REPORT

Deliverable 5.1

Guidelines and examples of good practice

Publisher:

Aneta Kurpiela
Felicitas Rädel
Jörg Lange

This report includes 47 pages.

Date of issue: September 20th, 2011
<table>
<thead>
<tr>
<th>Prepared by</th>
<th>Aneta Kurpiela, Felicitas Rädel (TU Darmstadt)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drafting history</td>
<td></td>
</tr>
<tr>
<td>Draft version 1</td>
<td></td>
</tr>
<tr>
<td>Draft version 2</td>
<td></td>
</tr>
<tr>
<td>Draft version 3</td>
<td></td>
</tr>
<tr>
<td>Draft version 4</td>
<td></td>
</tr>
<tr>
<td>Final</td>
<td></td>
</tr>
<tr>
<td>Dissemination Level</td>
<td></td>
</tr>
<tr>
<td>PU</td>
<td>Public X</td>
</tr>
<tr>
<td>PP</td>
<td>Restricted on the other programme participants (including the Commission Services)</td>
</tr>
<tr>
<td>RE</td>
<td>Restricted to a group specified by the Consortium (including the Commission Services)</td>
</tr>
<tr>
<td>CO</td>
<td>Confidential, only for members of the Consortium (including the Commission Services)</td>
</tr>
<tr>
<td>Verification and approval</td>
<td></td>
</tr>
<tr>
<td>Coordinator</td>
<td></td>
</tr>
<tr>
<td>Industrial Project Leader</td>
<td></td>
</tr>
<tr>
<td>Management Committee</td>
<td></td>
</tr>
<tr>
<td>Industrial Committee</td>
<td></td>
</tr>
<tr>
<td>Deliverable</td>
<td></td>
</tr>
<tr>
<td>D5.1 Guidelines and examples of good practice</td>
<td>Due date: Month 14 Completed: Month 36</td>
</tr>
</tbody>
</table>
Contents

1 State of the art .......................................................................................................................... 4
  1.1 Introduction .......................................................................................................................... 4
  1.2 Openings .............................................................................................................................. 4
    1.2.1 Comments on existing structures .................................................................................... 5
    1.2.2 Examples of existing structures ....................................................................................... 6
  1.3 Fixings .................................................................................................................................. 14

2 Thermal behaviour - Principles of good practice .............................................................. 17
  2.1 Fabrication of sandwich panels ......................................................................................... 17
  2.2 Installation of sandwich panel constructions ..................................................................... 19
  2.3 Joints sealing openings ....................................................................................................... 20

3 Building without frames ...................................................................................................... 21
  3.1 Introduction .......................................................................................................................... 21
  3.2 Requirements of connecting details and constructive solutions ....................................... 21
  3.3 Drawing catalogue .............................................................................................................. 23
    3.3.1 Schematic overview ......................................................................................................... 23
    3.3.2 Bottom wall connection .................................................................................................... 25
    3.3.3 Wall to wall connection ................................................................................................. 29
    3.3.4 Wall to ceiling/roof connection ....................................................................................... 33

4 Repairing of local defects of the face .................................................................................... 39
  4.1 Introduction .......................................................................................................................... 39
  4.2 Materials and technique ...................................................................................................... 39
  4.3 Practical remarks ................................................................................................................ 41

5 Retrofitting of sandwich panels (by using claddings) ............................................................ 42
  5.1 Introduction .......................................................................................................................... 42
  5.2 Subject area and limitations ............................................................................................... 43
  5.3 Definitions and symbols ...................................................................................................... 43
    5.3.1 Cladding systems ........................................................................................................... 43
    5.3.2 Cladding based on thin-walled purlins and sheetings ..................................................... 44
    5.3.3 Cladding based on additional panels and monopanels ................................................... 45
  5.4 Remarks for the calculation ............................................................................................... 46
  5.5 Practical remarks ................................................................................................................ 46
1 State of the art

1.1 Introduction

Though the market share of sandwich elements is constantly growing and the market share reached up to today is an immense of over 100 Mio Square meters of wall and roof claddings per year in Europe, sandwich elements are still seen as a “new” construction product. Most people do not really know much about this construction. So the aim of this deliverable is to present the state of art for some important details of sandwich panel constructions. Furthermore examples of good practice will be given and also some research findings of the last few years are presented.

1.2 Openings

Self-supporting sandwich panels are used to cover external and internal walls and roofs. Most of the walls and roofs include openings due to doors, windows, HVAC lines and other technical inlets. Therefore the covering components in walls and roofs are also penetrated and cut with openings of different sizes and geometries.

Until now it is necessary to attach additional structural elements around the opening of the panel to support the structure in the area of the opening. Thus, all applied loads on the window and door openings are to be transferred to the spaced structural supports, e.g. framework, by longitudinal beams and cross beams. The replacing concept results always in further structural components and substantial effort. According to the technical information of today the additional support is not always needed, which also benefits the visual and architectural appearance.

