TWEHA

2021 TWEHA'S TECHNICAL GUIDE

* BONDED CLADDING
* ADVANTAGES OF ADHESIVES
* BONDING PROCESS
* SUPPORTING STRUCTURES
* TYPES OF CLADDING MATERIALS
* IFU: APPLICATION EXPLAINED
* STATIC CALCULATIONS
* QUALITY CONTROL
* PRODUCT REQUIREMENTS
* DURABILITY TEST PROGRAM

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TWEHA's adhesive systems in practice

Foreword

This textbook has been written for the course "TWEHA's adhesive systems in practice". In this course all the important aspects of bonding façade panels are addressed and explained. The processor of the adhesive systems of façade panels gets a better insight into the process of bonding, and mistakes due to ignorance can be avoided.

The training of skilled appliers who process the adhesive, contributes to an adhesive joint which satisfies the required expectations and requirements.

The course "TWEHA's Technical Guide" is important to everybody who will come in contact whit the process of bonding of façade panels, directly or indirectly, for a small or big project. The guide is suitable for the person who will be using the adhesive systems or the administrators who will be coordinating the project. The guide will also be interesting however for the foremen who have to judge the work. It is also useful for the retail vendors of building materials, for whom it is an amplification of their material knowledge and constructions, through which they can better advise their clients.
Of course this guide can also be used by the "prescriptive and controlling" parties like architects, designing engineers and developers, to enlarge their knowledge on the bonding of façade panels.

With the **TWEHA Academy** we want to use personal methods to pass on our knowledge on the usage of the adhesive system, in order to maintain the highest standards. This course is considered a valuable asset to the quality of our adhesive systems.

Mario van Leeuwen

Introduction

Nowadays the building industry cannot do without bonding anymore. Over the years, more and more architects and contractors have discovered the profitable benefits of bonding and they want nothing else. Why choose complex and labour-intensive constructions and connection methods if it is also possible to do it fast, simple and efficient!

Years ago, the building industry could take an example to the automotive and aircraft industry concerning bonding. At that time in these industries connection methods like screwing and welding were already replaced by bonding, meeting the highest requirements regarding safety and durability. The process of bonding was not completely unknown in the building sector. Years of experience were gained in the process of bonding limestone elements, gypsum blocks, tiles, roofing materials, wooden window frames, ceiling panels, wooden frames, flooring and skirting boards.

The bonding of façade panels is gradually gaining ground. This is probably due to the big economical, aesthetic and durable advantages that bonding offers. Bonding is more often chosen than traditional mechanical connection methods in which anchor blocks, screws, nails, clamps or pins are used.

Is there a more beautiful system of applying façade panels than the bonding system? The adhesive joint with which the panels are fastened are on the back side and is invisible and easy to process. To guaranty that bonding results in a secure and durable way, it has to fulfil two terms: the bonding system has to be suitable and it has to be applied and processed in the right way.

Bonding simplifies and alleviates the work activity on the building site and it saves money. With the eye on efficiency, simplicity and economization, a lot of entrepreneurs have broken with traditional, mechanical connection methods and have chosen for bonding. By applying an elastic adhesive joint, labour intensive and complex constructions are replaced by a solid and swift connection method.

Research by the Ministry of Economic Affairs has shown that by administering these bonding techniques, a cut down in costs of 30% in the building costs can be achieved. To hold on to the mechanical way of façade fastening not only takes more time and costs more money, it also holds back the competing developers who do choose the latest techniques.

The constructive possibilities do not determine the limits. Various materials, in all different shapes and sizes, horizontally and vertically, can easily be attached in any combination, so that architects can be optimally creative.

The possibilities are greater than can be imagined!

Chapter 1 Properties of bonding

§ 1.1 Advantages of bonding

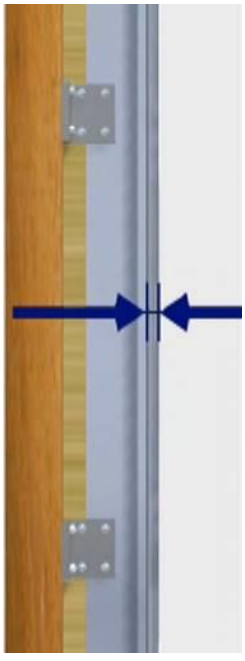
- **Adhesive joints are "unbroken" joints**
  With a mechanical joint like rivets, screws or bolts, you weaken the joining material with one or more holes. In the case of adhesive joints this weakening and deformation of the material to be joined is not an issue.

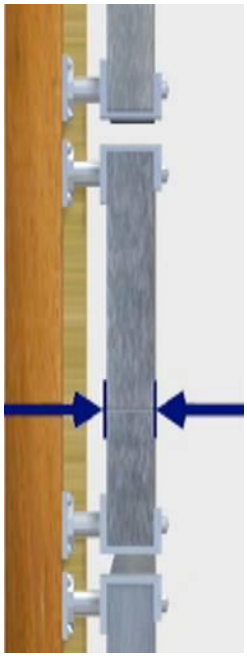
- **Bonding leads to an optimal stress distribution**
  Adhesive joints ensure an optimal stress distribution in the joint. Due to the elasticity of the adhesive and because the adhesive can be applied to a larger surface, the force can be transferred in an optimal way to the supporting structure. These forces result from the contraction and expanding of the façade panels due to temperature differences, the weight of the panels and the wind load. This has an advantage in as such that a high exhaustion strength is reached because these invasive powers ensure that there will be no fraction in the (adhesive) joint.

- **Deformation of the façade panels are prevented**
  The elasticity of the adhesive contributes to the fact that there will be no deformation of the façade panels, because the adhesive gives the possibility to deform with the panels. By using screws for example, the contraction and expanding of the panel cannot be received, whereby the panel will "puff up" and in worst case break loose from the façade.

- **An adhesive joint is an invisible (blind) joint**
  Compared to a mechanical fastening method, like screws, the advantage is that the face side of the panel is not disfigured by screw heads in the panel surface and therefore no atmospheric pollution can occur. An invisible joint results in an optimum aesthetical result.

- **Possibility to apply thinner façade panels**
  By using bonding, the pressure transfer of the façade panels occurs on a larger surface, so that thinner panels can be applied. Panelling materials that require a certain material thickness when using a mechanical method, due to their flexibility (for example natural stone, ceramic or composite materials), can be less thick due to the fact that there is no concentrated load and the flexibility strength is established. This also offers and economical advantage.





By using thinner façade panels (less dead weight) it also has the advantage that a lighter back structure can be applied and that the fastening is simplified, due to the lighter weight of the panel.
Remarkable is also that in relationship to the stretching properties of a screw joint, a minimal thickness of 30 mm is necessary. With bonding a thickness of 18mm suffices.

- **Bonding has structural physical advantages**
  An adhesive has the possibility to moderate vibrations like shaking and sound (traffic, etc.).

- **Lack of heat- and cold bridges**
  By using an adhesive, a positive influence occurs on the so called heat- or cold bridge

- **An adhesive is fluid- and gas tight**
  This prevents electrolytic crevice corrosion. This is however only applicable in the shipping industry.

- **The measurements tolerance can be less tight when the adhesive has the right crevice filling properties**

- **The design possibilities are enlarged**
  Various materials, in all different shapes and sizes, horizontally and vertically, can simply be attached in any combination, so that architects can be optimally creative. Therefore the design- and construction time can significantly be reduced.

For building applications the following advantages of bonding are relevant compared to other techniques:

- The possibility to join unequal and extremely thin materials
- A tighter control of the tolerances
- The construction of non-visible joints
- The fact that the diameter of the material remains equal and is not weakened by drilling holes
- A greater stiffness (depending on the elasticity of the adhesive)*
- The reduction of the sensitivity to fatigue *
- The reduction of capital and labour costs *

* In case of a good design and production process.

§ 1.2 Possible comments on bonding

- **To create an adhesive joint requires expertise**
  It is necessary for the processor (skilled applier) of the adhesive that he has enough knowledge about amongst other the adhesive, the conditions under which it can be applied, the amount of adhesive to be applied, the open time of the adhesive. Without this knowledge, there is a possibility that an adhesive joint occurs which does measure up to the demanded requirements. This means that the processor always has to follow the TWEHA guidelines.

- **The quality of the bonding is not easily controllable**
  It is not easy to check correct bonding of the façade panel, because the fixation is (invisibly) attached on the reverse side of the façade panel, and because the adhesive joint can only be destructively tested.

- **The bonded façade panel cannot be adjusted**
  A drying- and hardening time must be taken into account. As soon as the façade panel has been bonded, the panel cannot be adjusted any more. To be sure of an optimal joining, the connection must be positioned properly over a longer period of time. If it appears that the panel is not positioned properly, than the whole façade panel must be taken down and bonded again.

- **Weather conditions**
  The fastening of façade panels by using adhesion cannot take place in all weather conditions. Always consult your Instructions For Use in this case. However, TWEHA has been providing the solution for bonding at lower temperatures for years. Where other systems fail due to the use of their products simply do not function at lower temperatures.
  TWEHA's bonding systems makes it possible to process the adhesive system at low temperatures (<5 °C).
  Recent research by one of our relations in Austria has shown that the bond with the TWEHA products works well at -15 °C (5 °F)!

These comments can however be forestalled by a well-controlled and proper application of the adhesive. In this case the skilled applier must set up a quality control system, in which is clearly stated in which way and under which conditions the bonding has taken place. Besides that it is necessary that the skilled applier has sufficient knowledge in order to judge the different aspects which have an influence on the quality of bonding. If necessary he must be able to intervene when one of these factors could have a negative influence on the end result. (for more information see chapter 17: guideline applier)

By committing to the various conditions and by ensuring that the skilled applier has sufficient up-to-date knowledge on the product, no unacceptable risks will be taken in the bonding of façade panels. This way all the advantages of bonding will be shown and the bonding of façade panels will be an economic, aesthetic and durable alternative option to a mechanical fixation.

§ 1.3 Fundamentals of adhesion

Selecting the proper type of adhesive requires consideration of environmental, surface, appearance and other performance requirements.

Adhesion is the molecular force of attraction between unlike materials. Surface contact is fundamental to adhesive performance. The strength of attraction is, besides clean, dry and fee of grease, determined by the surface energy of the material. The higher the surface energy, the greater the molecular attraction. The lower the surface energy, the weaker the attractive forces.

Greater molecular attraction results in increased contact between an adhesive and substrate. In other words, a high surface energy material, the adhesive can flow (or "wet-out") to assure a stronger bond.

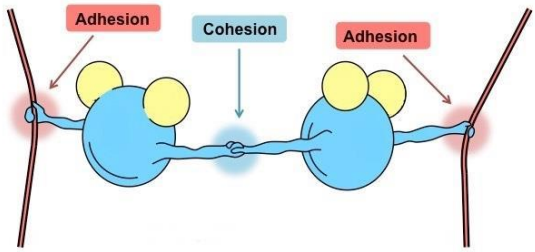
Consider an automobile that has not been waxed for a long time. When water contacts the surface it spreads in large puddles. The unwaxed car surface exhibits high surface energy — the molecular attraction allows the water to flow. In comparison, water beads up into small spheres on freshly waxed car. It is an example of low surface energy — the liquid (or adhesive) does not flow out.

TWEHA adhesives, based on Silane modified polymers, are polar and therefore have a relatively high surface energy. Therefore achieve these adhesives an optimal adhesion to polar substrates (e.g., glass or metal) with a relatively high surface energy.

MSP- and SMP-Adhesives will not readily adhere to substrates with a low surface tension (apolar substrates) such as polyethylene (PE), polypropylene (PP), polystyrene (PS), polytetrafluoroetthylene (PTFE) and polyoxymethylene (POM), silicones and powder coatings.

§ 1.4 Adhesion and cohesion explained

Adhesion and cohesion are both based on the root word 'hesion', which is an equivalent to 'stick'. They are nouns that describe a state of molecules sticking together. The difference between them is that adhesion refers to the clinging of unlike molecules and cohesion refers to the clinging of like molecules.
Cohesion is the attraction of particles within the adhesive that holds the adhesive mass together. In other words the strength of the adhesive itself. A fixed fact. Adhesion on the other hand, is variable as a result of the mutual attraction between unequal molecules that cause them to stick together. The defining feature is that adhesion occurs between two different substances. For example the adhesion of TWEHA's Bonding Systems to the several types of façade panels.



Type of cohesive failure
In case of a cohesive failure in the adhesive, there will still be an adhesive layer on the surface at both material sides. In that case there is an excessive tensile or

shear stress, in which the breaking stress in the adhesive joint has proved to be the critical factor.
Because this material property does not depend on the features of the substrate, the characteristic strength can be determined on the basis of the manufacturer's declaration which is determined according EN 54505.
The calculation rule of the model must be such that the result corresponds to a probability of inferential statistic is < 5%, so that the required reliability is achieved (the minimum strength is determined from tests and then reduced by a material factor).

Type of adhesive failure
In the case of an adhesive break, the adherence of the adhesive to the substrate will prove to be the limiting factor and thus the weakest link in the connection.
The bond breaks are due to the fact that the physicochemical connections are not created between the adhesive and the substrate.
Even for the failure of the adhesive joint at the interface between the adhesive and the substrate, hardly any theoretical models are available. As long as there are no good models for adhesive collapse, the design philosophy is used, the starting point is that this collapsed shape may never occur.
Determination that an adhesive break does not occur can only be done with the help of tests. For this reason, the characteristic adherence strength must be determined for each type of substrate on the basis of a test series.
CONSEQUENTLY A bond fails if either the adhesive separates from the substrate or the adhesive breaks apart. In cladding industry the adhesive strength of the adhesive must be firm enough so the cohesive strength of the bond fails before the adhesive one.
So, the effectiveness of a bonded connection is determined by the adhesion force on the substrate. In other words, the bonded connection must always collapse cohesively, a fixed value which can be used in static calculations.

§ 1.5 Surface tension

The surface tension of a substrate is of great importance for the adhesion of our bonding systems.

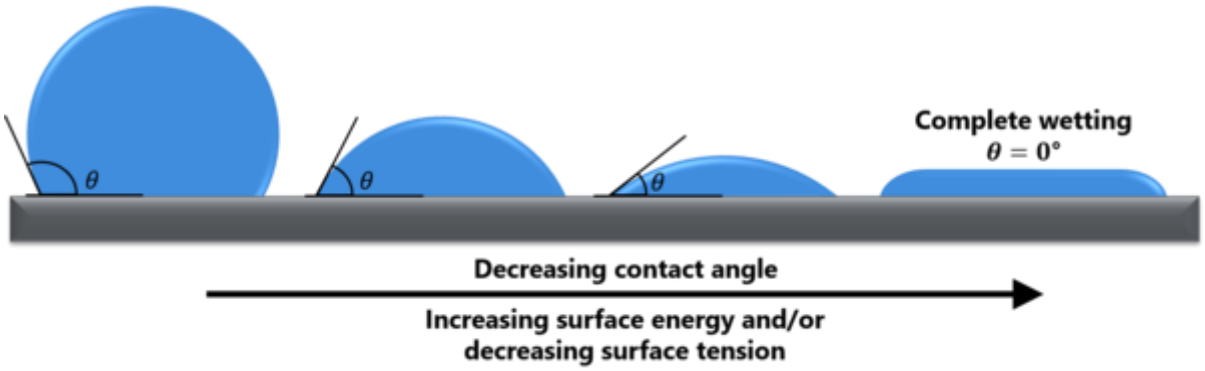
Surface tension arises because the molecules on the surface of the substrate strongly attract. Because the molecules attract one another a tension of the surface occurs. This can be seen as a tension between the molecules. The molecules continue to attract each other and will remain close together as long as possible. Because of this they do not give passage, because then they have to be separated. This physical activity at the surface substrate makes the adhesive flows out well, and then can adhere well to the surface. This is called 'wetting'.

It can be illustrated well with a drop of water. When a drop is placed down on very clean glass , it spreads completely. This is because of the high surface tension of glass. By contrast, the same drop deposited on a sheet of plastic, with a very low surface tension, the drop remains stuck in its place.

By nature some materials and with manufacturing of some facade panels sometimes processing aids (mold release agents) are used e.g. to allow the panel

come out of the mold easily. In the event a protection foil is applied on the facade panels, the surface is pre-treated in order to lower the surface tension and thereby facilitating the detachment of the foil. Please take notice of the fact that these substances reduces the chemical activity at the surface and must be removed from the surface before bonding to.

drop on the surface. If the drop of water remains lying than the surface tension of the substrate is low (eg Teflon). If the waterdrop flows out the surface tension of the substrate is high. TWEHA tested and approved materials on this issue also. Unless otherwise indicated, bonding without addition or modification with TWEHA's bonding products is allowed.



Good wetting is achieved when the surface tension of the adhesive is lower than the surface tension of the surfaces to be bonded. The TWEHA adhesives, based on Silane modified polymers, are polar and therefore have a relatively high surface energy. Therefore achieve these adhesives an optimal adhesion to polar substrates (e.g., glass or metal) with a relatively high surface energy.

Critical is bonding on materials with a low surface tension (a-polar substrates) such as most polymers (plastics) which are characterized with low to very low surface tensions. It explains why it is so difficult to achieve good adhesion to low surface tension materials such as polyethylene, polypropylene, silicones and polytetrafluoroethylene (Teflon™).

The surface tension of the substrate is, moreover, easy to indicate by placing (demineralized) water, in the form of a

Chapter 2 Bonding process

In order to be able to check whether the proposed method is being followed, one can use quality control. To be able to control the ambient conditions, it is useful to record the temperature and humidity on a regular basis. Other matters which are part of the quality control are the monitoring of the used materials, the sustainability of the stored adhesive, the dimensions, the execution of the surface treatment and the bonding process. Hereby a direct correlation exists with the ensued work process.

The implementation of the bonding process requires a great discipline in the compliance of the application procedure, the handling of the tools, the pre-treatment of the parts which are going to be used and the ability to handle the adhesive itself. In order to practice the bonding process, it is advisable to do this on a small scale first. Important is the fact that the work force must be well trained and familiar with the bonding process.

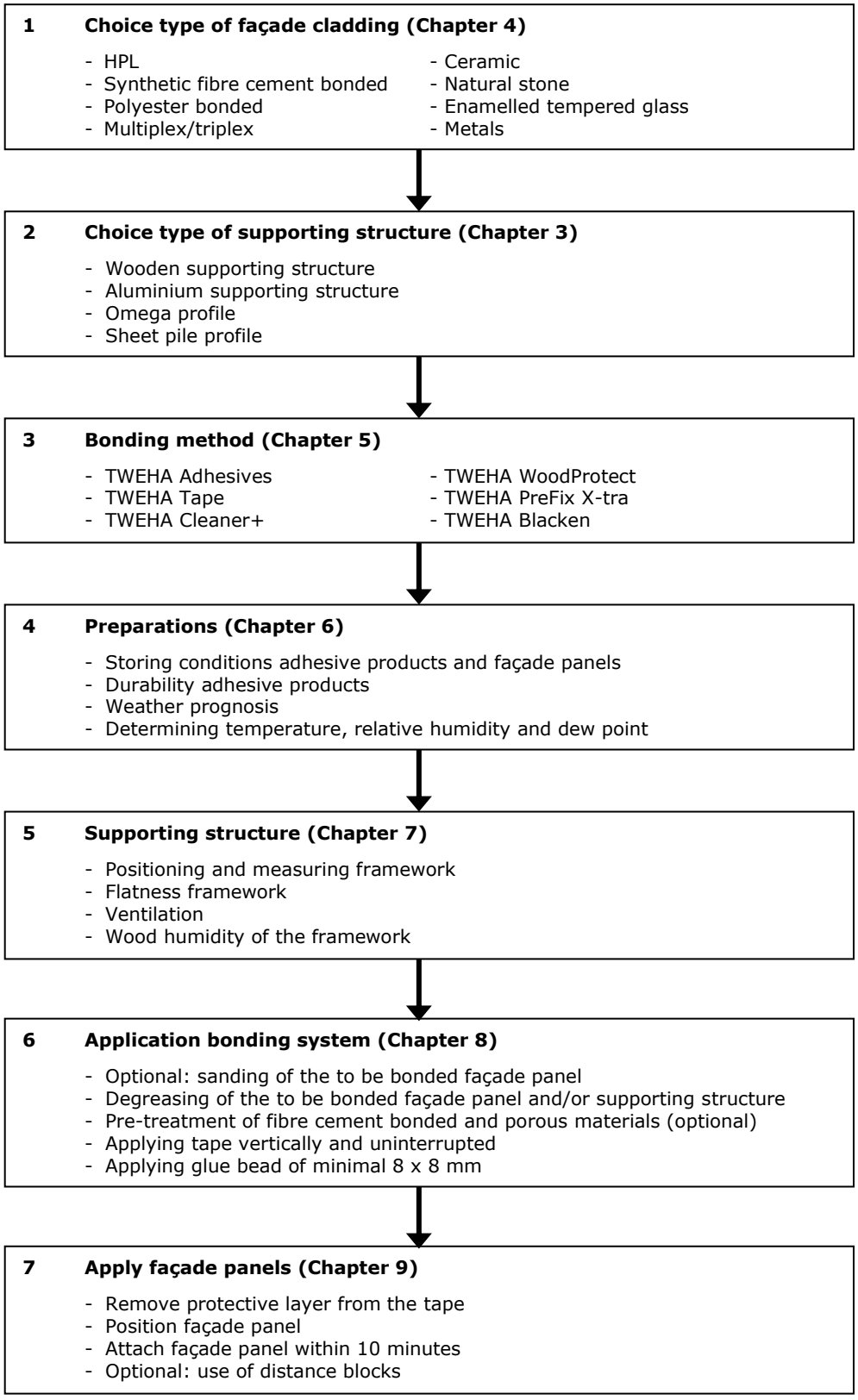
§ 2.1 Instructions For Use

The Instructions For Use needs to clearly, completely and unambiguously contain all information that is needed for a correct processing of the bonding product, this in order to prevent opinion- and interpretation differences.
There need to be definite regulations on the following:

- The way of pre-treating the supporting structure as well as the façade panels
- The amount of adhesive applied
- The optimal weather conditions in which the adhesive must be applied
- The retained drying times
- The retained measurements and the support centre distance supporting structure, where one also must keep into account the requirements of the manufacturer of the used panel
- The cleaning of the excess adhesive.

