FALSE CEILINGS

SEISMIC

ENGINEERING

atena

FALSE CEILINGS AND COVERINGS

FALSE CEILINGS AND COVERINGS

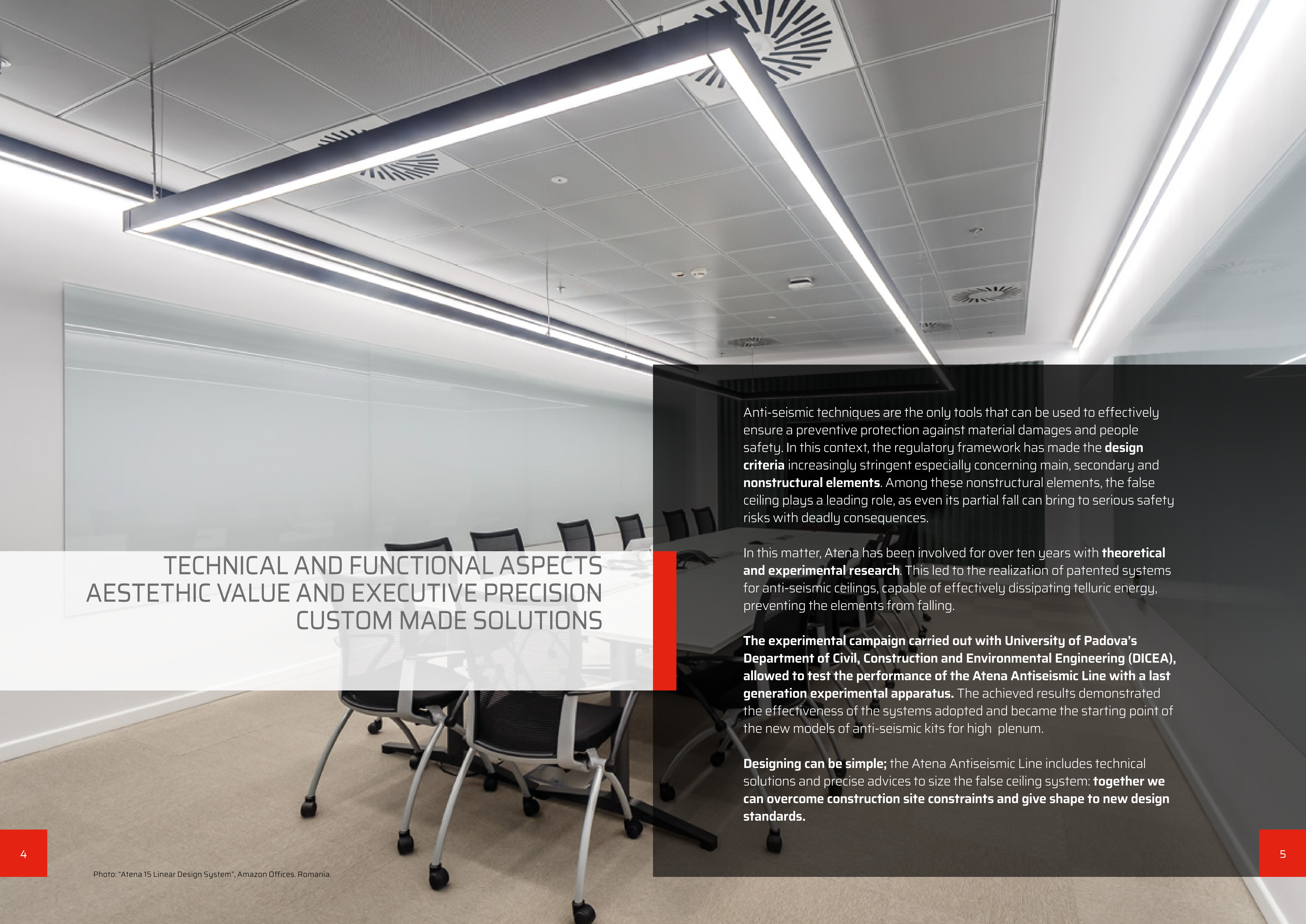
INNOVATIVE ARCHITECTURAL SOLUTIONS
HIGH PERFORMANCE SYSTEMS
ORIGINAL EXPRESSIVE POSSIBILITIES

Photo: "Atena Monolithic Islands System", new Danieli Autyomation S.p.A. offices, Mingotti Architetti associati studio. Buttrio (UD).

Atena has been conceiving and manufacturing false ceilings, external coverings and high quality marine fittings for over 30 years, producing in its factory in Italy and distributing in over fifty countries, through its dealers and partners.

Without any limit to the technical development, Atena offers innovative solutions to transform the designers vision into real works, all over the world. It stands out for the capability to make executive the most challenging projects by creating special metal products for interiors and facade architecture.

In addition to the commercial synergies with different international realities, Atena cooperates with designers and construction companies, following customers at all levels from the idea to the installation; providing a qualified executive design service and specialized consultancies in acoustic, lighting and seismic engineering.



TECHNICAL AND FUNCTIONAL ASPECTS
AESTETHIC VALUE AND EXECUTIVE PRECISION
CUSTOM MADE SOLUTIONS

Anti-seismic techniques are the only tools that can be used to effectively ensure a preventive protection against material damages and people safety. In this context, the regulatory framework has made the **design criteria** increasingly stringent especially concerning main, secondary and **nonstructural elements**. Among these nonstructural elements, the false ceiling plays a leading role, as even its partial fall can bring to serious safety risks with deadly consequences.

In this matter, Atena has been involved for over ten years with **theoretical and experimental research**. This led to the realization of patented systems for anti-seismic ceilings, capable of effectively dissipating telluric energy, preventing the elements from falling.

The experimental campaign carried out with University of Padova's Department of Civil, Construction and Environmental Engineering (DICEA), allowed to test the performance of the Atena Antiseismic Line with a last generation experimental apparatus. The achieved results demonstrated the effectiveness of the systems adopted and became the starting point of the new models of anti-seismic kits for high plenum.

Designing can be simple; the Atena Antiseismic Line includes technical solutions and precise advices to size the false ceiling system: **together we can overcome construction site constraints and give shape to new design standards.**

Photo: "Atena 15 Linear Design System", Amazon Offices. Romania.

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Photo: Atena 24 Linear Tegular System

SEISMIC ENGINEERING

Seismic engineering studies the mechanical response of structures to earthquakes, the methodologies to conceive new buildings and to adapt the existing ones, according to anti-seismic criteria to reduce the seismic risk.

Anti-seismic techniques are the only tools that can be used to effectively ensure a preventive protection against material damages and people safety.
Therefore, the structural dynamics plays an important role both in the design from scratch, and in the reinforcement of existing structures, so that they can withstand severe dynamic actions, due for example to earthquakes, hurricanes, wind, etc.

The fundamental principle of conventional anti-seismic constructions is that of realizing works that allow saving human lives, while sacrificing the structural integrity of buildings.

Using the latest generation of seismic isolation techniques, the structures are no more subjected to soil vibrations. The seismic isolators placed between the foundations and the superstructure, reduce the stress transfer from the ground to the superstructure.
The isolation system therefore limits the intensity of the seismic action and consequently the transmission of the movements induced by it.

Through a suitable isolation system, the time period of building vibration can be increased and the seismic force at the base of the structure can be cut to let the building enter in a lower accelerations range. This is a winning point of isolated constructions, compared with the traditional ones.

By decoupling the motion of the ground from the motion of the building in this way, the structure remains intact within the elastic field.

SEISMIC RISK

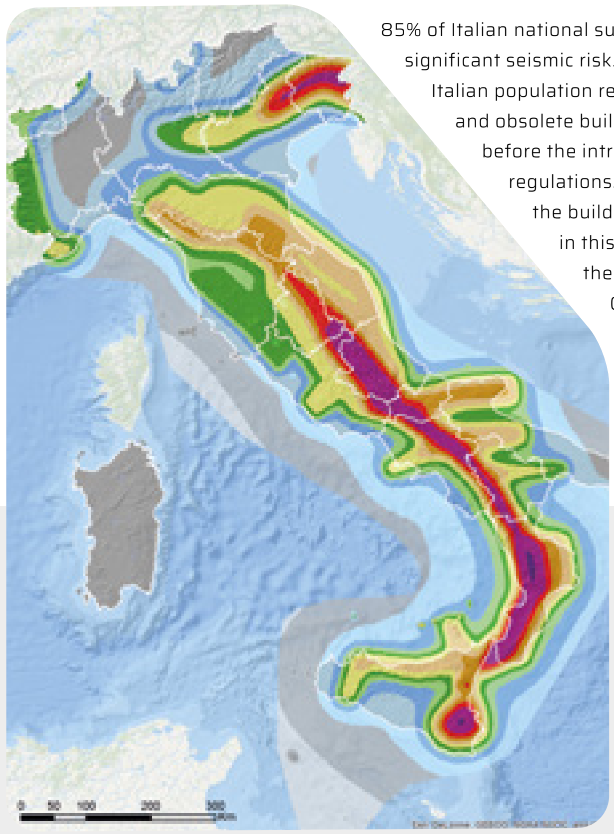
SEISMIC HAZARD MAP

The seismic hazard map of the national territory introduced with the Ministerial Decree 14.09.2005 provides a picture of the most dangerous areas in Italy in terms of **horizontal acceleration of the soil** with a probability of excess of 10% in 50 years, referred to rigid soils (V s30> 800 m/s; cat. A, point 3.2.1 of Ministerial Decree 14.09.2005). The subsequent **PCM ordinance n.3519/2006** has made the map an official reference tool for seismic design, and has introduced a new calculation system based on a **point-distributed statistical approach**, which allows to precisely define the seismic hazard of a site.

For each construction it is therefore necessary to consider a specific reference seismic acceleration value, identified on the basis of the geographical coordinates of the project area, depending on the nominal life of the work.

When the Technical Standards for Construction, NTC, (Ministerial Decree 14.01.2008 updated with Ministerial Decree 17.01.2018) entered into force, the anti-seismic design criteria have also been extended to non-structural construction elements, such as false ceilings, which must be verified together with the connections to the structure.

85% of Italian national surface is characterized by a significant seismic risk. In these areas 80% of the Italian population resides insecure and obsolete buildings, built in most cases before the introduction of anti-seismic regulations. The interventions to reduce the buildings vulnerability are inserted in this context, in order to reduce the seismic risk of the overall Country System.



Expected acceleration with a probability of 10% in 50 years (g).

0 - 0.25 g
0.025 - 0.05

0.05 - 0.075
0.075 - 0.1
0.1 - 0.125
0.125 - 0.15

0.15 - 0.175
0.175 - 0.2
0.2 - 0.225
0.225 - 0.25

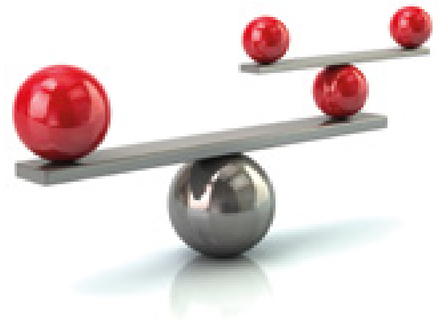
0.25 - 0.275
0.275 - 0.3

zonesismiche.mi.ingv.it - GdL MPS, 2004;
ref. PCM Ordinance of 28 april 2006, n. 3519, All. 1b

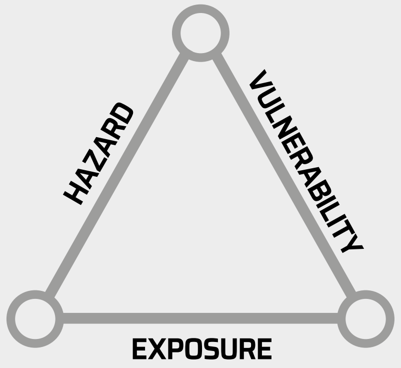
SEISMIC RISK

The **seismic risk** is the measure used in seismic engineering to assess the expected damage following a possible seismic event, and is a function of three variables:

Risk R = H x V x E



The Hazard is the **probability that a certain shaking value will occur in a given time interval**. Once some input elements and reference parameters are known (such as source zones, acceleration or displacement shaking, type of soil) it is possible to define the **seismic hazard**. **The more likely it will be to have a seismic acceleration of a given value within a certain time frame, the higher the seismic hazard will be.**



The Vulnerability is the **measure of the buildings' ability to withstand the earthquake**, as it indicates the **possibility that an area suffers in terms of economical damage, lifes loss, or cultural heritage damages**. It should be remembered that the earthquake is a non-periodic natural dynamic load, as its intensity, direction and / or position varies over time. In this sense, one of the most important applications of the theory of structural dynamics is surely that of analyzing the response of structures to earthquakes.

The Exposure is intended as the **socio-economic evaluation of the consequences of an earthquake**, in relation to population density, quantity and value of historical, artistic and monumental heritage of a given place.

The **seismic risk** depends on the interaction of 3 factors:

Hazard (H)
Vulnerability (V)
Exposure (E)

To reduce the seismic risk it is necessary to intervene on the factors that determine it. Not being able to intervene on the Hazard, which is the probability that the earthquake will occur, it will be necessary to work in order to reduce Exposure and Vulnerability.

HAZARD, VULNERABILITY, EXPOSURE

Specifically, the **seismic vulnerability** of a structure is represented by an **indicator that relates the resistance capacity and / or the structure displacement with the request in terms of earthquake resistance and / or displacement**. The indicator used to describe the seismic vulnerability is defined as "the relationship between the seismic action corresponding to the achievement of the capacity of the structure and the seismic demand at the ultimate limit state".

The indicator estimation, according to the design procedure foreseen by paragraph 8.5 of the NTC, is based on analysis, calculations, tests and linear and non-linear calculation methods.

To reduce the vulnerability index of the structure, structural and non-structural building adaptations can be implemented.

The use of a suitable false ceilings, for example, lower the vulnerability index (Fig C), while the application of seismic insulators between the foundations and the superstructure reduce the intensity of the seismic action, lowering both the vulnerability index and the exposure factor (fig. B).

In the images here aside, four different conditions are shown, where for the same hazard in a given geographical area, the seismic risk changes in relation to the exposure and the vulnerability.

Let's think for example about a school building:

figure A describes a condition of maximum hazard: there are people in the building, even if it is not suitable in relation to the degree of seismic hazard of the area in which it is located;

In **figure B** the exposure is reduced preventing access to the structure but thus compromising its use;

In **figure C** the risk is reduced due to a decrease in vulnerability only through interventions on structural, secondary and non-structural components of the vulnerable buildings;

In **figure D**, the ideal situation is drescribed, the interventions of design from scratch or renewal are radical and therefore a double action occurs which affects both the vulnerability and the exposure.

Figure A

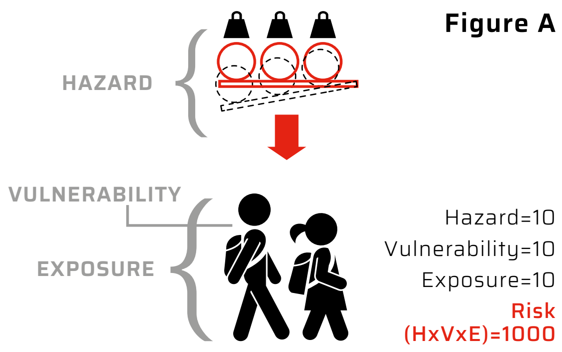


Figure B

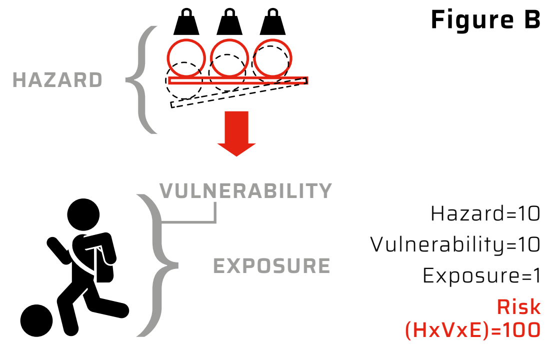


Figure C

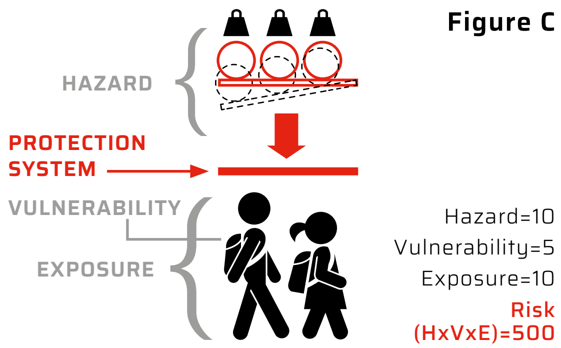
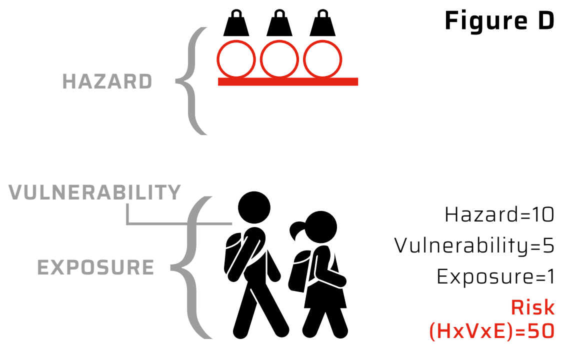


Figure D



REGULATORY FRAMEWORK

The **first anti-seismic regulation in Europe** was set in the **Kingdom of Naples**, by the will of the Bourbons, after the devastating earthquake that struck Calabria in 1783, but only with the law of February, 2nd, 1974, n.64, containing provisions for buildings placed in seismic zones, the anti-seismic criteria were introduced in the structural design practices of buildings.

