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Travaux de recherches et de fabrication d'éléments de béton précontraint, réalisés à la « Field Test Unit, Ministry of Works » à Londres

Forschungsarbeiten und Herstellung von vorgespannten Eisenbeton-Fertigteilen, durchgeführt von der « Field Test Unit, Ministry of Works »

Research work and test production of prestressed concrete units at the Field Test Unit, Ministry of Works, London

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Anticipating the increasing difficulties in the supply of timber and steel — and of foreign exchange, 1946, the Chief Scientific Adviser to the Ministry of Works gave instructions to investigate the use of prestressed concrete as a substitute for timber and steel for transmission poles, telegraph poles, structural beams, floor units, etc. Being the Consultant to the Ministry on prestressed concrete the Author submitted the program and supervised its execution.

The specification of the materials employed in all experiments and test production were :—

Steel : 140-150 ton tensile; 2 per cent proof stress 110-120 ton per sq. in. Twin-twisted strands of compressor wires of S. W. G. 12 and 11. No creep under fatigue test between 75 and 85 ton per sq. in. Wire delivered in coils shall straighten when uncoiled. Concrete : cube crushing strength, age 7 days, 6 000 lb per sq. in; age 28 days, 9 000 lb per sq. in.

1. The initial investigations dealt with the determination of the embedding length required to develop the full tensile strength of the wire strands in the concrete. Result : The anchorage length of twin strands, at their ultimate tensile strength, amounts to less than 120 dia. of the single wires.

2. Investigations on the bond of wires in castings of rope capping metal for the purpose of gripping and stretching. Composition of metal : 80 % lead + 15 % antimony + 5 % tin. Preliminary tinning of the wires to

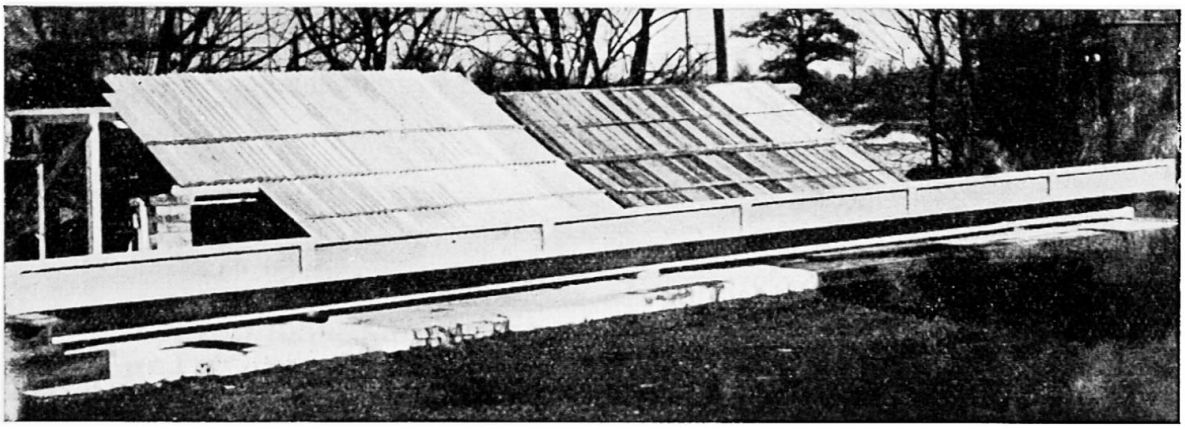

Fig. 1. Prestressed concrete joist. Depth-span ratio 1:45.

improve bond. Result : The anchorage length of twin strands amounts to approx. 60 dia. of the single wires.

3. Investigations on mechanical devices to grip compressor wires. Type suitable to anchor single wires : tapered pins fitting into tapered holes of steel plates with grooves to receive the wires; pins and bushings of holes to be of hardened steel. Type suitable to anchor twin strands : as above, but pins one side flattened and cross riffled, or split with central thread gripping.

