ANTI-SEISMIC SYSTEMS: HISTORY, DEVELOPMENT AND SCIENTIFIC BASIS

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REZUMAT. În lucrare este prezentată evoluția sistemelor antiseismice către tehnologiile de construcție ce au generat invențiile din ultimul sfert de secol, cu baza științifică recentă aferentă, în scopul înțelegerii atât a situației actuale, cât şi a trăsăturilor fundamentale ale unei noi arhitecturi antiseismice. Aceasta îi va determina pe proiectanți şi pe ceilalți specialişti să-şi desăvârşească rolul profesional în domeniul ingineriei structurale, pătrunzând pe „teritoriul seismic".

Cuvinte cheie: tehnologie de construcție, sistem antiseismic, inginerie structurală.

ABSTRACT. The history of anti-seismic systems, their evolution in <Building Technology> and the subsequent and recent <Scientific Basis>, which gave body to inventions over the past quarter Century, are considered preliminary and fundamental to the better understanding of both the <State of the Art, research and application> both the best features of the framework of <New horizons for one Anti-seismic Architecture>, which might be driving for designers and computers which - by completing their specific professional role of structural engineers - are called to work in areas and the broadest <seismic territory>.

Keywords: building technology, anti-seismic system, structural engineering.

1. INTRODUCTION

Authorities, dear Collegues, Mister President of AGIR (General Association of the Engineers in Romania), we would like to begin our speech with an apology. In this auditorium, where science is sovreign, we must apologize if we will appear less scientific as well as less technical, maybe even a bit superficial.

In fact we will not talk about organic and systematic classified knowledge, such as those which belong to Constructions' Applied Mechanics or to Materials' Science. We will not be able to talk about applied rules that can be contained and described by Contructions's Technic. We will talk about activities of Engineering, Architecture and Research, following rules which are predetermined and deriving from knowledge and experience. Therefore we will talk about activities, which sometimes still use intuition more than reasoning.

A great master of Theoretical and Applied Mechanics, Professor Lighthill, who we met at a Seismic Engineering Symposium in Grenoble, France, opened up his speech with the following sentence: "I apologize in the name of the Mechanics; in the vision of the world, Mechanics has attributed to determinism a role which we know cannot be acknowldged to it". This argument leads as immediately to the central part, that means the heart, of our problem.

Even in determinism, which characterizes often our way of being, we must be convinced that it is necessary to live together with natural calamities, we can surely mitigate their consequences, but we can never reach "certitude" and therefore "safety". Earlier, at the beginning of the century (1920-1921), Laura, wife of the grand italian Physician Enrico Fermi, affirmed literally in the book "Atoms in the family": "Men must accept what nature reserves for them, whatever thing, unpleasant and painfull! Ignorance is never better than knowledge".

The major natural calamities that happen in the world are consuquences of seims and hurricanes (according to the information of the Disaster Bulletin of the United Nations referred to the years 1995-2005). Seims are indeed much less frequent calamities than hurricanes, and above all than floodings. Nevertheless we know that every year seims cause more than twenty thousand (20.000) victims and more than two millions (2.000.000) of homeless people in the world (based on recent years' information).

Therefore we must recognize that:

– Engineering, Architecture and Research can mitigate the risks of building in a seismic zone;

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– in every part the world there can always be a seism of greater intensity than the one which can be expected and assumed on the basis of the “project of construction”;

– even if the level of our knowledge would be complete, a construction in a seismic zone could never have the mathematical guarantee of surviving.

We will now enter the specific topic of the conversation.

2. EVOLUTION

2.1. Technological Mutation

We already talked about the studies and the patent by Calantarients; even in 1909 those pointed out some of the fundamental problems that characterize an isolation system. In summary this isolation systems requires:

• elements with greater liberty, therefore having a good expansibility and flexibility, that provide to make the movement of the structure indipendent (disarticulating it) from the sedimentation on which the bearer's foundation will be placed.;

• particular devices, expecially designed and constructed, that allow a direct connection of the elements (charge and discharge water conducts, gas conducts, electric cables, etc.) that belong to the technologic installations, directly on the near floor on which the construction is based. In fact it is widely known that in order to eliminate the big risks of structures of an anti-seismic isolated construction, it is necessary to proceed with the introduction of a protection system for the installations (conducts, cables, etc. – see attachment 1 to the Introduction of this Volume);

• mechanisms and/or equipments, as support, that constitute a particular attache for the structure in relation to the base floor of the surrounding soil. Those “supports” develop their valid action in case of modest entity pushes and therefore for the protection of modest entity seismic actions.

