GENERAL INFORMATION

AWARD OF THE NEW ZEALAND NATIONAL SOCIETY FOR EARTHQUAKE ENGINEERING

The Society has instituted an Annual Award to recognize meritorious papers on aspects of earthquake engineering presented by members of the Society for publication in the Bulletin (or other publication).

Conditions of the Award

1. The award shall be made annually.
2. The award shall be made to the author(s) presenting the best paper during the three years ending 30 June preceding the date of the award in the Bulletin of the Society, or in some other publication at the discretion of the Management Committee.
3. To qualify for eligibility at least one of the persons presenting the paper shall be a financial member of the Society.
4. Nominations, for consideration as recipient of the award, with respect to papers published or presented overseas shall be sought through the Bulletin of the Society at the time of closure of each year of eligibility.
5. In the case of multiple presentation, such as at an Earthquake Engineering Conference followed by formal publication in the Bulletin of the Society or other official publication, the date of first presentation shall normally take precedence.
6. The criteria for selection of the award paper shall be merit and the degree to which the paper advances the objects of the Society, that is "to further the objects of the International Association for Earthquake Engineering as applicable to New Zealand and to foster the advancement of the science and practice of earthquake engineering".
7. The process of selection of the recipient of the award shall be administered by the Management Committee of the Society.
8. The award shall be a sum of money for the purchase of books to the value of $50 initially, to be reviewed every three years, plus a certificate. In the case of multiple authorship, the award shall be made individually to each author.
9. The award shall be known as "The Award of the New Zealand National Society for Earthquake Engineering".
10. The inaugural period of the award shall be that ending 30 June, 1977.

Call for Nominations of Papers

The call for nominations of papers published or presented overseas is to ensure as far as possible that all eligible papers are considered for the award in a particular year.

Nominations are hereby sought with respect to papers published or presented overseas within the three years preceding 30 June, 1977 and satisfying the conditions of the award. Nominations should be in the hands of the Administrative Secretary no later than 15 August, 1977.

ROMANIAN EARTHQUAKE, MARCH 1977

SUMMARY REPORT ON A STUDY OF EARTHQUAKE DAMAGE IN BUCHAREST, ROMANIA, 4TH MARCH 1977

R. I. Skinner

INTRODUCTION

After discussions between the Governments of Romania and New Zealand, the writer was invited to Romania for a co-operative study of the damage arising from the earthquake of March 4, 1977, and for discussions on steps in reconstruction and in the planning of programmes to give added assurance during future major earthquakes. Effective co-operation was made possible by the activities of the Government appointed Secretariate for the co-ordination of the activities of visiting National Delegations, and by the staffs of the Building Research Centre INCERC and the Centre for Earth Physics and Seismology. All visiting delegates were encouraged to stay at the same hotel to facilitate co-ordination and a free interchange of information.

The writer was in Romania from the 1st to the 19th of April. His time was spent in observation and study of the damage to old and new buildings, in discussion on methods of building repair and strengthening, and in discussion on future research and design techniques which might be adopted to reduce the consequences of future earthquakes. Two days were spent observing damage in Craiova, Pitesti and Balin, and the remainder of the time was spent in Bucharest.

GENERAL

The earthquake attack in Bucharest was unexpectedly severe, resulting in the complete or partial collapse of 32 old tall buildings and 3 modern buildings, with tragic fatalities and important economic consequences.

The severity of the attack appears to have resulted from the very high velocities of the ground motion, and from the unexpectedly long periods of the motion which selectively attacked the taller buildings, usually of 8 or more storeys. The understanding of the building actions is greatly increased by the record of ground acceleration obtained at INCERC, on the eastern edge of the city. While it has been common practice in many countries to design buildings against earthquake motions similar to those which have been recorded in the western part of the United States of America, this accelerogram demonstrates that earthquake motions in Bucharest may be quite different; their spectra corresponded more closely with the spectra of motions recorded on the flexible ground in Mexico City.

In many instances damage and collapse mechanisms were closely similar to those observed by the writer in Caracas, Venezuela 1967, and in Manila, the Philippines 1968 and 1970. In particular, the collapse of the columns in the modern 3-storey Electronic Computing Centre of the Ministry of Transport and Telecommunications had a parallel with the collapse of the 7th storey columns in the Charaima building at the Macuto Beach north of Caracas. Again the results of the interaction of brick and masonry wall panels with the reinforced columns and beams of Bucharest buildings had many parallels with similar interactions in Caracas and in Manila. The reduced number of wall panels at the first storey level (ground floor) of many tall buildings in Caracas contributed to severe damage and to the collapse of four buildings. It is understood that many of the old buildings which collapsed in the central part of Bucharest also had reduced wall panels (including no transverse panels at one end) at the first storey level, owing to the presence of restaurants, coffee rooms and shopping facilities.

