The new Friuli Earthquake Damage (Fr.E.D.) database

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ABSTRACT After the May 6, 1976 earthquake in Friuli Venezia Giulia (NE of Italy) the buildings in the shaken area were investigated and 84780 forms were filled in. After a first organization of these data, we provided a re-designed database in order to make the data more usable. Thanks to the new technologies that have emerged in the last years, the original data were enlarged, adding, where possible, the geographic coordinates for each form acquired. We are now able to exploit new information for deeper studies and analyses to a level of detail unthinkable until a few years ago. All this information is now available on-line upon request.

1. Introduction

On May 6, 1976, an earthquake of magnitude 6.4 on the Richter scale struck central Friuli, a region located in the north-eastern part of Italy at the borders of Austria and Yugoslavia (now Slovenia). The devastated area covered about 1800 km^2. Over one hundred villages were almost destroyed. More than 17,000 houses, a large number of schools, churches, town halls and factories were ruined. 45 municipalities were declared "destroyed", 41 "damaged", 52 "damaged"; there were about 150,000 homeless.

After the May 6, 1976 main shock, the legislative council of the Friuli Venezia Giulia Region enacted law No. 17, dated June 7, 1976 that concerned both the identification of usable buildings and the restoration of the damaged ones. The purpose of the law was also to point out the buildings that were not completely damaged, determine the amount of repair needed and estimate the cost.

As a consequence of the law, 416 teams of engineers and architects were assigned the task of compiling the forms for each investigated building in the whole shaken area.

The survey lasted three years and 84780 forms were acquired in all. This huge amount of data, making up a unique set of data describing in great detail buildings and related damage as a consequence of the earthquake, had been used to define the core information that, has over the years, given birth to the Friuli Earthquake Damage (Fr.E.D.) database.

At present all the original paper forms are kept in the "Centro di Documentazione del Terremoto del Friuli" located in Venzone (UD), Italy.

2. The forms of Law n. 17/76

Each form includes 5 different sheets that cover all the necessary information needed to pursue the aims of the law. These forms were created from scratch in one week and immediately used by the teams of technicians. The first form was filled in on June 7, 1976.

Sheet 1 contains the general characteristics of the building, organized in four sections. Information about localization, address, number of floors, number of sides in common with other buildings, presence of a basement and/or a garret, cellar, number of lodgings, age, presence of outhouses or productive activities are provided. The damage suffered is briefly described: destroyed, not restorable, partially restorable, totally restorable with structural work, totally restorable without structural works. The sheet also reports the estimated restoration cost for each flat, plural dwellings, outhouses or productive activity with, possibly, notes regarding the restoration.

Sheet 2, used to acquire information about the building depending on its typology, is divided into 4 sections. The first section is relative to lived-in houses and includes the number of rooms used, if the house is for rent or not, etc. The second section is relative to rural buildings eventually annexed to the house and their volume in cubic meters. The third section provides the same information as the second section but regards commercial activities. In the fourth one some information relative to the owner are provided.

Sheet 3 provides an estimate of the building's volume and the repair costs; there are three distinct sections. In the first section, the volume is associated to each typology of use (civil or rural dwelling, outhouses, productive activities). In the second section, a summary evaluation of the building before the earthquake based on unitary values according to the typology and the state of preservation is given. The third and fourth sections allow the computation of the total amount of restoration costs based on the unitary values of sheet 4 defined by the Regional authority.

Sheet 4 is divided into two parts: 4-A and 4-B. The first one is used mainly for civil or rural dwellings while the second one for outhouses and productive activities. It contains an outline used to determine the unitary amount of restoration works; the calculation is organized by structural elements and by the typology first quantifying the percentage of its composition compared to the total building and then evaluating what amount of these elements needs total or partial restoration. The unitary cost for each element was determined a priori.

Sheet 5 is simply a free hand sheet where the technicians can make notes and proposals about technical methods for restoration.