§ 2.2 Method

The next page shows the compressed version of the method, also showing the chapters in which they will be explained in full.


1 Choice type of façade cladding (Chapter 4)
- HPL
- Synthetic fibre cement bonded
- Polyester bonded
- Multiplex/triplex
- Ceramic
- Natural stone
- Enamelled tempered glass
- Metals
2 Choice type of supporting structure (Chapter 3)
- Wooden supporting structure
- Aluminium supporting structure
- Omega profile
- Sheet pile profile
3 Bonding method (Chapter 5)
- TWEHA Adhesives
- TWEHA Tape
- TWEHA Cleaner+
- TWEHA WoodProtect
- TWEHA PreFix X-tra
- TWEHA Blacken
4 Preparations (Chapter 6)
- Storing conditions adhesive products and façade panels
- Durability adhesive products
- Weather prognosis
- Determining temperature, relative humidity and dew point
5 Supporting structure (Chapter 7)
- Positioning and measuring framework
- Flatness framework
- Ventilation
- Wood humidity of the framework
6 Application bonding system (Chapter 8)
- Optional: sanding of the to be bonded façade panel
- Degreasing of the to be bonded façade panel and/or supporting structure
- Pre-treatment of fibre cement bonded and porous materials (optional)
- Applying tape vertically and uninterrupted
- Applying glue bead of minimal 8 x 8 mm
7 Apply façade panels (Chapter 9)
- Remove protective layer from the tape
- Position façade panel
- Attach façade panel within 10 minutes
- Optional: use of distance blocks

Chapter 3 Type of supporting structure

As in a mechanical fixture, the quality and build of the supporting structure plays an important role in the bonding of façade panels. This is decisive for the durability of the total façade construction.

The most important demands that are made of a supporting structure are the ability to carry the weight of the façade panels and to withstand the invasive wind load. All the stress that is put on the façade panels and the adhesive will be taken over by the building via the supporting structure. A fixation of a façade panel by means of a bonding system can be executed so well, but if the fixation of the supporting structure is not sufficient, the risk of damage is enormous. Therefore it is of great importance that the construction is executed well.

The supporting structure is the construction onto which the façade panels will be attached. The build of the supporting structure can differ and depends on the following factors:

- Condition of the anchoring foundation
- Insulation yes or no
- Situation of the building
- Height of the building
- Corner façade compared to the horizon
- Wind stress of the façade
- Dead weight of the façade cladding

§ 3.1 Wooden supporting structure

A wooden supporting structure can be placed single or double.

With a single wooden supporting structure, <u>without</u> insulation material, the vertical framework is directly attached to the anchoring foundation. With a double wooden supporting structure, the vertical framework is attached to a horizontal framework. This supporting structure is generally created as follows:

- <u>Horizontal framework</u>
  The horizontal framework is fixed on the under- and upper side with corner anchors, to the anchoring foundation (concrete, sandstone, brickwork etc.).

The diameter of the framework depends on the thickness of the insulation. On the whole one sticks to 150 x 45 mm (w x l) of a 45 mm + thickness of the insulation material. The support centre distance of the framework depends on the total load the façade construction can withstand. This must be determined by the engineer's static calculation.

- **Insulation**
  The insulation material is placed between the horizontal framework.

- **Damp proof, water resistant foil**
  The damp proof water resistant foil prevents damp from entering the construction and helps to prevent the insulation material getting wet. The foil is tightly fixed to the horizontal framework. By omitting the damp proof foil, there can be a negative influence on the durability of the construction. The insulation material behind the façade cladding can get wet and long-term damp accumulation can occur, which can lead to:
  - Dry rot
  - The origination of false damp load, because the façade panels dry on warm days on the front side, and on the back side a very humid environment occurs, and so there exists a very wet panel. Due to these differences in dampness, the panels will create friction due to which the façade panel can warp.
  - Insulation material will lose its insulation worth due to the humidity.
  - The damp proof water resistant foil can also prevent the insulation material from sagging against the façade.

- **Vertical framework**
  The vertical framework is attached directly to the horizontal framework. The bonding of the façade panels takes place onto the vertical framework. For making the vertical framework one can choose to use:
  - Non preserved wood
    The wood must minimally be of durability category 4 (according to NEN 5461). In most cases pinewood is used, but also other types of wood are possible, like meranti. When using non preserved wood, it is advisable to treat the wood with a wood preservation material. This prevents damp from entering the wood, so the framework is not so easily affected.
  - Preserved wood
    In the case of pinewood, it mostly is pinewood which has been impregnated under high pressure. When using this wood for bonding, it must be determined whether this impregnated wood needs further treatment or that one can use the adhesive on it directly.
  - Refined wood with addition of chemicals.
  - Hardwood.

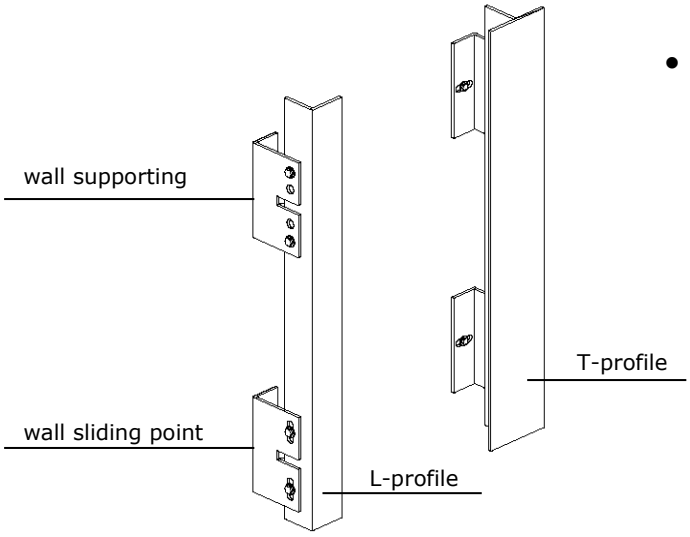
Wood types which retain a lot of resin, like pine and Oregon pine, can cause problems when used as vertical framework. That is why it is advisable not to use these types. The resins in this wood create a "greasy" surface, so that the adhesive cannot attach itself so well. If this application is unavoidable, we urgently advise to contact us at TWEHA.

The use of panel materials like *triplex*, *OSB* and *MDF* is **not allowed** as vertical framework. The reason is that these materials are build up out of different thin layers of wood or fibres which have been stuck together. Due to dampness these glued parts can detach themselves (de-laminate) and in worst case scenario the panel can "fall apart". This can cause catastrophic effects when attaching the façade panels.

When using a wooden supporting framework, the humidity percentage of the wood must be lower than 18%, before it can be processed. Prior to the application, by taking random samples, the moist content in the wood must be measured, in order to control whether the framework complies to the issued requirements.

§ 3.2 Aluminium supporting structure

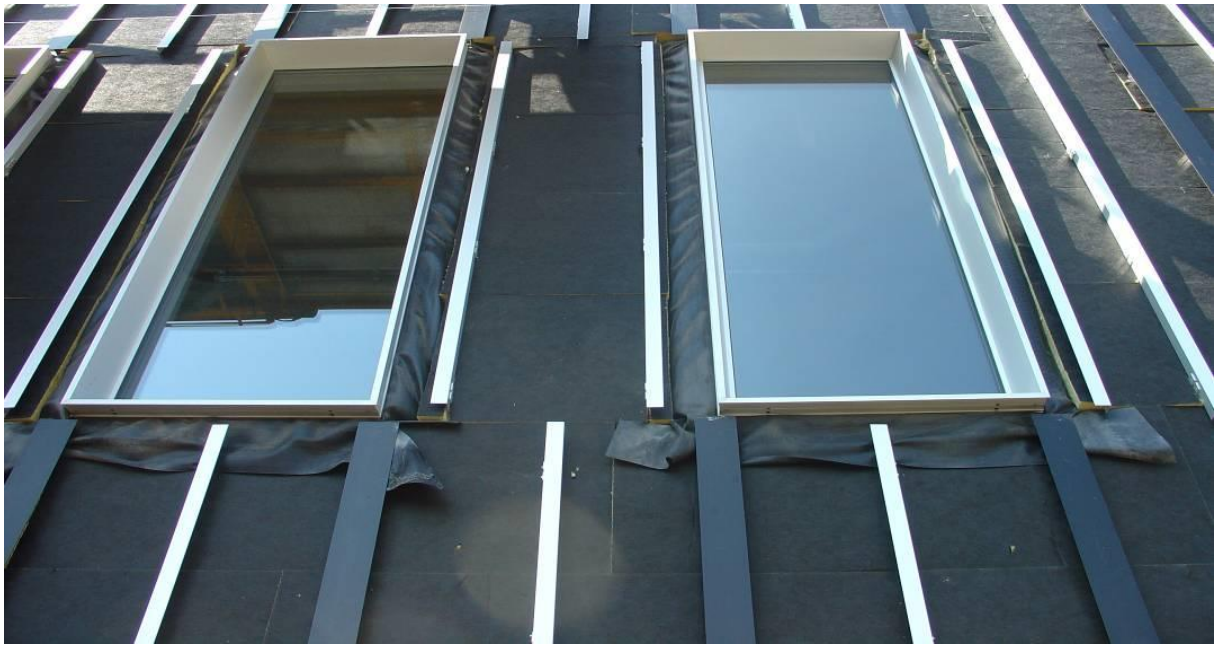
With an aluminium or a metal supporting structure, the application of a horizontal framework is not necessary, because the vertical framework will be attached directly to the concrete or sandstone wall of the building.



- **Vertical framework**
  The supporting- and sliding points are attached to the anchoring foundation (concrete, sandstone, brickwork etc.)

  For vertical framework, the following materials can used:
  - Brut aluminium has a good resistance against corrosion en must be clean, dry, dust- and grease free before adhesion. Aluminium construction parts must be composed of parts with a quality indication of AlMgSi (AA6101) or AlSiMgMn (AA6351) en must preferably be furnished with an anodized layer with a thickness of ± 30µm.
  - Anodized aluminium can be obtained in various colours and gives a better protection against corrosion than blank aluminium. It must be clean, dry, and dust- and grease free before adhesion.
  - Galvalume gives a better protection against corrosion than blank aluminium and has at the same time a higher temperature resistance. It must be clean, dry, and dust- and grease free before adhesion.

- **Insulation**
  The insulation material is placed between the aluminium profiles. One must take into account that there must be enough ventilation between the insulation and the back side of the façade panel.
  The insulation material is generally provided with a (black) layer, which makes the damp proof foil redundant.



§ 3.3 Omega profile

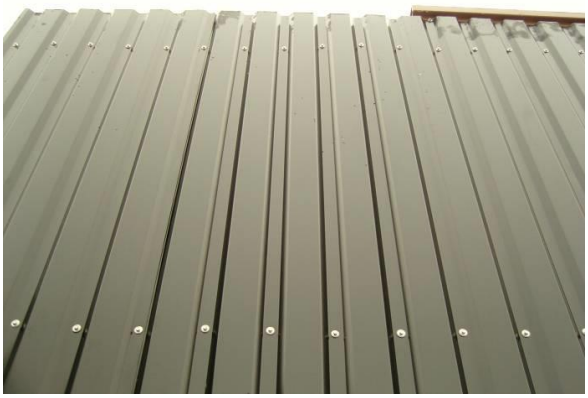
An omega profile can be used instead of an aluminium framework if insulation material is not being used. The omega profiles are directly attached to the anchoring foundation.

As materials one can choose:
- Aluminium
- Galvanized steel
- When galvanizing steel, electrolysis is used to coat the steel with a layer of metal.
- Galvanizing steel makes the steel corrosion resistant.
- Chamfered steel, by chamfering the steel, a thin layer of zinc is applied to the steel. This layer protects the steel against corrosion. There is a difference between thermal chamfering (the product is immersed in a bath of liquid zinc) and electrolyte chamfering (the layer of zinc is beaten down electrolytic way from a watery zinc solution).

3.4 Sheet pile profile

The sheet pile profile can directly be attached to the anchoring foundation. The profile of a sheet pile ensures optimal ventilation and good water drainage.

As materials on can choose:
- aluminium
- galvanized steel
- chamfered steel
- polyester cladding
- PDF cladding



Attention:
Types of metals must be treated against rust beforehand.

Although very different in composition, in the context of bonding, powder coating layers are considered as plastics.
The adhesion on powder coated surfaces shows very different results because powder coatings contains fluoropolymer additives as surface-tension modifier polytetrafluoroethylene (PFTE, also known as Teflon), polyethylene (PE) waxes which significantly alter the surface characteristics and flow- control additives, which function are to reduce the surface tension of the powder particles as they melt. These additives are an important ingredient in the formulation of powder coatings.

Because of the variation and low surface energy we strongly advise against bonding on powder coated material.

Eventually you can assess the quality of adhesion on powder coated layers by means of adhesion tests, which are performed prior to the start of application of the substructure!

The TWEHA adhesives, based on Silane modified polymers, are polar and therefore have a relatively high surface energy. Therefore achieve these adhesives an optimal adhesion to polar substrates (e.g., glass or metal) with a relatively high surface energy. Critical is the use of materials with a low surface tension (a-polar substrates) such as silicone, polyethylene and polypropylene.

So powder coated metals are in general also suitable as a supporting structure, but it is possible that for a powder coated metal framework, a different pre-treatment is needed.

The supplier of any kind of coating must guaranty that the bonding of the coating ons the specific substrate is strong enough to take the weight of the panel.

When using a coated metal framework it is therefore important to get information from TWEHA beforehand.

Metals with a powder cladding must always be tested for bonding suitability by TWEHA.

Chapter 4 Façade cladding

There is a great spectrum of different panel materials on the market. The characteristics of the panel materials differ a lot whereby it can be necessary to take special preliminary precautions before bonding. In this chapter a short description, their characteristics and possible application will be given of each specific panel material.

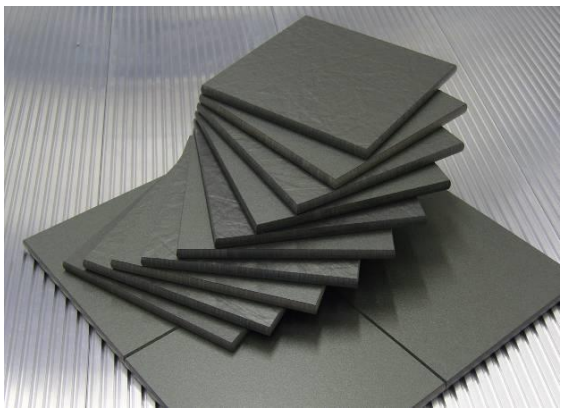
§ 4.1 HPL (High Pressure Laminate)

An HPL-panel is a flat panel based on thermal- hardened resin which has been strengthened in the core with wood fibre and cellulose layers. The impregnated fibres and/of cellulose layers are compressed with the top layers under high pressure at high temperature. In order to protect the face side of the panels during transport and processing, the panels are provided with a layer of foil. Sometimes the backside of the panel is also provided with foil. This foil must prevent the panel from curving and offers protection to the panel surface.

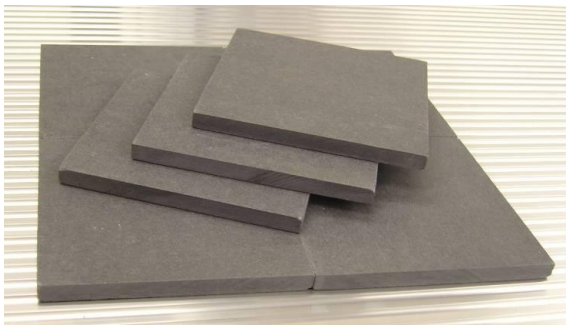
Characteristics
HPL-panels are durable panels with a high durability against chemicals. When permeated by damp, the panels can expand. HPL-panels often shrink at rising temperatures, because they are drying. The different expansion coefficients do not work cumulatively, but work against each other whereby the total expansion remains limited. One has to keep this into account when using the panels. The maximum contraction and expansion depends on the type of panels and is mainly determined by the build up of the panel, In respect to the expansion, at a statistical review, always follow the advice of the panelling manufacturer.

Expansion coefficient = 0,016 - 0,025 mm/mK
Flexibility strength = 90 - 120 N/mm²
Specific weight = 14000 N/m³

Applications
Interior building (doors, cupboards, walls, counters), façade panels.



§ 4.2 Synthetic fibre cement bonded



A concentrated synthetic fibre cement panel is a flat panel which is composed of a homogeneous mixture of cement and fibres, which strengthen the panel. The top layer can be untreated or hydro fibred or provided with a water resistant cladding, which comes in several colours.

Characteristics
Concentrated synthetic fibre cement panels are durable panels with a limited expansion when exposed to humidity. In relation to the strength of the panel the minimal thickness of the panel must be 8mm, when used as a façade panel.

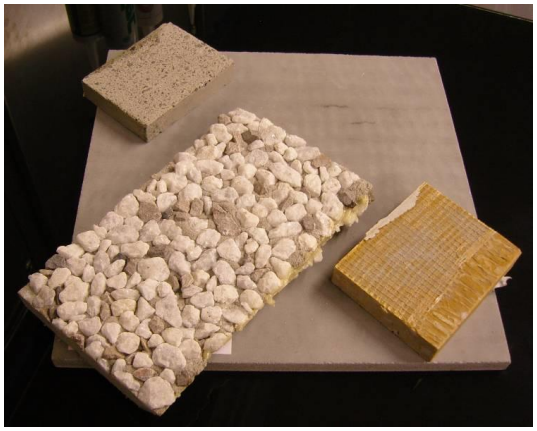
Expansion coefficient = 0,012 - 0,016 mm/mK
Flexibility strength = 16 - 26 N/mm²
Specific weight = 17000 N/m³

Applications
Façade- and wall cladding (interior and exterior)

§ 4.3 Polyester bonded material

Polyester concrete is cast composite stone. The material mainly consists of approximately 90% stone granules and 10% polyester resin. The finishing can take place by means of blasting, light sanding, and polishing. There are different surface types possible when using polyester concrete:

- A finishing with stone granules, glass granules or a combination of both materials
- Spilled clean unto a flat template
- Spilled clean unto a profiles template



Attention: When the product is going to be bonded on the template side, the possibility of wax residues exists.

Characteristics
Polyester concrete is produced out of a perfected composition of polyester resin, quartz sand and quartz granules.

Expansion coefficient = 0,018 mm/mK
Flexibility strength = 20 - 30 N/mm²
Specific weight = 21000 - 23000 N/m³

Applications
Façade cladding, façade element, panel filling, roofing finish

§ 4.4 Multiplex/Triplex

Triplex is a panel material build up out of three layers of large surfaces of wood veneer that have transversally been stuck together in opposite wood- grain direction. This way a stable panel of wood is created with a very large surface. If the panel consists of more than three layers, then it is generally known as 'multiplex'. Depending on the different types of adhesive, there are different qualities available, which can be classified in class 1 to 3. Class 1 used in interior, class 2 in sheltered outdoor places and class 3 for exterior projects.

When bonding wooden façade panels one must take into account the type of finish. Because there are a lot of different types of cladding, TWEHA must be consulted beforehand, whether the applied cladding is suitable for bonding.

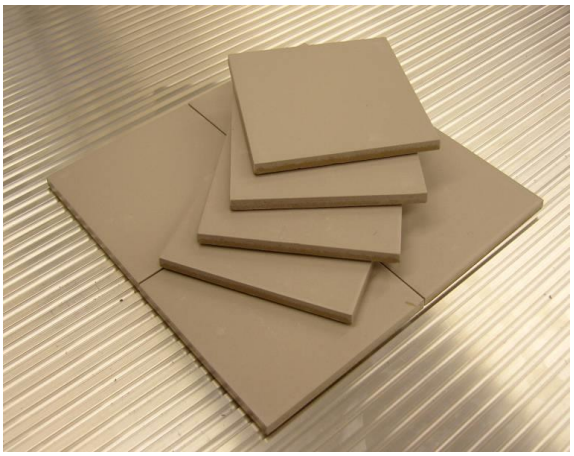
Characteristics
Multiplex/ triplex's characteristics are strongly dependent on the build up and the applied wood type. On the whole it can be indicated that the force in the width and length of the panel is at a minimum (0,1%). It is however larger (approximately 2%) in the thickness.

