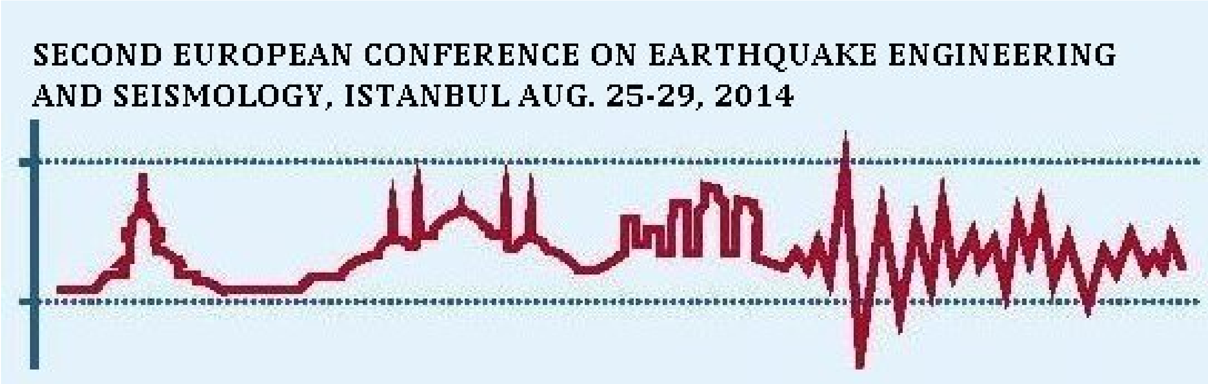

CLEARINGHOUSE TYPE SYSTEM AND DATABASE FOR POST-SEISMIC BUILDINGS ASSESSMENT

Claudiu-Sorin DRAGOMIR[1], Daniela DOBRE[2], Emil-Sever GEORGESCU[3]

ABSTRACT

The paper presents the outline and function of a system for field assessment and the structure of a database for post-earthquake inspections, to be used with the Romanian methodology for rapid buildings assessment, indicative ME003/2007 and for other research purposes. Functioning mode of the system for assessment in emergencies caused by earthquakes and the structure of the data collected by the field teams that participated in post-earthquake inspection are presented in this paper. For this purpose the legal basis for operation of the assessment, specific requirements and the structure of proposed interdisciplinary assessment system were presented.

A system for interdisciplinary assessment was taken into account for strong Vrancea intermediate earthquakes, but it will be useful also for crustal earthquakes of local or regional extent. Interdisciplinarity is given in the proposed theme that involves many logistical and human resources in areas such as earthquake engineering, seismology, geotechnical engineering, geodesy, economy, IT.

The proposed system envisages a coordination centre and a clearinghouse at Bucharest, in NIRD “URBAN-INCERC” that coordinates branches of the territory (Iasi, Timisoara and Cluj Napoca). Given the extensive area, the system will pursue the establishment of regional centres and cities of Brasov and Constanta, where there are universities in this field.

To demonstrate the relevance of the system, the paper presents a case study of two buildings located in the Bucharest center. By exploiting a software application created at INCERC, numerical values and graphics can be obtained for all buildings investigated by INCERC inspectors.

INTRODUCTION

The accelerated expanding of urbanization at globally level makes that almost half the world's population live in cities. Many of these are large cities and are expanded through uncontrolled development, although they are located in areas exposed to many natural hazards, including borders of tectonic plates, in areas prone to destructive earthquakes. The presence of numerous types of vulnerable structures aggravates this seismic risk. To establish an interdisciplinary research field system and with advanced informational techniques on the effects on buildings with different

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functions, in emergency situations caused by strong earthquakes, we studied data from USA, New Zealand and Japan and EU countries.

In USA, according with FEMA154 (2002) the rapid visual screening procedure (RVS) has been developed for a broad audience, for post-seismic buildings assessment, involving building officials and inspectors, government agency and private-sector building owners, to identify, inventory, and rank buildings that are potentially seismically hazardous. Although RVS is applicable to all buildings, its principal purpose is to identify (1) older buildings designed and constructed before the adoption of adequate seismic design and detailing requirements, (2) buildings on soft or poor soils, or (3) buildings having performance characteristics that negatively influence their seismic response.

In New Zealand, structures damaged following the earthquake in September, 2010 was limited mostly to unreinforced masonry buildings. Following inspections it was reported that there was significant damage to about 500 buildings in Christchurch. According with EERI (2011) following the assessment of buildings in central Christchurch it has been estimated that 50% of buildings were unreinforced masonry buildings and about 50 % of them will be demolished this where they collapsed in the earthquake.

