Chapter 23
European First Recyclable Façade System with Reclosable Fastener Fixation: Research Development, Grants of Patents, Pre-certification Testings and Product Publication of Façade System StoSystain R

Ferdinand Oswald

Introduction

The aim of the façade research project facade4zeroWaste is to develop a fourth-generation façade. Man-made structural envelopes have passed through three major stages of development in the past:

1. The main purpose of the first structures was protection from the weather (Fig. 23.1a).
2. The next stage began with conscious design of the envelope that took visual aspects into account (Fig. 23.1b).
3. Due to the energy crisis in the 1970s, the third step was towards reducing heating energy by means of thermal insulation (Fig. 23.1c).
4. Triggered by the climate change debate, the construction industry has for some time been exploring the topic of sustainable building. This ushers in the next, and thus the fourth stage of development: the aim of the façade research project facade4zeroWaste is to develop a sustainable, efficient successor for the currently predominant exterior insulation finishing systems (Fig. 23.1d). As one of the market leaders in exterior insulation finishing systems (EIFS), STO is thus the ideal partner for developing and introducing such a façade system on the market.

The name of the project is the fourth-generation façade, Façade Four Point Zero Waste. The 4.0 included in the title is thus to be seen as the first version of the next generation of façades. facade4zeroWaste combines design qualities such as appropriate surfaces (textures) and a high level of variability with the simplicity of EIFS in terms of installation, adding the characteristics of sustainability which will become increasingly important in the future.

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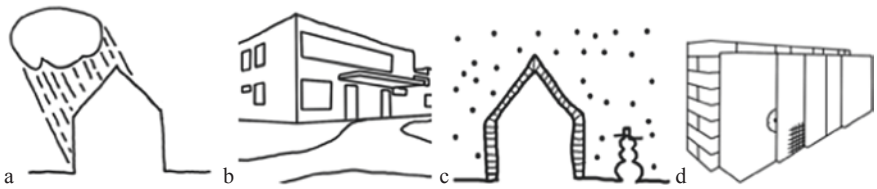

Fig. 23.1 (**a**) Protection from weather [1], (**b**) visual aspects [2], (**c**) reducing heating energy with thermal insulation [1], (**d**) insulation finishing systems (EIFS) and facade4zeroWaste with fastener fixation [2]

Fig. 23.2 Demolition of EIFS (Source: https://www.immoclick24.de/wp-content/uploads/2015/07/MM05-13_2_500x400.jpg)

Examination of the problem

The status of EIFS is that there is no sustainability assessment of the entire life cycle (including profitable separation, disposal and recycling) and no positive recycling behaviour of building components at the end of the period of use (recovery of resources) (Fig. 23.2).

Methods of reutilization for EIFS are:

1. One method is the reutilization of materials that the materials and macromolecules can survive. This works with a shredding process than the extraction of EPS fragments (extruded polystyrene insulation). This is the so-called solvolysis process (solvent liquids). After doing this solvolysis process, the extraction of polystyrol is possible. This is a very rare method because the procedure is expensive by making it in small amounts.
2. A very common procedure is energetic reutilization. It is the combustion of macromolecules by burning them by extraction of gas, electricity and vapour.

3. The aim of the research project "facade4zeroWaste" was to develop a product which can be recycled. Aim is then the separability of facade components, the recovery of resources and easy clean separation—a sorted recyclable EIFS. In detail, the target was recycling and reuse of facade components like the insulation and mechanical fixation.

Research and Development

Fixation Without Glue/Mortar (Sorted Component Recycling)

First idea prefabricated click-insulation façade module with reclosable fastener fixation (Fig. 23.3). This "click" façade system works like parquet floor. The disadvantage of this façade system was that it is reusable but no recyclable. There is no chance of separability of facade components because insulation and surface plaster are glued together.

But in this façade concept the idea was born to develop a façade system without using glue, but fixation with reclosable fastener and mechanical fixation.

Reclosable Fastener for Façade System

What is reclosable fastener and is it useful for a façade system?

The simple fixing of grip fixing system is inspired by the burdock plant from nature (Fig. 23.4). The prickly heads of these plants are noted for easily catching onto fur and clothing, thus providing an excellent mechanism for seed dispersal.

The first artificial reclosable fastener fixation, the "hook-and-loop fastener", was conceived in 1941 by Swiss engineer, George de Maestra. The hook-and-loop fasteners are known as Velcro® in the USA, and in German speaking countries as "Klett".

