A REPORT ON VULNERABILITY ANALYSES CARRIED OUT IN THE BALKAN REGION

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SUMMARY

The framework of a UNDP/UNESCO Balkan project is first presented, describing the role played in 1981-1982 by the WG.B on Vulnerability analysis in the ensemble of objectives and activities. The conceptual framework of WG.B activities, based on the philosophy developed under the auspices of UNDRO in order to deal with natural hazards and vulnerability and adapted in order to deal with the case of seismic vulnerability is then summarized. Methodological aspects related to the vulnerability analysis are discussed. Case studies and results obtained in the countries involved in WG.B work are then briefly presented. A critical appraisal of the state-of-the-art is then given. The closing remarks are related mainly to needs of future developments .

INTRODUCTION

Following the earthquake of 15 April 1979 of the Southern Adriatic Coast, a new UNDP/UNESCO project, "Earthquake Risk Reduction in the Balkan Region" (RER/79/014), was initiated. This project, in which Albania, Bulgaria, Greece, Romania, Turkey and Yugoslavia were engaged, set further the activities of a previous project, "Study of the Seismicity of the Balkan Region" (1970-1976). The immediate objectives of the new project were related (Ref.1) to evaluation of seismic hazards and prediction of ground motion characteristics, evaluation of vulnerability based on experiences of recent earthquakes, development of methods for applying risk reduction criteria, development of the basis for earthquake resistant design, disaster preparedness and improvement of equipment.

Five Working Groups were organized in order to cover the objectives referred to (Ref.2) :WG.A on Seismic Hazard and Earthquake Prediction Studies; WG.B on Vulnerability ; WG.C on Seismic Risk Studies and Model Code Development ; WG.D on Dynamic Behaviour of Soils ; WG.E on Dynamic Behaviour of Structures and Structural Components. The Convenors of the WG's were elected respectively from Greece, Romania, Bulgaria, Turkey and Yugoslavia. The Chief Technical Adviser of the Project was E. M. Fournier d'Albe .

The members appointed in WG.B were :from Bulgaria, I. Paskaleva and L. Tzenov ; from Greece, H. Mouzakis and C. Syrmakezis; from Romania, H. Sandi (Convenor) and D. Vasilescu; from Turkey, N. Akkas ; from Yugoslavia, V. Mihailov and B. Pavicevic . Albania did not appoint WG members, but sent a contribution too. The work carried out in Romania benefitted also from the contribution of D. Cazacu and C. Constantinescu. The Yugoslav contribution was based on the work in a national project coordinated by J. Petrovski.

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The work of WG.B was initiated, according to the guidelines of (Ref.2), by a meeting in Herceg Novi (May 1981) and closed by a second meeting in Skopje (November 1982). During the second meeting, the WG.B members assigned the Convenor the task of proposing this report for presentation at the 8-th WCEE. The work is being continued in 1983 in the frame of a Task Group on the same subject and with essentially the same membership. The data and results of this report rely basically on the work carried out in 1981 and 1982.

CONCEPTUAL FRAMEWORK

In accordance with the decisions of the Coordinating Committee of the Project (Ref.2), the conceptual framework of WG.B was in agreement with that adopted by UNDRO in (Ref.3). The five main concepts considered are : Natural Hazard, Vulnerability, Specific Risk, Elements at Risk and Risk. According to (Ref.3) "VULNERABILITY means the degree of loss to a given element at risk (...) or set of such elements resulting from the occurrence of a natural phenomenon of a given magnitude and is expressed on a scale from 0 (no loss) to 1 (total loss)".

The need was felt to adapt the UNDRO general concepts to the case of seismic risk and the following more detailed definition was adopted (Ref.4) : "VULNERABILITY OF A TYPE OF BUILDING OR STRUCTURE means the degree of loss resulting from the occurrence of ground motions with specified characteristics defined under the following conditions :

1. Ground motions are defined in terms of macroseismic intensity initially, with possible reference to a range of oscillation frequencies and to direction, using the information offered by macroseismic surveys and, whenever possible, by instrumental records.
2. The degree of damage will be estimated by means of a method consistent with the MSK methodology, with a calibration from 0 (no damage) to 1 (collapse).
3. The degree of damage will be considered as a random variable and basically represented by means of histograms or of probability densities, as related to some nominal values of ground motion parameters.
4. The vulnerability functions, relating statistically parameters of ground motion and degree of damage, may be approximately represented in a discrete form by matrices (e.g. different columns corresponding to different intensities and representing damage degree histograms)".

