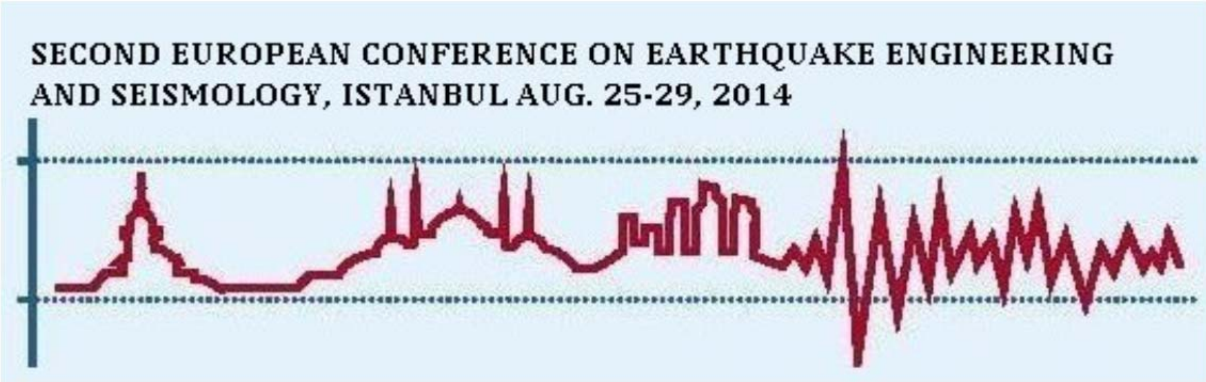

APPLICATION AND REVISION OF THE EUROPEAN NORM EN 15129 ON ANTI-SEISMIC DEVICES

Renzo MEDEOT [1]

ABSTRACT

The European Norm on Anti-seismic devices is the result of a long process that lasted 18 years. In fact, the European Committee for Standardization (CEN) officially established the Technical Committee CEN-TC 340: *Anti-seismic Devices* in 1993 and the Norm EN 15129 came officially into force in the European Union on August 1st, 2011.

The scope of this Technical Committee was to proceed with the standardization of the seismic hardware for use in structures erected in seismic areas and designed in accordance with EUROCODE 8: *Design of Structures for Earthquake Resistance*, with the aim of modifying their response to seismic action.

This Norm summarizes the experience gained in Europe over the past 40 years in the field of seismic hardware, which is dealt with through the application of very advanced criteria. This favours progress inasmuch as it promotes loyal competition through clear and fair rules that protect the interests of the community.

The European Standard on Anti-seismic Devices represents the most complete and up-to-date document in this field presently available to Seismic Design Engineers and Seismic Hardware Manufacturers. In effect, said Standard aims to cover all types of Seismic Hardware in existence and leave a door open to future progress.

It is important to observe that, after only four months from EN 15129 enforcement, the TC 340 deliberated the creation of Working Group WG 5 for its revision. This is a clear indicator of the rapid development of the seismic engineering sector in progress.

The scope of this paper is that of summarizing the aspects which render EN 15129 unique and innovative, as well as illustrating the guidelines on which WG5's Work Programme is founded, which regard the trend in the seismic design sector.

INTRODUCTION

An increasing number of Congresses and Symposia - as well as other professional meetings - give testimony to the significant strides made by earthquake engineering during the last quarter century. Progress has been the result of a better understanding of the seismic behaviour of structures as well as improved knowledge of the characteristics of seismic actions.

In relation to these two aspects, newly developed design strategies have been devised and implemented entailing the use of special mechanical devices to be included in the structural system in order to substantially change its overall behaviour (e.g. seismic isolators) and/or dissipate most of any input energy (e.g. energy dissipating braces) or provide a different behaviour under service and seismic actions (e.g. Shock Transmission Units),.

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Thousands of applications have been implemented all over the world to many types of structures of varying size. However, such a large number could still be inadequate, when one considers the fact that structural safety can be easily improved by one order of magnitude using passive control systems.

