RECONFIGURATION OF THE UNIVERSITY SQUARE BASED ON AN EMBLEMATIC PLACEMENT OF THE NATIONAL THEATRE

Prof.Dr.Eng. M. Ieremia
Technical University of Civil Engineering Bucharest

INTRODUCTION

The buildings that compose The National Theatre of Bucharest assembly were designed between 1963 and 1968. There weren't significant degradations of the structural elements after the 1977 earthquake. On 17.08.1978, a fire burst in the Main Hall building and after that the theatre was totally rebuilt on the outside and partially on the inside. It had to disappear the reinforced concrete "hat" and the old edifice was totally covered with a carcass, which gives its actual shape. Following the State's directions in that period, in 1983, The Institute of Design "*Carpați*" elaborated a remodelation model of the Section A building – Main Hall – which changed the stress structure of the building. In this way the Main Hall's capacity was increased, by removing 4 from the 8 curved reinforced concrete walls, and it had been created a new facade that loads in a forbidden way the structural elements of the adjacent parking lot.

1. SEISMIC SPECIFICITY OF BUCHAREST CITY: LOCATION OF THE NATIONAL THEATRE

The city of Bucharest is located in the central part of the Moesian sub-plate, in the Romanian Plain. The seismic hazard in this area is due to the Vrancea sub-crust source, with a focal point at the depth of $h = 60–170$ *km*, located at approximately 150 *km* North-East of the city.

The destructive earthquake which took place in Vrancea on March 4, 1977 (h = 109 *km*), with a magnitude of M_{GR}=7.2 (M_W=7.5) was characterized by a narrow frequency range and a fundamentally long soil vibration span (T_C=1.1÷1.5 *s*), as well as relatively small values of the PGA and EPA in the central area of the city, where the theatre stands (on an essentially clay-based soil).

2. SHORT HISTORY OF THE NATIONAL THEATRE RECONSTRUCTION

- **1836 - 1852: the beginnings**
- 1834 – The Philharmonic Society is founded, following an initiative by Ion Heliade Radulescu and Ion Campineanu;
- 1836 – The Philharmonic Society buys a piece of land called Hanul Campinencii for the purpose of building a National Theatre;
- 1840 – Ruling Prince Alexandru Ghica approves the project;
- 1845 – Viennese architect Heft's plan is chosen for this purpose; the building, in the Baroque style (fig.1), was to last until 1944 when it was blown up by Nazi bombardments.
- **1852 - 1864: The Great Theatre**
- 1852 – The Great Theatre in Bucharest is opened, its first managing director being Costache Caragiale. The auditorium, with a small number of seats, having initially been built for high class audiences, was enlarged in order to accommodate other categories of audiences as well.

Figure 1. The old National Theatre (1852 - 1944).

- 1864 – 1877 Official acknowledgement of the National Theatre
- 1864 – The Great Theatre becomes a public cultural institution when, by decree signed by the then Prime Minister Mihail Kogalniceanu "decided that the building must be managed by the state and become a national institution".

- 1875 – Alexandru Odobescu, general manager of the theatre, places the name of **National Theatre** on the front of the building.
- 1877 – following an initiative by Ion Ghica,

general manager of the theatre, the Parliament promulgated the Theatres Law, inspired by the Comédie Française regulations written by Napoleon.

During the Independence War, the theatre organized shows for the support of wounded soldiers and for hospital maintenance. During the shows, audiences were informed by the state of things on the front line.

- **In 1942** the National Theatre Museum was founded, thanks to George Franga's efforts.
- Liviu Rebreanu, general manager of the National Theatre, inaugurated the Theatre Museum on September 10, 1942.
- **August 24, 1944** – The building of the National Theatre on Victory Road (Calea Victoriei) is destroyed during the bombardment which took place towards the end of the Second World War.
- **1944 – 1948: Transition towards "a new world"**
- 1944 – 1948 – the assault of Bolshevik type Communist ideology: authors and plays serving the ideological direction of the Party are imposed. The theatre continues to present its shows in the following halls: Comedia (Majestic), Studio Hall (in Amzei Market area), festivity halls of high schools St. Sava and Matei Basarab, as well as at the Military Circle; after a while, only Comedia and Studio halls remained in its possession.
- **In 1967** - the location of the new National Theatre (Figure 2 - first illustrations), which had been chosen by the Gheorghe Gheorghiu-Dej regime in 1963, began to be cleared off.

