# Recent Worldwide Application of Seismic Isolation and Energy Dissipation and Conditions for Their Correct Use

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**SUMMARY:**
About 20,000 structures, located in over 30 countries, have been protected by seismic isolation (SI) and other anti-seismic (AS) systems and devices. Their use is increasing everywhere, but it is strongly influenced by earthquake lessons and the features of the design rules used. All seismically isolated structures located in areas hit by violent earthquakes survived them without any significant damage. As to design rules, SI is considered as an additional safety measure in some countries, while, in others, the codes allow to partly take into account the reduction of the seismic forces acting on the superstructure that is caused by the use of this technique. This paper summarizes the application of the AS systems in the most active countries, by devoting particular attention to SI of Italian buildings, stresses the conditions for the correct use of this technique and mentions recent initiatives of the Italian Parliament to ensure it and to possibly extend it to the high risk chemical plants.

*Keywords: Seismic isolation, new constructions, retrofits, seismic input, high risk plants*

## 1. INTRODUCTION

According to recent data, made available at the 12th World Conference on Seismic Isolation, Energy Dissipation and Active Vibrations Control of Structures of the *A*nti-*S*eismic *S*ystems *I*nternational *S*oc*i*ety (*ASSISi*), held in Sochi (Russian Federation) on September 19-23, 2011, and later, approximately 20,000 structures in the world have been protected by anti-seismic (AS) techniques such as seismic isolation (SI) or energy dissipation (ED) systems, shape memory alloy devices (SMADs), or shock transmitter units (STUs) (Eisenberg et al., 2011; Martelli et al., 2012a,b; Mazzolani and Herrera, 2012). They are located in more than 30 countries (Fig. 1) and concern both new constructions and retrofits of existing structures of all kinds: bridges and viaducts, civil and industrial buildings, cultural heritage and industrial components and installations, including some high risk nuclear and chemical plants. They are made of all types of materials: reinforced concrete (r.c.), steel and even wood (Martelli et al., 2012a).

The use of the AS systems and devices in a civil context already includes not only the strategic structures (civil defence centres, hospitals) and the public ones (schools, churches, commercial centres, hotels, airports), but also residential buildings and even many small and light private houses. Everywhere, the number of such applications is increasing, although it is strongly influenced by earthquake lessons and the availability and features of the design rules used.

Most SI systems rely on the use of rubber bearings (RBs), namely High Damping natural Rubber Bearings (HDRBs), Neoprene Bearings (NBs), Lead Rubber Bearings (LRBs), or (especially in Japan) Low Damping Rubber Bearings (LDRBs) in parallel with dampers; in buildings, some plane surfaces steel-Teflon (PTFE) Sliding Devices (SDs) are frequently added to the RBs to support their light parts and (if they are significantly asymmetric in the horizontal plane) to minimize the torsion effects. Moreover, Curved Surface Slider (CSS) devices have been used, in the USA (where the Friction Pendulum System – FPS – was developed several years ago) and in other countries. In the latter, devices derived from the FPS using different sliding materials, like the German Seismic Isolation Pendulum (SIP) and, recently, the Italian CSS, have also been applied (Martelli et al., 2011a).

It shall be stressed that, to the knowledge of the authors, all structures protected by RBs that were located in areas hit by even severe earthquakes (including those struck by the *2011 Tohoku* event in Japan) exhibited an excellent behaviour, in spite of the fact that the violence of such earthquakes was frequently underestimated (Eisenberg et al., 2011; Martelli et al., 2011a and 2012a,b; Mazzolani and Herrera, 2012).

