SAVE - Updated Tools for the Seismic Vulnerability Evaluation of the Italian Real Estate and of Urban Systems

Coordinators: Prof. Mauro Dolce and Prof. Giulio Zuccaro

Introduction

The fundamental objectives of the project are:

- Realising updated maps of seismic vulnerability and risk of the Italian residential building stock, of the public buildings inventoried by the Lavori Socialmente Utili (LSU) project in Southern Italy and by other initiatives, of the monumental buildings of some areas of great environmental and monumental value (parks), of some small urban systems.
- Completing and rationalising the most important existing data-bases, particularly those relevant to LSU projects.
- Comparing and improving the methods for the evaluation of the vulnerability of different structural types (ordinary buildings, monumental and historical buildings, churches), when applied to the above mentioned data bases, in order to integrate and harmonise them.
- Developing models for the evaluation of the indirect losses and of the socio-economical consequences of earthquakes

The SAVE Project has nominally started on September 2002. This report, therefore, is relevant to 7 months of activities only. Moreover the activities of the project depends, in a great extent, on the full availability of the original LSU data and of the research funds allocated for SAVE. Both these prerequisites have been missing, for different reasons, which cannot be ascribed to the coordinators of the project. The original LSU data, which are only partially available in an electronic database, have not been delivered yet to the project coordinators. The reasons are related partly to problems raised up after the collapse of the S.Giuliano school due to the Molise earthquake, partly to a transfer of competences within the Department of Civil Protection. The problem is just being solved, thus allowing the activities for rationalising and integrating LSU data bases to start. The research funds have been delivered to the project responsible only at the end of 2003, and the transfer of funds to the research units has been carried out very recently, due to the balancing the books period. Therefore only recently it has been possible to start expensive activities.

In the meanwhile, an earthquake struck Molise and Puglia on 31.10 and 01-11.2002. This earthquake represents an excellent test for some inspection procedure and vulnerability assessment, whose improvement is one of the main objectives of SAVE, and for the increase of the existing damage/vulnerability database of buildings.

For all the above reasons the activities have been developed according to a different scheduling with respect to the original working programme. A series of activities for the set up of tools for the inspection, vulnerability assessment and analysis of data relevant to the Molise earthquake have been carried out. At the same time the already available electronic data bases of LSU have been partially processed. Finally, the collection of a large set of data has been started, to be used for the next activities.

Task 1. Inventory and Vulnerability of the Residential Building Stock in Italy, Seismic Risk Maps and Socio-Economic Losses

Scientist Responsible: Giulio Zuccaro

As said in the introduction the Molise earthquake has suggested to change the working programme to take advantage from a detailed survey of the damage and by a prompt test on the field of some new tools of vulnerability evaluation in progress.
In November 2002 a team of researchers coordinated by Prof. Dolce and Prof. Masi (University of Basilicata) and by Prof. Zuccaro of the Naples' University surveyed San Giuliano collecting data on structural characteristics and damage of buildings. The main goal was the interpretation of a strong disomogeneity in the damage distribution, with high concentration of damage along the main road of the village. The data were collected by using a modified AeDES form and the new MEDEA form.
Method: The data collection has been performed on all the buildings of San Giuliano. The objective was to compare different parameters involved in the vulnerability evaluations and/or in the structural safety judgements and modelled by different data collecting techniques on the same complete, homogeneous and reliable set of data.

First results: A preliminary analysis of the damage and of the structural types has shown that the San Giuliano settlement could be subdivided in 5 homogeneous zones. Within these zones the vertical and horizontal structural distributions have been identified. More than 70% of the buildings has masonry structures, mainly of poor quality, and more than 50% has wooden or steel beam floors. The seismic vulnerability has been evaluated by combining the vertical and horizontal characteristics. Damage scenarios have been prepared for Intensity I_{EMS} = VI, VII e VIII. The damage has been classified according to the 1998 European Macroseismic Scale. The damage distribution surveyed in the 5 zones has been compared to the estimated ones. The damage registered has shown the presence of high level of seismic vulnerability in the urban centre as a whole, however strong variations in the different zones have been observed. The first analyses, based on the comparison between evaluated and observed damage, show that the observed damage in the historic centre is basically due to the building vulnerability. On the opposite, the strong damage occurred in the zone along Corso Vittorio Emanuele, much bigger than that observed in the historic centre, cannot be caused by the building vulnerability only, and local amplification effects could have had a significant role. Detailed analyses to assess the influence of the different factors are in progress.
The first correlations between damage, structural types and collapse mechanisms have confirmed the ones assumed by the MEDEA approach. The out of plan overturning mechanisms have resulted to be the most vulnerable ones. These mechanisms have been mainly observed in the weakest class "A". However the same mechanisms were the most dangerous even for class "B" or "C" buildings. On the other hand the most frequent collapse mechanism, mainly observed on buildings with low level of damage, is the in-plan shear mechanism, due to the low quality of masonry. (see diagram).
A San Giuliano GIS has been produced in order to show the different themes of the studies in progress, also for future microzonation analyses.