Expansion coefficient = 0,010 mm/mK
Flexibility strength = 12 - 30 N/mm²
Specific weight = 5000 - 7000 N/m³

Applications
Façade cladding, interior build, roofing finish.

§ 4.5 Ceramic

Ceramic tiles are relatively thin panels of ceramic material in diverse shapes, diameter and thickness. Ceramic tiles are



made out of a mixture of clay, sand and another natural substance.

Characteristics
Ceramic tiles are hard, strong, hygienic, easy to clean, non-flammable and fire-resistant. These are general advantages and differ per type of tile. Tiles are solid, they do not bend or warp. These are also advantages which are inherent to the nature of ceramic material.

Glassed tiles have a top layer of coloured enamel. This way a lot of important design characteristics come into existence like colour, sheen, decoration, nuance etc. and

technical characteristics like hardness, density, etc. All these characteristics depend on the type of enamel and can be very diverse.
Unglazed tiles have a universal character in surface as well as thickness, mostly these tiles do not have any design or patterns. The tile can be compact, thick or - as they say in the industry - impenetrable. On the other hand, tiles can have pores which are correlated to each other. To be able to measure the degree of porosity, the amount of intake of water is measured (water absorption test) under certain conditions. The higher the intake, the higher the degree of porosity.

Ceramic tiles do not only differ in their appearances en production techniques but also in their technical characteristics. The most important characteristics of tiles can be distinguished as follows:

- Water absorption; indicates the degree of porosity
- Dimension and appearance; there can be minute differences in dimension and

appearance or the tiles are not completely flat.

Expansion coefficient = 0,0069 mm/mK
Flexibility strength = 5 – 15 N/mm²
Specific weight = 20000 N/m³

Applications
Façade cladding, stair-steps, floors

§ 4.6 Natural stone

Stone is a natural product with an endless amount of variety. Stone can be distinguished from each other by the way of origination:

- Igneous rock; also known as granite. This igneous rock mainly consists of silicon dioxide.
- Sedimentation or mineral deposit; also known as marble. These rocks mainly consist of calcium carbonate (= petrified lime).
- Metamorphosed rock; for example quartzite. A metamorphosed rock-type, due to heat and/or high pressure.

Characteristics
Stone is a heavy building material. It is 2 to 3 times heavier than water and very resistant to influences from outdoors. Stone is above that a bad insulator but a good accumulator, this means that stone easily releases heat, but also retains a lot of heat. This characteristic is important in the façade cladding. The stone cladding not only acts as an umbrella, but also protects against temperature changes. During the day stone absorbs the warmth from the sunshine, and releases it when the temperature decreases.

Expansion coefficient = 0,0069 mm/mK
Flexibility strength = 10 - 20 N/mm²*
Specific weight = 20000 N/m³*
* depending on the type

Applications
Façade cladding, floors, kitchen worktops

§ 4.7 Enamelled tempered glass

Enamelled glass is glass that has been provided with an opaque enamel later on the back side, which has been burned onto the glass surface by means of a thermal treatment. The enamel is obtained by fitting a mixture of glass powder, metal oxides, water and binding agent onto the glass; the colour layer and the glass melt together to form a unity.

Characteristics
Enamelled glass has the same characteristics as pre-tensioned hardened glass. However, during the production process, the glass is provided with a fused paint layer, the enamelled layer. By using this production method, enamelled glass has the same properties as pre-tensioned hardened glass and a far greater thermal and mechanical resistance than normal glass. Besides that enamelled glass has a high durability: the colours are almost completely insensitive to sunshine, weather conditions and pollution.

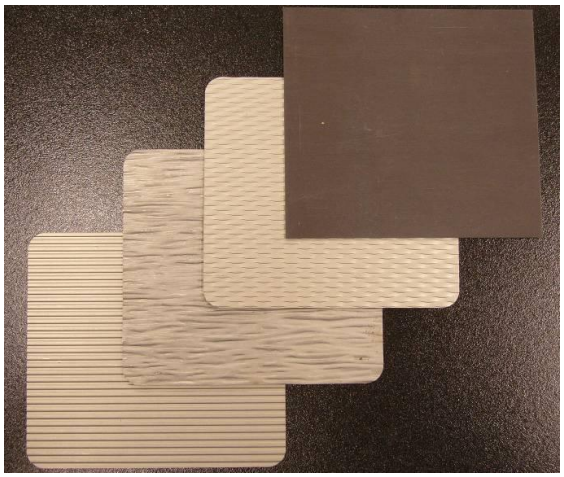
Expansion coefficient = 0,090 mm/mK
Flexibility strength = 40 N/mm²
Specific weight = 25000 N/m³

Applications
The cladding of façades, possibly composed to a insulating sandwich panel to improve the thermionic insulation.

Related to the UV-resistance of the adhesive also translucent panels (including enamelled glass) can be used as façade panels, with the help of a UV-blocker.

§ 4.8 Metals

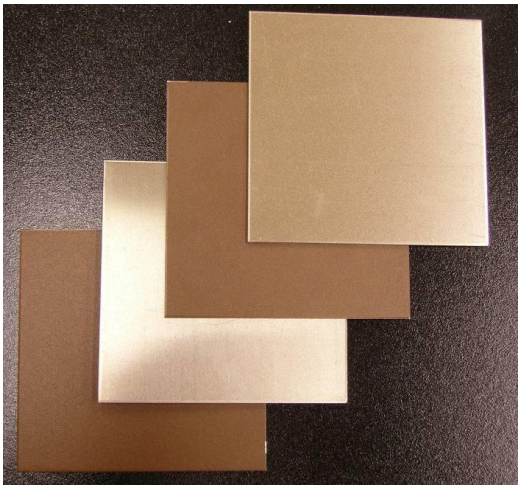
A distinction can made in the following metals:



- **Zinc**
  Zinc can be used amongst other things as roof panelling, because of its ideal properties. Zinc combines a very long working life with a very high workability. Zinc has such a high longevity, because it has a high corrosion resistance. But it is also often used because it is easy to assemble.

  Characteristics
  Expansion coefficient = 0,029 mm/mK
  Flexibility strength = 3 N/mm²
  Specific weight = 70000 N/m³

Applications
Façade cladding, industrial applications like gutters, roof panelling etc.

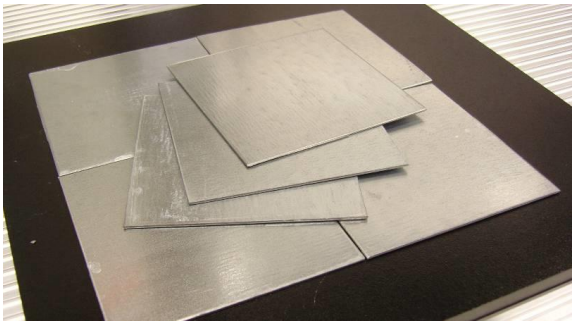


- **Aluminium**
  Aluminium is light, strong, abrasion- and corrosion resistant, except tension corrosion. Aluminium is not ferromagnetic, does not spark, is workable, has a high reflective capacity and has an attractive, decorative appearance. The following special characteristic of aluminium make it a very diverse material:
  - advantageous strength/density combination
  - advantageous electric conductance/ density combination
  - good corrosion resistance
  - good ductility

  Aluminium is suitable for almost all known operational- and fabrication methods. It can be anodised, enamelled and coloured.

  Characteristics
  Expansion coefficient = 0,025 mm/mK
  Flexibility strength = 3 N/mm²
  Specific weight = 260000 N/m³

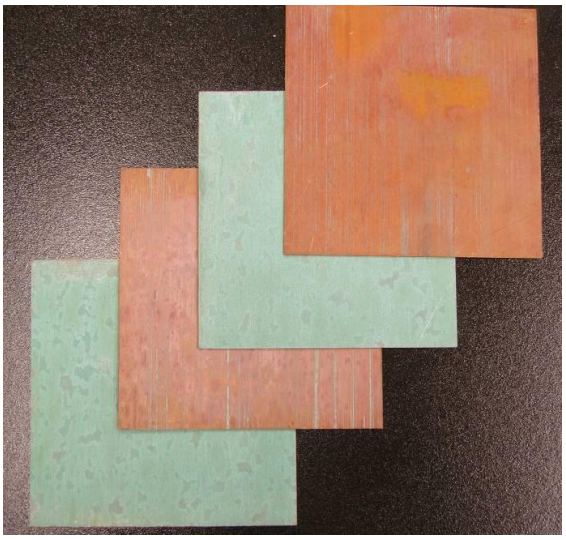
Applications
Façade cladding, industrial applications like gutters, roof panelling etc.



- **Steel**
  Steel is made out of iron ore. The iron ore is heated up in a blast furnace at a temperature of up to 17000 degrees Celsius. Cast iron with a high degree of carbon, originates out of the blast furnace. This cast iron, sometimes with addition of scrap iron (old iron), is heated in an oven (convector) by adding oxygen (because of this the carbon degree decreases, and steel arises). Steel is iron with very little carbon.

  Characteristics
  Expansion coefficient = 0,012 mm/mK
  Flexibility strength = 4 N/mm²
  Specific weight = 780000 N/m³

Applications
Façade cladding, industrial applications like gutters, roof panelling etc.

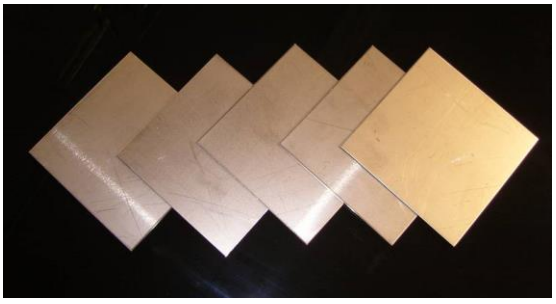


- **Copper**
  Copper is a reddish metal. With oxidation a green layer arises on the copper, which is fixed oxide.

  Important applications:
  - good heat conduction;
  - good electric condition;
  - bad for casting;
  - good for soldering
  - good for processing;
  - melting point at 10840 °C.

  Characteristics
  Expansion coefficient = 0,017 mm/mK
  Flexibility strength = 3 N/mm²
  Specific weight = 86000 N/m³

Applications
Façade cladding, industrial applications like gutters, roof panelling etc.



- **Stainless steel**
  Stainless steel is an alloy and is obtained when bringing together different types of metal. The most important elements in the alloy are chrome and nickel.

  Characteristics
  Expansion coefficient = 0,012 mm/mK
  Flexibility strength = 4 N/mm²
  Specific weight = 78000 N/m³

Applications
Façade cladding, industrial applications like gutters, roof panelling etc.

§ 4.9 Materials reinforced with fiberglass mesh

Some materials, such as ceramics are reinformed with a fiberglass mesh at the backside to increase the flexural strength. Bonding on this fiberglass mesh is no problem. We have tested and approved several types of reinforcement by fiberglass.

Chapter 5 Bonding system

§ 5.1 Accessories bonding system

A bonding system consists of different components which are necessary for a good adhesion of the façade panel. The composition of a bonding system depends on the applied materials (the façade panel, the supporting structure and the adhesive).

On the whole a bonding system consists of the following components:

- **TWEHA Adhesives**
  Herewith the eventual connection takes place between the façade panel and the supporting structure.

- **TWEHA Cleaner+**
  Universal Cleaner+ and degreaser. Before bonding, the panel and/or framework must be cleaned.

- **TWEHA Tape**
  This double sided self-adhesive tape, with a thickness of 3mm, is used for the first attachment, until the adhesive has hardened and guaranties the minimum required glue bead thickness.

Depending on the bonding material and the supporting structure, there are also a couple of optional components:

- **TWEHA WoodProtect**
  Wood preserving material for a supporting structure of (preserved)wood.
- **TWEHA PreFix X-tra**
  Surface enhancer for treatment of porous materials.
- **TWEHA Blacken**
  When using a brut aluminum supporting structure, the appearance of the brut aluminum in the joints between the cladding panels can be experienced as disturbing. Using black anodized aluminum is the most obvious solution but for cost reasons you can also decide to paint the aluminum black.

§ 5.2 Adhesive

TWEHA adhesives are a homogenous, highly elastic, one-component high-end hybrid-polymer smooth adhesive, and specially designed for use with various panels and wall cladding materials.
Its unique formulation provides the highest values for adhesion, tensile and shear strength.
The use of an aggressive adhesive primer is unnecessary, which results in significant savings in time and money.

The complete TWEHA Bonding Systems includes a special made TWEHA Adhesive, TWEHA Cleaner+ and TWEHA Tape and eventually TWEHA WoodProtect or TWEHA Blacken.
Please refer to each product's Technical Data Sheet and our comprehensive list of approved substrates.

The elasticity of the adhesive is determined by two factors:

- **The formulation of the adhesive**
  The hardness of the adhesive (=Shore A) is necessary to receive the contraction and expansion of the façade panel. On the whole it is considered that the more elastic the adhesive is, the lower the maximal strength is. To prevent the adhesive from having high elasticity, but not enough strength to carry the weight of the façade panel, a minimum adhesion strength is required. The elasticity ultimately decides what dimensions of façade panel can be applied. At a higher elasticity of the adhesive, façade panels with a larger diameter can be applied, provided that the adhesive allows it.
- **The thickness of the glue bead**
  The thicker the glue bead is, the more friction the adhesive can take. The thickness of the adhesive cannot infinitely be enlarged. Creep, whereby the bonded façade panel sags through its dead weight, is influenced by the properties of the bonding product. The decided glue bead thickness is in most cases 3mm, which is obtained when using the double-sided self-adhesive tape.

§ 5.3 TWEHA Cleaner+

TWEHA Cleaner+ is a universal cleaner and degreaser for cleaning the backside of façade-panels and/or supporting structures as for aluminum or galvanized steel.

It is possible that on the backside of the façade-panels (the side which has to be bonded) a production residue remained on the surface. The residue may come from:

- **Discharge fluids**
  When producing HPL-panels, many panels, sometimes 40 to 80 at the same time, are pressed together under high pressure. To be able to take the panels apart (in separate layers), a special "discharge fluid" is used between the panels. These discharge fluids are mainly based on silicon.
- **Foil applied for protection of the façade panel**
  Some brands of HPL-panels, apply a protective foil on the front- and/or backside of the panel, in order to prevent the panel from curving. When removing the foil, it is possible

that a small layer (residue) remains left on the panel. The panel must be lightly sanded and then cleaned, before it can be bonded.

§ 5.4 TWEHA Tape

TWEHA Tape is a double sided self-adhesive foam tape with a thickness of 3 mm and a width of 12 mm.
Any other dimensions are available on request.
Use TWEHA Tape in combination with a TWEHA bonding system for the bonding of rainscreen or ventilated cladding.
TWEHA Tape provides the initial bond and guaranties the minimum required glue bead thickness.
TWEHA Tape adapts to irregular surfaces by its high flexibility, prevents absorption and the ingress of moisture.
Apply TWEHA Tape on a dry and free of dust and grease substrate.
See the instructions for use for a comprehensive description of the application.

§ 5.5 TWEHA WoodProtect

TWEHA Woodprotect is a black-coloured wood preservation material providing an excellent protection to a wooden supporting framework against moisture, chemicals and acids where contacted by concrete, steel or brickwork.
To be used on a supporting structure of untreated white pinewood. TWEHA Woodprotect can be used to obtain a black joint between the façade panels.
See the instructions for use for a comprehensive description of the application.
TWEHA WoodProtect ensures, by it closed cell structure, an outstanding protection against wood rotting and provides a perfect adhesion for the TWEHA Tape and the TWEHA Adhesives.

TWEHA WoodProtect is **not** a primer and can therefore be processed in advance. Adhesion of the panel material can take place at any time, taking into account the prescribed drying time.

TWEHA WoodProtect may NEVER be applied to the backside of façade panels.

For interior applications is the use of TWEHA WoodProtect not needed! Only for obtaining a black joint if needed.

TWEHAWoodProtect may **never** be applied to painted wood, multiplex, aluminium and other types of metal.

§ 5.6 TWEHA PreFix X-tra

TWEHA PreFix X-tra is suitable for the pre-treatment of fiber cement bonded materials and stone-like materials with a porous surface.
The degree of density of a solid (the substrates to be bonded) allows water to penetrate between the solids of the material. In a porous material, as the word says, the water easily can find a way in the pores of the material.
Each material increases moisture to a greater or lesser extent. Tension due to its own weight and wind load is partly absorbed by the grain tension in the material of the panel. The remainder of this tension is absorbed by the water tension.
Normally this causes a slight change in shape, but in porous material it reacts different. Then the grains will slide over

and even roll. This process gives water the opportunity to fill the available spaces. This process continues to repeat which ultimately will result in the development of a water film between the adhesive mass and the porous material until the adhesion of the glue joint collapses.
The surface enhancer TWEHA Prefix X-tra closes the pores on the surface of the substrate, distributes the tension over a larger surface, thus eliminating the above-described phenomenon, thus preventing the detachment of the bonding due to this described process

Attention: TWEHA PreFix X-tra is **not** a "bonding primer", but only serves as an impregnation material.

§ 5.7 TWEHA Blacken

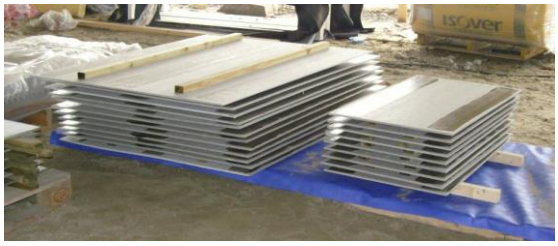
When using a brut aluminum supporting structure, the appearance of the brut aluminum in the joints between the cladding panels can be experienced as disturbing.
If there is a need to color the aluminum profiles in black the use of black anodized aluminum is the most obvious solution but for cost reasons you can also decide to paint the aluminum using TWEHA Blacken. However, aluminum is a difficult material to paint. In spite of sufficiently clean, dry and grease-free aluminum with the TWEHA Cleaner+, it presents problems with adhesion with traditional paints. The knowledge that afterwards also (partly) a durable adhesive bond must be realized on the applied black paint layer implies that specific demands must be made on this paint layer.
TWEHA Blacken is a black paint developed especially for this purpose with the high demands for a durable adhesion to the aluminum and the (partly) creation of a durable bonding surface for the TWEHA adhesive systems as a requirement.
With TWEHA Blacken, by the way fast drying, a black surface can be applied over the width of the joint (or wider) on the brut aluminum profiles, thus eliminating the disturbing 'shiny' appearance of the brut aluminum. The adhesive can then be (partially) applied to the black paint layer two hours after application

Chapter 6 Preparations

§ 6.1 Storing conditions

In order to guarantee the quality of the materials, a good storage is necessary. This storage often takes place at the building site. It is therefore necessary to create special facilities, to get the right storage conditions. Below the minimal storage conditions for the different materials are given:

- **Façade panels**
  The panels must be stacked horizontally on a dry and flat surface, in a covered and well-ventilated space. The maximum height of the pile is 1 meter.



  It is important to store the necessary pre-treated materials dirt- and damp free. Hereby one must ensure that no deformation due to climate change and no damages due to transportation occur. With some types of panels, big changes in the climate (temperature and relative humidity), lead to warping of the panel. Façade panels which have been so badly warped and have to be attached under pressure, are not suitable for bonding any more. With this is meant that the panel has to be forcefully pressed against the tape, in order to get it straight again.

  The panel material must be delivered custom-made, and must be provided with a numeration in accordance with the valid building plan, which must be present on the site.

- **Adhesive system**
  Must be stored, dry and frost- free. The adhesive must have a minimum temperature of +5°C, before bonding. This is to prevent the adhesive from getting "thicker", and therefore difficult to administer.

§ 6.2 Durability

Before use, the expiry date of all the components of the bonding system must be checked. Products passed their due-date, cannot be used any more. In order to prevent transgressing the due- date, it is advisable to work using the principle "first in, first out". Products which have been in storage the longest must be used first. In case of the adhesive, the batch number, which shows the due- date, must be recorded. Leftovers may not be put back into storage, for later use.

§ 6.3 Climate

When bonding, it is important to keep control of the surrounding condition. Important parameters are temperature, the relative humidity, possible wind load, and to keep the adhesive parts, clean, dry, dust- and grease free.

On the day of application, one must check the weather forecast for that day. In the following cases it is <u>not</u> possible to adhere

In case of, in the first coming days of application, a storm is expected with great wind- speed (wind-force 8 or higher), the bonding of façade panels is not permitted. In such a case, the possibility can occur for a façade panel to come off, because the adhesive has not hardened enough.

Of course measures must be taken to ensure a dry application of the façade panels.

By continuously measuring and monitoring the outdoor climate, the by TWEHA introduced humidity meter supports the warranty administration. The external temperature sensor communicates 24/7 with the data logger for the registration, storage and display of temperature, relative humidity and dew point. With the supplied software, the measurement moments are read into your PC or laptop and added to the warranty documents as an Excel file.

If there is no rain, frost or strong wind, it is still necessary to check and note what the temperature and the relative humidity (RH) are at that moment before starting the application. In this way the dew point can be determined. Controlling the dew point is therefore, in addition to making the surfaces to be bonded clean, dry and grease-free, the key to the quality of the bonded connection. The moment that dew or condensation forms on the surface to be bonded, this always results in insufficient adhesion.