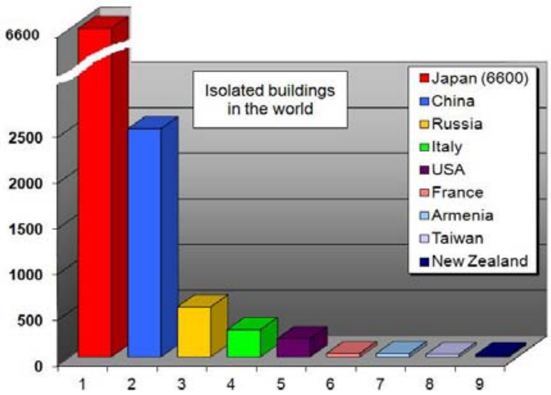


**Figure 1.** Numbers of isolated buildings in the most active countries (most updated available data)

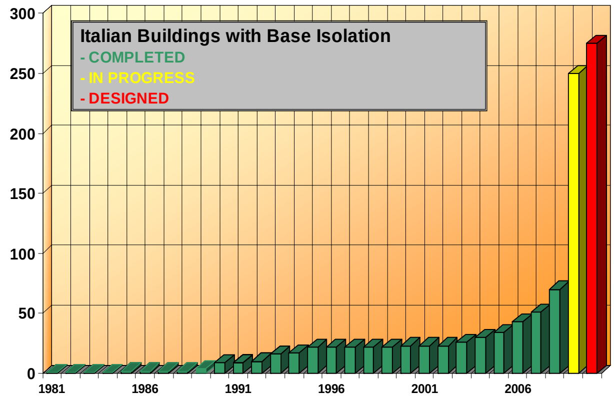


**Figure 2.** Overall number of seismically isolated buildings in Italy during years

## 2. APPLICATION IN JAPAN

Japan, thanks to the availability of an adequate specific code since 2000, the free adoption of SI since 2001 (Martelli and Forni, 2010) and the excellent behaviour of isolated buildings in violent earthquakes, is more and more consolidating its worldwide leadership on the use of the AS systems and devices, with over 6,600 buildings or houses protected by SI (Fig. 1) and over 900 large buildings provided with other type control systems (in about 70 cases the latter are active or semi-active) (Eisenberg et al., 2011). Moreover, there is a large number of houses where ED systems have been installed (2,000 in 2009, see Martelli et al., 2011a).

More precisely, Japan, where the first application of base SI dates back to 1983 (Eisenberg et al., 2011), is continuing the extensive adoption of the AS systems initiated after the excellent behaviour of two isolated buildings near Kobe during the 1995 *Hyogo-ken Nanbu* earthquake. To the knowledge of the authors, this behaviour was confirmed by all Japanese buildings protected by SI in all subsequent severe events (Eisenberg et al., 2011; Martelli et al., 2011a and 2012a,b; Mazzolani and Herrera, 2012). With regard to the 2011 *Tohoku* earthquake, it is noted that the related seismic hazard was considerably underestimated, as for several previous violent events all over the world (Martelli et al., 2011a,b). In spite of this, to the knowledge of the authors, the 118 isolated buildings which are located in the *Tohoku* area and those erected in other Japanese sites behaved well, at least without considering the effects of the subsequent tsunami (Eisenberg et al., 2011; Martelli et al., 2011a and 2012a,b; Mazzolani and Herrera, 2012). A similar behaviour was shown, for the isolated bridges and viaducts, by most of those protected by RBs (LRBs or HDRBs), although a certain number of them was later destroyed by the tsunami (due to deck rotation toward the upstream side, resulted from the uplifting force, see Martelli et al., 2011a).

Japanese, on the one hand, have confirmed the trend, initiated some years ago, to isolate even high-rise buildings and sets of buildings supported by a common isolated r.c. structure (the so called *artificial ground*, a solution which enables large savings of construction costs) and, on the other hand, are more and more increasing the number of even very small private houses protected by SI (Martelli and Forni, 2010; Martelli et al., 2012b). The isolated high-rise buildings are now rather numerous and included

250 condominiums in the middle of 2011, while the isolated houses were already about 4,000 at the same date (Martelli et al., 2011a). More generally, in the middle of 2011 46% (1,100) of the Japanese isolated large buildings (e.g. excluding houses) were condominiums, 20% offices, 12% hospitals and 2% schools and most of these large buildings were new constructions (the retrofits of those existing were 90 some months ago, see Martelli et al., 2011a).