Immediately afterwards, in 1920-1925, Applied Mechanics academics (in England, France, Austria and Italy) executed a variation on the already patented system, consisting in the introduction - as isolation materials - of wooden (hard structures) and/or rock rolls, mixed with layers of sand.

In particular in Italy a special commission was nominated in 1910 from the Public Works Ministery, intitled of study and suggest techniques and technologies capable of reconstructing historical and logistic buildings of the City of Messina. This commission, coordinated by Francesco Ruffolo, an engineer, born and educated in Calabria but having completed his studies in the School of Bridges and Roads of the University of Naples, started its works in March 1910 and concluded with a presentation to the Ministery in 1912 of a *Relation-Dictionary* in which it also was proposed to adopt during the reconstruction of new buildings, the system, created by Calantarients, of isolating the base of constructions in interponing sand and rolls of rock-like material, proportioned accordingly and depending on the particular works of adjusting in the building site.

In 1912 Ruffolo published in the roman press (The Electrician, Rome-Naples, November 1911) a very precious volume entitled *Seismic Stability of Buildings*. In the conclusion of this volume Ruffolo made two proposals to the Public Works Ministery and to the Public Instruction Ministery:

– institution of the Chairs of Seismology and Anti-Seismic Constructions in every school for Engineers;

– construct a house with usual structure and materials, resistant to earthquakes, as well in a low level seismic danger zone as in a zone affected by very violent and catastrophic earthquakes.

We can see after one century (1911-2007), that the first proposal was indeed realised after the institution of the teaching of Seismology in the Chairs of Physics and Geology, and only in recent years (1990) of the teaching of Constructions in seismic zones in the Chairs of Engineering and Architecture; the second proposal is yet waiting a necessary and clear answer.

The suitability of sand as isolator between the foundation structure and the construction itself was confirmed, because it was a material which had already been applied in very ancient times, developed and used in the Hellenistic and Hellenistic-Roman age.

Starting in the years of Calanatarients' patent and during the Thirties and subsequent until 1945, there was an large development and enhancement of the primordial anti-seismic systems and the related applications were started. This also happened as a result of the indirect effect of the discoveries, inventions and applications of the industrial revolution from the XVIIIth to the XXth century, with application of hydraulic, termic, electric energy and with the design and construction of adequate motoric and operative machines, that simplified many processes of work, that required the use of quite large forces as well as the application of consequential efforts in relatively concentrated zones and areas.

In particular starting in the Thirties a defense system from the seismic events was developed, that can be connected to the ancient classical systems, that is to articulate the building in two parts: the one starting on the foundation and including the first floor, the other one comprehending the structures of the first floor to the ones of the last floor.

The structures of the construction therefore, divided from eachother by one floor that is ortogonal to the axe of the vertical structural elements; corresponding to this floor, a flexibility is created between the two parts. This “flexibility floor” has the function to isolate the above positioned floor from the one containing the foundation structures and, therefore, in case of a seismic event, the relative movements will be stopped in the zone of discontinuity, without being trasmitted from the lower part to the superior part. But it has been recognized, that in the zone of the “flexibility floor” there was a large rising of tensional statuses exactly in correspondence of the vertical structural elements (pillars and/or columns); risings that could be absorbed from the sections – even if well planned and calculated – of the same pillars.

For this reasons, the above described system, after having been used for several years and having caused bad inconviencies, became obsolete and was not adopted anymore.

Indeed it has to be recognised that - starting in the Seventies – the big and rapid growht of the defense model, connected to the seismic isolation of the basis structures, was mainly responsible for the development of new materials and of the relative applied technologies, and of course of the related times of production. The diffusion of these materials and their singular mechanic properties allowed the rapid development of more modern and complex systems. In particular the production and the development of natural and synthetic rubbers (neoprene) has mainly contributed to the realisation of the most recent base isolation systems.