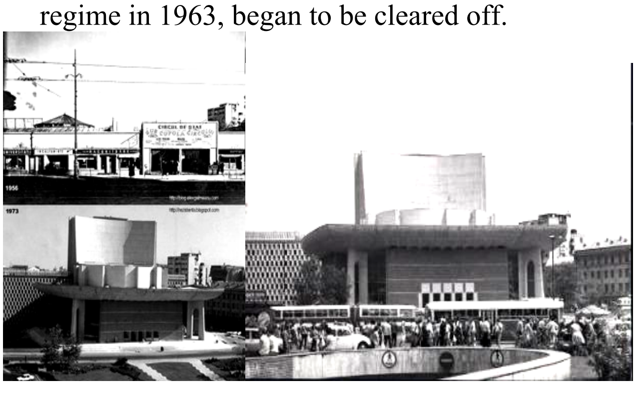

Figure 2. Old and new building of the Theatre.

- **December 20, 1973** was the inauguration date of the new building of the National Theatre (Figure 2 - second illustration), with its three auditoriums: Main Hall, Small Hall, and Workshop Hall
- On **August 17, 1978** the Main Hall was destroyed by fire, and it was then that the idea of re-modelling the Theatre came up.

2. DESIGN, EXPERT ASSESSMENT AND REDESIGNING OF THE NATIONAL THEATRE ASSEMBLY

The assembly of buildings forming the National Theatre in Bucharest comprises four main parts/sections, as follows:

- Section A – the Main Hall and the stage tower;
- Section B – Annexes ;
- Section C - Studio Hall;
- Section D – Technical room and underground parking lot.

The technical assessment of the existing stress structure of the theatre was made by Project Building Industry Ltd., its beneficiary being the National Theatre in Bucharest, represented by its general designer S.C. PECCON INVEST Ltd., cessionary of copyright.

The buildings included in the National Theatre assembly in Bucharest were designed in 1968 by "Proiect Bucureşti" Institute, chief designers of the project being architects Horia Maicu, Romeo Belea and Nicolae Cucu; the structural design chief was Professor eng. Alexandru Cismigiu.

No significant damages of the stress structure were noticed after the earthquakes of 1977 (the strongest of them all), 1986, 1990 and following.

On August 17, 1978 the section of the Main Hall (Section A) was affected by a fire which, however, did not damage the stress structure.

Ceausescu did all his best to find pretexts for imposing his own style on the city architecture. Following the earthquake of 1977, he decided to reconstruct Bucharest in North-Korean style. He took advantage of the 1978 fire at the National Theatre and imposed his point of view. The facade of the theatre was completely changed; inside, only partial changes took place. The reinforced concrete "hat" that Ceausescu associated with the bourgeois regime had to be replaced. Also, the exterior frescoes depicting the history of the theatre were never finished. Architect Cezar Lazarescu covered the old building completely with a carcass which gives it the existing, inconspicuous shape. However, the theatre re-modelling took place at the same time with the construction of the Civic Centre and the People's House. The urban planning of the area around Dambovita River required a relocation of the Musical Comedy Theatre (formerly bearing the name of "Queen Maria"), so it was also moved in the University Square, once the stylish building that had once hosted it (in the former Senate Square, now called United Nations Square) was demolished.

Similarly, following certain decisions of the State leaders of the time, the Design Institute "*Carpați*" elaborated, in 1983, a project for further changes of the Section A building – Main Hall – which included the following:

- the enlargement of the hall capacity from 900 to 1,400 seats;
- a new space layout, with two more auditoriums on the ground floor and underground floor;
- development of exhibition spaces (5,000 m^2) by over-flooring;
- a new, higher facade was placed over the old roof.

All these changes and restructurings led to major, as well as difficult changes in the stress structure of the building (Section A – Main Hall), as well as in the way in which gravitational loads were disposed, unacceptable from the point of view of the design requirements.