To reduce the costs and the amount of work new possibilities to design sandwich panels with openings were developed. These possibilities tend to show that additional support should not be installed if not really needed and that the sandwich panels have an adequate bearing capacity and allowable span also with openings. Furthermore careful analysis of stresses shall be made covering all load cases and also the strength in the area of the openings.

The openings differ by size and location, also the direction of the span of the panel is significant.

Professor Torsten Höglund [1] investigated the influence of windows in wall sandwich panels on the bearing capacity of the panel. The results were verified in corresponding tests.

The research of Torsten Höglund [1] was followed by Courage/Toma [2] who worked on experimental and numerical tests on sandwich panels with openings. The aim was to analyse the stress around the opening. Courage/Toma [2] derived formulas to compute the remaining
bearing capacity of panels with openings. The shear force capacity decreases proportional to the remaining cross section.

Openings in wall sandwich panels which do not infect two panels and which were not bigger than the width of one element have also been investigated by Marc Böttcher [3]. The results show that only with extensive experimental research it was possible to compute the allowable wrinkling stress in the cross section around the opening for a single panel.

The relation of stress to opening width and the estimation of the bearing capacity of the panel's longitudinal joint is compared to earlier assumptions based on the save side. Furthermore Böttcher developed a mechanical model for a panel system with three panels and an opening.

Lars Heselius [4] dealt with mineral wool elements. In his research he showed, that the formulas for the PUR-elements are also valid for panels with mineral wool core. The experiments pointed out that the calculated results are always more optimistic than the experimental values caused by stress peaks which are lower in the calculation than the measured values. The loss of strength due to the opening is approximately 10% greater than the expected reduction according to the reduction of the cross section. Lars Heselius also showed in his work that the effect of stress peaks may be increased by panels with low bonding strength.

Until the beginning of EASIE all research has been performed on wall sandwich panels.

1.2.1 Comments on existing structures

Mechanical behaviour

In most cases reinforcement is recommended by the manufacturer which increases the cost of the total panel system. In Northern Europe the transmission of load from window to panel without reinforcement is anyhow frequently used by small windows. It is important to create rules for the effect of openings and when reinforcement is needed and when not. Further information is given in the deliverables of work package 1.

Thermal behaviour

In many cases there seems to be a significant effect of thermal bridges by flashings and metal profiles around the window opening used for fastening and protection. In Northern Europe solution are developed for reducing the effect of thermal bridges. Also special window solutions exist which seem to have reduced effect of thermal bridges. In most cases good attention is given to air tightness. (see chapter 2 for further information)

Cost efficiency

Many of the solutions are requiring quite a lot of installation work on site. These solutions are
on the other hand flexible for different kind of window solutions. There are special window solutions available with in-built lock system giving fast installation. The cost for the supporting structure can be remarkable and gives importance to develop rules for taking account of the effect of openings on the mechanical behaviour.

1.2.2 Examples of existing structures

FECH Jet System

Example on click-click fast installation system, little additional flashings required
Arcelor Mittal

Example on panel to window connection with supporting frame

Opening flashings - secret fixing panel ARCTHERM 2003BI

1 - Sandwich panel ARCTHERM
2 - Self-tapping fastener
3 - Fastener washer (pressure spreader)
4 - Beam acc. to a construction project
5 - Butyl seal
6 - Steel flashing APP-01/panel thickness
7 - Impregnated PUS seal
8 - Particular steel flashing
9 - Rivet
10 - Particular steel flashing
11 - PUR foam (assembly)
12 - PVC or AL frame window
13 - Sealant (neutral silicone)
14 - PES seal
Italpanelli

Example on a special connection of panel to round window openings

Lunghezza guarnizione: 2,75 m  
Lunghezza guarnizione: 2,15 m

Lunghezza guarnizione: 1,75 m  
Lunghezza guarnizione: 1,56 m

Lato interno  
Lato esterno  
Spage  
Elemento di bloccaggio
M-Profile

Example on traditional panel to window connection with supporting frame
Paroc Panel System

Example on panel connection-on site solution- small opening without reinforcement
Paroc Panel System

Example on panel connection solution detail to avoid thermal bridges-on site solution- small opening without supporting structure
Ruukki Construction

Example on panel connection to reduce thermal bridges-on site solution-no supporting structure

Example on window panel connection –installation integrated with panel installation
ThyssenKrupp

Developed panel window connection-installation integrated with panel installation-supporting frame
References


1.3 Fixings

General

Fixings are necessary to connect the sandwich panels to the substructure. In the IFBS Technical Rules for Lightweight Metal Construction “Installation” [IFBS 8.01] a good overview on the right use of fixings and fasteners is given:

Fixings mean connections of profiles to the supporting structure. The supporting structure can be made of steel, timber or concrete with embedded steel fixing strips.

