EFFECTS OF MAINTAINING A BUILDING CONSTRUCTED IN THE IMS SYSTEM (ŽEŽELJ) WITH AN APPROXIMATE ANALYSIS OF HYDRODYNAMICAL SHOCK AND THE ANALOGY WITH LATERAL SOIL EXPANSION WITH CAVERN EFFECTS DURING LIQUEFACTION

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Abstract: The paper indicates the problems of maintaining buildings constructed in the IMS system, founded on piles with a basement floor. Also presented are the problems with the installations of buildings with a roof terrace, such as downpipe verticals that are extending through the building, or installations of water supply and sewerage that run through the technical floor at ground level. An approximate analysis of the hydrodynamic impact is presented. The analogy of the effects of caverns in sandy soil with lateral soil expansion during liquefaction was also used. Given the change in climatic conditions, it is necessary in some cases to analyze the influence of atmospheric conditions in the soil-structure interaction. The advantage of buildings built in the frame IMS system (Žeželj) in seismically active areas was also indicated. These buildings are also more resistant to problems that may arise later in construction of deep foundations.

***Key words**: Prestressed and Reinforced Concrete Framed Structures IMS, Seismic Strengthening System, Soil Pile Structure Interaction, Earthquake Resistant Structures.*

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1. INTRODUCTION

The building of Agro Vojvodina and Beton (tower AV), was designed and built in the IMS system in the late 60's of the 20th century [2], as an office building. It is located in Novi Sad at the corner of the intersection of Oslobodjenje Boulevard and Car Lazar Boulevard. Diagonally across, there is the building of Elektrovojvodina, and opposite to Naftagas and Mercator, and on the other side, across the read, there is the Promenade building in front of the stadium.

The Oslobođenje Boulevard is one of the central boulevards of Novi Sad, at one end, on the slopes of Fruška Gora, connecting Sremska Kamenica, via the bridge of Freedom, across the Danube, with the Bus and Train stations at the other end. This boulevard represents the border between Liman II and III.

2. ON THE STRUCTURE AND AGROVOJVODINA BUILDING

The grid of pillars is square with 4.20 m sides, so it is identical in both perpendicular directions. In the longitudinal direction, that is the direction of Oslobođene Boulevard, there are 6 spans, and in the transverse direction 4 spans. There are no cantilever ceilings. The building has basement + ground floor + 15 floors. The foundations were supported on Franki piles. Vertical communication is realized by a staircase and two elevators. The staircase has multiple flights with intermediate landings. The staircase admits daylight through the windows, along the entire height, and along one span. Inside the stairwell is an air space separated by a railing. Although already a decade before, buildings had been constructed in the IMS (system), such as four-storey buildings and later even higher on Liman 1, this is the first high-rise building built in that system in Novi Sad. Soon after, high-rise buildings became commonplace in Novi Sad's Liman areas.

Liman is a word of Turkish origin, meaning swamp or pond, which exactly was the condition of those areas until the middle of the 20th century. In order to urbanize that area of Novi Sad along the Danube, those wide areas were covered with sand, with a total area of several hundred hectares. Sand covered marsh and swamp soil is one of the reasons why low buildings were built in Liman areas, i.e. in order to avoid the expensive funding on piles. IMS buildings have the advantage of having a lighter weight than classic buildings, and due to the better connection of the ceilings on the floors, they are more resistant to earthquakes [2].

This is still the old housing system of IMS, the new one started to be applied in the early 80's. The ceilings of this tower are fine-ribbed and have only the top AB slab. The bottom slab, i.e. the ceiling of the lower floor is formed by a wooden grill and plasterboard panels.

The wooden grill is hung on a fine-ribbed ceiling, that is, it is tied to it with a wire, through the provided holes in the ribs. The old system has 4 groups of ropes per trough. On the façade, the ceiling forms one side of the trough and the other is formed by the edge element. Prefabricated facade AB parapets, which are designed as sandwich panels, are supported by the edge beams. Thermal insulation is placed inside the two-layer concrete.

3. ON THE IMS SYSTEM

Industrial prefabricated construction system (IMS, system) began to be implemented in the late 50’s of the XX century. The author of the system is B.Sc. constr. Professor and academician Branko Žeželj, and the Institute for Testing Materials of Serbia from Belgrade (IMS, Institute) is the holder of a license for the application and development of this system.