It was also necessary to distinguish between observed (VO) and predicted (VP) vulnerability : "OBSERVED VULNERABILITY means vulnerability as derived from post-earthquake surveys and statistical analysis, for some definite types of buildings or structures. PREDICTED VULNERABILITY means vulnerability as derived from engineering analyses, the results of which are to be expressed in probabilistic terms".

A further discussion of conceptual and methodological aspects of vulnerability analysis was presented in (Ref. 5). Since the vulnerability analysis was related at that stage to individual structures only, it was convenient to express vulnerability in terms of distributions (or histograms) conditional upon the intensity of ground motion at the (unique) site. In the more general cases of lifelines, urban systems etc., it becomes necessary to consider distributions conditional upon the magnitude of an earthquake (Ref. 6,7,8). The concepts used in the Yugoslav national contributions were to some extent different and the methodological features related to these aspects are presented in a contribution by J. Petrovski at the 8-th WCEE. The vulnerability characteristics defined in the previous terms are in agreement with the concept of damage probability matrix, used for example in (Ref. 9,10). Some further methodological elements related to the post-earthquake analyses carried out in Romania and Yugoslavia after the earthquakes of 1977 and 1979 are given in (Ref. 11,12) respectively.

METHODOLOGICAL ASPECTS

The following symbols are used throughout the text : CB: class or category of buildings ; DD: damage degree ; I: ground motion intensity (which can be expressed e.g. in terms of a kinematic parameter or of macroseismic intensity) ; V: vulnerability ; VO: observed vulnerability; VP: predicted vulnerability .

The activity of WG.B was oriented towards the analysis of VO for various CB's. The VO - characteristics (or "functions") were intended to express basically the statistical distribution of DD, conditional upon I. Given the fundamental interest of using VP - characteristics in risk analyses required by earthquake engineering activities, the problem of using VO - characteristics determined for various CB's in order to derive homologous VP - characteristics was raised as a main task of ulterior developments .

The derivation of VO - characteristics requires basically :

a) definition of CB's for which VO - analyse were to be performed (a CB should satisfy two conflicting basic requirements : sufficient homogenity with respect to a system of significant criteria ; providing of sufficiently large samples) ;

b) appropriate damage characterisation and DD quantification for a CB considered ;

c) adoption of a system(or methodology) of characterising I ;

d) collection of data on DD - distribution in each CB studied during post-earthquake surveys ;

e) selection of sub-samples of various CB's, believed to have been subjected to homogeneous I ;

f) derivation of the statistical DD - distributions, conditional upon I, for each CB considered .

The derivation of VO - characteristics may rely in practice on a single data category :the observed DD provided by post-earthquake surveys. The use of one single source in order to derive the two kinds of data required by VO - analysis, i.e. DD - distribution and I - assessment leads basically to a tautological approach. This bias can be exceeded in principle by gradual refinement and use of a bayesian approach. A more analytical discussion in this direction was made in (Ref.5) . Besides that, it must be kept in mind that past post-earthquake surveys were not designed in principle for VO - analyses. Given these facts, the case studies performed had to accept some compromises and to adapt to the nature of primary data provided by already existing post-earthquake survey. Differences in the approaches of different countries were thus unavoidable .

CASE STUDIES AND RESULTS

The contributions to WG.B activities were based on the analysis of post -

earthquake data obtained during the last two decades in the region. Besides that, a concern for the development of appropriate methodologies for vulnerability analysis was present in most of contributions, given the novel character of the task and the very limited literature related to this field. The summary presented in this section is based on a detailed presentation of (Ref.4), where national contributions and a summary report were prepared.

The Albanian contribution included general reports on two earthquakes (Dibra district, 1967, and off the Adriatic coast, 1979) that provided general seismological information and data on the nature and extent of damage. Emphasis was put on the factors influencing the damage distribution .