All these examples are a proof that post-earthquake investigation and assessment is a time consuming and difficult operation and a system-approach is necessary.

RECENT EUROPEAN EXPERIENCE ON POST-SEISMIC INVESTIGATION

In Europe, the post-seismic investigations are required by tradition and Eurocode 8, part 3. Field investigations are performed by professional associations in collaboration with ministries in civil engineering and planning domain or earthquake engineering.

The damage caused by April 6, 2009 earthquake to the constructions in the L'Aquila region was investigated by representatives of 11 countries, Greece, Turkey, Romania, Macedonia, Slovenia, Italy, Germany, Spain, Portugal, USA and Japan, using tools of the STEP Project(Strategies and Tools for Early Post-Earthquake Assessment).

Therefore, in the context of the European Union, the main purpose of this investigation was to evaluate the possibility of participating in the damages investigation of international teams of experts in the event of major earthquakes that will hit some regions. On the other hand, a comparison between the results, obtained by the application of assessment methodologies specific to the two types of forms, Italian AeDES forms and those used in Bovec, Slovenia, in the STEP Project (2008) was desired. After strong earthquakes one of the main concerns is the safety of buildings against further shocks in order to protect human lives. Since 2010, Goretti and Giannini presented a model for evaluate the aftershock risk for a type of buildings. In that study an application has been made based on parameters of the 2009 L'Aquila sequence. Obtained results are very important in relation to the desirable advances in the methodologies in present used for buildings post-seismic assessment (Goretti and Giannini, 2010).

The field inspection program referred to the following activities:

- in the first stage, teams were established to investigate, stating that the investigation will be done in parallel with the Italian expert teams.

- the field international inspectors teams have carried out the following activities:

  • assessing visual field investigation of buildings;
  • visiting Command and Control Directorate established in L'Aquila, in the first hours after the earthquake, on 06.04.2009, and viewing a few places and important buildings of L'Aquila, which were badly damaged and subsequently evacuated, including local San Salvatore Hospital.

A demonstrative application of Dr.House Project was held in 2013 in Alessandria. The ASA Module (Advanced Seismic Assessment) is coordinated by EUCENTRE and it was aimed at performing fast post-earthquake structural evaluation of strategic or complex structures using combined numerical and experimental techniques. ASA technology is based on the technology developed within the European STEP project (Dr.House Project, 2010). The main objective was to estimate both the damage level and the residual capacity of the structures (Dolce et al., 2012).

Particularly, a special mobile unit (MU) equipped with instrumentation, workstations and servers, was used to perform and coordinate experimental testing activities as well as advanced assessment of buildings. The mobile unit has also functions of data repository and wireless hub. Field data are transferred from ASA teams to MU via satellite connections and wireless technology. The safety assessment was based upon a detailed geometrical survey of the building and non-destructive in-situ tests and can be performed on multi-storey reinforced concrete or pre-cast buildings, masonry buildings, towers, churches and landslides. In some cases, the field investigation will use instrumental measurements of material and dynamic characteristics on buildings.

For detailed analysis, we remarked recent studies developed Ponzo et al. (2010) and by Ditommasso et al. (2012), undertaken by DPC-RELUIS Projects funded by Italian Department of Civil Protection, by using the method of signal analysing based of S-Transform compared to the classical techniques for the time-frequency analysis, this transformation shows a much better resolution.

As general lessons, useful to the earthquake preparedness in Romania, we mention:

- The investigation of state buildings is required by law. In the days after the earthquake, the investigation teams dealing with the present state of the buildings are on the field. This is particularly important in the restoration of normality shortly after the earthquake.
- Investigation of building and data collection is done by Civil Protection-Firemen, Chamber of engineers, Order of Architects, some universities. In the investigation teams were six members of different professions.
- A large amount of data were gathered and transferred after earthquakes and a special IT capacity was necessary in this respect.

A very important issue for Romania will be to cover the entire affected area. For this reason, the European cooperation is beneficial to the establishment of emergency tent camps in the available spaces, ensuring all the facilities to people would live in these facilities after a strong earthquake.

ROMANIAN REGULATIONS AND EXPERIENCE ON EMERGENCY INVESTIGATION

In Romania, the regulation on the prevention and management of specific emergency risk from earthquakes and / or landslides, established by Ministerial Committee held at the Ministry of Regional Development and Public Administration - MDRAP, in case of destructive events requires notes, operative reports and evaluation reports intervention, for NSESM (National System of Emergency Situations Management) computer system. They are the basis for applying the immediate intervention measures according to Methodology ME 003-2007 and establish of intervention solutions and other measures under Ordinance no. 20/1994 for seismic risk reduction.