![Figure: Roof panel with different substructures [SFS intec GmbH]](image)

Perfect quality fixings and anchorage must comply with the provisions of the building inspectorate approvals and moreover fulfil the following requirements:

- Only building inspectorate approved fasteners must be used, with suitable corrosion protection being taken into consideration.
- Fasteners must be at right angles to the surface of the profiled sheet/ component in order to ensure safe support and where necessary a sealing connection. Attention should be given to ensuring the alignment is flush.
- According to the German Approval No. Z-14.1-4, Paragraph 4, screws in existing connections that have already been subjected to loading must be replaced with thread-
forming screws of larger diameter, whereby the hole for the thickers screw has to be
Drilled out accordingly. With sandwich panels, another measure may be necessary (Z-
14.4-407, Section 4)
- Deviations from surface flatness in the immediate vicinity of connections are system-
related
- The heads of screws made from corrosion resistant materials are not coated. Covering
with plastic caps has not proven to be successful. Supporting structures whose
thickness is less than the length of the shaft of the screws used will be penetrated by
the fasteners. Removal of the protruding tip is not allowed and covering it over is not
common. If covering over is desired, this has to be agreed as an additional service.

These points comply with the acknowledged rules of technology. They are therefore not
irregularities in this respect.

**Fixing of sandwich panels**

In Germany only fasteners that are regulated by the general building inspectorate approval Z-
14.4-407 for fasteners or the building inspectorate approvals for sandwich panels of the
manufacturers can be used to fix sandwich panels.

![Drilling screw with shank](image1) ![Drilling screw](image2) ![Self tapping screw](image3)

**Figure: Different types of screws**

The approval Z-14.4-407 regulates exclusively the fixing of sandwich panels with steel
covering layers. This means that for panels with aluminium covering layers the necessary
tensile forces (“unbuttoning values”) for the verification of the fastener forces must be taken
from the approvals of the sandwich panel manufacturer.

The minimum screw-in depth of the fixings in a supporting structure made of steel or timber
must be adhered to, whereby the lengths of welded-on drill tips or hardened tips should not
be included. The specifications of the fastener manufacturer concerning clamping thicknesses
should be observed.

Fasteners should be screwed in place using the depth stop.

For trouble-free fixing of sandwich panels, the fastener must be screwed in so deep that the
seal under the head of the screw is lightly deformed. This results at the same time in a slight
indentation in the upper covering skin of the sandwich panel. Thus with sandwich panels light
def ormation in the area of the screwed connections on the upper covering skin is system-
related and unavoidable. Dents in the covering skins of sandwich panels with a PUR core
should be smaller than 2 mm in the area of the screwed connections (can effectively only be
checked with single-span supports and end supports). Slight dents may also be visible in the
outer skin as a result of temperature-induced deformation. This is system-related and
unavoidable. If dents larger than 2 mm occur more frequently, the proper functioning should
be checked.
Recommendation:

To reduce the susceptibility to denting, larger sealing washers should be used to improve load distribution. Instead of Ø16 mm sealing washers, Ø19 mm or Ø22 mm should be chosen. Denting of the covering skin can be reduced by using screws with supporting threads. [IFBS 8.01]

Figure: Correct seating of screws and sealing washers [SIZ]

References

IFBS 8.01 - Industrieverband für Bausysteme im Metallleichtbau, Installation, Technical Rules for Lightweight Metal Construction
SIZ - Stahl-Information-Zentrum, Merkblatt 191, Wellprofile aus Stahl
2 Thermal behaviour - Principles of good practice

To fulfill the limit values for air and water tightness, some important requirements have to be considered. One can distinguish these points in two groups – manufacturing and installation.

2.1 Fabrication of sandwich panels

Panels with core material of closed cell structure

At first the geometry of the joint itself can restrict great air streams and the penetration of water. The key and slot joints of panels have a positive influence on the tightness. In this context it is very important that the abutting ends and surfaces of the panels fit into one another very well. For a good insulation it is also important that the metal faces have as little penetration into the core as possible like it is shown in the right picture of figure 1.1. A bad solution is to have the metal face bent into the core as it is done in the panel to the left in figure 1.1. The problem is of particular importance for thin panels (thicknesses up to 80 mm) where there are cases where the metal faces almost touch each other in the joint. Joints always form a line of higher thermal conduction as in the panel area and the penetration of metal worsens this [IFBS 4.03].

![Figure 1.1: Experimental set-up](image)

The next important point is the sealing tape. These days it is absolutely state of the art to use sealing tapes in every longitudinal joint of the panels. Different kinds of sealing tapes exist in the market [IFBS 4.02]. The most important differentiation can be made by the cell structure. One can distinguish between open cells, partly open cells and closed cells. All of them are used in modern sandwich panels.

These different structures lead to very different characteristics regarding the air permeability. Closed cell structures are practical completely airtight as soon as they have contact to the joint, whereas open structures need some compression. The required level of compression is depending on the cellular material. According to [Galileo], the following table gives some guide values:
In addition to this good experiences have been made with rope seal or rubber piping made of EPDM.