The Japanese structures provided with ED systems include several high-rise buildings; these and the similarly protected private houses make use of various kinds of dampers (Martelli and Forni, 2010): for instance, the applications of Buckling-Restrained Braces (BRBs) were already over 250 in 2003. Moreover, approximately 40 Japanese buildings were seismically controlled by Tuned Mass Dampers (TMDs), of active or hybrid types, in June 2007, and so-called *Active Damping Bridges* (ADBs) had been installed between pairs of adjacent high-rise buildings to reduce the seismic response of both of them, based on their different vibrational behaviours (Martelli and Forni, 2010).

The use of the AS systems and devices also recently increased in Japan for the protection of cultural heritage and for that of bridges and viaducts (Martelli and Forni, 2010; Martelli et al., 2011a). For the latter it had began rather later than for buildings; it is being largely based on the use of HDRBs and LRBs and considerably extended especially after the *Hygo-ken Nanbu* earthquake which struck Kobe in 1995 (by becoming obligatory for overpasses in this town).

Finally, as to the industrial plants, besides detailed studies for the SI (even with three-dimensional – 3D – systems) of various kinds of nuclear reactors, the *Nuclear Fuel Related Facility* was erected on 32 LDRBs and LRBs (Martelli and Forni, 2010). Application of SI to large industrial factories also began in 2006: the first, concerning the fabrication of semi-conductors, is a 5-storey steel and SRC (mixed steel-concrete system) structure, with a height of 24.23 m and a total floor area of about 27,000 $m^2$, which was built on LRBs, Viscous Dampers (VDs) and oil dampers; at least 2 further similar factories were also already in use at the end of 2009 (Martelli and Forni, 2010; Martelli et al., 2012a).

## 3. APPLICATION IN THE P.R. CHINA

In the Peoples' Republic (P.R.) of China very ancient monasteries, temples and bridges, protected by means of rough sliding SI systems, are still standing, which withstood numerous earthquakes, including very violent events, up to M = 8.2; however, the application of modern SI systems began only in 1991 (Dolce et al., 2006). In any case, initially the SI systems, then the ED ones too have rapidly got a footing since that year, so that the isolated buildings were already 490 in June 2005. Many of these applications were to dwelling buildings and no less than 270 to the masonry ones (Dolce et al., 2006).

At the end of 2006 the number of the Chinese isolated buildings had increased to more than 550 and included even rather tall constructions. SI had also already been used, for the first time in the P.R. China, to protect *Liquefied Natural Gas* (LNG) tanks (Martelli and Forni, 2010). In May 2007 the Chinese isolated buildings were 610 and those protected by ED systems 45 (Martelli and Forni, 2010). The first included the so-called *Isolation House Building on Subway Hub*, near the centre of Beijing, which consists of fifty 7- to 9-storey buildings, all separately isolated above an unique huge 2-storey isolated structure containing all services and infrastructures, including railways and subways (Dolce et al., 2006). In the same years, Chinese application of 3D SI systems to civil buildings and of isolators or SMADs to cultural heritage had also begun (Martelli and Forni, 2010). In October 2008, the number of isolated Chinese buildings was about 650.

The number of the newly erected Chinese isolated buildings per year doubled after the *Wenchuan* earthquake of May 12, 2008, by increasing from 50 to 100 (Martelli and Forni, 2010). This more rapid increase of the number of building applications of SI was due to both the excellent behaviour of two r.c. isolated buildings and even a 6-storey masonry one during the aforesaid earthquake (although its violence had been largely underestimated, by a factor 10 for the peak ground acceleration!) and the fact that the Chinese code permits to reduce the seismic loads acting on the superstructure of such buildings (Martelli and Forni, 2010).