3. First Fr.E.D. database implementation

The huge quantity of information acquired with the forms was a very good starting point for further analyses, as it could be considered as a "real hands-on field experiment". In the 1990s an extensive research on all the acquired sheets was carried out (Grimaz, 1992,1993). Together with the forms, the magnetic tape containing parts of these data were found too. This first electronic storage was done by INSIEL (Fig. 1), and it was necessary so as to speed up all the financial necessities according to the acquired data for the restoration. Of course, not all the information present in the five sheets was taken into account, but only those that were important for the real necessities. In particular, all the information included in sheet 1 and sheet 2 was used, and a bit of summarized information from sheets 3 and 4. In this phase, a first quality check was carried out; incomplete data or missing data forms were not taken into account. In a second step, all the data present on tape were converted in a more usable format; a Microsoft® Access™ relational database. For some municipalities (Fig. 2) all the information from the sheets was added.

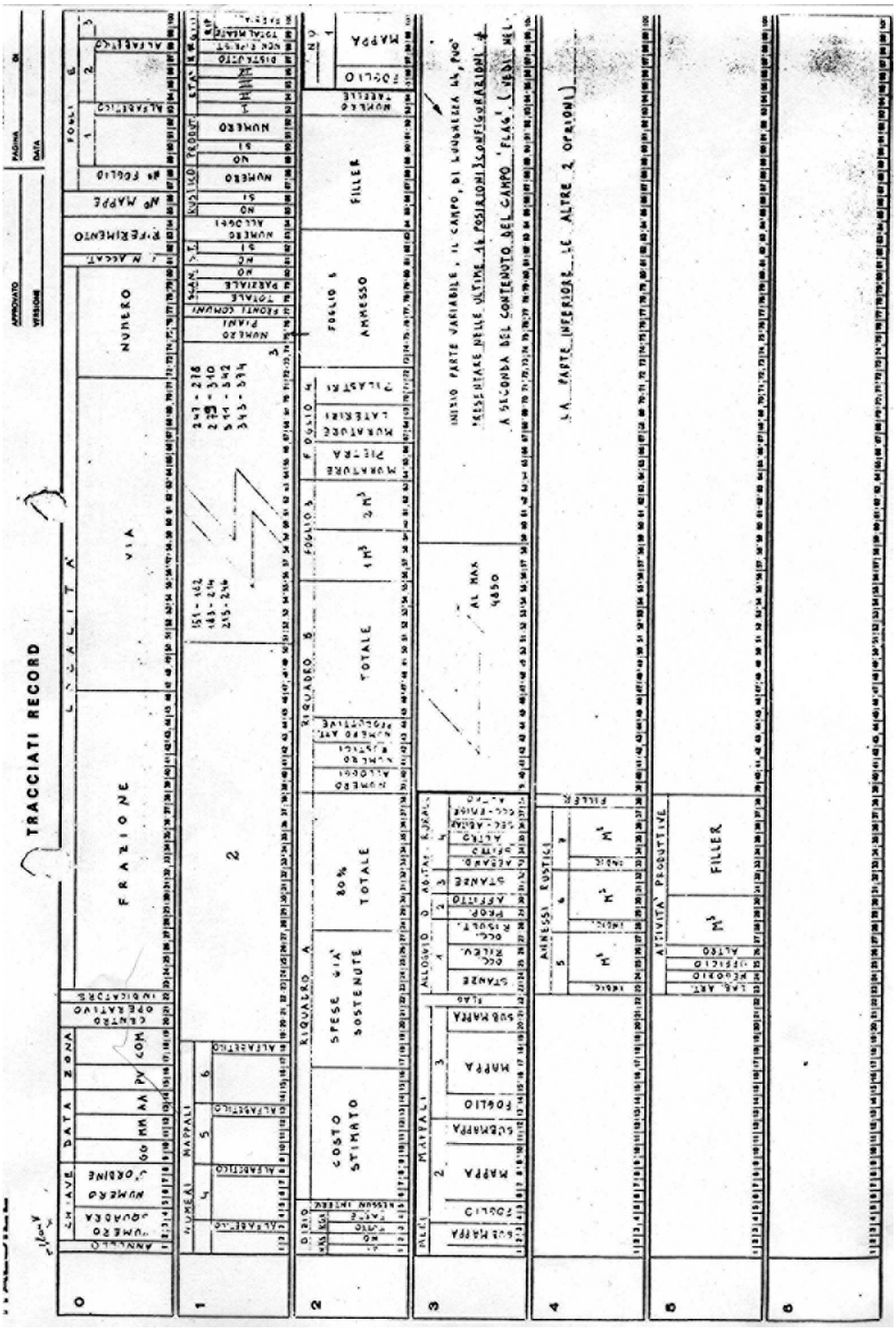

Fig. 1 - Field scheme for the INSIEL tape relative to each form.

