Folded slabs in latticed steel construction

Autor(en): **Samuely, Felix J.**

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Faltwerke in aufgelöster Stahlkonstruktion

Lajes dobradas trianguladas de aço

Dalles pliées en treillis d'acier

FELIX J. SAMUELY
London

Latticed steelwork to form a «shell» construction was well-known a long time before reinforced concrete shell construction was invented. After its initial appearance, however, no further development took place until recently. Generally speaking, the theory of latticed work is somewhat simpler than that of solid slabs, requiring less mathematical knowledge for the analysis. However, this is correct only if all deformations remain small compared with the differential dimensions of the construction.

Just as a latticed girder can always replace a plate girder, a latticed construction can always be substituted for any portion of a shell or folded slab. This allows the employment of any prefabricated material such as steel, timber, precast concrete, used in conjunction with lightweight roof covering.

With steelwork, as much as possible should be assembled in the workshop to reduce the number of site connections. In the following examples, it may be noted that each latticed girder has tubular chords which lend themselves particularly well to this application because of the connections being in a different plane from that of the actual girder. Plates are welded to each of these chords, and when two lattices are fitted together the corresponding plates are connected by bolts to take the required shear. In analysing the stresses in such a lattice the procedure is similar to that for concrete. Forces acting at the cranks, i. e. the intersections of two consecutive girders, are resolved into the planes of these lattices, and each latticed girder has to transmit two sets of loads which may add to or subtract from each other.

The two chord members which adjoin each other cannot elongate separately, and it is therefore correct to assume that both together take the sum of the calculated forces. For instance, if one of the members has to take 20 tons in compression, and the other 40 tons, they will in fact each have to take 30 tons in compression.

Unfortunately, with this type of construction it is impossible to keep the two members on the actual centre line, and in the transmission of shear from one to the other certain local bending moments will be introduced. However, as the shear is just near the supports where the members are usually not otherwise fully stressed, if the distance between

FIG. 1

the two members is kept to a minimum, little material is needed to take these additional stresses. As the connection between two lattices is tantamount to a hinge, the first calculation can be taken as correct if, as mentioned before, the deformations are not too large.

The shape given in Fig. 1 approximates more to that of a shell, and is the roof of a factory of three aisles 50′0″, 110′0″ and 50′0″ wide respectively. Here, the outward appearance is that of a continuous curve, apart, of course, from the north light, and curved cement asbestos was used as roof covering. There are six latticed girders, and the angle between any two adjoining ones is very obtuse. If the deflection is obtained as described in the paper on folded slabs, it will be found that this is relatively large with such obtuse angles, and in fact, so large that the whole transmission of forces is altered. There are two ways of dealing with this problem – (a) by calculating these deflections, re-calculating the forces and obtaining a progression similar to that described for reinforced concrete, and (b) by introducing a special degree of stiffness between the various latticed girders strong enough to reduce deformations to a reasonable amount. In the example shown in fig. 1 a certain amount of rigidity has been produced by welding two consecutive latticed girders

