This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement Nº 691768

Prototypes of framing systems compatible with XL format and large thickness photovoltaic glazing units

Project report

ONYX SOLAR

March 2017

Summary

This document is the deliverable associated to the task “T3.4: Framing systems compatible with XL-formats and large thickness BIPV units” within “WP3: BIPV modules based on crystalline silicon technology” of the PVSITES project.

The main content of this deliverable is divided in three main points: First of all, several existing commercial framing systems compatible with XL BIPV are analyzed in terms of architectural design and mechanical characterization. Secondly, a selection of framing options for curtain wall/skylights and façades are further studied in terms of design, hidden wiring strategies and mechanical analysis. Final sections of this deliverable include a cost analysis and the description of prototypes to be tested within the scope of Task 3.7 (Indoor Validation Testing).

Acknowledgements

The work described in this publication has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement Nº 691768.

The present report was prepared by PVSITES project partner ONYX SOLAR. The report was originally submitted to the European Commission as Project Deliverable D3.5 in March 2017.

Disclaimer

About the PVSITES project

PVSITES is an international collaboration co-funded by the European Union under the Horizon 2020 Research and Innovation program. It originated from the realisation that although building-integrated photovoltaics (BIPV) should have a major role to play in the ongoing transition towards nearly zero energy buildings (nZEBs) in Europe, the technology in new constructions has not yet happened. The cause of this limited deployment can be summarised as a mismatch between the BIPV products on offer and prevailing market demands and regulations.

The main objective of the PVSITES project is therefore to drive BIPV technology to a large market deployment by demonstrating an ambitious portfolio of building integrated solar technologies and systems, giving a forceful, reliable answer to the market requirements identified by the industrial members of the consortium in their day-to-day activity.

Coordinated by project partner Tecnalia, the PVSITES consortium started work in January 2016 and will be active for 3.5 years, until June 2019. This document is part of a series of public reports summarising the consortium's activities and findings, available for download on the project's website at www.pvsites.eu.

The PVSITES consortium:

Tecnalia Research & Innovation	CTCV	FormatD2
Onyx Solar	Flisom	Vilogia
BEAR-iD	Cricursa	R2M Solution Research to Market
Nobatek	CEA	CADCAMation
Film Optics	Acciona Infraestructuras	WIP - Renewable Energies

Contents

Tables

Figures

1 EXECUTIVE SUMMARY

1.1 Description of the deliverable content and purpose

The aim of this work is to complete ONYX´s current activities on XL-BIPV units by analyzing the existing possibilities in terms of full BIPV system integration. In this sense, ONYX has already covered the different processes from the glazing manufacturing point of view in relation to the design, installation and optimization of new equipment and manufacturing materials compatible with XL BIPV glazing.

However, ONYX had not accomplished the building integration strategy in terms of full PV system integration. Therefore, Onyx faces in task 3.4 of this project the prototyping of framing solutions compatible with XL-formats and different building solutions (curtain walls, vertical façades and skylights) where the mechanical aspects and hidden wiring strategies are elucidated.

The main content of this deliverable is divided in three main points: First of all, several existing commercial framing systems compatible with XL BIPV are analyzed in terms of architectural design and mechanical characterization. Secondly, a selection of framing options for curtain wall/skylights and façades are further studied in terms of design, hidden wiring strategies and mechanical analysis. Final sections of this deliverable include a cost analysis and the description of prototypes to be tested within the scope of Task 3.7 (Indoor Validation Testing).

1.2 Relation with other activities in the project

Table 1.1 depicts the main links of this deliverable to other activities (work packages, tasks, deliverables, etc.) within PVSITES project.

Table 1.1 Relation between current deliverable and other activities in the project

Project activity	Relation with current deliverable
Task 1.1	Market and stakeholder analysis and present and future stakeholder´s needs are considered and serve as a basis for the design of framing systems for XL BIPV. Mentioned analysis are detailed in D1.1.
Task 2.1	This task includes the definition of the technical specifications for the PV modules and their manufacturing processes. The basis of PVSITES product design is established in this task.
Task 2.3	All the products resulting from the PVSITES project will form part of a BIPV product portfolio developed under this task.
Task 3.6	Under this task a complete simulation of the BIPV modules at element and building level will be done. The task provides as well direct feedback to task 2.3 and the generation of information for dissemination materials.
Task 3.7	Within task 3.7, several prototypes of framing systems for XL BIPV will be subjected to intensive testing to comply with applicable standards. Samples for indoor validation testing will be defined in D3.8 (M15) and results in D3.9 (M24)
Task 1.3	Standardization needs and testing sequences to be considered in T3.7 are shown in D1.3 as a result of an exhaustive analysis of current applicable standards.
Task 3.8	The results of the analysis of this deliverable will serve as a basis for the prototypes to be developed for demonstration in outdoor test benches. D3.10 (M21) will define prototypes and results will be shown in D3.11 (M30)

The following figure schematizes the relation between the mentioned tasks.

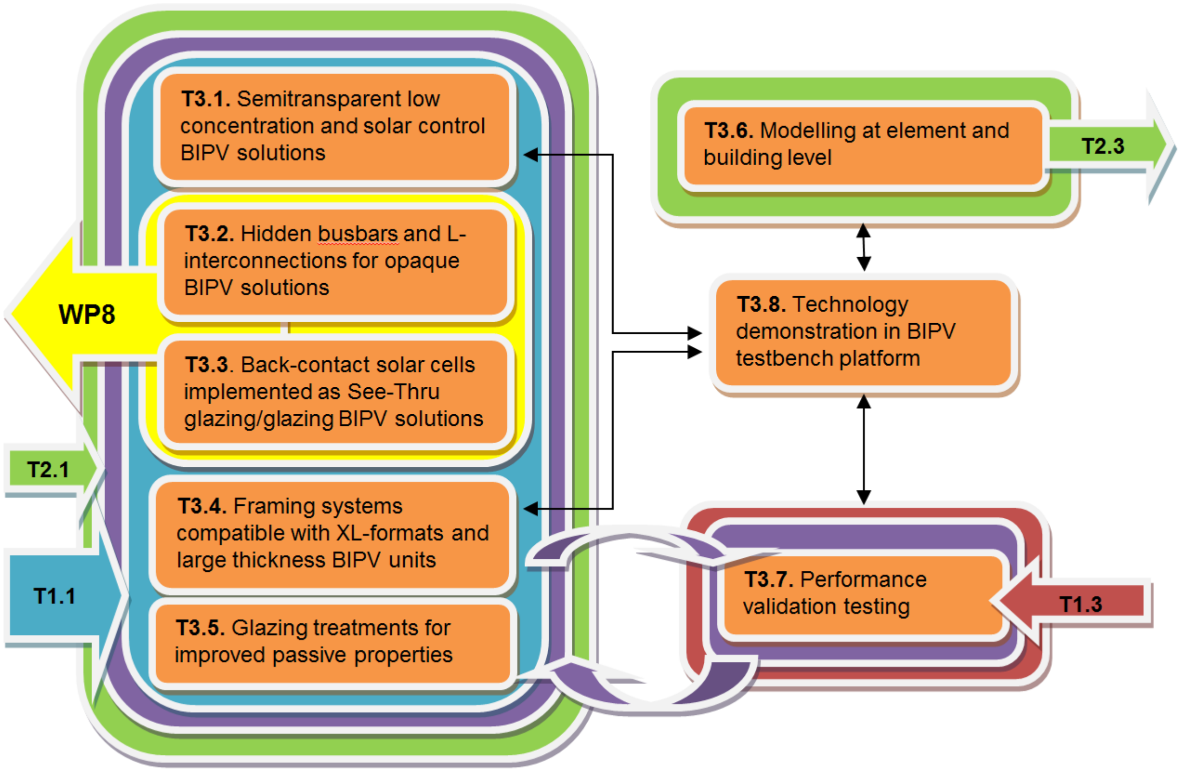


Figure 1.1 Relationship between T3.4 and other tasks

1.3 Reference material

This deliverable has used some data from PVSITES deliverable D2.1: Technical specifications for BIPV modules.

1.4 Abbreviation list

a-Si: Amorphous Silicon

BIPV: Building Integrated Photovoltaic

c-Si: Crystalline Silicon

EU: European Union

H2020: Horizon 2020

HQs: Headquarters

M: Month

PV: Photovoltaic

ROI: Return of the Investment

WP: Work Package

XL BIPV: Large format BIPV

2 DESIGN OF FRAMING SYSTEMS FOR XL BIPV

2.1 Architectural design

Ventilated façades, skylights and curtain walls made of PV glass are some of the most common ways to integrate solar PV energy in buildings by using multifunctional elements that also provide interesting passive properties such as thermal and acoustic insulation, solar control and natural illumination, offering the same features that conventional glass.

Figure 2.1 BIPV skylight and curtain wall (left) and BIPV ventilated façade (right). Source: ONYX

Architectural designs of these systems are usually carried out under the same requirements than the ones made for conventional glazing, taking into consideration some differences due to the fact that PV systems play now an important role in the following aspects:

- The installation is usually optimized to produce the maximum amount of energy and this predetermines some design factors as the position and orientation of the glazing within the building.
- PV technology, normally first or second generation PV cells embedded in the glass layers change the visual appearance in comparison to normal glazing so that new integration strategies must be studied.
- Electrical installations as PV junction boxes and cables must be integrated into the system generating the minimum visual impact. The solution to hide electrical systems varies depending on several project factors: type of BIPV solution, type of structure, architectural designs, etc.
- Sometimes structural systems and framing must be adapted to accommodate the mentioned electrical installations or some minor format changes of PV glass configuration in comparison with traditional glass configuration.

