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Fatigue of Reinforcements with Pressed Sleeve Splices

Fatigue des armatures avec joints par manchons pressés

Ermüdung von Bewehrungsstählen mit Pressmuffenstössen

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SUMMARY

The pressed sleeve splicing of reinforcing bars is a noteworthy method among the range of mechanical connections. Tests of plain, not embedded, splices have shown advantageous behaviour in load capacity and fatigue strength in the range of 12—40 mm bar diameters. The good resistance to fatigue is demonstrated by Wöhler diagrams. The influence of these splices on the crack pattern of reinforced concrete beams under static, sustained and fatigue load was also examined.

RESUME

La jonction des armatures par des manchons pressés est un moyen important parmi les jonctions mécaniques usuelles. Lors d'essais sur des barres d'armature non bétonnées de diamètre 12 à 40 mm, on a observé un bon comportement du point de vue de la résistance et de la fatigue. La bonne résistance à la fatigue est attestée au moyen des courbes de Wöhler correspondantes. On a en outre contrôlé l'influence de ces jonctions sur la formation des fissures de poutres en béton armé, sous des charges statiques instantanées et de longue durée ainsi que sous des charges répétées.

ZUSAMMENFASSUNG

Das Verfahren des Stossens von Bewehrungsstählen mittels Pressmuffen nimmt unter den üblichen mechanischen Verbindungsmethoden eine Sonderstellung ein. Bei nicht einbetonierten Stählen vom Durchmesser 12 bis 40 mm konnte ein gutes Verhalten in bezug auf statische Festigkeit und Dauerfestigkeit nachgewiesen werden. Das Dauerfestigkeitsverhalten wird anhand entsprechender Wöhlerkurven beschrieben und der Einfluss der Muffenstösse auf das Rissbild unter ständiger Last und bei Ermüdungsbelastung gezeigt.

1. INTRODUCTION

There is wide interest in mechanical splicing of reinforcing bars due partly to the technical-technological disadvantages of welded bar splices, and partly, to the new technical facilities.