These aspects have been made more stringent after the tragic events of 2007 in Peru and 2008 in Italy.

Therefore **specific anti-seismic design criteria also for plants and for non-structural elements (par. 7.2.3) have been introduced only with the entry into force of the Technical Regulations for Constructions (NTC - 14/01/2008)**, replaced now by the **2018 update** (D.M. dated 17,01,2018 entered in force on 22.03.18) and the publication of the guidelines for the reduction of vulnerability of non-structural elements (issued by the Department of Civil Protection of the Presidency of the Council of Ministers in 2009).

7.2.3. DESIGN CRITERIA OF SECONDARY STRUCTURAL ELEMENTS AND NON-STRUCTURAL BUILDING ELEMENTS

Some structural elements can be considered "**secondary**"; in the analysis of the seismic response, the **stiffness** and the **resistance** to the horizontal actions of these elements can be overlooked.
These elements are conceived to withstand vertical loads only and to follow the movements of the structure without loosing their bearing capacity.

The secondary elements and their connections must therefore be conceived and equipped with construction details to support the gravitational loads, when subjected to displacements caused by the most unfavorable of the CLS design seismic conditions, evaluated, in the case of linear analysis, according to § 7.3. 3.3, or, in the case of non-linear analysis, according to § 7.3.4.

Under no circumstances the choice of the elements to be considered as "secondary structure" may determine the transition from an "irregular" structure to a "regular" one, as defined in §7.2.1; nor the total contribution to stiffness and the resistance to horizontal actions of the secondary elements may exceed the 15% of the analogous contribution of the primary elements.

NON-STRUCTURAL BUILDING ELEMENTS

As non-structural constructive elements, we mean those with stiffness, strength and mass such as to significantly influence the structural response and those which are equally significant for the purposes of security and / or people safety, while not affecting the structural response.

The capacity of non-structural elements, including any structural elements that support and link them, must be greater than the seismic demand corresponding to each of the limit states to be considered (see § 7.3.6).

When the non-structural element is built on site, it is the structure designer's responsability to identify the demand and calculate the element capacity according to proper formulations and it is a task of the construction manager to verify its correct execution. When, on the other hand, the non-structural element is assembled on site, tasks are splitted as follows: the structure designer has to identify the demand, the supplier and / or installer has to provide elements and connection systems with adequate capacity while the construction manager has to check the correct assembly.

If the **distribution** of non-structural elements is highly **irregular in plan**, the effects of this irregularity must be evaluated and taken into account.
This requirement is considered satisfied if the accidental eccentricity referred to in § 7.2.6 is increased by a factor of 2.

If the **distribution** of non-structural elements is strongly **irregular in height**, the possibility of strong concentrations of damages must considered where levels are characterized by significant reductions of non-structural elements in comparison to the adjacent ones.
This requirement can be considered satisfied if the seismic demand on the vertical elements (pillars and walls) of the levels with a significant reduction of non-structural elements is increased by a factor of 1.4.

SEISMIC DEMAND

The seismic demand on non-structural elements can be determined by applying a horizontal force F_a defined as follows:

$$F_a = (S_a \cdot W_a)/q_a \qquad [7.2.1]$$

where

F_a is the horizontal seismic force distributed or acting in the center of mass of the non-structural element, in the most unfavorable direction, which result from the distributed forces proportional to mass;

S_a is the maximum adimensionalized acceleration, in relation to the gravity, that the non-structural element undergoes during the earthquake and corresponds to the analyzed limit state (see § 3.2.1);

W_a is the weight of the element;

q_a is the behavior factor of the element.

In the absence of specific determinations, for S_a and q_a, documents of proven validity can be used as a reference.
The explanatory memorandum of the NTC 2018 n.7 of the C.S.LL.PP. of 01/21/2019 reports the method of calculating the adimensionalized acceleration (S_a) and establishes the factor q_a equal to 2. Among the international normative references, the Manuals for the visual survey of potential risk situations of the Federal Emergency Management Agency (FEMA 154, FEMA 155, FEMA 178) of the USA can be considered as an example. These protocols refer to seismic risk, but methods, concepts and methods for summarizing the results can be considered valid in general.

LIMIT STATES

In structural engineering, a limit state is a condition beyond which, the considered structure or one of its components no longer comply the requirements for which it was conceived.

The limit states are divided into:

1) U.L.S.

Ultimate Limit States

2) S.L.S.

Serviceability Limit States

ULTIMATE LIMIT STATES

U.L.S.

The **Ultimate limit states** are associated with the extreme value of the bearing capacity or with other forms of structural failure that can endanger the safety of people. Some examples of the causes that can lead to **U.L.S.** are the stability loss of the whole structure or part of it, the breakage of structure critical sections, the structure transformation into a mechanism, the instability following excessive deformation, the deterioration following fatigue, the deformations due to fluage or cracks, which cause a change in the geometry such as to require the replacement of the structure. **The exceeding of an ultimate limit state is irreversible and is defined as collapse. With regard to seismic actions (dynamic U.L.S.) the ultimate limit states are divided into** (D.M. 14.01.2008): 1) **L.L.S. Life Safety Limit State** and 2) **C.L.C. Collapse Prevention Limit State.**

LIFE SAFETY LIMIT STATES

L.L.S.

Life Safety Limit State means when, following the earthquake, the **non-structural elements and plant components of the building sustain breakages** and **collapses, while, the structural components undergo considerable damages** with a significant loss of stiffness in relation to the horizontal actions. **The overall building maintains a part of its strength and stiffness against the vertical actions and a safety margin against the collapse due to horizontal seismic actions**.

COLLAPSE PREVENTION LIMIT STATES

C.L.S.

Collapse Prevention Limit State means, when following the earthquake, the structural components of the building sustain serious damages and the non-structural components collapse;

The construction still maintains a safety margin against the vertical actions and a small safety margin against the collapse due to horizontal actions.

Picture: "Atena Brett parallel System"
La Macchina del Tempo-Museo Alfa Romeo. Arese.

SERVICEABILITY LIMIT STATES

S.L.S.

The **Serviceabiliy Limit States** are satisfied when **the set service requirements** are no longer satisfied. The exceeding of a serviceabiliy limit state can be **reversible** or **irreversible**: in the first case the deformations are reversible and cease as soon as the cause that led to the exceeding of the S.L.S. is eliminated; in the second case, unacceptable and unavoidable permanent damages or deformation occur and remain even if the cause is eliminated. According to the Ministerial Decree 14.01.2008 with regard to seismic actions the Dynamic **Serviceabiliy Limit States** are divided into:

1) O.L.S. Operational Limit States

2) D.L.S. Damage Limit State.

OPERATIONAL LIMIT STATES

O.L.S.

Operational Limit State means, when following the earthquake, the construction as a whole (including the structural elements and the non-structural elements, etc.) **not sustains significant damages and considerable use interruption;**

DAMAGE LIMIT STATE

D.L.S.

Damage Limit State means, when following the earthquake, the **construction** as a whole (including the relevant equipments, the structural and non-structural elements, etc.) **sustain damages that do not endanger the people safety and do not significantly compromise the resistance capacity and the rigidity of the building against both the vertical actions and the horizontal ones, maintaining an immediately usable even in the partially equipments use interruption.**

VERIFICATION OF LIMIT STATES

For all primary and secondary structural elements, non-structural elements and plants, it must be verified that the value of each project application, defined in table 7.3.III for each of the required limit states, is lower than the corresponding value of the project capacity.

The verifications of the **primary structural elements** (ST) must be carried out, as set in schedule 7.3.III, in relation to the Use Class (UC):

- in case of non-dissipative structural behavior, in terms of stiffness (**RIG**) and resistance (**RES**), without applying the specific rules related to the construction details and capacity design; ;

- in case of dissipative structural behavior, in terms of stiffness (**STI**), resistance (**RES**), and ductility (**DUT**) (when required), applying the specific rules of construction details and capacity design. The verifications of the secondary structural elements are carried out only for ductility.

The verifications of non-structural elements (**NS**) and systems (**S**) must be carried out for functioning (**FUN**) and stability (**STA**), as set in schedule 7.3.III, in relation to the Use Class (UC).

SCHEDULE 7.3.III

Primary structural limit states, non-structural elements and systems.

LIMIT STATES		UC-1	UC-2			UC-3 e 4		
		ST	ST	NS	S	ST	NS	S
SLS	OLS					STI		
	DLS	STI	STI			RES		
ULS	LLS	RES	RES	STA	STA	RES	STA	STA
	CLS		DUT**			DUT**		

(*) For III and IV CU only, fixed furnishings also fall into systems category.
(**) In the cases explicitly indicated by these rules .

LEGENDA

UC = use class
ST = structural elements
NS = non structural elements
S = systems
SLS = serviceability limit state
ULS = ultimate limit state
OLS = operational limit state
DLS = damage limit state
LLS = life safety limit state
CLS = collapse prevention limit state
STI = stiffness verifications
RES = resistance verifications
STA = stability verifications
DUT = ductility
DIS = absolute displacement

REQUIRED PERFORMANCES IN RELATION TO THE LIMIT STATES

Application Guideline n°292017 SCH.C7.3.I

Limit States
Primary structural elements
Non Structural elements and Plants:

Requirements and verifications.

LIMIT STATE			Requirement description	ST			NS	S		USE CLASS		
				STI	RES	DUT / DIS	STA	FUN	STA	1	2	3|4
SLS	OLS	NS ST	**Damage limitation to non-structural elements, or to walls for concrete construction**	7.3.6.1								x
		S	Systems functioning					7.3.6.3				x
	DLS	ST	Structural elements damage check		7.3.1							x
		NS ST	**Damage check of non-structural elements, or of walls for concrete construction**	7.3.6.1						x	x	
ULS	LLS	ST	Structural elements Damage level consistent with the behavior of the factor adopted, absence of fragile breakages and unstable local / global mechanisms		7.3.6.1					x	x	x
		NS	Absence of non-structural elements collapses that are dangerous for people safety, even in widespread damage presence.				7.3.6.3				x	x
		S	Ultimate capacity of systems and connections						7.3.6.3		x	x
	CLS	ST	Sufficient safety margin against vertical actions and little margin against horizontal actions			7.3.6.1 DUT					x	x
		ST	Devices displacement capabilities in costructions equipped with seismic isolators			7.10.6.2.2 DIS					x	x

VERIFICATIONS

NTC 2018 7.2.3

The new NTC 2018 substantially introduce a "**stability verification** (**STA**)", also for non-structural elements for which "magistries must be adopted to avoid possible expulsion under the action of the (**Fa**) Horizontal Seismic Force (see § 7.2.3) in relation to the (**LS**) Limit State and the considered (**UC**) Use Class".

In this regard, compared to the 2008 edition, the verifications to be carried out on the secondary elements do not change and must always be carried out for the **Life Protection Limit State** (**L.L.S.**). The new rules essentially specify that only for the II, III and IV Use Classes a stability verification must be carried out, although the required performance is unchanged.

UNI EN 13964 4.3.7

Seismic Resistance

Specifically for the false ceilings, the same harmonized standard 13964 specifies - "in the event that the false ceiling is exposed to seismic shocks, the ENV 1998-1 must be taken into account. **The false ceiling must be conceived in order to avoid damages and collapse due to both the vertical seismic actions and the horizontal ones"**

Suspended ceilings must be checked for limit states LLS | OLS and for buildings in III and IV Use Class they must not sustain damages.

BUILDINGS USE CLASS

D.M. 17/01/2018 2.4.2

The D.M. 17/01/2018 has divided the constructions into four classes of use in relation to the consequences due to operations interruptions or possible collapse:

I Class: Construction with **occasional presence of people**, for example agricultural buildings

II Class: Buildings whose use involves **normal crowding**, without environmental dangerous contents and without essential public and social functions. Industries without environmental dangerous activities. Bridges, infrastructural works, road networks that do not fall into III or IV use class, railways whose interruption does not cause emergency situations. Dams whose collapse does not cause significant consequences. For example, **residential buildings** belong to this class.

III Class: Buildings whose use involves **significant crowding**. Industries with environmental dangerous activities. Extra-urban road networks that do not fall into IV use class. Bridges and railway networks whose interruption causes emergency situations. Dams whose collapse causes significant consequences. This category may include, indicatively, schools, theaters, museums, as buildings subjected to overcrowding and with the simultaneous presence of very large comunities.

IV Class: Buildings with **important public or strategic functions**, also in relation to the Protection Civil Management in the event of a disaster. Industries with special environmental dangerous activities. A or B types of road networks, as set in Ministerial Decree 5/11/2001, n. 6792, "Functional and geometric rules for road construction", and C types when belonging to routes connecting provincial capitals which are not connected by A or B roads types. Bridges and railway networks which have a main role to maintain the communication routes, particularly after a seismic event. Dams related to the aqueducts operations and to the electricity production plants. Buildings such as hospitals, barracks, town halls, etc. belong to this class.

WIND LOAD RESISTANCE

The safety checks of civil constructions take into account all those actions that can induce stresses in a structure. This in order to ensure that the construction is able to withstand the actions it may be subjected to, with adequate security, respecting the necessary conditions for its normal exercise and to ensure its durability.

These actions are divided into:

a) **direct actions** (forces):

- permanent loads (own weight and other fixed loads);
- variable loads (service loads, snow, wind, earthquake, earth pressure, dynamic forces, etc.);

b) **indirect actions** (transmitted deformations), thermal variations, shrinkage, pretensioning, constraint displacements, assembly defects, etc.;

c) **chemical-physical actions** due to: aggressive agents, humidity, frost, harmful materials, etc.

Actions to be considered in the constructions generally include:

- weights of the constituent elements;
- permanent loads;
- variable overloads;
- temperature changes;
- settlement of constraints;
- wind loads;
- snow loads;
- seismic and dynamic actions in general;
- exceptional actions (hurricanes, bumps, explosions, etc.).

Regardless of adopted verification method, admissible tensions or limit states, in each verification the actions must be adequately combined according to load conditions such as to be more unfavorable than the individual verifications, taking into account the reduced probability of simultaneous intervention of all actions with respective most unfavorable values.

Photo: Starbucks Roastery, Milan.

UNI EN 13964 4.3.5

The reference technical standard UNI EN 13964 "Suspended ceilings - requirements and test methods" defines the characteristics of false ceilings in relation to **wind loads resistance**.

If the false ceiling is expected to be subjected to the **internal wind load** (for example in the case of windows, sliding doors), **all necessary design measures must be taken** into account to make the membrane components and the substructure able to **withstand the upward and / or downward wind loads**.

In conditions of internal wind loads, the membranes and the ceiling substructures must **maintain their stability** and integrity. Even if some deformations may be acceptable, **false ceilings and their parts must be conceived not to collapse under the conditions above mentioned**.

Suspended ceilings for outdoor application *have* ***always to be sized*** *to withstand the action of the* ***wind*** *in combination with other normal loads. Exceptional actions such as* ***earthquakes****, explosions, hurricanes, etc., should not be added / combined, but calculated individually.*

Also the ***false ceilings for internal use*** *must be conceived considering both the action of the* ***wind*** *and the action of the* ***earthquake****.*

The ***NTC 2018*** *§ 3.3.8.5 specify that the* ***internal pressures*** *of the buildings depend on the surface of the openings towards the outside. The NTC 2018 identify* ***3 different cases*** *with specific calculation methods and different values, both for the internal pressure coefficients and for the reference heights.****To calculate the internal pressure, is therefore important, at the design stage, defining the category the false ceiling belongs to****.*

EXPERIMENTAL CAMPAIGN

With the will to investigate the topic of its products safety, further testing their performance, **Atena started a cooperation in 2015 with the Department of Civil, Construction and Environmental Engineering (DICEA) of the University of Padua**, which led in 2016, to the start of a research project aimed at testing the anti-seismic false ceilings performances, including **the patented Atena anti-seismic kits**.

