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Impact Resistance on Prestressed Concrete Masts[1])

Résistance à l'impact des poteaux en béton précontraint

Stoßwiderstand von Spannbetonmasten

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In connection with the electrification of British Railways the question whether steel or prestressed concrete masts shall be used to carry the high voltage wires will have to be decided. In the summer of 1956 a few cantilever and portal masts in prestressed concrete were located adjacent to steel masts near Southend, to investigate their suitability when in use (figs. 1 and 2). Previously, the resistance of these masts to heavy impact had been investigated in view of a possible derailment and the fear that prestressed concrete masts

Fig. 1. Prestressed Concrete Cantilever Masts near Southend (England).

1) This paper was originally presented at the 5th Congress, I.A.S.B.E. at Lisbon at Theme I (b).

might collapse instantaneously in the event of sudden impact. For this purpose, a number of steel and prestressed concrete cantilever masts were placed parallel to an auxiliary railway track (fig. 3) and subjected to impact while the full live load, a horizontal force of 800 lb., was applied at the top of each mast.

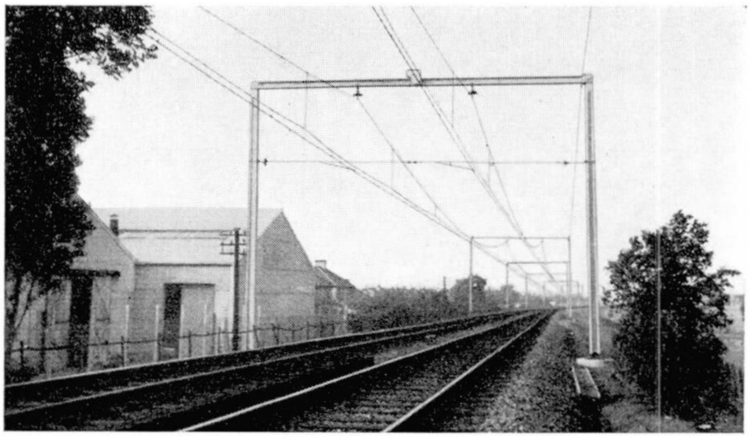


Fig. 2. Prestressed Concrete Portal Matst near Southend (England).

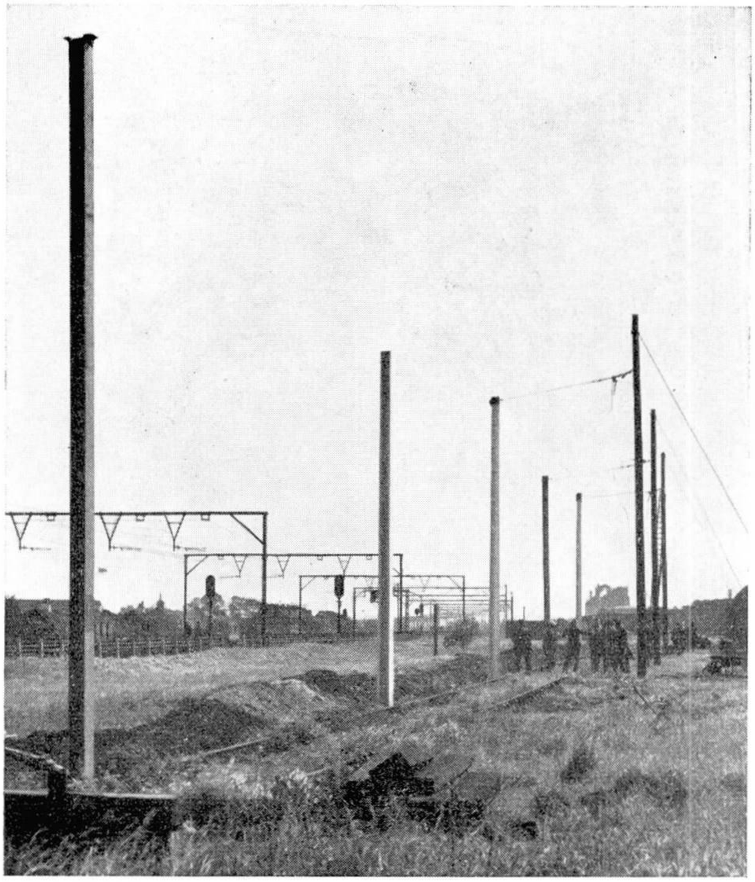


Fig. 3. Romford Impact Tests. General View.