One of the first construction companies that started the application of this system was the Beton from Novi Sad, which designed and built the AV office building. The main investors were the Agro Vojvodina and Beton. The symbols of these companies still stand on top of this building, even if they are no longer illuminated at night. The Beton occupied about 4-5 floors of this building, and Agro Vojvodina approximately the same. The factory production of prefabricated concrete elements of the Beton was on the Liman III towards the Dunavac.

In the 70's of the 20th century, the Beton was integrated with the Neimar and several other companies, in order to have a better and single representation in our and foreign markets. After the integration, the name GDP Neimar was retained, even though the Beton built more surface area of apartments a year. The new complex company Neimar then had about 7,500 employees.

4. BASIC ELEMENTS OF IMS STRUCTURE

The basic elements of IMS (system) are: columns, ceilings (interior and cantilever), edge elements (located in the facade at the level of ceilings), staircase flights and landings, stiffening bearing walls, facade elements (can extend along the entire floor height, or only as cantilever attic). RC bearing walls can be both prefabricated and monolithic. In some instances, prefabricated sanitary blocks were used, which considerably accelerated the finalization of the buildings.

The basic prefabricate RC elements of the IMS system, (columns, ceilings and edge beams), are connected with prestressing cables, after installing.

The axial layout of the AV tower, consists of 6 spans in the longitudinal direction and 3 spans in the transversal direction, see figure 1. (4,20x6=25,20 m; 4,20x3=12,60 m)

The external dimensions of the building are 25,80x13,20m. The columns have cross-section 38x38cm

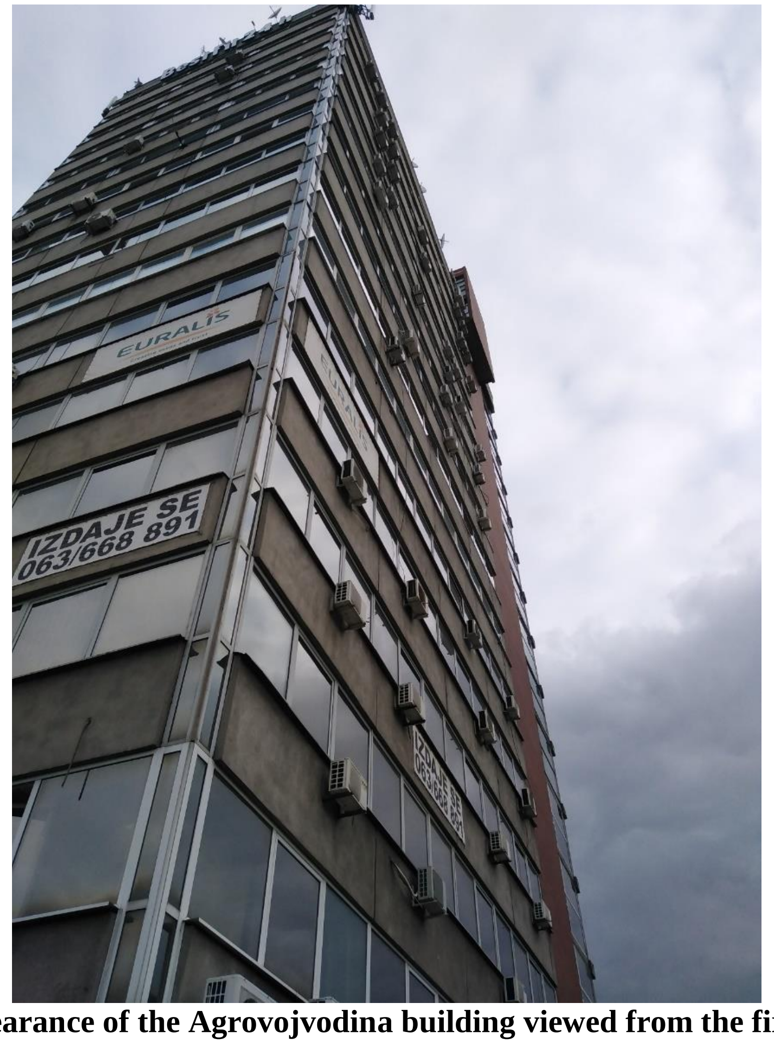

Figure 1. The appearance of the Agrovojvodina building viewed from the first floor to the top. On the right, longer side is the Oslobodenje Boulevard, and on the left, transversal side is Car Lazar Boulevard

The following plans were reproduced from the working excerpts of the design, from the design bureau Neimar 76, dated to 1968. The designer is arch. Breda Šelken. These plans do not fully correspond to the actual building, in part due to the damage of the print paper, resulting from handling and old age, but they provide a good starting point for the preliminary analysis of the building.

