JOINT U.S.-ROMANIAN SEMINAR ON EARTHQUAKES AND ENERGY

SPONSORED BY THE NATIONAL SCIENCE FOUNDATION (U.S.) AND THE NATIONAL COUNCIL FOR SCIENCE AND TECHNOLOGY (ROMANIA)

BUCHAREST 2-9 SEPTEMBER 1985

VOLUME 1: INTRODUCTION AND SUMMARY

ORGANIZING GROUPS:
ARCC
UCLA
INCERC

EDITORS:
SAMUEL ARONI
ROMULUS CONSTANTINESCU

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and Energy. Bucharest, 2-9 September, 1985.

Volume 1: Introduction and Summary
Volume 2: Earthquakes
Volume 3: Energy

Architectural Research Centers Consortium, Inc.

1. Seminar, Earthquakes, Energy, U.S.-Romania
I. Aroni, Samuel, II. Constantinescu, Romulus

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INTRODUCTION

The Joint U.S.-Romanian Seminar on Earthquakes and Energy was held September 2-9,1985, at the Romanian Building Research Institute (INCERC) in Bucharest. The seminar was supported by the National Science Foundation (NSF) Division of International Programs (Grant No. INT 85-03889) and the Romanian National Council for Science and Technology (CNST), under the U.S.-Romanian Cooperative Science Program. During that week over seventy researchers from Romania and the United States met in intense and vivid discussions about topics of building research, with the focus on earthquakes and energy conservation. The seminar provided an opportunity for exchanging scientific research information, and encouraging the establishment and planning of future joint research cooperation.

The groundwork for the seminar began in the spring of 1984, when the Architectural Research Centers Consortium (ARCC) was searching for ways to further international cooperation. ARCC is an organization of over forty academic institutional members devoted to supporting and encouraging research in the fields of architecture and building. The membership of ARCC includes leading university-based research centers and has a broad geographical distribution within the United States. ARCC has also conducted seminars with other overseas researchers, including those in Sweden and the United Kingdom. The initiative for this seminar was taken by Professor Samuel Aroni of UCLA. With the encouragement and help of NSF, he traveled to Romania in September 1984 and met with Dr.Eng. Romulus Constantinescu of INCERC, the Romanian Building Research Institute. INCERC is a large and impressive research organization in Bucharest under the direction of the Central Institute for Research, Design, and Guidance in Civil Engineering (ICCPDC), established in 1950 and consisting of four sections and six laboratories. Earthquake research and energy conservation are prominent in its activities, representing two of its four sections. During the September 1984 visit, an agreement was reached to organize a seminar, to be held at INCERC in Bucharest as a first step of collaboration between Romanian and American institutions and researchers in areas of mutual interest. The two subjects selected were earthquake issues and energy conservation. In addition to their intrinsic importance, the decision to focus on both of them stemmed from the belief in the advantage of synergism. There is some interaction between them, and having two subjects for the seminar enhanced the possibilities of finding areas of future collaboration, and encouraged cross-fertilization of research ideas.

We are well aware of the earthquake dangers facing the Pacific coastline of the United States, as well as many other locations within the national boundaries. Significant research has been conducted and much more is needed. Among the important topics of recent research interest have been the problems of old buildings, their repair, strengthening and reconstruction, issues of vulnerability and risk of both buildings and lifelines, non-structural elements, performance of emergency facilities during earthquakes, issues of human behavior and injuries, and planning for earthquake preparedness and disaster mitigation. Romania is also located in a seismic region and suffered greatly from the earthquake of March 4, 1977, in which some 1,600 persons were killed, over 11,000 were injured, 33,000 buildings collapsed or were severely damaged, industrial facilities were seriously damaged, and damage totaled over $2 billion. There is much to be learned from this major earthquake, which has been studied in great detail by Romanian researchers and is the subject of a recent comprehensive Romanian book. The third most important event in the modern seismic history of Romania was the recent earthquake near Tulcea in the eastern part of the country, on November 13, 1981. The epicenter was near settlements which have developed rapidly in recent years, and the behavior of modern high-rise construction as well as the non-structural damage are of particular interest. The Romanian earthquakes are of special international importance because of the proximity of a large number of prefabricated industrialized buildings. This is probably the first time that such newer buildings have been subjected to major earthquakes on such a large scale, and their seismic behavior is of great interest. Serious seismic research in Romania has gone on for a long time at their Building Research Institute (INCERC), both in Bucharest and at the Jassy branch of the ICCPDC, where some of the earliest earthquake testing facilities, including shaking tables, were developed.

During the last ten years, energy conservation in buildings has been the subject of research interest in the United States. The use of solar energy, active and passive systems, utilization for hot water and space heating, and the upgrading of existing buildings have all been topics of both field work and research activity in both countries. Romania has also put an emphasis on energy conservation at a larger urban scale. Romanian solar installations during the last five years have included some 600 projects for hot water or space heating and some 14,000 apartments. The solar hot-water installation in Baneasa (Bucharest), consisting of 2239 apartments, is the largest in Europe and possibly in the world. Industrial applications include an interesting ice manufacturing plant using solar energy, and large projects for heat recovery from industry for storage and use by some 20,000 apartments for both hot water and space heating. A two-story experimental solar house, which includes four apartments, has been erected at INCERC for comparative research of active and passive systems for both space heating and hot water.

The seminar consisted of an opening session, followed by four working sessions, with the participants divided into two groups discussing earthquakes and energy respectively. The presentations and discussions on the subject of earthquakes covered the spectrum of seismic vulnerability and behavior of buildings, urban systems and critical facilities, as well as human behavior and injuries during earthquakes. Those dealing with energy conservation, included solar passive and active systems, retrofitting, daylight applications, total building performance, and problems of energy conservation at an urban scale. Each of the four working sessions, concentrating on a specific group of related topics, consisted of one or two presentations of American papers, a summary of the relevant Romanian papers presented by a rapporteur, and an open discussion. The seminar was enriched by field visits to a large scale solar installation and to the Jassy Seismic Testing Station and laboratory. The final day, devoted to research needs and areas of future cooperation, proved to be very fruitful and productive.

Romanian participants included engineers, architects, planners, and sociologists from INCERC and over a dozen other institutes, centers, laboratories, and universities throughout Romania. They prepared sixty-one papers, thirty-seven on the subject of earthquakes and twenty-four on energy topics. The American team consisted of nine academics, from seven different universities, each with a paper on earthquakes (four papers) or on energy (five). A bilingual program and abstracts of all the papers was prepared by INCERC and distributed at the seminar. The seminar was co-chaired by Dr. Constantinescu and Professor Aroni.

We would like to thank all those who in various ways contributed to the seminar and made it possible, including all the seminar participants. Mr. George Matache of CNST, and Eng. Valeriu Cristescu, the General Director of ICCPDC and INCERC, provided significant help and guidance. Eng. Emil Sever Georgescu of INCERC was of invaluable help in the seminar organization. The excellent work of a number of staff, and scientific translators at INCERC is gratefully acknowledged. Our gratitude is expressed to Dr. Gerson Sher, Ms. Bonnie H. Thompson, and Ms. Deborah L. Wince of the NSF Division of International Programs and to Dr.William Anderson and Mr. Gifford Albright of the NSF Directorate of Engineering for their support and assistance. In the United States , the seminar participants were selected with the help of an Advisory Committee consisting of Professor David S. Haviland (Dean, School of Architecture, Rensselaer Polytechnic Institute), Dr. Frederick Kringold

(Associate Dean for Research and Extension, College of Architecture and Urban Studies, Virginia Polytechnic Institute and State University, and President of ARC), and Professor Samuel Aroni.

The work of the joint seminar is presented in three volumes. Volume 1 contains an introduction and summary of all papers, sessions and discussions. Significant contributions were made in the writing of this volume by Professor Daniel Abrams, Professor Volker Hartkopf, Professor Henry Lagorio, Dr. Horea Sandi, Professor Robert Shibley, and Eng. Teodor Teretean. Volume 2 contains the forty-one papers on the subject of earthquakes, and volume 3 the twenty-nine papers on topics of energy. The editorial help of Mr. William Fulton, in the United States, is much appreciated. The reproduction of these volumes was performed at INCERC.

The American participants express sincere thanks and gratitude to the Romanian hosts for their outstanding hospitality, both scientifically and socially. Finally, we hope that this publication will prove to be useful and will further contribute to the achievements of the goals of the seminar.

Professor Samuel Aroni, Ph.D.
Graduate School Of Architecture
and Urban Planning, UCLA

Dr. Eng. Romulus Constantinescu
Deputy Scientific Director
Romanian Building Research
Institute, INCERC

SEMINAR PROGRAM

<u>Monday, September 2, 1985</u>

Arrival in Bucharest of the American participants

<u>Tuesday, September 3, 1985</u>

OPENING CEREMONY

- Welcome by Director Gheorghe Polizu of ICCPDC
- Response and comments by Professor Samuel Aroni
- Description of INCERC, and the participating institutions, by Director Romulus Constantinescu

EARTHQUAKE SESSIONS

Session I:	Experience of Past Earthquakes. Performance of Buildings and Behavior of Occupants. Summary of Lessons.
Session II:	Evaluation of the Existing Building Stock. Vulnerability and Risk Analysis. Repair and Strengthening of Structures.

ENERGY SESSIONS

Session I:	The Themes of Energy Papers. Building Performance.
Session II:	Research Needs. Building Standards, Strategies and Conservation.

<u>Wednesday, September 4, 1985</u>

EARTHQUAKE SESSIONS

Session III:	Earthquake Preparedness. Critical Facilities. Urban and Sociological Aspects.

Session IV: Structural Performance Under Earthquake Loading.
Structural Design.

ENERGY SESSIONS

Sessions III and IV:
Solar Energy in Buildings.
Daylighting.
Energy Storage.

FILMS

<u>Thursday, September 5, 1985</u>

TECHNICAL VISITS IN BUCHAREST

Building Research Institute, INCERC

Baneasa Housing Project

<u>Friday, September 6, 1985</u>

TECHNICAL VISITS OUTSIDE BUCHAREST

Cîmpina: INCERC Solar Houses

<u>Saturday, September 7, 1985</u>

Jassy Branch of ICCPDC: Visits and Discussion Session

<u>Sunday, September 8, 1985</u>

Visits of Historical Buildings and Monuments
Return to Bucharest

Monday, September 9, 1985

FINAL SESSIONS

Conclusions and Ideas for Future Research and Cooperation

Tuesday, September 10, 1985

Departure of the American participants

LIST OF PARTICIPANTS

<u>United States Participants</u>

Prof. Daniel P. Abrams *	Department of Civil Engineering, University of Illinois at Urbana-Champaign
Prof. Samuel Aroni *	Graduate School of Architecture and Urban Planning, UCLA
Prof. Charles C. Benton *	Department of Architecture, University of California, Berkeley
Prof. Baruch Givoni *	Graduate School of Architecture and Urban Planning, UCLA
Prof. Volker Hartkopf *	Center for Building Diagnostics, Carnegie-Mellon University
Prof. Barclay G. Jones *	Department of City and Regional Planning, Cornell University
Prof. Walter M. Kroner *	Center for Architectural Research, Rensselaer Polytechnic Institute
Prof. Henry J. Lagorio *	Center for Environmental Design Research, University of California, Berkeley
Prof. Robert G. Shibley *	Department of Architecture, State University of New York at Buffalo

Romanian Participants

Dr. Dorel Abraham *	Sociologist, IPCT
Dr. Eng. Decebal Anastasescu *	Design Institute, Timisoara
Dr. Eng. Mircea Balcu	ICB
Dr. Cristian Bergthaller *	Center of Mathematical Statistics, Bucharest
Dr. Ana Maria Bianchi	ICB
Prof. Dr. Eng. Cornel Bianchi	ICB
Dr. Eng. Constantin Bogos	Jassy Branch of ICCPDC
Eng. Dan Cazacu *	Scientific Researcher, Earthquake Engineering and Structural Dynamics Dept., INCERC
Eng. Vladimir Ceaus *	Installation Dept., INCERC
Eng. Gheorghe Ciuhandu	Timisoara Branch of ICCPDC
Eng. Cristian Constantinescu *	Scientific Researcher, Earthquake Engineering and Structural Dynamics Dept., INCERC
Assoc.Prof.Dr.Eng.Dan Constantinescu	ICB
Eng. Dan Constantinescu *	Head, Solar Energy Research Group, Installation, Solar Energy and Heat Recovery Dept., INCERC
Dr. Eng. Romulus Constantinescu *	Deputy Scientific Director, INCERC
Eng. Paul Cosmulescu	Senior Researcher, Jassy Branch of ICCPDC
Eng. Silvia Covali	Senior Researcher, Jassy Branch of ICCPDC
Arch. Adrian Cristescu *	IPCT

