Scenarios of seismic damages in Friuli and Veneto

Scientific Coordinator: Prof. Marcello Riuscetti

INTRODUCTION

The objective of the project is to define, with the best possible approximation, the seismogenic potential of the area and to draw acceptable seismic scenarios for the city of Vittorio Veneto after a complete revision of the earthquake catalogue especially devoted to evaluate the possible existence of silent sources and relocation of the strongest known shocks. Modelling of potential sources together with new attenuation laws gives input data for the modelling of the site response in Vittorio Veneto. A detailed vulnerability analysis in the older quarter of Vittorio Veneto and a simplified one for the rest of the city put together with exposure data will end in the scenarios.

Task 2.1 – Seismic source parameters (A. Rebez)

The objective of the second year was to give a geometric and cinematic characterization of the active faults in the NE-Italy. The definition of a new picture of seismogenic sources in the easternmost Southern Alps resulted from the collaboration of CNR-IGAG and Uni-Udine. Hypotheses of seismic zonation of NE Italy resulted from the collaboration between CNR-IGAG and the coordination of the task 2.3 (A. Rebez).

The data set for the pinpointing, for the description (both in outcrop and in deep) and finally for the parameterization of the active faults derived from: 1) detailed geological mapping and dating of Quaternary deposits (partially inside the CARG Italian Project: national geological mapping: Udine and Maniago sheets); 2) geomorphologic and morphotectonic mapping of selected areas; 3) analysis of aerial photos 4) mesostructural and cinematic analysis of detected structures; 5) analysis and reinterpretation of seismic lines of the Friulian plain (ENI/Agip) and of the Eastern Veneto plain (provided by the British Gas).

Since February 2002, we tried to make hypotheses on the geometry of the seismogenic sources in the investigated area, based on the segmentation of the thrust system affecting the northern border of the Venetian-Friulian plain. The preliminary document was represented by the prototype segmentation proposed in the 1st year report. The new segmentation resulted from further large-scale geomorphologic investigations and from structural data (superficial and sub-superficial). Structural data have been provided by the RU Uni-Udine, and have been checked and discussed in order: 1) to test the reliability of the geomorphologic data on the location of the tips of the single segments and 2) to define the sub-superficial geometries. The formulation of hypotheses about the sub-superficial fault geometries has been fundamental to define 3-D pictures of the seismogenic sources.

Once superficial segments and sub-superficial geometry of the faults have been defined, sources have been drawn through the identification of the thrust ramps, i.e. those parts of the fault planes characterized by higher dip. We believe, indeed, that

thrust ramps represent the portions of active compressive structures which are prone to trigger earthquakes. The geometries of the sources indicate that while the length of a single source is the same of the superficial segment, the down-dip width has been corrected for the representation in plan view.
Based on the comparison between source geometry and damage distribution related to historical earthquakes, hypotheses of association of earthquakes to specific sources have been made. The evaluation of the Mw from source areas (by means of the classical equations linking Mw with geometrical parameters of the sources) and the comparison of the obtained Mw values with the M values of the associated earthquakes reported in the catalogues define a general consistency of the proposed source/earthquake associations.
Available data define 10 seismogenic sources all related to thrust faults, between Thiene (Veneto region) and Pozzuolo (Friuli region). Each source is characterized by parameters defining the geometry (rupture length, rupture area, ...), kinematics (rake, and qualitatively poor slip rates), associated Mw and historical earthquake. Two of these are silent sources. One of these source, i.e. Montello-Conegliano, is particularly interesting for the present project. The absence of historical earthquakes, i.e. a probable silent behavior during the last 8 centuries, defines a high level of seismic hazard. The Montello-Conegliano source, together with the Mt. Cansiglio-Mt. Cavallo and Polcenigo-Maniago sources should be used to define damage scenarios for the Vittorio Veneto area.
The defined sources have been used to draw a new seismogenic zonation of NE Italy A seismogenic zone has been defined by drawing a polygon including all the sources which may be responsible for earthquakes with M=6. This zonation is presently layered, the uppermost layer (modeled on the base of the sources) defines the contribution to the hazard of the M=6 earthquakes. A second and larger zone includes the earthquakes with 5.1=M=5.9, while the lowest zone includes the M=5 earthquakes. Tests are going on in order to check the reliability of this seismogenic zonation. Ongoing detailed investigations are presently dedicated to the other silent source, i.e. the Maniago-Ragogna source. In particular, during 2002, large scale geomorphologic investigations have been performed on the Sequals basin by means of the analysis of aerial photographs, in order to define the origin of the basin. Radiocarbon dating of deposits collected through drilling has been made, aimed at defining the chronology of the basin. The analyses will be continued during 2003; the results will be reported at the end of the current project.

