# NATIONAL CENTRE FOR SEISMIC RISK REDUCTION

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## ABSTRACT

The aim of the present paper is to describe the seismic risk reduction efforts in Romania. Seismic risk reduction in Romania can be achieved through several types of actions from which the major ones are (i) seismic vulnerability assessment, (ii) seismic rehabilitation of existing buildings and modern earthquake-resistant design for new buildings, (iii) increased number of recorded strong ground motions in conjunction with accurate soil characterization, and (iv) education and information of citizens. In this respect, a great support for Romanian efforts for seismic risk reduction came through a Japan International Cooperation Agency (JICA) project in Romania, implemented by the National Centre for Seismic Risk Reduction (NCSRR) in the period of 2002-2008. The Project and NCSRR's activities are described in the present paper.

## INTRODUCTION

The Ministry of Regional Development and Tourism in Romania (MDRT) is currently developing 3 main programs for seismic risk reduction in Romania:
- Program for the retrofitting of multi-storey residential buildings – Romanian Government is currently supporting from public funds the retrofitting of multi-storey seismic vulnerable residential buildings, irrespective of the ownership type;
- High emergency retrofitting program for public interest buildings – this program addresses to the high importance buildings, historical monuments, etc. The retrofitting of these structures is supported by MDRT;
- Program for risk mitigation and preparedness for natural disaster co-financed by Word Bank and International Bank for Reconstruction and Development.

As a result of the seismic evaluation in Bucharest, 392 residential buildings were ranked as seismic risk class I (on a scale from I to IV), and MDRT decided to retrofit them with high priority.

Based on the first program 15 buildings have been retrofitted, 6 are under retrofitting work and for 19 buildings the retrofitting work is being prepared to start the works. Moreover, design for seismic retrofitting is ready to start or undergoing for 23 buildings.

The World Bank program for seismic risk reduction worth of 73.7 mil USD (from which 56.9 mil USD are to be paid by International Bank for Reconstruction and Development and 16.8 by Romanian Government) and co-financed by the owners with 108 mil USD lead to the retrofitting of 8 public buildings of high importance. 17 buildings are under retrofitting and 18 buildings will follow.

Moreover, MDRT is paying efforts towards issuing and revision of seismic design, evaluation and retrofitting codes and guidelines for quick inspection of damaged buildings after the earthquake. At central governmental level a comprehensive risk management program is under development. This comprises all kind of hazards: natural hazards, industrial hazards, pollution etc. MDRT is coordinating the cell of the Commission for Emergency Management handling the earthquake related hazards. MDRT is constantly supporting the management and development of the engineering seismic networks within it's specialized subordinated institutions.

While the public authorities are responsible for issuing modern regulations, implementing

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the effective construction quality control system and easy access of owners to the technical and legal tools, the research institutes and universities are called to play the major role in seismic risk mitigation by extensive research and education of practitioners and general public.

In this respect, a great support for Romanian efforts for seismic risk reduction came through a Japan International Cooperation Agency (JICA) project in Romania, implemented by the National Centre for Seismic Risk Reduction (NCSRR) in the period of 2002-2008. The Project and NCSRR's activities are described in the present paper.

## NATIONAL CENTER FOR SEISMIC RISK REDUCTION

Since modern or/and cost time-effective retrofitting strategies and techniques were not fully available to Romanian structural engineers, at the initiative of Technical University of Civil Engineering Bucharest (UTCB), the Romanian Government requested in 1998 to the Japanese Government (Japan International Cooperation Agency, JICA) to begin a technical cooperation on the seismic risk reduction focused on the improvement of retrofitting techniques. Extensive negotiations started and several Japanese investigation teams visited Romania. Also, from 2000 a long-term Japanese expert was dispatched at UTCB for supporting the construction of the cooperation Project.

