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RESULTS OF TESTS MADE AT THE U.S. NATIONAL BUREAU OF STANDARDS ON THE FIRE RESISTANCE OF PRESTRESSED CONCRETE BEAMS

by

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Introduction

A systematic programme, undertaken co-operatively by the Building Research Station and the Joint Fire Research Organization, was carried out on linearly scaled beams of selected types of "full scale" beams to establish the factors which must be taken into account in the design of prestressed concrete beams with post-tensioned steel to give fire resistances up to 4 hours. Limitations of size imposed by the furnace and equipment at the Fire Research Station made beams of 10 ft. span the largest which could be tested, and these are referred to as the $\frac{1}{2}$-scale units in the series. Other beams of $\frac{3}{8}$ - and $\frac{1}{4}$-scale were included for the purpose of discovering whether a relationship existed between fire resistance and scale which would enable extrapolation to full size. Fire resistance was measured by the test specified for beams in B.S.476 : 1932.

The results of the tests on the types of beam designated A, B and C, when plotted as fire resistance against scale, gave very nearly straight lines for types A and C beams under conditions of simple end support and a loading equivalent to the assumed dead load + $1\frac{1}{2}$ times the live load (1). Since extrapolation to full size represented an extension equal to 200 per cent of the range of data its validity was extremely doubtful and means were therefore sought to obtain points on the graph closer to full scale. Only one floor furnace exists which is larger than the Elstree furnace and which can give the heating conditions defined in B.S.476. This furnace is at the U.S. National Bureau of Standards and enquiry brought a generous offer of co-operation to carry out tests in accordance with British requirements on beams up to 4/5-scale, a total of six tests being agreed.

Description of beams

In order to make the results of the American tests as consistent as possible with those already obtained, the beams were manufactured at the Building Research Station and shipped to the United States of America. Correlation between the furnaces and the testing techniques of the two countries was made possible by including one $\frac{1}{2}$-scale type A beam with the 4/5-scale beams. A similar $\frac{1}{2}$-scale beam cast at the same time was kept in this country to undergo the fire test on approximately the same date as the comparable beam in America.

In the beams of $\frac{1}{2}$-scale the maximum size of the gravel aggregate was $\frac{3}{8}$ in. and the size of the wires in the cables was 12 S.W.G. For the beams of 4/5-scale the aggregate size was increased to $\frac{3}{4}$ in. and the wire diameter to 0·2 in., using the Magnel-Blaton system of post-tensioning. As in the smaller scales straight cables were used with haunchings at the ends of the beams. The beams arrived at the National Bureau of Standards without damage.

The following list gives briefly the distinctive features of the five 4/5-scale beams tested and the reasons for the selection of each of the five.

1) Type A beam consisting of a rectangular precast element on which a flange was cast after tensioning the steel, to represent a section of floor slab. The concrete cover (both side and bottom) to the cable was 3 in. All dimensions were linearly scaled from the $\frac{1}{2}$ size beam.

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(1) Fire Research 1952. H. M. S. O.

2) As beam (1) but with an encasement 1 in. thick of vermiculite concrete.

3) Type D beam similar to type A but having larger dimensions in the precast element to give a concrete cover (side and bottom) to the cable of $4\frac{1}{2}$ in.

4) Type E beam having the rectangular element of the dimensions of Type A but without the top slab.

5) As beam (4) but with an encasement 1 in. thick of vermiculite concrete.

The Type A beams (1) and (2) were required to give further points on the graph of fire resistance against scale; the Type D was intended to check whether the estimated figure of $4\frac{1}{2}$ in. cover for a fire resistance of 4 hours was correct; the unprotected Type E beam was included to obtain information on the behaviour of beams having their zone of high compressive stress subjected to fire, with particular reference to continuous beams; and the protected Type E beam served to show whether the same increase in fire resistance could be obtained with a given protection as for Type A beams.

Results of Tests

The time to failure of the $\frac{1}{2}$-scale beam at the Bureau of Standards was 1 hour 29 minutes. This compares with a time of 1 hour 36 minutes in the test on the companion beam at Elstree and 1 hour 42 minutes obtained in the earlier series (mean of two tests).

In Table 1 the results of the tests on the $^4/_5$-scale beams are summarised and predicted results from the tests on smaller scale Type A beams are included for comparison.

Table 1

No.	Type	Duration of test hr.	min.	Estimated time to failure hr.	min.
1	A unprotected	2	36	2	54
2	A protected	6	02 (did not fail)	5	30
3	D unprotected	3	40	4	00
4	E unprotected	1	$55\frac{1}{2}$	-	
5	E protected	4	$39\frac{1}{2}$	-	

If the lower result of 1 hr. 36 min. obtained in testing the $\frac{1}{2}$-scale beam is used for estimating the time to failure of the $^4/_5$-scale unprotected Type A beam, extrapolation from the fire resistance/beam scale graph gives 2 hours 46 minutes instead of 2 hr. 54 minutes.

