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Essais sur des cadres en béton précontraint réalisés pour des bâtiments à étages

Versuche an vorgespannten Betonrahmen von mehrstöckigen Gebäuden

Tests on precast prestressed concrete frames in multi-storey buildings

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The substitution of precast reinforced concrete elements for structural steel work for multi-storey buildings meet with practical and economic difficulties.

The difficulty lies in connecting the elements on the site by means of protruding reinforcement encased in situ, this connection requiring much labour and time.

Attempts have been made to mould complete reinforced concrete frames with two or three legs and to transport them to the site, lift them in position and connect them with the frames below by means of pinjoints or the like.

Transport difficulties, however, are considerable here.

The underlying idea of the prestressed precast concrete frames is as follows :

Applying the Freyssinet method of non-bonded but anchored cables, the latter to be grouted in after completion, frames are constructed from prismatic beams and by elements. These elements have no protruding parts except short steel plates for connecting the frame of one storey to the storey above by simple welding, which plates are connected to the elements by short welded mild steel bars. The precast elements are of simple shape and contain only enough M. S. for handling purposes.

On the site the frames are assembled by tensioning and anchoring the cables, producing a pre-compression sufficient to ensure at each joint a tensile stress nearly nil.

Should a load higher than the design load occur the butt joint would open and close again after disappearance of the load.

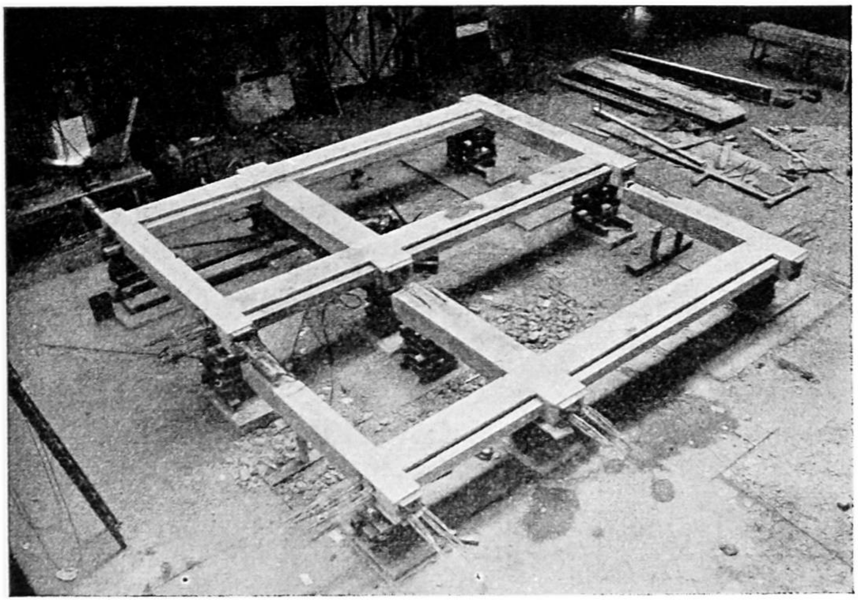


Fig. 1. Two separated frames, prestressed but not yet assembled.

The system was planned by the author for a London County Council 10 storey block of flats. Frames were at 14 feet crs., the slabs, spanning 14 feet and 7 feet respectively.

Extensive full scale tests were carried out at the initiative of Messrs. Structural & Mechanical Development Engineers, Ltd., Slough, Bucks., by the Buiding Research Institute under the guidance of Dr F. G. Thomas.

The strain measurements were made by a number of telescopic mirror gauges and checked by means of the acoustic strain gauge developed by the Building Research Institute.

The frames were loaded by hydraulic jacks placed in the centre of a beam, spans for the live load and a horizontally acting jack representing wind load on the two uppermost storey of a 10 storey frame.

As it was only possible to carry out the test in the flat position on a two storey frame, the action of the dead weight of the columns was