The first application of seismic isolation, according to modern criterias, was in Macedonia, in Skopje, city that was affected by a significative and devastating earthquake in 1963. The chosen building was the school *Enrico Pestalozzi*, whose realisation was donated by the Swiss Government to this of Serbia after the abovementioned seismic events. The general project was led by Alfred Roth, architect, whereas the design of the anti-seismic structures was made by a team of technicians (C. Hubacher, E Staudacher and R. Siegenthal), all originary of Zurich. The construction was realised in the years 1967-1968.

The isolating anti-seismic design was realised applying sixteen bearings of natural rubber with a low absorbability (that means not additive) to the foundation structures, in the form of a an ashlar, with plant dimension of 700 mm x 700 mm and 350 mm of height. The vertical burden of the project was 550 kN and the additional movement of the build-up was ± 200 mm. The isolators were very simple: they were formed of seven layers of non armed rubber, each having a thickness of 50 mm, matching one to eachother and united to eachother with a cold adhesive. In 2006 these isolators were substituted by others, realised according to more modern methods (please see Contribution of Alessandro Martelli).

Also starting in the Seventies, exactly in 1974, the anti-seismic protection of bridges, viaducts and buildings is adopted as a standard in New Zealand using devices of seismic isolation or energy dissipation, or such having the same function (please see Introduction). In the below attached tab some of the early applications in this country have been enlisted.

Structure	Year of realisation	Type of device
Rangitikei Bridge	1974	Torsional elastoplastic dissipator
Bolten Street Bridge	1974	Estrusion lead dissipator
Aurora Terrace Bridge	1974	Estrusion lead dissipator
TocToc Bridge	1978	Rubber-lead isolator
King Edward Street Bridge	1979	Clipboard elastoplastic dissipator

Numerous other applications followed to these which used isolators in “rubber-lead” (*Lead Rubber Bearing* or LRB) or dissipators that use lead technology, or steel isteretical dissipators (please see again Introduction, with the respective attachments). Nearly at the same time as New Zealand, important applications of seismic isolation were adopted in the Sovietic Union, in France and (even if limited) in Mexico. Among these applications, which are being treated synthetically in Alessandro Martelli’s contribution, the french ones distinguish themselves, because even applied on nuclear plants.

In Italy the first application of seismic systems was executed by the firms ALGA S.p.A (Milan) and FIP Industriale (Selvazzano Dentro, Padova) at the beginning of the Seventies.

With respect to the first application of ALGA - realised in cooperation with the german firm MAN GHH on the structures of the Fiumarella Viaduct, on the river Noce in Calabria - we can observe that more than being a real application of seismic isolation, it consisted in the installation of a system of auxiliary bond made of hydraulic brackets, which would have caused an equal dipartition of the produced forces in case of an earthquake.

The first sistematic installations of anti-seismic devices, designed and realised in Italy, were made at the end of the Seventies (1976-1980) and were executed on the highway Udine - Carnia - Tarvisio, particularly on the Fella 1 and Somplago Viaducts. Whereas the second is the first Italian application of seismic isolation, even if rudimental, executed by FIP Industriale (please see Contribution of Alessandro Martelli), in the first one ALGA's technicians used the first elastoplastic dissipators. These dissipators used formable elements made of special steel shaped in form of "Ω" (Nicuage). Afterwards these isteretic dissipation elements experienced some evolutions, as well in the geometry as in the characteristics and typology of the used materials. Regarding the dissipators made by ALGA there has also been the realisation of shaped elements in form of "E" and "C"; elements which, at the end of the Eighthies, produced several patents (Patent ALGA - Professor V. Ciampi, 1989). Isteretic dissipators having other forms and devices of other typologies were then developed also by Italian firms in the sector of handicraft (please the different contributions in this Volume).

2.2. Anti-seismic Systems

As already mentioned in the Introduction and in the part of this contribution dedicated to the historical development of anti-seismic devices and systems, in order to protect buildings and structures from the seism, techniques of seismic isolation (not only on the basis) and of energy dissipation have been adopted and are currently used, nowadays in a consistent number of cases. At the moment the status of improvement of knowledges, of research and the simultaneous development of materials, of technologies and works allows us to obtain constructions, protected by such techniques, which are far more reliable compared with respect to the past, particularly reflecting the damage of the buildings and/or structures.

