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BEHAVIOUR OF LARGE PANEL BUILDING DURING THE ROMANIA EARTHQUAKE OF MARCH 4,1977

By

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Summmary

The experience gathered from the failure of several prefabricated buildings caused by the Agadir earthquake of 1960 could give only few data concerning the behaviour of precast structures during earthquakes.However,a general conclusion is made that precast structures suffer more damage than the monolythic structures.

During the Romanian earthquake of March 4,1977 which affected one third of the whole territory of Romania,the behaviour of different prefabricated large panel systems could be observed.In this structural systems over 120.000 apartments have been constructed.

Due to the fact that the behaviour of these systems is considered favourable as compared to other structural systems,more systems were analysed in detail in order to define their behaviour during earthquakes .

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Our experience gathered from the failure of several prefabricated buildings caused by Agadir earthquake of 1960 could give only few data concerning the behaviour of precast structures during earthquakes.However a general conclusion is made that precast structures suffer more damage than monolythic structures.

We could say that up to the Romania earthquake there were almost no data about the behaviour of precast structures during strong earthquakes.During this event, the behaviour of the entire precast system in a wider range could be verified for the first time,this specially refering to large panel systems which in romania have been applied as mass construction during the last twenty years.The large panel systems constructed on the territory of the whole country amounting 120.000 - 150.000 appartments(out of which Bucharest has 75.000,Ploesti 12.000 and Kraiova 6000 - 8000 appartments) give a good possibility for analysis of their behaviour including parameters like :earthquake intensity,frequency content ,soil conditions,height of the building,types of members,connections and so forth.

The earthquake epicenter of the March 4,1977 earthquake was on the slope of the Karpathian chain,at a depth of about 100 km and a magnitude of 7.2 according to Richter scale.

The failures and damage due to the earthquake effect were experienced on an area of 80.000 km^2 which is 1/3 of the whole Romanian territory.Also,some distruction is evident in Bulgaria along the River Danube.The earthquake was felt in Yugoslavia,too,with different intensities(fig.1).

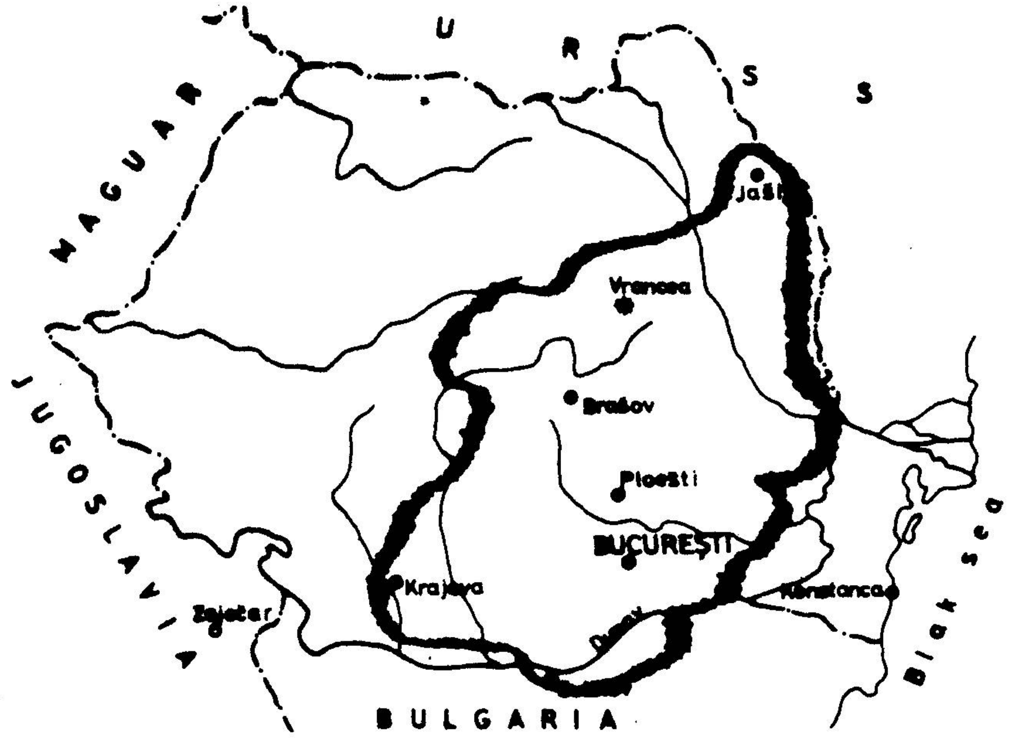

Fig. 1 Map of the Romania showing the region affected by the March 4,1977 earthquake

The geological,geophysical and geomechanical characteristics of the territory as well as the large energy released in the epicenter clarify the destruction and damage of such a vast area.