4. Test production of prestressed concrete I-Joists No. 12, 45 ft long each. See fig. 1. Cross section $6'' \times 12''$, $2''$ flanges, $1\ 1/4''$ web, dead weight 35 lb per lin. ft. Compressor wires 28 twintwisted S. W. G. 12, weight of steel 1.62 lb per lin. ft evenly distributed over the whole cross section, ten in each flange, eight in the web. Initial pre-tension 90 ton per sq. in, effective 75 ton per sq. in. Effective uniform precompression of the concrete one ton per sq. in. There is no preliminary bending in these units. The units have equal resistance to positive and negative bending, positive or negative shear, left and right hand torsion. Bigger units of this type are intended to replace R. S. J's in structural engineering. Profile No. 12 as above is designed to carry a floor load of 1 cwt per sq. ft (in

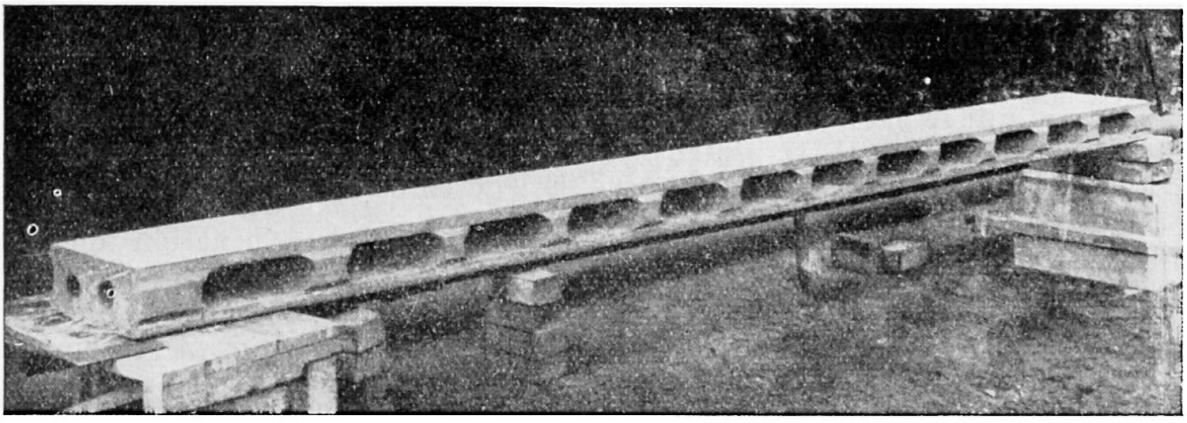

Fig. 2. Prestressed concrete hollow floor unit.

public buildings) over a clear span of 30′0″ and with cantilevers of 7′6″ at each end to carry the outer walls — depth of building 45 ft — the prestressed concrete beams being spaced at 18″ c/c.

5. Differential shear stresses. During the production of one of these units 2 wires positioned in the web slipped when all wires were stretched together. The two wires were not re-stretched but embedded without prestress. After release, a longitudinal crack appeared in the beam between the two slipped wires, 3/4″ wide at the end, and 6′ 9″ long, progressing towards midspan.

Conclusion : With so high prestresses, it is essential to keep the precompression uniform over the whole cross section.

6. Test production of prestressed concrete hollow floor units, 21 ft long. See fig. 2 Cross section 5″ × 12″ with central cavity 3 1/2″ × 10″, 3/4″ slabs top and bottom, each containing 10 compressor wires single S. W. G. 16, parts of web omitted. Dead weight 24 lb per sq. ft, weight of steel 20 lb per sq. yd of floor.