Regarding energy dissipation, in the Introduction we clarified that this technique consists in positioning in certain zones of the structure, usually on the diagonal (where the maximum differential movements result), particular devices named *damper*. Through these devices, even if less effective as isolators (see Introduction), a great part of the energy transforms in heat, whereas, in their absence, the transformation energy-heat would be realised by the material damaging of the structural elements and not, or even because of the real collapse of the structures or their parts. The dissipators produces by the national and international industry have different types (viscous, elastoplastic, viscoelastic, electroinductive, etc.): but this was already treated in the Introduction and examples are mentioned in Alessandro Martelli's contribution.

I refer as well to the Introduction and the contribution of Alesaandro Martelli for other anti-seismic systems developed and used beyond the isolators and dissipators, particularly:

- so-called *Shock Transmitter Unit* (STU), oleodynamic devices, that leave the structure free of deforming in the case of slow deformations, as such of termin origin, but that block tightening the structure itself, in case of fast deformations, as such that can be producted by a seism;
- form devices on memory alloy (SMAD), that allow to connect the separated structural elements, during the course of the seism, with the principal effect to maximally limitate the variation of weights acting on these elements during the variation of the relative movements.

I only add that between the innovative anti-seismic technologies, the so-called "CAM Method" ("Active Fissures of the Wall"), developed and nowadays applied in Italy, that uses a totally new technology, lend by the one of wrapping: it consists in steel strip that wrap the structures and is anchored to those in spots and/or zone determined during projecting.

2.3. Modern Evolution

From the end of the Seventies to the beginning of the Eighties the evolution of anti-seismic systems, based as well on the principle of isolation of the foundation as on energy dissipation, is relatively fast, but organic and rational.

This – as it was already recalled – happened mainly depending on the advanced development of materials and contributive working technologies of the same; technologies that in the last years, have strongly innovated the traditional rules of foundation physics, as well as those of modern syntetic and material producing chemistry, exceptional with regard to mechanic properties (new limits of induction and compression mechanical resistance), as well as in the technological properties (new limits of resistance and abration, used materials teflon and derivatives).

In the middle of the Eighties there has been first applications of elastometric isolators with high damping (HDRB, *High Damping Ribber Bearing*), obtained by the union of natural rubber with particular oils and resins (see Introduction). A complexive mixed function of the installed device, that combines the typical characteristics of the initial elastometric isolators with low damping (therefore allowing fast linear movements of the structure) with those of dissipation, becomes consistant caused by the isteretic behaviour introduced by the additives. This behaviour is analogue to the one of the already cited LRB (that allow a dissipation based on a greater energy and therefore more reduced movements of the higher structure) and to the one of the systems in which isolators at low damping are accompained by dissipators (design solution that can mainly be found in Japan – see Introduction and constribution of Alessandro Martelli).

A first international application of HDRB was in 1985 and was made in California State, exactly on the city of San Bernardino (*County of San Bernardino*). The application was executed on the structure of a large public comploex called *Foothill Communities Law and Justice Center*.

In Italy the first application with HDRB was made in 1987 for the new center of the Regione Marche for Telecom Italia (at that time SIP – Societá Italiana Poste e Telegrafi), realised in Ancona, with mixed structures of steel-concrete for a total of eight floors and a maximal height of about 25 meters. Contractor was SEAT (Rome) and design was by Gian Carlo Giuliani, engineer (Milan). The HDRB were designed, constructed and positioned by ALGA, which was assisted by Professor James M. Kelly from Berkeley (California, USA), already consultor for various realisations of anti-seismic isolation, included the one in San Bernardino.

After some years, in 1986, a new device has been developed in the USA (and there and in Japan found its first applications), named FPS (*Friction Pendulum System*). Inventor and designer was Victor Zayas. A few years ago, from the abovementioned device, the german firm Maurer Söhne derived the so-called *Sliding Isolation Pendulum* (SIP) and most recently, based on the same principles but characterised by important innovations, it was developed and applied also by ALGA, that so extended its productive process to the production of "controlled friction" materials.

