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Tensile Creep Properties of Concretes from the Viewpoint of Thermal Crack Protection

Tsuguhiro NONAKA

温度ひびわれ防止効果からみたコンクリートの
引張クリープ特性について

野　中　資　博

Tensile creep property of concrete is necessary to avoid thermal cracking in mass concrete structure. In this paper, tensile creep experiments with ordinary portland cement concrete, B type of blast furnace slag cement concrete and C type of fly ash cement concrete were carried out, and the differences of tensile creep properties were investigated in such three types of concrete.

The results are as follows.

1) With instantaneous elastic coefficient, C type of fly ash cement concrete is smaller than ordinary portland cement concrete but larger than B type of blast furnace slag cement concrete.

2) With specific tensile creep, C type of fly ash cement concrete is much larger than ordinary portland cement concrete and the same as B type of blast furnace slag cement concrete with regard to the loaded ages 15th, 25th day but larger than this concrete with regard to the loaded age 5th day.

3) With the total effect about avoiding thermal cracks, the order is fly ash cement concrete type C, blast furnace slag cement concrete type B and ordinary portland cement concrete.

1. Introduction

Since tensile creep of concrete greatly influences thermal stress in mass concrete, it is necessary for thermal stress analysis to get this property. Futher, this property is necessary to avoid thermal cracking in mass concrete structure.

Thus the author has made tensile creep experiments with ordinary portland cement concrete, B type of blast furnace slag cement concrete and C type of fly ash cement concrete for a long time. Some results in those have been already reported.[1)] In this paper, the differences of tensile creep properties are investigated in such three types of concrete.

Incidentally, tensile creep of concrete is less than compressive creep and is influenced by drying shrinkage. It is rather difficult to get satisfactory test results sufficiently.

* 農業施設工学研究室

2. Tested concretes and test method

Tested concretes were designed as mass concrete; those conditions were 260kg/cm² in compressive strength, 10 cm in slump and 2% in air content. Maximum size of coarse aggregate, however, was 20 mm from the size of a specimen. Those design mixes and fundamental test results are shown in Tables 1-6.

The specimen's shape is a bobbin type; its height is 60 cm and center cross section is 50 cm². The mold was removed at 48th hour after casting. In addition, the specimen was cured in water untill the previous day of the testing.

The tested ages were 5th, 15th and 25th day, but with ordinary portland cement concrete, they were 3rd, 7th, 14th and 28th day. Then the test was conducted in the room of which temperature and humidity were 20°C and R. H. 50% constantly.

To get the tensile strength, splitting tension test was carried out before tensile creep test. Thus the direct tensile strength was 90% of it and the stress level was 40% of the direct tensile strength. This load, moreover, was converted into spring displacement, because the testing machine was made of spring. The test conditions are shown in Tables 7-9 with respective concretes.

Table 1 Physical properties (Normal)

Cement								
Specific gravity	Fineness cm²/g	Setting		Soundness	Comp. strength kg/cm²			
		Initial	Final		1 day	3 day	7 day	28 day
3.15	3390	2h04′	3h11′	good	31	127	165	311

Fine aggregate			Coarse aggregate		
Specific gravity	Absorption %	F. M.	Specific gravity	Absorption %	F. M.
2.53	1.92	2.93	2.68	1.91	6.31

Table 2 Mix proportion (Normal)

Slump cm	Air %	W/C %	s/a %	W kg/m³	C kg/m³	S kg/m³	G kg/m³
10	2	50	47.5	206	397	781	922

Table 3 Physical properties (Blast furnace slag B)

Cement								
Specific gravity	Finenese cm²/g	Setting		Soundness	Comp. strength kg/cm²			
		Initial	Final		1 day	3 day	7 day	28 day
3.04	4630	4h38′	7h38′	good	38	136	207	340

Fine aggregate			Coarse aggregate		
Specific gravity	Absorption %	F. M.	Specific gravity	Absorption %	F. M.
2.53	2.01	2.84	2.64	1.99	6.08

Table 4 Mix proportion (Blast furnace slag B)

Slump cm	Air %	W/C %	s/a %	W kg/m³	C kg/m³	S kg/m³	G kg/m³
10	2	50	47.0	212	424	749	879

Instantaneous elastic strain appears immediately at loading, tensile creep strain follows under constant load. Since drying shrinkage also occurs at the same time, the dummy specimen must be measured in strain. As the method of measurement is electronic method, dynamic strain meter, X-Y recorder and digital static strain meter are used.