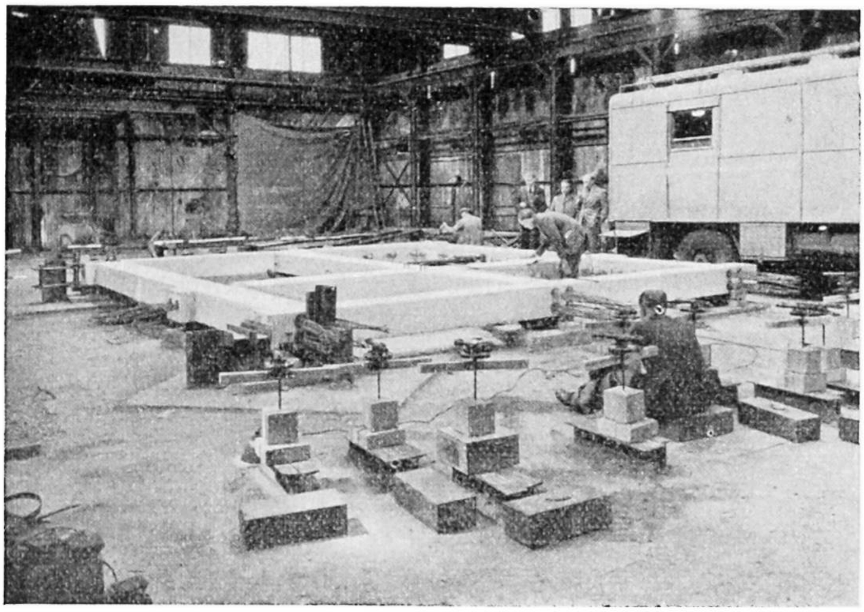


Fig. 2. Two frames assembled and under loading test with mirror deflectometers and accoustic strain gauges.

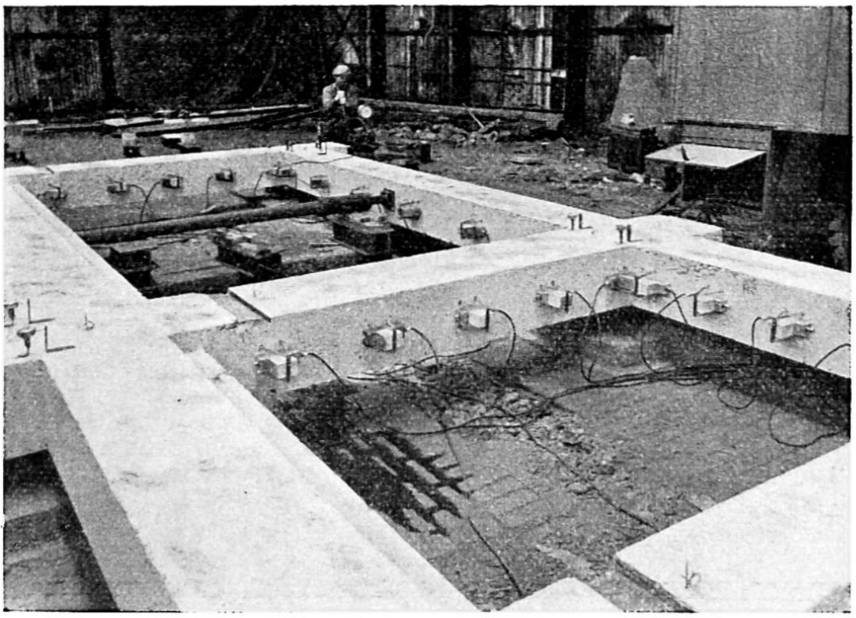


Fig. 3. Detail of the measuring apparatuses with accoustic strain gauges.

neglected and therefore the results were on the unfavourable side with regard to the tensile stress in the columns.

The tests for wind load were carried out with the design wind load of 25 lb/sq. ft on one side only, by inserting a jack on the uppermost corner, the force being of 6.5 tons, increased gradually up to 13.6 tons.

The vertical design load for the beam test was estimated to correspond to a single load of 5.6 tons applied at mid span of the longer beam. This was gradually increased up to 10.9 tons.

The results of these tests can be summarized as follows : No cracks occurred in any of the members at the design load but the joint between the centre columns and the top beam opened at one end by 0.004″.

At a load of 9.2 tons the opening of the joint between the centre column and the top beam became 0.01″ and slight cracks occurred at each of the welded joints with maximum width from 0.004″ to 0.011″.

