

Zeitschrift: IABSE congress report = Rapport du congrès AIPC = IVBH
Kongressbericht

Band: 2 (1936)

Artikel: Illuminating and constructional considerations in the arrangement of
long span saw-tooth roofs with steel frames

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DOI: <https://doi.org/10.5169/seals-3348>

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VIIa 5

Illuminating and Constructional Considerations in the Arrangement of Long Span Saw-Tooth Roofs with Steel Frames.¹

Lichttechnische und konstruktive Gesichtspunkte für die Anordnung weitgespannter Sägedächer mit Traggerippe aus Baustahl.¹

Les points de vue de l'éclairage et de la construction dans la disposition des sheds de grande portée avec fermes métalliques.¹

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I. In the case of industrial single storey buildings which form the simplest special case of multiple bay sheds, the structural features are primarily influenced by the character of the daylighting, ventilation, rainwater, drainage, crane equipment and the placing of the supports as governed by operating conditions. A further condition is imposed on the design in that impressive and aesthetically satisfactory interiors as well as exteriors are to be realised.

II. As regards the arrangement of *daylight openings* in an industrial single storey building, there are a surprisingly large number of possibilities which have been tried in practice, but these vary greatly in their merits from the point of view of illumination. Ordinary skylights (see fig. 1, whether with inclined or vertical glass surfaces (Boileau roofs), result in intensities of lighting which are not uniform, and which, in their maximum values, tend to be excessive. At any time during the day, whatever may be the position of the daylight openings, sunbeams may enter. During the summer this is bound to give rise to uncomfortable greenhouse conditions of temperature in the building, and will at any time of the year tend to dazzle the workers, apart from which, in many cases, the sun's rays are undesirable for the sake of the product under manufacture.

All these disadvantages can be avoided by the adoption of *saw-tooth roofs*, which guarantee a quality of lighting in the workshop equal to that in an artist's studio, and do this under economically reasonable terms.

To assess the quality and uniformity of the daylighting use is made of the concept of the daylight ratio TQ. (*Tageslichtquotient*), which is defined as the ratio of the intensity of the illumination existing on, for instance, a horizontal

¹ Supplement to the report VIIa 9 in the Preliminary Publication: Development of structural steel-work.

element of surface within the room, to the intensity of illumination on a horizontal element of surface under the open sky.²

Fig. 1 shows the T.Q. curve for a recently completed factory building having gable skylights, which illustrates the disadvantages explained above; nor can these be overcome by the usual expedient of coating the glass surfaces exposed to the sun with whitewash or the like.

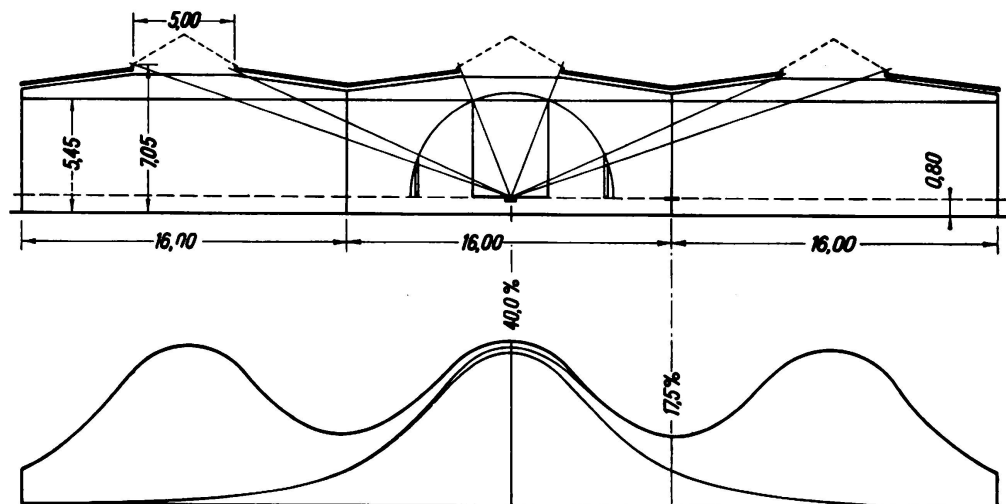


Fig. 1.

