



Dissertation

Master in civil engineering

***Calculation and comparison of steel structures of public  
building considering the seismic loads according to the  
Ukraine Norms***

**Zhmykhova Veronika**

Leiria, 2018



Dissertation

Master in civil engineering

***Calculation and comparison of steel structures of public building considering the seismic loads according to the Ukraine Norms***

**Zhmykhova Veronika**

Dissertation developed under the supervision of professor Hugo Filipe Pinheiro Rodrigues, adjunct professor at Department of Civil engineering of the Polytechnic Institute of Leiria and co-supervision of professor Sergiy Kolesnichenko , professor at the Donbas National Academy of Civil Engineering and Architecture .

Leiria, 2018

## Resumo

---

De acordo com os códigos de construção da Ucrânia B.1.1-12-2014 "Construção em regiões sísmicas da Ucrânia" [1] um edifício na Ucrânia pode sofrer os efeitos de ações sísmicas. Áreas com maior perigosidade estão localizadas na Ucrânia Ocidental, a região de Odessa e a Crimeia. Mapas de zoneamento sísmico geral, mostram que uma vez em 1000 anos com uma probabilidade de 10%, quase metade do território da Ucrânia pode ser submetido a um terremoto.

Atualmente, na concepção de edifícios e cálculo de estruturas fora das áreas da atividade sísmica mais perigosa geralmente não é considerado efeitos sísmicos. Em cargas sísmicas são calculadas apenas a construção de grau V.

A relevância deste tópico: A probabilidade de ocorrência de eventos sísmicos na Ucrânia que podem levar à destruição, perda de ativos e perdas de vidas humanas.

Caso de estudo: Estudar o grau de influência da ação sísmica na estrutura do edifício, dependendo da ação considerada.

Métodos de cálculo e análise:

- método dos elementos finitos, implementado no complexo de software SCAD;
- Análise do estado de tensão-deformação dos elementos estruturais e comparação dos mesmos com o máximo admissível.

Novidade científica. Determinação do impacto da carga sísmica nos esforços e nos deslocamentos da estrutura metálica do edifício por modelação numérica de diferentes intensidades sísmicas.

Palavras-chave: ação sísmicas, modelo de cálculo, deslocamento, deformação, carga sísmica, modelação numérica, Ucrânia.

# Abstract

---

According to State Building Codes B.1.1-12-2014 "Construction in seismic regions of Ukraine" a building in Ukraine may be prone to seismic effects. Especially dangerous areas are the Western Ukraine, Odessa region and Crimea. Maps of general seismic zoning (GSZ), show that once in 1000 with a probability of 10%, almost half the territory of Ukraine may be subjected to an earthquake measuring at least 6 points.

Currently in the design of buildings and calculation of structures outside the areas of the most prone seismic activity is usually not to considered seismic effects. The seismic loads are calculated only building V grade.

The relevance of this topic: - The propability of earthquakes in Ukraine may lead to destruction and losses of assets and fatalities.

Subject of study. The degree of influence of seismic loading on the structure of the building, depending on the intensity of the earthquake.

Methods of calculation and analysis:

- finite element method, implemented in software complex SCAD;
- Analysis of the stress-strain state of structural elements and comparing them with the maximum permissible.

Scientific novelty. Determining the impact of seismic loading on stress and displacement in the steel frame of the building by numerical modeling at different intensity earthquake.

**Keywords:** seismic loads, calculation model, displacement, strain, seismic loading, seismic activity, stiffness, numerical modeling, Ukraine.

## List of figures

---

- Fig. 2.1. The new seismic zoning map of Ukraine for 1000 years return period repeat
- Fig.2.2. Example building design complex shapes in seismic areas.
- Fig.2.3.1. Basic concepts of seismology.
- Fig. 2.3.2: longitudinal waves (compression or dilation).
- Fig. 2.3.3:Shear wave (shear wave).
- Fig. 2.3.4: Love surface waves.
- Fig. 2.3.5: Surface Rayleigh waves.
- Fig. 2.3.6. Akselerohrama, velosyhrama, seismograms.
- Fig. 3.1. Payment schemes buildings:  
a - as multimass console rod, b - in the form of cross multimass system, c - as a spatial dynamic model.
- Fig.4.1. Sectional building model
- Fig.4.2. Design model plan
- Fig.4.3. Diagram public buildings
- Fig. 5.1.1. Selected columns for analysis
- Fig. 5.1.2. Selected main beam analysis
- Fig. 6.2.3. Examples of systems energy-absorbing elastic-friction connections (a). Plastic energy-absorbing in communication systems steel frames (b).
- Fig.8.1. Location of additional bonds in the background.
- Fig.8.2. Location of bonds in the transverse direction.
- Fig.8.3. Location of bonds in the longitudinal direction.
- Fig. 6.1. Seismic protection classification methods.
- Fig.6.2.1. Example of Adaptive seismic isolation 1 - bearing risers, 2-coherent panel.

Fig.6.2.3. Examples of systems energy-absorbing elastic-friction connections (a). Plastic energy-absorbing in communication systems steel frames (b).

Fig.8.1. Location of additional bonds in the background.

Fig.8.2. Location of bonds in the transverse direction.

Fig.8.3. Location of bonds in the longitudinal direction.

## List of tables

---

Table 2.4.1 - MSK-64

Table 4.1 - The coefficients for the combination of static loads.

Table 4.2 - Values of coefficients for the seismic load combinations.

Table 5.1.1. Table of stresses and displacements from static loads.

Table 5.2.1 Table angles to cosines and their application of seismic loading.

Table 5.2.2. Comparison of static and seismic load in 5 points for selected elements.

Table 5.3.1. Comparison of static and seismic load in 6 points for selected elements.

Table 5.4.1. Comparison of static and seismic load in 7 points for selected elements.

Table 6.4.1. Comparison of seismic load in 6 points for a building with normal sections and buildings with sections increased by 20%.

Table 6.5.1. Comparison of stress and displacement values for normal and building buildings with additional structural elements.

## CONTENT

Resumo.....	3
Abstract.....	4
List of figures.....	5
List of tables.....	7
Chapter 1.....	10
1.1 Introduction.....	10
1.2 Objectives on Motivation.....	10
1.3 Organization of the document.....	11
Chapter 2 The general state of the problem.....	13
2.1 Introduction.....	13
2.2 Basic requirements for the consruction in seismic areas....	14
2.3 Basic concepts of earthquake.....	20
2.4 Crading scale earthquake.....	24
2.5 Seismocity different regions of Ukraine.....	28
2.6 Maps zoning of Ukraine.....	31
Chapter 3 Methods based on seismic loads.....	39
3.1 Spectral method of calculation.....	40
Chapter 4 Program and methodology of experimental studies of numerous changes of stresses and displacements in the metal frame of seismic loads.....	44
4.1 Methods of analysis of the calculation results.....	46
4.2 Initial data studied building.....	47
Chapter 5 Study changes in stresses and displacements metal frame of the building from seismic loadind at 5,6,7 points.....	51
5.1 Calculation and analysis of stresses and displacements in the metal frame of the building static loads.....	58
5.2 Calculation and analysis of stresses and displacements in the metal frame of the building from seismic load intensity of 5 points.....	74

5.3 Calculation and analysis of stresses and displacements in the metal frame of the building from seismic load intensity of 6 points.....	79
5.4 Calculation and analysis of stresses and displacements in the metal frame of the building from seismic load intensity of 7 points.....	85
6. Methods seismic protection. General features methods.....	86
6.1 Traditional methods provide earthquake resistance.....	86
6.2 Special seismic protection.....	88
6.3 Strengthening the building frame sections basic way to increase the load-bearing structures.....	91
6.4 Boost frame building means the installation of additional structural elements.....	96
7. Recommendations for the design of the results of the calculation.....	104
8. General conclusions on research.....	106
References.....	107

# **Chapter 1 Introduction**

## **1.1 - Introduction**

Portugal is located in an active seismic zone. The quake there can be up to eight points or more. On average earthquake happens 1 time in 2 years. The most devastating and deadly earthquake struck Oct. 1, 1755, while Lisbon - Portuguese capital, has turned into ruins. The strength of this earthquake according to data of geologists was about 8.7 magnitude. This event was starting to the birth of modern seismology [19].

According to State Building Codes B.1.1-12-2014 "Construction in seismic regions of Ukraine" [1] building in Ukraine may be prone to seismic effects. Especially dangerous areas are the Western Ukraine, Odessa region and Crimea. Maps of general seismic zoning (GSZ), show that once in 1000 with a probability of 10%, almost half the territory of Ukraine may be subjected to an earthquake measuring at least 6 points. According Ukrgeology earthquakes seismicity of these areas can grow two or more times.

Currently in the design of buildings and calculation of structures outside the areas of the most dangerous seismic activity is

usually not considered seismic effects. In seismic loads are calculated only building V grade.

The relevance of this topic - the likelihood of earthquakes on the MSK-64 6 - points or more in most parts of Ukraine. Not account such important factors may lead to destruction of, loss of assets and the worst - death.

## **1.2 – Objectives and Motivation**

The main objective of the present study is to analyze the impact of seismic loads in tension and moving elements in the frame of the building in the area of seismic activity, namely by:

- Examine the existing methods based on seismic loads;
- Evaluate the effect on a a public building design model in the software sector SCAD;
- Apply to the calculation model is static, seismic activity and perform the calculation;
- Determine the change of stresses and displacements in the elements of the building from seismic load;
- Perform amplification by increasing the frame sections bearing structures;
- Perform amplification by introducing a new constructive scheme yelementiv frame;
- Analyze the results and to recommend their choice of design and technical solutions frame building.

## **1.3 Organization of the Document**

The present work was organized in seven chapters. The present chapter introduces and explain the motivation for the work that has been developed.

Chapter 2 presents a review of the literature, which describes earthquakes in Ukraine, provides recommendations for designing for territories with seismic activity, and seismic measures that are applied in the territory of Ukraine.

Chapter 3 discusses methods for calculating buildings for seismic loads.

Chapter 4 presents a case study of a fourteen-story metal frame, designed in accordance with the building codes of Ukraine for construction in an inactive seismic zone. The methodology of developing an experimental model and analyzing the results is described.

In Chapter 5, considering the seismic design rules, the values of stresses and displacements under seismic load of intensity 5.6 and 7 points were obtained experimentally.

In Chapter 6, with the use of traditional methods, namely, increases in the cross-sections of load-bearing elements and the establishment of additional structural elements, the values of stresses and displacements for the same ballistics were also calculated.

In Chapter 7, based on the data of the foregoing sections, conclusions were drawn about the effectiveness of seismic protection methods and recommendations for design were given. The main conclusions and future work are presented.

# **CHAPTER 2 STATE OF THE PROBLEM**

## **2.1 Introduction**

In Ukraine the calculation, construction, reconstruction and overhaul of reinforced concrete, metal, stone, wood structures of buildings and structures erected or placed in areas with seismicity 6 points or higher on a scale of seismic intensity according to ISO B . 1.1-28: 2010 [20], to protect against the negative impact of seismic events on the safety of people and the preservation of material and cultural values carried out according to the requirements of State Building Code B.1.1-12: 2014 [1].

The International Geophysical Journal №3 2006 published an article "New maps of general seismic zoning of Ukraine. Model features long seismic hazard [19]. " According to this study, the probability of an earthquake and its power as a result of technological activities may increase by 2 points (Fig. 2.1). So the higher hazard zones in Ukraine are the Crimea and Odessa region.

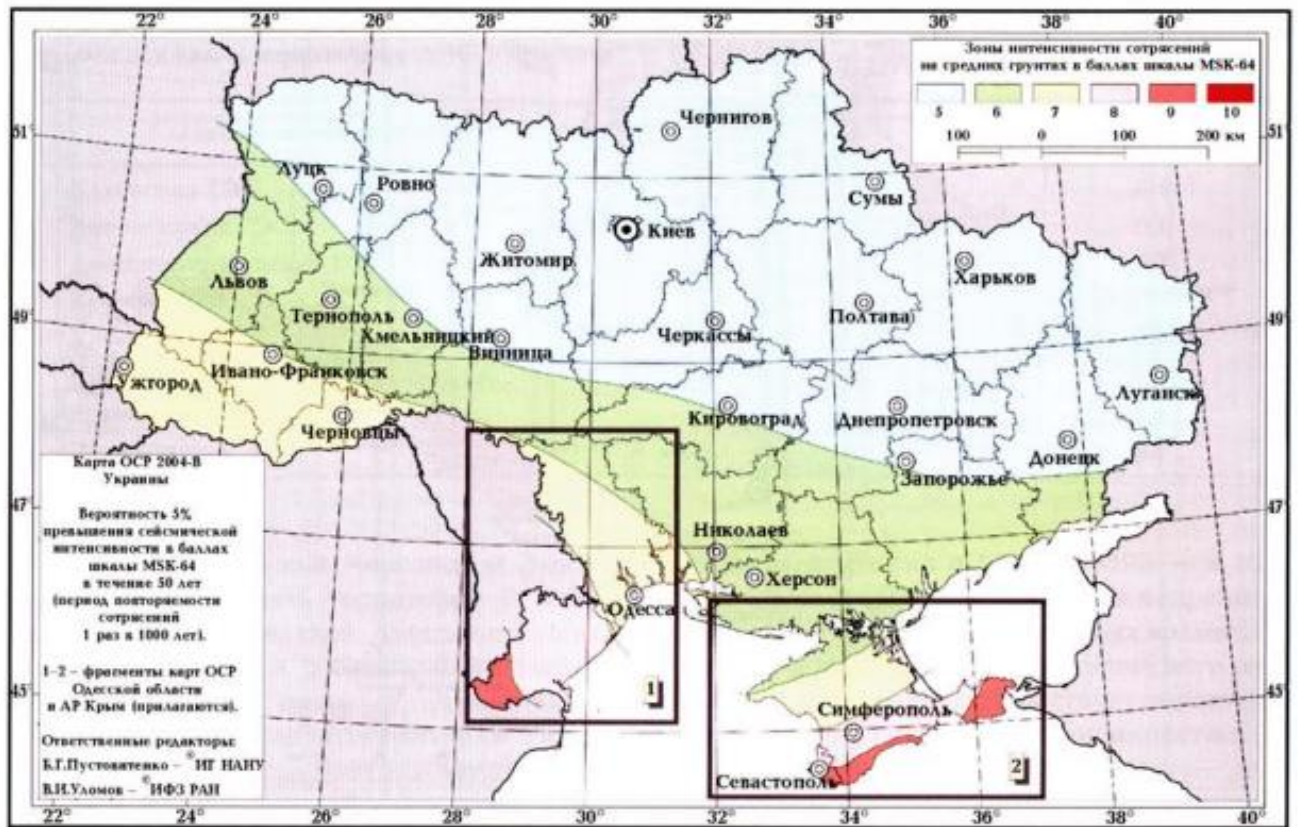


Fig. 2.1. The new seismic zoning map of Ukraine for 1000 years return period repeat.

## 2.2 Basic requirements for construction in seismic areas.

Basic requirements for construction in seismic areas are reduced to taking the following measures[1]:

1. The choice of sites for construction.
2. Select a constructive solution (CR) and space-planning decisions (ODA).
3. Ensuring high quality construction.
4. Separation buildings antiseismic seams. Building sites for settlements and structures are selected on the basis of geological

data, away from potential or apparent faults, away from steep slopes, threatening landslides and landslides. Unfavorable for building considered loose soils and fractured rock.

When choosing a site for development into account such things as seismic construction projects and seismicity of the construction site.

The ability of soils, buildings and structures to resist seismic called seismic. Measures to improve the earthquake resistance of buildings used in areas with seismicity of 7 points or higher. Normative justification for these measures carried out by State Building Code (SBC) C B.1.1-12: 2014. "Construction in seismic regions of Ukraine." For more seismic 9 points of capital construction of buildings is prohibited.

Seismicity construction site depends on the seismicity of the area and seismic soil, which are ground and are divided into categories. Seismic intensity construction site is determined based on the results of the seismic zoning (SZ), which is performed for areas with seismicity 6 points or more. In the absence of seismic zoning maps may be simplified definition seismic construction site on the basis of geological surveys.

When designing buildings usually take regulatory seismicity of the construction site, which corresponds to the second category. For soil category 1 settlement seismicity decreased by 1 point, and for soils 3rd category - increased by 1 point compared to normative. We know that buildings are constructed in seismically dangerous areas, are designed to meet the various criteria for the conduct of various intensity earthquakes.

When designing earthquake-resistant buildings adhere to the following principles:

1. The principle of symmetry, rigidity and weight should be distributed evenly and symmetrically about the plane of symmetry passing through the center of gravity of the building. That building project in terms of simple shape and symmetrical (circle, square, rectangle). Buildings complex shape in plan is divided into compartments simple form seismic seams in a pair of walls (wall of buildings) or the even frames (in frame buildings).

2. The principle of harmony, proportionality must be observed in the size of the building, with its length or height should not be very large. Limit the size, number of floors, the height of floors of buildings taken according to SBC B.1.1-12: 2014.

3. The principle anesthetic: to design the building as easier, with the center of gravity located low as possible.

4. The principle of elasticity of materials used in the construction of desirable durable, lightweight, having elastic properties; the design of which should have homogeneous properties.

5. Providing closed loop: load-bearing structural elements to be interconnected to form a closed loop both vertically and horizontally.

6. Ensuring reliability of foundations, structures for earthquake-resistant foundation should be strong enough deeply laid, preferably in layers of pliable or special substruksiyah substitute weak soils, to ensure consistency and strength of soil base. Belt teams lay the

foundations for one mark and make continuous. Pile foundation raft made low, buried in the ground. We recommend using a solid slab foundation. Basement is located under the whole compartment. In frame buildings Column footings interconnecting continuous reinforced concrete foundation beams in the form of cross belts.

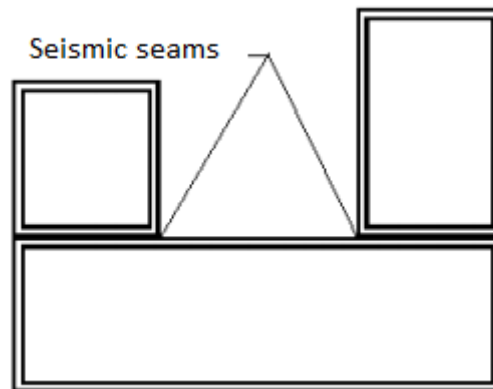


Fig.2.2. Example building design complex shapes in seismic areas.

7. Use seismic isolation: advisable to use devices that reduce the intensity of oscillatory processes transmitted from the ground to the building. During the construction of dams and bridges reinforce their base, arrange more gentle slopes. New construction buildings increase the cost of construction, but it eventually pays off, saving the lives of many people, saves from destruction expensive industrial facilities.

Buildings and facilities should be separated seismic seams in cases where:

- building or structure has a complex shape in plan;
- areas adjacent building or structure with elevation of 5 m or more. In single-storey buildings up to 10 m in settlement seismicity

of 7 points anti-seismic joints are allowed to organize. Seismic joints have to share buildings and structures across the top. Joints not arranged in the basement, except when a seismic seam coincides with a sedimentary layer. Stairwells should be closed, such as with external walls and window openings. The location and number of staircases should be determined by the calculation performed according to the requirements of SBC B.1.1-7-2016 "Protection against fires. Fire safety of buildings and structures" but take at least one staircase seismic seam between tall buildings over three storeys. Seismic joints should be performed by bringing the pair of walls or frames,

#### The strength of building materials seismic loads.

The strength of building materials and structures depends not only on the physical properties but is largely determined by the conditions in which they are operating under stress. In terms of earthquake strength characteristics of the material, of course, determined the seismic characteristics of the load. One of these features characteristic of any earthquake is the brevity of the load, that is a small number of cycles of its repetition. Another factor which is important for building structures and materials, is the frequency of the load. As shown by numerous experimental studies, structures vary with the frequency corresponding to the frequency of natural oscillations, regardless of the frequency of external influence. Same period of free oscillations of most buildings is about 0.1 ... 2.0 s, and, therefore, the frequency of dynamic loads affecting the building in terms of earthquakes be located primarily within 0.5 ... 10 Hz. Considering the carrying capacity of structures and materials, keep in mind that a strong earthquake - a phenomenon

relatively rare, so ensuring the operational usefulness of objects after the earthquake may be uneconomical since the service life of these buildings may be less than the recurrence period of strong earthquakes. Therefore, in earthquake engineering is not a requirement to ensure the full preservation and suitability for further operation of buildings that have undergone seismic loads; most importantly - to ensure the safety of people and the preservation of the most valuable property. Considering the carrying capacity of structures and materials, keep in mind that a strong earthquake - a phenomenon relatively rare, so ensuring the operational usefulness of objects after the earthquake may be uneconomical since the service life of these buildings may be less than the recurrence period of strong earthquakes. Therefore, in earthquake engineering is not a requirement to ensure the full preservation and suitability for further operation of buildings that have undergone seismic loads; most importantly - to ensure the safety of people and the preservation of the most valuable property. Considering the carrying capacity of structures and materials, keep in mind that a strong earthquake - a phenomenon relatively rare, so ensuring the operational usefulness of objects after the earthquake may be uneconomical since the service life of these buildings may be less than the recurrence period of strong earthquakes. Therefore, in earthquake engineering is not a requirement to ensure the full preservation and suitability for further operation of buildings that have undergone seismic loads; most importantly - to ensure the safety of people and the preservation of the most valuable property. since the lifespan of such buildings may be less than the recurrence period of strong earthquakes. Therefore, in earthquake engineering is not a requirement to ensure the full preservation and suitability

for further operation of buildings that have undergone seismic loads; most importantly - to ensure the safety of people and the preservation of the most valuable property. since the lifespan of such buildings may be less than the recurrence period of strong earthquakes. Therefore, in earthquake engineering is not a requirement to ensure the full preservation and suitability for further operation of buildings that have undergone seismic loads; most importantly - to ensure the safety of people and the preservation of the most valuable property.

### **2.3 Basic concepts of earthquake engineering**

Earthquake are oscillatory motion of the upper layers of soil strata. Earthquakes usually occur in zones of faults where tectonic processes are most active, and the strength of the crust is reduced. Seismic vibrations may also have other causes: explosions, rock bursts in underground mines, volcanic activity, traffic, etc. But such fluctuations are weaker and more usually felt only a short distance from the source of origin.

Deep land area covered by seismic dislocations, called a fire or earthquake hipotsentralnoy area and focus the projection to the surface of the Earth - epitsentralnoy area. Central point of this area is called the epicenter and the distance from it to the object - epicenter distance (Fig. 2.3.1).

The biggest strength of the earthquake is usually epitsentralnoy area. As the distance from the power of the earthquake it falls. Lines of equal strength earthquake that separate the different areas balnosti called Iseists (Fig. 2.3.1).

In appearance form isoseists affect focus, topography, soil conditions, and some other factors.

From earthquake to surface apply two types of seismic waves, called deep, longitudinal and transverse.

The longitudinal waves (compression or dilation) define compression - stretching soil volume element (Fig. 2.3.1). Particles in this range in the direction of wave propagation.

Shear wave (shear wave) shear strain determining the basic amount of soil (Fig. 2.3.3). Soil particles range in this perpendicular direction of wave propagation.

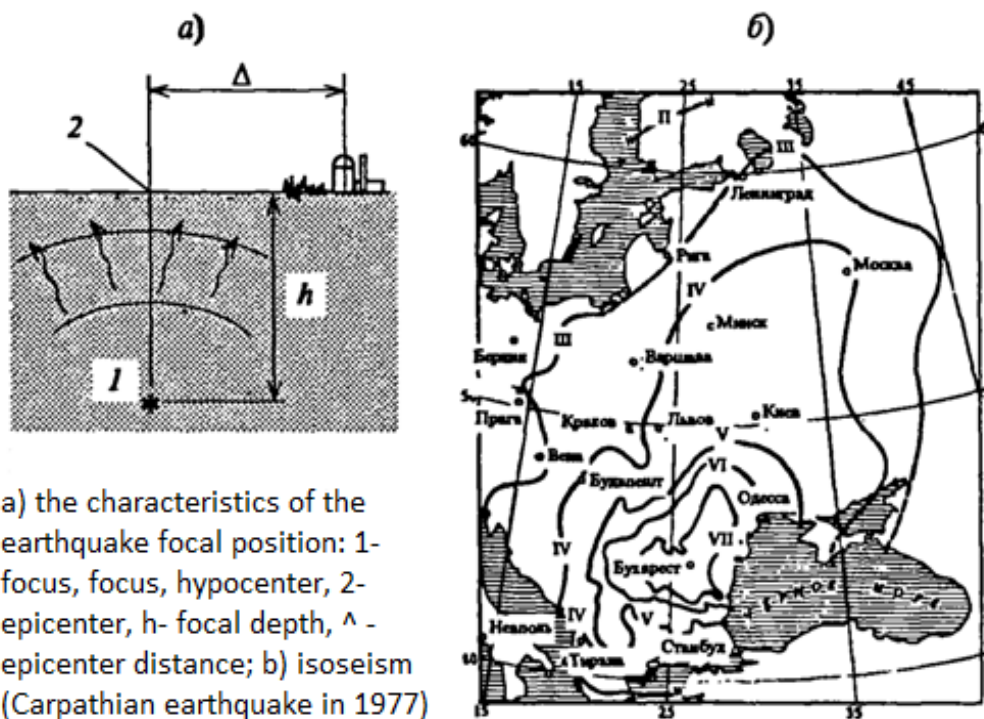
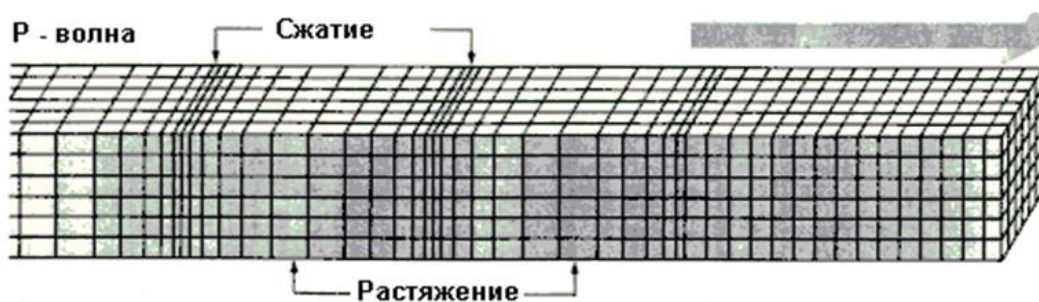


Fig.2.3.1. Basic concepts of seismology.

