7. FASTENINGS

7.1 Basic principles

7.1.1 Loads on fastenings

Fastenings at supports are loaded by tensile forces caused by wind uplift loads and temperature differences between the faces of the panel. Fastenings may be loaded also by shear forces caused by the self-weight and weight of additional building components on a wall and roof, by the temperature expansion of the faces and, additionally, by possible diaphragm action (see Chapter 2).

Whereas the sandwich panel itself has to be designed against static loads, the fastenings may be more sensitive to repeated loading than the panels themselves and repeated loading should usually be considered in the design.

<table>
<thead>
<tr>
<th>Comment:</th>
<th>The following loads may arise in the fastenings connecting a sandwich panel to supporting substructure: All are likely to be repeated:</th>
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<tbody>
<tr>
<td></td>
<td>Tensile forces - static or repeated</td>
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<tr>
<td></td>
<td>Shear forces - these occur mainly in the inner face</td>
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<tr>
<td></td>
<td>Imposed deformations - imposed differential movements of the faces causing bending of the fasteners and/or yield/folding of the outer face and/or deformations or yield in the supports.</td>
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7.1.2 Types of fastenings to supports

The following principles of fastening may be distinguished and are embraced by these Recommendations:

(a) Fastening within the width of the panel
   1. Fastening through the overall depth of the panel
   2. Fastening through the substructure into an insert

(b) Fastening at the sidelap
   1. Fastening through the overall depth of the sidelap with attachment of the outer face
   2. Fastening of the inner face only
   3. Fastening of some part of the panel without attachment of the outer face

(c) Proprietary designs not covered by (a) or (b)
Fig. 7.1 Types of fastenings to supports.

End support = support of the end of a panel
Intermediate support = support in between the length of a panel

Comments:

1. When fastening is through one skin only, local strengthening of the panel may be necessary in order to avoid crushing, delamination or peeling of the fixed face at the point of fixation.

2. Both types of fastenings are common at end supports as well as at intermediate supports.

3. The characteristic strength of type (b) fastenings at end supports is usually not so high as at intermediate supports.

4. The outer face shall preferably be fixed to the framework.

7.1.3 Types of fasteners

In sandwich panel construction, the following fastener types are commonly used for connecting sandwich panels to light-gauge metal supporting structures:
a), c) self-tapping screws

b), d) self-drilling screws

Fig. 7.2 Fasteners for common applications in light-gauge metal constructions.

In addition to these fasteners, nowadays, special fasteners for sandwich panels which have a face-supporting thread beneath the head of the screw are often used. The types of screw are the same as above:

Fig. 7.3 Special fasteners for fastening sandwich panels.
For connecting sandwich panels, as well as conventional sheeting, to concrete supports, a special nail has been designed, which already has been approved in some European countries. This nail is hammered through the panel into a predrilled hole in the concrete.

Fig. 7.4 Special fasteners for fastening to concrete frames.

7.2 Failure modes of fastenings

7.2.1 Failure modes of fastenings loaded in shear

In sandwich construction, the same failure modes can arise as for fastenings in sheeting, as described in the European Recommendations for the design and testing of connections in steel sheeting and sections; Ref. /ECCS 1983a, Section B1.1.1/

Fig. 7.5 Yield of inner panel sheet only.
Fig. 7.6 Yield of inner panel sheet and/or supporting structure.

Fig. 7.7 Shear of the fastener.

Comment: This mode may occur when the sheets are thick in comparison to the fastener diameter, or when an unsuitable fastener is used.

In addition, the following failure mode may also occur in fastenings of sandwich panels:
Fig. 7.8 Tilting of the fastener with folding of the inner face of the panel.

**Comment:** The failure mode involving tilting of the fastener together with folding or tearing of the inner face of the panel usually arises when the fasteners are relatively flexible. The inner face will carry most of the shear load and can be assumed to carry all of the shear load for the purposes of design.

Fig. 7.9 Bending of fastener due to imposed deformation, $u$.

**Comment:** A temperature difference between the faces of the panels causes a relative displacement $u$ which, in turn can cause yield and/or folding of the outer face of the panel and bending of the fastener. In thin supports (e.g. cold-formed members) deformations in the supports may also be caused. At a certain value of the displacement '$u$', the fastener may break.
7.2.2 Failure modes of fastenings loaded in tension

Similar failure modes can arise as for fastenings in sheeting as described in Ref. /ECCS 1983a, Section B1.1.2, Figures 5-11/.

Fig. 7.10 Tension failure of the fasteners.