T.Q. line for saddle-shaped skylight.

It will be explained below that when a saw-tooth roof is adopted, the choice of the pitch of the transparent and non-transparent roof coverings, as well as the width of the glass surfaces, depends to a great extent on daylighting considerations. Fig. 2 shows a comparison between the following two cases, assuming a saw-tooth unit 7 m wide:

- a) Non-transparent roof covering inclined at 30° .
Transparent roof covering inclined at 60° .
- b) Non-transparent roof covering inclined at 30° .
Transparent roof covering vertical.

The T.Q. lines indicate that in case a) considerably better conditions are obtained than in case b). The T.Q. for the "characteristic" horizontal element — a concept which is also used below — in the middle of the second saw-tooth unit, amounts to 16.7 % in case a) and to 12.3 % in case b).

Fig. 3 shows how the saw-tooth units should be arranged with vertical glass surfaces in case c), so that the "characteristic" element of area already mentioned will have a T.Q. of equal value to that obtained in case a). The considerably greater amount of both transparent and non-transparent roof covering required in case c) as compared with case a) will be noticed. In the effect of illumination nothing is altered if, with a view to economy in case c), the transparent roof

² See *Maier-Leibnitz: Der Industriebau, die bauliche Gestaltung von Gesamtanlagen und Einzelgebäuden*, Berlin, 1932, p. 74 ff.; also DIN Sheet 5034. In the experiments on illumination described below very long strips of glass are assumed. The very simple construction for T. Q. may be seen from the illustrations.

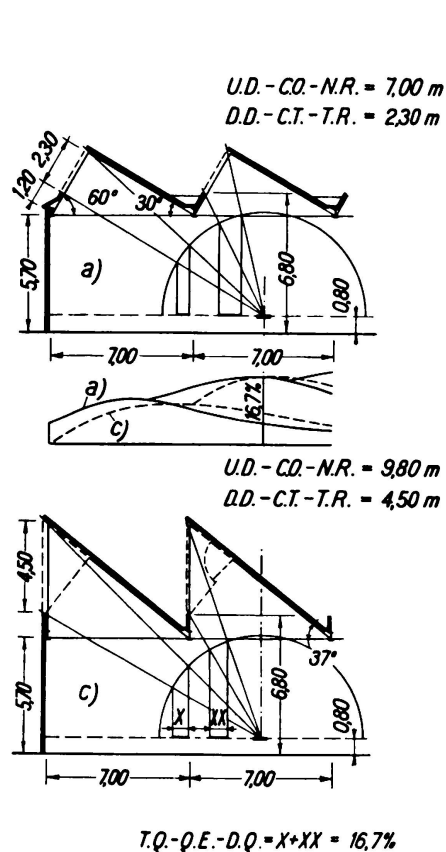
Figure 10 consists of two diagrams, (a) and (b), illustrating the design of a stepped embankment with a semi-circular crest. Both diagrams show a cross-section of the embankment with a crest radius of 7.00 m and a top width of 2.30 m (for a) and 2.90 m (for b). The slope angle is 60° for (a) and 30° for (b). The diagrams include a cross-section view below the main profile, showing the internal structure and the crest radius. The diagrams are labeled with dimensions and angles.

Diagram (a) shows a three-stepped profile with a crest radius of 7.00 m, a top width of 2.30 m, and a slope angle of 60°. The cross-section view below shows the internal structure with a crest radius of 7.00 m and a top width of 2.30 m. The slope angle is 60°.

Diagram (b) shows a similar profile with a crest radius of 7.00 m, a top width of 2.90 m, and a slope angle of 30°. The cross-section view below shows the internal structure with a crest radius of 7.00 m and a top width of 2.90 m. The slope angle is 30°.