In Bucharest,a ground surface acceleration of 0.20 g(component N-S) was recorded by SMAC instrument,while at a distance of about 700 km in Nis,Yugoslavia, a ground acceleration of 0.04 g, E-W component was recorded by SMA-1 instrument. Interesting to be mentioned here is the frequency content of this earthquake if it is compared to some other earthquakes(Fig. 2).

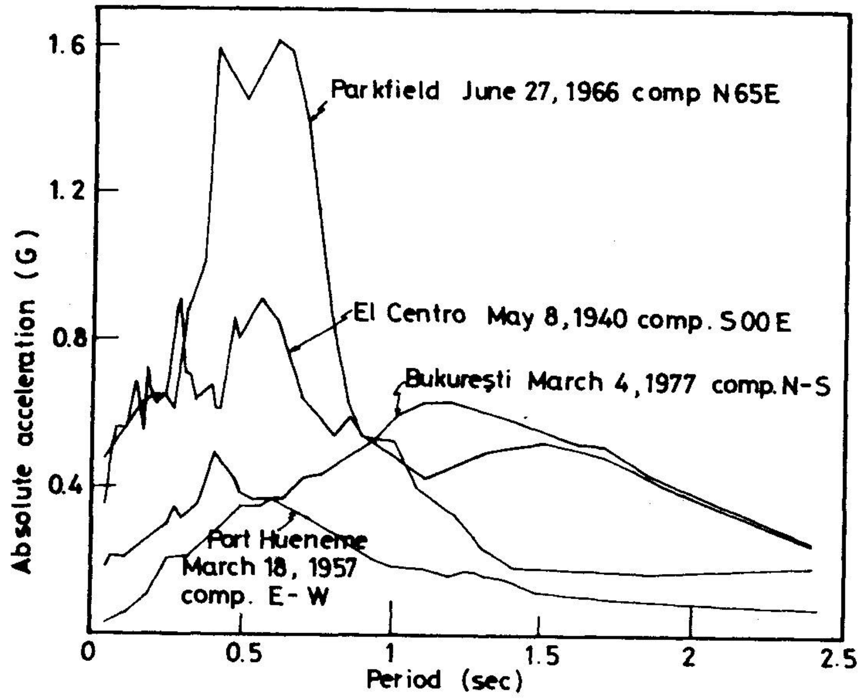

Fig. 2 Absolute acceleration response spectra for damping 5% of critical

The behaviour of different structural systems during the earthquake could be summarized in general,as:

Slender reinforced concrete frame structures with brick masonry infilled walls constructed between 1930 - 1940 ,without earthquake resistant design requirements,with low quality characteristics of concrete,insufficient percentage of reinforcement and unfavourable structural composition.About 30 structures of this type failed while a lot of them were badly damaged.

Structures constructed during tha last twenty years in monolythic reinforced concrete sysrems :bearing walls,infilled frame systems and composite systems consisting of frames,shear walls and bearing walls.These systems give relatively good performance showing different types of damage which are mainly cracks which correspond to their postelastic behaviour.It should be mentioned here that the first Codes of Romania were enforced after the Romania earthquake of November 10,1940,while the contemporary regulations based on spectral analysis were brought in 1963.

The experienced behaviour of the precast structural systems was satisfactory above all expectations,in spite of the different qualities of construction of different types of structures.

The large panel structures were introduced in Romania about twenty years ago. A priority was given to these systems during the last ten years,so today, about 75.000 apartments have been constructed in Bucharest in this system of 5-11 storey height.In Ploesti,which according to the seismic zoning map is included in zone of higher seismic intensity,the number of stories is limited to 5 stories.

According to the European practice Romania has adopted the "two-way " system. Usually,all the panel walls both internal and facade ones are bearing walls. In Bucharest,,there is a panel system constructed 15 years ago,of eight storeys, the external walls of which are not bearing walls.The foundation structure as well as the basement are monolythic.An exception to this is a ten storey building in Bucharest which has precast basement on monolyth foundations.The first slab above the basement was constructed differently,both monolythic and precast, however in Ploesti it is almost always monolythic structure.