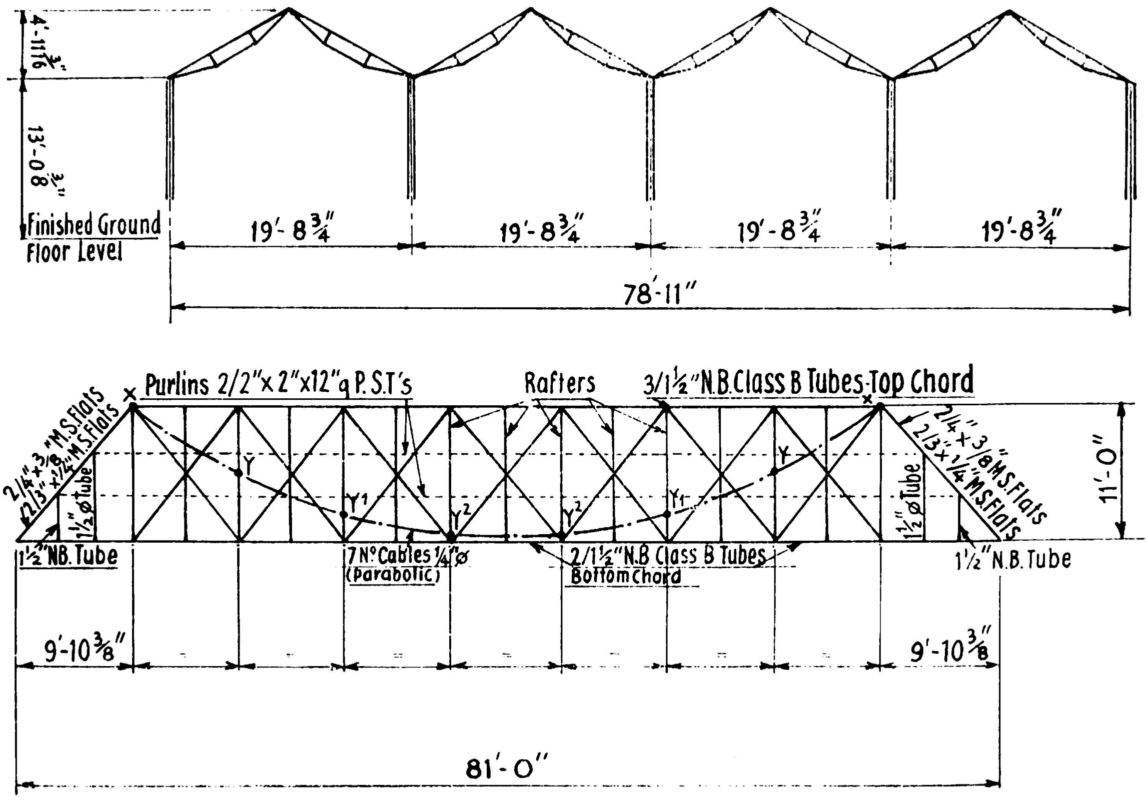

FIG. 2

together instead of bolting them, and even this small amount of rigidity was sufficient to stabilise the latticed construction. More stringent measures may have to be taken, as for instance, the introduction of a rib or of local stiffening plates, as shown in fig. 5. Method (a) is, of course, suitable only where deformations are appreciable, but not so large that they could in themselves prove a danger to stability. For steelwork it is usually more advantageous to have a smaller number of facets, with more acute angles between them. This is particularly so because very frequently the roof covering becomes simpler the smaller the number of cranks.

In fig. 2 a construction is shown which has been used for two workshops respectively 90′0″ x 90′0″ and 80′0″ x 80′0″. In this case the latticed girders are placed in the inclined planes of the roof. The trussed beams shown in the cross section serve to distribute the loads to the eaves and ridges, and the whole girder is in fact post-tensioned by means of a number of jacks at the points Y, Y_1, Y_2, which transfer a large part of the load to the cable XX. The economy effected by this cable would have been even larger if the roof had not been hipped for architectural requirements, and if the cable could have been carried