From figs. 1—3 it is seen that the prestressed concrete masts differed but little in size from the steel masts. This was achieved by making full use of the tensile resistance of the concrete under working conditions, which is particularly advantageous if loading in opposite directions occurs. Freedom from

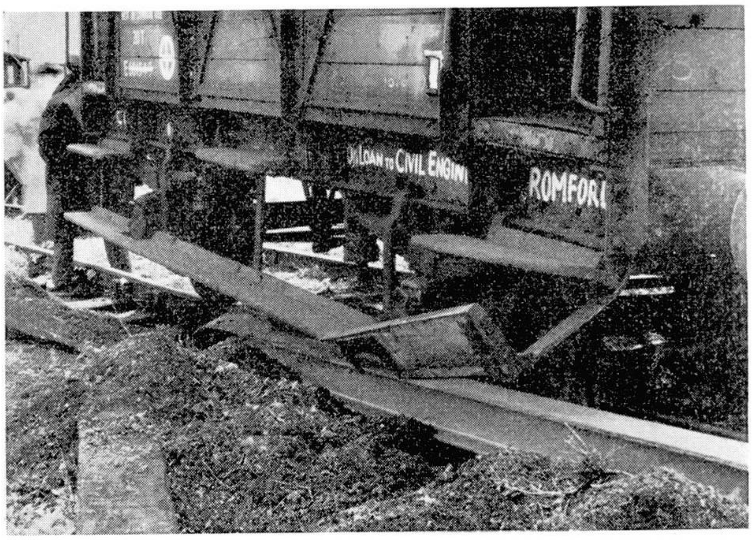


Fig. 4. Romford Impact Tests. Steel Mast After Direct Impact.

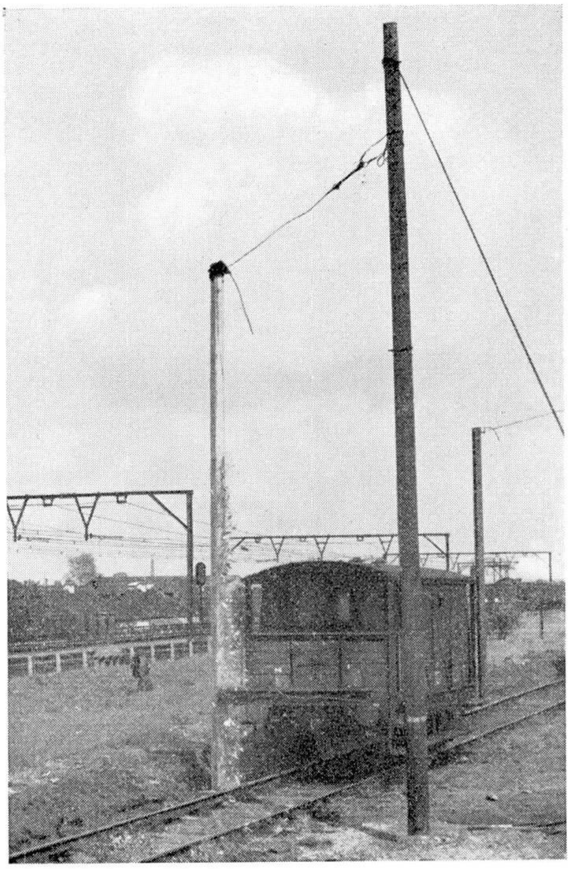
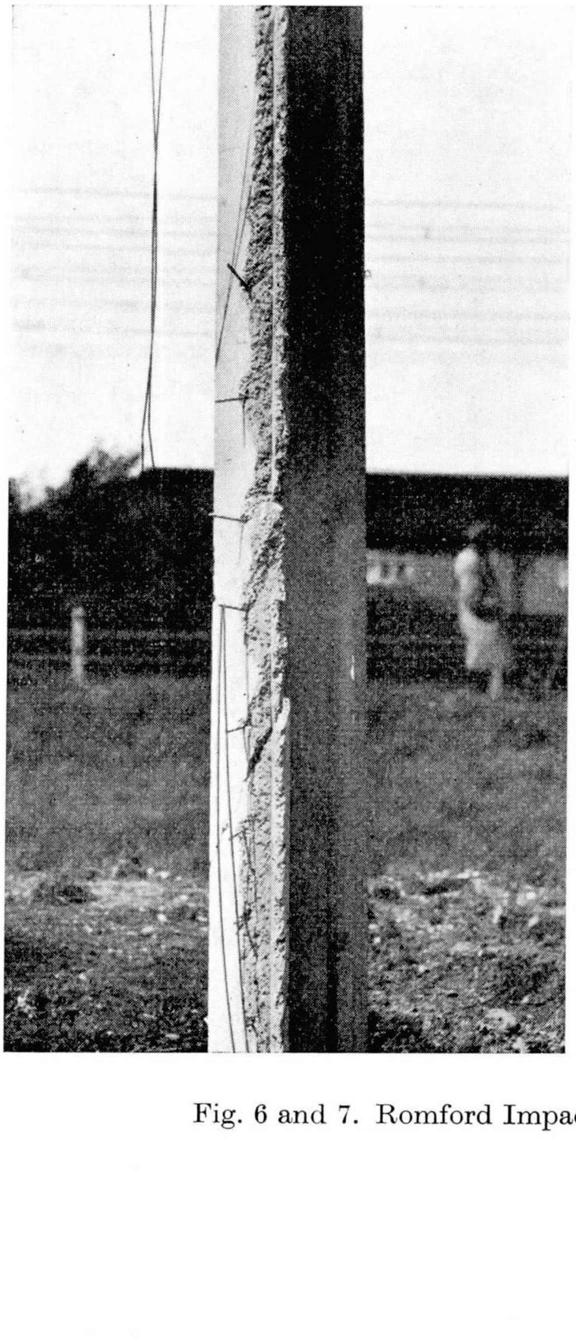