Nowadays, the number of applications of the AS systems is really strongly increasing in the P.R. China: in fact, it was reported at the 2011 Sochi Conference that about 2,500 buildings and 80 bridges and viaducts have already been protected in this country by SI, in addition to about 400 buildings and 50 bridges provided with dampers, 36 buildings or towers equipped with passive TMDs and 8 bridges and 5 towers with active or hybrid systems (Eisenberg et al., 2011). SI has been applied not only at the building base or at the top of the lowest floor, but also on more elevated floors (for risings or for erecting highly vertically asymmetric constructions), or at the building top (to sustain, in the case of retrofit, one or more new floors acting as a TMD), or also on structures that join adjacent buildings having different vibrational behaviours. Recent applications also included large groups of individually isolated buildings, sets of buildings on *artificial grounds*, base and roof SI of stadiums and other large span structures and the protection of valuable items (e.g. electronic equipment and art objects) by means of SI tables (Martelli and Forni, 2010; Martelli et al., 2012b).

## 4. APPLICATION IN THE RUSSIAN FEDERATION

The Russian Federation is now third for the number of isolated structures, with about 550 applications to buildings or bridges (according to the updated information provided at the 2011 Sochi Conference) and numerous new buildings protected by AS systems (including dampers) are being erected (Eisenberg et al., 2011). The use of modern SI systems, formed by RBs, frequently in conjunction with SDs and/or dampers (similar to those adopted in the other countries), is going on replacing that of the previous so called *low cost* isolators (reversed mushroom-shaped r.c. elements), which had been installed since the years 1970s. After the retrofits of some important historical buildings (Dolce et al, 2006; Sannino et al., 2009), recent Russian application includes even high-rise buildings, in particular in Sochi, where the 2014 Winter Olympic Games will take place. For some of these, Italian HDRBs have been used (Eisenberg et al., 2011; Martelli et al., 2011a & 2012b).

## 5. APPLICATION IN THE USA

The USA are now at the third place, after Japan and the P.R. China, for the overall number of applications of the AS systems and devices (Eisenberg et al., 2011). In this country, however, such applications are satisfactorily progressing only for bridges and viaducts and for buildings protected by ED systems. They concern both new constructions and retrofits. More precisely, at the end of 2009, HDRBs, LRBs and, more recently, ED devices and STUs had already been installed in about 1,000 U.S. bridges and viaducts, located in all U.S. states, while over 1,000 buildings had been provided with dampers of various kinds (Martelli and Forni, 2010): VDs and friction dampers (FDs) already protected approximately 40 and, respectively, 12 buildings in 2001 and BRBs 39 further buildings in 2003 (Dolce et al., 2006).

On the contrary, as far as SI of buildings is concerned, the number of new applications remains still limited (recently 3 or 4 per year), in spite of the excellent behaviour of some important U.S. isolated buildings during the 1994 *Northridge* earthquake (Dolce et al., 2006) and the long experience of application of this technique to such structures (since 1985). This is a consequence of the very penalizing design code in force in the USA for the isolated buildings: according to the available information, the US seismically isolated buildings are now not more than 200, although they are mostly very important and half of them are retrofits, even of monumental buildings (Martelli and Forni, 2010).

SI of US buildings has been performed using HDRBs, LRBs (in some cases in conjunction with LDRBs, SDs, VDs and other ED devices) and, more recently, the FPS too. With regards to the design earthquake levels adopted in California, it is noted that they correspond very large magnitudes M (e.g.

M = 8.3 for the new *911 Emergency Communications Centre* erected in San Francisco in the years 1990s and M = 8.0 for the *San Francisco City Hall* retrofitted with 530 LRBs in 2000, see Martelli and Forni, 2010): this imposes the use of SI (as the only possibility) for these applications, in spite of its large implementation cost in the USA.