The reflection of deep waves of the earth's surface there



Rayleigh surface waves and Love. Rayleigh waves similar to waves on the surface, v. E. The particles are displaced perpendicular to the surface (Fig. 2.4), and Love waves shift occurs in the plane of the earth's surface.

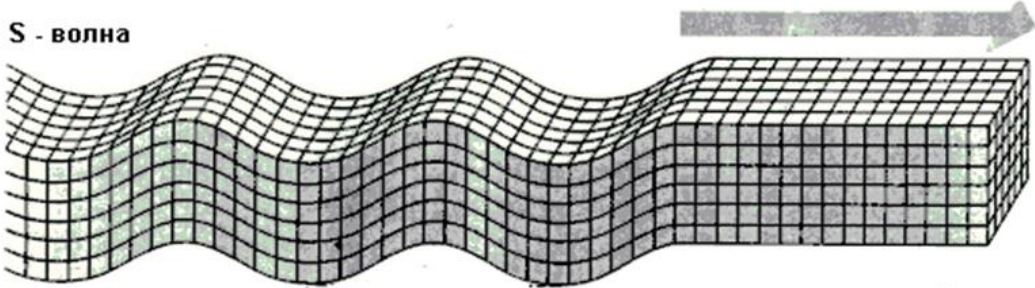


Fig.

2.3.2: longitudinal waves (compression or dilation).

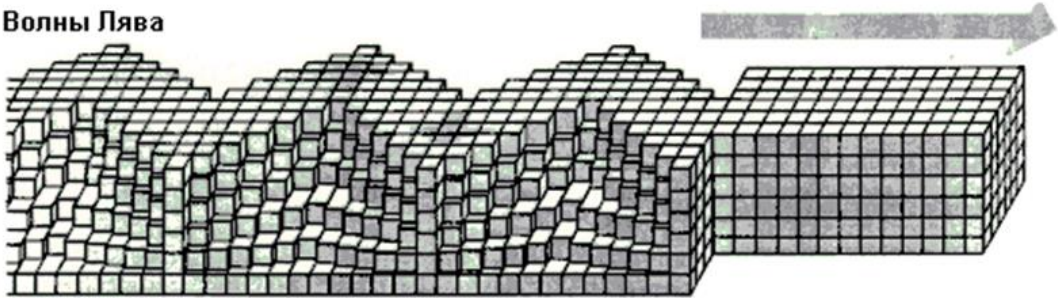


Fig. 2.3.4: Love surface waves.

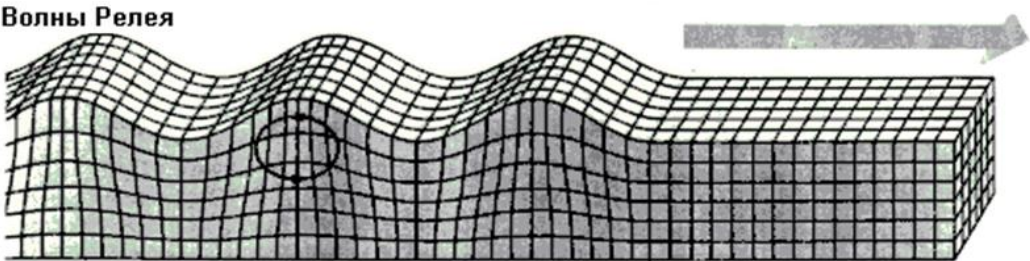


Fig. 2.3.5: Surface Rayleigh waves.

Velocity of deep waves depends on the density of the medium and its elastic properties. Shear waves propagate approximately 1.5

times slower longitudinal. Even less velocity of propagation of surface waves.

Therefore, during the earthquake exposed structures consistently longitudinal, transverse and surface waves.

Length of seismic waves and, therefore, the period seismic waves depend on the seismic fault. Since the rupture of the crust cracks appears a large number of different sizes and each of them at the time of its formation emits waves of the earthquake is characterized by a wide range of oscillations with a period of ten seconds to a few hundredths of a second.

Fluctuations in soil mass points during earthquakes are characterized seysmohramu, velosyhramy and akselerohramamy, representing a schedule change under displacement, velocity and acceleration discussed points in time (Fig.2.3.6) [2].

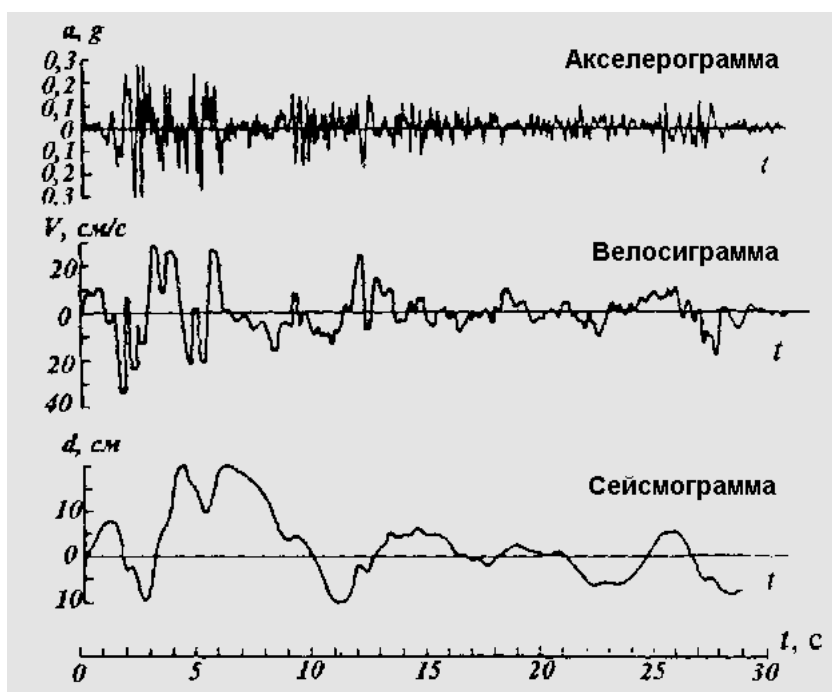


Fig. 2.3.6. Akselerohrama, velosyhrama, seismograms.

## **2.4 Grading scale earthquake**

The degree of the impact of the earthquake on the objects reflected seismic scale scores depending on the degree of destruction of standard buildings, witness's sensations, changes in the earth's surface.

The intensity of the earthquake on the surface manifestation measured in points, depending on the depth of focus and magnitude earthquake, which is a measure of its energy. The maximum value of a certain magnitude approaching nine. The magnitude of total energy associated with earthquakes, but this relationship is not direct, but logarithmic, with increasing magnitude per unit of energy increases by 32 times, ie when the shock of magnitude 6 is released 32 times more energy than a magnitude 5 and nearly 1,000 times greater than a magnitude four. The intensity is greater the closer to the center of the surface is, for example, if the earthquake with a magnitude equal to 8, at a depth of 10 km, the intensity of the surface will be 11-12 points, with the same magnitude, but at a depth of 40 - 50 km impact on the surface is reduced to 9.10 points.

Developed several scales to determine the intensity of earthquakes. The first one was proposed in the 1883-1884 biennium. M. and F. Rossi trout, according to the intensity of this scale was measured in the range of 1 to 10 points. Later, in 1902, the US has developed a more advanced 12-point scale, known Mercalli Intensity Scale (named after the Italian volcanologist). This scale, modified, and now widely used by seismologists US and other countries. In our country and some European countries use 12-point international scale of earthquake intensity (MSK-64), known as the first letters of the authors (Medvedev-Shponhoyera-Karnyka).

The duration of earthquakes is different, often creates a number of aftershocks swarm of earthquakes, including previous (Foreshock) and following (aftershock) shocks. Distribution of the strongest push (main earthquake) within the swarm is random. The magnitude of the strongest aftershock of 1.2 fewer than the main shock, aftershock those involving its secondary series of aftershocks.

All these scales have two parts: macroseismic (descriptive) and instrumental. The first sets of earthquake intensity based on subjective evaluations, the second - the quantitative characteristics of seismic ground motions obtained by instrumental records.

Table 2.4.1 - MSK-64 [21]

Mark	Criteria
One Point	Men do not feel an earthquake, except for isolated observers who are particularly sensitive places and in high position. The tremors are recorded only specialized seismographs.
Two Points	The earthquake is very weak. Fluctuations in soil felt few people who are alone, especially in the uppermost floors of the buildings located in the vicinity of the epicenter.
Three Points	Earthquake weak. Vibrations are felt in areas, mainly in the upper floors of tall buildings. During the earthquake swing hanging objects, especially chandeliers, creaking and begin to move the door dissolved. Those cars is starting to wobble slightly

	on springs. Some people are able to estimate the duration of the shock.
Four Points	Moderate earthquake. It is felt by many people, especially those who are in the room. Few people can feel an earthquake outdoors, and only those who currently is at rest. Some people on the night of the wake of the earthquake. At the time of the earthquake swing hanging objects, rattles windows, clap doors, ringing utensils, cracking wooden walls, cornices and ceilings. Visibly swaying on springs are cars.
Five Points	Tangible earthquake. It is felt by all people, wherever they are. Wake all sleeping. Doors swing open on hinges and spontaneously, banging shutters, closed and open windows. The liquid in the vessels swings and sometimes overflow. Beats of dishes, cracked glass, sometimes in plaster cracks, thrown furniture. Pendulum clocks stop. Sometimes swaying telegraph poles, supporting poles, trees are tall objects.
Six Points	A strong earthquake. It is felt by all people. Many people fear leaving the room. At the time of ground motion and after gait becomes unstable. Beat windows and glassware. Some objects fall from the table. Fall picture. Begins to move and thrown furniture. There are cracks on the walls in masonry. Visibly shaking trees and bushes.
Seven Points	A strong earthquake. People hardly kept on legs. In

	<p>instinctive fear of running out of space. Tremble suspended objects. Broken furniture. Many homes received severe damage. Chimneys break off at roofs. Plaster falls off badly stacked bricks, stones, tiles, cornices and parapets specifically unfortified. There are large cracks in the soil. The ongoing landslides and rock falls on stony and clay slopes. Involuntary bells are ringing. The rivers and open water mutniye water. Water splashed out of the pool. Crumbling concrete irrigation canals.</p>
Eight Points	<p>The devastating earthquake. Typical buildings receive significant damage. Sometimes partially destroyed. Old buildings are destroyed. There is a panel of lead frames. Swaying and falling furnace and factory chimneys, monuments, towers, columns, water towers. Broken pile. Break off branches of trees, there are cracks in the wet ground and on steep slopes.</p>
Nine Points	<p>The devastating earthquake. From the action of the earthquake there is panic. Buildings are destroyed. Seriously damaged dam and reservoir board. Torn underground pipelines. At the Earth's surface there are significant cracks.</p>
Ten Points	<p>Destroys earthquake. Most of the buildings crumbling to the ground. Afflict some well-built wooden structures and bridges. Serious damage to get the dams, embankments and dams. At the Earth's surface there are numerous cracks, some of which</p>

	<p>have a width of about 1 m. There are large gaps and large landslides. Water pouring out of the channels, riverbeds and lakes. Begin to move sand and clay soils on beaches and low-lying areas. Slightly bend rails for railways. Break large branches and trunks of trees.</p>
<p>Eleven Points</p>	<p>The catastrophic earthquake. There are still only a few particularly strong stone buildings. Crumbling dams, embankments and bridges. On the ground there are wide cracks that go deep into the subsoil. Underground pipelines completely breaking down. Strongly bubbled rails for railways. On the slopes there are large shifts.</p>
<p>Twelve Points</p>	<p>Strong catastrophic earthquake. Complete destruction of buildings. By drastically changing the landscape shifted rocky areas, zsuvatysya slopes, there are large gaps. Earth's surface is wavy. Formed waterfalls, new lakes, rivers change. Vegetation and animals are killed by landslides and scree. The debris of stones and objects vmetayutsya high into the air.</p>

## **2.5 Seismicity on Ukraine regions**

In Ukraine, the force of shocks and vibrations during earthquake made to measure 12-point scale of intensity. Also often

used magnitude (strength earthquake the Richter scale). Because its seismographs record and intensity determined by the force of destruction.

Significant seismic there are processes in western Ukraine, including Transcarpathia where once were earthquake intensity of 6-7 points. Epicenters these earthquakes were in the area Long, Teresva, Mukachevo, Uzhgorod. Earthquake Oct. 15 1834. (7 points) covered a large area of Transcarpathia (Svalyava about to Rakhov).

In the central part of Western Ukraine earthquake intensity of 6 points in the epicenter were recorded in Kamenka-Bug and Zalischyky. With in Chernivtsi region one earthquake recorded intensity 5 points.

South of Ternopil, Khmelnytsky, Vinnytsia and Odessa regions contours of isoseists intensity of 6 points. Isoseists to 5 extends north up to the line Berestechko-Rivne-Kiev-Pereyaslav-Khmelnytsky-Dnipropetrovsk. In the extreme south of Ternopil, Khmelnytsky, Vinnytsia and Odessa regions in the west are Isoseists intensity of 7 points. And these earthquakes occur here many times. Most earthquakes are associated with tectonic movements in the mountains Vrancea (On the border of South and East Carpathians in Romania).

For Crimea also characterized by intense (5-6 points) seismic activity. Crimean earthquake epicenters are usually located mainly in Black sea (Mainly between Alushta and Foros). For example, the earthquake Isoseists to 5 held November, 11th 1927, reached the extreme northern part of the peninsula; Isoseists earthquake of the same intensity to 8 points most of contours Crimean mountains.

Thus, a large area of southwestern and southern Ukraine belongs to the seismically unsafe. This fact must always be considered when justifying the placement of new construction.

Ukraine has a national network of seismic studies comprising 18 seismic and 14 integrated geophysical stations. The oldest is a seismic station "Lviv" Which is based 1899 year. Digital seismic station "Kiev" organized 1994, and is part of the Global Seismic Network.

For engineering and seismic assessments, an increase of seismicity in southern Ukraine than 1.5 points, and therefore it was determined that in some areas 30-50% area does not meet the current level of seismic risk and engineering.

In Donbass crust has a large enough capacity that is protection against earthquakes. At the beginning of the XX century recorded, weak seismic manifestations in Lisichansk and other places that did not cause significant damage. But in the Donbass well known dangerous manifestations of sudden coal and gas mining, rock bursts and other geodynamic phenomena. Periodic increase tectonic stresses caused by earthquakes, in conjunction with mining activity leads to disastrous consequences.

August 7, 2016 was occurred in the Donetsk region earthquake a magnitude of 4.6 points. The epicenter of the earthquake was located 78 km south of Donetsk and 21 km north of the town. Old Crimea Mariupol region, epicenter depth - 10 km.

As you can see, the threat of earthquakes is increasing every year, so even this seemingly quiet place on the planet as Ukraine, should be prepared for disasters. Most of the country is in a safe area, magnitude 4.5 earthquakes can not cause substantial damage or

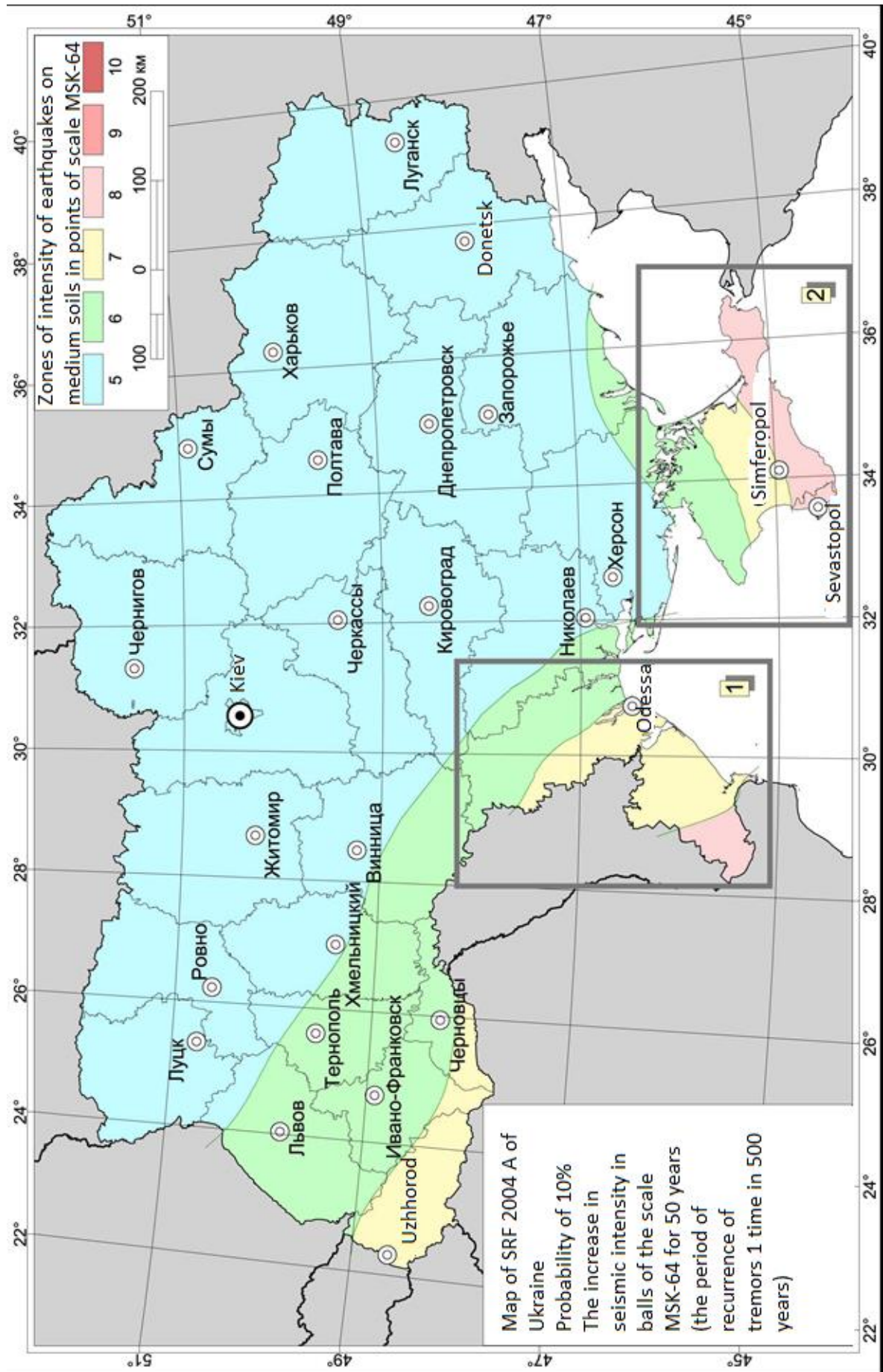
buildings or people. But it is necessary to consider the fact that the building and construction in Ukraine do not provide tremors, so more prone to mechanical damage due to possible earthquakes.

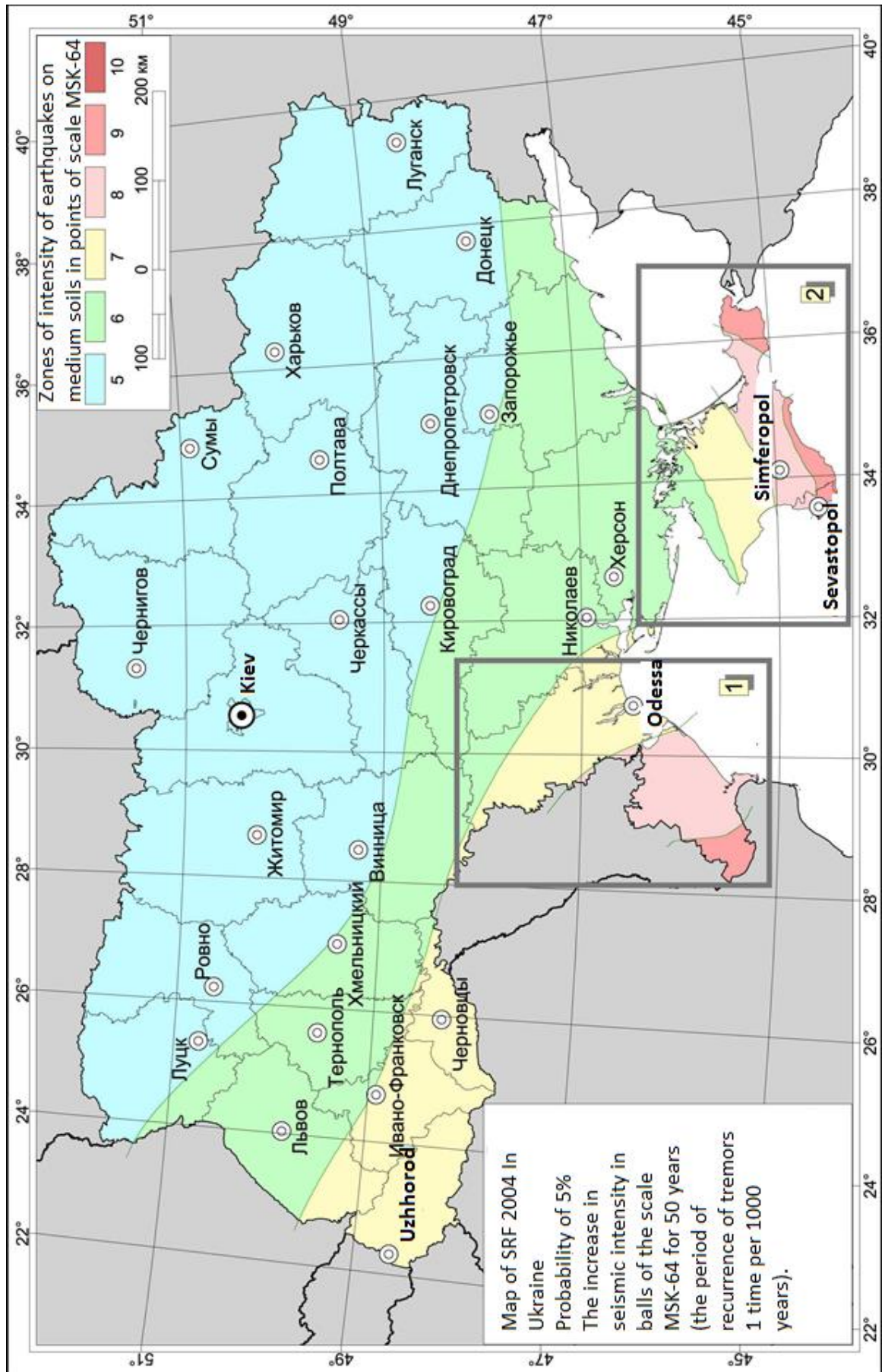
## **2.6 Maps zoning of Ukraine**

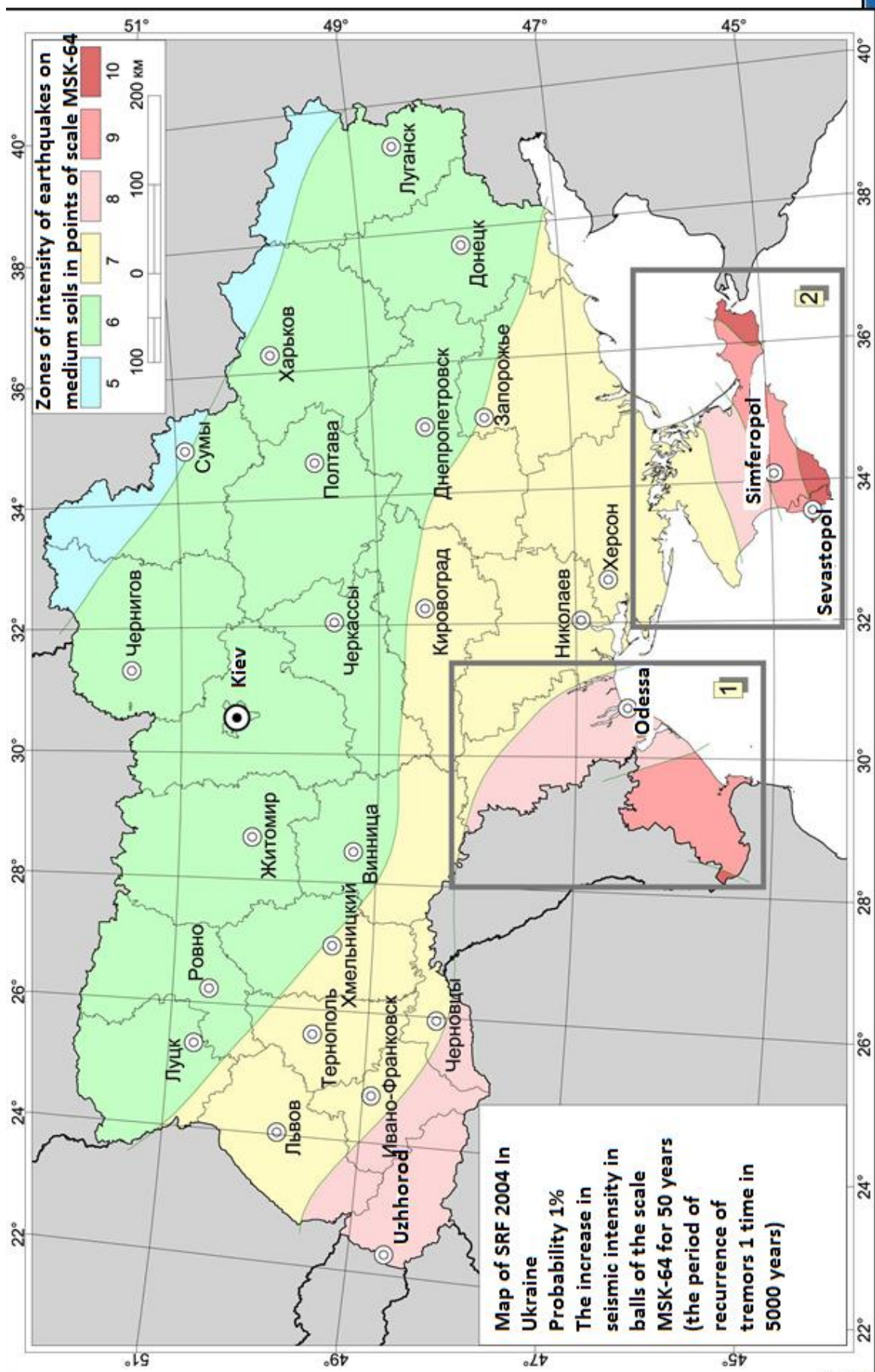
There are seismic zoning maps (Fig. 2.6.1.), That bear the same areas with the expected intensity of earthquakes. For such cards in Ukraine are in standards [1]. It should, however, bear in mind that these cards give the average ("background") intensity values, while devastating earthquake heavily dependent on the characteristics of the geological structure and soil conditions specific construction site. Therefore, when choosing sites for critical facilities, including nuclear power, carried out extensive geological and seismological research ("mikroseysmodivided") to determine the real seismic risk. [1]