After four years of intensive efforts the Project Design Matrix (PDM) was defined and agreed, and on August 1, 2002, the Record of Discussions (RD) was signed between MDRT of Romania and JICA. The JICA Project started on October 1st, 2002 with NCSRR as the implementing agency. The initial planned duration of the Project was five years, but after Romanian side request, an extra half year was accepted, and the Project ended on 31 March 2008.

According to the RD of the JICA Project the purpose was “Improving and dissemination of the technologies for reducing building collapse in case of devastating earthquakes are achieved”. The target of the Project were the Romanian citizens, in particular those in Bucharest. All along the project was carried out a sustained activity of dissemination to the Romanian civil engineers of modern techniques and methodologies, and seminars for disaster prevention education were held for citizens.

The implementing agency of the JICA Technical Cooperation Project on the Reduction of Seismic Risk for Buildings and Structures was the National Centre for Seismic Risk Reduction (NCSRR) as a public institution of national interest, a specialized legal entity created in 2002, subordinated to the MDRT of Romania. The main activities of the NCSRR are as follows:

- Studying, evaluating, applying and disseminating new technologies for retrofitting the earthquake vulnerable buildings and structures;
- Supporting the revision of codes and regulations for earthquake resistant design, seismic evaluation and retrofitting;
- Seismic instrumentation (with focus on Bucharest) and soil testing;
- Transfer of state-of-the-art knowledge in the domain of earthquake engineering to specialists through the organization of seminars, symposiums and conferences;
- Issuing documentation regarding education of the population for preventing the seismic consequences;
- Improvement of technical knowledge by training, studies and documentation, seminars, courses and lectures in Romania and abroad;
- Promotion of the international cooperation in the domain of seismic risk management;
- Publishing papers, studies and publications in the field of earthquake engineering;
- Other activities related to national and international projects.

The activities of NCSRR were carried out in partnership with Technical University of Civil Engineering Bucharest (UTCB) and National Institute for Research and Development in Construction and Construction Economics (INCERC) Bucharest. The main Japanese research institutions that supported JICA were the National Institute for Land and Infrastructure Management (NILIM) and the Building Research Institute (BRI).

During the JICA Project period, twenty nine (29) Romanian researchers/engineers were trained in Japan, seven (7) Japanese long-term experts and thirty seven (37) Japanese short-term

experts were dispatched to Romania. Within the Project, equipments for seismic instrumentation, for soil investigation and soil testing, and for seismic testing of structural elements rising up approximately to 260 million yens (i.e. 2.2 million USD) were donated by JICA to Romania, through NCSRR. The total JICA financed Project cost was 7 million USD.

The activities of the NCSRR were carried out in four divisions, namely:

- Division 1 - Building Retrofitting and Design Codes
- Division 2 - Seismic Observation Network
- Division 3 – Technical Experimentation for Soil and Structures
- Division 4 – Dissemination of Knowledge and Training of Engineers.

**NCSRR experimental research on structural elements**

The main purpose of the structural testing conducted at NCSRR was to try to identify the behavior of structural members designed according to the Romanian state of practice at different periods of time. This objective implies the identification of the failure pattern and the evaluation of the parameters that can describe in a favorable manner the member's behavior (e.g. for reinforced concrete members: yielding force and displacement, displacement ductility, ultimate bending force, ultimate shear capacity, etc.). While some of these parameters can be reliably evaluated by analytical means, other can only be identified by experimental research. For example, the analytical procedures available for the evaluation of the shear capacity of reinforced concrete elements are calibrated to be used in the design of new structural system, therefore these procedures offer conservative values of the capacity. These values cannot be used to reliably identify the capacity of the structural system although they are perfectly suited for the checking of the performance objectives criteria. Moreover, worldwide developed capacity assessment or design equations can be used only after a reliable confirmation by structural testing in a particular country. The suitability of each relation strongly depends on the state of practice in each country given not only the traditional construction materials and techniques but also quality of workmanship.

Therefore, structural testing is an essential tool in the process of issuing or revising design, evaluation and retrofitting codes. The experimental testing was developed as key component of the seismic risk reduction in Romania within the JICA technical cooperation project.