THE EARTHQUAKE

An earthquake of Richter magnitude 7.2 occurred at the local time of 21.22 on Friday 4 March, 1977 with a focal depth of 110 km and an epicentral distance of about 120 km NNE from Bucharest. There were no significant foreshocks and the aftershocks were of small magnitude with the largest recorded as magnitude 4.5, nine days later. The earthquake is thought to have arisen from fracture of the Black Sea plate where it is thrusting under the south eastern corner of the Transylvanian plate. Both plates have a continental thickness of about 100 km with the boundary of the Black Sea plate extending down to a depth of about 200 km.

The acceleration was measured on the ground at INCERC, Pantelimon, on the eastern side of the city where soil conditions were probably typical of those for most of Bucharest. The dominant feature of the measured horizontal acceleration was a cycle of east-west motion with a maximum value of 0.16 g followed by a cycle of north-south motion with a maximum of 0.2 g. These two cycles of acceleration were followed by somewhat periodic motions of much reduced amplitude predominantly in the N-S direction.

For the N-S acceleration both the major motion and the reduced motion appeared to contain a dominant period of about 1.5 seconds, which implies relatively high maximum velocities, probably about 50 cm/sec. Acceleration response spectra for the N-S component showed maximum responses at a period of about 1.5 seconds, with a secondary maximum about 2/3 as large at about 0.5 seconds.

The long period of the maximum response would have resulted in relatively high loads on the taller more flexible buildings. Moreover, analysis will probably demonstrate that, for buildings of shorter period, a high ductility would be required in order to provide a moderate inelastic reserve. The variation of Romanian Code loadings with structural period is consistent with the assumption of an "El Centro" character for the design earthquakes, and hence design provisions for tall buildings were likely to be less adequate for resisting the recorded earthquake than those for typical building of only a few storeys.

PERFORMANCE OF MODERN BUILDINGS

During the last 16 to 18 years, some thousands of modern buildings have been constructed in Bucharest, which now has a population of over 2 million. The majority of the buildings are apartment blocks of 5 to 12 storeys. The apartment blocks are usually several bays long and 2 to 3 bays wide. Often 4 or more almost identical blocks are built end to end with construction joints between them. In many cases the joints have been formed by vertical panels of wood 30mm thick, which are left in place. A considerable number of the adjoining blocks have joints which are larger and clear with flexible corrugated cover plates. Recent practice appears to be the provision of open joints or of fully separated blocks. Apartment blocks usually have reinforced concrete frames and exterior and interior walls of brick or concrete blocks, without separation. The first storey level often has reduced panels, particularly on exterior walls, to provide for shops or access. Such buildings, when located at the end of a row, may have no first floor panels in the transverse end wall, resulting in fewer panels and torsional unbalance.

Some recent buildings have slender shear walls with the apparent objective of reducing seismic damage to unseparated panels and reducing the consequences of omitting first storey panels. A number of buildings of between 5 and 8 storeys were constructed of pre-cast wall panels with reinforcing from adjoining panels welded together and then covered by poured concrete. It was stated that these buildings performed well, with at most minor cracking along panel joints.

Apart from the 3 modern buildings which collapsed the writer saw only one modern building which had suffered dangerous structural damage. However many had suffered significant structural damage to reinforced concrete frames, and to slender shear walls and some of the associated beams. A great many of the modern buildings, including some with shear walls, suffered damage to non-structural panels which is expensive to repair.

Two apartment blocks collapsed; a 10 storey block on Stefan Cel Mare Street and an 11 storey block, OD 16, on Armata Poporului Street. Each collapsed block was at the western end of a closely jointed row of blocks with an approximately E-W axis. The damaging attack was evidently due to N-S ground motions. At the first storey level of the 10 storey building there were no panels on the western end and few elsewhere at that level. For N-S forces the block was unbalanced and maximum deformations were concentrated in the 3 first-storey columns on the western end. The tops of the exterior columns sheared off and the columns splayed outwards allowing the building to drop vertically until it crushed the second storey and then came to rest with the remaining 8 storeys tilted southwards about 7° from vertical. The absence of total collapse no doubt saved the lives of most of the occupants.