The connections of panels both horizontal and vertical are usually wet connections placed in concrete in situ with welded anchor reinforcement,which is a characteristic of European systems.

Structural systems are mainly designed and analysed according to the existing aseismic regulations,applying static methods for definition of the static values while the stresses are defined for ultimate stress state.

The principal structural characteristics of the systems used are as follows:

1. Two way system of eight storeys and nonbearing facade panels.These structures have no basement and the prefabricated system is placed on monolyth foundations. It was constructed in series some 15 years ago in Bucharest.It is solved with monolythic horizontal and vertical joints,welded reinforcement of vertical panels and monolyth slabs above the last precast structure.Fig.3

2. Two way system of ten storeys with basement.It is a precast basement structure on monolythic foundations.The system is constructed in series in Bucharest and its use will continue in future,no matter of the recent earthquake event.Fig.4

3. Many structures in Bucharest have 5 storeys and monolythic basement.Fig. 5. gives details of some members and connections of this system.It should be mentioned here that all panel systems in Bucharest have shear base coefficient of 7-9%,up to ultimate state.

4. In Ploesti which is closer to the epicentral region,construction of large panel structures is limited to 5 storeys.They always have monolyth basement with monolyth floor slab above it.The walls are in two-way system.Fig.6. gives details of the most frequent type of system used.It should be noticed here the enlarged section of the monolythic column in order to increase its shear strength.This system was previously constructed without this enlargement for shears.The base shear coefficient is 15%.

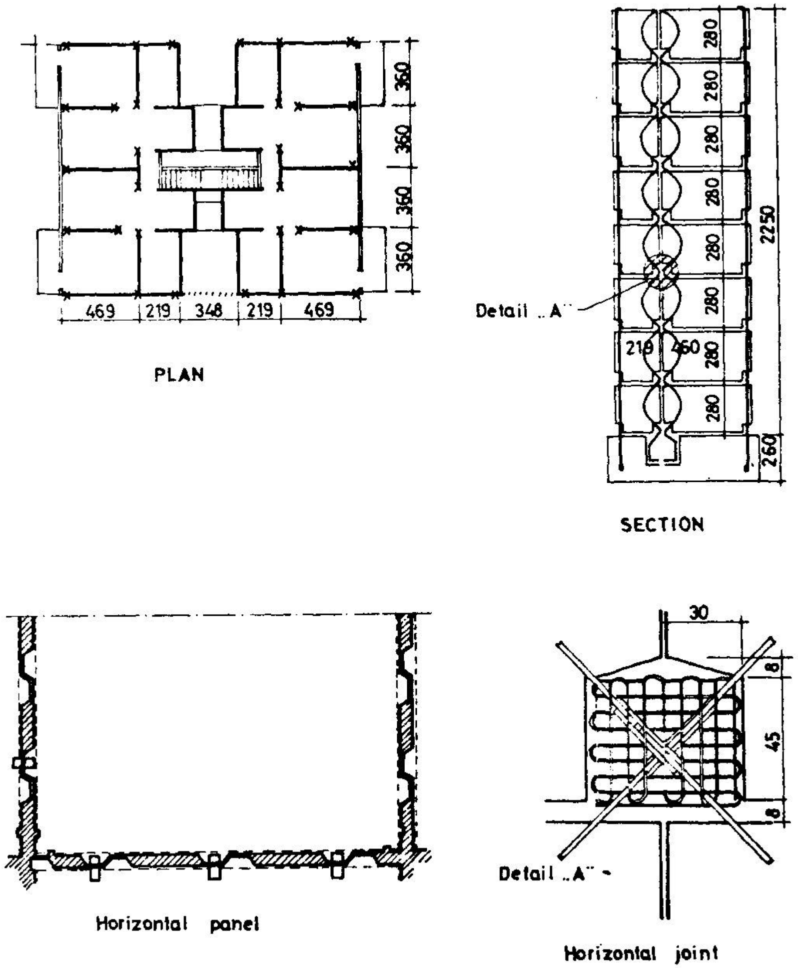
360
360
360
360
469
219
348
219
469
PLAN
280
280
280
280
280
280
280
280
2250
260
219
260
Detail „A"
SECTION
Horizontal panel
30
8
45
8
Detail „A"
Horizontal joint