A historical approach to estimate the completeness of the seismic catalogue CPTI in Belluno/Cansiglio and Asolo/Vittorio Veneto areas - *Goal*: definition of time intervals of completeness for earthquakes with M = 5.5 in the above mentioned zones, to be used for seismic hazard assessment with a traditional approach. The investigation was devoted primarily to the place of Vittorio Veneto, and then to Belluno, Asolo, Treviso, Bassano del Grappa for the time-window 1100-1899. The seismic history of each place has been obtained by merging the intensity values observed and available in the data banks DOM and CFTI and the calculated ones (using the seismic catalogue CPTI) for those earthquakes for which no observations are available at the investigated sites. The set of data obtained has then been analyzed, with the primary goal to understand the informative background put

together so far by historical seismology studies. Useful suggestions have emerged, which have been translated into guidelines for the following research steps, aiming at identifying and collecting historical essays and primary sources hitherto not considered. This investigation, though not an exhausting one, has highlighted which are the time-windows characterized by serious gaps in the documentation on the history and evolution of each place. Such gaps could in fact be attributed either to particular and local situations or to the loss in the central repositories of the various governments which have ruled each place along the centuries.
The seismic histories, prepared for each place as in the example shown above, go over the fundamental changes in the geopolitical and administrative evolution of the place and highlight the main natural events (floods, landslides and earthquakes) as they are remembered by each source as having affected the place.
A critical merging and analysis on what it is known about the history in general and the seismic history in particular has resulted in a preliminary assessment of the time intervals of completeness of the available data for various macroseismic intensity thresholds (9-10, 8-9, 7-8).
Conclusions: The results obtained by means of the historical approach have been compared with those suggested by statistical considerations. The comparison has shown that the intervals obtained according to the historical approach are more optimistic than those defined through the statistical approach. A first conclusion deriving from the above described results is that, from 1300 onwards – if not from an earlier period -, no earthquake with M=6.3/6.4, that is approximately equal to expected Mmax for the Montello seismogenic source, is missing from the current catalogue. Finally, by using the results obtained through the historical approach as guiding elements and those obtained through the statistical approach as "propagation" elements, a new set of time intervals of completeness have been assessed for the piedmont area between the Garda Lake and the Friuli region. This new set is available for hazard assessment according to a traditional approach and it results more optimistic than the data set used in PS4.

Inversion of macroseismic field - We performed three kinds of analyses:
A) the validation of our new technique of automatic source inversions. The inversion, which was used to validate the technique, was still produced with a I/KF relation calibrated by us in California (where I is synthetic macroseismic intensity, and KF is the non dimensional variable radiated by the source according to the KF model). The inversion was done by two techniques: the grid-search, and the use of a Niching Genetic Algorithm. To perform this validation, we were obliged to treat a series of well documented earthquakes, which were only available in the Great Los Angeles Region, California, where the site effects were minimized. In particular, we successfully inverted the regional intensity pattern of the Whittier Narrows, 1987 earthquake. This success was instrumentally controlled;
B) to obtain a new empirical relation I/KF in NE Italy; we needed new preliminary inversions in the area. In 2002, it came out that the Italian intensity data base of the May 6 Friuli, 1976 event was not ready for inversions due to the absence of the Slovenian and Austrian data. Thus, we ought to prepare a new data base. We also performed one new source inversion in Friuli: that of the Tolmezzo shock of 1928.

The result was validated with the hypocentre and the fault-plane solution based on instrumental measurements, which were obtained independently from our study;
C) the automatic source inversion of two destructive earthquakes which hit Vittorio Veneto in the past: we refer to the earthquakes of Bosco Cansiglio (1936) and of Belluno (1873). The inversion result, obtained from the DOM data base of the 1936 shock, was validated by comparing the obtained source with the hypocentre and with the fault-plane solution found from instrumental measurements, independently from this study. The source of this event, which was retrieved by inversion, is a segment of the so-called Aviano Overthrust. Then, two minimum variance sources were automatically retrieved for the Belluno, 1873 event: one of these sources appears to be plausible from the seismotectonic point of view. These new findings contributed to the definition of the possible causative faults/sources in the area.