Figure 2.2 shows an example of a PV skylight hidden wiring strategy. Cables and connections are dissimulated by placing them between the wooden structure and the metallic skylight structure [2]

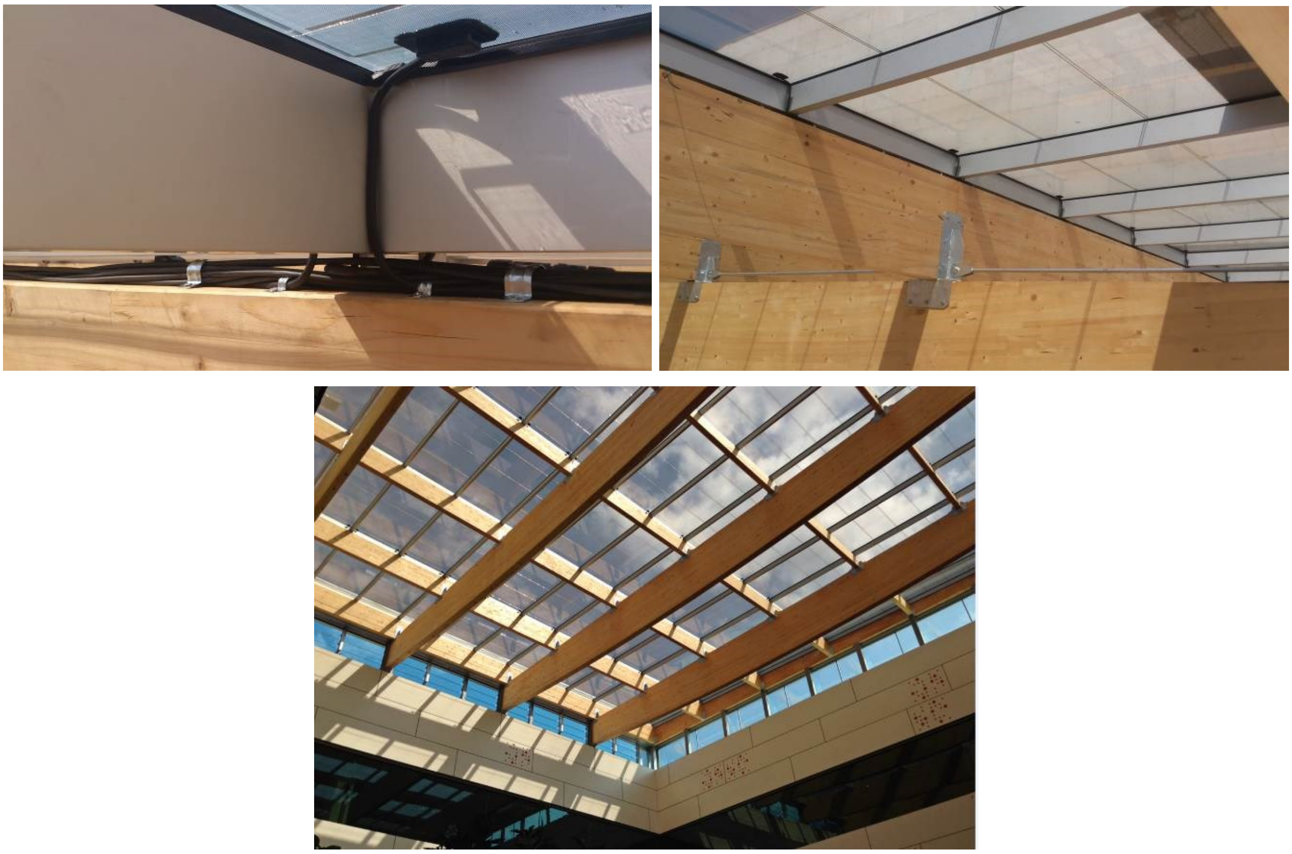


Figure 2.2 Hidden wiring strategy used in the BIPV skylight executed for ING Bank HQs in Madrid. Source: ONYX

XL BIPV glazing using PV glass dimensions superior than 3m x 2m have some particularities in terms of architectural design that must be studied. This format normally involves thick glass (around 40mm) and electrical installations that must be integrated. In order to do this, a technical analysis of existing framing solutions compatible with XL formats is carried out in the next section. Then, detailed constructive details of some selected structural systems elucidating hidden wiring strategies and a case study of mechanical analysis are provided.

2.2 Technical description and mechanical characterization of structural systems

The aim of framing systems for XL format glazing solutions is to guarantee proper mechanical resistance and at the same time getting adapted to the electrical installation by means of hidden wiring strategies. In this regard, it is necessary to take advantage of previous experience of framing products existing in the market for different building solutions and then adapt them to the particularities of large format PV glazing.

ONYX has made a selection of some of the most adequate structural solutions for XL BIPV glazing (see Table 2.1 Selection of structural systems). Technical data of these solutions compatible/adapted to BIPV large format is given in the following pages [3] [4] [5]

Table 2.1 Selection of structural systems

CONSTRUCTIVE SOLUTION	PV VENTILATED FAÇADE			PV CURTAIN WALL/SKYLIGHT	
PROVIDER	SILVA&VENTURA	SB FIJACIONES	SCHÜCO	SCHÜCO	SILVA&VENTURA
SYSTEM	S-VITECH FIXING POINT MODEL: FP4001PV	SB FIXATION GLASS	SCHÜCO VENTILATED FAÇADE SYSTEM	Schüco FW 50+/FW 60+	HEXAHEDRON FIXING POINT (SPIDERS). MODEL: FS1004PV

2.2.1 S-Vitech system

Silva&Ventura has developed systems adapted to BIPV façades and curtain walls: S-Vitech fixing point model FP4001PV for PV ventilated façades and hexahedron fixing points model FS1004PV for curtain walls and skylights.

S-Vitech FP4001PV is a system that completely conceals PV junction boxes and wiring, hiding cables by passing then directly through the interior of the fixing point of the steel structure as detailed in [3] .

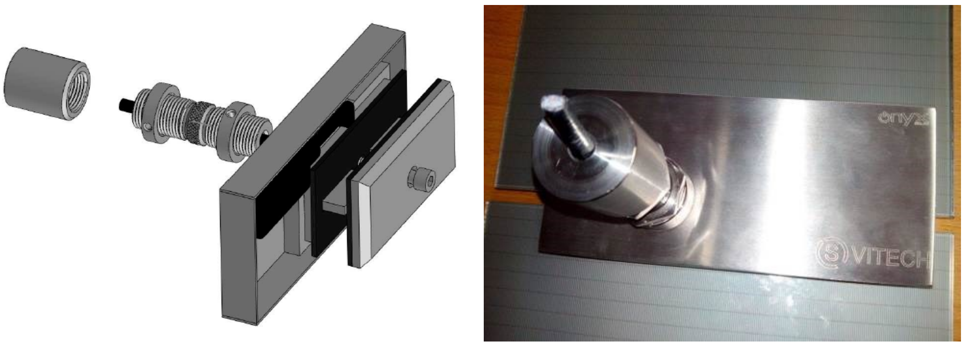


Figure 2.3 3D model and picture of S-Vitech FP4001PV for PV ventilated façades

The system is compatible with glazing **up to 50mm thick.** Basic characterization and materials are detailed in the following tables and figures:

Table 2.2 Main parameters and dimensions of S-Vitech FP4001PV system. Source: Vitech / Silva&Ventura

P4001PV FIXING POINT	
Weight	1,950 kg
Dimensions	200x90x60 mm
Glass thickness	10-50 mm
Model	FP4001PV

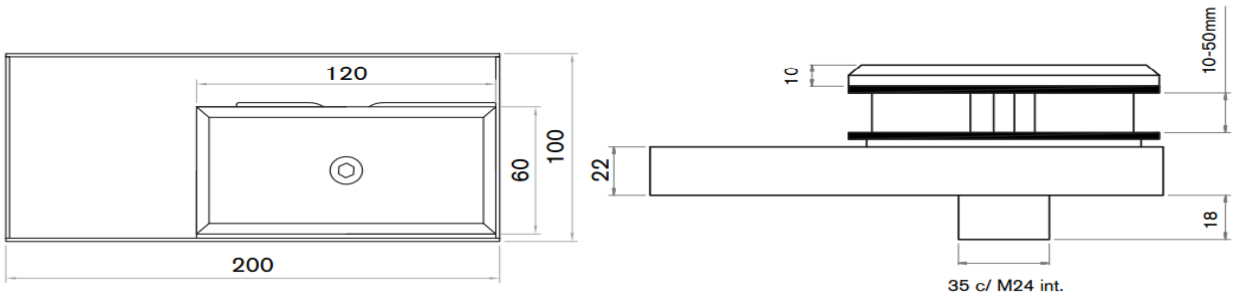


Table 2.3 Composition materials of S-Vitech FP4001PV system. Source: Vitech/Silva&Ventura

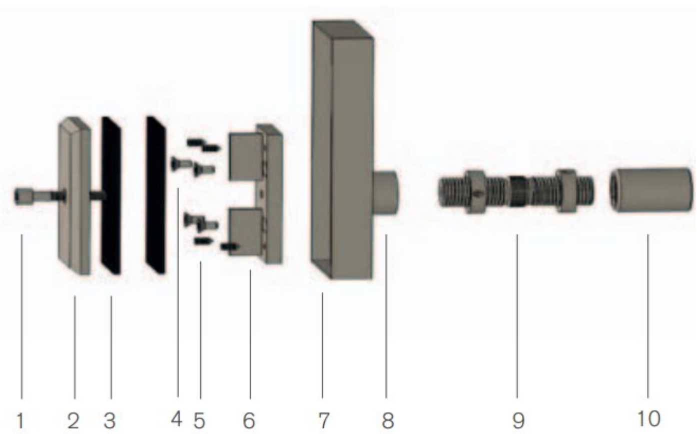
No	Qt.	Designation	Material	Figure
1	1	Screw M8x50	Aisi 316	
2	1	Lid of outside grip	Aisi 316	
3	2	Separator Rubber	Neoprene	
4	4	Screw M6x6	Aisi 316	
5	5	Screw M6x6	Aisi 316	
6	1	Crosshead support	Aisi 316	
7	1	Clamping coupling junction box	Aisi 316	
8	1	Clamping bushing	Aisi 316	
9	1	FA7001PV reference	Aisi 316	
10	1	FA7002PV reference	Aisi 316	

Table 2.4 Mechanical characterization of Vitech fixing point for ONYX vertical façades. Source: Vitech/Silva&Ventura

Condition	Ø (mm)	Elastic Limit: Rp 0,2 min N/mm^2)	Elastic Limit: Rp 1,0 min (N/mm^2)	Tensile strength: Rp min (N/mm^2)	Elongation: AMin(Long/Trans) %		HB (Brinel) max hardness
Hyper Tempered	12-100	200	275	500-700	40	30	215

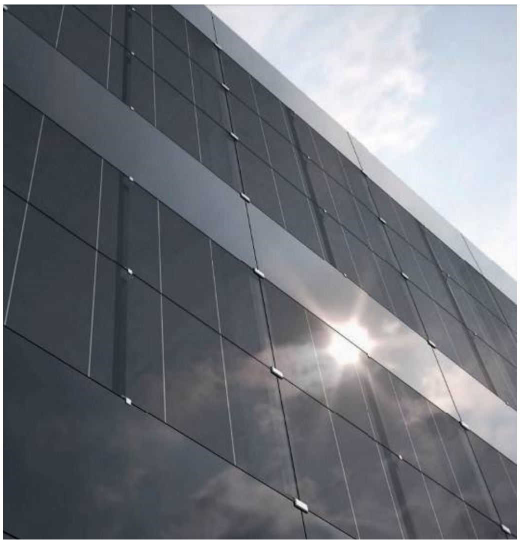


Figure 2.4 Integration example of S-Vitech FP4001PV ventilated façade system. Source: Vitech/Silva&Ventura

ONYX has used S-Vitech structural system to implement a PV ventilated façade in ONYX´s manufacturing facilities within the H2020 Advanced BIPV project. The structural system has been designed and developed to hold large format 4x2 m BIPV modules. The systems consist on a tubular metallic structure that is anchored on a floor concrete surface and on the existing façade in such a way that each XL format PV glass lays on 6 points (4 in corners and 2 central). Staples are designed for glass thickness superior than 25mm and are connected to the supporting framework. The system is detailed in next figure.

