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INFLUENCE OF EXISTENCE OF CONSTRUCTION JOINTS ON FATIGUE BEHAVIOR OF REINFORCED CONCRETE BEAMS

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Synopsis

Results of fatigue tests on T-beams having a span of 3m, a reinforcing deformed bar of 22mm diameter with a special type of coupler joint and two construction joints of concrete were discussed and compared with those of monolithic beams. It was certified that construction joints of concrete had not any effect on fatigue behavior of reinforced concrete beam.

Keywords: fatigue, cracking, flexure, beam, reinforced concrete, deformed bar, precast concrete, concrete joint,

1. Introduction

One of the most important problems to be solved in design and construction of reinforced concrete beams assembled of precast elements is the influence of existence of joints on fatigue behavior of beams concerning flexural strength and cracking behavior under repeated loads. This problem contains two items; the one concerns the construction joints of concrete and the other the joints of reinforcing bars.

The present paper deals with a discussion on the former item on the basis of the results of both tests previously reported and lately conducted by the author's team.

2. Fatigue Behavior of Monolithic Reinforced Concrete Beams

About 100 reinforced concrete beams having T-shape cross sections of 28 x 30cm, a span of 300 cm and reinforcing deformed bars were tested under repeated loads with less than two million pulsations at a rate of 250 cycles per minute (1)(2)(3). The results shows that, in case of under-reinforced beams, the failure of beams is always caused by fatigue fracture of reinforcements and that the increase of crack openings and deflections hardly occures by dynamic loads, when steel stresses are under 0.8 times yielding point of the reinforcing steel, even when the initial crack openings were 0.3mm. Fig.1 shows a typical test result(1).

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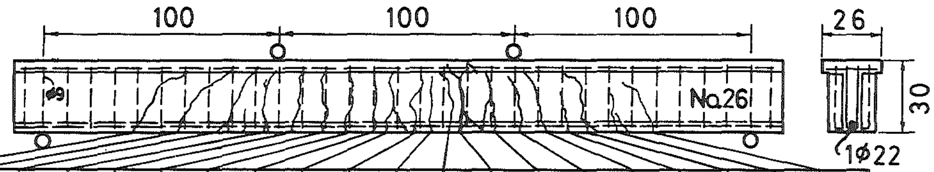


Number of repetition N (x 10³)																				
(1)		100	75		50	150	75	100	75	100	50	50	50	75	50	100	25	75	75	50
10	50	150	100	25	75	25	100	150	100	100	50	75	100	50	75	100	100	100	125	50
20	50	150	50	25	50	250	100	150	100	75	75	50	100	50	75	100	75	100	150	50
30	50	150	50	25	75	250	100	150	100	75	50	75	100	50	50	100	100	150	150	50
50	50	150	50	25	50	250	150	150	125	100	50	75	75	50	125	100	100	150	175	50
70	50	150	50	25	50	250	150	150	125	100	50	75	75	50	125	100	50	125	200	50
100	50	150	50	25	50	250	100	125	100	75	100	50	100	75	75	100	75	125	150	50
200	50	150	75	25	50	200	100	150	75	75	75	75	75	50	125	100	100	125	200	50
300	50	200	75	50	75	250	75	175	125	100	125	100	100	100	100	125	125	100	50	175
500	100	150	100	50	75	250	75	200	150	125	75	75	100	75	100	125	125	100	100	100
700	50	150	50	25	50	250	200	200	150	100	50	75	75	50	125	100	100	175	200	75
1000	50	150	50	25	25	200	150	200	150	150	50	50	125	50	75	75	50	150	200	50

Figures show crack widths under max. loads in 10^{-3} mm
Test beam: span 3m, Reinforcement: twisted bar FY2° 1φ22(σ_{sy}=42.3 kg/mm²),
max. steel stress σ_0 = 32.53 kg/mm², stress ratio s=0.276, N at failure=1418.8×10³

Fig.1 Result of fatigue test on monolithic reinforced concrete T-beam

A more precise investigation on reinforced concrete beams(4) shows that a slight increase of crack widths is observed under repeated loads (Fig.2). This may be understood as follows:

A crack width is generally expressed by

$$w = \left(\frac{\sigma_{so}}{E_s} - \frac{\bar{\sigma}_{cm}}{p E_s} \right) l$$

where σ_{so} = steel stress in the cracked section,
σ_{cm} = meam stress of surrounding concrete in a given section,
$\bar{\sigma}_{cm}$ = mean value of σ_{cm} over the length l,
p = ratio of cross-sectional area of the bar against that of concrete,
l = crack spacing.