Table 5 Physical properties (Fly ash C)

Cement								
Specific gravity	Fineness cm^2/g	Setting		Soundness	Comp. strength kg/cm^2			
		Initial	Final		1 day	3 day	7 day	28 day
2.79	3152	4h47′	5h37′	good		79	110	217

Fine aggregate			Coarse aggregate		
Specific gravity	Absorption %	F. M.	Specific gravity	Absorption %	F. M.
2.59	2.31	2.88	2.63	1.80	6.75

Table 6 Mix proportion (Fly ash C)

Slump cm	Air %	W/C %	s/a %	W kg/m^3	C kg/m^3	S kg/m^3	G kg/m^3
10	2	46	48.0	169	368	863	949

Table 7 Test condition (Normal)

Loaded age days	σ_p kg/cm^2	$\sigma_t=0.9\sigma_p$ kg/cm^2	$0.4\sigma_t$ kg/cm^2	Relaxation load kg	Creep load kg	Spring displacement mm
3	15.7	14.1	5.6	443	282	1.49
7	22.5	20.3	8.1	636	405	2.15
14	27.3	24.6	9.8	772	492	2.61
28	29.4	26.5	10.6	831	529	2.80

Table 8 Test condition (Blast furnace slag B)

Loaded age days	σ_p kg/cm^2	$\sigma_t=0.9\sigma_p$ kg/cm^2	$0.4\sigma_t$ kg/cm^2	Relaxation load kg	Creep load kg	Spring displacement mm
5	19.1	17.2	6.9	540	344	1.82
15	20.6	18.6	7.4	583	371	1.97
25	26.2	23.6	9.4	740	471	2.50

Table 9 Test condition (Fly ash C)

Loaded age days	σ_p kg/cm^2	$\sigma_t=0.9\sigma_p$ kg/cm^2	$0.4\sigma_t$ kg/cm^2	Creep load kg	Spring displacement mm	Elastic strain $\times 10^{-6}$
5	10.5	9.4	3.8	190	1.00	18
15	11.9	10.7	4.3	215	1.13	17
25	17.1	15.4	6.2	310	1.63	22

3. Test results

The relations of instantaneous elastic strain and tensile creep to loaded age are shown in Figs. 1-6 with ordinary portland cement concrete, B type of blast furnace slag cement concrete and C type of fly ash cement concrete respectively. From these results, each concrete hardens smoothly; elastic coefficient increases as age increases; specific tensile creep decreases as loaded age increases.

These characteristics are the same as any concrete has.

4. Comparison of tensile creep properties

To compare the above creep properties, Figs. 7, 8 are shown with three cement concretes.

The results are as follows; with instantaneous elastic coefficient, C type of fly ash cement concrete is samller than ordinary portland cement concrete but larger than B type of blast furnace slag cement concrete; with specific tensile creep, C

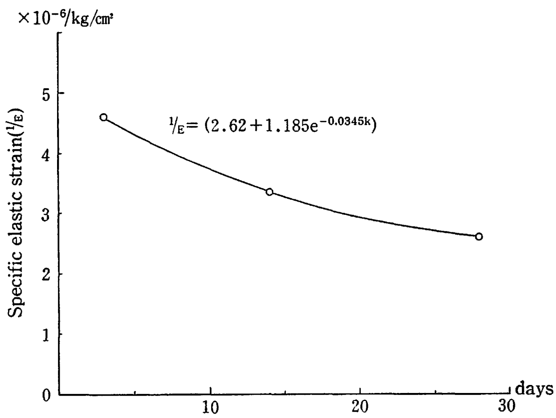

Fig. 1 Specific elastic strain-Testing age (Normal)

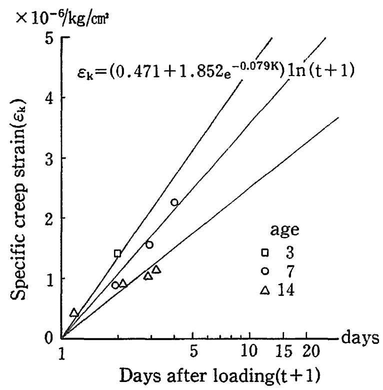

Fig. 2 Specific creep strain-Days after loading (Normal)