Fig.3

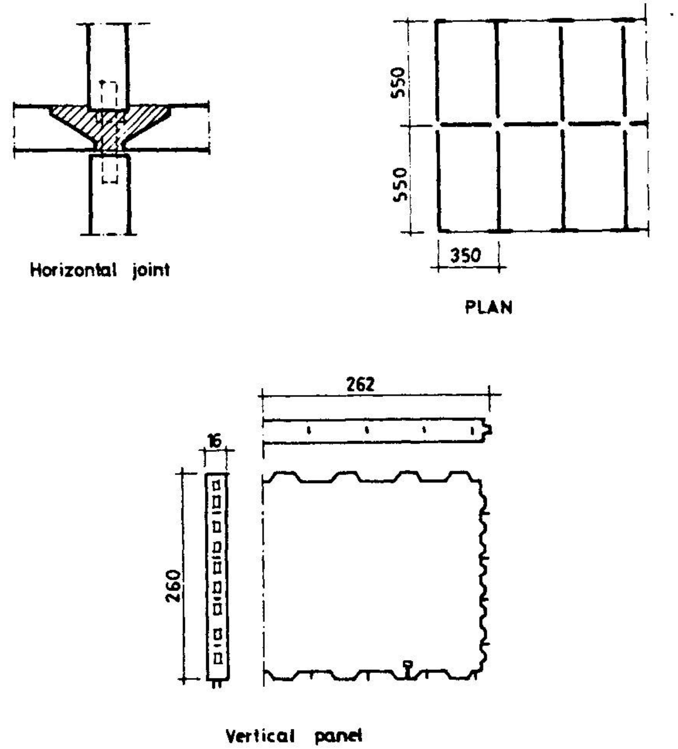
Horizontal joint
550
550
350
PLAN
262
16
260
Vertical panel