Newly conceived design strategies could not have found useful application without a parallel development of the hardware needed to implement them. Thus, many research laboratories and certain pioneering, specialized industrial concerns decided to invest important resources in this field, inventing or improving a series of devices that exploit well known physical phenomena to seismically protect the structures.

As it is often the case, when technological growth in a given field reaches important levels of development - as well as a reasonable degree of maturity - a need spontaneously arises to establish ground rules to define principles of general validity. These rules ultimately become a part of increasingly important documents like *recommendations, guidelines and standards*.

Within the spirit of the above, in March, 1992, the Italian Standardization Institute (UNI) forwarded to the European Committee on Standardization (CEN) a formal request calling for the creation of a Technical Committee charged with drafting a norm to cover anti-seismic hardware.

Within the framework of existing procedures, CEN launched an inquiry amongst the member nations with a July, 1992 deadline. Fourteen of them responded to the inquiry with 11 votes in favour and 3 against. In September 1992. the Bureau Technique Secteur 1 (BTS1) as the competent body in construction within CEN, responded favourably to the UNI request upon examination of the inquiry results.

After having paid due bureaucratic tribute, the first meeting of the officially nominated Technical Committee finally convened in Vienna in October, 1993. This occasion saw the creation of a work program with fixed target dates, the election of a Chairman (this author) and the installation of four Working Groups, each with an appointed "Convener".

Eleven years have transpired before a preliminary document (prEN 15129) was completed in June, 2004 and, after having been translated into the three official EU languages - French, German and English - was submitted to Public Inquiry (January – June 2005).

Public Inquiry represents an important stage in the drafting process of a European Standard and entails the right of any one person to submit observations, comments and suggestions in writing for a 6-month period subsequent to the prEN's official publication.

All such information must be examined by the Technical Committee (actually, it is the Working Groups tasked with the relevant sections who do it) and there are two possible outcomes:

a) observations may be accepted as valid and thus lead to prEN modifications, or

b) comments may be rejected, in which case the reason for rejection is forwarded in writing to the proponent, on a case by case basis.

When the results of a Public Inquiry demonstrate insufficient agreement on the prEN (i.e., an excessive number of comments, their relative importance, etc.) a second Public Inquiry on the revised prEN, normally lasting 2-months but up to a maximum of 4 months, may be decided by the Technical Committee. Further inquiries are not allowed.

A second Public Inquiry also becomes necessary when a Technical Committee decides to introduce relevant modifications such as adding new sections. This is precisely the case with that occurred with this Norm - because the TC 340 deliberated to include new types of isolators at year's end in 2005 (specifically, the Lead Rubber Bearing and the Sliding Pendulum®) which were subject to a patent pending situation in the past.

However, it should be emphasized that the lack of inclusion of a type of device within a Norm's stipulations does not necessarily imply its being excluded from the European market – it only means that a need arises for a European Technical Approval (ETA).

Approval of the final version of a Norm is carried out through a formal vote by CEN member nations. Each of them is entitled to a number of votes which is proportional to its population (i.e., a weighed voting procedure). All votes are unconditional but editorial comments may nonetheless be made. All negative votes must be accompanied by a justification.

If the outcome of the voting is positive, the CEN Technical Board notes the approval of the EN and establishes a target availability date. If the outcome is negative, the Technical Board decides what further action is to be taken.

The EN 15129 was approved by Formal Vote in November 2009 and entered into the one-year "coexistence" period with national Norms (if any) on August 1^{st}, 2010. Thus, the Norm has become effective and mandatory in all the CEN Member States on August 1^{st}, 2011.

All the same, these stringent rules, which are often defined as "technological democracy", afford fair treatment and equal opportunity to all, but also exact their "pound-of-flesh", comprised of long and convoluted time frames.