Figure 2.5 S-Vitech PV ventilated façade structural system installed in ONYX´s facilities. Source: ONYX

Silva&Ventura has also developed **Spider systems** that can be used in large format BIPV glass units for integration in curtain walls and skylight solutions. Some of the most relevant technical parameters of this solution are shown below:

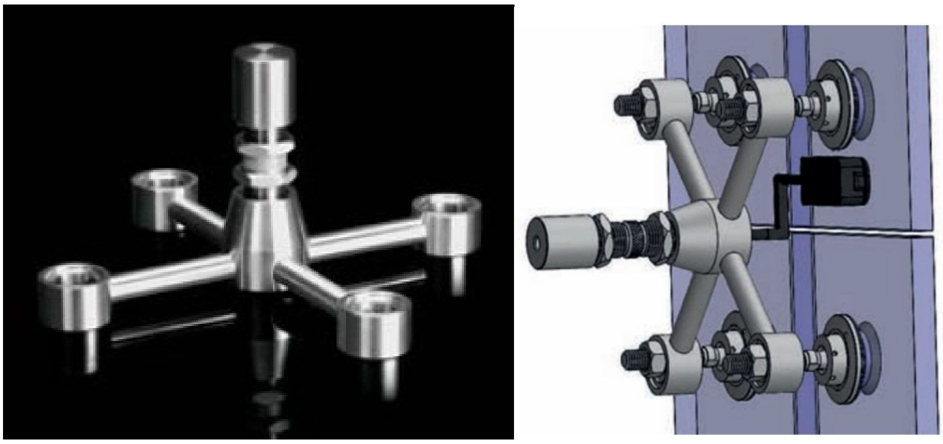


Figure 2.6 3D model and picture of S-Vitech FP1004PV for skylights and curtain walls. Source: Vitech/Silva&Ventura

Table 2.5 Main parameters and dimensions of S-Vitech FS1004PV system. Source: Vitech/Silva&Ventura

HEXAHEDRON FIXING POINT	
Weight	1,634 kg
Dimmensions	280x280x50 mm
Model	FS1004PV

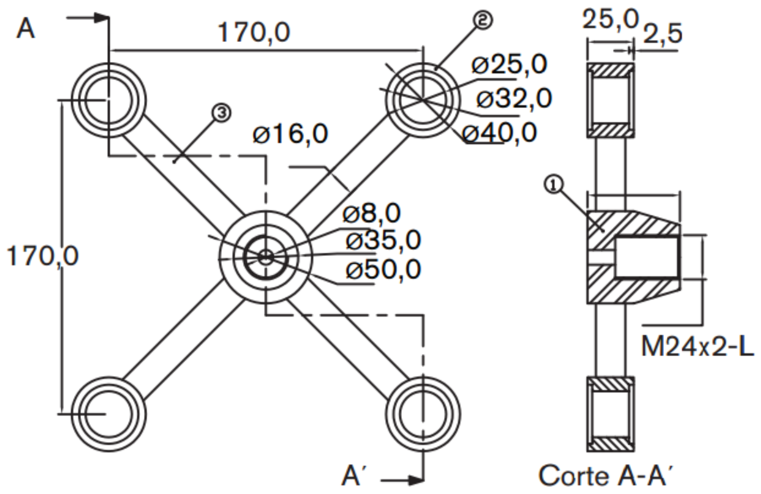


Table 2.6 Composition materials of S-Vitech FS1004PV system. Source: Vitech/Silva&Ventura

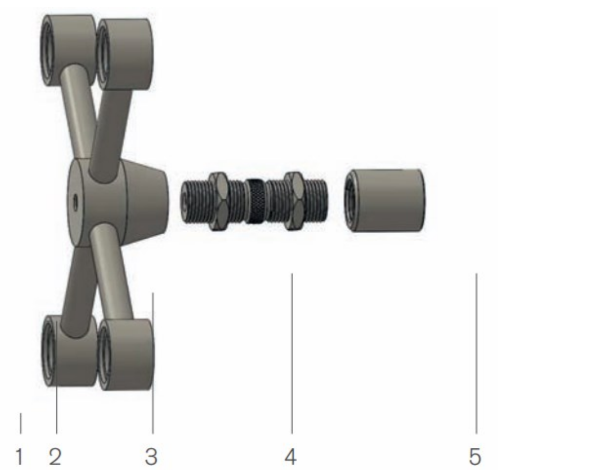
No	Qt.	Designation	Material	Figure
1	4	Hole	Aisi 316	
2	4	Rod	Aisi 316	
3	1	Central body	Aisi 316	
4	1	FA7001PV reference	Aisi 316	
5	1	Screw M6x6	Aisi 316	

Table 2.7 Mechanical characterization of FS1004PV system for skylights and curtain walls. Source: Vitech/Silva&Ventura

Condition	Ø (mm)	Elastic Limit: Rp 0,2 min N/mm^2)	Elastic Limit: Rp 1,0 min (N/mm^2)	Tensile strength: Rp min (N/mm^2)	Elongation: AMin(Long/Trans) %		HB (Brinel) max hardness
Hyper Tempered	12-100	200	275	500-700	40	30	215

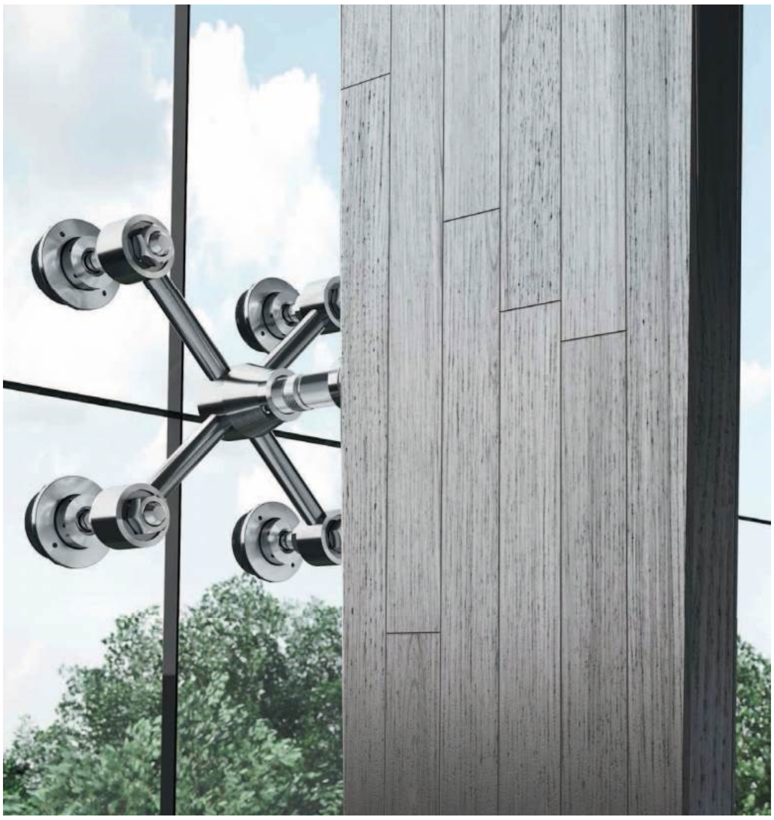


Figure 2.7 Integration example of S-Vitech FS1004PV system for curtain walls and skylights. Source: Vitech/Silva&Ventura

2.2.2 SB Fijaciones system

SB fixation glass is a system that can be used in glass ventilated façade applications. One of the main advantages of this system is the ease of installation and its versatility for different glass formats, only requiring a few assembly components. Glass panels are attached to the existing wall by using mechanical locking systems made of aluminum clips and adhesives. Main system components are aluminum, vertical profiles, angle brackets, anchor fixing points, panel-tack adhesive-fixing, stainless-steel staples and steel screws. Technical and mechanical parameters, as well as schemes and pictures are shown in the following pages.

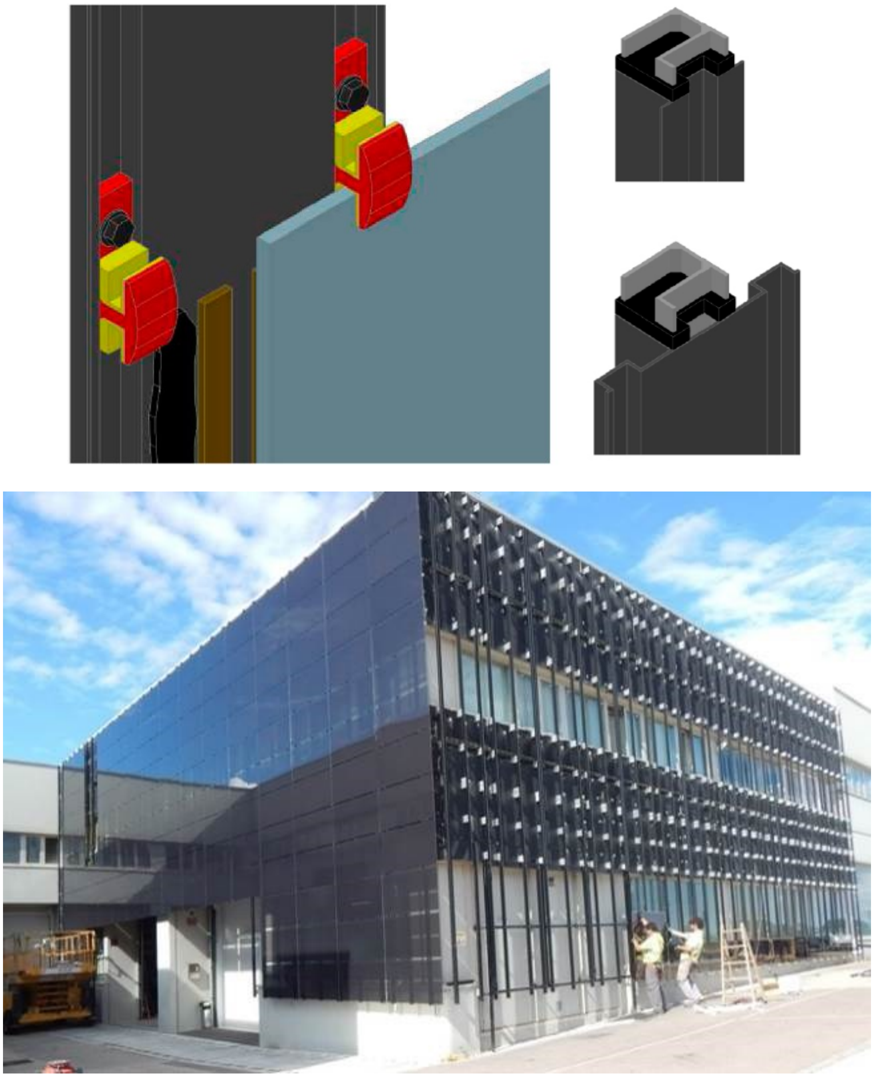


Figure 2.8 PV ventilated façade project in ONYXS´s HQs (Ávila) using SB Fijaciones system. Source: SB Fijaciones/ONYX)