The RU GNDT-AQ has performed a specific investigation having the same goals and using the same survey forms on the municipality of Casalnuovo Monterotaro (Foggia), which experienced a 7 MCS shake. This territory was carefully studied in the emergency phase and particular attention was paid to the organization of the census data of the seismic safety of the buildings (AEDES form). The data are now complete of geographic reference. The first analyses performed on the data base and on the GIS have given interesting results, both for the safety evaluation procedure and for the vulnerability and damage correlation. Some of the results are shown in the diagrams in appendix.

The completion of the computerization of the inventory data-base of dwelling buildings of Mid-Southern Italy collected in the LSU/96 and LSU bis projects, has been only recently started, because of the above mentioned difficulties on the accessibility to the original data. Therefore no feasibility feed back is available yet. However the integration and harmonization activities of data bases, already available in Italy and not yet utilized as a whole, are in progress. The main data base of the structural types of 78 Italian Municipalities developed by the Centro di Ricerca LUPT of the University of Naples in two previous projects supported by SSN (35 Communes) and by GNDT-CNR (43 Communes) are being merged with the data of:

- 18 Municipalities in the Vesuvian area, collected by the Centro di Ricerca LUPT within a previous project supported by GNDT-OV-INGV;
- 3 Municipalities in the Campi Flegeri caldera the collection and organization of which are in progress within another project supported by GNV-INGV;
- 20 Municipalities in the area of Potenza and 3 Municipalities of the Pollino area put at disposal by DiSGG ;
- 18 Municipalities of the Matese area collected by GNDT-AQ;
- the city of Catania, collected within the Catania project supported by GNDT-CNR.

Investigations and compatibility checks on other Italian data sets are still in progress.
The selection and representativeness criteria of the urban settlements to be included in the Data Base have been defined and contacts with ISTAT for the availability of the census 2001 data have been taken. Finally the working group is upgrading the characterization study of the structural types in the Italian urban settlements, derived from previous research experiences of LUPT-GNDT-SSN, through the merging between: the data-base available and the compilation of the guided interview protocol.

As far as the activities relevant to the vulnerability of masonry and R/C buildings and to the improvement of the analysis tools are concerned, besides the activities carried out for the Molise earthquake, the attention has been focused on the review of the different methodologies to evaluate the seismic vulnerability of buildings, with particular reference to the Italian experience. The research work in the second half of ninety's has clarified the conceptual frame of reference, produced a new first level procedure for the survey and measure of vulnerability factors and seismic damage of ordinary buildings (AeDES form), calibrated Damage Probability Matrices for different vulnerability classes and macro-seismic MCS intensities.
In the present research a direct reference to the new European Macroseismic Scale EMS 98, both for vulnerability classes and local intensities, has been assumed.

Therefore a first hypothesis has been suggested for building's classification, modifying a previous proposal presented to a SSN Working Group.

As far as the evaluation of human losses, damage and in direct losses, several activities have started, which are summarised as follows.
The evaluations of the economic impact, in the San Giuliano event, connected with direct and indirect economic losses, and social losses (people involved) are in progress. The cost of the earthquake has been estimated through damage vs.repair/retrofit cost correlations, for different levels of structural and non structural damage.
The losses stemming from interruption of activity (industry, tourism, commerce, etc.) have been analyzed. The "Sistema Starter" has been employed, which includes more than 1000 province-based territorial indicators, 600 of which also contain details at municipality level. The database will feed data to a statistical model, based on multivariate analysis techniques. It will first be adjusted on a pilot area recently involved in a seismic event – both pre- and post-event conditions will be assessed (settlement configuration, quality of buildings, levels of production in the three economic sectors, etc.). It will then be tested on other pilot areas, in order to stabilize the estimates of the regression parameters and to evaluate indirect annual costs stemming from the destruction/activity interruption on a national scale.
Correlation functions between damage – typology and casualties are being studied and data sets relevant to earthquakes in Italy and in the world are being collected.