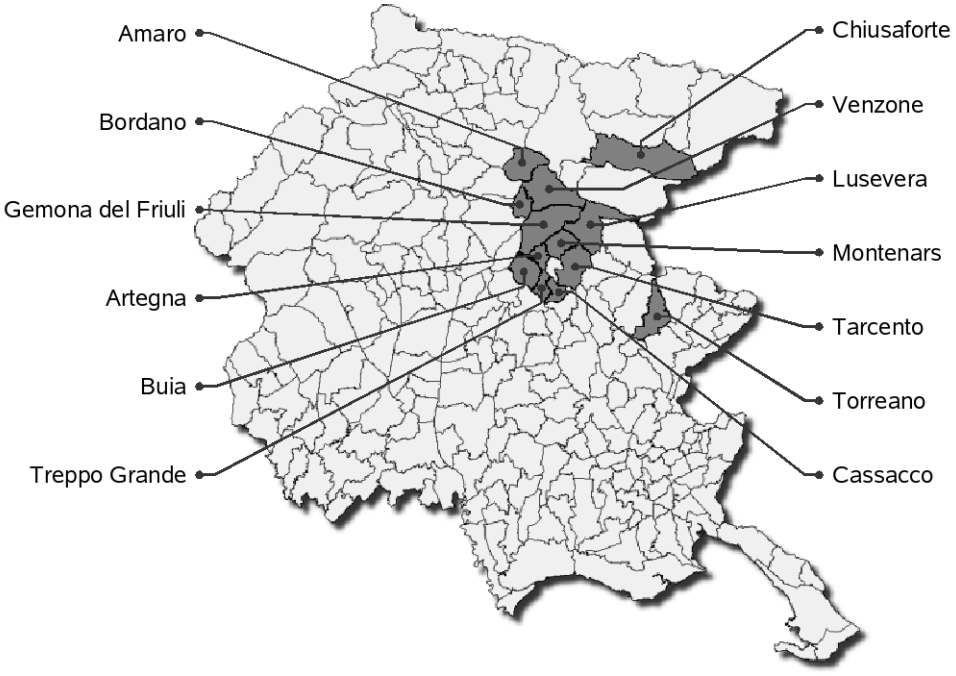

Fig. 2 - The thirteen municipalities for which the complete data from all the sheets have been added to the database.

At the end of this step, all this information was more easily retrievable for deeper studies and analyses (Carniel *et al.,* 1994, 2001; Cella *et al.,* 1994, 1995a, 1995b; Grimaz *et al.,* 1995, 1998; Riuscetti, 1997; Riuscetti *et al.,* 1997; Cecotti *et al.,* 2003). It was possible to extract the data needed and let the researchers use them. Conseguently, the storage method was not optimal yet since the database had been created with just one very big table containing all the data, without considering the memory optimization, retrieving performances and usability.

4. Fr.E.D. database redesign

Exploiting new database technologies and data representation, we started a further development phase where our database, has been completely redesigned in style and structure. The new structure now reflects the relational paradigm and the information contained therein is now more accessible and better structured.

As result of the redesigning, all the original data (previously stored in Microsoft® Access™ database) have been moved, using special scripts, to the new format. The number of tables containing the data are now increased, but not the memory requirements or the flexibility. Moreover, these tables better reflect the intrinsic logic of the managed information (Fig. 3).

The main table is “verbale” (“form”). Here we can find all the common information relative to the form. In particular, data about the building address, team code, form code number, and acquisition date, and other information described above.

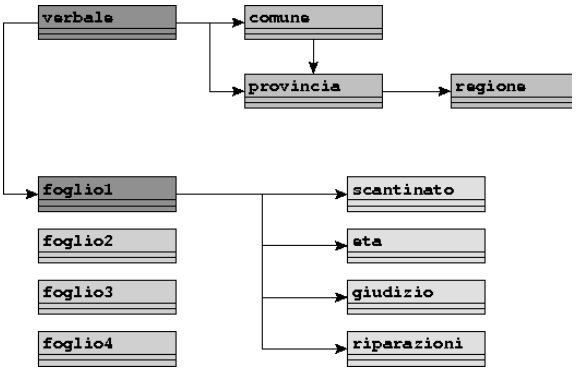

Fig. 3 - The database main structure (table names are in Italian).