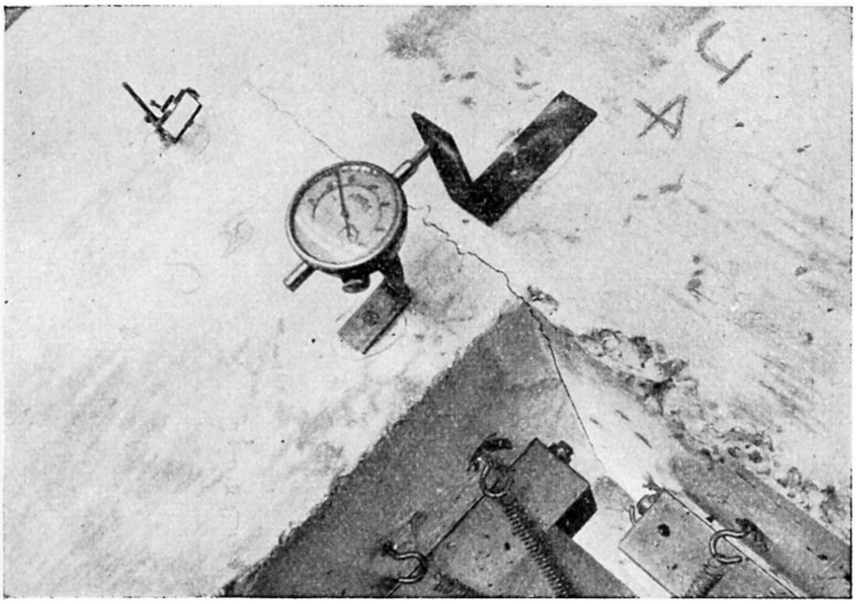


Fig. 4. Opening of one butt joint under excess load.

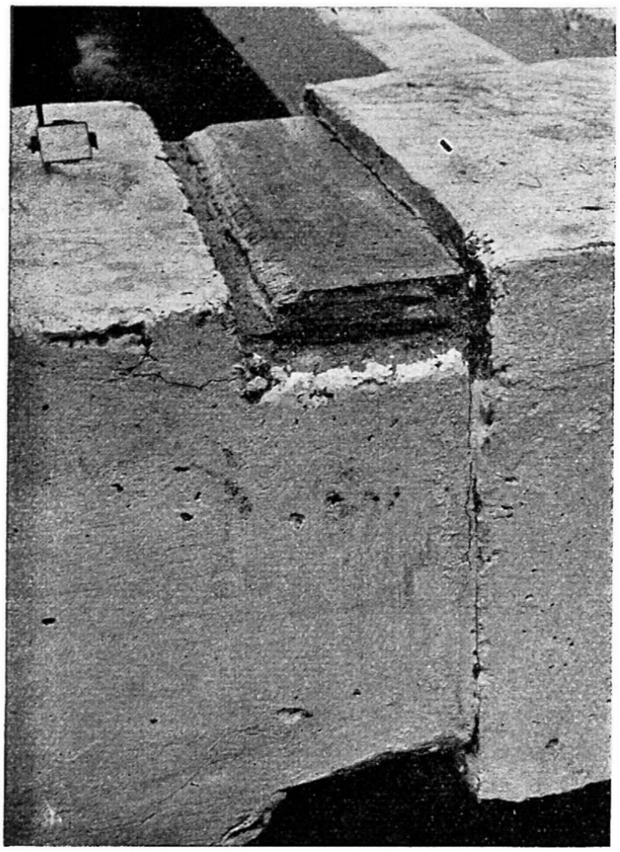


Fig. 5. Crack under excess load at welded joint.

After the beam test, when lateral loading of the frame was continued a crack in the upper column to which the load was applied was observed at about 1 1/2 times the design load. With increasing loading openings appeared at all beam column junctions, and at twice the design load cracks or opening of the joints varying between $0.001''$ and $0.008'''$ appeared in the column on which the wind load of 13.6 ton i. e., double the design wind load was applied. *On removal of the load all cracks in the concrete disappeared.* The conclusions drawn by the Building Research Institute were :

1. The strength and stiffness of the frame at the time of the test were adequate for the load for which it was designed;
2. Cracks are unlikely to occur in the member of the frame work unless the frame work is *seriously* overloaded. Cracks developed during a period of overload will disappear on its removal.

The test showed further that bending moments obtained by analysis agree with bending moments calculated from measured strains except that the welded steel joints showed greater strains than the adjacent prestressed concrete sections.