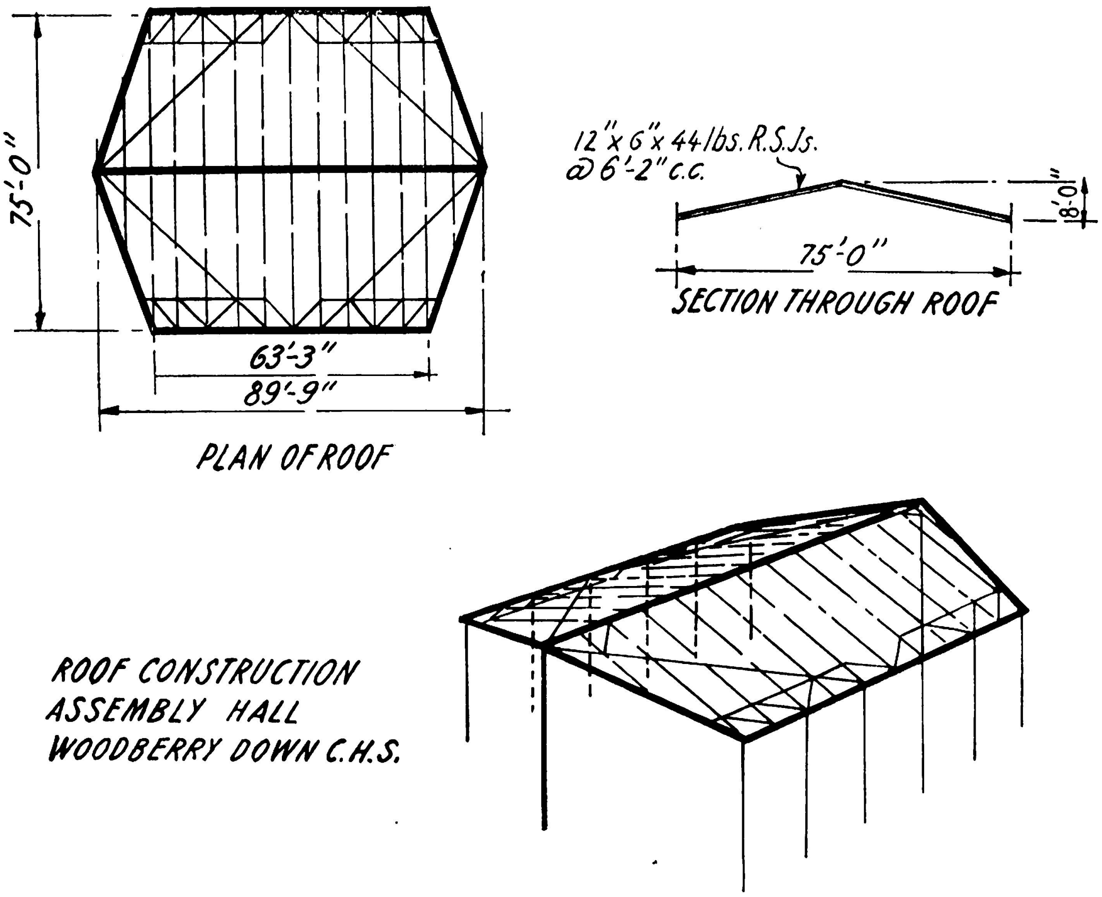

Fig. 3

from support to support. It was possible in this case to erect each strip of roof 90′0″ x 22′6″ in one operation with temporary struts between the eaves.

Fig. 3 shows a similar roof construction for an Assembly Hall. This was flatter than would have been desirable from an engineering point of view. Note that where large areas are concerned it is not possible to have a parallel girder over the whole area, as all connections would have to be done at the site, but part only of any one plane can be latticed, or, as in this example, have a three-pin frame in each, which is more easily produced than a deep latticed construction.

In fig. 4 many of the members are from timber, particularly the compression boom along the ridge. The distribution from eaves to ridge is made by prestressed trussed beams, with the main boom from timber.

Finally, in fig. 5 a shell roof over a gymnasium is shown, which consists of a series of rectangular standard timber frames laid side by

