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INFLUENCE OF THE LONG-TERM AND REPEATED LOADING ON FRACTURE MECHANICS OF THE PARTIALLY PRESTRESSED BEAMS

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Abstract
Tests results from long-term and short term experiments on partially prestressed concrete beams are reported. The paper analyses effect of static and repeated loading before or after long-term previous loading on the resistance to crack propagation and deflection of the normal and lightweight concrete beams.

1 Introduction

The behaviour of partially prestressed beams under static and repeated loading after long-term load is analysed. The magnitude of the long-term load was 55% of the bearing capacity. The long-term and short-term strain, the cracking state (i.e. the crack width and crack space) and the deflections are given. The influence of static, repeated and long-term loading on above characteristics is set into evidence. The experiments at long-term loading lasted for 730 days, after which the shrinkage and creep phenomena were completely stabilised.

2 Investigated parameters

The following parameters have been taken into account :

- prestressing degrees:
  k = 0.21; 0.43; 0.70, were k is the ratio between the decompressing bending moment and the working (serviceability) bending moment;
- loading type: static or repeated;
- loading duration: short and long-term;
- type of concrete: normal and lightweight.

3 Experimental program

Beams of 120 x 250 x 3200 mm have been tested at 28 days and 2 years.
The beams tested at the age of 2 years have been subjected previously to long-term load of 55% of their bearing capacity ($M^S = 0.55\ M_u$). The testing of all elements has been carried out by applying two concentrated forces at each third of the beam span, resulting a central zone with a constant bending moment. The long-term loading has been carried out in a room, with controlled climate (the relative humidity of 65% and temperature of 20°C).
The static monotonous testing aimed at determining of the element at bending:

- corresponding to crack widths of 0.01 mm, 0.1 mm and to serviceability $M^S = 0.55\ M_u$;
- to decompression ;
- to ultimate strength capacity M_u.

The testing under repeated loading followed the pattern 1000 cycles in the range of $0.1M^S \dots M^S$.
Some specifications of investigated elements are:

- concrete grade Bc 30;
- prestressed reinforcement is made up to 7 ∅ 3 mm strands of TBP 12 type;
- passive reinforcement is of deformed bars PC 52 type with tensile strength of 520 N/mm^2.

The elements have at 28 days the same maximum capacity.

4 Experimental results

4.1 Cracking

Bending moment at the appearance of the cracks ($M_{cr}^{0.01}$) is affected from the 2 years of long-term bending moment $M^S = 0.55\ M_u$, Fig.1

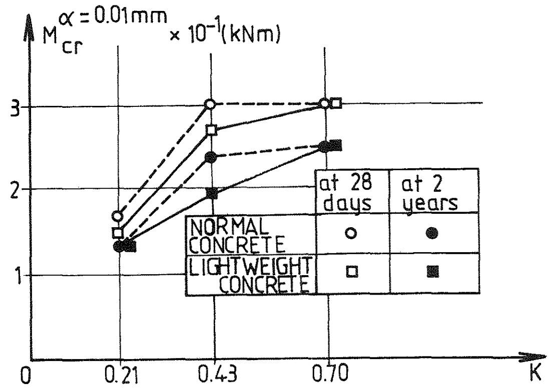

Fig.1. Appearance moment of crack $M_{cr}^{0.01}$ vs. prestressing degrees

In the case of beams tested at 2 years, the values $M_{cr}^{0.01}$ is lower than the values at the 28 days, for normal and lightweight concrete.

The cracking state determined for 730 days by recording the maximum crack width is presented in Fig.2.

On loading the beams at 28 days, exhibited a maximum crack width 0.01 mm for k = 0.70 and 0.1 mm at k = 0.43 and 0.21. At 365 days, maximum crack width reaches about 0.1 mm for k = 0.43 and k = 0.21 after then α_{cr}^{max} is established.