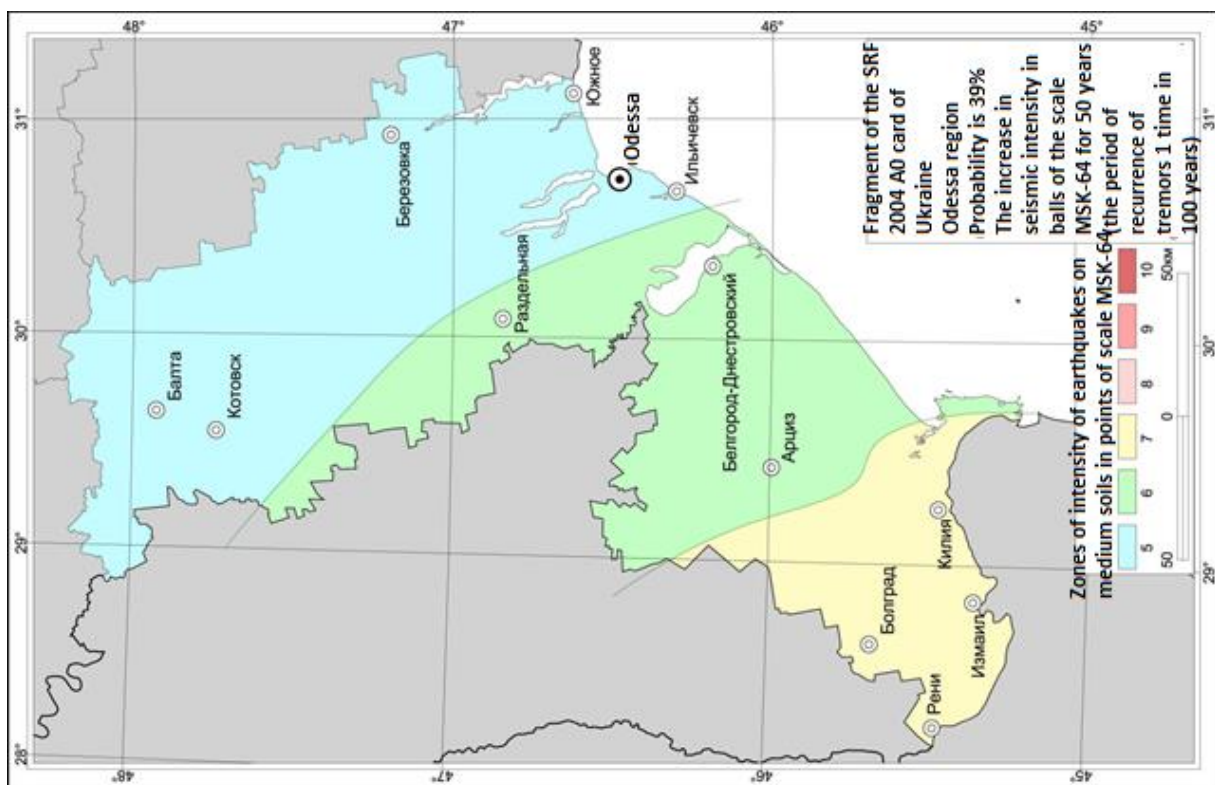
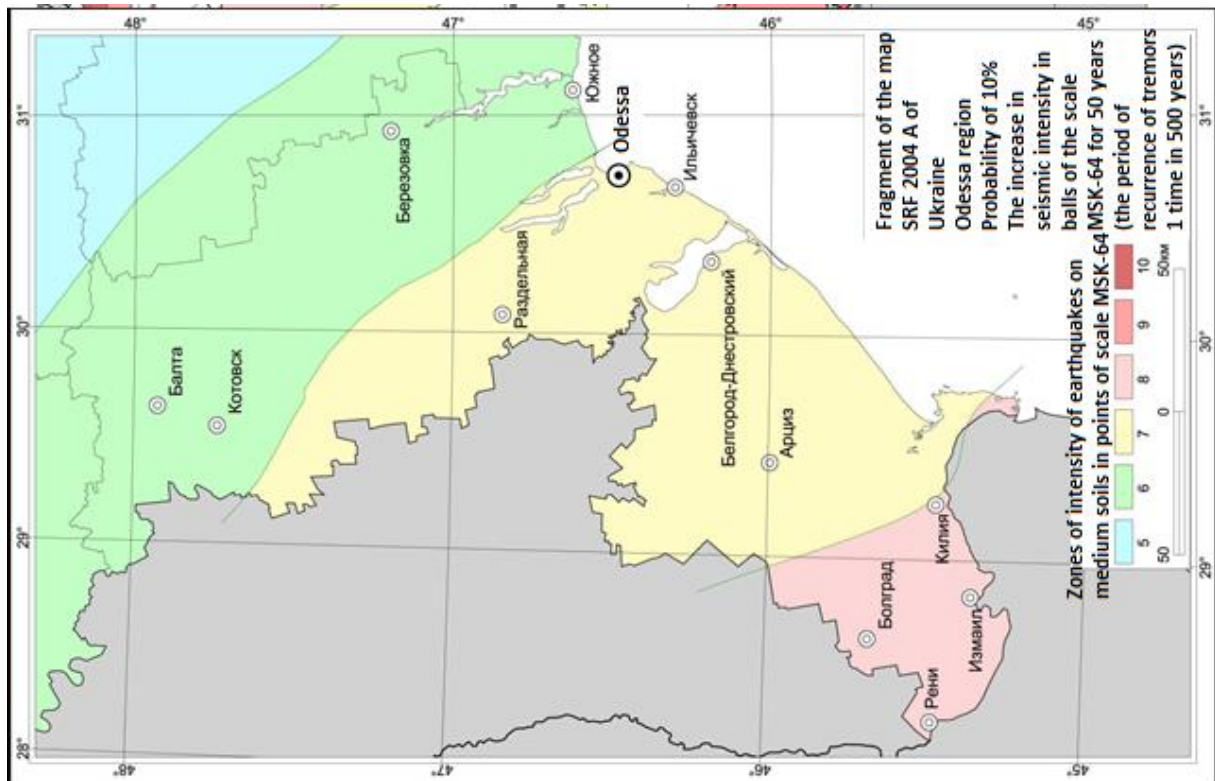
Maps of general seismic zoning (GSZ) in Ukraine with insert cards of the Autonomous Republic of Crimea and Odessa region with periods of recurrence once in 500 years (map A), 1000 (map B) and 5000 years (Map C) for medium soil conditions and probability exceeding the estimated intensity for 50 years, 10%, 5% and 1% respectively.

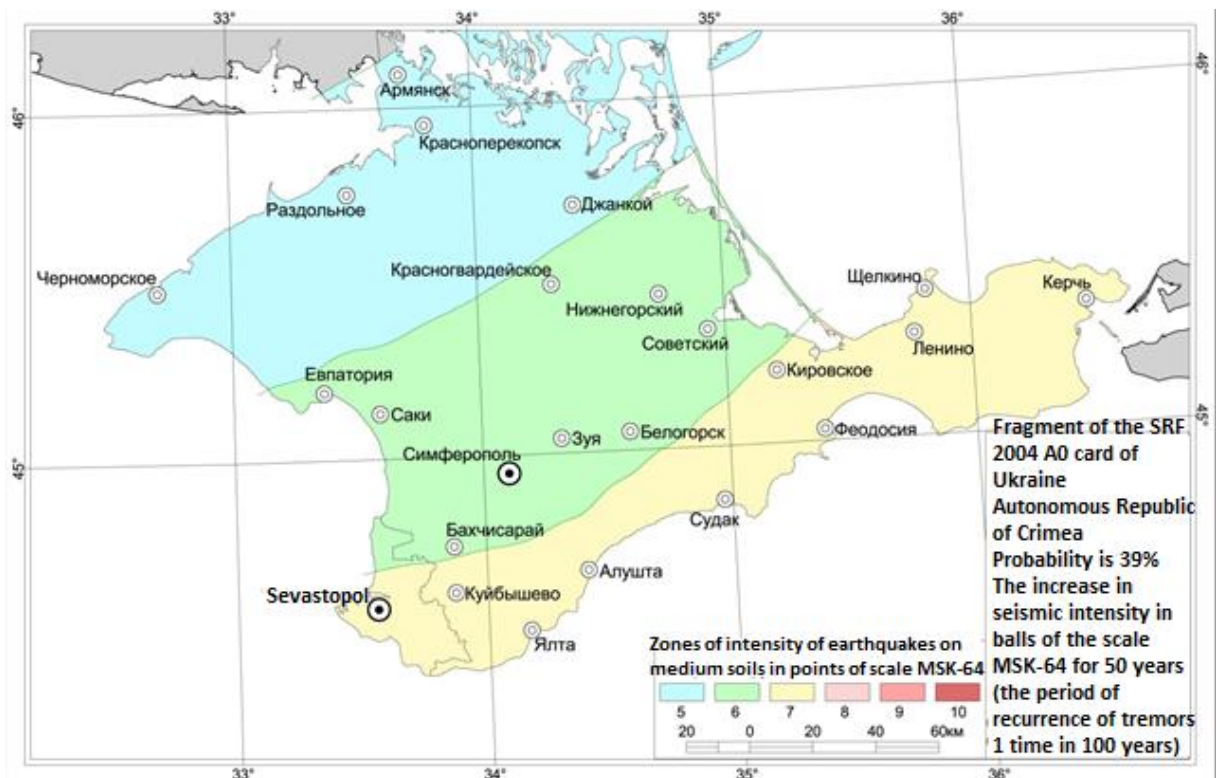
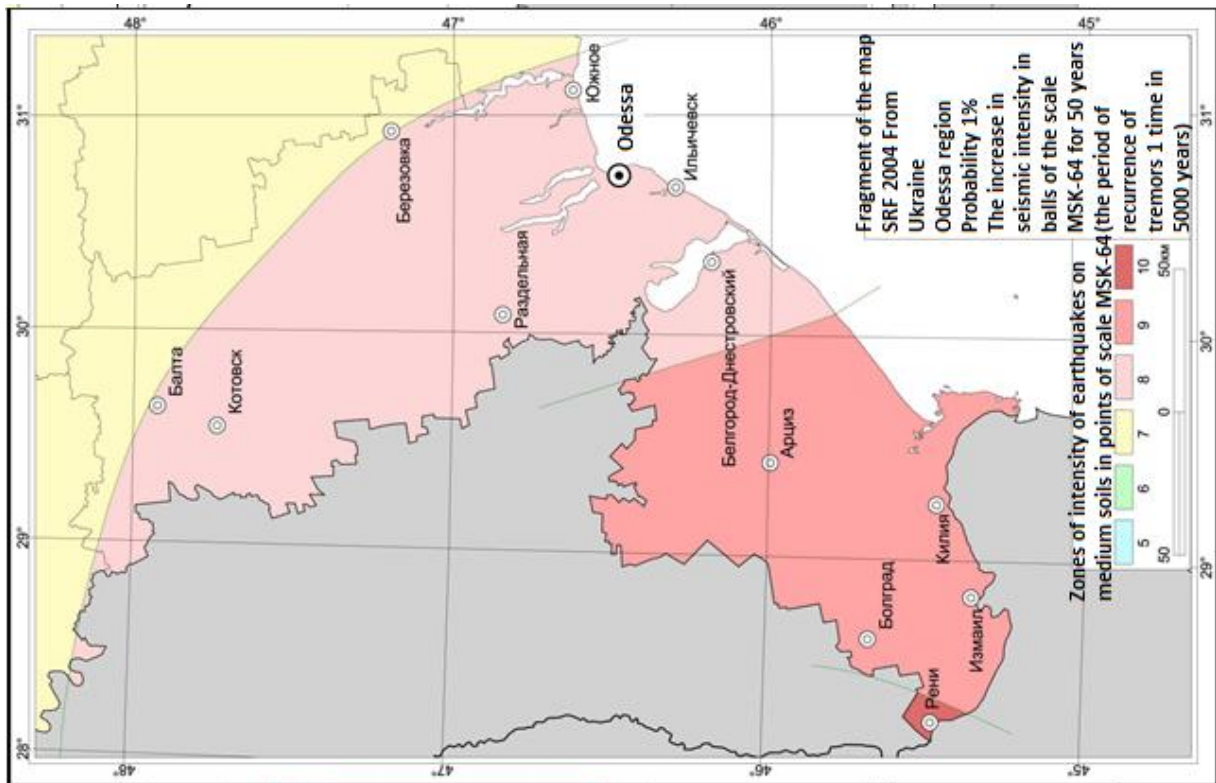
SRF Insert cards in AR Crimea and Odessa area, in addition to card A, B, C, supplemented by maps A0 for the average recurrence period of 100 years the probability of exceeding a given intensity 39% over 50 years [1].

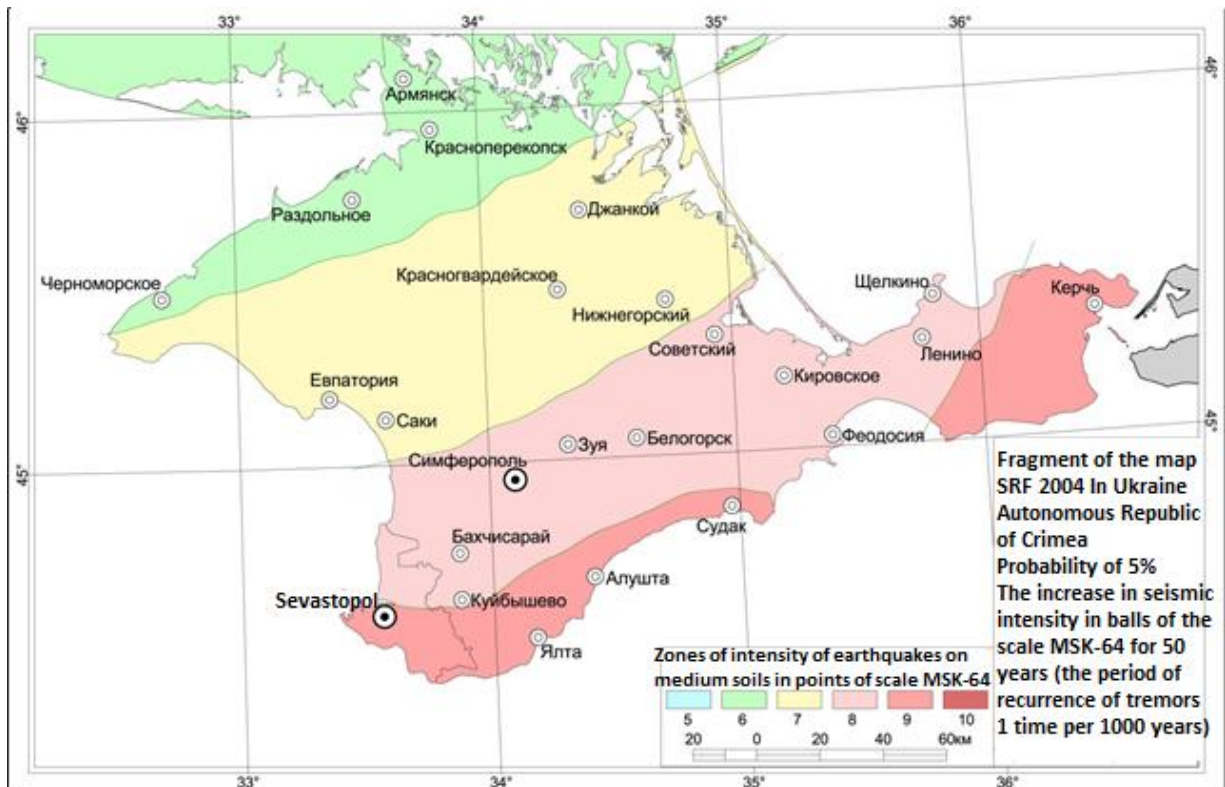
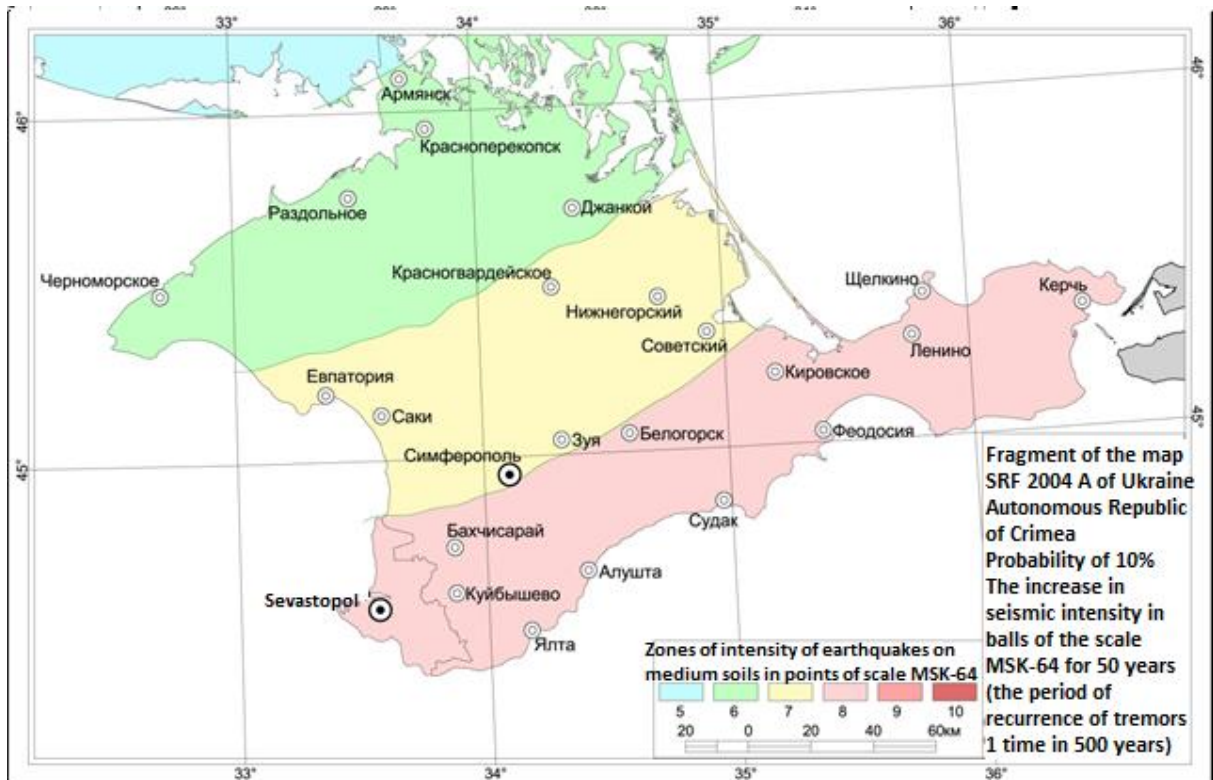












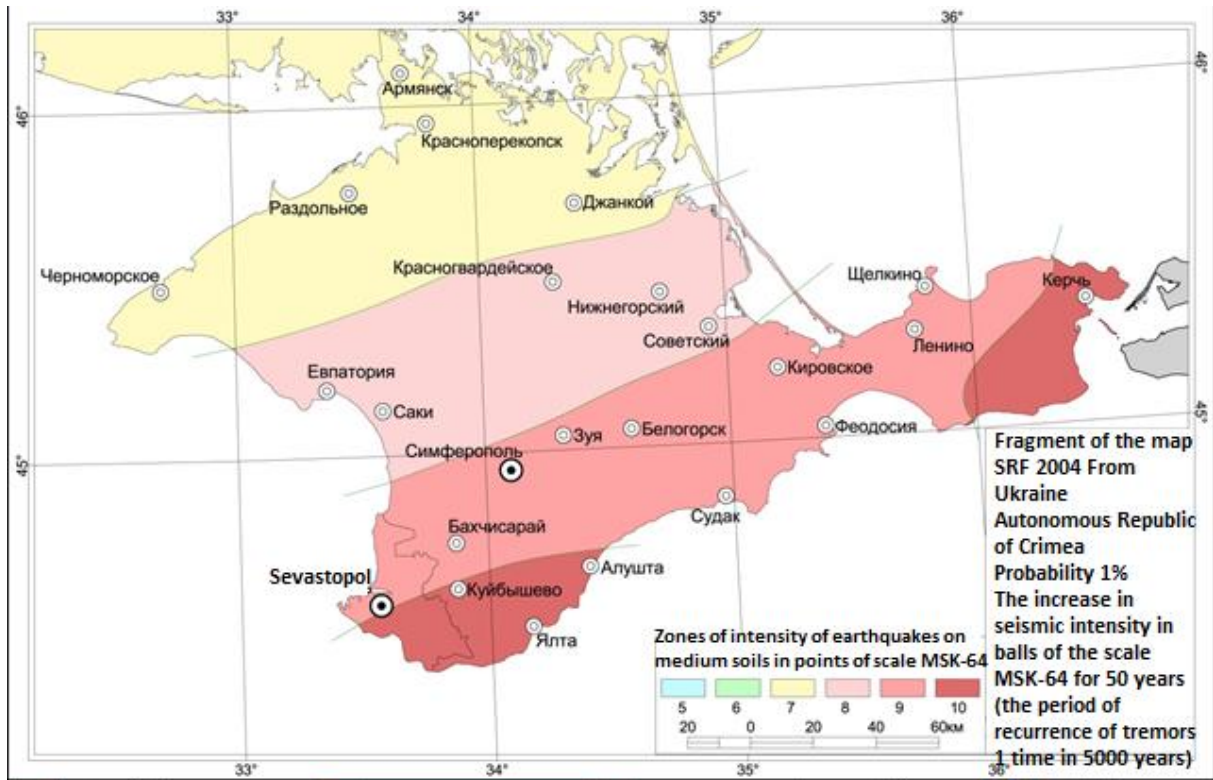


Fig. 2.4.1: SRF cards in Ukraine.[1]

# **Chapter 3 Methods based on seismic loads**

## **3.1. Introduction**

Calculation of structures and foundations of buildings and structures for construction in seismic areas should be carried out on the basic and special combination of loads based seismic action. In a special combination of loads include permanent, possible long-term and short-term loads, seismic actions and actions that caused deformities basis for soaking soil subsidence.

Calculations structures on the special combination of loads based seismic actions shall be implemented using:

a) spectral method - should be carried out for all buildings. This method is sufficient for works of simple geometric shapes symmetrical and regular deployment of mass and stiffness of the smallest size in terms of no more than 30 m;

b) direct dynamic method - using instrumental records acceleration of ground during earthquakes or standard set of synthesized accelerograms - for works particularly critical height of over 50 meters (over 16 floors) and structures with spans more than 30 meters or a fundamentally new design solution. In these calculations should consider the possibility of inelastic deformation structures. Seismic actions can have any direction directions in space. The maximum amplitude of acceleration grounds foundation, foundation should be taken at least 100, 200 or 400 cm/s<sup>2</sup> at seismic

construction sites 7, 8 and 9 points respectively. For buildings of simple geometric shapes estimated seismic load should be taken such that the horizontal force in the direction of longitudinal and transverse axes.

When calculating the structures of complex geometric shapes should be considered the most dangerous for the design or its elements directly sending seismic action. The vertical component of the seismic action must be considered in the calculation:

- console horizontal and inclined structures;
- span bridge structures;
- frames, arches, trusses, spatial coverages buildings span of 12 ... 24 meters or more, depending on the seismicity of the area;  
buildings, structures and foundations for stability against overturning or slip;
- high pile structures raft;
- strength load-bearing walls of masonry;
- seismic isolation support elements.

### **3.2. Spectral method of calculation.**

In determining the design values of horizontal seismic loads on buildings height  $H$  exceeding two or more times its width  $B$  and length  $L$  is allowed to make design scheme (Fig. 3.1, a) as multimass elastically deformed cantilever rod firmly fixed on basis, which is concentrated mass weight  $Q_k$ , located on level floors, and makes vibrate in one of the directions ( $x$  or  $y$ ). With the width of the building in which three or more times less than two of its other dimensions ( $H$  and  $L$ ), allowed to make design scheme (Fig. 3.1, b) as multimass elastic-deformed cross-system with concentrated at

nodes masses located on level floors. Typically, the recommended settlement spatial dynamic models with lumped masses at the nodes (Fig. 3.1, c).

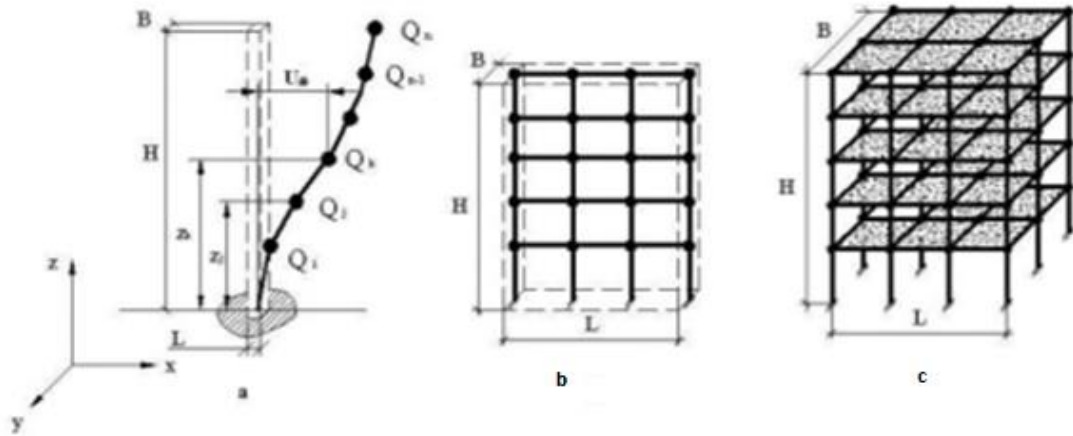


Fig. 3.1. Constructive schemes buildings:

a - as multimass console rod, b - in the form of cross multimass system, c - as a spatial dynamic model.