Considering the current rapid development of the seismic engineering sector, after only a few months of being an enforced Norm, the Technical Committee TC 340 deliberated to proceed with its revision in October of 2011.

At the time this author prepared the Abstract of this presentation (December 2013) the revision work appeared to be on the verge of beginning. Nonetheless, nothing occurred so far, although certainly not through any fault of the Experts commissioned to carry out revision work.

THE STRUCTURE OF THE STANDARD

The structure of the European Standard on Anti-seismic Devices has been modified several times. Its definitive version includes the following:

1. Scope
2. Terms, definitions, symbols and abbreviations
3. General Design Rules
4. Rigid Connection Devices
5. Displacement Dependent Devices
6. Velocity Dependent Devices
7. Isolators
8. Installation
9. In-service Inspection

Informative Annexes accompany the various Sections of the Standard, in order to give useful comments and explanations to the reader.

Much attention has been focused on the definition of the various types of devices.

GENERAL DESIGN RULES

General design rules are consistent and strictly related to those stated in the EN 1998, Part 1: *Buildings* and Part 2: *Bridges*, particularly for devices used in seismic isolated structures, which are dealt with in specific sections.

According to the two limit states referred to in EC8, EN 15129 considers as fundamental the following types of requirements:

- *No failure requirement*
- *Damage limitation requirement*

Both are referred to the relevant seismic intensities defined in EN 1998-Part 1 for the:

- *Ultimate Limit State* and for the
- *Damage Limitation State* respectively.

The first one requires that devices retain their functional integrity and residual mechanical resistance, including, when applicable, residual load bearing capacity after the seismic event.

The second requires that devices withstand the corresponding seismic action without the occurrence of damage and associated limitations of use, whose costs would be disproportionately high in comparison to the cost of the structure itself.

Reliability differentiation is required for different types of buildings or civil engineering works and is implemented by classifying structures into different importance categories. To each category, an importance factor γ_I is assigned and applied to the seismic action.

The values of the factor γ_I are recommended in the corresponding parts of EN 1998.

Increased reliability is required of the devices, in terms of the crucial role they play within the structural system.

This requirement is already stipulated in EN 1998-Part 1 and EN 1998-Part 2 for seismic isolation devices. However, in EN15129, it is extended to devices used in applications other than seismic isolation.

In order to comply with this requirement, according to EN 1998-1 (edifices) a magnification coefficient γ_x=1,2 shall be applied to the design seismic action effects on the devices and their connections to the structure.

The mechanical and physical properties of devices, of their components and of their connections to the structure shall be assessed by laboratory tests through appropriate procedures.

Amongst functional requirements, specific emphasis is placed upon the need that devices and their connections to structures shall be designed, constructed and installed in such a way that their routine inspection and replacement are possible during the service lifetime of the construction.

Moreover, replacement of a device after it has sustained damage shall be possible without resorting to major interventions.

Devices used for replacement shall comply with the Norm EN 15129 and with additional requirements originally defined by the owner, unless otherwise requested by him at the time of the replacement.

In order to account for the inevitable variability in device characteristics due to the dependence of the mechanical behaviour of their materials on several factors, such as temperature and other environmental conditions (age, strain rate, etc.,) the upper and lower limits of the mechanical parameters of the core materials and of the devices shall be checked through experimental tests.

It is of interest to also remind the innovative criterion developed by this author and adopted in the Norm to evaluate the re-centring capability of an isolation system, which is based on energy concepts.

In the case of an equivalent linear analysis, to ensure adequate re-centring capability of a seismically isolated structure, it shall be verified that, for a deformation from 0 to the design displacement d_{Ed} :

$$E_S \geq \frac{1}{4} \cdot E_H \qquad (1)$$

where: E_S is the elastically (reversibly) stored energy and E_H is the hysteretically (irreversible) dissipated energy.

Finally, in the Clause “General Design Rules” of EN 15129 specific concern is given to Validation of Anti-seismic Devices.