Great Vrancea earthquakes occur every few decades, and approximately 60% of Romanian territory, mostly the S-E area, is directly affected. Therefore, the investigation requires a great effort and it should be prepared in advance, because loss of data concerning the earthquakes effects would be irrecoverable. Romania cannot afford to lose field data observations and must be correlated with those from instrumental records. For these reasons, it is necessary to organize a specific system of effects investigation (Dragomir et al., 2012).

After a first edition in 1999, a new methodology for emergency investigation of post-seismic safety of buildings and framework solutions for intervention was enforced in 2007 (MTCT, 2007). The quick inspection is followed by a rapid evaluation, based on specific criteria and record forms, with application of four types of coloured placards, in view of building usability. The emergency intervention measures for safety of living inside buildings include techniques and drawings for provisional shoring and/or local repair.

The methodology is limited to residential, socio-cultural and administrative buildings, as well as to buildings with other functions, as applicable. For buildings and facilities with other functions, one should apply specific regulations and if they do not exist one can tentatively take-over provisions from this regulation.

For detailed assessment in Romania, Existing Buildings Seismic Evaluation Code P100-3/2008 provides temporary seismic instrumentation of buildings.

Since 2002, Romania is a signatory country of "EUR-OPA Major Hazards Agreement", the Open Partial Agreement on prevention, protection and assistance in the event of major natural and technological disasters (http://www.coe.int/t/dg4/majorhazards/default_en.asp). Countries are focused on prevention and early intervention, including:

- Harmonization of procedures and protocols for data exchange and online information on the effects of disasters and the demands and proposals for emergency assistance;
- Procedures and techniques of risk assessment, of the stability of buildings and civil engineering works, safety of facilities in the chemical, radiological, vital systems, of evaluating losses.

THE PROPOSED STRUCTURE OF ROMANIAN INVESTIGATION SYSTEM

When a destructive crustal earthquake occurs in the north or western region of Romania regional centers can handle the situation almost alone. But in case destructive Vrancea earthquake occurs, it affects about 50% of the Romanian territory and ministerial committee must seek specialists in the center and west of country.

The specific situation of Romania seismic areas requires the implementation of an effective system for ensuring the investigation sites built after earthquakes. The center will be based on technical coordination of investigations and data collection, including the organization of a database with a close collaboration with regional centers for better coverage of the territory.

The proposed system for field assessment will meet the requirements of the Regulation on the prevention and management of emergencies of MRDPA, it will use the existing institutional structures and their staff, and other specialists or partners required or prescribed in the Regulations. For this aim, a structure for the management of the operational interdisciplinary investigation, based on regional centers (where specialists have to be trained), will be established.

The core of the system is represented by Bucharest INCERC Branch of NIRD "URBAN-INCERC", which will coordinate the collaboration of branches of NIRD "URBAN-INCERC" from territory (Iasi, Timisoara and Cluj Napoca), as some regional centers which will work with the State Inspectorate in Construction (ISC) and with university centers (Figure 1).