Fastening systems as the presented one have been used in different fields of economy in the past years and decades, such as automotive and aerospace industry,

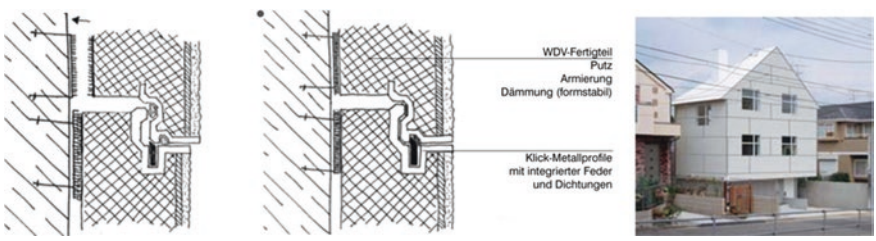

Fig. 23.3 Prefabricated click-insulation facade module with reclosable fastener fixation [3]

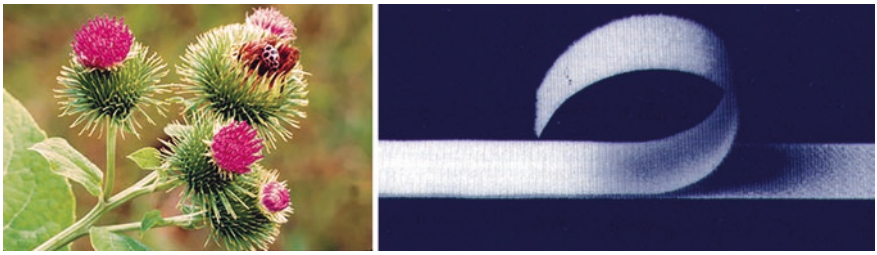

Fig. 23.4 Burdock plant, loops of the plant [4] and hook-and-pile fastener [5, 13]

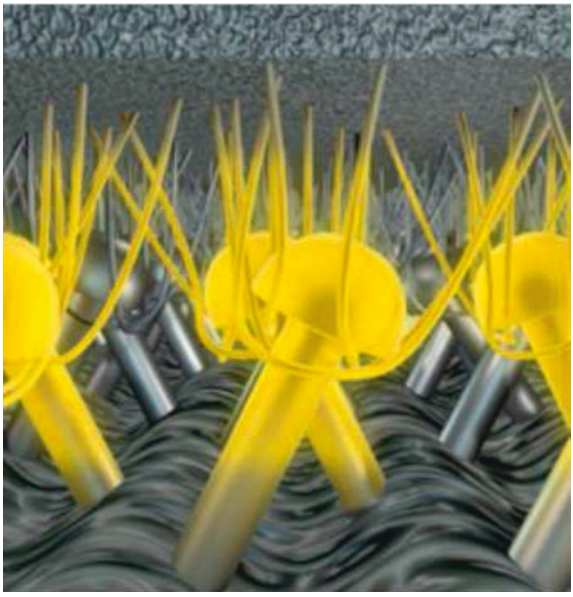

Fig. 23.5 Hook-and-pile fastener [13] for the facade4zeroWaste system [3]

medical engineering and textile industries. Moreover, applications in the building construction industry have been recently established.

We made a deep analysis of different reclosable fastener fixations to find the perfect one for a façade system. There are many different types of them like metal fasteners, pile–pile fasteners (mushroom-shaped heads), touch fasteners, hook-and-loop fasteners and hook-and-pile fasteners. Criteria for the decision for the perfect Klett have been thermal conduction and heat expansion, very high grip performances for heavy loads, easy to remove, etc. Finally, in cooperation with a hook-and-loop fastener manufacturing company we done the decision for the hook-and-pile fastener, because it is possible to have fixation on different stages (Fig. 23.5). Users can contact softly and then it is possible to repeat calibration (piles integrated in fleece). Also the hook-and-pile fastener hast very high shear stress performance, this is important to compensate the vertical façade loads. With the fastener manufacturing

Fig. 23.6 Evaluation bonding force [6]