A dew point is achieved because cold air can absorb less water than warm air. By cooling warm, moist air (for example at night), the moisture from the air will precipitate on cold materials such as the facade panel or an aluminum framework. This dew point changes again as soon as it gets warmer during the day.

When the dew point is reached, a water film (dew) is created on the battens and façade panel, which frustrates the adhesion of the adhesive. A dry surface is necessary for a good connection. In such a case, wait until the outside temperature rises somewhat and the dew point accordingly moves up, dry the surfaces to be bonded, and if necessary heat them briefly with a 'hair dryer'.

Chapter 7 Supporting structure

§ 7.1 General

Not in all cases shall the skilled applier, who will take care of the bonding of the façade panels, also be responsible for the supporting structure. It is of great importance that the skilled applier, prior to the adhesion of the façade panels, can judge the solidity of the supporting structure. Only when this construction meets the demanded requirements, one can start with placement of the façade panels. In any case, first it is necessary to discuss the possible consequences of the identified deviations with the person responsible for the supporting structure and with TWEHA.

The supporting structure must be and according to the guideline of the panelling manufacturer applied even and resistant to wind- and weight load conform the valid standards. The supporting structure takes the load of the façade panels (wind- load, dead- weight) on to the supporting structure (sandstone, brickwork, concrete etc.)

The supporting structure is one of the most important elements in relation to the application. In the end the façade construction consists of different elements, including:

- Foundation (anchoring foundation)
- Insulation material
- Supporting structure
- Panels

The panels can be applied with the adhesive, in many different ways:

- On vertical struts of an aluminium or wooden supporting structure
- In rabbets: processing of the panels like in glazing

The reason why façade panels are applied to a supporting structure:

- The possibility to erase roughness's on the supporting structure is greater
- An optimal ventilation cavity is created by constructing the vertical profiles at a distance to the architectural constructions
- The number of fixing points on the supporting structure decreases

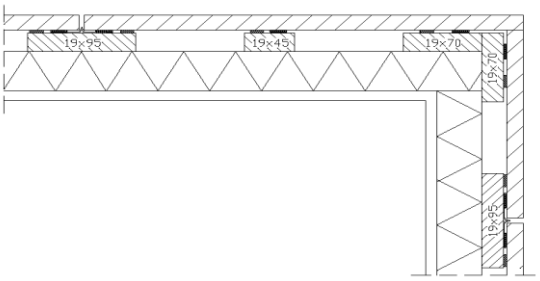
If the anchoring foundation is not flat (due to which the insulation material must also be adjusted), the diameter of the fixing bars and the horizontal beams, must be chosen in such a way that the supporting structure can be executed according to the guidelines.

The amount of fixing points per m² of the supporting structure is determined by the dead weight of the construction and the wind load/traction. With regard to the employed wind load, we refer you to the local instructions such as EN 1991-1-4.

§ 7.2 Measurements

The prescribed width of the vertical supporting wood framework:

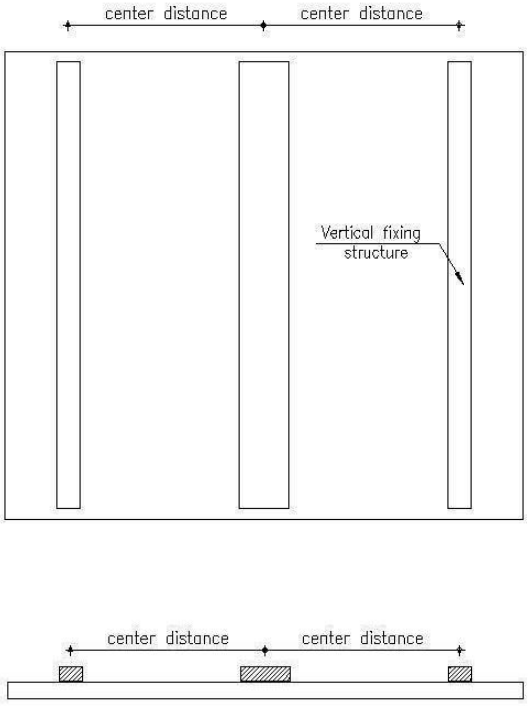
- Thickness : 18 mm
- Vertical muntins : 45 mm
- If open joints applicable : 95 mm
- End- and angle battens : 70 mm



The measurements of the wooden or aluminium vertical supporting framework can (especially in the width) vary a bit per bonding system. The mentioned width and length are minimal measurements. It is not permitted to use smaller measurements for the framework than the ones stated above. These minimal measurements are necessary to realise sufficient ventilation behind the façade panels (thickness) and to create enough surface for the adhesive (width).

§ 7.3 Support centre distance

The support centre distance, is the distance between two vertical battens. This distances depends on the panel type, the thickness, the flexibility and the guidelines of the manufacturer. The support centre distance ought to be determined using statistical calculations.



The support centre distance of the vertical framework depends on a couple of factors:

- **The wind load on the building**
  The higher the wind load on the façade panels, the smaller the support centre distance is made on the framework. Therefore it is possible that with a tall building, the lower levels have a different (higher) support centre distance than on the higher levels of the building.

- **Thickness of the panel**
  With some types of panel material, a thin panel will get a smaller support centre distance of the framework than a thick panel. This is done in order to prevent thin façade panels from warping too much and possibly in the case of stone, break.

- **The position on the façade**
  On the corners of buildings, one is confronted with wind turbulence, due to which a heavier standard of the framework is applied. Because the wind turbulence is higher on the edges than anywhere else on the building, a smaller support centre distance is applied to the edges of a high building. This has to be determined using statistical calculations.

There are several factors which can have an influence on the support centre distance of the framework. It is therefore not possible to make a general guideline for this. For the exact measurements it is advised to contact the panels manufacturer, the supplier of the adhesive and the constructor in charge of the building site.

§ 7.4 Flatness

The assembly of the horizontal framework has to be executed in such a way that everything is on one line. This is aesthetically necessary, but also because a large variation of the vertical framework can cause differences in the glue bead thickness or tension in the façade panels. These tensions are created when the façade panel is put on an uneven framework or is positioned with a hollow or a bulge against the tape.
The flatness and solidity of the horizontal framework also has to checked before the start of the application. The deviation may not be more than 2mm.

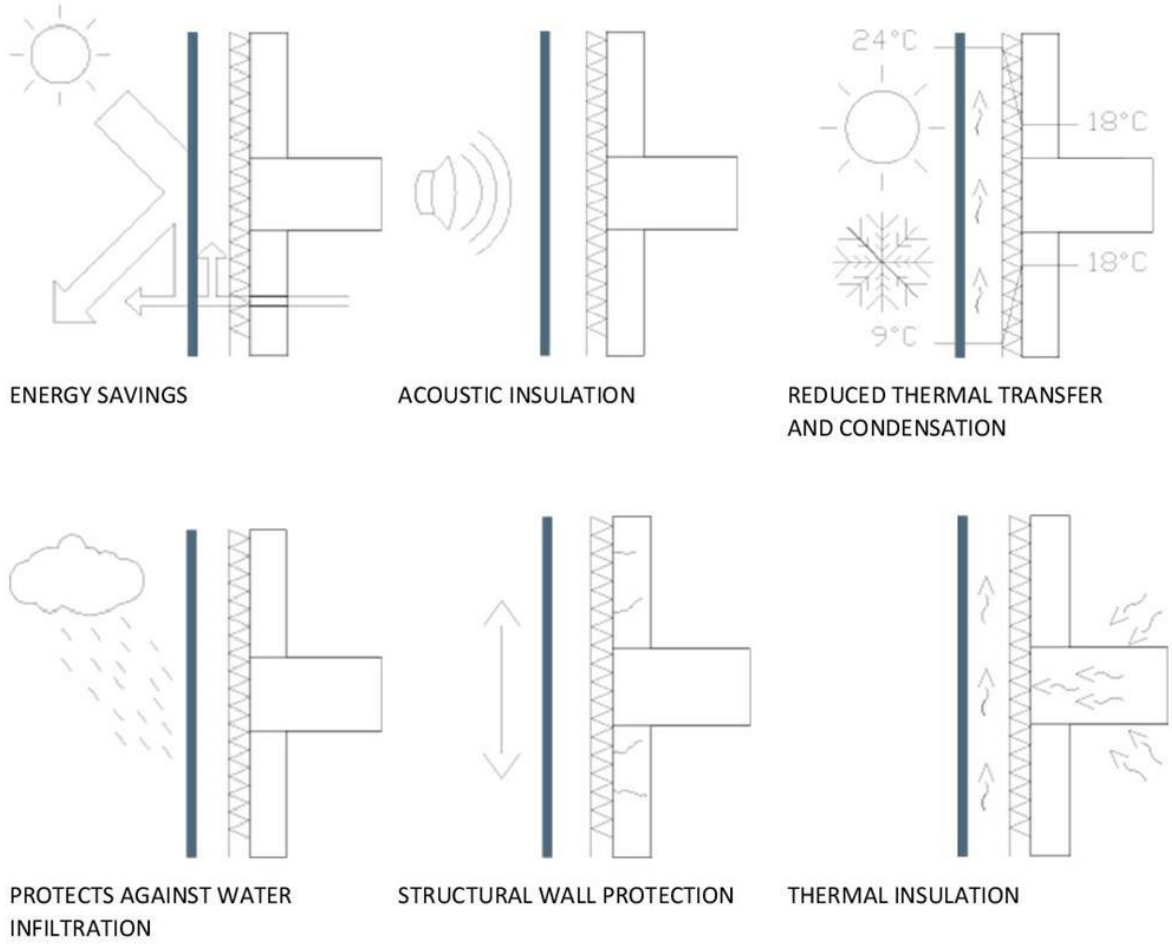
§ 7.5 A bonded cladding is always a ventilated façade!

This ventilation allows for an exchange of air between the outside and the cavity behind the cladding panels, providing the solution for venting any moisture away from the facade, improving the thermal conditions inside the building and installing the insulation on the outside so to avoid thermal bridging.

The ventilation is produced by openings located at the top and bottom of the cladding or by the open joint pattern causing a 'chimney effect'.

The cladding elements are fixed to the substrate wall by means of a lightweight substructure which can be made of different materials, being metal a preferred choice. the façade panel, increase so much that the panel can loosen

itself in places, from the supporting structure.



In order to have sufficient ventilation, the following requirements must be met:

- **A minimal air space (cavity) of 20 mm on the backside of the façade panel**
  This air space must have a direct, uninterrupted opening to the outside, on the upper as well as the bottom side.
- **Sufficient in and out flow openings on the under- and upper side of the façade**
  These openings must have a diameter of at least 100 cm^2/m^1.

When applying a metal roof trim or roof paving, one must take care not to attach them too tight to the façade panel, so that the ventilation on the upper- and under side is hampered.

The balance between wetting, drying, and safe storage is critical to the long-term performance of building enclosures. Where wetting cannot be controlled to acceptable levels, safe storage and drying become critical. Many common building materials have little safe storage

capacity—that is, they cannot be exposed to high levels of moisture for long periods of time.

The sheathing is one building component often made of moisture sensitive materials placed directly behind the cladding and separated by only a thin membrane and air gap. For some periods of time, the sheathing can be expected to be exposed to rainwater wetting from the exterior or condensation wetting (air leakage or vapor diffusion) from the interior.

Protecting the sheathing from moisture is seen as important and has been the goal of many product manufacturers, builders, and practitioners over several decades.

However, experience has shown that accidental leaks can still occur; therefore, the role of drying is very important to the moisture balance.

§ 7.6 Checklist supporting structure

It is the skilled applier's job to check whether the execution of the construction conforms to the minimal requirements of ventilation, measurements etc. This check must be executed on the following parts:

- **The assembly and attachment of the supporting structure**
  Is the construction strong enough to carry the façade panels
- **Panel dimension**
  Are the panels not too large to be bonded. The elasticity of the adhesive must be compared to the expansion coefficient of the façade panel.
- **Ventilation**
  Is sufficient ventilation possible to prevent fluid accumulation on the backside of the façade panels. It also has to be checked whether other materials are blocking the ventilation space or openings. If this is the case, these must be removed before bonding. An example would be the end-pieces of the water resistant, damp proof foil, which are not attached to the framework. These might hang in front of the ventilation openings and therefore must be attached.
- **Position of the vertical framework**
  Is the framework on which the façade panels are going to be attached, placed in the right position? At the inspection one must check, the support centre distance and the right position of the end-battens. Especially the presence of a seam (with prescribed measurements) between the attachment of two panels or at an end-beam must always be checked well.
- **Flatness of the framework**
  Does the frame to which the framework is attached conform to the requirement of a deviation of maximum 2mm. Whether this requirement has been met, can be measured by stretching a wire between the two end-battens where a façade panel is going to be attached. If one of these frameworks are more than 2mm off the line of the wire (including the two end-battens), these obstacles must be dealt with before the façade panel is being bonded.
- **Wood moisture level of a wooden framework**
  Every day, before every application, a random test of wood moisture level of the framework must be executed in different beams (minimum of 5). These must be measured and registered. If the wood moisture level is higher than

18%, the next precautions must be taken:

1. The random check must be expanded to measurements in 25 different beams.
2. If it concerns only one beam, with a moisture level higher than 18%, this beam must be removed and then be replaced, or this part of the façade must not be bonded to. As soon as the beams have dried back to under the 18%, the beams can be bonded.
3. If the majority of the beams have a moisture level higher than 18%, the application has to wait until the moisture percentage has dropped to under 18%.
4. When using TWEHA WoodProtect, a daily measurement is not necessary, because the wood is protected against moisture intrusion. Before applying the TWEHA WoodProtect it is important that the wood moisture percentage is not higher than 18%.

Apart from the inspection of the construction, a daily inspection of the to be bonded façade panels is necessary. Curved panels may not be bonded. There is no set definition of how crooked a panel may be. On the whole it can be stated that the crookedness is too great, when in the process of adhesion, the panel is pressed against the tape of the various vertical beams and the panel comes loose from the framework. In this case, the panel must be immediately removed from the façade. The extent of crookedness of this panel is straight away a reference point to the allowed distortion of a panel. Before a new panel can be bonded, all the old adhesive- and tape leftovers must be removed.

Apart from curved panels, damage to the panels is of course also not allowed. This can be aesthetic damages on the front-side of the façade panel or damages of the panel which can influence the durability of the façade panel, like big scratches in the possible back-cladding(cladding of the backside of the panel).

Chapter 8 Application bonding system

§ 8.2 Sanding of the panel

When using HPL- façade panels, it might be necessary to sand the panel on the backside before cleaning and bonding the surface. This sanding is necessary to remove possible residues of the panel surface. Such a residue is often left-over from production or from when a protective foil has been applied to protect the panel surface. Such a residue can have a negative influence on the adhesive of the panel. By lightly sanding the panel's backside with a fine abrasive and using a good Cleaner+ and primer afterwards, the residue can be removed. An additional advantage of sanding is that the panel surface is slightly roughened. This makes the bonding possibly even better. After sanding, the backside of the panel must be made dust- and grease free.

Working details and design
This bonding system is meant for ventilated façade constructions.
Ventilation is stipulated!
Between insulation and cladding an air space (cavity) of > 20 mm is required:

- This avoids large temperature differences in front of and behind the panels.
- Condensation and penetrating moisture are evaporated due to the ventilation.
- This prevents the formation of mould, decay or corrosion of the supporting structure or its components and the insulation material does not become damp (thermal insulating capacity is retained).
- Do not place the metal trim directly against the façade paneling! Use the TWEHA roof gutter clip!
- Consult the instructions of the panel manufacturer. TWEHA therefore advises that the upper and lower side of the façade surface be provided with the following ventilation opening: minimum 100 cm^2 / m^1.

Weight of the façade panels
Loads due to the weight of the panels itself are not significant when considering creep or ultimate strength. In horizontal applications such as ceilings or canopies the distance between the support rails must be reduced to 50% of the distance used in vertical application. The main support rails should be mounted square to the facade support rails. It will also be necessary to temporarily support the panels until the adhesive is fully cured.

Wind loads
Wind loads should be determined through the applicable Regulation.
For Europe wind suction calculation according to EN 1991-1-4.

Fire behaviour
Tests performed according to EN 13823 conclude that TWEHA's Adhesives meet the fire class B-s1,d0 as described in EN 13501-1.

Durability
To ensure sustainable security, we recommend bonding on an (anodized) aluminum substructure. The use of a metal (aluminum) supporting structure is a more sustainable application than the use of a

wooden supporting structure. The applicator has to meet the standards according to BRL 4104, besides working according to these Instructions for use by TWEHA.

Maximum panel size
The elastic properties of TWEHA's Bonding Systems prevent possible deformation of the façade panels due to thermal expansion. This means that façade panels with a maximum diagonal can be bonded with PanelMate.

Minimum joint width
Follow the guideline of the panel manufacturer. From an aesthetic point of view, we recommend a joint of 8 mm.

Working conditions
Possible working temperature of TWEHA's Bonding Systems is between -20°C and + 40°C. The surfaces to be bonded must be clean, dry, and free from dust and grease. During the bonding process the relative humidity must not be higher than 90% and the substrate temperature must be 3°C higher than the dew point. Note: condensation is something different than a moist surface. A moist surface is due to the surface tension, while condensation means that the moisture is on the surface as water droplets. In the event of diverging conditions we advise you to contact our helpdesk or check out at our app TWEHACalc.

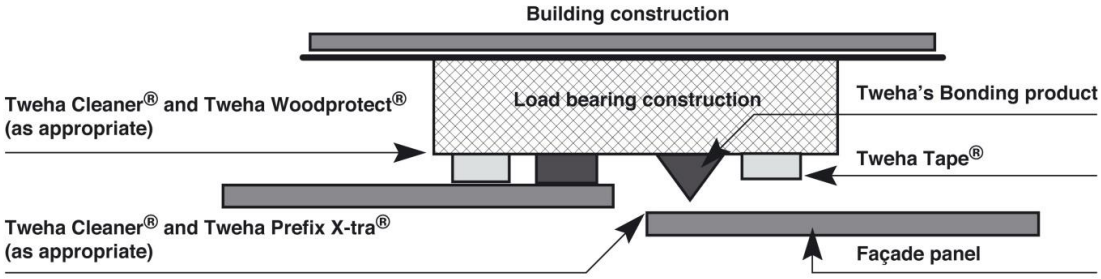
Supporting wall structure
The construction of the supporting wall structure is the essential element when bonding façade cladding. The supporting structure transmits the occurring loads to the supporting wall structure of load bearing brickwork, concrete, wood etc.

This supporting structure is often executed in aluminum, wood or a combination of these materials and should be tested to valid national guidelines. Fixing structures need to be installed according to manufacturers' and suppliers' instructions.
• Determine the exact dimensions of the façade surface with regard to gridlines and levels.
• Check the supporting wall structure (concrete: pressure or tension zone, or brickwork).

Aluminum supporting structure EN-AW-6060 or 6063
• Attach the supporting point and sliding point upright to each other using the designated materials.
• Cut the insulating layer where a load bearing or restraint support will be fixed (this reduces the possibility of insulation leaks!)
• In the support the vertical elements, L-, T- or sleeve profiles are connected which sustain the cladding panels.
Note: per length only one fixed anchorage-point and multiple sliding/restraint anchorage-points.
• Check the supporting structures regarding flatness and strength! The support center-to-center distance depends on the bending tensile strength of the panel, thickness and the panel manufacturers' instructions. Every panel has to be bonded onto a minimum of two vertical support profiles.
• The number of fixing points per m^2 of the supporting structure is determined by the weight of the façade panel and the wind load/ tension to the façade panels.
• The panel can be bonded directly onto the aluminum L- or T- profiles after the TWEHA Cleaner+ has evaporated.

• Note: if the aluminum profiles are provided with a coating, should be determined whether both the adhesion of the coating on the aluminum as the adhesion of the adhesive on the coating is sufficient.

• For bonding onto other types of (preserved) wood: consult our helpdesk.



Supporting structure of wood

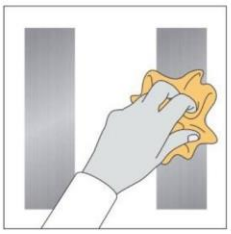
• When using a double-layer supporting structure the basic wooden structure, made of horizontally placed planed beams, they must be fixed using static tested angle brackets on top and bottom.
• Place insulation and if desired damp proof foil according to the manufacturer's instructions.
• Apply the vertical battens. The minimal thickness of the vertical supporting batten, determined by calculation, is 19 mm. Determine the minimal thickness of the vertical supporting batten according to the applicable national guidelines.
• When bonding onto (impregnated) wood always use TWEHA WoodProtect for preservation. Please ask TWEHA for more information. Wood is a natural product and therefore has various changing components. For that reason, an adhesion test has to be performed.
• The wood must be dry (humidity percentage < 18%, drying class 2, air dried).
• Check the supporting structures regarding flatness and strength!

Basic wooden structure with black anodized aluminum Z-profile EN-AW-6060 or 6063

• When using a double-layer fixing structure the basic wooden structure, made of horizontally placed planed beams, must be fixed using static tested angle brackets on top and bottom.
• Place insulation and if desired damp proof foil according to the manufacturer's instructions.
• Apply the Z-profile. Note: one fixed anchorage and multiple restraint points by means of screws through slotted holes per length.
• Check the supporting structures regarding flatness and strength!
• The panel can be bonded directly onto the Z-profile after the TWEHA Cleaner+ has evaporated.