Fig. 5. Romford Impact Tests. Prestressed Concrete Mast During Impact.

visible cracks is ensured under the static working load and untensioned steel has been included to assist in the resistance to impact by the increased resilience thus provided, and also to ensure the required factor of safety against failure. Note in fig. 2 the slight difference between prestressed concrete and steel portal masts, the former with hinges at the top and the latter (2nd mast and following masts) with rigid upper corners.

The impact was applied by means of a brake van of 20 tons weight which was projected into the mast with a speed of approximately 10 miles per hour. For each individual test the track was slewed so that either the entire mast or only part of a flange was hit. The tests have proved, as was to be expected, that in the event of a direct hit both types of mast become unserviceable. The steel mast was entirely bent down (fig. 4), although it had been expected by those favouring steel that it would only be bent slightly and would still be able to carry the high voltage wires in the air; the prestressed concrete



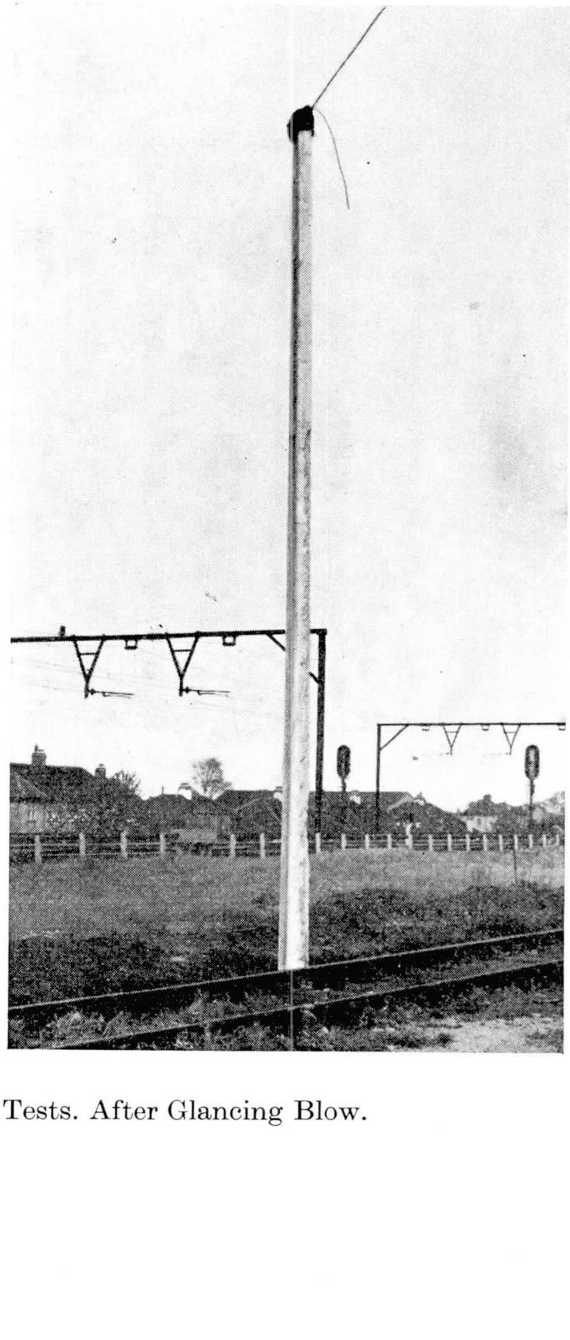


Fig. 6 and 7. Romford Impact Tests. After Glancing Blow.

mast was cut into two pieces, and when falling down a considerable part of the concrete disintegrated.