Any type of device shall be subjected to a technical validation procedure, which shall contain elements proving that the device conforms to its functional requirements.

Type tests are required for the validation of new systems, or of existing systems when materials are changed, as well as of existing systems in ranges of use outside those previously validated.

The mechanical properties of the devices needed in the design for the anticipated service lifetime of the system, together with their ranges of variation, shall be determined by the type tests.

Full-scale devices are required for these tests, unless otherwise specified in the relevant clauses of this standard.

A given percentage of the devices to be installed in a structure shall be subjected to acceptance tests, before putting them into place, to confirm that their properties conform to the design values.

THE ANTI-SEISMIC DEVICES

Before defining the structure of the Standard, and similar to what happened in other scientific fields (e.g., Biology) there was an attempt to create a "systematics" of present seismic hardware, that is to say, to group existing devices on the basis of the functions they perform or the common principles governing their functioning.

Thus, the starting point was the creation of divisions of a general character and then moving toward increasingly detailed subdivisions.

After several reconsiderations and changes of mind, the existing seismic hardware has been subdivided into the following four groups according to the functions they perform:

- Rigid Connection Devices

- Displacement Dependent Devices
- Velocity Dependent Devices
- Isolators

It is worth summarizing the essential features of these fundamental groups of devices.

Rigid Connection Devices:

These are devices that temporarily or permanently link two structural elements without transmitting bending moments and vertical loads.

They include Fuse (or Sacrificial) Restraints and Shock Transmitters.

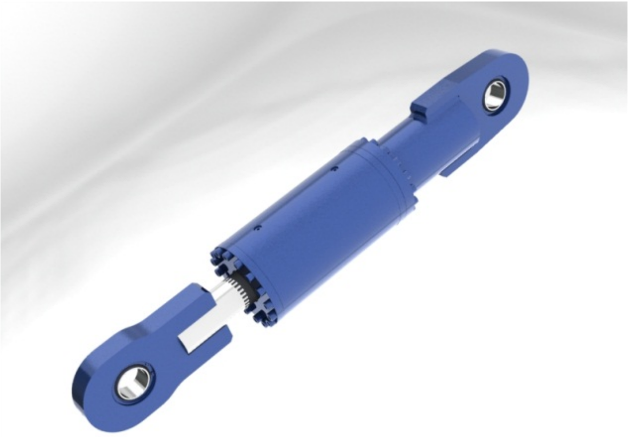

Figure 1**:** Shock Transmission Unit (STU), an example of Rigid Connection Device.

Displacement Dependent Devices

Displacement Dependent Devices are devices that do not carry vertical loads, whose behaviour is mainly displacement-dependent rather than velocity-dependent.

Velocity Dependent Devices

Are devices which do not carry vertical loads and whose behaviour is mainly velocity-dependent rather than displacement dependent.

Figure 2: Hydraulic Viscous Dampers, an example of velocity Dependent Devices

Seismic Isolators:

These are devices that decouple the prevailing mass of the structure by accommodating the large horizontal displacements produced by seismic actions whilst still safely supporting the gravity load of the structure (see Figure 3).

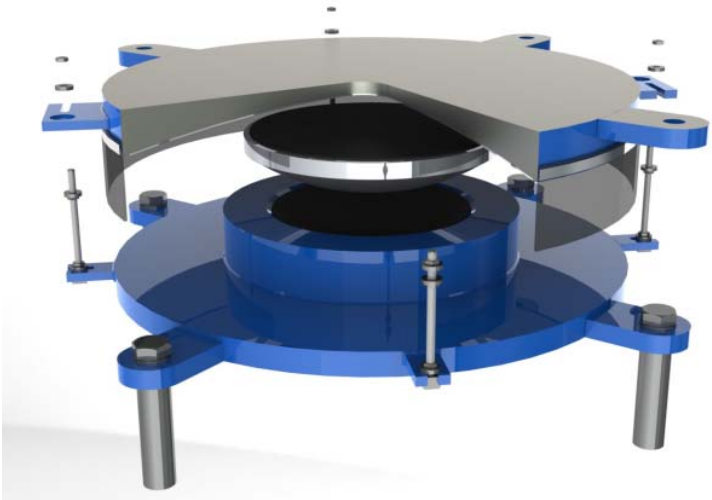

Figure 3: Exploded view of Sliding Isolation Pendulum, an example of Seismic Isolator

The seismic devices in this group afford excellent control of relative displacements, i.e. the response of the structure during a seismic attack.