T.Q.-lines for horizontal elements.

- a) T.R. = Transparent roof covering inclined at 60°.
N.R. = Non-transparent roof covering inclined at 30°.
- b) T.R. = Transparent roof covering vertical.
N.R. = Non-transparent roof covering inclined at 30°.



T.Q.-lines for horizontal elements.

- a) T.R. = Transparent roof covering inclined at 60°.
N.R. = Non-transparent roof covering inclined at 30°.
- c) T.R. = Transparent roof covering vertical.
N.R. = Non-transparent roof covering inclined at 37°.

Fig. 4 gives the TQ. curve for case a₁); which is fundamentally similar to case a) except that the non-transparent portion of the roof covering has an overhang which extends to a point lying vertically above the lowest point of the glass strip. In the "characteristic" horizontal element of the second saw-tooth unit there is obtained a TQ. value of 12.3 %, equal to that for case b), whereas in case a) the value is 16.7 %. In case d) it is shown to what width the strip of glass has to be reduced (1.7 m instead of 2.30 m) in order that the characteristic element may receive the same TQ. as in case a₁). If, in case d), the upper

portion of the non-transparent roof covering is made movable, a certain "dosage" of daylight may be obtained, and just as in case a_1) the entry of sunbeams into the room may effectively be prevented under even unfavourable conditions, such as the height of summer.

Without detriment to the T.Q. value further savings in the transparent and non-transparent roof coverings might be effected by reducing the pitch of the transparent covering to, for instance, 45° .

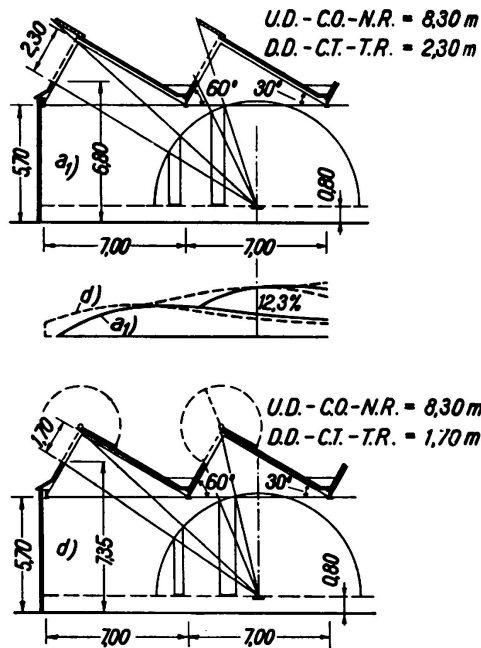


Fig. 4.

Saw-tooth roofs, 7 m — units.

T.Q.-lines for horizontal elements.

- a_1) T.R. = Transparent roof covering inclined at 60° with cantilever.
 N.R. = Non-transparent roof covering inclined at 30° .
 d) T.R. = Transparent roof covering inclined at 60° .
 N.R. = Non-transparent roof covering inclined at 30° .

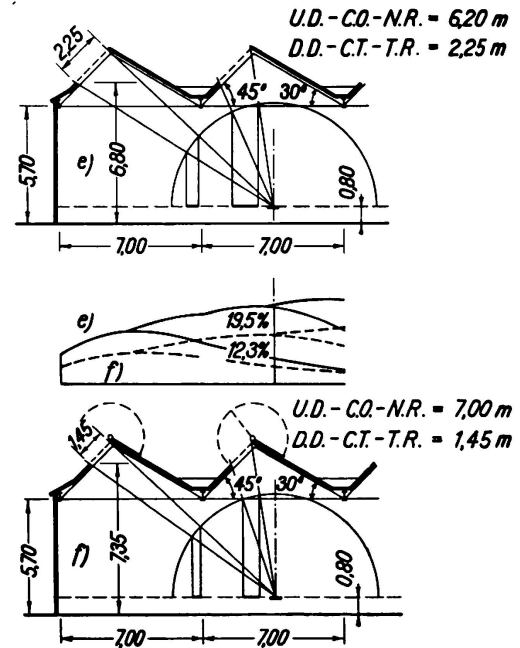


Fig. 5.