Since $\bar{\sigma}_{cm}$ is the stress which is transmitted by the bond from steel to concrete, the increase of w may be caused by gradual relaxation of bond stresses which does not necessarily result in a detrimental failure of the bond, because the static flexural test after fatigue test shows that the bond stresses are restored at higher loads than that in the fatigue test as shown in the figure.

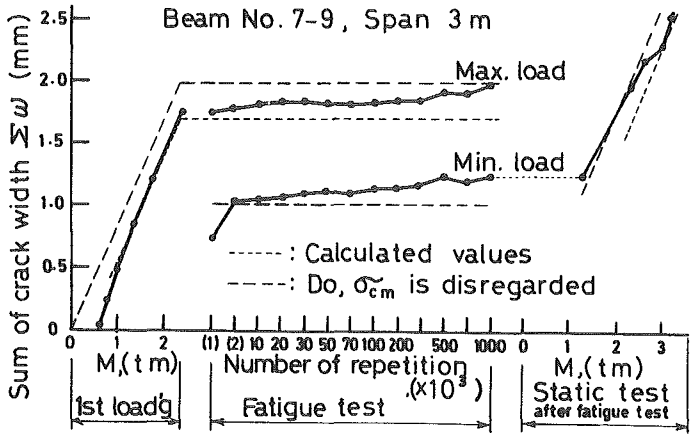


Fig.2 Test results showing effect of fatigue on sum of crack widths in RC beams

3. Fatigue Behavior of Reinforced Concrete Beam Having Construction Joints of Concrete

Tests on the influence of existence of construction joints of concrete on fatigue behavior of reinforced concrete beams were carried out by the author's team as follows:

MATERIALS AND TEST PROCEDURE

The ordinary Portland cement was used. Seashore sand of 2.17 fineness modulus and river gravel of 15mm maximum size were used.

The concrete used in the test had a gravel/sand ratio of 1.53 by weight, a cement content of 271 kg/ m^3, a water/cement ratio of 0.60 and a compressive strength of about 350kg/cm^2 at 28 days under the standard curing. The reinforcing bars used were of twisted deformed ones as shown in Fig.3, 22mm in diameter and of nominal yield point of 40kg/mm^2.