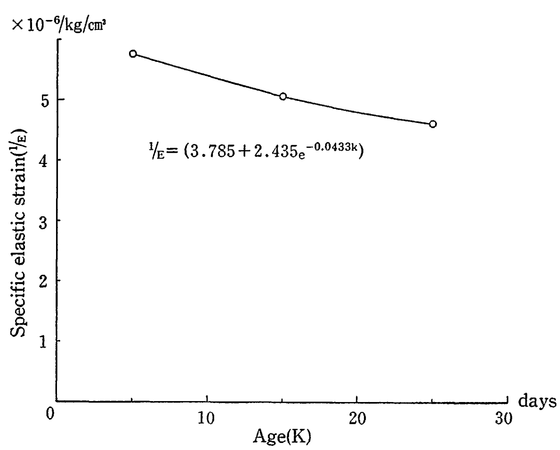

Fig. 3 Specific leastic strain-Testing age (Blast)

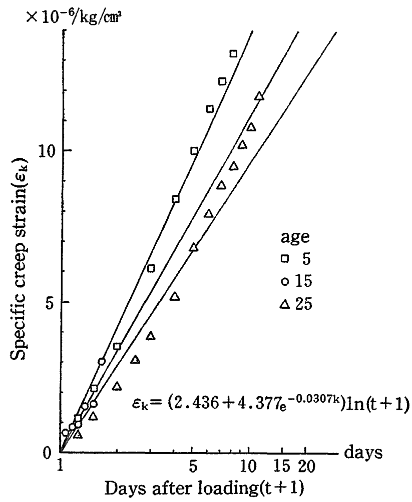

Fig. 4 Specific creep strain-Days after loading (Blast)

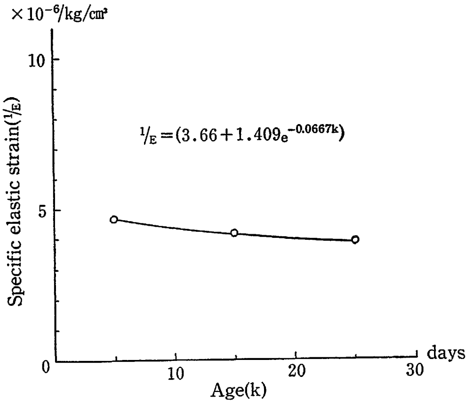

Fig. 5　Specific elastic strain-Testing age (Fly ash)

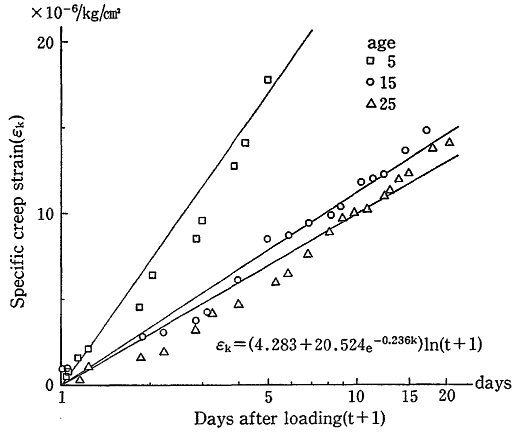

Fig. 6　Specific creep strain-Days after loading (Fly ash)

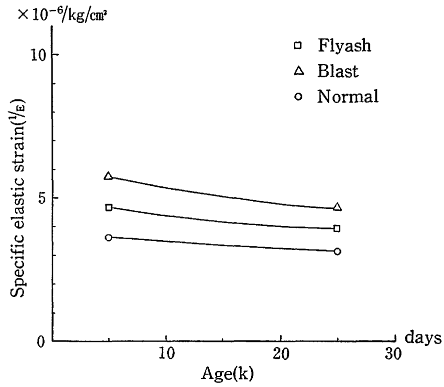

Fig. 7　Comparison of specific elastic strain

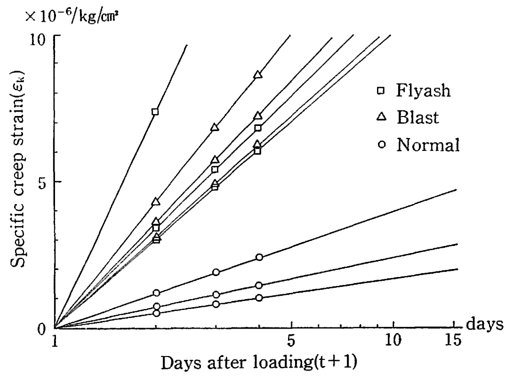

Fig. 8　Comparison of specific creep strain

type of fly ash cement concrete is much larger than ordinary portland cement concrete and the same as B type of blast furnace slag cement concrete with regard to the loaded ages 15th, 25th day but larger than this concrete with regard to the loaded age 5th day.