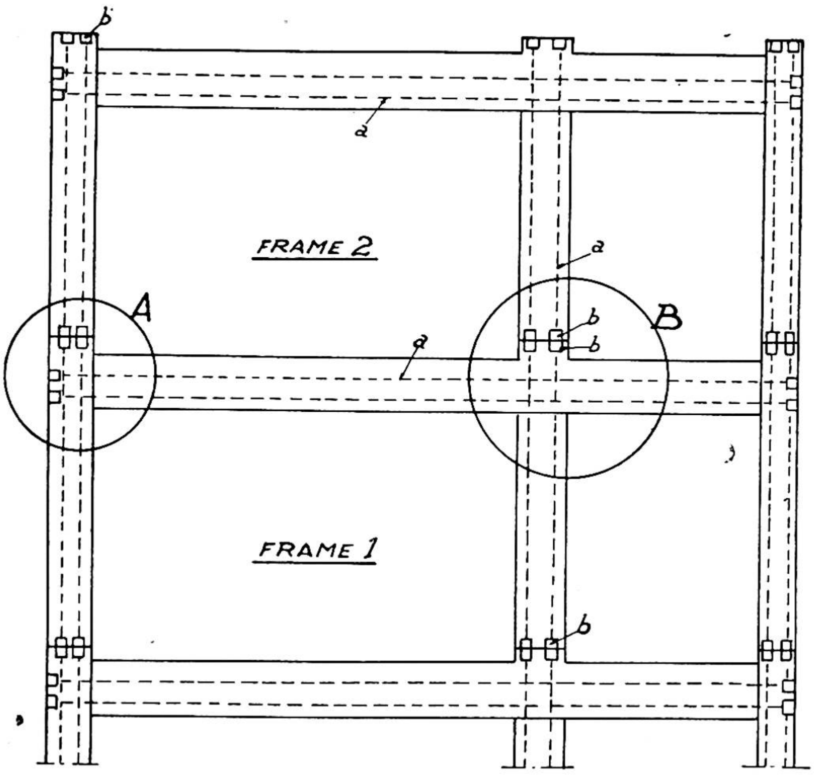


Fig. 6. Schematic drawing of two frames for testing :
a. — Non-bonded cables;
b. — Anchored cables.
For details A and B see figures 11 and 12.

This resulted in a shifting of the points of contraflexure towards the welded joint thereby slightly increasing the bending moment on the top.

When comparing this system with the usual system of steel framework assembled by cleats and bolts or rivets it should be borne in mind that the steel frame work usually is not designed with the assumption of completely stiff nods but as a semi-rigid system taking in account the yield of the connections. The assumptions therefore for which the prestressed concrete frames had been tested are more rigorous than that of the usual steel skeleton. Although the wind load applied was one sided and of great magnitude the openings and cracks generally closed after the removal of the load even when double the design load had been applied, except very fine cracks in the cover of the welded steel plates.

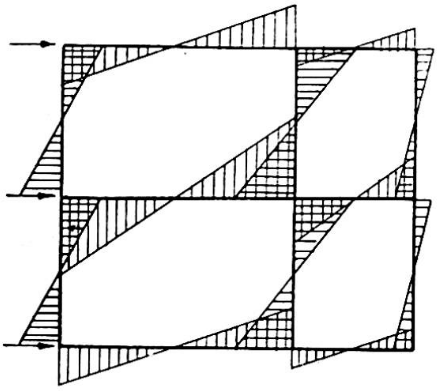


Fig. 7. Diagram of wind load moments.

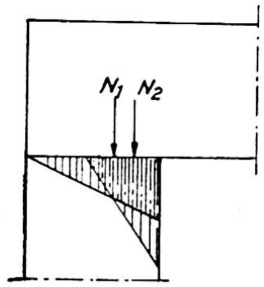


Fig. 9. Horizontal butt joint.

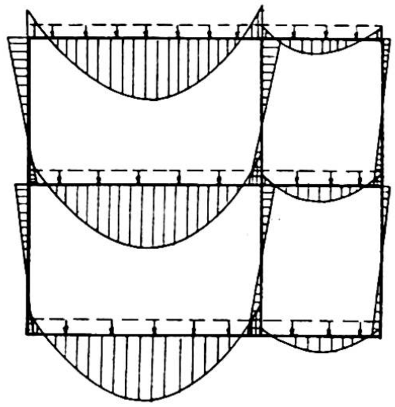


Fig. 8. Moments by S. I. loads.

N_1 : Normal force for designed load.

N_2 : Normal force for exaggerated load, with opening of the joint.

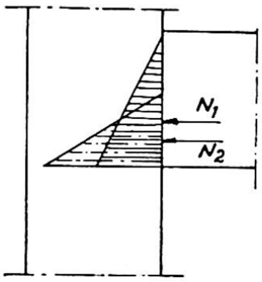
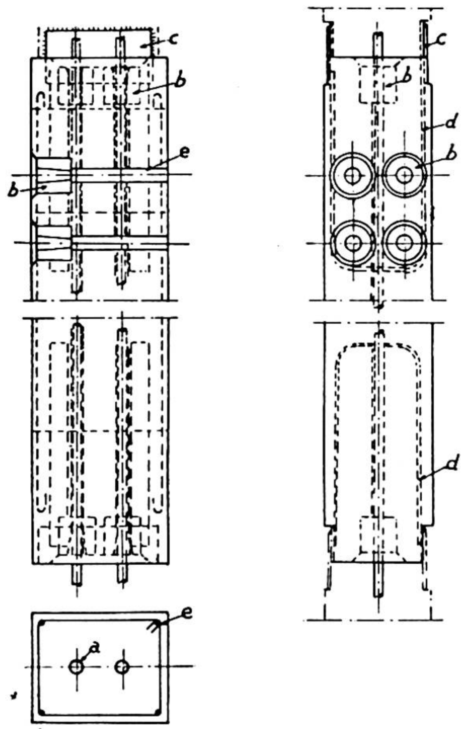


Fig. 10. Vertical butt joint.