The structural testing facility consists of a steel reaction frame, loading control device, data acquisition and processing systems. The reaction frame is similar to the one existing at Building Research Institute, Tsukuba, Japan. The maximum weight of tested specimens is 70kN and the maximum dimensions of the specimens are 2.5m by 3.0 m.

The following load combinations are possible with this provided equipment: bending with shear force for beam testing; bending with shear and axial force for column, shear wall and portal frame; bending and shear tests for frame joints; shear test for slabs.

This structural testing facility, worthy of approximately 1 million US$, was donated by JICA to the NCSRR and installed in March/April 2004 at the NCSRR UTCB site, Bucharest Figure 1.

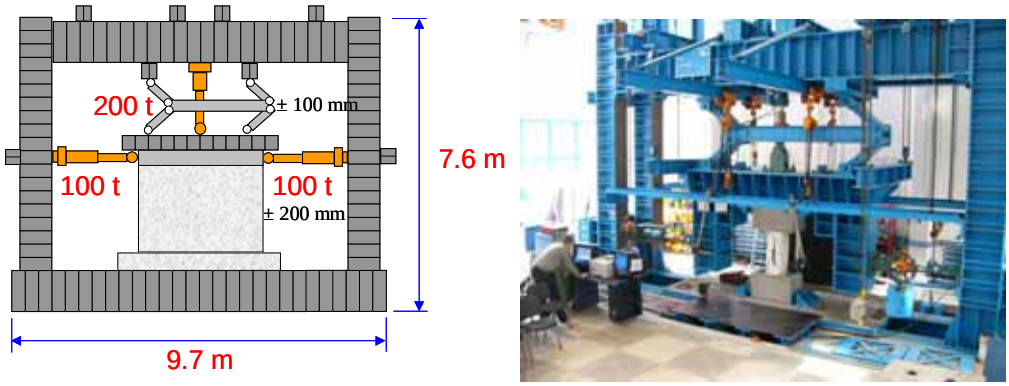


Figure 1. Overall dimensions, force and stroke capacities of reaction frame loading system

The number of tested specimens since 2004 is presented in Table 1. At the beginning, the testing effort concentrated on vulnerable concrete elements designed and detailed according to the state of practice in Romania at the middle of the 20th century. Subsequently, masonry walls, RC slabs, and steel braces were tested.

Table 1. Current status of structural tests

| Structural element | Number of tested specimens since 2004 |
|---|---|
| RC columns | 22 |
| RC walls | 5 |
| Masonry walls | 45 |
| Steel braces | 3 |
| Energy dissipation device | 1 |
| RC slabs | 14 |

**Strong ground motion observation and soil investigation**

The main objectives of NCSRR activities for seismic strong motion observation and soil testing are:
- Seismic strong ground motion data collection (in free field and boreholes);
- Seismic strong motion data collection in buildings to study buildings behavior;
- Revision of strong ground motion design parameters and developing new models for strong ground motion studies;
- Ground condition characterization (especially at seismic station sites) through site investigation and laboratory soil testing.

The equipment for strong ground motion observation, NCSRR staff installed soil testing and investigation donated from JICA in 2003 with technical support from Japanese experts and technicians from OYO Seismic Instrumentation Corp. dispatched in Romania especially for this purpose. Starting from 2005 NCSRR network was enlarged with Romanian investment (within the budget ensured by MDRT), other sites and buildings being instrumented with Geosig equipments and technical support. Nowadays NCSRR digital network consists of 40 accelerometers (6 ETNA, 11 K2, 10 IA-1, 3 GSR), 34 under exploitation and 6 under installation.

***Free-field seismic stations for ground motion attenuation analysis***
Six Kinemetrics ETNA stations were installed in 2003 on the SW direction starting from Vrancea epicentral area toward Bucharest, for ground motion attenuation analysis. All of them are in buildings with 1 or 2 storeys, which can be considered as a free field condition. Ground conditions are under investigation. One Geosig IA-1 accelerometer was installed in 2007, on a perpendicular axis to the SW, direction that will be further instrumented.