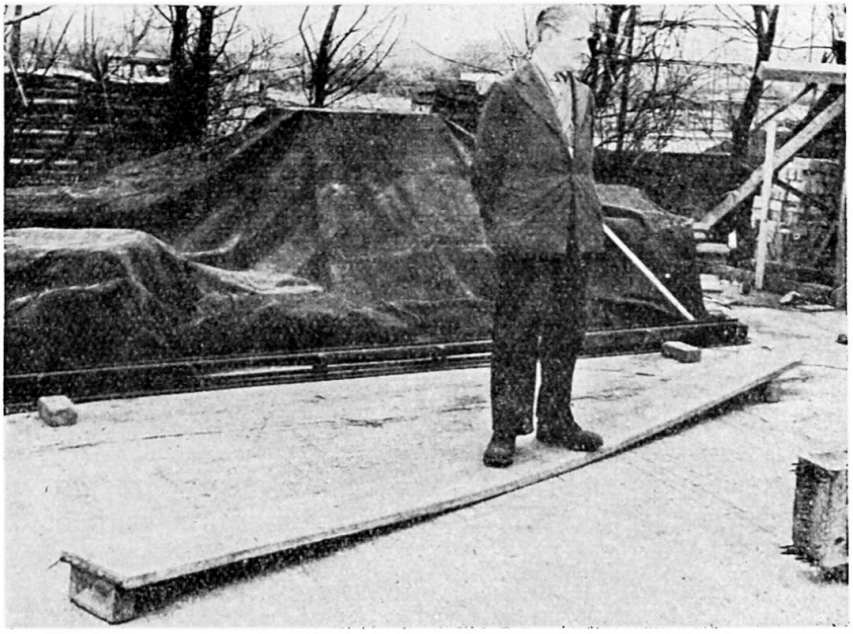

Fig. 3. Prestressed concrete plank 1 1/4″ thick, 12 ft span.

These floor beams are designed to span 20 ft from the front wall to the back wall of standard houses. The spine wall may be positioned anywhere from 7 ft to 13 ft distance from the front wall. The load bearing spine wall in the ground floor may be erected after the prestressed concrete units forming the first floor have been laid. To take the live loads the prestressed concrete units work as a continuous floor over three supports.

For loading tests and fire tests see seperate Reports issued by the Building Research Station, Watford, and Fire Testing Station, Elstree.

7. Test production of prestressed concrete planks, 1 1/4″ tick, 12″ wide, 12′9″ long. The elasticity of the planks is shewn by fig. 3. The concrete is precompressed to 400 lb per sq. in only.

Prestressed concrete planks, compressed to one ton per sq. in, 3/4″ thick, 9″ wide, have been designed to be used as scaffold boards, 5 ft long, laid on longitudinal supports.

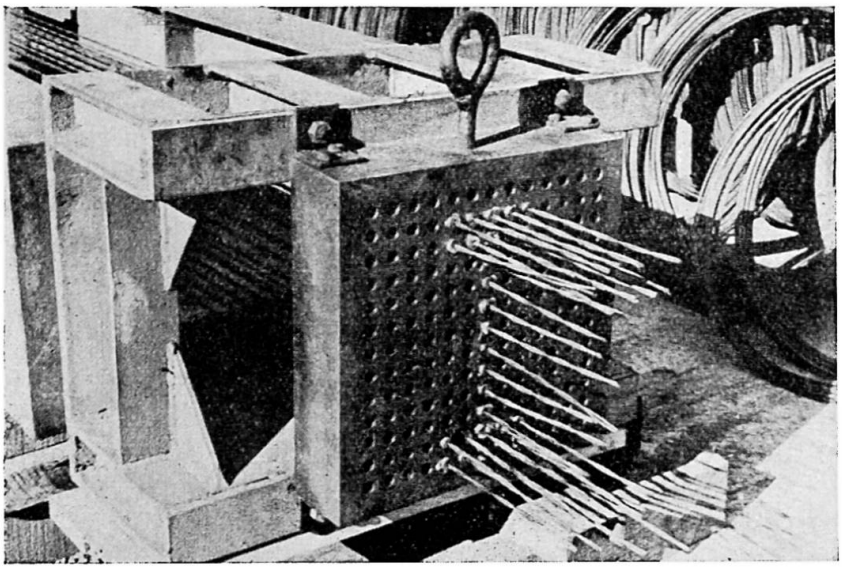

Fig. 4. Universal cross head and grid plate.

To illustrate the elasticity of prestressed concrete, similar planks, 2″ thick, have been designed to be used as diving boards.

8. Test production of Compound Reinforcement. Compound reinforcement is a member consisting of compressed concrete pipes containing stretched steel wires, the internal reactions between both materials being transferred by cement grout bonded to both.