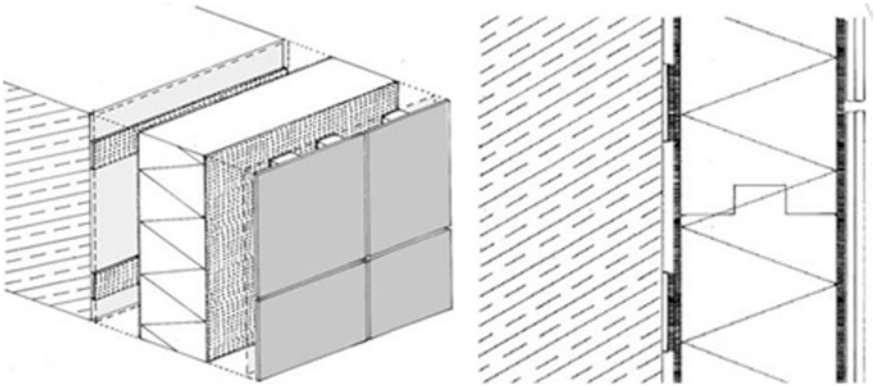

Fig. 23.7 Different façade system concepts with fix hook-and-pile fasteners [3]

company have been done test realization in the laboratory due to closing force, bonding strength, cohesion strength (Fig. 23.6). Even the micro-structure of the bonding strength have been investigated with computer tomography (CT).

Dismantling and Sorting by Component Type for Recycling

It was a crucial question how we can fix the hook-and-pile fasteners on different building components. We made a huge study to verify the different possibilities to fix hook-and-pile fasteners on insulation, loadbearing walls, façade panels or use additional a mechanical fixation and we developed different façade concepts with hook-and-pile fasteners (Fig. 23.7).

Tolerances Compensation

A significant problem needs to be solved: loadbearing walls—the main application for the proposed developments—regularly show small irregularities that could hamper the application of insulation systems in general. Such irregularities can be,

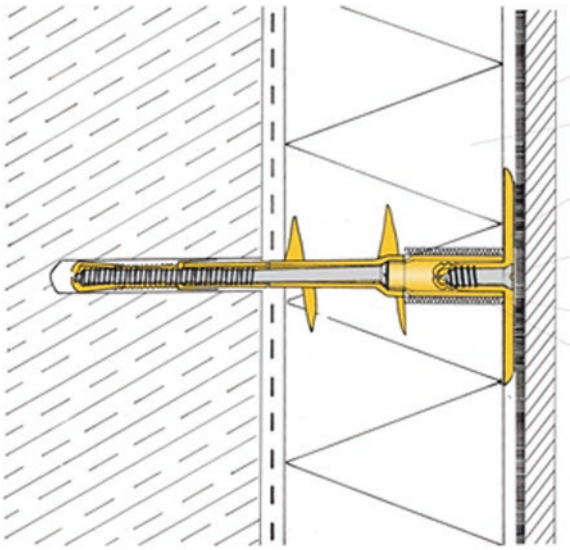

Fig. 23.8 "Stellfuch" (adjust fox) to adjust tolerances between insulation and wall [3]

for instance, caused by not totally planar surfaces. Glue does compensate tolerances in EIFS between insulation and wall. In a façade system without glue there isn't this function and benefit any more. Therefore, we first tried to find a solution with the German product called "Stellfuch" (adjust fox) to adjust these tolerances between insulation and wall (Fig. 23.8). This mechanical fixation system has a screw thread and therefore can adjust these tolerances between insulation and wall by moving the insulation forward and backward. The mistake here is that after adjusting there can arise air gaps or even worse ventilation slits between insulation and wall. This rise up the problem of reducing the insulation performance at the façade system.

To find a solution to compensate irregularities of the load-bearing wall, we developed a façade system with a façade panel and a new specific mechanical fixation element (Fig. 23.9). On the façade panel are integrated the hook-fasteners. The mechanical fixation element is round shaped (rotunda) with pile fastener and has a screw thread for adjusting irregularities of the load-bearing wall by moving the façade panel forward and backwards. There is solely a thin layer of air outside of the insulation and irregularities of the load-bearing wall can be balanced (±1.5 cm) (Fig. 23.10).

Prototypes have been manufactured in different manufacturing techniques like laser sintering, laminated object modelling and CNC milling. In the development phase of the project we commissioned companies in Germany and the Institute for Production Engineering at TU Graz, Austria to produce these prototypes. Later a huge anchor company was integrated into this research project for serial production (Fig. 23.11).

