Report Nº

TRADUCTION OF DICTUC REPORT Nº 869240: "CRYSTAL CURTAIN WALLS MODULES ADHERED TO ALUMINIUM PROFILES BY MEANS OF 3M ADHESIVE TAPE CYCLIC SHEAR TEST AND MONOTONIC EMPTYING TEST, January 13, 2010"

For:
3M CHILE S.A.

Prepared by:
DICTUC S.A.
Structural Engineering Laboratory

Santiago, December 28, 2010.

REQUESTED BY	:	**3M Chile S.A.**
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WORK REQUESTED	:	Cyclic shear and emptying test of curtain wall composed by crystals adhered to an aluminum frame by means of adhesive tape 3M.
NORMATIVE	:	AAMA 501.4-00 Recommended Static Test Method For Evaluating Curtain Wall and Storefront System Subjected to Seismic and Wind Induced Interstory Drifts.

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REPORT

CRYSTAL CURTAIN WALLS MODULES ADHERED TO ALUMINIUM PROFILES BY MEANS OF 3M ADHESIVE TAPE CYCLIC SHEAR TEST AND MONOTONIC EMPTYING TEST

1.- INTRODUCTION

The present report gives the obtained results of 2 cyclic shear tests and 2 monotonic emptying tests to a curtain wall conformed by crystal attached to an aluminum perimetric frame by means of 3M adhesive tape. The samples that were subjected to test were provided by the client. The assembly of the samples was carried out by an external company hired by the client.

The tests were carried out at the request of Mr. Cristián Alcota in representation of 3M Chile S.A. in the Laboratory of Structural Engineering of DICTUC S.A., branch of the Pontifical Catholic University of Chile.

The tests carried out have as their objective to determine if the curtain wall system (crystal, adhesive tapes and anchorages of the aluminum frames to the resistant structure) it is able to accept the seismic deformations which can be subjected the building to which it will be anchored and of resisting the efforts of emptying to which it can be subjected the system due to the wind and earthquake action.

The present report is divided into: Antecedents, Tests Carried Out, Tests Results, Conclusions and Observations.

2.- ANTECEDENTS

2.1.- Curtain wall system general characteristics

The curtain wall system subjects to shear and emptying tests corresponds to the system denominated as "unitized", since they are totally assembled in plant, according to the client. The curtain wall under test consists of two modules, those that are conformed to each by an aluminum perimetric frame to which a crystal of determined characteristic is attached by means of a 3M adhesive tape. These modules are located one after the other and connected with two aluminum profiles placed vertically in the ends of the system of the curtain wall.

The module of the curtain wall is fixed to the steel frame that simulates the resistant structure to which the curtain wall system is connected under real conditions, by means of two vertical aluminum profiles that are fixed by means of screws to the steel frame and another central aluminum vertical profile that is fixed to the steel frame by means of a steel angle and a special guide. The horizontal aluminum profiles are connected with the steel frame by means of steel guides welded to the steel frame that allows for the free displacement of the curtain wall module according to their plan and impede their displacement in transverse direction to their plan. The assembly and the used elements correspond to those commonly used in the curtain walls of the tested type, as was pointed out by the client. The

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glasses used in each of the modules are different, existing a case in which corresponds to a thermo-panel and in the other case to laminated glass. In Figure 2.1.1 a general outline of the tested curtain wall system is presented.

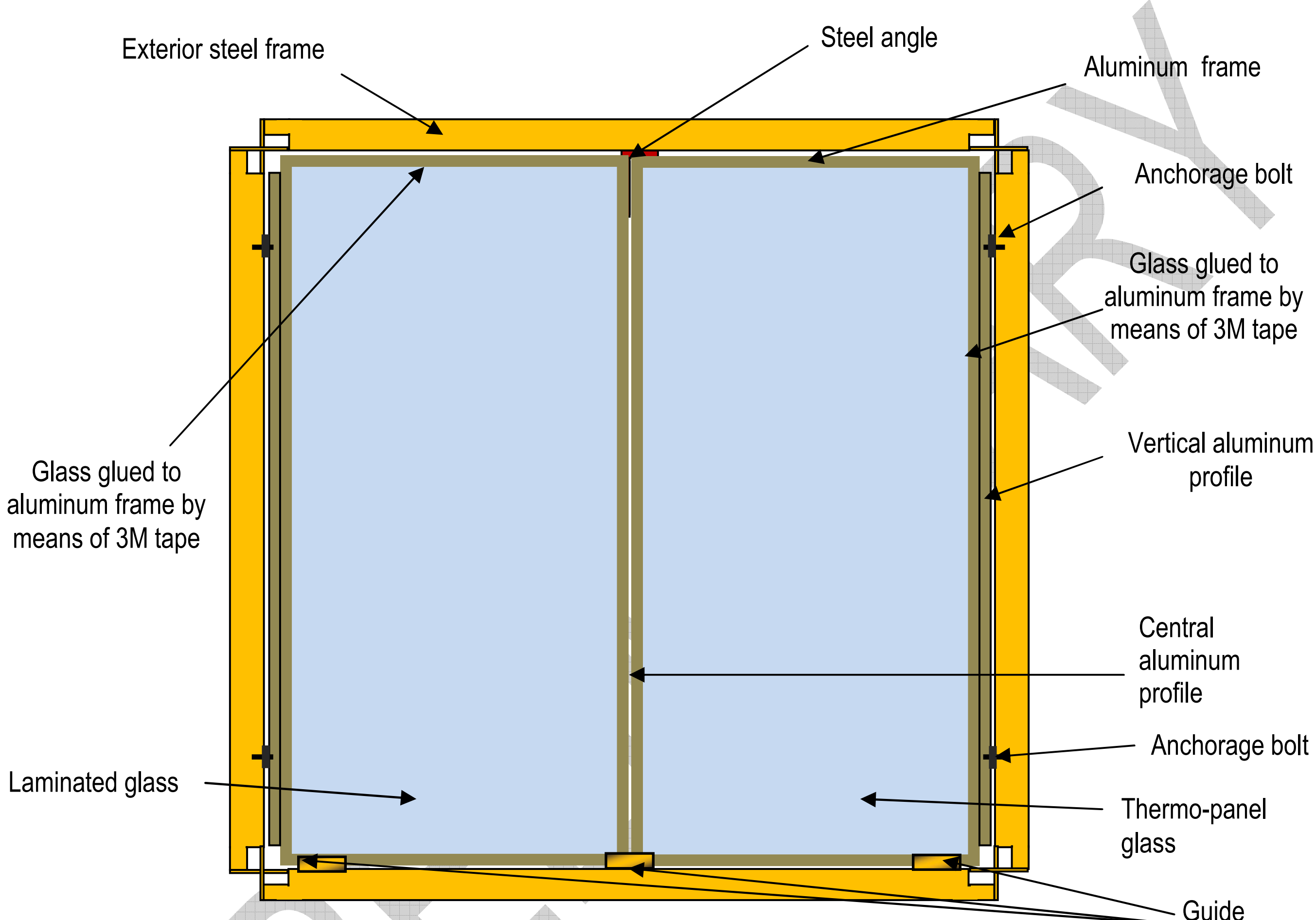

Figure 2.1.1. General outline of the curtain wall system that is composed by two modules conformed by an aluminum frame and glass joined by means of 3M adhesive tape

In point 2.2, a brief description of the frame load used in shear tests is presented, in point 2.3 are described, in a general form, the elements that conform the curtain wall and some details of the connection system among them.

2.2.- Load frame

The load frame used in the shear tests is of Japanese origin, with capacity of inducing to the samples a vertical load of 100 tons and a stress of horizontal shear of 50 tons in alternate cyclic form.

The load frame is basically conformed for:

- A base beam and two columns.
- A top reaction beam, a top load beam and a pantograph.
- Two horizontal reaction columns.
- A vertical load jack with pump and load cell of 100ton capacity.
- Two horizontal load jacks with a pump and load cell of 50ton of capacity.

Due to the dimension of the sample, it was necessary to carry out some modifications in the original configuration of the load frame. These modifications correspond mainly to the elimination of one of the load jacks and to the modification of the height of the top beams.

In Figure 2.2.1 an outline of the modified load frame is shown that it was used in the tests. In Picture 2.1 a general view is presented where it is possible to appreciate the utilized load frame.

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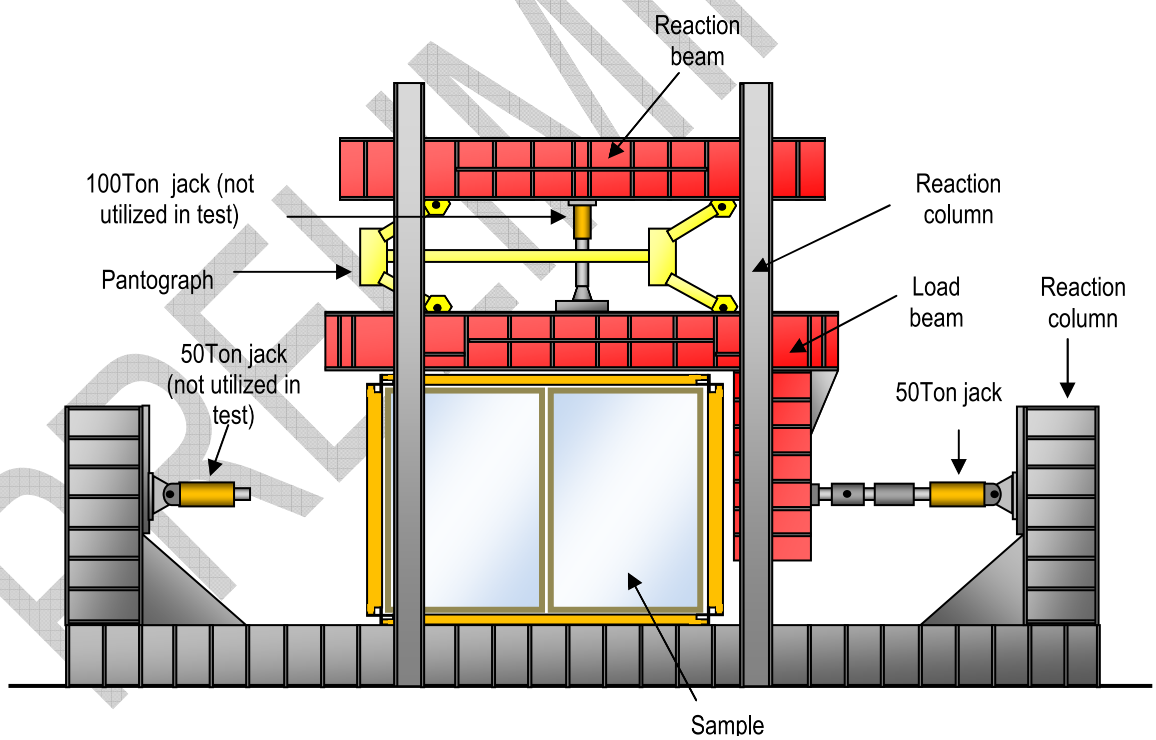

Figure 2.2.1. General outline of the load frame used in the cyclic shear test, and of the general location of the sample in the system

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Photograph 2.1: General view of the load frame utilized in the shear test as well as the general view of the sample.

2.3.- Curtain wall components elements antecedents

2.3.1.- Aluminum perimetric frame

Each of the modules that makes up the curtain wall has an aluminum frame which the respective glass is adhered to. For the tested case, the aluminum frame of each module has approximately 3305mm high, and 1730mm wide (measured on the external faces of the frame). The frame is constituted by complex geometry sections, since the profiles located on the short side (width of module) possess special shapes to generate a connection with the external steel frame, and the profiles located on the long side (height of module) they also possess special shapes to generate the connection with the aluminum vertical profiles fixed to the steel external frame. In Figure 2.3.1.1 a geometry outline is presented for both profiles cases. The module, and consequently the aluminum frame, was manufactured and assembling in plant. In Pictures 2.2, 2.3, 2.4 and 2.5 are shown general views and details of the aluminum frame, profiles sections and connections. Larger details were not provided about the properties of the aluminum profiles.

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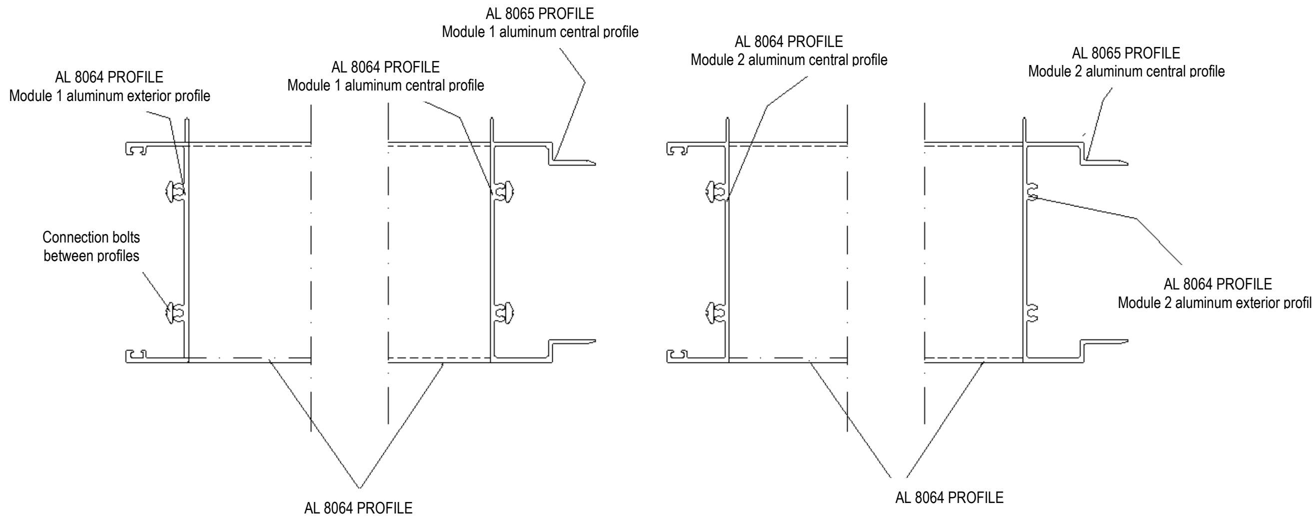
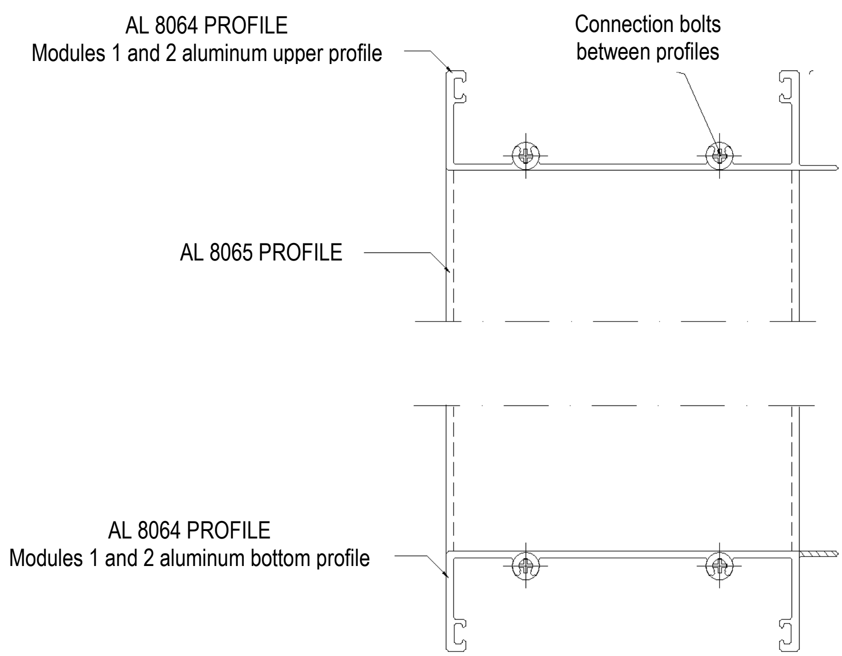


(a) Geometry outline of the aluminum frame vertical profiles.