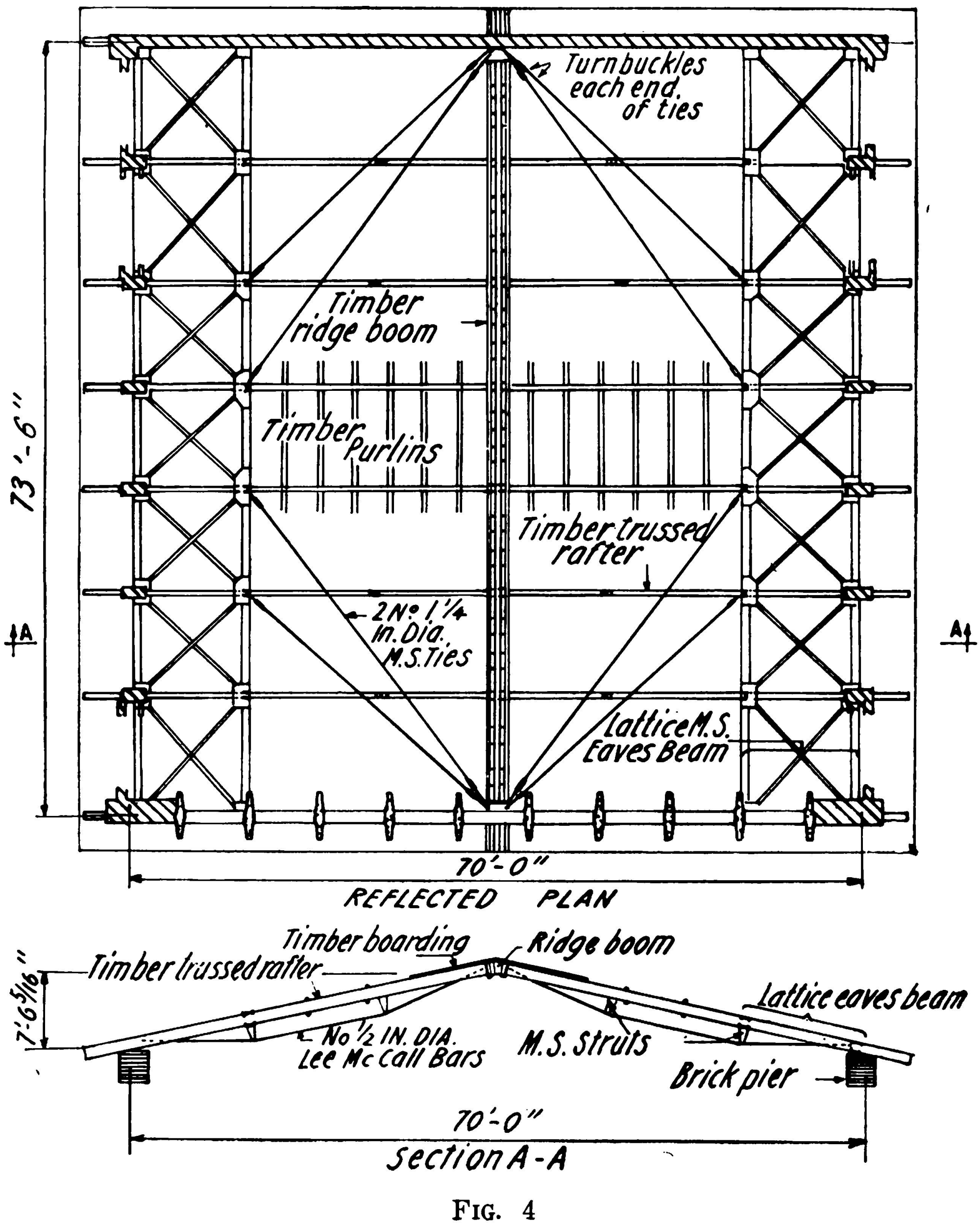

FIG. 4

side. Each frame has two stressed bars crossing each other which hold the frame rigid, and each two consecutive frames are bolted together. The main longitudinal tension occurs along the eaves, and is taken by post-tensioning all the frames together by the Lee McCall method. As the radius is rather large it was found necessary to stiffen some of the joints by a steel plate acting in a cross plane, which is capable of transmitting a certain amount of bending from frame to frame and thus prevents any deformations, which would in their turn have given rise to increased stresses.

Because of the reduced weight, a steel shell construction can very well hold its own economically in a comparison with reinforced concrete.