Estimated value of horizontal seismic load  $S_{ki}$ , applied to the point and meets  $k$   $i$ -th form of natural vibrations of a building or structure shall be determined by the formula:

$$S_{ki} = k_1 \cdot k_2 \cdot k_3 \cdot S_{0ki}$$

where  $k_1$  -factor considering inelastic deformation and damage to local buildings and elements taken from Table 2.3 [1];

$k_2$  - coefficient liability structure is taken from Table 2.4 [1];

$k_3$  - coefficient accounting storeys buildings over 5 floors, is given by:

$$k_3 = 1 + 0,06 \cdot (n - 5)$$

where  $n$  - number of floors in the building. Maximum  $k_3$  taken no more than 2.0 (including the frame, and the frame-v'yazevyh

v'yazyvyh systems) and for wall and modular wall systems design - less than 1.8;

$S_{0ki}$  - horizontal seismic load and th form of natural vibrations of structures determined assuming elastic deformation structures of the formula:

$$S_{0ki} = Q_k \cdot a_0 \cdot k_{rp} \cdot \beta_i \cdot \eta_{ki}$$

where  $Q_k$  - load weight corresponding adopted as concentrated at the point k and is determined by considering factors 2.1.1 [1].

$a_0$  - the relative acceleration of soil, which is assumed to be 0.05; 0.1; 0.2 and 0.4 respectively for seismic regions 6, 7, 8 and 9 points; using maps A and - depending on the calculated values A0 according to Table 2.5 [1].

$k_{rp}$  -factor taking into account nonlinear deformation of soil is introduced when determining seismic area made on the basis of geological engineering survey according to Table 1.1 [1], and is taken from Table 2.6 [1];

$\beta_i$  -dynamic spectral coefficient that corresponds to the first form of natural vibrations of a building or structure; adopted in accordance with 2.3.2 [1];

$\eta_{ki}$  -factor depending on the shape of natural oscillations of the building or structure and the location of the load (Figure 2.1 [1]); is given by:

a) cantilevered design scheme:

$$\eta_{ki} = \frac{U_i(z_k) \sum_{j=1}^n Q_j U_i(z_j)}{\sum_{j=1}^n Q_j U_i^2(z_j)}$$

where  $U_i(z_k)$  and  $U_i(z_j)$  - moving a building or structure with its own variations for the i-th form; n - number of concentrated loads;

b) cross-spatial and settlement schemes:

$$\eta_{ki} = \frac{U_i(z_k) \sum_{j=1}^n Q_j U_i(z_j) \cos(U_{ki}, U_0)}{\sum_{j=1}^n Q_j U_i^2(z_j)}$$

where  $\cos(U_{ki}, U_0)$  - cosines of the angles between the directions of movement  $U_{ki}$  seismic impact and vector  $U_0$ [1].

It is important to choose a number of forms of natural oscillations. There are times when their first 6-7 forms do not affect the decision. The direction of the seismic loading is given in combination SCAD program using direction cosines. It is necessary to go through many such areas, to find it a disadvantage, and they are different for different factors.

# Chapter 4 Case Study

## Introduction

To determine the changes in values of tension and displacement adopted is given constructive scheme of the building in the complex SCAD program. Was selected a building with irregular shape, consisting of two blocks. First block is a 14-storey building with a typical step column 6x6 m. Size in terms of 18x30. Floor height of 3 m. The second unit is a 10-story building the size of 9x9 m in plan, with a steel frame and rigid system of vertical connections.

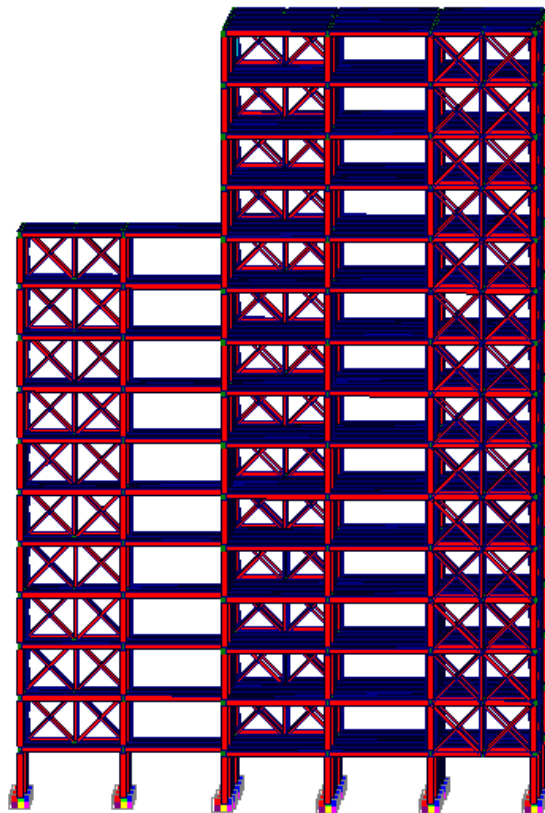


Fig.4.1. Sectional building model

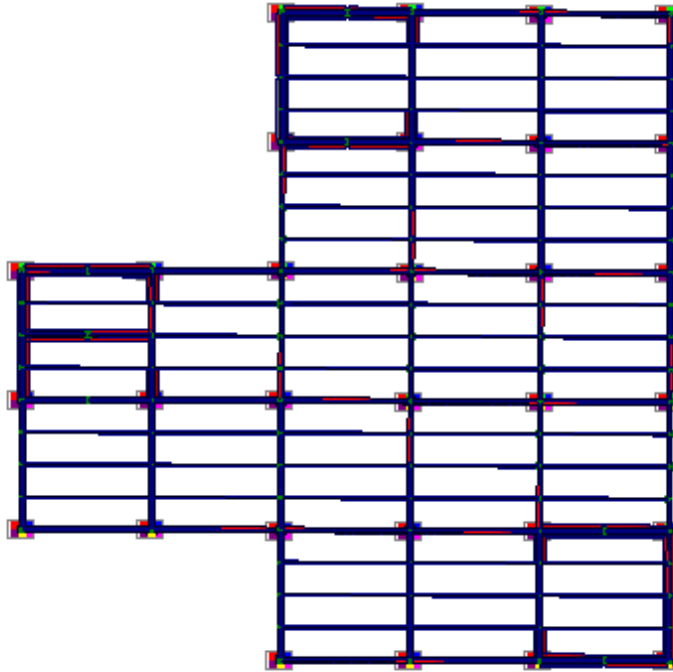


Fig.4.2. Design model plan

The procedure for forming the structural scheme of the building in the complex SCAD program:

- create a design model;
- will appoint stringent specifications of elements (elements sections taken according to calculations by the first and second group of boundary conditions)
- Assign a fastening column (tough conditions of stability)
- to apply load (own weight, snow, wind, poleznaya load)
- create a DCS (enter coefficients depending on the duration of load and consider mutually exclusive load)
- Check the permissible limit voltage and displacement
- to apply dynamic load (seismic force prykladyvaem 5, and 6 points)

- - choose characteristic analysis of constructions  
(columns, beams)
- - perform the calculation buildings
- - analyze the result

Table 4.1 - The coefficients for the combination of static loads.

Types of stress	The coefficient
1 Constant load	1
2 Long Load	0.95
3 Short load	0.9

Table 4.2 - Values of coefficients for the seismic load combinations.

Types of stress	The coefficient
1 Constant for concrete, stone and wooden	0.9
2 The same for metal constructions	0.95
3 Temporary prolonged	0.8
4 Short (on the floor and cover)	0.5

#### **4.1. Methods of analysis of the calculation results**

When processing data for the research results increase forces and displacements in the frame of the building with the variable number of floors of the seismic loading perform:

- analysis of the calculation results determined efforts and move from static load and DCS at certain points (nodes at abutment floor to ceiling columns), the values recorded in the table. The points, which are determined efforts and move selected based on their structural significance - abutment junction of the main beams to

columns, as well as the maximum in these forces and displacements;

- determine the movement of forces and seismic load of the same points (nodes at the overlap floor on pillars), the values recorded in the table;
- compare the significance of the values with valid regulations. If the values exceed permissible - wonder new baseline data;
- compare the significance of the values and express their attitude in %.

When processing data for the research results determine the degree of influence of seismic loading on the skeleton of the building depending on the intensity of the earthquake:

- determine the movement of forces and seismic loads at certain points (nodes at the overlap floor on pillars), the values recorded in the table;
- compare the significance of the values with valid regulations. Determine whether it is possible reduce the impact of seismic loading on the skeleton of the building. If yes - then adjust the estimated model building;
- compare the significance of the values and express their increase in%.

#### **4.2. Initial data studied building.**

Initial data:

- altitude - 119 m;
- wind area - 1;
- payload on the floor - 250 kg / m<sup>2</sup>;

- the building frame type;
- frame - steel;
- number of floors -14;
- building height - 42 m;
- floor height - 3.0 m;
- the basic step of columns - 6 x 6 m;
- column welded intersection 356h406h393;
- main beam - dvutavr №36,
- -dvutavr deck beams №24;
- Step main beams - 6 pm;
- a step deck girders - 1.5 m;
- the main beams are placed in the longitudinal direction;
- overlap - precast concrete;
- slab thickness - 220 mm;
- coating thickness - 200 mm.

### The design of the building.

In the SCAD program complex was developed calculation model building. Types of finite elements - spatial shaft (Fig. 4.3.).

Quantitative characteristics of the design scheme.

Design model is characterized by the following parameters:

Number of elements - 1581

Finite Element number - 4551

The total number of unknown displacement and rotation - 381648

Number of downloads - 15

The number of combinations downloads - 4 (7)

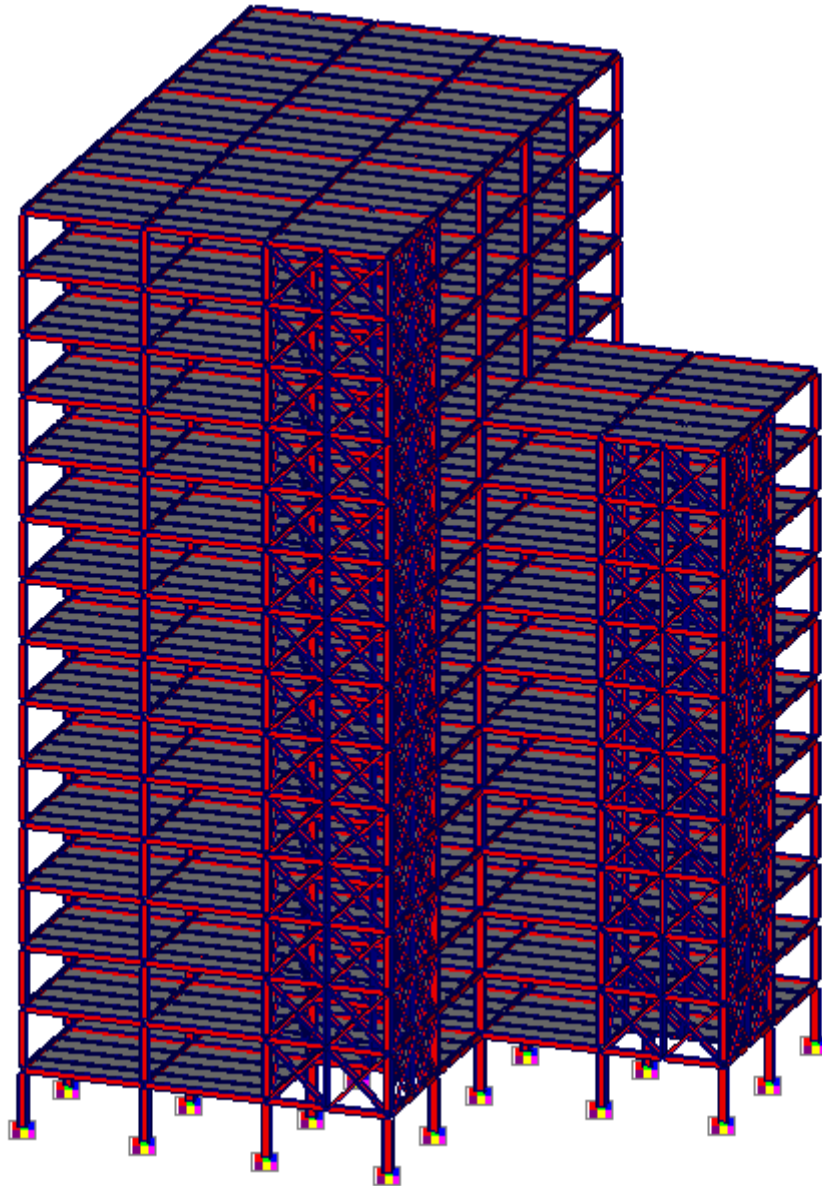


Fig.4.3. Diagram public buildings

Conclusions:

1. A calculation model of the building in the complex SCAD program.
2. Before the calculation model applied static and seismic loading.
3. Determined efforts and moving in the frame of the building.

4. For the calculation takes 6 forms with different periods:

Form 1 period 2.67 sec  
Form 2 period 2.21 sec  
Form 3 period 1.69 sec  
Form 4 period 0.87sec  
Form 5 period 0.70 sec  
Form 6 period 0.59 sec.

For values entered in the table, form 2 was adopted for a period of 2.21 seconds. As the most unfavorable with the maximum values of stresses and displacements.

# **Chapter 5 Result analysis**

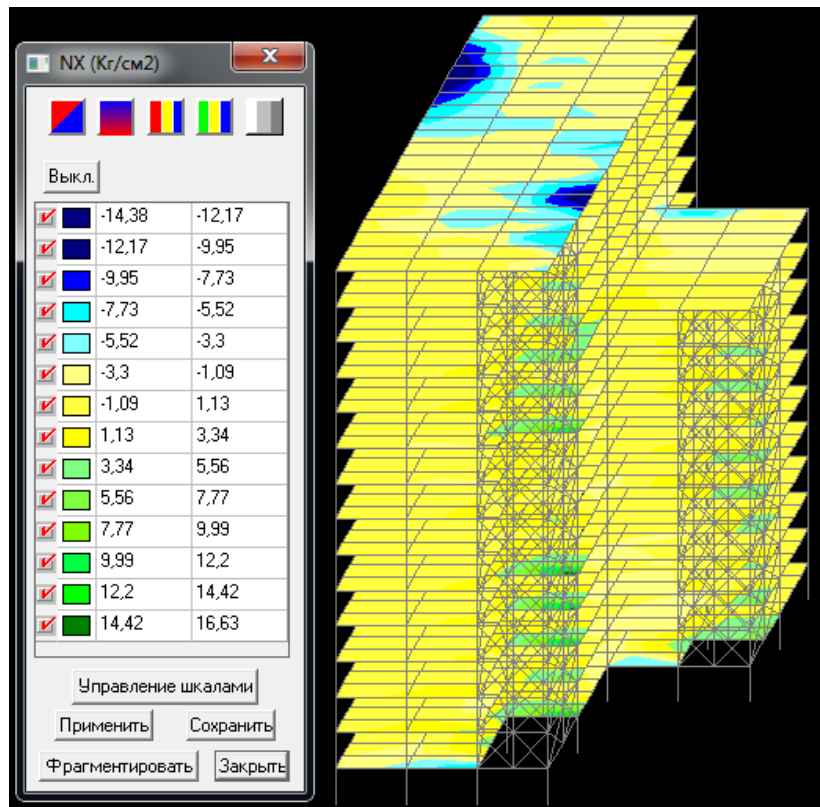
## **5.1. Introduction**

To study the changes of stresses and displacements in steel frame public buildings was applied load at 5, 6, and 7 points. For selected for analysis items the frame of the building calculate the stress and displacement under seismic loading and comparable static. Depending on how many times the increased examined characteristics will depend recommended ways to increase seismic frame.

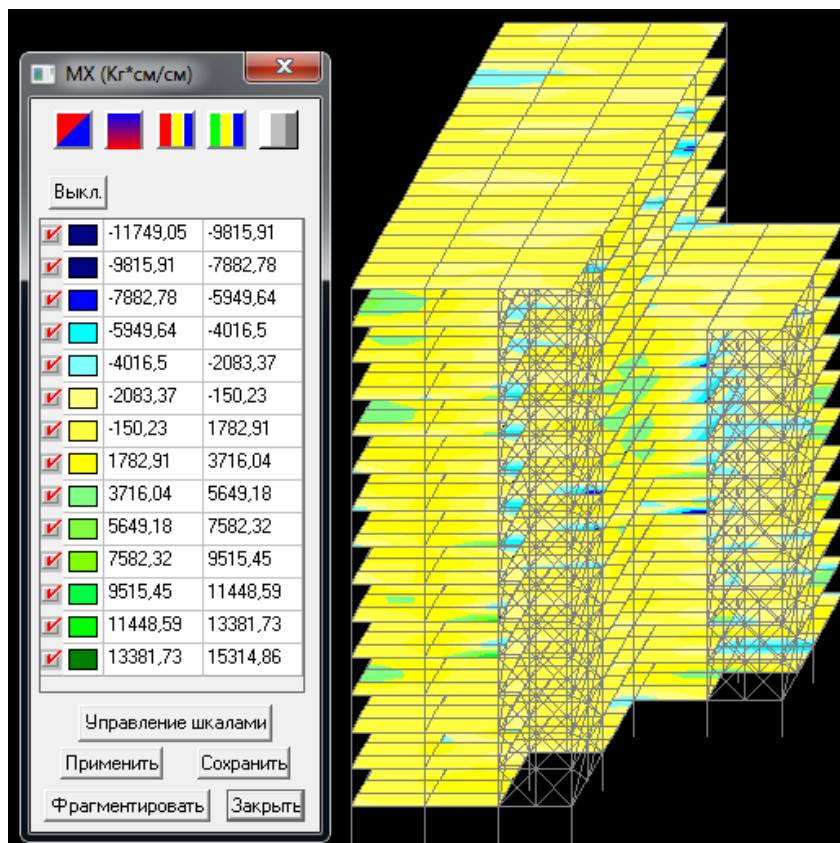
## **5.2. Calculation and analysis of stresses and displacements in the metal frame of the building static loads.**

The calculation considered the most unfavorable combination of loads. Until such schemes applied load, self-weight construction, wind and snow load payload. Loading collected in the estimated load combination with appropriate coefficients. After loading and calculation were obtained the following results:

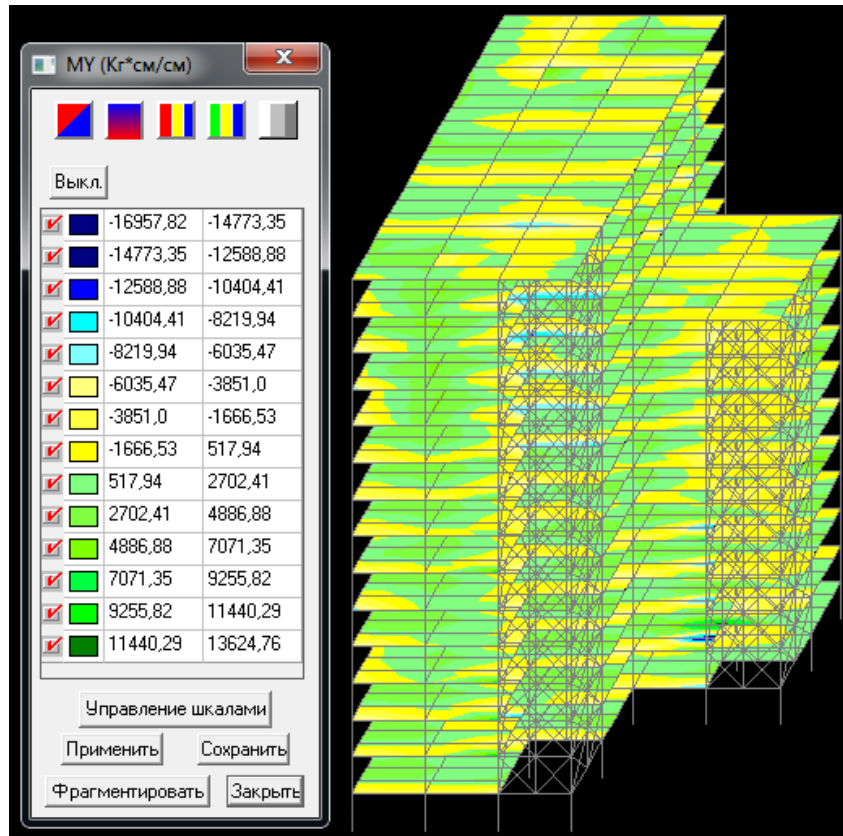
Paul stresses  $N_x$  at calculation of the combination of efforts



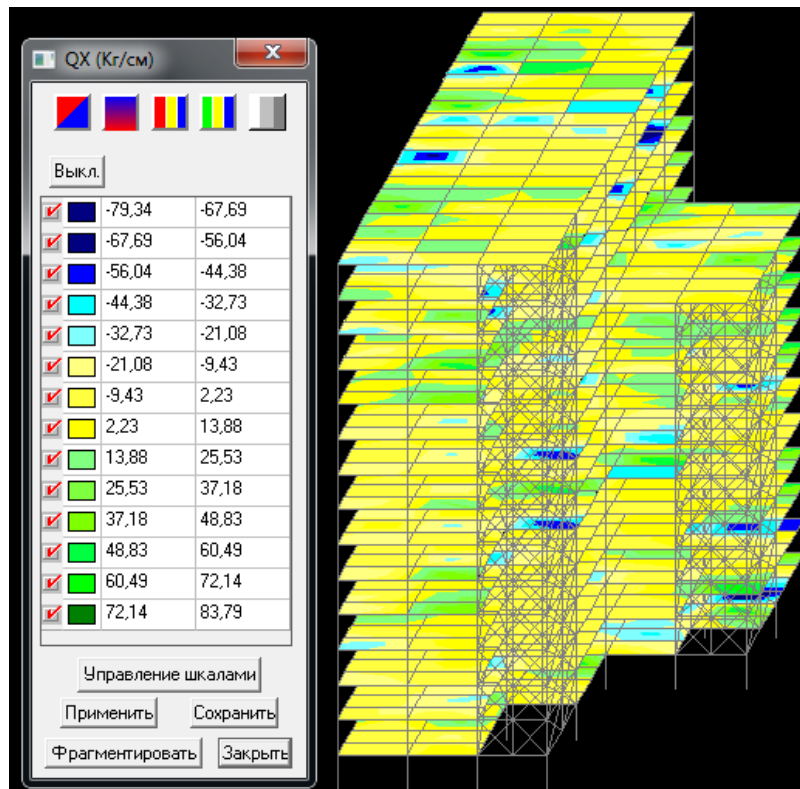
MX stress field in the calculation of the combination of efforts



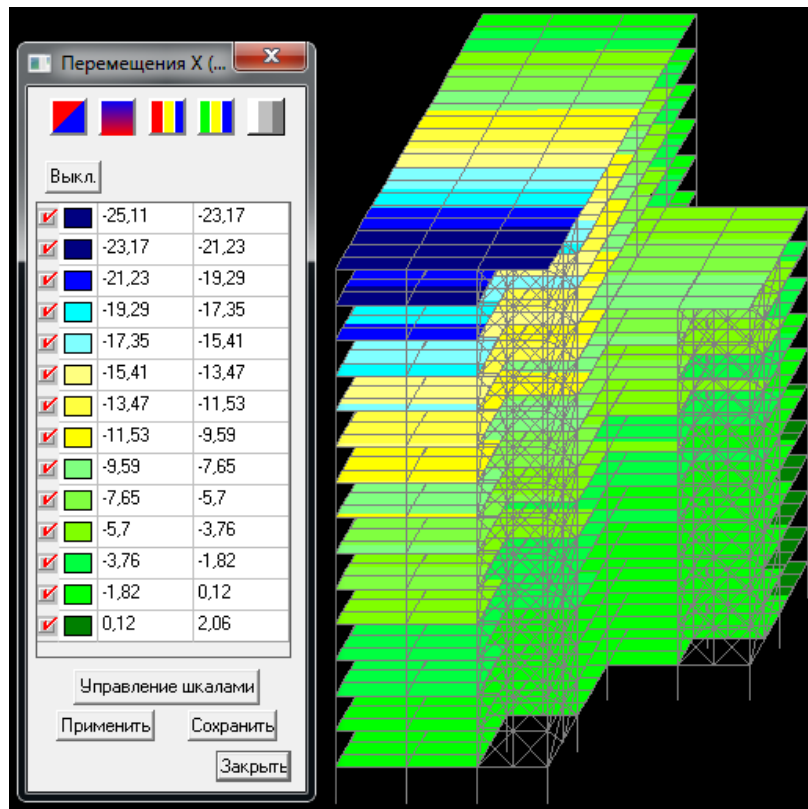
Mu stress field in the calculation of the combination of efforts



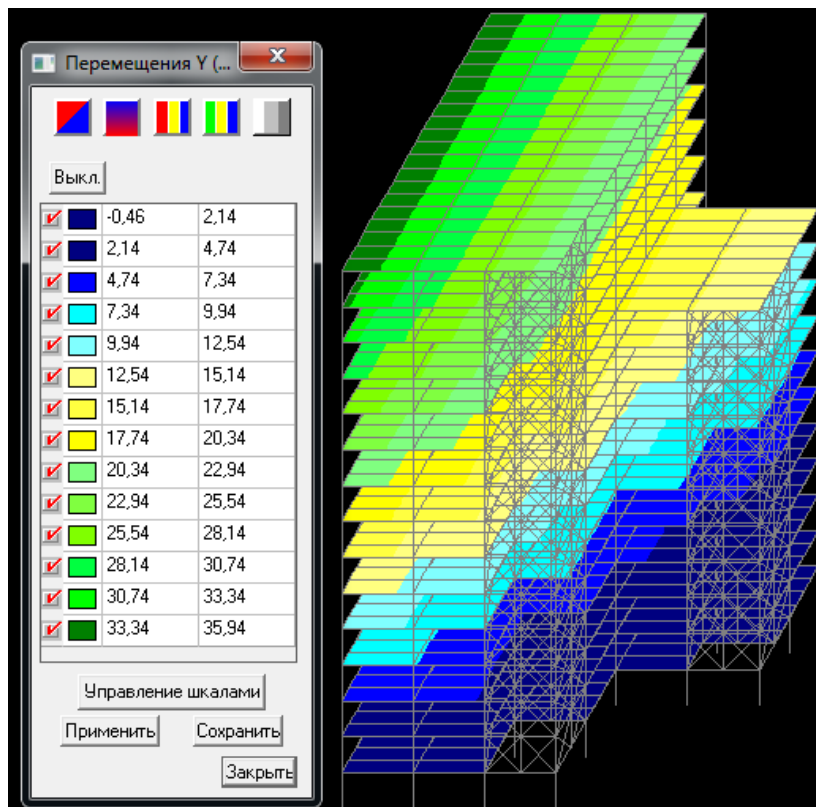
Qx stress field in the calculation of the combination of efforts



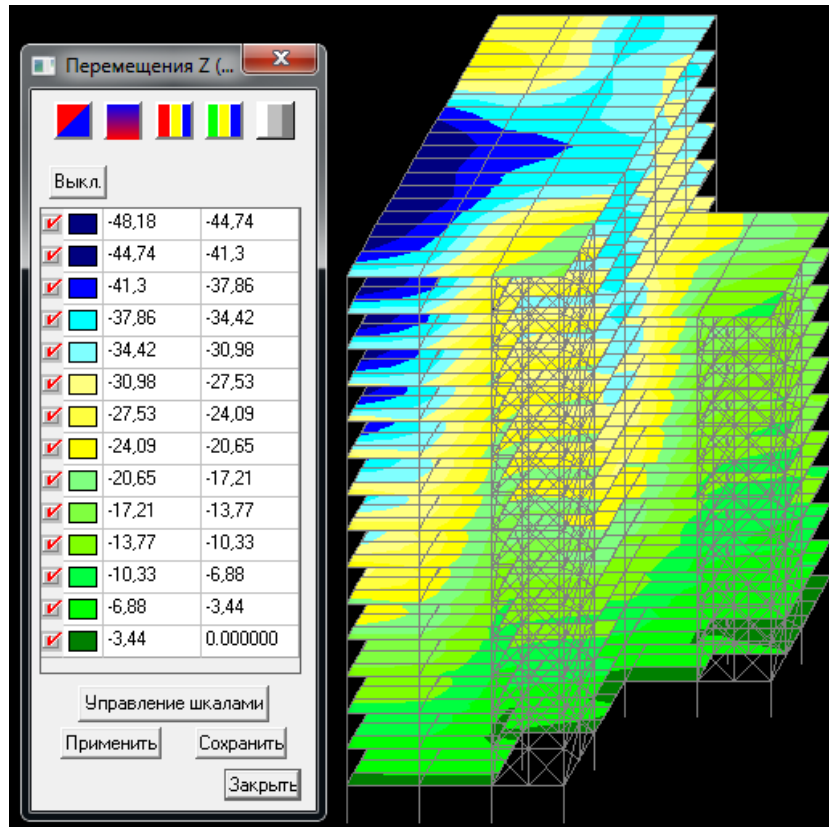
Displacement the X axis, mm.