Another important table is "foglio 1" ("sheet 1"). All the information acquired in the first sheet of the form are managed here. Note the additions to the four support tables named "scantinato" ("cellar"), "età" ("age"), "giudizio" ("judgement"), and "riparazioni" ("repairs"). We know, for example, that there can be four classifications for an examined building: destroyed, not repairable, totally repairable or partially repairable. In this case, in the table "verbale" there will be a numeric key to join the corresponding entry in the table "giudizio". Two more pieces of information, not present in the original database, have been added here. These two factors indicate the building "typology" and "category" (where category indicates the vulnerability class) (Fig. 4). To avoid continuous calculations to determine these values based on the information present in the database, we decided to define once and for all of them in the table.

The two main tables, "verbale" and "foglio 1", are joined using a unique key that is the composition of the number of the survey team and the number of the form. Two different forms filled in by the same team cannot have the same number, and this can be used as a unique key for each different form.

At the end of this step, it was already possible to use the data in a more efficient way, but some improvements could still have been introduced, two in particular: the geographical coordinates and a better access using a web interface.

5. Data geo-localization

A quite interesting piece of information that could have been very important for deeper analyses, which was missing in the original data, was the geographical position of the building surveyed. It would be very useful to assign a geographical position, expressed in terms of latitude and longitude (and/or with kilometre coordinates), for each building in the database. Discarding a priori the possibility of acquiring the coordinates for each of the 84780 buildings directly in the field using a GPS receiver, we need to take advantage of what the new technologies provide us with. On many web sites, we can find map-generation engines based on addresses (street, number, town, etc.). A particular map generator has been chosen because, besides the map itself, it returned also the latitude and longitude of the requested address. An automatic routine, to extract the information from the database, used the necessary fields to generate a web request in the correct format, load the web results and extract (parsing) the coordinates. If the generated coordinates are considered valid, they are inserted into two new fields (latitude and longitude) of the "verbale" table (Fig. 5). At the end of the first run, the routine was able to find approximately

BUILDING TYPOLOGY	BUILDING CATEGORY	TYPOLOGICAL CHARACTERISTICS		
		AGE	SIDES IN COMMON	NUMBER OF FLOORS
T1	A	Before 1920	Isolated	1 – 2
T2	A			3 – 5
T3	A		Not isolated	1 – 2
T4	A			3 – 5
T5	C	Between 1920 and 1950	Isolated	1 – 2
T6	B			3 – 5
T7	B		Not isolated	1 – 2
T8	B			3 – 5
T9	F	After 1950	Isolated	1 – 2
T10	D			3 – 5
T11	E		Not isolated	1 – 2
T12	D			3 – 5

Fig. 4 - Scheme for the definition of the different building typologies and categories.

60,000 valid coordinates. In fact, the building address should have been the same as the expected address for the map generator. We have to remember that the original data were acquired on paper, and different teams, quite often, wrote down the same address using different abbreviations. So, for example, a street address like “Stretta San Valentino” was present in the database in different ways (e.g. “S.tta S. Valentino” or “via san Valentino” and so on), and many of these ways were not compatible with the map generator. In the second phase, we tried to correct all ambiguous street addresses “by hand” and run the procedure on those buildings, not