Task 2.2 – Attenuation models in north-eastern Italy (D. Slejko)

As the aim of the task 2.2. is to develop new attenuation relations of regional validity to be applied in the seismic hazard assessment for the Vittorio Veneto region, a detailed analysis of the obtained results was performed and this led to an improvement of the previous results. More precisely, the effect of data truncation, the robustness of the earthquake magnitude values, and the dependence of the attenuation model used on some parameters have been investigated and a new attenuation model is here proposed. Furthermore, it has been tried an unification of the attenuation relations from weak to strong motion by taking into consideration effects of saturation with increasing magnitude.
For doing this, the data set has been incremented with recordings updated to February 2002, including a magnitude 4.9 earthquake which occurred on February 14 in northern Friuli. We have also decreased the minimum magnitude threshold from 3 to 2.5. Furthermore, we have considered the accelerometric records of the 1976 Friuli sequence taken from the European Strong Motion Database. The resulting data set now comprises 1032 weak- and strong-motion recordings to be used for the calibration of an unified regional attenuation relation.
In the first year of the project, we considered the duration magnitude from the OGS bulletins. Recently, in CNR Milan routines for the numerical simulation of the Wood-Anderson seismometer have been developed and an Ml scale for north-eastern Italy was calibrated. Having recognised that the choice of the magnitude type is critical for attenuation studies, we have applied extensively this new procedure and computed Ml for all earthquakes of our data set.
It is known that regression analysis with attenuation data is biased by non-triggering stations. To avoid the problem we have experimented the use of truncated regression analysis (TRA). Furthermore, as the triggering level may change in time due to variations of the background noise level, we have developed the theory for randomly truncated regression analysis. We have shown that, for the available data set, randomness of truncation is present but negligible. Then, it is possible to use simple TRA assuming that data from each station are truncated at the lowest value observed by that station.

We have used TRA to estimate the parameters of the attenuation model:

$\log(y)=a+(b+cM)M+(d+eM^3)\log(r)$ $\qquad r=(D^2+h^2)^{1/2}$

for the available data set, ranging from Ml 2.5 to 6.3. Regressions have been performed for both PGA and SA. The agreement with strong-motion attenuation relations of literature is excellent for magnitude 6.5 along the whole distance range. For lower magnitudes (5-6), the agreement is good in the near field (distance lower than 20 km) while our new model predicts much higher attenuation in the far field.

Task 2.3 – Modelling of the expected ground motion (A.Rebez)

Ground motion modelling and ground shaking scenarios. Seismic ground shaking scenarios at regional scale for the October 14, 1936, M=5.8 Cansiglio event - We have concluded the study with the computation of the complete ground shaking scenario for an extended source. We have used specific structural models in a number of different areas of the study region, and we have specified the shallowest layer of the model (i.e., the layer which simulate the soil coverage) depending on the receiver location. Three different seismic moment distributions and a large number of source nucleation points have been considered in order to build an exhaustive ground motion scenario. At a given site (i.e., receiver), the scenario consists of the statistics built up on the set of values of a given ground motion index (i.e., PGA) obtained from the simulations performed for all the source models, i. e. the mean value, the first standard deviation, and the maximum and minimum values. Figure 1 displays the PGA scenario computed for Vittorio-Veneto. The mean PGA predicted at this site is of about 60 and 30 cm/s2 for the horizontal and vertical components, respectively. The mean PGA plus the first log-normal standard deviation is about three times larger the mean PGA. The maximum horizontal PGA reaches about 500 cm/s2. This value is unlikely, but not impossible.

Validation of the methodology (modelling of recent weak events) **-** The approach used for the computation of the seismograms and used for the construction of the ground shaking scenario has been validated by modelling three weak local events (2.7<M<3.2), that have been recently recorded by the OGS seismometric network. The comparison between the recorded and the synthetic seismograms shows that both arrival times and amplitudes of the main phases are correctly reproduced. On the other hand, the recorded seismograms feature a long coda that can likely be ascribed to either site response or medium scattering. A further analysis should be performed to investigate this aspects.

Seismic ground shaking scenarios at regional scale for an hypothetical M=6.7 event in the Montello seismogenic area - The aim of this work is to build-up a seismic ground shaking scenario for a hypothetical reference earthquake associated to the Montello thrust. The seismic wave propagation modelling is performed using the Wavenumber Integration Method (WIM), while the overall approach for computing seismograms for an extended source is an improved version of that used for the modelling of the Cansiglio event. In particular, we have used interpolation to increase the computational efficiency, and we have improved the seismogram computation in the medium-high frequency band, where the full-deterministic approach fails, by developing a hybrid deterministic-stochastic approach. The scenario for the extended source is built up considering three different seismic moment distributions and 338 different nucleation points.

SPEM 2-D detailed ground motion scenario at Vittorio-Veneto for the Cansiglio event - The aim is to build up a detailed ground shaking scenario along some transect crossing the area of Vittorio Veneto. We compute the full-waveforms by the 2-D Spectral element method. This method solves the propagation of the seismic field through complex geological structures and accounts for the effects of deep crustal structure, superficial geology and irregular topography on the ground shaking. Numerical simulations are being performed along three 2-D vertical planes NE-SW oriented. With this approach, the source is a point shear dislocation with no torsion (double-couple model). The source time history simulates in a simplified way the rupture of both an asperity and the whole fault segment. The reference earthquake is the October 14, 1936, M=5.8 Cansiglio event. The reference earthquake is the M=5.8, October 14, 1936, Cansiglio event. The structural model has been defined by means of the available geological sections. The shallow structure of the model will be defined in detail in the next future, using the information obtained by the geophysical surveys, which are currently on going and will provide useful indications about the geometry and physical properties of the shallowest soils. The simulations will be performed as soon as the structures will be completely defined.