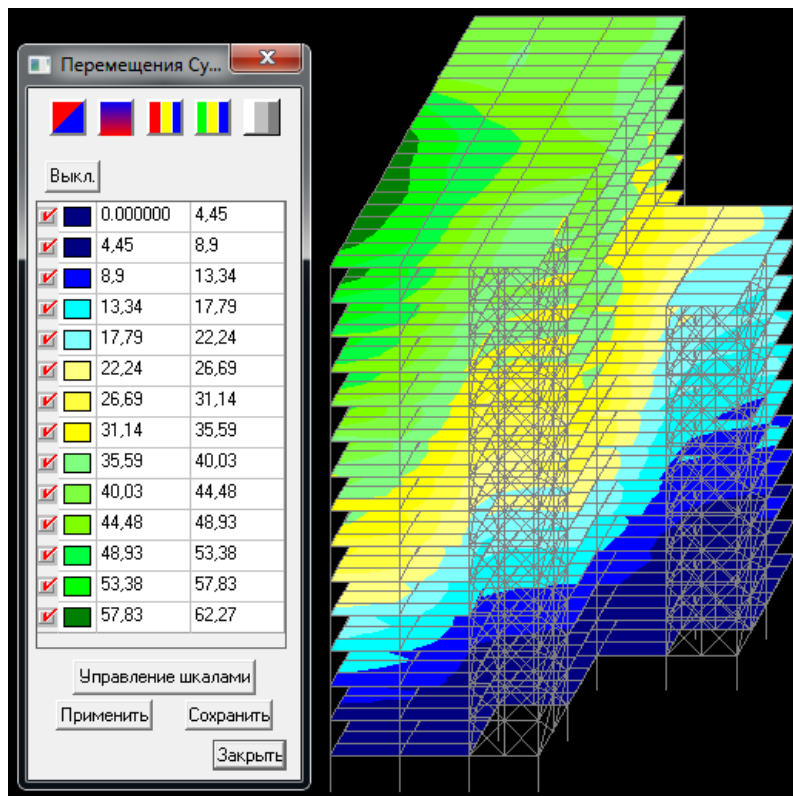
Displacement the axis in mm.



Displacement on axis Z, mm.



Total displacement mm for static loads.



Static movement building:  $H / 500 \geq \Delta = 42000/500 = 84\text{mm}$   
 $\geq 62,27\text{ mm}$ ; - the condition is met. The stability of the building is provided.

Analyze the data obtained and is listed in the table (Table. 5.1.1). To choose the analysis of characteristic elements, such as columns and main beams in the first, fifth, tenth and chotyrynadtsyatomu floors. Fig. 5.1.1. and 5.1.2. shows selected columns and beam analysis, respectively.

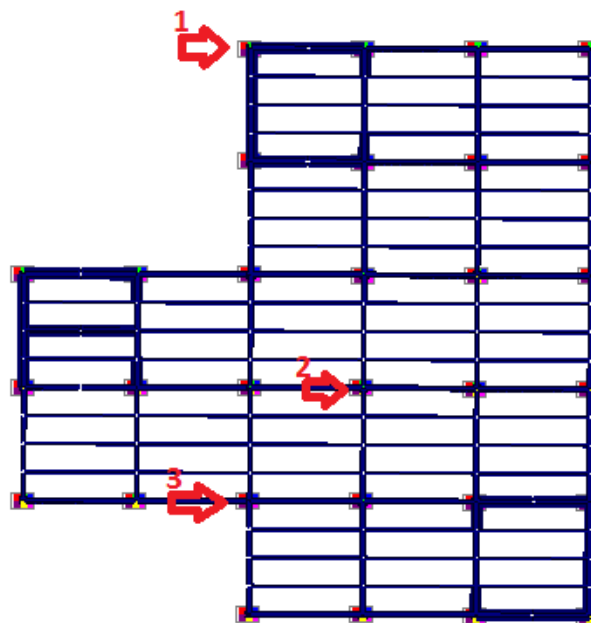


Figure 5.1.1. Selected columns for analysis

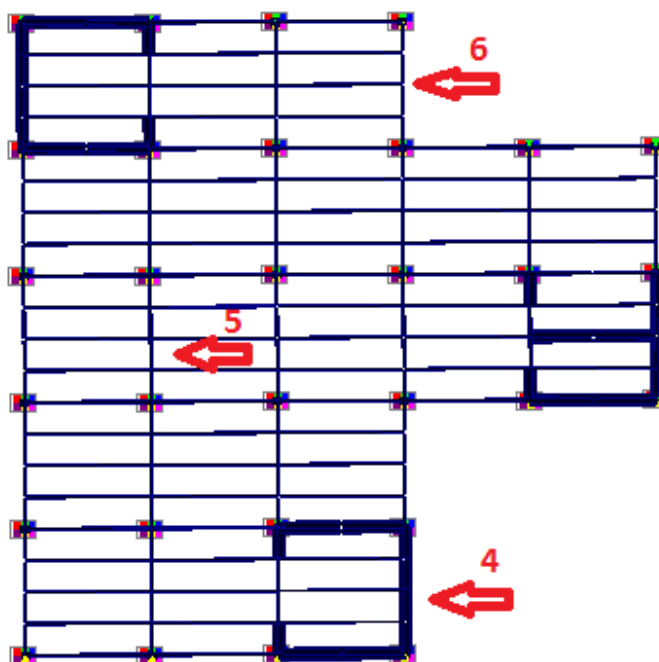


Figure 5.1.2. Selected main beam analysis

Table 5.1.1. stresses and displacements from static loads

Item number	Floor number	Force			Stress, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm
		My, kg · cm	Mz, kg · cm	N, kg		
1	1 (0.000)	-363206.7	64379.42	-300046	1,990.27	3.57
1	5 (15.000)	-213611.2	132,239.1	-174634	1,608.47	12.25
1	10 (30.000)	-150490.6	93237	-109663	1651.1	27.1
1	14 (42.000)	71949.24	66956.79	66696.7	1516.28	36.62
2	1 (0.000)	-45709.91	-811,883.5	-1254356	2160.5	7.18
2	5 (15.000)	-226602.8	-724072,	-897682.9	2127.8	21,22
2	10 (30.000)	-337310.9	-651891.3	-417864.3	2140.24	37.75
2	14 (42.000)	-34261.1	-219085.6	-28092.84	1509.56	45.12
3	1 (0.000)	-1309034	-590325.8	-1126493	2129.31	6.35
3	5 (15.000)	-1106730	-503194.9	-793651.8	2049.14	18.54
3	10 (30.000)	-1142352	-291549.7	-318046.6	1599.5	32,12

3	14 (42.000)	1375766.6	-95315.43	-16223.79	1582.9	36.76
4	1 (0.000)	-664893.5	-4064.69	26372.35	1577.7	4.32
4	5 (15.000)	-653786.1	-1459.95	33184.26	1536.4	11.02
4	10 (30.000)	-726061.6	1094.23	17862.4	1580.7	27.69
4	14 (42.000)	527242.5	-6776.99	-812.3	1417.6	36.62
5	1 (0.000)	-1912850	-232.45	494.32	2173.45	5.36
5	5 (15.000)	1927166.3	108.38	394.01	2192.7	21.0
5	10 (30.000)	1822982.4	-369.31	313.41	2052.6	43,44
5	14 (42.000)	147,257.3	305.8	-366.13	1543.8	52.25
6	1 (0.000)	-665030.3	-761.2	-47.07	1494.7	7,17
6	5 (15.000)	749377.4	681.5	87.8	1510.6	20.36
6	10 (30.000)	-674555	-53.55	177.15	1519.9	35.99
6	14 (42.000)	771974.2	-77.07	48.09	1540.8	38,27

Further results will need to compare the stress and displacement values under seismic loading 5.6 and 7 points.

### **5.3. Calculation and analysis of stresses and displacements in the metal frame of the building from seismic load intensity of 5 points.**

The building is not symmetrical in plan. Identify ways in which we get the greatest pressure and movement changes from cosine angles between the directions of movement vector and seismic action.

For this:

- Composition table of cosines for the application of seismic loading (tab. 5.2.1).

- will make seismic loads to the frame of the building at angles every 30°, setting the direction of its actions through cosines of angles;

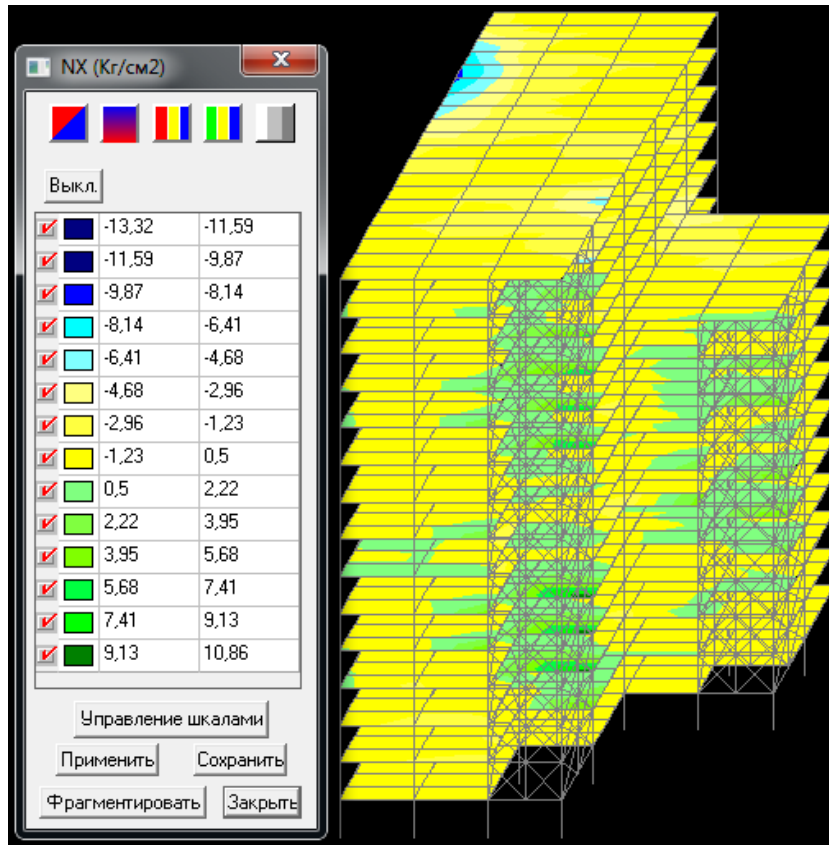
- calculates the building;

- analyze the results and make conclusions.

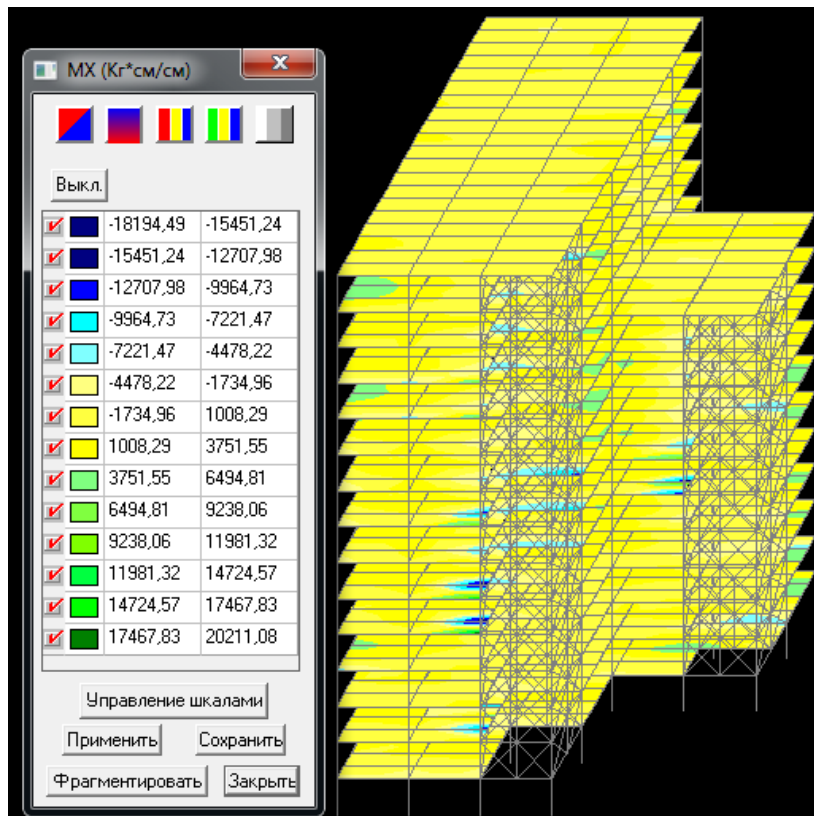
Table 5.2.1.angles to cosines and their application of seismic loading

X		Y		Z	
A	cos $\alpha$	A	cos $\alpha$	$\alpha$	cos $\alpha$
0°	0	90°	1	0°	0
				30°	0.5
				60°	0.866
				90°	1
30°	0.5	60°	.866	0°	0
				30°	0.5
				60°	0.866
				90°	1
60°	.866	30°	0.5	0°	0
				30°	0.5
				60°	0.866
				90°	1
90°	1	0°	0	0°	0
				30°	0.5
				60°	0.866
				90°	1

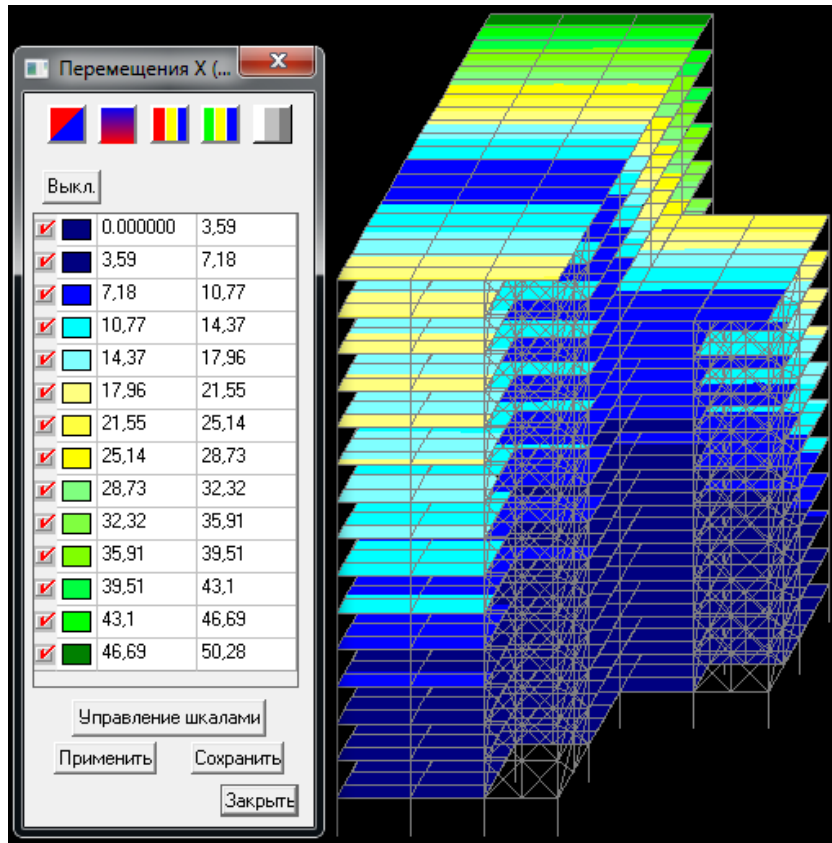
### NX at X0 Y90 Z0



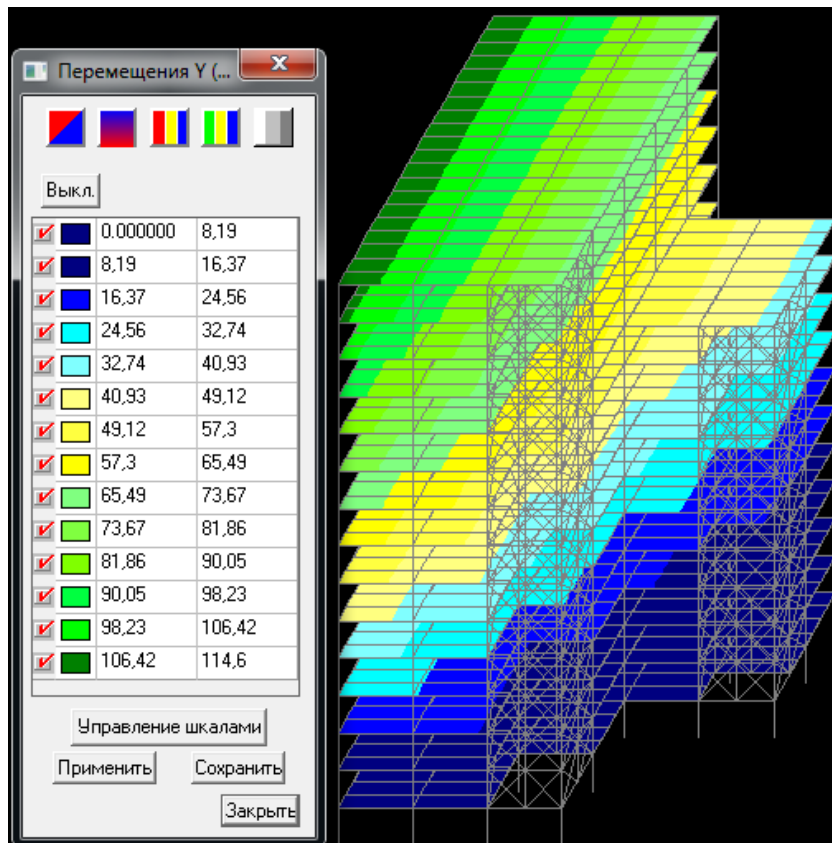
### MX at X0 Y90 Z0



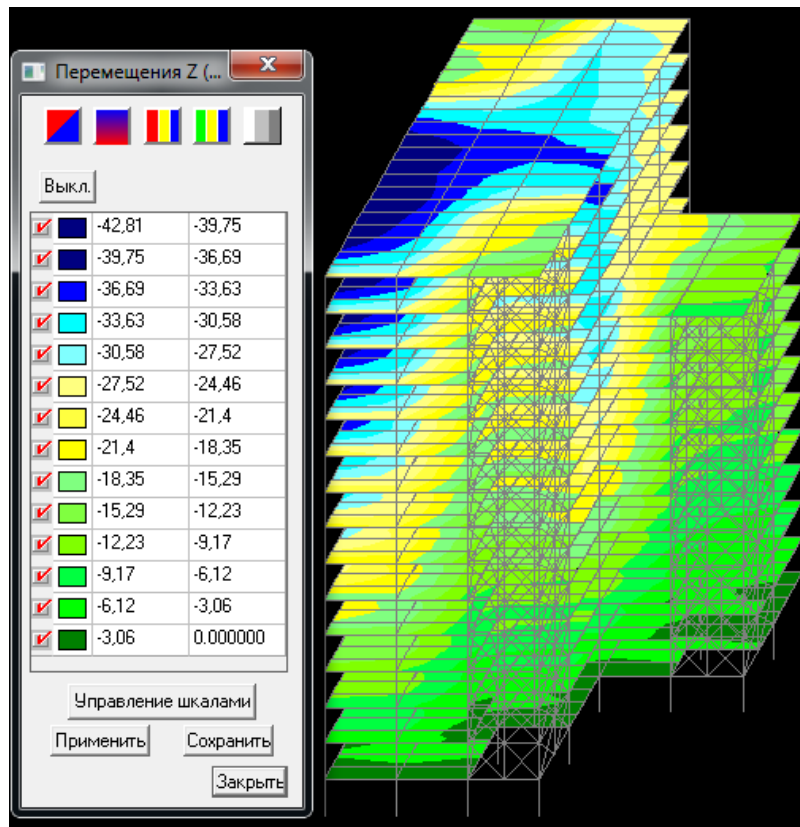
### Displacement on axis X mm at X0 Y90 Z0



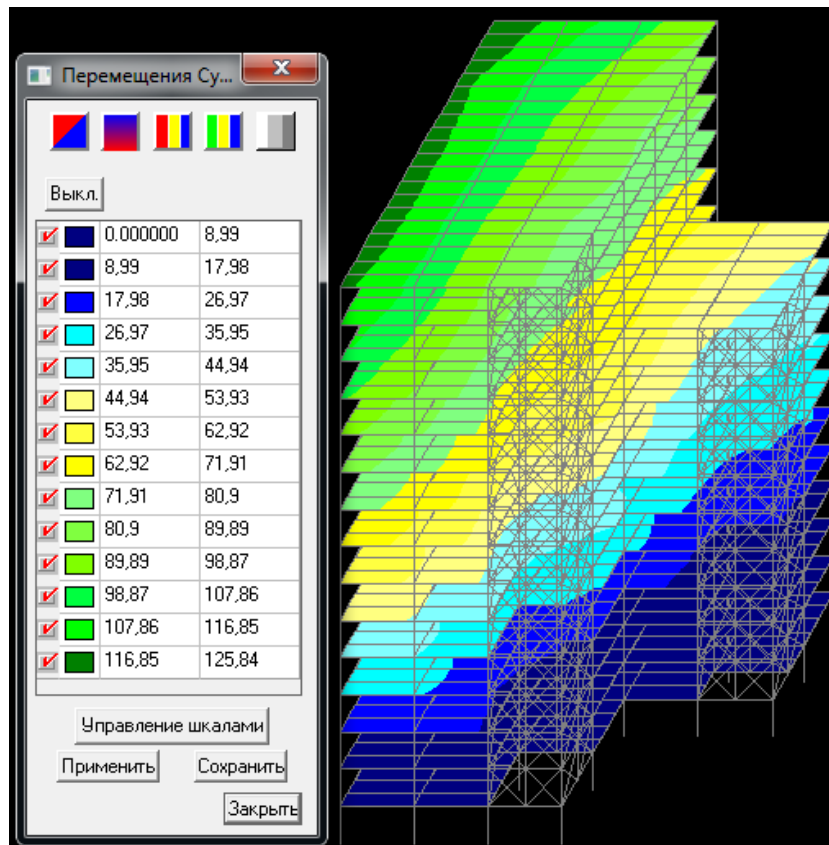
### Displacement the axis Y, mm, X0 Y90 Z0