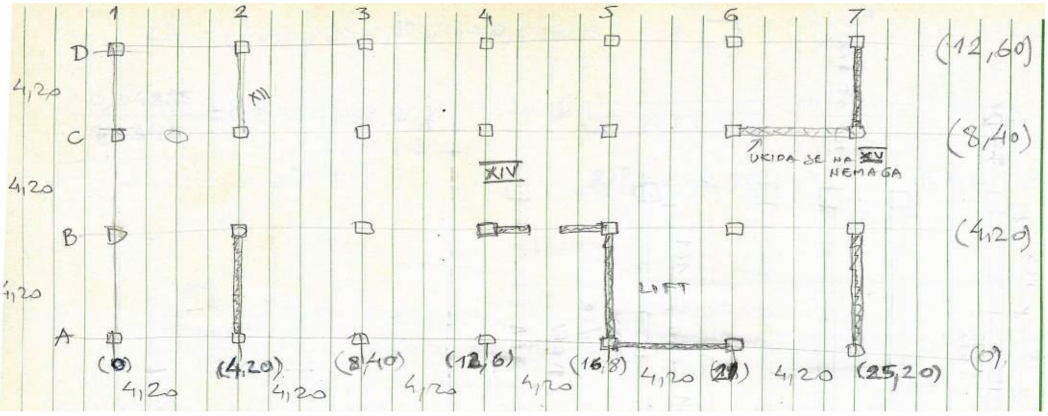

Figure 2. Ground floor plan (date design, April 1968). In reality, in the axis C/1-2 there is a bearing wall with an opening, but the working plan from the design does not have it, so it is not drawn here either.