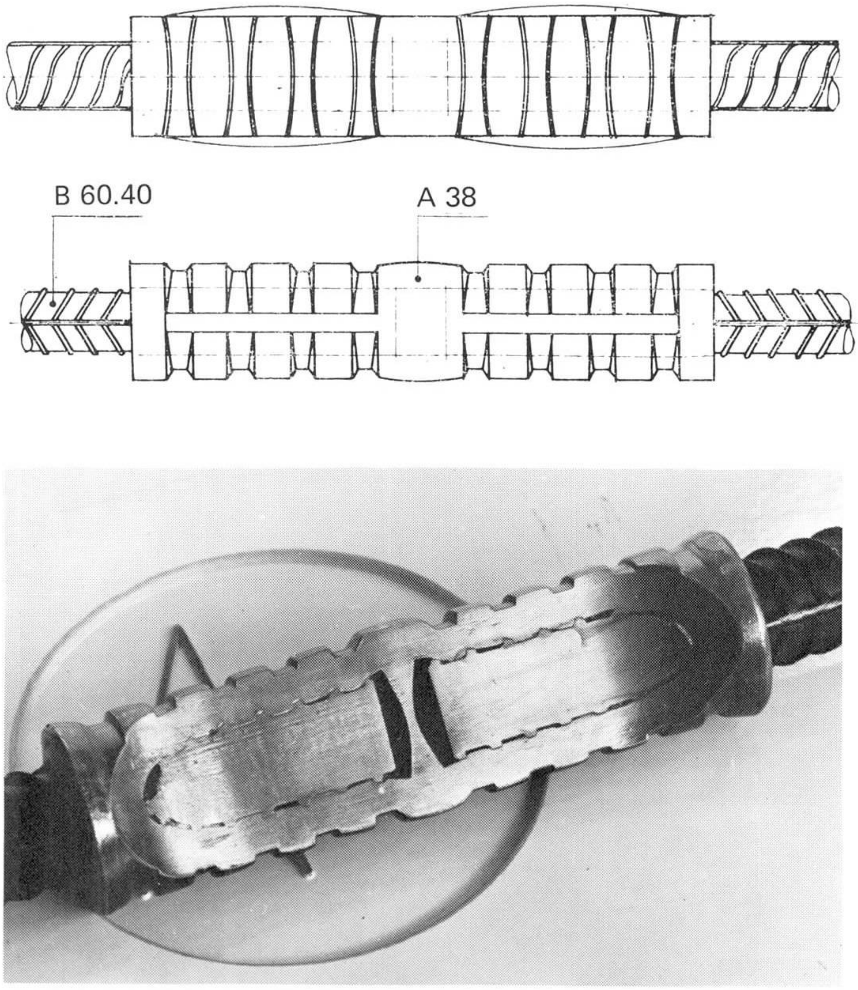

Fig. 1. Pressed sleeve splice

Among mechanical splicing methods, splicing that by pressed sleeves, outstanding in its simplicity, easy handling and good mechanical characteristics, becomes increasingly applied in several countries [2].

Pressed-sleeve reinforcing bar splicing is made by pulling the splicing sleeve onto the deformed bar, then pressing on it by cold forming normally to the bar axis while bar ribs get compressed against the sleeve strain wall (Fig. 1). After pressing, the splice remains in a state of residual stress pattern [3].

This method, suiting both workshop and site work.

2. STATIC TEST RESULTS

Suitability of pressed sleeve reinforcing bar splices has been fundamentally confirmed in tensile tests showing a connection with equal carrying capacity [3]. A high number of tests demonstrated two load capacity criteria of the splices: there was no splice failure up to the standard load capacity of the basic material; and no relative displacement was found at the sleeve butt end between bar and sleeve exceeding 0.15 mm at a stress in the bar of 340 MPa, and within this range, the relationship can be considered as linear (Fig. 2).

Also deformation vs. load values at interfaces with the hardened concrete are favourable, as seen in Fig. 3.

Splices stored in open air did not suffer load capacity decrease even after two years – microscopy of the pressed section through bar rib and sleeve revealed no harmful alteration. Nor did exposure of the splices to temperatures of 250 to 350 °C affect the load capacity differently than in the case of the reinforcing bar without splices.

From among load capacity tests, checking of pressed splices within beams is rather meaningful (see also [1]). Rectangular beams, 200 by 350 mm in cross section, 3.90 m long were reinforced to tension by two ∅ 22 mm bars with a standard yield point of 400 MPa either with or without splices. Tests showed neither load capacity decrease nor crack width increase for beams with splices. Load capacities and crack patterns of beams with and without splices proved to be equal. A group of beams were exposed to sustained loading for 8 months – without excess deformations in beams with spliced reinforcement (Fig. 4).