A local fire burst out in the Studio Hall (Section C) in 2005, but it probably did not significantly affect the stress structure of the building (no lab samples were taken in order to determine the rigidity and resistance of various critical elements in the area, based on statistic processing).

3. GEOTECHNICAL PROFILE OF THE SOIL AT THE NATIONAL THEATRE LOCATION

Land surveys showed the presence of a dusty clay base with limestone noodles – for the entire area – with admissible pressure levels of up to 4 daN/cm^2. The sub-soil depth was set so as to avoid reaching the groundwater point, which would have involved special water shutting-off requirements; however, the thermal unit was partially insulated due to floor lowering.

Under the foundations, the soil continued to settle under the long term action of gravity loads.

The adopted foundation systems were the classical ones, that is, including partial slab foundation, isolated foundations and continuous foundation strips.

4. COMPUTATION OF MECHANICAL STRESSES BASED ON LAB SAMPLES

The Civil Engineering Laboratory in Bucharest used the combined method of non-destructive tests on structural stress elements from the theatre (pillars and diaphragms). The resulting average resistance for the pillars was of 220.8÷251.1 daN/cm^2, corresponding to a class C12/15÷C16/20 concrete type B200÷B250. For the reinforced concrete diaphragms the resulting average resistance was of 238.0÷244.8 daN/cm^2, corresponding to a class C12/15÷C16/20 concrete of type B200÷B250. A number of manufacturing flaws were noted, referring to concrete flow breaks (pouring joints), homogeneity variations of the concrete at diaphragm level and cracks on the diaphragm width.

5. METHODS USED FOR THE TECHNICAL ASSESSMENT OF THE BUILDING STRUCTURE

According to the provisions of technical standard P100-92 paragraph 11.2.1 t
he methods used for fulfilling the technical assessment were as follows:

- Method E-1 for qualitative in-situ assessment;
- Method E-2 for current computation, corresponding to methods in Category A pt. 6.2 – the numerical analysis on a spatial model.

6. STRESS STRUCTURE – INITIAL AND PRESENT STATUS

In its initial form (Figure 3), from a structural point of view, the building was erected around flat or curved, high capacity structural walls, strong cells, highly ductile beams and resistant slabs which transmitted the inertial forces towards all structural elements. Damages following the 1977 earthquake were practically non-existent, thereby confirming the fact that the structure was appropriate and highly resistant. The initial project was mainly focused on preserving the elasticity of the entire system under stress from the earthquake-driven forces. Unfortunately, the massive fire of August 17, 1978 destroyed most non-structural elements, but the stress structure remained intact.

Figure 3. Initial form of the National Theatre.

Figure 4. Structure of Section A
Main Hall, following the changes made in 1983.

The theatre then duly required repairs and new finishing touches, and the respective works also involved dismantling some of its critical elements, resulting in second degree support, in a pillar-beam type. These changes were made at the expense of the seismic performance of the structure and, at the time, were received with protests and counterarguments based on existing seismic standards, still valid today under the Seismic Standard no. P100-2006.

The technical assessment identifies two major problems in the case of this construction: the slow concrete flow was accelerated by the fire; and the building capacity of taking up the earthquake-driven loads diminished, since one of its walls was torn down. Phase DE of the project, now under way, takes into account the conclusions of the technical assessment and the initial designers' recommendations, with the purpose of ensuring at least the stress level and stability of the building prior to 1978.

In Section A – Main Hall – the overhead floor is made of beams supported by a frame girder at one end, the other end being supported by a reinforced concrete cross-beam, as well as by structural walls which are empty inside.

Sections B and C show high levels of torsion, due to the lack of symmetry of their structural elements; pillars are in a critical position during the seismic energy dissipation mechanism.

Following the changes made in 1983, the stress structure of Section A – Main Hall – was fundamentally changed (Figure 4), fully ignoring the technical legislation in force at the time, and with even less concern for the present day requirements of designing codes.