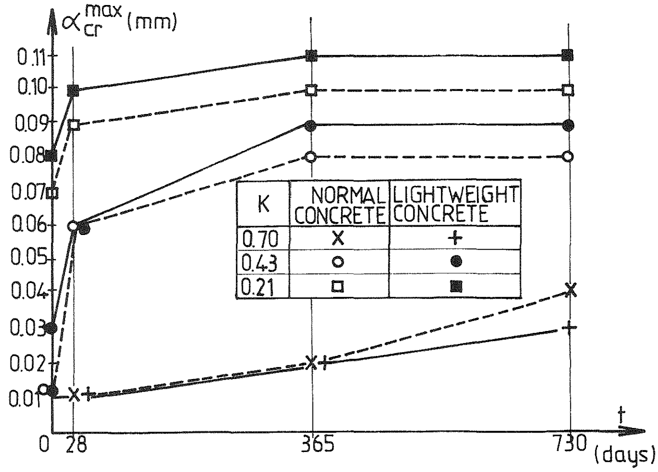

Fig.2. The cracking state in time

The beams tested at the age of 2 years have been subjected previously to long-term load, are the bending moment at $\alpha_{cr}^{max} = 0.1$ mm in all case, the same value, $M^S = 0.55\ M_u$ (Table 1).

Table 1. Cracking moment

Concrete	k	M x 10^{-1} KNm			
		$\alpha_{cr}^{max} = 0.01$ mm		$\alpha_{cr}^{max} = 0.1$ mm	
		28 days	2 years	28 days	2 years
normal	0.70	3.00	2.45	-	3.00
	0.43	3.00	1.28	3.00	3.00
	0.21	1.67	1.28	3.00	3.00
light-weight	0.70	3.00	2.50	-	3.00 x)
	0.43	2.69	1.90	-	3.00x)
	0.21	1.48	1.25	3.00	3.00 x)

Note: x) after 1000 cycles $0.1\ M^S - M^S$

The average cracks space for $\alpha_{cr}^{max} = 0.1$, 0.2 and 0.3 mm are given in Fig.3. For the same crack width,

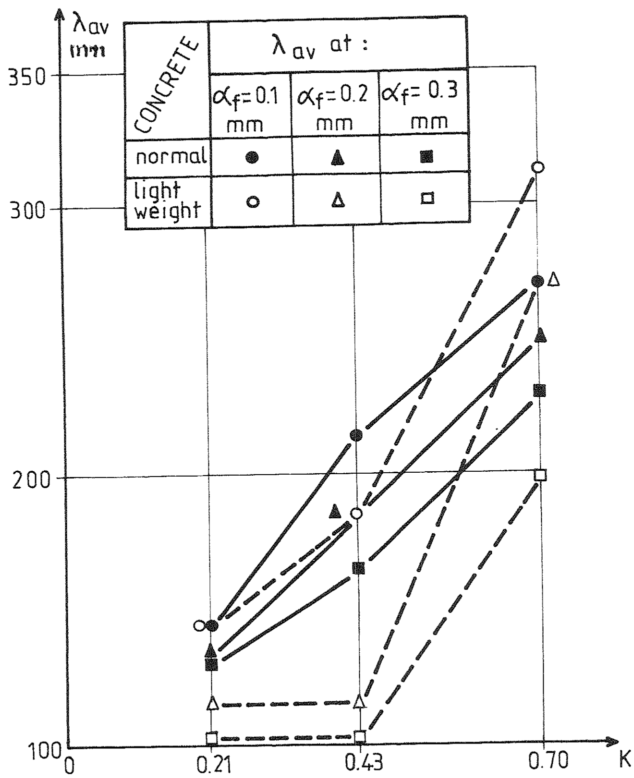

Fig.3. Average cracks space vs. prestressing degree

the average cracks space increase by about 2 times with the prestressing degree k = 0.7 ... 0.21.

Under the service value of the bending moment (M^S) it can be seen that, Fig.4:

- the loading has a minor influence in the range 0.1 M^S ... M^S in the case of the elements with k = 0.7 ... 0.21 tested at 28 days or 2 years;
- if prestressing degrees increases, the ratio $M/M_{break} = M/M_u$ is decreasing, where M is the bending moment for the crack width $\alpha_{cr}^{max} = 0.1$, 0.2 and 0.3 mm.