***Seismic stations for site effects assessment in Bucharest***
NCSRR installed in 2003 in Bucharest seven (7) Kinemetrics K2 stations with sensors at ground surface (close to free-field conditions) and in boreholes at two levels of depth: the first level at about 30m depth and the second level between 52m and 153m depth. In 2005 another site in Bucharest was instrumented with Geosig equipments (free-field and a 30m depth borehole). In 2011 a borehole station is envisaged to be installed in the city of Iasi (NE from Bucharest). At all the stations the soil profile of the boreholes is known, and NCSRR and Tokyo Soil Corp. (Japan) performed down-hole tests. A brief description of the borehole instrumentation is given in Table 2.

***Seismic stations for structural monitoring***
Two residential buildings and two public buildings were instrumented in 2003 with Kinemetrics instruments. In 2006 the Technical University of Civil Engineering Bucharest UTCB main building and in 2008-2009 the Faculty of Civil Engineering Brasov were instrumented with Geosig instruments.

All sensors are tri-axial acceleration sensors, their orientation follows the transversal and longitudinal directions of the buildings. In the case of Kinemetrics instrumentation, all sensors are connected to one K2 acquisitions station that also has an internal sensor. In case of Geosig instrumentation are used two acquisition stations with internal sensors. The building instrumentation is described in Table 3.

Table 2. NCSRR Seismic Network – free field and borehole instrumentation in Bucharest

| No. | Site | Surface sensors location | Shallow borehole depth | Deep borehole depth | Type of instruments |
|---|---|---|---|---|---|
| 1 | UTCB Tei/NCSRR | free field | -28 | -78 | *K2/FBA-23DH* |
| 2 | UTCB Pache | 1 storey building | -28 | -66 | *K2/FBA-23DH* |
| 3 | INCERC/NCSRR | 1 storey building | -24 | -153 | *K2/FBA-23DH* |
| 4 | Civil Protection Hdq. | 1 storey building | -28 | -68 | *K2/FBA-23DH* |
| 5 | Filantropia Hospital | free field | -28 | -151 | *K2/FBA-23DH* |
| 6 | City Hall | free field | -28 | -52 | *K2/FBA-23DH* |
| 7 | Municipal Hospital | free field | -30 | -70 | *K2/FBA-23DH* |
| 8 | UTCB Plevnei | free field | -30 | - | *GSR24/ AC23-DH* |

Table 3. NCSRR Seismic Network – Building instrumentation

| No. | Site | Station(s) location | Sensor 1 | Sensor 2 | Sensor 3 | Type of instruments |
|---|---|---|---|---|---|---|
| 1 | Stefan cel Mare 1 | 10$^{th}$ floor (base) | 10$^{th}$ floor (top) | 4$^{th}$ floor | basement | *K2/Episensor ES-T* |
| 2 | Stefan cel Mare 2 | basement | 7$^{th}$ floor (top) | Free field | - | *K2/Episensor ES-T* |
| 3 | *TVR* Tower | 13$^{th}$ floor (base) | 13$^{th}$ floor (top) | basement | - | *K2/Episensor ES-T* |
| 4 | *BRD-GSG* Tower | 19$^{th}$ floor | 3$^{rd}$ basement | - | - | *K2/Episensor ES-T* |
| 5 | Faculty of Civil Engineering, Bucharest | 3$^{rd}$ floor (top) & basement | - | - | - | *IA-1* |
| 6 | Faculty of Civil Engineering, Brasov | 8$^{th}$ floor top & basement | - | - | - | *IA-1* |

Since its installation in 2003, the NCSRR network recorded almost 200 seismic motions from over 30 earthquakes (from Vrancea subcrustal and crustal seismic sources, and also from Bulgaria and North Dobrogea shallow sources) with moment magnitudes ranging from Mw=3.2 to 6.0. The October 27, 2004 Vrancea earthquake (Mw=6.0, focal depth 98.6km) is the strongest recorded until now by the NCSRR seismic network and is the strongest event since 1990. The earthquake was felt on large areas but produced almost no damage (as reported by news agencies). In Figure 2 are presented examples of ground motions recorded during the October 27, 2004 earthquake.