According to that information it is essential for the tightness that the geometry of the joint allows the required compression of the sealing joint.

If the shadow gap is closed for example before the sealing joint is compressed, it will not be possible to get an air tight construction. Also the needed contact pressure plays an important role. If the necessary compression can only be reached by high pressure, the right mounting equipment has to be used.

### Cellular Material

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Minimal compression for air tightness</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUR-foam, open cells</td>
<td>60 – 80 %</td>
</tr>
<tr>
<td>PUR-foam, open cells, impregnated by acrylate</td>
<td>50 – 60 %</td>
</tr>
<tr>
<td>PVC-foam, partly open cells</td>
<td>30%</td>
</tr>
<tr>
<td>PE-foam, partly open cells</td>
<td>15 %</td>
</tr>
<tr>
<td>PE-foam, closed cells</td>
<td>-</td>
</tr>
</tbody>
</table>

**Figure 1.2: Examples of sealing tapes**

**Figure 1.3: Examples of longitudinal joints**
Panels with core material of open cell structure

For panels with core material of open cell structure as mineral wool a different sealant solution is necessary. By these panels a sealant strip of tight material with big flexibility shall be placed in the longitudinal joint between the metal sheets. Here it is very important to seal the joint between the sheets; otherwise an air stream through the open cell structure of the core is possible. The joint profile geometry shall be designed for this sealant strip. Two examples are shown in figure 1.4. The sealant shall be placed on the warm side. In special cases, e.g. walls with high wind pressure, sealants in both faces as shown in figure 1.4 (on the left) are considered helpful.

Figure 1.4: Examples for a good sealing of mineral wool panels
[www.Ruukki.com], [www.fischerprofil.de]

Also for mineral wool panels, the tolerances play an important role. They have to be small enough to assure the sealing.

2.2 Installation of sandwich panel constructions

Sandwich panels are usually optimised for fabrication by the panel manufacturer. Due to the fact that the joints are fabricated in an industrial process very small tolerances are possible. So the question of tightness is mostly a question of a correct installation. For example TKS writes in his installation recommendations: “It is not possible to correct the position of subsequent panels by realigning the longitudinal joint. Sealing of the longitudinal joint is achieved by factory-applied sealing strips. Tightness, however, is only ensured when the modular laying dimension is exactly adhered to.”

For mounting the panels air- and watertight an exact knowledge of the tolerable width of the shadow gap (see fig. 1.3) is necessary. This is the only possibility for the fitter to check the correctness of the construction and to guarantee a tight building envelope. The tolerances
have to be small enough to assure the required compression. Fabricators shall give a value for the nominal shadow gap. Tests shall be performed with a nominal gap + 1 mm.

2.3 Joints sealing openings

Beside all the rules for longitudinal joints which are important for joints sealing openings as well there is another point to give attention to. In a lot of cases the vertical and horizontal joints of an opening look different. Because of different joint geometries also different sealing strips are used. Especially in the corner of openings an inexact installation of the sealing will lead to untight constructions. So it is very important that all the sealings are applied in the same plane and overlap in the corner regions of the opening (see figure 1.5).

![Figure 1.5: Example for an installed window in laboratory with longitudinal and horizontal sealing tapes](image)

Further information on the thermal behaviour can be found in the following report, which can be downloaded at www.easie.eu:

Deliverable D1.1: Design guidelines for good panel joints and joints sealing openings focussing on air and water tightness

REFERENCES

Galileo – Kreatives Bauen mit Sandwich: Basis Info, chapter 4.9, Version 2009-11-D1

IFBS 4.02, Bauphysik – Fugendichtheit im Stahlleichtbau, IFBS e.V., Düsseldorf, 11/2004

IFBS 4.03, Bauphysik – Wärmebrückenatlas der Metall-Sandwichbauweise, IFBS e.V., Düsseldorf, 03/2010
3 Building without frames

3.1 Introduction

Sandwich components are proven building products for the outer shell of a building (external walls, roof) as well as walls and ceilings inside the building. Sandwich components manufactured in continuous production with a covering layer of metal or another material e.g. glass fibre reinforced plastic are used for this. This type of production means it is possible to arrange the components lengthways with a high quality joint structure in line with the key and slot joint principle, so that a functioning joint can be created when installing the components by simply sliding the components into each other. The components generally have only a straight, blunt edge on the end face because they have been cut to the required length in the factory. Connections to these sides of the components require additional building measures to satisfy requirements.

By contrast for components not manufactured in continuous production all the component sides can be arranged in such a way that it is possible to insert the individual components into each other in every direction through special shape forming, form components and reinforcing elements. Components of this type are often combined into complete building systems using the appropriate post and beam method. For economic reasons the use of this type of design is limited to special cases.