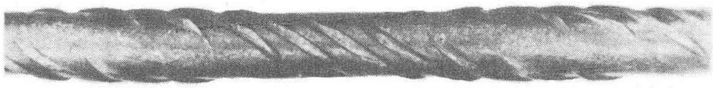


Fig.3 Tested bar

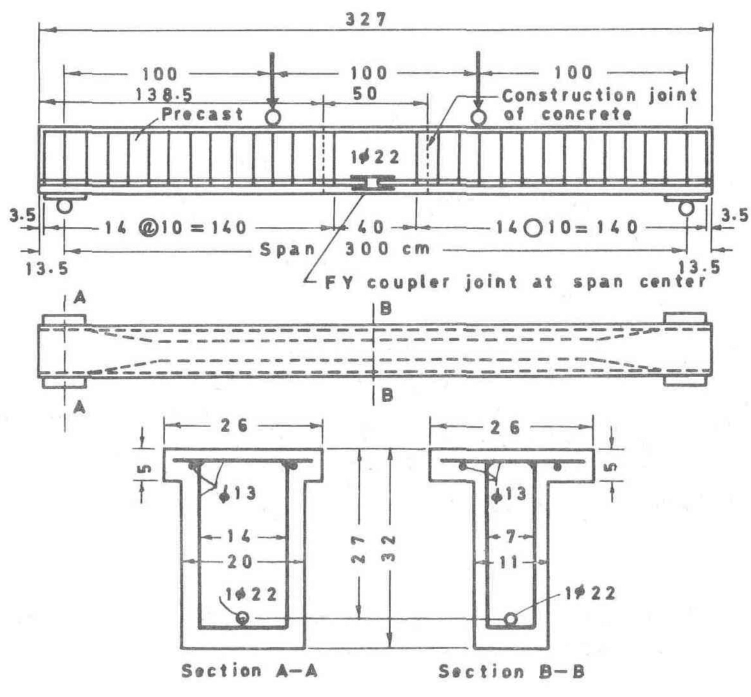


Fig.4 Dimensions of test beam

The dimensions of the test beams are shown in Fig.4. The loads were applied to the beam at third points. All the beams had a FY-coupler joint for reinforcing bars at midspan. The FY-coupler is a special type of screw-threaded coupler (Fig.5) which was developed by the author's team and experimentally tested to secure the transmission of the entire strength of the bar to be joined(5).

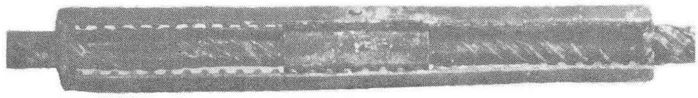


Fig.5 Fy-coupler

A total of 8 beams were tested, among which 3 beams had two construction joints of concrete as shown in Fig.4 and the others had not any concrete joint.

Beam tests were carried out by Lohsenhausen type fatigue machine at rate of 250 cycles per minute. In the fatigue test the ratio of minimum load to maximum load was set to 0.3. The maximum range of loads was set to a magnitude which caused initial crackings of 0.2mm or more maximum width.

TEST RESULTS AND DISCUSSIONS

A view of typical state of crackings of beam which had construction joints of concrete and the variation of crack widths under repeated loads were as shown in Fig.6 and those of beam without construction concrete joint were as shown typically in Fig.7.

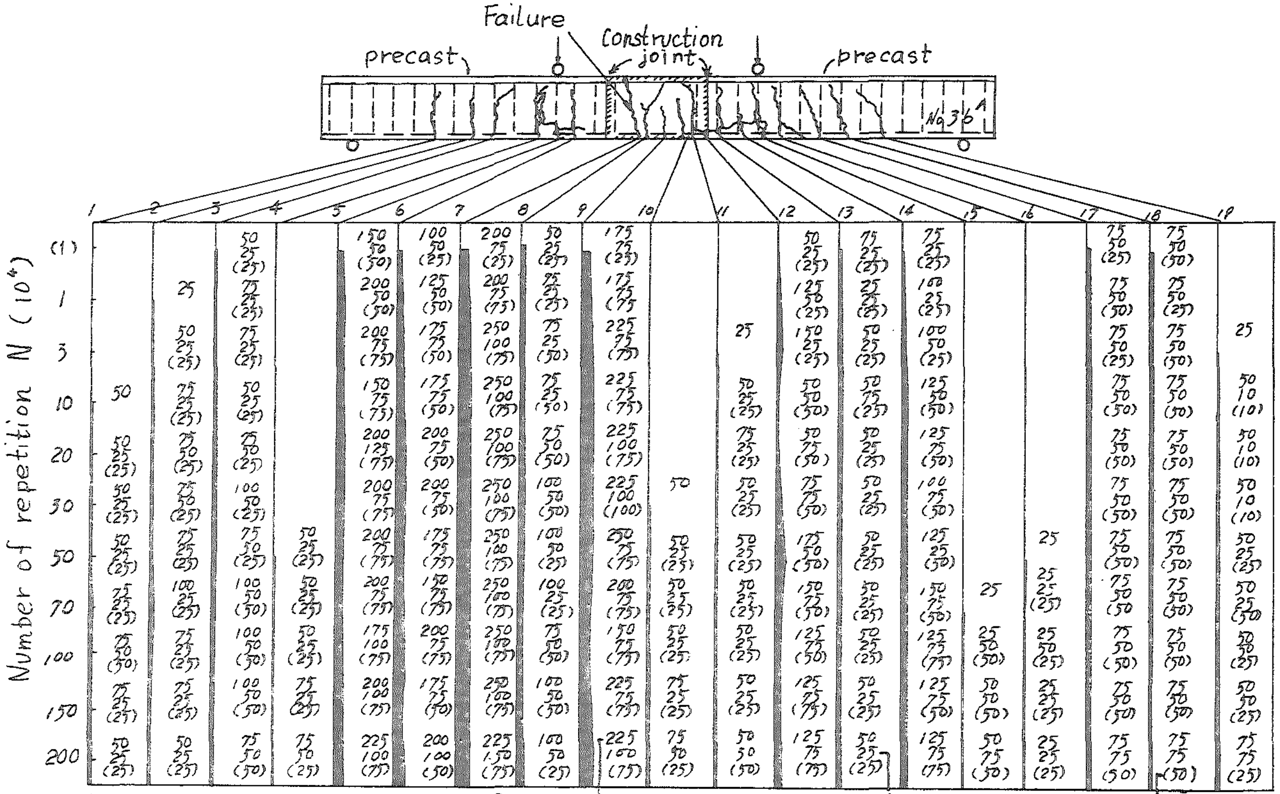
These figures show that the line of construction joint did not always coincide with one of cracking lines, and that the failure of beam took place through one of cracking lines of larger width which did not coincide with any of the joint lines, and moreover that the increase of crack openings was hardly observed irrespective of existence of construction joints of concrete.

