THE PROJECT "RISKSOLVE" – "EVALUATION AND INVESTIGATION OF SEISMIC RISK REDUCTION SOLUTIONS FOR BUILDINGS, BEFORE AND AFTER EARTHQUAKES" – A STARTING POINT IN THE SCIENTIFIC COOPERATION OF NIRD URBAN-INCERC, ROMANIA WITH IEM HARBIN, P.R. OF CHINA

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ABSTRACT

The paper presents the framework and outcomes of a Joint Research Project between NIRD URBAN-INCERC, Bucharest, Romania and IEM Harbin, P. R. of China with the topic "Evaluation and Investigation of Seismic Risk Reduction Solutions for Buildings, Before and After Earthquakes". The Project "RISKSOLVE" aimed at an exchange of information between experts from Romania and P.R. of China on legal framework for seismic design of buildings, seismic risk reduction and disaster prevention in each country. The study of sites with seismic risk, processing and evaluating the strong motion recordings was associated with the study of earthquake resistance and behaviour of building systems, correlation of damaged buildings patterns, properties and characteristics of materials and seismic site conditions. On the other hand, the design code solutions, as well as adequate retrofitting methods and construction details were evaluated, based on dynamic – seismic and static experimental tests on chosen solutions. The counterparts obtained promising results and information, useful to earthquake engineering researchers, in view of achievement of top scientific and technological results and future cooperation Romania – China.

Keywords: earthquake; Romania; China; seismic risk reduction.

REZUMAT

Articolul prezintă cadrul de desfăşurare şi rezultatele unui Proiect de Cercetare Comun dintre INCD URBAN-INCERC, Bucureşti, România şi IEM Harbin,, R. P. Chineză cu tema "Evaluarea si investigarea soluţiilor de reducere a riscului seismic pentru clădiri, înainte şi după cutremure". Proiectul "RISKSOLVE" a urmărit un schimb de informaţii între experţii din România şi R. P. Chineză asupra cadrului legal al proiectării seismice a clădirilor, reducerea riscului seismic şi prevenirii dezastrelor în fiecare ţară. Studiul unor amplasamente expuse riscului seismic, al prelucrării şi evaluării înregistrărilor de mişcări seismice puternice a fost asociat cu studiul rezistenţei la cutremur şi comportării unor sisteme de clădiri, cu corelarea caracteristicilor de avariere proprietăţile materialelor şi condiţiile seismice de teren. Pe de altă parte, au fost evaluate soluţiile de proiectare din coduri, ca şi metodele şi detaliile adecvate de consolidare, pe baza unor teste experimentale seismice şi statice asupra soluţiilor alese. Partenerii au obţinut rezultate şi informaţii promiţătoare, utile pentru cercetătorii din ingineria seismică, în vederea unor rezultate ştiinţifice şi tehnologice de vârf şi a viitoarei cooperări România - China.

Cuvinte cheie: cutremur; România; China; reducerea riscului seismic.

1. THE LEGAL FRAMEWORK

The "RISKSOLVE" Project "Evaluation and Investigation of Seismic Risk Reduction Solutions for Buildings, Before and After Earthquakes" was financed under contract 615/01.01.2013 by UEFISCDI - Executive Agency for Financing Superior Education, Research Development and Innovation, Romanian Ministry of National Education, in the framework of Capacities Program, for cooperation with P.R. of China. The Project duration was January 2013 - December 2014.

The Romanian Partner was The National Institute for Research and Development in Constructions, Urban Planning and Sustainable Spatial Development „URBAN-INCERC", Bucharest, Romania, represented by General Director Assoc. Prof. Dr. Arch. SR I Vasile Meiţă, with Project Director Dr. Eng. Emil-Sever GEORGESCU, Scientific Director of NIRD URBAN-INCERC – Codirector of Project of Romanian side.

The P. R. of China Partner was IEM - Institute of Engineering Mechanics / CEA – China Earthquake Administration, Harbin, P.R. of China, represented by Prof. Dr. Eng. Junwu DAI – Research Director, with Project Director Prof. Dr. Eng. Lingsxin ZHANG – Codirector of Project of Chinese side.

2. THE CORRELATION OF THE ROMANIA-CHINA PROJECT WITH THE SEISMIC SETTINGS AND RESEARCH PRIORITY AREAS

Experience has shown that strong earthquakes having disastrous effects also make possible data collecting, experimental measurements and observations and information registering on the behavior of some types of buildings exposed to seismic events. Collected data are extremely valuable and they are needed to confirm or refute assumptions about buildings' behavior during earthquakes and construction solutions to be adopted for designing earthquake resistant buildings are based upon it. Because in Romania earthquakes occur less frequently to make possible analyzing the structural damage and the validation of code structural solutions data exchange, with countries that have such events more frequently but also who demonstrated the ability to learn from disasters and to transfer knowledge or participate in joint studies, are necessary.