Task 2. Inventory and Vulnerability of the Public and Strategic Buildings of Southern Italy

Scientist Responsible: Mauro Dolce

The programmed activities for the first year of TASK 2 can be summarised as follows: a) analysis and extension of the existing data base to rationalise it and get statistical parameters, as well as to make it usable by all the research units; b) Identification of the peculiar characteristics of the structural types of school and hospital buildings; c) collection of further data on the buildings for school and civil use; d) start of the «analytical» vulnerability evaluations of schools and hospitals. All these activities have been started and taken to an advanced level of development, with the exception of a), for the reason explained in the introduction. In the meanwhile, one of the activities pertaining to the second year of the project has been started, precisely the one relevant to the refinement of the survey methods and of the vulnerability evaluation procedures for public buildings.

The vulnerability census of public, strategic and special buildings has been carried out in seven "Regioni" of Southern Italy: Abruzzo, Basilicata, Calabria, Campania, Molise, Puglia ("provincia" of Foggia) and Eastern Sicily. The data of 42000 buildings were collected by using the GNDT 1st and 2nd level inspection forms and reported in an electronic database. The purpose of the buildings has been classified in: Instruction (49,6%), Civil (26,8%), Public health (9,7%), Military (4,7%), Mobility and Traspportation (3,8%), Tecnological (2,6%), Religious (1,8%, excluding churches). 37,9% of the buildings has masonry structure, 59,4% R/C structure, 1,9% steel structure. All

masonry buildings have been surveyed with the 2nd level form, while the other buildings have been surveyed normally with the 1st level form. For the objectives of the research project a check of the database has been made, from which the presence of incomplete or uncorrect data relevant to about 1.5% of the buildings resulted. These shall be checked with the original forms and, eventually, corrected.
As far as the improvement of the knowledge of the structural characteristics and the vulnerability is concerned, specific analyses have been programmed on the whole sample and on sub-sample relevant to single "regione" and "provincia". The work has started from the school category, which includes 20890 buildings. 7.379 (35,3%), 13.041 (62,3%) and 384 (1,9%) buildings have masonry, R/C and steel structure, respectively. Masonry buildings have been analysed in greater detail, due to their higher vulnerability and the more detailed information available (2nd level form).
About 80% of masonry school buildings has less than 4 stories (23% one story, 29% two, 28% three). More than 50% has a volume less than 2500 m^3 and about 10% more than 10000 m^3. 90% was built before 1970 and 28.5% before 1945. The first level form contains the description of the types of vertical and horizontal structures and of the stairs. A first characterisation has been made by elaborating these pieces of information. The presence of some prevailing vertical structures, differently distributed in the territory (see map). Type G masonry ("tufo" blocks or cut stones – 37.9%), type L (brickwork - 24.8%) and C (roughly squared stones – 12.7%) are the most frequent in the whole sample. In the different "regioni" quantitative differences as well as the significant presence of peculiar types are observed, due to the local history and traditions.
The information on the building characteristics drawn from the database has been used also to group buildings into vulnerability classes, according to two different criteria, whose one is the definition of the EMS classes. Even this description of the structural quality show important difference between the different "regioni".
From the 2nd level form of masonry buildings a vulnerability index Iv, defined in a 0-100 range, has been evaluated, by summing up the scores associated to 11 parameters affecting the seismic behaviour. The whole sample has an average vulnerability score equal to 21.5, with a queue towards the upper bound and a maximum value equal to 80. 229 buildings with Iv>50 are found (3% circa). Differences in the index average of sub-samples relevant to single "regioni" and "province" exist. The correlation between Iv and the EMS classes has also been analysed (see diagrams). Further elaborations will be soon carried out to improve the evaluation of the vulnerability index, by both re-examining the additive vulnerability model utilised and by improving the 2nd level with the 1st level information, e. g. to account for past seismic retrofits.

In the meanwhile the activity of finding documentations and information on a limited sample of school buildings for detailed analyses has started. This activity has been made easier by the great attention towards the vulnerability of school buildings after the collapse of the S.Giuliano school. Due to a contract with the "Provincia" of Potenza, the RU of UNIBAS could find detailed information on about 130 school buildings pertaining to the "provincia" of Potenza (high schools) and to the relevant municipalities (nursery, primary and secondary schools). Inspections and geometrical surveys have been or are being carried out on all these buildings, while the design, construction and final check documentations have been found, whenever possible.

Finally information on interventions and transformations carried out during their life as well as on damage produced by past earthquakes. They have also been analysed by a procedure for the evaluation of their seismic resistance in terms of PGA, determining the structural collapse. On part of them a series of accurate site investigations on the materials (compression tests on concrete cores, rebound and ultrasonic tests on concrete, tests on masonry) will be carried out, in order to assess the actual mechanical characteristics of the structural materials and improve the seismic resistance evaluations.