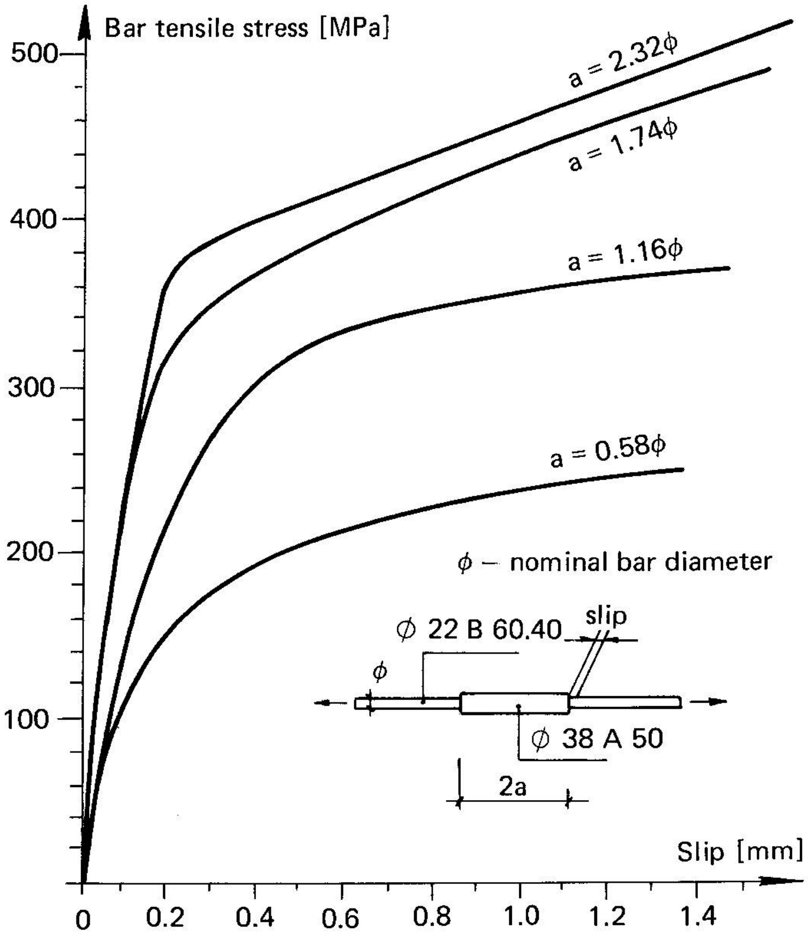

Fig. 2. Bar stress – slip relationship
(single load)

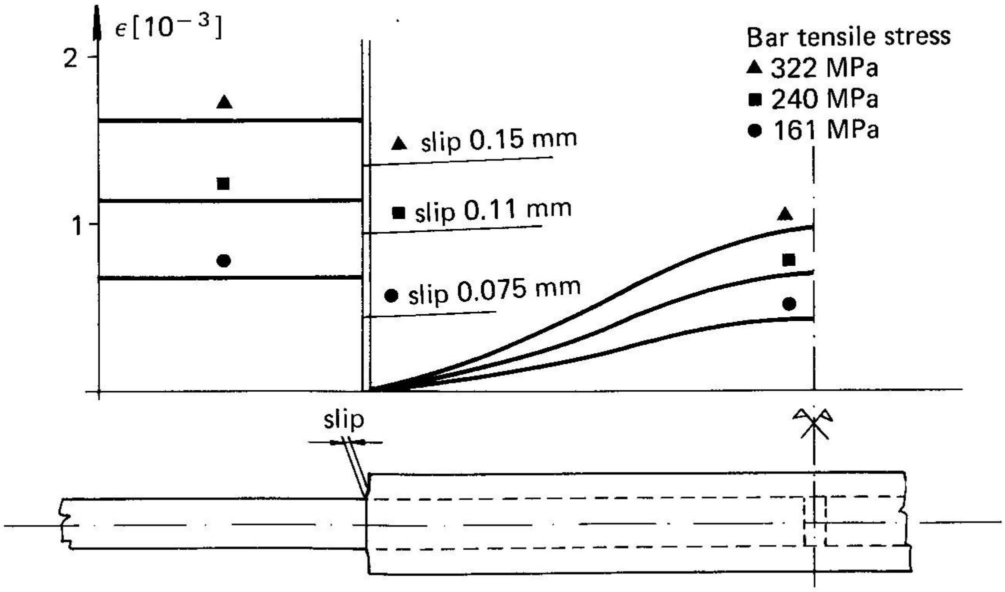

Fig. 3. Strains and slips at spliced reinforcement – concrete interface

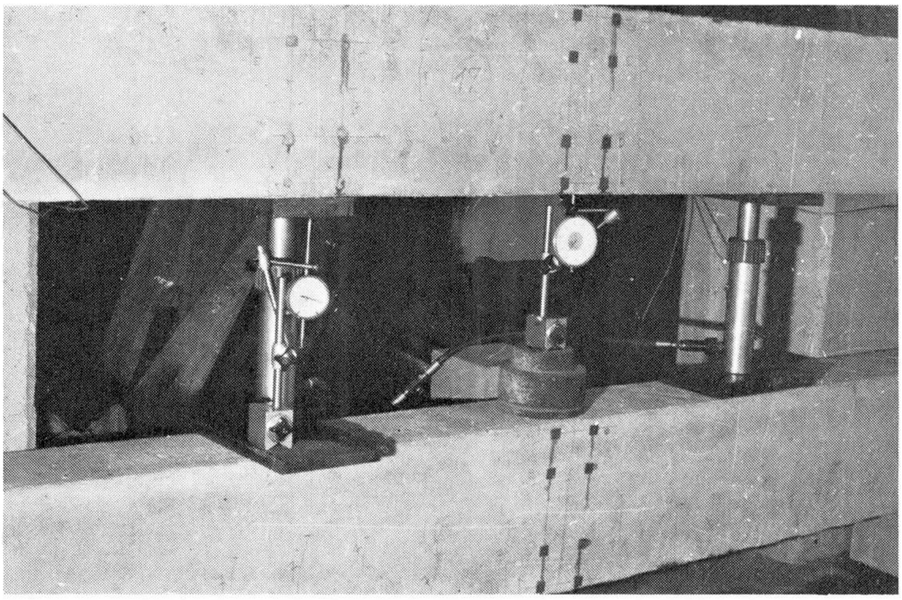

Fig. 4. Beams under sustained load

3. FATIGUE TEST PROGRAM

Fatigue tests were an important part of checks on pressed-sleeve bar splices. The testing program comprised:

- tests on free splices (a);
- tests on concrete embedded splices (b);
- tests on splices in beam tensile reinforcement (c).

Tests (a) on free splices was aimed at determining the fatigue strength for two million pulsating stress alternations. In addition, tests (b) examined concrete cracks starting from the sleeve butt end. Tests (c) were intended to see the effect of load repetitions on the crack pattern in the surroundings of splicing in beams where all tensile bars were spliced.

Characteristics of test materials have been compiled in the following table:

Table 1. Characteristics of tested materials (standard values)

Test type	Bar ∅ mm	Steel type	Bar yield point MPa	Bar tensile strength MPa	Sleeve yield point MPa	Sleeve tensile strength MPa
(a)	12	B 60.40	400	600	240	380
	22	B 60.40	400	600		
	28	B 60.40	400	600		
	40	B 50.36	360	500		
(b)	40	Bst 42/50	420	500	240	380
	40	B 50.36	360	500		
(c)	25	B 50.36	360	500	240	380

4. FATIGUE TESTS ON FREE SPLICES

Pressed-sleeve bar splices were exposed to a high number of pulsating stress alternations where the lower limit of tensile stresses was uniformly 50 MPa – the upper limit was changed until at least one of the six specimens attained not more than two million load repetitions. Test results have been plotted in Wöhler diagrams. Fig. 5, characteristic of fatigue tests on pressed-sleeve splices, represents the upper stress limit at failure in fatigue vs. load repetition number as well as the mode of failure. The Wöhler diagram in the case of splices of ⌀ 40 mm bar is similar to Fig. 5. The number of all ⌀ 40 mm specimens where the upper limit was due to failure at the sleeve was negligable.