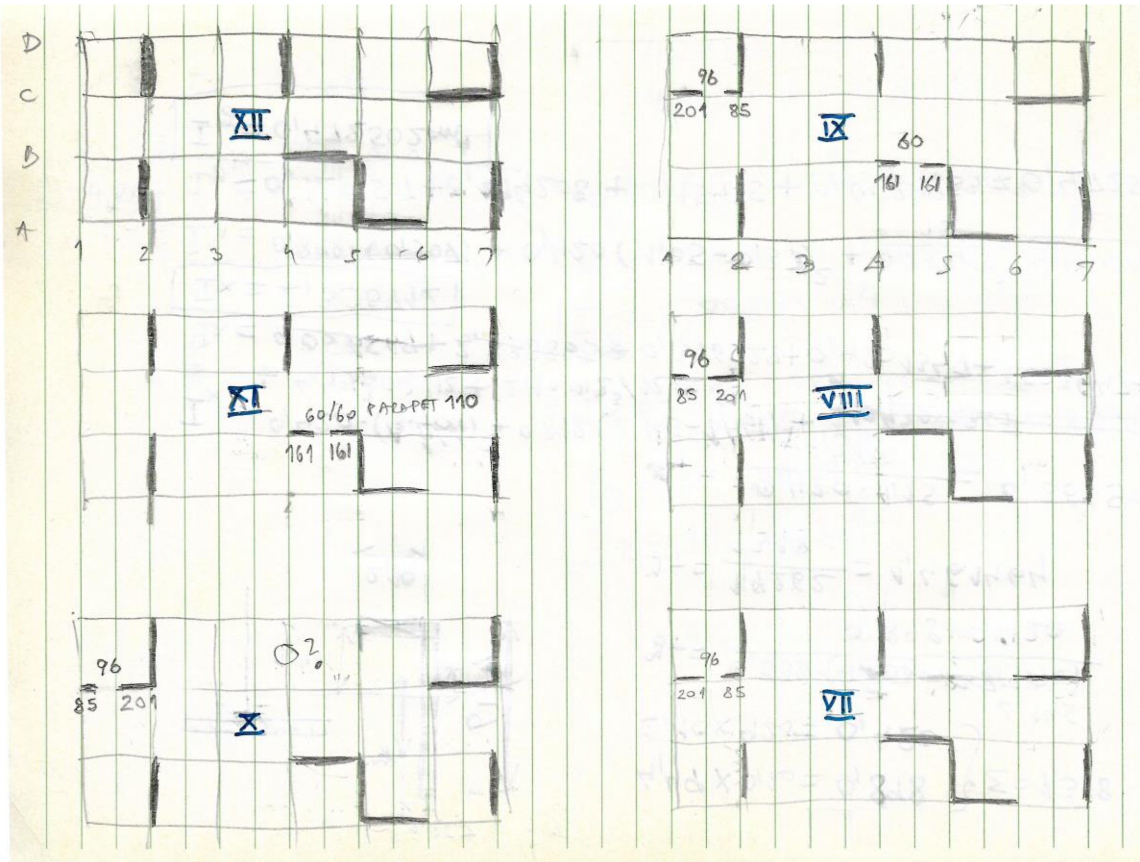

Figure 3. Floor plan from the 9th to the 12th floors (date design, April 1968). In reality, on the 10th floor, in the axis 4/C-D there is a bearing wall, but the working plan from the design does not have it, so it is not drawn here either.

5. CLOGGING OF THE ROOF TERRACE DRAIN IN 2004

In July 2004 due to the heavy rains, and as a consequence of poor maintenance of the roof, because the property ownership rights were not clearly defined, the roof terrace became a shallow pool. For this reason, the water leaked through to the lower floors of the building and soaked the ceiling plasterboard panels.

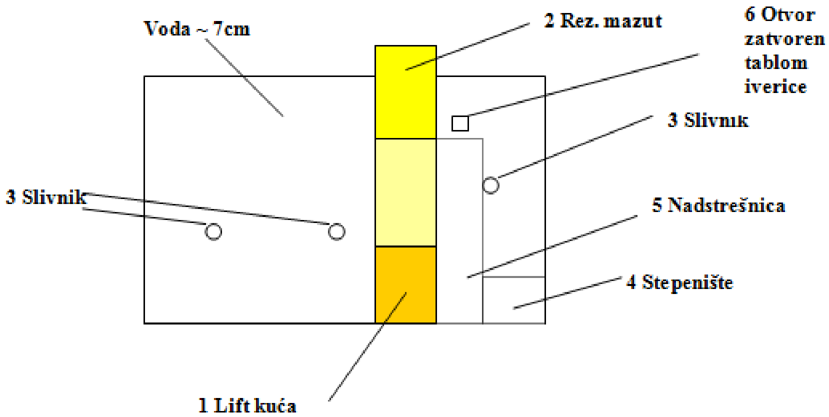

Figure 4. Plan of the roof and roof terrace of the AV tower. 1 Elevator equipment room. 2 Heating oil tank. 3 Drain. 4 Staircase. 5 Overhang. 6 Opening covered with plywood panel. Average water depth cca 10-11cm. Smaller roof terrace is in the right hand side of the image. Drawing is not drawn to scale.

The approximate amount of water on the larger roof terrace is around 30 m^3. The height from the roof to the outlet pipe from the basement floor is around 50m. The free fall velocity is $v = \sqrt{2gh}$, and if losses of 50% are assumed, it is $v = 0.5\sqrt{2gh} = \sqrt{9.81 m/s^2 \cdot 50 m} \cdot 0.707 = 22.36/0.707 = 15.81 m/s$. After the drain clogging was unblocked, water was not let out successively, but it was let out with no restrictions, abruptly, which caused the hydrodynamic shock, which shattered the drain shaft on the side of the Oslobođene Boulevard. It was visible as the soil settled on one side of the shaft for around 25cm. Figure 9, shows the current condition of this shaft. The metal cover was replaced with a RC slab.

Figure 5. A view of the flooded roof terrace and unplanned roof plants near the attics. July 2004.

Figure 6. A view of the flooded roof terrace and unplanned roof plants near the attics. July 2004.