## 6. APPLICATION IN ITALY

Fifth and first in the Western Europe for the overall number of applications of the AS devices remains Italy (Figs. 1 and 2). There, the use of the AS systems began in 1975 for bridges and viaducts and in 1981 (namely 4 years before the USA and 2 years before Japan) for buildings (Martelli et al., 2008; Eisenberg et al., 2011). It is worthwhile stressing that the design of the first two Italian suspended buildings protected by AS systems, located in Naples, had been completed before the 1980 *Campano-Lucano* earthquake, when the Naples area was not yet considered as seismic: after such an event, that area was classified in "seismic category 3" (i.e. with moderate seismic hazard): thus, in order to avoid large modifications of the buildings designs, neoprene bearings were added on the roof of such buildings, together with other AS devices inside them (Dolce et al., 2006; Martelli et al., 2012a,b).

**Figure 3.** *Francesco Jovine* school of San Giuliano di Puglia, after its collapse in the 2002 earthquake

**Figure 4.** The isolated complex including the new *Francesco Jovine* school and *Le Tre Torri* Poly-functional Centre in San Giuliano di Puglia (2009) and view of some the isolators supporting its common base slab

**Figure 5.** One of the three tanks of the company *Polimeri Europa* of the Italian ENI Group located in Priolo, which were seismically retrofitted using U.S. FPS devices in the years 2005-2008 and one of the isolators during and after its installation; this is the only application of SI to chemical plants and components so far existing in Italy (prior to the 2009 *Abruzzo* earthquake, it was also the only application of CSS devices in Italy)

In spite of the aforesaid pioneering role of Italy in the development and application of the AS systems, in the years '90s their use remained rather limited several years long, due to the lack of design rules to the end of 1998, then due to their inadequacy and a very complicated and time-consuming approval process to 2003 (Dolce et al., 2006). However, significant application of the AS systems (especially of SI) has restarted in Italy for some years, initially as a consequence of the collapse of the *Francesco Jovine* primary school in San Giuliano di Puglia (Campobasso) during the 2002 *Molise & Puglia* earthquake (Fig. 3) and the subsequent enforcement of a new national seismic code (in May 2003), which freed and simplified the adoption of the AS systems in Italy (Figs. 4-8) (Martelli et al. 2008; Martelli and Forni, 2010).

The use of SI became particularly rapid especially after the *Abruzzo* earthquake of April 6, 2009, as a consequence of the large damage caused by this event to the conventionally founded structures and cultural heritage (Martelli and Forni, 2010 & 2011a). Thus, in 2009, Italy overtook the USA for the number of isolated buildings and industrial structures and components: those in use were about 70 before the aforesaid earthquake, with further 20÷30 ones under construction or design, while they are now approximately 300 and several further applications to new-built and retrofitted structures of these kinds are in progress (Martelli et al., 2011a & 2012a).

**Figure 6.** Main building of the Civil Defence Centre of Foligno (Perugia), isolated by 10 HDRBs and certified as safe by A. Martelli in 2011

**Figure 7.** Block B of the Romita High School in Campobasso, isolated by 12 HDRBs and 10 SDs, under reconstruction with SI, after its demolition in 2010 (it had been found unsafe by ENEA, CESI and the University of Basilicata in 2003); the structural safety of the new building will be certified by A. Martelli in 2012

**Figure 8.** 8-storey isolated building (the tallest of this kind in Italy) under construction in Messina on 22 LDRs and 2 SDs (its structural safety will be certified by A. Martelli in 2012)

**Figure 9.** One of the 184 pre-fabricated houses (wood, or r.c., or steel structures) erected in L'Aquila to host up to 17,000 homeless residents after the 2009 Abruzzo quake and detail of one of the 40 CSS devices, manufactured in Italy, which have been installed at the top of columns (made of steel or r.c.) to isolate its supporting slab