5. Discussion of test results

It is recognized that the tensile creep property of C type of fly ash cement concrete is a little larger than that of B type of blast furnace slag cement concrete and much larger than that of ordinary portland cement concrete. This result is quite the same as was gained in tensile stress relaxation test before.[2] It was, then, concluded that the tensile stress relaxation of C type of fly ash cement concrete was same level as that of B type of blast furnace slag cement concrete and larger than that of ordinary portland cement concrete. It was, moreover, found that in early age, final relaxation coefficient of C type of fly ash cement concrete was smaller than that of ordinary portland cement concrete about 10%. Since creep is contrary phenomenon to relaxation, the above results are obviously true.

In the next section, therefore, the protection against thermal cracking is mentioned according to these results.

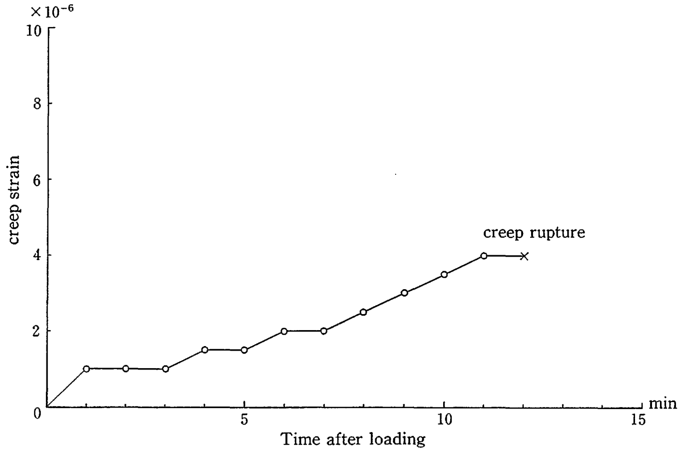

Fig. 9 Creep strain (Fly ash, loaded age 25, stress level 60%)

6. Effect about avoiding thermal cracks

It is already reported that the main factors of concrete regarding protection against thermal cracks are heat of hydration and relaxation elastic coefficient, i. e. the product of instantaneous elastic coefficient by relaxation coefficient. Then it was shown that as compared with ordinary portland cement concrete, C type of fly ash cement concrete has about 15% higher safety regarding occurrence of thermal cracking. From the results before mentioned, incidentally, relaxation elastic coefficient of B type of blast furnace slag cement concrete is equal to that of C type of fly ash cement concrete, because of smaller instantaneous elastic coefficient and tensile creep. Hydration heat of B type of blast furnace slag cement concrete, however, is much greater than that of C type of fly ash cement concrete. Consequently the total effect about avoiding thermal cracks of this concrete is inferior to that of fly ash cement concrete type C.

As a result, the order regarding to protection against thermal cracking is fly ash cement concrete type C, blast furnace slag cement concrete type B and ordinary portland cement concrete.

7. Conclusion

As another cement for mass concrete, there is moderate heat portland cement concrete. The same test, then, will be conducted with that cement concrete. In addition more test, if it is possible, will be carried out with each cement concrete. In any case, I will make effort to collect those data.

Incidentally, there is the opinion that the tensile creep limitation is to be used as definition to occurrence of thermal cracking. When the tensile creep test, loaded stress level 60%, was made with fly ash cement concrete type C, the creep rupture happened in Fig. 9. This result, then, suggests that the tensile creep limitation is lower than 60% stress level. This fact must be examined further. In any case, I will publish the result as soon as I will get.

Acknowledgement

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References

1. NONAKA, T. : Bull. Fac. Agr. Shimane Univ., **17** : 119–122, 1983 (in Japanese).
2. NONAKA, T. : Trans. JSIDRE, **113** : 75–80, 1984 (in Japanese).