In the case of a glancing blow only local damage occurred with the steel mast; with the prestressed concrete mast, a part of the flange was cut away (fig. 5) and two wires were severed. In addition, a number of heavy cracks occurred particularly near the bottom of the mast (fig. 6). Nevertheless, the mast was capable of carrying, in its damaged state, the maximum working load which would occur only occasionally when adverse weather conditions are involved (fig. 7). The equivalent of this load was re-applied and sustained for 24 hours without any noticeable deterioration.

It has thus been shown that prestressed concrete adequately serves the requirements since it will be capable of carrying the overhead wires even after an accident similar to the second test until a replacement is available. In the event of a derailment with the consequence of a direct hit, both materials, steel and concrete, would become completely unserviceable. The static and impact test have proved that an I-shaped section is very suitable and preferable to a type of mast often used with considerable openings in the web (Vierendeel type of construction).

In the latter case, there are separate booms, which may be sometimes in

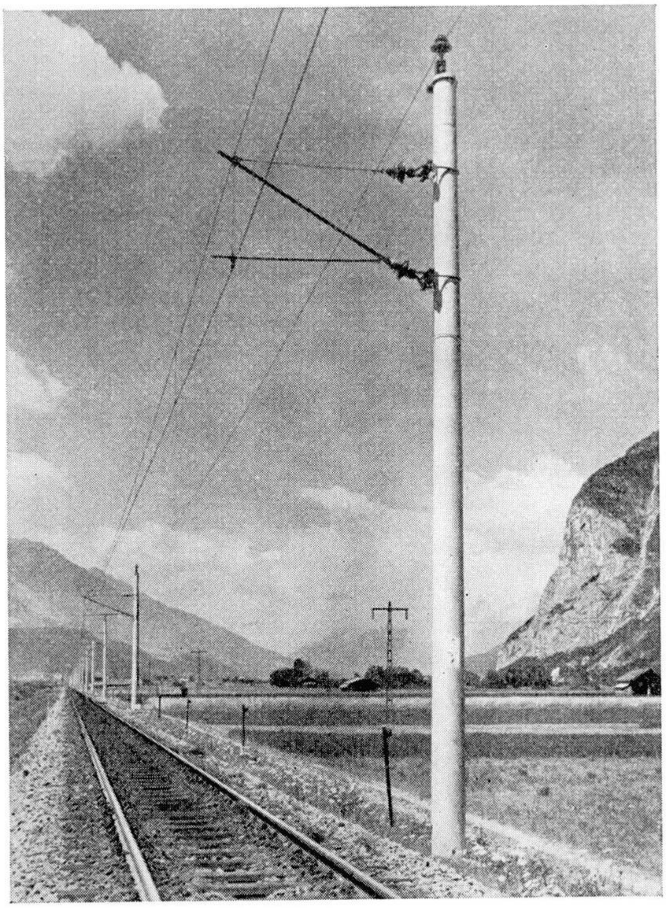


Fig. 8. Spun Concrete Cantilever Masts near Innsbruck (Austria).

compression and sometimes in tension according to direction of the load and act entirely independently. Thus the structure is less capable of resisting impact and taking up ultimate load.