Looking at the high school building sample (see diagrams), only 50% are designed with seismic criteria. About 80 % are R/C buildings and little more than 10% are masonry buildings, with few buildings having steel structure. The buildings constructed before 1970 and after 1980 sum up to 80%. The characteristics of the sample of the nursery, primary and secondary school building sample are quite different. Buildings are generally smaller, with a large percentage of masonry buildings (35%) and a lower percentage of after 1980 buildings (15%). Generally speaking, the available sample is well distributed over all the characteristics that can affect vulnerability, and represent an excellent database to improve vulnerability analyses. However, further documentation is being found relevant to buildings from other Italian "regioni" (Molise, Abruzzo, Toscana, Campania, etc.), which should permit to extrapolate the results of the detailed analyses to a larger population.

The availability of detailed information and documentation on a big number of school buildings makes it opportune and necessary to re-modulate the working programme, taking also account of the 30% reduction of the funds allocated for SAVE. Therefore the detailed analyses on hospital buildings (about 20 buildings in the original programme) will not be carried out.

As said above, two new procedure for the quantitative measure of vulnerability have been set up, in order to fully exploit the available pieces of information. Starting from the observation of the prevailing structural characteristics, story collapse mechanisms are identified for which it is possible to make simplified calculations. As far as masonry buildings are concerned, their structural characteristics, particularly the presence of R/C–tile slabs, makes it to exclude the possibility of out-of-plane collapse of the walls. Therefore seismic resistance depends only on the in-plane strength of walls. As far as R/C buildings are concerned, the positive contribution of masonry infills, whenever effective, is taken into account. Both procedures are implemented in an electronic sheet and are being improved through the application to the real cases under examination.

Finally an important occasion to verify both the potential of the AEDES form (for usability and damage of buildings) and the vulnerability evaluation drawn from the LSU database can be obtained from the analysis of the data collected on the school buildings in Molise, after the earthquake. Information on both structural types and damage are reported on these inspection forms, which permit to evaluate the relevant correlations. This activity will start as soon as these data become available.

Task 3. Inventory and vulnerability of the monumental buildings of the national and regional parks of Southern Italy

Scientist Responsible: Sergio Lagomarsino

In the first year, the Project activity, focused on two particular aims, was carried out: 1) the critical review of the methodologies applicable to the territorial scale for the monumental heritage, through a definition of the state of art of the vulnerability models available in the literature; 2) the acquisition of the vulnerability data surveyed in the LSU-Parks Project.

The critical review of the methodologies available for a vulnerability analysis of the monumental buildings has taken into account some prerogatives: the need to survey and to analyse a wide population of buildings, on a widespread territorial scale; the historical-architectonic value, that normally imposes a more detailed approach in comparison with the models used for the vulnerability analysis of the ordinary buildings; the need of a validation of the models through the damage patterns effectively caused by the earthquakes.

For these reasons, apart from the level of detail of the analysis, the data must be collected through forms correlated to the constructive, typological and material aspects that have been highlighted as fundamental in the judgment of the vulnerability, from the damage observation after the past earthquakes. The methodological review has been carried out to organize the vulnerability analysis in three levels, through the definition of various vulnerability models, which represent a progressive deepening, based on the greater detail of the available data.

The first level of analysis is based on poor data; in this case the approach must necessarily be typological; the vulnerability is mainly connected to the kind of the monument (palace, church, tower, castle, etc). The model individuated as the more effective and versatile is the one developed within the TRAIANO Project (that is one of the projects funded by the GNDT); it is based on the attribution of a vulnerability index to each single building, defined in function of the typology of the monument and corrected through modifier scores, that are correlated to some easy noticeable parameters (state of maintenance, material quality, structural regularity, etc).

The model is based on a very simple form and represents, therefore, a tool of quick and immediate application on the territory, which allows us to elaborate damage scenarios for each monumental typology.

The limit of the first level methodology is due to the aspect that the vulnerability is considered in a global way; on the contrary, the damage observation has highlighted how, according to the architectonic complexity of such kind of buildings, to the constructive characteristics (constructive phases, transformations, etc.) and to the poor tensile strength of the masonry, the damage and collapse often take place locally. An effective approach for studying the problem is to decompose the construction in macroelements, parts of the building characterized by a substantially independent seismic response and simply associable to an architectonic element.