The failure of all the beams was caused by fatigue fracture of reinforcing bars, this being the same as in case of monolithic beams previously mentioned.

The test results were plotted all together as shown in Fig.8 showing relation between maximum loads in steel stresses σ_0 and number of cycles at fatigue failure of beam. It can be seen from this figure that all the plotted points fell approximately on a same curve irrespective of existence of concrete joints. This shows also that the existence of construction joints of concrete had scarcely affected fatigue behavior of reinforced concret beams.

CONCLUSIONS

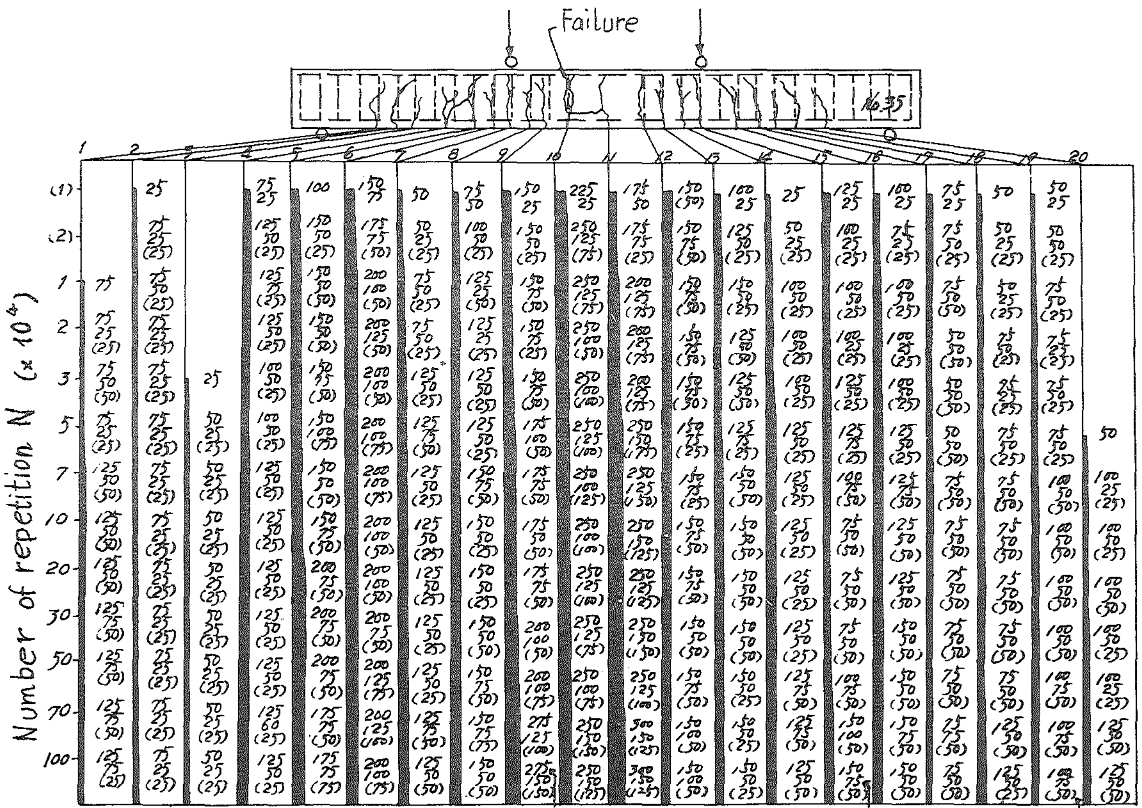
In case of reinforced concrete beam where a beam consists of precast elements having deformed bars as reinforcement, the elements are joined by connecting bars by meams of secrew-threaded couplers which are statically strong enough to secure the transmission of the entire strength of the bar to be joined, and each gap between two adjacent elements is filled up by pouring concrete of the same quality as that of precast concrete. the existence of construction joints of concrete has scarcely affected fatigue behavior of beam concerning flexural strength and cracking under repated loads with less than two million pulsations.



