Certification of anti-seismic devices according to the European Standard EN 15129:2009: Tasks for manufacturers and notified bodies

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Summary
The European Standard EN 15129 is today the most updated standard on anti-seismic devices. The norm specifies functional requirements and design rules, provisions for material characteristics, manufacturing and test requirements, as well as acceptance, installation and maintenance criteria. Since August 2011 the conformity to the European Standard EN 15129 is mandatory for anti-seismic devices that are marketed within the European market.
The paper surveys the tasks for the manufacturer and for Third Parties (the Notified Bodies) involved in the procedure of attestation of conformity. Furthermore it reviews the experience of Politecnico di Milano, in its position of Notified Body for Testing, Inspection and Certification of antiseismic devices, over one year from the enforcement of the standard.

Key words: EN 15129, anti-seismic devices, CE marking, notified body

1. THE SCOPE OF EN 15129

The term “anti-seismic device” designates a wide class of devices that are provided in structures with the aim of modifying their response to the seismic action.
The document which firstly established rules on the dimensioning and the use of anti-seismic devices was the AASHTO Guide Specification for Seismic Isolation Design in 1991. Since then, a number of national standards and codes were drafted worldwide to regulate the use of such devices. Nevertheless the requirements of the various codes were often different and even contrasting, entailing the manufacturers to follow different design rules, manufacturing prescriptions and testing procedures depending on the final destination of the products.
A decisive step towards the harmonization of the market of anti-seismic devices in the countries of the European Union came with the European Standard EN 15129, drafted in 2009 by the European Committee for Standardization (CEN).
The standard was published on the Official journal of the European Communities on March 2011 and since August 2011 it took the status of “harmonized” standard, replacing national standards and becoming legally binding in the countries of the European Union.

1.1 Rationale of the standard

The philosophic approach followed by the Technical Committee 340 of CEN when preparing the norm was to have a standard open to technological innovation, that would not impair technological progress by favouring what is already established over what might be developed in the future. To achieve this scope, three leading rules were followed (Medeot, 2010):
a) requirements should be expressed in terms of performance as much as possible;
b) only those characteristics that can be verified by a given method shall be included; and
c) the Standard must represent an objective state-of-the-art and thus must not exclude any systems whose validity has been proven through successful applications.

Though it was not possible to draft a standard that is purely performance oriented, a fair compromise between “product oriented” and “performance oriented” requirements was achieved in EN 15129, providing at the same time compliance with the criteria (b) and (c) above.
The standard EN 15129 covers all the stages of the life-cycle of anti-seismic devices (design, manufacturing, testing, installation and maintenance).
The standard prescriptions are oriented to have anti-seismic devices that shall be capable to withstand seismic action effects without any local or global failure (*No Failure Requirement*), and also retain a residual mechanical resistance and a residual load bearing capacity after the seismic event (*Damage Limitation Requirement*). Additionally, the anti-seismic devices shall be designed and manufactured to withstand a seismic action having a larger probability of occurrence than the design seismic action, without the occurrence of damage and the associated limitations of use, the costs of which would be disproportionately high in comparison with the costs of the structure itself.
Other requirements established by the standard concern the performance at either the Ultimate Limit State (ULS) and the Serviceability Limit State (SLS), while the functional requirements permit to ensure that the anti-seismic device is able to maintain design characteristics and tolerances during the service life.
Only materials already approved and qualified, e.g. conforming to existing European or National standards, or covered by Technical Approvals, are allowed for the manufacturing of anti-seismic devices. The functional characteristics of the materials shall be assessed in a way that is adequately representative of their behaviour under strain and strain rate conditions that can occur during the design seismic situation and under different environmental conditions. All materials shall be identified and their compliance with the product requirements shall be verified by means of inspection certificates in accordance with EN 10204.