As such, the Main Hall was extended by removing the curved fan-shaped structural walls (four of the eight reinforced concrete diaphragms being removed), various areas were torn down or reshaped locally, in order to make way for the official box lobby (in an atypical position, by special request from the state leaders of the time); exhibition spaces were created, using the terrace over-flooring method (at levels 4 and 5); a new facade was built, in the shape of a high portico, in front of the original roofing, and this facade added a significant, inadequate load on level 2 of the nearby parking lot, and so on.

That is why it is paramount to revert to the initial parameters of the stress structure, conforming to in force technical standards (but also to the standards which were valid at the time of the 1982 elaboration of the project that aimed at extending the theatre capacity).

The technical assessment made in December 2006 analyzed the effects of the earthquake on the stress structure of the National Theatre assembly, by comparing standards (seismic design codes) elaborated in 1963, 1992 and 2006 respectively, and reaching the conclusion that consolidation works should mainly concentrate on the elements of Section B (the Annexes) – Figure 5. The frame type structure, which does not comply with para-seismic requirements, in the absence of continuous flooring at each level, as well as the initial design, which did not take into account the specificity of conventional seismic forces from the Vrancea area – all these were as many major arguments in favour of the decision to consolidate this building section with the help of a flexible structure with a high vibration range. There are no seismic protection expansion joints between the buildings, the existing one being just a dilatation joint. That is why the building of Section B had to be stiffened in the end areas (corner areas), in the vicinity of the other sections.

Section C – Studio building (Figure 6) – largely lacks seismic protection, especially in its cross section.

Also, the specific vibration of this unconsolidated building determines extremely dangerous assembly torsion combined with translation movements on both directions, thus proving its unreliability in the case of seismic action (Figures 7, 8, 9). The building structure must undergo consolidation at stress structure and rigidity level.

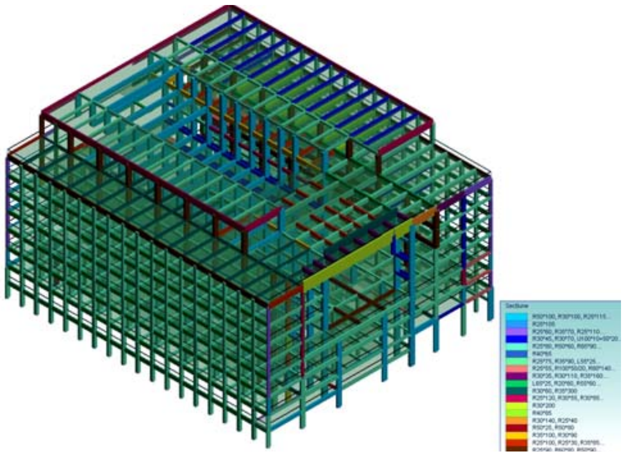

Figure 5. Structural model of Section B The Annexes

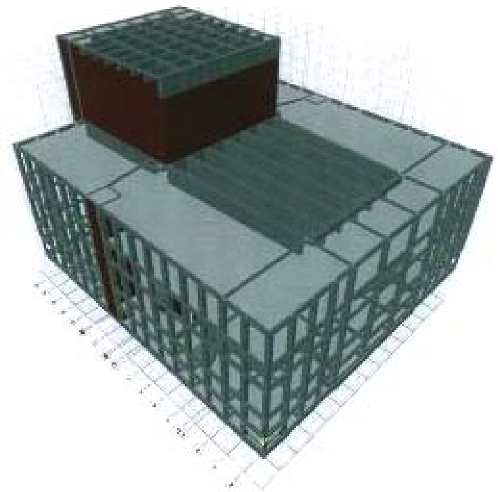

Figure 6. Structural model of Section C Studio Building.

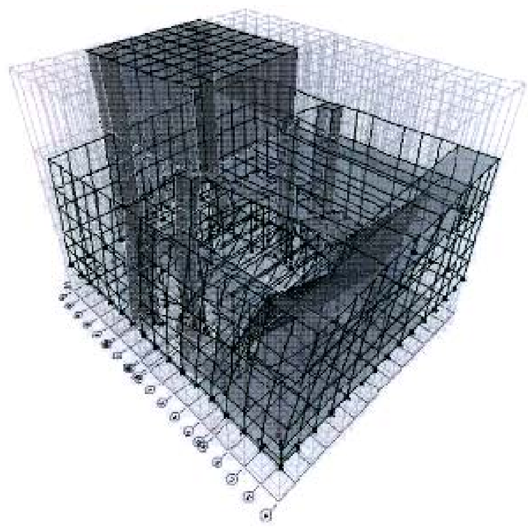

Figure 7. Mode of vibration no 1.

