SEISMIC ASSESSMENT OF PUBLIC AND HISTORICAL BUILDINGS, STRATEGIC OR RELEVANT FOR CIVIL PROTECTION DURING AN EARTHQUAKE: THE LATIUM REGION PROGRAM

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ABSTRACT

This paper presents the activities carried out by Latium Region (LR), whose capital is Rome, in cooperation with the National Department of Civil Protection (NCPD), aimed to the seismic safety assessment of public and historical buildings, strategic for civil protection or relevant for the consequences of a collapse. A national effort in this field started after the October 2002 San Giuliano di Puglia earthquake, where 29 people died under collapse of a school, highlighting once again the vulnerability of many existing structures. After the earthquake the Ordinance of the President of the Ministers' Council (OPCM) 3274 of march 2003 enforced the seismic assessment of all the strategic and relevant constructions. Another OPCM granted funds to support this action. LR, like almost all other regions joined this effort. This project develops a new pathway to reduce the seismic risk in Italy, through the definition of annual programs for seismic assessment and rehabilitation works, the issue of regional technique guidelines and the documentation of the results through a synthetic form summarizing the assessment data and results. Furthermore LR constituted a Regional Scientific Technical Committee (RSTC) to monitor the effort and technically advise involved professionals (Structural Engineers, Architects and Geologists). This first economic and technical effort of LR, that, with the 50% cofounds of NCPD, reaches about 28 million of Euro (about 44Ml USD) in two years, allows to face only a minimal part of the Latium needs, nevertheless it is an important step towards the seismic risk reduction.

KEYWORDS: Seismic Assessment, Civil Protection, Seismic Risk, Latium Region, Financings

1. INTRODUCTION

The National Seismic Assessments Program for public and historical structures, strategic or relevant for Civil Protection during an earthquake event [OPCM 3274 March 20, 2003; OPCM 3362 July 8, 2004], started following Molise earthquake (October 31st 2002, M=5.4), during which 27 children and 2 teachers died, due to the collapse of the elementary school of San Giuliano di Puglia village (*fig 1*).

Figure 1 School collapsed in S. Giuliano village - earthquake M=5,4

This first seismic prevention program involves NCPD, Regions and Municipalities. As from 2003 National and Regional codes [OPCM 3274 March 20, 2003; DGR Lazio 766 August 1, 2003] have allowed to invest public funds in order to carry out seismic assessments of strategic and relevant structures. The list of these strategic or relevant structures has been shared between State and Regions with the aim to give main outline to identify the historical and public properties, which eventually amounted to 75.000 buildings [Dolce et al., 2007]. Following these shared criteria, the LR code [DGR Lazio 766 August 1, 2003] identifies as strategic structures these typologies of structures: municipal building, hospital, barracks, radio broadcasting and telephone installations, electrical plant. Functionality of the aforementioned structures is strategic to guarantee Civil Protection after a seismic event. The relevant structures include the following typologies: churches, schools, university colleges, bridges, museum, sport courts, factory, prisons, kindergartens. Said buildings are deemed as relevant because of social consequences, in case of collapse.

The seismic assessment program lasts 5 years and LR has already carried out two annual plans of Regional seismic assessment and rehabilitation of buildings, approved and financed by NCPD [DPCM June 6, 2005; DPCM March 5, 2007] with about 14,3 million of Euro and by LR [DGR Lazio 551 August 4, 2006] with about 13,2 million of Euro as well (Tab 1). Each of these two annual plans indicates: Definition, Owner, Seismic zone, Volume or Area of each structure, Conventional costs of each seismic assessment as established by legislation [OPCM 3362 July 8, 2004], Percentage of regional financing invested, Beneficiary Administration. Thanks to these financings, the beneficiary administrations of the local Municipalities can charge professionals of carrying out structural assessments and designing rehabilitation works without investing their own budget. So far, 1170 buildings, located in Municipalities included in high and very high Latium seismic zones, have undergone seismic assessment and in 13 buildings, considering their high structural seismic risk, seismic rehabilitation works have started (Tab 1).

Table 1 Latium Region Seismic Assessment Program

	First Year Number of structures	First Year Funds in Euro	Second Year Number of structures	Second Year Funds in Euro
ASSESSMENT	**562**	8.861.911	**595**	7.259.313
REHABILITATION	**5**	5.460.000	**8**	6.000.000
TOTAL	**567**	14.321.911	**603**	13.259.313
Total in two Years	**1170**	27.581.224		
LR total funds		13.233.994		
NCPD total funds		14.347.230		

Table 2 shows the calculation of seismic assessment cost in relation to own volume, the unitary and conventional costs defined by the legislation [OPCM 3362 July 8, 2004]. The minimum conventional cost of a seismic assessment is 3.600,00€, while for the financed rehabilitation works, the legislation establishes 150,00€/m^3 for buildings and 450,00€/m^2 for bridges.

