Thermal elongation in trapezoidal and corrugated aluminium sheeting for sheet thicknesses from 0.5 to 1.5 mm

1. Elongations ΔL and forces F

   Temperature difference from -20 °C to + 80 °C, ambient temperature 10 °C:

   Summer ΔT= + 70 K, winter ΔT= - 30 K

   Elongation:

   $\Delta L = \alpha_{th} \cdot \Delta T \cdot L$ where $\alpha_{th} = 24 \cdot 10^{-6}$ / K

   L = 6 m

   Summer ΔL = + 10.2 mm (1.7 mm/m)

   Winter ΔL = – 4.3 mm (– 0.72 mm/m)

   Forces:

   $F = \alpha_{th} \cdot \Delta T \cdot E \cdot A$ where E = 70 000 N/mm²

   A = 1500 mm²/m (e.g. trapezoidal sheeting 50/167-1.0)

   Summer F = 176 kN (= 17.6 t)

   Winter F = 76 kN (= 7.6 t)

2. These forces are so large that they produce elongated holes in the aluminium sheet. The forces cannot be accommodated using the joining elements commonly used in lightweight construction!

3. Where there is a direct screwed joint between aluminium and steel of the same thickness, the elongated hole will always form in the aluminium. A prerequisite for this is that the strength values of both materials are within the usual range.

4. The joint is always designed in such a way that a deformation of 3 mm must be possible without any loss in load-bearing capacity (load-bearing capacity in this case: elongated hole in component II made of steel)

5. Shear tests with a combination of 1 mm steel and 0.8 mm aluminium show:

With a sliding distance of 3 mm, an elongated hole 1 mm long forms in the aluminium (force ≈ 1.5 kN), the ultimate failure load is ≈ 2 kN (elongated hole in the steel after bending the screw to an angle).

The elongated hole in the aluminium does not constitute failure provided it does not have any effect on the pull-out force of the screw from the supporting structure. With any combination of components, as long as the elongated hole first forms in component I (in this case, aluminium), failure of component II (in this case, steel) is not expected.

In the tests with 1 mm steel, the elongated hole always forms first in the aluminium, so that one does not have to worry about a failure of the joint, and especially not if the steel is thicker.

6. Whereabouts of the changes in length

- The length changes in the aluminium relative to the supporting structure are only partially compensated for if the thermal elongations in the latter are less than those in the aluminium.
- The length changes are spread uniformly over the length of the profiled sheets. The support conditions, e.g. sliding point–fixed point arrangement, ductility of the supporting structure, symmetry conditions, determine the displacements that occur.
- At each fastening point, there will be compensation from both sides via tensile or compressive stresses for those movements in opposing directions that can be taken up by the connection there.

7. Evaluation of structures:

<u>Roofs</u>

- Aluminium roof decking on Z-shaped profile, diagonally, with 3 mm thermal gap in between
- Two methods of fastening are common:
    - Joint in the bottom flange
    - Upper-flange joint with or without a special washer

  Length changes are accommodated via the flexibility of the joint (bendability of the shaft of the screw, possible rotation in the tapped thread), the low bending strength of the Z-shaped profile and the elongated holes in the aluminium.

  If a top-hat profile is used instead of a Z-shaped profile, compensation for length changes resulting from the low bending strength no longer applies but the flexibility of the joint and the elongated holes in the aluminium can suffice. Joining to the upper flange is more beneficial here.

- On timber:

  Depending on the direction of the fibres, the coefficients of thermal expansion of coniferous timber are 5×10^{-6} (parallel) and 50×10^{-6} (perpendicular), in other words about either a fifth or twice that of aluminium. The length changes are accommodated by the flexibility of the supporting structure (twisting of the purlins), the joint (screws are at least partly embedded and thus anchored more rigidly in the support structure than in thin steel) and due to the formation of elongated holes. Joining to the upper flange is beneficial for larger/thicker timber cross-sections.

- Transversal joints on roofs should usually be sliding joints. Allowance should be made for the minimum supporting width together with the expected shortening of the lower profile.
  If the width of the upper flange is inadequate, two timber supports should be laid in parallel so that the supports are completely separated.

  Fixing is carried out either only on the ridge-side profiled sheet or for each profiled sheet separately.

  Sealing strips are arranged between the profiles that are installed underneath the fastener (on the eaves-side).

- With transversal joints in the area of roof apertures, one can forego the sliding joint where the length of the sheets to be installed is less than 6 m. With longer profiled sheets, a decision has to be made based on the expansion situation.

Wall cladding

Horizontal installation

- Mostly screwed to adjacent flange.
- With horizontally installed profiled sheets, the length should not exceed 6 m. Arrange pilaster strips between them. Length changes must not be allowed to cumulate at the pilaster strips so that flexible joints are necessary on the pilaster strips.
- Limiting the length of profiled sheets to 6 m has proven to be good building practice because the thermal elongations can be accommodated by the constructions commonly used today.
- One needs to ensure that the overlapping of the profiled sheets does not act as "butt straps" that lead to a cumulation of the length changes.
- Stiff pilaster profiles should be supported so rigidly that part of the length changes is deflected as forces or is compensated for by elongated holes in component I.
- Profiled sheets should not be joined at the transversal joints by means of overlapping. Overlapping can lead to visible signs of sliding, about which there are often complaints but which are inevitable with overlapping. With roof coverings, this is usually not critical.
- Provision for possible sliding is necessary with butt joints in structural parts.

Vertical installation:

- In contrast to horizontal installation, it is common practice in this case to overlap the profiles. When installed, one cannot see gaping butt joints here.

- With horizontal pilaster strips careful consideration has to be given to proper functioning of the drainage to the outside and to ensuring that the pilaster strips can also expand.

8. Conclusion: The material will expand or contract. The resultant forces cannot be accommodated by the supporting structures and the joints of the lightweight construction. The thermal elongations will be either

- impeded by very large or lots of smaller (support) forces (examples: clamping between massive end supports = horizontal corrugation between two gable walls or lots of supports with relatively small forces = principle of railway tracks)
- or compensated for by the thermal elongations of the surroundings (example: soft supporting structure or flexible joints)
- or reduced by expansion as a result of deflection out of the plane (example: bending of trapezoidal sheeting out of the sheet plane)

The three possible means of compensation usually occur simultaneously. A part of the forces does not occur at all because the supporting structure also moves, the joint yields or elongated holes are formed, or there is deformation due to bending; another part or the remainder will be accommodated by the reaction forces.

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