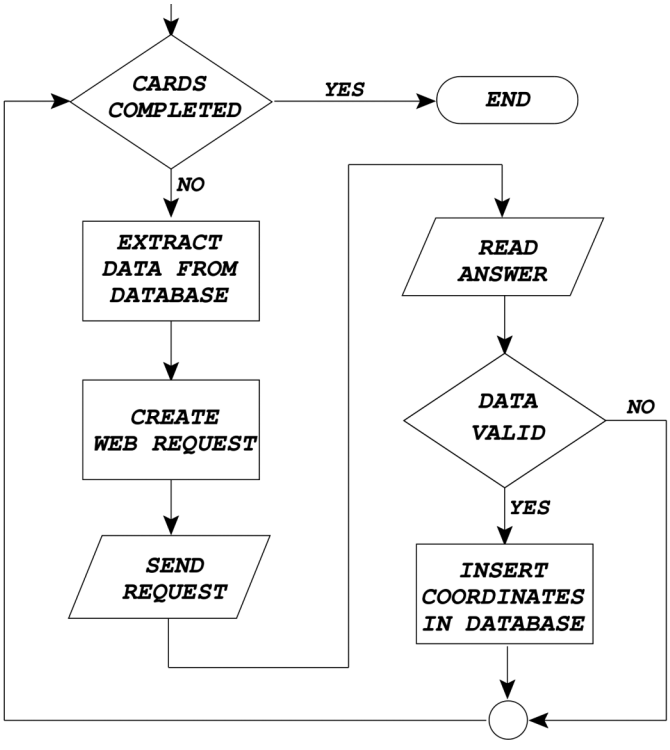

Fig. 5 - Flow chart describing the procedure for the automatic latitude and longitude insertion in the database.

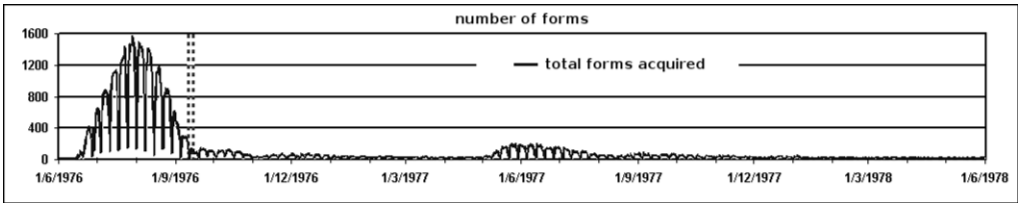

Fig. 6 - Number of forms acquired after May 1976. The two vertical dotted lines represent the two earthquakes that occurred on September 11 and 15, 1976.

referenced in the first run, again. In the end, we successfully defined 69127 geographical coordinates over 84780. It was impossible to find the coordinates, due to non-existing addresses or errors in the original data for the remaining buildings.

Of course, we cannot expect all the coordinates we found to be exact and coherent with the situation in 1976. Many streets have been removed, others have been moved around within the municipality. Working on "large numbers", we can consider the errors, that are surely present, to be not so significant at a statistical level (Fig. 6).

We then applied a transformation from polar to kilometric coordinates. With these data, we were able to geo-localize every single building (where the coordinates were defined) onto the

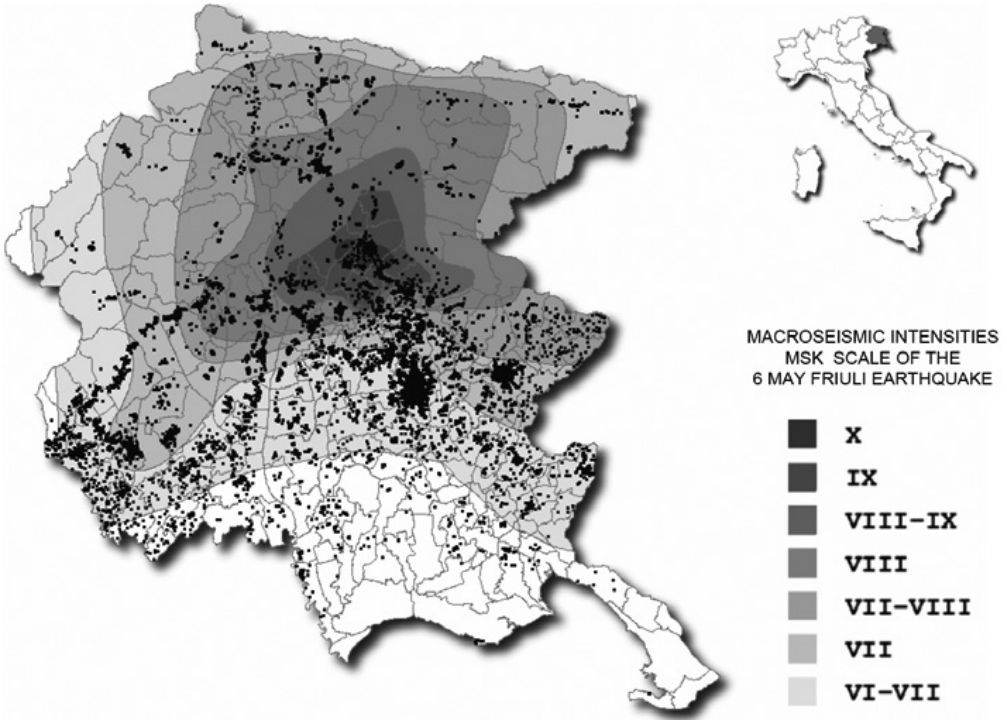

Fig. 7 - Distribution of buildings of the Fr.E.D. database (dots) in the different isoseismal areas.