Table 2 Calculation of seismic assessment conventional costs (Building only)

Volume of structure in m^3	Unitary Cost in €/m^3	Conventional cost of assessment in €
up to 10.000	2,50	2.50€ for whole volume
from 10.000 up to 30.000	1,80	25.000,00€ + 1,80€/m^3 surplus 10.000€
from 30.000 up to 60.000	1,20	25.000,00€ + 1,20€/m^3 surplus 30.000€
from 60.000 up to 100.000	0,60	25.000,00€ + 0,60€/m^3 surplus 60.000€
More than 100.000	0,30	25.000,00€ + 0,30€/m^3 surplus 100.000€

2. SEISMIC ASSESSMENT

Due to the particular seismic conditions of LR, most of structures are located in very high and high seismic hazard zones (seismic zones 1 and 2 in figure 2) and mostly of them are built without any anti-seismic criteria.

This urgent assessment action has been launched in all Italian Regions at the same time. As damages in structures can weaken the emergency management system, the knowledge of their functionality after a shock is fundamental to reduce the seismic risk [Dolce et al., 2007]. The aim of the seismic assessments is, both, to check if the adequacy level of buildings and bridges conforms to the parameters foreseen by new seismic Italian legislation, and to define a priority list of rehabilitation works. These seismic assessments are compulsory for structures built before 1984 and for all structures located in areas where the 2003 regional seismic zonation [DGR Lazio 766 August 1, 2003] increased the seismic hazard value with respect to the 1984 seismic zonation.

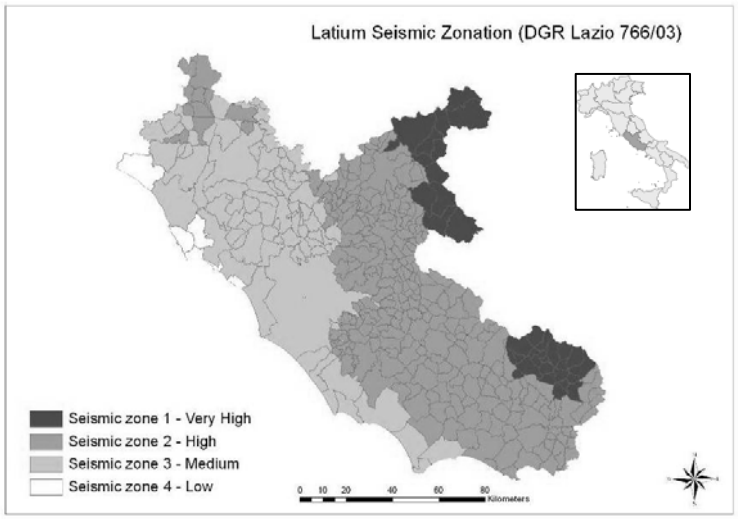

Figure 2 Seismic zonation of Latium Region (DGR Lazio 766/03)

Figure 3 shows the typological subdivision of the seismic assessments of Latium Region for both years. Schools, Infrastructures and Churches reach 67% of the structures financed, while most of the infrastructures, mainly bridges, were financed in 2005 . Historical heritage is only 4.4% of the structures financed, though it should be noted that many offices, churches and municipality buildings are declared as historical buildings from the State.

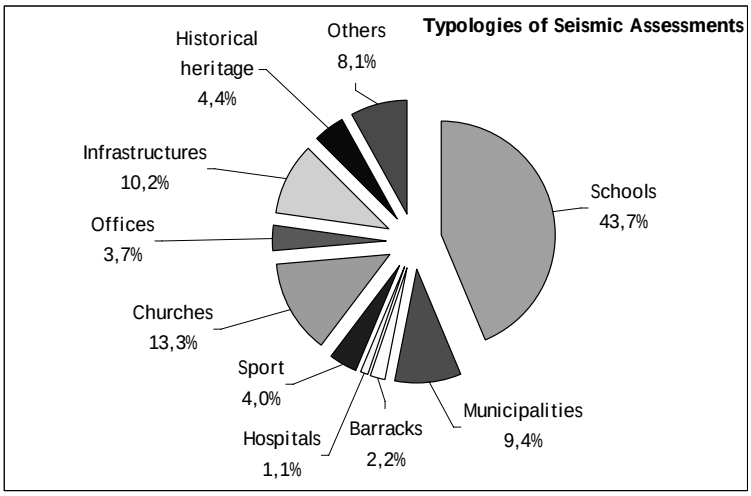

Figure 3 Typological subdivision of the Latium seismic assessments for annuities 2004-2005