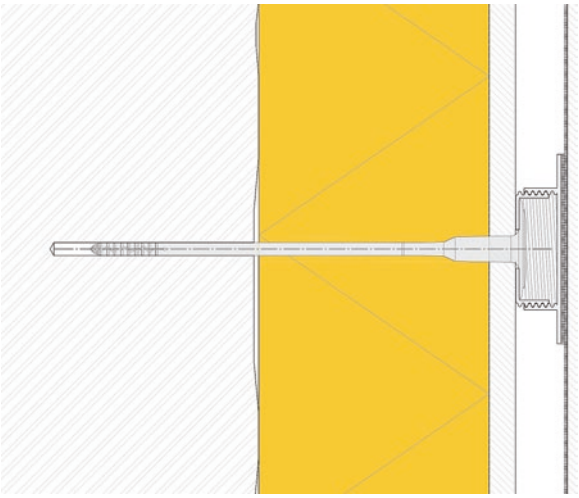

Fig. 23.9 System with façade panel and mechanical fixation to adjust tolerances [3]

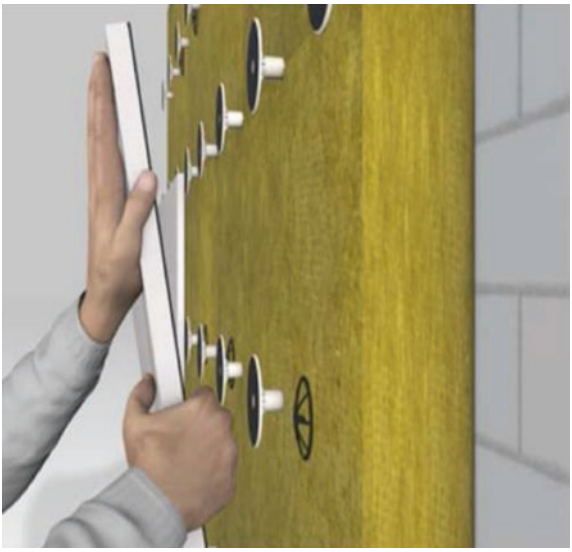

Fig. 23.10 Façade panel and mechanical fixation element (round shaped) during assembly [7]

Patent Grants

Different patents have been granted at the European Patent Office (EPO) for this project, like *fixing element, fixing system and facade system, it* was published on 4th of April 2012 with the European patent number: EP 2436851 A2 (Fig. 23.12).

Fig. 23.11 Prototypes manufacturing techniques of mechanical fixation: laser sintering, laminated object modelling and CNC milling [3]

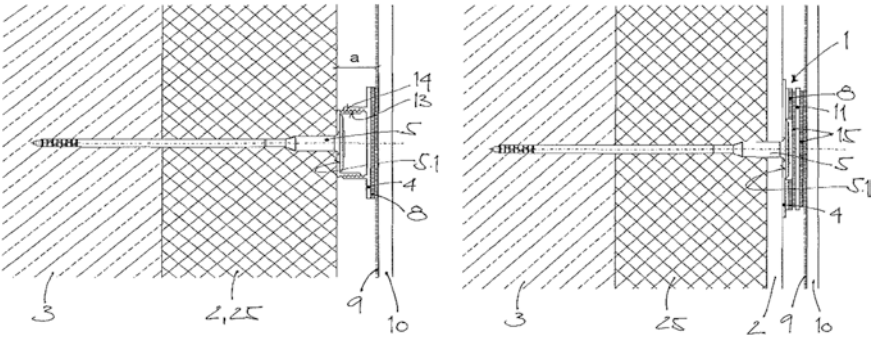

Fig. 23.12 Patent grants: fixing element, fixing system and facade system [8]

Pre-certification

Under the leadership of Institute of Architecture Technology, TU Graz has been made several initial tests to become the pre-certification of the new façade system. It was the implementation of fire tests, construction statics tests, weathering tests, building physics simulations and trial installations.

Test Constructions

In the realization of many trial installations we would like to find out the conformability of the craftsman with the construction details and construction workflow. Secondly we would like to proof the detailing of the construction and architectonical design opportunities.

We adapt the construction details due to the conformability for the craftsman's like the handling on construction site and the simplicity of assembly (Fig. 23.13). Also the development of crucial details like corners and openings detail-situations has been made. For example, the EIFS has at the corners a surface bonding with glue. The façade4zeroWaste-system has only a mechanical fixation. Therefore we developed a simple fastener-fixation-corner-angle to have the corner detail fixation (Fig. 23.14).

Also the architectonical relevance should be evaluated, which means, which architectonical design opportunities are possible with this system. In Fig. 23.15 there is a façade design example with visible gaps.