Saw tooth roofs, 7 m — units.

T.Q.-Lines for horizontal elements.

- e) T.R. = Transparent roof covering inclined at 45° .
 N.R. = Non-transparent roof covering inclined at 30° .
 Level of gutter same as for cases a — d incl.
 f) T.R. = Transparent roof covering inclined at 45° .
 N.R. = Non-transparent roof covering inclined at 30° .

Fig. 5 shows two such cases. In case e) the same conditions are chosen as in cases a) and a_1), both as regards the gutters and their top edges. At the "characteristic" point the T.Q. value is 19.5 %.

In case f) the strips of glass are only 1.45 m wide, but in spite of this there is obtained at the "characteristic" element the same T.Q. value of 12.3 % as in cases a_1), b) and d), the inclination of 30 % for the non-transparent roof covering being retained. In both cases e) and f) it is assumed that movable parts for dosing the daylight are fitted. Case f) approximates to the desired minimum of building and operating cost.

For cases a) and b) the T.Q. curves of the vertical elements of area are shown in Fig. 6.

III. As regards constructional considerations affecting the *rainage and ventilation of saw-tooth roofs*, the criticism that saw-tooth roofs are difficult to venti-

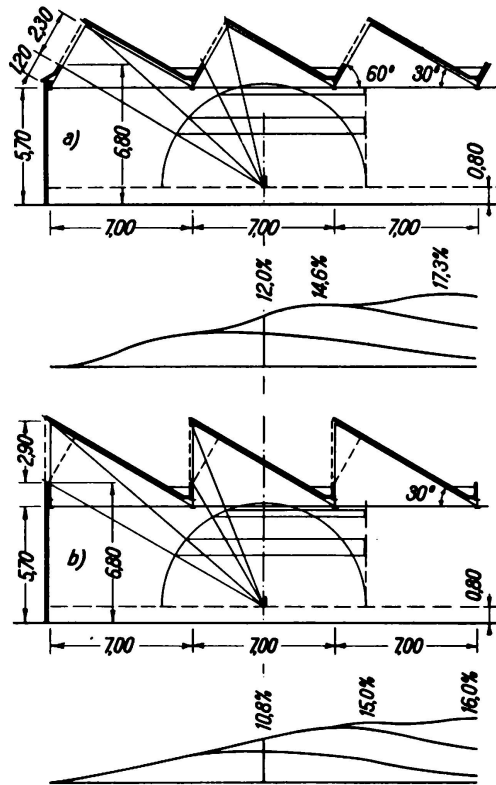


Fig. 6.

Saw-tooth roofs, 7 m — units.
T.Q.-lines for vertical elements.

a) T.R. = Transparent roof covering inclined at 60°.

N.R. = Non-transparent roof covering inclined at 30°.

b) T.R. = Transparent roof covering vertical.

N.R. = Non-transparent roof covering inclined at 30°.

late is overcome by the provision of ventilating flaps, as shown in Fig. 3 for case c) or by the provision of suitably arranged ventilators of cylindrical profile on the ridge of the saw-tooth roof. This ensures at least as good ventilation as is