Eng. Valeriu Cristescu	General Director, ICCPDC and INCERC
Eng. Serban Dabija	IPCT
Prof. Dr. Eng. Constantin Dalban	ICB
Eng. Daniel Diaconu	Director, Jassy Branch of ICCPDC
Eng. Mircea Dima	Design Institute for Railways, Bucharest
Eng. Elena Dragomirescu	IPCT
Dr. Eng. Liviu Dumitrescu *	General Inspector, ICCPDC
Eng. Liviu Dumitrescu Jr. *	Installation Dept., INCERC
Assoc.Prof.Dr.Virgil Fierbinteanu	ICB
Prof. Dr. Eng. Dragos Georgescu	ICB
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Eng. Rodica Grigore	IPCT
Dr. Eng. Silvia Hagiescu	Scientific Secretary, INCERC
Assoc.Prof.Dr.Eng. Mircea Ieremia	ICB
Eng. Nicolae Ile	Central Laboratory, Ministry of Industrial Construction, Bucharest
Eng. Florin Iordache *	Scientific Researcher, Installation Dept., INCERC
Mr. Mircea Kivu	Sociologist, IPCT

Prof.Dr.Eng. Nicolae Leonachescu	ICB
Prof.Emeritus Eng. Panait Mazilu	ICB
Dr. Eng. Constantin Mihai	Senior Researcher, Jassy Branch of ICCPDC
Assoc.Prof.Dr.Eng. Cornel Mihaila	ICB
Prof. Eng. Mircea Mihailescu *	Faculty of Civil Engineering Polytechnical Institute, Cluj-Napoca
Dr. Eng. Stefan Mihailescu *	Design Institute "Proiect", Bucharest
Eng. Mircea Mironescu	Design Institute "Carpati", Bucharest
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Eng. Ahile Petrescu	IPCT
Dr. Arch. Gheorghe Polizu	Director, ICCPDC
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Eng. Mircea Radulescu	IPCT
Eng. Sanda Radulescu *	IPCT
Dr. Eng. Horea Sandi *	Head, Earthquake Engineering and Structural Dynamics Dept., INCERC

Eng. Gheorghe Serbanescu	Senior Scientific Researcher, Earthquake Engineering and Structural Dynamics Dept., INCERC
Eng. Mihail Stancu	Senior Scientific Researcher, Earthquake Engineering and Structural Dynamics Dept., INCERC
Eng. Olga Stancu	Senior Scientific Researcher, Earthquake Engineering and Structural Dynamics Dept., INCERC
Eng. Teodor Stefan Teretean *	Head, Installation, Solar Energy and Heat Recovery Dept., INCERC
Dr. Eng. Magdalena Toma	Cluj-Napoca Branch of ICCPDC
Dr. Eng. Frimu Tomsa	Deputy Scientific Director, INCERC
Eng. Dumitru Vasilescu	Senior Researcher, Jassy Branch of ICCPDC
Eng. Victor Voinescu	Senior Researcher, Installation, Solar Energy and Heat Recovery Dept., INCERC

<u>INCERC Seminar Staff</u>

Ms. Marina Alecsandru

Ms.Elisabeta Asadurian

Ms. Otilia Borcia

Ms. Mihaela Dinu

Mr. Gheorghe Geboiu

Ms. Cecilia Manoila

Ms. Iulia Mera

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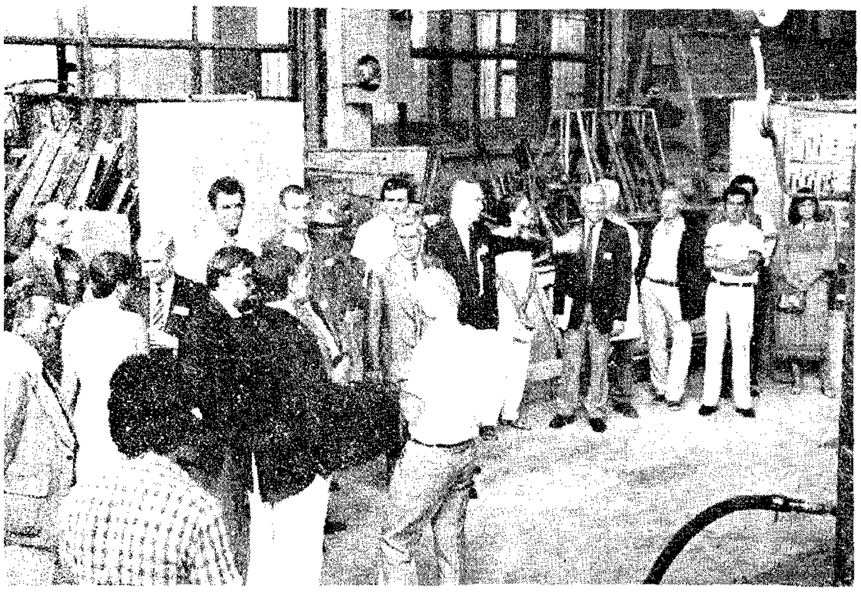
*Participants in the technical visits outside Bucharest, with the following route: Bucharest - Ploiesti - Cîmpina - Jassy - Suceava - Piatra-Neamt - Brasov - Bucharest.

Abbreviations :

ICB	Institute for Civil Engineering, Bucharest
ICCPDC	Central Institute for Research, Design and Codes in Civil Engineering
INCERC	Building Research Institute, Bucharest
IPCT	Design Institute for Typified Buildings



A. EARTHQUAKES

The seminar dealt with the subject of earthquakes over a wide range of topics and issues. The presence of engineers, architects, planners, and sociologists, enriched the discussions beyond their international character. Leading to the final day, when conclusions and ideas for future research and cooperation were considered, the work took place in four sessions at INCERC, in Bucharest, the viewing of two films, and a significant visit to the Jassy Branch of ICCPDC. Because of the large number of papers prepared for the seminar, and their extensive coverage, each of the four working sessions focused on a number of related topics. Each session consisted of one or two presentations of American papers, a summary of the relevant Romanian papers given by Dr. Horea Sandi and an open discussion.

This section describes the presentations and discussions of each session, the films, and the visit and discussions at the Jassy Branch of ICCPDC.

I. SESSION I: EXPERIENCE OF PAST EARTHQUAKES. PERFORMANCE OF BUILDINGS AND BEHAVIOR OF OCCUPANTS. SUMMARY OF LESSONS.

1. PAPERS

1. S. Aroni, and M. E. Durkin :
   Injuries and Occupant Behavior in Earthquakes.

2. H. Sandi :
   The Romania Earthquake of March 4, 1977: Notes on the Effects, the Post-Earthquake Reaction, and the Future Action Needs.

3. P. Mazilu, M. Ieremia, M. Neicu, and L. Rosca :
   Seismic Behavior of Some Industrial and Telecommunication Structures: Solutions for Seismic Risk Reduction.

4. C. Dalban, and E. Dragomirescu :
   Some Conclusions on the Behavior of the Steel and Composite Structures Subjected to Seismic Action.

5. M. Mihailescu :
   Dynamic Behavior of Spatial Structures and Shells During the March 4, 1977, Earthquake in Romania.

6. G. Sandulescu :
Considerations of the Causes of Collapse or Damage of Some Dwellings in Bucharest During the March 4, 1977, Earthquake.

7. D. Anastasescu, and R. Marinov :
Earthquake Protection of Existing Low-Rise Residential and Mixed-Occupancy Buildings.

8. A. Nestor, E. Iliescu, and G. Pitis :
Remarks and Conclusions Concerning the Effects of the 1977 Earthquake in the Prahova County: The Behavior of People and Buildings, Social and Technical Actions for Recovery After the Earthquake.

9. C. Mihai, S. Covali, and G. Palamaru :
Behavior of Residential Buildings in Jassy During the 1977 Vrancea Earthquake.

10. A. Mihalache, A. Liulica, and V. Mihailovici :
Design and Performance of Prefabricated Buildings Located at Sites with Difficult Ground Conditions During the March 4, 1977, Earthquake.

11. A. Mihalache :
Seismic Behavior of Dwellings with Coupled Shear Wall Structure Located at Sites with Difficult Foundation Conditions During the Earthquake of March 4, 1977.

2. GENERAL CONSIDERATIONS

The seismicity of Romania is the result of the activity of several source zones. The most important one is the intermediate depth source zone located close to the curvature of the Carpathians, referred to often as the Vrancea zone. Besides this zone, there exist source zones of crustal earthquakes located in several parts of the country: the Fagaras mountains (Southern Carpathians), the South of Banat (Southwest Romania, West of the Carpathians), the Western part of Romania (in the region of the city of Timisoara), the Northwest of Romania (in the region of the town of Satu-Mare), the Northeast of Romania (in the region of the town Mangalia), and in the middle of Transylvania (in the region of the town of Medias). The dominant source is that of Vrancea, which generates several strong earthquakes every century. During the last two centuries the destructive earthquakes of magnitudes higher than 7.0, which occurred in 1802, 1940 and 1977, must be mentioned. The sequence of earthquakes of magnitudes higher than 6.5, which occurred in 1802, 1838, 1868, 1908, 1940, and 1977, may be also mentioned in order to emphasize the strong tendency of periodicity in the occurrence of destructive events. The other sources referred to are of secondary importance, according to historical data. They have affected relatively small zones, with intensities that did not exceed VII or VIII MSK (or MM).

The experience of the earthquake of March 4, 1977, plays a dominant role. This earthquake generated intensities of VII or higher over some 100,000 km^2 (38,500 square miles), which affected directly about one half of the building stock and population of Romania. According to official data, there were 1570 casualties, and economic losses of more than US $2 billion. Some summary data concerning the ground motion and the effects of the earthquake are given in paper I.2.

The experience of the 1977 earthquake of Romania was important on an international scale too, due to the features of the natural phenomenon and those of the affected building stock. The ground motion was characterized by an unusually low attenuation of intensities, as well as by long dominant oscillation periods, determined primarily by the local ground conditions of important parts of the territory (particularly the Southern Romanian plain). The building stock subjected to the earthquake consisted to a great extent of buildings built using industrialized systems (large panels, cast-in-place shear wall structures, etc.), designed to resist seismic action. The proportion of collapsed apartments designed to resist earthquakes was low, namely 10^{-4} in Bucharest (the most severely stricken area), and 0.3×10^{-4} for the whole area affected by intensities of VII or higher. The lessons of the earthquake, in relation to the development of codes, the adoption of favorable layouts and detailing, are of obvious importance.

3. ACTIVITIES IN ROMANIA

The scientific and technical activities in Romania were practically confined during the pre-war period to some limited analyses of the features of actual earthquakes and of seismicity. The post-war period witnessed a considerable development of the activities of seismology and earthquake engineering. Research work by seismologists and engineers was devoted to the investigation of the activity of seismic sources, the attenuation phenomenon, and the spectral content of ground motion. Earthquake engineering research was devoted to the analysis of performance of various structural solutions, using analytical, numerical, and experimental approaches. Particular importance was given to applied research concerning the development of earthquake resistant solutions and the efficiency of these activities were directly confirmed by the experience of the earthquake. As mentioned previously, the performance of structures designed to resist earthquakes was satisfactory, in spite of the relatively low consumption of steel.

Sustained activities were devoted to the analysis of the earthquake of 1977 from both the scientific and pragmatic points of view. Besides the analysis of seismological and strong motion records and a standard macroseismic survey which benefitted from answers to more than 10,000 questionnaires, a more in-depth macroseismic analysis of ground motion was carried out in Bucharest, where more than 18,000 buildings were inspected, in order to derive conclusions on the distribution of intensities, as related to several different intervals of oscillation periods. The information obtained in this way was used afterwards to derive vulnerability matrices for several classes of buildings. Data of this nature are given in references (1) and (16) of paper I.2. A sustained concern for the evaluation of existing buildings and for repair and strengthening, some of them original, were developed and applied, such that the emergency interventions were completed within a rather short period of time for a considerable number of buildings. Activities related to the evaluation of the existing building stock, including the concern for risk analysis and for appropriate decision making techniques for intervention, were initiated afterwards and applied to date under pilot study conditions.

The main research centers in the field of earthquake engineering are those of INCERC, Bucharest, and of the Jassy Branch of ICCPDC. Research and development activities in this field also may be noted, nevertheless, at the Cluj-Napoca and Timisoara Branches of ICCPDC, in the Civil Engineering faculties of Bucharest, Jassy, Cluj-Napoca and Timisoara, and in several design institutes. The activities of INCERC are concentrated primarily in the Division of Structural and Earthquake Engineering, with a personnel of some 80 people, of which 35 are professionals. Its activities relate to the analysis of structural performance and safety, engineering seismology, the investigation and development of structural systems, the evaluation of the existing building stock, the development of research equipment, etc. International activities may also be mentioned, including contributions to World and European conferences on Earthquake Engineering, lectures at Regional Seminars on Earthquake Engineering organized by the European Association, presentation of introductory remarks at the seminars organized by the UN Economic Commission of Europe, participation in three UNDP Balkan projects related to earthquake protection, consulting in the framework of UNDRO and UNIDO assistance projects, and bilateral cooperation with institutes of several countries.