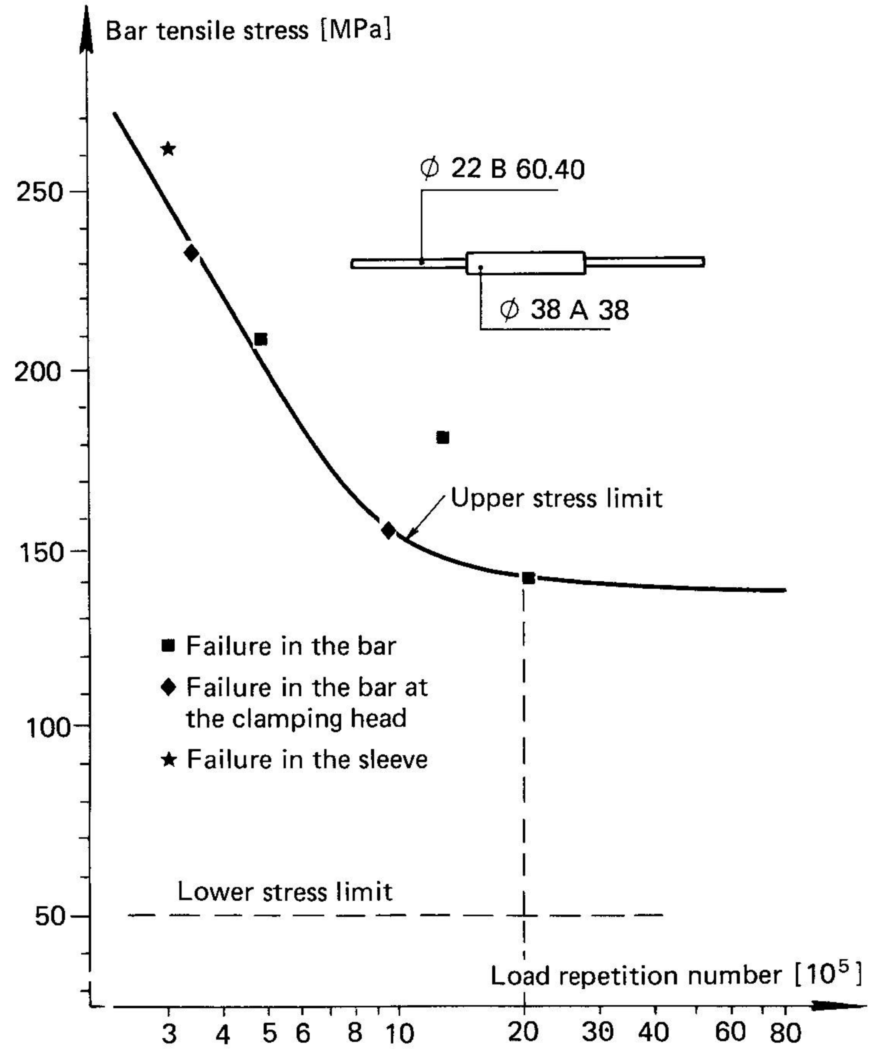

Fig. 5. Wöhler diagram of a characteristic pressed sleeve splice

Microscopy enlargement (200 times) of an interface between sleeve and bar after two million load repetitions (case in Fig. 5) is shown in Fig. 6.

Tests revealed but few instances of failure in fatigue within the splice – nevertheless it is advisable to apply a reducing factor of 0.9 on the fatigue limit of the basic material. Different failure modes were encountered, irrespective of the bar diameter – which necessitates a uniform reduction of the fatigue limit.

Deformed bars of type B 50.36 where cross ribs are inclined at 30°, must be indented at the ends to be spliced before pressed sleeve splicing, to obtain an equivalent load capacity. These are, however, more sensitive to fatigue because of cold formed notches. In these cases, the fatigue limit of the basic material has to be multiplied by 0.75.

Fig. 6. Microscopy of sleeve-bar interface after fatigue test

5. FATIGUE TESTS ON CONCRETE EMBEDDED SPLICES

Spliced steel specimens of type Bst 42/50, ⌀ 40 mm, were embedded in concrete prisms of square section, 150 mm wide, and 1120 mm long (Fig. 7). A crack was made artificially at the butt end of the pressed sleeve. The test was intended, in addition to determining the pulsating tensile fatigue limit, to indirectly demonstrate relative displacement between bar and sleeve at the sleeve butt end vs. load repetition number. Pre-indented specimens of type B 50.36, ⌀ 40 mm, were prepared as described above, to be tested under alternating stresses. No remarkable effect of the splice was observed.