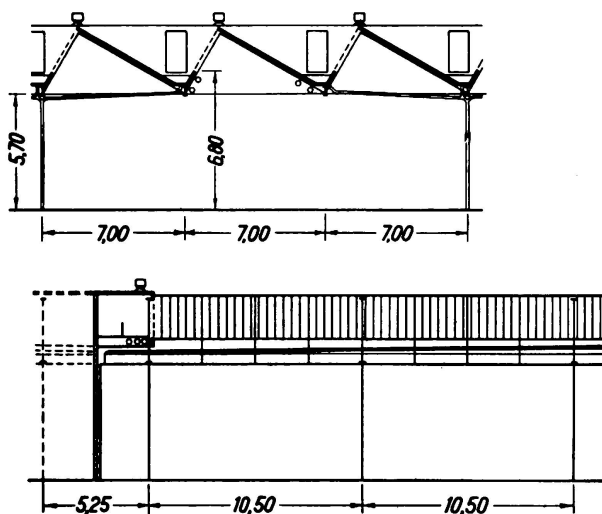


Fig. 7.

Inspection gangway on the east and west side of a building.

possible with gable skylights. Ventilation may be considerably simplified if, as shown in Fig. 7, an inspection gangway is provided either on the east or

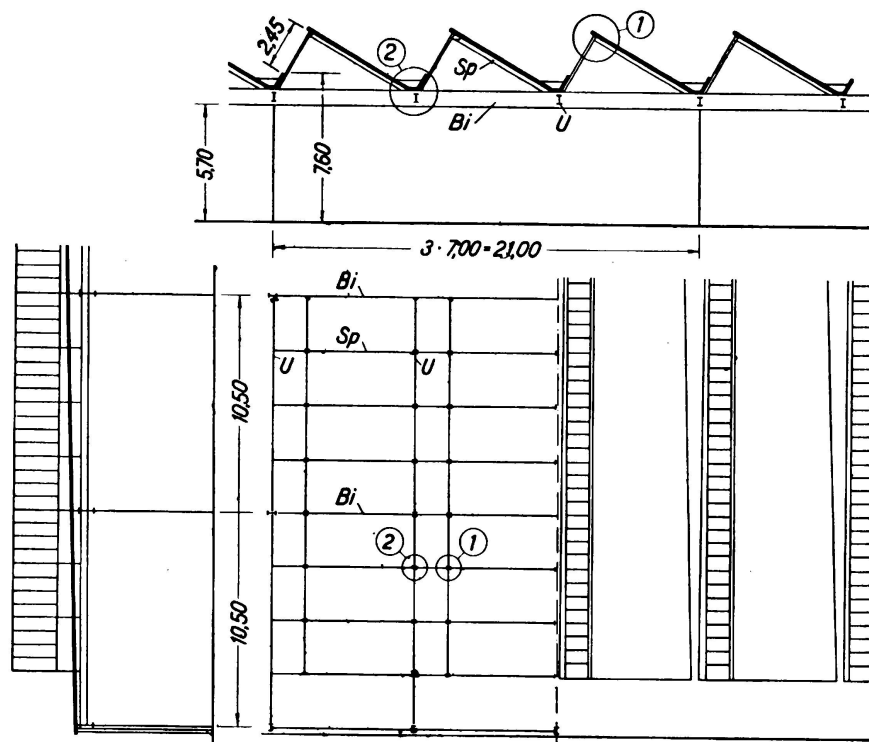


Fig. 8.

Case A: Supporting rib for bays of $21 \times 10,5$ m, plate webbed main girder running north and south.