Structural Laboratory Tests

By the implementation of construction statics tests we realized a wind suction and pressure test due to ETAG 017 (European Technical Approval Guidelines) (Fig. 23.16). The tests have been made at Laboratory for Structural Engineering at TU Graz and we commissioned Prof. Stefan Peters from Institute of Structural Design, TU Graz to supervise the tests and results evaluation. In comparison to the

Fig. 23.13 Trial installations for conformability of craftsman [3]

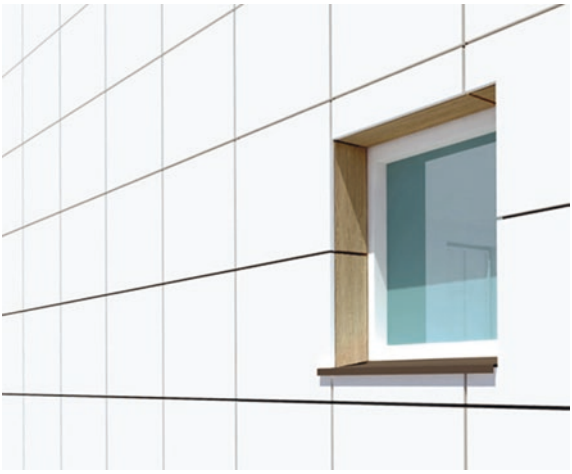

Fig. 23.15 Architectonical relevance design opportunities, façade design example with visible gaps [3]

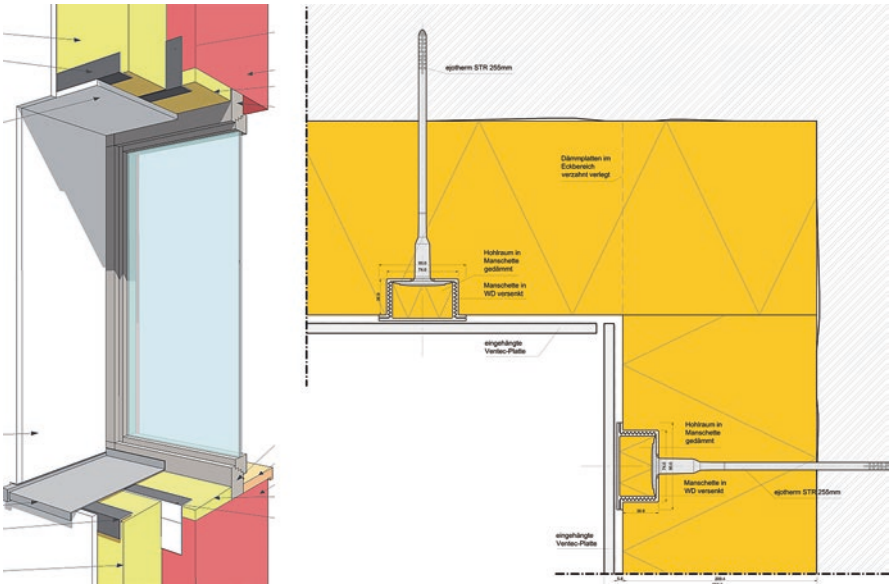

Fig. 23.14 Fastener-fixation-corner-angle for corner detail fixation [3]

EIFS System which has a surface bonding with glue, here the façade system is a mechanical fixation only with fastener fixation/Klett. In many sequences we had wind load assumptions of suction and pressure. The full wind load pressure was +5.232 Pa and the wind load suction –4802 Pa. The result has been very positive, because mainly the anchor damage (red points) and there was no removals at the fastener fixations (Fig. 23.17).

Fig. 23.16 Implementation of construction statics tests wind suction and pressure test [3]

Weathering Experiments

The implementation of EOTA test application (European Organization for Technical Assessment) was made with weathering tests due to ETAG 04 (European Technical Approval Guidelines). The tests carried out at Sto SE & Co. KGaA laboratories in

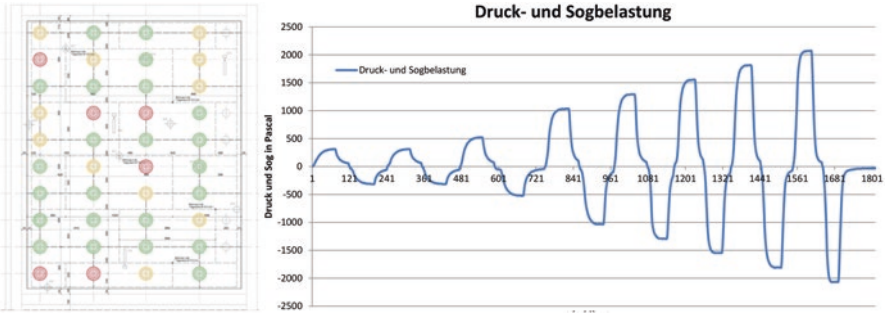

Fig. 23.17 Left: Construction statics tests: anchor damage (red marked), right: Sequences wind load assumptions of suction and pressure [3]