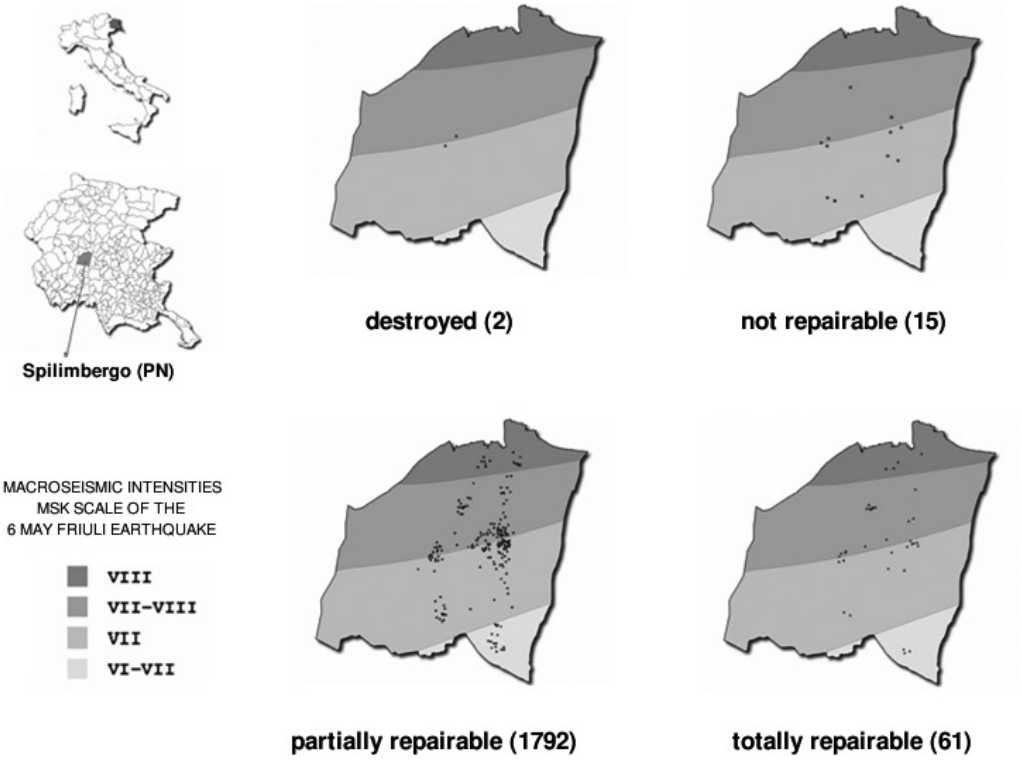

Fig. 8 - Buildings damaged by the May 6, 1976 earthquake in Spilimbergo (PN) municipality with indication of the number and localization of buildings destroyed, not repairable, partially repairable, and totally repairable.

maps from the "Carta Tecnica Regionale" (CTR, 2007). As a first consequence, we have been able to assign each of these buildings to the intensity it belongs to. Before, we only knew if the municipality, in its extension, belonged to one or more isoseismal areas, without any information on the single building. Fig. 7 shows the regional distribution of buildings of the FrE.D. database compared to the MSK isoseismal map. Fig. 8 shows an example of a possible use of the database. In particular, Fig. 8 illustrates the distribution of buildings that suffered different levels of damage for the municipality of Spilimbergo (PN).

6. Online data accessibility

As the database is now ready and filled up with the information we need, it is necessary to create a user friendly interface. It would have been possible to create an application for the people interested in using the information present in the database, but this solution would have been quite complex to manage. In fact, it should have been developed for all the operative systems most used (taking into account all the possible variants). Moreover, continuous updates and relative distribution to the users would have been necessary.