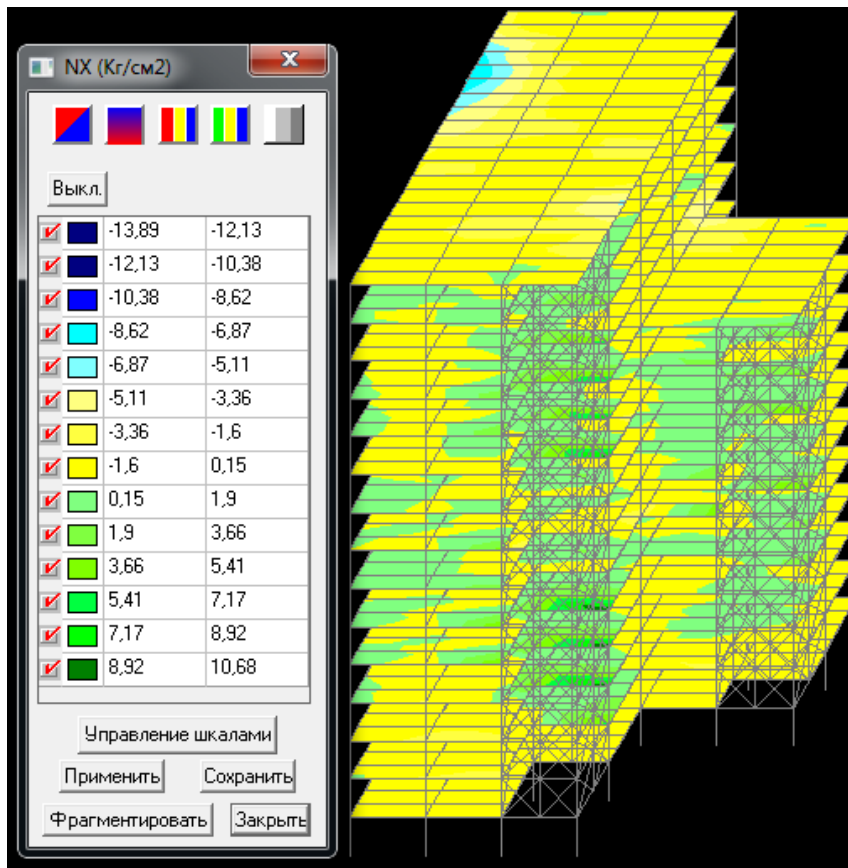
Displacement on axis Z, mm, X0 Y90 Z0



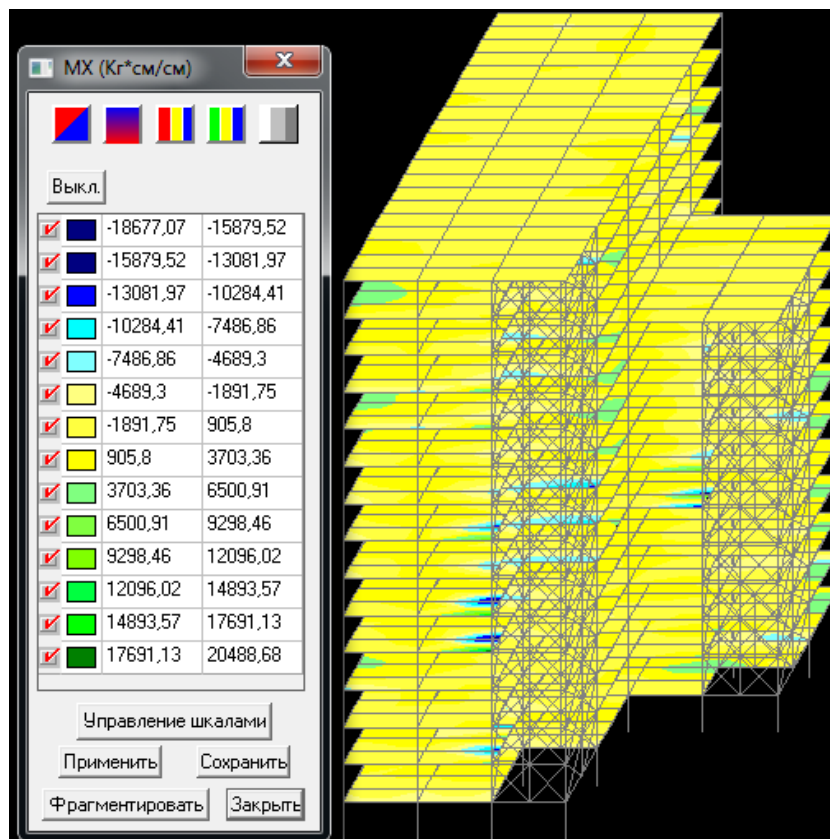
Total displacement mm at X0 Y90 Z0



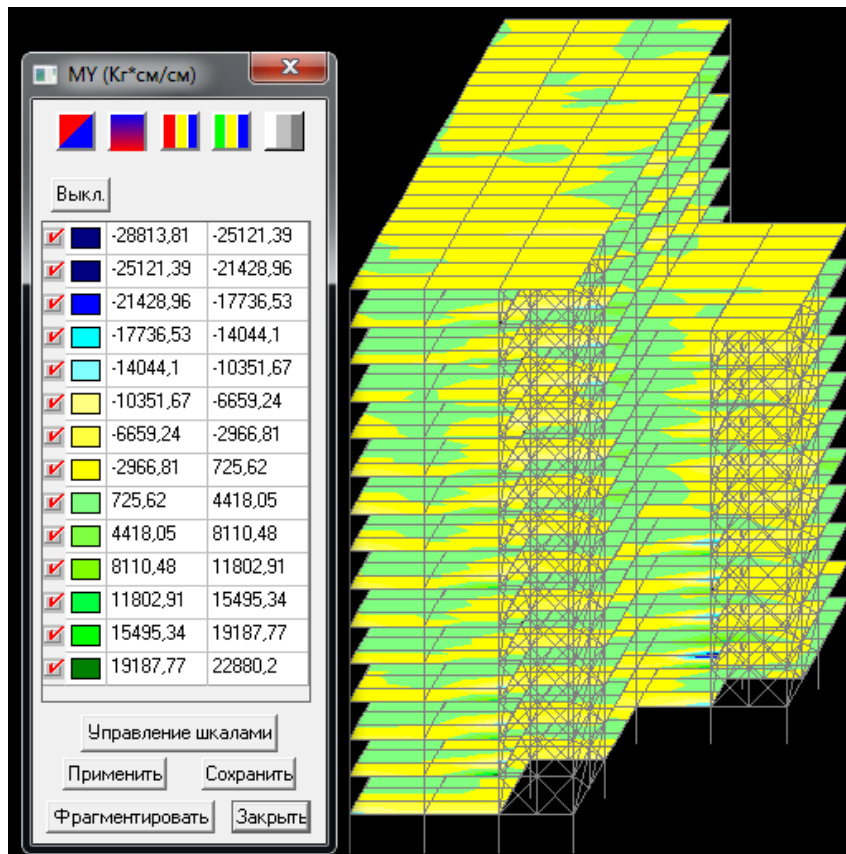
NX at X30 Y90 Z0



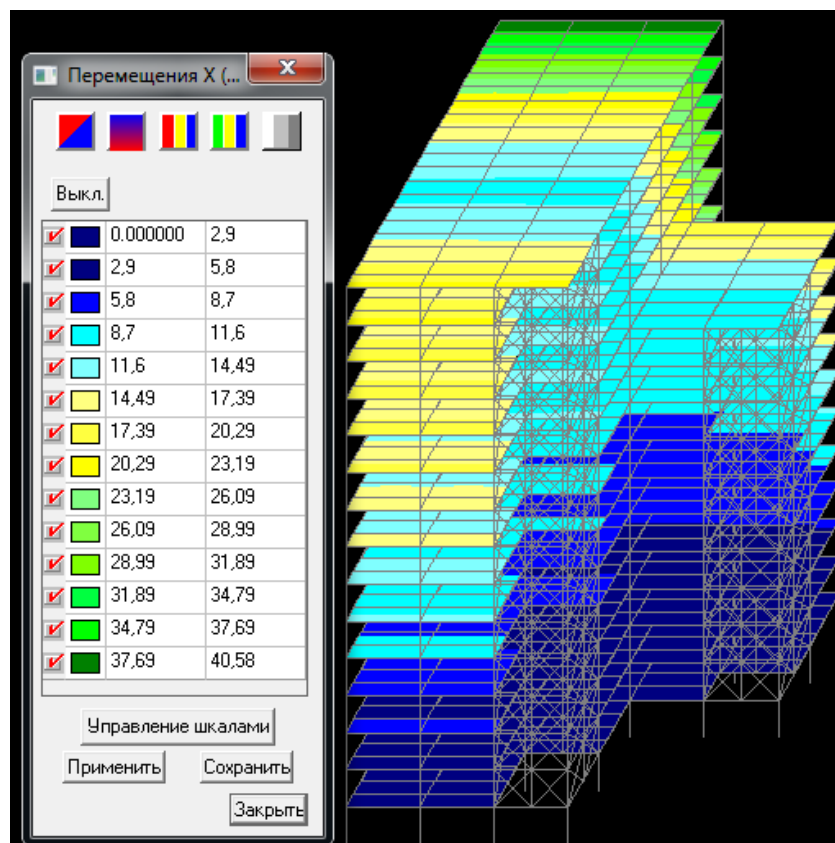
MX at X30 Y90 Z0



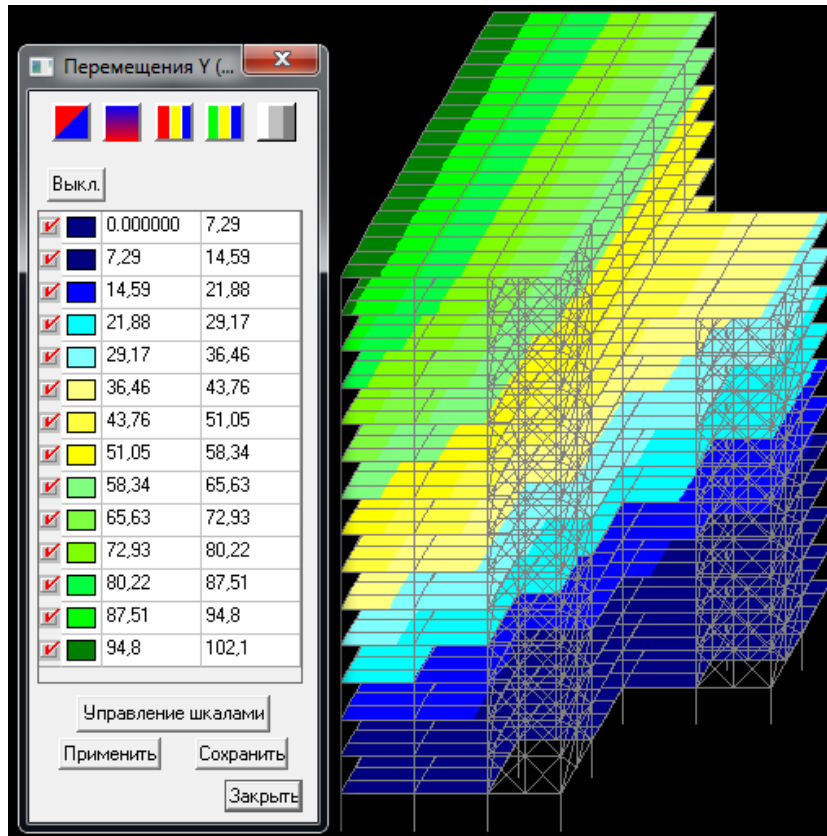
MY at X30 Y90 Z0



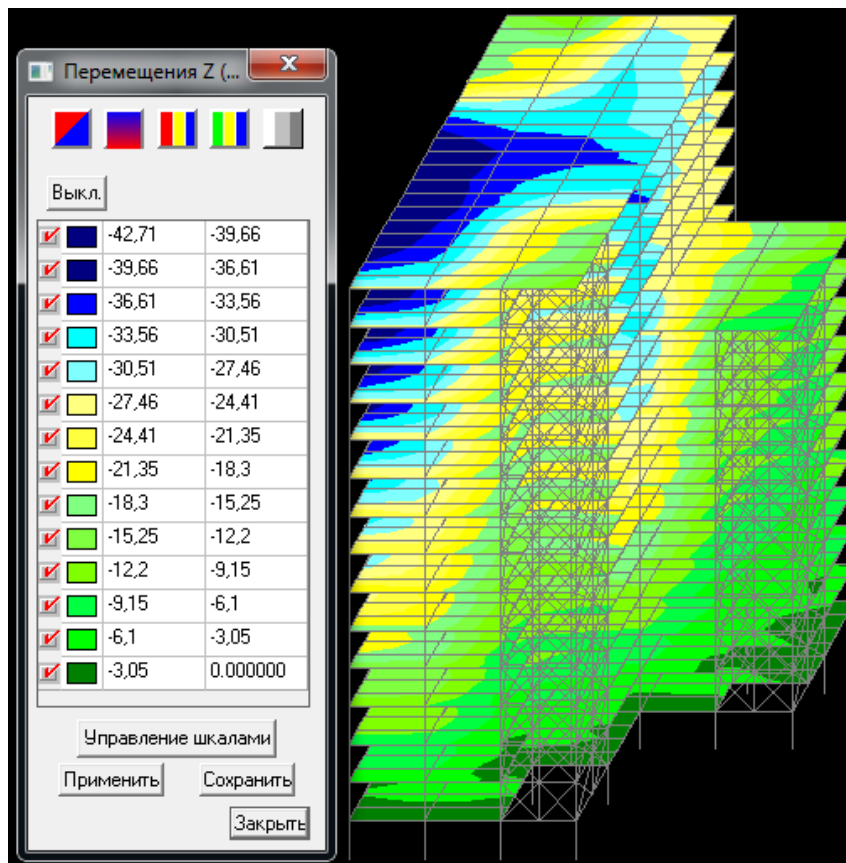
Displacement on axis X mm at X30 Y90 Z0



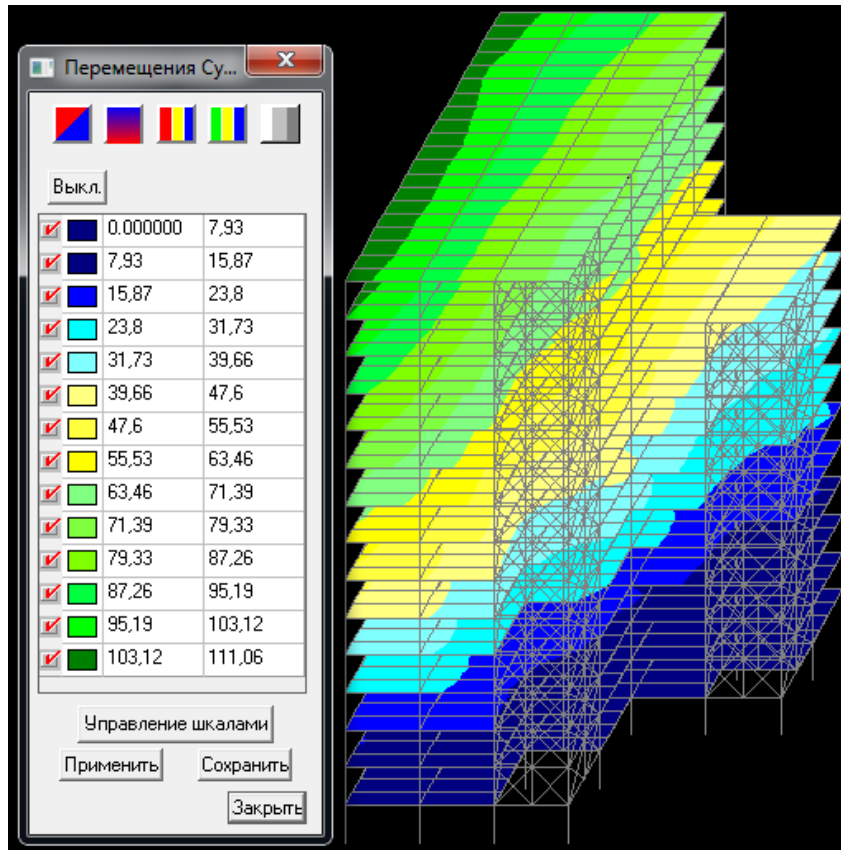
Displacement the axis Y, mm at X30 Y90 Z0



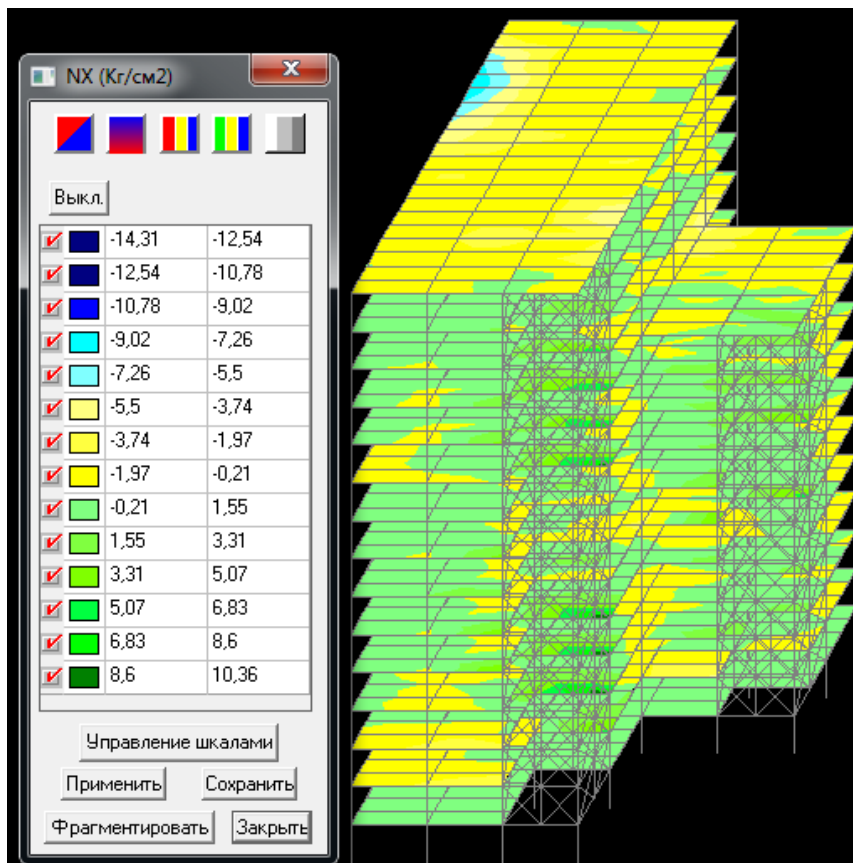
Displacement on axis Z, mm at X30 Y90 Z0



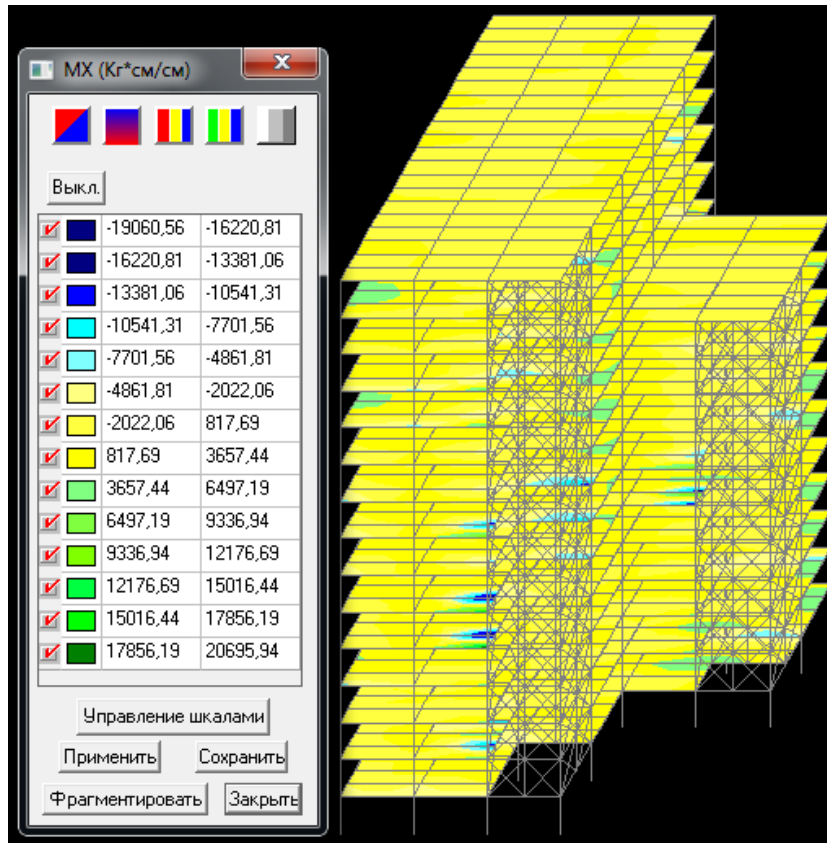
## Total displacement mm at X30 Y90 Z0



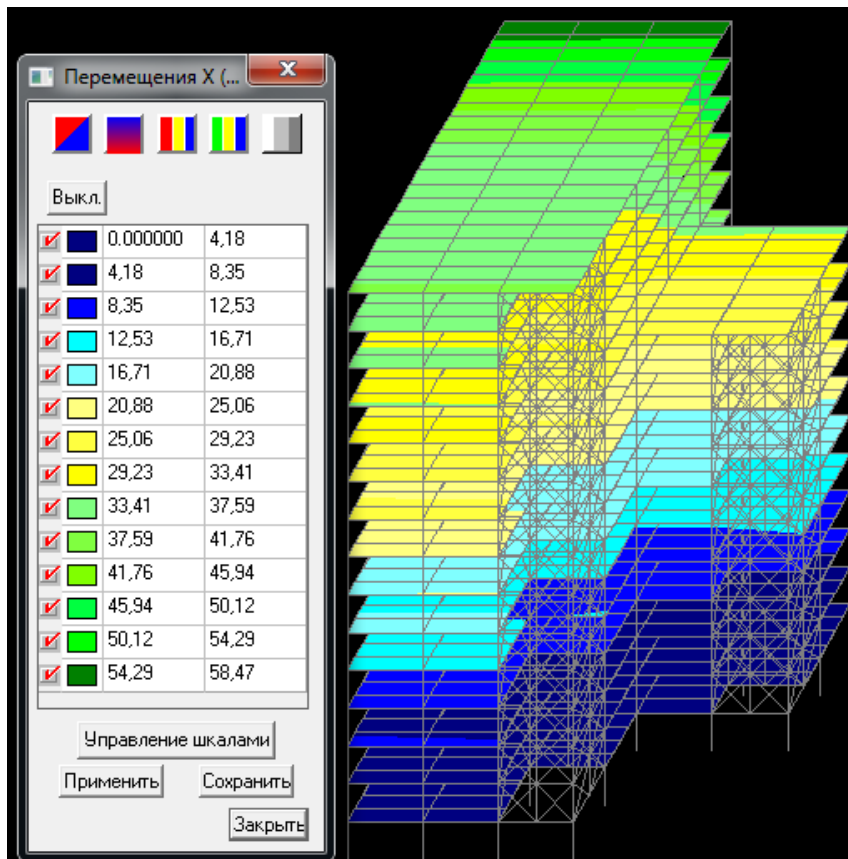
## NX at X60 Y90 Z0



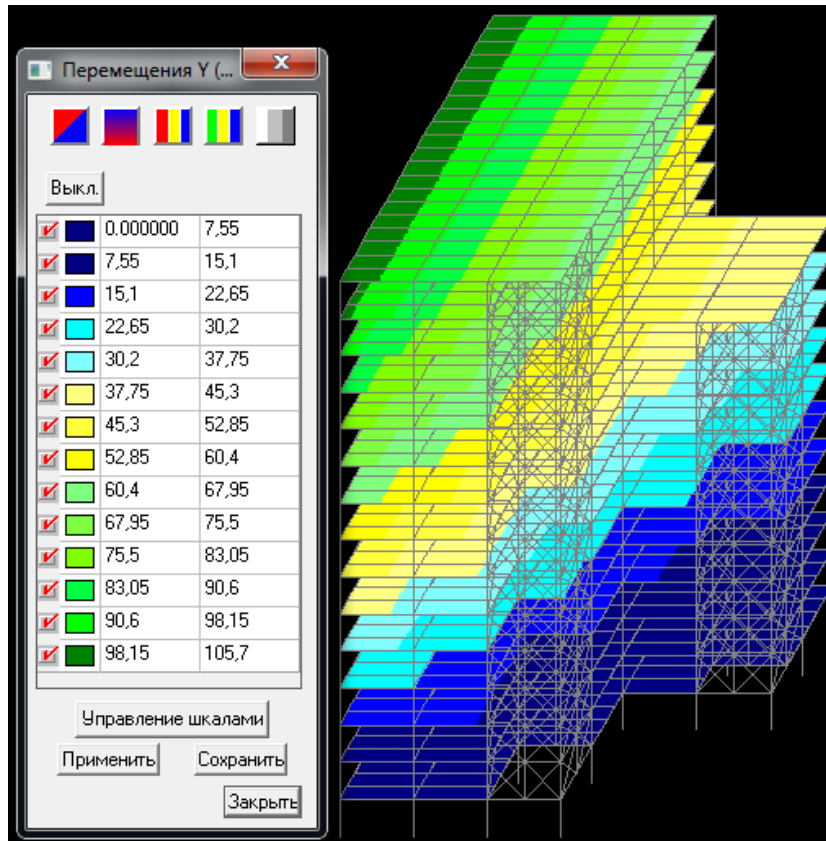
### MX at X60 Y90 Z0



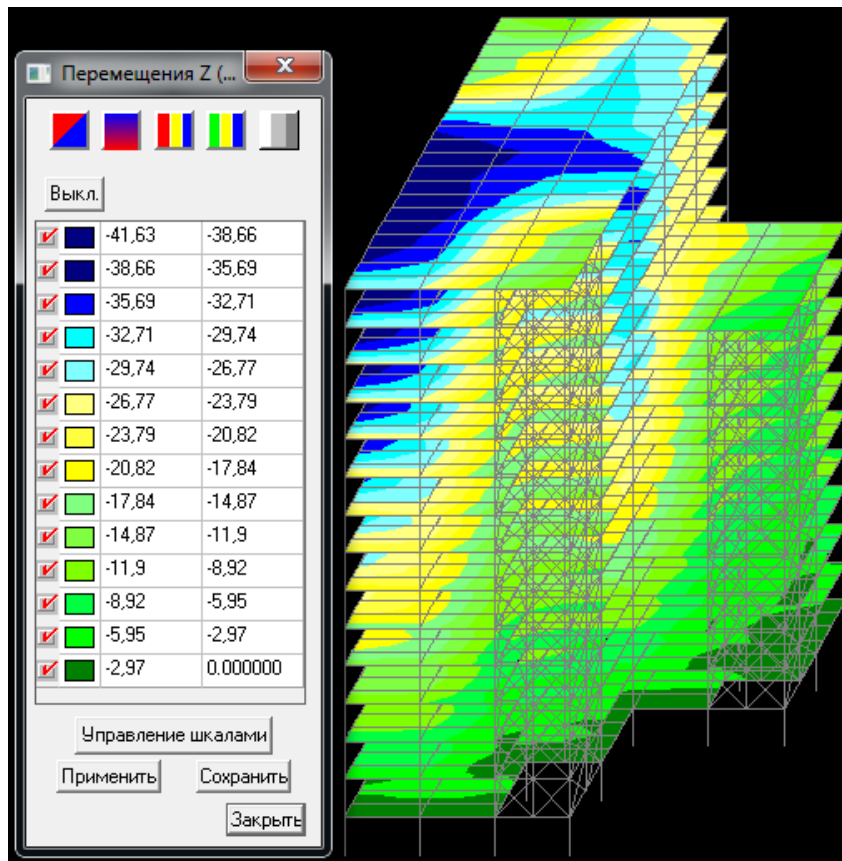
### Displacement on axis X mm at X60 Y90 Z0



