BUILDING DIGEST

CENTRAL BUILDING RESEARCH INSTITUTE INDIA

PRECAST PRESTRESSED TRUSSES FOR LONG SPAN ROOFS

Introduction

The accent of the Third Plan being on industrialisation, a large number of factory and storage buildings are expected to be taken up for construction in the next five years. One of the economical alternatives to steel trusses for spans exceeding 40′ (12.19m) is the precast prestressed truss which is very widely being used in the Soviet Union, Poland, Czechoslovakia and other Continental countries. In these countries, such trusses have been standardized and catalogued for various spans. They save steel to the extent of as much as 70%. The trusses are usually produced in a factory and transported to the site for erection. As there are not many factories turning out precast prestressed products in this country and as transportation of these units over long distances by rail or road poses several problems, it is more economical, under the present conditions, to set up a casting yard to fabricate and stress the trusses at the site. This note describes a design developed at the Central Building Research Institute for a precast prestressed truss of 45′-0″ (13.7lm.) span.

Description of the truss

The truss described here is a reinforced concrete truss with the members cast monolithically. Only the tie, which carries heavy tension, is post-tensioned by a single straight cable. Casting the truss in one piece makes it more rigid so that deflections under loads are negligible. The prestressing involved being quite simple, this type of construction is within the reach of contracting organisations and government departments, which do not have experts in prestressing on their staff.

Span and spacings

The span of the truss is 45′-0″ (13.7lm.) centre to centre and it may be supported either on masonry walls or on R.C.C. columns which are spaced 15′-0″ (4.57m) apart.

Shape

Although the ideal shape of truss for a simply supported span would be a parabola, the shape of the Howe truss was chosen to facilitate the use of straight Asbestos-Cement sheets. The rise of the truss is one in five and the nodes are spaced 5′-1½″ (1.57m.) horizontally to suit the commonly available size of sheeting.

Weight of the truss

The truss weighs 1.54 tons (1567 kg).

Design loads

It is designed for the following loads:

Self-weight including purlins	—	10.00 p.s.f.
Dead load of A.C. sheets	—	4.00 ,,
Allowance for other loads Including ceiling	--	8.00 ,,
		22.00 p.s.f. (110.00 kg/m²)

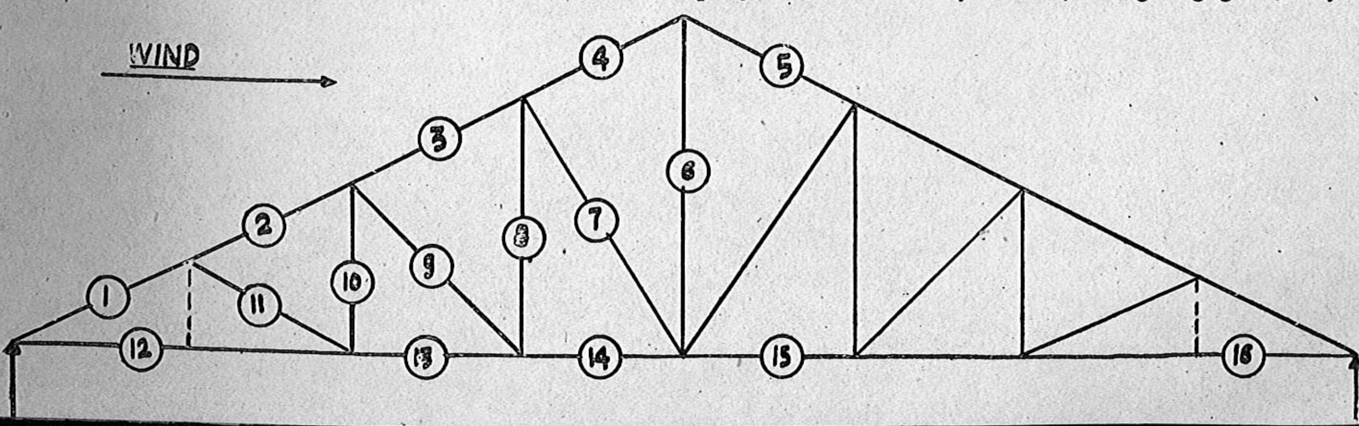
A wind pressure of 10 p.s.f. (50 kg/m²) on the windward side and 10 p.s.f. suction on the leeward side have been provided for as per I.S. specification 875-1959 clause-4. 5.2.