The seismic assessment codes [OPCM 3274 March 20, 2003; DGR Lazio 532 August 4, 2006] establishes a technical procedure aiming at the determination of the Risk Index α, defined as the ratio between seismic intensity bringing the structure to a given limit state (capacity) and the expected seismic intensity at the site (demand). The final Risk Index α (PGA/PGA_{ref}) must be computed as:

$$\alpha = PGA/PGA_{ref,} = PGA/(\gamma_I S S_T PGA_{Z,}) \quad (1.1)$$

where PGA is the building structural capacity in terms of acceleration and PGA_{ref} is the acceleration demand, γ_I is the importance factor of the structure (*1.4 for strategic structure and 1.2 for relevant as well*), S is the soil amplification parameter, S_T is the topographic amplification parameter, and PGA_Z is the bedrock acceleration, based on the current seismic zonation (Figure 2). This index yields a measure of the structure adequacy; when it is equal or larger than 0.7, it means that the capacity of structure is good, while if it is lower than 0.7, the capacity is not sufficient, while the risk is higher for values closer to zero. For each seismic assessment the code requires calculation of the Risk Indexes for collapse (CO), severe damage (DS) and limited damage (DL) limit states . High Risk Index indicates an urgent rehabilitation of the structure, while medium Risk Index implies rehabilitation works, though not so urgently as in the previous case, the urgency being inversely proportional to its value [Dolce et al., 2007], as shown in Figure 4.

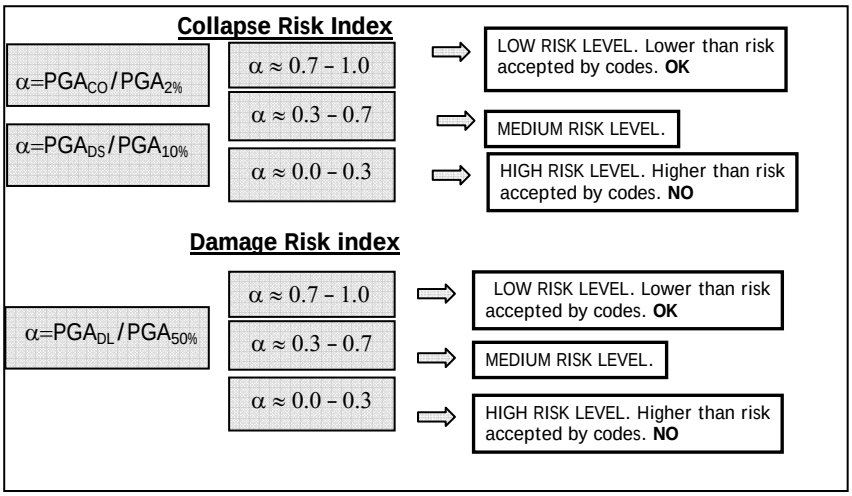

Figure 4. Risk Indexes and ensuing actions (redrawn from Dolce et al. 2007)

In 2006 LR Geological Service, in collaboration with the NCPD, issued the Guidelines for both carrying out the seismic assessment and filling in the relative results forms [DGR Lazio 532 August 4, 2006]. Such Guide Lines allow professionals to perform homogeneous, objective, technically correct seismic assessments.

Table 3 Distribution of seismic assessment with the conventional costs

ANNUITY 2004			ANNUITY 2005		
Assessment cost in €	*n. assessments*	*%*	*Assessment cost in €*	*n. assessments*	*%*
<10000	279	52,8	<10000	409	68,7
10001<x<20000	138	24,6	10001<x<20000	82	13,7
20001<x<30000	46	8,2	20001<x<30000	41	6,9
30001<x<40000	39	6,9	30001<x<40000	20	3,4
40001<x<60000	21	3,7	40001<x<60000	16	2,7
60001<x<75000	10	1,8	60001<x<75000	11	1,9
75001<x<100000	9	1,6	75001<x<100000	15	2,5
x>100001	2	0,4	x>100001	1	0,2
TOTAL	562	100	TOTAL	595	100
Median in €		9000,00	*Median in €*		5133,00
Mean in €		15796,00	*Mean in €*		12000,00

In order to prevent loss of human lives, the main purpose of this program is, firstly, to map the structural conditions of strategic and relevant public and historical buildings and, secondly, to reduce structural seismic risk by planning rehabilitation of highly vulnerable structures, and during the seismic assessments all geological, geotechnical, historical, architectural, structural conditions must be analyzed [Colombi et al., 2007].