4. CONTRIBUTIONS TO THE SESSION

The paper (I.1) by S. Aroni and M. E. Durkin proposes a comprehensive conceptual framework for earthquake injuries. It presents preliminary results of an epidemiological study of the role of physical environment and occupant behavior in earthquake injuries, involving the injuries during the 1978 Santa Barbara, 1979 Imperial County, and 1983 Coalinga, California, earthquakes. Work in progress concerning the injuries in the 1985 Chile earthquake is also described. Not only the type of injury, but also the physical agent responsible, is documented for past earthquakes. The relationship of the injury to factors such as building type, damage level, and personal characteristics are analyzed. Of major importance was the behavior of the building occupants during the earthquake. The manner in which specific actions either contributed to or helped prevent earthquake injuries is described. Several previous studies of occupant behavior in past US earthquakes are reviewed. These involve the behavior of patients and staff in five hospitals heavily damaged in the San Fernando earthquake, and the response of office workers in the five-story Imperial County Services Building in the 1979 Imperial County earthquake. Finally, some suggestions are made for future research on the subject.

The paper (I.2) by H. Sandi is devoted to an analysis of the connections between the activities of control and mitigation of seismic risk on one hand and the experience of the 1977 earthquake on the other. Some general data on the 1977 earthquake and its effects are given. The performance of old buildings, not designed to resist earthquakes, is analyzed, demonstrating the causes of poor performance. Attention is given afterwards to the performance of buildings designed to resist earthquakes, successively considering various structural systems. The urban systems as a whole are dealt with next, emphasizing the importance of non-structural life-threatening damage. The post-earthquake activities of a pragmatic and scientific nature are then reviewed. The factors that have prompted an efficient post-earthquake reaction are discussed. The final part is devoted to the needs of future action, dealing with the aspects related to the control and mitigation of seismic risk and to the earthquake preparedness, both from the pragmatic and the scientific points of view.

The paper (I.3) by P. Mazilu, M. Ieremia, M. Neicu, and L. Rosca, presents the layout of some industrial and telecommunication structures, which were affected by the earthquake of 1977. The structural performance is analyzed and repair and strengthening solutions adopted are presented. The ability of the structures to resist a subsequent earthquakes is discussed.

The paper (I.4) by C. Dalban and E. Dragomirescu analyzes the performance of industrial steel structures during the 1977 earthquake. Besides the satisfactory average performance, cases were observed of damage of partial collapse for structures with heavy roofs under conditions of improper detailing. The causes of damage are investigated and conclusions concerning the improvement of the design code P.100-78 are presented.

The paper (I.5) by M. Mihailescu is devoted to the analysis of the performance of spatial structures and shells during the 1977 earthquake. Eight types of shells and a double grid structure are dealt with.

The paper (I.6) by G. Sandulescu is devoted to the analysis of the causes of collapse or heavy damage in buildings exposed to the 1977 earthquake. The importance of correlating instrumental data (monitoring of ambient vibrations) with direct observations of effects is emphasized. The causes related to the layout, as well as to the detailing of reinforced concrete structures, are discussed. The importance of considering the evaluation of the vulnerability during their lifetime is stressed.

The paper (I.7) by D. Anastasescu and R. Marinov, which relies on the experience of repair and strengthening projects designed after the 1977 Romania earthquake and after the 1980 Algeria earthquakes, emphasized, on the basis of some specific examples, the importance of appropriate layout and detailing of the structure (considered as a spatial system) and of the foundations system. The correlation with functional and architectural aspects is considered. The importance of the duration of ground motion and the aftershocks is emphasized, pointing out the gradual decrease of resistance and stiffness. The problems raised by the existing building stock are then discussed, considering the scale of individual buildings and the scale of urban systems, with reference to the particular situation in the city of Timisoara.

The paper (I.8) by A. Nestor, E. Iliescu and G. Pitis is devoted to analysis of behavior of people and of the performance of buildings and industrial structures, observed in the county of Prahova. The rehabilitation activities organized after the earthquake are presented. The causes of damage and the needs of mitigating the risk affecting the existing building stock are analyzed, stressing also the need of extending the regulatory design basis.

The paper (I.9) by C. Mihai, S. Covali and G. Palamaru is concerned with analysis of damage and the residual resistance of some old buildings in the city of Jassy. The features of the layout of buildings not designed to resist earthquakes are analyzed. The possibilities of evaluation of the pre-war buildings are discussed. Attention is finally paid to the problems of the historic monuments.

The paper (I.10) by A. Mihalache, A. Liulica and V. Mihailovici is devoted to an analysis and performance of five-story, large-panel buildings in Jassy, under difficult ground conditions and strong seismic action. Some aspects related to the degradation of resistance during a lifetime, and to its effects, are analyzed. The general requirements to be considered for the design of prefabricated buildings under such conditions are discussed.

The paper (I.11) by A. Mihalache deals with the ground conditions of the city of Jassy, which may plan an unfavorable role during earthquakes. The design and performance of buildings related to this factor are discussed. The possibilities of evaluating the influence of the soil are analyzed. Some recommendations for the design of shear wall structures under such conditions are given.

5. DISCUSSION

The discussion in this session, stimulated by the presentations and the summary of the Romania papers, focused on research topics for future work. The following ideas emerged:

(a) In terms of damage control of non-structural component, it is necessary to assess the performance of non-bearing partitions in a building and its relationship to the structural system. Comparative studies between Romanian construction characteristics and those in the U.S. are required. The question of the isolation, or detachment, of non-bearing partitions from basic structure needs joint, cooperative investigation. In U.S., most partitions are lightweight and therefore the problem is not as great as in Romania, where partitions are usually heavy masonry. Japan has developed details for handling heavy walls which are designed to accept movements of up to 8 to 10 cm.

(b) Work is needed to analyze the feasibility of developing lightweight building panels as seismic shear walls. The theory is that the steel reinforcing could be developed to take larger seismic loads. Work should be related to Prof. Bertero's experimental research in laboratory testing. Characteristics of test specimens would differ between Californian and Romanian methods and techniques.

(c) It is necessary to clarify research objectives and benefits of injury studies. The potential exists for great benefit from these studies, such as social and economic impacts related to public health and safety. For example: why spend critical funds for improving seismic performance of nonstructural components if they are not a major cause of injuries? Current policy includes recommendations to bolt-down bookcases, file cabinets, etc., but to date the extent of injuries caused by the overturning of these elements is not really known. Injury studies will result in better use of limited resources and indicate priorities for action.

(d) Objectives of seismic research in Romania is determined by studies of recent earthquakes. Focus is on older, existing buildings in which the projected performance of the existing building stock must be evaluated. In the 1977 earthquake in Romania, only one out of 7,000 newer buildings collapsed, indicating that the new buildings are not the major problem. A priority of earthquake hazard reduction programs in Romania is the replacement of existing, hazardous buildings at as high a rate as possible. Replacement is emphasized over strengthening as the first priority. It is necessary to identify and quantify buildings with a high potential of major damage, such as for example, older existing frame structures or bearing wall structures.

(e) More work is required on the development and testing of methods and techniques for the repair, strengthening and rehabilitation of existing buildings in order to improve their seismic performance. Comprehensive studies for the evaluation of the existing building stock on an urban scale are needed in order to identify most critical cases.

II. SESSION II: EVALUATION OF THE EXISTING BUILDING STOCK. VULNERABILITY AND RISK ANALYSIS. REPAIR AND STRENGTHENING OF STRUCTURES.

1. PAPERS

1. B.G.Jones, D.M.Manson, C.M.Hotchkiss, and M.J.Savonis :
   Determination of Building Stock for Urban Vulnerability Analysis and Earthquake Loss Estimation.

2. R. Constantinescu :
   Romanian Technology for Strengthening Reinforced Concrete Structures by Sheathing with Fiberglass Tissues Glued with Epoxy Resins.

3. H. Sandi :
   Current Possibilities for Analysis and Mitigation of the Seismic Risk Affecting the Existing Building Stock.

4. H. Sandi, D. Cazacu, C. Constantinescu and M. Stancu :
   A Summary of Studies on the Seismic Vulnerability of Buildings, Carried out in Bucharest Subsequent to the March 4, 1977, Earthquake.

5. C. Constantinescu, and M. Stancu :
   Statistical Studies for the Prediction of Seismic Damage of Reinforced Concrete Structures.

6. M. Simonici :
   Research on Strengthening Methods for Earthquake Damaged Masonry.

7. D. Vasilescu, and D. Diaconu :
   Possibilities of Assessing Seismic Resistance of Old Buildings.

8. C. Mihai :
   Observations Concerning Vulnerability and Seismic Risk of Residential Buildings of Medium Height.

9. V. Fierbinteanu, M. Balcu, D. Petrovici, and M. Dima :
   Choice of Strengthening Solution by the Evaluation of Post-Shaking Strength Capacity of a Multistory Building Having a Steel Skeleton Structure and Brick Masonry Infilling.

10. M. Neicu, and Z. Apostol :
    The Strengthening Strategy of Existing Buildings Damaged by Earthquakes.

11. M. Mironescu, A.Bortnowschi, T.Brotea, and A.Stanescu :
    Simplified and Medium Complexity Methods to Estimate the Resistance and Deformation Capacity of Existing Buildings. Case and Statistical Studies Using These Methods.

12. L. Neagoe, L. Baltateanu, and St. Mihailescu :
    Strengthening Solutions for Some Large Span Framed Structures.

2. GENERAL CONSIDERATIONS

The experience of Romania in 1977, similar to that of numerous other countries where destructive earthquakes have occurred recently, demonstrates the fact that it is the older building stock, not designed to resist earthquakes, which represents a major source of risk. In fact, the difference in performance between the buildings designed to resist earthquakes on one hand, and the buildings not designed to resist earthquakes, was extremely strong in Romania, where almost all collapses and loss of lives were related to older buildings. In this category, the older buildings damaged during the 1940 earthquake and not rehabilitated afterwards at a satisfactory level due to war conditions, were the most hazardous elements.

Direct experience has shown the technical, economic and also logistic difficulties facing the attempt to rehabilitate and upgrade existing buildings. Obviously, the problem of mitigating the seismic risk related to the existing building stock must be dealt with keeping in mind the features of seismic hazard, as well as the projects of development at an urban scale. The conditions of Romania are such that earthquakes generating intensities comparable to those of 1977 in Bucharest, as well as in other zones, may be expected to occur two or three times a century. On the other hand, a very important favorable circumstance in the mitigation of seismic risk is represented by the relatively fast pace of replacement of the existing building stock, in connection with the general activity of urban renewal.

The activities of vulnerability and risk analysis are of direct and great interest for the mitigation of risk connected with the existing building stock. Most of the older buildings are such that is very difficult, if not practically impossible, to conduct detailed engineering analyses for them. The lack of technical drawings, information on the quality of building materials, information about the history of these building, etc., all contribute to these difficulties. In addition, the number of buildings pertaining to the older building stock is high, making practically impossible individual consideration of the buildings, at least at an initial stage. It is therefore of great interest to deal with the existing building stock, at least initially, in statistical terms, in order to get some general ideas about the risk level, the extent of necessary rehabilitation and upgrading work, etc. Data on vulnerability, expressed in terms of vulnerability matrices, as well as use of methodologies of risk analysis, are therefore of highest interest.

The intervention on existing buildings, in particular on buildings damaged by strong earthquakes or other overloading, requires appropriate techniques of design and construction. The design of repair and strengthening is in most cases technically more difficult than the design of new structures. The repair and strengthening works also require construction techniques that are different from those used in the case of new construction. All these factors require a special concern for dealing with existing buildings.

3. ACTIVITIES IN ROMANIA

The activities related to the mitigation of seismic risk in connection with the existing building stock were started, after the 1977 earthquake, as emergency activities, aimed at removing the most immediate sources of risk. These activities were gradually extended, to cover the problems raised by various categories of buildings and structures, building materials and damage inflicted by the earthquake. The use of several repair and strengthening solutions was endorsed after carrying out laboratory tests aimed at checking their validity. The emergency repair and strengthening works required by cases where apparent damage due to the earthquake was observed were completed within a relatively short period of time (the task was practically finished by the end of 1978).

Projects aimed at tackling the problem of evaluation of the existing building stock were started in 1979. A documentation on evaluation methods developed in USA and Japan was followed by attempts to deal in a more consistent way with decision making problems of needed work on the existing building stock. Methodological aspects related to the evaluation of resistance and risk were dealt with, and a pilot study was recently conducted on a limited sample of buildings in Bucharest.

Studies on the vulnerability of buildings were initiated in 1981, in the framework of an international UNDP/UNESCO/UNDRO Balkan project. The processing of information on damage distribution, provided by the post-earthquake surveys, made it possible to develop vulnerability matrices for several classes of buildings, defined on the basis of criteria related to building materials, structural systems, age and degree of engineering (results published in 1984 by UNESCO). Methodological studies on the risk analysis and a rational approach to decision making were also conducted. One of the outcomes of these studies was represented by the contribution to the development of a manual in the framework of an international UNDP/UNIDO Balkan project (published in late 1985 by UNIDO).

4. CONTRIBUTIONS TO THE SESSION

The paper (II.1) by B. G. Jones et.al. is devoted to an analysis of input data related to the existing building stock, as required for analysis of urban vulnerability. Some general methodological aspects related to vulnerability and risk analyses are dealt with. Attention is focused thereafter at the specific features of urban systems, for which some relationships between population and building stock development are discussed. To deal in more specific terms, the case of Wichita, Kansas, is considered. The structure of the building stock is discussed, by categories related to the use, or the location within different zones of the town, and several tables are presented. Further data are given in relation to the distribution of replacement cost of the building stock, the population and building density, and the building area. Finally, the use of these categories of data is discussed.