Required width of the supporting structure

End battens and angle joints:	min. 70 mm.
In between battens/profiles:	min. 45 mm.
When open joints or joint profile applicable:	min. 95 mm.


Treatment supporting structure: aluminum EN-AW-6060 of 6063

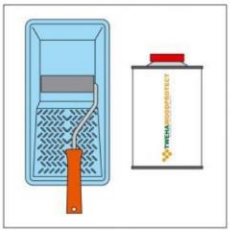
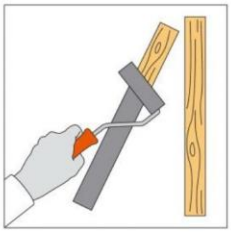
Aluminum, anodized or not, can be bonded onto directly.

- The surfaces to be bonded must be dry, dust- and grease free. To achieve this use TWEHA Cleaner+.
- Cover the front of the metal base construction with TWEHA Cleaner+ and wipe off in one direction, preferably using either plain steel wool, Brillo pads or Scotch-Brite by hand, with a hand pad block or similar. Be sure to dry the part before bonding.
- Allow the TWEHA Cleaner+ to evaporate fully for 10 minutes.
- Ensure that the treated adhesive surface is fully protected against dirt.

Coloring vertical profiles black

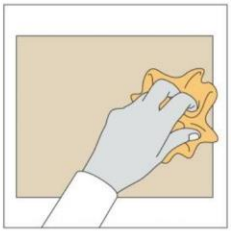
If there is a need to color the aluminum profiles in black, use TWEHA Blacken.

- The surfaces to be bonded must be dry, dust- and grease free. To achieve this use TWEHA Cleaner+.
- Cover the front of the metal base construction with TWEHA Cleaner+ and wipe off in one direction, preferably using either plain steel wool, Brillo pads or Scotch-Brite by hand, with a hand pad block or similar. Be sure to dry the part before bonding.
- Allow the TWEHA Cleaner+ to evaporate fully for 10 minutes.
- The TWEHA Blacken is easy to apply using the sponge cap supplied.
- Shake the TWEHA Blacken tube well before use.
- Apply TWEHA Blacken in one thin, full-cover layer (never more!).
- Do not use TWEHA Blacken on painted wood, multiplex, or other types of wood.
- TWEHA Blacken is not a primer and can be pre-processed. Bonding of the façade panel can take place 30 minutes after applying the TWEHA Blacken.
- Ensure that the treated adhesive surface is fully protected against dirt.

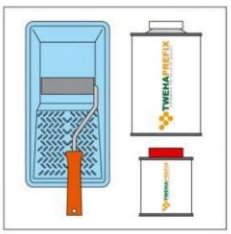
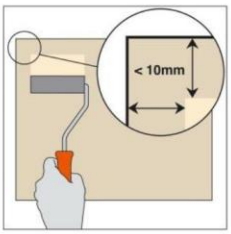
Treatment supporting structure: untreated pinewood or preserved wood

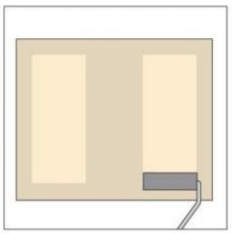
• In case of an exterior application, the untreated pinewood has to be protected all round with TWEHA WoodProtect.
• Preserved wood (creosoted, celcurised or improsol-treated as per NEN 3251/ BRL0601) has to be pre-treated on the bondable side with TWEHA WoodProtect.
• The vertical frame construction or battens must be dry (wood moisture percentage < 18%, drying class 2 (NEN-EN 5461), air dried), dust- and grease free.
• Before being attached untreated white pinewood must be treated with the wood preservation material TWEHA WoodProtect.
• For the application of TWEHA WoodProtect use a paint tray with a clean, fine structure roller. Shake TWEHA WoodProtect thoroughly before use.
• Apply TWEHA WoodProtect in one thin, full-cover layer (never more!).
• Do not use TWEHA WoodProtect on painted wood, multiplex, aluminum or other types of metal.
• TWEHA WoodProtect is not a primer and can be pre-processed. Bonding of the façade panel can take place 2 hours after applying the TWEHA WoodProtect.


Degreasing the cladding slab with TWEHA Cleaner+

The cladding slab must be dry, clean, and free from dust and grease.
• Cover the back of the façade panel with TWEHA Cleaner+ and wipe off in one direction, preferably using a paper tissue or a clean lint free cloth.
• Allow the TWEHA-Cleaner+ to evaporate fully for 10 minutes.
• Ensure that the treated adhesive surface is fully protected against dirt.
• TWEHA Cleaner+ is not an aggressive degreaser and using it has no appreciable effect on the surface of the façade panels. Besides degreasing the surfaces to be bonded, TWEHA Cleaner+ can also be used to remove adhesive residue (before it is cured).




Pre-treatment of synthetic fiber cement slabs or other porous materials such as some types of natural stone with TWEHA Prefix X-tra

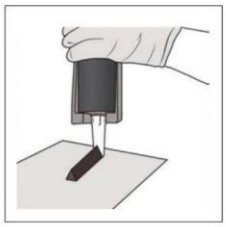
For optimum bonding, pre-treatment with TWEHA Prefix X-tra surface improver is necessary.

- Before treatment the façade panel must be clean, dry, and free from grease. To achieve this use TWEHA Cleaner+.
- Add the full contents of TWEHA Prefix X-tra component B (hardener) to the full contents of TWEHA Prefix X-tra component A (resin). Mix both components well for minimum 2 minutes with a stirrer until the components are evenly mixed. Then pour the substance over into a paint tray to check if the components are completely mixed. Do not add water or other products. Note: do not subdivide the supplied contents of the package!
- Apply TWEHA Prefix X-tra vertically to the area to be bonded (± 10 cm wide) with a brush or fine structure paint roller in one thin, but full-cover layer.
- Apply and process the TWEHA Prefix X-tra within 30 minutes! Note: bonding of the façade panels is only possible after the prescribed drying time of minimum 12 hours.
- Ensure that the treated adhesive surface is fully protected against dirt.
- The surfaces to be bonded must be dry, dust- and grease free. To achieve this use TWEHA Cleaner+.


Application of TWEHA Tape

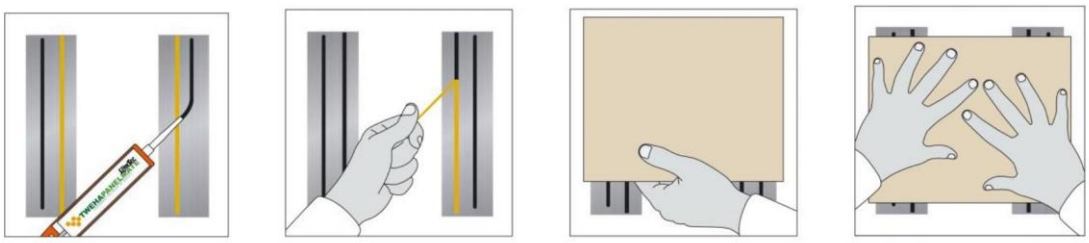
- TWEHA Tape provides the initial bond and guaranties the minimum required glue bead thickness of 3 mm.
- Apply the TWEHA Tape after complete drying of the TWEHA Cleaner+ and-or TWEHA WoodProtect.
- Position the TWEHA Tape vertically in an unbroken strip on the vertical frame construction of the (pre-treated) wood or cleaned metal. Then press down the TWEHA Tape firmly and cut with a sharp knife. For the correct positioning and the length of the TWEHA Tape take into account the size of the support posts, the dimensions of the façade panel and the necessary space for the glue bead. Remove the protective layer only after applying the glue bead!





Apply glue bead

- To obtain the prescribed glue width/thickness of minimum 12 x 3 mm use the supplied nozzle or otherwise cut a standard nozzle in an V-shape of minimum 8 x 8 mm. The V-shape is necessary to prevent air bubbles being trapped and unnecessary loss of adhesion.
- Then cut open the cartridge or sausage, fit the nozzle and by using a glue gun apply the glue bead.
- Apply the adhesive 10 mm away from to the TWEHA Tape in an unbroken required V-shape bead.
- Place the façade panel within 10 minutes, otherwise a skin will form on the adhesive!



Attach façade panel

• Check the supporting structures regarding flatness and strength! The support center-to-center distance depends on the bending and tensile strength of the type of panel, thickness and the panel manufacturers' instructions. Every slab has to be bonded onto a minimum of two vertical battens or aluminum profiles.
• After the prescribed drying time of TWEHA Cleaner+ and, if applicable, TWEHA-Prefix X-tra the façade panel can be applied.
• Remove the protective layer from the TWEHA Tape.
• Press the cleaned side of the panel gently against the adhesive to enable subsequent correction. Press down the panel firmly when it is correctly positioned, so that the façade panel makes good contact with the TWEHA Tape.
• To achieve an optimum ventilation, use the TWEHA RoofGutter Clip!

When applying the glue bead, one has to proceed as follows:

- Apply the glue bead from top to bottom. The glue bead may not be interrupted, otherwise the bonded surface becomes too small, and possibly too little adhesive has been applied to ensure a strong and durable attachment of the façade panel. To apply the adhesive in dots is **not** permitted. This causes extra tension in the panel, because acting tensions are not equally spread.
- The glue bead must be applied on approximately 10 mm distance of the tape. This gives the adhesive enough space to "flow" to all sides when the façade panel is pressed. If the adhesive beam is applied too close alongside the tape, the risk might occur that the adhesive might flow over the tape, through which the tape will not adhere properly and a first adhesion by the tape is not guaranteed. The glue bead may also not be applied too close to the edge of the batten or proile, because the adhesive might flow past it when the façade panel is being pressed.

- After applying the adhesive, the façade panel must be applied within 10 minutes (open time). When one waits too long with the application of the façade panel, the glue bead on the outside will have dried-out so that a skin of adhesive appears (skin-formation). With skin-formation it is possible that there is not sufficient adhesion of the façade panel. When applying the adhesive do not work ahead more than 10 minutes. Only with small panels it is possible to work ahead.

In able to fully encumber the bonded parts, one has to take into account the given time-span (approximately 14 days).

Chapter 9 Attach façade panels

§ 9.1 Functions façade cladding

In newly builds as well as in renovation procedures, façade cladding fulfils several functions:

- Thermal and acoustic insulation
- The formation of a rain-proof screen
- To cover the building in an aesthetically responsible way
- To pass on acting loads on the massive supporting structure

§ 9.2 Joints

The fastening of the façade panels must be executed in such a way that horizontal and vertical joints, at the height of the mutual attachments of the panels, are left open. This is to intercept expansion of the panel due to temperature and/or moisture. This prevents the panels from "butting in on each other". Which could cause the panels to deform. For aesthetic and practical reasons, a joint-width of 8 to 10 mm is frequently used in practise. This also depends on the panel diameter and the expansion coefficient.

The beams can be finished in several different ways:

- An open joint where the beam of wood is finished with TWEHA WoodProtect or the aluminum profile is blackened with TWEHA Blacken.

§ 9.3 Positioning of façade panels

Before applying the façade panel, the panel itself must be inspected for the following:

- Presence of damages
- Possible unacceptable curvatures
- The proper pre-treatment of the adhesive surface (sanding and/or cleaning), according to the instruction guidelines or advice by TWEHA.
- The adhesive surface must be clean, dry, dust- and grease free.

When these conditions have been met, the façade panel can be applied to the façade. The next steps have to be followed:

- Apply a placing beam on the under-side of the façade panel, as an extra assistance. Using a placing beam can only be done before applying the adhesive, to prevent skin-formation. If façade panels have been applied already under the façade panels which still have to be applied, it is best to use distance cubes of the right thickness (= seam thickness).
- Remove the protective foil from the tape.

- Place the façade panel in the right position, on the placing beam or the distance cubes, and press the façade

panel with the cleaned side softly against the adhesive.
- Now position the façade panel exactly on the right place, by carefully shifting the panel. This shifting can only be several millimetres. Shifting it too much can lead to insufficient adhesion of the façade panel.
- Firmly press the façade panel against the tape. Now it is not possible to change the position of the façade panel any more.

§ 9.5 Maintenance or inspection plan for bonded façade cladding

In general, we recommend drafting a maintenance and inspection plan for every façade based on an overall evaluation of the façade structure.
The overall evaluation of the façade structure will determine any failure mechanisms which may play a role in the various components over time. Here, particular attention should be given to potential process faults due to design and/or application errors.

The maintenance and inspection plan should describe the method for investigating whether the failure mechanisms in question have occurred. It should also detail the required inspection frequency and the specific points to be examined during the inspection.
Experience has shown that if there is no immediate reason to perform upkeep on the façade envelope, then it is generally prudent to conduct an overall evaluation at least twice during the service life of the façade cladding. The first evaluation should be performed when the façade envelope is around 1 year old. In practice, the majority of incidents of damage to façade cladding occur within the first few years of delivery, as a result of shortcomings during the design and/or execution phase. A second inspection should be conducted when the façade envelope is at least around 20 to 30 years old, in order to gain insight into the façade envelope's durability. One exception to the above is façade systems cladding a wooden structure, whose durability may come into question after as little as 5 to 15 years.

In cases of façade cladding envelope, this frequency can be increased. Here, you should consider an initial check one year after delivery and a second one two years after delivery. This will provide timely detection or prevention of incidents due to shortcomings during the design and/or execution phase.
After these two years, it is safe to assume that there will be no more incidents due to shortcomings from design errors and/or execution. Therefore, attention should be shifted to subsequent inspections focusing on durability and ageing in both the structure and the components in the façade structure. Here, we recommend conducting an inspection once every five years, starting immediately after delivery.

You can use visual inspections to 'monitor' the façade cladding. This can be done, for instance, by inspecting the most critical sides of the building's façade, either visually or with endoscopy. In cases of noticeable anomalies, you can proceed with a destructive test if necessary. Destructive testing with the possibility of repair can be performed by using a cutting wire to remove one or more façade panels and visually checking whether any detectable changes have occurred. In this

inspection, check not only the bonding adhesion, but also the structure, and assess the façade panel for discoloration, deformities, corrosion, cracks in the glue and for cracking/detachment between the glue and the mounted substrates.

Checklist for first visual inspection:

1. Are there any loose parts on one or more façade panels? Check the corners of the façade panels in particular.
2. Are there any major deformities in the façade panel, such as concave or convex warping between the different studs in the underlying structure?
3. Is there any cracking or breakage in the façade panel?
4. In the morning, is the underlying structure visible through the façade panel due to condensation (which may be an indication of inadequate ventilation)?
5. Are there adequate ventilation openings in the façade (large amounts of moisture behind the façade panels is an indication of inadequate or blocked ventilation)?

If any of the anomalies mentioned above is detected, by means of endoscopy or destructive testing, then further study is necessary in order to determine whether there may be:

1. Blocked ventilation (due to bulging insulation or vapor barrier)
2. Glue strips applied incorrectly or in the wrong location.
3. Deformations in the façade panel.
4. Glue layers of inadequate thickness.
5. Cracking in the glue strip.
6. Detachment of the glue on the stud frame and/or the façade panel.
7. Corrosion or wood rot on the underlying structure.
8. Anomalies in temperature and humidity.

Another option is to check the strength of the glue by applying a uniformly distributed load on a mounted façade panel. For this check, use a vacuum system, made up of two rows of three vacuums each with a diameter of approx. 300 mm connected in a uniformly distributed manner at the location of the underlying structure. Determine the applicable load based on the location, building height, wind shape factor and material factor in accordance with (local) Building Act.

Afterwards, appropriate measures can be taken according to the nature and severity of any findings.

One of the main causes (but not the main cause) of glue failure is penetration of moisture into the façade panel and/or underlying structure. It cannot be emphasized enough that adequate ventilation is necessary for durability of the structure. This ventilation will ensure that the underlying structure is able to dry out, which can prevent wood rot/corrosion.
It also prevents large differences in temperature between the front and back of the façade panels. This, in turn, limits expansion and contraction of the underlying structure and the façade panels.

In short, the following steps should be followed in the inspection:

1. Gather all available information on the design of the façade cladding,

on the implementation of the façade cladding and on any maintenance work performed.
2. Based on the information available, examine which failure mechanisms could play a role in the façade cladding in question. This examination must be carried out for each individual component of the façade envelope, i.e. both for façade elements, the underlying structure and their connections.
3. Visually inspect the façade cladding. During this inspection, all visible shortcomings must be recorded. It is also necessary to check very carefully whether or not any potential failure mechanisms established in step 2 have actually occurred.
4. Analyze the information from the first three steps. This analysis should demonstrate whether enough information is available for a reliable assessment of the overall façade cladding. If there is, then proceed to step 7; if not, go to step 5.
5. Conduct an additional detailed examination on the façade envelope. This examination must go beyond a mere visual inspection and will usually amount to (semi)destructive testing.
6. Analyze the additional information from step 5.
7. Give a final assessment of the façade envelope.
8. Give any relevant recommendations for maintenance and repairs.

§ 9.5 Removing façade panels

After the façade panel has been gently pressed against the adhesive, the façade panel cannot be removed from the façade again without consequences, because for example, the positioning was not right. If the façade panel is removed even if the adhesive has not hardened yet and the open time has not yet passed, the adhesive has to be removed and be re-applied.

To be able to remove the façade panel and to re-apply it, one has to work as follows:

- If the adhesive has not hardened completely, the panel can be pulled loose from the façade. With the help of a putty knife, the applied adhesive can be removed from the framework and the panel. As soon as the largest amount of adhesive has been removed, the last bits must be cleaned away using TWEHA Cleaner+. As soon as the Cleaner+ has completely dried out and new tape has been applied, the bonding can start again according to the described procedure.
- If the adhesive has completely hardened, the façade panel can be removed by cutting panel on the backside, using a so-called wire saw. The wire must be approximately 1 mm thick and longer than the width of the panel. Attach grips on the ends of the wire and position the wire in the open joint seam on the upper side. Cut with a sawing motion through the 3mm thick glue bead. As soon as the panel is loose, the left-over adhesive must be removed using a chisel or a Stanley-knife. After the adhesive has been cleaned away and the beam has been made dust-free, one can proceed with bonding in the described procedure.

Attention, the adhesive thickness has to be 3mm.

Chapter 10 Constructive calculations and consequences

Most attention in current research of adhesive bonding is focused on the selection of the most optimal adhesive system, as well as on the control of the application process. This is not so surprising, given that a proper combination of adhesive and pre-treatment, in relation to the materials and the ambient conditions, must be chosen in order for the adhesive bonds to be successfully applied. The application itself is an important step in that process; following the adhesive procedures incorrectly or not controlling the ambient conditions may eventually lead to adhesive joints which do not meet the necessary requirements. For constructive applications, however, the designing engineer must be able to demonstrate that the adhesive joints will be able to withstand the load they must carry for the total duration of their lifespan. Thus, proper guidelines and static testing are vital when designing reliable adhesive joints and offer new opportunities for constructive application of adhesive joints.

§ 10.1 Choosing bonding

Bonding, alongside welding, soldering and mechanical joining, is but one of the many methods used to join materials to each other. The industrial engineer and designing engineer must choose which method to use case by case. When making the choice for a certain method it is necessary to take into account many considerations, such as:

1. **Which requirements are stated for the specific joint?**
   The characteristics of the joint will be determined by the design of the joint in relation to the materials and joining techniques that have been chosen. The design itself is also a factor, a very important one in fact, which determines the characteristics of the joint. Sometimes clear requirements must be met regarding the flexibility of the joint, the conduction, and regarding its resistance to the effects of UV-light, its resistance to fatigue, etc.

2. **Which requirements are stated for the adhesive product?**
   This could pertain to strength of the adhesive, and thus also to the strength of the adhesive joint, as well as to durability regarding the influence of air and moisture, temperatures (including extremely high temperatures of a fire, smoke formation, and such), impact loading, etc. Aesthetic aspects too can play a substantial role in this process, as each method influences the appearance of the façade cladding in its own manner.

Choosing a certain joining technique also depends on the kind of façade cladding. Dissimilar materials will be not be welded together easily, or not at all, certain metals or plastics will be very difficult to bond, and other metals and plastics will be difficult to weld together, while damage to the materials, caused by drilling holes, may be undesirable from the point of view of strength, fatigue characteristics and / or from an aesthetic point of view.
In addition, there is still too little attention being paid to the fact that the choice of

materials can partly also depend on the most desired joining technique.

The variables of and during bonding are also of great importance. This, for example, concerns the run time, the expected performance of the joint (partly depending on the design), the laboriousness (due to the necessary pre-treatment, for example), and any required post-curing and / or post-treatment.
So too may the realisable level of quality assurance be a determining factor.
Naturally the choice made for a certain joining technique will eventually be determined based on economic and aesthetic considerations. Furthermore, it is often very difficult to weigh the costs (as well as the benefits!) of several joining techniques against each other. In order to calculate the price of a joint, one must not only take into account the price of the adhesive, for example, but also the costs of the application equipment, the cycle time, design time, etc.