The team's work initially focused on the local study of T-shaped load-bearing profiles connections, through **laboratory tests** at the University. Then the analysis continued with the construction of an **innovative experimental apparatus**, able to test the global seismic behavior of Atena's false ceilings.

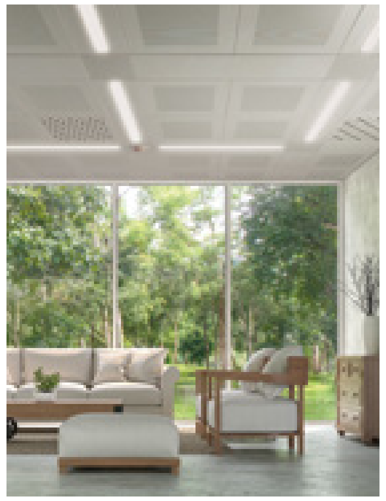
For the first time at international level, a **Fragility test** protocol was used as a test method to assess the system's response to the induced stresses. The collapse of the panels, the breaking of the internal joints, the deformation of the profiles and the interaction of the false ceilings with the lighting bodies and the pipe systems represent, in fact, the main causes of collapse and therefore it is necessary to prepare a correct analysis of the seismic behavior of these non-structural elements.

TEST METHODS

Currently it is possible to study the anti-seismic response of the false ceiling using two different types of test:

Qualifying test, a method usually associated with tests on a vibrating table, which allows to verify if the system satisfies a predetermined acceptance criterion.

Fragility test, this method, based on quasi-static cyclic tests and allows the analysis of the progressive system damage and its correlation to the parameters of interest.



Università degli Studi di Padova | ICEA

NEW STUDY PROTOCOLS

The effectiveness of the Atena anti-seismic systems was verified experimentally by the Department of Civil, Construction and Environmental Engineering (DICEA) of the University of Padua, which conducted the first international campaign of cyclical, quasi-static and monotonous tests on seismic behavior of the anti-seismic Atena ceilings.

Photo at page 20: "System Atena Domino" | Photo at page 21: "test set-up of Atena Easy Antiseismic"

FRAGILITY TEST AND TESTING EQUIPMENT

The **Qualifying test** conducted on a **vibrating table has some limitations that should not be underestimated**, such as, for example, the application of a test protocol that uses an American formulation to estimate the force to be applied, the use of a single sample and the type of result: the sample, in fact, will simply «pass» or «not pass» the text in relation to the specific force applied according to the test protocol provisions.

Thanks to the cooperation with the University of Padua, Atena S.p.A. has been able to use a valid alternative to study the seismic behavior of false ceilings: an innovative experimental equipment conceived by the research group, for the realization of quasi-static cyclic tests.

The used **testing equipment** is a frame structure made of steel columns that supports the XLAM slab. The false ceilings were installed inside the metal frame, anchoring the suspensions to the XLAM slab.

The false ceiling suspension systems were made up of hangers anchored to the slab and hooked on the ceiling bearing profiles. Inside the testing equipment two twin samples of false ceiling were placed, each of which was equipped with an anti-seismic cross bracing reinforcement with its applicable joint.

In this way the samples are subjected to controlled displacements, induced at a constant speed by a trapezoidal screw jack, while a load cell allows to monitor the force applied to the system.

A horizontal frame appropriately braced and constrained to such instrumentation allows the application of an uniform displacement to the whole system (condition of rigid plane).

Photo: "Test Set Up"

Photo: "Test Set Up of Atena Matrox System"

BUILDING LOADING HISTORY

The load history is defined in compliance with the protocol set by the FEMA461 guidelines for non-structural elements.

Ultimately the set up, **in the rigid floor configuration**, allows to test at the same time:

- The **effectiveness of** the false ceiling perimeter **constraints**;
- The **ability of false ceilings suspension hangers** to withstand the horizontal movements without unhooking;
- The false ceiling **membrane resistance**, that is the ability to transmit the horizontal forces imposed on the bracing system without preventive breaks;
- The **mechanical response** (stiffness, resistance, ductility, etc.) of false ceilings anti-seismic joints that is returned by recording the load-displacement curves.

MECHANICAL RESISTANCE AND EVALUATION OF MOVEMENT

In addition to the evaluation of the mechanical resistance of the bracing system up to the breaking point, the displacement of the components was monitored and evaluated. These aspects are important to evaluate the effectiveness resistance of the overall system to stress and prevent it from falling. **Specially, for all types of Atena anti-seismic kits, two tests were carried out: a monotonic thrust test up to failure and a quasi-static cyclic test with cycles of increasing amplitude up to failure.**

While the monotonic test imposes a single increasing thrust, the cyclic test is carried out by performing 10 loading steps, each of which consists of two cycles of equal width. The cycles amplitudes definition is based on the definition of the lightest and the most serious state of damage. The latter are identified according to the protocol, a priori, through the monotonic test.

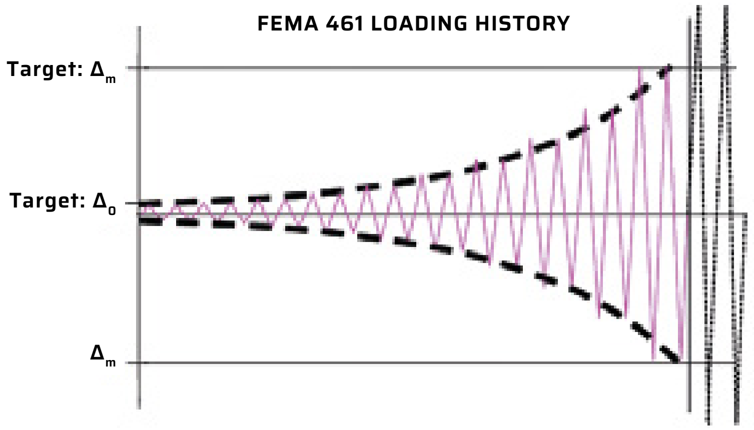
In the specific case of the tests performed, **in no case the preliminary monotone tests showed a state of initial damage that could be univocally defined**. Furthermore, **the load-displacement curves did not make it possible to identify a point of complete damage to the system within the maximum stroke capacity of the jack (10 cm); value already significantly higher than the perimeter gaps granted for the implementation of these systems**. Based on these observations, the load history was defined uniformly for all the cyclic tests, assuming the maximum jack stroke as the last cycle width and deriving from this measure the amplitude of the previous cycles.

TEST PARAMETERS

- The **displacement was applied at a constant speed** of 18 mm/min using a trapezoidal screw jack;
- The load was monitored through a **2.5 t load cell** interposed between the screw of the jack and the set-up;
- The **loading history** was defined in compliance with the protocol set by the FEMA461 guidelines for non-structural elements;
- The protocol requires a monotonic test to **monitor the progression of the damage**;
- $\Delta 0$: **minimum amplitude** related to the slightest state of damage;
- Δm: **maximum amplitude** related to the most severe state of damage;
- The protocol requires at least **ten load steps**, each of which consists of two cycles of equal width.


Photo: "Atena Easy Antiseismic Test Set Up"

$$a_{i+1} = 1.4\ a_i$$



QUASI-STATIC CYCLIC TEST PROTOCOL

The graph represents the magnitude of the damage induced by the jack, according to the load protocol.

RESEARCH TEAM

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Eng. Laura Fiorin
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Eng. Monica Iogna Prat
R&D manager Atena S.p.A.


Photo: "Atena Brett Parallel System"

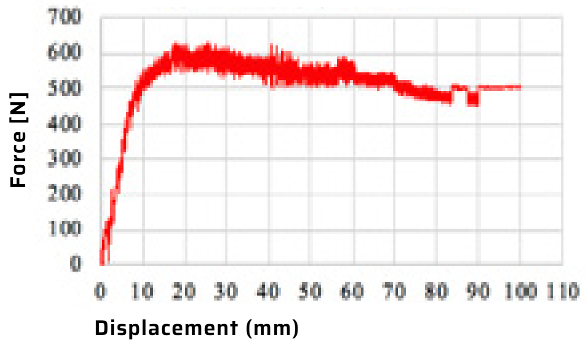
RESULTS OF CONDUCTED TESTS

In general, **the data obtained from the tests, conducted on the different types of Anti-seismic kits, have demonstrated the resistance of the systems conceived and manufactured by Atena against the transmitted stresses.**

Thanks to these results the Atena **false ceilings anti-seismic range was optimized and innovative technologies were patented.** On the research side, the University of Padova team will continue elaborating the tests results, to create numerical models able to predict the seismic behavior of the systems under study.

LOAD DISPLACEMENT CURVE MONOTONIC TEST

Test 1: Monotonic T24-Plan



LOAD DISPLACEMENT CURVE QUASI-STATIC CYCLIC TEST

Test 1: Cyclic T24-Plan

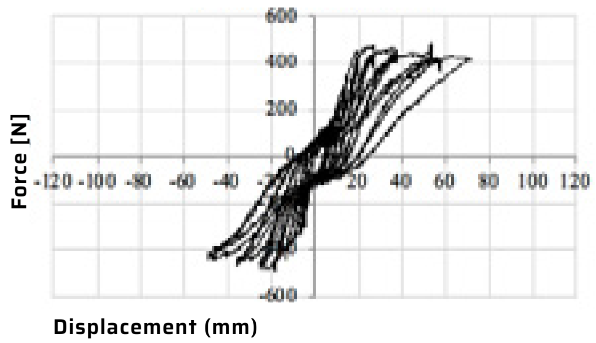



Photo: "Atena Multichannel System", Luigi Lavazza S.p.A. - Turin

The graphs here shown, describe the test results for **patented EASY ANTISEISMIC T24 with Atena PLAN steel panels**. From the monotonic test it emerges that the system is characterized by an initial elastic stretch up to a displacement value equal to 5 mm, which is followed by a plastic section until it reaches a maximum resistance for the single bracing system equal to 600N and a last value of resistance equal to 500N.

The behavior of the cyclic test is analogous to that found with the monotonic test. **Furthermore, in both tests the collapse of any panel did not occur, but only their lifting due to the shortening of the antiseismic bracing rods caused by their destabilisation.** The test was also conducted with lightweight plasterboard panels.

In both tests, the shortening of the main profiles, due to the instability phenomenon and the poor deformability of the plaster modules, caused a shift and a partial displacement of the latter from their seat, without causing the collapse of any panel.

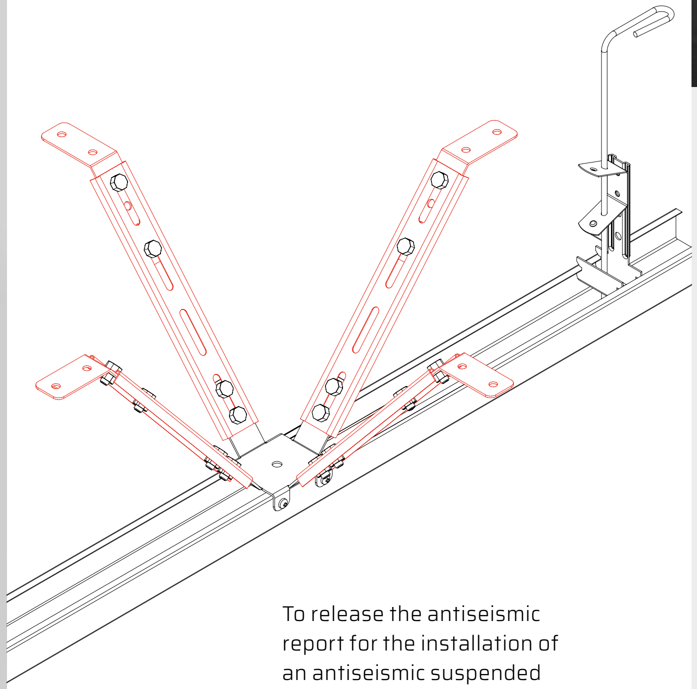
It follows that the **Atena Easy Anti-seismic Kit is effective both with lightweight plaster modules and with the Atena steel panels and it is with these latter that the system achieves the maximum performance.**

ANTI SEISMIC FALSE CEILINGS

All Atena false ceilings can be reinforced with the Atena anti-seismic kit, properly conceived to allow the correct dissipation of seismic energy and prevent the ceiling from falling.

Atena offers a specialized technical consultancy and, on request, releases a specific anti-seismic report, where numbers and types of reinforcing elements are indicated, in relation to the ceiling model, the seismic zone and the project requirements.

Atena antiseismic report complies with NTC and European standard for the building test and the antiseismic certification.



To release the antiseismic report for the installation of an antiseismic suspended ceiling Atena S.p.A. requires the following information:

- **Location and intended use of the building**
- **Construction type of the building and of the floors (masonry, reinforced concrete, ...) where false ceiling will be installed**
- **Updated plants and sections in 1:100 scale (paper format or Cad) of the areas subjected to calculation.**
- **Geological report, if available**
- **Special provisions if required**

GOOD ANTI-SEISMIC DESIGN STANDARDS

1. **Evaluate** the complete system: false ceiling/**building.**
2. **Evaluate the fixings** by extraction tests on site, to verify the type of existing slab and to install the hanger correctly.
3. **Check the plenum space** and conceive the hangers in order to withstand the pendulum effect.
4. **Plan for expansion joints** in relation to the false ceiling features.
5. **Check the plants configuration** in order to adequately size the anti-seismic system.
6. **It should be remembered that lighting fixtures and systems must be independently** evaluated to be properly **suspended and braced;** as they do not fall within the scope of false ceilings
7. For historic or dated buildings **light false ceilings with a weight of less than 8 kg per square meter are reccomended.**

INCIDENCES EVALUATION

BRACING CALCULATION

According to the current legislation, the calculation of the **anti-seismic kits incidence** is carried out considering the **specific acceleration** identified on the basis of the geographic coordinates of the project area, depending on the nominal workload.

In the same seismic zone, each geographical coordinate has a punctual acceleration coefficient.

Therefore within the same Municipality the incidence of anti-seismic kits to be applied can vary. A specific calculation is therefore always necessary in relation to the false ceilings features, the building characteristics and the geographical location.

The following tables show some examples. Specifically, the anti-seismic kits per sqm were calculated according to the following parameters::

- **Atena anti-seismic kit for big heights** (plenum greater than 1.2 m)
- **Atena Easy Anti-seismic Structure T24** ATENA maximum load 12 kg per sqm
- **Building Classes of use: 2-3-4**
- **Plenum Height: h**
- **Subsoil category: D**
- **Life Safety Limit State LLS**

Incidence of anti-seismic kits for sqm

h = plenum height | CL = class of use of the building

ROME seismic zone 3

h (m)	CL. 2 (m^2)	CL.3 (m^2)	CL. 4 (m^2)
1,00	12,92	11,46	10,53
1,50	8,61	7,64	7,02
2,00	6,46	5,73	5,26

FLORENCE seismic zone 3

h (m)	CL. 2 (m^2)	CL.3 (m^2)	CL. 4 (m^2)
1,00	10,85	9,41	8,56
1,50	7,23	6,27	5,71
2,00	5,42	4,71	4,28

VENICE seismic zone 4

h (m)	CL. 2 (m^2)	CL.3 (m^2)	CL. 4 (m^2)
1,00	20,02	17,55	15,79
1,50	13,34	11,70	10,53
2,00	10,01	8,77	7,90

L'AQUILA seismic zone 2

h (m)	CL. 2 (m^2)	CL.3 (m^2)	CL. 4 (m^2)
1,00	5,45	4,74	4,29
1,50	3,63	3,16	2,86
2,00	2,72	2,37	2,15

Data source: Studio Ing. Roberto Galasso

As can be seen from the above data, the role of the seismic acceleration of the site is evident regardless of the seismic zone in which it is located. Therefore zones having the same seismic classification have different incidences of antiseismic kits.

For this reason Atena supports the importance of performing precise calculations for each project.