The second level analysis must, therefore, be still defined on a typological-qualitative approach, but the appraisal is more detailed because: a) it is referred to the single macroelement and not to the overall construction; b) the vulnerability parameters are analysed taking into consideration the collapse mechanisms, recognized after the systematic observation of the damages of the past earthquakes.

Such approach is currently possible only for the churches, which represent, however, beyond the 80% of the Italian monumental heritage; the UR of Genoa has developed a methodology that is based on a critical revision of the forms used for the survey of the damage caused by the last Italian seismic events (Lunigiana and Garfagnana, Reggio Emilia, Pollino, Lazio, Umbria and The Marches and Val Tiberina, Asti and Alessandria) and for some preventive assessment campaign of vulnerability analysis (LSU-Parks Project, Molise Project). Having at disposal beyond 6000 relieves of churches damaged by the earthquake, it has been possible to define the damage probability matrices (DPM), for different classes of vulnerability. The obtained histograms are well-fitted by the binomial distribution, characterized by only one parameter, the medium damage d:

$$p_k = \frac{5!}{k!(5-k)!} d^k (1-d)^{5-k} \tag{1}$$

The medium damage may be correlated to the macroseismic intensity I, for different vulnerability classes (associated to a value of the vulnerability index V_I, obtainable from the compilation of the form), through the analytical function:

$$d = 2.5 \cdot \left[1 + \tanh\left(\frac{I + 6.25 \cdot V_I - 13.1}{2.3} \right) \right] \tag{2}$$

The approach for macroelements and collapse mechanisms is useful, also, for the definition of a third analysis level, based on the mechanical appraisals of the seismic vulnerability. Such approach must, however, maintain the characteristics of a simplified analysis. Only in this way, the method could be automatically applicable on a meaningful number of buildings, even if lesser than the typical sample of the methods of I and II level, in order to respect the territorial approach of the vulnerability analyses. The solution proposed is based on the equilibrium limit analysis, taking into consideration static and kinematic theorems, applied to the masonry, considered as rigid body with no resistance to tensile stresses; the earthquake, therefore, is simulated as a horizontal static force, proportional to the masses, and the obtained collapse multiplier represents the spectral acceleration.
This approach allows us to estimate, with few geometrical and typological parameters, a macroelement capacity curve, estimating the effectiveness of some aseismic devices (tie-rods, buttresses, etc). The III level method represents also a tool of validation and calibration of the qualitative methods (I and II level), otherwise bases only on the interpretation of the observed damage.

- *Molise Activity*

The seismic event, that has shocked the Molise Region in the October- November 2002, has determined a direct engagement of the RU to support the activities coordinated by the COM of Larino (Function 9). Such activity has allowed us to apply, critically, various assessment tools, both institutional (published on the GU) and developed from the RU. After the critical revision of the existent methodologies,

carried out in the project and described in the previous paragraph, we individuated the need to modify the form used in the Umbria and The Marches earthquake; the seismic event of the Molise has represented the opportunity to operate some modifications and to immediately verify on the field the applicability and the validity of the new form.
A critical point of the previous form was in the vulnerability survey, as it was mainly thought for the damage survey; in fact, each collapse mechanism was characterized only by two vulnerability indicators. In the new form, the vulnerability survey is carried out regarding a double approach: aseismic devices and vulnerability indicators.
For example, the presence of a buttress or a tie-rod can be considered as an aseismic device, that contrasts the activation and the development of a mechanism, while the presence of pushing elements or concentrated masses on a vault, represent a source of vulnerability (in the previous version, the aseismic devices were posed in negative, asking to the technician to express about the absence of these features; the vulnerability survey was not clear and, sometimes, conceptually not correct). For every damage mechanism, it has been inserted a list of aseismic devices and vulnerability indicators, and it is possible, in any case, to integrate them with specific constructive detail of the building (according to the judgment of the technician).
Another change has been the increase of the number of the damage mechanisms from 18 to 28; this has been necessary, in particular, for the big churches, in which, many macroelements are present (transept, lateral chapels, etc). A more detailed articulation of the mechanisms in the several macroelements allows us to better graduate the weight of the local damage for the appraisal of the total damage; moreover, the uncertainties in the compilation and the arbitrariness, generated in the original form, caused by its excessive synthesis, are limited. Even if the new form appears longer and articulated, the features of an easy and quick applicability are not, absolutely, loosen.