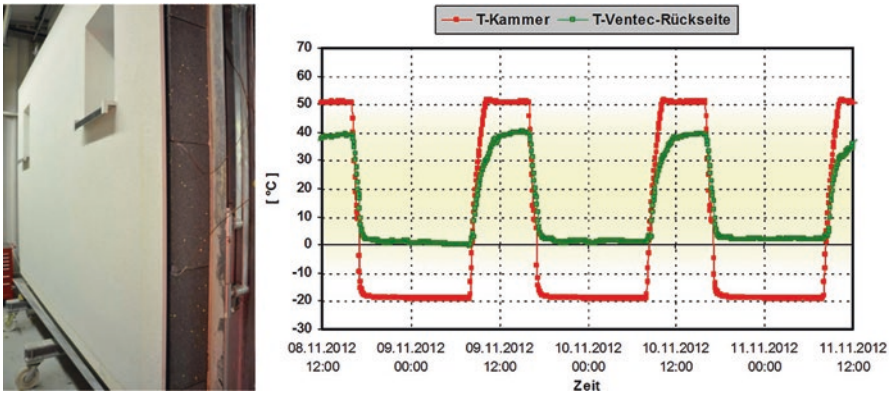

Fig. 23.18 EOTA test application (European Organisation for Technical Assessment) weathering tests due to ETAG 04 (European Technical Approval Guidelines) [9]

Stühlingen, Germany. Here the hot and cold temperature cycles have been tested in a simulated long-term test (Fig. 23.18). The temperature ranges have been from –15 till +50 °C and ran in fast and high sequences (Fig. 23.19). The test result was very positive and it was without affect or destroying any component of the façade system. Additionally the building physics behaviors has been examined and calculated by the Consulting Engineers Rosenfelder and Höfler. There is no risk of condensation or similar danger within the façade system [12].

Fire Testing

By the implementation of fire tests to evaluate the hazard category it was made a *single burning item (SBI)* at *IBS—Institute for Fire Protection and Safety Research* in Linz, Austria (Fig. 23.20). The SBI tests were made due to the *ÖNORM EN*

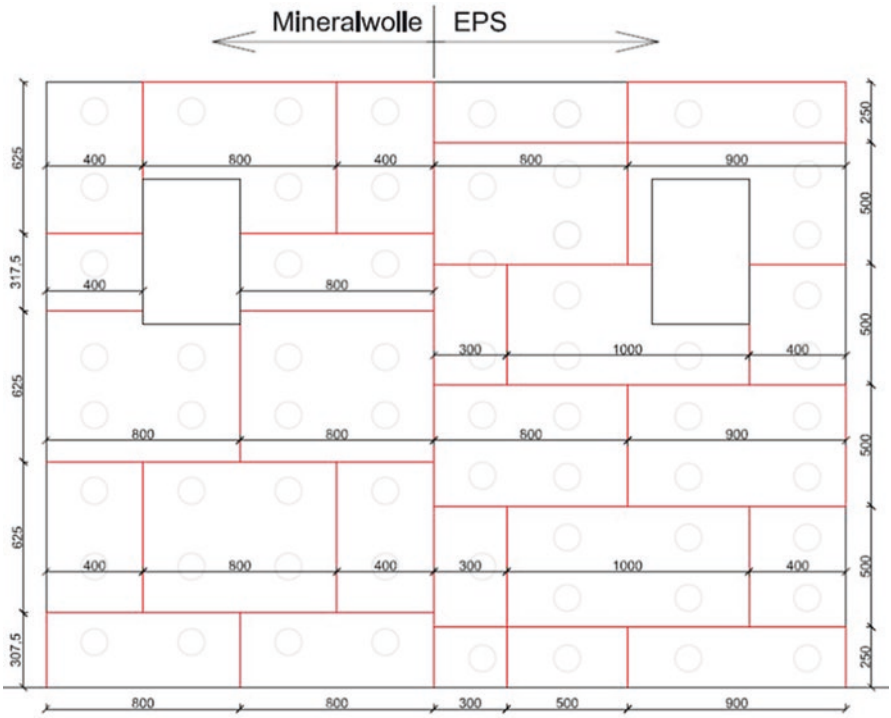

Fig. 23.19 Drawing of façade construction for EOTA test application: left mineral wool and right extruded polystyrene insulation (EPS) [3]

13823-2011-01 [1]. We used two types of the insulation material for the façade construction: extruded polystyrene insulation (EPS) and mineral wool (Fig. 23.21).