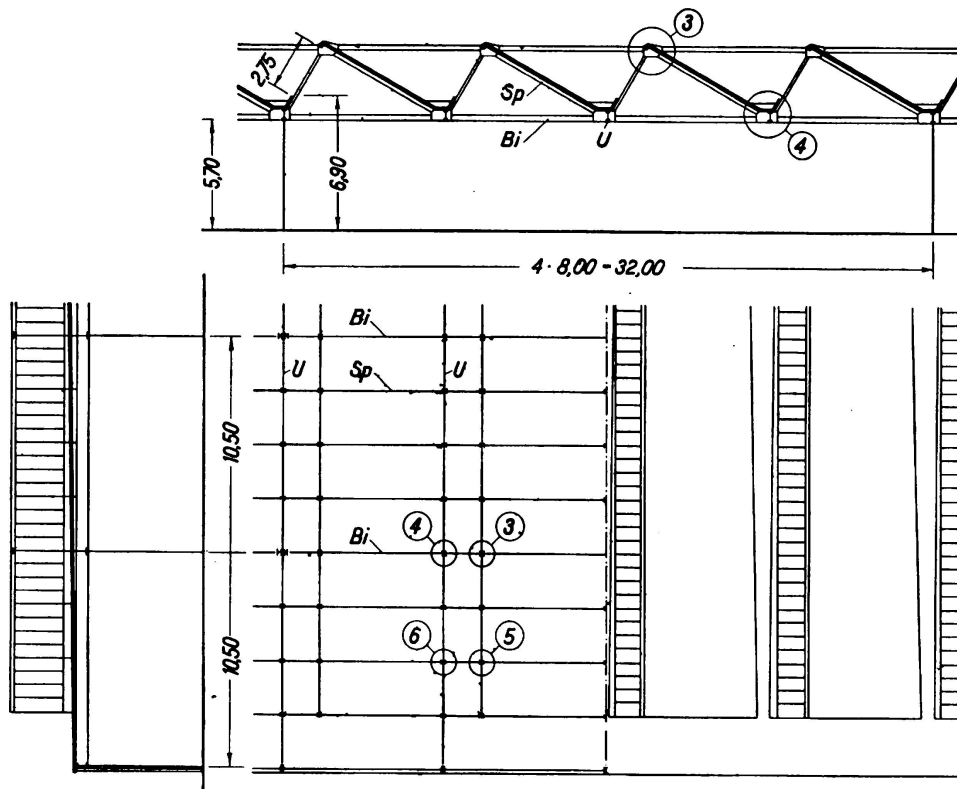


Fig. 9.

Case B: Carrying ribs for bays of $32 \times 10,5$ m, main girder of open frame construction running north and south.

the west side of the saw-tooth roof. Such a gangway also brings the gutters in the valleys between the saw-teeth within easy reach. The inner spaces below the saw-tooth roof are connected, for the purpose of ventilation, by a transverse