In the tests on the unprotected beams deterioration of the concrete after exposure to heat for some time led to spalling off of the cover to the cable, resulting probably in an earlier failure than if the concrete had remained in place.

Conclusions

1. The fire resistance tests on $^4/_5$-scale beams appear to confirm the empirical straight line relationship between scale and fire resistance which the tests on smaller beams had indicated.

2. Unprotected beams of gravel aggregate concrete having a concrete cover to the cable exceeding 2 in. require steel mesh reinforcement in the cover if the protective value to the cable of the concrete is to be fully utilised.

3. Beam encasements can give a large increase in fire resistance. Vermiculite concrete is a good insulator and 1 in. thickness may raise the fire resistance by about 3 hours.

The spalling was not violent and was of the kind referred to as sloughing in the United States of America.

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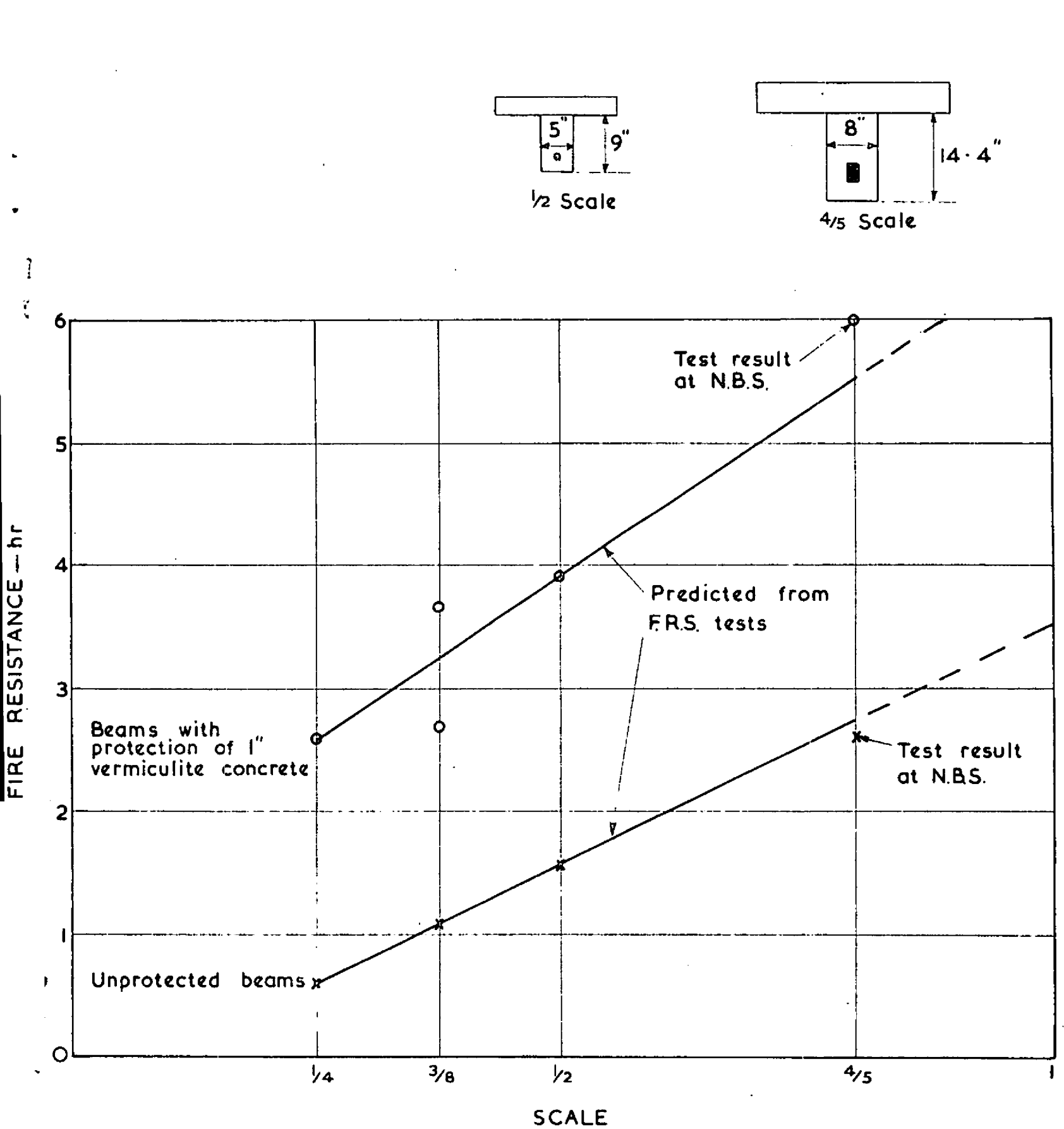

FIG.I. FIRE RESISTANCE AND SCALE OF TYPE A BEAMS