CRACKING RESISTANCE OF CHEMICAL PRESTRESSED REINFORCED CONCRETE

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1. INTRODUCTION

The chemically prestressed reinforced concrete (CPRC) is produced with expansive concrete and re-bars are prestressed by the concrete's expansion. To date, there have been many studies considering the flexural behaviors of CPRC [1].

Recently, CPRC has been introduced as one of methods to control the cracking of structure. However, information about the cracking resistance of CPRC and knowledge on its mechanism are still very limited. As the result, the cracking behavior of CPRC is not well understood and the effective design of CPRC cannot be done. Therefore this study is an attempt to inspect the cracking load, crack width, and crack spacing of CPRC and grasp its governing mechanism.

2. EXPERIMENTAL PROGRAM

Totally 15 CPRC beams were tested in this study. There are two groups of specimens; group A which is made from mortar and group B which is made from concrete. Sizes and reinforcement profiles of both group A and B are shown in Fig. 1.

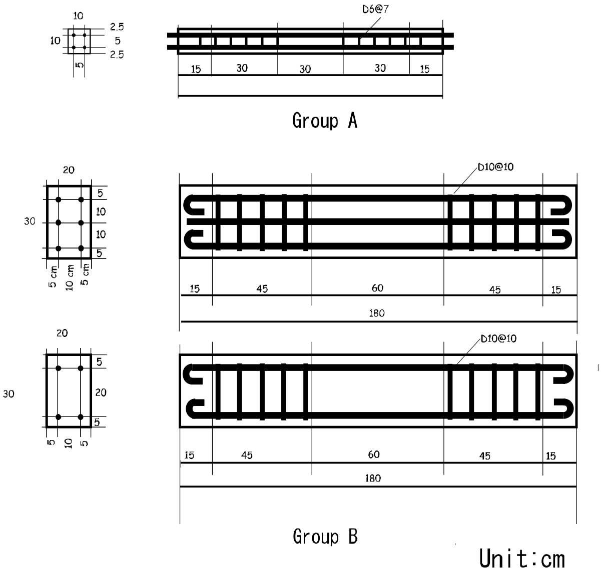

Fig.1: Details of Specimens

The restraining levels in each specimen are varied by changing the re-bars' sizes and number of re-bars. Details about the loading condition and curing of each specimen are given in Table 1.

The structural details including reinforcing ratio are usually determined according to the loading conditions, and then the adoption of expansive concrete is discussed in terms of durability aspect at the construction stage. In this usual situation chemical prestress, which is the compressive stress stored in concrete as counter action from restraining body, and chemical prestrain, which is the tensile strain stored in reinforcement due to expansion of concrete, show the similar tendency of increasing and decreasing according to the content of expansive agent. Thus, it is very difficult to grasp the rolls of those two factors on the enhancement of cracking resistance in research point of view. To avoid this problem and distinguish their contributions the restraining level is controlled by changing the reinforcing ratio to introduce the opposite tendency to chemical prestress and chemical prestrain. With this treatment it is expected to make clear the relations of chemical prestress and chemical prestrain to cracking resistance in CPRC.

Table 1: Details of loading and curing condition

Specimen	Shear Span (mm)	Constant Moment Span (mm)	Number of Bars	Curing Condition
A-4NW-6	300	300	4	14 days wet
A-4NW-10	300	300	4	14 days wet
A-4NW-13	300	300	4	14 days wet
A-4ED-6	300	300	4	7 days wet - 7 days dry
A-4ED-10	300	300	4	7 days wet -7 days dry
A-4ED-13	300	300	4	7 days wet - 7 days dry
A-4EW-6	300	300	4	14 days wet
A-4EW-10	300	300	4	14 days wet
A-4EW-13	300	300	4	14 days wet
B-6N-13	450	600	6	14 days wet -14 days dry
B-6N-16	450	600	6	14 days wet -14 days dry
B-6E-13	450	600	6	14 days wet - 14 days dry
B-6E-16	450	600	6	14 days wet - 14 days dry
B-4E-13	450	600	4	14 days wet - 14 days dry
B-4E-16	450	600	4	14 days wet - 14 days dry

*Names are indicated by the first capital letter followed by the number indicating number of reinforcing bars, type of concrete; normal (N) or expansive (E), and curing condition; wet (W) or dry (D). The number at the end of each specimen's name means the size of reinforcing bar.

3. EXPERIMENTAL RESULT

3.1 Improved Cracking Load of CPRC

Table 2 shows the cracking load, F_{cr} of each specimen with chemical prestress, CPS and chemical prestrain, CPN. The improvement of cracking load from the effect of chemical prestress can be calculated as Fo. This value is calculated as the load that makes the stress of concrete at bottom fiber zero.

The interesting point is that the difference between the cracking load of CPRC and that of RC is larger than the improvement by the chemical prestress.