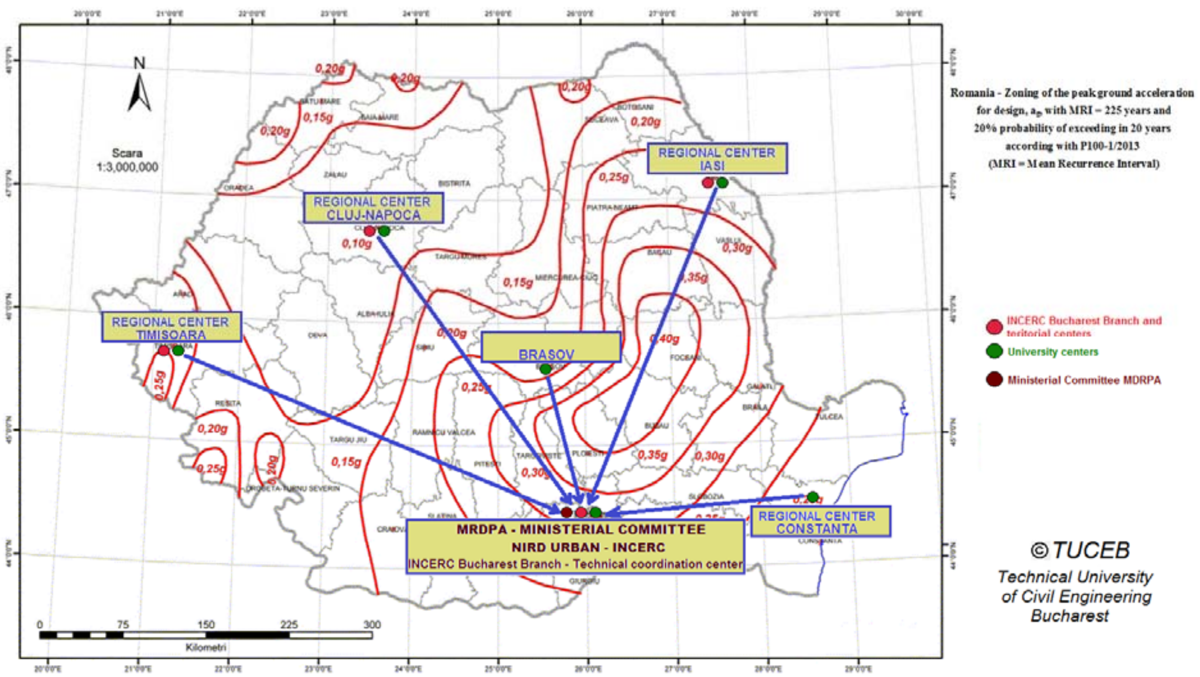


Figure 1. The territorial structure of the post-seismic investigation system

Taking into account the extensive area that will be affected by any Vrancea earthquake, the establishment of regional centers in Brasov and Constanta will be also considered, as there are faculties in the civil engineering field. The structure of Regional Centers will rely also on Prefectures / City Hall, State Inspectorate for Emergency Situations (IGSU), professional associations as

Associations of Earthquake Engineering in Romania - ARIS, Association of Civil Engineering in Romania - AICR and Association of Structural Engineering - AICPS, etc (Dragomir et al., 2011).

The following sources of staff are considered: specialized personnel engaged in local councils - municipalities, specialized personnel of the MRDPA, specialized personnel of the ISC, structural engineers and technicians in the institutions, business firms and design offices, institutions of higher education, institutes and centers research in construction activity recognized, engineers and technicians involved in volunteer activities earthquake, engineers and / or construction companies hired for specific tasks (supporting emergency, demolition etc.), university teaching staff from educational centers with technical profile (construction), students in technical universities (construction).

In Figure 2 the functioning scheme of integrated system for post seismic assessment according with Romanian methodology, indicative ME003-2007 is shown. According with the scheme post-seismic assessment of buildings in case of strong earthquake is coordinated by Ministerial Committee for Emergencies established alt Ministry of Regional Development and Public Administration, named here MDRAP.