1.2 Anti-seismic devices

Among the drafting criteria of EN 15129 there was the idea that the standard shall represent an objective state-of-the-art and thus not exclude any systems whose validity has been proven through successful applications. Therefore the standard covers almost all kinds of anti-seismic devices that have found practical application in the last decades for seismic protection of buildings or structures.
The modification of the seismic response of the structure may be obtained in different ways, by increasing the fundamental period of the structure, by modifying the shape of the fundamental mode, by increasing the damping, by limiting the forces transmitted to the structure and/or introducing temporary connections that improve the overall seismic response of the structure. There are several types of anti-seismic devices that can be used to the end, each device with different possibilities of location within the structure.
Anti-seismic devices are categorized into four groups (figure 1.1) according to the functions they perform:

- Rigid Connections Devices (including Permanent Connection Devices, Fuse Restraints and Temporary Connection Devices);
- Displacement Dependent Devices (including either Linear and Non Linear Devices);
- Velocity Dependent Devices;
- Isolators (including Elastomeric Isolators and Sliders).

The category of Rigid Connection Devices includes different kinds of devices, like Fuse Restraints and Temporary Connection Devices, that are used to constrain movements in one or more directions. .
Fuse restraints (or Sacrificial Restraints) impede any relative movements between connected parts below a certain pre-established force threshold (breakaway force), whereas they break and freely permit the movements after the threshold force has been exceeded. Temporary (dynamic) Connection Devices (also referred to as Shock Transmission Units), are hydraulic devices which provide an output force that depends on the velocity only; they allow with minimal resistance displacements at low velocity (e.g.: thermally-induced movements), but prevent movements of sudden onset due to an earthquake or braking forces.
Displacement Dependent Devices are used to produce a reaction force that is mainly dependent on the imposed displacement. They are subdivided in two main sub-categories, namely Linear Devices, which are characterised by a linear or quasi-linear behaviour provided by a rubber element and are

usually used to generate a restoring force in the isolated structures; and Non-Linear Devices, which are characterised by a strongly non-linear (hysteretic) behaviour and are generally used to change the dynamic characteristics of a structural system by introducing significant energy dissipation.
The category of Velocity Dependent Devices typically includes hydraulic dampers, which produce a reaction force that depends on the velocity of movement. These devices are used to increase damping of the structure by means of energy dissipation produced by the passage of a highly viscous fluid through a system of orifices and valves.
Seismic Isolators are devices that are introduced between the superstructure and the foundations to decouple the prevailing mass of the structure from the ground motions, thus limiting accelerations and shear forces during an earthquake. EN 15129 regulates elastomeric isolators, including both high damping rubber bearings and isolators equipped with a polymer plug or a lead core to provide additional damping characteristics, and sliding isolators, like the Curved Surface Slider, or sliding pendulum system.

