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Properties of Ultrarapid-Hardening Polymer- Modified Concrete with fiber content

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ABSTRACT: This paper deals with the effects of fiber content and polymer-cement ratio on the properties of ultrarapid-hardening polymer-modified concretes with SBR latex and Acrylic emulsion. The ultrarapid-hardening polymer-modified concretes are prepared with various fiber contents and polymer-cement ratios, and tested for slump, flexural, compressive and tensile strengths and water absorption. As a result, the flexural, compressive and tensile strengths of the ultrarapid-hardening polymer-modified concretes tend to increase with increasing polymer-cement ratio and fiber content, and reach maximums at a fiber content of 0.15%. The water absorption tends to improved by the increasing of fiber content and polymer-cement ratio.

1 INTRODUCTION

In recent years, the rapid deterioration of various reinforced concrete structures has been a widely recognized problem in the world. The chloride ion penetration to concrete and the use of alkali-reactive aggregates in the concrete reinforced structures are found to be the major cause of premature corrosion of reinforcing bars and to promote their deterioration.

Consequently the development of effective protective or repairing materials for the concrete structures is demanded in the construction industry[1,2]. In the present paper, ultrarapid-hardening polymer-modified concretes using various polymer dispersion are prepared with various fiber contents and polymer-cement ratios, and tested for flexural, compressive and tensile strengths and water absorption.

2 MATERIALS

2.1 *Cement*

Ultrarapid-hardening cement was used as a cement. The properties of the cement are listed in Table 1

2.2 *Fine and coarse aggregates*

River sand was used as a fine aggregate, and brushed stone was as a coarse aggregate. The physical properties of the aggregates are given in Table 2.

2.3 *Polymer dispersions for cement modifier*

Polymer dispersions used as cement modifiers were a styrene-butadiene rubber (SBR) latex and acrylic (AC) emulsions. The properties of the polymer dispersions are listed in Table 3. Before mixing, a silicone emulsion-type antifoamer agent was added to the polymer dispersions in a ratio of 0.7% of the silicone solids of the antifoamer agent to the total solids of the polymer dispersions.

2.4 *Reinforcing fiber*

Ultrarapid-hardening cement was used as a reinforcing fiber. The properties of the fiber are listed in Table 5

Table 1. Physical properties of ultrarapid-hardening cement

Blaine Specific Surface (cm^2/g)	Setting Time (min)		Compressive Strength (MPa)				
	Initial Set	Final Set	3-h	6-h	3-d	7-d	28-d
3,960	8-11	12-15	25	28	37	42	45
	11-14	15-18					

Table 2. Physical properties of aggregates

Type of Aggregate	Maximum Size (mm)	Density (g/cm^3)	Water Absorption (%)	Fineness Modulus
River sand	2.5	2.54	2.29	2.60
Brushed stone	13	2.61	1.95	6.68

Table 3. Mix Proportion of Ultrarapid-Hardening Polymer Modified Concretes

Emulsion Contents (%)	W/C (%)	S/a (%)	Mix Proportion (kg/m^3)				
			Cement	Emulsion	Water	Sand	Gravel
0	48	58	400	0	192	931	693
5	43	58	400	42	150	932	693
10	37	58	400	84	104	939	699
15	32	58	400	126	62	940	699

Table 4. Properties of polymer dispersions

Type of Polymer Dispersion	Density (20℃,/cm^2)	pH (20℃)	Viscosity (20℃, mPa·s)	Total Solids (%)
SBR	1.00	9.4	84	47.8
AC	1.07	9.1	62	47.5

Table 5. Physical of properties nylon fiber

Type	Diameter (㎛)	Length (mm)	Density (g/cm^3)	Tensile strength (MPa)
Nylon fiber	23	6	1.16	919

