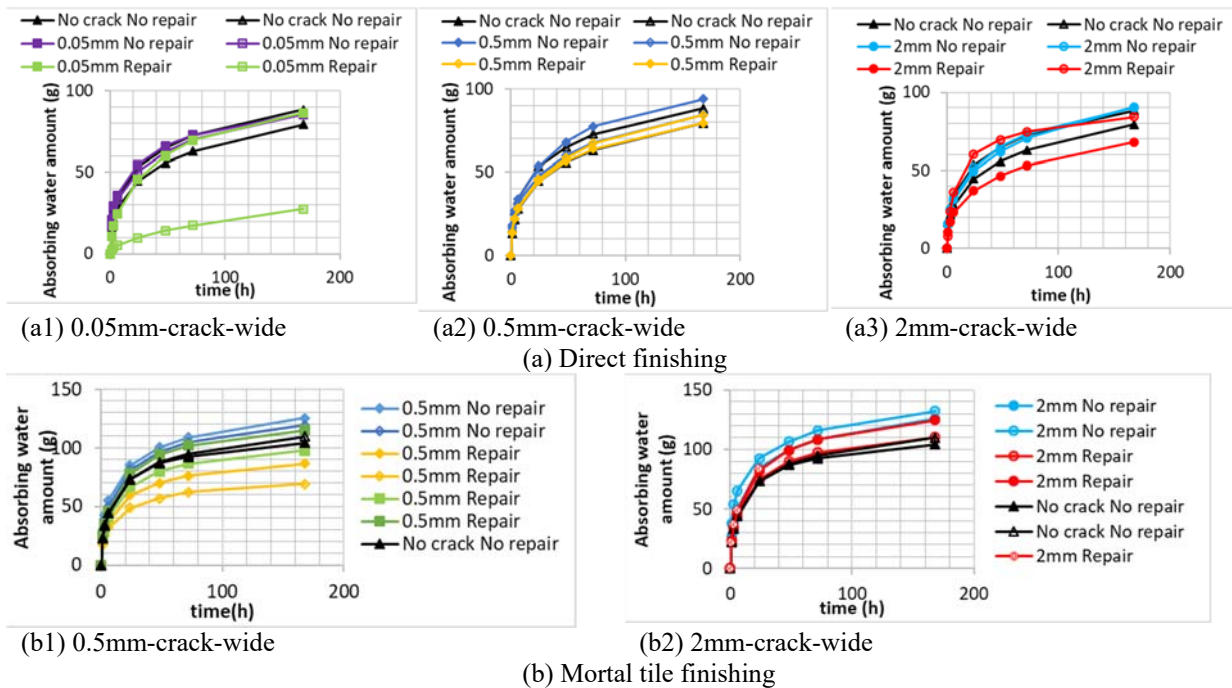


Figure 7. The amount of absorbed water

4.2.3 Discussions

In the case of the no-repair, the carbonation went rapidly located in 2cm around the crack but not rapidly at 10cm far from a crack, regardless of any finishing.

On the other side, the carbonation of the specimens repaired went evenly from the exposure side and that were similarly to the no-crack case, although there is an exception.

From these, the repairing service have advantage of the carbonation resistance compared to crack left case, though it is not confirmed durability of the repair materials in itself.

On a side note, the carbonation depth averaged located at 10cm around the crack of the no-repair specimens were close to that of the area far from a crack, and close to the no-crack case. It indicate that the influence of a crack appear little in large mass.

4.3 The Amount of Water by Absorption Test

Figure.7 shows the results of the amount of absorbed water from the bottom side. From the results, the amount of absorbed water of the specimens having a crack were bigger than the no-crack specimens. Also, those of the specimens repaired were smaller than that of the no-repair, however there were exceptions.

5 Conclusions

- The aim of this paper is to study on advantage of the repairing a crack of concrete for the carbonation resistance and water absorption resistance by the experimental way. Then, this paper shows the results of the accelerated carbonation test and water absorption test. Prepared concrete specimens were distinguished as the finishing type,

the crack width, taking repair or not, and the repair materials. The results in this study indicate as following.

- The mortar tile finishing have larger resistance to the carbonation than the direct finishing have.
- The carbonation went rapidly located in 2cm around the crack in the case of the no-repair specimens, regardless of any finishing.
- From the results of the repair case, the carbonation went evenly from the exposure side. It was the same process as the no-crack case.
- The amount of the absorbed water of the specimens having a crack were bigger than the no-crack specimens, and some specimens repaired a crack were smaller than that of the no-repair case.
- Many repairing service have advantage of the carbonation resistance as well as water absorption resistance compared to a crack left, though it is not confirmed durability of the repair materials in itself.

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