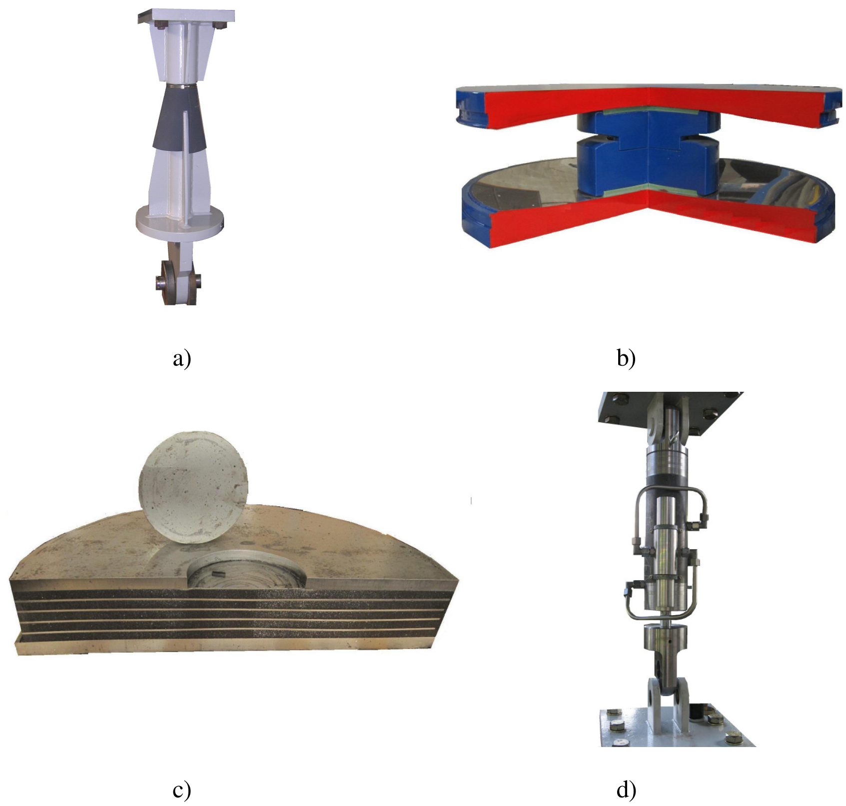

Figure 1.1: Examples of anti-seismic devices: a) hysteretic steel device (Displacement Dependent Device); b) sliding pendulum (Curved Surface Sliding Isolator); c) high damping rubber bearing (Elastomeric Isolator); d) Fluid Viscous Damper (Velocity Dependent Device)

For each category of the anti-seismic devices, the Standard regulates the design and manufacturing, and the characteristics of the constituent materials, establishing functional requirements and technical validation procedures. These procedures shall prove that the device remains operative within its domain of use, including the seismic situation, over its whole service life.

2. CERTIFICATION OF CONFORMITY TO EN 15129

After the coming in force of EN 15129 as harmonized standard in August 2011, within the framework of the current European Directive on Construction Products 89/106/EEC, and of the forthcoming

European Regulation no. 305/2011, the compliance of anti-seismic devices to the standard confers a presumption of fitness for the intended uses and is mandatory in the countries of the European Union.
The Certification of Conformity of anti-seismic devices to EN 15129 shall be performed by a Third Party (the Notified Certification Body) in accordance with the scheme defined in the Annex ZA of the standard, by means of initial type testing and approval of the system of control of the production process established by manufacturer.
The conformity of the anti-seismic device with the declared performance in relation to the essential characteristics covered by harmonised standard is attested by the manufacturer by affixing the "CE marking" on the device.

2.1. Tasks for manufacturer

The Standard prescribes that the manufacturer shall establish and maintain a permanent Factory Production Control (FPC) system to ensure that the manufactured products keep the compliance with the stated performance characteristics.
The FPC shall consist of procedures and schemes of regular inspections and tests and/or assessments appropriate to the product and manufacturing process, suitable to demonstrate conformity of the product at appropriate stages, including raw materials or components, equipment, the production process and the final product. Tasks and responsibilities in the production control organisation shall be documented and this documentation shall be kept up to-date. The typical content of the FPC is detailed in Table 2.1

Table 2.1: Tasks under the responsibility of the manufacturer

Tasks	Content
Factory Production Control (FPC)	1) preparation of procedures and instructions relating to factory production control operations; 2) verification of raw materials and constituents; 3) traceability of materials and products; 4) controls and tests during manufacture; 5) verifications and tests on finished products; 6) calibration and maintenance of control, measuring or test equipment; 7) treatment of non-conforming products.

The manufacturer shall have available the installations, equipment and personnel which enable him to carry out the necessary verifications and tests of materials and products, or alternatively he may conclude a sub-contracting agreement with external laboratories having the necessary skills and equipment. However it is the manufacturer's responsibility to calibrate or verify and maintain the control, measuring or test equipment in good operating condition, whether or not it belongs to him, with a view to demonstrating conformity of the product with its technical specification.
The extent and frequency of factory production control verification by the manufacturer shall be conducted in accordance with the extent and frequency stated in the standard for the specific anti-seismic device. In addition, the manufacturer shall check by means of the relevant inspection certificates that the incoming raw materials and components comply with the relevant specifications.
The manufacturer has also the responsibility to carry out Type Tests on the raw materials to evaluate the characteristics of the anti-seismic device concerning the durability aspects against ageing, temperature, corrosion.