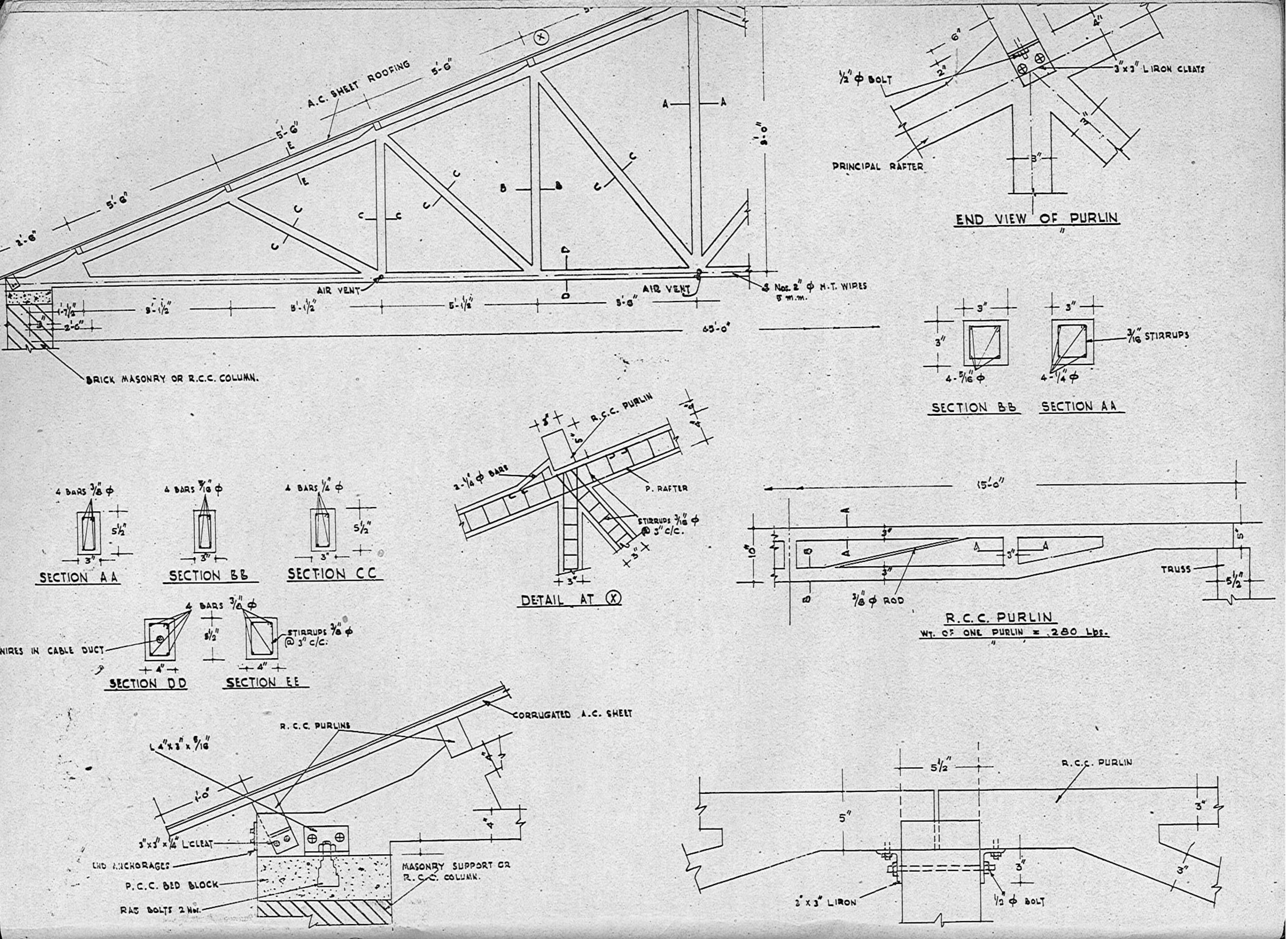
Purlins

The purlin is shaped to conform to the bending moment diagram, so that the steel consumed is a minimum (Fig. 1). The purlin, weighing 280 lbs (127 kg), is easily handled and hoisted into position by four men.