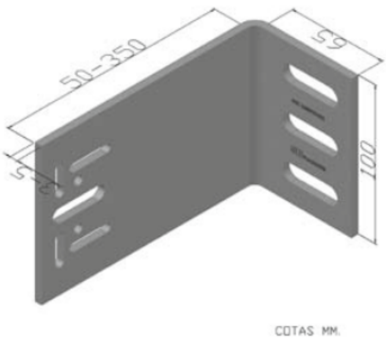
Table 2.8 Main components and materials of SB system. Source: SB Fijaciones

COMPONENT	MATERIAL
Vertical profiles	Al 6063 T5
Support brackets	Al 6063 T5
Staples	Al 6063 T5
Adhesive	ISR 70 08
Screws and anchoring	AISI 304/316

Table 2.9 Mechanical parameters of SB vertical Profiles, support brackets and staples. Source: SB Fijaciones.

Specific Weight (Kg/ m^3)	Modulus of elasticity (N/mm^2)	Poisson coefficient	Tensile strength (N/mm)	Shear strength (N/mm^2)	Elastic limit. Rp 0,2%(N/mm)	Elongation. L_{0mm}/L_{50mm} (%)
2700	69.500	0,33	215	140	160	12/14

Figure 2.9 Example of support bracket of SB fixation system



100x65x50x3	100x65x50x5
100x65x60X3	100x65x60X5
100x65x75x3	100x65x75x5
100x65x100x3	100x65x100x5
100x65x125x3	100x65x125x5
100x65x150x3	100x65x150x5
100x65x175x3	100x65x175x5
100x65x200x3	100x65x200x5
100x65x225x3	100x65x225x5
100x65x250x3	100x65x250x5
100x65x300x3	100x65x300x5
100x65x350x3	100x65x350x5

Figure 2.10 Dimensions of angle brackets of SB fixation system

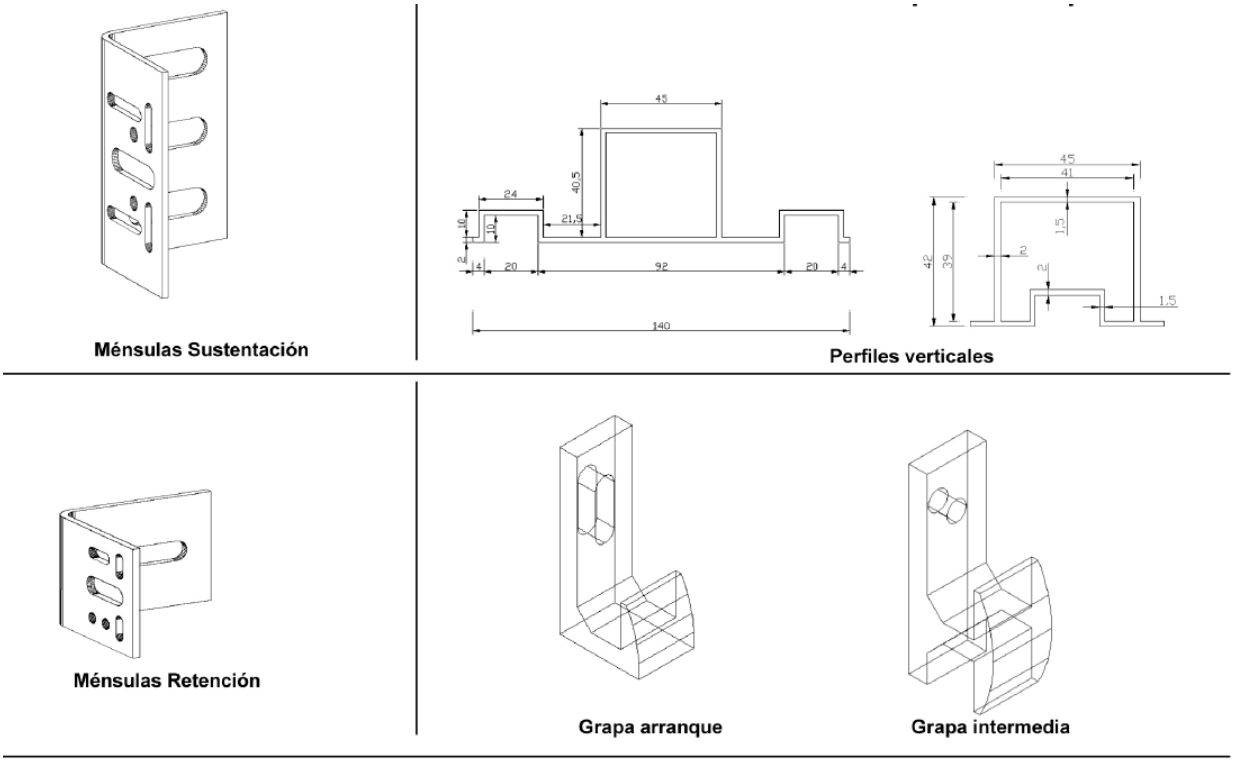


Figure 2.11 Technical details of angle brackets, support brackets, vertical profiles and staples of SB fixation system

2.2.3 SCHÜCO system

Schüco façade systems can be manufactured in all size categories between approx. 200 mm x 300 mm and 2,400 mm x 5,100 mm. In this way, architecturally high sophisticated building ideas can be created.

Ventilated façade

Schüco has developed a special framing solution for PV ventilated façades. Main product benefits are the following:

- Narrow face widths of 50 mm or 60 mm
- Module widths up to 2,600 mm, module heights up to 2,200 mm
- Thermal insulation adapted to passive house standard
- Installation height up to 40 m

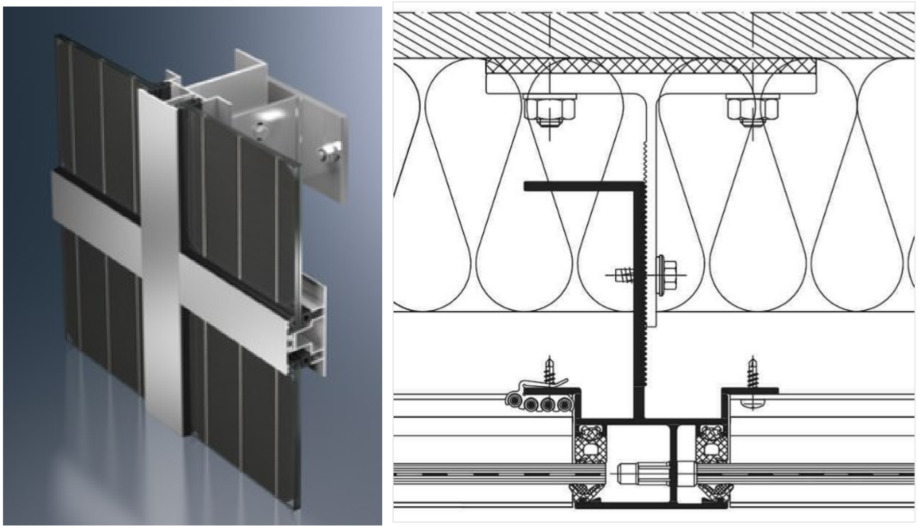


Figure 2.12 Detail of Schüco ventilated façade system for BIPV applications. Source: Schüco

Curtain wall/skylight

Schüco offers a variety of systems compatible with BIPV curtain wall and skylight systems. Among them it is convenient to highlight FW50+ and FW60+ systems due to their robustness for holding XL BIPV glass formats and the possibility of hiding the electrical wiring in the structure. Some other benefits of these systems can be summarized as follows:

- From passive house-certified façades with maximum thermal insulation to standard thermal insulation, the FW 50^+ systems offer the right solution for every scenario and all climate regions.
- Geometrically complex skylight constructions can be easily constructed.
- A wide range of cover caps offer outstanding design options for a variety of façade styles.
- Bullet resistance, burglar resistance and blast resistance options.
- Can also be used as a fire-resistant façade.
- Electric cables are concealed within the façade system, but can be accessed for inspection.