2.2. Tasks for notified bodies

Certification of a product is a mean of providing assurance that it complies with specified requirements stated in the relevant standards. According to the product certification scheme of EN 15129, the tasks of the Notified Bodies include performing of tests to evaluate the performances of the anti-seismic device and the assessment, approval and continuous surveillance of the manufacturer's factory production control (Table 2.2).

Initial Type Tests shall be performed at the beginning of the production of a new device or at the beginning of a new method of production (where this may affect the stated properties). However tests previously performed in accordance with the provisions of EN 15129 may be taken into account.
The tests can be carried out on full-scale devices or on reduced scale specimens (but with a geometrical scale ratio not less than 0.5) if the device capacity exceeds the range of performance of the testing equipment. In cases where the assessed characteristic of the anti-seismic device can be directly related to material properties, like e.g. for hysteretic non-linear devices or elastomeric isolators, the Standard allows to substitute the tests on the final product by tests performed on the constituent materials.

Table 2.2: Responsibilities of the product Certification Body

Tasks	**Assessment**
Initial type testing	1) Load bearing capacity or Axial load transmission capability; 2) Shear modulus or Horizontal stiffness; 3) Rotation capability or Re-centring capability; 4) Friction coefficient or Energy dissipation capability; 5) Horizontal distortion capability or Lateral flexibility.
Initial inspection of factory and of FPC	Conformity of FPC procedures to EN 15129
Continuous surveillance, assessment and approval of FPC	Effective implementation and continuous operation of FPC, at least twice per year.

Initial Type Testing includes also the review of the calculation notes drafted by the manufacturer in accordance with the pertinent design requirement clauses for the evaluation of the final performance of the anti-seismic device.
For combined devices, the extent of Initial Type Testing shall be such that the control for each type of component within the combined device is equivalent to that specified for the component in the relevant clause of EN 15129.
The characteristics to be assessed and the relevant test methods are described in Table 2. 3.
The execution of tests on real scale anti-seismic devices, reproducing their operational conditions during seismic actions, requires that the test laboratory shall have available equipment capable to apply high loads at huge velocities and frequencies, and to reproduce the actual environmental conditions (temperature, humidity, etc.) when these may have impact on the test results. A survey of the testing requirements for typical sizes of anti-seismic devices is illustrated in Table 2.4.

Table 2.3: Initial Type Tests under the responsibility of the Notified Body: characteristics and methods of assessment

Characteristic	**Method of assessment**					
	Rigid Connection Devices	**Displacement Dependent Devices**		**Velocity Dependent Devices**	**Elastomeric Isolators**	**Sliding Isolators**
		Non Linear Devices	**Linear Devices**			
Load bearing capacity or Axial load transmission capability	Service load test Break-away test Pressure test	N/A	N/A	Pressure test Design calculation	Compression test Shear test Creep test Design calculation	Creep test Design calculation
Shear modulus or Horizontal stiffness	N/A	Ramp test Cyclic test: Effect of : - amplitude - cycling frequency - temperature	Cyclic test Ramp test Effect of: - amplitude - frequency - temperature - repeated cycles Low temperature crystallization	Constitutive law test	Effect of: - repeated cycles - frequency - amplitude - temperature - ageing Low temperature crystallization	N/A
Rotation capability/ in radians or Re-centring capability	Design	Design calculation	Design calculation	Design	Design calculation	Design calculation
Friction coefficient or Energy dissipation capability	N/A	Cyclic test	Cyclic test	Damping efficiency test	Cyclic test: - frequency - amplitude - temperature	Sliding service behaviour Sliding isolation behaviour
Horizontal distortion capability or Lateral flexibility	Fatigue test Design calculation	Ramp test	Ramp test	Stroke verification test Low velocity test	Shear test Shear bond test	Shear test Design calculation