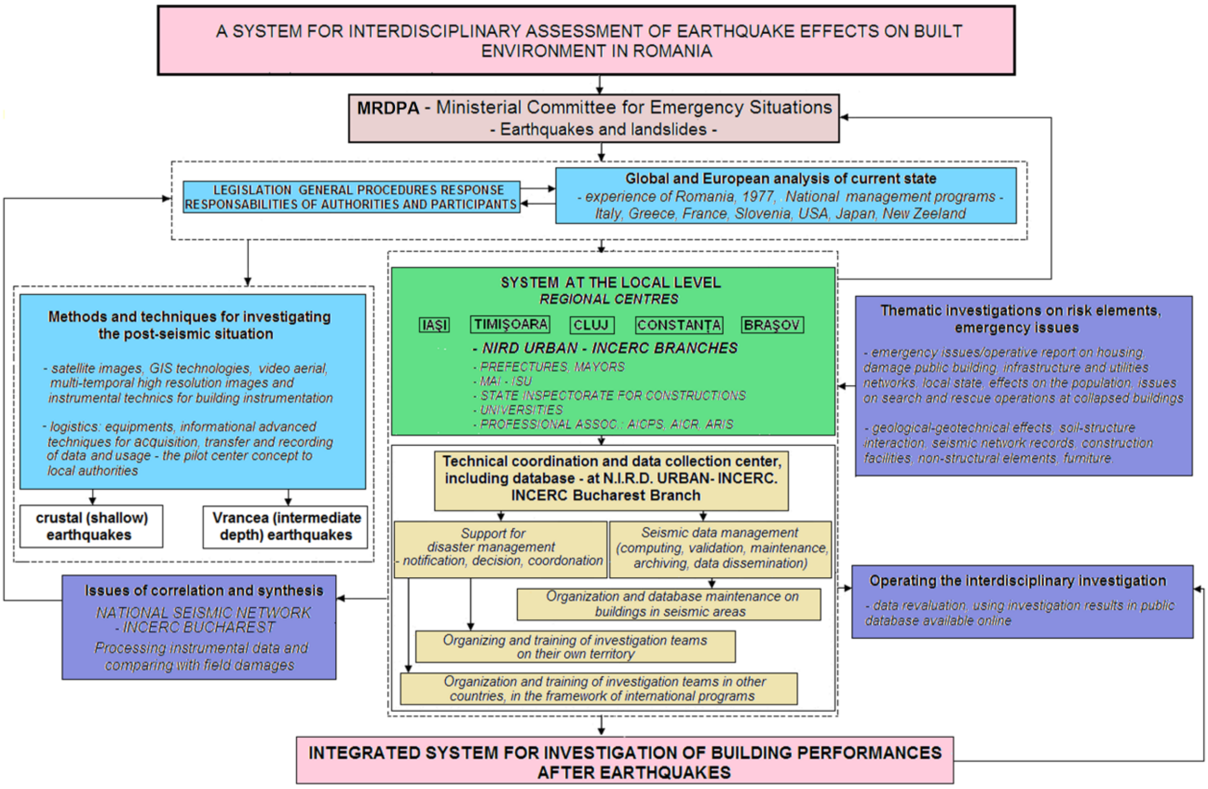


Figure 2. The scheme of system of the post-seismic investigation system, to be used with the Romanian methodology, indicative ME003-2007 and for research purposes

Regional centers should provide an early distribution and correlation sending teams in different areas with the local technical staff available. From specialists with special training and experience, a collective territorial center that will be responsible for technical guidance field teams, will check daily reports and will travel to cases where it is difficult or complaints arise will be organized.

During a specific emergency, the specific activities are carried according to laws, regulations, plans and technical regulations in force at the central and local public authorities. Organizing, coordinating, implementing and monitoring the legal and administrative measures and actions on post-seismic investigation in the management of specific emergency are assigned to:

- the National Committee for Emergencies at national level;
- Emergency Ministerial Committee held in Ministry of Regional Development and Public Administration - MDRPA, at central level;
- the County Committees / Committee Bucharest and local committees of its districts,

municipal, town and city emergency, in the territory;

Coordination of technical, construction of emergency investigation, including endowments, shall be made as follows:

- At central level by the Ministerial Committee for emergencies, the Ministry of Regional Development and Public Administration.
- At the local level by county committees / committee and local committees Bucharest its districts, municipal, town and city emergency by:
- Prefects, mayors and their staff and/or Emergency Inspectorate;
- Chief Inspector of the Inspectorate/County/Bucharest in buildings and staff appointed by them.

METHODS AND TECHNIQUES IN THE FIELD INVESTIGATION OF EARTHQUAKE EFFECTS

Taking into account the issues raised in the inspection of buildings after the earthquake of March 4, 1977, when the data taken by the institutions that dealt inspections have different formats, it’s necessary that the data gathered to be interpreted in the same way, using the same techniques and the same methodology, thereby focusing on creating a database which will contain all information about the condition of the buildings. By processing this information subsequently integrated to be able to draw conclusions on the vulnerability of the buildings on structural categories.

For proper functioning of the interdisciplinary research field system is need that the technical coordination center and five regional centers have software used internationally for processing satellite/aerial images to detect areas with severe damage and technical teams within each territorial and also they need have satellite images taken before the earthquake to be compared with those made after the event.

Classical forms will be used but the latest information technology means will be used to investigate the damage, according to the experience of the STEP European project. An alternative to using Palm Computer according with DrHouse European projects will be the PC tablets or small laptops (max. 10"), equipped with wireless connection and data transmission possible through mobile internet. In this way the data will be stored and transmitted in time intervals, for example 3 times a day at the end of each day to update the database created at Bucharest INCERC Branch.

The existing of a mobile laboratory equipped with the necessary equipment (sclerometer, pachometer, jacks, ultrasonic devices for determining the mechanical properties of construction materials, seismic instrumentation equipment, thermography, etc.) for structural investigation, model used in the post-seismic buildings assessment exercise organised in the framework of DrHouse European Project in Alessandria, Italy, 2013;

- Creation of stock inspection forms for each center and the availability of minicomputers to complete forms electronically. This method would help reduce the time needed for intervention and a quick update existing data center technical coordination within Bucharest INCERC Branch when satellite data are transmitted.
- Creating database of articles within the fields used for field inspection forms, which will contain data on the 1977 building investigations and will be updated after each strong earthquake.