ANTI-SEISMIC KIT

FOR PLENUM ≤ A **1,2 meters**

- EASY ANTI SEISMIC
- ENIGMA, MATROX, STAVES AND BAFFLES SYSTEMS
- SPECIAL SYSTEMS
- PLASTERBOARD SYSTEMS

PLENUM ≤ 1,2 m

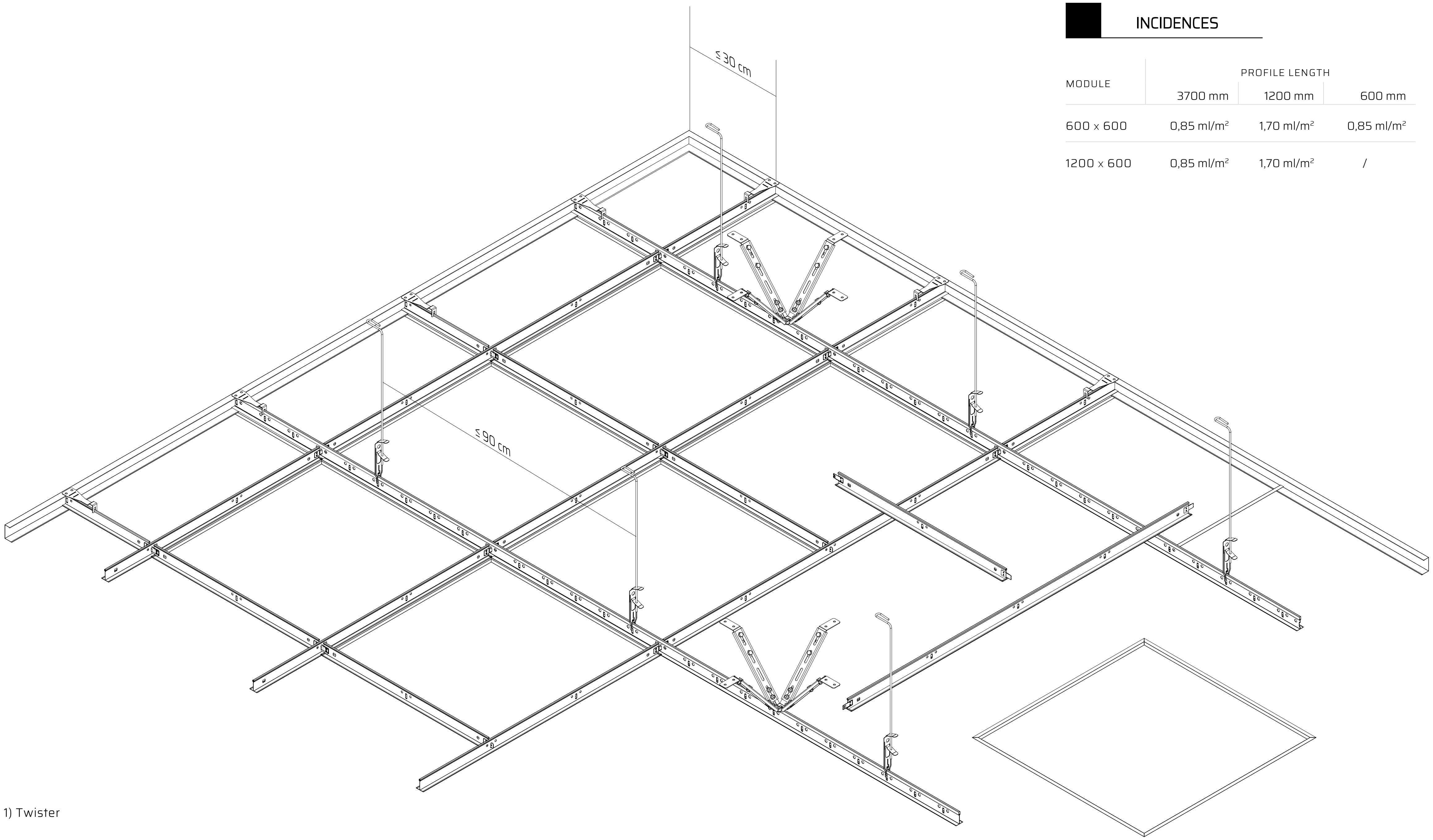
Photo: "Atena Plan System"

ANTI-SEISMIC KITS FOR CEILINGS

Atena Anti-seismic kits for plenums lower than 1.2 m are essentially made up of **1 cross connection** and **4 holed bracing profiles** to be fixed to the slab.

For each false ceiling system Atena has conceived a **specific cross connection**, to **couple the bracing profiles with the primary or secondary structure**.

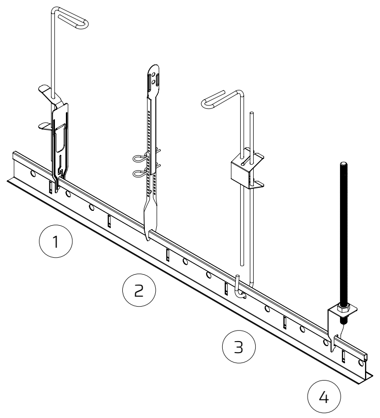
Among the visible structure models, Atena **Easy Antisismico** ensures high performance in terms of **safety**, **stability** and **ease of installation**.



INCIDENCES

MODULE	PROFILE LENGTH 3700 mm	1200 mm	600 mm
600 x 600	0,85 ml/m²	1,70 ml/m²	0,85 ml/m²
1200 x 600	0,85 ml/m²	1,70 ml/m²	/

HANGING OPTIONS



1) Twister

2) Nonius

3) Standard hook with spring

4) 90° hanger

TWISTER

EASY
RESISTANT
SAFE

Utility model
VE2009U000005

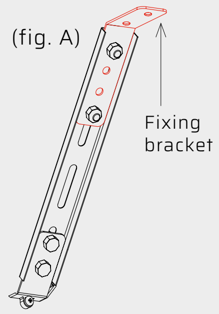
Thanks to its special shape, **Twister** can be hanged to the T-shaped profiles by just a simple fingers pressure.

Breaking strength over 60 kg (traction test with a force of 617N). **In seismic zones, maximum allowable load is 45 Kg.**

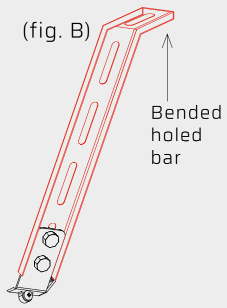
BRACING

To fasten the bracings to the slab, as an alternative to the **traditional system with connecting brackets** (fig. A), it is possible to bend the holed bars on site using the appropriate bar bending tool "Flexa" (B) and fix them directly to the ceiling.

(fig. A)



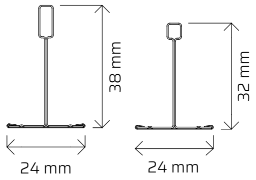
(fig. B)

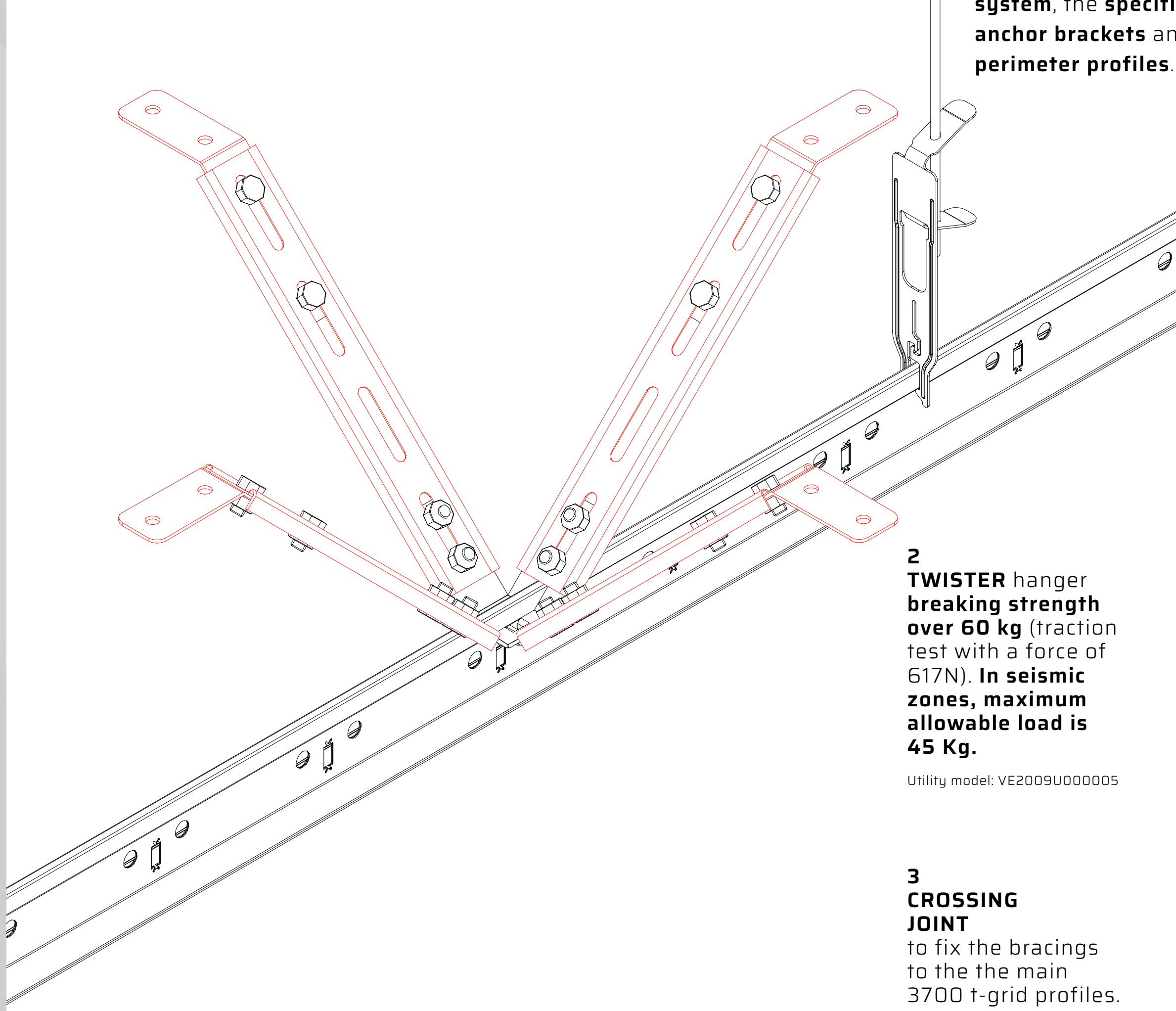


EASY ANTI-SEISMIC

1
Easy
ANTI-SEISMIC

3700 mm h32
1200 mm h32
600 mm h32

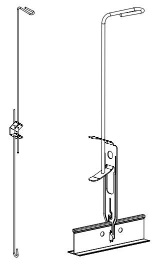




The Atena anti-seismic ceiling has been conceived to exploit the **synergic action** of various elements such as: the **Easy Anti-seismic structure**, the **cross connection**, the **bracing system**, the **specific hanger**, the **anchor brackets** and the special **perimeter profiles**.

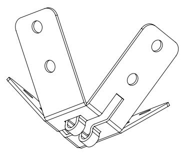
2
TWISTER hanger **breaking strength over 60 kg** (traction test with a force of 617N). **In seismic zones, maximum allowable load is 45 Kg.**

Utility model: VE2009U000005

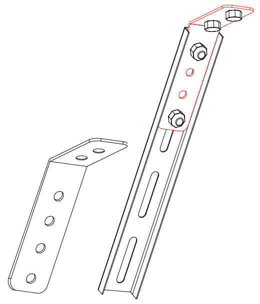


3
CROSSING JOINT
to fix the bracings to the main 3700 t-grid profiles.

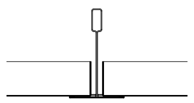
Patent N° VE2009U000007



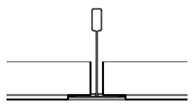
4
BRACINGS
holed bars and brackets for slab fixing.



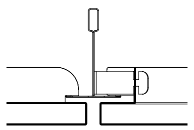
TILES



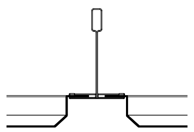
PLAN



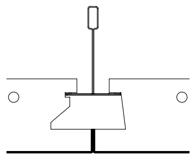
FLAT 24



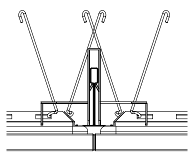
ENIGMA ESCAPE



24 L. TEGULAR

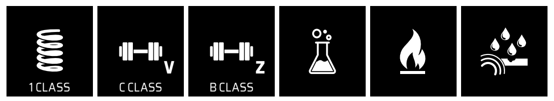


ENIGMA TRIM



24 SYNCRO EVO

REI 120 in combination with 75 and 15 mm thick mineral wool panels and 15 mm mineral fiber panels.



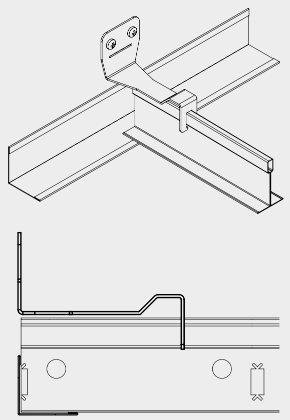
PATENTED HOOK

Maximum safety, combined with the highest installation speed.

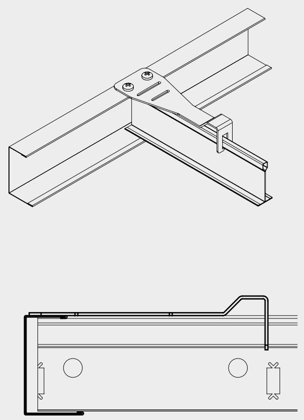
The **Easy Antiseismic** hook, in stainless steel, covered by an international patent, has a **tensile strength of 240N**.

Simple to insert, Easy Anti-seismic hook does not unintentionally release, thanks to its particular geometry that **allows to ensure the frame** favoring kinetic energy dissipation in the event of an earthquake.

"Atena Easy Antiseismic" - patent n ° VE2009U000006

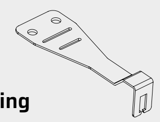


"L" 30x30 | 25x25 mm



"C" 18x42x25mm

EASY ANTI-SEISMIC WALL ANGLE BRACKETS



Acts by **friction** only.
Keeps the T-profiles **aligned**.
Prevents the panels **from falling** in the event of an earthquake.

The **Easy Anti-seismic** bracket is fixed to the C-shaped wall angles using M4,2x13 screws.
For application with L-shaped wall angles, the brackets must be bent at the nibbling.

ATENA ANTI-SEISMIC RANGE

ANTI-SEISMIC KIT

FOR HIDDEN STRUCTURE SYSTEMS AND CARRIERS

The **Metal Modular** anti-seismic ceilings with hidden structure such as **Enigma**, **Enigma Open**, **Enigma Escape** and **Matrox**, require the application of the anti-seismic kit exclusively with the double structure, both with 49x27 channels and holed "U" profiles.

For **Staves** and **Baffles**, the **anti-seismic kit** will be fixed directly to the carriers.

For false ceilings weighing more than 10Kg/m² the use of the double structure is required.

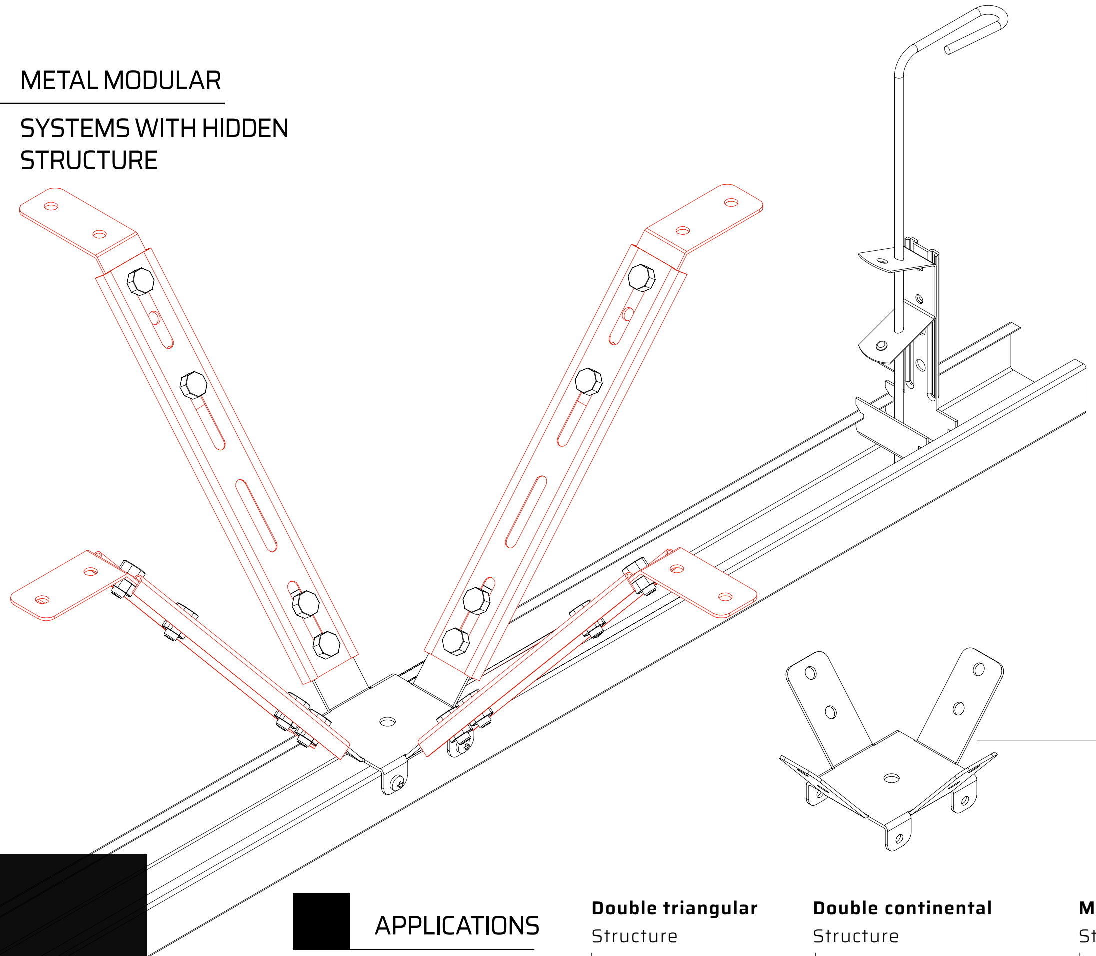
Photo: "Atena Enigma system", Amazon offices. Romania.