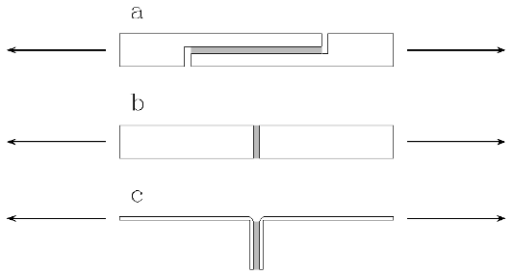
When designing a constructive adhesive joint, the designing engineer goes through an initial, a conceptual, an optimising and a validation phase. The following aspects play an essential role in each of these phases:

- Selection of a bonding system;
- Constructive design;
- Development of a production process.

In order to attain a successful application of the bonded joints, the designing engineer must have a solid grasp of the knowledge regarding these aspects.

§ 10.2 Mechanical stress of an adhesive joint

In order to bond two materials with an adhesive, the designing engineer has an almost infinite amount of possible solutions at his disposal. The lay-out of the illustration below demonstrates a rough lay-out of the mechanical stress that may arise in the bonded constructions.



When designing, it is important to know which loads and stress will occur during the operational period. (Avoid line transients: these are mostly caused by a elastic modulus of the materials to be bonded, which is too low due to the minimal thickness of these materials and due to fixed adhesive layers). The most important loads that affect the bonded joints are:

- Static loads; loads with a short duration.
  An occasional, non-variable load is employed for a short period of time.
  Example: window washing equipment "parked" against the façade while the windows are being washed.
- Impact loads.
  The load is applied but for a fraction of a second, during which the response from the material characteristics clearly will be different than in a static situation.
  Example: window washing equipment becomes detached from the façade due to suction from the wind and

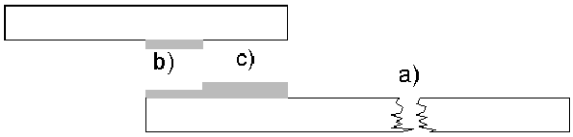
strikes the façade with an impact load when it returns to its original position.

- Static loads; loads with a long duration. A static load is applied for a longer period of time, which may cause the bonded joints
  to start to "creep".
  Example: A façade panel's dead weight.
- Fatigue load.
  The size of the load alternates during time, which may lead to the forming of tears in
  the adhesive layer that may continue to grow in size.
  Example: fluctuating wind pressure / suction.

Aside from these "mechanical" loads, the designing engineer must also take the ambient conditions into account, which have to do with alternating temperatures, rain water, transportation of moisture through the construction, and UV radiation. The strength of the bonded joint may decrease due to this "ambient load", and it is crucial to the design that the magnitude thereof should be known, or that the possibilities to reduce deterioration should be known.

Should these loads not be taken into account, adhesive joints may give way in the ways described below. If, however, construction occurs according to the regulations this will not happen!

- in one of the materials;
- in the adhesive layer (cohesive failure);
  The failure will occur where the tension is most unfavourable;
- On the border between the adhesive and the material (adhesive failure);
  There is also the possibility that an in-between layer, a cladding on the material, for example, may fail.



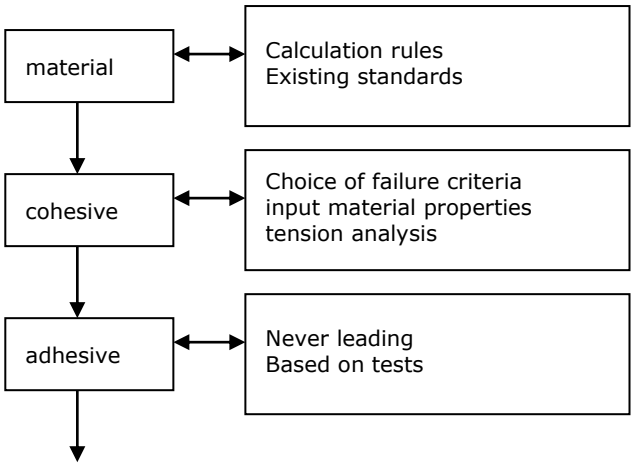
failure: a) in the material b) in the adhesive layer c) on the border between adhesive and material

§ 10.4 Form of failure, material properties and tension analyses

Using a suitable model, the distinctive force becomes calculable. What constitutes a suitable model for the adhesive joint to be designed is up to the designing engineer; he or she will be able to attain the necessary clarity to make that decision by answering the following questions:

- What is the expected form of failure?
- Which are the relevant and important material characteristics that ought to be considered and how are these determined?
- Which theoretical model can be used to run a suitable tension analysis?

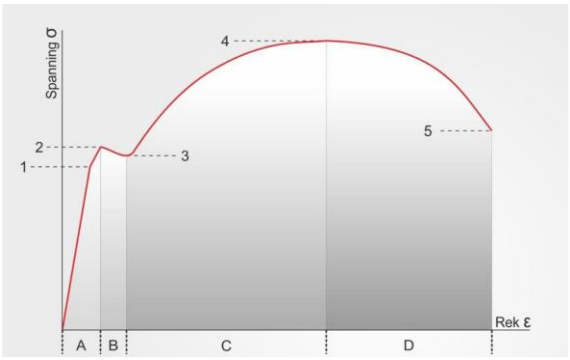
If these questions have been answered, the designing engineer will be able to calculate the distinctive force of the bonded joints and subsequently test them to see whether or not they meet the necessary requirements. There are three ways in which a bonded joint may fail. For each of these forms of failure a further explanation will now be given as to how the force (strength) must be tested.



testing strength form of failure

§ 10.5 Characteristic shear response of structural adhesives

The stress-strain diagram shows the mechanical properties of the adhesive. From the diagram it can be deduced how much, at an amount of applied stress (vertical axis), the material stretches (horizontal axis). To properly understand the stress-strain diagram, it is important to know a number of concepts.



In the first phase A of the stress-strain diagram, an elastic behavior is shown. As soon as the applied stress is removed, the material will regain its original length. There is complete restoration. In this first phase, the stretch is proportional to the applied stress. This is also called linear elastic or proportional distortion. The limit of
the proportional elasticity is called the proportionality limit. The proportionality limit is indicated with point 1. From the proportionality limit to the elastic limit, there is also elastic deformation, but this no longer runs linearly. Non-linear elastic means that with increasing stress the length of the material increases relatively more, or the increased strain is greater than the increased stress.
The elasticity limit (upper yield strength) indicates where the deformation is elastic in nature. The material under this point will return to its original length and shape when the stress is removed. The elasticity limit is just below the elastic limit or upper yield point, indicated with point 2.
In the phase B, the yield point indicated by point 3, the material begins to flow. The applied stress creates plastic deformation. From here, the material is permanently deformed.
From the yield strength to the maximum stress there is plastic deformation (this phase, designated C, is called reinforcement). The maximum stress is the limit to which the material can deform without causing constriction / breakage. The the actual rupture strength or ultimate strength is indicated with point 4.
Then the material is pulled apart so much that it dilutes locally until it finally breaks, indicated by point 5: the rupture strength or breaking stress. This is the point at which the material ultimately collapses under the applied stress. The constriction preceding this begins at the tensile strength until the break point is reached. The breaking stress is lower than the maximum stress.

Theoretical surface failure of a bonded connection

The durability of SMP adhesives (Silyl Modified Polymers, also known as MS Polymer Adhesive (Modified Silane Polyether) is good, because they are only sensitive to high concentrations of solvents, which in practice will be used little on facade panels.

The cohesive properties of the used adhesive products from TWEHA are known. This is a constant value. Because this material property is not substrate dependent, the characteristic strength can be determined on the basis of the manufacturer's specifications.

The adhesive properties, on the other hand, are variable under the influence of the respective substrate and environmental conditions. It is therefore important to determine whether long-term adhesion is at all possible to a substrate.

A bonded failure mechanism is how an adhesive bond can break. In the rare cases that an adhesive connection still comes loose over the years, it is caused by poorly execution. In those cases, it is not the adhesive product itself that is responsible, but caused by poor implementation (f.e. insufficient (pre-) treatment of the substrate), incorrect detailing or use of another, often unreliable, adhesive system.

The failure mechanism of an adhesive connection will have to be approached as follows: an optimum adhesive connection fails with a cohesive fracture. This is a breakage in the adhesive material.

A bonded connection consists of a maximum of 9 components, namely:

- the part to be bonded (the façade panel)
- the interface between adhesive or surface improver (1) and the part to be bonded (façade panel)
- in case of densification of porous surface: a surface improver (1)
- interface between adhesive and surface improver (1)
- the adhesive
- interface between adhesive and a wood preservative (2)
- in case of application of a wooden framework: a wood preservative (2)
- the interface between substrate and adhesive or a wood preservative (2)
- the substrate (framework / facade / supporting structure

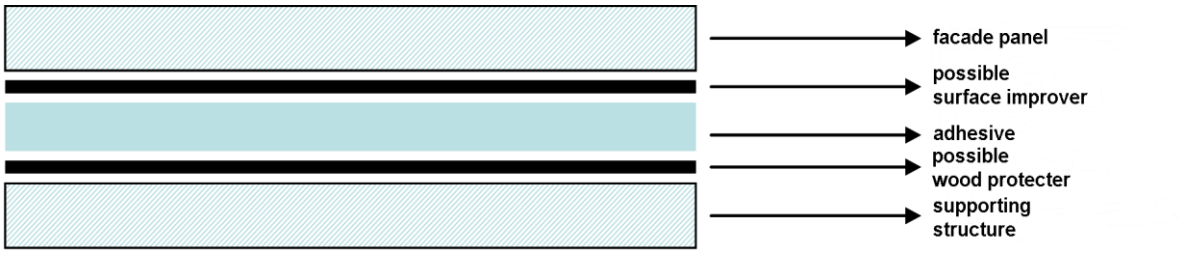
Newly made adhesive bonding of two materials depends on the strength of the aforementioned nine factors (links).

In order to achieve a good quality adhesive connection, quality control must be achieved by implementing appropriate methods and measures. The aim is to achieve a quality that only varies within acceptable limits, depending on the economic and safety consequences in case of failure of the connection.

And the failure mechanism can be analysed as follows:

An optimal bonded connection fails (collapses) with a cohesive fracture. This is a break in the adhesive material.
However, a bonded connection can collapse in several ways. For each of these failure forms it is indicated how the strength should be tested
The bonded joint can be represented as a chain, the weakest link of which determines

the strength. There are nine failure links to distinguish, namely:



- cohesion strength of the façade panel itself;
- adhesion strength between the dried surface improver and surface façade panel;
- cohesive strength of the dried surface improver itself;
- adhesion strength between the cured adhesive layer and the dried surface conditioner;
- cohesive strength of the cured adhesive layer itself;
- adhesion strength between the cured adhesive layer and the dried wood preservative;
- cohesive strength of the dried wood preservative;
- adhesion strength between the dried wood preservative and the support structure;
- cohesion strength of the supporting structure itself.

In the case of a further assessment of the quality of an adhesive joint, the quality of these nine links must be known.
The system can fail on or in each of these components as well as on the boundary layers (where the components contact each other). This does not have to be limited in or to one of these components, but this can also be divided over the different components. In the case of failure at the interfaces, is called 'adhesive failure'. In the case of failure in the adhesive, the primer or the substrates is called a 'cohesive failure'.

It is also possible that the substrate or the part to be bonded fails. After failing it is very important to find out what the cause of the failure was and where it occurred. In this approach, pre-treatments of the substrate or part to be bonded (for example with primers) are considered.
In the specific case of façade panels, the supporting structure is a substrate and the façade panel the part to be bonded. In principle, many combinations are possible between the materials in this system. In order to introduce some systematics here, we now have an overview of the possible causes of failure in each of the components.

Possible causes in the event of a failure of adhesive connection

- the supporting structure

Thanks to a good adhesion between the facade panel and adhesive, the supporting structure can fail, so that a piece of its material (f.e. wood) can be found on the failed system. Another possibility is that one of the components from the adhesive affects the supporting structure.

- the interface between supporting structure, wood preservative or the adhesive

The adhesive or wood preservative has not properly adhered to the (pre-treated) surface of the supporting structure or has been released over time. This should result in a "clean" surface after failure, showing only a small part of the adhesive or, for example, wood preservative.

- the surface improver and / or wood preservative

A cohesive break in the surface improver or wood preservative is very clearly visible because it adheres both to the substrate (the façade or supporting construction) and the adhesive.

- The adhesive

The adhesive itself is torn; cohesive failure. This can be related to creep or, for example, embrittlement due to chemical attack. This is very clearly visible because it adhered to the substrate (the façade panel or supporting structure) on both sides.

- - interface between adhesive and surface improver and/or wood preservative

The adhesive or surface improver has not properly adhered to the (pre-treated) surface of the façade panel or has been released over time. This should result in a "clean" surface after failure, showing only a small part of the adhesive or, for example, wood preservative.

- The interface between adhesive or surface improver and the façade panel

The panel has been released due to a poor adhesion between adhesive or surface improver on the façade panel. This is due to poor adhesion of the adhesive or surface improver on the façade panel, which can be caused by insufficient pre-treatment. It is also possible that an adhesive has been used that affects the façade panel.

- The façade panel

Finally, the material of the façade panel itself can also fail, leaving a piece of façade panel behind on the façade with the adhesive. This could happen, for example, because a bonded glass plate breaks.

Experiences

In the four decades that bonded façade cladding are used, relatively few cases of damage are known. Experience figures and research teaches us, if there is a failure of the adhesive connection, causes can generally be subdivided as follows:

1. In 45% of cases, the failure is due to:
   - o incorrect structural design and / or implementation of the connections. The durability of a connection is largely determined by the way in which it is established. In most cases, façade panel bonding systems come with a processing instruction with instructions for pre-treating the façade, applying products and the conditions under which bonding can take place. These instructions are often very detailed and the environmental factors must fall within a bandwidth (for example the air humidity or the wood moisture content of the framework).
   - o corrosion of embedded metals;
   - o failing construction to accommodate tolerances, displacements and / or differences by thermal expansion;

2. In 40% of the cases, a strength reduction of the subsurface or support structure as a result of exposure to the "outside world" was found;
3. In 15% of cases, as a result of leakage towards the inside of the cladding construction, in combination with the absence of a drainage and / or drainage system for penetrated water.

In accordance with available experience from practice, the risk of damage due to mechanical aging (creep and dynamic loading) of the adhesive system is low. On the one hand, this is the result of a relatively low static load on the adhesive system, since much more bonding material is often used than theoretically is required to absorb stresses due to the weight of the façade panel and the occurring wind load. On the other hand, the applied adhesive systems are hardly sensitive to a dynamic load caused by, for example, the wind.

§ 10.5 Ageing

Where constructions are concerned, water vapour and moisture always have a part to play. In the Netherlands, the relative humidity outdoors is an average of 83%, the temperature is an average of 9,3°C, rain on an average of 130 days per year, and in buildings, during a large part of the year, there is transportation of moisture from the warm indoor climate outward. (source: TNO report 97MI-00923)
Despite the fact that the adhesive hardens and sets with the help of moisture, due to the lack of figures based on experience, up until now, the principle is followed that under such conditions, the strength of the bonded joint deteriorates as time goes by.

There are still many uncertainties regarding the mechanisms and processes that play a part in the ageing of a bonded joint. The conditions that have the greatest effects are water (both as fluid and as vapour), alternating temperatures, duration of exposure and constant stress. In addition, scientists are of the opinion that the effects of water may be the most important factor that affects the ageing process.

Thus, the performance of the adhesives may, amongst other things, be affected by:

- Plastification of the adhesive due to absorption of moisture, causing the strength and rigidity to decrease
- Water molecules reacting with the adhesive, causing the strength and rigidity to decrease
- Expansion of the adhesive, causing residual stress to build up in the adhesive layer
- Tear forming in the glue bead causing the strength to decrease

The performance of the joint between the adhesive and the material may be affected by:

- Repression of the adhesive by water molecules
- Changes in the chemical bonding between the adhesive and material, causing the strength to decrease
- Corrosion of the surface of the material, causing the strength of the construction to decrease to zero.

The aforementioned negative effects do not apply to an MSP adhesive as it is a moisture-setting product. It ought, however, to be clear that the diversity of effects makes it difficult to accurately predict the decrease in strength.

In each design of a bonded joint, the designing engineer must ask himself what the effects of ageing will be on the strength. Not only the conditions and the adhesive, but also the surface of the material, the choice of pre-treatment and the controlling of the conditions during production play a part in this.
These days, a correct assessment can only be made by running ageing tests.

In order to restrict the duration of such tests, accelerated ageing has become the most commonly used method, involving reaction processes being accelerated at high temperatures. The conditions too, can be enhanced, for example, by simulating changes in temperature and humidity causing the ageing process to intensify. When running such tests, it is an art to make wise choices, as the conditions ultimately must be able to reflect reality. In addition, there are still many uncertainties regarding a good way to translate the data of the test into real conditions. For this reason, an assessment by an expert is required for each separate case.

Series of tests have been executed in order to gain experience with regard to estimating and forecasting ageing behaviour. These tests have recorded practically no decrease of the strength in a number of joints. The assumed variables in these series of tests are that the dominant air humidity is equal to 95%; using test samples out aged by 40 years.

As there are no real available figures based on experience regarding the ageing process, it must be concluded that any decrease in strength clearly affects the reliability of the bonded joint. This factor should be taken into account in the calculation rules. It is for this reason that it has been established in the BRL 4101 that the distinctive strength should be reduced by a conversion factor η.

§ 10.6 Calculation models

In construction, it is preferred that bonded joints should be placed as overlapping joints that absorb the most stress in the case of shear. More than 50 years ago the first models where drawn up to calculate the stress on, and elasticity of, adhesive joints. Since then, a great deal of extensive research has been made in that field. Shear stress and tensile stress applied vertically onto the adhesive layer, currently, seem to be the most important factors.

According to established methods of calculation, there are calculation rules for the calculation of the characteristic value of the strength Rk; values with an underestimating probability of 5%, as well as nominal (average) values, respectively, were used for the input of the parameters of the material characteristics and for geometric purposes.
In order to ensure that the value of the strength Rd meets the reliability requirements, the characteristic value is increased by the conversion factor η due to partial safety factor γR.

§ 10.7 Stress on the façade constructions

The actual goal of bonding façade panels is to absorb the stress of the loads that exert their forces on them. If the panels were to float in the air by themselves, without moving out of place in the wind, they would not have to be bonded at all. Façade panels, in fact, have no constructive (supporting) function in a building. Floating façade panels, however, do not exist, and so they must be bonded in order to be able to resist the stress that is exerted upon them.

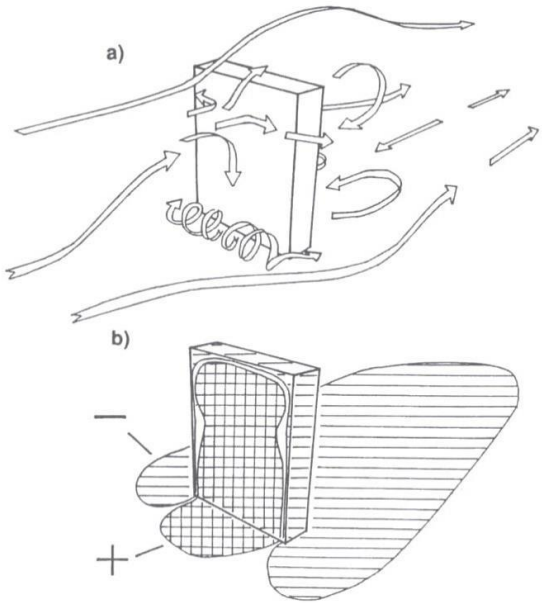
§ 10.7.1 Weight of the façade panels

Everything on earth that has any weight must be supported in order for it not to fall. This is an effect of gravity. Façade panels too undergo the forces of gravity and must be supported by the supporting structure. Thus, the forces are transferred through to the bonding.

- Weight of the façade panel is a constant load.
  As such, this load is always present. Thus, the bond will not only have to be strong enough on the short term, but also for the long term. Moreover, the bonded façade panel must not keep sagging, meaning that the bonding may not 'creep' over time. For this reason, a fairly large safety margin has been built in to cope with the stress from its dead weight. A safety factor of 10 is assumed in construction.

- The bonding receives stress by shear. Due to its dead weight, the panel has the tendency to sag compared to the supporting structure, which causes shear in the adhesive layer.
  The strength of the bond to withstand shear is very important to the panel's dead weight. The so-called shear strength of the adhesive layer must be a minimum of 1 N/mm^2. The value resulting from the test can be used as a variable for construction. Using this value, it can be calculated how much adhesive surface will be necessary to carry the weight x the safety factor of the façade panel. When determining the value, the ageing of the adhesive must also be taken into account.

§ 10.7.2 Windloads explained



Wind is nothing more than moving air. When a building, for example, stands in the wind the moving air comes to a standstill against it, which causes pressure. Wind, however, is a dynamic process: gusts of strong wind interchange with soft breezes. Furthermore, swirls of wind form near

the corners and edges of a building, because of which alternating forces can form: mainly pressure, but also tensile force caused by so-called 'wind suction'. The bond must be able to absorb this pressure and tensile force, which is exerted on the façade panels.