RETRIEVAL OF DATA COLLECTED BY INVESTIGATION TEAMS ON THE FIELD - PUBLIC DATABASE ON-LINE ACCESS

The database structure was created at INCERC and it contains data on all types of construction collected from inspections carried out by research teams. It is noted that these issues will be established following:

- The number and qualifications of staff involved as collaborators/volunteers (students, master students, doctoral students, assistants) during periods of emergency created by incidence of an strong earthquake are not yet known;
- The relationship of the regional centers with the technical coordination center, or with the operating center and with SMISU, is not yet established;

Given the issues mentioned above, we have detailed a database only for buildings for which we have coverage and detailed technical and extension will be able to obtain consensus on users (for compatibility between users).

The database created for civil engineering buildings include fields and items such as: location information about building, details about the construction of the building (the date on which it was designed, executed that building), the structural model of the building, changes in performance (both in irregularities and elevation) building plans, structural elements, overall damage, non-structural damage, injured or dead, functionalities, failures in terms of geotechnical disposals.

To simplify inspection forms, some certain structural categories, such as masonry buildings, concrete buildings and concrete buildings, should be grouped. Some issues to be considered to achieve the database structure for different categories of construction:

- For dwellings and socio-cultural buildings, first question refers to the issue of safety of life, so the structural damage is the most important aspect;
- In industrial buildings, an important aspect of industrial business interruption is due to an equipment failure.
- In case of massive structures it will be studied how they behave under seismic actions and how is affected their functionality from their damage.
- In the case of bridges, it is essential that in addition to damages related to their structural elements, to inspect and state soil near the abutments, as the bridge may become inoperative due not necessarily damage the structure.

Among the most important items of the database must be found the followings:

- Description of the building (address, property type, height mode), type of construction, production layout, the type of damage;
- For the same type of building, it is necessary to know not only how many buildings have been damaged, but all were not damaged. The sources of data describing the damage do not provide consistently (or frequently) also this type of information.

A database SIS INV TEREN (System interdisciplinary field investigation with techniques and advanced information impact on constructions with various function, in emergency situations caused by earthquakes) was created, which includes all data collected in the field by teams of inspectors.

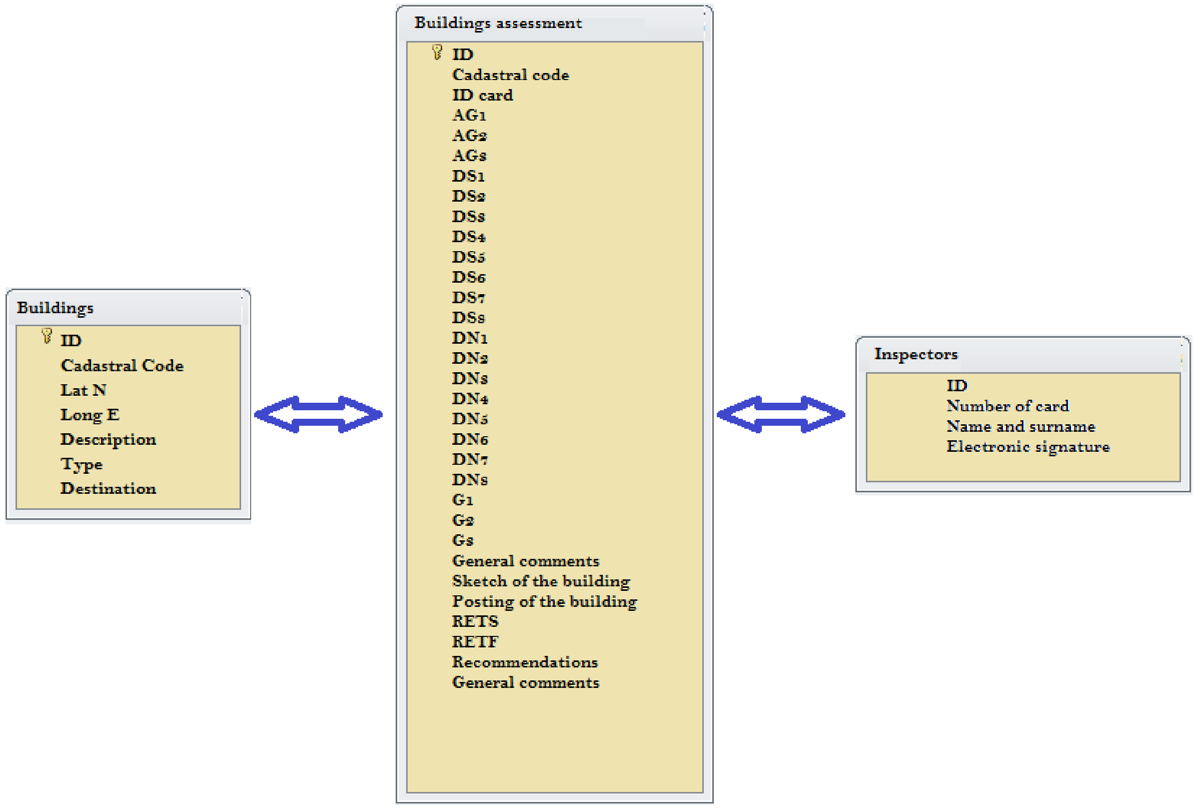
By exploiting software created at INCERC, numerical values and graphs for all buildings investigated by specialists from INCERC Bucharest Branch can be obtained.