Therefore they constitute by far the most numerous category to date present on the market and still attract important resources from the manufacturers in R&D programmes.

Each of the above groups has been further subdivided. To the family of Rigid Connection Devices belong three distinct groups of devices, as shown in Figure 4 below.

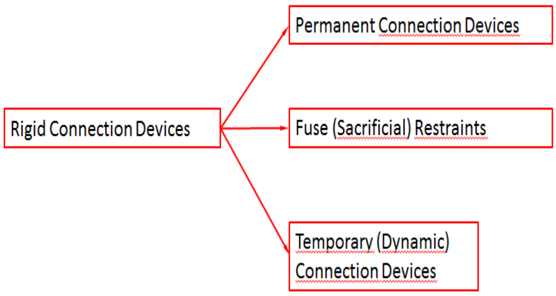

Figure 4: Subdivision of Rigid Connection Devices

Permanent Connection Devices do not modify the natural period of the structure nor dissipate energy.

They can consist of Restraint Structural Bearings governed by EN 1337-Part 8.

Fuse Restraints provide a rigid connection between two structural elements in service conditions only, while they break away at the occurrence of an earthquake, thus permitting the movements between the adjacent structural elements, thus allowing the “seismic isolation”.

Conversely, Temporary Connection Devices (Shock Transmitters) perform the opposite function.

Displacement Dependent Devices have been subdivided as shown in Figure 5 below.

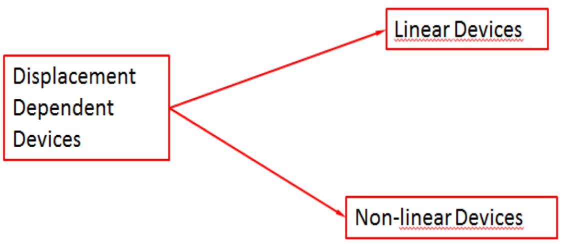

Figure 5: Subdivision of Displacement Dependent Devices

The Seismic Isolators have been subdivided as shown in Figure 6 below.

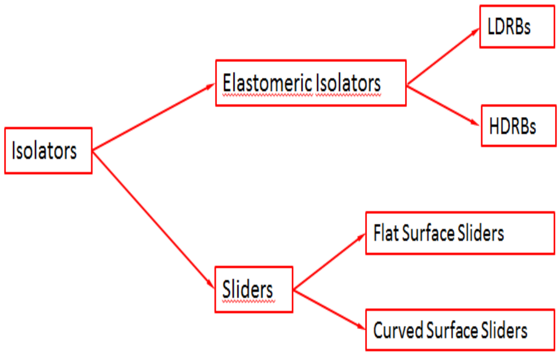

Figure 6: Subdivision of Seismic Isolators

Due to their extension, the sections dedicated to all the types of devices need a dedicated lecture.

It is important to keep in mind the fact that the Norm takes into consideration all the types of devices presently in existence on the European market – even those developed outside Europe, e.g. Lead Rubber Bearings and Friction Pendula®.

However, it should be emphasized that in Europe the lack of inclusion of a type of device within a Norm's stipulations does not necessarily imply its being excluded from the European market.

It only means that a need arises for a European Technical Approval (ETA).