Professionals and beneficiary administrations should always follow optimal procedures to achieve the best safety level. Table 3 shows the distribution of the percent of seismic assessments with the conventional cost; both years show a major concentration of assessments with costs lower than 20.000€, while median and mean decrease in 2005 [Colombi et al., 2007].

Figure 5 shows the last page of the "Synthetic results form" "*Scheda di Sintesi*", prepared by the Latium Region [DGR Lazio 532 August 4, 2006] with all the information that professionals must acquire during the seismic assessment activity. This form is then used by Latium Region to develop a database on the adequacy of historical and public properties involved in seismic assessments The form is divided in three parts: the first one includes general information (identification, location, typologies of material, eventual rehabilitation works, foundations). The second part includes geological, geotechnical and seismic data, while the last part includes the structural data and the results in terms of capacity, demand and Risk Index α.

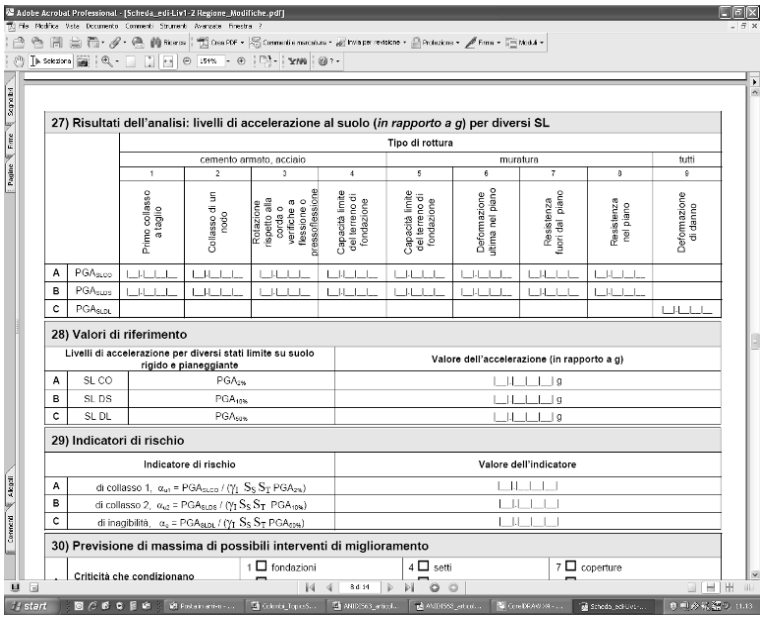

Figure 5. Synthetic results form ("Scheda di Sintesi")

On May 2007, LR appointed a Regional Scientific-Technical Committee (RSTC) of both supervising the seismic assessments by random sampling, and supporting professionals during all assessment phases. RSTC is composed by Engineers and Geologists from LR, NPCD and University. Its goal is to ensure a control activity over the seismic assessments to compare and objectively evaluate according to the Guidelines the results obtained by the professionals [Colombi et al., 2007].

As regards 2004 annuity, the Median value of volume of structures is 2.625m^3 and the geometric Media value is 4550 m^3. Since 2004 19.6% of the structures are located in seismic zone 1 (the highest) and 80.4% in seismic zone 2. 18.3% of structures are strategic for civil protection, while the remaining 81.7% are relevant structures; the topographic amplification is one of the factors to investigate and to indicate in the Synthetic form because it affects the index α in (1.1) and because 13.9% of the structures are located on crests. Another important factor in (1.1) is the soil parameter; the code [OPCM 3274 March 20, 2003; DM January 14, 2008] foresees five foundation soil types, collected in three main groups: A, seismic bedrock, B, C and E, soils with varying geotechnical parameters, and D, the worst soil foundations. From seismic assessments results, 34,2% of the structures are located on hard soil, 53,4% on intermediate soil, and only 12.4% on poor soil. LR established a 20% of seismic assessment cost is dedicated to geological studies. Most of Geologists in charge investigated the foundation soils with geotechnical samples and geophysical surveys. In this second case a good ratio between benefit/cost it was represented by MASW (Multichannel Analysis of Surface Waves) method. MASW investigation is used to obtain the Vs_{30} parameter (V_S weighing Media value of first 30 meters of soils), as requested by new Italian Codes. This method is simple and cheaper than other methods, but above all is really

reliable. For Second Annuity RSTC obliges to Geologists to carry out at least one MASW for seismic assessment which total cost (structural and geological assessment) is more than 12.500,00€. If the cost of seismic assessment is up to 50.000,00€ a Down Hole investigation is requested.