The advantage of concrete, as compared with steel, is obviously the fact that maintenance is reduced to a minimum. When the concrete is dense, as obtained by centrifugal moulding or vibration, there is no danger of corrosion, even if there are permanent fine hair cracks which cannot be avoided with ordinary reinforced concrete. Fig. 8 shows cantilever masts of the Austrian Spun Concrete Works, Hoffman & Co., Kirchdorf, designed by the author in 1934 [1]. High strength steel of a strength of 142 000 lb/in^2 (100 kg/mm^2) was used and the design was based on a factor of safety against failure of 3 with nominal working load stresses of approximately 40 000 lb/in^2 for steel and 3000 lb/in^2 for concrete. Hair cracks developed at half the working load. These masts have been in use since 1934 near Innsbruck (Tyrol, Austria) where the weather conditions are not too favourable and in spite of permanently open fine hair cracks they are still in good condition, as the chief engineer of the Austrian Federal Railways has informed the author; this is again a proof that fine hair cracks are harmless[2]) [2]. With prestressed concrete, no cracks should occur under working load, though relatively fine cracks would develop due to occasional excess load which would however, close completely, even if the excess load had reached double the design load upon return to normal, as static teste have proved, provided that a factor of safety against failure of 2.5 is obtained.

The impact tests described were carried out at Romford, Essex, England, in May 1955 by the Chief Civil Engineer's Department, British Railways, Eastern Region, in conjunction with the Chief Electrical Engineer of the British Transport Commission, and the writer is grateful to the Chief Civil Engineer, Mr. A. K. Terris , M.I.C.E., for permission to show these photographs.

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Summary

Comparative tests are described carried out by British Railways, Eastern Region, 1955, to investigate the impact resistance of steel and prestressed concrete masts. Each type became entirely unserviceable at a direct hit by

2) This applies obviously only to dense concrete, as with porous concrete corrosion takes place even without any cracks.

a 20 ton waggon projected into the mast with a speed of 10 miles/hour, but remained temporarily serviceable at a glancing blow. Further, the suitable shape of prestressed concrete masts is discussed in connection with appropriate design considerations and finally 20 years' experience in Austria with non-prestressed spun concrete masts with high strength steel reinforcement is reported as satisfactory in spite of unavoidable fine hair cracks.

Résumé

L'auteur décrit des essais comparatifs qui ont été effectués sur les chemins de fer britanniques (Région de l'Est), en 1955, afin d'étudier la résistance au choc des poteaux en acier et béton précontraint. Ces deux types se sont révélés entièrement inutilisables dans le cas du (plein) choc direct d'un wagon de 20 tonnes animé d'une vitesse de 15 km/h. En revanche, les deux types étaient temporairement utilisables dans le cas du choc non direct, l'aile seule étant atteinte.

L'auteur étudie en outre la section qu'il convient de donner à un poteau, en corrélation avec les principes adoptés pour l'établissement des projets. Enfin, il expose l'expérience acquise au cours de vingt années en ce qui concerne les poteaux en béton centrifugé, armés avec un acier à hautes caractéristiques et non précontraints, poteaux qui se sont comportés d'une manière satisfaisante, malgré d'inévitables fissures capillaires.

Zusammenfassung

In diesem Artikel werden Vergleichsversuche beschrieben, die bei den Britischen Bahnen (Eastern Region) im Jahre 1955 durchgeführt wurden, um den Stoßwiderstand von Stahl- und Spannbetonmasten zu untersuchen. Beide Typen erwiesen sich im Falle eines direkten (vollen) Anpralles eines 20-t-Wagens auf den Mast (mit einer Geschwindigkeit von 15 km/Stunde) als völlig unbrauchbar; aber beide Typen blieben temporär brauchbar sowie der Anprall nicht direkt erfolgte, sondern nur der Flansch des Mastes gestreift wurde. Überdies wird in dem Artikel der zweckmäßige Querschnitt eines Mastes im Zusammenhang mit entsprechenden Entwurfsprinzipien besprochen und endlich wird über die 20jährige Erfahrung mit nicht vorgespanntem, mit hochwertigem Stahl bewehrten Schleuderbetonmasten berichtet, die sich trotz unvermeidlicher Haarrisse zufriedenstellend bewährt haben.

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