THE REVISION PROCESS

As we have seen, drafting a Norm, especially in Europe, requires considerable effort, and is in many ways quite tedious because of the obligation to follow meticulous requirements specified in the so-called PNE Rules, which set out CEN/CENELEC Internal Regulations for the structure, drafting and presentation of European Standards (EN).

They even establish which verbal forms are admissible or not for each type of sentence (normative or informative), for the Notes, the Examples, etc.

The work of revising a Norm is even more demanding, because you must work on a pre-existing text, adapting it to the new demands, the idea of re-writing the Norm "ex-novo" being inconceivable.

OBJECTIVES OF THE REVISION

The objectives of the WG5 in charge of the EN 15129 revision are (in ascending order of importance) to:

1. edit the text
2. correct technical mistakes
3. align technical and textual styles among the clauses
4. remove reported interpretation difficulties
5. conform with Eurocode EN 1998*: Design of structures for earthquake resistance*
6. address environmental issues, as requested by the CEN Guide 4
7. update the content to the present state-of-the-art

The motive for item 3. stems from the fact that the twelve (12) Clauses (Chapters) and the eleven (11) important Annexes of EN 1529 have been drafted independently by four (4) individual Working Groups and therefore the structure and the style of the Clauses differ substantially, creating problems for the users of the Norm.

Unfortunately the aforementioned PNE Rules, despite being very detailed, do not address the order in which the different subjects are to be presented, much less the terminology to be used, because every sector of science and technology has its own, not always unambiguous, glossary.

As a logical consequence of the above the activities to be performed by WG5 are the following:

a. corrections of textual and technical errors

b. updating references to Eurocodes and other European or international Standards

c. check of consistency with Eurocode 1998

d. set up of a common layout (structure) among the Clauses, particularly those devoted to seismic hardware

e. removal of the difficulties in interpretation of the requirements, particularly those of the CE marking

f. improvement of the present technical content and addition of environmental aspects

g. inclusion of newly developed technologies, design approaches, testing procedures etc., so that the revised Norm will be representative of the actual state-of-the-art at the date of the Public Enquiry (now referred to as "CEN Enquiry").

The last three activities will be based on the comments received from the experts or from the WG5 members.

ORGANISATION AND APPROACH TO WORK

Considering the difficulties that have delayed the start of revision work, and the necessity of obtaining an updated Norm within a short timeframe due to its importance to this sector of engineering, the first idea that springs to mind is that of operating in parallel with ad-hoc groups of experts.

This decision would however be in distinct contrast with the objective 3.- *align technical and textual styles among the Clauses,* and therefore has not been taken into consideration, as the homogeneity of style throughout the Norm represents an essential prerequisite.

Appreciating the experience accrued from the parallel TC 167 WG1, which is completing the revision of the Norm 1337: *Structural Bearings*; the decision was taken to adopt from their operational procedures those that appear most advantageous, while avoiding those decisions that led to negative outcomes.

In order to expedite the achievement of the abovementioned objectives, and at the same time to assure a high quality of work, the Experts of WG5 will be organized in three teams that operate in distinct modes, namely:

- The base team, which carries out the fundamental activities listed in the preceding chapter, deliberates on the actions to be taken, fixes the dates and venues of the meetings and produces the technical documentation.
  This team will be comprised of a limited number of experts, who participate in all the meetings, have considerable experience in the seismic engineering sector, have a historical background with TC 340 activities and are familiar with European standardisation procedures.
- The team of specialists in specific subjects, that will be at times invited to participate in the WG5 meetings to bring their decisive contribution to the introduction of newly developed technologies, materials, design approaches, testing procedures etc.
- The team of corresponding members (who will not be requested to attend WG5 meetings) to whom the base team assigns general or specific tasks.

The WG 5 Convener will annually illustrate to the TC340 the progress of revision work and requests deliberation on the items of specifically assigned to the Technical Committee (e.g. approval of Business Plan updating, approval of Final revised Norm ready for CEN Enquiry etc.).