To produce a compound reinforcement precast pipes are laid in one line, and the wires are threaded through. The wires are then stretched and the pipes are compressed by means of end anchorages. Grout is filled into the central hole and establishes solid connection between the wires and the pipes. The end fittings are removed after the grout has hardened. Example : External diameter of concrete pipes 4″; thickness of wall 1″. Compressor wires : 24 wires S. W. G. 10. This unit is equivalent to a reinforcement of 3 ⌀ 1 1/8″ mild steel bars, the cross-sectional area of which is approx. 10 times greater than that of the compressor wires 24 ⌀ S. W. G. 10.

Although this Compound Reinforcement is a prestressed concrete unit, the concrete structure in which it is used is, for all intents and purposes, an ordinary reinforced concrete structure, and the builder is not concerned with any prestressing apparatus.

9. Equipment developed during experimental production.

a) Gripping devices.

Concrete blocks cast around ends of wires, and wires stretched in groups. See paragraph 1.

Castings of rope capping metal round ends of wires, and wires stretched in groups. See paragraph 2.

Mechanical grips. Wires stretched singly or in groups. See paragraph 3.

b) Stretching devices.

3-ton hydraulic jack to stretch single compressor wires or strands. Universal crosshead and grid plate, see fig. 4, which can be employed for units with up to 169 wires or wire strands. Maintenance of stretching force by steel struts.

c) Gauges.

Statimeter gauges of up to 100 ton.

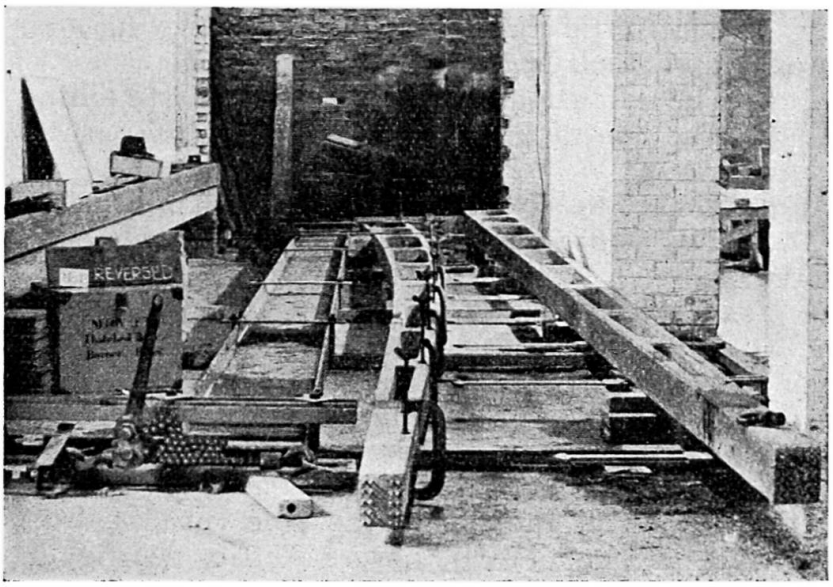

Fig. 5. Prestressed concrete pole under test load 2 100 lb.

10. Test production of prestressed concrete transmission poles.

Specification : Class B, British Standard 607-1946. O/a length 36 ft. Planting depth 6 ft. Ultimate load, 2 ft from top, 1 250 lb in a direction transverse to the transmission line.

Design A. See fig. 6.

A Vierendeel frame with two legs 2 1/8″ thick, the cross section tapering from 17″ × 7.2″ to 5″ × 6″. The diaphragms spaced from 4′3″ to 3′0″ centres, are not prestressed; neither is the 2″ web extending over the planting depth. Each leg is precompressed by 10 twin wires S. W. G. 11; the diaphragms and web are reinforced by high tensile steel.

Design B. See fig 6.

A full web I-section tapering from 13.8″ × 6.2″ to 11″ × 5″ with flanges 2 1/8″ thick and the web 1 1/4″ thick above ground level and 1 3/4″ thick below ground. The whole cross section is precompressed by 28 twin wires S. W. G. 11, ten in each flange, eight in the web.