The official result of the façade construction with EPS insulation was B-s2, d0, which means limited smoke emission and no combustible drips/no dropping.

Utilization Testing

Installation

The assembly is craftsman conform. It has very good handling requirements on construction site. Finally the assembly time is very short. This is because it is a dry construction site and there is no need for drying time. In contrast to EIFS there is the need of drying time for the glue. This is a huge benefit because it is the reduction of construction time and in the same way than reduction of costs for workmen (Fig. 23.22).

Fig. 23.20 Implementation of fire tests single burning item (SBI) at IBS—Institute for Fire Protection and Safety Research [3]

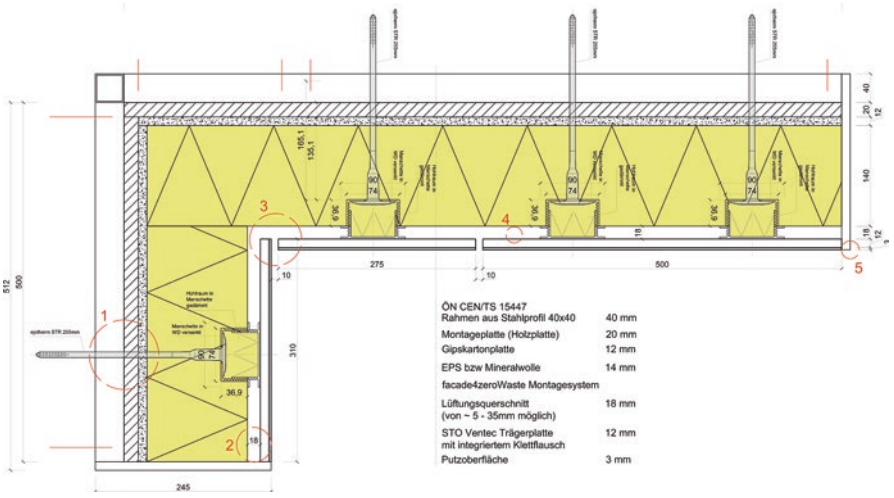

Fig. 23.21 Drawing of façade structure, fire tests single burning item (SBI) due to ÖNORM EN 13823-2011-01 [3]

Disassembly/Dismounting

The disassembling is possible without specific construction instruments. The removal process is possible with common instruments like palette knives or triangles (Fig. 23.23). For disassembling the facade4zeroWaste façade system we also granted a patent as shown in Fig. 23.24.

Fig. 23.22 Fast assembly time because dry construction site (no glue) [3]

Regardless of Weather Conditions

The assembly is regardless of weather conditionings. We tested the winter assemble with temperature –10 °C (the lowest processing temperature of each single component has to be consider). With that cold temperatures assembling and dis-assembling works without any problems because it is a dry construction site and there is no need for glue and drying process. This is a great advantage regarding construction do not need to stop in wintertime. Another benefit of having a façade system without glue is the avoidance of pollution and dirty water by cleaning construction equipment. It is a clean and dry construction site (Fig. 23.25).

Sorting Component Uniform for Recycling and Reuse

The dismantling is simple, dust- and noise-reduced and it has nearly unmixed separation as well as reuse and recycling of the system components (Figs. 23.26 and 23.27).

Conclusion

The idea of a recyclable facade insulation system that can easily be dismantled after its lifetime and reused thanks to an innovative grip fixing system consisting of mushroom-shaped heads and loops—grip fixing instead of adhesive. The benefits at a glance:

Fig. 23.23 Disassembly with common instruments [3]

- Nearly unmixed separation as well as reuse and recycling of the system components.
- Free choice of insulation material.
- Surface variety with individual render surfaces from StoSignature.
- Render carrier board made of recycled glass.
- High-quality mushroom hook and loop grip fixing technology for increased reliability and durability.
- Simple fixing thanks to grip fixing system inspired by the burdock plant.
- Simple, dust- and noise-reduced dismantling.