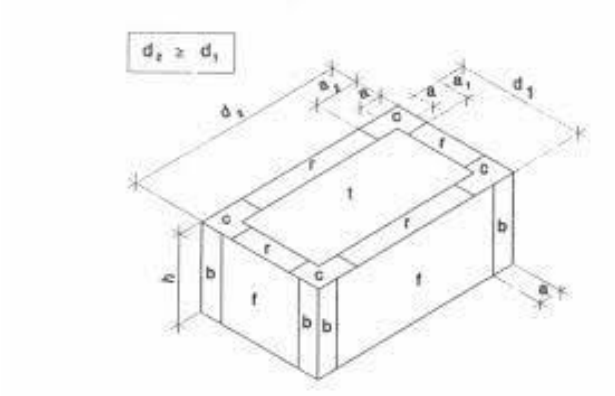
So, wind originates due to air movement from high pressure- to low pressure areas. Due to attrition with the earth's surface (buildings, forests), however, the air movement in the lower air layers will be slowed down: wind speed increases proportionately by height. This degree of increase is again determined by the roughness (construction) of the earth's surface. Above sea e.g. a less high air layer will be slowed down. This explains why in the coastal regions the wind blows on average more than in inland areas. Due to the friction of the air layers, swirls and gusts also occur. Especially in constructions that are sensitive to time-varying wind loads, it is considered advisable to take this into account. Wind nuisance occurs not only within a large complex of buildings such as e.g. the centre of a city, but also in the immediate vicinity of a building.

- • On the one hand, the fact that constructions such as buildings, cranes and towers experience certain wind loads must be taken into account of.
- • On the other hand, one has to deal with the occurrence of wind nuisance, especially in the vicinity of tall buildings.
- • Another important factor that must be taken into account when orienting buildings, in relation to each other and locating the entrances, etc., is the most common wind direction.

The wind causes a load on a structure, where we can distinguish between external pressure (or suction, or friction) and internal pressure (or suction). Local Standards therefore indicates that the most unfavourable combination (s) of simultaneous effective wind loads must be directive in the calculations.

Term used	Beaufort scale	Speed in km/h	Speed in m/s	Speed in knots
Calm	0	Less than 1	0 to 0,2	Less than 1
Weak wind	1-2	1 to 11	0,3 to 3,3	1 to 6
Moderate wind	3-4	12 to 28	3,4 to 7,9	7 to 16
Strong wind	5	29 to 38	8 to 10,7	17 to 21
Strong wind	6	39 to 49	10,8 to 13,8	22 to 27
Very strong wind	7	50 to 61	13,9 to 17,1	28 to 33
Storm wind	8	62 to 74	17,2 to 20,7	34 to 40
Storm	9	75 to 88	20,8 to 24,4	41 to 47
Strong storm	10	89 to 102	24,5 to 28,4	48 to 55
Very strong storm	11	103 to 117	28,5 to 32,6	56 to 63
Hurricane	12	More than 117	More than 32,6	More than 63

Local Standards (as in Europe the Eurocode 1, the European standard for determining the wind load on buildings (EN 1991 1-4 including the accompanying National Annexes)), are the basis for all your calculations. Depending on, among other things such as geographical differences, the building height and the surroundings, these Standards indicates a value for the maximum 'Windloads'. In the Eurocode 1 it is a measure of expected value of wind in a storm that can occur once every 50 years.

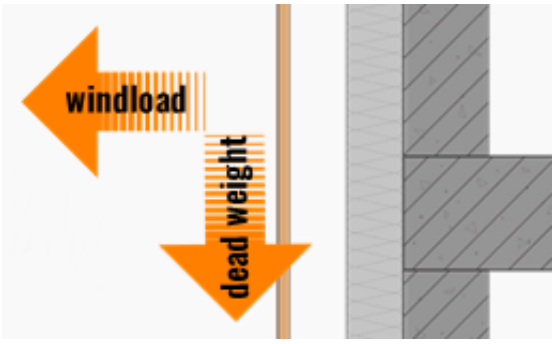


At the corners or at the edges of a building, the wind loads are much heavier and turbulent than in the middle area due to wind-suction. Therefore Standards provides special calculation rules to

determine the width of the strip of the building- and roof-edges on which a heavier and more turbulent wind load occurs. Standard indicate that the external load must be regarded in a number of situations both in the form of pressure and in suction. A local external form factor expresses the fact that high wind loads can occur in typical local situations. Thus, for example, the load resulting from wind suction often will be normative along the edges of a building.
New buildings to be reconstructed in an already built-up area mutate the wind load on the existing buildings. This all related to the shape and dimensions of the buildings, the mutual distance and the roughness of the surroundings. In such cases the wind load has to be determined by measurements on scale models in a wind tunnel model. This has to be carried out in the so-called design phase so the influence of, and on, the existing surrounding buildings can be taken into account. This is especially for construction engineers and façade builders of importance, but also for owners of buildings where a new building is scheduled nearby.

- Wind load exerts a tensile or a compressive stress on the bond. Due to the fact that the compressive stress is never critical where a bond is concerned, the tensile stress is of importance in this case. The so-called tensile strength of the bond must be a minimum of 1 N/mm^2. Here too the resulting value of the test will be used as a variable for construction. This variable can be used to calculate the adhesive surface necessary to withstand the wind stress exerted x the safety factor. As was the case with the shear strength, the ageing of the adhesive must be taken into account in the case of the tensile force.

In order to construct taking wind stress into account, the fact that wind stress will be greater at corners and edges of the building than in the middle of the façade has been taken into account, which is why the spacing at the edge of a façade is often made smaller.



§ 10.7.3 Contraction and expansion

When façade panelling is exposed to maximum sunlight it will begin to heat up. The panelling will be heated up far more than the supporting constructing will, as it is not directly exposed to the sun. Furthermore, the panelling allows for partial thermal insulation. Panels that heat up begin to expand, while the specifications of the supporting structure will not change. The bond must be able to compensate for, and cope with, these differences, and must remain fixed to both the façade panel and the supporting structure.

Due to the fact that the panel becomes larger than the supporting structure the bond will begin to shear. A similar, though

opposite, effect will occur if the façade panelling becomes colder than the supporting structure and starts to contract. The adhesive layer will only be able to compensate for the shear of the panelling caused by contraction or expansion, if the adhesive layer is adequately elastic and thick enough.

Elasticity
When bonding façade panels, contraction and expansion of the panel caused by temperature and/or moisture, are important aspects which must be taken into account. It is a well-known fact that HPL-panels are particularly prone to considerable contraction and expansion due to the climate. For such a panel, it is crucial that the size of the panel should match the elasticity of the adhesive. The elasticity depends on the applied adhesive and may vary considerably per adhesive. Generally, an adhesive with a high elasticity will have a lower strength. For this reason, the choice of the adhesive is often made based on the strength and elasticity of the adhesive and the expansion coefficient of the façade panel. MetalMate and Mosil HSP are very strong adhesives with a high elasticity.

Calculation of the maximum dimensions of panel
The permitted maximum elasticity of an adhesive has been calculated for KOMO certified adhesives. This elasticity may be used to ascertain what the maximum dimensions may be of panel that may be bonded. The calculation of permitted maximum dimensions of a panel is as follows:
The KOMO certificate pertaining to the adhesive states the permitted maximum elasticity of the adhesive system in millimetres (taking into account a safety factor of 2,5). This elasticity may be used, together with the expansion coefficient of the façade panel, to calculate what the maximum diagonal measurement of the façade panel may be.

Formula for the maximum of the diagonal measurement of the panel:

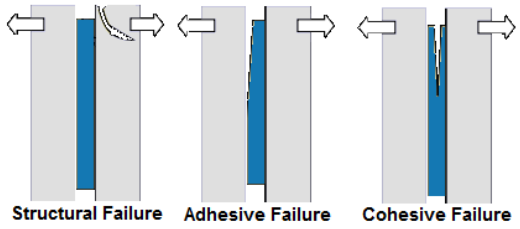
$$\text{Maximum diagonal measurement (m)} = \frac{\text{expansion coefficient of the panel (mm/m)}}{}$$

Thickness
In principle, the double sided self-adhesive tape, will ensure a fixed adhesive thickness of 3 mm. Thicker adhesive layers (greater than 3 mm) are useful to compensate for the expansion or contraction behaviour of the panelling, as thicker adhesive layers are more elastic and more capable of absorbing movement (this only reigns true for the thickness of the adhesive layer, not for its width). Thus, applying a thicker adhesive layer may be the solution.

Important: A problem that may occur when using thicker adhesive layers is greater/more creep.

Chapter 11 Application errors

Besides selecting a suitable adhesive system and optimising the constructive design, the designing engineer formulates a suitable assessment method, using the procedural instructions of the application procedure. The choice of the means of production and the order of the procedural steps are crucial in this. As a result of several factors in production and conduct of business, all sorts of errors may occur in the adhesive (bond) that may affect its reliability. Important factors, for example, would be the ambient temperature, the temperature of the substrates, the relative humidity, the purity of the surfaces to be bonded, the spreading of the adhesive across the surface, the time period between the application of the adhesive and the pressing, and the time period between the application of the Cleaner+ and that of the adhesive.



Type of failure: cohesive
In case of a cohesive failure in the adhesive, there will still be an adhesive layer on the surface at both material sides. In that case there is an excessive tensile or shear stress, in which the breaking stress in the adhesive joint has proved to be the critical factor.

Because this material property does not depend on the features of the substrate, the characteristic strength can be determined on the basis of the manufacturer's declaration which is determined according EN 54505.

The calculation rule of the model must be such that the result corresponds to a probability of inferential statistic is < 5%, so that the required reliability is achieved (the minimum strength is determined from tests and then reduced by a material factor).

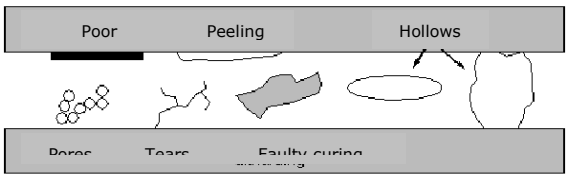
Type of failure: adhesive
In the case of an adhesive break, the adhesion of the adhesive to the substrate will prove to be the limiting factor and thus the weakest link in the connection
The bond breaks are due to the fact that the physicochemical connections are not created between the adhesive and the substrate.

Even for the failure of the adhesive joint at the interface between the adhesive and the substrate, hardly any theoretical models are available. As long as there are no good models for adhesive collapse, the design philosophy is used, the starting point is that this collapsed shape may never occur.

Determination that an adhesive break does not occur can only be done with the help of tests. For this reason, the characteristic strength must be determined for each substrate on the basis of a test series

§ 11.1 Possible flaws in the adhesive joint

The adhesive layer of the bond can contain several kinds of flaws. A distinction ought to be made between the flaws of the set adhesive layer and the flaws situated near the bordering space between the adhesive and the material.



overview of flaws in a adhesive joint

A number of these shortcomings may already be caused during the manufacturing process, and another number of these may be caused during the operational lifespan of the joint.

Flaws that may occur during adhesion, and the causes thereof, are:

- **Poor adhesiveness**
  Caused by a dirty adhesive surface, pre-treatment carried out in a faulty manner, or an unsuitable adhesive/material combination, the adhesiveness between the material and the adhesive layer is insufficient.
- **Pores in the adhesive**
  These are mostly the result of insufficient pressing of the parts to be bonded. This occurs mainly in the case of fumigating adhesives, for example in the case of one-component (solvent-containing) polyurethane adhesives. Air pockets may, however, occur in dual-component adhesives as well during their mixing.
- **Faulty curing**
  Due to poor mixing of the dual-component adhesives, the adhesive is not able to set sufficiently. In the case of single-component adhesives, the setting may be adversely affected by alterations in temperature which may occur.
- **Hollows in the adhesive**
  Due to the absence of adhesive in several places or other, for example, due to an interruption in the dosing out of adhesive, hollows may form. Places that are difficult to reach also require a certain amount of concentration when the adhesive is being applied. In order to prevent entrapped air, a triangular bead is used during the application process.

Defects that may occur during the operational lifespan of the bonded joint and the causes thereof, are:

- **Tears**
  Due to alternating stress or temperature, tears may begin to form in the adhesive layer, which may subsequently grow to impermissible dimensions.
- **Peeling**
  As a result of moisture penetration into the adhesive layer or into the material, the adhesiveness between the material and the adhesive layer is affected in some form or other.

Also the adhesive properties are variable under the influence of the respective substrate. It is therefore important to determine whether any long-term adhesion is possible on a substrate at all. In order to determine the adhesive properties, which substrate is dependent, on each substrate, after a progressive environmental test, a so-called Quick-Knife-test or Peel-Adhesion-Test the adhesion must be executed.

Adhesion strength on substrates

The influence of the properties of the different substrates concerned, have their

effect on the application. In TWEHA's laboratory procedure for ageing conditions for bonded cladding the baseline is, in addition to the specific strength properties of the adhesive only, the assessment of the extent of adhesion on the substrate since damage is most likely to occur as a result of an adhesive fracture.

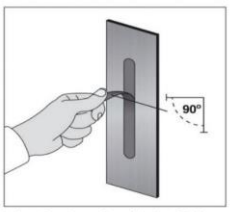
Current practice for determining the adhesion strength of bonded substrates can be classified as tensile strength test of a composition of materials only.
This tensile strength test is based on a commonly used method whereby a tensile stress is applied perpendicularly to the adhesive surface.
After curing or completing courses in different circumstances, test pieces are tested in a universal draw / press bench with a deformation rate of 5 mm / min. for tensile tests and 20 mm / min. for shear tests to rupture.

Adhesion influences on substrates

The circumstances that we face in practice, as well as the influence of the properties of the different substrates concerned, have their effect on the application. In TWEHA's laboratory procedure, in addition to the specific strength properties of the adhesive only, we investigate the influences by temperature and moisture on adhesion on the substrate since damage is most likely to occur as a result of an adhesive fracture. To determine whether any adhesion takes place and remains present on a substrate, procedure 4.2.1. is performed.

On each substrate, the test must be commenced within 2 days after receipt, whereby test pieces provided with a adhesive bead are checked by means of a so-called Peel-Adhesion Test

1. Make a vertical cut approx. 5 cm (two inches) long in the length of the glue bead only.



2. Grasp the cut loose piece of glue bead firmly between the fingers and pull down at a 90° angle or more, and try to pull the glue bead off.

on a suitable substrate, with the requirement that after *testing* no adhesive failure may occur.

The adhesive properties are variable under the influence of the respective substrate. It is therefore important to determine whether any long-term adhesion is possible on a substrate at all
All these errors, depending on their magnitude and shape, have an effect on the strength of the bonded joint. In order to guarantee reliability, managing the entire adhesive process is crucial. Strict adherence to an Instructions For Use is vital.

§ 11.2 Examples of imperfections in the application process

Example 1

Cause:

- Horizontal framework applied

Effect:

- Ventilation frustrated

Example 2

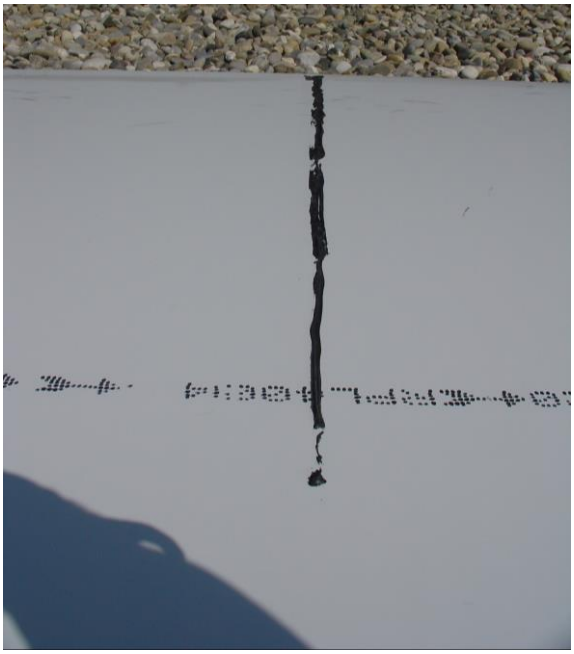
Cause:

- Panels not stored in a dry location

Effect:

- Contamination of the bonding surface
- Possibility of warping of the panel

Example 3



Cause:

- Not bonded within the allowed time period (10 minutes)

Effect:

- Foil formation of the adhesive, causing peeling of the panel

Example 4

Cause:

- Moisture level of the wood too high when applying the wood preparation
- Drying time of the wood preparation material have not been maintained

Effect:

- Wood preparation material has not bonded to the wooden framework

Example 5

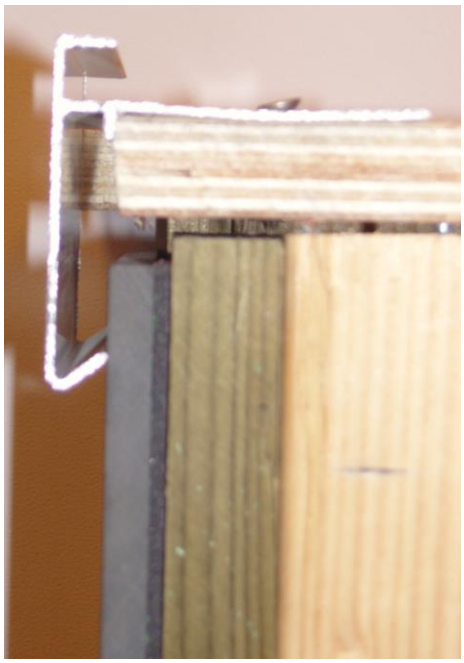
Cause:

- Adhesive applied horizontally and in dots
- Framework only applied horizontally
    - No application of permeable foil

Effect:

- No optimal adhesiveness
- No possibility of ventilation

Example 6



Cause:

- Roof trim placed too tightly against the façade panelling
- Pavement placed too tightly against the façade panelling

Effect:

- No inlets or outlets present, therefore no possibility of ventilation

Example 7

Cause:

- Triangular bead not applied
- Dimensions of panel too large
- Façade panel not degreased properly

Effect:

- Peeling of the façade panel

Example 8

Cause:

- Only horizontal framework placed
- Joint in the dimension between axes

Effect:

- No possibility of ventilation
- Too little space to allow for the application of both the tape as well as the adhesive

Chapter 12 Quality

The first designs of bonded joints for constructive application were made in the aircraft industry. Since the Second World War and up to the present day, the classification societies have only accepted design solutions which have been submitted to an extensive testing program. As such, the development of new designs takes many years and requires considerable funds.
In the automobile industry, adhesives were introduced in the nineteen-eighties. Despite the fact that the production costs ought to be lower than what is the norm in the aircraft industry, the reliability of the design is tested with extensive series of tests as well. The additional elevated costs may be covered easily due to the large scale of production.
In the other branches of industry, such as the construction sector, designing engineers frequently work on unique projects which must make it off the drawing table in a short period of time and with a limited budget. Thus, extensive series of tests are not considered in order to demonstrate the reliability of bonded joints. The only possibility in this case is to apply guidelines and calculation rules specifically developed for bonded joints.

§ 12.1 What is quality

When one considers the quality of a product, one considers the suitability of the product for its application. Whether or not a product meets the specified requirements often only becomes apparent at the level of the customer: if the product meets the requirement, it is of good quality.

- The quality of a bonded product is determined by:
- The suitability of the applied materials
- The suitability of the processing products
- The efficiency of the procedures and the auditing
- The expertise of the staff

In order to obtain a good bonded product, the quality must be managed. The following activities fall under the concept of quality management:

- Formulation of standards (product/procedural qualifications)
- Execution of appropriate procedural auditing during the production of the product
- Assessment of the product according to the standards (product qualifications)
- Taking corrective and preventive measures
- Operation according to accurately described procedures
- Training and certification of the staff

Quality care, as it is described in NEN-ISO-9001, calls for constant and systematic regard of, and realisation of, fulfilling all the requirements which pertain to the organisation's functioning properly, as well as looking for and carrying out, continuous possibilities of improvement. Complete quality care ought to extend to encompass all activities and all the employees of an organisation.

Regarding this matter, several areas of thought ought to be considered:

- Formulated quality policies, including the quality goals pertaining thereto

- Client orientated disposition throughout the entire organisation, not only in the departments traditionally charged with dealing with clients
- Internal client/supplier relations, as each activity has a principal and a client and it is of great importance that the wishes of his internal client should be known and taken into account
- Control of the generation process using control loop models using feed-forward and feedback
- Structured training programmes intended to keep everyone's knowledge and skills up to date
- Clear relationships with suppliers with regard to purchases, as well as outsourcing
- An ongoing improvement process, as stagnation is regression, so too in the field of quality care

In order to be able to supply and/or offer services which meet the needs and demands of the clients, carried out in a controlled and verifiable manner, the entrepreneur must be engaged in a great many aspects of quality care.

§ 12.2 The three links in a adhesive joint

The adhesive joint is not unlike a chain of which the strength is determined by the weakest link. There are three links which can be distinguished from one another:

1. The adhesion strength between the cured adhesive layer and the first adhesive surface
2. The cohesion strength of the cured adhesive layer itself
3. The adhesion strength between the cured adhesive layer and the second adhesive surface

The quality of these three links ought to be established where a more thorough assessment of the quality of the adhesive joint is concerned.
In order to constitute a qualitatively sound adhesive joint quality control should be involved. The latter can be obtained by following the appropriate procedures and measures, which aim to achieve a level of quality varying only within the accepted boundaries. These boundaries depend on the economic and safety consequences in case the joint should fail. Appropriate procedures and measures must be established in the qualified procedures.