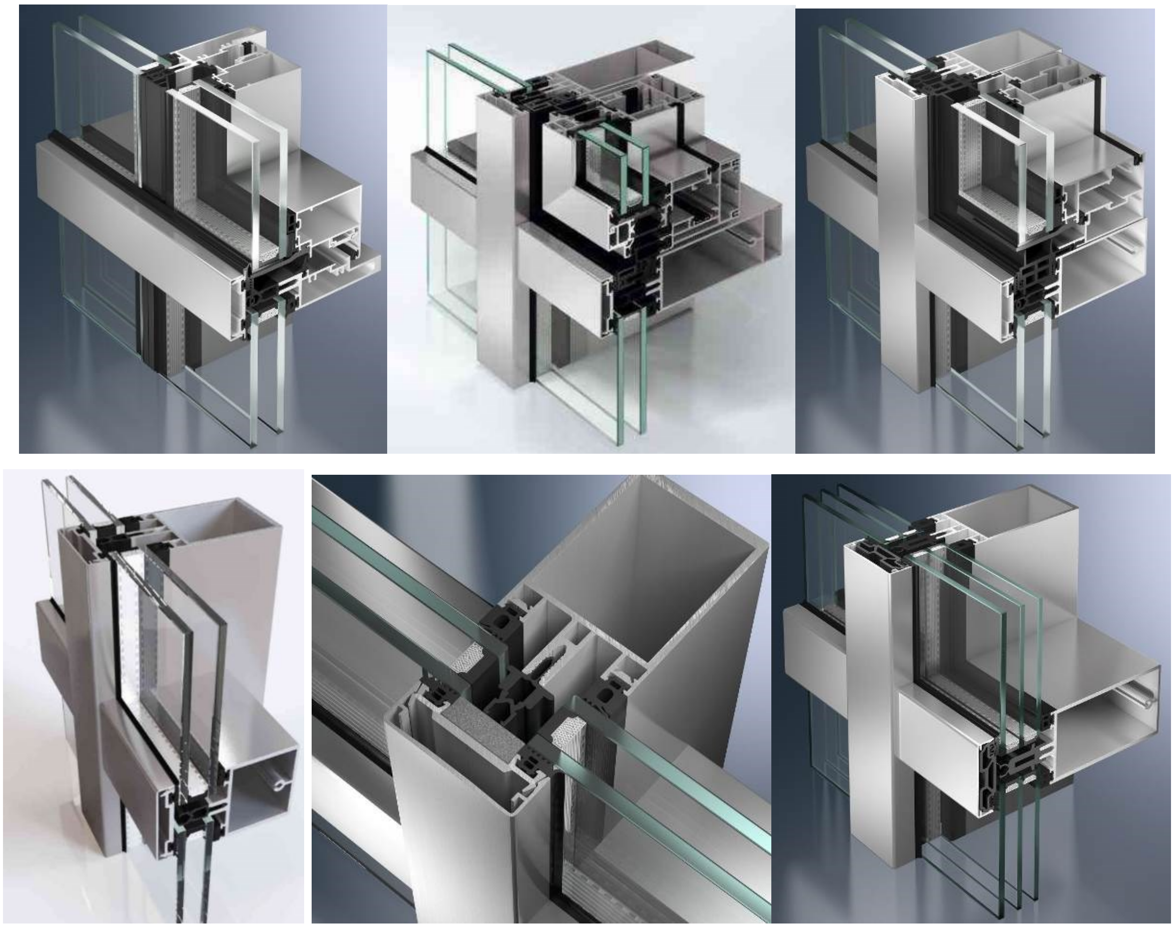


Figure 2.13 3D details of Schüco FW 50+ (above) and FW60+ (below) structural systems for skylights and curtain walls. Source: Schüco

2.3 Integration of electrical systems. Hidden wiring strategies.

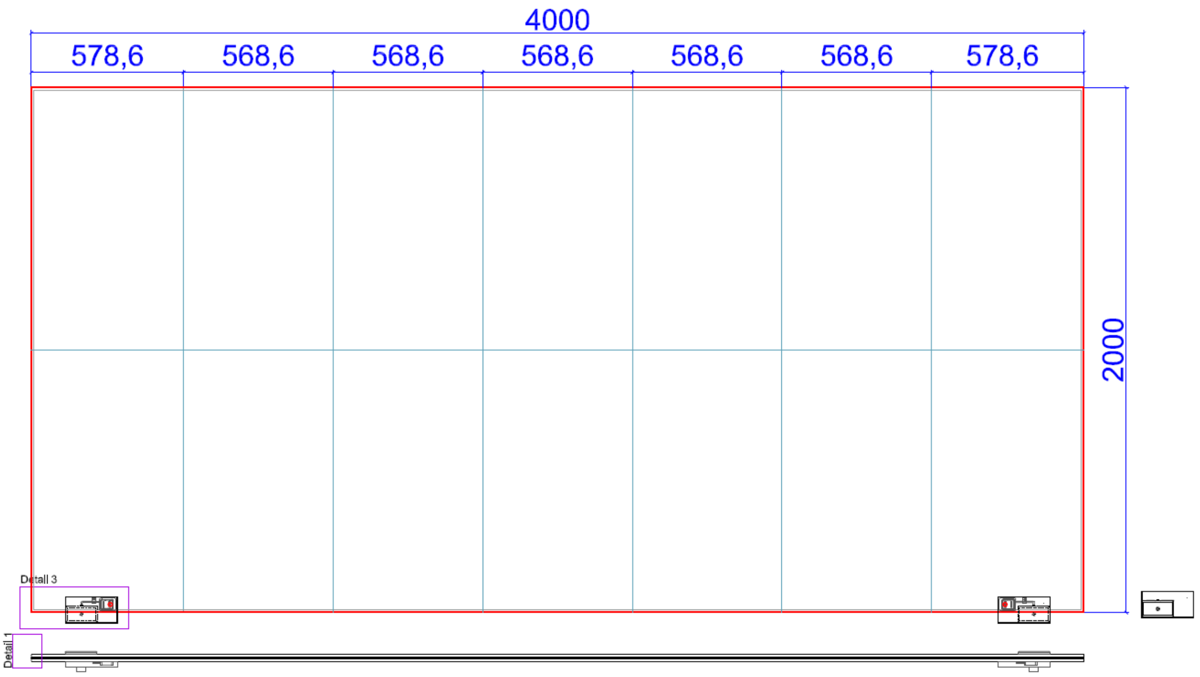
ONYX has analyzed different possibilities in terms of hidden wiring strategies applicable to XL format PV ventilated façades and curtain walls. The commercial systems selected for this study are S-Vitech FP4001PV and SB Fijaciones systems for PV ventilated façades (see sections 0 and 2.2.2) and Schüco FW50+/FW60+ for curtain walls and skylights (see Section 0). Several construction details focusing on hidden wiring strategies are provided in the following pages.

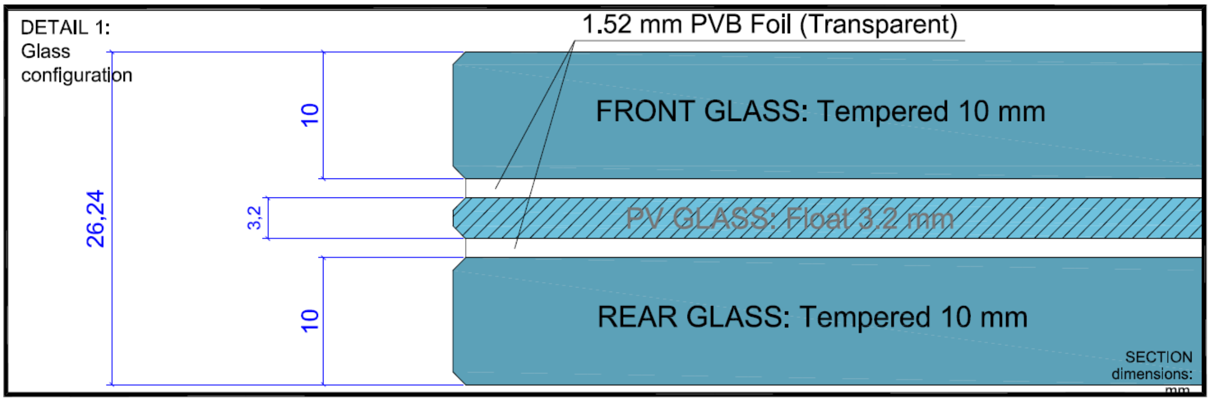
In Annex I, these construction drawings can be consulted more in detail.

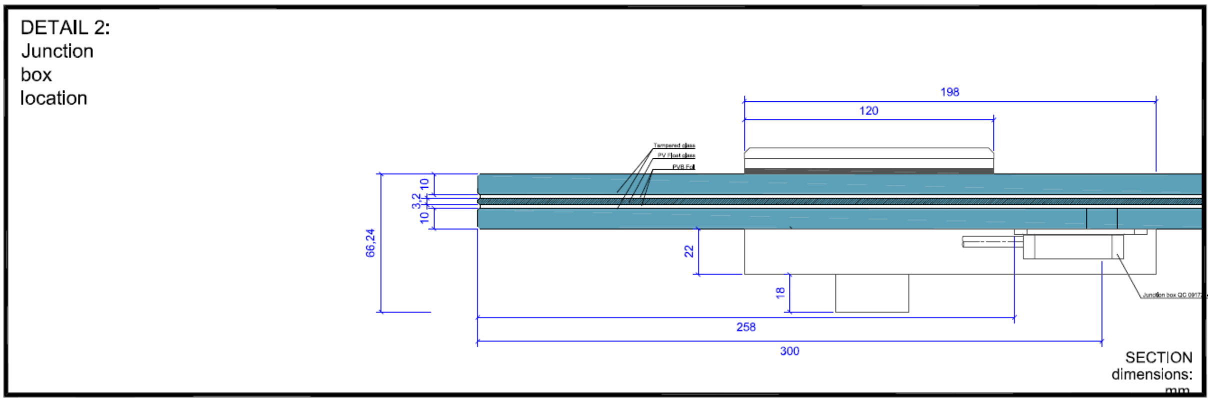
2.3.1 PV ventilated façades

S-Vitech FP4001PV system

The following construction detail corresponds to a large format BIPV glazing integration using Vitech fixation system. This system is specifically designed for BIPV and cabling can be hidden inside the fixing points in such a way that the aesthetical quality of the integration can be noticed. Junction boxes are placed in the extra space of the cable box with respect to the pressure staples.