The facade system *facade4zeroWaste* won the award of the EQAR—Recycling Prize 2015. The prize ceremony was held at 8th May 2015 at the "Congress of Construction Material Recycling in Europe" in Rotterdam, Netherlands (Fig. 23.28). *facade4zeroWaste* was also nominated for the Green Tech Award 2016 in Germany. In January 2017, the façade system was presented from Sto SE & Co. KGaA Germany as the product *StoSystain R* on the building fair BAU 2017 in Munich (Fig. 23.29).

Fig. 23.24 Disassembly patent [10]

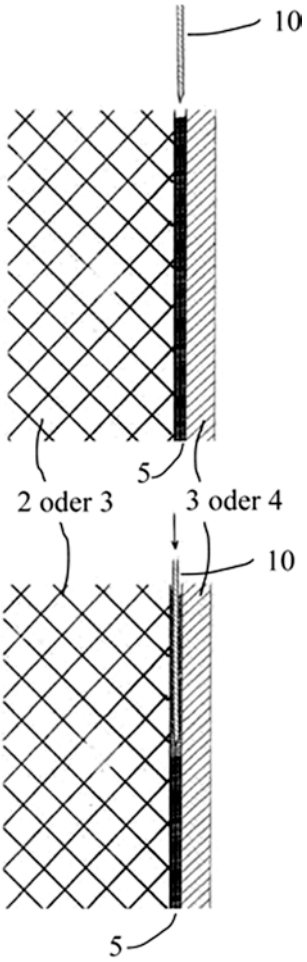

Fig. 23.25 Weather independent assembly tested winter −10 °C [3]

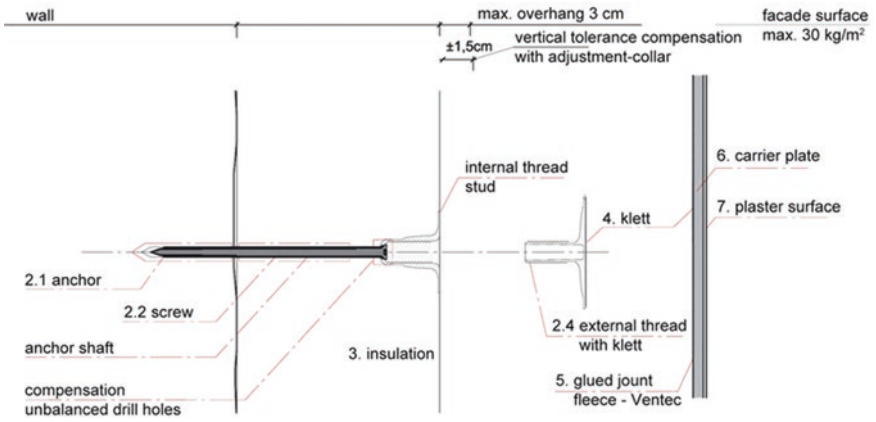

Fig. 23.26 Overview of facade4zeroWaste façade system [3]

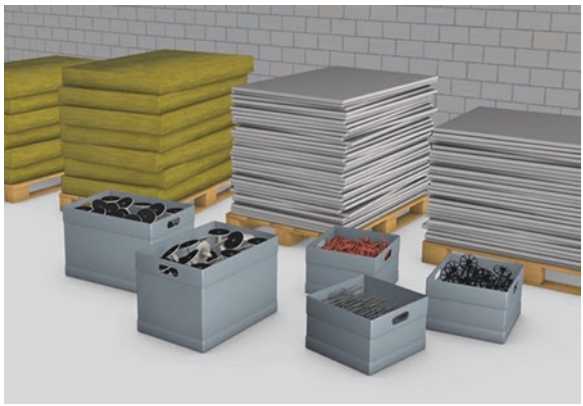

Fig. 23.27 Sorting by component type for recycling + reuse and transportation, StoSystain R façade system [7]

Fig. 23.28 Prize ceremony EQAR—Recycling Prize 2015: from left: E. Messow (Sto), G. Gretzmacher (EQAR and BRV) and F. Oswald (TU Graz) [1]

Fig. 23.29 StoSystain R on the building fair BAU 2017 in Munich [7]

There the façade system was getting the award: *Innovation Award for Architecture and Building* [11]. The first building projects with the *StoSystain R* system were realized already in year 2017 and in the near future objects with *StoSystain* with visible gaps are planed [5].

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