Design

Studies made at the C. B. R. I. with the Begg's apparatus show that the trusses of this shape and span may safely be designed, assuming the members to be pin-jointed. Secondary stresses, being negligible, may




A.C. SHEET ROOFING
5'-6"
5'-6"
5'-6"
2'-6"
AIR VENT
AIR VENT
2 Nos. 2" ϕ H.T. WIRES 5 m.m.
3'-1½"
8'-1½"
5'-1½"
5'-6"
1'-7½"
2'-0"
65'-0"
8'-0"
BRICK MASONRY OR R.C.C. COLUMN.
½" ϕ BOLT
3"x3" L IRON CLEATS
PRINCIPAL RAFTER
END VIEW OF PURLIN
3/16" STIRRUPS
4-5/16" ϕ
4-¼" ϕ
SECTION BB
SECTION AA
4 BARS ⅜" ϕ
4 BARS 5/16" ϕ
4 BARS ¼" ϕ
5½"
SECTION AA
SECTION BB
SECTION CC
R.C.C. PURLIN
2-¼" ϕ BARS
P. RAFTER
STIRRUPS 3/16" ϕ @ 3" c/c.
DETAIL AT (X)
15'-0"
⅜" ϕ ROD
TRUSS
R.C.C. PURLIN
WT. OF ONE PURLIN = 280 Lbs.
4 BARS ⅜" ϕ
WIRES IN CABLE DUCT
STIRRUPS ⅜" ϕ @ 3" c/c.
SECTION DD
SECTION EE
CORRUGATED A.C. SHEET
R.C.C. PURLINS
L 4"x3" x 5/16"
1'-0"
3"x3" x ¼" L CLEAT
END ANCHORAGES
P.C.C. BED BLOCK
RAG BOLTS 2 Nos.
MASONRY SUPPORT OR R.C.C. COLUMN.
R.C.C. PURLIN
5½"
5"
3"
3" x 3" L IRON
½" ϕ BOLT

be ignored. The stresses in the various members of the truss are as shown in table 1.

TABLE 1

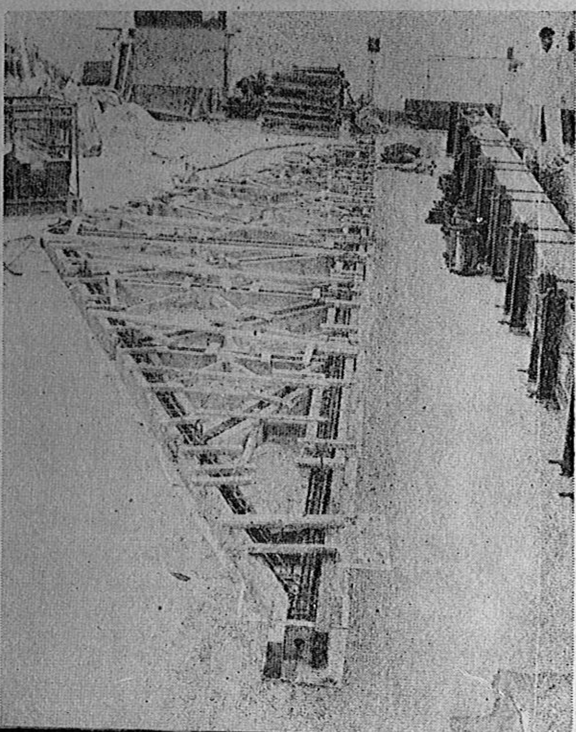
Member	Stress due to dead load (1856 lbs. at Node)	Wind load 860 lbs at node (Suction on leeward side ; Pressure on Wind-ward side)	Total
1.	−17486 lbs.	−2520	−20006 lbs. (9077 kg)
2.	−14999 ,,	−1634	−16633 ,, (7540 ,,)
3.	−12493 ,,	−731	−13224 ,, (6000 ,,)
4.	−10005 ,,	+170	−9835 ,, (4461 ,,)
5.	−10005 ,,	−170	−10175 ,, (4615 ,,)
6.	+5569 ,,	+1393	+6962 ,, (3158 ,,)
7.	−3620 ,,	−1815	−5435 ,, (2465 ,,)
8.	+1856 ,,	+929	+2785 ,, (1263 ,,)
9.	−2970 ,,	−1488	−4458 ,, (2022 ,,)
10.	+928 ,,	+464	+1392 ,, (631 ,,)
11.	−2505 ,,	−1246	−3751 ,, (1701 ,,)
12.	+16242 ,,	+3483	+19725 ,, (8947 ,,)
13.	+13922 ,,	+2282	+16204 ,, (7350 ,,)
14.	+11605 ,,	+1152	+12757 ,, (5786 ,,)
15.	+11605 ,,	−1152	+10553 ,, (4787 ,,)
16.	+16242 ,,	−3482	+12760 ,, (5788 ,,)