3 TESTING PROCEDURES

3.1 *Preparation of specimens*

According to KS F 2403 (Method of making and curing concrete specimens), the polymer-modified concretes were mixed with polymer-cement ratios (P/C) of 0%, 5%, 10% and 15%, and fiber contents of 0%, 0.15% and 0.3%, and their slump was adjusted to be constant at 18.0±1.0cm by controlling the water-cement ratio. Before mixing of the polymer-modified concretes, the respective polymer binder was prepared by blending the SBR and AC in a reactor for 2h. The mass ratio of the SBR to AC 1 : 1. The mix proportions of the polymer-modified concretes are given in Table 3. Cylindrical specimens φ10×20cm for compressive and splitting tensile strengths, and 6×6×24cm for flexural strength and water absorption tests were molded, and then subjected to a combined wet/dry curing [2d-20ºC-80%(RH) moist plus 5d-20ºC-water plus 21d-20ºC-60%(RH)-dry curing].

3.2 *Slump and slump loss*

Slump and slump loss according to KS F 2402 (Testing method for slump of portland cement concrete). This test was selected in order to check the workability

3.3 *Water absorption test*

According to JIS A 1171 (Test methods of polymer-modified mortar), the cured beam specimens were dried at 80℃ for 48 h, immersed in water at 20℃ for 48 h, and then their water absorption was determined.

3.4 *Flexural, compressive and tensile strength tests*

The cylindrical specimens were tested for compressive strength in accordance with KS F 2405 (Method of test for compressive strength of concrete), and tested for splitting tensile strength according to KS F 2423 (Method of test for splitting tensile strength of concrete). The beam specimen was tested for flexural strength in according to KS F 2407 (Method of test for flexural strength of concrete).

4 TEST RESULTS AND DISCUSSIONS

4.1 *Slump loss*

Fig. 1 show the relationship between the fiber content and slump loss of ultrarapid-hardening polymer-modified concretes with polymer-cement ratios of 0, 5, 10 and 15%. Regardless of the polymer-cement ratio, the slump loss of the ultrarapid-hardening polymer-modified concretes tend to increase with increasing fiber content. Irrespective of the fiber content, the slump loss of the ultrarapid-hardening polymer-modified concretes tend to decrease with increasing polymer–cement ratio. In case of the ultrarapid-hardening polymer-modified, the slump loss tend to rapid with reducing at 15~20 minute.
In this study, it is possible the slump loss extend to 40~50 times due to the incorporation of maintenance agent. From the test results, it is solved various problems by slump loss in case of constructing the ultrarapid-hardening polymer-modified concrete in the field.