Figure 7. Opening on the roof closed off with the plywood panel. Waterproofing damaged in one part. July 2004.

Figure 8. A view of a smaller roof terrace and a drain. July 2004.

Figure 9. Lower right hand corner shows the shaft now covered with a RC slab**.** Photo taken in 2022.

Figure 10. Leaking of the ceiling around the lighting fixture. July 2004.

6 FORMATION OF A CALCULATION MODEL

During the inspection of the basement floor of the building in 2004, the janitor who maintained the building for some companies, reported that for years there had been leakage of water from the water supply and sewage pipes below the basement floor slab. It was attempted to pour sand in the cavities in the soil where it was possible to identify and access. The exact condition of the foundation soil is not known to the authors.

In order to check the impact of soil leaching under the basement slab, it is necessary to include piles into the model, whereby it is necessary to simplify the upper structure, due to the limited computer resources at the time. More precisely, the available resources at the time could not support such a complex model, so grills were approximated first. The coffered ceiling grills are presented with solid 6.5 cm thick plates. Instead of the existing grill ribbed ceiling system, solid slab system can be substituted via the command: stiffness modifiers.

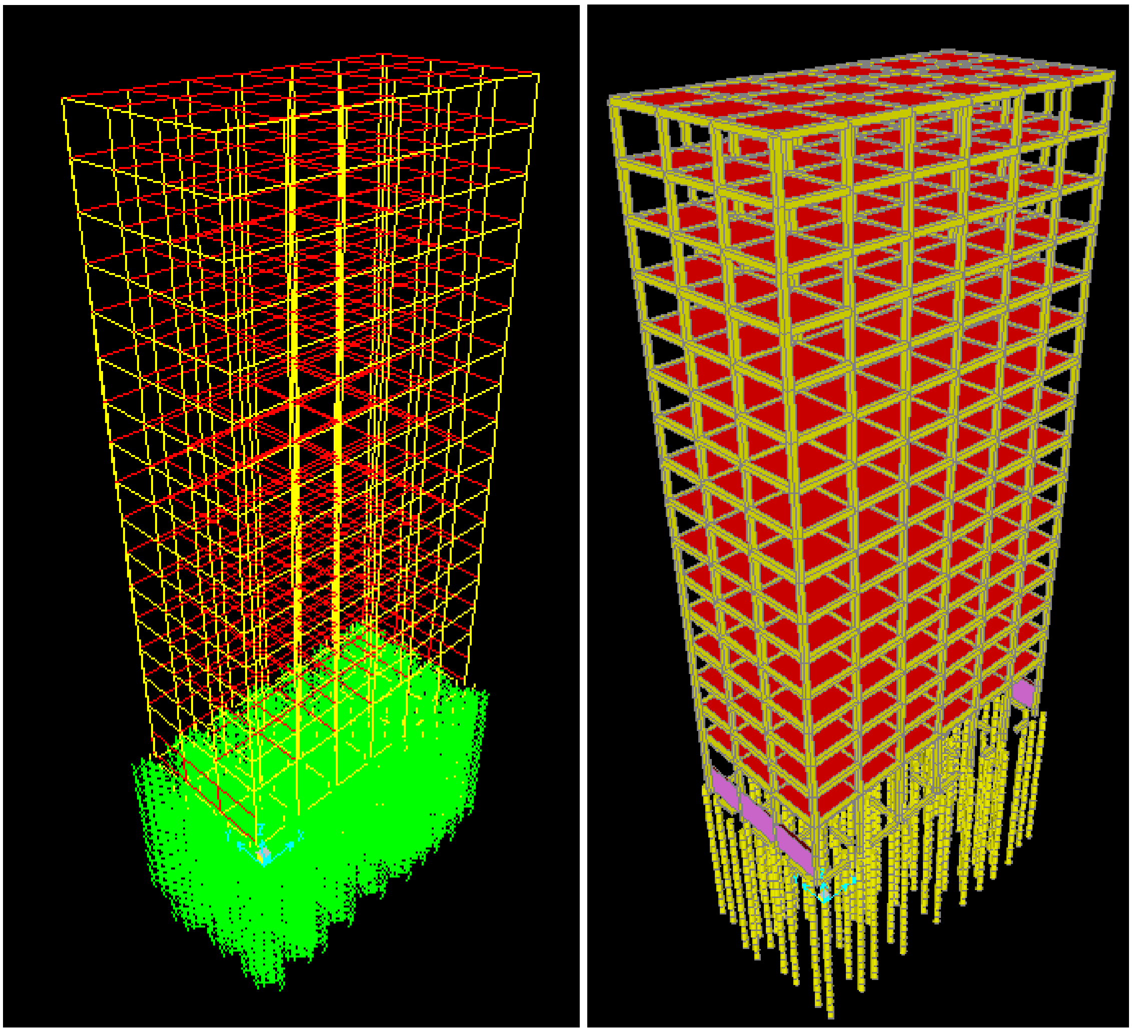

Figure 11. Simplified model of AV tower.