Up to now sandwich components have generally been fastened to a load-bearing sub-construction and they are therefore not a part of the primary supporting structure of buildings. On the basis of tests as well as using a demonstration property EASIE has shown that the construction of pure sandwich structures is possible. This was achieved using connecting details, which have a proven history in building practice with sandwich components. Evidence has been provided that these connections are capable of absorbing the normal loads, which occur for one-storey building structures.

3.2 Requirements of connecting details and constructive solutions

Similar requirements usually apply to the connections between various building components such as the roof/ceiling, walls and wall connections to the floor, which are composed of sandwich components. All the building component connections must satisfy the following criteria:

- Sufficient mechanical interconnection

The components are generally joined to blunt component edges. The steel covering layers are connected through end plates, which are fixed mechanically using screws or rivets. Plastic profiles are used for glass fibre reinforced plastic coverings, to which adhesive is preferably applied. Alternatively connections without a cover profile but with two-component joint compounds have also proved to be good. The almost rigid jointing provides a homogeneous connection between the covering layers. The relevant manufacturers’ instructions are to be considered for using them.
The mechanical connection of the covering layers is primarily intended to secure the position of the components/elements. Applying additional adhesive to the insulating core has a positive effect on the load-bearing capacity.

- **Heat insulation/ avoiding thermal bridges**
Thermal bridges are avoided by filling the joint cavities with foam. Continuous steel covering layers are in principle to be avoided when high demands are placed on the structures. Layered cuts are to be provided at the component edges for this. It is possible that a thermal cut is sufficient or needs to be added additionally. For deep-freeze rooms it is necessary to take measures with regard to the flooring so that the foundations do not freeze.

- **Air tightness/ vapour tightness**
The required air tightness is ensured by covering the joints with profiles using sealing tapes and filling joint cavities completely with foam. As the temperature gradient between the inside and outside of the building increases, so too does the level of requirement. A gapless vapour barrier layer is to be created on the warm side for cold storage rooms and particularly for deep-freeze rooms. All the end plates or covers profiles are to be connected for this in a vapour-tight manner by using appropriate sealing tapes and/or seals. Barrier sheets are to be arranged on the floors.

Panel manufacturers and their associations give recommendations for mounting and installation basing on these principles. In the following solutions for a range of typical connection details based on these recommendations are shown. In this context applies to the EASIE project partners APIP’NA, ColdKit, ThyssenKrupp and ECP special thanks for their support of the author.
3.3 Drawing catalogue

3.3.1 Schematic overview

Floor plan (horizontal section)
3.3.2 Bottom wall connection

Exterior wall

<table>
<thead>
<tr>
<th>without special requirements</th>
<th>exterior</th>
<th>interior</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sandwich panel (wall)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>screw</td>
<td>floor</td>
</tr>
<tr>
<td></td>
<td>fitting foam glue</td>
<td>floor insulation</td>
</tr>
<tr>
<td></td>
<td>Z section</td>
<td>moisture barrier</td>
</tr>
<tr>
<td></td>
<td>L section</td>
<td>base plate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>special requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere</th>
<th>exterior</th>
<th>interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>facing (GFRP)</td>
<td>sandwich panel (wall)</td>
<td></td>
</tr>
<tr>
<td>elastic adhesive</td>
<td>plastic profil</td>
<td>elastic adhesive</td>
</tr>
<tr>
<td>expansion joint / perimeter isolation strip</td>
<td>waterproof layer</td>
<td></td>
</tr>
<tr>
<td>screw</td>
<td>floor</td>
<td>floor insulation</td>
</tr>
<tr>
<td>folded sheet</td>
<td>U section</td>
<td>moisture barrier</td>
</tr>
<tr>
<td>Z section</td>
<td>fitting foam glue</td>
<td>base plate</td>
</tr>
</tbody>
</table>
deep freeze rooms, cool rooms

Diagram showing the setup of deep freeze rooms, including exterior and interior views with details on sandwich panel (wall) with permanently elastic sealing, system panel joint, thermal separation cut, and various protective layers such as skirting protection, floor, and vapor barrier.
### Interior wall

<table>
<thead>
<tr>
<th>without special requirements</th>
<th>special requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>interior</strong></td>
<td><strong>interior</strong></td>
</tr>
<tr>
<td>sandwich panel (wall)</td>
<td>sandwich panel (wall)</td>
</tr>
<tr>
<td>folded sheet</td>
<td>facing (GFRP)</td>
</tr>
<tr>
<td>expansion joint / perimeter isolation strip</td>
<td>elastic adhesive</td>
</tr>
<tr>
<td>floor</td>
<td>plastic profil</td>
</tr>
<tr>
<td>floor insulation</td>
<td>elastic adhesive</td>
</tr>
<tr>
<td>base plate</td>
<td>screw</td>
</tr>
<tr>
<td>fitting foam glue</td>
<td>fitting foam glue</td>
</tr>
<tr>
<td>L section</td>
<td>U section</td>
</tr>
<tr>
<td>moisture barrier</td>
<td>moisture barrier</td>
</tr>
</tbody>
</table>
deep freeze rooms, cool rooms
3.3.3 Wall to wall connection