Fig. 4

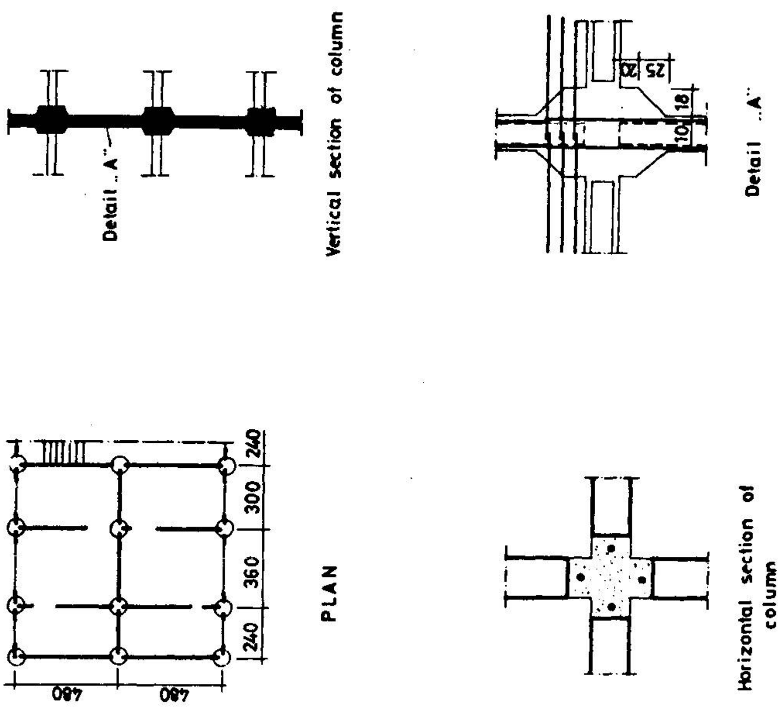

Fig.6

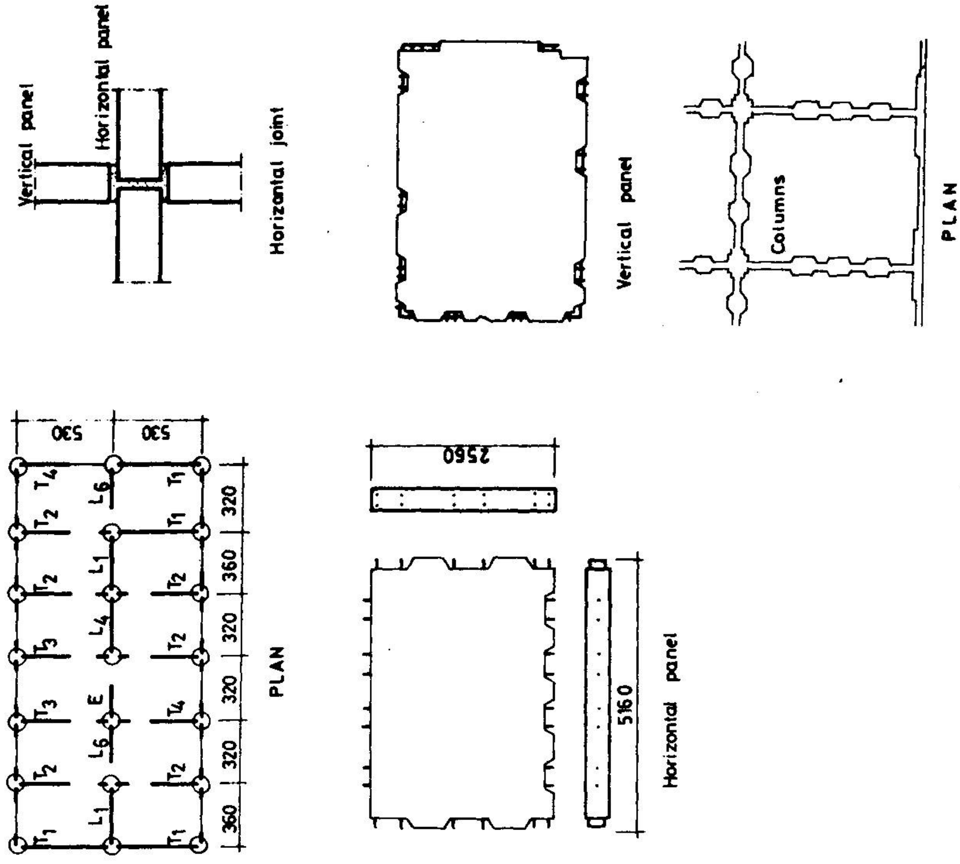

Fig. 5

In Kraiova, buildings with same design, same number of storeys and similar solutions are constructed. The plan of reinforcement distribution is given in Fig. 7 These structures have a shear base coefficient of 10-12 % up to the yield point in bending of the reinforcement.

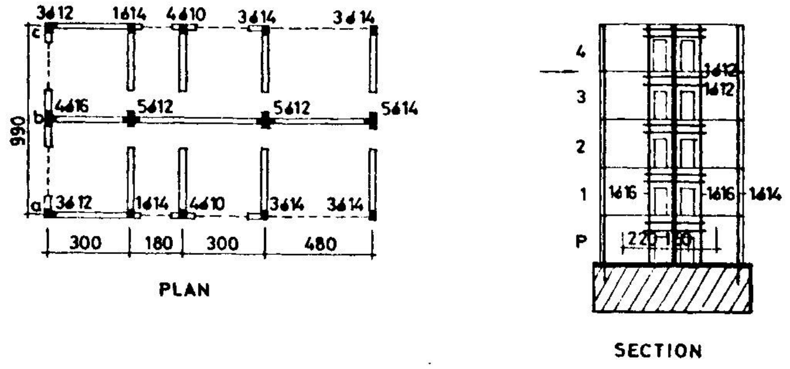

Fig.7

5. In Kraiova a large panel system is both prefabricated and constructed. It is a 5 storey system of box type, i.e. complete room. Each apartment consists of 3,5 boxes monolythically connected in sity along the edges by welding and placed concrete. Each corner is then prestressed by vertical cables of 12 t (wire of 7Ø4 mm.) along the height of the building. The prestressed cables are then anchored to the monolythic basement walls which were constructed in situ together with the foundation. Fig.8