Photo: "Atena Baffle System", Sanofi offices. Panama.

Mosh Benjamin - Pro Pixel Panama - Mallol Arquitectos

METAL MODULAR

SYSTEMS WITH HIDDEN STRUCTURE

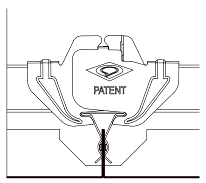


Cross connector for "C" channels

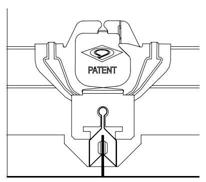
PLENUM ≤ 1,2 m

APPLICATIONS

Double triangular Structure

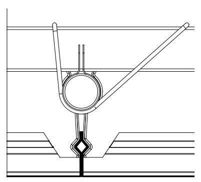


Double continental Structure



Tiles: **ENIGMA | E. OPEN | E. ESCAPE**

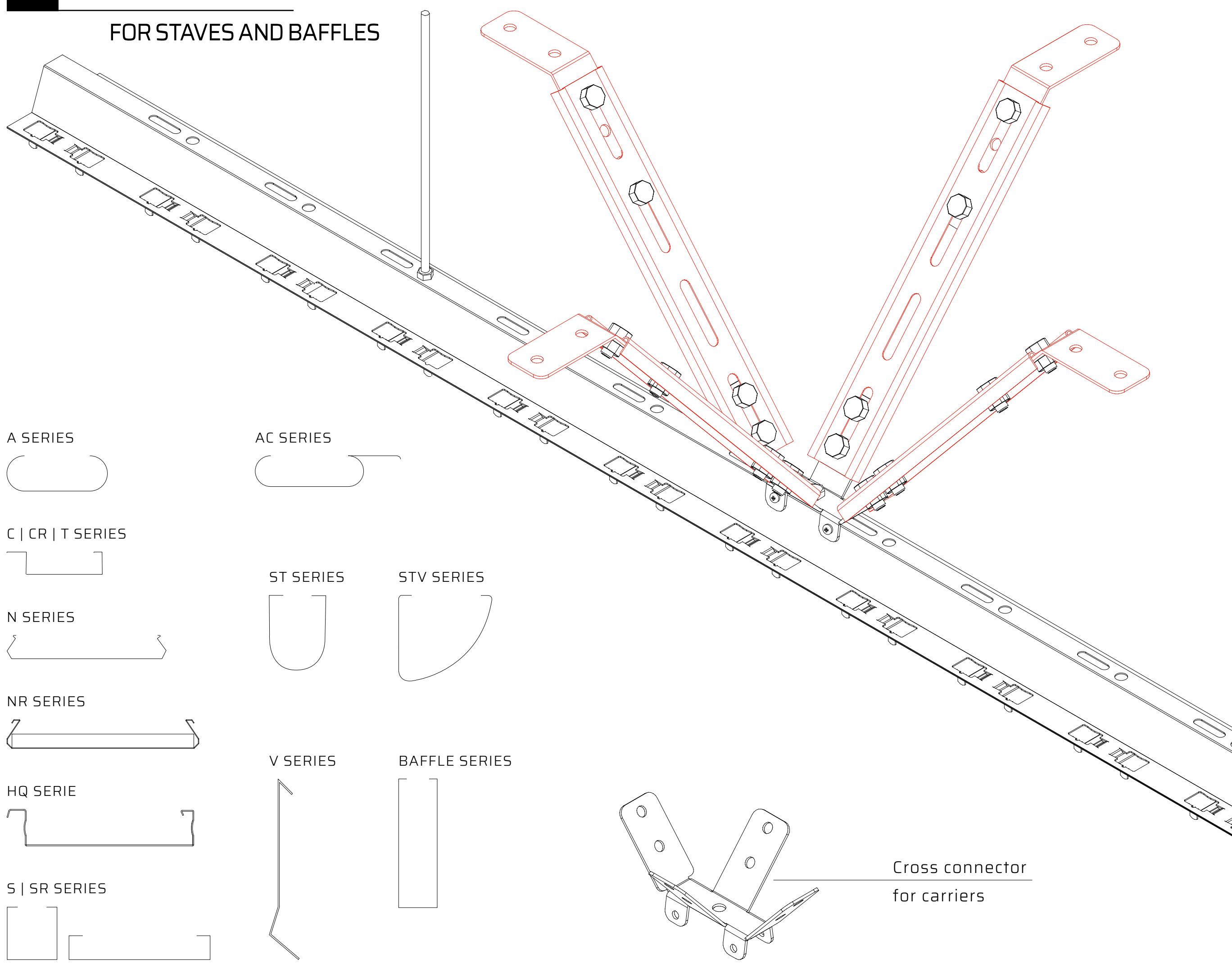
Matrox Structure



Tiles: **MATROX**

SYSTEMS WITH CARRIERS

FOR STAVES AND BAFFLES



Cross connector for carriers

ANTI-SEISMIC KIT FOR SPECIAL SYSTEMS WITH "U" SHAPED PROFILES

All parallel (without spacers) systems of Atena Metal Shapes range, use the **holed "U" shaped profiles** as primary structure in order to fix the secondary one at the right interaxe, making easy the system installation. When necessary also crossing systems can be reinforced with double structure.

Each metal ceiling system has properly connection brackets with specific suspensions and can be **reinforced** through the application of **anti-seismic kits.**

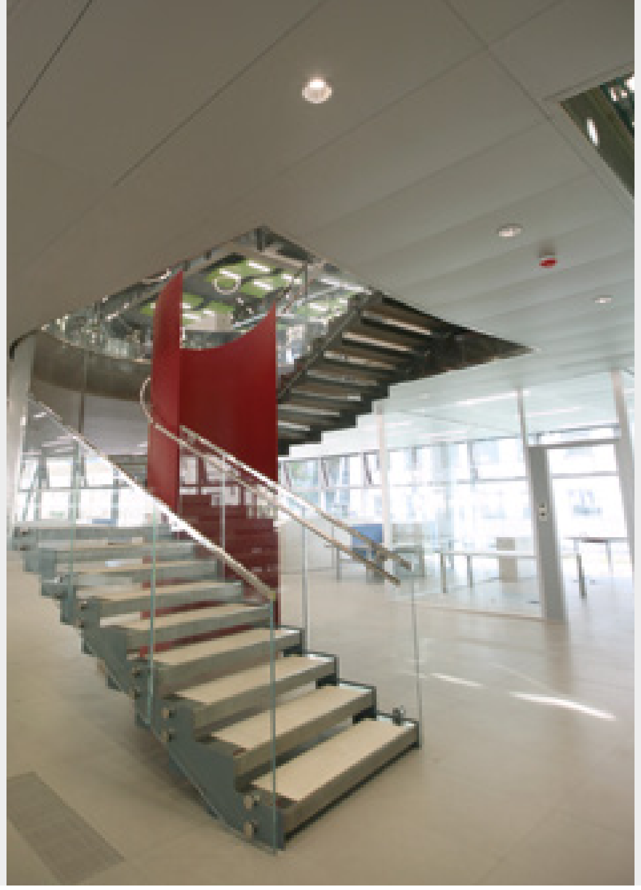
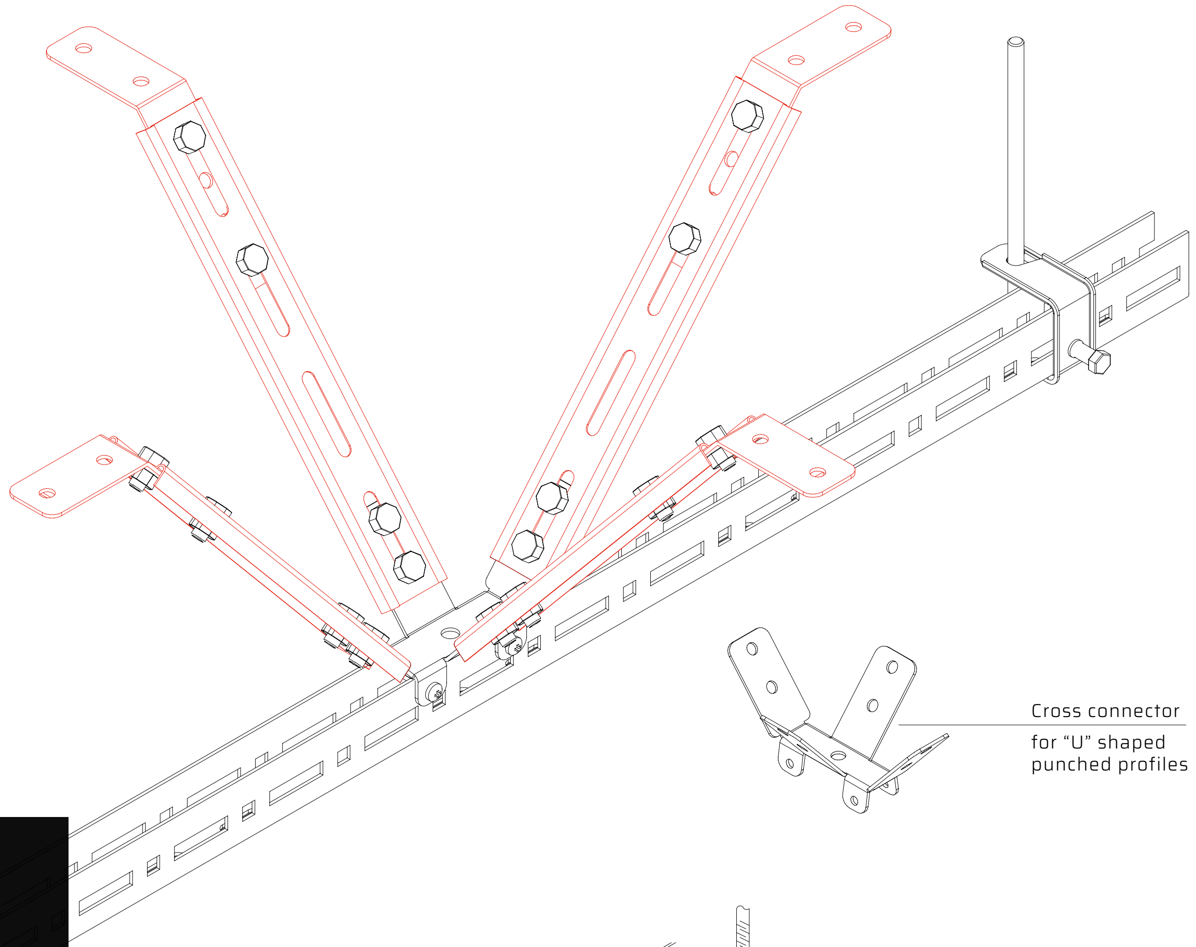
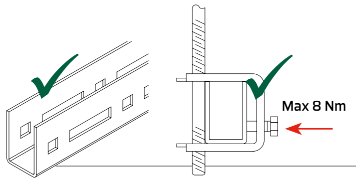


Photo: "Atena Z-System Wide Spaces", new offices Danieli Automation S.p.A., Carlo Mingotti studio Mingotti Architects associated, Buttrio (UD).



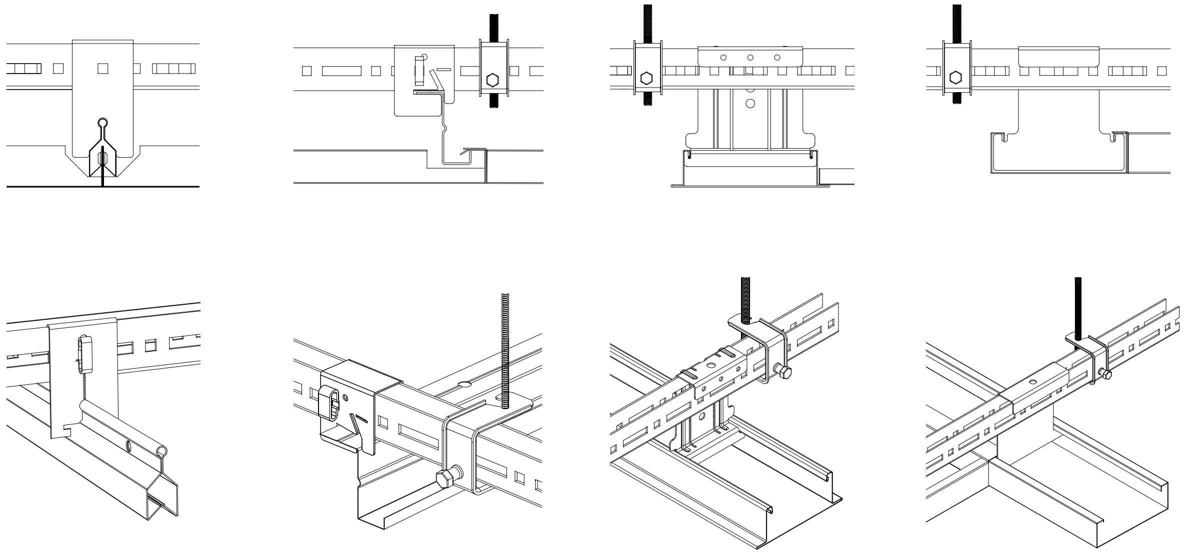
Cross connector for "U" shaped punched profiles



Right application of the suspension system

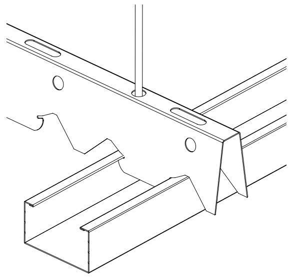
PLENUM ≤ 1,2 m

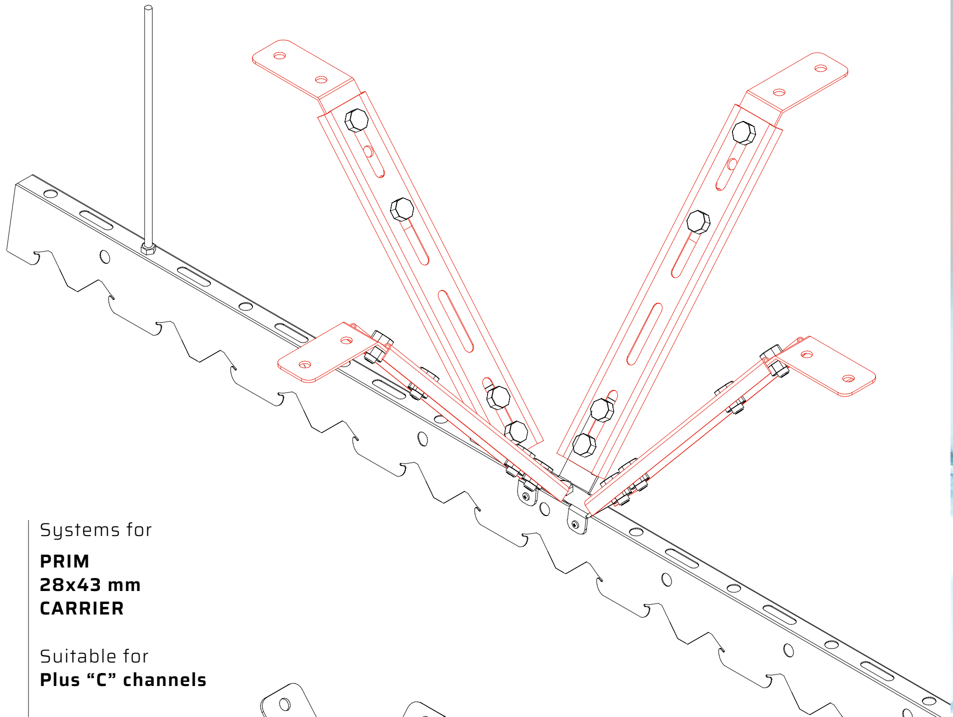
APPLICATIONS



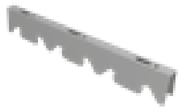
Systems **ENIGMA** **ENIGMA OPEN** **ENIGMA ESCAPE**	Systems **"Z System" WIDE SPACES** **"Z System" WAVY**	Systems **BANDRASTER PARALLEL**	Systems **BRETT PARALLEL**
Structure **Continental with "U"**	Structure **"Z System"**	Structure **Bandraster**	Structure **Brett**