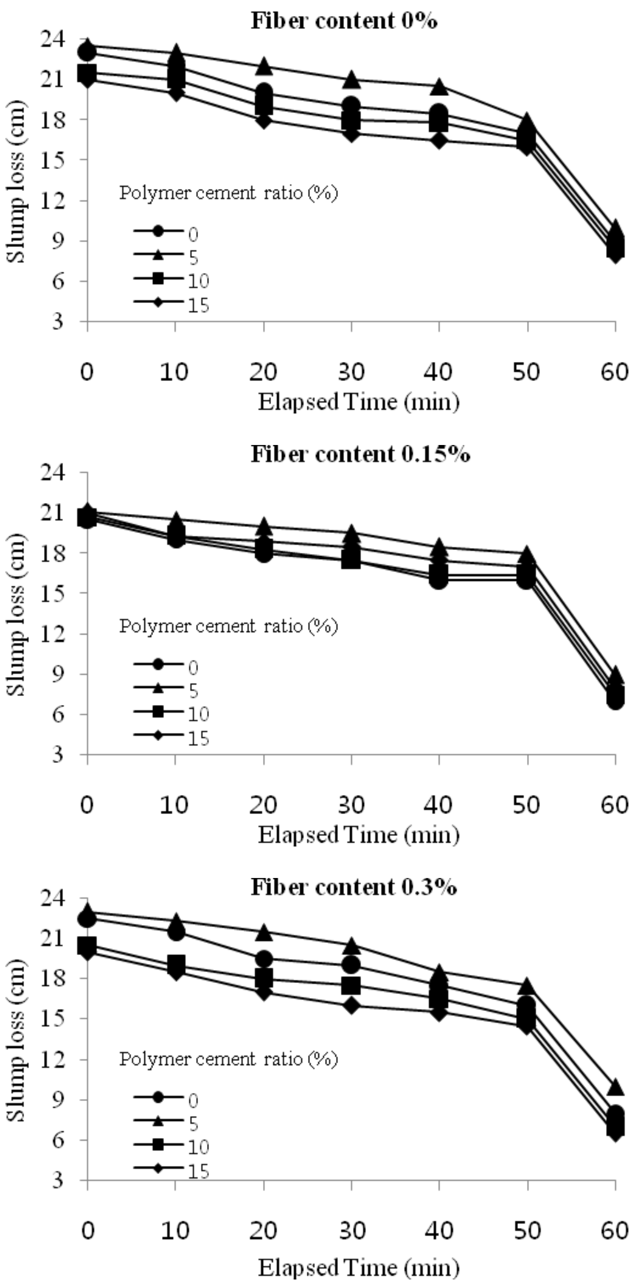


Figure 1. Elapsed Time Versus Slump Loss of Ultrarapid-Hardening Polymer-Modified Concretes with fiber content

4.2 *Water absorption test*

Fig. 2 show the relationship between the water immersion period and water absorption of ultrarapid-hardening polymer-modified concretes with fiber content and polymer-cement ratios of 0, 5, 10 and 15%. The water absorption of ultrarapid-hardening polymer-modified concretes with fiber content increase with increasing water immersion period. The water absorption of the ultrarapid-hardening polymer-modified concretes is reduced to about 1/2 of that of the unmodified concrete. Regardless of the fiber content, the water absorption of the ultrarapid-hardening polymer-modified concretes decrease with increasing polymer–cement ratio. This may be explained to be due to the impermeable polymer film formed in the matrixes by polymer modification.