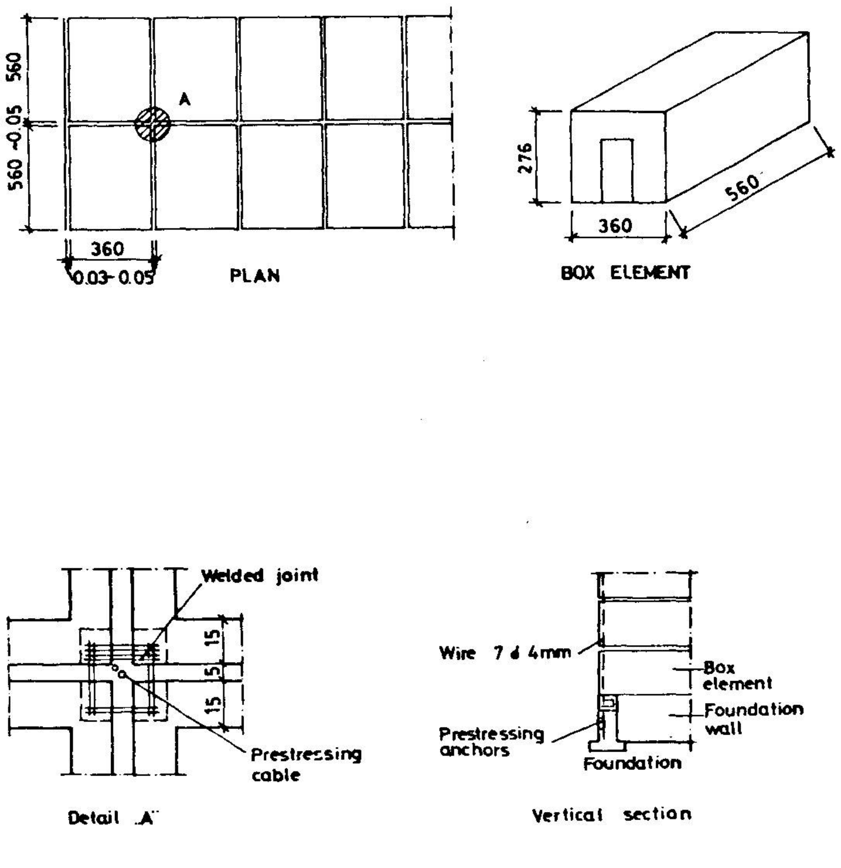

Fig.8

In all Romanian towns all the large panel structures behaved very well and generally speaking ,they did not suffer any significant structural damage.

The overall performance of members within the structural system was qualified as:

- Damage of the foundation structure has not been observed.

- Horizontal panels performed as horizontal rigid diaphragms,without damage.

- In vertical panels there are no observable cracks.Exception is the same building where several longitudinal internal panel walls (without openings)developed fine vertical cracks.

- Also,in some structures on the first and second floor,there are shrinkage cracks in joints in the contacts between the concrete placed in situ and the panels which specially refers to the vertical joints especially in flanged joints.The order of these cracks is from 0.1-0.3 mm. rarely bigger than that. The cracks are mainly concentrated on the first and less on the second floor and as a rule in the intermediate infilled panel walls.

- The horizontal joints occasionally develop cracks close to the place where vertical cracks appear and stretch 1 - 2,0 m. from the contact edges towards the middle of the room.

It should be mentioned here that such cracks in the vertical joints close to horizontal cracks are observed on much smaller number of structures,regardless -he system and the location(Bucharest,Ploesti and Kraiova).

- Sometimes,very fine cracks appear in the connection with a prefabricated staircase.

- Some interesting case of Kraiova should be mentioned here,namely in some structures the reinforcement is anchored to the belt course at the level of the floor slab above the basement.In such a structure ,there was a case of opening of a joint under the first slab in the place where the column reinforcement was anchored.

The satisfactory performance of the system,as compared to other systems,during the March 4,1977 earthquake can be explained by:

- High base shear coefficient as compared to the predominant natural dynamic characteristics of structures,soil conditions and the type and intensity of the earthquake motion - frequency content.

- Sufficient number and favourable distribution of the panels in the two-way system.

- High level of the cast in place of connections,the required length,which provides sufficient monolythic effect regardless the bad quality of construction.

- The whole building worked as a box system with capacity for energy dissipation in the ground at the soil-foundation level.

- Possibilities for bigger damping of the whole system due to joints.

- Energy dissipation in the fine cracks on the contact in vertical and partly in horizontal joints in the zones of shrinkage cracks.

- The quality of concrete is much better than in the case of monolythic structures even if there are some faults in the cast in place joints and welding of reinforcement.

CONCLUSIONS:

The large panel system is extensively used all over Europe ,today.The satisfactory performance of these structures during the Romania earthquake would only contribute to wider application of this system,even for taller buildings in seismic zones.

However,these conclusions should not be generalized since real behaviour of structures during earthquakes depends upon the earthquake intensity and frequency content,the soil conditions and the structural parameters.

Having in mind that,for the first time such a big zone covered by large panel systems with over 150.000 apartments ,was affected by strong earthquake ,an international research project which would investigate the behaviour of these structures during strong earthquakes is necessary,which will enable elaboration of recommendations and instructions for aseismic design of large panel systems in future.

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