Microtremor observation is another activity developed within the Project by Division 2. Portable acquisition stations and sensors were also donated by JICA. Microtremors were measured on buildings and on ground (single-station of array measurements) for the identification of building dynamic characteristics, for the evaluation of site response characteristics and for identification of seismic velocity profiles.

Until today the following measurements were performed:

- Single station measurements of ground ambient vibrations – 19 locations
- Array measurements of ground ambient vibrations – 5 locations
- Measurements of building ambient vibrations – 7 buildings.

A joint activity of Divisions 2 and 3 is the borehole geophysical investigation (PS-logging tests) for identification of seismic velocities at different sites. The equipments were also donated by JICA. Until today, more than 30 PS logging tests were performed.

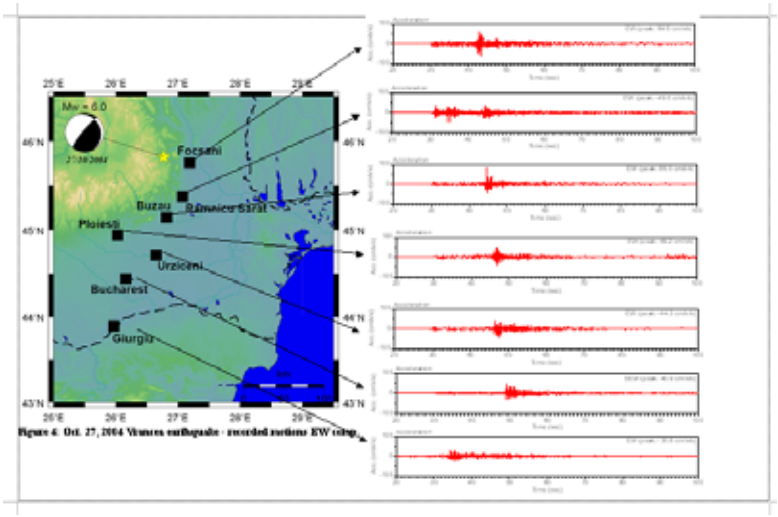


Figure 2. Seismic records obtained in NCSRR network during Vrancea earthquake of October 27, 2004

Starting with 2003, NCSRR received, as a donation from JICA, the drilling equipment FRASTE Type Multidrill XL, which has as attachments an automatic device used for Standard Penetration Test. In July 2004, NCSRR received as donation from JICA the CPT equipment from Geomil, Holland. In July 2003 the triaxial equipment manufactured by Seiken Inc. Japan and donated by JICA was installed at NCSRR. The equipment fulfils all the requirements of the Japanese Geotechnical Society, 2000. In Figure 3 and Figure 4 are presented the Division 3 equipments.

Researches of the dynamic characteristics of soil have been carried out using laboratory soil testing and in situ tests, including geophysical methods. Using the equipments donated within the Project, Division 3 performed the following activities:

- Drilling boreholes – 17
- CPT tests – 5
- SPT tests – 35
- Surface wave tests – 6
- Dynamic triaxial tests – 43
- Static triaxial tests – 45
- Bender element tests – 15.

Figure 3. Drilling equipment on truck

Figure 4. Dynamic triaxial equipment

**NCSRR activities for dissemination and education of citizens and engineers**

Seminars for engineers, inhabitants of vulnerable residential buildings and students were organized by NCSRR in cooperation with MDRT and Bucharest City Hall Office. The total number of seminars amounted at 32, out of which 4 were for citizens, 7 for students and 21 for engineers. The importance of preparedness for the next big earthquakes such as adequate behavior in the earthquake and seismic evaluation and retrofitting of the vulnerable buildings were emphasized in these seminars.