Seismic assessment procedure foresees the possibility to choose the analysis method (linear or non-linear analysis) to obtain the structural capacity; note that 50% of professional have chosen to adopt a non-linear method, especially, Push-Over analysis. As to the Risk Index as defined in Figure 4, the seismic assessments carried out depict a not reassuring situation of the adequacy level of structures investigated; 65.7% of the structures show a high Risk Index, 23.4% a medium risk, and only 10.9% in line with the seismic code. In particular, Figure 6 shows the Risk Index distributions for both strategic and relevant structures for 2004 seismic assessments.

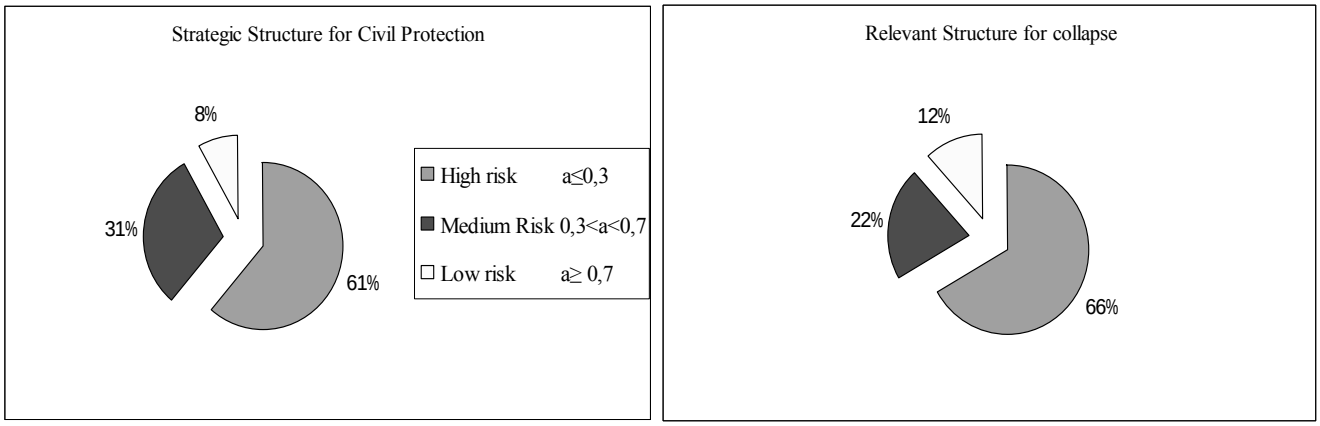

Figure 6 Risk Index for Strategic Structures (left) and Relevant Structures (right)

The statistic analysis of the seismic assessments results allows to put in relation the percentage of structures with a determined risk index α, as indicated in fig. 4, and clusters indicating four periods of construction year. Referring to the history of Italian seismic zonation and the evolution of seismic legislation in Italy from 1908 (Messina Earthquake M=7.5, 80.000 died) to 1984 (first national seismic zonation), Authors have identified three fundamental years for LR territory: 1917, when powerful technical seismic codes was issued after the dramatic Avezzano earthquake (M=7.1, 35.000 died) occurred in Central Italy and part of Latium Municipalities was classified; 1950, when the reconstruction in Italy after the end of Second World War started up again, and, at last, 1976, when a new modern national seismic legislation was issued. Analysis was carried out by either the reinforced concrete structures and or the masonry ones. Table 4 furnishes the percentages of masonry structures in relation to α value and cluster of periods of construction. It appears clearly a powerful decrease of percentage of high seismic risk structures moving towards the 70's and a correspondent increase of percentage low risk structures; the meaning of these data could derive by a better constructions in line to the seismic parameters of masonry structures year by year. Unluckily the trend of low risk structures increase does not present the same linearity of high risk structures decreasing.