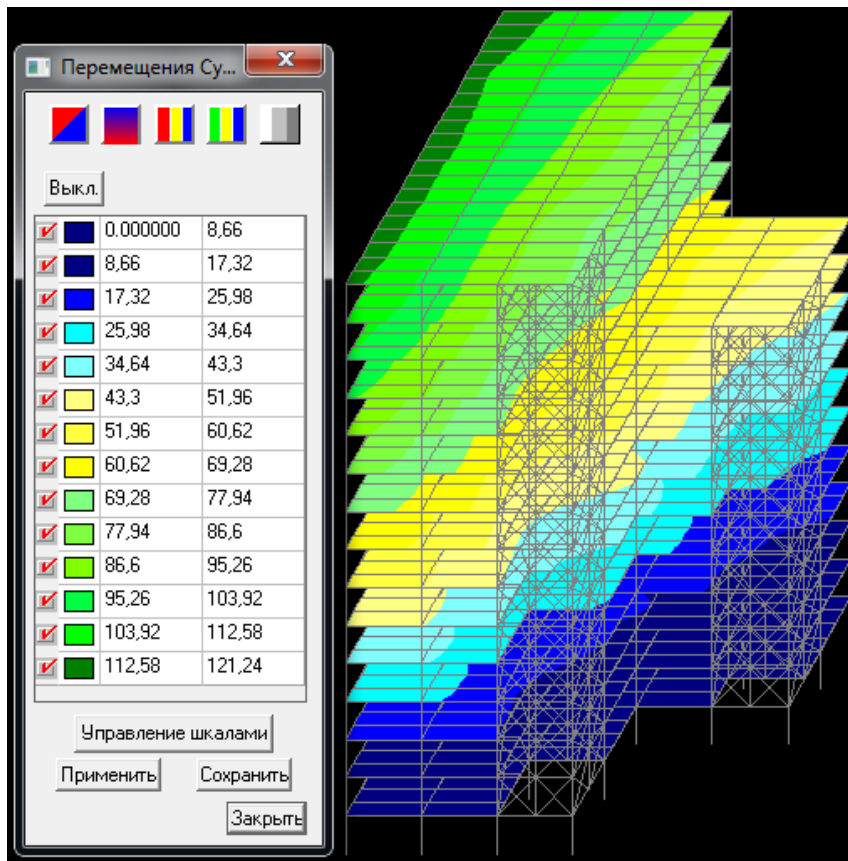
Displacement the axis Y, mm at X60 Y90 Z0



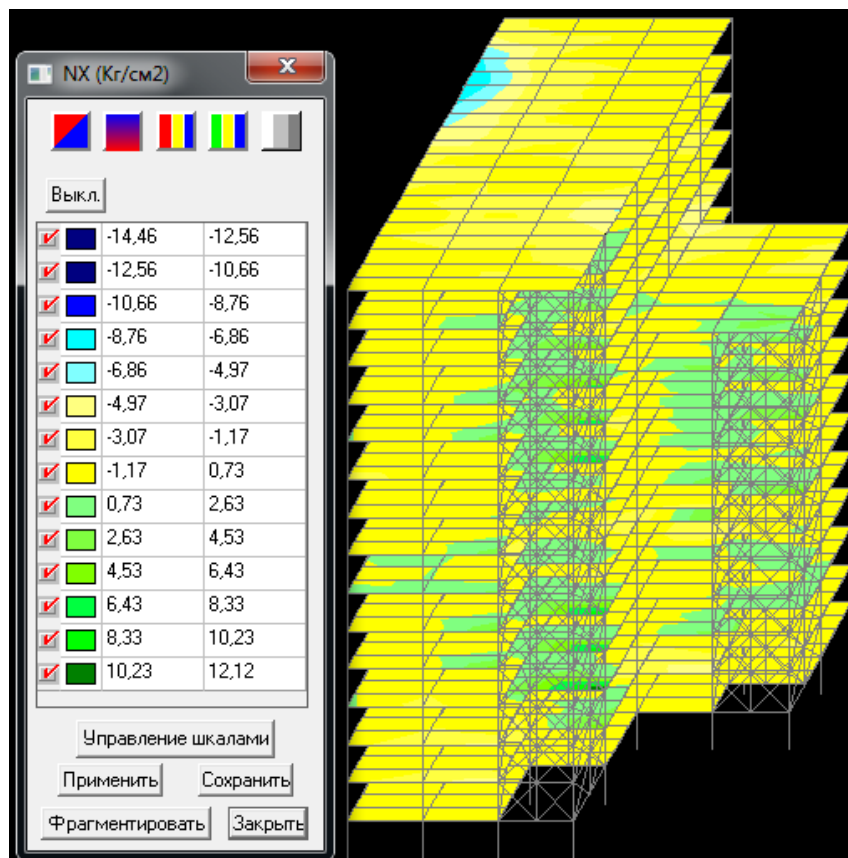
Displacement on axis Z, mm at X60 Y90 Z0



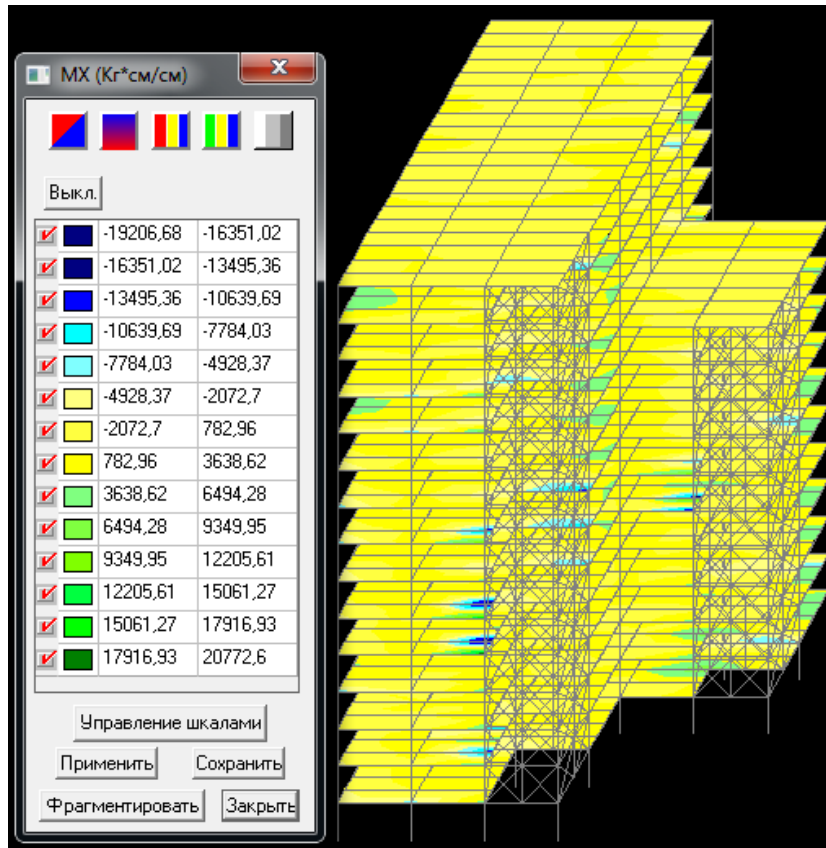
## Total displacement mm at X60 Y90 Z0



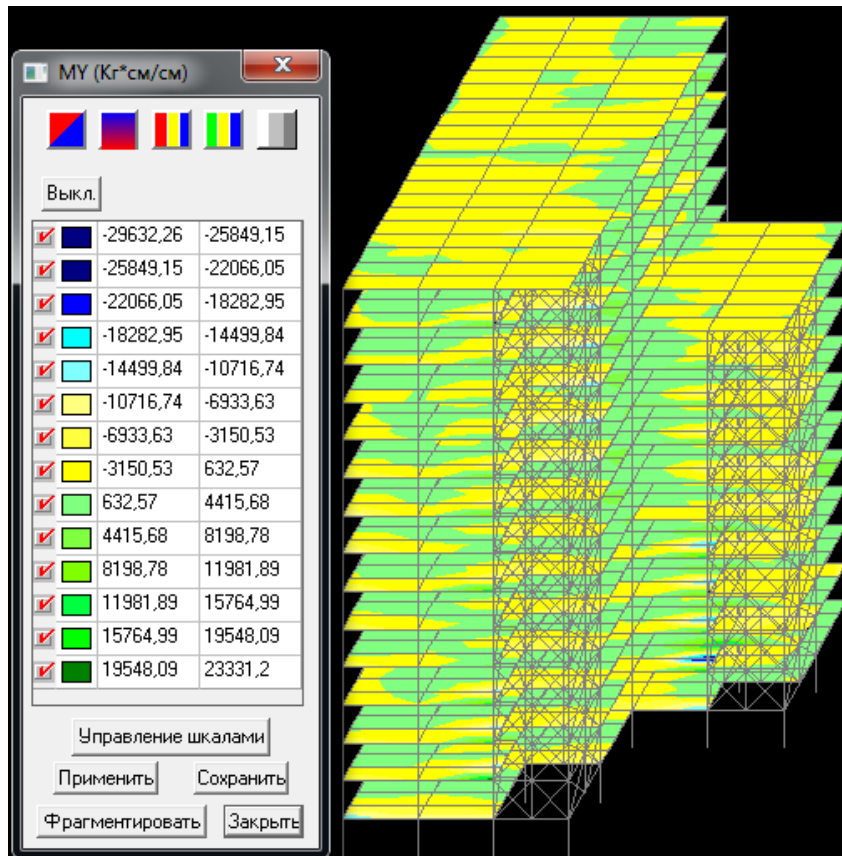
## NX at X90 Y90 Z0



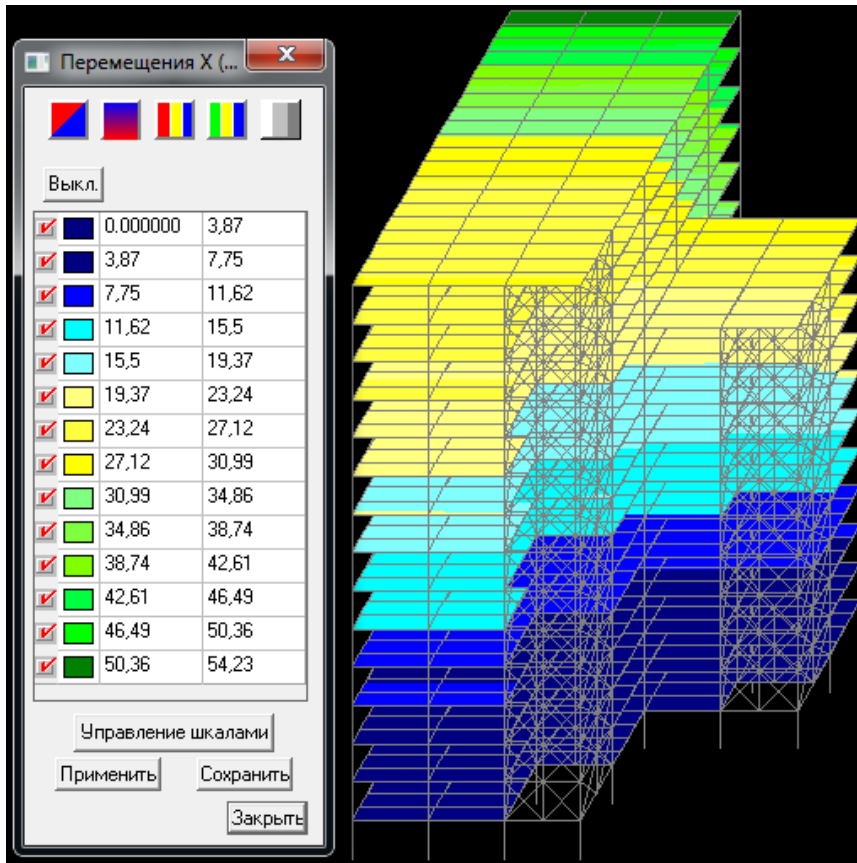
MX at X90 Y90 Z0



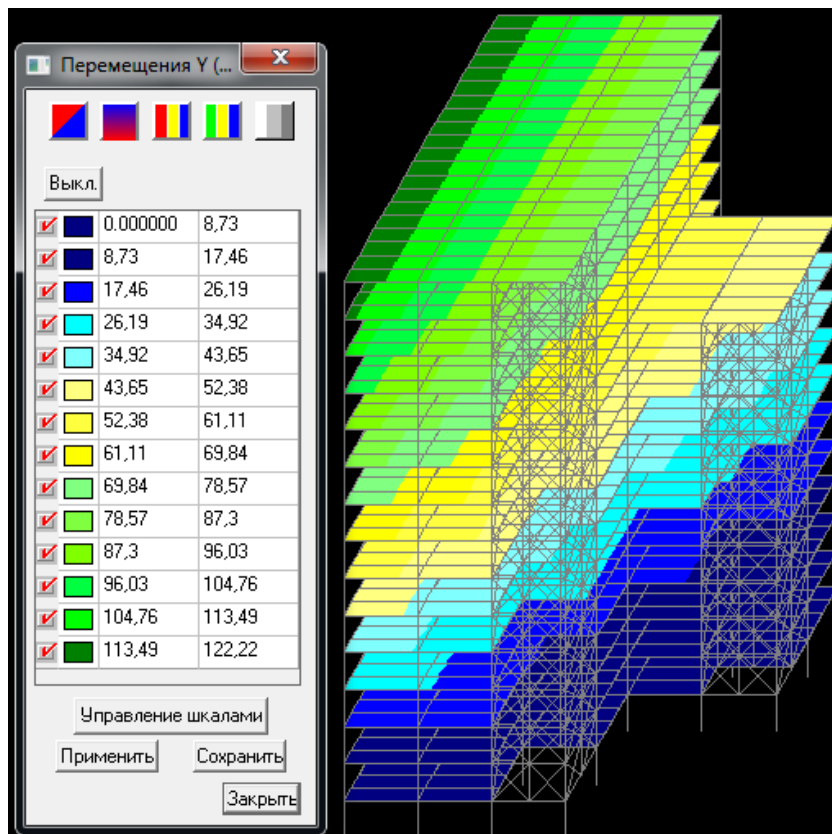
MY at X90 Y90 Z0



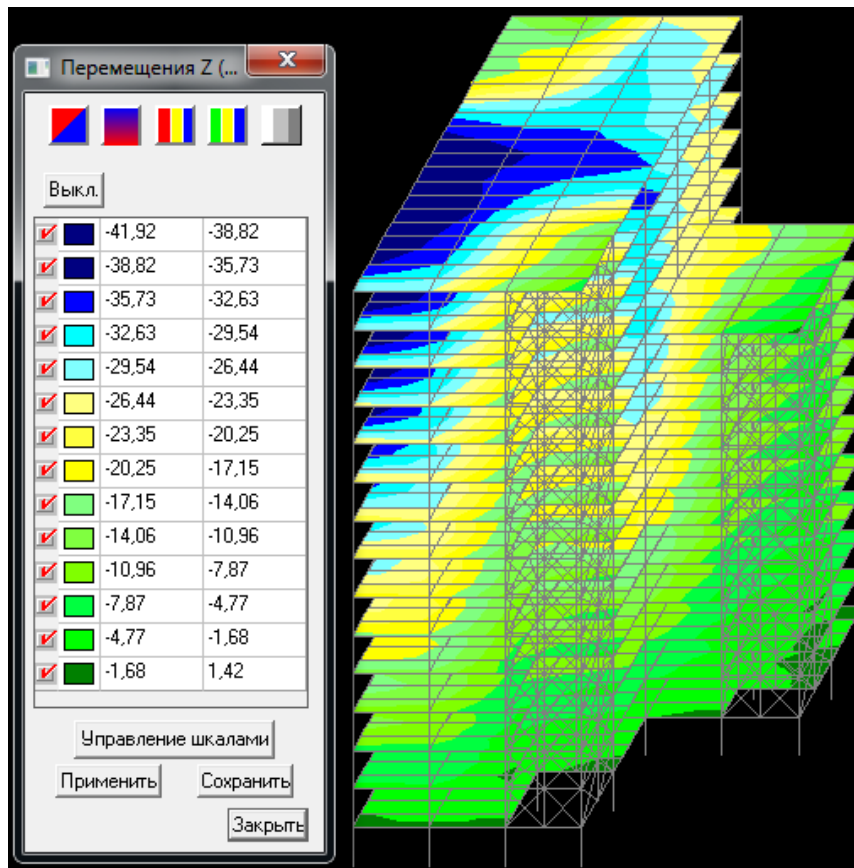
### Displacement on axis X mm at X90 Y90 Z0



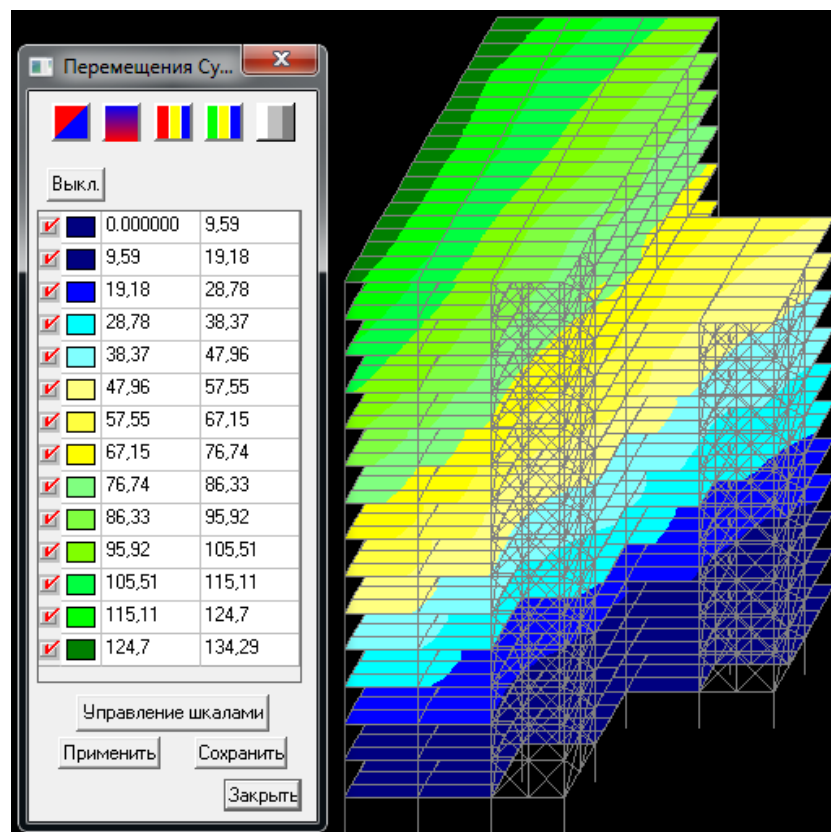
### Displacement the axis Y, mm at X90 Y90 Z0



Displacement on axis Z, mm at X90 Y90 Z0



Total displacement mm at X90 Y90 Z0



Analyzing these data we can see that the greatest pressure and moving the points appear when the acceleration vector grounds directed along the principal axes X, Y, Z. To analyze the results of calculation to be mentioned in the direction of the principal axes.

Analyze how much stress and displacement have changed in specific locations (tabl.5.2.2.).

Table 5.2.2.-Comparison of static and seismic load in 5 points for selected elements

Element number	Floor	Static load		Seismic 5 points	
		Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm	Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm
1	1 (0.000)	1990.27	3.57	668.8	10.23
1	5 (15.000)	1608.47	12.25	942.7	28.04
1	10 (30.000)	1651.1	27.1	1,487.84	54.04
1	14 (42.000)	1,516.28	36.62	760.11	69.68
2	1 (0.000)	2160.5	7.18	2494.5	12.88
2	5 (15.000)	2127.8	21,22	2416.95	38.36
2	10 (30.000)	2140.24	37.75	2174.53	71.42
2	14 (42.000)	1509.56	45.12	967.5	92.11
3	1 (0.000)	2129.31	6.35	1953.57	12.24
3	5 (15.000)	2049.14	18.54	1887.52	36.5
3	10 (30.000)	1599.5	32,12	1689.02	67.56
3	14 (42.000)	1582.9	36.76	1,643.83	87.65
4	1 (0.000)	1577.7	4.32	1687.24	8.69
4	5 (15.000)	1536.4	11.02	1749.19	23.16
4	10 (30.000)	1580.7	27.69	1777.01	55.28
4	14 (42.000)	1417.6	36.62	1617.31	71.5
5	1 (0.000)	2173.45	5.36	2358.26	7.59
5	5 (15.000)	2192.7	21.0	2288.1	34.63
5	10 (30.000)	2052.6	43,44	2,256.97	77.78

5	14 (42.000)	1543.8	52.25	1727.24	100.06
6	1 (0.000)	1494.7	7,17	2641.65	8.38
6	5 (15.000)	1510.6	20.36	2668.20	33.26
6	10 (30.000)	1519.9	35.99	2566.14	71.96
6	14 (42.000)	1540.8	38,27	1682.98	93.44

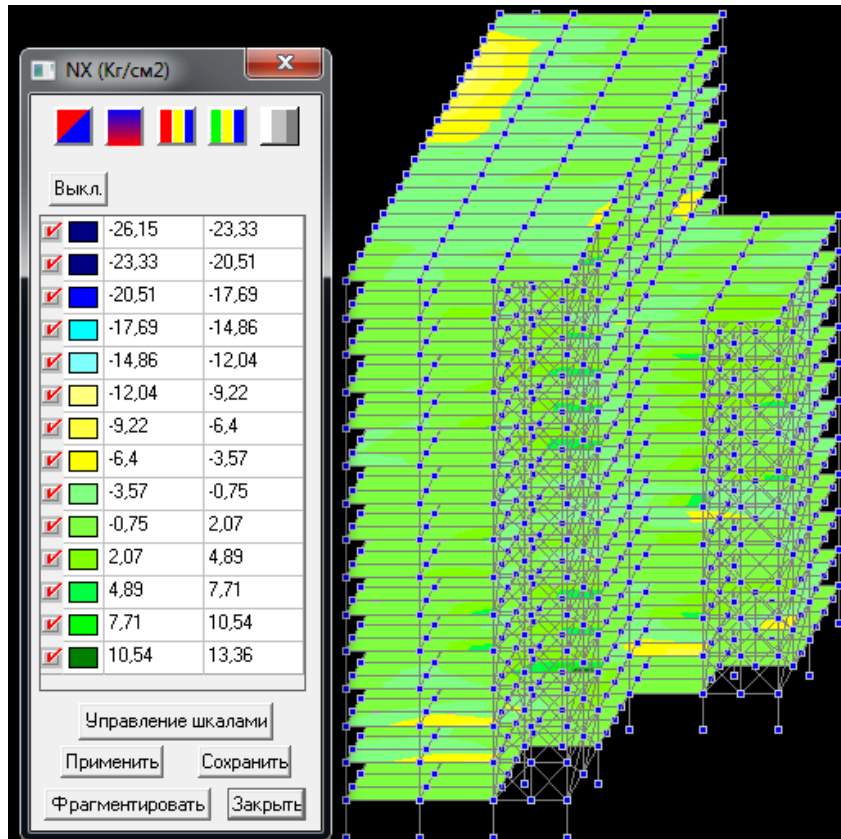
According to data obtained conclusions can be drawn:

- Premischennya frame buildings with seismic intensity exercise 5 points to 1.6 times the maximum allowable.
- The stresses in the elements at seycmichnomu load intensity of 5 points in the columns of the first floor of the middle row has increased 1.2 times, and the tension in the main beams 10 and 14 floors increased 1.7 times.

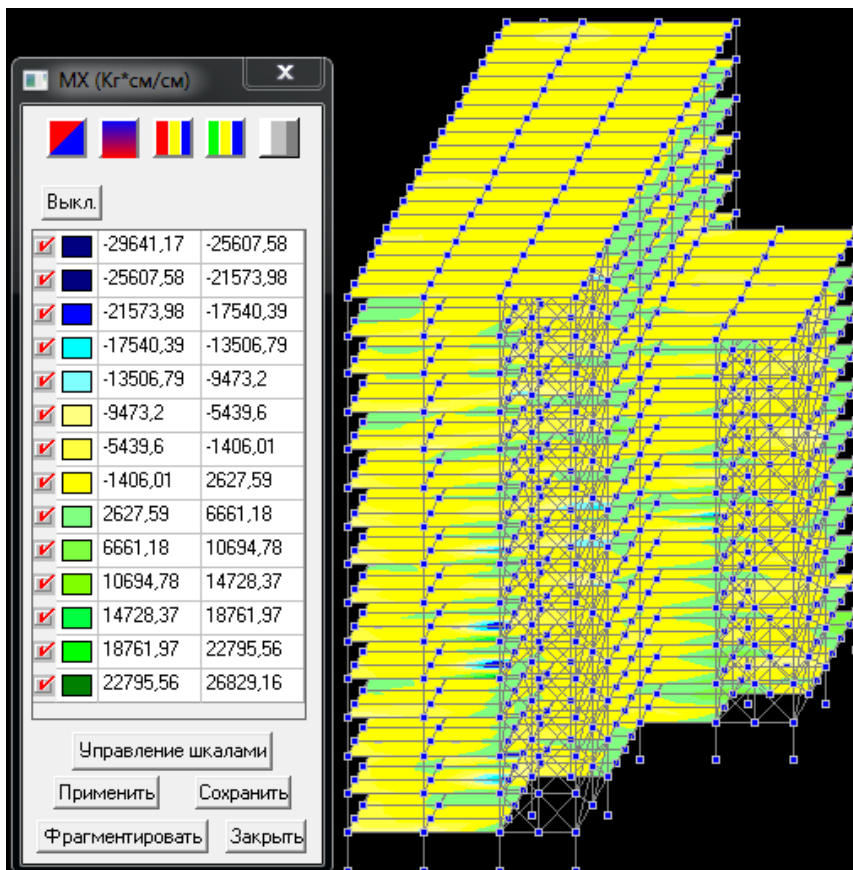
#### **5.4. Calculation and analysis of stresses and displacements in the metal frame of the building from seismic load intensity of 6 points.**

After analyzing the data in the previous section, it was determined that the greatest pressure and moving the points appear when the acceleration vector grounds directed along the principal axes X, Y, Z. Therefore, to analyze the results of calculation to be mentioned in the direction of the main axes.