The earthquake of March 4, 1977 (MGR = 7.2, *Mw* = 7.4 ... 7.5) in Romania is a reference event which caused 2.048 billion U.S. $ loss, approx. 1.420 billion were in construction field (buildings, water supply, etc.), of which 1.030 billion were housing units, being the most affected sector, due to the destruction or serious damage of 156,000 apartments in urban areas and 21,500 in rural areas; other 366,000 urban apartments and 117,000 rural homes needed repairs. Bucharest accumulated 70% of loss accounting 1.4 billion U.S. $. (Georgescu and Pomonis, 2008).

Contemporary data of 1977 lead us to 1578 deaths and 11,321 injured (90% of the deaths and 67% of the injured in Bucharest), 32,900 houses collapsed or badly damaged, 35,000 homeless families, tens of thousands of buildings damaged, many other damages and destruction in the industry and economy (Balan et al, 1982; Georgescu and Pomonis, 2008).

Buildings collapsed in Bucharest were concentrated down-town, in the historic area of the city in which were low and classic buildings and also tall old reinforced concrete buildings.

Concerning the codes, after 1940 Vrancea, Romania earthquake, the first seismic design guidelines were initiated in 1943, while the specific research was done essentially after 1960. The first mandatory Seismic Design Code P13-63 was endorsed in 1963 and revised in 1970. The March 4, 1977 Vrancea earthquake was the first strong, destructive, event with accelerographic instrumental information on ground motion (Balan et al, 1982; Sandi 1999; Sandi et al, 2004).

The automated seismic strong-motion network of ICCPDC-INCERC (existing since 1967) obtained three accelerographic records: at INCERC - Bucharest (at ground level), at the top level of a building in South – East Bucharest and a partial record in Vrâncioaia-epicentral zone (Berg et al., 1980; Balan et al., 1982). It is worth to remind that the record of INCERC – Bucharest provided a PGA value of about 2.0 m/s^2 that was in the expected range, but the dominant period interval around 1.5 s was quite a surprise. Consequently, the spectral curve of the new Seismic Code P100 was drastically changed to fit long-period motions. The Romanian Seismic Code evolution after 1977, as well as novel vulnerability and seismic risk studies in INCERC were significant (Sandi, 1999; Craifaleanu, 2008). The complex specific of

Vrancea intermediate source is a matter of further studies in view of influence of its mechanism versus that of local conditions upon spectral content of ground motion (Sandi et al., 2004; Borcia, 2012).

In 1977, several teams of foreign experts from China but also from countries like Japan, USA, USSR, Venezuela, New Zealand, France, Germany, Turkey, Greece, Iran, Bulgaria, etc., visited and investigated areas and damaged buildings, and published extensive reports (Balan et al, 1982; Berg et al, 1980). In 1977 China donated seismological equipment and INCERC (currently INCERC Branch of NIRD URBAN INCERC) cooperated with China before 1989.

China has a millenary seismic history and it is fast developing at this time based on a new vision which is reflected in the state of transport infrastructure, in the large number of new tall buildings, spectacular public buildings, etc. China has a high exposure to the seismic hazard and risk, over half the territory is classified as MSK VII or higher degree, including 23 capitals of provinces and two thirds of cities with over 1 million inhabitants; 75 earthquakes have produced only during 2005-2007, of which 33 caused disasters. First seismic design code wasn't introduced up until 1978, after the Tangshan disaster (1976), so there are many vulnerable buildings, although annually funds have been allocated for building strengthening; between 1998 and 2000 money were collected through public loans in the form of treasury bonds for strengthening important public buildings.

But China has undergone a major challenging disaster as Wenchuan earthquake in Sichuan Province, China, May 12, 2008 (Ms = 8) that produced extended damage, direct losses reaching 100 billion US $. On Wenchuan earthquake, the fault rupture length was over 200 km, with horizontal and vertical displacements of meters and hundreds of powerful aftershocks; the earthquake's isoseist map includes areas of IX-XI degrees on the Chinese scale, similar to the MMI; in the center of the affected area, the epicentral seismic intensity reached XI degree, with many geological disastrous effects (ruptures, landslides with rocks rolling down), concentrated in the areas from two districts which were the most affected.