**Comment:** This mode may occur when the strength of panel is high in comparison with the fastener or when an unsuitable fastener is used.

Fig. 7.11 Pull-out of the fastener by disturbing the thread in the substructure.

**Comment:** This mode may occur when the support member is thin, or when there is insufficient anchorage of the fastener.
Fig. 7.12  Pull-over of the outer face of the panel.

**Comments:** 1. In sandwich panels, the failure mode of "pull-over" is influenced by the stiffness of the core material, as shown above.

   2. Pull-over of the outer face of the panel may cause loss of weathertightness.

In addition, the following can also occur in sandwich panels:

Fig. 7.13  Delamination of the inner face (fastening of some part of the panel on inserts without attachment to the outer face).

**Comment:** Delamination of the inner face may occur when the pull-out strength of the insert is higher than the tension strength of the affected core area. This detail is not generally recommended although it is sometimes used when hygienic requirements preclude the use of fasteners which are visible on the non-fastened face.
Fig. 7.14 Failure of the core.

**Comment:** Failure of the core may occur in side-lap fastenings when only part of the panel without the outer skin is attached.

Fig. 7.15 Delamination of the inner face.

This type of fastening is not recommended as a sandwich panel fastening system.
This type of fastening is not recommended as a sandwich panel fastening system.

Fig. 7.16 Pull-out of the inner face.

**Comment:** Attention should be paid that the fastening systems in the figures 7.15 and 7.16 above have very low characteristic strength. In some European countries they are not recommended.

This type of fastening is not recommended as a sandwich panel fastening system.

Fig. 7.17 Peeling of the inner face.

**Comments:**

1. Delamination of the inner face or pull-out are the likely modes of failure when only the inner skin is fastened and there is no local strengthening of the panel (see also note on "peeling" below)

2. Peeling of the inner face is the likely mode of failure when only the inner skin is fastened at the **sidelap** and there is no local strengthening of the panel. Except in special cases, the design of fastenings which fail by **delamination** or peeling is **not** recommended.
7.3 Characteristic resistance of fastenings

7.3.1 Characteristic resistance of fastenings under static load

The characteristic resistance of a fastening shall be obtained by testing. At least five, and usually ten, tests should be carried out on a given arrangement and the results interpreted in accordance with clause 5.1.2. The strength of a fastening should be taken as the lower of:

- the ultimate load
- the load achieved with a deformation of 3 mm at the inner face in case of shear.

7.3.1.1 Characteristic resistance of fastenings loaded in tension

The characteristic resistance $F_{LR}$ under both static and repeated tensile load shall be determined by testing in accordance with the procedures described in section 5.2.18.1. Depending on the particular fastening arrangement, the tests may be carried out using either a representative portion of the complete sandwich panel or material from the outside face only.

It is assumed that load is applied centrally and that the diameter of the head of the fastener or washer minus the diameter of the fastener is at least 7 mm and the washer has sufficient rigidity to prevent it from being appreciably deformed or pulled over the head of the fastener. When this is not the case and there are no specific data available from tests on sandwich panels, the following values (obtained from profiled sheeting) may conservatively be taken.

When the attachment is at a single quarter point, the design value of the resistance shall be 0.9 $F_{LR,rd}$ where $F_{LR,rd}$ is the design value of the characteristic resistance (after application of the material factor). When the attachment is at both quarter points and the distance apart of the screws is less than 70 mm, it shall be 0.7 $F_{LR,rd}$ otherwise $F_{LR,rd}$ may be used.

\[ 1.0 F_{LR} \quad 0.9 F_{LR} \quad 0.7 F_{LR} \quad 0.7 F_{LR} \]

**Note:** For the diameter of pre-drilled holes for screws, the manufacturer's guidelines shall be observed.
If the individual fasteners are too close together (typically less than about 250 mm), the characteristic resistance may be reduced by interaction between them. In such cases, the characteristic resistance shall be determined by tests on the complete fastener group.

7.3.1.2 Characteristic resistance of fastenings loaded in shear

The characteristic resistance under both static and repeated load should normally be obtained by testing in accordance with the procedures described in section 5.2.18.2. Depending on the particular fastening arrangement, the tests may be carried out using either a representative portion of the complete sandwich panel or material from the inner face only.

7.3.2 Deformation requirements for fasteners under static load

The requirements given for sheeting in clauses B1.3 and B1.4 of Ref. /ECCS 1983a/ are valid. The requirements for shear must be related to the inner face.

7.33 Requirements for fastenings under repeated load

Under repeated tension load, the requirements given for sheeting in clause B2 of Ref. ECCS 1983a/ are valid.