The 11-storey apartment block on Armata Poporului Street collapsed completely. While it was at the western end of a row of 5 blocks it was also in contact with a block further to the west which was set back one bay to the south. This block differed from the collapsed building in appearance and may well have had a dynamic character which contributed to the collapse. Local engineers stated that the collapsed building was defective in construction.

The third modern building to collapse was the 3-storey Electronic Computing Centre of the Ministry of Transport and Telecommunications. This reinforced concrete building of somewhat unusual construction was designed in 1967. The 9 columns were on a 12 m grid, while the 30 m square floors extended 3 m beyond the exterior column lines. The high-strength floors were of waffle construction, 55 cm deep with ribs on a 1.2 m grid, 30 cm wide on the column lines and 20 cm elsewhere. The waffle was closed top and bottom by 6 cm slabs. The storey heights were of 4.5, 4.95 and 4.95 m and side columns were of 70, 55 and 45 m square with heavier centre columns and lighter corner columns. The first storey columns were tapered, increasing to a 1m x 1m cruciform section (side columns) at the foundation pads, 1.5 m below the ground floor. Axial steel percentages on gross section varied between 1.5% and 2.5% over most of the column height, but increased to about 5% over the lower 1.25 metres of the second and third storey columns. All column ties were 8 mm, with a spacing of 20 cm except over the lower 1.25 metres where the spacing was 15 cm. The columns were surmounted by square pyramidal capitals which were 2.6 m on the sides and hence encompassed 4 waffle cells.

Under horizontal seismic loads the columns failed causing the building to collapse to between 50% and 60% of its original height, and it was possible to observe the principal mechanisms of failure. The floors and the floor-column connections resisted the maximum horizontal loads elastically. The first storey columns formed upper end hinges which deteriorated rapidly due to inadequate ties. However the first-storey columns did not form a side-sway mechanism because of the increased strength of the cruciform section. The second and third storey columns also formed rapidly deteriorating upper end hinges. Side-sway mechanisms occurred in the second and third storey columns by "shearing" fractures which resulted in column shortening of 1.5 to 3 metres or more. Shearing of the second storey columns was initiated at the termination of the majority of the vertical steel, 1.25 metres above the floor. Shearing of third storeys columns occurred at the same level in some of the columns and at a higher level in others. Typical second storey column "shear" failures were similar to those which occurred in the 7th storey columns of the 10-storey Charima building (north of Caracas on 29 July 1967). The columns of both buildings had similar percentages of vertical steel terminated at about the same height in the columns. The concentration of concrete stresses near the ends of the terminated steel (deformed bars bent through 90 degrees and continued for 3 diameters) was probably an important factor in the development of this "shear" failure mechanism, which appears to warrant considerable laboratory study.

The building was constructed with high strength floors and with columns of considerable strength but with low ductility under cyclic loading. It is evident that increased ties, including effective cross-ties, would have increased the ductility of the column-top hinges and resisted the formation of "shear" failures. However high column ductility calls for a ductile mechanism and this could have been aided by lapping the vertical steel within the central part of the column height and providing sufficient ties to ensure a column mechanism with highly ductile flexural hinges forming near the column ends. Particularly high ductilities could be achieved with a heavy spiral as secondary reinforcing. An alternative design approach, which retains the high strength floors, is the provision of high strength vertical diaphragms, but these would have tended to clash with the functional requirements for the building.

A more extensive report on the damage described briefly above is being prepared.

INCOMING LITERATURE

The following literature has been received by the Society. Members may borrow any items from the Central Library, Ministry of Works and Development, P.O. Box 12041, Wellington.

1. Hisada, T., "Preparations for Facing an Earthquake Disaster - Earthquake Preparedness of Big Cities in Japan", Kajima Institute of Construction Technology, Japan, September 1976, 12 pp. The report presents information on prediction of earthquake damage, administrative measures to minimise earthquake damage and preventive measures such as earthquake prediction, measures for evacuation, special town planning requirements and fire prevention.
2. Hisada, T., "Earthquake Loading and Seismic Code Requirements for Tall Buildings", Kajima Institute of Construction Technology, Japan, August 1976, 19 pp. Current Japanese seismic code requirements are presented, including horizontal and vertical forces, seismic regionalization, subsoil conditions, drift limits, and horizontal torsional