Task 4. Inventory and Vulnerability of Urban Systems

Scientist Responsible: Alberto Cherubini

In 1999 GNDT coordinated the technical and scientific activities of a Vulnerability Census of the infrastructures of some towns of Southern Italy, carried out by the Department of Civil Protection. 67 small and medium importance towns were selected on the basis of some parameters drawn from the 1991 Italian Census (ISTAT '91) data, such as: altitude, number of inhabitants, volume of buildings, seismic classification, etc.. 23922 inspection forms were compiled, relevant to:

- primary urbanization lifelines (water, gas, power and telephone supply system, city sewer system, etc.);
- railway and road network (only concerning the towns), both branches and nodes (bridges, viaducts, crossings, other structures, etc.);
- systems and subsystems affecting the urban vulnerability of the town (morphological structure, ways of escape, safe places, communication systems, services, etc.).

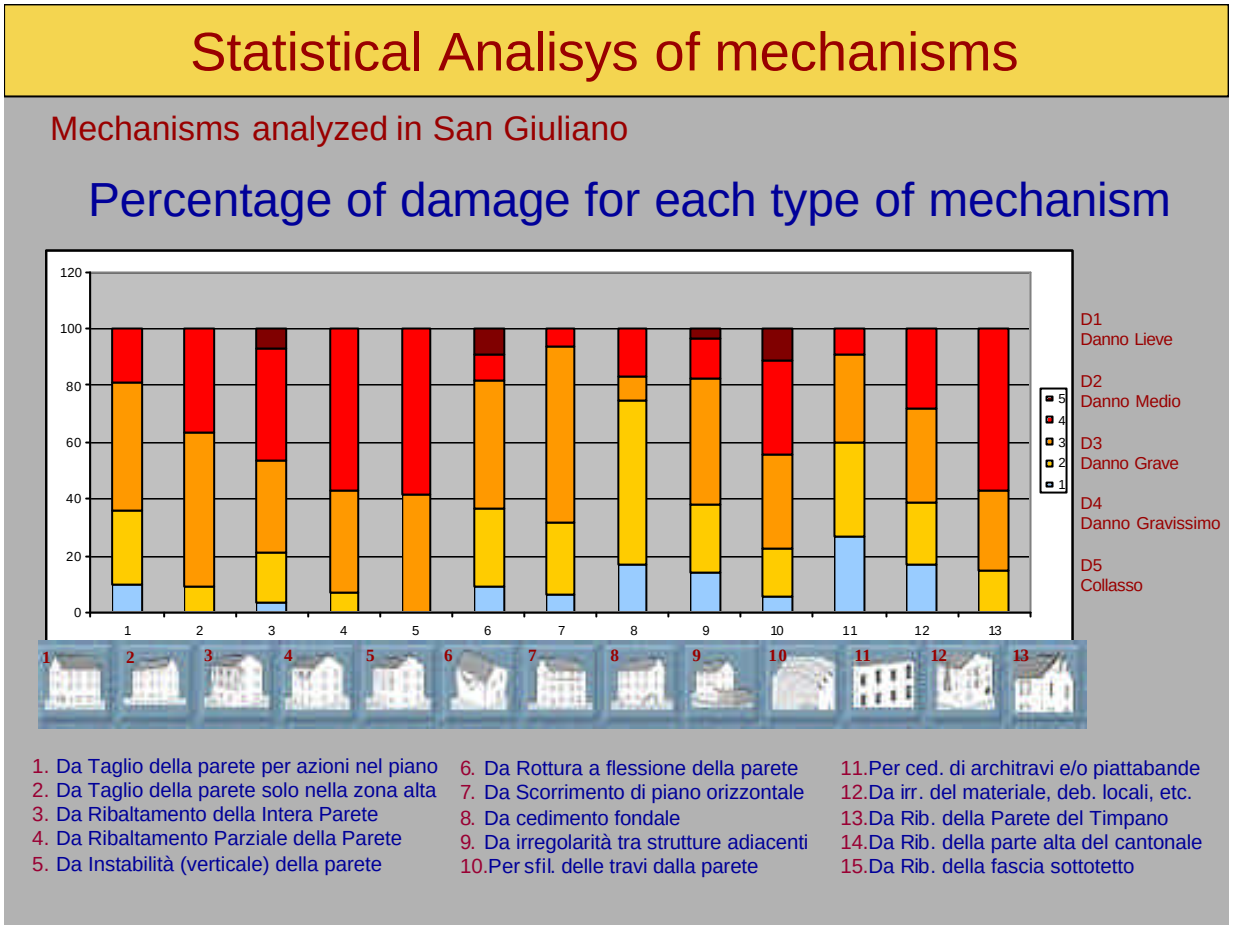
The original inspection forms and the documents collected during the survey (town maps, urban vulnerability forms, etc.) are deposited at the Civil Protection Centre, where also the data relevant to other censuses carried out between 1996 and 2000 are placed. A software to input this big amount of data in an electronic database has been set up and only 1764 forms are now in the electronic database, for the first elaborations.