(b) Geometrical outline of the aluminum frame horizontal profiles.

Figures 2.3.1.1. General outline of the profiles geometry that conform the aluminum frame of the curtain wall system.

Photograph 2.2: General view of the module with the aluminum perimetric frame.

Photograph 2.3: General partial view of the aluminum frame of one of the modules.

Photograph 2.4: Geometry detail of the aluminum frame vertical profile that is located in one of the module ends.

Photographs 2.5: Geometry detail of the aluminum frame vertical profile that is located in the other module end.

2.3.2.- Crystals

Crystals that are adhered to the aluminum perimetric frame were of two types. One corresponds to thermo-panel and the other to laminated glass. Both crystals are approximately 3300mm high and 1710mm wide.

The thermo panel is made up of two glasses separated by an air chamber. The crystals are colorless with a thickness of 6mm each; the central separator is 12mm. The total weight of the system is approximately 170 kg, the weight of each crystal is approximately 85kg. The thermo-panel inner crystal is the one that is directly glued to the aluminum frame by the 3M adhesive tape. There is a seal between the crystals which is located on the crystals ends. In Figure 2.3.2.1 part (a) an outline is presented with the thermo-panel typical section and of its connection (3M adhesive tape) to the aluminum frame used in tests. In Picture 2.6 a detail of this crystal type section is shown. The thermo-panel is connected to the aluminum frame directly by the 3M adhesive tape.

More antecedents about the thermo-panel were not given.

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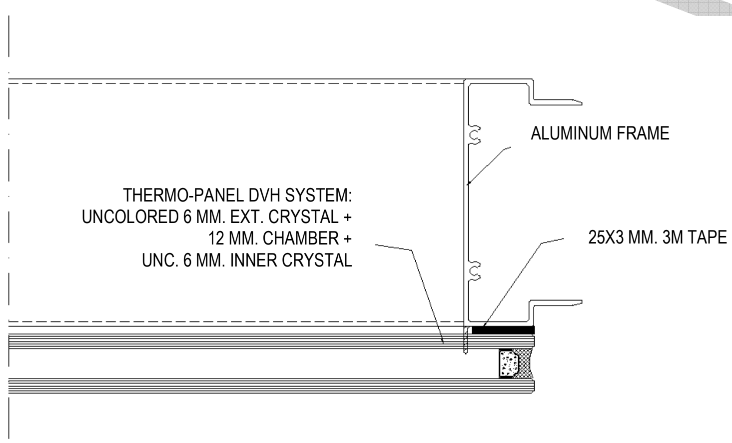
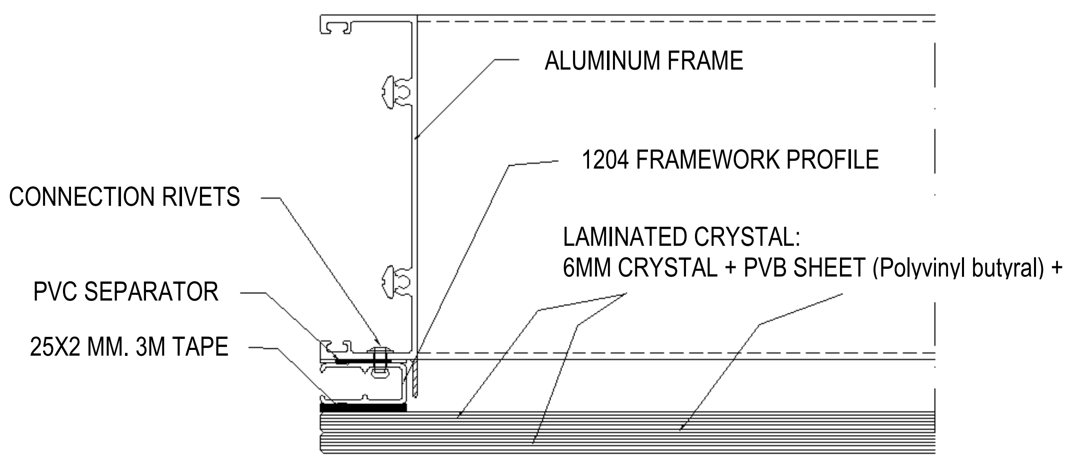
The laminated glass is composed by two 6mm thickness crystals with a central sheet of PVB (polyvinyl butyral). The glass weight is approximately 169 kg. In the laminated glass system, the inner crystal is adhered with 3M adhesive tape in its entire contour to an aluminum profile denominated framework. The framework is connected to the aluminum frame through a group of rivets, which are distanced at approximately 30cm. In Figure 2.3.2.1 part (b) an outline is presented with the laminated glass section and the connection system to the aluminum frame (aluminum framework and 3M adhesive tape) used in the tests. In Picture 2.7 a detail of the laminated glass section is shown. More antecedents about the laminated glass were not given.



(b) Thermo-panel system outline and its connection to the aluminum frame.



(b) Laminated glass system outline and its connection to the aluminum frame.

Figures 2.3.2.1. General outline of the two types of crystals adhered to the aluminum frame by means the 3M adhesive tape used in the wall curtain system tests.

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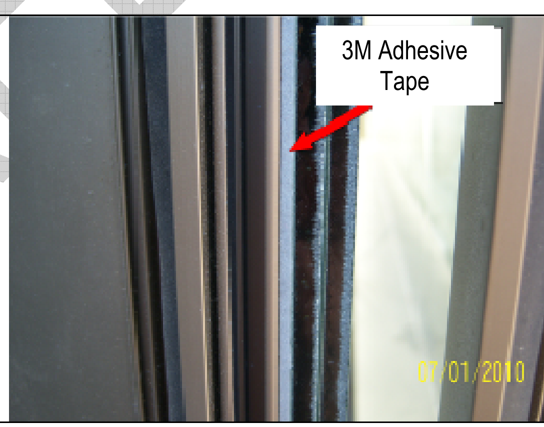
Photograph 2.6: Details of the thermo-panel system that is part of the modules used in the tests.	**Photograph 2.7: Details of the laminated glass system that is part of the modules used in the tests.**

2.3.3.- 3M adhesive tape

The element that was used to join the crystals to the aluminum profiles consisted on an adhesive tape manufactured by the 3M Company. As a commercial name this adhesive is called 3M™ VHB™ for Curtain Walls G23F. According to information provided by the client, it is a double faced foam acrylic adhesive tape of closed cell that has the capacity to develop a very high adhesive resistance and excellent long term retention power when it is adhered to crystal and metal. It was developed to replace the silicon structural sealants in the curtain walls systems.

The methodology and placement process of the 3M tape in the modules were carried out outside of Dictuc laboratory, by 3M qualified personnel. In Figure 2.3.3.1 a summary is presented with the main characteristics of the tape used in testing. All the presented information was extracted from a sheet of technical data and a technical guide. In Picture 2.8 a detail of the tape is presented, placed on one of the tested crystals.



Photographs 2.8: Details of the 3M adhesive tape utilized as a joint element between glasses and aluminum frames.

	VHB G23F - VHB B23F
Adhesive	High development acrylic
Adhesive support	Closed cell acrylic foam
Thickness	2.3 mm ± 10%
Density	720 kg/m3
Protector	Red polyethylene film
Roll length	33 m
Width	15 mm, 19 mm, 25 mm, 33 mm
Width tolerance	± 0,4 mm
Dynamic load design	8435 kg/m2 = 85 kPa
Static load design	173.5 kg/m² = 1.7 kPa

		VHB™ G23F – VHB™ B23F
Temperature resistance • Prolonged exposure • Brief exposure		90 ºC 150 ºC
Peel resistance Method: AFERA 4001. Substratum: steel Measurement 72 h. Speed: 300 mm/min Angle: 90º. Ambient temperature.		35 N/cm
Tensile strength Method: ASTM D 897. Substratum: aluminum. Measurement 72 h. Speed: 50 mm/min Adhesive surface: 6.45 cm². Ambient temperature.		0,48 MPa = 480 kPa
Dynamic shear Method: ASTM D 1002. Substratum: steel. Measurement 72 h. Speed: 12.7 mm/min Surface: 6.45 cm². Ambient temperature.		0,45 MPa = 450 kPa
Static shear Method: AFERA 4012. Substratum: steel. Measurement after 72 h. Surface: 3.23 cm². Time > 10000min	**20 °C** **65 °C** **90 °C** **120 °C** **150 °C**	1000 g 500 g 500 g **Caution: the higher the temperature, the higher prevalence of tape viscous component. Perform tests in real conditions always.**

Figures 2.3.3.1. Charts with technical data of the 3M VHB™ G23F adhesive tape for Curtain Walls.

2.3.4. - Steel frame (resistant structure) and aluminum vertical profiles.

In order to represent the resistant structure to which the curtain wall system is fixed in actual conditions of work, it was built a steel frame of 3700mm height and 3865mm width (measured on the profiles external face). This frame is composed of H profiles with screwed connections. The frame bottom profile possesses steel tabs located at the two ends and at the center of it, those that are adjusted with grooves that the aluminum frame has in its bottom profile,

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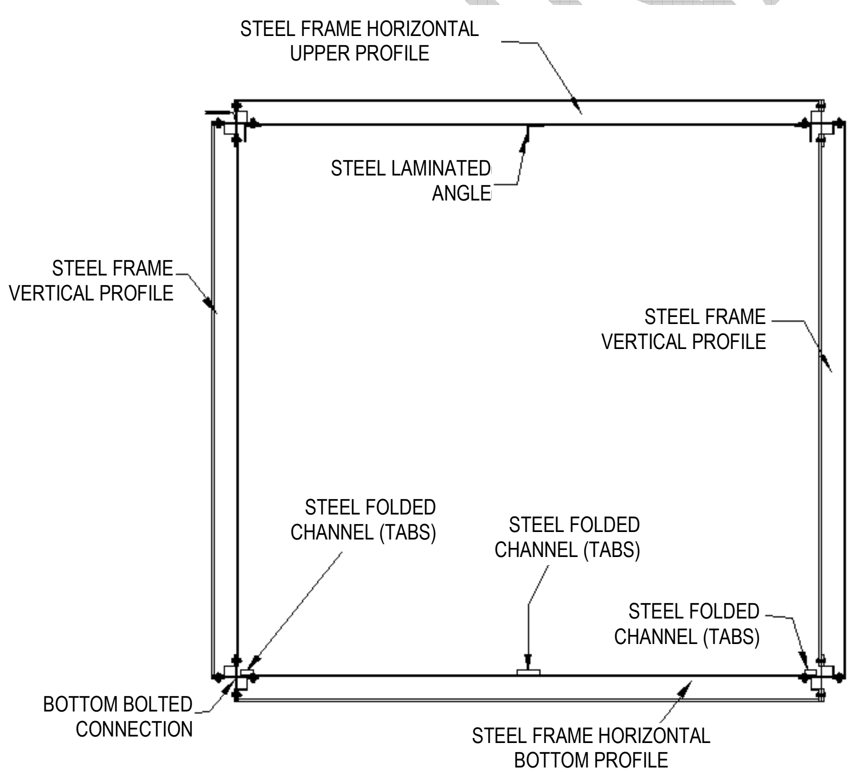
so as to generate a connection between the modules and the steel frame that simulates the resistant structure. In Figure 2.3.4.1 a general outline of the steel frame is shown, in the Figure 2.3.4.2 details of the connection type are presented between the profiles that make up the frame. In Pictures 2.9 and 2.10 details of the described frame are presented. Assembly of the steel frame was carried out at Dictuc Structures Laboratory.

	
Photograph 2.9: General view of the pieces that make up the steel frame.	Photograph 2.10: Details of the connection among steel frame profiles



Figures 2.3.4.1. General outline of the steel exterior frame used in the curtain wall system tests.

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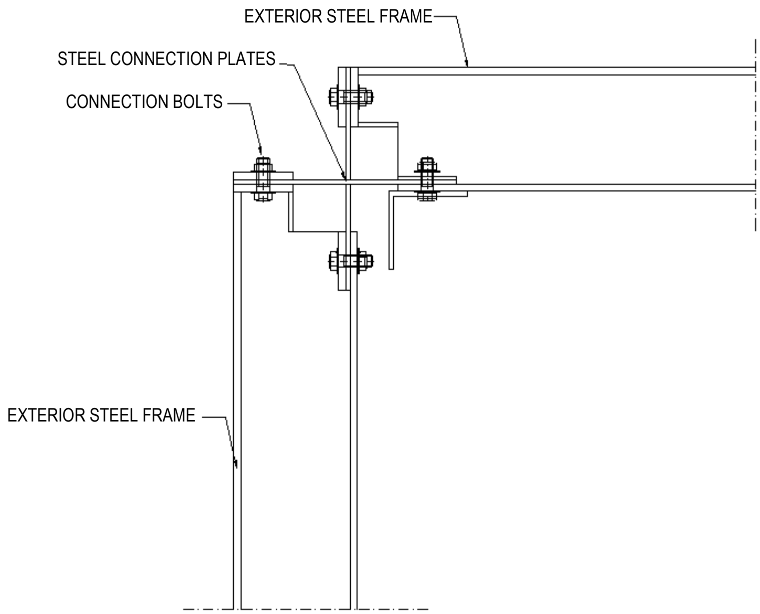
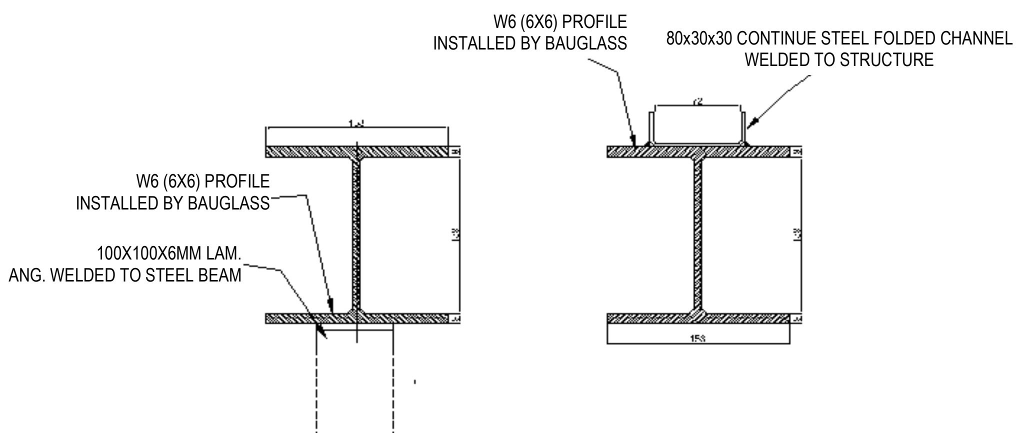
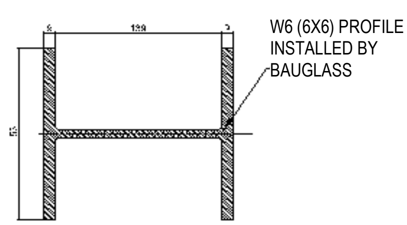


(a) Details of connections between profiles



TYPE OUTLINE OF STEEL FRAME HORIZONTAL PROFILES



TYPE OUTLINE OF STEEL FRAME VERTICAL PROFILES

(b) Geometry details of profiles that make up the steel frame.

Figures 2.3.4.2. Detail of the exterior steel frame used in the curtain wall system tests.

For the connection of the modules to the steel frames, two aluminum profiles were used that are located vertically in the sides of the steel frames, fixed by means of bolts. These present complex geometries, since they have special shapes, to be connected with the profiles of the aluminum frame. The vertical profiles have an approximate longitude of 2300mm (a little smaller than the height of the aluminum frame). A third element exists, which consists of a piece that is connected through a bolt to the steel angle fixed to the steel fame top profile. This piece has such geometry that it has an internally geometrical fits with the vertical profile of the aluminum frame. The length of this piece is approximately 10cm and practically the entirety of its extension is in contact with the aluminum profile. As it is pointed out in the plans, this piece is located in the ends and to the center of the steel frame (where the steel angles should also be). For these tests, it was only implemented the one that is located centrally. The Figure 2.3.4.3 shows outlines of the profiles used for the connection of the modules with the steel frame. The mentioned connection systems are additional to the steel tabs located in the steel frame bottom profile that it fits with the grooves carried out in the profiles base.