The solution adopted in the end, based on previous experience (Carniel *et al.,* 2004, 2006), was to create a web application that is able to allow easy access to the database, perform queries,

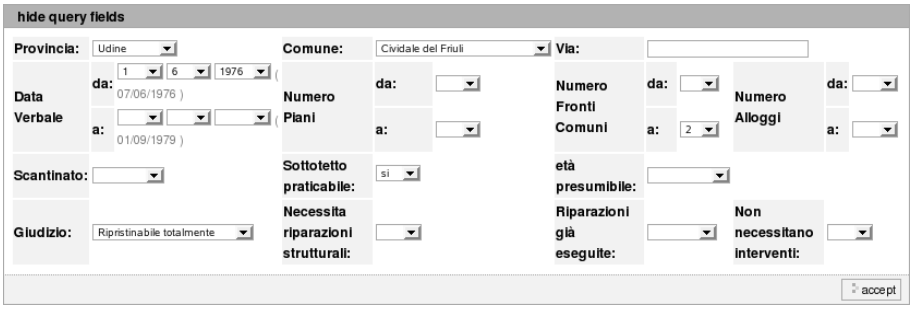

Fig. 9 - Section used for search parameters to be used in the query.

display the results and manage the user privileges. This system runs on a server in our department (the database could also be located on another server) and the user accesses the interface with an ordinary web browser. The advantage of this approach is, first of all, that the database is not distributed to anybody; secondly, it permits a powerful user privileges administration, defining the information each user is able to access, and, finally, a change in the system is performed on one machine only and it is immediately available to all the users.

The main page is divided into two sections; the first (Fig. 9) is used to define the query parameters while the second one (Fig. 10) is used to present the query results. The section regarding the search criteria presents a number of options, depending on the privileges assigned to each user. For each query, there are 40 entries displayed at the same time with the possibility of scrolling backwards and forwards using the classical "next" and "previous" links (Fig. 10). It is also possible to download, in ASCII format, the complete results list using the link "download all results". In this way, it is possible to perform local analyses. For each single result, it is also possible to display the complete set of information (depending on the user privileges). A mouse click on the corresponding entry in the "id" column in Fig. 10 will open a page as the one shown in Fig. 11.

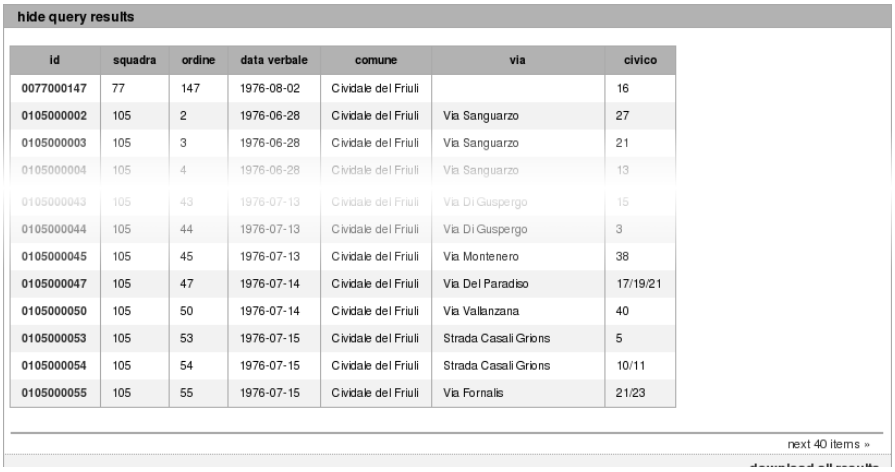

Fig. 10 - Section used for result presentation.

Fig. 11 - Page containing almost all the information relative to a particular form.

7. Database usage

The evolution in the Fr.E.D. database, especially since we introduced the geographical coordinates for the buildings, gives us the possibility of running new analyses that were quite difficult before. Analyses can be carried out taking into account the position of the buildings and correlating them to geological zones, impedance classes of soil and so on.

More in general, we can consider the data contained in the Fr.E.D. database as a "real on field experiment". Many scientific studies could be carried out, provisional model tuning could be performed, like statistical and correlation analyses.

8. Conclusions

Thanks to the use of IT technologies that have emerged in the last few years, a new release of the Fr.E.D. database has been implemented.

The important information on the field experience of the 1976 Friuli earthquake are now more easly available and consultable for research purposes.