The adhesive joint differs from the mechanical joint due to the fact that the elements that determine its strength are only realised during the production process. The strength of mechanical bonding parts can be tested, or qualified by the manufacturer prior to their being put to use.

In the case of brand new adhesive joints of two materials, with the adhesive as an in-between layer, their strength depends on the 3 factors mentioned hereabove.

1. Adhesion strength of the adhesive on both adhesive surfaces is the result of:
    - The characteristics of the adhesive material during the application state, for example its viscosity
    - The condition of the surfaces, for example whether or not they are soiled or oxidised when the adhesive is applied

2. The cohesion strength of the set adhesive layer depends on:
    - The adhesive during the application state, for example concerning its mixture ratio
    - The curing conditions such as moisture, temperature, humidity, pressure and curing time
3. The strength of the adhesive joint in its entirety depends on:
    - The quality of the materials
    - The condition of the materials, concerning their pre-treatment, such as degreasing, sanding, blasting, etching
    - The manner in which the adhesive procedure is carried out, for example concerning the pressure, the curing time and temperature
    - The adhesive used
    - The condition of the adhesive, for example, concerning its mixture ratio, application time, etc.
    - The post-treatment
    - The shape of the joint, such as the splitting width and the overlap
    - The design
    - The manner of stress

All these variables should be accurately described in the qualified application procedures. Where application procedures are concerned, it is assumed that one aspires to doing a reliable job, depending on the conditions and order of the job involved. In order to keep on guaranteeing the quality of the adhesive joints, the observance of the application protocols must be subject to inspection.

Large and expensive materials or products manufactured in large series call for a different type of quality control than that of adhesive joints of products which must demonstrate sound workmanship. In the case of the latter, the skilled labourer monitors the quality of his own work, which makes additional quality control unnecessary.

Accurately establishing procedures of adhesive bonding is of particular importance in the case of:

- Industrial production
- Involvement of high risk
- Disproportionally divided liability in case of any damage

§ 12.3 Quality control of the adhesive material

The physical quantities of the adhesive that must be determined are the mass and the viscosity, at least. Furthermore, the displacement, tensile, and tear, strength of the adhesive will be determined, depending on what the adhesive is being used for. It is also important to ascertain the reactivity and curing of the adhesive: when being used, the adhesive must reach a certain level of curing within a certain period of time.

Type examination test

The adhesive used for a construction is mostly chosen on the basis of experimentally established characteristics, taking into account the manner in which the adhesive is applied as well as the conditions of use and operational lifespan of the construction.
To do so, tests must be carried out by TWEHA and/or by the user. These design specifications are determined on the basis of a type examination test.

Entry control

The manufacturer of the adhesive product affirms that the manufactured products will not be used nor processed before the products meet the set requirements. Each production batch is examined after its production, tested for quality and certain characteristics and is then supplied bearing a certificate which asserts its quality.
The adhesive is a composite that is manufactured using chemical processes. Minute variations of the production process and of the raw materials may lead to deviations of the product's characteristics that have been asserted by the examination test and by the certification.
Even if the adhesive is supplied bearing certification, possible variations of the adhesive's characteristics ought to be taken into account when determining the design specifications. It is vital that there should be regular inspection into the characteristics of the adhesive before its use.
This inspection should take place right before application, particularly when concerning materials that may be affected strongly during storage by ambient conditions, such as temperature and humidity involving a maximum period of storage following the 'first in first out' principle, as well as a minimal storage capacity, which will lead to a controllable rate of circulation.
Aside from that, each production batch of adhesive will be allocated a traceable batch number.

Quality control during the bonding process

The qualification of the application procedure acts as a basis for the inspection of production. Inspections can be made in a great many ways, using very diverse assessment standards. In a great many cases, working according to qualified application procedure already sufficiently guarantees the quality of the adhesive joint.

Aside from a qualified application protocol, process quality control is another important factor that goes to assuring the quality of the bond joint. Process control during bonding should be focused on managing the process factors, such as:

- Tools, which must at all times meet the requirements regarding tools and must be re-certificated periodically
- Employees, with regard to their level of training, experience and expertise
- Ambient conditions, such as temperature, humidity, etc.
- Additional materials and resources, which must at all times be in accordance with the established guidelines and/or qualifications

Adhesive materials that are very sensitive to storage conditions must be managed in the production department as well. It is important that the room temperature of the adhesives in use should be recorded during the storage period, and that the remaining adhesive materials should be stored again under the prescribed conditions. Ageing of the adhesive materials, caused by being stored at temperatures that were too high or for too long a time, may decrease the cohesion strength of the cured adhesive, as well as a decrease of its flow and moisturising characteristics. The decrease of these two characteristics may lead to problems regarding the bonding of the adhesive.

§ 12.4 Adhesion quality control

Managing the adhesion quality is the most difficult part of the bonding process. In addition, there are as yet no ways and/or methods of checking the adhesion quality of a finished adhesive joint in a non-destructive manner.

Optimal adhesion quality requires:

- The adhesive to have the right physical and chemical properties
- The joining surfaces to have received the correct pre-treatment allowing for adhesion

Pre-treatment
The pre-treatment of the relevant combination of adhesive and material must always be executed with the greatest care and precision. Methods involving pre-treatment by manual sanding, blasting or degreasing of the adhesive surfaces are very difficult to check. Ideally, the adhesive should be applied almost immediately after pre-treatment, as the treated surfaces are highly sensitive to impurities, undesired oxidation and water absorption.
It is for these reasons that a 'simple' system using only a cleaning agent are particularly favoured.

Quality control test samples
As long as there are no effective non-destructive methods available to ascertain the adhesion quality, it is preferred that the adhesion to the specific substrate material should be tested beforehand. In addition, it is preferred that the quality control test samples should go through the same bonding procedure as the production parts.

§ 12.5 Cohesion quality control

When approved adhesives are used and bonded onto surfaces of which the adhesion properties can be guaranteed by meticulous process management, variations in the cohesion quality can only be caused by the curing conditions.

Curing quality
Aside from the aforementioned storage conditions, the variables involved in the adhesive's curing are the humidity of the air, the ambient temperature and the curing time. It should be noted that fluctuations of the factors mentioned here above will affect the duration of the curing process.

Destructive testing
The quality of the cohesive adhesive joint can be tested effectively by way of a strength test. This is not always necessary as only cohesion quality discrepancies can remain in the case of effective inspection of the adhesive, the application of the adhesive, the composition and construction of the product to be bonded, the pre-treatment process and the curing. These discrepancies in the cohesion quality have a minimal effect on the final strength. The design, however, ought to take into account possible variations in the cohesion quality.

§ 12.6 Quality requirements

Testing the adhesives and/or adhesive joints is part of a process called quality control. Apart from conducting tests, quality control also entails:

- Qualifying the application procedure
- Safe-guarding that procedures are followed

Quality of adhesives and adhesive joints not only applies to their properties, but also to their reliability and to how they function. An essential part of this process is having a description of the level of quality that needs to be achieved.

Quality control can be attained through the implementation of suitable guidelines and methods. The quality to aspire should be one that varies only within acceptable boundaries.
In order to be able to produce products in a responsible and sensible fashion, quality control requires business insight as well, alongside the technical know-how.
Implementation of quality control for bonded constructions leads to a number of advantages:

- Less rejected products, which leads to cheaper production
- Consistent quality, which boosts the product's reliability and demonstrates the reproducibility of the production process
- Better protection of the company with regard to product liabilities
- Boosting of the production employees' motivation

Registration of administration
The manufacturer of the adhesive product must register the way in which the registration of the quality data takes place. This also involves the setting of a retention schedule.

Testing and performance testing of the façade panels
The manufacturer of the façade panels must state which measurements must be made, as well as with which accuracy this must be done and the relevant suited testing, measurement and performance testing resources.
The manufacturer must conduct all the tests and performance tests according to the quality scheme in order to provide sufficient evidence as to the completed product meeting the necessary requirements.

Registration of the tests
The manufacturer of the adhesive must keep a system of registration, which must be regularly updated, in order to be able to provide sufficient evidence as to the approval and/or certification of the products in question according to the quality scheme.

Testing, measuring and performance testing tools
The manufacturer of the adhesive product must ensure that all the testing, measuring and performance testing tools are appropriately managed, calibrated and maintained.
The manufacturer of the adhesive must:

- Calibrate all the testing, measuring, and performance testing tools at the prescribed times
- Have at its disposal written and updated instructions regarding the calibration of the tools

Managing faulty products
The manufacturer of the adhesive product must take measures to prevent the use of faulty products. These measures must be stated in a procedural statement or in instructions.

Rectifying measures
The manufacturer of the adhesive must dispose of a properly functioning grievance procedure, meaning that a complaint book must be kept in which all the grievances shall be recorded that pertain to the products to which the certificate applies. The complaint book must also indicate, per complaint, in what way the complaint was analysed and in which manner the grievance was dealt with. Moreover, grievances must be evaluated periodically in a manner which can be demonstrated.

Training
The manufacturer of the adhesive product must employ competent personnel. If need be, the need for training of the personnel must be determined in order to ensure that additional, suitable education and training can be supplied.

Chapter 13 Product requirements

The lifetime of a product depends on the inherent durability and normal maintenance.
The latter depends on many factors, such as design, location of use (exposure), installation, use and maintenance, which are beyond the control of the producer.

A clear distinction must therefore be made between the assumed economic reasonable life-span for a product (also called "design life"), which underlies the assessment of sustainability in technical specifications and the actual life span (also called: "working life ") of an applied product.

Table 2.1 of the EN 1990: 2002 Eurocodes sets the requirement that for a product the life span during which the performance of a product will be maintained at a level that allows well-designed and executed works, in case of replacement of construction and/or components, the 'design life category: 2' and 'working life category: normal', a reference period of 25 years applies.

This also applies to wall cladding because it is also considered as a repairable element that can be replaced with light effort.

In order to achieve a high-quality and durable adhesive connection, quality must be achieved by implementing suitable methods and measures. The purpose of the tests described here is to establish a quality level that, from the point of view of economic and safety consequences, will assign the moment of failure of the adhesive connection within acceptable limits.

We are familiar with the cohesive properties of the adhesive connection. However, it is important to determine whether long-term adhesion is possible to a substrate at all.
In order to determine the adhesive properties, which substrate is dependent, the adhesion must be checked on each substrate, after a progressive environmental test, by means of a so-called quick knife test or peel test.

To determine whether strength and structure takes place and remains present on an adhesive tests, with the requirement that after testing no adhesive fracture (adhesion <95%)) may occur, are performed on suitable substrates of which you have determined the adhesive strength is stronger than the strength properties of the adhesive.

The variety of cladding materials used in ventilated façade constructions is diverse. In addition to the specific strength properties of the adhesive, the strength of the adhesive bond plays a decisive role in the functional properties of these façade constructions, since damage is most likely to occur as a result of an adhesive fracture.

The measurement of the specific adhesion strength on the substrate is thus critical for the design and application of structures with two or more materials.

Current practice for determining the strength of bonded substrates can be classified as tensile strength test of a composition of materials only.

The tensile strength test is based on a commonly used method whereby a tensile stress is applied perpendicularly to the adhesive surface. After curing or completing courses in different circumstances, test pieces are tested in a universal draw / press bench with a deformation rate of 5 mm / min. to rupture.
Besides pure tensile strength of the adhesive concerned, a general adhesion strength criterion is preferred to more realistically and adequately characterize the strength property of the adhesion.

In succession/addition to the outdated and/or expired guidelines BRL 4104-7 and BUtgb TWEHA developed this ageing procedure by making a distinction between:

the strength properties of the adhesive bond only, to be determined/controlled once a year (or when changes in formulation occurs), following EN 53504.

the adhesion strength of the adhesive bond on a specific substrate, to be determined when information about the influence of the specific substrate on adhesion strength, in relation to obtain a calculation value in the structural calculations, is required.

the interface adhesion strength on each specific substrate, to be determined on behalf of each type of substrate, and then valid for a period of 36 months (or when changes in material composition of the substrate occurs). Tests where assessment of no detachment is required.

§ 13.1 Product requirements of adhesive

The following requirements have to be applied to the adhesive in the case of applying of façade cladding.

The tensile strength of the adhesive must be a minimum of 1,0 N/mm² .

The shearing strength of the adhesive must be a minimum of 1,0 N/mm².
Incidental stress (on the surface of the façade), larger than 25% of the weight of the panelling itself, caused by additions made to the panelling, may not be transferred to the supporting structure by means of the adhesive only. In such a case, the panelling would have to be applied to the building construction without the medium of the adhesive in question.

The minimal elasticity of the adhesive must be > 250%.
The adhesive product must be, and must remain, sufficiently elastic both during its application and later on, in order to be able to absorb the contraction and expansion of the façade panelling.

The adhesive product must retain its characteristics (particularly regarding strength) in a durable manner. The deterioration percentage may contribute a maximum of 10%, alongside accelerated weathering and mechanical stress. Where temperature stress is involved, the accepted maximum deterioration percentage is 10% and 50%, respectively at -20 and 80 degrees Celsius.

§ 13.2 Product requirements of tape

During the first 24 hours following its application, the adhesive product will not be capable of exercising the necessary application function for which it is intended. During that period of time, the tape will ensure the necessary attachment.

The tensile strength of the tape must be a minimum of 0,2 N/mm².
The tape must be able to bear a tensile stress of 1000 N/mm² (1000 Pa) on the façade panelling.

The shearing strength of the tape must be a minimum of 0,2 N/mm².
The tape must be able to bear a shearing force equal to the weight of façade panelling.

The thickness of the tape must be at least 3 mm.
The adhesive product, meant for the application of façade panelling, must be able to compensate for the expansion and contraction of the panelling. To do this, the adhesive requires a certain minimal thickness, which has been formulated to be a minimum of 3 mm. The tape will ensure that this minimum will always be present.

Chapter 14 Guideline applier

TWEHA has made available a guideline for the application of the adhesive system. The specialised worker must carry out the bonding of the façade panels according to this guideline.

§ 17.1 Responsibilities

With regard to the personnel involved in the executing of the quality scheme, the assembling party must have the following matters recorded in writing:

- Responsibilities
- Competences
- Internal relations

The assembling party must ensure that suitable means and trained personnel are available, to execute quality checks.

The assembling party must appoint a quality officer who shall be charged with the task of ensuring the implementation of the quality scheme, as well as ensuring its level of performance. The competences and responsibilities of the quality officer shall be recorded in writing.

§ 17.2 Certification of process

A process certificate pertains to the application of façade panelling using an adhesive system. A process certificate declares the conformity to the 'process specifications' that consist of the Instructions For Uses. Frequently, these specifications can be derived from an attestation, as an attestation provides information about the suitability of a product, as well as about the correct way of application and assembly.

A process certificate is a clear indicator of a company's true capabilities. Process certificates are most useful where an elaboration of the design is required during execution of the job, or where the monitoring of the execution requires specialist knowledge.

In order to obtain process certification, the following steps must be carried out:

1. Submit request
2. Admission inquiry
3. Assessment of quality system
4. Issuance of process certificate
5. Inspection by external authority

§ 17.3 Execution requirements

Certain requirements have been set for the execution of the construction job, regarding the:

- **Preparation**
  Depending on the application and the adhesive system, a calculation should be available regarding the dimensions of the glue bead of each project. Checks will have to be performed to ensure that the following have been taken into account:
  - Values of the adhesive
  - Measurements of the panel
  - Properties of the panel
  - Supporting structure
  - Stress

- **Storage of materials**
  Checks must be carried out to ensure that the storage of the adhesive, the Cleaner+ and the tape to be used is in

accordance with the TWEHA handling guideline.

In the case of the façade panelling that is to be assembled, storage must ensure that these remain dry and that they are stored under the conditions indicated by the panel supplier.

- **Transportation of materials**
  Checks must be carried out to ensure that the materials have been transported to the site of construction in such a manner that no irreversible changes have occurred.

- **Inspection of the façade construction before bonding**
  - Checks must be carried to ensure that the adhesive system that is to be used (adhesive, tape, Cleaner+) visibly meet the requirements stipulated by BRL 4101, part 7. The storage life of the adhesive and tape that are to be used must be inspected before the application process, and must be prepared according to the TWEHA Instructions For Use.

  - Before commencement of activities, the skilled applier must check to ensure that the supporting structure is suitable for the application of the façade panelling. Attention must be paid to the following matters at least:
    - The measurements corresponding to the calculations
    - Moisture content of the wood a maximum of 18% (if applicable)
    - Surface temperature according to the TWEHA Instructions For Use
    - Levelness; deviation of a maximum of ± 2 mm

  - The measuring and application tools must be checked to be in optimal working order before commencement of activities.

- **Application of the façade panelling**
  - The façade panelling that is to be applied must be inspected before its use and repaired if need be, following:
    - Damage, defects or other flaws that may affect the quality of the panelling being applied
    - Moisture content (if applicable): solid wood a maximum of 20%, and ligneous panel materials a maximum of 12%
    - Surface temperature: according to the TWEHA Instructions For Use
    - Deformations (deformations that may lead to the façade panel becoming detached from the tape are prohibited)
    - Measurements corresponding to the calculations

  - Application of the façade panelling is to be done by a construction crew that is under direct supervision of qualified personnel. The application process is to be carried out under demonstrably frequent (once per day minimum) inspection of:
    - The homogeneity and batch number of the adhesive or Cleaner+

- The equipment
- The ambient conditions: relative humidity and temperature as prescribed by the TWEHA Instructions For Use

During the curing of the adhesive, the tape must carry the expected stress for a period of 24 hours. If it is expected that the conditions of the weather will be extreme during the first 24 hours (resulting in the tape not being able to fulfil its task) the applying of the panelling will not commence, or will be ceased immediately, or otherwise effective measures will be taken.

- **Expertise of personnel**
  Persons employed by the company, who are directly or indirectly involved in the application of façade panelling, due to their position, must be sufficiently trained and instructed in writing for them to be aware of:
  - The safety requirements during the application process
  - Any properties of the materials used which may have adverse effects on the environment or on safety
  - The storage and use of any toxic substances
  - The applicable handling guideline for the adhesive being used
  - The effects of a faultily executed application of the façade panels

  Employees charged with the fitting of the façade panelling must, in any case, demonstrate that they have sufficient training and that they have obtained the following diplomas or qualifications at the very least:
  - Basic safety VCA
  - Professional training or qualification regarding the application of adhesive systems

- **External quality assurance**
  The certification authority will conduct inspections unannounced three times each year to ascertain whether or not the fitting process and the internal quality control system of the certificate holder meet the requirements set by the BRL. Of these inspections, one shall take place at the company and two shall take place at the construction site.

APPENDIX I

Table for the ascertaining of dew point

Temp. (°C)	Relative humidity (%)										
	50	55	60	65	70	75	80	85	90	95	100
50	37	38	40	41	43	44	45	46	47	49	50
45	32	34	35	37	38	39	41	42	43	44	45
40	28	29	31	32	34	35	36	37	38	39	40
35	23	25	26	27	29	30	31	32	33	34	35
30	19	20	21	23	24	25	26	27	28	29	30
26	15	16	17	19	20	21	22	23	24	25	26
25	14	15	16	18	19	20	21	22	23	24	25
24	13	14	15	17	18	19	20	21	22	23	24
22	11	12	13	15	16	17	18	19	20	21	22
20	9	11	12	13	14	15	16	17	18	19	20
18	7	9	10	11	12	13	14	15	16	17	18
16	6	7	8	9	10	11	12	13	14	15	16
15	5	6	7	8	9	10	11	12	13	14	15
14	4	5	6	7	8	9	10	11	12	13	14
12	2	3	4	6	7	8	9	10	10	11	12
10	0	1	3	4	5	6	7	7	8	9	10
8	-2	0	1	2	3	4	5	6	6	7	8
6	-3	-2	-1	0	1	2	3	4	4	5	6
4	-5	-3	-2	-2	-1	0	1	1	2	3	4
2	-7	-5	-4	-3	-2	-1	0	0	1	1	2
0	-8	-7	-6	-5	-4	-3	-2	-1	-1	0	0
-5	-13	-12	-10	-10	-9	-8	-7	-7	-6	-6	-5
-10	-18	-17	-16	-15	-14	-13	-12	-12	-11	-11	-10

No dew point, safe for application
Potential of dew being on the materials, caution advised during application
High probability of dew, application is not recommended

APPENDIX II

Table for the ascertaining of the support centre distance

There are various factors that affect the support centre distances of the vertical frame. As such, it is not possible to formulate a general guideline. To ascertain the exact size, it is recommended that the panel manufacturer, the adhesive supplier and the designing engineer of the construction project should be contacted.

Panel type	Thickness	Building height 0 – 8 mtr.		Building height 8 – 20 mtr.	
		2 girders per panel	3 or more girders per panel	2 girders per panel	3 or more girders per panel
	mm	mm	mm	mm	mm
HPL	6	400 – 450	550	--	--
	8	500 – 600	650	500	500
	10	600 – 650	650 - 700	500	500
Fibre cement bonded	6	450	500	400	450
	8	500 (1)	600 (1)	450 (1)	500 (1)
Natural stone	15	600	600	600	600
Enamelled tempered glass	6	600	600	600	600
Metals	--	(2)	(2)	(2)	(2)

(1) An extra in-between girder is recommended along the edges of the building

(2) Calculation needed regarding the fatigue resistance of the material