Seminars for engineers are organized by NCSRR in cooperation with UTCB and INCERC. Lecturers in these seminars are Japanese experts and the staff of NCSRR. The Project contributed in the preparation of a series of educational leaflets to instruct disaster preparedness for school children as shown in Figure 5.


Figure 5. Manuals on disaster preparedness for school children

For efficient information of the students and engineers regarding the implementation of retrofitting works, a full scale model of one story frame was constructed at UTCB. Using this frame, Figure 6, various retrofitting techniques were applied: concrete infill wall, steel brace, steel jacketing, fiber carbon jacketing for columns and beams.

Figure 6. Model frame with retrofitting solutions

## EARTHQUAKE ENGINEERING INTERNATIONAL CONFERENCES IN ROMANIA WITH JICA SUPPORT

The International JICA Seminar "Earthquake hazard and Countermeasures for Existing Fragile Buildings" was organized at UTCB in 2000. The event was entirely supported by JICA. The International Conference ELERR "Earthquake Loss Estimation and Risk Reduction" was organized at the Romanian Academy in 2002 . The event was jointly supported by JICA and by two other international research projects (SFB 461 and RISK-UE).

The ISSRR2007 "International Symposium on Seismic Risk Reduction, The JICA Technical Cooperation Project in Romania" was organized at the Romanian Academy in 2007. The event was entirely supported by JICA and sponsors, and was attended by 188 peoples from 13 countries.

On the occasion of these events, the following publications were issued:

- Earthquake hazard and Countermeasures for Existing Fragile Buildings, 2001. Contributions from JICA International Seminar, Bucharest, Romania, November 23-24, 2000, Lungu, D., Saito, T. (Ed.), Independent Film, Bucharest, 315 p;
- Proceedings of the International Conference "Earthquake Loss Estimation and Risk Reduction", Lungu, D., Wenzel, F., Mouroux, P., Tojo, I., (Ed.), 366p + 421p;
- Proceedings of the International Symposium on Seismic Risk Reduction. The JICA Technical Cooperation Project in Romania, Ed. Orizonturi Universitare, Timisoara, 753p.

Within the JICA Technical Cooperation Project for Seismic Risk Reduction, NCSRR and JICA organized in the period July 25 – July 27, 2007 the Training Program on Seismic Risk Reduction. Ten engineers from universities and design offices participated in the program. The topics of the lectures covered the fields of seismic evaluation and retrofitting and geotechnical earthquake engineering.

## CONCLUSIONS OF THE FINAL EVALUATION FOR THE PROJECT

According to the evaluation report prepared by the Joint Evaluation Team, the Project has been implemented timely and properly according to the Record of Discussions towards the achievement of the Project Purpose. The Project Purpose and Overall Goal are valid and in line with the policy of MDRT as well as with the principle of Japanese cooperation to Romania.

In the Project, the followings are the most highly rated achievements:

- The first retrofitting design using modern techniques was completed for a soft-story building in Bucharest;
- seminars and meetings with the residents in vulnerable buildings, students and engineers were held frequently, which improved their understanding on the earthquake effects and countermeasures;
- as a result of the cooperation between JICA experts at NCSRR and INCERC, manuals of earthquake education for school students were issued;
- state of the art equipments were provided and are operated properly by Romanian counterparts.

In July 2010 MDRT decided to dismantle the NCSRR. All the NCSRR researchers involved in the JICA project, but two, are presently at UTCB.

## ACKNOWLEDGMENT

NCSRR deeply acknowledge the generous, continuous and long-lasting financial support of JICA during the implementation of the Project. The technical support of Building Research Institute (BRI), Tsukuba and National Institute for Land and Infrastructure Management (NILIM), Tsukuba, Japan provided to NCSRR staff is gratefully acknowledged. The partnership between NCSRR, UTCB and INCERC for the implementation of the JICA Project is valuated.

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