+Tension —Compression

In the design of the compression members, the slenderness ratio has been considered. The sizes of members and details of reinforcements are as shown in Fig (1). The tie is prestressed by a cable of 4 wires of 5 mm. stressed initially to 24000 lbs. (10899 kg). The weight of the truss and consumption of concrete can be somewhat reduced if the tension members are not encased. But encasing provides better fire-resistance.

Casting, stressing and grouting

A 5000 p.s.i. (350 kg/cm^2) concrete with an aggregate-cement ratio of 3.5 to 1 and a water-cement ratio of 0.44, both by weight, is usually suitable. The maximum size of aggregate is limited to 1/2″ in view of the small dimentions of the members.



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Wherever possible, the flooring of the building may be done in advance so that the trusses can be cast on it. To prevent bond developing between the concrete of the truss and the casting platform, it is necessary to have a layer of paper above the floor. The reinforcement is assembled on the platform to the marked profile of the truss. Welding or binding may be used in fabricating the reinforcement. The form work is set up around the assembled reinforcements (Fig. 2) and the concrete is poured. Needle vibrators are used for compacting the concrete, alongwith Kango hammers, applied to the shuttering. Curing is done in the normal way. Stressing of the cable is carried out as soon as the concrete attains the required strength.

The straight duct for housing the cable may be formed of G.I. sheets of 18 S.W.G. The duct is provided with air vents as shown (Fig. 1). The grouting mixture may be made up of 2 parts of cement to 1 part of sand passing B.S.S. 14 and retained on B.S.S. 100, the water content being 60% by weight. Aluminium powder at the rate of 0.004% by weight of cement may be added to counteract shrinkage. The grouting pressure may be 30 p.s.i. (2kg/sq.cm).

The wires may be stressed by any of the common prestressing systems.

Erection

The erection of the truss may be carried out by using an ordinary Ginpole derrick of 6″ dia. Hooks are left in the truss at the nodes during casting to facilitate its handling during erection.

Consumption of materials

The quantity of materials used in the truss are as follows :

	Truss	Purlins	Total
Mild Steel kg/m^2	2.73	2.93	5.66
High tensile steel kg/m^2	0.174	0.00	0.174
Concrete m^3/m^2	0.0105	0.0066	0.0171

It may be interesting to compare the consumption of materials for similar trusses standardized in the Soviet Union and Poland for various spans. The quantities given below are exclusive of purlins.

Span	*Wt. of Truss*	*Mild Steel kg/m²*	*H.T. Steel kg/m²*	*Concrete m³/m²*
Soviet Union				
18m.	4.75 tons	3.5 to 4.1	(Including H.T. Steel)	0.018
30m.	13.2-15 tons	5.0 to 6.5	(Including H.T. Steel)	0.029 to 0.033
Poland				
15 to 24m	2.5 to 8 tons	1.7 to 3.5	0.9 to 1.85	0.0115 to 0.023
30 to 40m	17 to 26 tons	5.2	3.0	0.04

These figures are higher than ours on account of the higher design loads used.

Assembly in segments

For larger spans, it will be more advantageous to cast the truss in two or more segments and assemble the pieces in position by post-tensioning the tie. High strength concrete is placed in the joints of the tie and compacted before the prestress is applied. The jointing of other members may be by bolting, site welding of plates, or welding together of reinforcements from the adjoining members followed by in-situ concreting.