Regional seismic hazard - As integration to the deterministic modelling of the ground shaking at Vittorio Veneto, it is here presented the probabilistic design strong-motion time history. For arriving to this, the probabilistic seismic hazard assessment (PSHA) for the broader Vittorio Veneto area has been done by the standard Cornell method taking into account the logic tree approach to take into account the uncertainties related to the different ingredients contributing to hazard. With the logic tree approach various options can be considered in the computation: they represent the confidence we have in topics like the seismogenic zonation, the maximum possible magnitude in the seismogenic zones (SZs), the wave attenuation model, etc. Each branch of the logic tree represents a series of choices by which the resulting hazard is conditioned. Each branch can be adequately weighted and combined with the others to obtain the final aggregate result. Different options have been considered for the *seismogenic zonation, maximum magnitude, and PGA attenuation relations* to compute robust seismic hazard estimates for the border area between the Veneto and Friuli - Venezia Giulia regions in NE Italy.
Three seismogenic zonations have been used in the present study: they represent different levels of seismotectonic knowledge. The first model, here referred as GNDT zonation is the zonation used for the Italian seismic hazard map and is quite general (80 SZs for whole Italy). The second, referred as Vittorio Veneto zonation, is a regional improvement of the previous one based mainly on the evidence from the recent seismicity in NE Italy. The third zonation, referred as 3 Level, is based on a different concept: strong earthquakes are associated to regional faults while the lower seismicity is associated to wider areas where tectonic deformation is present. More precisely, this zonation associates the seismicity with 3 zones: the high

seismicity (M>6) with the presently active front, the intermediate seismicity (M>5) with the wider foothill strip, and the low seismicity with the less active.
The maximum magnitude was estimated in 3 different ways. The first way simply takes the maximum observed magnitude in each SZ as maximum magnitude. The second extrapolates one step behind (0.3 magnitude units) the observed seismicity rates when the correspondent return period exceeds the time length of the earthquake catalogue (1000 years). The third applies a pure statistical approach.
As no specific attenuation relations of peak ground acceleration (PGA) are available for NE Italy, the most popular European and Italian relations were considered in the present study.
Fourteen branches constitute the *logic tree*: 3 zonations, 3 maximum magnitude estimates, 2 attenuation relations, but 4 branches are empty. The results coming from all branches, evenly weighted, contributed to the final aggregate seismic hazard map.
The *design strong-motion time history* for the Vittorio Veneto test site in NE Italy has been computed generating synthetic accelerograms that are compatible with the uniform hazard response spectrum for the site. The methodology used to compute the artificial record is based on the random vibration analysis approach. The response spectrum of this artificial time history has been compared and corrected with those of recorded events suitable to be considered design earthquakes for Vittorio Veneto. These last have been taken from the European strong-motion databank selecting real accelerograms matching an earthquake scenario coming from the *disaggregation* of the source contribution in the probabilistic seismic hazard assessment (conditional distribution of magnitude and distance). Furthermore, the artificial design response spectrum for Vittorio Veneto has been compared with other records of the European strong-motion databank suitable to be considered the extreme event for the study site.

Task 2.4 - Characterisation of the site effects in the test-site of Serravalle (Vittorio Veneto) (M. E. Poli)

Introduction - In conformity with the research-program of the second year, classical geological, geomorphologic and geophysical investigations (i.e. geological mapping, geophysical drill, geotechnical proofs, refraction seismic lines, down-hole measurement) were carried out in the Serravalle area. In addition, new investigations such as measurements of environmental seismic noise (tremors) and estimation of site effects from reference site spectral ratios were applied. A preliminary analysis of the collected data, shows a good agreement between the results of the spectral ratio amplifications (obtained from a ground-motion analysis) and the ones obtained from measurements of environmental seismic noise (see for example the area situated to the SE of Serravalle gorge where the first results indicate consistent amplifications). Moreover the presence of a "seismic bedrock" in the S. Andrea DI Bigonzo area is confirmed by both the seismic refraction lines and the mechanical drilling. A detailed study of damage distribution at Serravalle-Ceneda for the 1873 and 1936 earthquakes, is still missing to date. According to the memory of some local inhabitants, the area of Ceneda underwent some severe damage during the earthquake of 1936. We will focus our study also on this area in order to determine

possible zones of high amplification and point out the zones more exposed to seismic risk.
Considering the high interdisciplinarity of this task, we prefer to give a concise but distinct account of all the topics developed during the second year.