Figures show crack widths in 10^{-3} mm. └ under upper limit load, └ " lower limit load, └ residual.

Resut of Fatigue test on T-beam, span 3 m, reinforcement, twisted bar FYⅢ $\phi 22$ (SD(40), FY-coupler joint at center of span, upper limit stress of steel σ_{so} = 23.5 kg/mm², s = σ_{su}/σ_{so} = 0.3, N at failure = 200×10⁴.

Fig.6 Result of fatigue test on T-beam having two construction joints of concrete



Figures show crack widths in 10^{-3} mm., under upper limit load, " lower limit load, residual.
Test beam: T-beam of 3 m span. Reinforcement: twisted bar FYⅢ 1ϕ22 (SDC 40) with FY-coupler joint at spancenter. Loading: max. steel stress $\sigma_{50} = 23.5$ Kg/mm^2 ($0.49\,\sigma_{sy}$), stress ratio = 0.3
N at failure = 125×10^4 cycles. Monolithic beam Compressive strength of Concrete = 372 Kg/cm^2.

Fig.7 Result of fatigue test on monolithic reinforced concrete T-beam

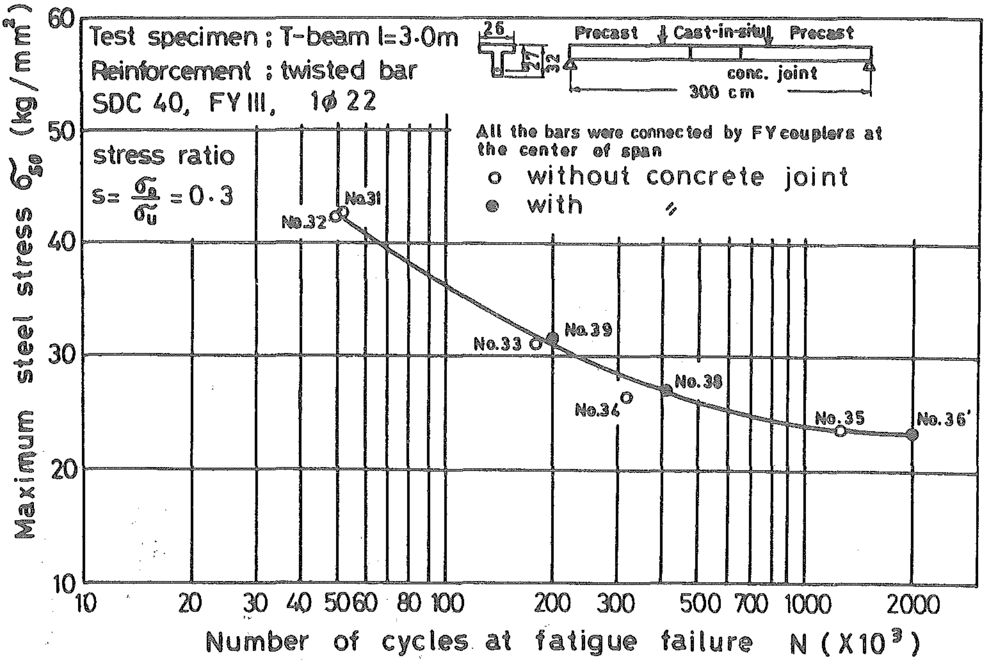


Fig.8 Result of fatigue tests of T-beam, showing the influence of existence of concrete joints on fatigue behavior of reinforced concrete beam

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