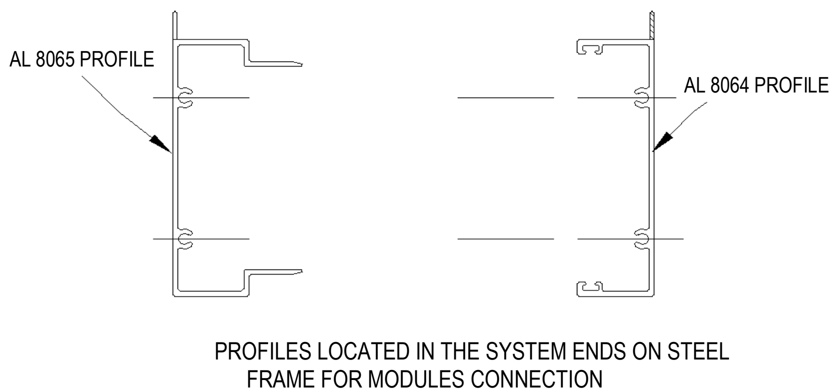


Figure 2.3.4.3. Details of the aluminum vertical profiles connected to the steel frame and to the curtain wall system modules.

2.3.5. - Assembly and systems of connection to the test tubes.

As mentioned above, the modules (glass attached to the aluminum perimetric frame by means of 3M tape) arrived to the Dictuc laboratory already manufactured and assembled. For the exterior steel frame, all parts were manufactured in factory and assembled in Laboratory.

2.3.5.1 - Samples assembly and connection systems in the load frame for the shear tests.

The assembly process of the curtain wall system for the shear tests was planned in the following way: the steel frame was located vertically in such a way as to be placed in the necessary position regarding the testing load frame. The bottom beam of the exterior frame was fixed to the reaction beam of the load frame, located in the floor of the Laboratory. In a later form and in a centered way regarding the height of the steel frame columns, they were fixed by means of bolts, the two vertical aluminum profiles on the sides, which were used for the connection between the modules of the curtain wall system and the steel frame. To make up for the existent distance between the final position of the aluminum profile and the external aluminum frame, aluminum sheets were used. In Picture 2.11 a general view of the assembly maneuvers is shown.

For the modules assembly, these are connected in their inferior ends to the bottom profile of the steel frame through the wedge of the existent tabs (in the ends and in the center of the steel profile) with the grooves in the profiles of the aluminum frame and by means of the connection with the vertical profiles of aluminum fixed to the steel frame. With one of the modules located in the steel frame (the one that will has their ends fixed in the steel frame center) the central piece of profile was located, the one that was connected through a bolt to the steel angle that was welded and screwed to the steel frame. This piece, as it is pointed out in the plans, should also exist in the ends, but it was not placed because the external profiles are screwed to the steel frame generating in this way the fixation to the steel frame. In Picture 2.12 the mechanism is shown between the grooves of the aluminum profiles and the steel tabs. In Picture 2.13 a detail of the top central system of connection is presented (angle - profile piece - aluminum frame profile).

For the shear tests case, it was contemplated that the module located in the east of the configuration (module with laminated glass) presented a connection type denominated as "clipped" to the vertical end profile, and is fixed to the center through the adjustment of the aluminum frame vertical profile to the profile piece that is connected to the steel frame through the steel angle. The west module is "clipped" to the vertical profile of the frame of the adjacent module and fixed to the aluminum external vertical profile. This way, according to information granted by the client, the typical condition of work would be represented, in the one which, the fixed connections and the "clipped" connections are interspersed. For the first test case, industrial silicon was used to seal the spaces between the aluminum profiles, and in the second test, this process was not carried out, leaving these spaces free. In Figure 2.3.5.1.1 an outline is presented with the general configuration of the tested system assembly. In Figures 2.3.5.1.2 and 2.3.5.1.3 details are presented, through the views of the cuts pointed out in figure 2.3.5.1.1, of the connection system of each one of the parts that compose the curtain walls. In Picture 2.14 a detail of the vertical connection is shown between the module and the aluminum vertical profile connected to the steel frame.

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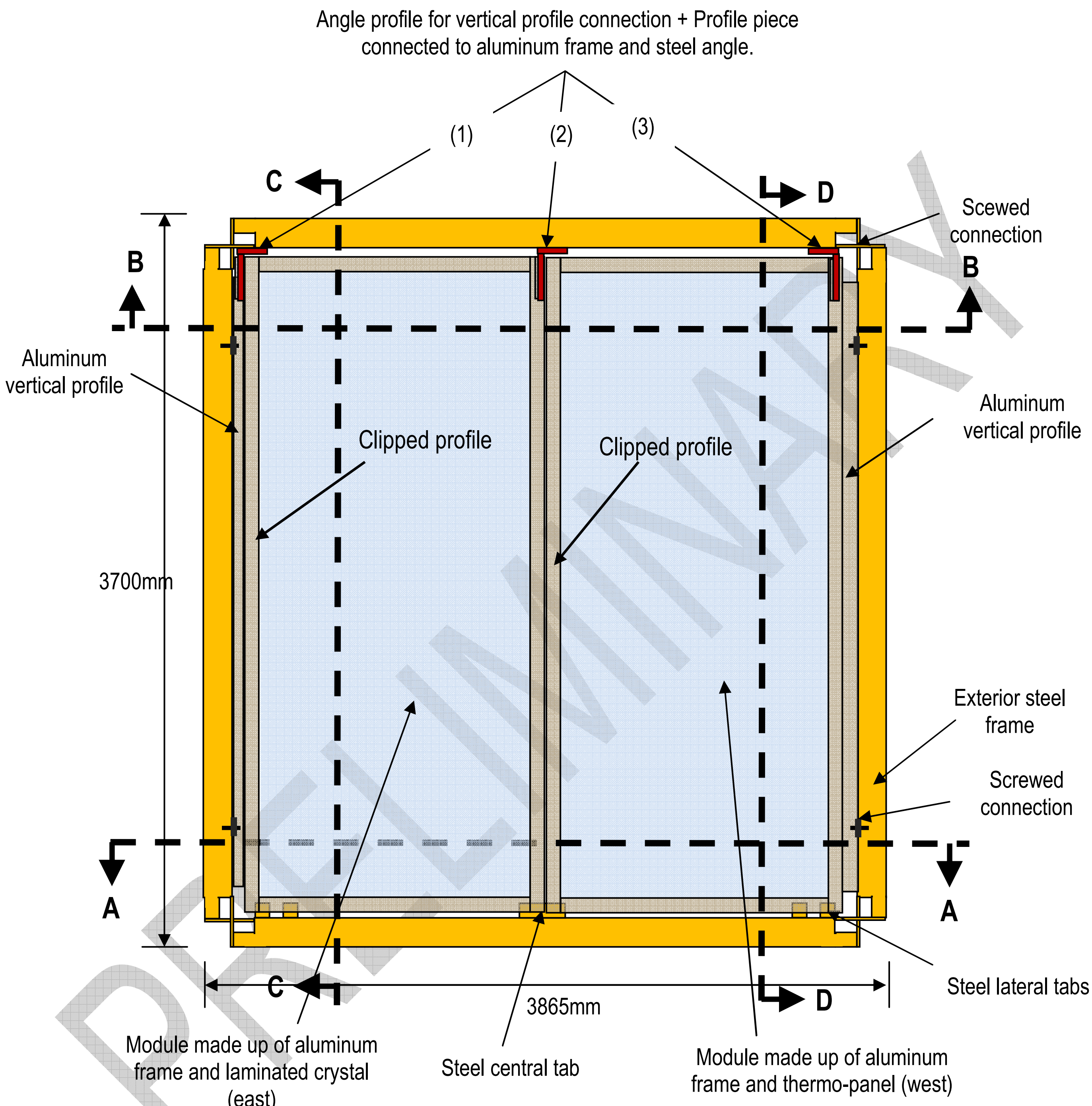
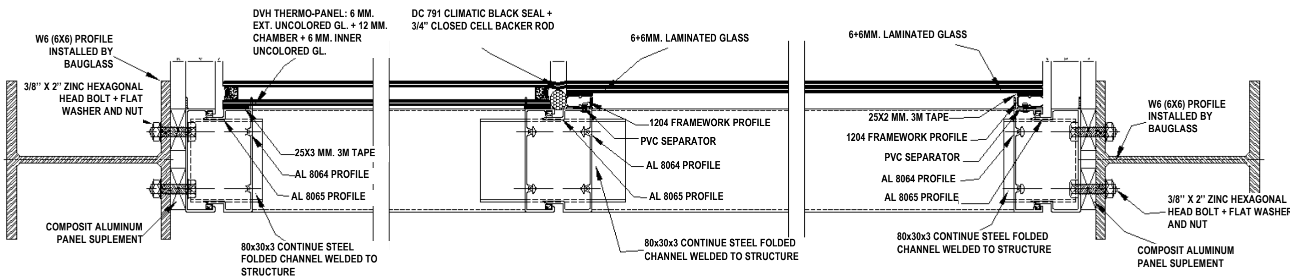


(1) An element that was not implemented in any of the tests.
(2) An element implemented in all the tests.
(3) An element that was only implemented in the emptying test.

Figures 2.3.5.1.1. Cyclic shear test assembly general outline.



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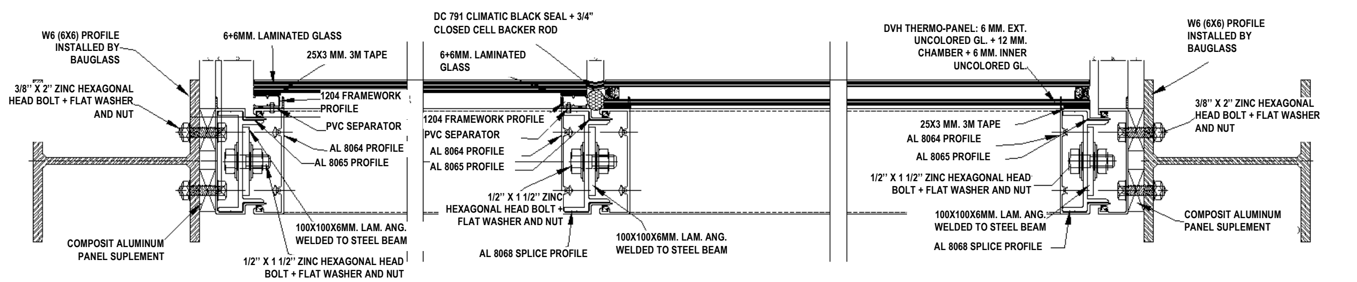

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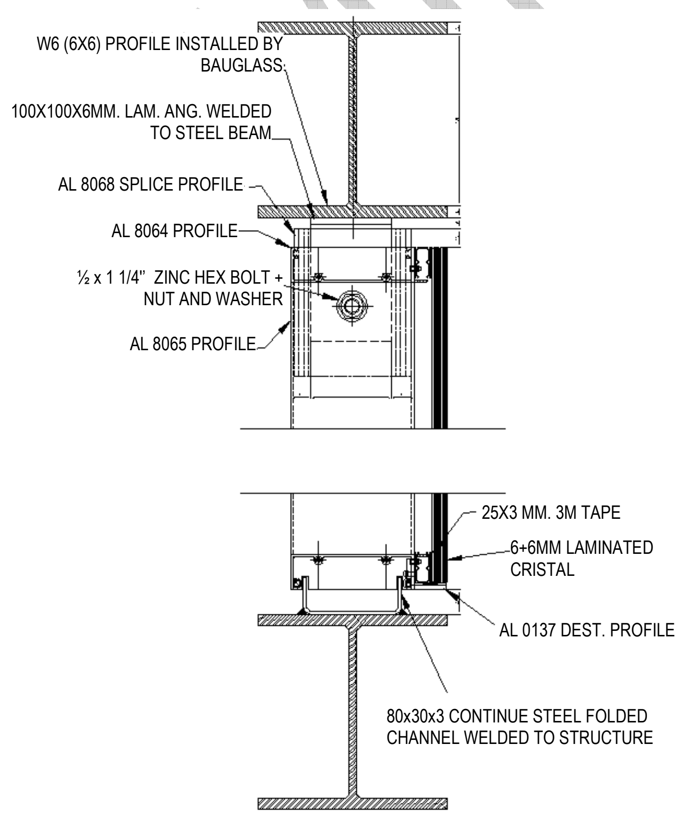

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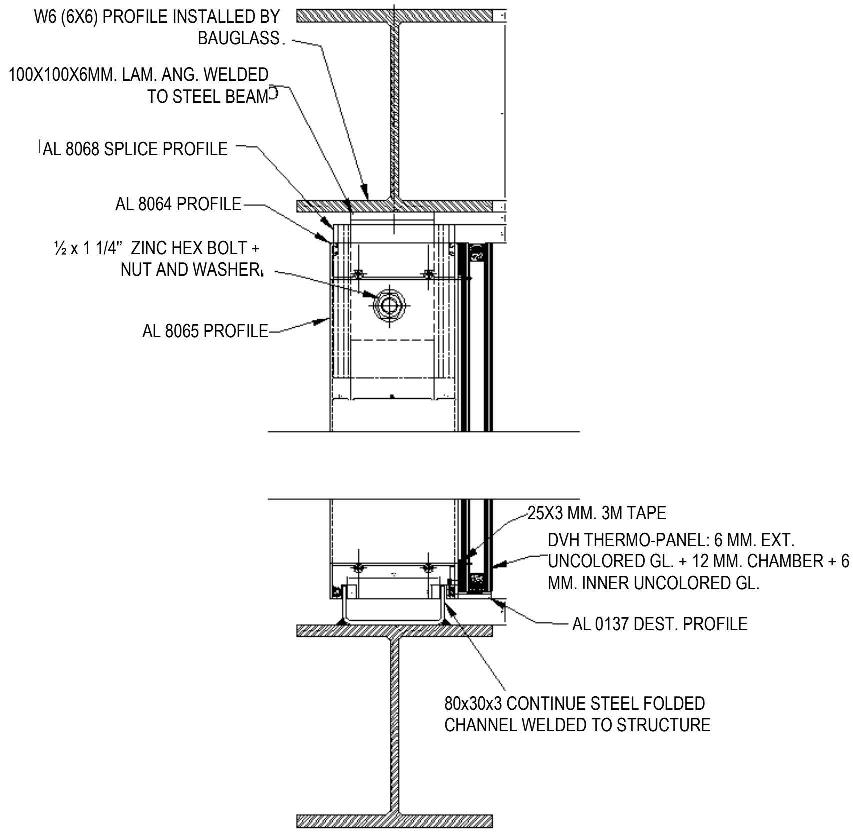

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Figures 2.3.5.1.2 Connection system details and assembly of the elements that compose the tested curtain wall system.

	
Photograph 2.11: General view of the assembly maneuvers of the modules in the steel frame.	Photograph 2.12: Details of the connection system between the aluminum profiles grooves and the steel tabs.

	
Photograph 2.13: Details of the central connection system between the aluminum frame and the steel frame (steel angle-piece of profile-aluminum profile)	**Photograph 2.14: Details of the connection of the aluminum external profile the steel frame and the aluminum frame.**

Mainly, in the assembly were used a hoist, an electric suction pad and manual suction pads. The assembly process was executed by an external company personnel designated by the client to carry out these works, with the Dictuc personnel collaboration.

2.3.5.2. - Assembly and connection systems of the test tubes for the emptying tests.