APPLICATION OF EN 15129

The application of a Norm can be carried out at various levels, as we will see below.

At this point it is appropriate to mention that in the European Union (EU), the matter of construction products is regulated by the Council Directives 93/68/EEC and 93/68/EEC.

For the purposes of said Directives, "construction product" means any product which is manufactured for incorporation in a permanent manner in construction works, including both buildings and civil engineering works.

All construction products shall bear the CE marking, which signifies their compliance with a relevant:

- European product standard or, where there isn't one, with
- National standard (provided it has been published in the Official journal of the European Communities), or
- European Technical Approval (ETA)

The EN 15129 is, effectively, a "product standard" that covers the design, manufacturing, testing and validation of the seismic hardware, i.e. the whole of the mechanical devices used in seismic engineering.

As already stated, this norm became effective in all member states of the European Union on August 1st, 2011, and therefore from that date all anti-seismic devices installed must bear the CE marking, which certifies their conformity with EN 15129.

Nonetheless this Norm was also adopted in countries outside the EU, even if only the requirements related to design, manufacturing and testing, that is, without necessarily affixing the CE marking.

Its adoption in individual projects is spreading in the Ex-Soviet countries, Mediterranean countries (including Turkey), as well as in Central and South America, with important demanding applications.

Amongst these we highlight the Bilkent School in Erzurum, Russkij Bridge in Vladivostock (largest cable-stayed bridge in the world) opened in the autumn of 2013 and the monumental Grand Mosque in Algiers (the largest in the world), still under construction.

In the latter case the Designer specified that all devices (Sliding Pendula and Hydraulic Dampers) must bear the CE marking.

İhsan Doğramacı Vakfı Özel Bilkent Erzurum Laboratuvar Lisesi - Kasım 2009

Figure 7: Bilkent School in Erzurum - Turkey

Figure 8: Cable-stayed Russkij Bridge – Vladivostok - Russia

Figure 9: The Grand Mosque in Algiers - Algeria

CONCLUSIONS

- Modern seismic design strategies, such as Seismic Isolation and Energy Dissipation, have been devised and implemented entailing the use of special mechanical devices to be included in the structures to substantially change their overall behaviour under a seismic attack.
- Newly conceived design strategies could not have found useful application without a parallel development of the seismic hardware needed to implement them and, on its turn, the latter called for the drafting of Norms to validate their suitability for the intended use.
- The *European Standard on Anti-seismic Devices* represents one answer to the above necessity and is considered the most complete document presently available to Seismic design Engineers and Seismic Hardware Manufacturers.
- In effect, the Standard aims to cover *all* types of Seismic Hardware in existence and leave a door open to future progress. This principally derives from the fact that the Standard is highly performance-oriented and this feature also constitutes *per se* a guarantee of equity.
- The wealth represented by alternative systems specified in the Norm, which are presently available on the market, ensures a freedom of choice to the design engineer insofar as the design strategy deemed most appropriate for his specific case.
- CEN has established very stringent rules regarding the structure and contents of a Standard as well how it is presented. However, this set of rules is far from being a handicap, in that it actually constitutes a useful tool to those who endeavour to draft a Standard.
- An inducement to revise the EN 15129 derived from several factors like the surging seismic engineering market, the expiration of international industrial patents on important types of devices, the development of new technologies and the need for new high-performance, durable and reliable materials
- Gaining profit from the experience accrued from the revision of the parallel Norm 1337: *Structural Bearings,* which is presently in progress, there is a reasonable expectation to complete the revision works of EN 15129: *Anti-seismic Devices* in about two years.

Acknowledgment

In his capacity as Chairman of CEN – TC 340, this author wishes to express his appreciation to all the expert members for the work performed.

In particular, the author his grateful to the Conveners of the TC 340 Working Groups, namely:

- Prof. Mauro Dolce,
- Prof. Philippe Bisch,
- Dr. Keith Fuller and
- Dr. Samuele Infanti.

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