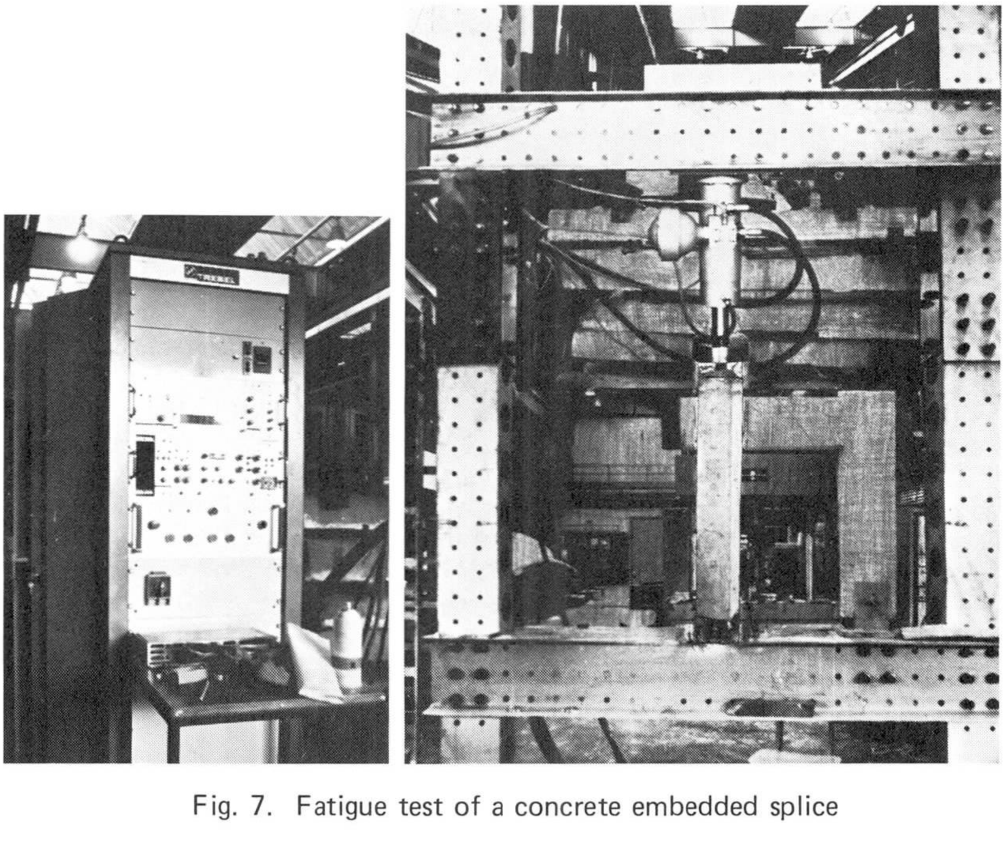

Fig. 7. Fatigue test of a concrete embedded splice

6. TESTS ON SPLICES IN BEAM TENSILE REINFORCEMENT

Much stress was laid on checking pressed-sleeve bar splices applied in structures subject to load alternations. The behaviour of beams with spliced or unspliced reinforcement under a high number of precalculated, alternating lower and upper load levels was examined (Fig. 8), with special regard to the crack pattern development, and to results of static tests up to failure following the fatigue tests. Each pair of beams was exposed to two million applications of fatigue loads generating lower and upper stresses of 59, and 203 MPa, respectively, in the bars. Beam fatigue tests demonstrate – under the given geometric conditions – that crack patterns and load capacity after fatigue tests of spliced and unspliced beams do not differ for less than two million repetitions of a pulsating tensile stress amplitude below 75 MPa in tensile bars.

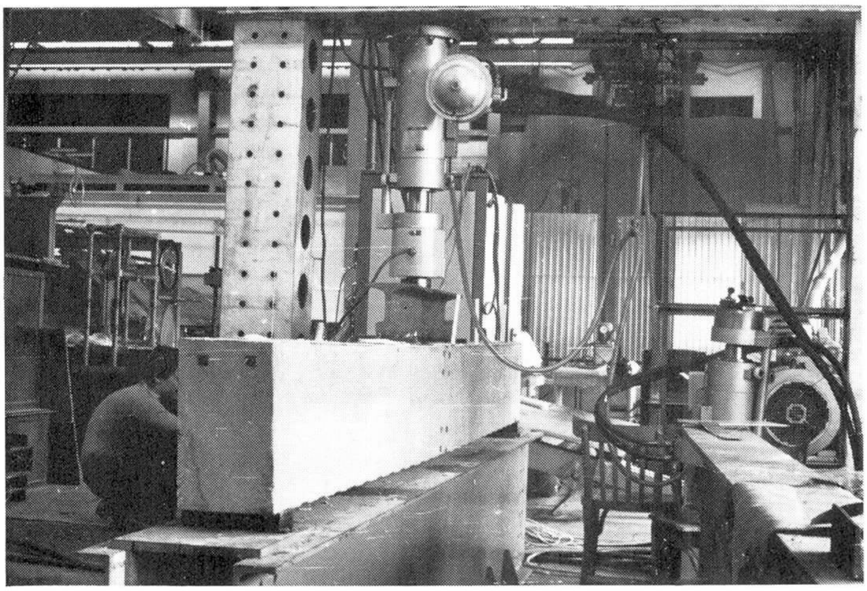

Fig. 8. Fatigue test of a beam with spliced tensile reinforcement

7. CONCLUSION

Experimental analysis of cold pressed sleeve splicing of deformed reinforcing bars justified that this mechanical splice offers the same load capacity as the basic material does, under short time, sustained and fatigue load as well.

The effect of the repeated loads was examined in versions plain without concrete, embedded in concrete and being built into beams.

As a result of the fatigue tests these mechanical splices can be used up to a 100 MPa pulsating zone.

The splices being embedded into concrete behaved more favourably under fatigue load than those without being concreted.

Beam test proved that sleeve splices do not effect the crack pattern, crack width and deflection of flexural reinforced concrete members under sustained and fatigue load.

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