Table 4 Percentage of masonry structures in relation to α value and year of construction

	before 1917	1917-1950	1950-1976	after 1976	Total structures
High risk (α ≤0.3)	111 (68,9%)	49 (65,3%)	77 (49,4%)	0 (0,0%)	237
Medium risk (0.3<α <0.7)	42 (26,1%)	18 (24,0%)	51 (32,7%)	0 (0,0%)	111
Low risk (α ≥0.7)	8 (5,0%)	8 (10,7%)	28 (17,9%	1 (100,0%)	45
TOTAL	**161**	**75**	**156**	**1**	**393**

Table 5 Percentage of reinforced concrete structures in relation to α value and year of construction

	before 1917	1917-1950	1950-1976	after 1976	Total structures
High risk (α ≤0.3)	3 (75,0%)	11 (68,8%)	82 (71,9%)	13 (81,3%)	109
Medium risk (0.3<α <0.7)	1 (25,0%)	2 (12,5%)	21 (18,4%)	1 (6,3%)	25
Low risk (α ≥0.7)	0 (0,0%)	3 (18,8%)	11 (9,6%)	2 (12,5%)	16
TOTAL	**4**	**16**	**114**	**16**	**150**

Different is the meaning of reinforced concrete structures statistic analysis. In fact table 5 shows values go against tendency with an increase of high risk structures percentages, above all, after the modern seismic legislation of 1976. When 2005 annuity has been completed too, a clear picture of these statistics will appear to confirm or to change these first statistical considerations.

3. MAIN PROBLEMS

Both administrative and technical problems have been coming up during the activities. One of the most administrative problems regards was the economic capacity of the beneficiaries administrations which benefitted from financings, because a number of them are small municipalities with restricted budgets. LR faced this problem granting the lacking funds for the seismic assessments but not for the rehabilitation works. The financing of the rehabilitation works (conventional cost of 150,00€/m^3) for 2004 annuity structures amounts to about 356 Million of Euro and even though LR intended to finance only the high risk index structure ($\alpha \leq 0.3$), the total amount would be over 261 Million of Euro. The 2004 annuity results show that about 15% of structures presents an α index equal o very close to zero (highest risk); in order to finance just these structures LR should invest more than 55 Million of Euro, that is three times than the seismic assessments budget foreseen for 2004-2005 annuities.

Among the technical problems, the most important was educating the professionals to the new rules stated in the new seismic code. The RSTC organized several meetings with Organizations of Engineers, Architects and Geologists. Furthermore, the RSTC reviewed a number of assessments and rehabilitation projects. Probably, this effort should have been bigger, considering the number of professionals involved and the number of new computer codes issued immediately after the code update. This updating process has reached only in January 2008 a stability with the new Building Code.

4. CONCLUSION

The dramatic consequences of San Giuliano di Puglia earthquake (October 31st 2002, M=5.4), with the death of 29 people under the collapse of an elementary school, has speeded up the activities to reduce seismic risk in Italy. The new Italian seismic codes [OPCM 3274 March 20, 2003; DM January 14, 2008] issued between 2003 and 2008 have given a first powerful answer to this problem, above all for that structures defined as strategic for civil protection activities after an earthquake, and also for relevant structures, whose collapse can produce loss of human lives or damages of artistic and historical heritage. This urgent assessment action has been launched in all Italian Regions at the same time, with the aim of undertaking a positive initiative before an earthquake hits the critical structures. Due to the particular seismic conditions of Latium Region, most of the structures are located in either very high or high seismic hazard zones and most of them are constructed without any anti-seismic criteria. So far, 1170 structures have been financed to get seismic assessments and for 13 buildings rehabilitation works have been undertaken.

At the moment, the seismic assessments are included in two annuities; 2004 annuity has been already carried out, whereas, 2005 annuity started on January 2008 and activities deadline is fixed by June 2009. In conclusion, seismic assessments results, related to 2004 annuity, describe, a worrying outline; in fact more than 60% of investigated structures present an high level of risk, that means, a large shift from the adequacy level provided in the codes of new Italian seismic legislation. This high percentage of risk can be partially explained considering many structures were built before the second world war and several before 18th and 19th century. Nevertheless it appears quite striking that most of structures investigated by means of seismic assessments were built after 1970, when the seismic legislation has already provided for more restrictive parameters and to prevent construction of unsafe buildings and structures. 2004 annuity show a budget for rehabilitation works that, at the moment, exceed the real economic possibility of LR, which should close the best strategy to finance the rehabilitation works activity.

LR dedicates a specific web-site including news, case-studies, examples of calculation, normative and whatever

can be useful to the Beneficiary Administrations and to the Professionals involved (*http://www.regione.lazio.it/web2/contents/ambiente/argomento.php?vms=5&id=55*).

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