The new version, completely redesigned, adds new information and improves the usability. The main improvement is the geo-localization of about 69,000 buildings. The information in the Fr.E.D. database has been implemented in a GIS allowing us to have an overview of the territorial distribution of the buildings surveyed and permitting studies on the distribution of different building typologies, levels of damage recorded, use destinations. All the information can be analyzed with reference to different macroseismic intensity zones or geo-morphological scenarios.

In the new release, all the information are available on-line upon request and an English version of the web interface will be available soon.

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REFERENCES

Carniel R., Casolo S. and Cecotti C.; 1994: *Uno studio di strong motion a 2 componenti per l'analisi strutturale.* In: Atti XIII Convegno Nazionale del Gruppo Nazionale di Geofisica della Terra Solida, Esagrafica, Roma, pp. 971-974.

Carniel R., Cecotti C., Chiarandini A., Grimaz S., Picco E. and Riuscetti M.; 2001: *A definition of seismic vulnerability on regional scale: the structural typology as a significant parameter.* Boll. Geof. Teor. Appl., **42**, 139-157.

Carniel R., Di Cecca M. and Jaquet O.; 2004: *Remote and user-friendly browsing and analysing of multimo multiparametric geophysical data.* Geophysical Research Abstracts, **6**, SRef_ID: 1607_7962/gra/EGU04_A_05108.

Carniel R., Di Cecca M. and Jaquet O.; 2006: *A user-friendly, dynamic web environment for remote data browsing and analysis of multiparametric geophysical data within the multimo project.* Journal of Volcanology and Geothermal Research, **153**, 80-96.

Cecotti C., Carniel R. and Riuscetti M.; 2003: *A proposal for an extension of the use of the structural typology as a signi_cative parameter for the evaluation of seismic vulnerability at a regional scale.* In: Proceedings of the Elsevier International Conference: "Response of Structures to Extreme Loading", Toronto, August 3-6, 2003.

Cella F., Grimaz S., Meroni F., Petrini V., Tomasoni R. and Zonno G.; 1994: *A case study for seismic vulnerability assesment using gis connected to expert systems.* In: Proceedings of the 9th Arc/Info European User Conference, Paris, France, October 5-7, 1994, pp. 421-448.

Cella F., Grimaz S., Meroni F., Petrini V., Tomasoni R. and Zonno G.; 1995a: *Assessment of seismic effective vulnerability using arc/info connected to nexpert.* In: Proceedings of the Fifth International Conference on Seismic Zonation, Paris, France, October 5-7, 1995, volume I, pp. 68-75.

Cella F., Grimaz S., Meroni F., Petrini V., Tomasoni R. and Zonno G.; 1995b: *An application on geographic information system connected to expert systems.* Cahiers du Centre de Geodinamique et de Seismologie, 9, Luxembourg, pp. 105-129.

CTR; 2007: *Carta tecnica regionale - Friuli Venezia Giulia.* URL http://www.regione.fvg.it/rafvg/territorioambiente/dettaglio.act?dir=/rafvg/cms/RAFVG/AT9/ARG1S.

Grimaz S.; 1992: *La vulnerabilità sismica degli edifici.* Rassegna tecnica del Friuli Venezia Giulia, **1**, 19-24.

Grimaz S.; 1993: *Valutazione della vulnerabilità sismica di edifici in muratura appartenenti ad aggregati strutturali sulla base di analisi a posteriori.* Ingegneria Sismica, **3**, 12-22 .

Grimaz S., Meroni F., Petrini V., Ranú G., Tomasoni R. and Zonno G.; 1995: *Expert system for damage assessment of buildings in seismic areas.* Cahiers du Centre de Geodinamique et de Seismologie, **12**, 83-103.

Grimaz S., Meroni F., Petrini V., Tomasoni R. and Zonno G.; 1998; *Il ruolo dei dati di danneggiamento del terremoto del Friuli nello studio dei modelli di vulnerabilità sismica degli edifici in muratura.* In: La scienza e i terremoti, Forum editore, Udine, pp. 89-96.

Riuscetti M.; 1997: *La vulnerabilità sismica del patrimonio edilizio del Friuli-Venezia Giulia.* Urb. Inf., **XXVI, 155**, 24-25.

Riuscetti M., Carniel R. and Cecotti C.; 1997: *Seismic vulnerability assessment of masonry buildings in a region of moderate seismicity.* Annali di Geofisica, **55**, 1405-1413.

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