The paper (II.2) by R. Constantinescu presents the results of laboratory tests of some strengthening solution developed for damaged reinforced concrete members (beams). T-shaped members were tested before and after strengthening. Strengthening solutions were based on epoxy injections and subsequent plating with fiberglass fabric embedded in epoxy resins. The experimental results led to the conclusion that it is possible to rehabilitate or even to improve, by this procedure, the ability of members to resist loads leading mainly to shearing forces.

The paper (II.3) by H. Sandi is devoted first to the presentation of the conceptual framework of risk analysis and of the decision on the intervention on existing buildings. Some basic definitions and relations are presented. The input data are discussed. The analytical developments are illustrated by some results of a parametric analysis of risk carried out for several categories of buildings.

The paper (II.4) by H. Sandi, D. Cazacu, C. Constantinescu, and M. Stancu summarizes the vulnerability studies carried out in Romania after the 1977 earthquake. The categorization of buildings, the quantification of damage and the estimate of intensity believed to have affected the buildings are presented. The development of the building stock and design regulations in Romania are summarized. The classes of buildings for which vulnerability matrices were developed are described and the outcome of analyses is presented. Some subsequent studies, aimed at correlating the observation-based vulnerability data with the outcome of engineering analyses, are then presented. The state-of-the-art is then discussed.

The paper (II.5) by C. Constantinescu and M. Stancu is devoted to the presentation of an approach aimed at predicting the vulnerability of some classes of buildings on the basis of experimental data related to the ambient vibrations. Data on the stiffness changes due to the damage and to repair and strengthening works are used in this connection. The possibilities of improving, on this basis, the mathematical models used in structural analysis are then discussed.

The paper (II.6) by M. Simonici presents some solutions of strengthening of masonry members damaged by earthquakes, which were investigated under laboratory conditions in order to verify their validity. A technology that provides considerable increase in the strength, stiffness and ductility of masonry walls was thus developed.

The paper (II.7) by D. Vasilescu and D. Diaconu is devoted to an analysis of various possibilities for assessing the earthquake resistance of existing buildings of various categories. A relatively simple method of predicting the carrying capacity of building structures is proposed. This approach relies on field data on the buildings in question and on the environmental conditions.

The paper (II.8) by C. Mihai presents a summary of results obtained in relation to the design and subsequent research analysis of buildings built from 1958 to 1965, under specific local conditions, in Jassy. Some assessments on the vulnerability and risk affecting some categories of buildings are made, based on the influence of earthquake induced damage, damage from other sources, and repair and strengthening works.

The paper (II.9) by V. Fierbinteanu, M. Balcu, D. Petrovici, and M. Dima is devoted to an analysis of a twelve-story steel structure in relation to a rehabilitation and upgrading project. The history of the structure and the effects of the 1977 earthquake are presented. The mathematical model developed for dynamic analysis is then presented. The results of a time history analysis were used as a background for the adoption of the strengthening solution.

The paper (II.10) by M. Neicu and Z. Apostol presents a summary view of a stock of some 2,500 high-rise buildings damaged by the earthquake. The main causes of damage of varying severity, including the collapse of 30 buildings, are analyzed. The design philosophy adopted for various categories of buildings under post-earthquake conditions is presented.

The paper (II.11) by M. Mironescu, A. Bortnowschi, T.Brotea, and A. Stanescu presents two methods of engineering analysis of the resistance to earthquakes of existing buildings. These approaches rely on the modal response spectrum analysis and the time-history analysis of an equivalent SDOF system respectively. These methods were applied to numerous cases, providing a background for the adoption of rehabilitation and strengthening solutions.

The paper (II.12) by L. Neagoe, L. Baltateanu, and St. Mihailescu is devoted to the repair and strengthening solution adopted for a system of framed structures in Bucharest. The buildings dealt with are described, with emphasis on the structural solutions. The nature of the damage and its distribution is then analyzed. The design conditions, defined by the code in force before 1977, are presented and a correlation is made with the damage recorded. Criteria considered for adopting the repair and strengthening solution are presented and the technical solution is described.

5. DISCUSSION

The following is a summary of the main points of the discussion which took place during this session:

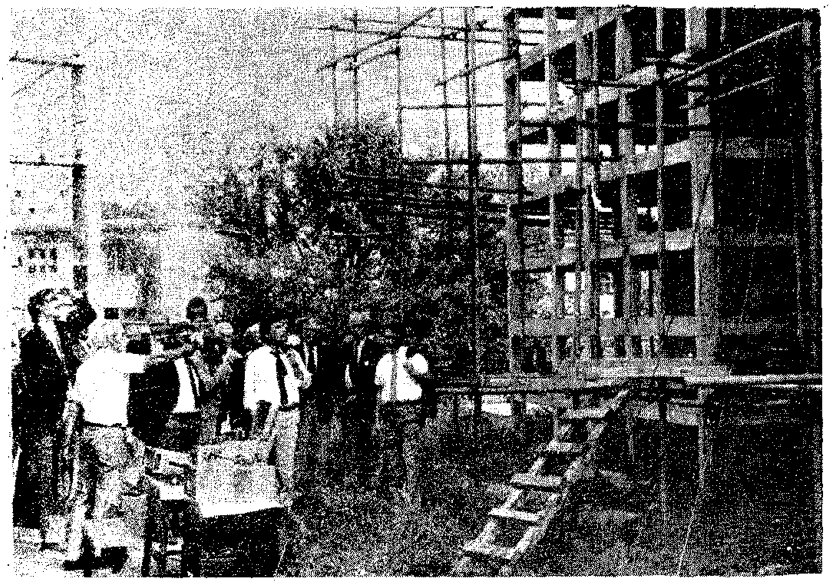
(a) Recommendations for actual human behavior in buildings during an earthquake are needed. There is a need to inform building occupants what behavioral patterns should be followed when an earthquake occurs. Currently, conflicting instructions are being distributed on this point. Clarification of this point would dispel much confusion

(b) The value of the comprehensive approach of modelling studies of existing building stock on an urban scale, such as those completed by B. Jones, must be clearly identified. Studies in this area are critical in obtaining an overall perspective on the anticipated performance of regional urban centers. These are most useful in preparedness planning and contingency programs.

(c) Objectives of vulnerability studies must be reinforced. These studies, many times, are oriented toward technical and economic problems. Where do social goals fit into this research topic? Elderly people are more vulnerable than others, and some recognition is needed in this area in an overall research agenda.

(d) The Managua earthquake indicated that social mobility is an important consideration in the development of earthquake hazard mitigation programs. Various traditional, indigenous construction methods and techniques must be reviewed in terms of earthquake hazard exposure, and compared to newer construction systems, for example adobe vs. newer methods.

(e) Utilization of B. Jones' research work has the potential of affecting city planners and urban designers. Methods need to be identified and developed to make the transfer of research results to other planning and design professionals viable as a factor influencing practice. These studies, which offer a better understanding of the urban environment and its exposure to damaging earthquake events, are a critical component of the total picture.



III. SESSION III: EARTHQUAKE PREPAREDNESS. CRITICAL FACILITIES. URBAN AND SOCIOLOGICAL ASPECTS.

1. PAPERS

1. H. J. Lagorio :
   Seismic Performance of Critical, Emergency Service Facilities.

2. S. Georgescu :
   Premises of a Romanian Earthquake Preparedness Program For Bucharest.

3. S. Georgescu, and D. Mandruta :
   Architectural, Engineering and Individual Reaction Elements Concerning the Opportunity to Evacuate Apartments During the Earthquake.

4. A. Cristescu :
   Town Planning Contribution for the Urban Vulnerability Mitigation.

5. D. Abraham, G. Gheorghe, N. Gheorghe, and M. Kivu :
   The Social Response to Earthquakes.

6. D. Abraham, A. Cristescu, G. Gheorghe, and M. Kivu :
   Social and Urban Aspects of Seismic Protection of Towns

2. GENERAL CONSIDERATIONS

The development of earthquake protection activities demonstrates increasingly the multifaceted aspects and connections characterizing this field. While the technical aspects related to the natural phenomena and the physical performance of the artifacts of man consist at present of a considerable stock of hard data and of methods of analysis with a hard background, the less classical aspects of earthquake preparedness and system problems raised by earthquake protection issues rely on rather soft information, and do not have as yet a comprehensive theoretical basis. At the same time they require the concern of interdisciplinary teams.

The importance of such less classical aspects is maae obvious by the fact that, in many cases, the earthquake induced losses may consist to an important extent, not of the immediate damage inflicted to buildings or other structures, but much more of chain effects and the disruption of complex networks of human activities.

The need and efficiency of earthquake preparedness measures is made obvious by the analysis of earthquake scenarios as well as the summary of earthquake experience. Earthquake preparedness, in the broad sense, must keep in mind the mitigation of risks on one hand and the enhancing of the societal ability to react efficiently in the event of destructive earthquakes. It must encompass, at the same time, pragmatic and scientific aspects. Appropriate preparedness activities may decrease dramatically losses in the event of strong earthquakes, and some positive examples, especially of Japan and China, should be noted in this context.

3. ACTIVITIES IN ROMANIA

It may be stated that activities in Romania in this field are only at a initial stage. The gap in development of this field as compared with the more classical fields of seismology, earthquake engineering of structures, etc., parallels the international scene. The initial activities, started after 1980, were aimed at an understanding of the problem, a summary of the available international experience, and the collection of some preliminary field data.

4. *CONTRIBUTIONS TO THE SESSION*

The paper (III.1) by H. Lagorio is devoted to the problems raised by critical facilities, like major hospitals, ambulance support systems, police and fire stations, and communication centers, that are of strategic importance for post-earthquake recovery efforts. The importance of four elements (geo-physical aspects and land use planning, technical performance of critical facilities and services, interrelationships of urban scale infrastructures, and socio-economic concerns of public health and safety) is stressed in this context. A detailed list of critical, emergency service facilities and structures is given. Some historic data on the vulnerability of such facilities for four earthquakes (San Francisco, 1906; Managua, 1972; San Fernando, 1971; Coalinga, 1983) are given. Current developments in performance standards are discussed. Problems of public policy in connection with the relative earthquake safety in buildings are dealt with. The California hospital act (1972) and its revisions (1983) are presented. The planning and design of five solutions are discussed thereafter. Problems of site planning and facilities location are finally dealt with.

The paper (III.2) by S. Georgescu presents a first attempt to analyze the ability of the city of Bucharest to withstand a strong earthquake. Some parameters are listed and analyzed related to the structure of the population. The pre-war highrise buildings (more than six-stories high) are considered as a major risk source. The state-of-the-art of lifelines is analyzed. Some assumptions are made on the damage and losses due to a future earthquake with intensities VIII to IX, as a background for a preparedness program. Some differences are presented with respect to the conditions of foreign countries.

The paper (III.3) by S. Georgescu and D. Mandruta is devoted to the human reaction under earthquake conditions, in interaction with architectural elements that are characteristic of modern residential buildings. Factors are analyzed that make the evacuation of buildings possible or even advisable. Factors related to the environment and the expected performance of the building components, equipment and furniture, are dealt with, as well as the experience of previous earthquakes.

The paper (III.4) by A. Cristescu is devoted to an analysis of the role of urban planning in influencing the seismic risk and its possible mitigation. The various possible interventions on existing buildings in relation to urban planning activities are considered. An increase in the ability of existing towns to withstand earthquakes may be achieved not only, or primarily, by means of interventions on the individual components, but also, and perhaps more efficiently, by tackling the urban system as a whole. The integration of urban planning in the general mitigation activities is thus considered.

The paper (III.5) by D. Abraham, G. Gheorghe, M. Gheorghe, and M. Kivu is based on the consideration of earthquake protection as a societal response to the earthquake situation, encompassing technical and societal measures. The analysis of the experience of the 1977 earthquake demonstrated the importance of educating the population for emergency conditions, the necessary emergency assistance and rescue measures, and the means of providing a speedy return to normal life conditions, including a convenient solution of the problems of provisional shelter.

The paper (III.6) by D. Abraham, A. Cristescu, G. Gheorghe and M. Kivu is based on the outcome of a Delphi type enquiry among specialists involved in earthquake protection activities. The importance of elements influencing urban protection was ranked in the study. The decisions on urban renewal in relation to various criteria are considered. The impact of the 1977 earthquake on the tendencies and projects of renewal is examined. Some general principles of urban renewal and planning under post-earthquake conditions are discussed.

5. DISCUSSION

The following ideas and points were raised during the session discussion:

(a) Planning for the delivery of health services in the immediate post-earthquake period requires a comprehensive systems approach. Will the hospitals be able to continue to operate? Can they become independent for a certain period of time? What about traffic congestion and disruptions?

(b) In considering earthquake preparedness, we need to focus not only on the initial costs and organization, but also on the important issues of maintaining and servicing the established preparedness.

(c) In terms of planning, it may be useful to think of functional requirements. In addition to present day building codes, we may need to develop different types of codes prescribing functional earthquake safety requirements. These would be aimed at the design of suitable physical and organizational systems, for the purpose of preserving stated levels and types of needed functions for buildings, institutions, factories, etc., as well as for parts of the urban system.