The emptying test assembly went similar to that of shear test, mainly presenting the following differences: the curtain wall system, including the steel exterior frame was mounted horizontally, supported in their vertexes in 20x20x20cm concrete cubes, outside the Laboratory. The height regarding the floor is of approximately 55cm. The crystals were located in the bottom face. For this tested system, silicon was not utilized between the modules. For the test assembly, one of the lateral connections of the steel angle was implemented, plus the piece of profile connected to the aluminum frame profile, specifically that of the top end of the module with the thermo-panel. (See Figure 2.3.5.1.1, note 3).

It is important to mention that in the emptying tests were used two of the modules that were previously subjected to shear test (which didn't suffer damages during the shear test), specifically, a module with laminated glass and the other one with the thermo-panel system. In the assembly process of the modules, carried out by an external company hired by the client, the total breakage of the thermo-panel external glass took place, reason why the system configuration decreases to the existence of the interior crystal only (crystal that is glued to the aluminum frame by means of 3M adhesive tape).

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3.- CARRIED OUT TESTS

3.1.- Curtain wall system cyclic shear test.

The cyclic shear test was carried out, in general terms, following the provisions of the AAMA 501.4-00, which consists on applying a controlled horizontal deformation to the of curtain wall system previously described. The external force to produce the deformation was applied by means of the action of a hydraulic jack located horizontally. The samples were subjected to cyclic deformations, which is to say, in one and another direction of the system main plane, with known and controlled amplitude. Each one of the cycles is completely executed twice, for then to increase the deformation applied to the following defined amplitude, until arriving, this way, to the defined maximum amplitude. For the present test, the initial cycle has 5mm amplitude, each increment is also of 5mm, until arriving to 50mm, that it corresponds to the maximum amplitude. The Figure 3.1.1 shows graphically the history of solicitation. The applied maximum displacement is obtained by applying a deformation of 1% of the system height plus a 1.5 factor of safety.

Maximum Amplitude = F.S. x (0.01 x system height) = 1.5 x (0.01 x 3305) = 49.6 ≈ 50mm.

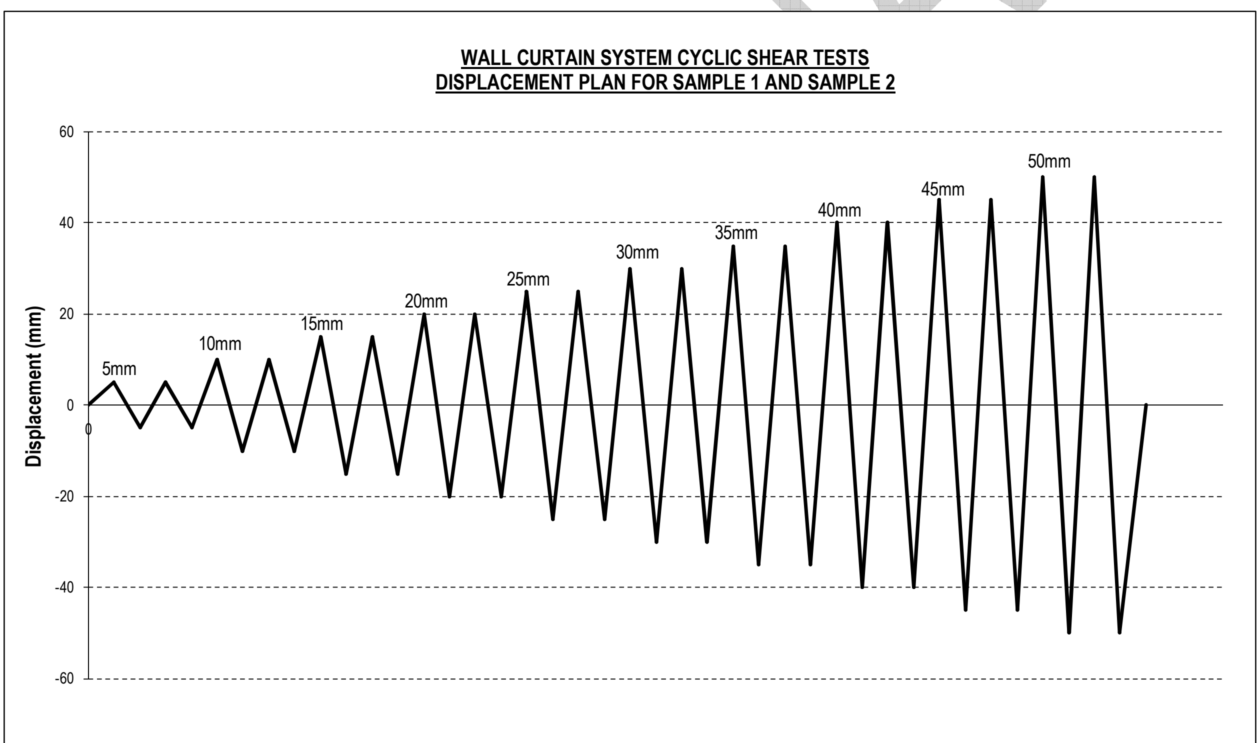

Figure 3.1.1. Cyclic shear test displacements plan.

The cyclic shear test implementation carried out on the curtain wall system consists of a mechanism of load application and deformations registration. Next the most outstanding aspects are detailed.

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For the load application, the action of the horizontal 50tonf capacity hydraulic jack located to the west of the general configuration was used exclusively. The transfer of the imposed deformations was carried out through a system based on beams and 1'' diameter steel tension bars. A tension bar was located horizontally on each side of the sample at the upper end of it, on the height of the beam of the steel external frame. The tension bars length allows them pass over the whole sample width and that it allows connecting them to two steel beams located in the ends. One of these beams was located in the east side, in the frame upper corner, a second beam was located on the same height but in the upper west end, in the external side of the load frame. These two beams are fixed and connected through the steel tension bars. Additionally there was a system conformed by elements of steel that was located between the load frame reaction beam and the upper east end of the sample outer frame, with the purpose of completing the deformation transferring to the samples (See Figure 3.1.2 and 3.1.3).

For the registration of the load applied during the test, two cells of 5tonf load capacity were used. One of the cells was located between the load frame and the beam of the implemented system upper east end; and the second one between the load frame and the upper east end of the steel external frame. With these two cells it is possible to register the applied load in both movement directions during the tests (east or west). For the deformations registration in the first test, only one displacement transducer was used, that was located on the steel frame upper beam, with which the system total lateral displacement was measured. In this test, a group of graduate rulers located in strategic points of the sample were used, to establish points of relative deformation that are interesting of measuring with more precision in the second test. In Figure 3.1.2 an outline of the first test implementation is presented. For the second test, besides the superior transducer that measures the total lateral displacement, 5 additional transducers were implemented that measured the relative deformations between the glass and the aluminum frame bottom profile, and the relative deformations between the adjacent glasses. It was maintained the existence and location of some of the graduate rulers of measurements in the second rehearsed sample. In Figure 3.1.3 and 3.1.4 an outline of the second test implementation is presented. The used nomenclature for the transducers and graduated rulers in the outlines is the same as the one used in the chart of results.

In Chart 3.1.1 and 3.1.2 are respectively presented the detail of the associated channel to the transducer and their location in the sample and of the used rulers in the first and second sample.

Chart 3.1.1. Location details of displacements measurement systems (Transducers and rulers) for sample 1.

Measurement system location detail. Sample 1		
Transducers		
Channel	**Location**	**Observation**
C3	Top	System total horizontal displacement
Rulers		
Nomenclature	**Location**	**Observation**
R1	Bottom wets	Horizontal displacement between thermo-panel and steel frame
R2	Bottom east	Horizontal displacement between laminated glass and steel frame
R3	West	Vertical displacement between thermo-panel and steel frame
R4	Central	Vertical displacement between laminated glass and steel frame
R5	East	Relative displacement between thermo-panel and laminated glass

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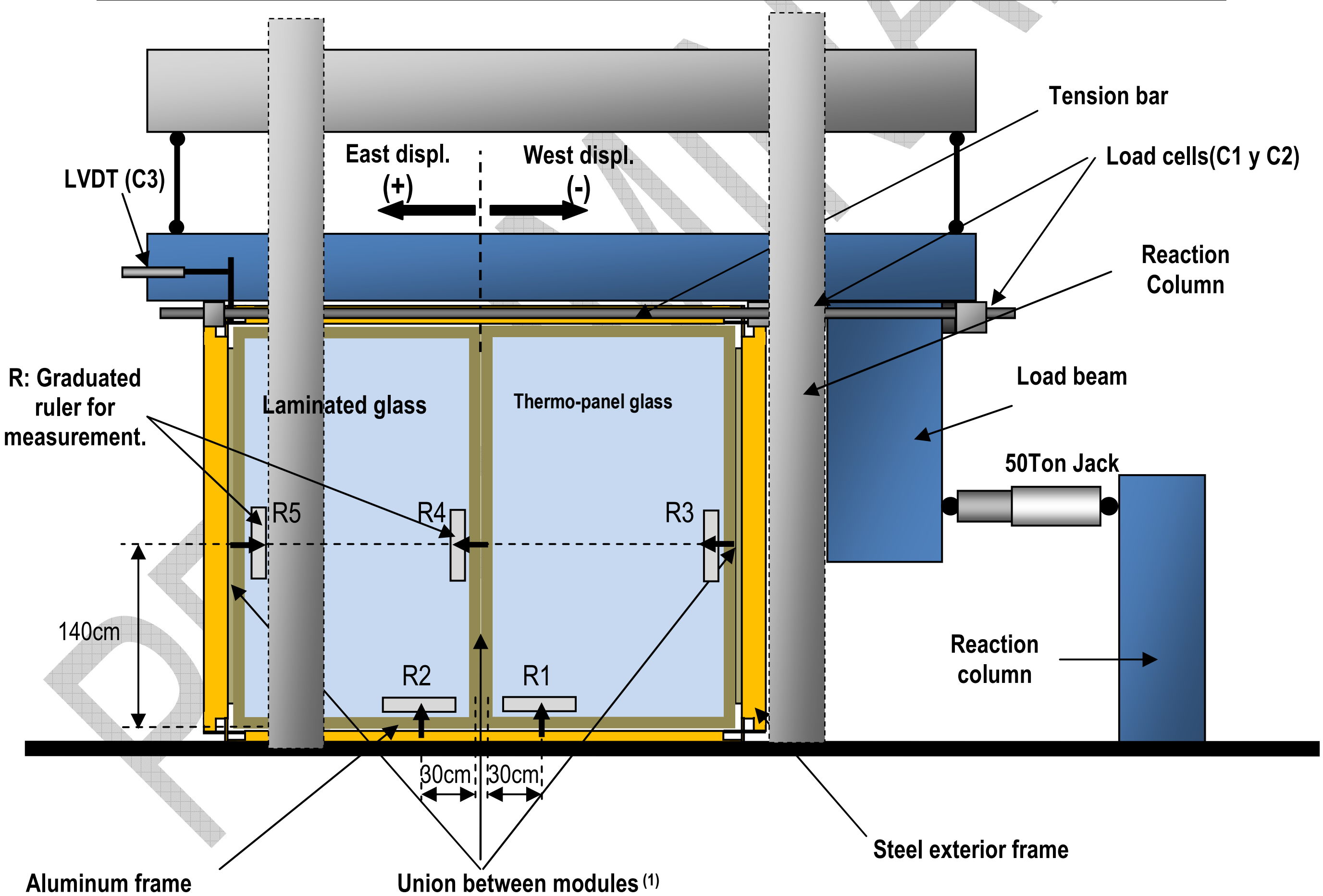
Chart 3.1.2. Location details of displacements measurement systems (Transducers and rules) for test tube 2.

Measurement system location detail. Sample 2		
Transducers		
Channel	**Location**	**Observation**
C3	Top	System total horizontal displacement
C4	Bottom west	Displacement between thermo-panel and aluminum frame
C5	Bottom central	Displacement between thermo-panel and aluminum frame
C6	Bottom central	Displacement between laminated glass and aluminum framework profile
C7	Bottom east	Displacement between laminated glass and aluminum framework profile
C8	Central	Relative displacement between thermo-panel and laminated glass
Rulers		
Nomenclature	**Location**	**Observation**
R1	Bottom west	Horizontal displacement between thermo-panel and steel frame
R2	Bottom east	Horizontal displacement between laminated glass and steel frame
R3	West	Vertical displacement between thermo-panel and steel frame
R4	East	Vertical displacement between laminated glass and steel frame



Note (1): In the union between the aluminum profiles, silicon is used as a sealant.

Figure 3.1.2. General outline of the curtain wall system cyclic shear test (with glasses glued with 3M adhesive tape) for sample 1.

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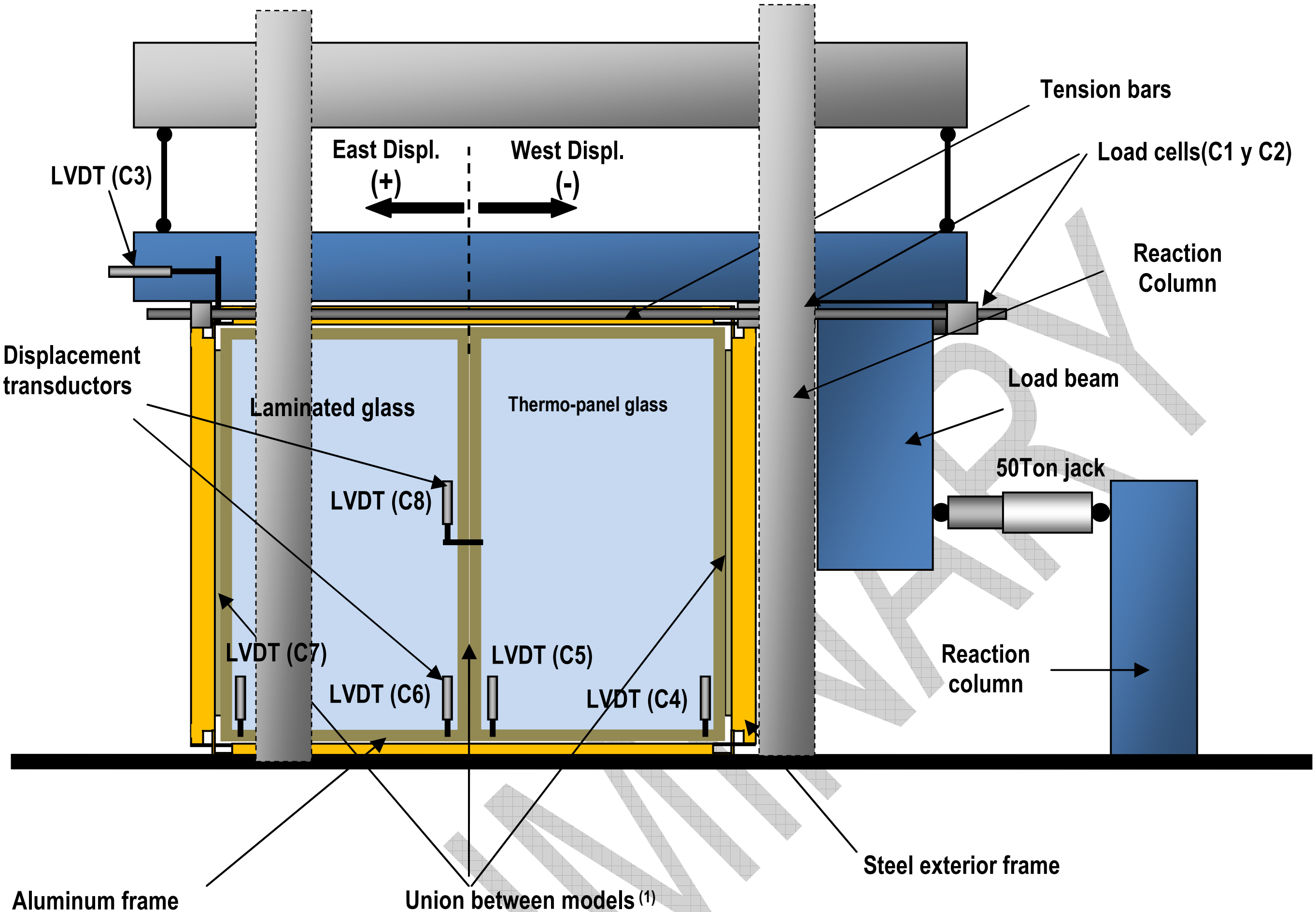

Note (1): In the union between the profiles of aluminum silicon is not used as a sealant.