Corner

<table>
<thead>
<tr>
<th>without special requirements</th>
<th>folded sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>srew/rivet</td>
</tr>
<tr>
<td></td>
<td>sealing tape</td>
</tr>
<tr>
<td></td>
<td>fitting foam glue</td>
</tr>
<tr>
<td></td>
<td>thermal separation cut (as required)</td>
</tr>
</tbody>
</table>

sandwich panel (wall)

<table>
<thead>
<tr>
<th>sandwich panel (wall)</th>
<th>screw/rivet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sealing tape</td>
</tr>
<tr>
<td></td>
<td>folded sheet</td>
</tr>
<tr>
<td></td>
<td>srew/rivet</td>
</tr>
<tr>
<td></td>
<td>sealing tape</td>
</tr>
</tbody>
</table>

exterior

interior

<table>
<thead>
<tr>
<th>special requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere</th>
<th>folded sheet</th>
</tr>
</thead>
<tbody>
<tr>
<td>srew/rivet</td>
<td></td>
</tr>
<tr>
<td>sealing tape</td>
<td></td>
</tr>
<tr>
<td>facing (steel)</td>
<td></td>
</tr>
</tbody>
</table>

sandwich panel (wall)

<table>
<thead>
<tr>
<th>sandwich panel (wall)</th>
<th>srew/rivet</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>facing (steel)</td>
</tr>
<tr>
<td></td>
<td>elastic adhesive</td>
</tr>
<tr>
<td></td>
<td>plastic profil</td>
</tr>
<tr>
<td></td>
<td>facing (GFRP)</td>
</tr>
</tbody>
</table>

exterior

interior
highest requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere

deep freeze rooms, cool rooms
T-connection (dividing wall)

**without special requirements**

<table>
<thead>
<tr>
<th>exterior</th>
<th>panel joint (system dependent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sandwich panel (wall)</td>
<td>sandwich panel (wall)</td>
</tr>
<tr>
<td>fitting foam glue</td>
<td></td>
</tr>
<tr>
<td>sealing tape</td>
<td>sealing tape</td>
</tr>
<tr>
<td>srew/rivet</td>
<td>srew/rivet</td>
</tr>
<tr>
<td>folded sheet</td>
<td>folded sheet</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**special requirements on hygiene**
(frequent wet cleaning)
or aggressive interior-atmosphere

<table>
<thead>
<tr>
<th>exterior</th>
<th>facing (steel)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sandwich panel (wall)</td>
<td></td>
</tr>
<tr>
<td>fitting foam glue</td>
<td></td>
</tr>
<tr>
<td>elastic adhesive</td>
<td>elastic adhesive</td>
</tr>
<tr>
<td>plastic profil</td>
<td>plastic profil</td>
</tr>
<tr>
<td>elastic adhesive</td>
<td>elastic adhesive</td>
</tr>
<tr>
<td>facing (GFRP)</td>
<td>facing (GFRP)</td>
</tr>
</tbody>
</table>

**interior**
highest requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere

deep freeze rooms, cool rooms
3.3.4 Wall to ceiling/roof connection

**Corner**

- Without special requirements, watertight panel roof

**Diagram:**
- Folded sheet (wall)
- Screw/rivet
- Fitting foam glue
- Sealing tape
- Sandwich panel (ceiling)
- Exterior
- Interior
special requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere

highest requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere
### T-connection (dividing wall)

**without special requirements, dividing wall as end support**

<table>
<thead>
<tr>
<th>exterior</th>
<th>interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>sandwch panel (ceiling)</td>
<td>sandwch panel (ceiling)</td>
</tr>
<tr>
<td>sandwch panel (wall)</td>
<td>sandwch panel (wall)</td>
</tr>
<tr>
<td>fitting foam glue</td>
<td>fitting foam glue</td>
</tr>
<tr>
<td>sealing tape</td>
<td>sealing tape</td>
</tr>
<tr>
<td>srew/rivet</td>
<td>srew/rivet</td>
</tr>
<tr>
<td>folded sheet</td>
<td>folded sheet</td>
</tr>
<tr>
<td>sealing tape</td>
<td>sealing tape</td>
</tr>
</tbody>
</table>