(d) In structural engineering it is relatively easy to design for survivability, i.e., for prevention of collapse. But preventing the loss of some function of the building, for example because of excessive drifts, is much more difficult. Research should address this problem of interaction between structures and social functions of buildings.

(e) Another potentially troubling problem, needing careful planning and research, is the coordination of recovery in the post-earthquake emergency period.

IV. SESSION IV: STRUCTURAL PERFORMANCE UNDER EARTHQUAKE LOADINGS. STRUCTURAL DESIGN

1. PAPERS

1. D. P. Abrams :
   Computation and Testing of Dynamic Response for Reinforced Concrete Structures.

2. H. Sandi, M. Stancu, O. Stancu, and C. Constantinescu :
   A Biography of a Large-Span Structure, Pre- and Post-Earthquake, After the Provisional and Final Strengthening.

3. S. Georgescu, and D. Radulescu :
   Architectural Demands and Limits Imposed by the Aseismic Structural Concept: Case Study Starting from the Damage Caused by the March 4, 1977, Vrancea Earthquake on a Building Type with Peculiar Architecture and Structure.

4. D. Diaconu, D. Vasilescu, and M. Manolovici :
   Important Aspects Concerning Seismic Response of Entirely Precast Structures for Single-Story and Multi-Story Industrial Halls.

5. D. Diaconu, and P. Cosmulescu :
   Aspects of Dynamic Interaction Between Structural and Nonstructural Members.

6. D. Diaconu, D. Vasilescu, and S. Marinescu :
   Peculiarities in the Seismic Behavior of Various Structural Systems Made of Entirely Precast Large Panels.

7. G. Sandulescu, and M. Decusara :
   Seismic Risk Reduction Using Prestressing in Reinforced Concrete Structures.

8. F. Dabija, D. Capatina, and S. Dabija :
   Dynamic Analysis of Multistory Building Structures with Cores of Precast Components Assembled by Prestressing.

9. D. Constantinescu :
   Analysis of the Seismic Response of a 9-Story Large Panel Building

10. D. Georgescu :
    Spatial Interaction Effect on Behavior of Single-Story Mill Buildings Subjected to Seismic Action.

11. D. M. Ghiocel, A. Popovici, and D. Ghiocel :
    Seismic Risk Evaluation for Buildings Including Soil-Structure Interaction Effects.

12. G. Ciuhandu, and A. Minaescu :
    Studies Concerning the Behavior of Reinforced Concrete Shear Walls with Openings Under Alternating Horizontal Loading.

2. GENERAL CONSIDERATIONS

The structural performance under earthquake loading plays a key role in the general societal ability to resist earthquakes.

In fact, it may be stated that this is the domain in which one can note the most important efforts of specialists of various countries involved in earthquake protection activities. The problems raised by the general goal of providing satisfactory earthquake resistance for structures are multi-sided, requiring the development of the ability to analyze the physical performance and the safety of structures, as well as the development of appropriate structural solutions, from the viewpoints of layout and detailing. These aspects require appropriate cooperation between researchers and designers, keeping in mind the fact that the suitable methods of analysis are not the same for research and design activities, and keeping in mind also the need of close cooperation during the development of new structural solutions. The conditions of Romania must be emphasized in this connection. There, the major part of buildings and industrial structures is build on the basis of standardized designs, which are being developed under conditions of permanent cooperation between designers and researchers.

3. ACTIVITIES IN ROMANIA

The activities of analysis of structural performance and of development of new structural solutions under seismic conditions have absorbed an important and increasing share of engineers during the last three to four decades in Romania. Efforts were devoted to several aspects related to engineering calculations and experimental activities. The necessary software (in the pre-computer era and, afterwards, in the computer era, that started in 1970) was developed almost entirely by means of local efforts. A large number of computer programs, covering various approaches, from conventional linear model analyses to non-linear time-history analyses, are available and used at this moment. Research activities were devoted to the development of appropriate force-deflection models, models of artificial accelerograms, etc., as well as corresponding computer programs. Stochastic models and techniques were applied to various engineering problems, and safety analyses could be performed on this basis. Experimental activities were organized under laboratory conditions (quasi-static tests, cyclic tests, dynamic tests for models or components installed on shaking tables) and under full scale conditions (in most cases, monitoring of ambient vibrations, for a wide range of structures). The standardized solutions for buildings and other structures were developed on the basis of careful engineering analyses and physical testing. The activities devoted to building structures were extended also to the field of several categories of equipment installed in industrial plants.

The impact of the earthquake of 1977 was particularly important in this field. Many case studies devoted to the investigation of the performance of buildings, and to the effects of the earthquake, were initiated, and they contributed considerably to a better understanding of structural performance and of the problems of structural engineering as a whole. Some studies in this field were devoted to the historical analysis of structures (pre- and post-earthquake, pre- and post-rehabilitation). The activities in this direction are related also to those considered in relation to Session II of the seminar.

4. CONTRIBUTION TO THE SESSION

The paper (IV.1) by D. P. Abrams presents research carried out at the University of Illinois on the behavior of physical and theoretical models of structures. A summary of experimental work is presented, which includes earthquake-simulation tests of reduced scale ten-story concrete buildings, and force-reversal tests of structural components. Numerical representations of hysteretic behavior are presented and simple ways to incorporate these models with models of building response are analyzed. The concluding remarks include comments on the state-of-the-art, emphasizing the fact that an appropriate adoption of simple numerical models makes it possible to demonstrate the main features of dynamic behavior.

The paper (IV.2) by H. Sandi et. al. is devoted to the presentation of a biography of the structure of the main exhibition hall of EREN (Exhibition of the Achievements of the National Economy). This structure consists essentially of a 96 m. (315 ft.) span dome, supported by 32 couples of columns, and is practically axi-symmetric. The analyses were carried out using experimental means (monitoring of ambient vibrations) and analytical ones (which led to the use of computer programs for the linear and non-linear stage, to the identification of failure mechanisms etc.). The analyses were related to five stages: pre-earthquake, immediately after the earthquake, after the provisional strengthening, prior to the final strengthening and after the final strengthening.

The paper (IV.3) by S. Georgescu and D. Radulescu is devoted to an analysis of the relationship between architectural and structural design, considering the experience of a case study related to the performance of an eleven-story building. The nature of damage generated by the earthquake is described, and conclusions for a more reasonable design are derived on the basis of engineering analyses and experimental data.

The paper (IV.4) by D. Diaconu, D. Vasilescu, and M. Manolovici is devoted to the presentation of the dynamic response and the failure mechanisms for standardized precast industrial structures, as obtained from shaking table tests. The influence of the type of roof diaphragm is also discussed. Some data are related to multistory structures used in industry.

The paper (IV.5) by D. Diaconu and P. Cosmulescu is devoted to studies related to the interaction of structural and non-structural components of buildings. The influence of masonry infill walls is analyzed, demonstrating its positive role. Comparative response data is presented, dealing with shaking table tests, with and without infill walls.

The paper (IV.6) by D. Diaconu, D. Vasilescu, and St. Marinescu is devoted to an analysis of the peculiarities of performance of various large panel solutions. Research is summarized related to various solutions, ranging from five to eleven story structures, and for various layouts in the horizontal plane. Some features of the performance of such structures during the 1977 earthquake are also discussed. Criteria for adopting a suitable layout are then considered.

The paper (IV.7) by G. Sandulescu and M. Decusara is devoted to the possible use of prestressing in the development of new solutions for earthquake resistant structures. The need is discussed to adopt both a resistance and a survival mechanism for a structure. The advantages that may be provided by the prestressing, in order to limit the earthquake damage, are analyzed. Some general recommendations are presented on the development of structural solutions based on prestressing.

The paper (IV.8) by F. Dabija, D. Capatina, and S. Dabija is devoted to the analysis of structures consisting of several prestressed resistant cores. The layout of a solution is presented, together with the results of linear and non-linear computer analysis of the dynamic response to earthquake loading.

The paper (IV.9) by D. Constantinescu presents the main results of an analysis of a nine-story, standardized, large panel building. This is a first attempt of non-linear analysis carried out in Romania and besides the behavior of the structure, it also considers ground compliance. A more detailed model is analyzed for static loading, while a simplified one is used for accelerograms of the Bucharest motion of 1977 and of the El Centro motion of 1940. The internal forces at the joints are given special attention.

The paper (IV.10) by D. Georgescu is devoted to the analysis of some industrial, one-story, steel structures. The problems raised by the overall torsion in a horizontal plane are discussed, and some suggestions are formulated for a future revision of the provisions of the earthquake resistant design code in force in Romania.

The paper (IV.11) by D. M. Ghiocel, A. Popovici and D. Ghiocel is devoted to the application of stochastic techniques to the modeling of earthquake motion and of ground characteristics. The computer analyses carried out are based on a non-linear finite element approach. The influence of soil characteristics and of the presence of neighboring buildings are considered.

The paper (IV.12) by G. Ciuhandu and A. Mihaescu describes model tests of various solutions of five-story shear walls with openings. Results obtained are related to strength, stiffness, ductility and energy absorption capacity, and were used to suggest improvements of the design rules for shear wall buildings.

5. DISCUSSION

A few technical points were mentioned in the discussion of this session:

(a) In the tests described by D. P. Abrams, the main variable was the wall. The conclusion was reached that the flexible structures deflected less because of the inelastic deformations.

(b) Very interesting interactions exist between stiffness, strength, and drifts, and these are related to the type of earthquake. In Romania we had short frequencies and long periods, and such earthquakes are much less relevant for very stiff structures.

(c) The importance was emphasized of using simple methods of analysis.

(d) The use of base isolation in design was considered in Romania, but found impractical because of the nature of local earthquakes.

(e) Soil-structure interaction can be beneficial, when the soil acts to limit overturning moments for low frequencies.

V. FILMS

Two films were screened after the last earthquake session:

1. DYNAMIC TESTS OF REINFORCED CONCRETE STRUCTURES WITH STRONG BEAMS AND WEAK COLUMNS.

This film showed response of a reduced-scale nine-story test structure, which was subjected to simulated earthquake motions on the shaking table at the University of Illinois. The test structure was constructed at approximately one-twelfth scale using small-scale concrete and reinforcement. The structure consisted of two planar frames that were designed such that failure would occur in the columns rather than more conventionally in the beams. The purpose of the study was to investigate the tolerable limits of lateral deflection for this type of construction.

Response was shown in the film to four earthquake simulations. Maximum base accelerations for the first two test runs were 0.35 g, which represented the design basis earthquake. The third and fourth test runs examined response for intensities of approximately two and three times that of the initial runs. Collapse of the structure was observed during the fourth run as a result of the formation of hinges at the base story and subsequently, at one of the intermediate stories.

The test program was executed by Mr. Art Schultz, under the direction of Professor Mete Sozen.

2. DYNAMIC TESTS OF ROMANIAN SYSTEM EME.

This film presented the dynamic testing of the Romanian building system EME, designed for export to Venezuela. The system consisted of large prefabricated and prestressed concrete box units, with slabs placed between them. It can be used up to four stories in height. The tests were performed on a quarter-scale model, with maximum applied accelerations of 0.9 g, and demonstrated good seismic behavior.

VI. JASSY BRANCH OF ICCPDC

The visit to the Jassy branch of ICCPDC included a tour of their experimental facilities, presentation of past experimental studies, description of a new laboratory in construction, and a discussion leading to suggested possible topics for future cooperative work. A summary of these activities is presented below.

1. TOUR OF EXPERIMENTAL FACILITIES

Director Daniel Diaconu provided an extensive tour of the structural engineering testing facilities and the current experimental research programs at Jassy. The tour included descriptions of the shaking table research and the testing of reinforced concrete structural components and subassemblies.

Existing dynamic test equipment includes a large shaking table (10 x 10 m., 140 tons, 0.25-12 Hz., 4.3 g harmonic) and a medium size table (3 x 3 m., 15 tons, 1-30 Hz., 5.0 g harmonic). Each simulator platform is suspended on a film of water which is pressurized from an elevated water tank. Excitation is provided in a single direction with a hydraulic actuator. Precise replication of earthquake records is not intended, but base motions do result in forms of shaking acceptable for study. Smaller tables for model testing include 0.6-ton and 1.0-ton tables. Data is acquired digitally on a hard-disk facility using a PDP-11 computer.

At the time of the visit, several experimental programs were underway, and were described by Director Diaconu. On the large shaking table, a 0.3 scale three-story frame structure was being constructed. The structure was a replication of typical construction used for industrial buildings where the roof system is supported by beams that rest on column haunches. Precast beams at lower levels are connected to column members with a welded detail that provides flexural continuity. Transverse beams are cast in place.

In the yard of the laboratory, remnants of several past experimental programs could be seen. Former test specimens included a 0.3 scale model of a 5-story large-panel structure, several 7-story and 3-story reinforced concrete frames with monolithically cast infills, reinforced concrete planar frames with walls, and concrete frames with brick infills. With the exception of the large-panel structure, which had been tested on the shaking table, the other specimens were subjected to a slowly applied single lateral force at the top level.