4000
578,6
568,6
568,6
568,6
568,6
568,6
578,6
2000
Detail 3
Detail 1


DETAIL 1:
Glass
configuration
1.52 mm PVB Foil (Transparent)
FRONT GLASS: Tempered 10 mm
PV GLASS: Float 3.2 mm
REAR GLASS: Tempered 10 mm
26,24
10
3,2
10
SECTION
dimensions:
mm


DETAIL 2:
Junction
box
location
198
120
66,24
10
3,2
10
22
18
258
300
SECTION
dimensions:
mm

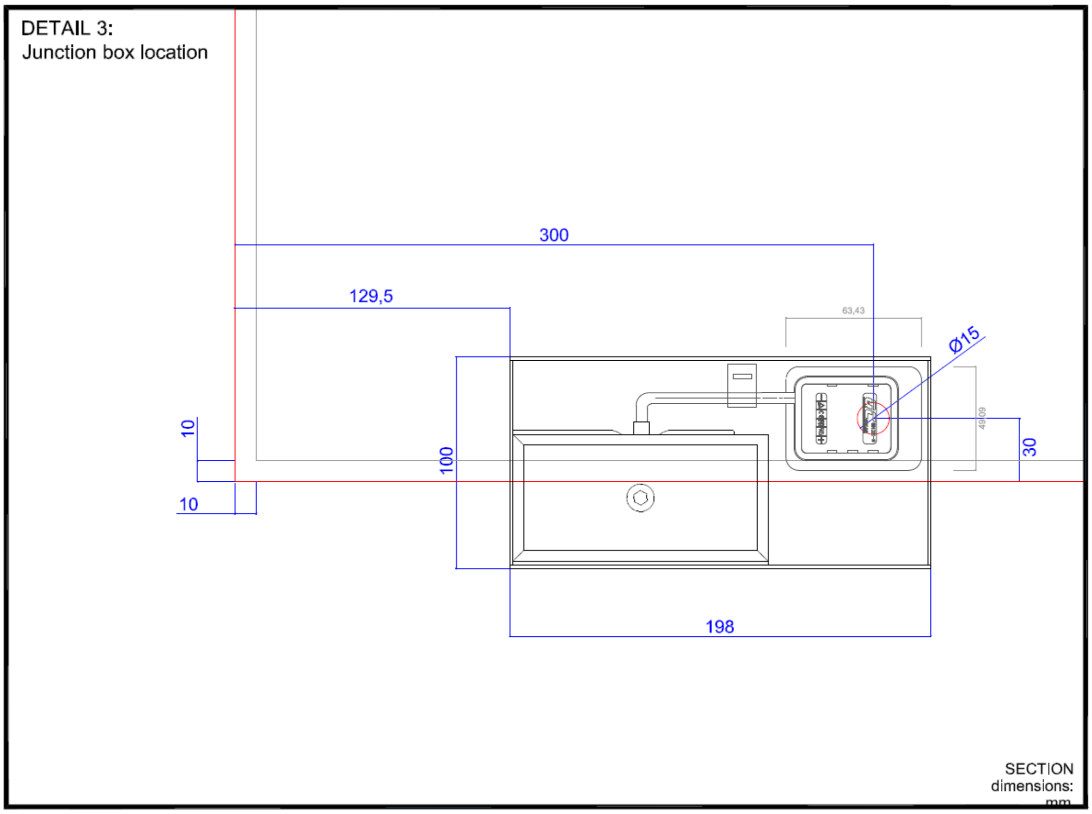
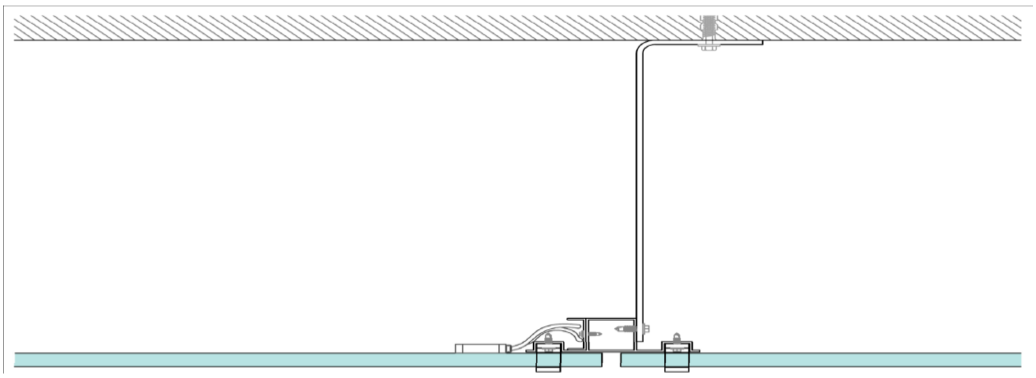


Figure 2.14 System details of application and hidden wiring strategies for S-Vitech FP4001PV in a PV ventilated façade. Source: ONYX

SB Fijaciones System

Different views of the construction systems formed by anchor elements, vertical profiles, staples and screws are provided. Junction boxes are placed in the bottom right corner of the PV glasses. Cables are hidden between the existing wall and the ventilated façade. PV glass connections and cables are guided to inverters and electrical switch boards by means of cable trays.



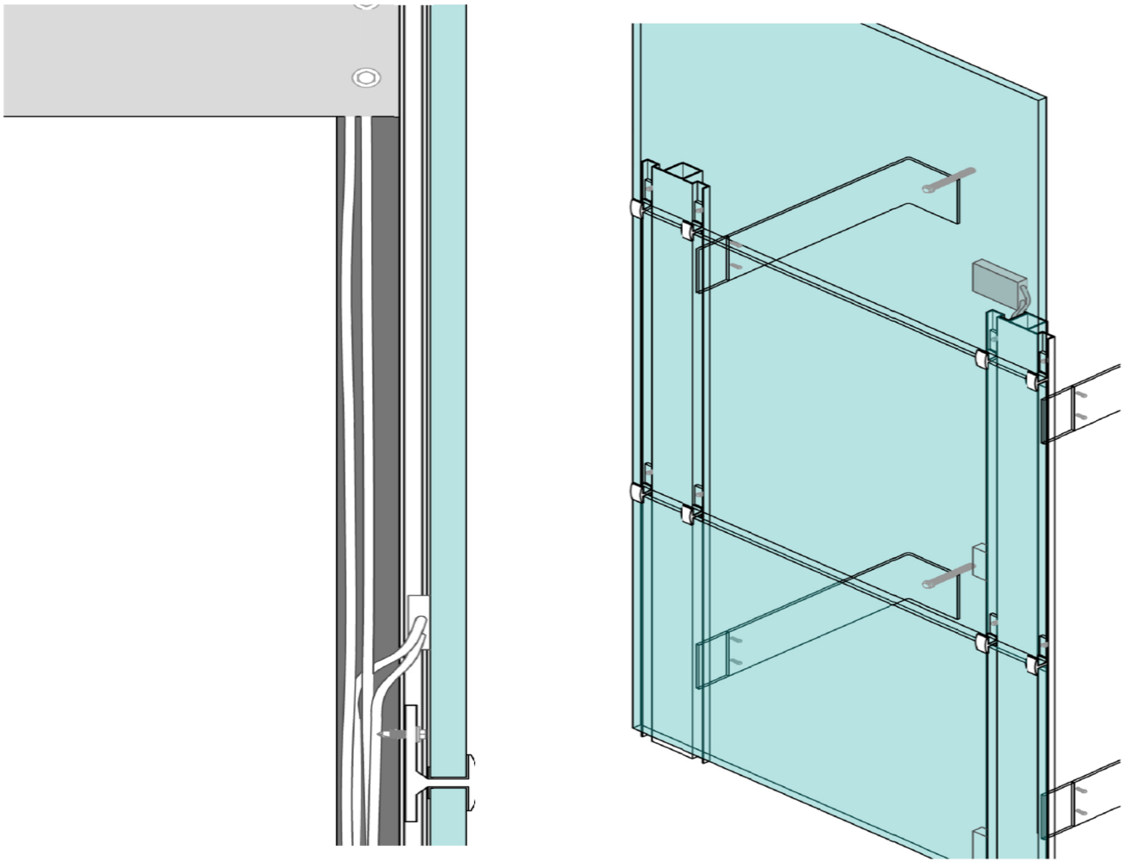


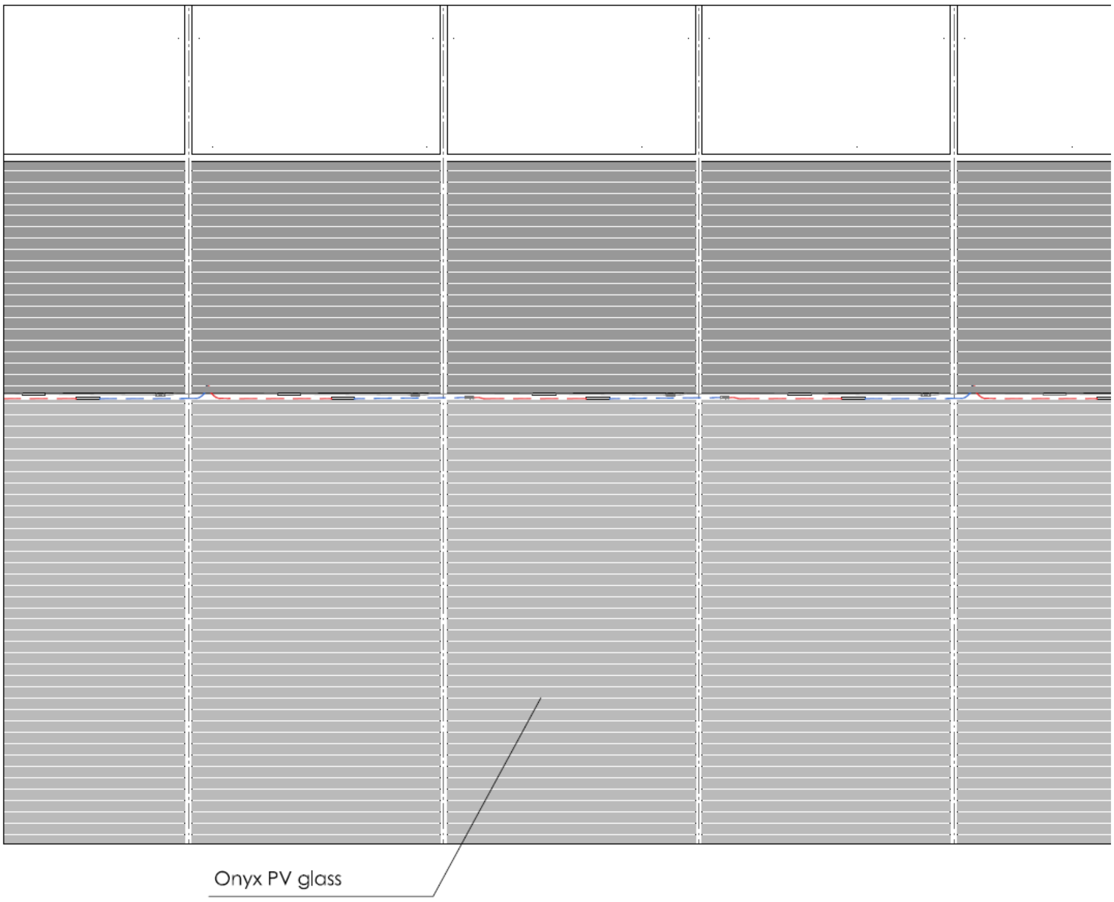
Figure 2.15 System details of application and hidden wiring strategies for S-Vitech FP4001PV in a PV ventilated façade. Source: ONYX