Presentations of CEA-IEM Harbin researchers and especially Proceedings of 14-th WCEE, 2008 include a very rich data about this disaster that were detailed during exchange of views during the RISKSOLVE Project. The number of death reached 69,225, 17,939 people were missing and 379,640 were injured, mostly caused by the collapse of buildings and houses, most of them being public buildings like schools, hospitals, offices, shops etc.; the city of Dujiangyan is cited as an example counting 3075 deaths , of which 990 in schools (32.2%) and 345 in hospitals (11.2%). Direct losses reached 100 billion U.S. $ meaning 2.81% of China's GDP and indirect losses can be comparable or even higher than direct losses; infrastructures have suffered greater losses than during any other earthquake in China. After the disaster, based on new projects, immediate measures, as search and rescue and reconstruction were taken (Wang, 2008; Proceedings of 14-th WCEE, 2008; EERI, 2008; Jiangrong, 2014).

China has 1160 strong motion recording stations; records of the main shock of May 12, 2008 have been obtained in 460 stations in 17 provinces; the seismic network in the area had been completed in 2007 and 211 records were obtained in Sichuan; 120 of these records have exceeded PGA values of around 0.1 g (100 gal); the nearest station was located at 22.2 km from the epicenter and there was recorded PGA values of approx. 0.95 g (956.7 gal); vertical components were very strong, with an unusual ratio of 2:1 compared to the duration of horizontal components and the duration of ground motion exceeded 100 seconds.

Since 2004, the State Seismological Bureau (SSB) was transformed in China Earthquake Administration (CEA), which shows the intention of more intense applied development towards the engineering and disaster management, an area in which since 1998 there is new legislation, including provisions regarding emergency intervention. It is noteworthy the activity of China Earthquake Administration - CEA,

subordinated to the State Council, along with the IEM-Institute of Mechanical Engineering. For these reasons the cooperation with China Earthquake Administration - CEA, subordinated to the State Council, with the IEM-Institute of Mechanical Engineering of Harbin, was considered as suitable and necessary.

In terms of objectives and expected benefits, working with China is also important and necessary because an extremely large number of Chinese researchers have published papers with advanced scientific content, they presented theoretical and experimental research in seismology and earthquake engineering, new software, seismic testing on large shaking tables and pseudo-dynamic testing with reaction walls, provided seismic education of the population as it is taken into account as a cost effective and very necessary. The scientific cooperation relationship with China is visible in advanced countries like Japan and USA.

3. GENERAL OBIECTIVES OF THE "RISKSOLVE" PROJECT

The general objectives of the "RISKSOLVE" project were:

- Evaluation of state-of-the-art situation and of efficacy of methods and solutions for seismic risk assessment, investigation and reduction for specific types of buildings from Romania and P.R. of China;
- Creating knowledge for the achievement of top scientific and technological results, globally competitive, to increase international visibility of Romanian research and subsequently transfer the results to socio-economic practice – through the cooperation with China;
- Increasing Romanian economy competitiveness through innovation, impacting the economic and knowledge transfer to economic practice - to designers and contractors in construction field in Romania and China;
- Increase social quality and finding technical - scientific solutions supporting social development and improve its human dimension by the seismic risk mitigation and seismic disaster prevention, compared with the previous situation in Romania and China.
- Development of research capacities and opening the Romanian RDI system towards the international scientific environment as well as towards the national socio-economic field, a country with a fast development, as China is, respectively.
- Participation and answer of NIRD URBAN-INCERC to the joint thematic call for a partnership with China, in correlation with the strategy of seismic risk reduction of MDRAP - Ministry of Regional Development and Public Administration.

4. SCIENTIFIC AND TECHNICAL ACTIVITIES

The Project "RISKSOLVE" had the following main activities, with associated deliverables:

- Exchange of information between experts from Romania and P. R. of China, description of relevant legal framework for seismic design of buildings, seismic risk reduction and disaster prevention in each country.
- Study of selected sites with seismic risk, processing and evaluating the strong motion recordings and motion parameters. Study of earthquake resistance and behaviour of pilot building systems in selected seismic areas.
- Study and correlation of damaged buildings patterns, properties and characteristics of materials and seismic site conditions.
- Analysis of the design code solutions, as well as adequate retrofitting methods and construction details possible to be applied for different types of buildings, based on dynamic – seismic and static experimental tests on chosen solutions and validations of the results.
- Final report for dissemination of the obtained knowledge and information.

(Papers, manuals and reports publishing for local authorities and designers may be considered additionally by each partner or jointly).

In 2013 and 2014, two Romanian researchers of NIRD URBAN-INCERC visited P.R. of China, while two Chinese researchers visited Romania for discussions and exchange of experience. In this framework the visits included institutes and laboratories of IEM Harbin and IEM Yanjiao, CEA-China Earthquake Administration, Beijing, CENC - China Earthquake Networks Center, China Academy of Buildings Research (CABR) – Laboratories of Yanjiao Zone of Economic and Technological Development, Seismic Station near National Park Xianshan, Institute of Disaster Prevention (IDP) of CEA. Also, the Romanian delegates presented papers at The 1-st Huixian International Forum on Earthquake Engineering for Young Researchers, held at IEM, Harbin, 17-18 August 2014, at IEM - Institute of Engineering Mechanics Harbin.