KIT FOR PLASTERBOARD FALSE CEILINGS

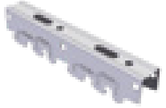




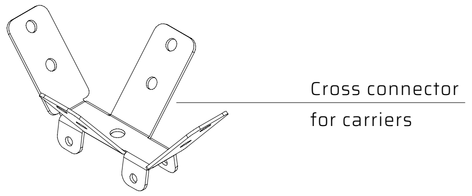
Systems for
ROMPITRATTA 45x15 mm CARRIER
Suitable for both **Standard and Plus "C" channels**

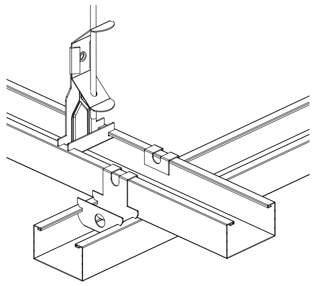


Systems for
DUPLEX 28x43 mm CARRIER
Suitable for **Standard "C" channels**

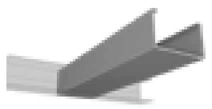


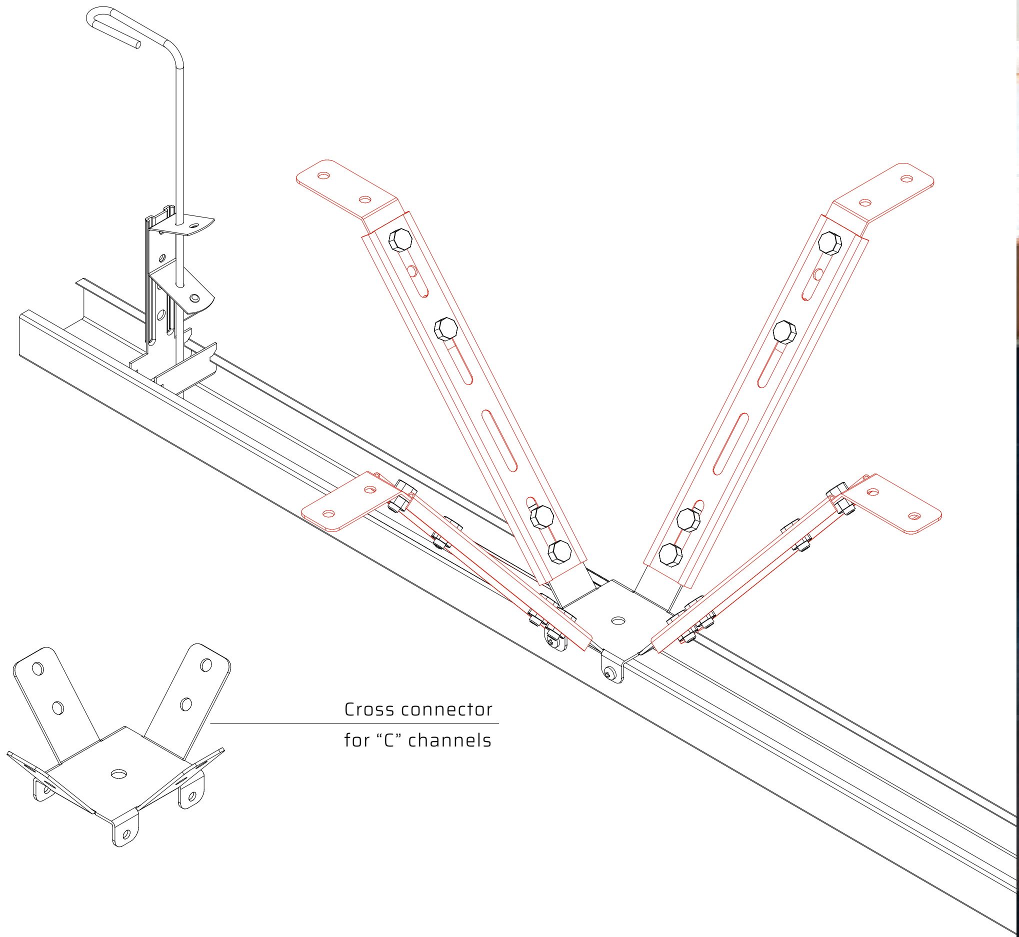
Systems for
PRIM 28x43 mm CARRIER
Suitable for **Plus "C" channels**





Systems for **49x27 Standard and Plus "C" channels**





ANTI-SEISMIC KIT

FOR HIGH PLENUM > A **1,2 meters**

HIGH PLENUM SYSTEMS
APPLICATIONS IN METAL FALSE CEILINGS
APPLICATIONS IN PLASTERBOARD FALSE CEILINGS

PLENUM > 1,2 m

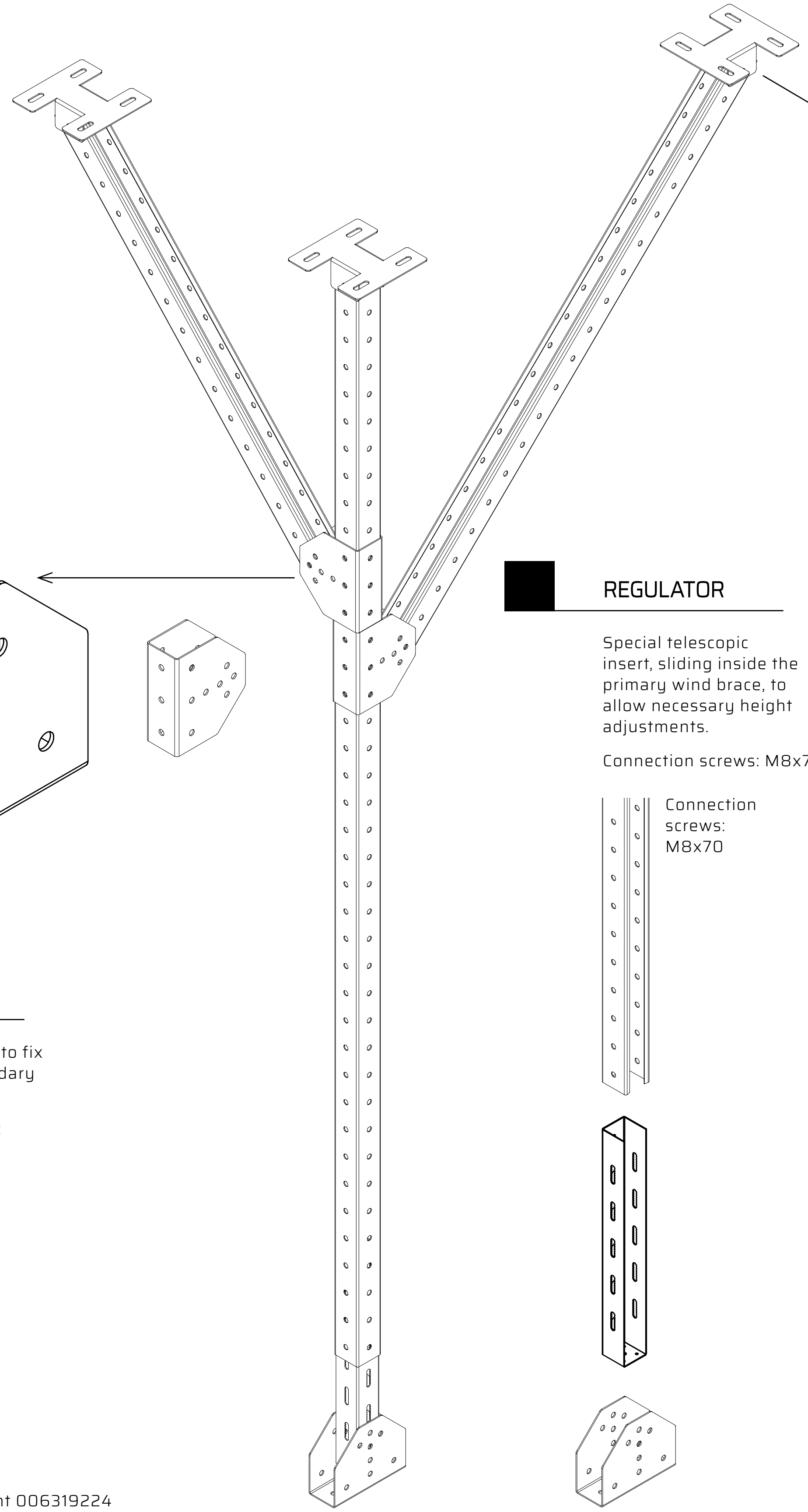
Photo: "Atena Z-System Wide Spaces", Marco Polo Airport. Venice

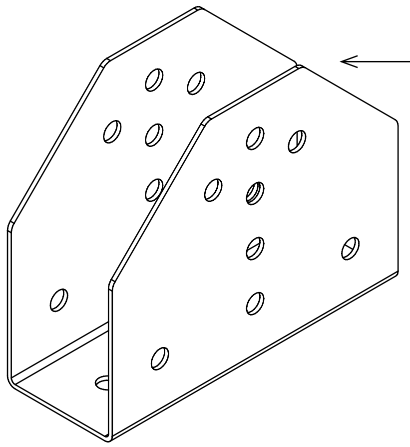
HIGH PLENUM

The anti-seismic kit for high plenum has been properly conceived to make **anti-seismic bracings when plenum is higher than 1,2 meters.**

Thanks to a tubular system with pitch holes and a series of universal joints and brackets, installation is **quick and easy** even in the most critical installation conditions.

Maximum height 2,50 m





CONNECTOR

A single connector to fix primary and secondary bracings.

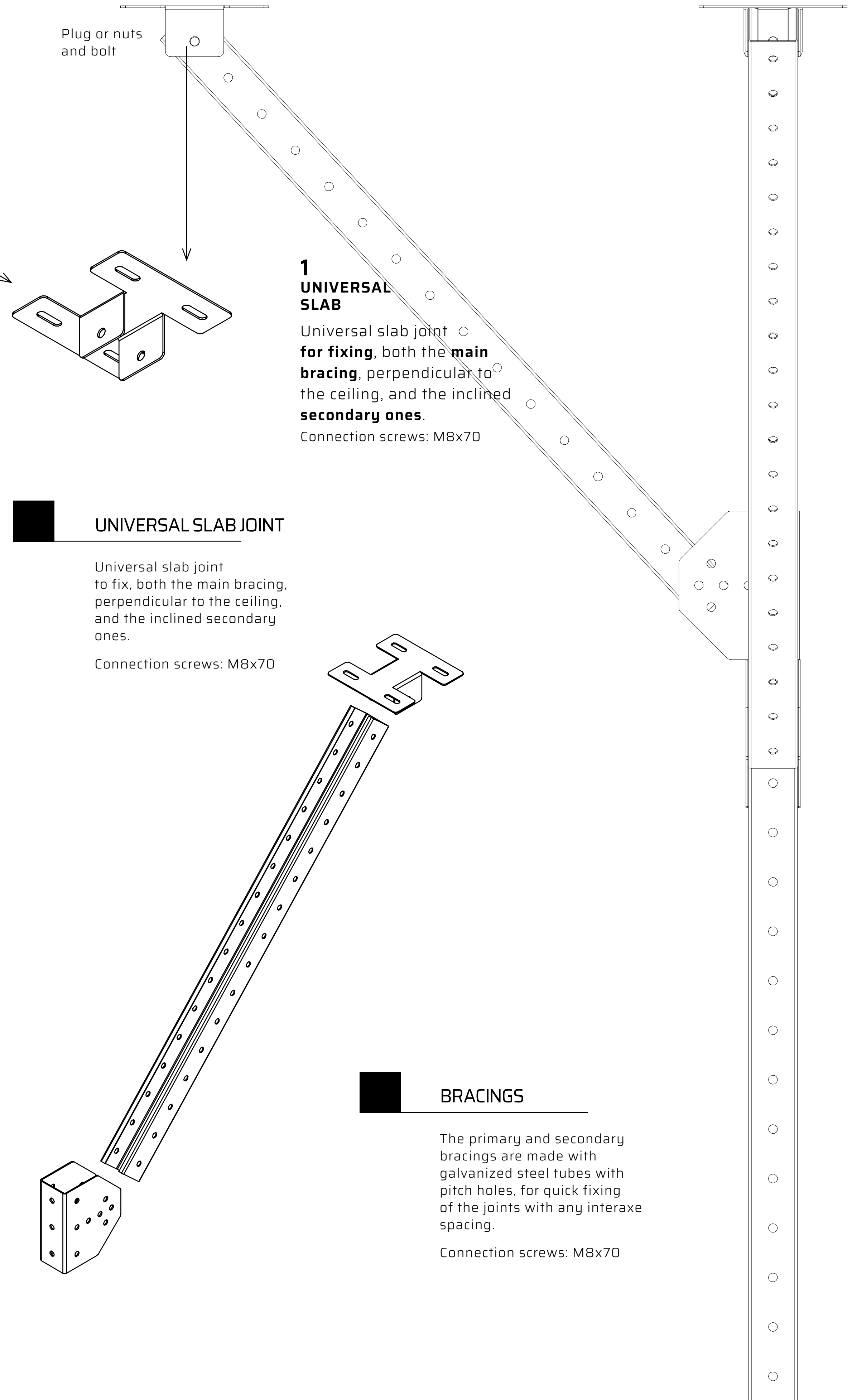
Connection screws: M8x70

REGULATOR

Special telescopic insert, sliding inside the primary wind brace, to allow necessary height adjustments.

Connection screws: M8x70

Connection screws: M8x70



1
UNIVERSAL SLAB

Universal slab joint **for fixing**, both the **main bracing**, perpendicular to the ceiling, and the inclined **secondary ones**.

Connection screws: M8x70

UNIVERSAL SLAB JOINT

Universal slab joint to fix, both the main bracing, perpendicular to the ceiling, and the inclined secondary ones.

Connection screws: M8x70

BRACINGS

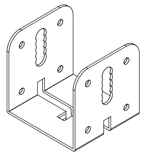
The primary and secondary bracings are made with galvanized steel tubes with pitch holes, for quick fixing of the joints with any interaxe spacing.