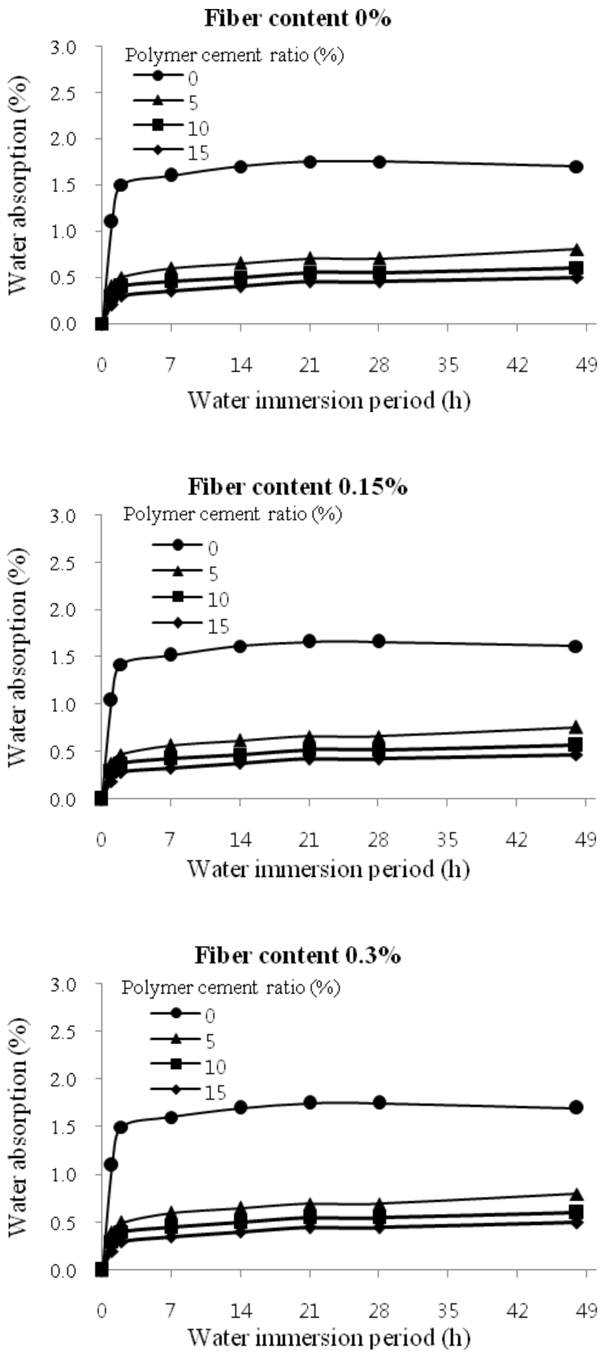
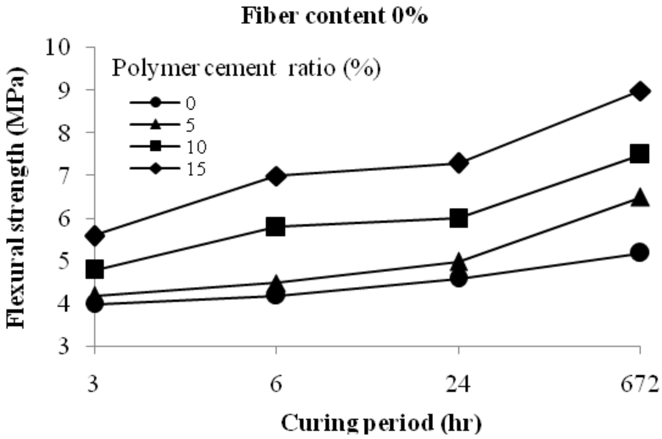
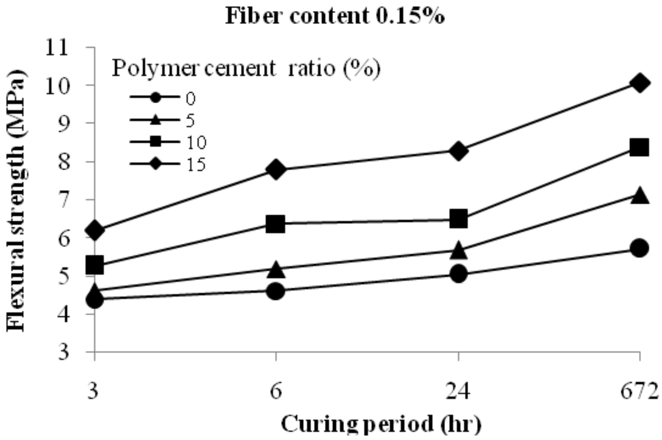


Figure 2. Immersion period Versus water absorption of Ultrarapid-Hardening Polymer-Modified Concretes with fiber content

4.3 *Flexural strength*

Fig. 3 show the relationship between the curing period and flexural strength of ultrarapid-hardening polymer-modified concretes with polymer-cement ratios of 0, 5, 10 and 15%. Regardless of the polymer-cement ratio and curing time, the flexural strength of the ultrarapid-hardening polymer-modified concretes increases with increasing fiber content, and reaches a maximum at fiber content of 0.15%. The flexural strength tends to increase with increasing polymer-cement ratio irrespective of the fiber content and curing time. The flexural strength of the ultrarapid-hardening polymer -modified concretes with a fiber content of 0.15% and polymer-cement ratios of 15 % is about 20 higher than that of the unmodified concrete with a fiber content of 0%. Especially, the flexural strength of the ultrarapid-hardening polymer-modified concretes with a fiber content of 0.15% and polymer-cement ratios of 15% is about twice higher than that of the unmodified concrete with a fiber content of 0%. Such a high flexural strength development is attributed to the marked high tensile strength of fiber and improved bonds between cement hydrates and aggregates due to the incorporation of polymer dispersion[6]. In particular, the improved bonds between the cement hydrates and aggregates are most effective for the high strength development. In the unmodified concrete, adhesive failure occurs at the interfaces between the cement hydrates and aggregates, and the traces of the coarse aggregates falling out from the cement hydrate. In the ultrarapid-hardening polymer-modified concretes, adhesive failure does not occur at the interfaces between the cement hydrates and aggregates, and many coarse aggregates are failed, that is, the cohesive failure of the coarse aggregates. As mentioned above, the high strength development is also explained in terms of the movement of the highest peaks of the pore volume from the larger pore radii to the smaller pore radii and a slight decrease in the total pore volume at both high fiber content and polymer-cement ratio.