Geological investigations and 1D modelling - During the second year, a georeferenced data set concerning the subsurface data drawing from the stratigraphies of water wells and oil drills scattered in the Vittorio Veneto plain, was created. Unfortunately, the geotechnical quality of these data is low; in particular, there is no direct information about the dynamic geotechnical characteristics of the Quaternary sediments bored in the study area, neither SPT penetrometric results, from which the dynamic characteristics and the moduli decay could be estimated by empirical relations. In particular because of in the Serravalle area data set was very scanty, a drilling in Sant'Andrea di Bigonzo area was carried out. The drilling, 80 m in depth, didn't reach the geological bedrock but pointed out the presence of a thick clay level in the first 10 meters. A monotonous sequence of coarse gravel characterises the rest of the stratigraphical column. Moreover in order to define the elastic characteristics of the soils, geotechnic proofs on undisturbed samples (in collaboration with the Geotechnical Laboratory of the Trieste University) and a routine 1D down-hole energised by the MiniVib, are in progress. Moreover a set of N-S and E-W geological cross sections were carried out in order to define the thickness of the Quaternary deposits in the Vittorio Veneto basin.

Refraction seismic surveys - Considered the impossibility to undertake a transect – even discontinuous - through the urban area of Serravalle, three sites have been selected for the refraction seismic surveys: 1) Parco Fender, (on the western slope beyond the railway line). Here the sedimentary coverage shows a thickness varying between 6 and 8 m, and a P-wave velocity between 550 and 600 m/s. The velocity of the S-waves was observed between 250 and 270 m/s. The underlying formation shows an agreement with the topography of the sites, with P-waves velocities varying between 1250 and 1400 m/s. 2) Via Rio dei Casai, (on the eastern slope). Here the sedimentary coverage appears similar to site 1, with a thickness varying between 4 and 7 m, and a P-wave velocity between 500 and 550 m/s. The speed of the S-waves was observed between 250 and 270 m/s. The underlying formation shows an agreement with the topography of the sites, but with greater P-waves velocities, between 1700 and 2000 m/s. 3) Area Borca, near Sant' Andrea di Bigonzo. Here three layers were observed: an underlying unit that shows velocities similar to those of the first two sites (2200-2300 m/s) and its sedimentary coverage that shows a speed contrast between a first superficial layer with 2 - 3 m thickness (480-530 m/s) and a second, deeper layer (1300-1450 m/s). Meaningful differences are not found among the speeds determined for the orthogonal seismic profiles, thus suggesting a substantial medium isotropy. The depth of the interface between the sedimentary coverage and the underlying unit varies between 7 and 16 m. The velocity of the shear waves of the sedimentary coverage, varies between 200 and 250 m/s, with modest variations among the different seismic lines. Moreover along the N-S and E-W seismic lines, two profiles have been performed for the dispersion analysis.

The seismic source used for all P waves analysis was a cannon mini-bang, with Kiln 8 type bullets. The interpretation of the seismic profiles were carried out by the two-layers GRM method (Palmer, 1980).

Estimation of site effects from reference site spectral ratios - We have performed a 6 months experiment to study the site amplifications of the ground motion in Serravalle. During the time span of the experiment, we have selected the data corresponding to 35 events and determined the Fourier amplitude spectra for the S part of the seismograms. In our preliminary analysis, we have used the spectra of 11 events and found the site amplifications at the 10 sites where it was deployed a temporary array of stations. Our results show that amplifications up to eight times the mean reference level are observed at site VV02 (located within the elementary school in via Parravicini) at frequencies of about 5 Hz. Amplifications peaked also at 5 Hz and of 5 times the reference site are observed at site VV01. Similarly, site VV04 in the school of Music, displays the same amplification level but at higher frequencies (8-9 Hz). In contrast, the remaining sites do not exhibit large level of amplifications.

Measurements of environmental seismic noise for site response estimation - A survey of environmental seismic noise (tremors) has been carried out in the urban area of Vittorio-Veneto (Treviso, Italy) from December 2002 to January 2003. The noise has been recorded at about 50 different sites. Seven of these sites are aligned with the trace of one of the transects that will be modelled during the project (i.e., transect GNDT3). In addition, an array measurement has been performed at Sant'Andrea di Bigonzo site using 13 stations simultaneously (sites R01-R13). Additional 20 measurements are planned in the near future to complete the survey.
The resulting HVSR reveal that most sites do display a clear resonant peak, with variable HVSR amplitudes, while only few of them feature a flat response. The large amplitude of the HVSR peaks usually found suggests the presence of a large impedance contrast between the sediment coverage, with varying thickness, and the underlying formation (Bard, 1999). Two examples of HVSR estimated at two sites located close to the centre town (S.Andrea di Bigonzo) and at the southern part (Ceneda bassa), show that the ratios obtained from the seismic noise measurements clearly detect the fundamental mode of vibration at about 6 Hz for S.Andrea di Bigonzo and 10.5 Hz for Ceneda bassa, respectively.