The Bulgarian contribution was related to two earthquakes (bend of the Carpathians, in Romania, 1977, and Velingrad region, 1977) . The proper vulnerability studies were based on data obtained in the town of Svishtov in relation to the first earthquake. Some general considerations and data of geological and seismological nature were provided, and a discussion on methodological aspects was presented. The damage classification form (based on the MSK methodology (Ref. 13,14)) was given too. The ground motion was expressed in terms of MSK intensities. The vulnerability characteristics were expressed in terms of the dependence of the "vulnerability coefficient U" (equivalent to the average degree of damage, recalibrated for the interval 0 to 1) on MSK intensity. The vulnerability characteristics are given in fig. 1. The differences between adobe buildings (1), half-timbered houses (2) and brick masonry houses (3) versus steel structures (6) and reinforced masonry buildings (7) are obvious .

The Greek contribution was related to the Corinth earthquakes of 1981 (effects in the village of Perahora) . Geological and local conditions, the condition of structures and their earthquake loading biography were presented. Ground motion was expressed in terms of MCS intensities, while DD was evaluated on the basis of the MSK methodology, with a calibration (0,1) . Four classes of buildings : (A) pre-1930 stone masonry ; (A1) post-1930 stone masonry ; (B) r.c. without earthquake resistant design ; (B1) r.c. with earthquake resistant design, were investigated. The results obtained are given in fig. 2 in terms of DD histograms for the village as a whole.

The Romanian contribution was related to the earthquake of 1977. General data on the building stock development, on the Romanian seismicity and on the post-earthquake studies and corresponding results were given. The vulnerability analysis was related to the effects in the cities of Bucharest and Jassy. A summary of lessons from the earthquake and some economic figures were given . An extensive discussion on the conceptual and methodological aspects, based on the developments of (Ref. 5,8) was presented. The ground motion was expressed in terms of MSK intensities, which were related, for Bucharest, to some ranges of oscillation periods, (Ref.11) . The DD evaluation was based on the MSK methodology (Ref. 13,14), with additional detailing for various types of structures (brick masonry, r.c. framed or bearing wall structures etc.), as in (Ref. 11) . Appropriate damage evaluation forms were given. The vulnerability characteristics are given in terms of intensity-dependent histograms, $\overline{DD}$'s and r.m.s. DD's in fig. 3. They are related for Bucharest to : (A1) low quality material buildings ; (A2) pre-1940 masonry buildings with flexible floors ; (A3) post-1940 buildings of same type ; (A4) pre-1940 masonry buildings with rigid floors ; (A5) post-1940 buildings of same type ; (A6) r.c. framed structure buildings ;(A7) high-rise buildings with r.c. bearing walls (small inter-wall intervals) ;(A8) same type with larger inter-wall intervals . For Jassy, they are related to : (B1) old buildings ;(B2) post-1950 masonry buildings with cast-in-place r.c. floors ; (B3) same, with precast floors ; (B4) five-storey large-panel buildings ; (B5) buildings with framed or composite r.c. structure; (B6) r.c. shear-wall buildings. The bulk of data was represented by the outcome of the large-scale engineering survey of earthquake effects, presented in (Ref. 11) . Some data were given on the costs of repair and strengthening. The activities were continued in 1983 with analyses of correlation of VO - characteristics with some engineering measures (e.g. log of critical acceleration) and with developments on the use of vulnerability characteristics in risk analysis and in subsequent cost-benefit analysis required by the decision on intervention on existing buildings (Ref. 8,15) .

The Turkish contribution was related to several earthquakes : Varto (1966), Adapazari (1967), Gediz (1970), Burdur (1971), Bingol (1971), Lice (1975) , Caldiran (1976) . A discussion on hazard and ground motion measures, as well as on vulnerability and value, was presented. The ground motion was expressed in terms of MSK intensities, while the DD was expressed in terms of L (light), M (medium) and H (heavy) damage. DD distribution histograms were given for some definite types of buildings, the averaging being done over the whole area affected by each of the earthquakes. Results related to the stronger earth - quakes are given in fig. 4 .