Test production of 10 poles, 5 of each type.

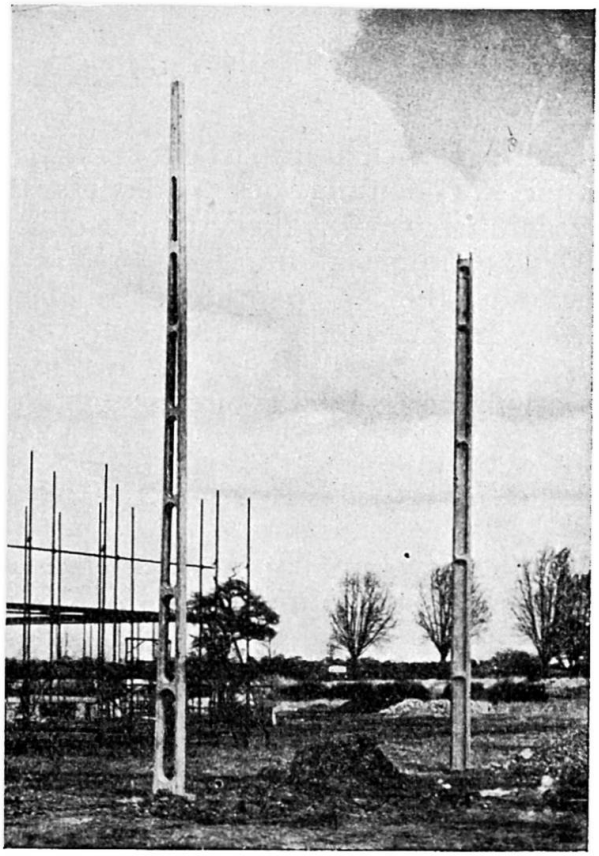

Fig. 6. Two types of prestressed concrete poles.

Specification of concrete and steel, and prestresses, as before.

To control the stresses set up the following alterations in length were measured in each specimen :—

a) The extension of the steel during stretching;

b) The contraction of the ram with the piston running back during release;

c) The contraction of the concrete pole during release;

d) The contraction of the concrete pole after release, while it is stored.

For loading tests of all ten specimens see separate Report issued by the Structural Section of the Ministry of Works. The most remarkable result of these tests is the small divergence of the characteristic load values in all ten poles.

The first cracks appeared under loads between 1 200 and 1 400 lb.

Failure occurred under loads between 2 000 and 2 250 lb.

Deflection at the top of the pole, just before failure, reached up to 40 in, 97 percent of which were elastic. See fig. 5.

Résumé

Les travaux pour le développement des éléments en béton précontraint, réalisés sous la direction de l'auteur pour le compte du Ministère des Travaux, Londres, au cours des années 1947-1948 se subdivisent en deux parties :

1. Recherches des diverses méthodes pour la fixation, l'ancrage et la tension des fils ainsi que l'adhérence du béton.

2. La fabrication et l'essai des éléments en béton précontraint, notamment des poutres, dalles et poteaux.

Zusammenfassung

Die Entwicklungsarbeit an vorgespannten Betonfertigfabrikaten, die unter der Leitung des Verfassers für das Bauministerium in London ausgeführt wurde, gliederte sich wie folgt :

(1) Untersuchung von verschiedenen Methoden für die mechanische Fassung, die Verankerung und das Spannen der Drähte; die Haftung zwischen den Drähten und dem vorgespannten Beton, etc.

(2) Die Herstellung und Prüfung von vorgespannten Betoneinheiten, wie I-Trägern, Deckenplatten und Freileitungsmasten.

Summary

The development work on prestressed concrete carried out under the Author for the Ministry of Works, London, 1947-48, consisted of two parts :—

(1) Research on various methods for the gripping, fixing and stretching of compressor wires, the bond between the wires and the compressed concrete in the prestressed unit etc.

(2) The experimental manufacture and test loading of prestressed concrete units, such as I-joists, floor slabs and transmission masts.