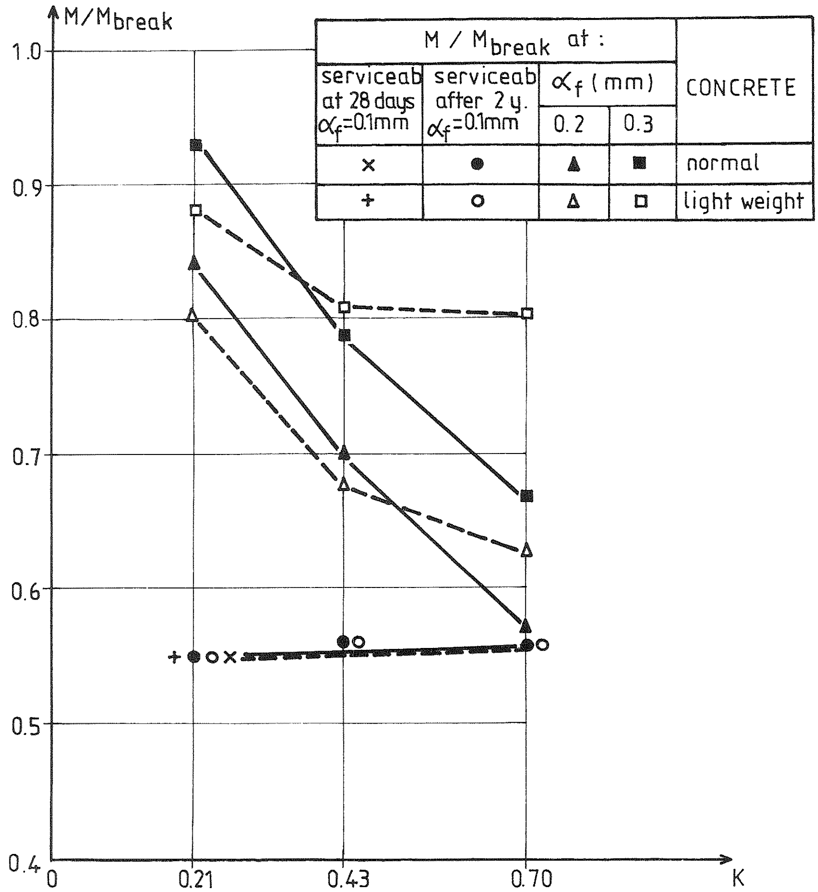

Fig.4. M/M_{break} vs. prestressing degree

4.2 Deflection

For the element with several prestressing degrees tested at 28 days or 2 years of age under static and repeated loading of serviceability limit state value M^S, for normal and lightweight concrete are presented in Fig.5 and 6.

We can seen that:

- 2 year of long-term bending moment M^S, value the deflections increased, but not exceed the limit value accepted , 1/200 (where 1 is the opening of beam);
- under repeated loading of serviceability, limit state value, the deflections increased at about 15%.