In Excel tables, all the data submitted in the six forms of investigation by the two inspector’s delegates from INCERC (Database - data collection teams.xls) and SIS INV TEREN.DBF were taken.

For SIS INV TEREN.DBF database some tables (imported from databases - data collection teams investigare.xls) and the relationships between these tables are presented. In Figure 3 are presented the attributes of database created using Ms. Access software. Also the output data are presented in the form of reports created in Access (Dragomir et al., 2013). The output data is in the form of lists containing data on buildings investigated using the following query: buildings with reinforced concrete frame structure declared safe buildings, buildings with reinforced concrete frame structure declared unsafe buildings, buildings with masonry bearing walls declared safe buildings, masonry bearing wall buildings declared unsafe buildings, individual homes declared unsafe buildings, public buildings for have been made recommendations related to their technical expertise of structure.

Beside Excel tables containing drawings and graphic representations of buildings, scanned signatures of inspectors, the description of buildings and general remarks submitted by inspectors in the inspection form were used.

It is worth mentioning that the database will keep electronic copies of the inspection forms that will be useful to conduct studies after producing another seismic event and when performing detailed technical expertise.



Legend:

AG - General aspects; **AG1** - Collapse, partial collapse; **AG2** - the building or one of the floors are tilted; **AG3** - other aspects ;
DS - structural damage; **DS1** - Foundations; **DS2** – roof structure/frame; **DS3** - floors (for vertical loads); **DS4** - columns, pillars, RC columns embeded in masonry; **DS5** - floors (as diaphragms) horizontal bracing; **DS6** - structural wall, vertical bracing; **DS7** – joints of prefabricated elements; **DS8** - other aspects;
DN - degradation of non-structural elements; **DN1** - parapets, ornaments; **DN2** - Plywood , windows /glass; **DN3** - ceiling lighting elements; **DN4** - inner partition walls; **DN5** - elevators; **DN6** - stairs, exist ways; **DN7** - electricity, gas; **DN8** - other aspects ;
G – Ground/Geotechnical dangers; **G1** - Landslide; **G2** – ground movements, cracks; **G3** - other aspects;
RETS - Recommendations for technical expertise of structure; **RETF** - Recommendations for technical expertise of foundations ;
MI - Minor; **MO** - Average; **SE** - Serious.

Figure 3. Database atributes using ACCESS software

CASE STUDY OF BUILDINGS LOCATED IN BUCHAREST

A data base of measured natural periods for some 50 high-rise buildings existed prior to Vrancea, March 4, 1977 earthquake and it was possible to compare the pre- and post-earthquake natural periods, i. e. to correlate them with the damage and further on with the effect of strengthening. Other measurements were performed after the 1977 earthquake for over 100 standard design condominia. (Sandi et al., 1985).

Several valuable records were possible in buildings during Vrancea earthquakes of 1986 and 1990. The Romanian experience of INCERC after 1977 proved that low damage was associated to increases of natural periods by 20...25%. Multiple, but relatively light damage, may rise periods up to 25...50%, while systematic damages or local and significant ones raised periods by more than 50%. Spectral content was a major issue, since buildings having natural periods closer to high spectral values have been heavily damaged (Balan et al., 1982).

According to Sandi et al. (1985) some urban-mark buildings, like the trussed large span Dome of the National Exhibition have been investigated using these techniques.

Since the number of high-rise structures is increasing, field surveys, laboratory testing and instrumental data are a background in this respect and the recent Romanian Earthquake Design Code (2013) and its companion Romanian Existing Buildings Seismic Evaluation Code P100-3/2008 (2008) that provides a framework for advanced instrumental monitoring. Strong-motion Seismic Networks in Romania are used in Romania for engineering purposes and structural health monitoring. INCERC Bucharest Branch operates the Strong-Motion National Seismic Network for Constructions, the larger in Romania (Georgescu et al, 2010). The Network has an agreement with the State Inspectorate for Constructions to operate its instruments. Since 2010, NIRD "URBAN-INCERC" incorporated the seismographic network donated by JICA Project to NCSRR (The former National Center for Seismic Risk Reduction). Thus, a total of 117 equipments exist under INCERC maintenance, out of which 4 in buildings, and 39 instruments in Bucharest, out of which 7 in buildings according Aldea et al. (2004). As much as new high-rise buildings are erected, the number of instrumented buildings is increasing.