Keywords: Expansive concrete, Chemical prestress, Chemical prestrain, Crack resistance, Drying shrinkage
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Table 2 : Comparison between the improvement of cracking load and the effect from the prestress and deformability

Specimen	CPN (micro)	CPS (MPa)	Fo (MPa)	Fcr (MPa)	Effect from Deformability (MPa)
A-4NW-6	small	small	0	0.67	-
A-4NW-10	small	small	0	2.45	-
A-4NW-13	small	small	0	2.87	-
A-4ED-6	739.25	1.712	2.01	4.57	1.885
A-4ED-10	210	1.109	1.41	4.98	1.11816
A-4ED-13	70.25	0.675	0.94	4.01	0.1966
A-4EW-6	1133	2.62	3.08	8.03	4.275646
A-4EW-10	595.5	3.145	4.00	10.01	3.5562
A-4EW-13	330.25	3.178	4.44	9.53	2.21822
B-6N-13	-	-	0	28.2	-
B-6N-16	-	-	0	19.1	-
B-6E-13	274.56	0.648	9.17	67.88	30.514237
B-6E-16	183.24	0.69	10.09	63.18	33.99197
B-4E-13	333	0.522	7.38	68.58	32.9965
B-4E-16	237.73	0.593	8.67	51.66	23.89014

These gaps are considered as improvements due to the higher deformability of CPRC and their value are larger in the case of higher chemical prestrain.

3.2 Load-Average Crack Width

Fig.2 and Fig.3 are examples of the load-crack width relationship. The average crack width of CPRC is much smaller than that of the reference normal RC at the same load level. This improvement seems great in the smaller reinforcing ratio in which larger chemical prestrain has been stored in advance. Furthermore, some part of this merit can maintain even if specimens are subjected to drying for 7days and drying shrinkage takes place. Thus, in these cases the cracking resistance of dried CPRC is still higher than that of the reference normal RC free from drying.

In group B, the improvement of cracking resistance due to expansive concrete are also compared among different restraining levels in terms of the load normalized by yielding load. Consequently, the similar effect of chemical prestrain is confirmed.

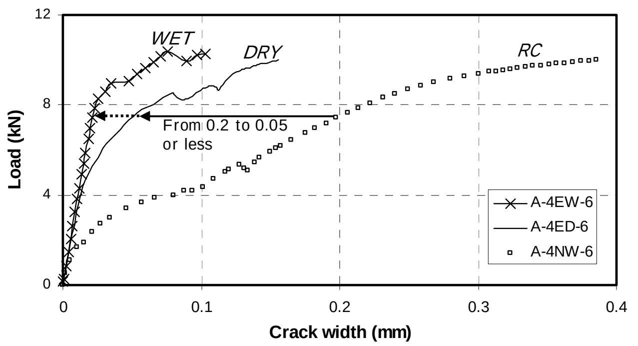

Fig.2 Load-average crack width of group A's beam with D6 bars

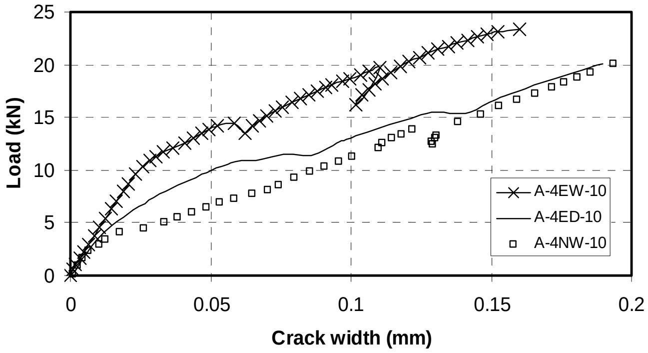

Fig.3 Load-average crack width of group A's beam with D10 bars

3.3 Crack Spacing

Fig.4 shows the examples of crack patterns after loading. The average crack spacing of each specimen is also given in the figure. It is clear that the crack spacing of CPRC is longer, in the other words; the number of cracks is less in CPRC.

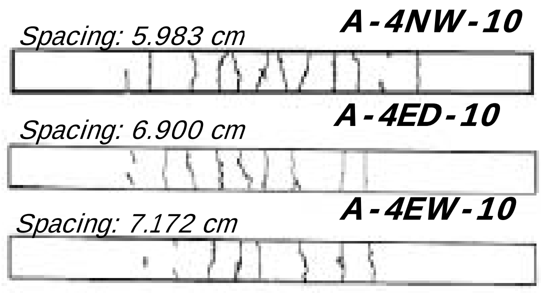

Fig.4 Examples of crack profile

4. DISCUSSION

The improvement of the cracking load of CPRC is related to the concept that restrained expansive concrete has high non-linearity under tension [2]. The non-linearity and the deformability of CPRC are related to the chemical prestrain of CPRC but the method of estimation has not been established so far.

In addition, since the crack width is the result of the slip between concrete and steel along the crack spacing, it is common that the reduced number of crack will increase the crack width of the structure. Therefore, it is very interesting that CPRC can reduce the crack width while number of cracks is reduced as shown in the results. To study this point further, the bonding of CPRC has to be inspected.

5. CONCLUSION

- The cracking load can be significantly improved by both the prestress and special deformability of CPRC.
- The CPRC can effectively reduce crack width as the same time as reduce the number of crack in the structure.

REFERENCE

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2. Hosoda, A. et al., "Behavior of Expansive Concrete Under Tensile Stress Including Tension Stiffening", the Eighth East Asia-Pacific Conference on Structural Engineering & Construction, 2001