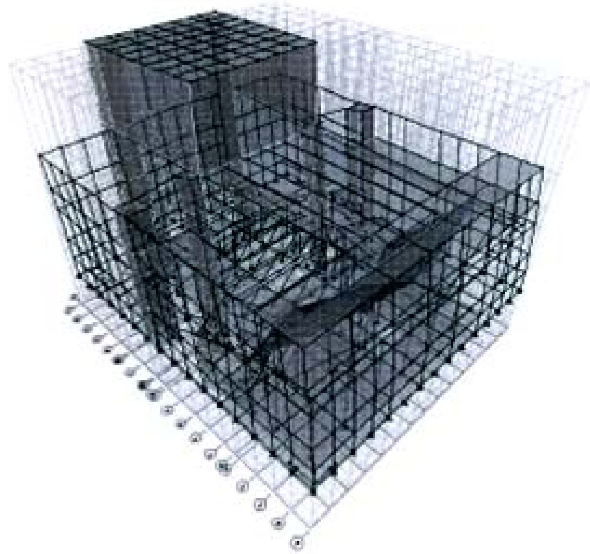

Figure 8. Mode of vibration no.2.

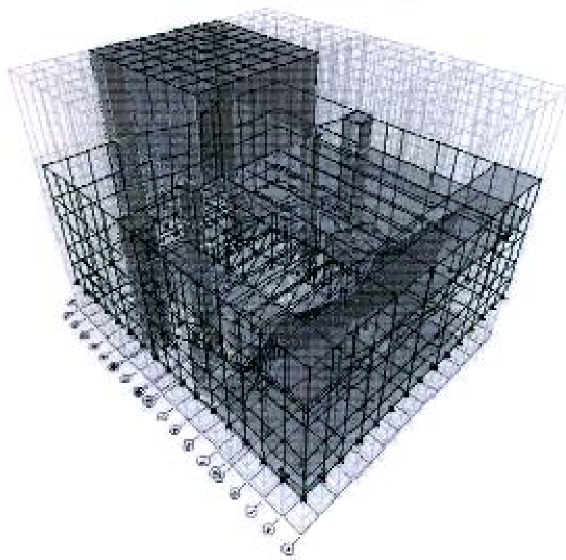

Figure 9. Mode of vibration no.3.

Taking into account all of the above, the consolidation works of sections B and C must be made during the same stage (simultaneously), and the site premises must be organized accordingly - Figure 10.

In what sections A and D (Main Hall and underground parking lot) are concerned, these must be re-modelled according to the original solutions, to comply with the existing technical standards, including the requirements of the Code for Seismic Design.

To this end, it is critical to take into account the structural redundancy. If this requirement is complied with, in the event of elements becoming plasticized or breaking up locally, the lateral seismic force would be distributed to other elements