Coming back to the Nineties, it seemed to be clear that at the beginning of those years, the use of anti-seismic systems and technologies was predetermined to have a rapid spreading in all applications, that were foreseen and designed (new buildings as well as existing buildings and such to be adapted to seismic) in the national Italian territory.

The possibility to enhance the seismic protection of buildings using those technologies, which are easy to use and with modest added costs, seemed to be even greater. Instead, against those previsions, in the years subsequent to the realisation of seismic isolation in the plants of Telecom Italia in Ancona (1987) and until nearly all the year 1998, the application of these systems was slowed down a lot.

We might think that this happened due to bureaucratic episode following the structural design of the building realised in Ancona for Telecom Italia. In fact the former Public Works' Ministry argued that the design of the structure, even being innovative, did not take place according to Law No. 64/1964 and this project was, therefore, should have been presented – for related discussion and approval – not only to the competent regional Building Authority, but also to the Higher Board of Public Works, through its Central Technical Service (president and general secretary).

It is proved – as shown in history - that the bureaucratic way started in 1989 and ended up 1992, i.e. in occasion of the deposit of the relation and of the certificate relative to the static trial of the structures with the responsible organs. Summing up, during the static trial, it was declared that – also due to a detailed analytic-experimental verified proof of the structures – the grade of security was reached, as well in the design as in the application of the anti-seismic systems, and that the structures themselves were statically appropriate for the roles distributed in the executive project and also resistant to seismic events.

Engineer Alessandro Martelli executed the role of the acceptance inspector (designated by Rule 5.11.1971, No. 1086, art. 7, comma II).

3. NEW RULES

3.1. Rules and Innovation

In the last years the evolution of seismic rule caused not only a more intensive and real research for possible solutions, but also a more coordinated and large co-operation between the different professional profiles interested.

For sure there is no easy and sole remedy to the problem. Starting with a correct analysis of the specific situation it is possible to recognize solutions and different approaches, based on a well studied combination between innovative systems and traditional elements.

From a conceptual point of view, it is out of discussion, that this approach, only finalized on the proof of the non-completion of the elastic conditions, is totally inadequate for a design that essentially deals with the behaviour of the structure in a non-linear field. This situation was not always accepted and will determine significant changes in university studies as well as in working instruments of the designers, who will have to provide all necessary updates with respect to operative modalities.

Nevertheless a last effort is necessary: a precise reference to an Ultimate Status Limit (SLU, see also contribution of Prof. F. Braga), to be reached when the structure is damaged and therefore suffer considerable excursion in non-elastic field, represents its real behaviour during a violent seism, in respect to which a design only finalized to obtain an elastic behaviour is not economically convenient, if not even impossible.

Furthermore, the abovementioned reference clarifies how a simple inspection of the tensional state, realised through the application of the admissible tensions' method, can lead to insufficient measurements: the capacity of a structure to resist violent earthquakes is to be evaluated with respect to its capacity to bear plastic deformations even superior to those which happen at an elastic limit, or synthetically, with respect to its flexibility.

It is also evident that an approach based only on deformations or movements, even if it is theoretically correct is already applicable with design and non-linear calculation instruments (available in that moment), would represent a too radical change towards the normal design practice.

It is for this reason that the new norm lines up to the elastic analysis, with fairly reduced actions in order to observe non-elastic behaviour, and the verification of the SLU resistance, special project procedures (method of the resistance of structures) and specific detail prescriptions, which are intended to guarantee the correct behaviour of the structure in a non-elastic field and a sufficient flexibility if the structural elements.

Once the impact with the new method is resolved, the use of the approach to the limit status allows the designer the execution of a correct analysis of the exercise situations in a different way with respect to those can happen by collapse of the structure, turning the greatest attention to non-linear dynamic behaviour of the designed and calculated structures in order to resist to seismic actions.

For the project of a new construction in a seismic zone, the rule provides a definition of the particular security premises and of the criteria to be adopted as projecting and verifying, considering the elastic and plastic phase of elements' deformation, the static and dynamic answer of the structure, the flexibility required to the single joint and to the available one.