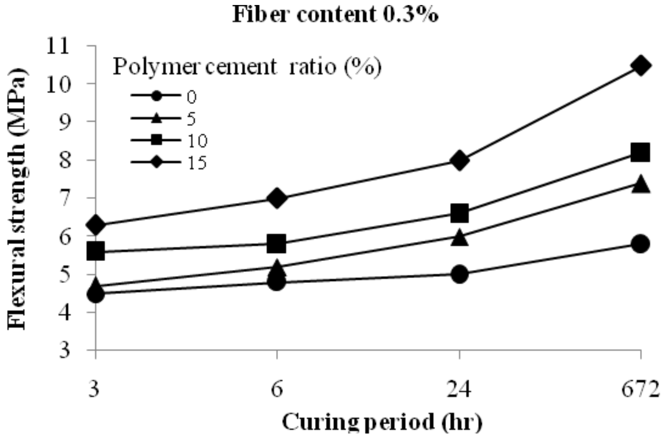


Figure 3. Curing period Versus Flexural Strength of Ultrarapid-Hardening Polymer-Modified Concretes with fiber content

4.4 *Compressive strength*

Fig. 4 illustrate the relationship between the curing period and compressive strength of ultrarapid-hardening polymer-modified concretes with polymer-cement ratios of 0, 5, 10 and 15%. Regardless of the polymer-cement ratio and curing time, the compressive strength of the ultrarapid-hardening polymer-modified concretes increases with increasing fiber content, and reaches a maximum at fiber content of 0.15%. The compressive strength tends to increase with increasing polymer-cement ratio irrespective of the fiber content and curing time. The compressive strength of the ultrarapid-hardening polymer-modified concretes with a fiber content of 0.15% and polymer-cement ratios of 10 to 15% is about 20% higher than that of the unmodified concrete with a fiber content of 0%. Such a high compressive strength development is attributed to the marked water-reducing effect and improved bonds between cement hydrates and aggregates due to the incorporation of polymer dispersion[6]. In particular, the improved bonds between the cement hydrates and aggregates are most effective for the high strength development. As mentioned above, the high strength development is also explained in terms of the movement of the highest peaks of the pore volume from the larger pore radii to the smaller pore radii and a slight decrease in the total pore volume at both high fiber content and polymer-cement ratio.