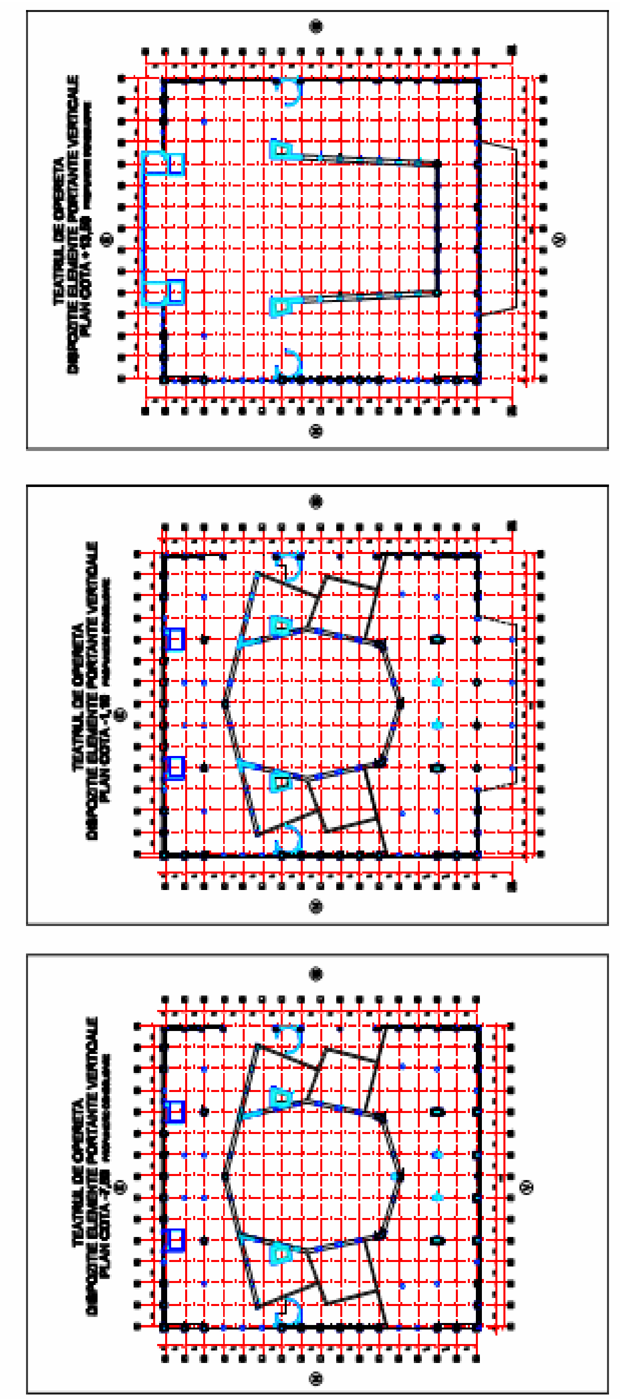

Figure 10. Musical Comedy Theatre.
Location of vertical supporting elements.

in the system, in order to prevent progressive breaking. The designer must "ensure that the breaking up of a single element or of a single structural joint does not endanger the entire structure due to a loss of stability."

An unfortunate example is given by the existing support system for the over-floored terrace pillars, using statically determined beams in the cantilever. Also, vertical breaks (pillars on beams, beams on beams) determine a deflection of loads, but also certain sudden changes of the rigidity and lateral stress at certain levels; these result in special vibration characteristics (especially at the level of the vertical seismic component) and load peaks due to the indirect load transfer. Referring to it, the existing seismic code requires "*…a direct, short length transmission of the inertia forces specific for the masses distributed throughout the building*".

The requirement for avoiding indirect support resulting in significantly increased loads, both vertically and horizontally, in the case of earthquakes, is emphasized: "***as a rule, supporting pillars on beams should be avoided***".

Therefore, the portico pillars are placing a significant pressure on the flooring over the underground parking lot (Figures11,12,13), and this area, in which the load is transferred from one building to another, is a danger zone from the point of view of the required security level, against permanent static gravity action, as well as against lateral and vertical dynamic, random actions.

Figure 11. Portico pillars in the parking lot.

Figure 12. Portico pillar in the parking lot.

It should be mentioned that during the works aimed at changing the Main Hall to its initial form and foyers a thorough analysis will be directed towards improving audiences' movement around.

Figure 13. Detail for Portico pillar in the parking.

Note: The technical assessment justly assumes that the original stress structure of the Main Hall of the theatre shows "a practically unlimited general stability in time for all certain or probable actions. Ensuring optimal building behaviour for such stresses was necessary in order to maintain it as long as possible within elasticity limits in the case of high intensity earthquakes". The seismic analysis made for this structure made of reinforced concrete diaphragms and frames resulted in a period of oscillation of T=0.53 s in the fundamental vibration mode, and **a super-unitary degree of resistance** to seismic action in the stress elements tested.

The following table shows the value of the global seismic coefficient - c_s – calculated for the theatre hall structure, according to various technical standards in force at various stages.