Comparison with other roofing schemes

The consumption of materials and approximate costs for two alternative schemes of roofing with steel and prestressed trusses are given in Table (2). The cost figures are for Roorkee. Figures applicable elsewhere may be worked out on the basis of the quantities given.

TABLE 2

Materials (for roof only)	45′ Span steel truss & Purlin			45′ Span Prestressed truss & Purlin		
	Qty/ sq. ft.	Rate	Amount	Qty/ sq. ft.	Rate	Amount
Concrete (cft.)				0.056	15 00	0.84
Mild Steel (lbs)	4.16	0.50	2.08	1.16	0.37	0.43
H.T. Steel (lbs)				0.036	00.81	0.03
A.C. sheet (sft)	1.02	0.90	0.92	1.02	00.90	0.92
(Glazed area extra)						
Total			Rs. 3.00			Rs. 2.22

Test to destruction

Tests to destruction were carried out on two full scale trusses of 40′ span which were very similar to the 45′ design described here. Failure occurred at 7000 lbs (3178 kg) load at each nodal point, which is 3.5 times the design load (Fig.3)

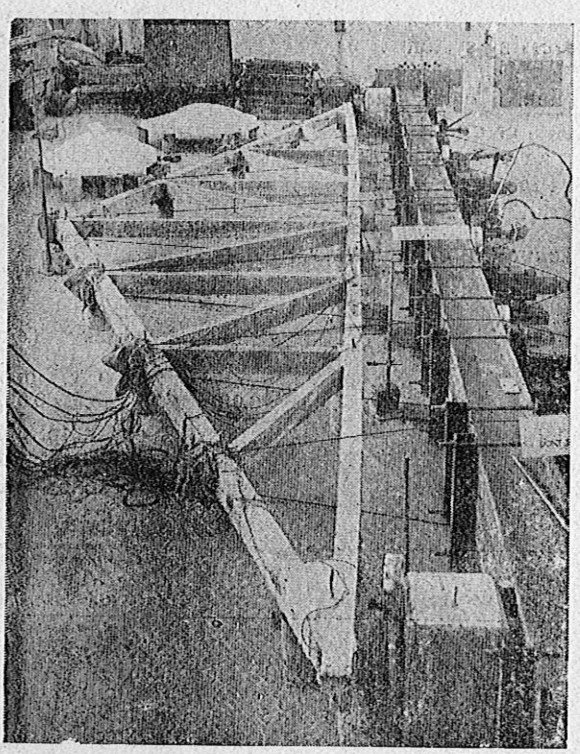

FIG. 3

Other applications

Although the design was primarily developed for roofing industrial and storage structures, the trusses are likely to find applications for roofs of pavilions, garages and railway platforms. Fig (4) shows a view of a pavilion designed and constructed under the supervision of the Central Building Research Institute for the Bengal Engineer Centre, Roorkee using 32′ (9.75m) cantilever precast prestressed trusses assembled on columns by prestressing.

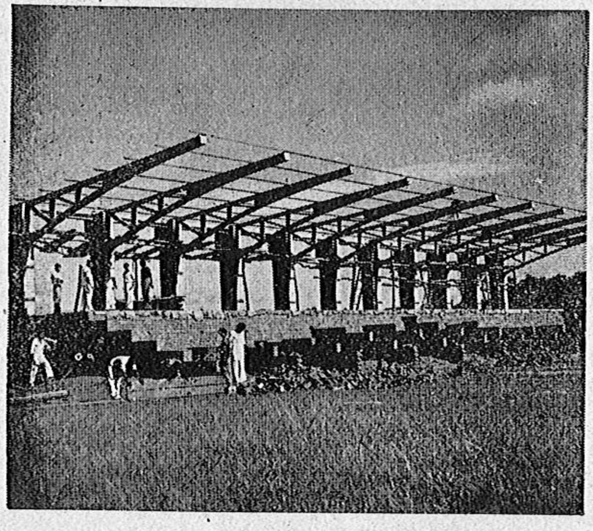

FIG. 4

There is a demand for short notes, summarising available information on selected building topics for the use of Engineers and Architects in India. To meet the need this Institute will bring out a series of building digests from time to time and the present one is the fourth in the series.

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