Figure 3.1.2. General outline of the curtain wall system cyclic shear test (with glasses glued with 3M adhesive tape) for sample 2.

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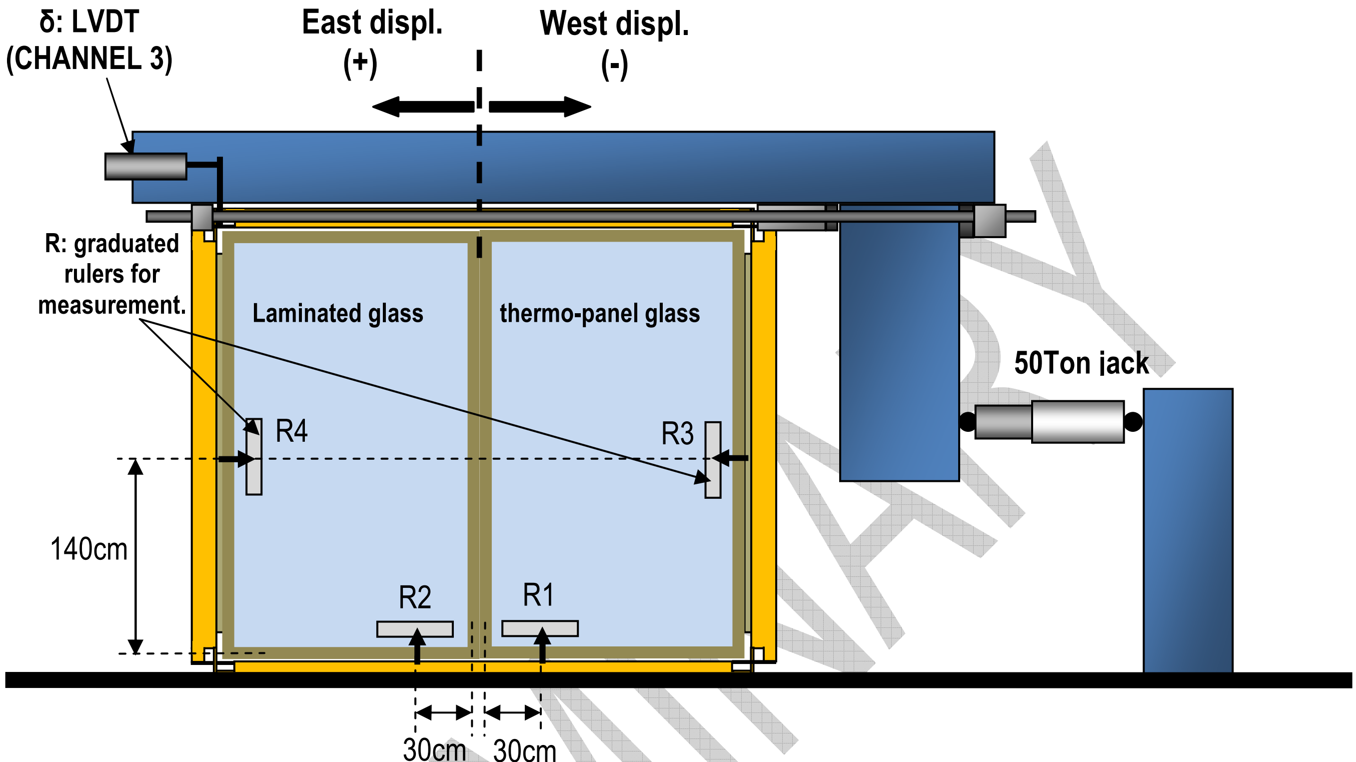

Figure 3.1.4. Nomenclature details and location of graduated rulers for the curtain wall system cyclic shear test in the test tube 2.

During the test, the obtained data, deformations and associated loads were registered by means of a TML brand Japanese origin data acquisition equipment, model TDS-302 connected to the two load cells and to all the instrumented transducers (each associated with a channel) in the samples. The registered deformations by means of the rules were only manually measured at the time it reaches the maximum amplitude of each of the cycles for the first time.

The nomenclature used in cyclic shear tests is the following:

MC – CC – (ML-MT) – 3M – 01

- MC: Curtain wall (Muro Cortina)
- CC: Cyclic shear test (Corte Cíclico)
- (ML-MT): System composed by a laminated glass module and adjacent thermo-panel module.
- 3M: 3M adhesive tape to connect crystal and aluminum profiles
- 01: Order Number

In Pictures 3.1 and 3.2 a general view is presented of cyclic shear test implementation and a detail of the transducer that measures the total horizontal displacement. Picture 3.3 shows a detail of one of the load cells. Picture 3.4 shows a detail of some of the used graduated rulers. In Pictures 3.5, 3.6 and 3.7 are presented details of the located transducers to measure relative deformations between the aluminum frame and the crystals, and between the crystals.

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Photograph 3.1: General view of the wall curtain system cyclic shear test implementation.	Photograph 3.2: Detail of the sample total horizontal displacement measuring transducer.
	
Photograph 3.3: Detail of one of the load cells implemented for the registration of the load applied to the system.	Photograph 3.4: Detail of one of the graduated rulers used to measure displacements in tests
	
Photograph 3.5: Detail of the central located transducer for vertical displacement measurement of the aluminum frame bottom profile. West side.	Photograph 3.6: Detail of the central located transducer for vertical displacement measurement of the aluminum frame bottom profile. East side.

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Photograph 3.7: Detail of the central located transducer for vertical displacement measurement between modules.

3.2.- Monotonic emptying test.

The emptying test consists on a force applying out of the system main plane with the purpose of determining the glass and its anchorages to the structure capacity and behavior in a seismic or wind solicitation.

In test execution, the sample was horizontally located and the emptying solicitation was through the application of a distributed load. This load is applied in growing form in a single cycle until producing some kind of failure, either of the crystal, of the connection system or of the general structure. The emptying test of the implemented system (two modules) was carried out independently for the two types of modules (thermo-panel module and laminated glass module), applying the load to a single module first, and then to carrying out the test in the adjacent module.

The test implementation main aspects and methodology are mentioned next:

The distributed load that simulates the system emptying effect was materialized through the application of water. This was applied directly on the surface of the crystals, on their inner face. This way is obtained the strength and behavior information for the most unfavorable condition for the adhesive 3M tape (bonding system being tested). For testing, a kind of pool was implemented, conformed of wooden boards reinforced with wooden planks (wall and resistant system). Inside polyethylene was placed that covers the whole surface (both the bottom as the sides) of the pool. The maximum possible to reach water height was 45cm. The load was applied in monotonically increasingly inside the pool. To measure the water height, a graduate ruler was used that was fixed to the bottom by means of a weight. The ruler location is approximately at the center of the loaded area. The water height was measured each 1cm. It is important to mention that the water height corresponds to the applied load to the system, where 1cm of water height is equal to apply 10kg/m2. In Figure 3.2.1 and 3.2.2 an emptying test implementation outline is presented.

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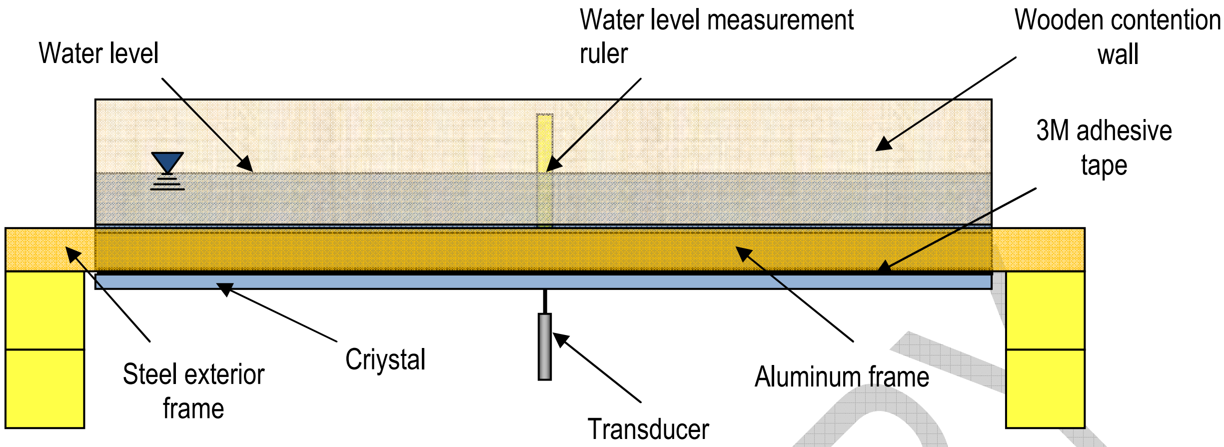

Figure 3.2.2. Outline of curtain wall system monotonic emptying test. Lateral view.

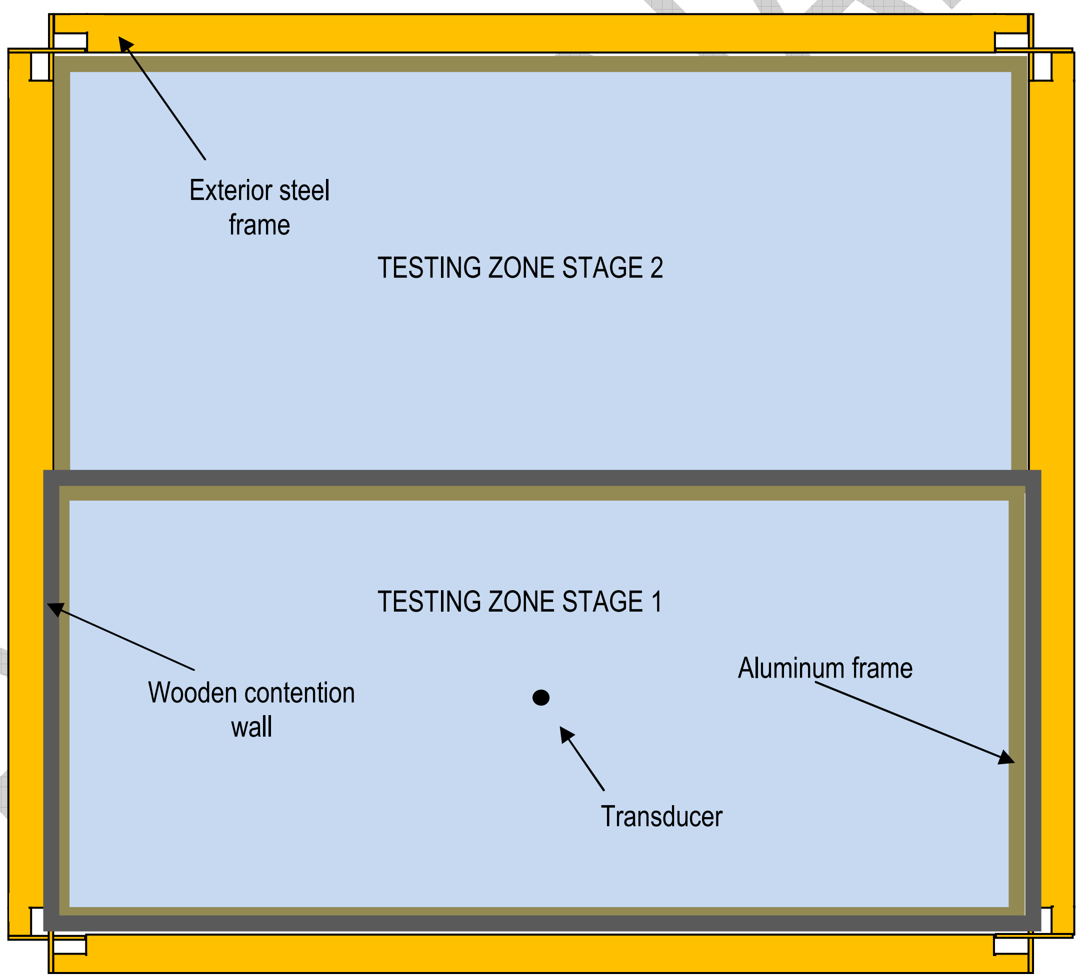

Figure 3.2.2. Outline of curtain wall system monotonic emptying test. Upper view.

Deformation was registered by means of a displacement transducer that was located approximately at the center of the loaded area, on the bottom face of the system (See Figure 3.2.1 and 3.2.2). Due to the destructive nature of testing and to protect the equipment, deformation was indirectly measured by means of a balancing bar, with one of its ends glued in the bottom surface of the crystal and in the other end a LVDT displacement transducer. The registration of each of the deformations is associated to a specific water height. The reading of this height was done manually and the registration of the transducer signal was by means of Japanese TML data acquisition equipment, model TDS-302.

The nomenclature used in emptying tests is the following one:

MC – MV – MT – 3M – 01

- MC: Curtain wall (Muro Cortina)
- MV: Monontinic emptying test (Ensayo Monotónico de Vaciamiento)
- MT: ML: laminated glass module; MT: thermo-panel module
- 3M: 3M adhesive tape to connect crystals and aluminum profiles
- 01: Order number

In Pictures 3.8 and 3.9 are general views and a detail shown of the curtain wall system emptying test carried out. In the Pictures 3.10 and 3.11 details of the deformation and water height measurement system, are shown respectively.

Photograph 3.8: General view of the monotonic emptying test implementation.

Photograph 3.9: Details of the implementation of one of the monotonic emptying test.

Photograph 3.10: Details of the central deformation measurement system.

Photograph 3.11: Details of the water height measuring system used during the test execution.

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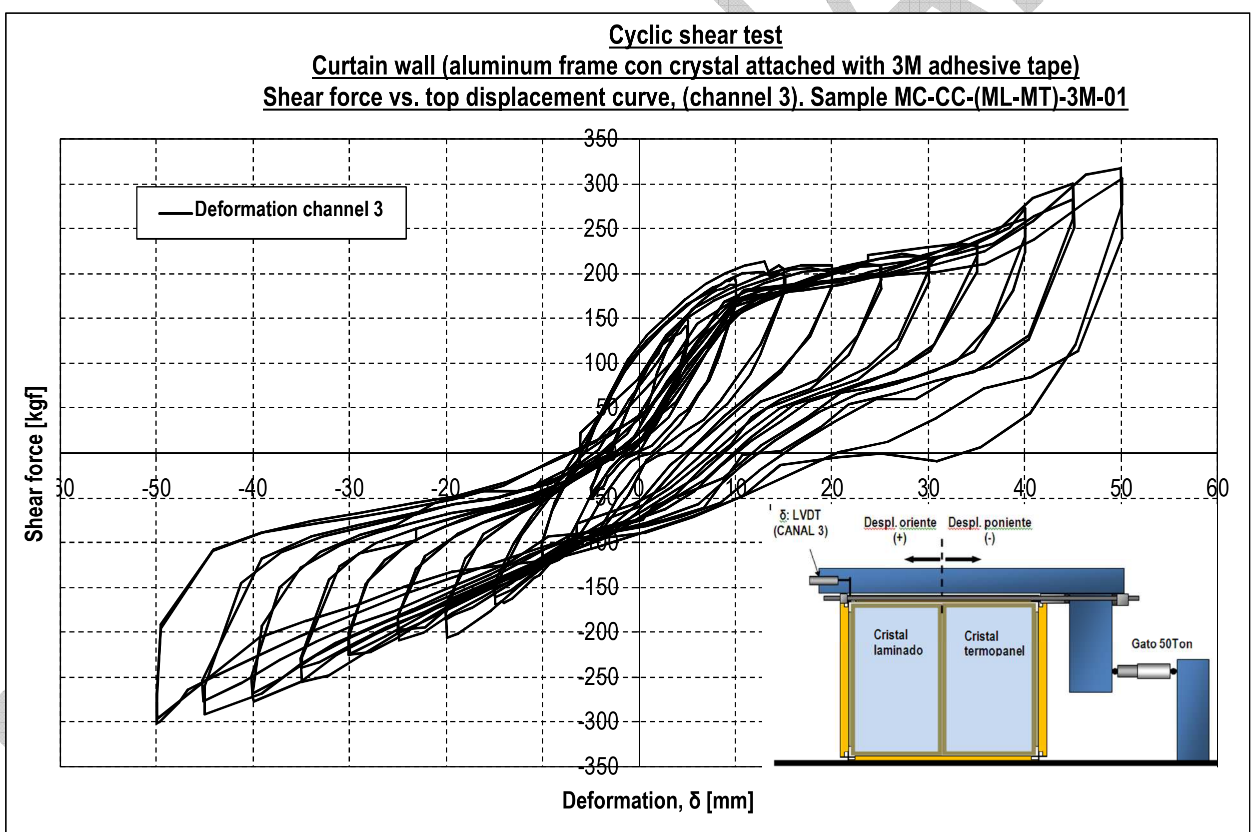
4.- TESTS RESULTS

The carried out tests results are presented numerically through results charts and behavior curves graphics.