In situ measurement of shear wave velocities of shallow soils from surface waves analysis and inversion - For a seismic refraction line, a surface wave analysis has been performed on single channel records, by inverting the Rayleigh wave fundamental mode, in order to provide a group of equivalent smoothed V_s profiles. The group velocity for the fundamental mode is measured for several seismic recording channels in the frequency range from 8 to 30 Hz.
Then, in a second step, we use the indications provided by the seismic noise HVSR ? the presence of a large impedance contrast at some depth? to constrain the solutions of the surface wave analysis inversion. We invert the fundamental Rayleigh mode using a non-linear technique and constrain the solution to feature an impedance V_S contrast higher than 2 in a depth range of 10-20 m. The constrained non-linear inversion provides two possible models, which display a sharp velocity

contrast at 14 m and 17 m, respectively. Both models feature a fundamental frequency of vibration of 6 Hz, which matches exactly that estimated independently by the HVSR.

Task 2.5 - Urban vulnerability (A. Bernardini)

The aim of the task is addressed to measure seismic vulnerability parameters of territorial systems and particularly building systems, in a suitable way to be combined with local intensity measures, to forecast damage scenarios and to evaluate the annual risk at a regional level. Particular attention will be focused on the historical centre of Serravalle (Vittorio Veneto).

Considering firstly the urban vulnerability in the Veneto area, the activity in the second year has been addressed to confirm the results obtained in the first year; such results have been partially used in the choice of the sample of Communes to be surveyed in the evaluation of residential buildings vulnerability.

In regard to the vulnerability of a transportation network, the vulnerability of its bridges and viaducts has been selected as the key point of interest.

In order to have a database useful to the research program, surveys were performed on the bridges along Piave and Brenta rivers, and some other surveys are in progress on the main roads in the area of Bassano del Grappa, Montebelluna, Conegliano, Vittorio Veneto, Belluno and Feltre In the dataset related to every bridge some indexes have been set up to predict the more likely level of damage of the bridge, according to the soil condition (i.e. using Peak Ground Acceleration, PGA), to the structural characteristics and to the building materials. In order to quickly evaluate the seismic vulnerability, in the set of attributes, indexes of the probability of exceeding a damage state will be defined versus the spectral acceleration or the permanent ground displacement (PGD).

The assumed procedure is similar to the well-known methodology developed in the U.S.A. to evaluate the seismic vulnerability of the transportation systems (Hazus, 1999) by means of fragility curves.

In regard to the vulnerability of the residential buildings, the extensive field survey has been initiated in selected Communes (Vittorio Veneto, Fonte, Pieve di Soligo in the Province of Treviso; Vas, Quero in the Province of Belluno; Porcia in the Province of Pordenone) and (in each Commune) in a certain number of selected Censual Sections. The final result of this activity should be the derivation from ISTAT 1991 data (analysed and corrected in a suitable manner through comparisons with survey data) of the distributions of EMS98 vulnerability classes in every censual section of the considered area. This activity has been planned and performed through a tied co-operation between the UR Pad and Milan (and moreover, in the third year of the research, Udine 1). In the second year preliminary models for EMS98 classifications from both ISTAT data and survey data derived by means of AeDES 05/2000 have been proposed and tested. Moreover both Damage Probability Matrixes coherent with EMS98 definitions and fragility curves for masonry building types (VULNUS) (particularly the traditional in masonry types extensively put to use in the area) have been tested to derive damage scenarios in the selected Communes. At the end of the second year nearly 1500 buildings have been surveyed with AeDES form and recorded in the database; moreover 70 buildings have been more accurately

observed obtaining the data useful for the application of the VULNUS procedure (nearly 50% of the final objective of the survey).
Last, in regard of the test site of Serravalle, in the second year the building alignment in via Casoni has been selected as of particular interest for the more precise static and dynamic numerical analyses to be performed in the third year, taking into account the forecasted strong motions scenarios. Therefore the photogrammetric survey of test-site buildings façades has been achieved by means of image digital rectification technique, using control points measured by classical topographic techniques.
Moreover in the second year a survey and a preliminary vulnerability analysis of the buildings have been performed according to VULNUS procedure, obtaining fragility curves of every building and of the buildings group as functions of the expected PGA.
A detailed study of the vulnerability of bridges on the rivers Brenta and Piave.

Task 2.6 - Seismic vulnerability of historical centres and monuments (C. Modena)

2nd year objectives:
1. Calibration of non destructive procedures and updating of identification methods (first semester).
2. Test-site of Vittorio Veneto (TV): application of the study methodology and contribution to the seismic vulnerability analysis (second semester).