**Figure 10.** The new headquarters of ANAS in L'Aquila, erected on 60 HDRBs after the 2009 *Abruzzo* earthquake and completed at the beginning of 2011, and view of some of its isolators

The recent applications of SI include 184 wood, r.c. or steel pre-fabricated houses erected in L'Aquila, each on a large isolated r.c. slab (Fig. 9), to provisionally host up to 17,000 homeless residents (at least in the first years). These have been seismically isolated, for the first time in Italy, using CSS devices manufactured in the country (Fig. 9); however, the use of the traditional HDRBs or LRBs, in conjunction with some SDs, is also going on, in both L'Aquila and other Italian sites, for several new constructions and retrofits (see, for instance, Figs. 10 and 11) (Martelli et al., 2011a,c; Martelli and Forni, 2011b). In particular, the new *Francesco Jovine* school (Fig. 4), protected by a SI system designed with the cooperation of ENEA and formed by 600 and 700 mm diameter HDRBs (61) and SDs (13), which has been the first Italian isolated school (certified as safe by the first author of this paper in September 2009), has been followed by several further projects of this kind: the seismic protection of schools by means of SI, besides that of hospitals and other strategic structures, is now a "priority 1" objective in Italy (Martelli and Forni, 2010 & 2011a; Martelli et al., 2011a).

**Figure 11.** The dwelling building of Via Borgo dei Tigli 6-8-10 in L'Aquila (Pianola area), which had been just completed before the 2009 Abruzzo earthquake (left) and damage caused to the building by this event; its retrofit by means of HDRBs and SDs was designed by the GLIS member Giuseppe Mancinelli, who recently passed away and the structural safety of the retrofitted building will be certified by A. Martelli

Moreover, the use of the AS systems is going on for bridges and viaducts (those with such systems were already at least 250 in 2009), as well as for cultural heritage (Martelli, 2009; Martelli and Forni, 2010 & 2011a; Martelli et al., 2008 & 2011a): new retrofit techniques using SI, applicable to monumental buildings (Martelli, 2009; Clemente et al., 2011) will also be applied for both reconstructing L'Aquila and for enhancing the seismic protection of some ancient constructions in Sulmona, an historic town close to L'Aquila which was not damaged by the 2009 event, but which is also very earthquake-prone. To the latter aim, a collaboration agreement with the local municipality will entrust ENEA with the check of the retrofit designs and supervision of the subsequent construction works (Martelli et al., 2011a).

## 7. APPLICATION IN OTHER COUNTRIES

The countries which follow Italy for the overall number of applications of the AS systems are South Korea, Taiwan, Armenia, New Zealand, France, Mexico, Canada, Chile and others (Martelli and Forni 2010 & 2011a): many applications in these countries make use of Italian AS devices (e.g. in Turkey, Greece, Portugal, Spain) and some (in Romania, Cyprus) have also been designed by Italians (Martelli et al., 2012a). Armenia, with 38 completed isolated buildings and 8 under construction (Eisenberg et al., 2011) remains second, at worldwide level, for the number of applications of such devices per number of residents, in spite of the fact that it is a still developing countries. In New Zealand, one of the motherlands of AS devices (in particular of those based on the use of lead, like LRBs and lead dampers) and third in the world for the number of applications of such devices per number of residents, the isolated structures had an excellent behaviour in both the 2010 *Canterbury* earthquake and the 2011 *Christchurch* event. Similarly, the isolated structures in Santiago had an excellent behaviour in Chile too, during the *Maule* earthquake (Martelli and Forni, 2011a; Mazzolani and Herrera, 2012).

## 8. REMARKS ON THE CORRECT USE OF ANTI-SEISMIC SYSTEMS AND DEVICES

The large effects of earthquake lessons and seismic design code features on the extent of the use of the AS systems in the various countries shall be stressed (Martelli, 2010; Martelli and Forni, 2010 & 2011a,b). In the codes of countries like Japan, the USA and Chile SI is considered as a safety measure additional to the conventional design; consequently, the use of SI obviously always introduces additional construction costs. Nevertheless, this technique is being widely adopted by the Japanese, due to their high level of perception of the seismic risk and because violent earthquakes are very frequent in their country (Martelli et al., 2011a & 2012a).