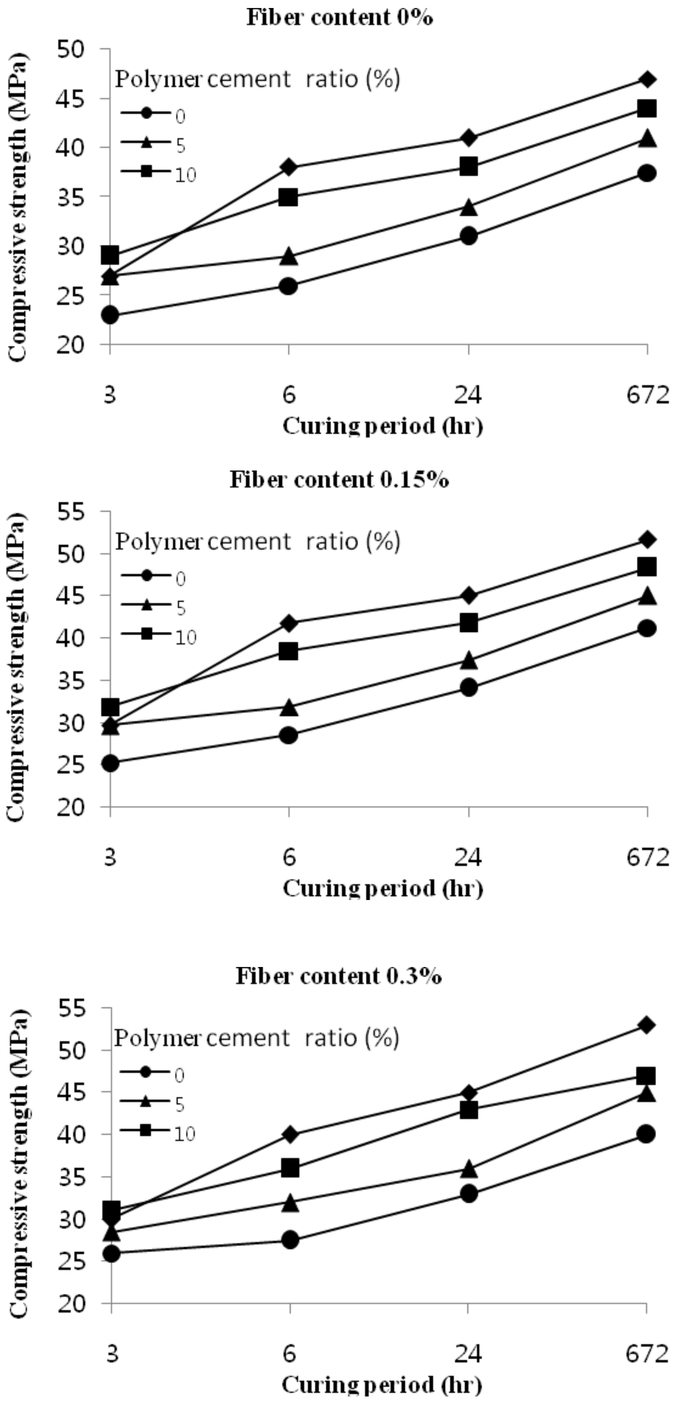


Figure 4. Curing Period Versus Compressive Strength of Ultra-rapid-Hardening Polymer-Modified Concretes with fiber content

4.5 *Tensile strength*

Fig. 5 show the relationship between the fiber content and tensile strength of ultrarapid-hardening polymer-modified concretes with polymer-cement ratios of 0, 5, 10 and 15%. Regardless of the polymer-cement ratio and curing time, the tensile strength of the ultrarapid-hardening polymer-modified concretes increases with increasing fiber content, and reaches a maximum at a fiber content of 0.15%. Irrespective of the fiber content, the tensile strength is greatly increase with increasing polymer-cement ratio. Especially, the tensile strength of the ultrarapid-hardening polymer-modified concretes with a fiber content of 0.15% and a polymer-cement ratio of 15% is about three or two times higher than that of the unmodified concretes with a fiber content of 0%. This is due to the addition of the tensile strength of the polymer films formed in the ultrarapid-hardening polymer-modified concretes to cement hydrates and the improved bonds between the cement hydrates and aggregates, developed by the polymer films[6].