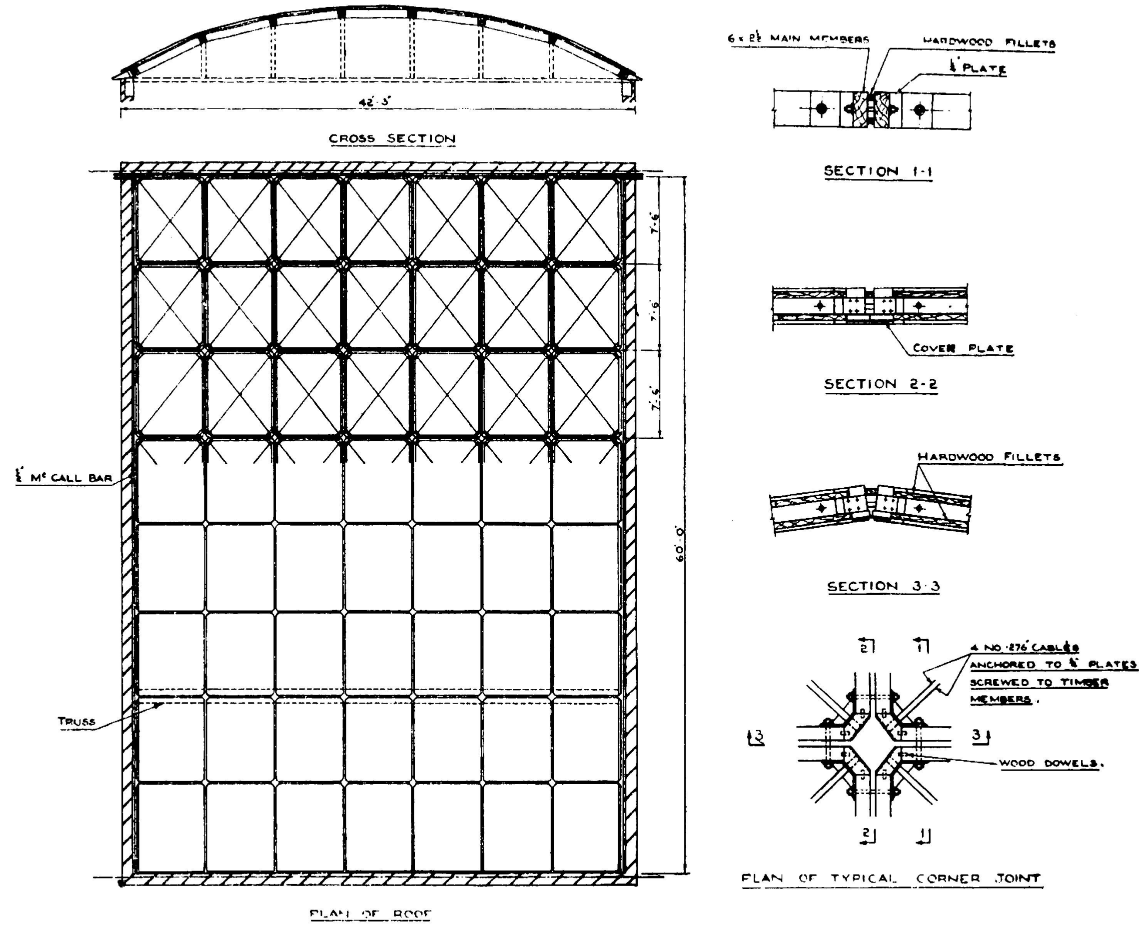

FIG. 5

In some instances it was found that the weight of steel in a steel shell construction was in fact smaller than the amount of reinforcement required in a comparable reinforced concrete shell.

SUMMARY

This is in principle similar to the contribution under II (c), but deals with steelwork in place of reinforced concrete.

In these cases latticed steel construction is arranged in the planes of the roof so that steelwork similar to a shell is achieved. Two structures are mentioned where timber has been used in the same way.

ZUSAMMENFASSUNG

Diese Tragwerke sind im Prinzip ähnlich denen des Beitrages unter II (c); es handelt sich jedoch um Stahlkonstruktionen an Stelle von Eisenbetonbauwerken.

Es wird eine Stahlgitterkonstruktion in den Dachflächen angeordnet, so dass eine Stahlkonstruktion ähnlich einer Schale entsteht. Zwei Bauten werden erwähnt, wo Holz an Stelle von Stahl in der gleichen Weise verwendet wurde.

RESUMO

Estas estruturas são, em princípio, semelhantes às descritas em II c, sendo aqui o betão armado substituído pelo aço.

A estrutura triangulada é, neste caso disposta nos planos da cobertura, de modo a formar um conjunto semelhante a uma parede delgada. Indica-se duas estruturas onde se empregou madeira de maneira semelhante.

RÉSUMÉ

Ces charpentes sont, en principe, semblables à celles décrites en II c, le béton armé étant ici remplacé par de l'acier.

La charpente en treillis est, dans ce cas, disposée dans les plans de la couverture de manière à former un ensemble semblable à un voile mince. L'auteur mentionne encore deux charpentes où l'on a utilisé du bois de la même manière.

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