2.3.2 Curtain walls and skylights

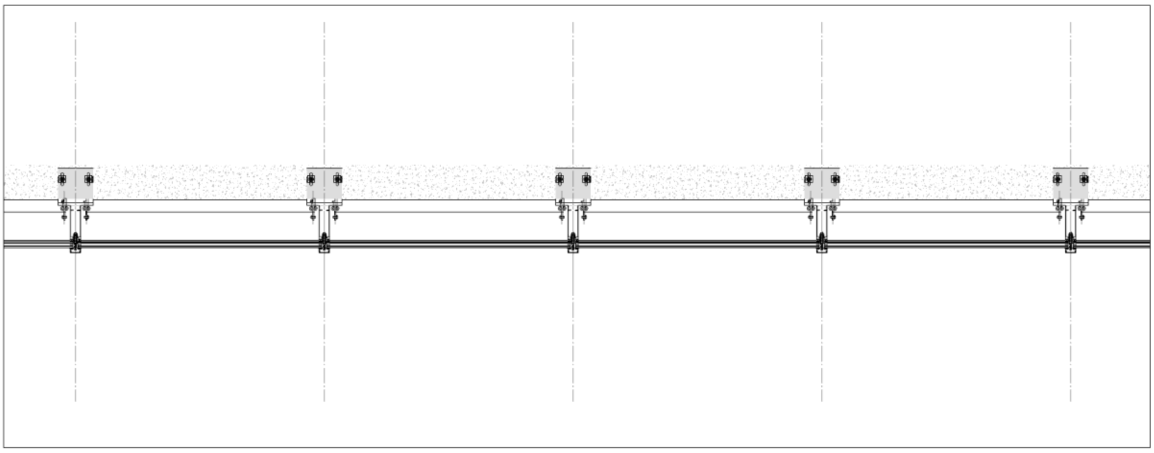
Schüco FW 50+/FW60+

In this system, lateral junction boxes are placed in the lateral edges of the exterior PV glass. Cables get out the junction box and pass through the crossbar, normally by means of little perforations made to this purpose. Once the cables cross the crossbars they are hidden in a chamber that allow electric maintenance and guide the cables to final electrical boxes.

FRONTAL VIEW



HORIZONTAL SECTION



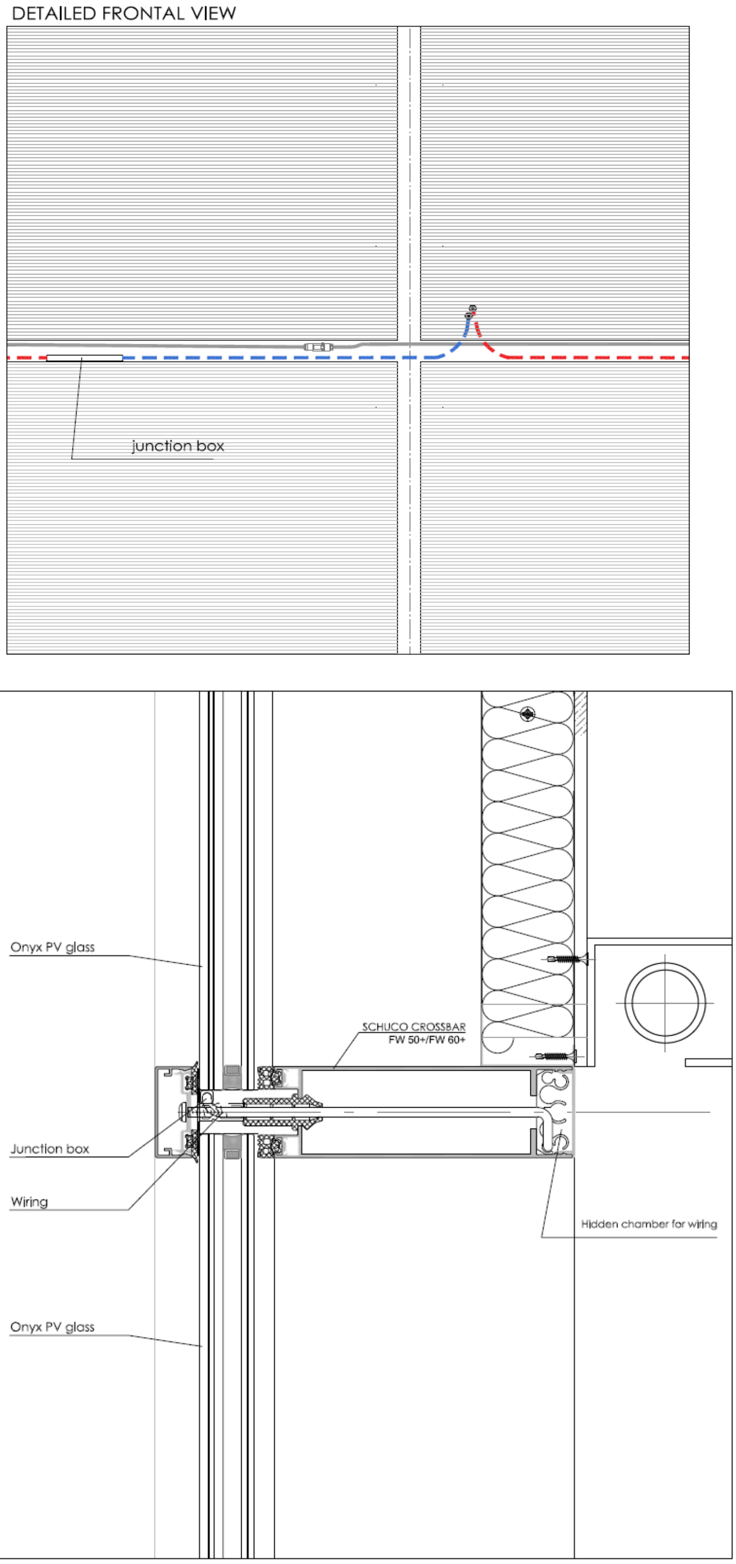


Figure 2.16 System details of application and hidden wiring strategies for Schüco FW50+/60+ in PV curtain walls and skylights. Source: ONYX

3 MECHANICAL ANALYSIS OF FRAMING SYSTEMS FOR XL BIPV

3.1 PV ventilated façade

This section summarizes a case study that shows the methodology of mechanical analysis that is carried out to verify the structural stability of SB Fixation system, valid for XL format PV ventilated façades. This system is the one selected to undertake an indoor validation testing within Task 3.7 whose results will complete the structural verifications.

First of all, it is necessary to perfectly characterize the materials used in the system. In this sense, SB provides all the details for the main elements of the system (vertical profiles, staples, angular brackets, screws, etc.). Some of these parameters are provided in Section 2.2.2.

The requirements that have to be met by the elements of the façade substructure and the whole ventilated façade system must be determined based on the building configuration and location. This information will be used to define the loads that the structure will need to withstand (thermal, wind, seismic...). Other considered loads to be considered depends on the structural configuration used and other factors: own weight, impact, etc.

Next step is to determine the number of brackets and its disposition within the wall, the fixation of these brackets to the vertical profiles and the type, number and disposition of the anchor elements that are fixed to the existing support structure. In this sense, for XL formats of glass, the fixing points should be located in the main floor building structure. The distance between the brackets connecting the ventilated façade and the building structure will be determined in accordance with the structural loads and the distance between vertical profiles, taking into account that maximum deflections in vertical profiles must not exceed L/200. Anchorage systems connected to concrete structures should be provided with CE marking.

Load combinations and security coefficients are determined according to national building codes. As a reference, the main regulation applicable in Spain in this field is the following:

- CTE: Technical Building Code.
- Eurocode 9: Design of aluminium structures.
- NCSR-02: Seismic-resistant building code.
- UNE-41957-1:2000: Anchorage systems for building façades.

Once the loads are determined and the system elements are dimensioned and characterized, several structural verifications must be undertaken. In general, resistance, stability and durability of the system must be guaranteed for the estimated loads and structural configuration. Some of the verifications to carry out are the following:

- Elastic limit of the material not exceeded.
- Maximum deflections in the system elements (profiles, staples, brackets,..) not exceeded.
- Maximum stress values in screws not exceeded.

These verifications must be done in staples, profiles, angle brackets and screws. Some details of calculations and verifications using WINEVA and SOLIDWORKS software are provided in the following pages.

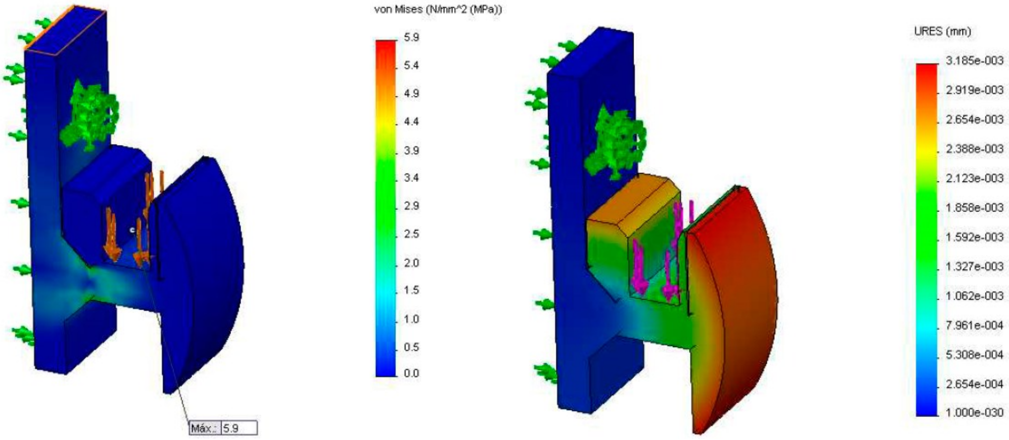


Figure 3.1 Example of stress and deflection analysis in the staples of the PV ventilated façade structural system. Source: SB Fijaciones