In the definition of the projecting actions, the new rule realises a substantial change with respect to Decree of the Ministry of Public Works of January 16, 1996. The seismic action of the project is in fact being described through elastic schemes of horizontal and vertical components for the different typologies of foundations and not through a sole project scheme, to be modified, from time to time, with enhancing coefficients.

Parameters of projecting determine the energy transfer from the sediment to the foundation, up to the structure and the logics that rule the mechanisms, based on which the energy which entered the structure of the building will be dissipated through plastic deformations of the structural elements. In order to consolidate with the regulations valid in countries which are up-to-date in matters of anti-seismic protection, such as Japan and the U.S.A., "project criteria that rely substantially on specific performances in non-linear field" of the bearing structure have been adopted, in order to assure prevention in occasion of high intensity seismic events.

This means that, against to what happens in a non-seismic situation, in the structure subject to this particular project action – that however happens really seldom – the exposures reach value that are able to cause ruptures in many parts more or less extended and deformations and movements exceed by far the values in the elastic and non-elastic field.

Another innovation, introduced by this type of approach, reaches to the attention of the building's function, that means to the capacity of meet the service for which the structure was designed, calculated and realised. This particular circumstance allows focusing the attention of the designer on the structures as well as on the technological equipments of the product. In this sense all systems turn out to be crucial with which the bearing structures of the building are being connected and/or indented with those having another function (blind frame, **divisionali** etc.).

Regarding innovation, with respect to traditional methodologies which were mentioned before, we can observe that seismic adjustment – in particular in an existing structure – can be reached by adopting one of the three philosophies:

– structural reinforcement of the element;
– seismic isolation of the structure;
– introduction of particular elements in the structure, for example dissipators.

These three intervention typologies present very different project, execution and static trial burdens. The role of a very good designer, calculator, executor of works and acceptance inspector and – finally – of the professional team, which is entitled by the contractor, is to find the only way to obtain maximum structural benefits with the use of minimum financial exposure.

Regarding topic a) - (structural reinforcement), there are numerous technical-scientific books and publications specialized on this topic; regarding topic b) and c) - the most interesting observations has been made in the Introduction and in related attachments.

3.2. The Scientific Foundations

Scientific foundations (from Latin *fundare* or *fundamentum*, that means foundations or that is at the basis of every scientific question), represent what is needed as the basis to a project, to a study, to something that has to endure time.

Through scientific, study, project, invention methods the reliable proof wants to be made on the basis of scientific foundations. Through criteria and aspects of science, leaving behind the others, we would like to know and prove in its reality what is still unknown, but which we suppose knowable in the natural order of things. As Leonardo da' Vinci also said: "…*of those fundaments that justified and made operative technical systems constructed just for one practice* ...", that means we passed from building practice, through elaboration of analytic-mathematic criteria and the joint elaboration of geometric forms, to the real scientific phase. And as it happened in the centuries and happens in the history of mechanics for hundreds of inventions, every practice inventions pass and is then affirmed by science's foundation.

Regarding the design of a structure with an anti-seismic isolation or with dissipation systems, it was pointed out in the Introduction that it consists in application of systems that allow gaining of a drastic reduction of seismic forces acting on the structure itself, differently from the conventional approach, which relies on its resistance. In particular, seismic isolation consists in decoupling the movement of the building from the one of the soil or sediment of foundation, filtering vibrations inducted by the earthquake through implementation, normally on the basis or corresponding to the lower floor, of flexible devices, called seismic isolators. Isolation, as was already said, is usually limited to an horizontal level, because the horizontal components of an earthquake are the most dangerous, and implicates therefore the use of extremely flexible devices in this level, but rigid on a vertical level. For example in attachment 4 of the Introduction some notes on a project of HDRB are listed, which are the most used isolators in Italy.

In the first applications of isolating and dissipating systems (we refer to the years 1975-1985) studies and experience on the devices have been conducted, without an organic classification. Improvements of the related technologies have helped their diffusion, for the protection of buildings and existing structures as well as for the design of new building, which should be protected from earthquakes. At the same time, with generalization of the use of those systems, the need to guarantee quality of the product that had to be installed grew. Steadily experimentation procedures and accompanying rules have been defined in all countries of the world, which started to mainly use these new systems and technologies, in order to allow correct and rational use of the systems.