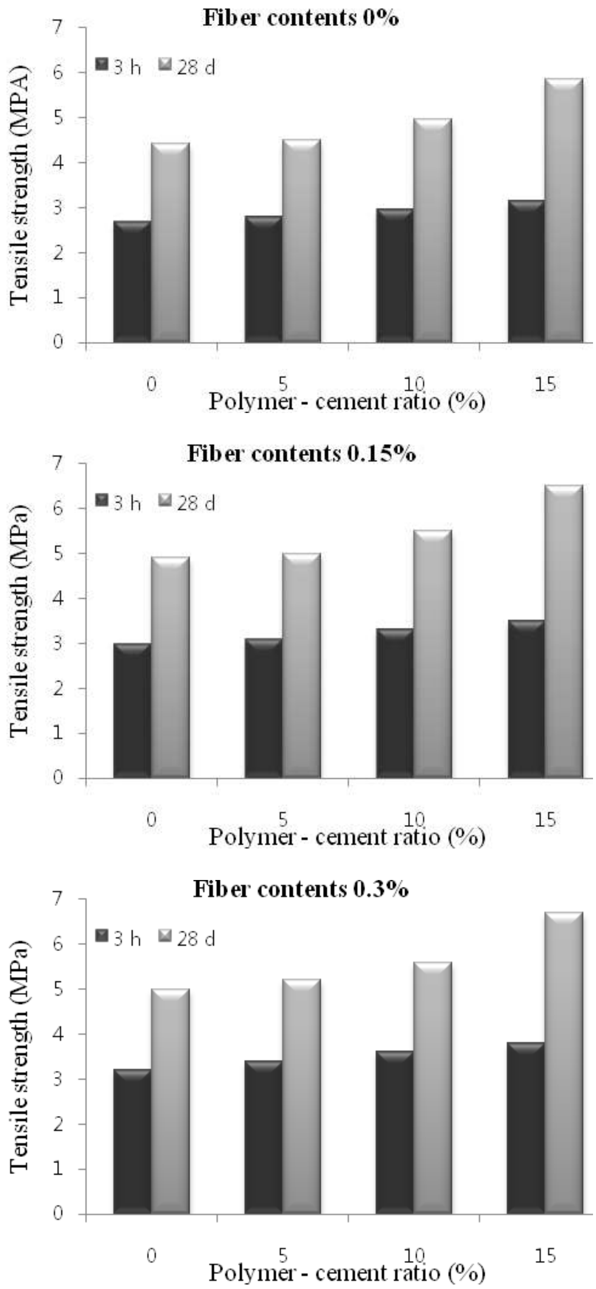


Figure 5. Curing Period Versus Tensile Strength of Ultrarapid-Hardening Polymer-Modified Concretes with fiber content

5 CONCLUSIONS

From the above test results, conclusions are summarized as follow:

1) Slump loss of the ultrarapid-hardening polymer-modified concretes rapid at higher fiber content and polymer –cement ratio.
2) Regardless of the fiber content, the water absorption of the ultrarapid-hardening polymer-modified concretes tend to decrease with increasing polymer-cement ratio.
3) Except for a few cases, the flexural and tensile strengths of ultrarapid-hardening polymer-modified concretes tend to increase with increasing fiber content, and to reach maximums at a fiber content of 0.15%. The strengths are inclined to increase with an increase in the polymer-binder ratio.
4) Ultrarapid-hardening polymer-modified concretes with higher polymer-cement ratio provide higher flexural and tensile strengths than unmodified concretes

6 REFERENCES

ACI Committee 226. Ground granulated blast-furnace slag as a cementitious constituent in concrete. *ACI Materials Journal*, 1987, **84**, No.4, 327-342.

Aldea C. M., Young F., Wang K. and Shah S. P. Effects of curing conditions on properties of concrete using slag replacement. *Cement and Concrete Research*, 2000, **30**, No.3, 465-472.

Madej J., Ohama Y. and Demura K. Durability of high-strength mortars incorporating blast-furnace slags of different finenesses. *Proceedings of the International Conference on Concrete under Severe Conditions (CONSEC`95)*, Sapporo, 1995, **2**, E&FN Spon, London, 1995, 1315-1324.

Joo M., Ohama Y. and Demura K. Strength properties of combined wet/dry-cured SBR-modified concretes using ground granulated blast-furnace slag (in Japanese). *Concrete Research Technology*, 2001, **12**, No.1, 55-61.

Joo M., Ohama Y. and Demura K. Effects of ground granulated blast-furnace slag and high-purity silica on properties of autoclaved polymer-modified mortars (in Japanese). *Cement Science and Concrete Technology*, 1999, No.53, 717-724.

Mindess S. and Young F. Concrete, Prentice-Hall, Englewood Cliffs, New Jersey, 1981, p.87.