Numerous three-dimensional beam-column assemblies had been tested under both static and dynamic rates. Specimens were cast in place, precast, or a combination of each. Other variables in the test program included the configuration of members framing to the joint, types and amounts of joint reinforcement, and construction schemes for joining precast members.

Another test program was currently underway to determine force-deflection relations for monolithic slab-column connections. Column members were subjected to cyclic lateral deflections from a single direction, which was either parallel or skew to the principal axes of the column member. A demonstration was given which consisted of cycling a previously tested specimen at approximately one cycle per second.

2. PAST EXPERIMENTAL STUDIES

The tour was followed by a slide presentation by Director Diaconu which summarized past experimental projects at the

Seismic Testing Station. During a quick review, he mentioned the following studies:

(1) studies of hysteresis models
(2) behavior of large-panel walls
(3) static and dynamic behavior of beam-column joints
(4) response of full-scale panel structures
(5) behavior of joint systems for precast structures
(6) harmonic testing of 8-story buildings
(7) response of 0.3 scale, 12-story frame structures
(8) behavior of 1- and 3-story reinforced concrete walls
(9) response of building systems with variable stiffness
(10) response of braced concrete frames
(11) frames with shear walls or masonry infills
(12) behavior of slab-column subassemblies
(13) response of 0.3 scale, 9-story post-tensioned building
(14) response of steel building structures
(15) response of industrial storage racks
(16) anchorage and response of cladding
(17) effectiveness of floor diaphragms
(18) response of buildings with nonstructural roofs
(19) response of industrial buildings
(20) response of frames governed by torsion of spandrels
(21) response of 4-story precast industrial buildings
(22) response of systems with long spans and weak columns
(23) response of prestressed reservoirs (10,000 l.)
(24) response of elevated water tanks
(25) response of components for nuclear power plants
(26) response of buried pipes used for metro tunnels
(27) response of retaining walls
(28) response of electrical components

3. NEW STRUCTURAL ENGINEERING LABORATORY

Ground has been broken for a new structural engineering laboratory in Jassy. The facility will include a separate building with four shaking tables (5, 30, 300, and 800 tons; three-dimensional control; maximum accelerations of 0.8 g), and areas for specimen fabrication. An adjacent building will house a strong floor and massive reaction walls suitable for biaxial lateral loading of large-scale specimens up to five-stories in height. The test floor is large enough for several large experiments. Servo-hydraulic equipment for the shaking tables and the portable actuators will be developed within Romania. A control room for recording test data is planned in a separate building adjacent to each laboratory.

Several experiments may be run concurrently within the laboratory, which should enhance the present scope of work greatly at Jassy. Completion of the facility is scheduled for April of 1986.

4. TOPICS FOR FUTURE COOPERATIVE RESEARCH

In the discussion which followed the visits and presentations, four general themes emerged as desirable topics for future cooperative research between the Jassy Branch of ICCPDC and United States researches and institutions:

(a) Establishment of hysteresis models for reinforced concrete connections and building systems.

(b) Joint testing of a particular type of structural system at different institutions.

(c) Investigations of dynamic response for precast systems.

(d) Design approaches for precast, prestressed systems.

B. ENERGY

The seminar discussions on the subject of energy took place in four sessions at INCERC, in Bucharest. The topics ranged from building performance, standards, and conservation, to solar energy, daylighting, and energy storage. The large number of Romanian papers prevented their full presentation. However, they were summarized by a rapporteur into broad themes, and individual abstracts were also available. The American papers were presented in the sessions, which also included time for open discussions. A number of technical visits were carried out, involving solar houses and research sites at INCERC and Baneasa, in Bucharest, and Cîmpina and the Hygro-Thermal Laboratory, in Jassy.

This section describes the presentations and discussions of each session, and the details of the field visits.

I. SESSION I: THE THEMES OF ENERGY PAPERS. BUILDING PERFORMANCE.

1. PAPERS

1. P. Mill, V. Hartkopf, and V. Loftness : Transdisciplinary Building Diagnostics and the Concept of Total Building Performance.

2. CONTRIBUTIONS TO THE SESSION

The paper (I.1) by P.Mill, V. Hartkopf, and V. Loftness introduces the concept of total building performance as well as the diagnostic instruments for measuring and estimating this performance. Thus, the fundamental issues of building performance (thermal, acoustical, space, lighting comfort, air quality, building integrity, etc.) are fully considered; the conditions for comfort (in physiological, psychological, sociological, and economic terms) are defined and their relations are identified. The paper suggests the possibility of assuring a new quality of optimum and safe conditions for the comfort of occupants in both new and existing buildings.

3. DISCUSSION

This first session opened with the consideration of the themes of papers on the subject of energy. Eng. Teodor Teretean placed all the Romanian papers in the context of three broad themes: **energy conservation** and its influence on architecture, construction, and installations in buildings; **solar energy** as a new energy source; and the **storage of energy.**

The "oil crisis" of 1973-1974 started a chain reaction with a heavy impact on the world economy. In 1985, the world consumption of energy was about 8.8×10^3 tons of equivalent oil (t.e.o.), and the amount projected for the year 2000 is at least 15×10^3 t.e.o. Due to the heavy energy demands of the national economy, the "oil crisis" represented both a burden and a challenge to science and technology for new solutions of energy conservation. The Romanian government provided important material and human resources for work on this energy problem. Some of the ideas and results reported in the six Romanian papers on energy conservation include the following:

- the use of porous foamed ceramic products, made of coal waste materials, have resulted in energy savings of about 25-85%, and cost reductions of 40-50%;
- in order to achieve conditions of minimum comfort, saving of electric energy for lighting uses must take into consideration comprehensive factors related to both technology and the consumer;
- the study of mass and heat transfer are needed for energy saving in the outer building elements, their performance and maintenance;
- the use of lightweight granulite concrete can result in important energy savings, and a payback period of 2-6 years.

Various aspects of solar energy are covered in twelve Romanian papers. Research on solar applications for hot water and space heating started at INCERC in 1971. The first studies were on theoretical aspects, followed by pilot installations and the development of norms and specifications. These were subsequently used for the design of new systems and projects. The importance of solar energy use in Romania is represented, in 1985, by some one-half million square meters of installed collectors for hot water in domestic, industrial, and animal husbandry buildings.

Energy storage, in terms of sensible and latent heat, represents an important question for non-conventional or secondary energy sources, and is the general subject of six Romanian papers.

The presentation of Eng. Teretean was followed by Professor Volker Hartkopf who established the context for the U.S. papers in terms of housing, urban design and non-residential buildings. Professor Hartkopf described the U.S. urban expansion in land area and the loss of population in the urban centers. He offered the example of the new energy efficient house located in the suburbs that reduces residential energy consumption while it greatly increases automotive fuel consumption for commuters to work and other services. It was stressed that there is a necessity to integrate energy more fully into planning and urban design picture.

This discussion was followed by an analysis of the amount of "disposable" income available to U.S. citizens which now is used to procure energy. The cost of fuel has been the major pressure behind new and retrofit energy conservation work as well as the energy conserving rehabilitation of abandoned inner city buildings.

Following the presentation of paper I.1, questions from the Romanian participants involved a search for a **few independent variables** which might be employed in evaluation, rather than the broad band of parameters suggested in the concept of total building evaluation. These few parameters might be shown to apply to most "ordinary" buildings. It was acknowledged that more evaluation variables may be needed in the commercial structures more common in the U.S.

The U.S. team indicated that most standards in the U.S. did focus on a few well-defined variables which do not address the broad range of concerns contained within the total building performance concept. The U.S. research team was critical of past U.S. efforts, largely due to the missed opportunities they represented. In general the U.S. team suggested that multiple performance criteria can lead to significant economies in several areas of building performance. The example of the air extract window with internal blinds was given to show a simple device which offered improved insulation, daylight, shade control, and acoustic separation. In short, the U.S. team was interested in improving several aspects of the whole building through the employment of multi-purpose energy strategies. The team was quick to acknowledge, however, that simple performance standards were very useful in the short term, citing the work on the Building Energy Performance Standards (BEPS) project as well as more recent State standards from California and Washington.

A direct approach to consumption standards was suggested by the U.S. team which involved three steps:

1. Assess what the industry can accomplish now in good conventional practice.

2. Make that performance level the standard.

3. Reduce the level of consumption by a modest percentage every year.

The percentage reduction should be directly related to potential industrial and professional design improvements.

II. SESSION II: RESEARCH NEEDS. BUILDING STANDARDS, STRATEGIES AND CONSERVATION.

1. PAPERS

1. W. M. Kroner :
   Energy Efficiency in Buildings:
   Research Needs for the Next Decade.

2. R. G. Shibley :
   Energy in Buildings: Trends in New and Retrofit Non-Residential Strategies.

3. G. Polizu :
   Energy Efficiency of Flows Involved in the Erection and Service of Buildings.

4. N. Leonachescu :
   An Energy Conservation Approach to Architectural Solutions and Aspects.

5. C. Pestisanu, and L. Popescu :
   Noise Absorption and Thermal Insulation.

6. C. Bianchi, and G. Chirita :
   The Share of Lighting in Building Energy Systems.

7. C. Bogos :
   Energy Saving By Thermal Protection of the Exterior Elements of Buildings.

8. D. Anastasescu, I. Ionescu, and I. Koreck :
   Energy Saving with Lightweight Granulite Concrete.

2. CONTRIBUTIONS TO THE SESSION

The paper (II.1) by W. M. Kroner presents the present stage of development in the field of conscious energy-efficient design for both commercial and residential buildings. It describes two categories of research needs:

- The first refers to the present stage of energy efficiency in new commercial and residential buildings, including innovations in energy conservation and in using passive solar systems.
- The second refers to long-term research requirements. Clear research needs exist in the field of residential and commercial building rehabilitation, the performance of new solar passive commercial buildings in terms of occupant behavior and their use and maintenance, and in the field of

energy planning and energy efficient systems.

The paper (II.2) by R. G. Shibley focuses on the fact that the state of the art in energy conservation has made significant advances over the past ten years in the United States. It emphasizes that these advances have found their way into some conventional practices and that additional institutionalization of proven strategies is occurring at a slower rate. It stresses that this success does not apply to the existing building stock. In effect, the U.S. is presented as a victim of its own "success" with a victory over the energy crisis declared too soon for the state of the art in building retrofit to advance. It provides the worldwide demographics which suggest that the real energy crisis may not (as yet) have occurred.

The paper (II.3) by G. Polizu is concerned with the problem of the overall energy efficiency involved in the erection and use of buildings. Its main conclusions deal with the special research and design needs required for achieving substantial improvements in energy efficiency. These involve building elements and materials, equipment, technologies used by the builder on the site, and conditions for building use, all according to design parameters.

The paper (II.4) by N. Leonachescu emphasizes the need, during the energy crisis and its consequences, to consider every architectural design from a new point of view, namely that of the energy saving and conservation.

The last four papers, (II.5) by C. Pestisanu and L. Popescu, (II.6) by C. Bianchi and G. Chirita, (II.7) by C. Bogos, and (II.8) by D. Anastasescu et.al., deal in a specific manner with four problems associated with energy conservation. These are noise absorption and thermal insulation, lighting, thermal protection of outer elements, and the use of lightweight concrete.

3. DISCUSSION

The second session was characterized by an effort to formulate fundamental questions which require attention. The discussion which followed the presentations of Professors Kroner and Shibley revealed several issues held in equal esteem by both the U.S. and Romanian teams, as well as a broadly based Romanian concern for residential building standards which address energy consumption. Five questions were presented which framed the discussion:

1. What about existing buildings?
2. How does one transfer the results of research into standards and standardized designs?

3. What is the advisability of multi-family high-rise, high density low-rise or individual unit construction?
4. What is the present status of the "so-called" energy crisis?
5. How does one establish a multi-disciplinary approach?

What about existing buildings?

Most members of both teams were in agreement that relatively little research has been done on existing buildings from the perspective of energy conservation or solar applications. One major exception involves the dramatic effort in domestic hot water installations in Romania. Similar efforts in the U.S. have been reduced in scale due to several factors: the loss of governmental support; high maintenance costs; and relatively poor returns on investment. It was suggested that, of all the energy consumed which will be directly attributable to buildings in the next decade, at least one-third will be related to the existing enclosure systems of the buildings, another third will be consumed due to transportation costs associated with poorly planned locations, and the last third will be related to mechanical system efficiencies. It was pointed out by the U.S. team that the U.S. research community in solar and conservation feel a strong need to do research on the existing stock of buildings while the commercial and governmental attitude is less enthusiastic.

How does one transfer the results of research into standards and typified (standardized) designs?

In general the U.S. and Romanian approach to technology transfer is similar in that both rely on a group of dedicated practitioners with interest in research, and both employ traditional academic or research seminars, symposia, conferences, and publications. The U.S. team reported on a concentrated effort to influence the schools of architecture with special courses for university faculty, commissions for the development of curricular materials, competitions between schools which seek innovation or skillful application, etc. There was also a period of several years when the American Institute of Architects led an effort at continuing education for architects which built on the direct experience of their research on building standards. There are relatively few current efforts by the U.S. government to enhance technology transfer in the field. U.S. utility companies are, however, taking more and more interest in reducing energy consumption by buildings and are thus taking new initiatives in technology applications.