It was observed that, at that time, there was no project procedure which was generally accepted. Afterwards working group has been established (in Europe on community level, additionally to the national), for scientific study and development of the rule, which have had very precise objectives:

– collect and compare results of available research, related to the behaviour of systems and technologies;

– propose a new coherent approach based on theoretical and empiric models;

– develop project methodologies, that would consider effects and weights incumbent on the structure on which the system should be applied.

A document which reflects all results has not yet been published, but adequate centres/offices for research and development of materials and structures and anti-seismic technologies have been installed in production factories.

In the last decade (1997-2007) systems and anti-seismic technologies and related studies and researches for new materials to be applied for their perfection has had a enormous development: as was referred to from Martelli in this Volume, building which have been projected with new anti-seismic technologies and/or adapted because already existing, are more than 5000.

Projecting techniques, calculation, execution and trial have experienced a great enhancement and science foundations have always been at the basis of those progress. All systems and related technologies have always been calculated and verified according to the rules of Applied Mechanics on structure as well as on constructions. Theories, based on non-elastic calculation are the classic one, which are contained in the disciplines of mechanic technologies (elasticity, plasticity and lamination theory, etc.) and of machines' construction. Moreover, for the missing data, it was referred to the related existing rule. In Italy, starting in 2003, subsequent to the Decree of the President of the Ministry Council

(OPMC) No. 3274, procedure and application of anti-seismic projecting and calculation was ruled, even leaving the interpretation problems of a decree, for those handling constructions.

Acknowledgments

We would like to point out that in Part 1 (History) and more exactly Paragraph 1.2, many references have been provided by the publications of Doctor Bruno Carpani, Section of Natural Risk Prevention and Effects Mitigation of the Research Centre ENEA of Brasimone (Bologna). Our most sincere acknowledgements go therefore to Doctor Carpani.

REFERENCES

[1] M. Dolce, A. Martelli and G. Panza - *Let us Protect Ourselves from Earthquake - The Modern Technologies and Methodologies and the New Seismic Code* – 2nd Edition 21mo Secolo, Milan - years 2005.

[2] A. Martelli, U. Sannino, A. Parducci and F. Braga - *Modern Systems and Anti-seismic Technologies: a guide for designer* - Edition 21mo Secolo, Milan – years 2008.

[3] A. Martelli - *Modern Methods for the protection of cultural heritage* - Proceedings of the Congress "Conservation a future History" – Ferrara, Salone dell'Arte del Restauro e della Conservazione – Ministero dei beni Culturali ed Ambientali - Rome years 2007.

[4] B. Carpani - Various pubblications - Sections of Natural Risk Prevention and Effect Mitigation of the Research Centre ENEA of Brasimone, BOLOGNA - years 2004.

[5] J.M. Kelly - *Base Isolation : origins and development* - National Information Service of Earth-quake Engineering - University of California, Berkley - years 1998.

[6] J.M. Kelly - *Seismic Isolation:* Chapter 11 in "Earthquake Engineering from Engineering Seismology to Performance – Based Engineering" - Edited by Yousef Borzognia and Vitelmo V. Bertero - CRC Press - years 2004.

[7] J.A. Calantarients - *Improvements in and Connected with Buildings and other Works and Appurtenances to Resist the Action on Earthquake and the Like* - Paper 325371, Engineering Libray Stanford, California - years 1909.

[8] *Isolation, Energy Dissipation and Active Vibrations Control of Structures* - Proceedings of10th World Conference, Istanbul (Turkey) - years 2007.

[9] A. Martelli and M. Forni - State of the Art of development and application of Anti-seismic Systems in Europe and other Countries - Proceedings of the 2008 Seismic Engineering International Conference Commemorating the 1908 Messina and Reggio Calabria Earthquake (MERCEA '08) - Volume 1020, A. Santini and N. Moraci – Editors, American Institute of Physics, Danvers MA – Part. 2 - years 2008.

[10] M. Baratta - *The Italy Earthquake – Saggio di Storia*, Geografia e Bibliografia Sismica Italiana Arnaldo FORNI SpA, Editor - years 1979 (Saggio, con ristampa anastatica, di edizione dello anno 1901).