The Yugoslav contribution was related to the off-Adriatic coast earthquake of 1979. An integral program aimed at mitigating earthquake consequences was presented (immediate damage and usability classification, code for repair and strengthening , collection and analysis of SM records, site conditions studies, seismic zoning and microzoning studies and vulnerability studies) . The IZIIS instructions for damage and usability classification were given , together with a comprehensive summary of earthquake efffects. A review of action taken to reduce earthquake effects was given too. Ground motion was expressed in terms of PGA, thanks to the availibility of numerous records. Some preliminary data were given (regression lines of percentage of struc - tures damaged beyond a certain threshold, versus PGA) . Some differences in terminology used must be remarked. The IZIIS studies coordinated by J.Petrovski were considerably developed in 1983 in relation to a national project. Given the recent methodological developments and the very numerous results obtained, reference is made to a paper by J. Petrovski proposed for the 8-th WCEE .

Some summary remarks

The case studies presented are all based on the use of post-earthquake data obtained during the last two decades in the region. An effort was made to homogenize the methodologies used in V-analysis, yet some differences were unavoidable. Such differences may be beneficial at this early stage of work in the region. The results obtained put to evidence the significant differences of V-characteristics for different classes of buildings and this result is of obvious immediate interest. On the other hand, the V-characteristics are characterized by a high scatter of DD-distribution, in cases when DD-histograms were explicitely given . The results obtained to date must represent, on one hand, a source of information for immediate practical activities, but, on the other hand, also a basic source of ideas for future methodological improvements.

COMMENTS ON THE STATE-OF-THE-ART AND ON NEEDS OF FURTHER DEVELOPMENTS

The existing experience permits to confirm the feasibility of VO-analyses in case appropriate methodologies and data are used. The concern for reduction of seismic risk in both new and existing buildings and other works, that is increasingly important in the region, as put to evidence for example by the work under way in the frame of a different project (Ref. 16) makes obvious on the other hand the needs for preocupation for VP-characteristics and for their use in subsequent risk analyses and decision making and permits to emphasize the need for further methodological developments .

In relation to the methodologies related to VO-analysis it is necessary to consider methodological developments on the classification of buildings (qualitative description, quantitative characterization of earthquake resistance, in a way that is suitable for the analysis of large samples of buildings or other works), on the characterization of ground motion (development of more adequate SM measures and methods of assessment of ground motion intensity for actual events) and on the damage characterization (development of measures that are related to the degree of exhaustion of earthquake resistance due to repeated loading, correlation between several techniques of damage characterization) .

In relation to the use of VO-characteristics in order to derive VP-characteristics it may be stated that a fundamental problem is that of research on the relationship between the measures of structural resistance characteristics (strength, ductility, resistance to repeated loading etc.) and of characteristics of post-elastic behaviour on one hand and the damage measures that are observable during post-earthquake survey on the other hand. Any progress in reconciliating the calculable and the observable measures of this field would be of far-reaching positive consequences .

The use of VP-characteristics in specific risk analyses raises no special difficulties as far as reliable and accurate data are available, provided the complementary necessary data on seismic hazard are available too at a satisfactory level (Ref. 8,9,16) . In order to carry out more complete risk analyses, it is necessary, on the other hand, to dispose of appropriate information on the elements at risk which, in many cases, may represent the most difficult task of data gathering .

The increasing interest in providing the appropriate degree of safety to systems other than individual structures (e.g. lifelines, urban systems) makes obvious the need for extension of the framework of vulnerability and risk analysis to such more general systems. A qualitative analysis of these requirements makes evident the need for appropriate generalizations of basic concepts and methodologies, along some ideas expressed in (Ref. 6,7,8,9) .

FINAL REMARKS

The vulnerability analysis carried out in this frame has led, already at this stage, to useful results from the view point of methodologies developed and of qualitative and quantitative data on the VO-characteristics made available. It may be recommended to use the data provided in practical activities related to the earthquake protection, especially for existing buildings.

It is particularly important for future to improve the methodological preparedness. Post-earthquake surveys should be based on more appropriate observation and investigation methods, development of appropriate damage evaluation forms and education of potential field investigation teams being the most acute need.