During the second year the experimental analysis phase on the building typologies detected in the first year (tower, free-standing wall, church), has been concluded. Results has been elaborated according to the following aspects:
- Mechanical characterisation of the buildings and calibration of the non-destructive investigation procedures.
- Upgrading of the dynamic identification procedures on the basis of the different vulnerability conditions detected in-situ.

The methodology analysis previously validated is therefore available for the analytical-experimental study of the urban centre of Vittorio Veneto, which the main activities of the 3rd year will be focused to. The main aspects considered are:
- Detection of the existing building typologies.
- Vulnerability analysis of pilot buildings.
- Application of the experimental diagnosis investigation procedures.

1. Calibration of non-destructive procedures and updating of identification methods

1.1 Calibration of non-destructive investigation techniques - For each building typology (tower, free-standing wall, church) the set of low obtrusiveness investigation methods has been defined for their mechanical characterisation. Such procedures have been calibrated on the base of the experimental results obtained in situ and allowed the refining of models describing the global behaviour of the structures or their components, both from the physical-mechanic point of view (Old Chorus of S.ta Giustina in Padova) and the analytic-numeric one (Cittadella curtain wall, S.ta Giustina Basilica façade, Watch Tower in Padova, S.Stefano Tower in Venice).

1.2 Updating of dynamic identification procedures - In the ambit of the application of the dynamic identification assessment the case study of the free-standing wall of the Verona Arena has been added to the previous ones (S.Stefano Tower in Venice, Roman theatre in Verona, S,ta Sofia Church in Padua). The dynamic characterisation allowed to upgrade the identification procedures on the basis of the monitoring measures, already active in many of the considered building, and to refine FE models for the possible simulation of interventions.

2. Test-site of Vittorio Veneto: application of the study methodology and contribution to the seismic vulnerability analysis

2.1 Cataloguing of the existing buildings - The cataloguing activity has been started on the test-site of Vittorio Veneto; data-base available and information directly collected in the centre allowed to detect the most relevant buildings, according to the typologies previously investigated in the project. Such typological catalogue is firstly focused on the specific site of Serravalle, but it will be extended (during the third year of activity) to the whole centre of Vittorio Veneto.

2.2 Seismic vulnerability analysis by using structural macro-modelling - The seismic vulnerability analysis has been concentrated on the site of Serravalle and is concerning the application of kinematics models which study the mechanical behaviour of structural components (macro-models). The analysis is performed at global level, for each building, by applying the VULNUS procedure and, locally, by selecting the main components in the buildings, and the subsequent application of the single kinematics models.
In particular, the work has been performed on 13 constructions included in two row buildings (Via Casoni complex) and on a single building (Palazzo Troyer, located in Via Martiri della Libertà).
Up to now the analysis has shown that:

- The vulnerability analysis is depending on the presence of the porch at the ground level, on the lack of ties for the improvement of the scarce connection among walls, floors and roofs, and the non-homogeneity of the foundation soil.
- The calibration of the Vulnus procedure allowed to detect the lowest resisting walls, both for in-plane and out-of-plane mechanisms. In particular, according to the seismicity of the zone (a/g=0,28), the 46,2% is vulnerable to out-of-plane mechanisms and the 53,8% both for in-plane and out-of-plane ones.
- The punctual assessment with the kinematics models confirmed the high vulnerability of the façade sects to global overturning mechanisms.

Therefore, by using the automatic procedures themselves, it will be possible to simulate some strengthening intervention cases (e.g. tying of the walls).

Task 2.7 - Damages and losses evaluation (L. Briseghella)

Information on building estate of the Vittorio Veneto municipality given by ISTAT data - 85,99% of the housing units included in the census are compounded in

building for exclusive dwelling use and only the 11,87% is located in building with mixed use destination (residential and not).
The lasting nearly 2% (143 units) is constituted by half of rural building and half of units in building destined only in minimal part for residence.
For the carrying structure of the building, the ISTAT institute distinguishes between houses in reinforced concrete (43,99%), houses in masonry buildings (49,55%) and other kind of buildings (6,17%). Absolutely negligible the number of buildings of non sure nature.
Within the reinforced concrete structures of the census, 26,98% is included in buildings defined with "open ground floor" and the lasting 73,01% are "closed with masonry".
Going on with the dwelling units, 28,19% are included in buildings made before 1912 and 69,68% have been made between 1919 and 1945.
On the side of the typification of buildings, there are 32,42% of houses for only one family, 24,16% bi-familiar or anyway houses with 2 flats, 13,78% of houses in formation or small palace, about 10% of small-medium joint-ownership and the same per-cent for buildings with 9-15 flats. At the end, there is 8,1% of big buildings, made mainly during the period of housing boom, with a number of flats up to 30.
Buildings with more than 30 units are at maximum 10 in all the municipality territory.
Another data is given by the number of elevating floors of buildings: there is a negligible percent of houses with only one floor (3,80%) and over the 5 floors (3,50%), while most of the buildings have 2 floors (47,02%) or from 3 to 5 floors (45,67%).
At the end, only 30,22% of the housing units is sited in buildings with elevator, while the 90,34% is registered by physical persons.
On the average the surface of each dwelling is 102 square metres.