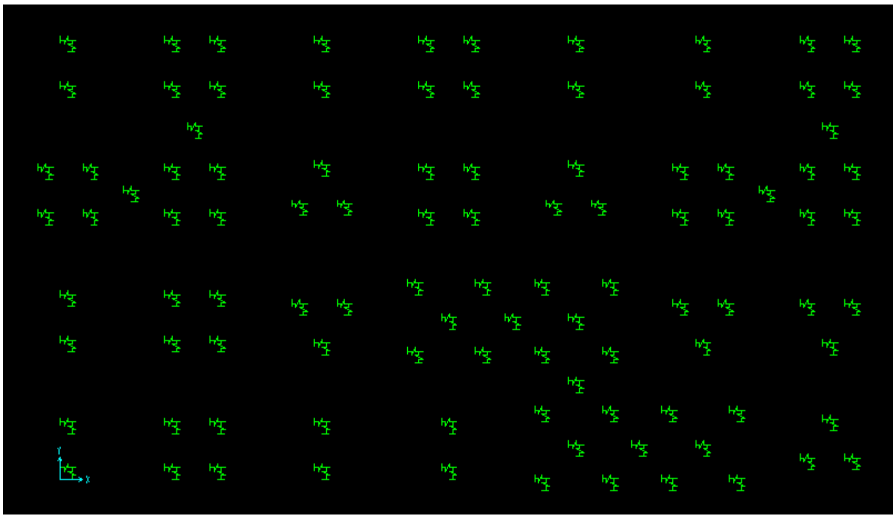

Figure 12. Arrangement of elastic supports on the tops of piles

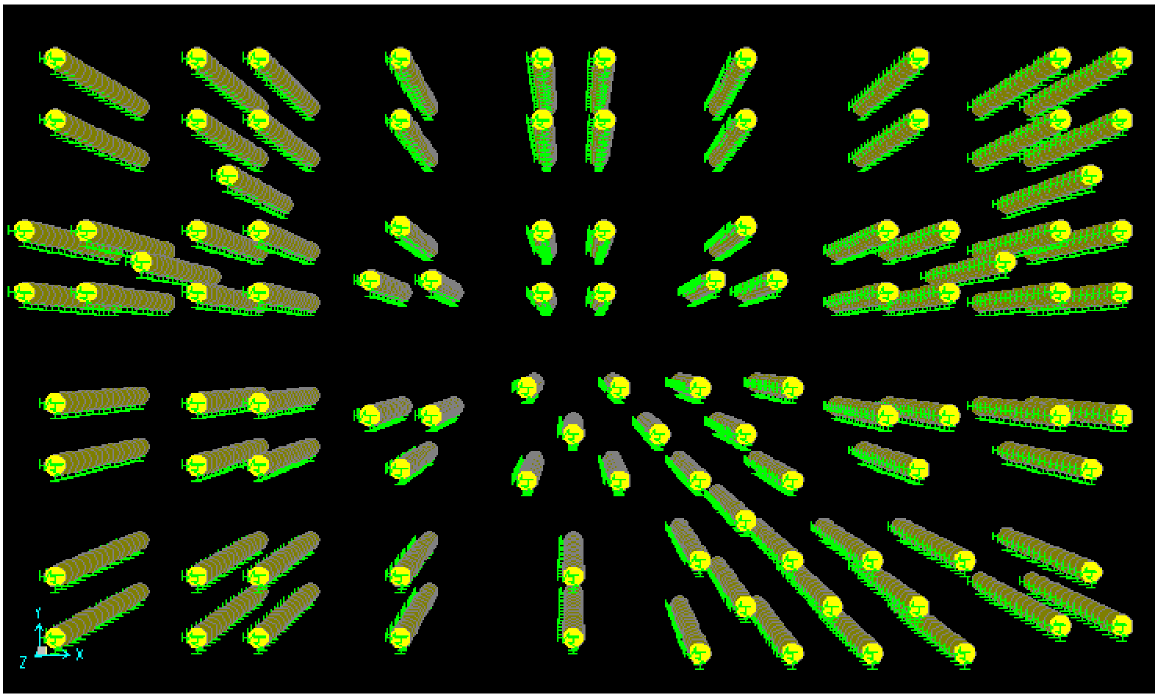

Figure13. 3D model of AV tower piles and elastic supports. Top view of the piles, from the ground surface (extrude view).

In 2010, several calculation models of this building were made. Most of them had a low practical value. Currently, only this one that is not fully complete is preserved. Due to the limited resources of the old computers, a new model will probably be made on a new computer with stronger resources, which is often easier than repairing an old complex model. If the need arises, the influence of caverns in the soil can be examined on a "stronger" computer, but some geomechanical survey of the soil under and in the immediate vicinity of the building should be performed first.

7 ANALYSIS OF THE SOIL-STRUCTURE INTERACTION PROBLEM

Some important analyzes can be performed by pure reasoning, based on knowledge of structures and geomechanics. Namely, the fact that the building is buried has its pros and cons. The technical floor is located in the basement, which makes any leak potentially unfavourable for the stability [4] and durability of the structure. On the other hand, the buried walls of the basement activate the resistance of the soil, if it is well compacted, and due to the action of horizontal forces, in certain cases it can considerably take the load off the pile heads. Therefore, it is necessary to examine not only the condition of the soil under the slab, but also 5 m around the basement walls of the building.

The building is based on Franki piles with a diameter of 520 mm. The groups consist of 2, 3, 4 and 5 piles. The groups are interconnected by RC connecting beams.

If there are larger caverns in the ground, either as a result of leakage of installations or weather, they can have an effect on the heads of piles during the earthquake, similar to liquefaction [1] [3]. It is assumed that the top few meters of the soil are covered with loose sand. Geomechanical data from neighbouring facilities may also be useful in the analysis. The Naftagas facility, built in the late 1980s, is also based on piles, but drilled HW, with a diameter of 