ACKNOWLEDGEMENTS

The author emphasizes again the contributions of WG.B members, mentions the competent and constructive activity of the Chief Technical Adviser of Project, E.M. Fournier d'Albe, and expresses his thanks for the competent cooperation of D. Cazacu in deriving the VO-characteristics for Bucharest.

REFERENCES

1. UNDP/UNESCO Project RER/79/014 : Project Document, 1980
2. UNDP/UNESCO Project RER/79/014 : First Session of the Coordinating Committee, Titograd, 1980 . Final Report .
3. UNDRO : Natural Disasters and Vulnerability Analysis. Report of Expert Group Meeting, Geneva, 9 to 12 July 1979 .
4. UNDP/UNESCO Project RER/79/014 . WG.B " Vulnerability and Seismic Hazard " : Vulnerability Analysis in the Balkan Region. Final Report, 1982 (to be published in 1983 by UNESCO) .
5. H. Sandi : Seismic Vulnerability and Seismic Intensity, Proc. 7-th ECEE , Athens, 1982 .
6. N.N.Ambraseys, J.A.Jackson : Earthquake Hazard and Vulnerability in the Northeastern Mediterranean : the Corinth Earthquake Sequence of February-March 1981. Disasters, vol.5 , no.4, 1981 .
7. L. Esteva : Seismicity (Chapter 6 in " Seismic Risk and Engineering Decisions ", edited by C.Lomnitz and E. Rosenblueth). Elsevier, Amsterdam - Oxford - New York, 1976 .
8. H. Sandi : Risk Analysis for Structures and Lifelines . Lecture, 10-th Regional Seminar on Earthquake Engineering, Skopje,1983.
9. R. Whitman, C.A. Cornell : Design (Chapter 9 in " Seismic Risk and Engineering Decisions ", edited by C.Lomnitz and E.Rosenblueth), Elsevier, Amsterdam - Oxford - New York, 1976 .
10. NSF - NBS - ATC : Tentative Previsious for the Development of Seismic Regulations for Buildings. ATC Publication 3 - 06, 1978.
11. St.Balan, V.Cristescu, I.Cornea (editors) : The Romania Earthquake of 4 March 1977 (in Romanian), Ed.Academiei, Bucharest,1983.
12. J. Petrovski, T. Paskalov (editors) : The Montenegro, Yugoslavia, Earthquake of April 15, 1979, IZIIS 80-65, Skopje, 1981 .
13. S.V. Medvedev : Engineering Seismology (in Russian). Gosstroyizdat, Moscow, 1962 .
14. N.V. Shebalin : On the Estimate of Seismic Intensity (in " Seismic Scale and Methods of Measuring Seismic Intensity ", in Russian), Nauka, Moscow, 1975 .
15. H. Sandi : The Decision on the Intervention on Existing Structures : Alternatives and Cost-Benefit Analysis. Proc. ICASP-4, Florence, 1983 .
16. UNDP/UNIDO Project RER/79/015 . WG.D " Damage Evaluation and Assessment of Seismic Resistance of Existing Buildings " : Draft Manual, 1983 (to be published in 1984 by UNIDO) .

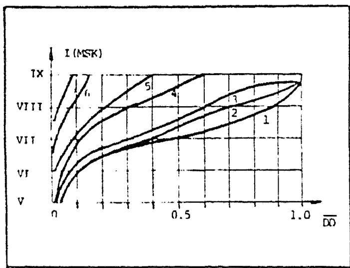

Fig. 1 (BULGARIA)

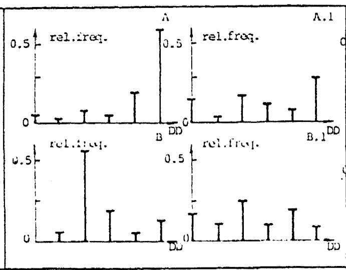

Fig. 2 (GREECE)

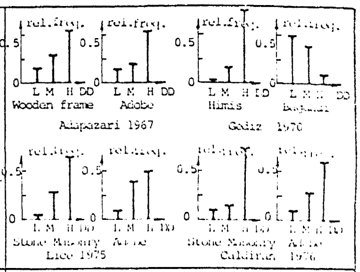

Fig. 4 (TURKEY)