The database of measured periods has been updated since 2009 thanks to the Project PN 09- 01 01Integrated investigation of buildings performances after strong earthquake, financed by the Ministry of Education and Research. So, the buildings presented in case study were monitorized in PN 09-14 01 01Project.

The buildings shown in Figure 4 were designed and erected in the years 1970's, consequently these buildings were subjected to Romanian earthquakes of 1977, 1986, 1990 and 2004. The buildings have the same height level of ten storeys and a reinforced concrete structure.

Figure 4. Images of two buildings: Block of flats no.16 (left side) and Block of flats no.21 (right side)

The results obtained by processing of recordings and provided of temporary seismic instrumentation for two buildings are presented in Table 1. It is noted that this comparative study records before and after a strong earthquake was used the classical method for the time-frequency analysis. It consisted in processing and obtaining the Fourier spectrum for recordings from four three-axial sensors and identify of frequency peaks to the four spectra obtained for each direction separately.

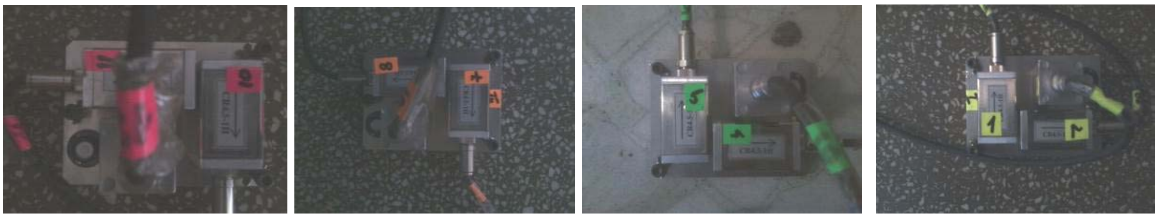
Table 1. Evolution of natural periods in time

Building	Period of measurements	Type of excitation	Directions	
			Transversal	Longitudinal
Block of flats no.16	Before of 1977	Microtremor	0.59	0.46
	After 1977	Microtremor	0.77	0.65
	2012	Microtremor	0.72	0.60
Block of flats no.21	Before of 1977	Microtremor	0.60	0.45
	After 1977	Microtremor	0.70	0.67
	2012	Microtremor	0.70	0.58..0.60

It is worth of mentioning that the recordings were made after two axial sensor placement schemes: one horizontal direction (four sensors located on the terrace of the building – Figure 5) and the other in the vertical direction (vertical four sensors located on the ground floor of the building, 2st floor, 5th floor and 10th floor – Figure 6).

In the case of two buildings the assessment was based on results of seismic instrumentation. Stiffness change detected as a result of temporary seismic instrumentation made in 2012 is probably due to structural interventions on two buildings after the 1977 earthquake. Note that changes in natural periods of oscillation are small, differences may arise due to precision measurement and equipment used in a time span of about 35 years. After assessment inspectors declared buildings as safe.

Figure 5. GEODAS 12USB equipment used for temporary seismic instrumentation



Sensor IV - storey 10 *Sensor III – storey 5* *Sensor II – Ground floor* *Sensor I – storey II*

Figure 6. Three-axial sensors location on vertical direction

CONCLUSIONS

The paper presented the outline and function of a system for field assessment and the structure of a database for post-earthquake inspections according with Romanian methodology for rapid buildings assessment, indicative ME-003-2007 and for research purposes.

A database including all data collected in the field by teams of inspectors was created at Bucharest INCERC Branch. By exploiting of software created, numerical values and graphs for all buildings assessed by INCERC inspectors including those investigated after L'Aquila earthquake.

Virtual space thus created will have two sections. A section of clearinghouse type where data from field investigation teams will be collected; also the information can be retrieve by authorized persons with access allowed based on codes and the second section dedicated to public information. The public can access the site and may have the information stored in databases created for this purpose. Reliance on information taken from the site is on the prestigious institution that has participated in inspections conducted after the 1977 earthquake.

It is proposed that the authorities will examine the need and the opportunity to promote a decision for the operation and resources of this system of interdisciplinary field investigation with techniques and advanced information of impact on constructions with various functions, in emergency cases produced by strong earthquakes.

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