The translation of research into standards, however, was not well addressed in the discussion. In general the approach cited in the first session avoids the issue by placing the burden for a regular schedule of improved performance on the building industry (design professionals as well as manufacturers of building products). As such, they must meet with the research community on a regular basis to modify their approach to service delivery and to the manufacture of building products.

What is the advisability of multi-family high-rise, high density low-rise, or individual unit construction?

Discussion on this issue was reduced to a question of surface to volume ratios and focused on the dominant strategy. As a general rule it was proposed that the reduction of amount of surface area in relation to the volume was a good conservation strategy. There is simply less exposure to the climate and therefore less need to moderate it. Regarding passive strategies however, the utilization of beneficial sun may dictate a different approach. The simplified approach that suggests that "large buildings are better" does not always permit the surface area exposure necessary for effective collection of and distribution of solar radiation. Other factors were also presented which mitigate against high-rise, high-density housing. Low levels of privacy and control, for example, have been significant sources of the failure rate in high-rise housing. Fire and seismic safety also suggest solutions other than high-rise. Most in attendance tended to believe that a high-density low-rise solution to multi-family housing was more worthy of serious consideration.

The single-family house solution was discussed as part of the ideal U.S. solution based on that culture, but it was otherwise seen as not ideal from an energy perspective when compared with more dense solutions.

What is the status of the "so called" energy crises?

Discussion on this topic from the U.S. team was addressed from two perspectives: one based on the viewpoint of the research community and the other based on current governmental and commercial interests. The Romanian team addressed the topic from a technical perspective, reminding us all that in terms of physics there is no energy crisis.

Considering the term energy crisis as a social as well as a physical phenomenon, however, a U.S. team representative suggested that the research and academic community believes the problem has not even begun yet -- worldwide population demographics and increasing expectations regarding high (energy-intensive) standards of living all suggest a much more severe crisis is yet to come. In terms of short-run economics, policy, and professional practice, however, the crisis in the U.S. is perceived to be virtually over.

How does one establish a multi-disciplinary approach?

Time allowed for only modest discussion on this topic. It was affirmed, however, that the synergy that results from multi-disciplinary work was essential for improved whole building performance.

III. SESSIONS III & IV: SOLAR ENERGY IN BUILDINGS. DAYLIGHTING. ENERGY STORAGE.

1. PAPERS

1. B. Givoni :
   Passive Solar Heating Systems.
2. C. C. Benton :
   Daylighting Applications in the United States.
3. L. Dumitrescu :
   Use of Solar Energy in Romania.
4. D. Constantinescu, and F. Iordache :
   Analysis of Thermal Performance of Active Solar Systems Used For Domestic Hot Water Production.
5. M. Dumitrescu, R. Filip, and D. Vartanian :
   Solar Energy Use for Domestic Water Heating for Dwellings.
6. M. Kuharts, P. Ciubotaru, and E. Patrat :
   Collecting Installations and Stations for Hot Water Production With the Help of Solar Energy in Industrial Units.
7. F. Iordache :
   Coupled Systems of Heat Pumps and Solar Installations Used in Space Heating and Hot Water Preparation.
8. A. Petrescu, D. Berbecaru, and V. Cucu :
   Aspects Regarding the Economic Energy Optimization in the Use of New Energy Sources in Buildings.
9. D. Constantinescu :
   Solar Energy Distribution System for Low Temperature Heat Consumers.
10. D. Constantinescu, and R. Mitrofan :
    Experimental Results on the Passive Heating Performance of the CS 3 Bucharest Solar House.

11. Gh. Savopol :
    Systems for Solar Energy Use for Space Heating in Dwellings.

12. I. Bogdan, and N. Petrasincu :
    The Use of Solar Energy for Space Heating in Passive Systems for Industrial Buildings.

13. I. Bogdan, G. Ivanescu, and D. Atanasescu :
    Industrial Building Reconstruction Using New Energy Sources for Heating and Ventilation.

14. F. Iordache :
    Thermal Characteristic Method - Method of Dimensioning Solar Installations Used in Hot Water Preparation.

15. D. Constantinescu, A. Paponi, and F. Iordache :
    Thermal Processes Specific to Units of Short-Term Heat Storage in Phase-Change Substances (PCHSU).

16. D. Constantinescu :
    Analysis of Heat Storage in Earthen Type Sensible Media - Plane Wave Heat Transfer Modelling.

17. F. Iordache, and C. Bergthaller :
    Modelling of Heat Transfer and Storage in Ground Seasonal Heat Storage Units.

18. D. Constantinescu :
    A Technical Solution for Heating Animal Husbandry Halls Using a Seasonal System of Storing the Heat Supplied by Solar Radiation Collectors.

19. C. Mihaila, and A. Ghiaus :
    Heat Storage in Large Capacity Tanks.

20. R. Grigore, D. Berbecaru, A. Costea, C. Hurduc, and V. Boca :
    Experimental Pilot Station for the Seasonal Solar Energy Heating System.

2. CONTRIBUTIONS TO THE SESSIONS

The paper (III.1) by B. Givoni describes the present stage of development in the field of passive solar heating for buildings. He pleads for an intensive but rational use of the passive heating system by using solar energy. The author presents a number of recent results obtained in the field. Conclusions are drawn concerning the necessity of continuing research on the quantitative contribution of heat storage capacity in direct gain systems, the interaction between the wall thickness and the overall thermal capacity of the heated space, the partitions between solar and non-solar spaces, and the solar overheating of certain spaces. Future research should also include work on simple mathematical instruments for designing passive solar heating systems.

The paper (III.2) by C. Benton demonstrates that unlike the passive solar techniques, the applications of natural lighting are efficient in commercial buildings with high energy use. Analytical techniques, including computer simulation and three dimensional modelling, are described and encouraging conclusions are drawn on the use of natural lighting for reducing peak electric consumption.

The paper (III.3) by L. Dumitrescu, is a survey of the research, design and performance of solar installations for domestic hot water in Romania; activities carried out since 1970. The paper also presents a few results obtained in controlling the service of these installations, as well as the future development of new energy sources.

The paper (III.4) by D. Constantinescu and F. Iordache, from INCERC, deals with certain detailed aspects of the service of domestic hot water installations. The problem of the heat transfer specific to flat-plate collectors with laminar flow conditions is presented, and the results of a new characteristic equation different from the classic one. The thermal efficiency of the installation is correlated with the heat carrier flow rates circulated through heat exchangers and with the heat exchanger thermal efficiency. The conclusion is that solar installation efficiency may reach maximum values for heat carrier flow rate values higher than 30 l/m^2-h and heat exchanger thermal efficiency values of about 80%. The results of this paper are used in updating the existing Romanian standards for designing solar hot water installations.

The papers (III.5) by M. Dumitrescu et.al. and (III.6) by M. Kuharts et.al., underline the fact that, under Romanian climatic conditions, solar energy for domestic hot water production can be used for both centralized systems and isolated buildings. Such installations offer important fuel savings (about 280 kgcc/year-apartment) and short payback periods of 8 to 10 years, depending of the building particulars (dimensions, number of inhabitants, type of solar collectors, etc.). Solar installations can also be used for industrial enterprises. These have hot water capacities between 8,000 and 115,000 l/day, at a temperature of about 45°C.

The paper (III.7) by F. Iordache presents a detailed analysis of the thermal response specific to solar installations coupled with compression heat pumps. The mathematical modelling of the thermal processes specific to hot water heating and/or production leads to conclusions allowing the development of a single method of design. The paper also includes an economic analysis for the possibilities of using this type of installation in Romania.

The paper (III.8) by A. Petrescu et.al. presents a methodology of calculating the additional capital cost recovery generated by the use of solar energy and heat pumps. The three numerical examples enrich the theoretical part. The problems of solar energy have been of great interest for over ten years, and presently many such solutions are being adopted.

The paper (III.9) by D. Constantinescu suggests a new original solution of a combined heating system for housing. The heat carrier is the hot air produced by solar collectors. Low temperature (22°C) is circulated through the inside and outside walls, heating the dwelling space and ensuring a satisfactory efficiency of the solar radiation collection. The same solar collectors produce hot water in the summer. The system is designed to be energy independent by supplying heat and hot water to other consumers. The theoretical system was developed in 1978 and applied to the CS 3 Bucharest solar house, which was tested at INCERC in the winter season of 1983-1984.

The paper (III.10) by D. Constantinescu and R. Mitrofan presents theoretical and experimental aspects of the passive heating system installed in the CS 3 Bucharest solar house. The study includes descriptions of the mathematical modelling and the processing of the data collected during 1984-1985.

The papers (III.11) by Gh. Savopol, and (III.12 and III.13) by two teams coordinated by I. Bogdan, are based on designs originating from the Design Institute for Typified Buildings (IPCT) and present technical and economic results of passive solar systems. These are characterized by a fuel saving of about 300 kgcc/year-apartment, representing some 25% of the heating fuel requirement.

The paper (III.14) by F. Iordache describes a graphic method of designing solar hot water installations. This is based on the existing Romanian standard method of calculation, developed by INCERC. Starting from the diagram of the solar collector thermal characteristics, the author determines in a similar manner the characteristics of the whole installation, taking into account the existence of the heat insulation and the heat exchanger.

The paper (III.15) by D. Constantinescu et.al. presents some theoretical aspects of the thermal processes specific to heat storage in phase-change substances. The Stephan problem is analyzed under various boundary conditions, using a variant of the perturbed parameter method and changes of variables specific to spherical and cylindrical geometries. Experimental results are also included, using both Glauber salt and maleic anhydride.

Finally, there is a brief presentation of results obtained at INCERC, in Bucharest, with a passive heating system using maleic anhydride as storage medium.

The papers (III.16) by D. Constantinescu, and (III.17) by F. Iordache and C. Bergthaller deal with mathematical modelling of long-term storage of heat in soil, supplied by secondary sources and solar radiation thermal conversion. The first paper includes the analysis of plane wave propagation and introduces an original analytical solution different from previous work. Quantitative estimates of storage geometry are included using specific heat density as the analysis parameter. The second paper presents the numerical analysis of the problem for the case of cylindrical geometry. An original method of determining eigenvalues is used; the authors present the possible results based on various random heat sources. In the next few years, it is planned to use the results of these theoretical papers in testing the possibilities of heat storage in soil.

The paper (III.18) by D. Constantinescu discusses another possibility of long-time storage of solar energy. It presents the theoretical aspects of heat storage in a 7,000 m^3 water tank; the energy to be used in heating an animal husbandry hall. The analysis includes considerations of the thermal diffusion process in the loading period, and the dynamic thermal response of the hall. The collectors are cheap; they are of passive type with a water heating membrane effect. In the transition season (spring) they are used as greenhouses. The system offers maximum energy and considerable economic advantage. The experimental installation will be soon put into service at Calarasi.

The papers (III.19) by C. Mihaila and A. Ghiaus, and (III.20) by R. Grigore et.al. show that the storage of solar or waste energy heat in high-capacity seasonal tanks is a plausible and favorable alternative. The first paper presents the theoretical research results of thermal conditions in seasonal water storage tanks, heated by solar or waste energy. The problems considered include the following: the physical model of thermal processes in the storage tank, the mathematical model of temperature distributions within the height of the tank at thermal loading and unloading, the determination of the efficient period of storage, and others. The second paper refers to an experimental storage pilot station, and presents details explaining the aims of the experimental program in progress.

3. DISCUSSION

Professor Baruch Givoni opened the third energy session of the seminar with a presentation on passive solar heating. The initial focus of his talk was on the differences between active and passive systems. The U.S. experience has shown that while similar thermal performance can be obtained from both active and passive systems, active systems cost up to three times as much to manufacture, install, and maintain. Professor Givoni has concluded that passive heating is the more practical of the two approaches.

Several issues were presented as a key to the development of passive heating in Romania as well as in the U.S. :

1. It is essential to find the best match between the architectural, structural, and energy systems in a building.

2. Predictive modeling methods are needed, not so much for the prediction of actual consumption as for improving our understanding of thermodynamics.

Professor Givoni stressed that passive systems design is more of an architectural problem than a heat transfer problem. He illustrated the point with slides of direct gain Trombe wall and water systems. He concluded his presentation with an example of a high-rise sun space design he has been developing for Israel.

Professor Chris Benton presented daylighting as a significant topic in the U.S., especially with respect to commercial buildings. He illustrated a variety of daylight strategies, described domestic research, provided a variety of example applications, and discussed the importance of daylighting as a technique to reduce peak electric power consumption. He also illustrated both mathematical and scale model approaches to the assessment of daylight proposals.

The daylighting presentation was followed by Dr. Liviu Dumitrescu and Eng. Dan Constantinescu on domestic hot water work and passive heating respectively. Dr. Dumitrescu presented the work that has been done since 1970 on active solar hot water collection. He illustrated an impressive array of agricultural, domestic, and industrial applications with a low of 2.4 years and a high of 11 years return on investment. The systems were presented as having a 20-year life cycle.