Under repeated shear load the requirements given for sheeting in clause B2 of Ref. ECCS 1983a/ are valid.

7.3.3.1 Imposed deformations under repeated load

The fastenings should be capable of sustaining the repeated lateral deformations associated with movements of the structure under load (e.g. thermal bow, inclination of the panel at the end support). A suitable test for this requirement is described in section 5.2.18.4.

The imposed lateral deformation ‘u’ should be taken to be the difference between the displacement of the inner and outer faces at the point of attachment. In calculating this displacement, the most unfavourable combination of loads at the ultimate limit state should be considered (see section 2.4.1).
Comments: 1. Due primarily to thermal expansion and contraction of the outer face, the heads of fasteners which pass through the full depth of the panel may be subjected to repeated cycles of imposed deformation. The test requirements should therefore be based on the expected cycles of temperature variation during the life of the panel.

2. A method of calculating ‘u’ is given in Appendix E. In most cases, it is sufficient to take account only of temperature differences when calculating ‘u’.

7.3.2 Characteristic strength with regard to peeling and delamination

The characteristic strength with regard to peeling and delamination shall be based on tests which take into account the effect of repeated loading.

This test should follow the loading spectrum given in the appropriate National Standard. In the absence of such a spectrum, satisfactory performance at the serviceability limit state may be demonstrated by a preliminary test in which the fastening is subject to 100 cycles of load up to the serviceability load. This preliminary test is satisfactory if the residual deformation is not greater than 10% of the maximum deformation achieved during the test.

Comments: 1. Investigation of these modes of failure will usually require testing of a complete panel assembly which should reflect the real situation as closely as possible.

2. Peeling and delamination should normally be regarded as serviceability limit states.

7.4 Design strength of fastenings

The design strength of a fastening should be obtained by dividing the characteristic strength by the material factor given in section 2.5.3.

7.5 Forces and deformations in fastenings

Primary forces in fastening are those caused directly by the actions (load or temperature). These must always be calculated and compared with the design strength of the fastening.

Secondary forces are those caused indirectly by the actions (e.g. by rotation of the point of attachment). They need only be calculated when the deformation requirements given in clause 7.3.2 are not satisfied. The combined effects of primary and secondary forces must then be considered.
7.5.1 Shear forces in fastenings

It may be assumed that shear forces are only present in the inner face of the panel. Primary shear forces may be caused, for example, by:

- dead load (e.g., of facades)
  - temperature changes in the face material
- secondary shear forces may be caused, for example, by:
  - rotation at the end of a panel fastened eccentrically with respect to its neutral axis
  - unintentional diaphragm action.

**Comments:**

1. Stressed skin (diaphragm) design in which sandwich panels carrying in-plane shear forces are used to replace wind bracing is beyond the scope of these Recommendations.

2. Shear forces in fastenings arising from variations in the temperature of the faces of the panel may be calculated taking into account slip in the fastenings, strain in the faces and deflection of the supporting framework. These shear forces may be neglected when there is sufficient deformation capacity.

3. Appendix 1.B.2 of Ref. /ECCS 1983a/ provides a calculation method for the shear forces caused by rotation and membrane action of the sheeting.

7.5.2 Tensile forces in fastenings

Primary tensile forces will generally be caused either by uplift loads or by temperature differences between the faces.

Secondary tensile forces may be caused by prying action under either upward or downward loads. A method for determining prying forces is given in Appendix I.A of Ref. /ECCS 1983a/.

7.6 Additional considerations with regard to fastening systems

- It should be verified that the performance of the fastening system will not be adversely affected by creep.
- It should be verified that the performance of the fastening system is not impaired by a rise in temperature of the core material.
- When designing the fastening system, the possible deleterious effects of corrosion should be considered. (See ECCS 1983a and ECCS 1983b).
- When designing the fastening system of panels for cold stores, it should be verified that the lateral deformations of the supporting substructures during the cool-down phase
cause additional forces in fastenings and panels and the additional forces in the fastenings and panels can be accommodated (see Fig 7.18).

**Comments:**

1. Creep occurs primarily in roofs. It can only occur in wall cladding if there is permanent externally applied load.

2. In general, the mechanical properties of core materials are adversely affected by a rise in temperature and this may influence the performance of fastenings. Where relevant, this may require testing at elevated temperature.

3. To avoid additional forces in cold store panels due to lateral deformations of the supporting substructures special designed clamps are recommended (see ref. Lightweight sandwich construction 2000).

Fig. 7.18 Example of special clamp in cold stores.