Table 2.4: Testing demands according to EN 15129 for typical sizes of anti-seismic devices

Characteristic to be evaluated	**Testing demand**		
	Equipment	**Capacity**	
Load bearing capacity or Axial load transmission capability	Compression bench	Compression load	400 – 5000 kN
Resistance to seismic loads/shock absorptions or Survivability against repeated load cycling	Tension-compression bench Climatic chamber	Axial load (tension/compression)	400 – 5000 kN
		Velocity	200 – 500 mm/s
		Temperature range	-25° – 50°C
Shear modulus or Horizontal stiffness	Biaxial systems Climatic chamber	Compression load	3000 kN
		Lateral Load	400 – 2500 kN
		Frequency	0.1 – 2 Hz
		Temperature range	-20° – 40°C
Friction coefficient or Energy dissipation capability	Biaxial system Climatic chamber	Compression Load	20000 kN
		Lateral Load	± 40 kN
		Velocity	500 mm/s
		Temperature range	-50° – 35°C
Horizontal distortion capability or Lateral flexibility	Tension-compression bench Biaxial system	Lateral load	10 – 500 kN
		Lateral displacement	10 – 200 mm

3. EXPERIENCE OF POLITECNICO DI MILANO

The Materials Testing Laboratory, established in 1927 as the testing laboratory of the Technical University (Politecnico) of Milan, has been notified as Body for Certification, Inspection and Testing of anti-seismic devices in accordance with EN 15129 in August 2011. However, even before the Standard became legally binding, the Material Testing Laboratory performed test activities according to the methods defined in EN 15129, which allowed to the Laboratory to gain experience and set out its procedures and facilities in accordance with the standard requirements.
In order to cover the testing demands for all size and categories of anti-seismic devices covered in the Standard, Politecnico di Milano contracted an agreement with the European Centre for Earthquake Engineering (EUCENTRE) in Pavia, Italy, which allows Politecnico to have access to the most outstanding equipments in Europe for testing of anti-seismic devices, like the Bearing Tester System and the Damper Tester. The Bearing Tester System (Figure 3.1, left) is a unique facility in Europe and allows to perform tests on real scale isolators replicating the actual load and displacement parameters characterizing the operation of the devices. It consists of a prestressed RC frame equipped with a series of servohydraulic jacks providing five degrees of freedom to the testing device: vertical load, horizontal load and rotation about three axes (roll, pitch and jaw). Both horizontal and vertical load jacks can be used to apply static and dynamic loads, with a peak velocity of 2200 mm/s in the horizontal direction and 250 mm/s in the vertical direction. The Damper Tester consists of a modular frame with servohydraulic jacks that accommodates dampers as long as 8 meters and is able to produce velocities as high as 600 mm/s.
The Materials Testing Laboratory has also designed and assembled a custom equipment, called the Sliding Materials Tester (Figure 3.1, right), to perform Long Term Friction test prescribed by EN 15129 on the sliding materials used in the surfaces of sliding isolators. The Sliding Material Tester is rated 300 kN in compression and is capable to perform tests at velocities up to 260 mm/s; it is also equipped with a thermal chamber to control the temperature of the specimen and measure the coefficient of friction in the range between -50°C and 50°C.
The main experimental facilities available at the Materials Testing Laboratory of Politecnico di Milano for testing in accordance with EN 15129 are illustrated in Table 3.1.