Estimation of economical value of the building estate of the municipality - The objective is to estimate approximately the monetary losses given by an earthquake with total destruction of the civil building estate of the municipality of Vittorio Veneto (TV).
For the first variable, the *location*, it is important to distinguish if the building is in the historical city centre, in the suburbs, or in the open country side. Usually, in a town as Vittorio Veneto, one building made with one or two floors, with only one dwelling, in a good maintenance status and destined to be residential, costs about 1.500,00-2.000,00 €/m^2, if it is in the historical city centre, and 750,00-1.500,00 €/m^2 if it is located in the suburbs. Located in the country-side, his value is about 500,00-1.000,00 €/m^2.
For the rural houses, that are anyway only the 2% of the whole building estate, it is to be used a different point of view. In fact, those buildings are made to increase the value of the land all around; they are investment made on the land and so they are not distinguishable from the land all around and don't have a separate market.
Unfortunately the given data are not georeferenciated, and to make a first evaluation there is the need to make an approximation: the idea is to place all the houses made before 1945, non rural, in building of the city historical centre, while the others (anyway, not the rural ones) are made in buildings of the suburbs.

Here we arrive at the approximation that the 35,12% of the housing units are in the city centre, while the others are in the suburbs or in the country-side.
Indeed, the price of one building is even function of his *use destination*: building units destined to directional/commercial are usually 30% much more expensive than the ones destined to residential use.
Moreover the given data don't give the classification on the base of the usage (residential-commercial-directional) but distinguish among houses part of buildings destined "only to dwelling use", buildings with "prevalent dwelling use" and "prevalent non dwelling use".
A second approximation consists in assigning to residential use 100% of the units of the first type, 75% of the second type and 25% of the third type; as a consequence, 25% of the second and 75% of the third will be considered with destination direction/commercial.
The result is that 95,14% of the total units is destined to residential, while the last 3,73 of the non rural units are destined to directional/commerce use.
The third factor is the *ageing*, the conservation situation of the building at the earthquake moment.
From the ISTAT data it is possible to make the distinctions in the following classes:

- buildings made before 1919 and never renewed;
- buildings made from 1919 to 1945 and never renewed;
- buildings made from 1945 to 1960 and never renewed;
- buildings made from 1961 to 1981 and never renewed;
- buildings made after 1981 or renewed after that year.

Basing on this classification, it is possible to define a coefficient of depreciation, compared with the price of one building in good conditions (class *e*) of the 50% for buildings of the first category, of the 40% for the second, of the 20% for class *c* and of 10% for class *d*.
Fourth and last factor is the *building typology*. The value for square metre of a building with up to 4 dwellings is compared to the 95% of the value for a single house; the one of a building with from 5 to 8 houses is obtained with a coefficient of 0,9; the one for a building with 9-30 dwellings is 0,85 and, at the end, for buildings with more than 30 dwellings, the coefficient is 0,8.
Starting from the price of a square metre for the reference unit, made in a building of 1-2 floors, with only one dwelling, in a good conservation state, with residential destination, and multiplying for the described coefficients, it is possible to obtain an unitary indicative price for each unit described by ISTAT census and so, adding the values, to quantify the complex real value of the estate of the civil buildings of the municipality of Vittorio Veneto.
This evaluation gives a value of about 1.000 millions of Euro.

CONCLUSIONS

At the end of the second year most of the delay due to the initial difficulties of the general management of the project, have been recovered. The seismotectonics of the area has been clearly delineated and a new zonation proponed. The main seimogenic sources have been parameterized and linked to major shocks in the well tested hypothesis that no earthquake with M>= 6.3 is missing in the completely

revised catalogue. Among the sources, two have been chosen as relevant to the risk in Vittorio Veneto: one linked to the Cansiglio earthquake (1936) and the second to the silent source of Montello. Ground motion in the test site has been simulated through different approaches but similar results.
The quick computation of the vulnerability of buildings has been performed on nearly 50% of the chosen sample. The positive test performed on the Friuli dataset allows to extend to the whole region the vulnerability assessment on the base of the ISTAT census data. A detailed study has been devoted to the vulnerability of bridges along the Piave and Brenta rivers. In Vittorio Veneto all the work, which will end in the scenarios is in progress. The completion has been reached by the evaluation of the real estate as far as ordinary buildings are concerned.

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