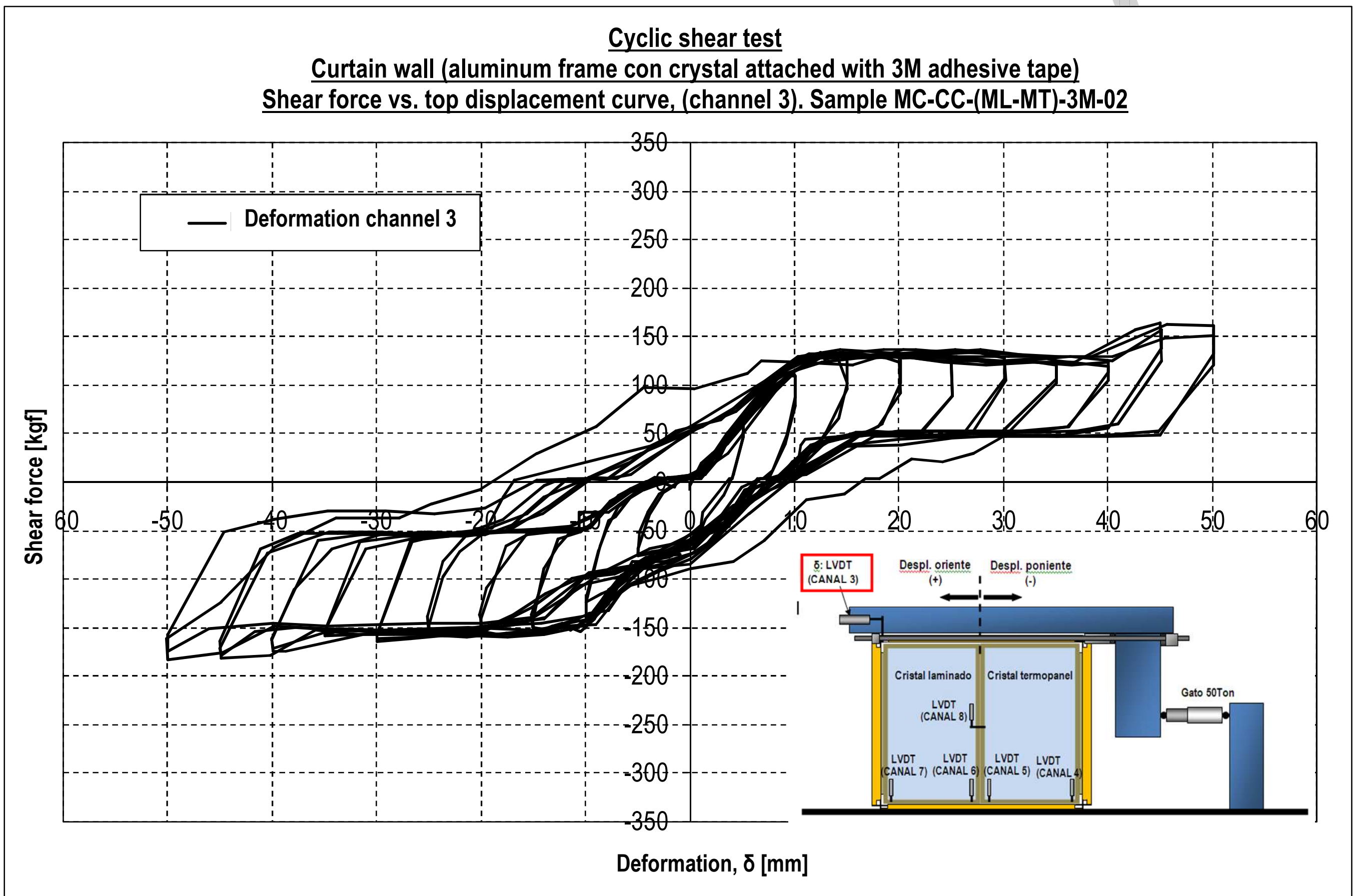
4.1.- Curtain wall system cyclic shear test.

In both tests similar results were obtained, except that in the first test a transducer was used which registered the sample total horizontal displacement, being deformation measured in other points by means of graduated rulers. In the second sample, using the information of the first test rulers, 5 additional transducers were implemented located in strategic points and which diminished the existence of rulers in the sample. That is what in the first shear test only one hysteresis curve was obtained, the one that is presented in Graph 4.1.1. In this curve is appreciated the deformation and load with which the curtain wall system reacts to each deformation level. In this behavior curve, displacement corresponds to total horizontal deformation registration.



Graph 4.1.1 Cyclic shear test Sample 1. Curtain wall (aluminum frame with adhered crystal with 3M tape). Shear force vs. upper displacement curves (Channel 3). Sample MC-DC-(ML-MT)-3M-01.

In second sample, the total horizontal deformation hysteresis curve of the total horizontal deformation is presented in Graph 4.1.2; and Graphs 4.1.3 to 4.1.7 show the curves for each one of the available transducers, being clearly pointed out the assigned nomenclature, the one that is in agreement with the one presented in Figure 3.1.3. These last curves correspond to the relative displacement between the thermo-panel glass and the aluminum frame bottom profile (channel 4 and 5), between the laminated glass and framework connected to the aluminum profile (channel 6 and 7) and between the thermo-panel and laminated glass (channel 8). (See Chart 3.1.2).



Graph 4.1.2 Cyclic shear test Sample 2. Curtain wall (aluminum frame with adhered crystal with 3M tape). Shear force vs. upper displacement curves (Channel 3). Sample MC-DC-(ML-MT)-3M-02.

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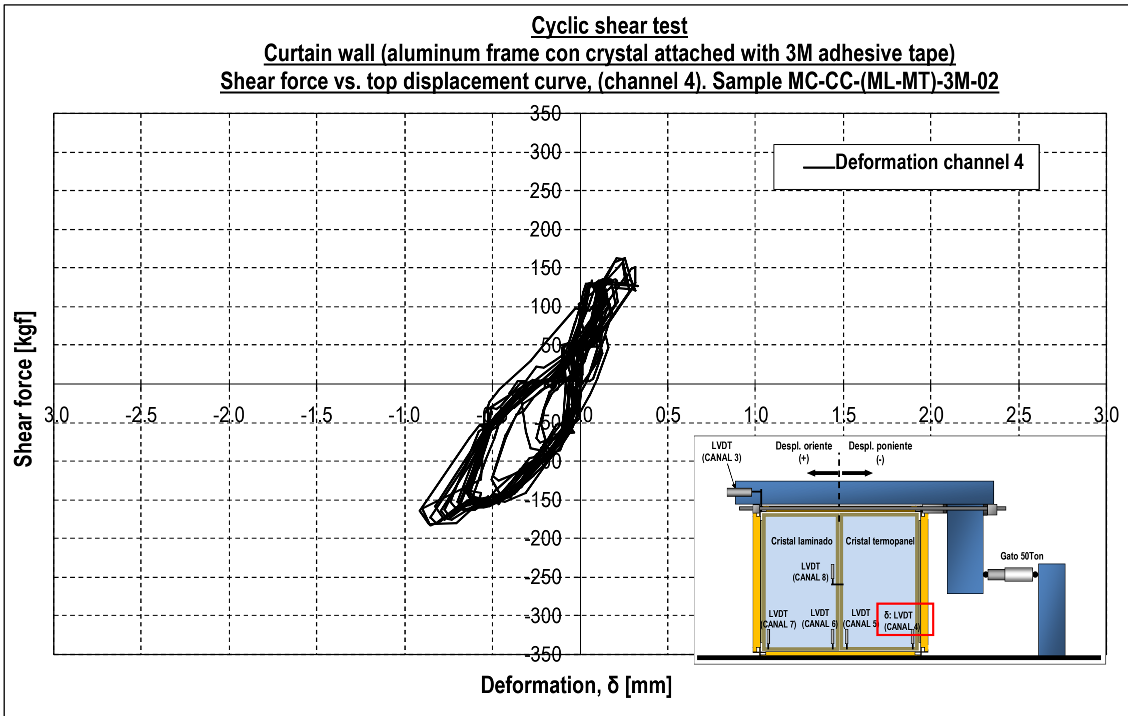
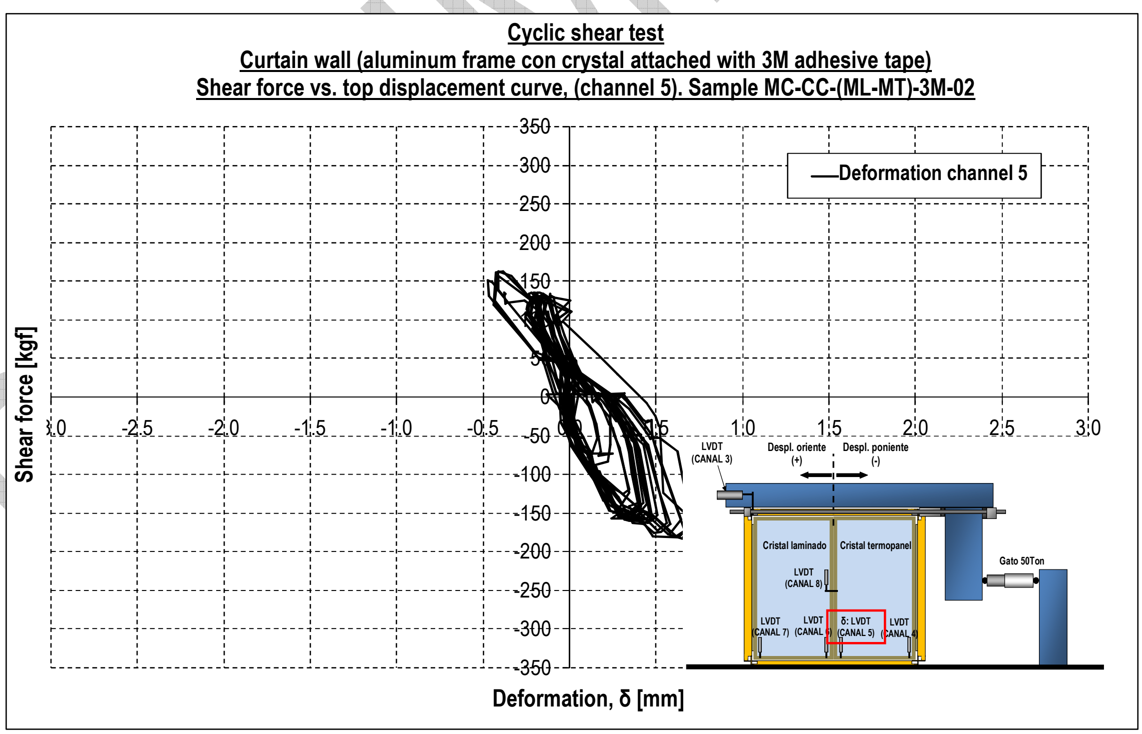


Graph 4.1.3 Cyclic shear test Sample 2. Curtain wall (aluminum frame with adhered crystal with 3M tape). Shear force vs. upper displacement curves (Channel 4). Sample MC-DC-(ML-MT)-3M-02.



Graph 4.1.4 Cyclic shear test Sample 2. Curtain wall (aluminum frame with adhered crystal with 3M tape). Shear force vs. upper displacement curves (Channel 5). Sample MC-DC-(ML-MT)-3M-02.

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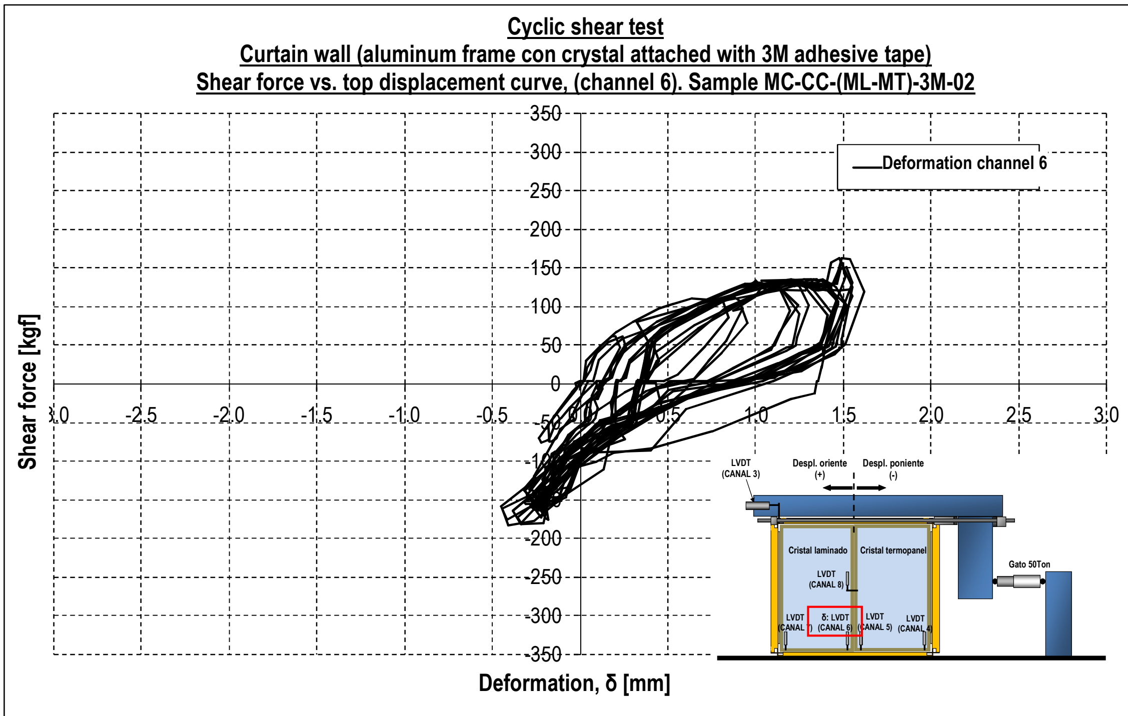
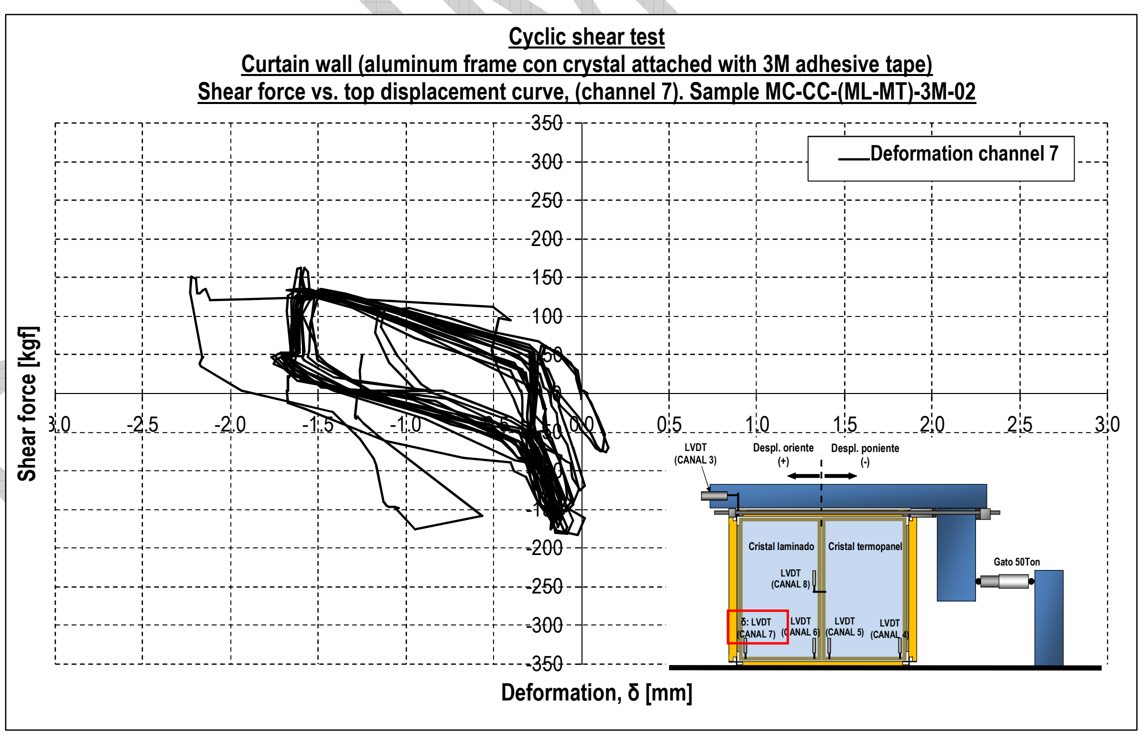


Graph 4.1.5 Cyclic shear test Sample 2. Curtain wall (aluminum frame with adhered crystal with 3M tape). Shear force vs. upper displacement curves (Channel 6). Sample MC-DC-(ML-MT)-3M-02.