800 mm and 1000 mm. During the driving of the steel pipe, a layer of hard clay about 2 m thick was found under one part of the building, which made it much more difficult to remove the pipe. The Mercator building, built in the first decade of the 21st century, has a combined effect of slabs and piles in the event of an earthquake. The Panorama facility was founded on RC diaphragms, but due to the change in the method of groundwater pumping in the foundation construction (so-called "saving"), after the commissioning of the facility, there were problems with groundwater on the lowest floor. During the geomechanical excavation of the first few meters of soil layers in Novi Sad's Liman areas, one can find dredged sand, light soil, mud, embankment, rubble, compacted clay, fine-grained gravel and the like. These are potentially very complex foundation constructing problems.

6 Conclusion

Considering that one beautiful Žeželj's bridge in Novi Sad was destroyed during the NATO aggression on the FRY, this building should be preserved for future generations because it represents one of the important features of the development of the IMS (system). It should therefore be declared a cultural asset, or at least listed as a cultural monument. When determining and prescribing the degree of protection, it should be borne in mind that the building has several owners, potentially a lot of work for the legal teams due to changed circumstances. Figure 1 also shows the outdoor air conditioning units, which are significantly present across the floors, so the possibility of introducing either a central or mobile type of air conditioning should be considered. Certain parts of the façade have been replaced by more energy-efficient joinery, so this protection should not be diminished by interventions. Three vertical downspouts pass through the interior of the building and in winter it presents a problem if some floors, especially the upper ones, are not heated.

Also in the assessment of the service life of a building and maintenance, the phenomenon of soil-structure interaction becomes progressively prominent [5] [6], as well as the changing and extreme weather-climate effects.

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