The first deliverable for the first year of the SAVE Project is relevant to the construction of a rational and integrated electronic database, where all the collected information are included. Unfortunately it has been impossible to carry out such activity due to the unavailability of the original forms. For the same reason it has not been possible to check the sample of towns, in order to ascertain their significance and the greater or less amount of information available, as it is, again, necessary to work on the original data. This latter activity is necessary because a certain number of towns has been modified during the project, due to some difficulties of access.

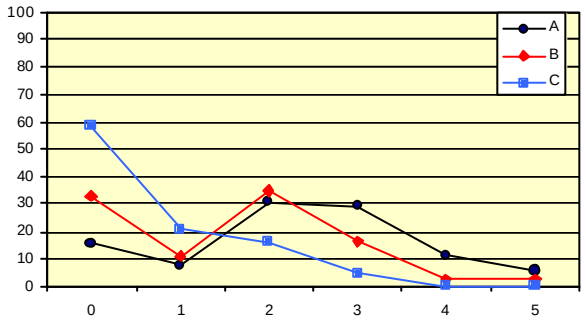
The second deliverable is a review of the methods of evaluation of vulnerability. In this respect it is necessary to distinguish between methods of evaluation of networks and methods of evaluation of urban systems. These latter are aimed at estimating the so-called Urban Vulnerability. For the former ones several approaches are found in the literature. One approach makes uses of logical-mathematical procedures applied to the branch-nodes components of the network. The inadequacy of a component in carrying its own task (from the reduction to the total collapse) due to a possible seismic event, results in the partial or total loss of functionality of the network. Another approach makes use of “expert” evaluation procedures, through qualitative indicators, by direct estimation or rules of association of the vulnerability of the single network components. Even for the evaluation of the vulnerability of urban systems different approaches are found in the literature. The analytical approach is based on a fast vulnerability evaluation of the built system as well as on some geometrical and geomorphological information which describe its shape and characteristics. A more global approach, utilised in the elaboration carried out on the data of the Census of the monuments in the Parks of Southern Italy, is referred to both synthetic parameters that describe the physical structure of the Town, and to correlation tables between systems (e.g. transport system, school system, Public Health system, etc.) and their efficiency after a seismic event.

Task Group 4 has had many meetings to examine the above said evaluation methods. Initially it was deemed opportune to consider both analytical and global approaches, in order to verify the quality and the type of obtainable information, even with calibrations on the first group of forms already available in the database. Previous experiences in the elaboration of other vulnerability censuses let us believe that both ways can be pursued.

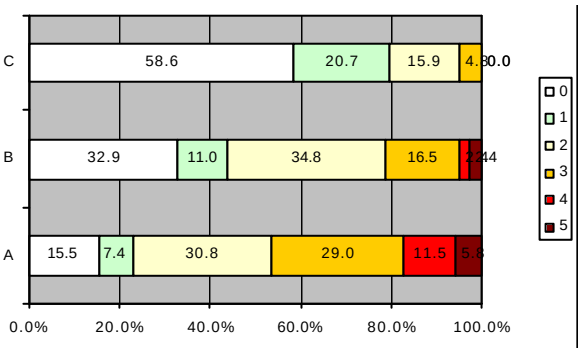
FIGURES RELEVANTO TO TASK 1



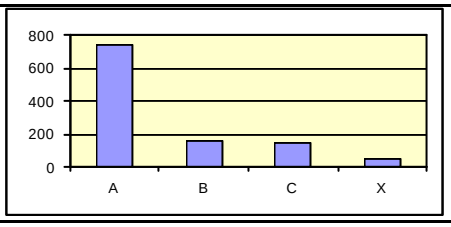
Statistical analysis of damage mechanisms detected in S. Giuliano



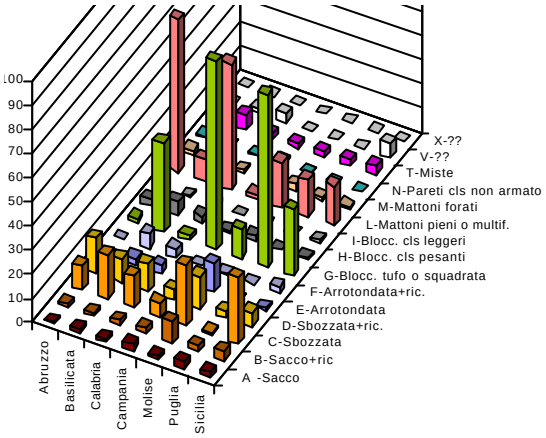
Distribution of buildings in the A,B,C EMS 98 classes, for each damage level