Connection screws: M8x70

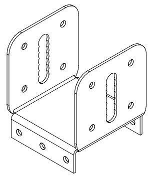
N°of deposited European patent 006319224

CONNECTOR MODELS

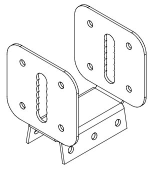
Specific cross connectors have been conceived for each **high plenum** false ceiling **anti-seismic kit.**



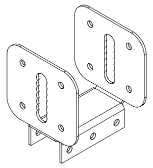
1
Connector for T-shaped structures



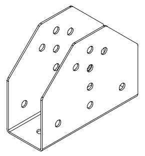
2
Connector for 49x27 “C” channels



3
Connector for carriers



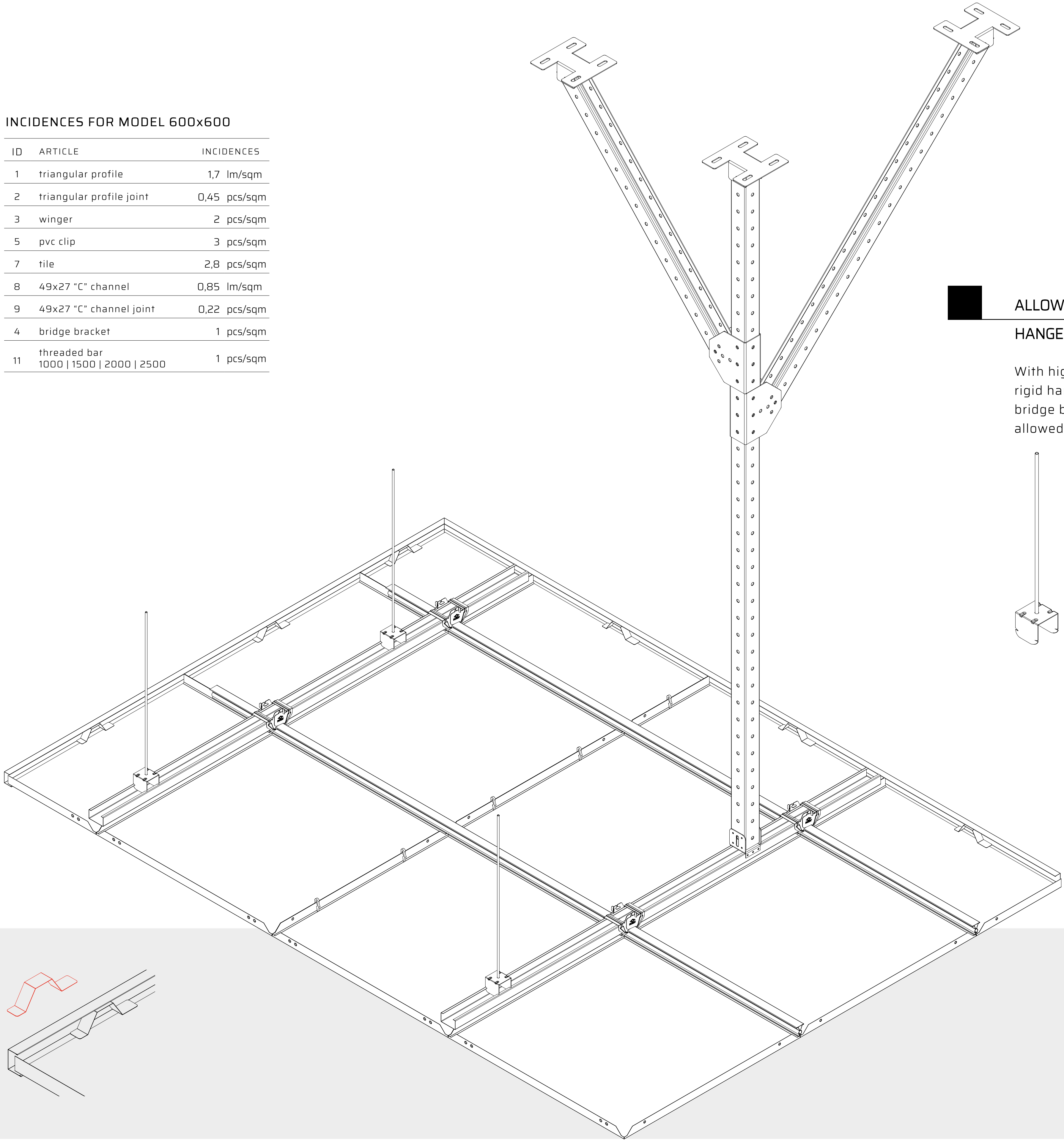
4
Connector for holed “U” shaped profiles



5
Connector / Universal bracket for special structures

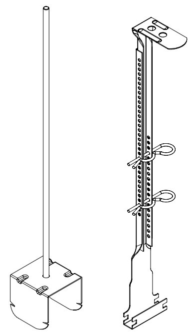
INCIDENCES FOR MODEL 600x600

ID	ARTICLE	INCIDENCES
1	triangular profile	1,7 lm/sqm
2	triangular profile joint	0,45 pcs/sqm
3	winger	2 pcs/sqm
5	pvc clip	3 pcs/sqm
7	tile	2,8 pcs/sqm
8	49x27 “C” channel	0,85 lm/sqm
9	49x27 “C” channel joint	0,22 pcs/sqm
4	bridge bracket	1 pcs/sqm
11	threaded bar 1000 | 1500 | 2000 | 2500	1 pcs/sqm



ALLOWED HANGERS

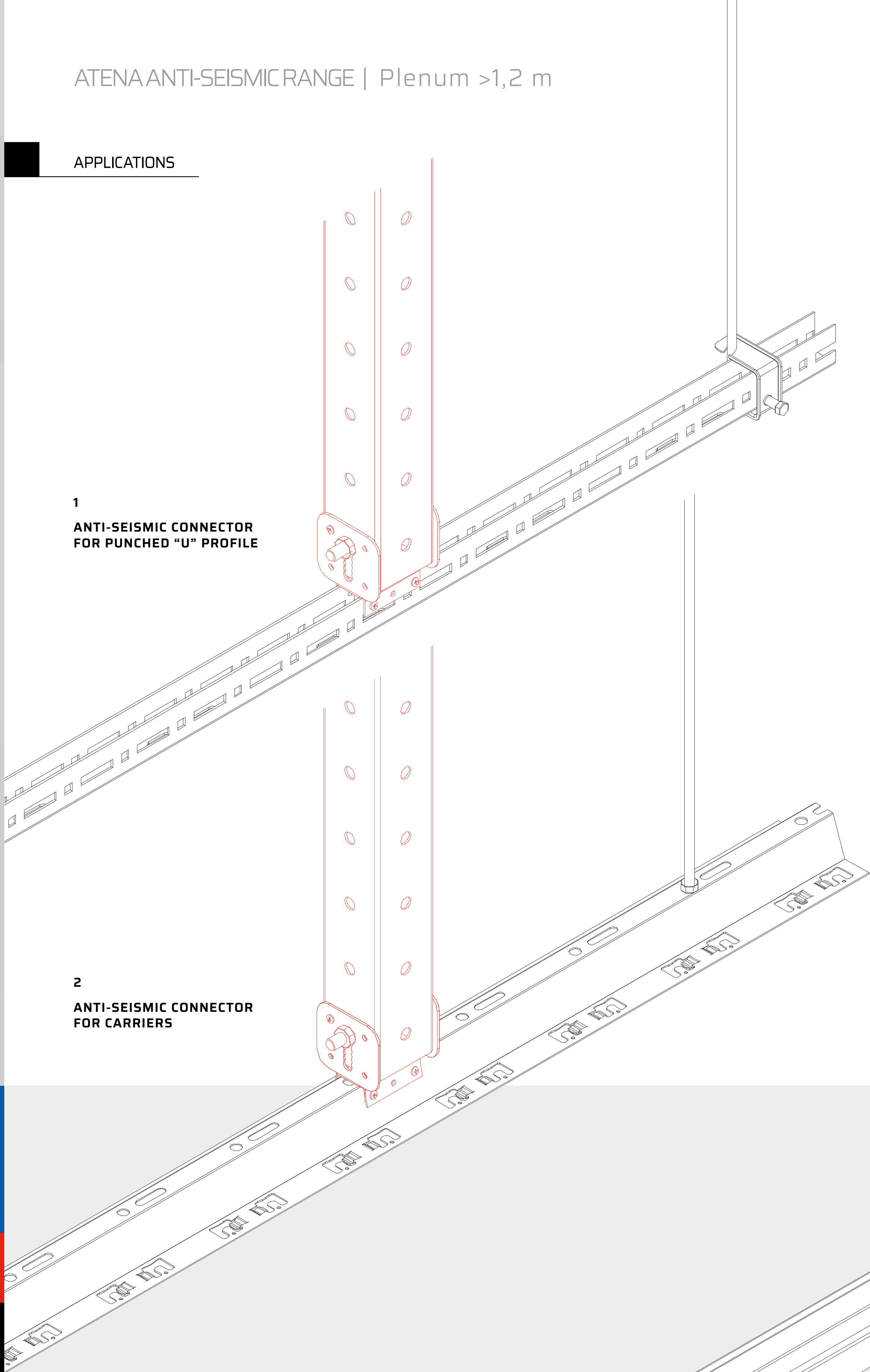
With high plenum anti-seismic kit, rigid hangers with threaded bars and bridge brackets or Nonius hanger are allowed.



WALL ANGLES

For systems that use the 18x33x25 “C” wall angles, omega safety springs must be inserted between wall angles and panels.

APPLICATIONS

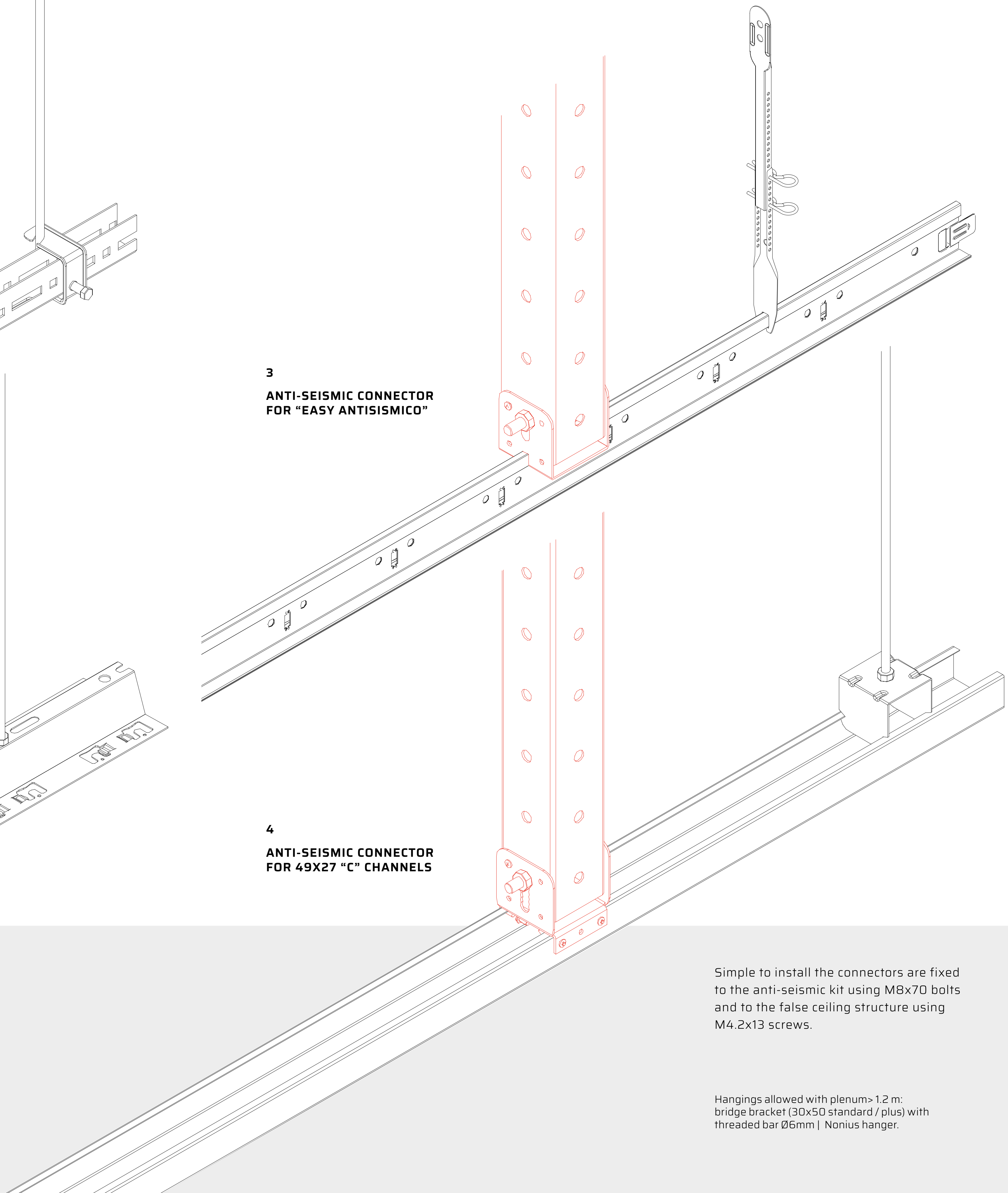


1

ANTI-SEISMIC CONNECTOR FOR PUNCHED “U” PROFILE

2

ANTI-SEISMIC CONNECTOR FOR CARRIERS



3

ANTI-SEISMIC CONNECTOR FOR “EASY ANTISISMICO”

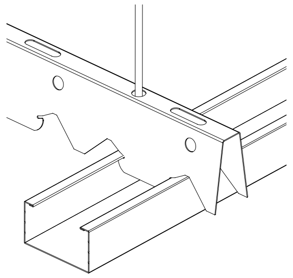
4

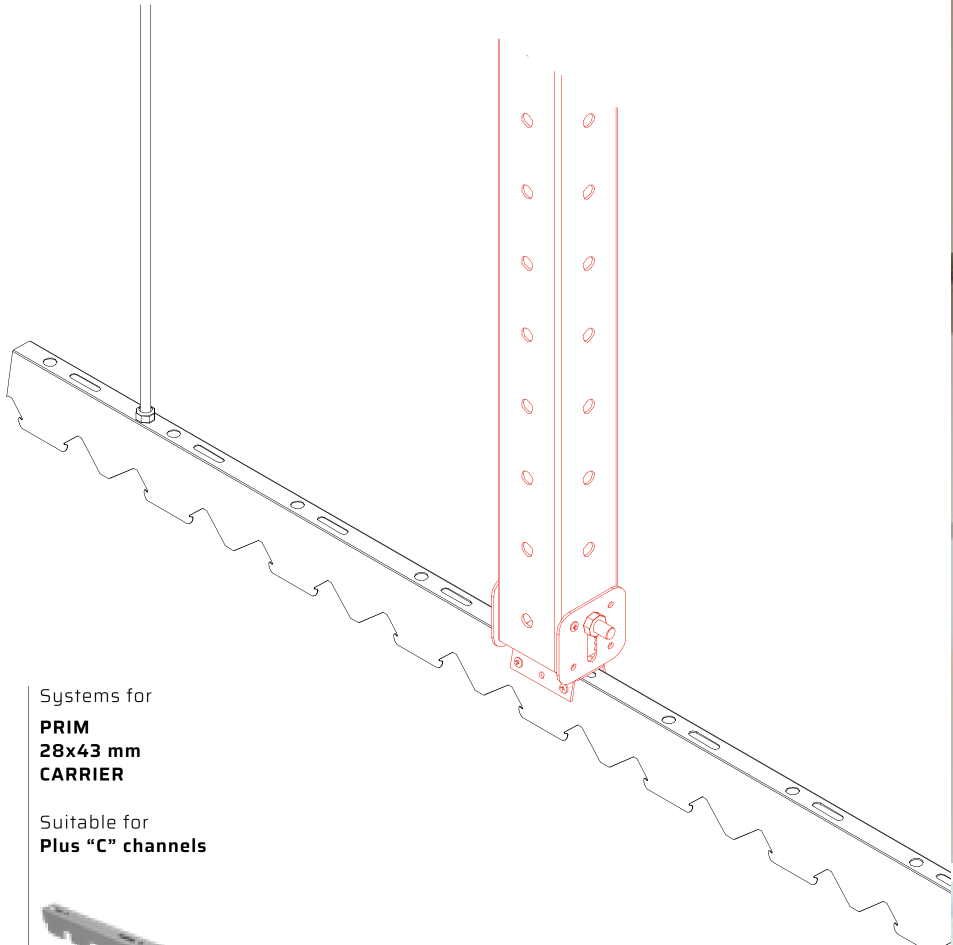
ANTI-SEISMIC CONNECTOR FOR 49X27 “C” CHANNELS

Simple to install the connectors are fixed to the anti-seismic kit using M8x70 bolts and to the false ceiling structure using M4.2x13 screws.

Hangings allowed with plenum> 1.2 m: bridge bracket (30x50 standard / plus) with threaded bar Ø6mm | Nonius hanger.