**without special requirements, dividing wall as intermediate support**

<table>
<thead>
<tr>
<th>exterior</th>
<th>interior</th>
</tr>
</thead>
<tbody>
<tr>
<td>sandwch panel (ceiling)</td>
<td>sandwch panel (ceiling)</td>
</tr>
<tr>
<td>sandwch panel (wall)</td>
<td>sandwch panel (wall)</td>
</tr>
<tr>
<td>fitting foam glue</td>
<td>fitting foam glue</td>
</tr>
<tr>
<td>sealing tape</td>
<td>sealing tape</td>
</tr>
<tr>
<td>srew/rivet</td>
<td>srew/rivet</td>
</tr>
<tr>
<td>folded sheet</td>
<td>folded sheet</td>
</tr>
<tr>
<td>sealing tape</td>
<td>sealing tape</td>
</tr>
</tbody>
</table>
special requirements on hygiene (frequent wet cleaning) or aggressive interior-atmosphere

light freeze rooms, cool rooms

EASIE WP5 Deliverable 5.1
REFERENCES

ECP Gesellschaft für GFK-Systemlösungen mbH
4 Repairing of local defects of the face

4.1 Introduction

There are few typical failure modes of sandwich panels which can occur in the time of the utilisation of the building. The failure modes in practice are blistering and failures cause by wrinkling of the face. But sometimes local faults and defects caused by vehicles and humans occur.

In this part of the Guidelines the possibilities for repairing and returning the resistance of the damaged parts of sandwich panels are shown.

Repairing of the defects of façades was a subject in EASIE project. Methods to repair defects caused by the blistering have been studied in separate development tests of RBM Europe BV.

4.2 Materials and technique

In the repairing actions four different types of materials and methods can be used. None of the repaired panels can reach the wrinkling stress of the initial non-damaged sandwich panel.

The resistance reduced even more when incorrect repairing actions are used.

The following materials can be used:

<table>
<thead>
<tr>
<th>Type</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>PU Glue</td>
</tr>
<tr>
<td>II</td>
<td>Affixed metal sheet</td>
</tr>
<tr>
<td>III</td>
<td>Polyester Filler</td>
</tr>
<tr>
<td>IV</td>
<td>Epoxy Resin</td>
</tr>
</tbody>
</table>

The repair shall be performed in the same way for all damage patterns. The repairing procedure is show in figures 4.1 to 4.6 by using the damage one type pattern as an example.

![Figure 4.1: Repairing of the damage. Abrading of the surface](image)

To get a better adhesion the damaged areas shall be firstly abraded with sandpaper. Thereafter, the edges of the cut shall be indented. This shall cause a larger cavity and small dents, which should lead to a better load transfer.
Figure 4.2: Repairing of the damage. Causing dents in the surface.

In the next step the repair material shall be introduced. The four types of materials which can be used were mentioned before.

Figure 4.3: Repairing of the damage. Type I (PU Glue).

Figure 4.4: Repairing of the damage. Type II (Affixed metal sheet).
In the last step the repaired area of the face sheet has to be matched to the surface of the original sandwich element. The exception is the adding of a metal sheet, which leaves a clearly visible sign of the repair. Therefore, this repairing action is questionable in most cases.

### 4.3 Practical remarks

Competent people are needed to evaluate and classify the defects, which can be repaired in practice. The damage may not be limited to the face layer only, but also the bond and core may have been influenced by the wrinkling failure and attack. In repairing of the bond and the core similar methods may be used as in repairing the defects caused by blistering. Expert knowledge is also needed in selecting the materials and methods in practice by taking into account the conditions of the work at the building site.
5 Retrofitting of sandwich panels (by using claddings)

5.1 Introduction

The goal of the repairing actions by using claddings is to improve the technical and visual properties, the functional behaviour and safety and to extend the service life of the structure. Reasons to the repairing actions are normally the ageing of the materials or the faults and damages caused by the environmental effects or by human activities. Reasons for repairing may also be the need to improve the thermal insulation properties, the air and water tightness or the mechanical resistance or further, the need to update the architectural appearance of the façade to correspond the style of the new time and place.

Typical systems to cover the panel in full with a new light-weight structure made typically of metal sheets, cassettes and purlins are shown below. Other possible solutions to cover a façade made of sandwich panels are different boards, panels, composite laminates and even brick walls.

Cladding means normally the covering of the external face of the sandwich panels. However, if needed, the same principles can be used to improve and update the properties of the internal faces.

Following items have to be considered by design and use of the new composite façade and roof panel:

- distribution of the external mechanical load such as a wind pressure and suction load between the additional cladding and the face of the ordinary panel
- distribution and effects of the temperature on the components of the cladding systems and on those of the ordinary sandwich panel
- local stresses and effects caused by the self-weight of the additional cladding
- static interaction between the ordinary sandwich panel and the additional cladding components
- effects of the local imperfections and damages
- long-term effects caused by ageing and repeated loads
- influence of the cladding on the thermal insulation power and other physical properties of the system

Repairing of sandwich walls and roofs is made today using case by case tailored systems. The systems of retrofitting depend very much on the local needs and the local practice and the way of the building.