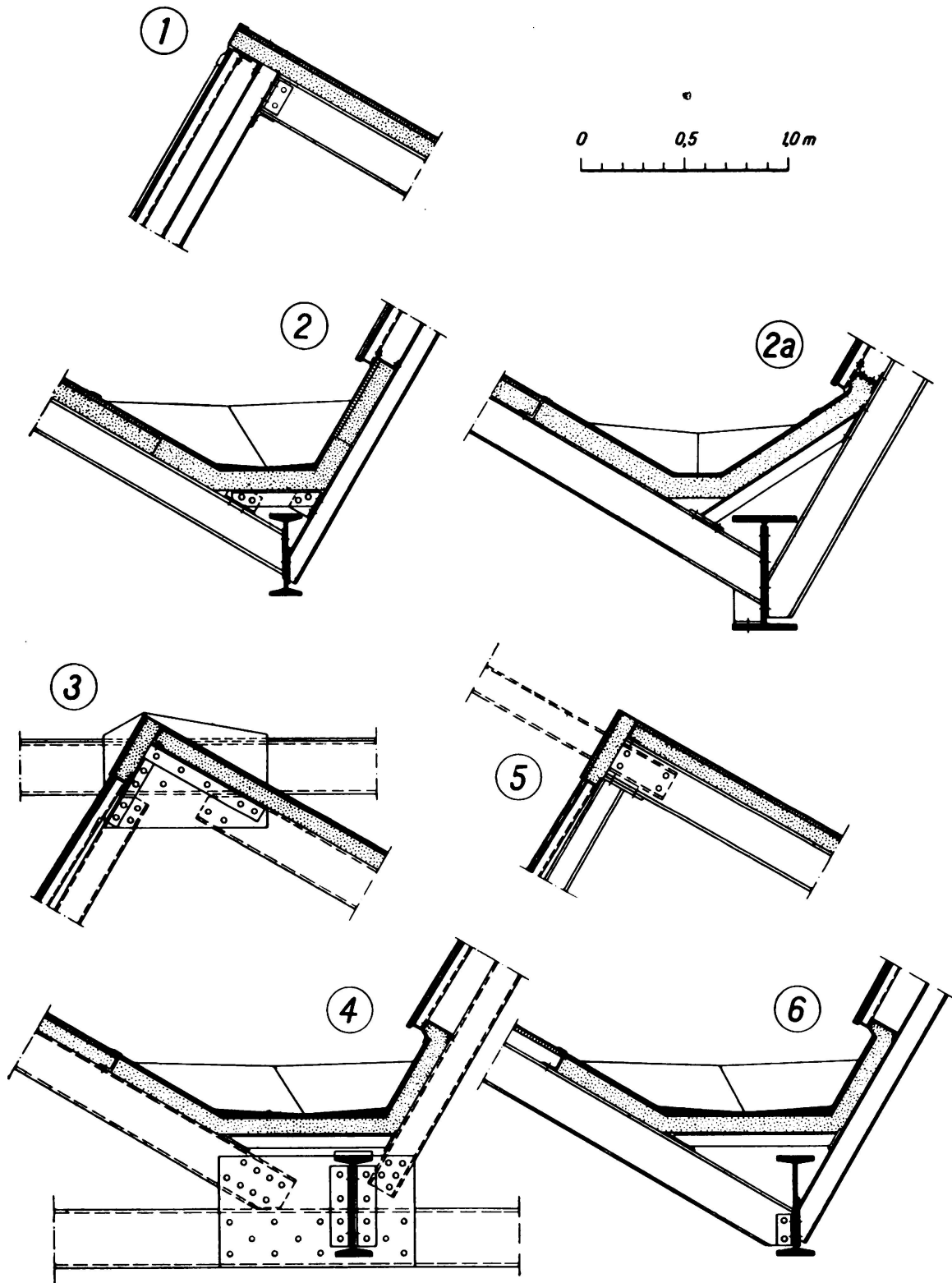


Fig. 10.

Details of the carrying ribs and arrangement of the roof covering for Figs. 8 and 9.

duct. On the transparent floor of the inspection gangway pipe lines can be laid running along the length of the building, and can easily be introduced into the spaces below the saw-tooth roof. The external design of a single storey building is greatly facilitated by the provision of an inspection gangway of this kind, and the objection that may be raised against saw-tooth roofs that they are ugly is in this way overcome.

IV. Among the different possibilities of arranging the *supporting frames of long span saw-tooth roofs*, reference will be made here only to that form in which the most important of the structural elements, namely, the main roof



Fig. 11.

Intersection point in the lower boom of a main girder in the framing system.

trusses, run north and south, i. e. the greatest spans between the stancheons are demanded in this direction. Here two cases are to be distinguished:

Case A: In Fig. 8 the spacings of the supports are at 21 by 10.5 m. The steel skeleton consists mainly of continuous plate girders (H.Bi) together with purlins (U) spanning 10.5 m, and rafters (SP) to which the non-transparent roof covering, in the form of pumice concrete slabs, is directly attached. The spaces under the saw-tooth roof are completely free from constructional members between the main girders.

Case B: Here use is made of continuous trusses of 32 m span and the purlins are so connected as to ensure their operation as continuous beams.

The details most essential to this design are shown in Fig. 10 for both cases. In the building indicated in the sketch 2a the continuous purlins are arranged over spans of $10 + 19.5 + 19.5 + 10$ m.

Fig. 11 shows a point of junction in the bottom chord of the trusses and the above mentioned connection of the purlins with a truss. There also are to be seen the lower inclined surfaces of the gutters. Enough space is left between the lower part of the gutter and the purlin to allow of running pipe lines from one saw-tooth unit to another.