The aforesaid level of perception is much lower elsewhere: this is the reason why, to limit or even sometimes balance the additional construction costs entailed by the use of SI (and, thus, to promote a significant application of this technique), the seismic codes of other countries (Italy, P.R. China, Armenia, etc.) allow for some lowering of the seismic forces acting on the superstructure when SI is used (Clemente and Buffarini, 2010). Thus, in these countries, a real safety will be ensured to the isolated structures if and only if great care is paid to: (a) the selection of the SI devices (taking into account the amplitude of vertical motion and low frequency vibrations), their qualification, production quality, installation, protection, maintenance and verification that their design features remain unchanged during the entire structure life; (b) some further construction details (structural gaps, their protections, interface elements – e.g. gas and other safety-related pipes, cables, stairs, lifts –, etc.). Otherwise, the isolators, instead of largely enhancing the seismic protection, will make the structure less earthquake resistant with respect to a conventionally founded one and, thus, will expose both human life and the entire SI technology to great risks.

Last but not least, a common key requirement for the optimal performance of all kinds of AS systems and devices (but especially of the isolators) is the realistic and reliable definition of seismic input (Martelli, 2010; Martelli and Forni, 2010; Martelli et al., 2011a; Panza et al., 2011), which cannot rely upon the oversimplified routine probabilistic methods, mainly when dealing with displacements definition (on which the design of isolated structures is based): thus, the ongoing rapid extension of the use of the AS systems and devices requires a considerable improvement of the *Probabilistic Seismic Hazard Assessment* (PSHA) approach, which is now in use in several countries (including Italy). Taking into account the unreliable results shown by PSHA for several violent earthquakes in the last decade (Martelli and Forni, 2011a; Martelli et al., 2011a; Panza et al., 2011), such a change is very urgent now and can be achieved by complementing PSHA through the development and application of deterministic models, e.g. the *Neodeterministic Seismic Hazard Assessment* (NDSHA). This particularly applies to the P.R. China, Italy, New Zealand and Japan, to ensure a safe reconstruction after the earthquakes of *Wenchuan* (2008), *Abruzzo* (2009), *Canterbury* and *Christchurch* (2010 and 2011) and *Tohoku* (2011), because SI is widely used in the concerned areas.

All said items were discussed in Italy by the 8th Commission on Environment, Territory and Public Works of the Italian Chamber of Deputies in 2010 and 2011, based on two proposals drafted by the first author of this paper, with the collaboration of other experts (Martelli et al., 2011a & 2012a). Following these discussion and audits of various experts (including those of the first and third authors of this paper), one of such resolutions (that most detailed), was approved, with minor changes, by the aforesaid commission and by the Italian Government on June 8, 2011 (Martelli et al., 2011a). The final document (Benamati et al., 2011), after some introductory remarks, contains recommendations for modifications of some parts of the existing Italian and European seismic codes that concern the AS systems and devices and the structures provided with them (experimental qualification of the new device types to be carried out on prototypes by subjecting them to at least bi-directional excitations, control of all construction phases to be performed by an expert in the field, recommendations and requirements to be provided by him in his final certificate concerning the structural safety of the structure, etc.), as well as the need for using the NDSHA together with the PSHA for the definition of seismic input (in particular for that of the design displacement, which is a key parameter for the design of isolated structures). These recommendations have been reported in detail by Martelli et al. (2011a).