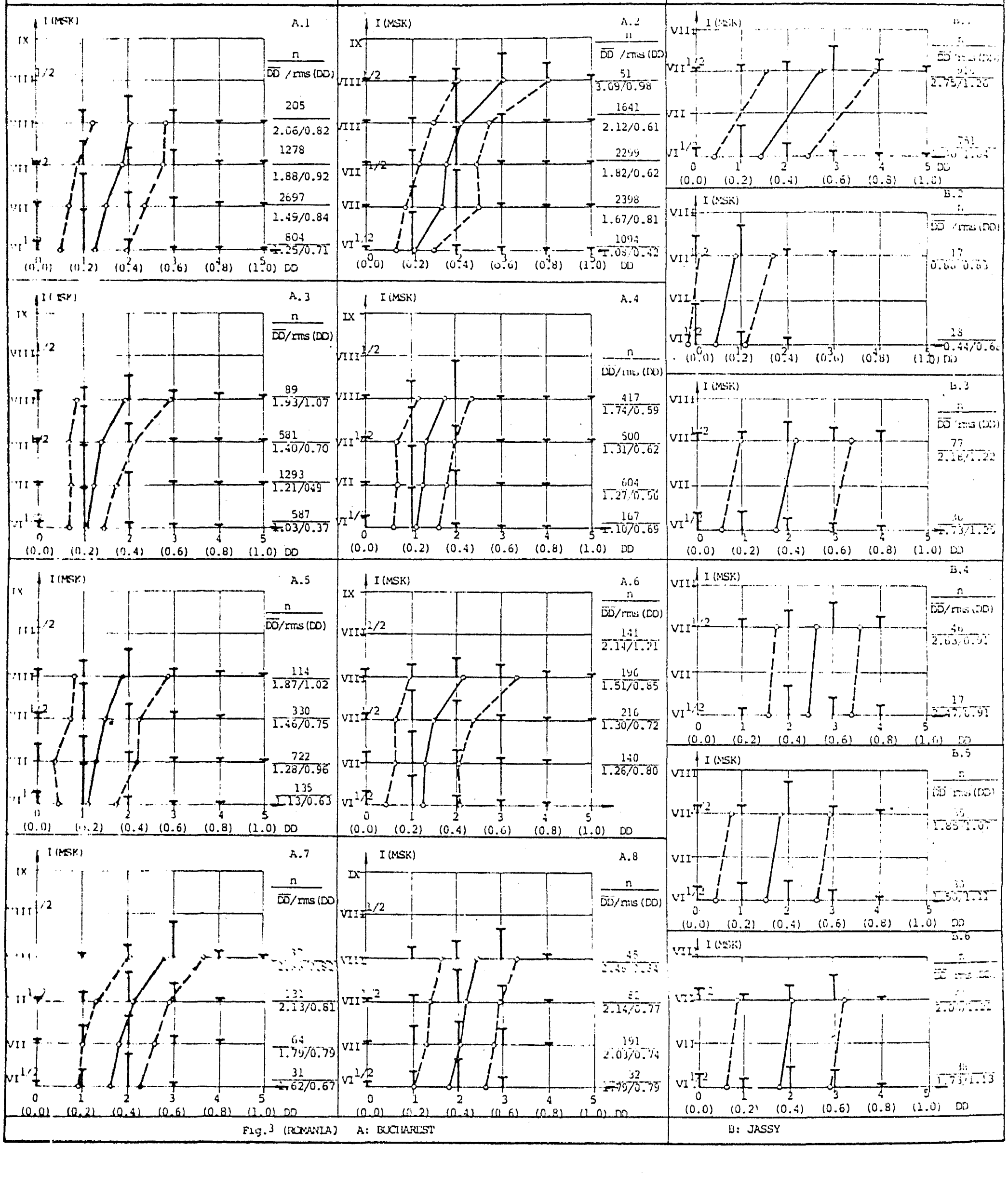

Fig.3 (ROMANIA) A: BUCHAREST B: JASSY