Graph 4.1.6 Cyclic shear test Sample 2. Curtain wall (aluminum frame with adhered crystal with 3M tape). Shear force vs. upper displacement curves (Channel 7). Sample MC-DC-(ML-MT)-3M-02.

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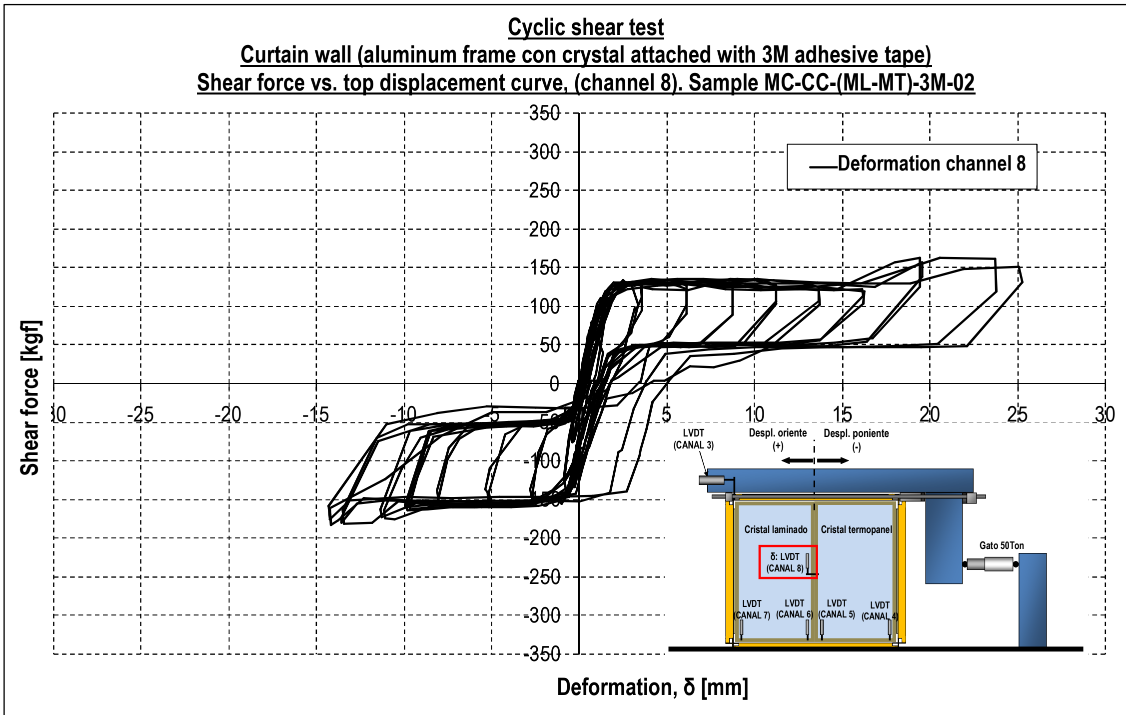

Graph 4.1.7 Cyclic shear test Sample 2. Curtain wall (aluminum frame with adhered crystal with 3M tape). Shear force vs. upper displacement curves (Channel 8). Sample MC-DC-(ML-MT)-3M-02.

In Chart 4.1.1 displacement applied maximum values and registered maximum shear force throughout the test are presented, separately specified the two movement directions.

Chart 4.1.1 Maximum applied displacement and registered maximum shear force results for each cycle throughout curtain wall cyclic shear test.

Sample	Maximum displacement [mm]		Maximum shear force [kgf]	
	East (+)	West (-)	East (+)	West (-)
MC-CC-(ML-MT)-3M-01	50.08	-49.97	317.03	-301.30
MC-CC-(ML-MT)-3M-02	50.12	-50.09	163.83	-186.83

In Charts 4.1.2 and 4.1.3 the most outstanding numeric results are presented respectively for samples 1 and 2, associated to each applied deformation cycle during tests. In Chart 4.1.2, applied total horizontal displacement real value is presented in each cycle (real destination displacement) and the shear force associated to this parameter. Chart 4.1.3 shows identical results but for Sample 2 and the registered deformation value of relative displacement measuring channel is also included (δ4= C4, ?5 = C5, δ6 = C6, δ7 = C7 and δ8= C8), which is associated with the real horizontal displacement applied (channel 3).

Chart 4.1.2. More outstanding results of the carried out curtain wall system cyclic shear test on sample 1.

Sample	Max. Disp.	Cycle	Registered máx. def. δ3 [mm](1)	V [Kgf](2)
MC-CC-(ML-MT)-3M-01	5mm	5mm East (+)	4,98	144,68
		5mm West (-)	-4,93	-50,76
		5mm East (+)	5,02	148,94
		5mm West (-)	-4,71	-47,52
	10mm	10mm East (+)	10,00	189,37
		10mm West (-)	-9,98	-123,11
		10mm East (+)	10,00	191,50
		10mm West (-)	-9,99	-122,03
	15mm	15mm East (+)	15,05	204,26
		15mm West (-)	-14,94	-168,47
		15mm East (+)	15,09	197,87
		15mm West (-)	-14,97	-160,91
	20mm	20mm East (+)	20,02	208,51
		20mm West (-)	-19,95	-206,26
		20mm East (+)	20,03	202,13
		20mm West (-)	-20,04	-185,75
	25mm	25mm East (+)	25,02	208,51
		25mm West (-)	-24,95	-208,42
		25mm East (+)	25,06	208,51
		25mm West (-)	-25,00	-197,62
	30mm	20mm East (+)	29,99	219,15
		20mm West (-)	-30,04	-224,62
		20mm East (+)	30,04	217,02
		20mm West (-)	-30,08	-224,62
	35mm	35mm East (+)	35,02	229,79
		35mm West (-)	-35,03	-255,94
		35mm East (+)	35,06	231,92
		35mm West (-)	-34,95	-239,74
	40mm	40mm East (+)	40,03	259,58
		40mm West (-)	-40,09	-273,22
		40mm East (+)	40,00	272,34
		40mm West (-)	-40,06	-267,82
	45mm	45mm East (+)	45,03	300,01
		45mm West (-)	-45,00	-291,58
		45mm East (+)	45,01	282,98
		45mm West (-)	-45,12	-277,54
	50mm	50mm East (+)	50,00	317,03
		50mm West (-)	-49,96	-301,30
		50mm East (+)	50,03	304,26
		50mm West (-)	-49,97	-290,50

(1) Total real horizontal displacement associated to the end of each one of the programmed cycles.
(2) Shear load value associated to horizontal displacement value.

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Chart 4.1.3. More outstanding results of the carried out curtain wall system cyclic shear test on sample 2.

Sample	Max. Disp.	Cycle	Maximum registered deformation (1)						V [Kgf](2)
			δ3 [mm]	δ4 [mm]	δ5 [mm]	δ6 [mm]	δ7 [mm]	δ8 [mm]	
MC-CC-(ML-MT)-3M-02	5mm	5mm East (+)	5,03	0,14	-0,15	0,24	-0,23	0,60	61,70
		5mm West (-)	-4,99	-0,20	0,13	-0,18	0,12	-0,32	-77,75
		5mm East (+)	5,03	0,08	-0,09	0,20	-0,21	0,53	61,70
		5mm West (-)	-4,97	-0,23	0,17	-0,22	0,14	-0,41	-79,91
	10mm	10mm East (+)	10,02	0,16	-0,16	0,81	-1,12	1,47	108,52
		10mm West (-)	-10,00	-0,47	0,31	-0,25	-0,01	-0,77	-128,51
		10mm East (+)	10,00	0,14	-0,16	0,91	-1,16	1,60	108,52
		10mm West (-)	-9,98	-0,46	0,29	-0,18	-0,05	-0,73	-145,79
	15mm	15mm East (+)	14,07	0,13	-0,15	1,12	-1,53	2,99	129,79
		15mm West (-)	-14,98	-0,58	0,36	-0,26	-0,09	-2,55	-156,59
		15mm East (+)	15,02	0,09	-0,14	1,12	-1,52	3,56	129,79
		15mm West (-)	-15,02	-0,58	0,35	-0,26	-0,09	-2,66	-154,43
	20mm	20mm East (+)	20,05	0,08	-0,14	1,15	-1,51	6,13	123,40
		20mm West (-)	-19,98	-0,60	0,36	-0,24	-0,15	-5,05	-158,75
		20mm East (+)	20,06	0,11	-0,16	1,25	-1,58	6,10	127,66
		20mm West (-)	-20,04	-0,59	0,39	-0,28	-0,12	-5,18	-163,07
	25mm	25mm East (+)	25,03	0,14	-0,18	1,28	-1,60	8,72	125,53
		25mm West (-)	-24,98	-0,60	0,38	-0,26	-0,13	-7,96	-160,91
		25mm East (+)	25,03	0,13	-0,17	1,30	-1,58	8,73	129,79
		25mm West (-)	-24,98	-0,59	0,36	-0,26	-0,14	-7,93	-161,99
	30mm	30mm East (+)	28,29	0,21	-0,23	1,03	-1,63	10,49	134,04
		30mm West (-)	-30,00	-0,66	0,42	-0,25	-0,16	-9,82	-168,47
		30mm East (+)	30,12	0,18	-0,21	1,41	-1,62	11,26	127,66
		30mm West (-)	-30,00	-0,68	0,45	-0,26	-0,13	-9,66	-166,31
	35mm	35mm East (+)	35,01	0,09	-0,21	1,46	-1,63	13,66	125,53
		35mm West (-)	-34,97	-0,71	0,47	-0,21	-0,18	-9,78	-163,07
		35mm East (+)	35,02	0,11	-0,22	1,41	-1,58	13,62	121,28
		35mm West (-)	-34,98	-0,67	0,43	-0,23	-0,15	-9,75	-161,99
	40mm	40mm East (+)	40,08	0,14	-0,24	1,44	-1,59	16,26	119,15
		40mm West (-)	-39,96	-0,76	0,53	-0,19	-0,17	-11,05	-178,19
		40mm East (+)	40,02	0,14	-0,24	1,53	-1,62	16,17	123,40
		40mm West (-)	-39,99	-0,74	0,51	-0,22	-0,14	-11,27	-176,03
	45mm	45mm East (+)	45,02	0,25	-0,41	1,48	-1,58	19,45	163,83
		45mm West (-)	-44,98	-0,86	0,63	-0,34	-0,08	-13,41	-185,75
		45mm East (+)	45,06	0,24	-0,41	1,49	-1,60	19,59	157,45
		45mm West (-)	-44,96	-0,82	0,62	-0,34	-0,09	-13,53	-181,43
	50mm	50mm East (+)	50,07	0,24	-0,43	1,54	-1,62	23,75	161,71
		50mm West (-)	-49,99	-0,85	0,65	-0,41	-0,02	-14,15	-186,83
		50mm East (+)	50,07	0,31	-0,47	1,52	-2,22	25,07	151,07
		50mm West (-)	-49,98	-0,78	0,58	-0,42	-0,95	-14,21	-179,27

(1) On channel 3, total real horizontal displacement associated to the end of each one of the programmed cycles. On rest of channels, it is the registered deformation value at the end of each one of the cycles.
(2) Shear load value associated to horizontal displacement value.

In Chart 4.1.4 and 4.1.5 results of registered deformations in each one of the rulers are presented, in the first and second sample respectively. Nomenclature of each ruler which is associated to the respective outline of test is appointed.

Chart 4.1.4. Displacement results measured through the graduated rulers located in Sample 1 of curtain wall system cyclic shear test.

Reading of graduated rulers, Sample MC-CC-(ML-MT)-3M-01					
Measured deformation (mm)					
Movement	**Ruler 1**	**Ruler 2**	**Ruler 3**	**Ruler 4**	**Ruler 5**
Center	0	0	0	0	0
(+) 5mm East	1	0	0	1	1
(-) 5mm West	-2	-2	-1	-1	0
(+) 10mm East	2	1	1	3	1
(-) 10mm West	-4	-3	-1	-2	-2
(+) 15mm East	3	1	1	4	2.5
(-) 15mm West	-4.5	-4	-1.5	-2.5	-2.5
(+) 20mm East	3	1	4	4.5	5
(-) 20mm West	-5.5	-5	-2	-4.5	-5
(+) 25mm East	2.5	-0.5	6.5	4.5	8.5
(-) 25mm West	-6	-6	-3	-6	-7
(+) 30mm East	1.5	-2.5	9	6.5	10
(-) 30mm West	-7	-8	-3	-7.5	-9
(+) 35mm East	3	-2.5	10.5	8.5	10.5
(-) 35mm West	-8	-10	-3.5	-9.5	-10.5
(+) 40mm East	5	-1	11.5	10	11
(-) 40mm West	-9	-11	-4	-11	-13
(+) 45mm East	8	1	12.5	11	12
(-) 45mm West	-10	-12.5	-4.5	-12	-15
(+) 50mm East	11	3	14	14	13
(-) 50mm West	-7	-13	-9	-14	-18

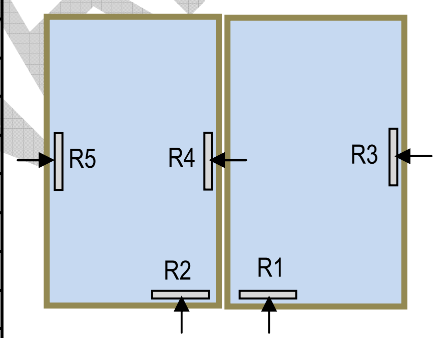

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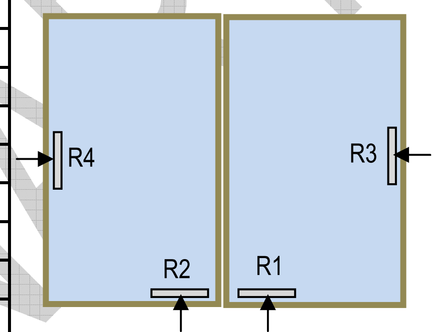
Chart 4.1.5. Results of the displacement measured through the graduate rules prepared in test tube 2 of recurrent cyclic test carried out to the curtain wall system

Reading of graduated rulers, Sample MC-CC-(ML-MT)-3M-02				
Measured deformation (mm)				
Movement	**Ruler 1**	**Ruler 2**	**Ruler 3**	**Ruler 4**
Center	0	0	0	0
(+) 5mm East	1	1	1	-2
(-) 5mm West	-1	0	-1	3
(+) 10mm East	2	0	3	8
(-) 10mm West	-1	-1	-1	2
(+) 15mm East	3	0	5	9
(-) 15mm West	-1	-2	-1	-1
(+) 20mm East	4	7	8	9
(-) 20mm West	1	-1	-1	-3
(+) 25mm East	4	1	10	10
(-) 25mm West	1	-2	-2	-6
(+) 30mm East	4	1	12	10
(-) 30mm West	0.5	-2.5	-3	-8
(+) 35mm East	3	1	14.5	10
(-) 35mm West	-4	-2	-3.5	-11
(+) 40mm East	-1	0.5	19.5	10
(-) 40mm West	-5	-2	-4	-14
(+) 45mm East	-1	1	21	10
(-) 45mm West	-6	-3	-4.5	-17
(+) 50mm East	0	1	21	11
(-) 50mm West	-6	-4	-7	1



Of the visual inspection during and concluded the cyclic tests result, the following aspects and behaviors are common for both samples:

- General system damages because of test were not observed, neither in crystals nor in bolted connections (See Picture 4.1).
- Detachment of the 3M adhesive tape was not observed, neither the existence of permanent deformations or elongations of this. (See Picture 4.2).
- It was observed that modules presented rotations and displacements regarding the steel frame (mainly risings of the opposed to the direction of the movement inferior ends), besides existing relative displacements between the modules. (See Picture 4.3).
- It was observed that for the more deformation cycles (35mm cycle and further) the steel tabs didn't reach to be connected with the module frame aluminum profiles grooves, specifically in the side that rise because of movement. (See Picture 4.4).