The working visit in Romania of Chinese researchers included NIRD URBAN-INCERC and research laboratories of INCERC Bucharest Branch, Iasi Branch, Vrancea seismogenic area, sites of seismic risk constructions and NIEP Magurele and knowledge about research in Cluj-Napoca Branch of URBAN-INCERC.

5. SYNTHESIS OF RESULTS AND CONCLUSIONS

Since the cooperation with a country as great as China was just initiated, in this earthquake engineering project the issue is not a result as object, technique or method, because seismic risk is depending on vulnerabilities accumulated during decades, thus its reduction is not at individual scale.

Anyway, besides scale differences of problems encountered in Romania and China, there are numerous similar approaches and results in earthquake engineering research from Romania and P.R. of China.

China has a strategy for seismic protection - Seismic Disaster Reduction National Plan (2006-2020) which aims by 2020 to provide earthquake resistance in general terms to earthquakes with a magnitude of class 6 to Chinese areas. Despite the whole extent of seismic disasters in China, in the recent 20 years a remarkable progress and the alignment with the scientific and advanced global trends are visible; the country is in a period of development and it has an ambitious strategy for seismic protection; in this context 4 categories of projects were achieved by 2010 and these measures will be applied in major cities and other urban areas, along with the construction of model buildings, alert systems for industry and utilities, and 40% of the population will be included in programs of seismic education.

Chinese government pays attention at the highest level to adapting the laws and forms of organization of earthquake engineering and disaster management to the new development policy of the country. Earthquake engineering research started to develop in a way comparable to that of Japan and U.S. Therefore, after 1990, China has changed priorities for urban earthquake resistance, focusing on disaster protection of cities to reach 100%, with an emphasis on tall buildings; since 2007 a standard for urban earthquake resistance was introduced; another technical specification refers to building and plans to avoid disaster for villages and towns; from the edition of 2001, a new seismic design code was published in July 2008.

Many fields show a prominent progress, especially in securing and developing a national research capacity, and it was an obvious condition allowing partnership with USA and Japan. We must remark that such a difference was not as great as nowadays in INCERC cooperation with China until 1989. For each general objective and research phase, the parts obtained promising results and information useful to Romanian researchers in view of future projects with China.

Researches concerning the simulation and forecast of earthquake damage of typical urban infrastructures, lifelines and buildings are very

important, as well as developing new laboratories for large scale testing of structures.

IEM-CEA Harbin plays a very special role, as strong pillar of CEA, as it is financed by national strategic research programs, operates and maintains a large network of strong motion recording equipments foe seismic protection of constructions. Also provides testing for all high-rise superstructures, has a major duty in specialized intervention after earthquakes, hosting master degree and doctoral programs, and has many young researchers.

The specific of this project requires a major part of valorization at national Romanian level of research and as possibilities of using results with economics value, we may estimate as socio-economic effects the following:

- protection of vital buildings and population, by improving structural safety, avoiding and reducing the loss of lives and injuries and financial losses;
- providing a background for strategic programs, in conjunction with technical and scientific solution for seismic risk reduction, which sustain the social development;
- creating and endorsing an advanced national strategy of earthquake protection;
- scientific and didactic impact, by knowledge transfer from URBAN-INCERC researchers as professors in Master Courses in UTCB, USAMV and UAIM, as well as in other technical universities in Romania;

It is especially necessary to create or impose a revival of a legal, institutional and financial framework to make possible checking by research and large scale tests, for all components and structures of public interest and great value, in national institutes like NIRD URBAN-INCERC, habilitated technically and scientifically, being impartial in front of investors. This procedure would be most necessary, either in case of financing from national budget and/or EU funds, either because of potential high-risk (e.g. new structural types exposed to Vrancea earthquakes, differing of crustal shocks, high-rise structures, elevated bridges, strategic bridges, IT facilities, chemical industry under EU SEVESO Directive etc.).

Since in earthquake engineering the public interest is prevailing, funding must have a prominent public source. But such a framework would make possible also a consistent private financing of public interest tests and research.

There is no reason to delay measures to allow the status of facility of unique and national interest, and technical refurbishment of large-scale testing labs that are necessary in earthquake protection engineering, as well as financing sources for hiring, training and rewarding young researchers, for:

- NIRD URBAN-INCERC Seismic Strong-Motion Network for Constructions;
- New equipments for INCERC Bucharest Seismic Research Station for large scale testing of constructions.

On this background, the future cooperation with CEA-IEM of P.R. of China will be feasible in interdisciplinary fields, as the Seismic Alert System to be used along with education of citizens for protection and on-line monitoring of earthquake response and building safety, for very important and usual buildings, accordingly.

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