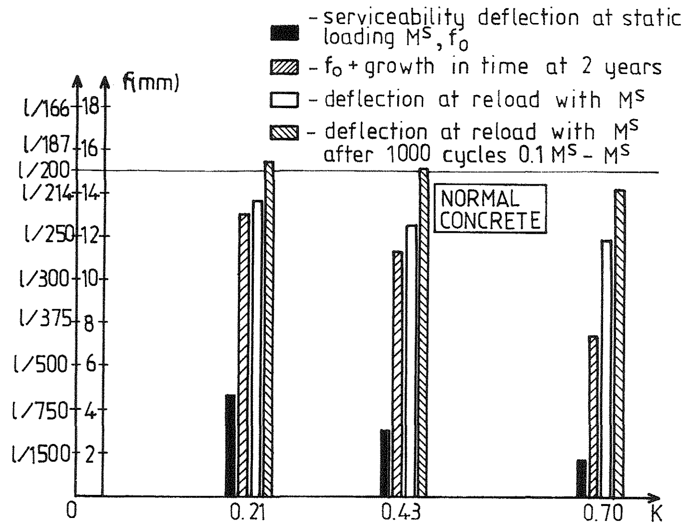

Fig.5. Deflection vs. prestressing degree at normal concrete

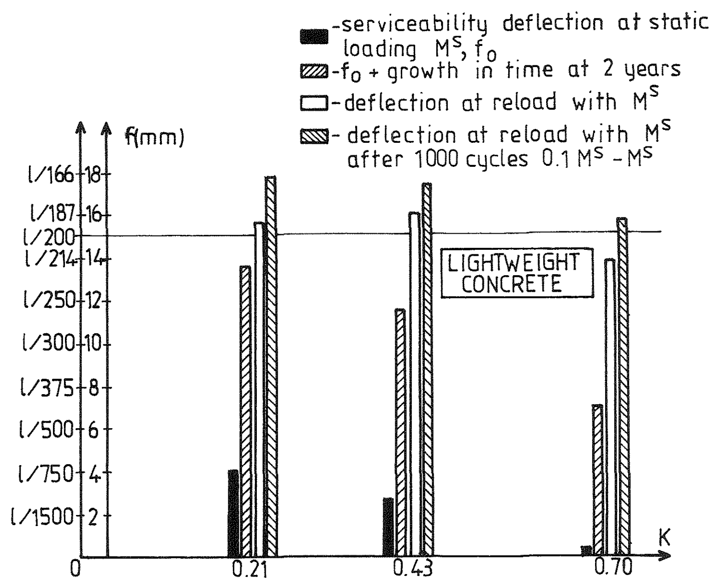

Fig.6. Deflection vs prestressing degree at lightweight concrete

for normal weight concrete and about 11% for lightweight concrete.

4.3 Strain

Fig.7 shows the compressive strains at bending moment at M^S before and after repeated loading aut at the ultimate bending moment (at the break) M_u.
After 1000 cycles, the compression strain are 1.1 to 1.3 time larger than at the static load.
The compressive strains at the ultimate bending moment, M_u , are 2...3 time larger than the serviceability M^S.
The lightweight concrete beams are in all cases, a much more compressive strain at ultimate bending moment as the normal weight concrete beams.

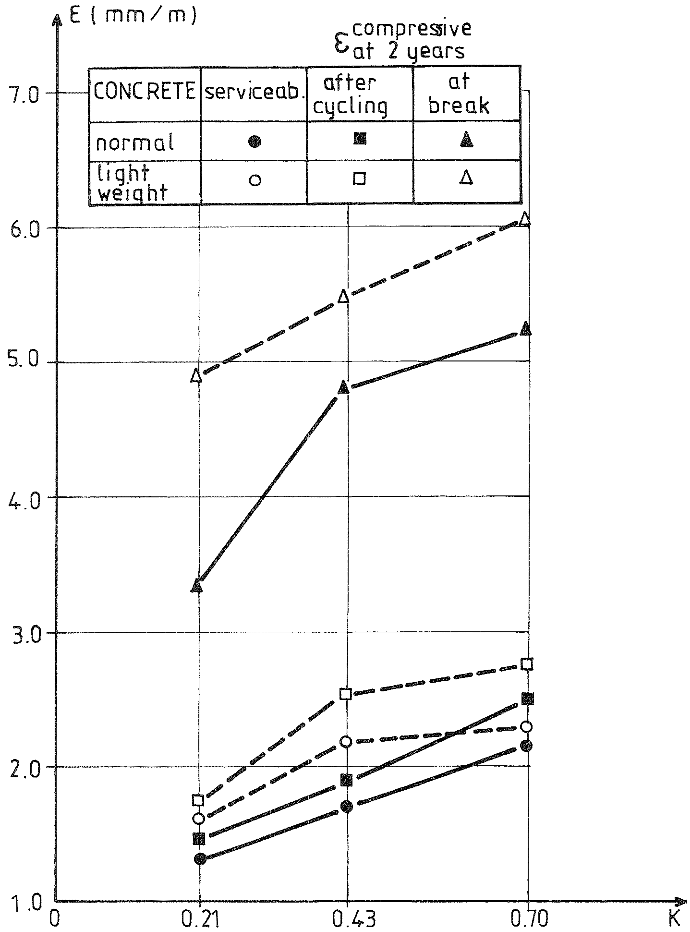

Fig.7. Strain vs prestressing degree

5 Conclusions

The experimental research carried out allows us conclude that the influence of long-term and repeated loading in the range 0.1 M^S ... M^S, upon the behaviour of the partially prestrssed concrete beams is situated within reasonable limits especially for cracks width and deflections.

The above experimental results in correlation with those regarding the bearing capacity (Tertea 1984a, Tertea 1984b) emphasize the fact that the partially prestressed concrete elements are properly designed have a good behaviour under static and repeated loading after their previous long-term loading regime, for normal and lightweight concrete beams.

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