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As a particular condition of the sample 1 cyclic shear test, there is:

- Damages were not observed in the aluminum frame.
- Deformation of silicon in modules joint was observed. This deformation increased as the amplitude of the displacements increased. (See Pictures 4.5 and 4.6).

As a particular condition of the sample 2 cyclic shear test, there is:

- For the 40mm cycle, a small break of the aluminum profile took place in the central sector, and in the 50mm cycle a break of the horizontal inferior profile of the aluminum frame that makes up the module with the laminate glass. This break has its biggest magnitude in the bottom east area. Presumably these events have been cause by the lack of a fine adjustment between the steel tabs and the aluminum profile grooves, generating an important pressure. (See Pictures 4.7& 4.8).

Photograph 4.1: General view of the final condition of one of the tested samples, where is possible to appreciate that it doesn't experience general system damages.

Photograph 4.2: Detail where it is appreciated that the connection between crystals and aluminum profile carried out with 3M tape remains without alterations during the whole shear test.

Photograph 4.3 Detail where the relative movement between the modules that conforms the system is appreciated.

Photograph 4.4: Details that it shows the disconnection between steel tabs and grooves of the aluminum profiles for deformation cycles equal or bigger than 35mm.

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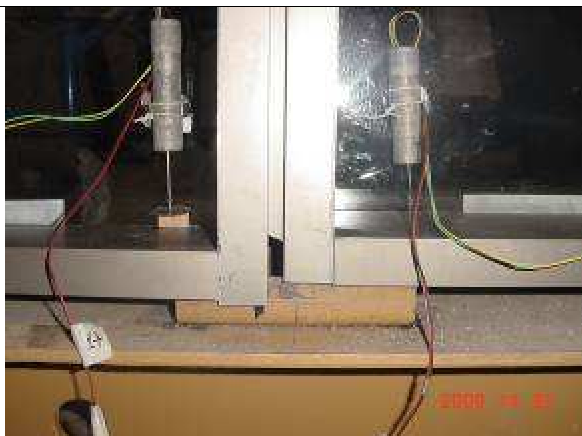
Photograph 4.5: Details that shows deformation of the silicon located in the vertical joints between modules and in their connections with the sides profiles.	**Photograph 4.6: Details of the silicon condition for the last displacements cycles in sample 1**
	
Photograph 4.7:Details where the small break is shown of one of the aluminum profiles in the bottom central sector of sample 2	**Fotografía4.8: Details of the bottom east horizontal profile break of the of aluminum frame of the module with the laminated glass, in the 50mm cycle of the sample 2**

4.2.- Monotonic emptying test.

The results of emptying tests are presented through charts and graphics. The results are separately presented for thermo-panel and of the laminate crystal emptying tests. Only one test was carried out in each system. The assembly of the test tubes was carried out within approximately a week of anticipation in an outdoor place. During this period the maximum ambient temperature was approximately 30°C. In Pictures 4.9 and 4.10 general views are presented of an instant of the thermo-panel and laminated glass, respectively.

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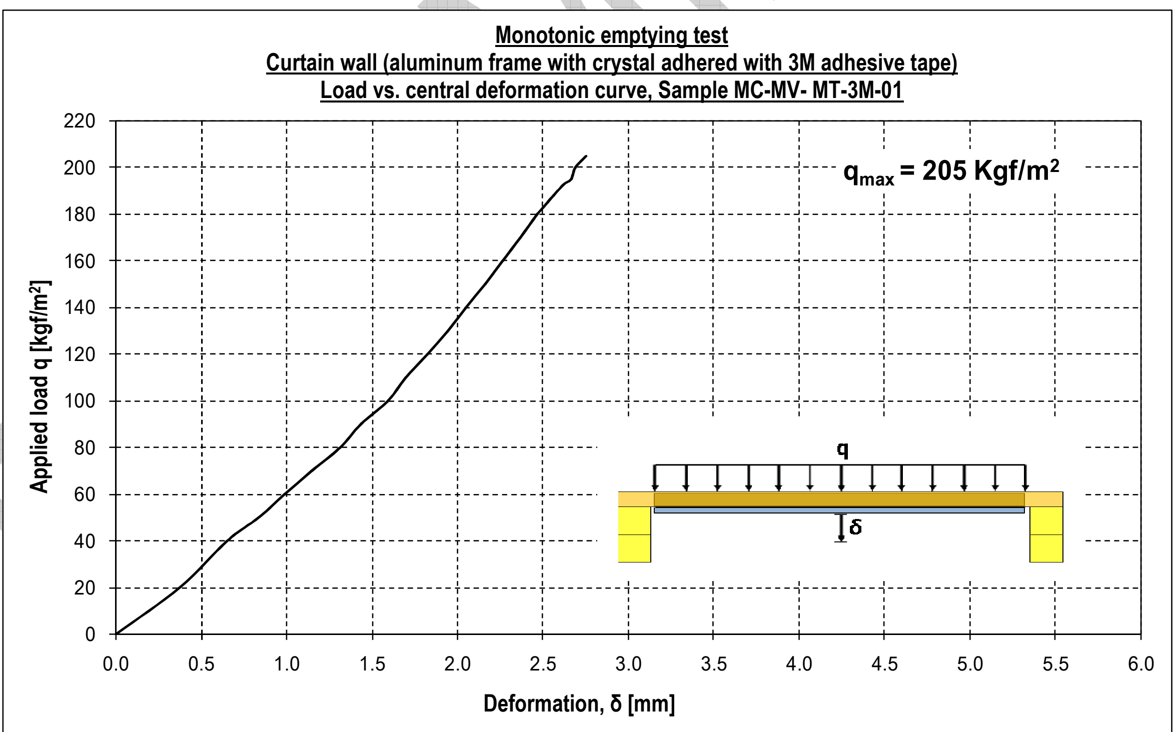
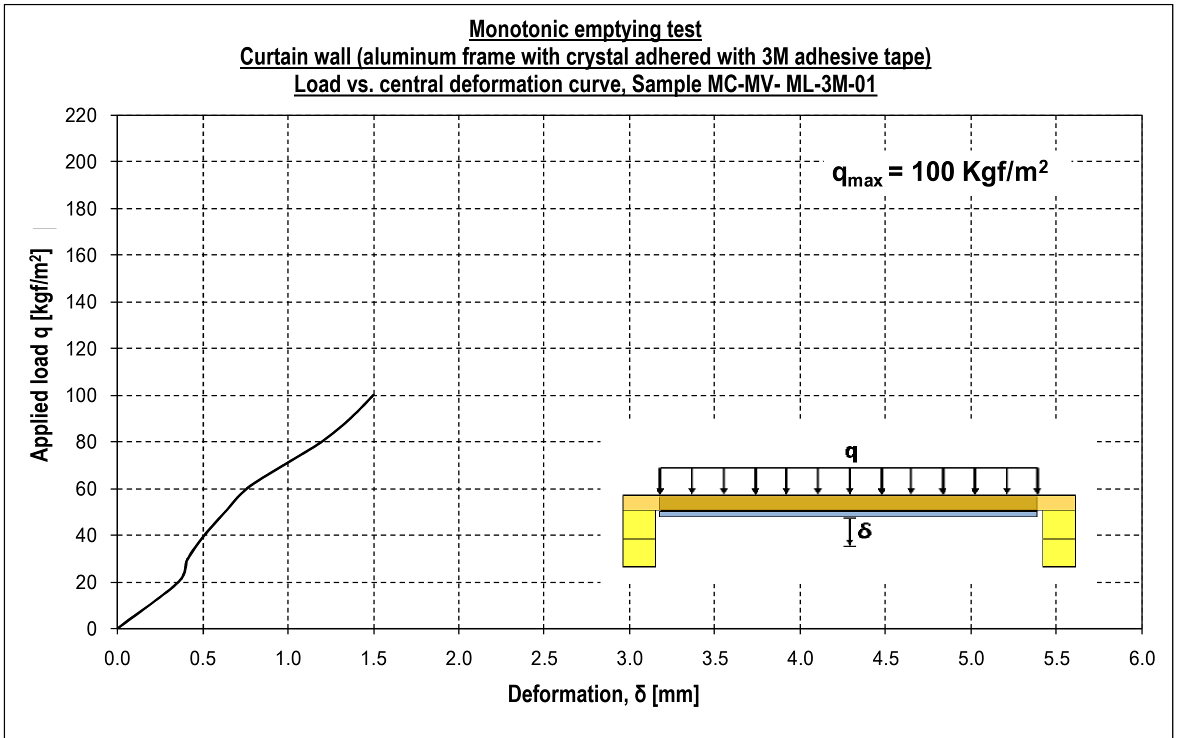
Photograph 4.9: General view of the emptying test (filled pool) to thermo-panel system module.

Photograph 4.10: General view of the emptying test (filled pool) to laminated glass system module.

Graph 4.2.1 shows the load applied vs. registered deformation curve of the thermo-panel emptying test, and in Graph 4.2.2, identical curves of laminate glass test is shown. In both graphics, applied load is expressed in kgf/m2 (since it corresponds to a distributed load) and the crystal center deformation in mm.



Graph 4.2.1 Monotonic emptying test, thermo-panel module. Curtain wall (aluminum frame with crystal adhered with 3M tape). Load vs. central deformation curve. Sample MC-MV-MT-3M-01.



Graph 4.2.2 Monotonic emptying test, laminated glass module. Curtain wall (aluminum frame with crystal adhered with 3M tape). Load vs. central deformation curve. Sample MC-MV-ML-3M-01.

In Chart 4.2.1 main results of test are presented. For both samples, it shows the maximum load resisted by the system and glass center registered deformation, associated to maximum load.

Chart 4.2.1. Monotonic emptying test results.

Sample	Maximum load q_{max} [Kgf/m2]	Central deformation for q_{max} [mm]
MC - MV - MT - 3M - 01	205	2.75
MC - MV - ML - 3M - 01	100	1.50

In thermo-panel module, the following behavior and failure mechanism was observed:

- During test, several noises were heard, attributable to previous to failure system accommodation.
- Aluminum vertical profile significant deformation was observed, mainly the one that is located in the central area (connection area between modules).
- The failure mechanism consisted in fragile crystal breaking (Because assembly reasons, the system had inner glass only). (See Picture 4.11)

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- Detachment of the aluminum frame regarding connection in the ends of the long side of the module was not observed (connection with external vertical profile and with the other module). (See Picture 4.12)
- Detachment of aluminum frame system - 3M tape - thermo-panel was not observed. The glass borders remained adhered to the aluminum frame by 3M tape. In some places, elongation of 3M tape was observed. (See Picture 4.13)
- Breaking of glass was in such a way that the whole central area was in pieces, but the border was adhered to the aluminum frame by means of 3M tape. Borders breaking was irregular, except in the four corners of glass, where the cracks radially, practically in 45° regarding the corner. (See Picture 4.14).

	
Photograph 4.11: General view of the final condition of thermo-panel module subjected to emptying test.	**Photograph 4.12: General view of the final condition of thermo-panel module subjected to emptying test.**
	
Photograph 4.13: Detail of one of the borders, where it is possible to observe a segment of elongation of the 3M tape, concluded the thermo-panel module emptying test.	**Photograph 4.14: Details of the breaking mechanism in the thermo-panel system corners**

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Of the laminated glass sample was observed the following behavior and failure mechanism:

- A single noise was only heard, attributable to system accommodations, a little time before the collapse of it.
- Significant deformation of the aluminum vertical profile was observed, mainly the one that is located in the central area (connection area between modules).
- The failure mechanism consisted on detachment of the framework profile regarding the aluminum frame, due to the failure of the rivets used for its union. The failure mechanism was fragile. (See Picture 4.15 and 4.16).
- No kind of detachment of the framework profile - 3M tape - laminated crystal system was observed. In most areas, crystal is completely adhered to the profile. There are other areas where adhesive tape elongation was observed, without presenting separation. (See Picture 4.17)
- Total disconnection took place between the module and the vertical profile that it is connected to the steel frame. (See Picture 4.18).
- The impact of loaded crystal against concrete produced the breakage of this, which was in multiple pieces which remained in its great majority connected between them through the central sheet. (See Picture 4.18).

Photograph 4.15: General view of final condition of the module with laminated glass subjected to emptying test.

Photograph 4.16: Details of failure mechanism product of framework profile detachment because rivets failure.

Photograph 4.17: Detail of one of the borders, where it is possible to observe a segment of elongation of the 3M tape, concluded the laminated glass module emptying test.

Photograph 4.18: General view of the aluminum frame upper east corner detachment, and crystal condition, once concluded the laminated glass module emptying test.

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5.- CONCLUSIONS AND OBSERVATIONS

As a result of the carried out tests, the following things can be concluded regarding the behavior of the subjected to shear and emptying test curtain wall system.

5.1.- The curtain wall system anchorage to the resistant structure (in this case, to the steel frame) is such that it accepts 1.5% of horizontal deformations, without inducing significant shear forces (<300kgf) in crystals and 3M adhesive tape that was used to fix crystals to the aluminum profiles.

5.2. - In cyclic shear tests, it was not observed that the 3M adhesive tape, used to connect the crystals to the aluminum frame, presents some kind of failure or detachment.

5.3. - For maximum shear deformations applied (1.5% of glasses height), the guides to prevent the curtain wall system transverse displacement, are disjointed from the aluminum profiles.

5.4. - The maximum registered shear forces in sample 2 were 40% smaller than the registered ones in sample 1 (317kgf of sample 1, regarding 187kgf of sample 2); difference probably attributable to structural silicon seal that was not used in sample 2.

5.5. - In shear test, relative deformations between aluminum frame bottom profile and thermo-panel glass, were less than 1mm

5.6. - In carried out emptying tests, it was not observed that 3M adhesive tape presented failure or that it had direct relationship with the presented failure mechanism.

5.7. - Of results of the emptying tests, there concludes that 3M adhesive tape resist transverse loads over [[205kgf/cm2 x (3.3m x 1.71m)] +85kgf] / [2 x (3.3m + 1.71m)] = **123.9 kgf/m**. This value includes thermo-panel approximate own weight (it was considered the glass contribution only of thermo-panel system that was full during test). This was information given by the client.

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