Percentage of buildings per damage level within each vulnerabilità class

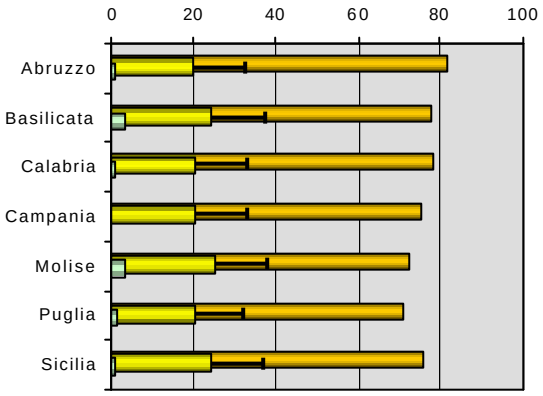
Casalnuovo Monterotaro (FG) ISTAT code 071013 Inhabitants ('91) = 2370 Houses 1410 ('91) Seismic zone S=9 (2nd category) No. of masonry buildings: about 1.000 No. of R/C buildings: about 100	
	Data of the historical centre collected with Aedes

FIGURES RELEVANT TO TASK 2

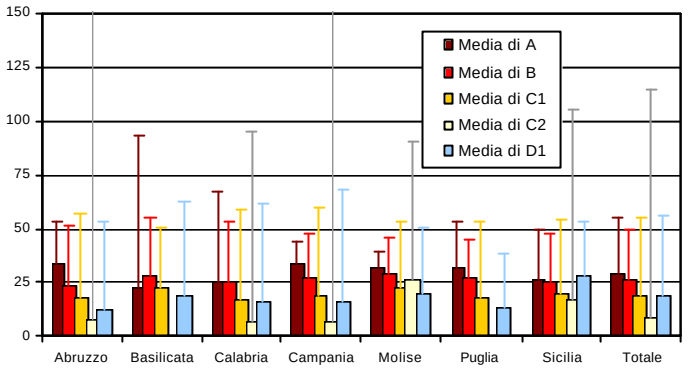


Vertical structural type per "regione"

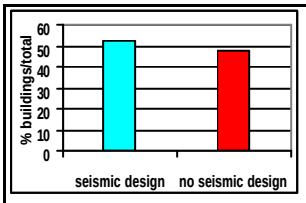
Prevailing vertical structural type

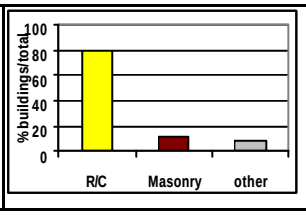


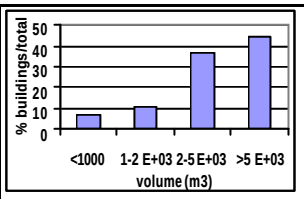
Minimum, mean, maximum and SD of the vulnerabilità index of masonry buildings

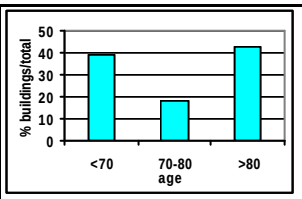


Mean values and CoV of the vulnerabilità index of masonry building for EMS classes

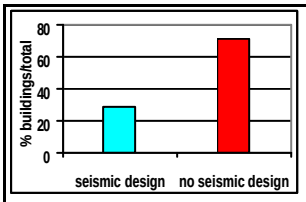


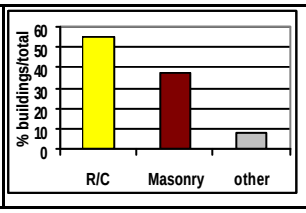


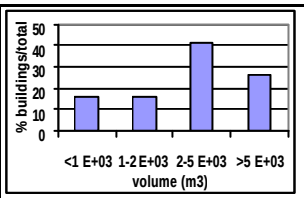


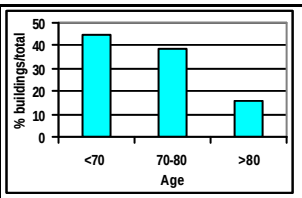


Characteristics of the buildings of the high schools of the "Provincia" of Potenza (whole population).









Characteristics of the buildings of the low schools of the municipalities of the "Provincia" of, Potenza (partial population).