It can be noted that this technical seismic coefficient, which amplifies the structure mass and produces the equivalent lateral conventional calculus force, increases by 39% if the pseudo-static analysis is made in conformity with the new seismic design code (2006) as compared to the analysis according to the previous seismic standard (1992). If we were to make a comparison with the seismic standard in force at the time when the theatre structure was designed (1963) we could note an important increment (by 62%) of the global seismic coefficient value, calculated according to standard P100-92, still valid today with reference to the consolidation of existing buildings. The 1963 standard did not start from a correct assessment of the Vrancea type seismic actions, being based on the Californian spectrum adopted for Romania, largely useless for large classed of semi-rigid structures (example: Main Hall section and Studio Hall section), and especially flexible ones (example: Annexes section, with a fundamental vibration period T_1=1.58 s).

The consolidation of fractured elements (beams, walls, masonry) is also targeted by means of crack injection with epoxy resins, or with the help of guided walls (approx. 6 cm thick) plated with ductile fastening iron nets.

The inserted ceiling placed at the +13.00 m quota will be consolidated and stiffened in order to be turned into non-partitioned offices that would change its present use as storage room.

Section D – Technical room and parking lot

The dismantling of the existing facade, made in 1983, will reduce the extra load exerted on the parking ceiling by the theatre facade and the subsequent over-flooring, while the roof from the main entrance will be displayed in its original form of 1968.

In order to increase the existing capacity of the parking lot and to redistribute loads across its stress structure, supplementary beams made of reinforced concrete will be mounted, observing the existing height limits.

Further on, the pillars supporting the parking lot will be coated – on their entire surface – in order to work jointly with the newly created cross beams.

7. PROPOSED STAGES; PROBLEMS THAT NEED TO BE SOLVED

- Consolidation of the stress structure (facade structure, main hall structure), stage tower and parking lot structure;
- Reshaping of the National Theatre building – section A, inspired from the London National Theatre – Barbican Hall building, as well as from theatres in Los Angeles and Copenhagen;
- Consolidation of section B (including offices, green rooms, gyms, smaller auditoriums), which suffered the most significant damages from earthquakes;
- Consolidation of section C – at present hosting the Musical Comedy Theatre (in the future it will host the Studio Hall of the National Theatre), which will be reshaped according to an Elizabethan-type variable geometry;
- Three more auditoriums will be set up ;

Tabel 1. Values for coefficient - c_s

Norm	**α (γ_1)**	**k_s**	**β**	**ε(λ*)**	**φ**	**α_{11}/ α_1**	**Ψ(1/q)**	**c_s**
P13.63	-	0.05	1.698	0.85	1	-	1.2÷1.0	0.079
P13.70	-	0.05	1.509	0.85	1	-	1	0.064
P100.78	-	0.2	2	0.85	-	-	0.25	0.085
P100.81	-	0.2	2	0.85	-	-	0.25	0.085
P100.91	1.2	0.2	2.5	0.85	-	-	0.25	0.128
P100.92	1.2	0.2	2.5	0.85	-	-	0.25	0.128
P100.1/ /2004	1.2	0.24	2.75	0.85	-	1.35	0.264	0.178
P100.1/ /2006	1.2	0.24	2.75	0.85	-	1.35	0.264	0.178

- The University Square will be reconfigured and several representative monuments will be added. Here are some examples:
  - "*The Clowns' Cart*" – a monumental sculpture displaying the main characters described by author Ion Luca Caragiale;
  - "*The Crystal Monument*", accompanied by an eternal flame, dedicated to the memory of 1989 heroes;
  - "*Caragiale's Hat*", meant to emphasize the National Theatre image according to the model used before 1983.
- The erection of a National Dance Centre (now operating inside the National Theatre building);
- Most building services from the National Theatre will be renewed; examples: the air conditioning system, the fire prevention system;
- The number of seats in the auditoriums will be almost double, from 1720 at present to over 3100.

8. FINANCIAL RESOURCES USED FOR THE NATIONAL THEATRE RECONSTRUCTION

The financial agreement for the National Theatre of Bucharest works is worth 51 Mil. € +VAT (of which 28 Mil. € are granted by the European Bank for Reconstruction and Development) and covers a time span of 28 months.

Recommended for publication: 14.04.2011.