Retrofitting was a subject in the EASIE project.
5.2 Subject area and limitations

The part of the Guidelines introduces two cladding systems. The precondition for the additional cladding of old walls and roofs is a functioning force-fit bonding between core and face and a solid core layer. The bond or the core shall not have been destroyed through mechanical loads, ageing or detach. The application area of the cladding systems introduced in this document is wall panels loaded by short-term loads, only.

5.3 Definitions and symbols

5.3.1 Cladding systems

Cladding systems based on thin-walled metal sheet components and mechanical fastenings are shown. The components may be made of steel or of stainless steel sheets, which have been cold-formed in shapes of purlins and corrugated sheetings. Also covering elements made of composite structures such as thin sandwich panels are possible components of the cladding systems. Design and testing of these components can be based on the European standards [1, 2, 3].

Self-drilling and self-tapping screws and rivets are well-known fasteners with a large variation of materials, diameters and shapes. The screws and rivets of the thin-walled components are not standardized products like the screws of ordinary steel structures. However, there are guidelines available for the testing and design of the mechanical fastening of thin-walled structures [4].

Adhesive fastening of the components provides a fluent flow of stresses between the parts without local stress concentrations. When using adhesive jointing, there will not be any holes penetrating the external face of the sandwich panel nor visible fastenings in the cladding. The challenges of the adhesive jointing in practice are the strict requirements for the cleaning and primary coating of the surfaces the methods and materials being dependent of the earlier coatings. The adhesive joints need possibly a prestressing during the hardening of the
adhesives. The work on the site may lay further limitations to the adhesive jointing concerning the humidity and temperature.

5.3.2 Cladding based on thin-walled purlins and sheetings

The cladding systems considered in this context consist of rails which are mounted on the external face of the sandwich panels. The cladding itself is in turn fixed on the rails. The rails are normally made of Z-profiles or hat profiles and the cladding profiles concern sidings, cassettes or corrugated or trapezoidal sheeting. Due to the own stiffness and strength of the additional components, due to the static interactions and due to the local effects, the additional cladding normally increases the stiffness of the ordinary sandwich panel but may improve or reduce the load-bearing capacity of the system compared to that of the ordinary sandwich panel.

![Figure 5.2. Cladding of vertical panels consists of vertical rails and horizontal cassette profiles.](image1)

![Figure 5.3. Cladding of vertical panels consists of vertical rails and horizontal sinusoidal sheets.](image2)
Figure 5.4. Cladding of vertical panels consists of horizontal rails and vertical trapezoidal sheets.

Two basic system layouts can be distinguished. The rails may be mounted in the transverse direction or parallel to the span of the ordinary sandwich panels. The cladding profile itself spans normally in the transverse direction to the rails. Examples of these are:

- vertical sandwich panels with vertical rails and sidings (Fig. 5.2),
- vertical sandwich panels with vertical rails and horizontally installed corrugated sheeting (Fig. 5.3) and
- vertical sandwich panels with horizontal rails and vertical trapezoidal sheeting (Fig. 5.4).

The same solutions are applied to sandwich panels, which are mounted in horizontal direction.

Fastening of the cladding system to the sandwich panels is typically made using mechanical fasteners, such as the self-drilling and self-tapping screws and rivets. The cladding profiles can be fixed to the rails also using mechanical fasteners. The siding panels may be suspended to the rails without any mechanical fastenings.

5.3.3 Cladding based on additional panels and monopanels

Cladding of sandwich panels may consists also of additional sandwich panels or of monopanels fixed to a face of the ordinary sandwich panel (Fig. 5.5). The monopanels are two-layer composite plates consisting of a core layer and of an external face. The additional panels may have similar faces and core but may also consist of different material compositions with different depths of the layers. The additional sandwich panels are mounted to the
direction of the span of the ordinary sandwich panels but may also be placed in the transverse direction to the ordinary panels.

Figure 5.5. Cladding with additional sandwich panels and monopanels.

Composite actions between the additional sandwich panels and the ordinary sandwich panels depend on the type and number of fastening between the panels. The composite action between the monopanel and the ordinary panel plays normally a minor role because of a low shear stiffness between the external faces of the monopanel and the ordinary sandwich panel.

5.4 Remarks for the calculation

Cladding systems are normally fixed in one face of the sandwich panel, only. Experimental information is needed about the shear and tensile resistance of the fastenings used in the fixings. Further, effects of repeated loads caused by the various actions shall be known as well.

Shear flexibility of the profiles between the cladding and the sandwich panel plays an important role in the static behaviour, distribution of the stress resultants and in the resistance of the cladding systems. The shear flexibility shall be determined experimentally. Advanced methods of analysis may provide useful information about the shear flexibility also.

5.5 Practical remarks

Following points to retrofitting by cladding have to be considered:

By choice of materials the compatibility, taking into account the corrosion risks shall be verified.

Only approved and appropriate fixing and fastening methods shall be used.

Ventilation of the air space between the components shall be possible.

Tolerances in cutting and mounting shall be considered.
References