## 9. CONCLUSIONS

SI and the other AS systems have already been widely used in over 30 countries and their application is increasing more and more, for both new constructions and retrofits, for all kinds of structures and their materials. The features of the design rules used, as well as earthquake lessons, have plaid a key role for the success of the aforesaid technologies. Japan is largely the leading country for the number of applications of both SI and ED systems. For the overall number of applications, it is now followed by the P.R. China, the Russian Federation, the USA and Italy. Italy (where the contributions provided by ENEA have been of fundamental importance) is the leading country at European level, with regard to both SI and ED of buildings, bridges and viaducts. In addition, it is a worldwide leading country for the use of AS systems and devices to protect cultural heritage (Martelli, 2009; Martelli and Forni, 2010). Its applications are being significantly extended after the 2009 *Abruzzo* earthquake. Italian AS devices have been installed in several other countries too.

SI is now worldwide recognized as particularly beneficial for the protection of strategic constructions like civil defence centres and hospitals (by ensuring their full integrity and operability after the earthquake) and for schools and other highly populated public buildings (also because the large values of the isolated superstructure vibration periods minimize panic). Some codes (e.g. those adopted in Italy, P.R. China, Armenia, etc.) allow for taking advantage of the reduction of seismic forces operated by SI: their use makes SI attractive for the dwelling buildings too, because the additional construction costs due to the use of this technique (if any) are very limited.

In order to really strongly enhance the seismic protection of our communities, an extensive but correct application of the anti-seismic systems is necessary (Martelli and Forni, 2011a; Martelli et al., 2011a & 2012a): to achieve this objective, regulatory and legislative measures, such as those that were recently proposed in Italy by the 8th Commission on the Environment, Territory and Public Works of the Chamber of Deputies for the isolated structures in general and for protecting the high risk chemical plants in particular, may considerably contribute, especially in the countries (like Italy) where the perception of seismic risk is not yet sufficient. In fact, the use of AS systems (in particular that of SI) will hopefully strongly increase not only for the protection of civil structures, but also for that of cultural heritage and high risk plants (Martelli and Forni, 2010). For the first, the problem is the compatibility with the conservation requirements (Martelli, 2009). With regard to the latter, SI has a great potential not only for nuclear structures, but also for chemical components like LNG tanks, for which, to date, only very few applications exist or have been planned (in South Korea, P.R. China, Turkey, France, Greece, Mexico, Chile and Peru): in fact, detailed studies have shown that SI is indispensable for such components in highly seismic areas (Dolce, 2006; Martelli et al., 2011a).

Thus, as recommended by a parliamentary question of the President of the 8th Commission of the Italian Chamber of Deputies in September 2011 (Alessandri, 2011), which has been fully reported by Martelli et al. (2011a) and by a resolution which was proposed by the same member of the Italian Parliament at the end of January 2012 (Alessandri, 2012), we hope that the use of SI will soon increase for high risk chemical installations in Italy. This applies, especially, to Sicily, in sites like those of Milazzo (near the area destroyed by the 1908 *Messina & Reggio Calabria* earthquake and tsunami) and Priolo (located in the Catania Plane, which was razed by the 1693 event): in both sites hundreds of quite seismically vulnerable cylindrical and spherical tanks already exist (only 3 retrofitted using SI, to date, see Fig. 5) and, in the latter, the construction of a large re-gasification terminal with LNG tanks has been planned (although this project is now under discussion, due to the aforesaid issues).

Generally speaking, however, it shall be kept in mind that the use of SI in countries like Italy, where the designers are allowed by the code to decrease the seismic forces acting on the superstructure when adopting this technology, requires: (a) first of all, a reliable definition of the seismic input, i.e. by means of intensive use of NDSHA; (b) then a very careful selection, design, manufacturing, installation, protection and maintenance of the SI devices during the entire life of the isolated structure; (c) finally, particular attention to be also paid to some further construction aspects (in particular, to the design, realization, protection and maintenance of the structural gaps and the safety-related pipelines – e.g. the gas ones – again during the entire life of the isolated structure). Otherwise, the seismic safety of these structures would be lower than that of the conventionally founded ones.

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