Table 3.1: Testing facilities available at Politecnico di Milano

Testing equipment	**Range parameters**	**Type tests**
Sliding Materials Tester	- max. vertical load : 300 kN - max. horizontal load ± 40 kN - max. velocity 260 mm/s - temperature range -70° – +90°C	Long term friction tests on sliding materials for sliding isolators
Compression bench	- max. vertical load : 5000 kN - max. stroke 150 mm	Static compression tests on elastomeric isolators
Tension/compression bench	- max. vertical load : ± 2500 kN - max. stroke ± 75 mm	Static and dynamic tests in tension/compressions on Shock Transmission Units and Fluid Viscous Dampers
Bearing Tester System	- max. vertical load : 50000 kN - max. horizontal load : 2100 + 1700 kN - max. velocity : ± 2200 mm/s - max. stroke : ± 500 mm	Static and dynamic biaxial tests (vertical and lateral loading) on elastomeric isolators and sliding isolators
Damper Tester	- max. vertical load : ± 5000 kN - max. stroke : ± 260 mm - max. velocity : 500 mm/s	Dynamic tests on Dampers

Figure 3.1: Bearing Tester System (left) and Sliding Material Tester (right).

All activities performed by Politecnico di Milano as Notified Body for the attestation of conformity to the European Standard EN 15129 are regulated by procedures approved by the Italian Notifying Authority, the Public Works Council of the Italian Ministry of Infrastructures.

In about one year of activity as Notified Body, the Materials Testing Laboratory has performed, or it is carrying out, the certification of some among the main European and non-European manufacturers of anti-seismic devices. More specifically, the Laboratory has been requested for conducting various tests on a number of devices as well as on their constitutive materials, either as Initial Type Tests or Factory Production Control tests.

The most frequent test on materials regards the characterization of rubber compounds used in elastomeric isolators. At present time about a dozen compounds with different stiffness and damping characteristics have been tested by Politecnico di Milano for various manufacturers. The Laboratory has also conducted several characterization campaigns on polymers for sliding isolators such as the friction pendulum.

Another typical situation that occurred several times was sub-contracting of Factory Production Control tests to the Material Testing Laboratory by manufacturers which have not availability of the large experimental equipment required for the tests, in particular tests on elastomeric and sliding isolators. on Fluid Viscous Dampers and on Shock Transmission Units. The tests are performed by the Engineers of the Laboratory according to the same procedures followed for Initial Type tests.

The second task performed by the Materials Testing Laboratory in the certification scheme of EN 15129 is the assessment, initial approval and surveillance of the Factory Production Control system. Assessment of Factory Production Control requires expertise and knowledge of both product technical specification and quality management system organizations. To have available the necessary skills and competencies on quality management systems, the Materials Testing Laboratory has stipulated an agreement with the Quality Advisor Service (SQuA) of Politecnico di Milano. The inspection of Factory Production Control is conducted by a team of Auditors that includes at least one technical inspector from the Materials Testing Laboratory and a Quality System advisor. Once the Factory Production Control system is approved by Politecnico, it is subjected to continuous surveillance on the basis of generally two inspections per year.

4. OPEN ISSUES

The European standard EN 15129 is a recent norm, and its application can disclose hints for improvement. In particular, the application of the experimental has revealed several issues that need to be taken into account in a future revision. For example, the requirements of the low temperature crystallisation test on the elastomeric compound used for seismic isolators are too restrictive and bring severe limitations to the use of rubber compounds which had been employed long before the drafting of the standard and whose effectiveness has been proved in many applications.
Additionally, very recent seismic protection strategies entail the use of anti-seismic devices that are not covered by the Standard, like the Tuned Mass Damper, laminated elastomeric isolators with reinforcing plates made of composite materials, or isolators with roller bearings. In this case the certification of the anti-seismic device requires the drafting of an European Technical Approval, which shall be used as the basis to prove the fitness for uses of the device.

5. CONCLUSIONS

The European Standard EN 15129 establishes provisions regarding design, manufacturing, controls, installation and maintenance of anti-seismic devices. Tasks are assigned to both manufacturers and Notified Bodies involved in the attestation of conformity.
The key task assigned by the standard to the manufacturers is the establishment and maintenance of a permanent factory production control to ensure that the manufactured products maintain the compliance with the stated performance characteristics.
The Certification of conformity to EN 15129 is performed by a Certification Body which shall have available both experimental installations and facilities to perform the type testing on full scale devices reproducing typical seismic actions, and expertise and skills in assessing and appraising the factory production control organization.

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