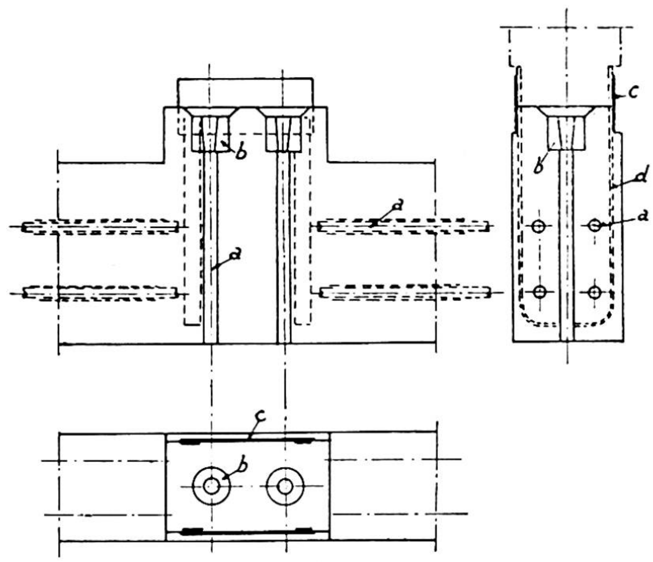


Fig. 11 (left). Detail « A » of figure 6 (plan and side elevation).

Fig. 12 (right). Detail « B » of figure 6 (plan and side elevation).

For practical applications it is preferable to apply the multiple frame system for the wind load only and to have the super imposed load supported by slabs spanning parallel to the wind frames. In this case the prestressing of beams and columns can be centrically applied as this is suitable for wind loads alternately on each side applied on one and the other side.

Résumé

En vue de la construction d'un bâtiment à dix étages en éléments préfabriqués en béton précontraint, des essais ont été poussés sur deux étages en grandeur nature.

Les éléments (poutres et colonnes) ont été bétonnés séparément puis assemblés en cadres à trois traverses d'après le procédé de Freyssinet, c'est-à-dire par des câbles à ancrage spécial.

Les essais ont montré la parfaite concordance avec les résultats des calculs pour les charges prévues; pour des surcharges importantes, il se produit des fissures se refermant après déchargement.

Le système utilisé constitue un développement du procédé bien connu de Freyssinet pour le montage de cadres à deux dimensions en éléments préfabriqués.

Zusammenfassung

Zur Abklärung der Aufstellung der Rahmen eines mehrstöckigen Gebäudes aus vorgespannten Fertigbetonelementen wurden Versuche an zwei Stockwerken des geplanten zehnstöckigen Gebäudes in natürlicher Grösse ausgeführt, und zwar für Wind- und Nutzlast.

Die Elemente, Balken und Säulen, welche einzeln betoniert wurden, wurden zusammengesetzt zu dreistieligen Rahmen nach dem Verfahren von Freyssinet, d. h. mittels unverwundener, speziell verankerter Kabel.

Die Versuche ergaben, dass das Verhalten der Rahmen mit der analytischen Berechnung übereinstimmt für die dem Entwurf zugrunde gelegte Last und dass bei einer grossen Ueberlastung Oeffnungen und Risse entstanden, welche sich aber wieder schlossen nach dem Entfernen der Last.

Das angewandte System ist eine Weiterentwicklung des bekannten Verfahrens von Freyssinet für die Montage von zweidimensionalen Tragwerken aus Fertigteilen.

Summary

For the purpose of erecting the frame work for multi-storey buildings by precast pre-stressed concrete elements, tests on a full scale have been carried out on 2 stories of a designed 10 storey building, for windloads and super imposed load.

The elements, beams and columns which had been precast, had been assembled to three leg frames by the Freyssinet method of non bonded especially anchored cables.

The tests have shown that the behaviour of the frames corresponded with the analytical computation for design load and that at serious overloading openings and cracks occurred, which however closed after removal of the load.

The system is an amplification of the known Freyssinet process of erecting structures by precast elements for two dimensions.