Eng. Dan Constantinescu reviewed the work on passive solar in Romania. He addressed the history on closing balconies in mid-rise apartments, on loggia systems, and on the innovations to the Trombe wall being tested at INCERC. He reviewed the climate data in Romania and addressed the relationship between specific climate circumstances and the current experimental program. Eng. Constantinescu stressed two important aspects of current work. One has to do with increasing the effectiveness of connective transfer in the modified Trombe developed at INCERC and the second has to do with reducing infiltration into the air space. Current experiments regarding both issues were discussed and are presented in the technical papers.

In parallel with the concluding session of the second day, Prof. Benton met with Prof. Cornel Bianchi and Dr. Gabriel Chitita to discuss lighting in more detail. The conversation centered on high-efficiency light sources, the integration of electric and daylight systems, visual performance evaluation and computer based simulation.

Professor Nicolae Leonachescu added to the discussion his interests in heat exchange and storage within the earth. As part of his presentation he discussed the difference between crisis (a human system) and critical (closed system) thinking regarding the energy situation in Romania. He suggested we must focus our research efforts on the relatively closed system related to current critical shortages. The U.S. team indicated that even in the relatively closed system, some elements of the human system must be addressed if we are to achieve success.

IV. TECHNICAL VISITS IN BUCHAREST

1. PASSIVE AND ACTIVE/PASSIVE HOUSING UNITS AT INCERC

One duplex, containing two uninhabited housing units, was constructed for test purposes in 1983 at the Building Research Institute INCERC, in Bucharest. Both units reflect in size and overall layout the present housing standard in Romania.

(a) Passive Unit:

This two-story unit has a Trombe wall of about 50 m^2 facing south. The crossection of the Trombe wall (from inside to outside) consists of a structural wall of 30 cm thickness made from cast-in-place gasbeton, an air space of 12 cm, and double glazing with wooden frames. The operable windows of the southern wall (non-Trombe) are triple glazed. The air intake for the Trombe wall is from the side of the lower part of the wall. This intake from the side represents a modification of the classic Trombe system which reputedly leads to increased turbulent flow and better heat exchange. The problems of this installation are air leakage through the framing material, and dust and insect build-up in hard-to-clean areas between glazing and wall. The results of the first year of operation demonstrate the possibility of increasing the indoor air temperature over outside air temperature between 12 to 16°C without auxiliary heat or heat gain from occupants. Once the inordinate amount of air leakage is eliminated, the solar contribution is estimated at 40-50%.

(b) Active/Passive Unit:

The active part consists of 24 m^2 of dual function collectors and 8 m^2 of DHW collectors mounted on the roof. The first solar collectors serve a double function. During the summer they produce enough hot water for DHW needs for the unit and two households beyond the solar unit. In winter the collectors produce hot air for space heating. In the basement a rock storage unit is installed for heat storage. In addition to the 24 m^2 dual function collectors on the roof, another 8 m^2 hot water collectors are installed. Frost protection is achieved for winter operation through glycol. The passive part consists of a direct gain system on the south, with triple glazed windows. The results have shown a solar contribution estimated at 75%.

2. BANEASA HOUSING PROJECT

The Baneasa housing project of 1983 has 2,300 apartments which receive domestic hot water by means of 5,000 m^2 of collectors. Because of the lack of glycol, the hot water collectors function only 6 months out of the year. The storage capacity consists of 180 m^3 water-filled tanks. A central plant houses pumps, heat exchangers, and oil-fired boilers for winter operation. During the winter heating season the piping system is used to supply heat to the apartments from the central plant by using the pipes from the collectors to the plant "in reverse". There appear only minor operational problems with this installation. Per year the system necessitates repairs of about 1 to 5%. Life expectancy of the installation and its parts is expected to be 20 years, which appears very high compared to generally accepted estimates elsewhere. In terms of results, starting with 100% energy reaching the collectors from the sun, the system is capable of delivering 31% of this energy in the form of hot water at the shower head. Collectors are able to transmit 45% of the energy which strikes their surface, the pump and heat exchanger lose 4%, and pipes and tanks another 10% of the total available energy.

V. TECHNICAL VISITS OUTSIDE BUCHAREST

1. ACTIVE AND PASSIVE SOLAR HOUSING DEMONSTRATION AT CIMPINA

The town of Cîmpina is about 25 km north-northeast of Ploiesti, which in turn is about 55 km north of Bucharest. The Cîmpina demonstration project contains two houses.

(a) Passive Solar House:

This one-story house was built in 1976 and is entirely passive, a "classical Trombe-Michel" system. it was built to introduce passive solar energy to Romania. It functioned for about four to five years. Its major features are: 40 m^2 of south facing Trombe wall made of 7 mm single glazing, 15 cm air space and a mass wall of 20 cm thick concrete. To protect against overheating in the summer, blinds have been installed in the air space and openings have been introduced at the bottom of the glazing. The solar contribution is estimated at 20 to 30%.

(b) Active Solar House

This two-story house was built in 1977. Almost all of its southern exposure is fitted with about 90 m^2 of active collectors, the first to be built in Romania. The collectors are made of steel plate with aluminum pipes mounted on top. The double glazing consists of tempered glass. The backs of the collectors are insulated with 20 cm of rockwool. The storage tanks in the basement hold 10 m^3 of water. The solar contribution is between 30 and 40%. These early collectors exhibit a number of problems including water leakage, breakage of glazing due to thermal expansion and contraction, selective peeling of paint coating, and air infiltration between the wall and solar collectors.

2. JASSY BRANCH OF ICCPDC: HYGRO-THERMAL LABORATORY

The primary purpose of the Hygro-Thermal Laboratory at the Jassy branch of ICCPDC is to determine the thermophysical and hygrophysical properties of full-scale components and joints.

The heart of the facility consists of two environmental chambers (approximately 4 m wide, 3.5 m deep, and 3.5 m high; allowing the testing of 3.4 x 3.9 m panels) and a room with data recording and analytical equipment. The environmental chambers allow the simulation of interior and exterior climatic conditions. Exterior air movement can range from 5 to 20 m/sec. Interior temperatures can range from 10 to 25°C, whereas exterior temperatures can be varied from -30 to +30°C. Typically, thermocouples are installed on a 25 x 25 cm grid. Finer spatial distribution of temperature measurements can be achieved with strips of Thermolux. The determination of thermophysical properties of building materials includes measurements of specific heat, thermal diffusion, thermal conductivity, and air and vapor permeabilities. Tests of hygrothermal properties of full scale components include thermal resistance, resistance to air infiltration/exfiltration, vapor migration, condensation, and thermal bridging.

During the first twelve years of its existence, the hygrothermal laboratory has conducted tests of 181 components. Depending on size, complexity, and duration of tests, 10 to 50 tests per year are possible. During our visit, a prefabricated concrete facade panel with one operable wood frame window was being prepared for testing.

C. FINAL SESSIONS

IDEAS FOR FUTURE RESEARCH AND COOPERATION

The final day of the seminar focused on all the previous discussions, presentations, and visits, and was directed at identifying areas of needed research and establishing a general framework for future collaboration. The participants first met separately, in earthquake and energy groups, and concluded with a general meeting where all the ideas were presented and discussed, including consideration of research topics reflecting a combined earthquake and energy concern.

This section summarizes the main ideas and conclusions reached during these final sessions.

I. EARTHQUAKES

(1) **Developing analytical procedures to represent nonlinear force-deflection relations for building structures and structural components.**

Suggested activities should include summaries of past research, new experimental programs, development of numerical models and experiments using these numerical models for a general class of building systems. The scope of the work should include:

a. Influence of nonstructural elements.
b. Detailing schemes.
c. Progressive damage.
d. Repair and strengthening designs.
e. Soil-structure interaction.

(2) **Analysis of vulnerability and risk for individual structures and urban systems with emphasis on the existing building stock.**

Activities should include a summary of existing information, development of analytical models, basic methodologies, and pilot studies pertaining to the following topics:

a. Appropriate quantifications for severity of ground motion with respect to damage and losses, and the individual and societal impacts.
b. Vulnerability analyses related to permanently and constantly exposed elements at risk (buildings and other structures).
c. Vulnerability analyses related to elements at risk with variable exposure (humans, activities, etc.).

d. Development of procedures for cost-benefit analyses and decision making.
e. Rehabilitation and upgrading of existing structures.
f. Regulatory basis to cover existing gaps.

(3) **Developing earthquake preparedness procedures for urban environments and critical facilities.**

Such procedures should include:

a. Establishment of prediction and warning systems and networks of strong-motion instrumentation.
b. Examination of reaction of humans under earthquake conditions.
c. Education of the community with regard to earthquake preparedness.
d. Impacts of eventual prediction on issues of preparedness.

(4) **Additional topics.**

Other topics that were proposed by individuals included:

a. Development of the concept of seismic intensity on the basis of instrumental data and structural damage.
b. Development of basic knowledge and the relationships concerning seismic ground motions and the vulnerability of various types of structures.
c. Development of probability based criteria for design of structures to resist earthquakes. Criteria for checking members with stochastic combination of stresses, and for structures with time-dependent masses such as storage silos.
d. Torsional problems in buildings with large aspect ratios in plan.
e. Soil coupling effect for adjacent buildings.
f. Soil-structure interaction for buried pipes.
g. Effects of subsequent earthquakes on partially damaged structures.

The meeting was concluded with a unanimous agreement to strengthen the exchange of information between investigators in both countries.

II. ENERGY

The two areas of substantial overlap of interest were identified as:

(A) **Passive heating systems** (especially for residential applications), and

(B) **Urban planning and design.**

A matrix was developed relating these two broad topics to four more specific areas of concern:

(1) New sources and approaches to energy conservation or generation.

(2) Energy storage mechanisms and modalities.

(3) Energy savings impact of solar systems (estimation methodologies and their validation).

(4) The evaluation of total building performance.

It was observed that U.S. interest was strong on the topic of existing buildings, while Romanian interest was strong on new buildings. Discussion on such differences led to the affirmation that a close relationship existed between both interests. The study of existing buildings clearly informs new approaches and avoids making the same errors over and over again. The investigations focussing on new facilities leaves ample room to identify missed opportunities in the existing stock of buildings and may well suggest retrofit strategies.

Major areas of shared interest are listed below with examples of specific research topics offered by Romanian (R) or United States (US) team members. The asterisk (*) by a topic indicates the item is believed to be especially significant by one or both of the teams.

(A) PASSIVE HEATING SYSTEMS

(1) New Sources and Approaches

a. Improved heating solutions for passive solar housing (R).

b. Improved geometric solutions for dwellings (R).

c. Studies on improved heat insulating systems on existing buildings (R).

d. Studies on hydro-thermic behavior of enclosure components under steady-state and non-steady-state conditions (R).

*e. Heat transfer through soils (R).

*f. Air permeability of building materials and components (R).

g. Passive solar control systems (US).

h. The modification/expansion of existing housing units to improve energy performance (US).

*i. Passive solar heating for non-residential buildings (US).

2. **Energy Storage Mechanisms and Modalities**
   - a. Energy recovery at several scales (US).
   - *b. Heat transfer through soils (R).

3. **Energy Savings Impact of Solar Systems**
   - a. Engineering calculation methods applied to dwellings (R).
   - b. Improved heat transfer simulation processes for new and existing buildings (R).
   - *c. Methods of assessing passive system performance in terms of comfort and energy (US):
     (i) Simulation.
     (ii) Field validation.
   - *d. Analysis of the applicability of assessment methodologies as applied to different building types (US).

4. **Total Building Evaluation**
   - *a. Methodologies of measuring occupant influence on energy strategy development and selection (US).
   - *b. Refinement of procedures for the physical measurement of existing buildings and the development of analytical techniques (US).
   - *c. Whole building performance measures (US).
   - d. Understanding the influence of building planning, design, construction, and use on energy consumption: an historic study (US).
   - e. Good field evaluation methods (US).

(B) **URBAN PLANNING AND DESIGN**

Most of the ideas in this area referred to combined concerns of earthquakes and energy, and are presented in the next section. No specific examples were mentioned relating this urban area and the four specific topics discussed above. However, they are of general interest to both countries and may be further developed at a later date.

Conclusion

The matrix and specific examples were selected from a list generated by all participants which described their beliefs about the most important topics for collaboration. It was acknowledged that several other areas of concern may well be part of the future United States - Romania collaboration. The spirit of the framework and specific topics above was to establish a starting point for further work. All participants were impressed with the breadth of mutual interest and the value of future collaboration.

III. COMBINED CONCERNS OF EARTHQUAKES AND ENERGY

(1) Research in **urban planning and design** for combined low energy consumption and seismic risk reduction.

(2) Study and development of urban-scale **performance design criteria**, combining seismic and energy objectives, for **residential buildings**.

(3) Studies on **the optimization of building geometry** to reduce both energy consumption and seismic risk.

(4) Studies, development, and testing of **prototypes**, considering seismic and energy objectives, for **low-rise high density housing**.

(5) Research similar to the above, except for **non-residential** buildings such as schools, offices, and industrial and health facilities.

(6) The development of special **prefabricated passive solar systems**, which have a high degree of seismic safety as well as energy performance.

(7) Exploration of innovative **super lightweight enclosures** (spatial envelopes and lightweight roofs), with good seismic and energy characteristics.

(8) **Daylighting** and seismic strengthening of industrial halls.