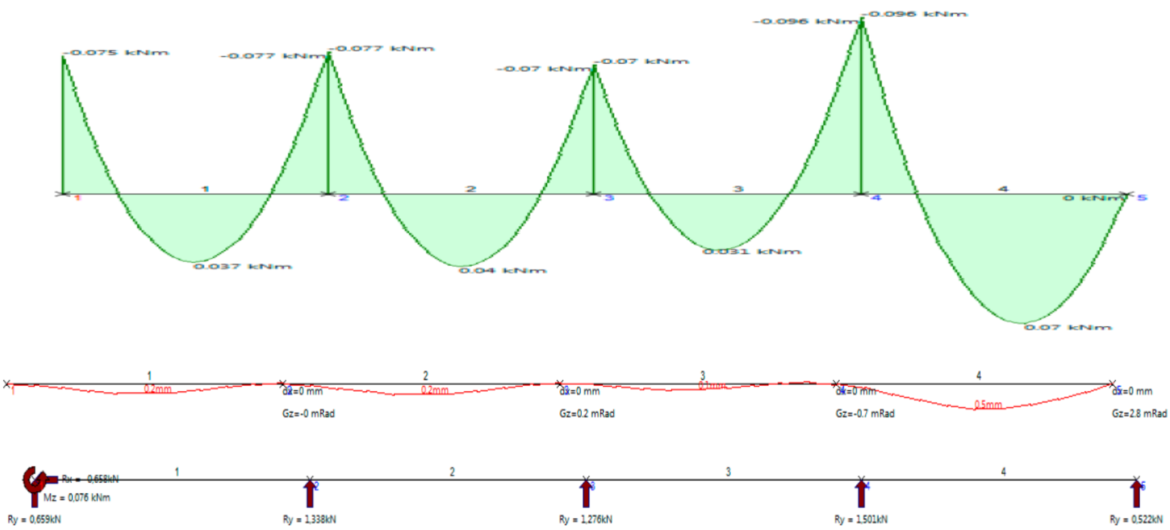


Figure 3.2 Example of diagrams of bending moments, deflections, rotation and reactions in the vertical profiles of the PV ventilated façade system. Source: SB Fijaciones

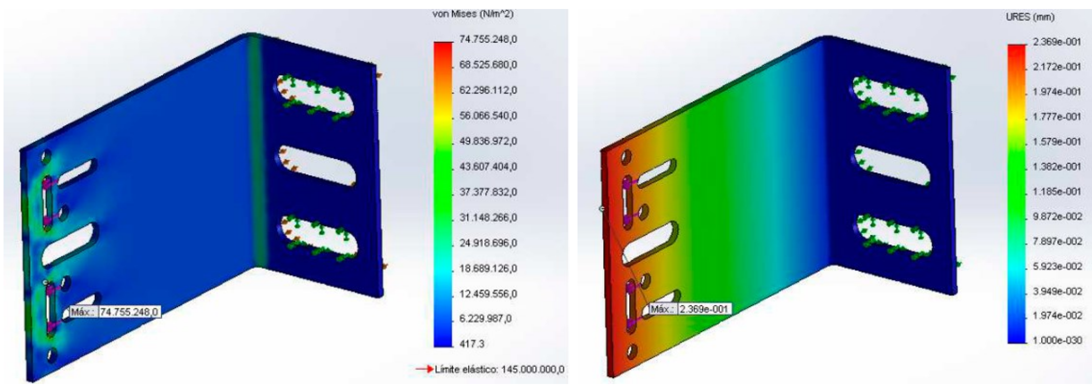


Figure 3.3 Example of stress and deflection analysis in the angle brackets of the PV ventilated façade structural system. Source: SB Fijaciones

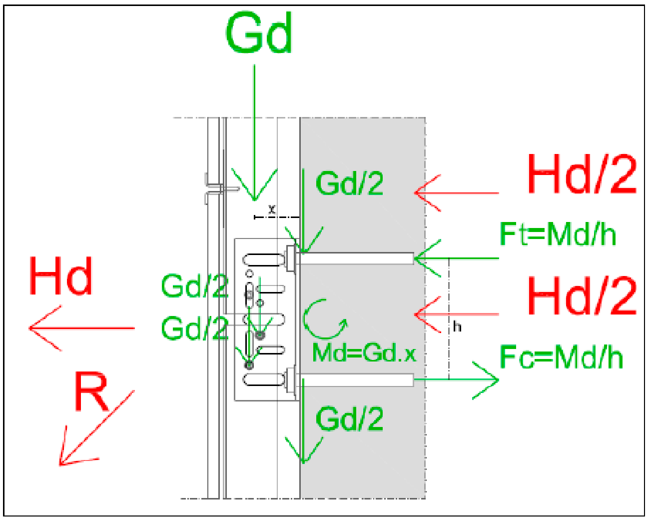
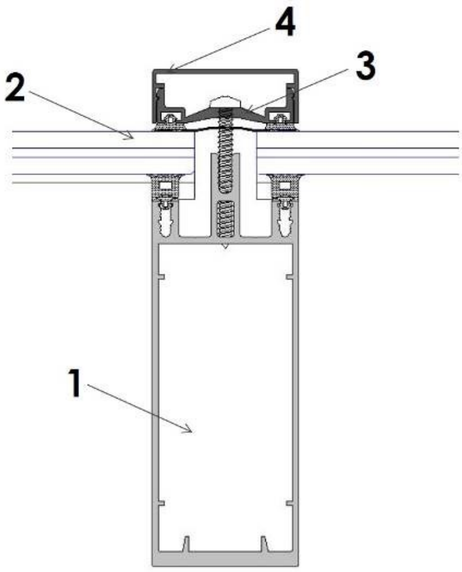


Figure 3.4 Example of load distribution in the support brackets of the PV ventilated façade structural system. Source: SB Fijaciones

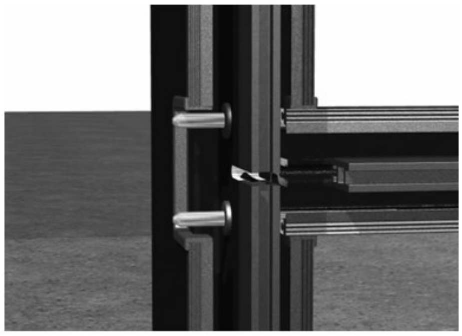
3.2 Skylights and curtain walls

ONYX has carried out mechanical load tests for PV curtain walls and skylights under the specifications of UL 1703 Standard for Flat-Plate Photovoltaic Modules and Panels. 2 samples consisting on PV glass mounted on the curtain wall frame with measures of 1245x1242mm (sample 1) and 1245x2456 mm (sample 2) have been tested including rails for simulation in neighbor modules. Framing base part height is 195mm. Mounting procedure of samples was carried out as follows:

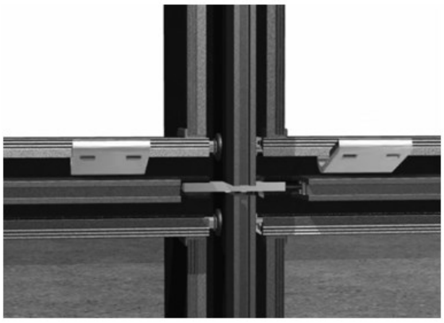
1. Installation of the structural support system.
2. Installation of the module with the necessary mechanical equipment on the base once fixed to the final structure.
3. Installation of the upper closing structure.
4. Installation and fixing of both structures giving the module the necessary waterproofness.



1. Fasten the structure to the wall or skylight



2. Install the crossbar and EPDM rubbers over the aluminum profile



3. Place two plastic wedges in the lower part of the structure for supporting the glasses.

4. Place the glass over the structure

Figure 3.5 Mounting instructions of PV skylight/curtain wall system for UL 1703 tests. Source: ONYX

Samples have been subjected to positive and negative load tests and both samples withstood test loads of 5400Pa (1,5 times the design positive load) complying with the condition of maximum deflection of the module: less than L/240. Test data and results are summarized in the following table:

Table 3.1 UL 1703 test data and results. Source: ONYX

Sample	Dimensions (mm)	Load direction	Design load (Pa)	Test load (Pa)	Total weight: Test load*Area (Kg)	L/240 (mm)	Deflection (mm)
1	1245x1242	Positive	3600	5400	851,3	5,2	**2,74**
		Negative	3600	5400	851,3		**4,58**
2	1245x2456	Positive	3600	5400	1683,4	10,2	**8,37**
		Negative	3600	5400	1683,4		**9,86**

4 FINAL PROTOTYPES FOR INDOOR VALIDATION TESTING

Prototypes necessary for indoor validation testing have been successfully designed and developed. In this sense, Onyx has manufactured the necessary PV glasses to test within ventilated façade and skylight/curtain wall framing systems. Necessary structural systems and components are ready and the prototypes will be mounted and tested by Tecnalia (task 3.7). More detail of prototypes and testing can be found in Deliverable 3.8: *Samples for indoor validation tests*. Once the indoor tests are undertaken, results will be exposed in Deliverable 3.9: *Report on indoor validation tests*. Finally, the results of the analysis carried out within tasks 3.4 and 3.7 will serve as a basis for the prototypes to be developed for demonstration in outdoor test benches (see detailed relationships between the different tasks in Section **Fehler! Verweisquelle konnte nicht gefunden werden.**).

5 COST ANALYSIS

The aim of this section is to provide estimated costs of the framing systems for XL PV glazing studied in this deliverable. Costs are separated by structural systems for the cases of PV ventilated façades and curtain walls. This study has been carried out considering existing commercial framing systems adaptable to XL format PV glass. As the aim of this deliverable is analysing framing systems, performance aspects and costs of the PV glass are not included as in the case of the other deliverables of WP3 related to PV products (PV glass with opaque connections, back contact solar cells, glazing treatments for improved passive properties,…). Costs include structure and assembly and reflects an average of the market prices of different systems existing in the market. CYPE software price database has been also consulted to contrast values [1]

Table 5.1 Cost analysis

	Framing systems for PV ventilated façades	Framing systems for PV curtain walls and skylights
Cost (eur/m^2)	80-120	150-250

6 CONCLUSIONS

With the work carried out under this deliverable, **ONYX has provided an answer to the need of a building integration strategy in terms of full system integration of XL format BIPV glass.** Therefore the objectives of this deliverable within Work Package 3 have been successfully fulfilled and several conclusions can be drawn, including the following:

1. ONYX has analyzed several possibilities to accomplish the structural part of the integration of XL BIPV units. In this sense, the options selected are applicable to this glass format.
2. ONYX has characterized and analyzed several commercial possibilities for framing systems in terms of architectural design, mechanical aspects and hidden wiring strategies.
3. Prototypes for indoor validation testing have been successfully developed.
4. The results of the analysis carried out within tasks 3.4 and 3.7 will serve as a basis for the prototypes to be developed for demonstration in outdoor test benches
5. ONYX has estimated the costs of framing systems for XL large format, in order to consider them for different purposes such as ROI and payback calculations of full constructive PV solutions.

7 REFERENCES

Websites:

[1] http://www.generadordeprecios.info

[2] http://www.onyxsolar.com

[3] https://sbfijaciones.com

[4] https://www.schueco.com

[5] https://s-vitech.com/