KIT FOR PLASTERBOARD FALSE CEILINGS



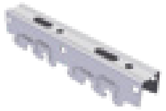


Systems for
ROMPITRATTA 45x15 mm CARRIER

Suitable for both **Standard and Plus "C" channels**

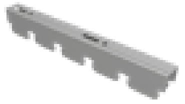
Systems for
DUPLEX 28x43 mm CARRIER

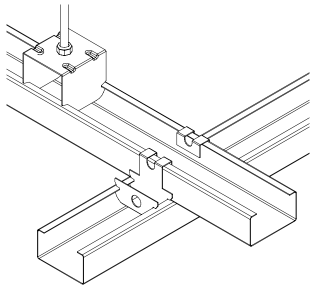
Suitable for **Standard "C" channels**

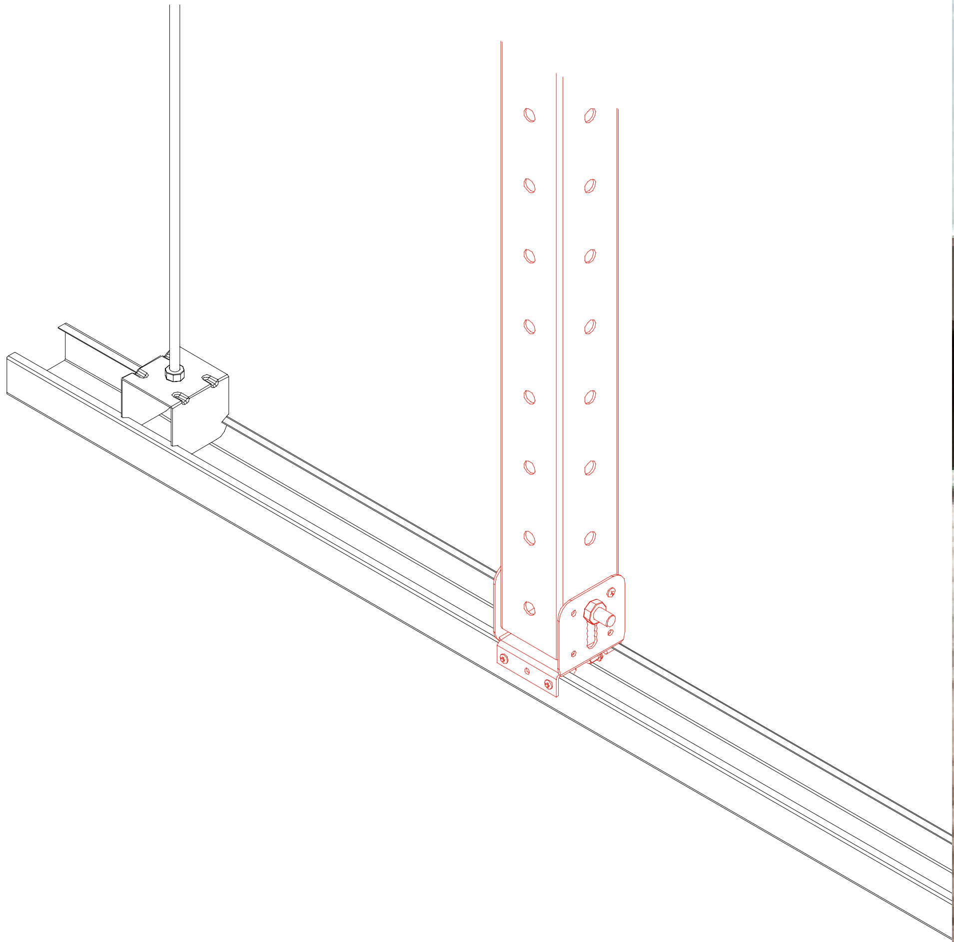


Systems for
PRIM 28x43 mm CARRIER

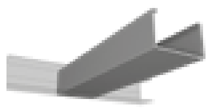
Suitable for **Plus "C" channels**







Systems for **49x27 Standard and Plus "C" channels**



Hangings allowed with plenum> 1.2 m:
bridge bracket (30x50 standard / plus) with threaded bar Ø6mm | Nonius hanger.

EXECUTIVE DESIGN

TECHNICAL CONSULTANCY

DIMENSIONING, TECHNICAL FEASIBILITY

FREQUENTLY ASKED QUESTIONS

FIXINGS, APPLICATION SCHEMES AND CERTIFICATIONS

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FREQUENTLY ASKED QUESTIONS

IS THERE A CORRELATION BETWEEN THE PLENUM HEIGHT AND THE CEILING SEISMIC RESISTANCE?

The experimental campaign was planned with the aim of responding to some common questions both to Atena S.p.A. and to the research group.

In this context it was therefore decided to test the most widespread types of Atena products with an initial plenum of 1.15m, in order to investigate the behavior of those false ceilings generally characterized by the presence of a rather cumbersome piping for HVAC and electrical system, a typical situation in buildings such as shopping centers.

Last tests (Enigma Matrox and Z-System - plenum 0.7m) were instead carried out to investigate the influence of the plenum height on the behavior of the false ceiling.

Further tests on the same type of false ceiling with differeces in plenum height will allow to correlate the behavior of the false ceiling solely with this parameter.

At the moment, in fact, the behavior of the tested false ceilings has been ascribed to several factors such as: plenum height, type of bracing anti-seismic connection, structure models (profiles, joints, panels).

IF THE SISMA IS AN IMPULSIVE FORCE, HOW IT CAN BE CONSIDERED IN AN QUASI- STATIC TEST?

The quasi-static cyclic tests are carried out at reduced speeds to monitor the progression of the damage level that affects the tested system. In this perspective it is as if the seismic phenomenon was simulated in "slow motion" in order to have the possibility of identifying the progression of the damage and on the basis of this, defining some parameters such as the system peak resistance, the ultimate resistance, the dissipative capacity and the maximum displacement capacity.

Working in this way, it is possible to characterize the behavior of the samples tested through physical quantities that are fundamental parameters for a correct evaluation of the stresses acting on the false ceilings. On the other hand, the vibrating table tests, differ from the quasi-static cyclic ones because of their dynamic nature. Thanks to vibrating table tests infact, it possible to check the false ceiling withstandanding to a given seismic acceleration, but it is not possible to characterize the behavior of the system, step by step. Moreover, in comparison to the quasi-static tests, the vibrating table ones have the advantage of being able to evaluate the dynamic effects and the vertical seismic accelerations.

To do this special vibrating tables, properly conceived to consider also these parameters must be used and the costs for their realization are much greater than those for the quasi-static tests.

For this reason, when we talk about quasi-static tests or dynamic tests we must refer to a different purpose of the same test itself. That is: the first characterizes the behavior of the sample in a continuous way, the second allows to define the overcoming of a predetermined acceptance criterion.

ON THE BASIS OF CONDUCTED TESTS, IS IT POSSIBLE TO SAY WHAT MAGNITUDE THE FALSE CEILING IS ABLE TO WITHSTAND?

The question has no answer. In the sense that the ability of a false ceiling to withstand a certain earthquake, depends not only on the false ceiling itself, but also on the characteristics of the building in which the false ceiling is installed, as well as on many other factors of which magnitude alone cannot take into account.

The quasi-static cyclic tests are carried out to investigate the behavior of the false ceiling for values of imposed forces, and therefore of increasing displacements. It will then be the designer, on the basis of the magnitude of the earthquake and of the characteristics of the building on which the false ceiling is investigated, to calculate the resistance needs of the false ceiling and therefore to design the anti-seismic restraints, based on the knowledge obtained from the quasi-static tests .

IMPOSED DISPLACEMENT IS UNIFORM?

The experimental set-up consists of a horizontal metal structure made up of square section profiles arranged in such a way as to form two square portions with dimensions of 2.4x2.4m and thus defining a rectangle with dimensions of 2.4x4.8 square meters. Inside each portion is placed a sample of a false ceiling equipped with its hanging system and three-dimensional bracings.

The load is applied as a displacement induced by a jack placed at the center of one side with a length of 4.8 m.

Thanks to the presence of two bracings, the two square portions maintain their shape without undergoing deformation, so the displacement applied is uniform.

This condition is called "rigid floor configuration of buildings" equipped with a rigid floor (slab) capable of imposing an uniform displacement on the non-structural components

WHAT ARE THE MOST IMPORTANT FACTORS FOR THE RESISTANCE OF THE FALSE CEILING TO THE SEISMIC FORCE?

The seismic acceleration experienced by a false ceiling placed inside a building is greater the higher is the position of the element itself inside the structure.

Considering a resistant approach, the non-structural element can respond to the stress through an element capable of absorbing the seismic action (the three-dimensional bracing) and limit the displacement demand due to the application of the forcing, so as to limit the phenomenon of hammering against the building perimeter.

In the case of a modular panel system, together with this anti-seismic device, the system should be equipped with some devices that can prevent the deformations of the false ceiling plane with consequent collapse of panels / profile distortions / breaking of joints.

These devices could be for example, connections between main and secondary profiles suitable for withstanding stresses, perimeter joints capable of maintaining the regularity of the false ceiling grid and preventing the perimeter panels from falling, and brackets that prevent the panels from falling due to sussultatory actions.

FIXINGS, APPLICATION SCHEMES AND CERTIFICATIONS

FIXINGS

Hangers and slab fixing are **fundamental and not negligible elements** for the safety of the false ceiling.

Inadequate fixings with respect to the load and the characteristics of the slab and **unsuitable or wrongly applied hangers** compromise the stability of the system and can cause serious damage.

During an earthquake the anchor is subjected to **load cycles** and to the **variation in the width of the cracks.**

The seismic action on the anchor:

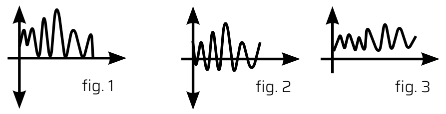
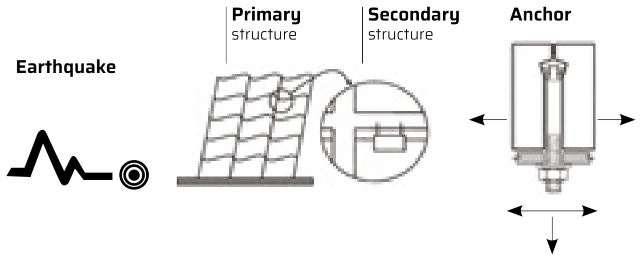
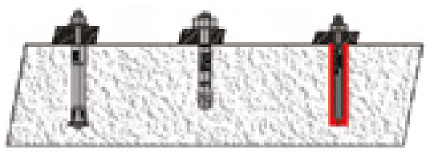


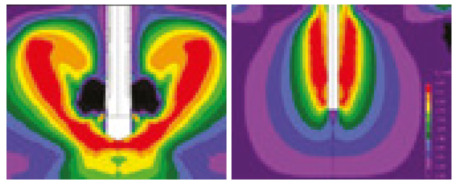
fig. 1 Crack width
fig. 2 Cutting (loads)
fig. 3 Traction (loads)



Mechanical | **Chemical**



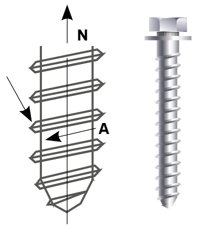
Mechanical anchor | **Chemical anchor**



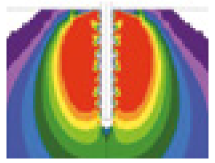
Pull out extraction tests and **FEA analyzes** for fasteners verification.

The **analysis of finite element stresses** (FEA Finite Element Analysis) allows to simulate the effects of static and dynamic stresses on a mechanical element.

Classification: the resistance is due to the combined action of **shape (R)** and **friction (A)**



Analysis of finite element stresses



The **pull-out** survey is a semi-destructive test for determining the extraction force of a metallic anchor, pre-embedded or post-inserted in the concrete element to be tested.

Atena supplies only accessories such as screws, washers and nuts to connect the elements it supplies; in collaboration with the most important companies in the sector, it supports designers, construction management and installers for the choice of slab and wall fixings, intervening with extraction tests on site.

Fixings for non-structural use - NTC 2018

Seismic level	CL. 1	CL. 2	CL.3	CL. 4
$a_g \cdot S \leq 0.05\ g$	ETA	ETA	ETA	ETA
$a_g \cdot S > 0.05 \leq 0.10\ g$	ETA C1	ETA C1	ETAC1	ETA C2
$a_g \cdot S > 0.10\ g$	ETA C1	ETA C2	ETA C2	ETA C2

CL. = Class of use of the building
ETA = European Technical Approval | C1 = low seismicity | C2 = high seismicity
$a_g \cdot S$ = Acceleration with a probability of exceeding 10% in 50 years
g= Gravity acceleration

The failure of a false ceiling is mostly due to:

- choice of unsuitable fixings in qualitative and functional terms.
- inadequate evaluation of the anchor in relation to the application and to the anchor floor.
- Incorrect installation as for wrong drilling diameters.

APPLICATION LAY-OUT

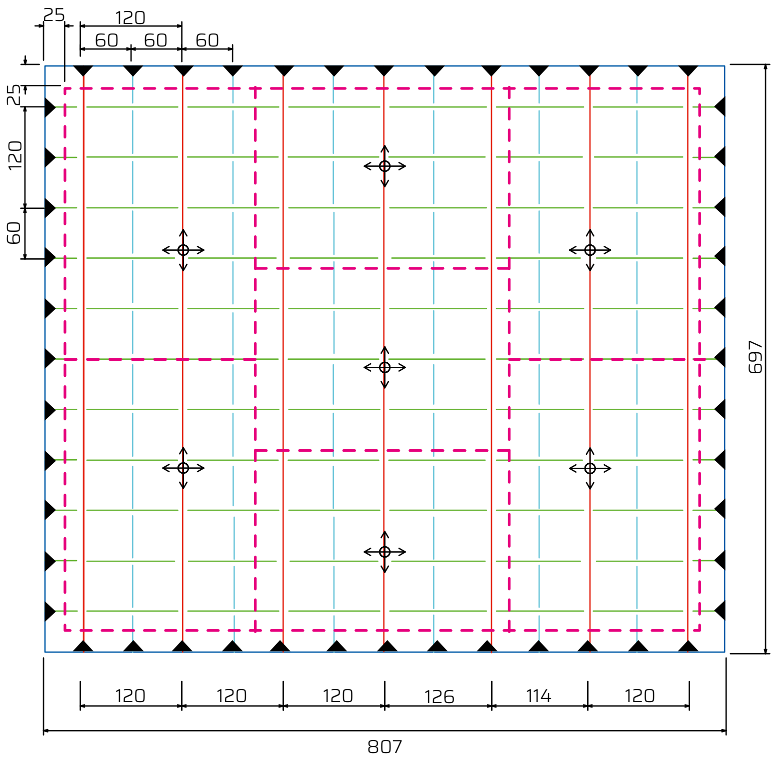
Example of application lay-out with Easy Anti-seismic system*

Position of ANTI-SEISMIC KIT
Expected situation
1 Kit every 8 m²
Hanger 1,2x1,0 m
---- Area of incidence

Position Easy Anti-seismic brackets

1 3700 mm main profile
2 1200 mm profile
3 600 mm profile
4 Perimeter profile

* The scheme has a purely illustrative value, bracing incidence and disposition will be sized according to each specific project.*



CERTIFICATIONS

All Atena false ceilings are produced for **indoor applications** and comply with the requirements of NTC 2018, the technical standards for constructions, and the specific applicable UNI EN 13964 standards. For **outdoor application**, false ceilings and coatings must be properly sized.

For internal application they are CE marked and electronically accompanied by the Declaration of Performance (D.o.P.) as required by the European regulation 305/11 about putting construction products on the market.

Reference standards
UNI EN 13964
NTC 2018
EUROCODES

FLEXION RESISTANCE (1 CLASS)	Maximum span mm 1200: 1 Class
DURABILITY OF POST-PAINTED ITEMS (C CLASS)	C Class
DURABILITY OF GALVANIZED ITEMS (B CLASS)	B Class
RELEASE OF DANGEROUS SUBSTANCES	NONE
FIRE REACTION	Smooth or perforated tiles with Viledon Plus: A1 Class Perforated tiles with Viledon standard: A2s1d0 Class
ENVIRONMENTAL COMPATIBILITY	All Atena products are recyclable and contribute to the acquisition of scores for obtaining LEED certification.
CORROSION RESISTANCE	Galvanized steel products: Class C2 Pre-painted galvanized steel products: Class C3 Post-painted galvanized steel products: Class C4 Pre or post-painted aluminum products: Class C5

For applications in particularly aggressive environments such as swimming pools, industrial plants with chemical and / or corrosive fumes, check the most suitable material and surface treatment with Atena S.p.A technical / commercial office.

TO BE INSPIRED

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Thinking about new projects...

Photo: 24 Linear Flow | Macramè mesh

ANTI-SEISMIC LINE Rev 3- 01/2022

Texts: ing. Laura Fiorin

Thanks for the contributions to:
Prof. Ing. Roberto Scotta
Ing. Sara Brandolese
Ing. Roberto Galasso
Ing. Gianluca Pasqualon
Ing. Antonio Masciariello Fisher S.p.A.

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READ QR CODE

The settings are reinterpreted with photorealistic reconstructions by Atena S.p.A.

All dimensions are nominal and expressed in millimeters.
All weights are expressed net of tare.
All technical specification data and information can be changed without advise.
More details concernings colours, perforations, perimeter profiles and laying instructions are described in technical data sheets suitable on line: atena-it.com
For further information please contact sales department:
tel. + 39 0421 75526 commerciale@atena-it.com

100% GREEN ENERGY · DOLOMITI ENERGIA

ISO 9001

FALSE CEILINGS AND COVERINGS

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