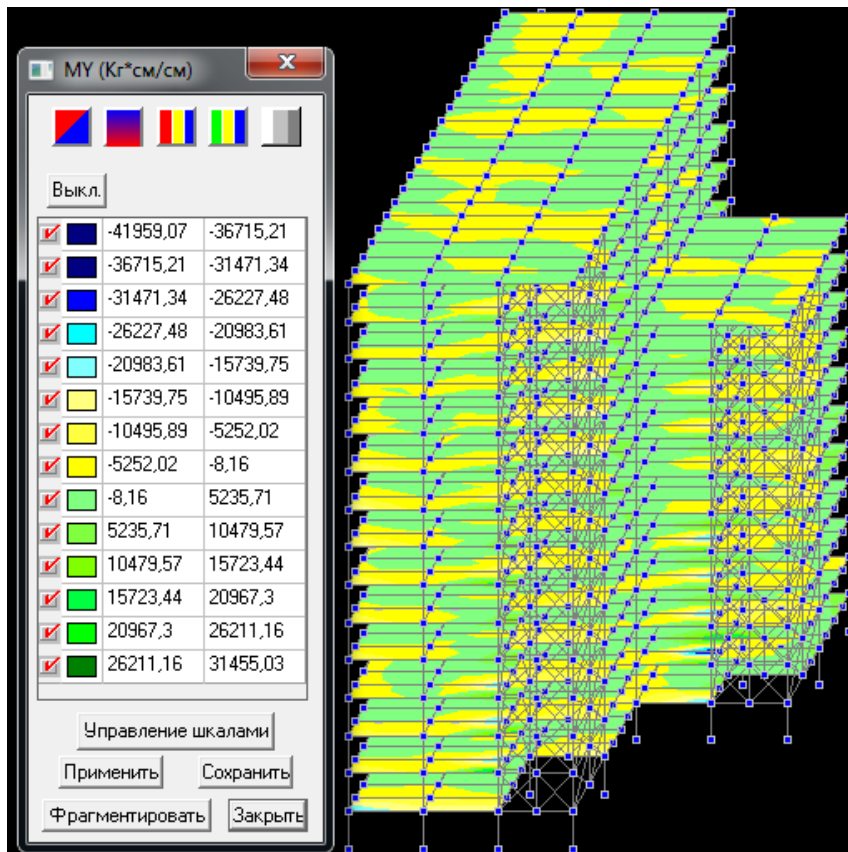
### NX at X90 Y90 Z0



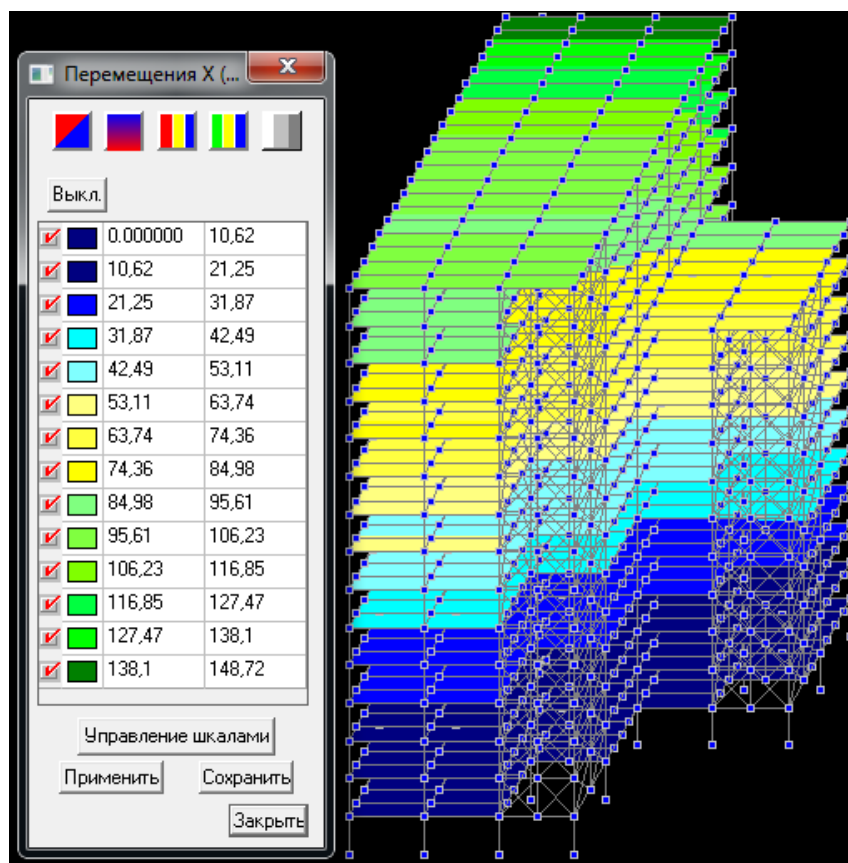
### MX at X90 Y90 Z0



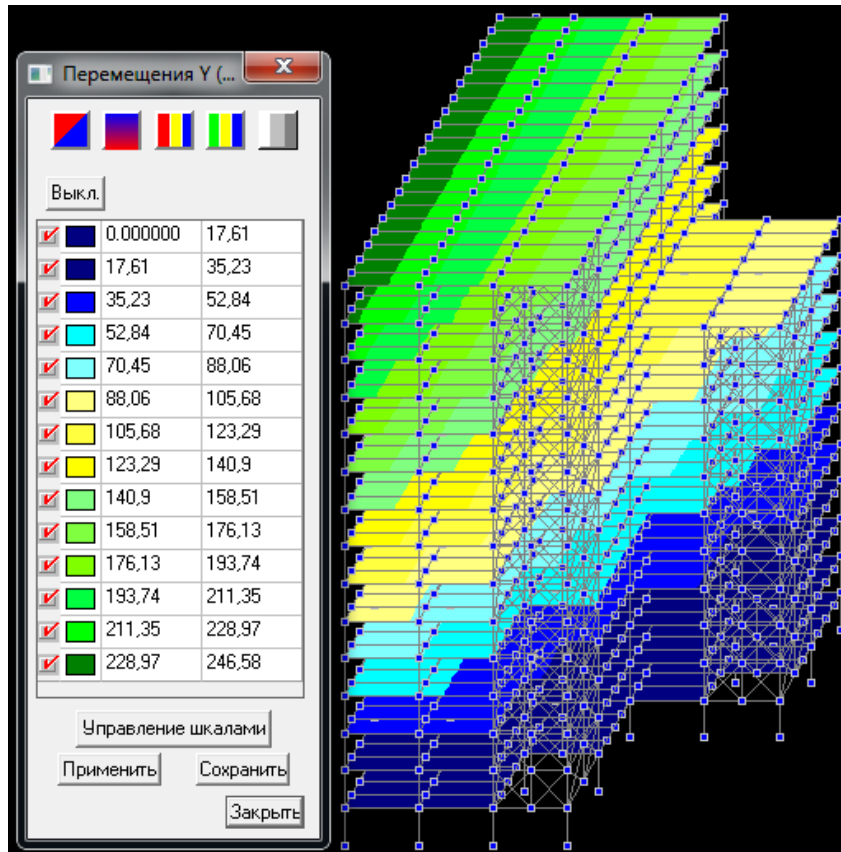
MY at X90 Y90 Z0



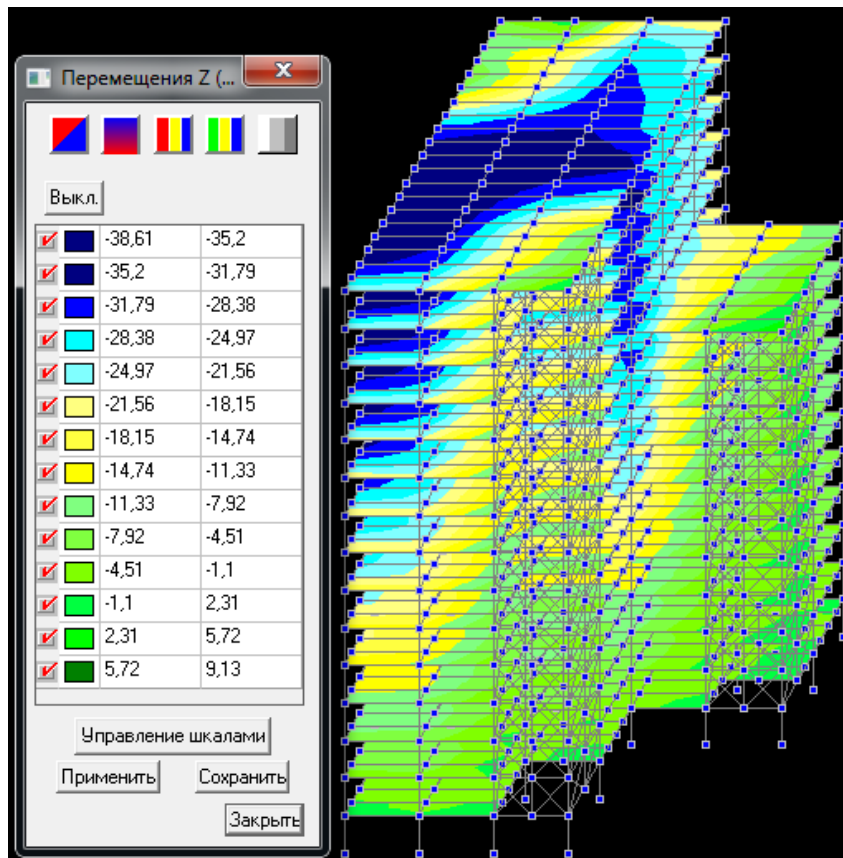
Displacement on axis X mm at X90 Y90 Z0



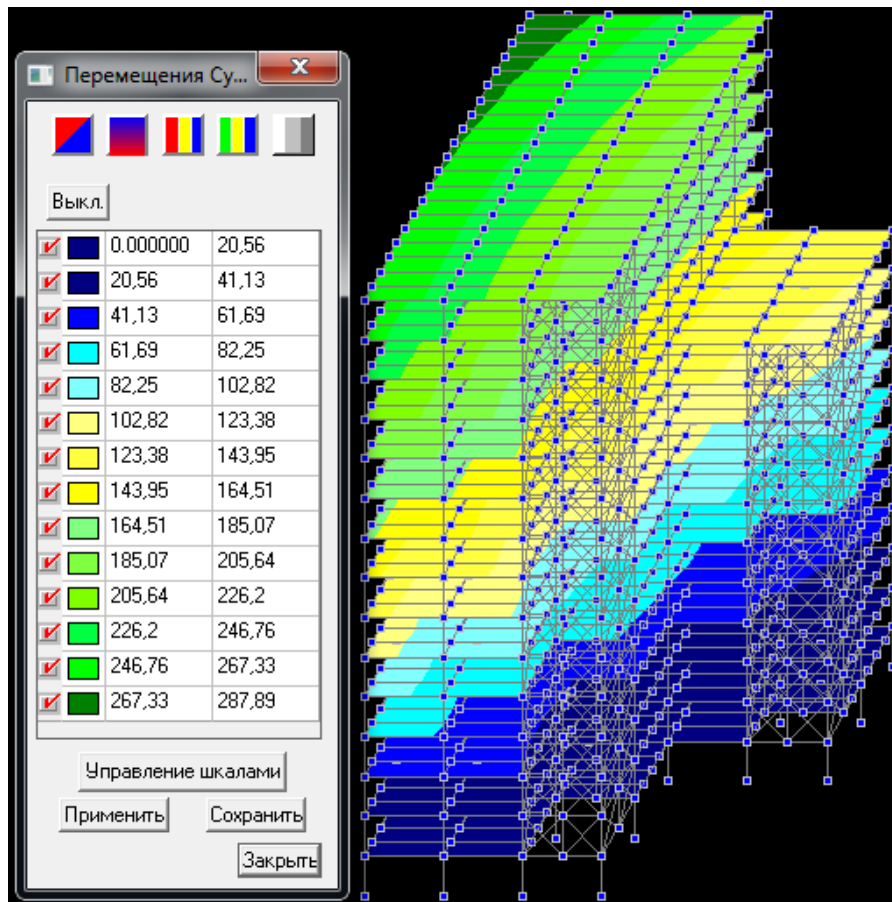
Displacement the axis Y, mm at X90 Y90 Z0



Displacement on axis Z, mm at X90 Y90 Z0



## Total displacement mm at X90 Y90 Z0



Analyze how much stress and displacement have changed in specific locations (tabl.5.3.1.).

Table 5.3.1.

Comparison of static and seismic load in 6 points for selected elements

Element number	Floor	Static load		Seismic 6 points	
		Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm	Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm
1	1 (0.000)	1990.27	3.57	2104.7	28.63
1	5 (15.000)	1608.47	12.25	2264.74	75.58
1	10 (30.000)	1651.1	27.1	1450.59	144.32
1	14 (42.000)	1516.28	36.62	1,491.58	190.42
2	1 (0.000)	2160.5	7.18	3207.3	29.72
2	5 (15.000)	2127.8	21,22	3223.97	87.06

2	10 (30.000)	2140.24	37.75	2767.6	166.18
2	14 (42.000)	1509.56	45.12	1905.4	219.28
3	1 (0.000)	2129.31	6.35	2425.48	27.68
3	5 (15.000)	2049.14	18.54	2438.78	81.43
3	10 (30.000)	1599.5	32,12	1962.19	155.41
3	14 (42.000)	1582.9	36.76	1503.15	206.07
4	1 (0.000)	1577.7	4.32	1913.21	22.28
4	5 (15.000)	1536.4	11.02	1634.46	59.74
4	10 (30.000)	1580.7	27.69	1597.55	144.32
4	14 (42.000)	1417.6	36.62	1502.79	190.42
5	1 (0.000)	2173.45	5.36	2645.57	16.65
5	5 (15.000)	2192.7	21.0	2528.65	79.04
5	10 (30.000)	2052.6	43,44	2406.7	185.15
5	14 (42.000)	1543.8	52.25	1611.22	243.09
6	1 (0.000)	1494.7	7,17	2882.76	15.81
6	5 (15.000)	1510.6	20.36	2813.8	71.2
6	10 (30.000)	1519.9	35.99	2700.66	165.61
6	14 (42.000)	1540.8	38,27	1930.79	219.92

According to data obtained conclusions can be drawn:

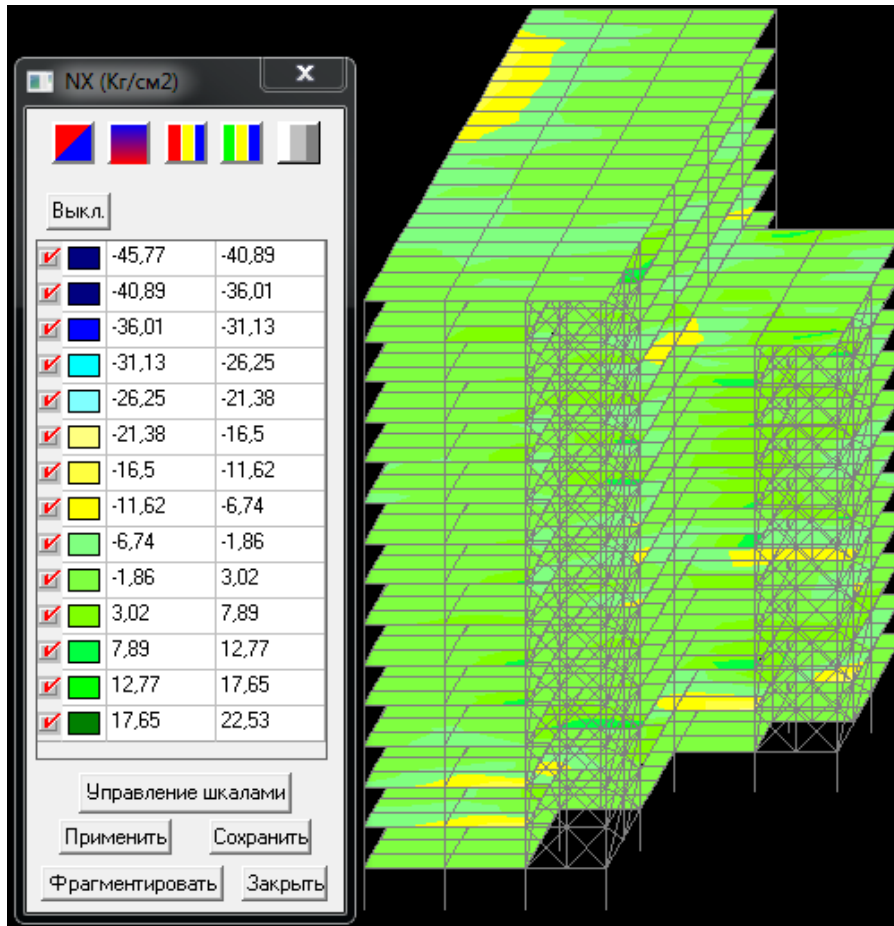
- Premischennya frame building under seismic loading intensity 6 points to 3.5 times the maximum allowable.
- The stresses in the elements at seychnomu exercise intensity by 6 points in the columns of the first floor of the middle row has increased 1.5 times, and the tension in the main beams increased by 2 times.

### **5.5. Calculation and analysis of stresses and displacements in the metal frame of the building from seismic load intensity of 7 points.**

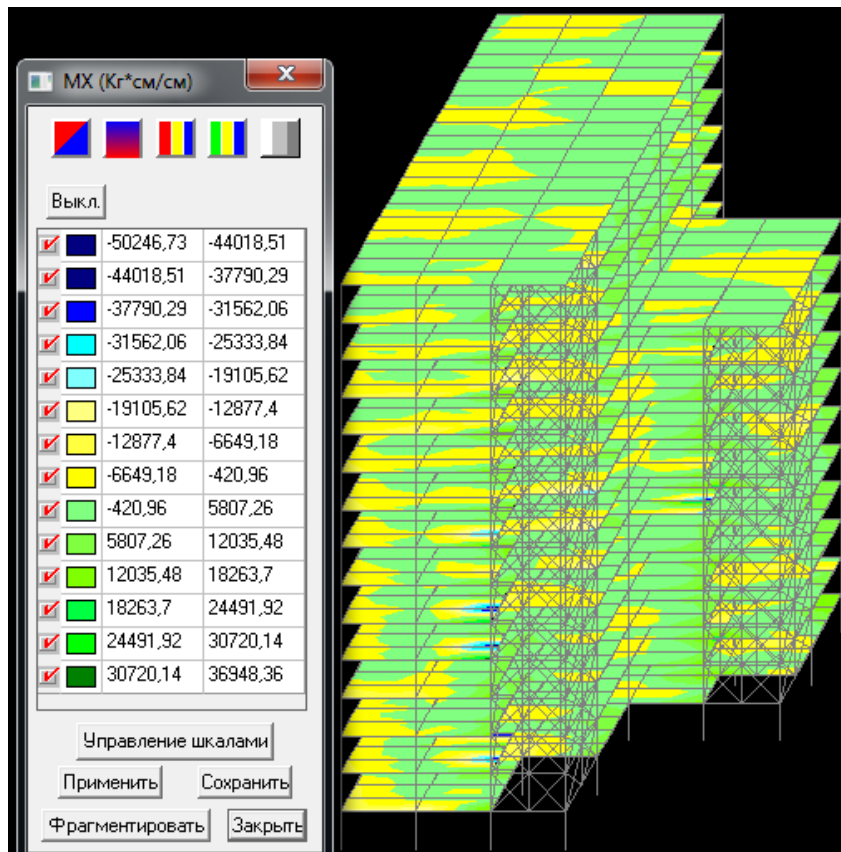
Similarly, section 5.3. perform the calculation and analysis of stresses and displacements of the seismic load intensity of 7 points.

In the specific elements chosen for analysis in Table 5.4.1'll show change stresses and displacements.

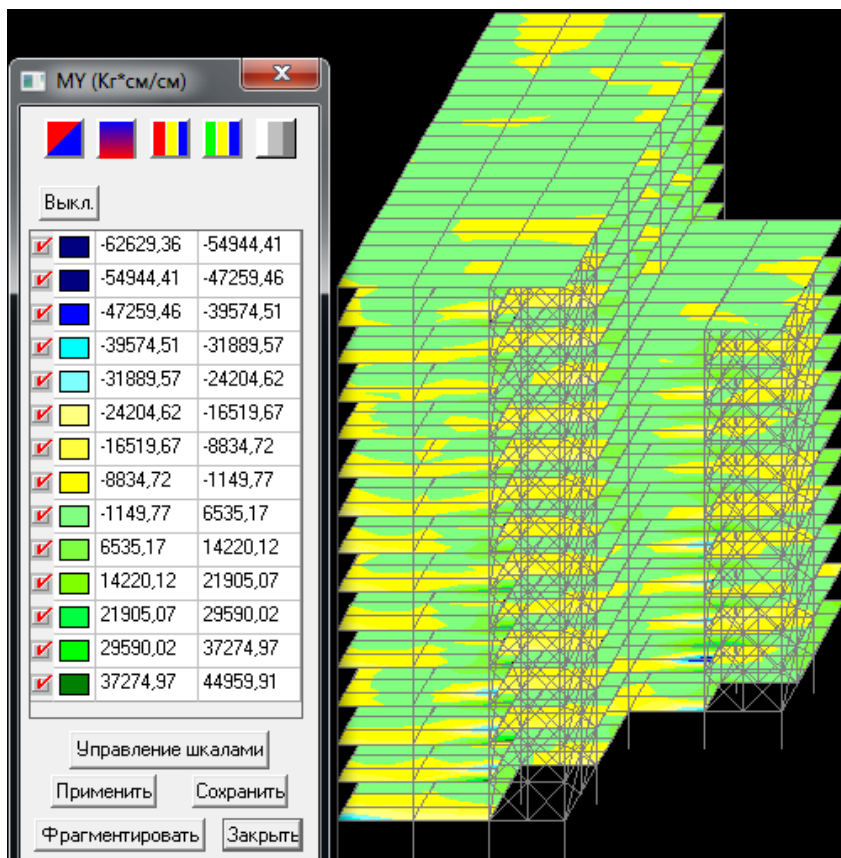
NX at X90 Y90 Z0



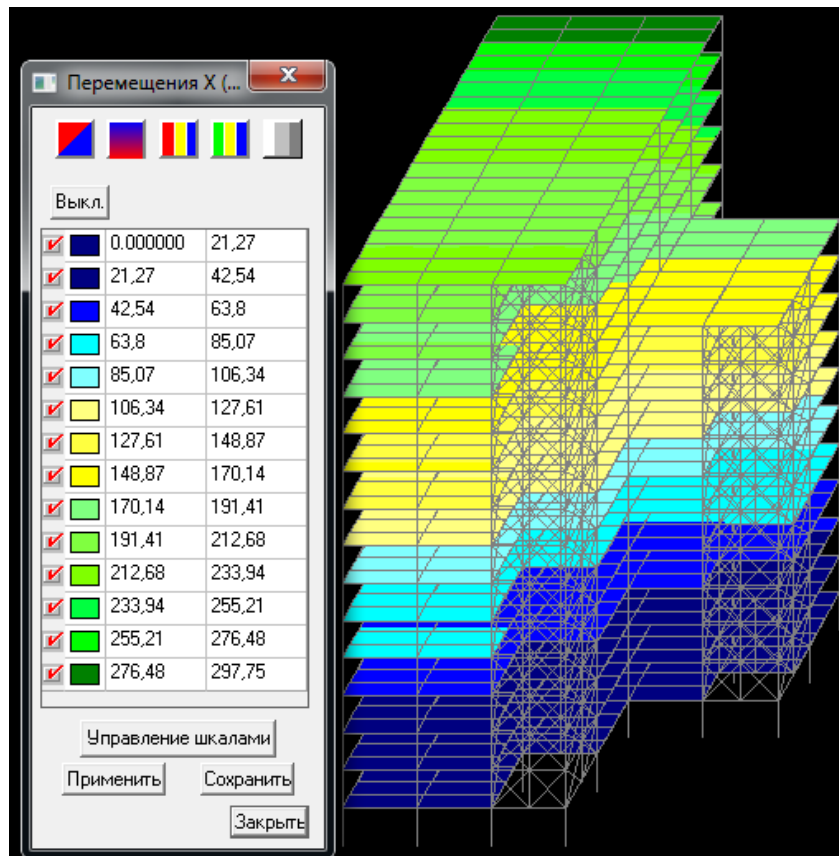
### MX at X90 Y90 Z0



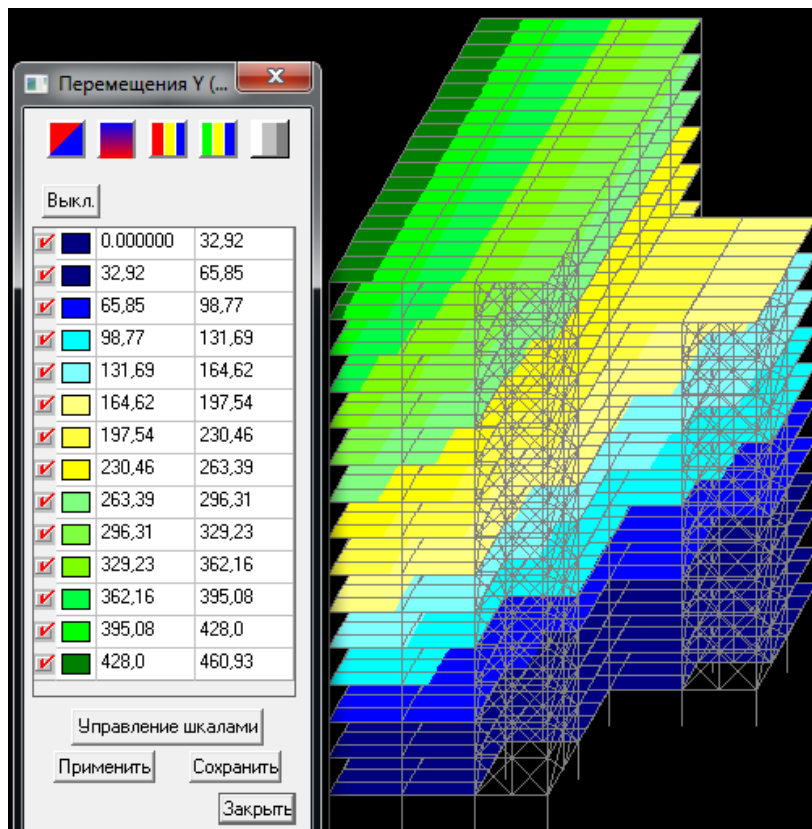
### MY at X90 Y90 Z0



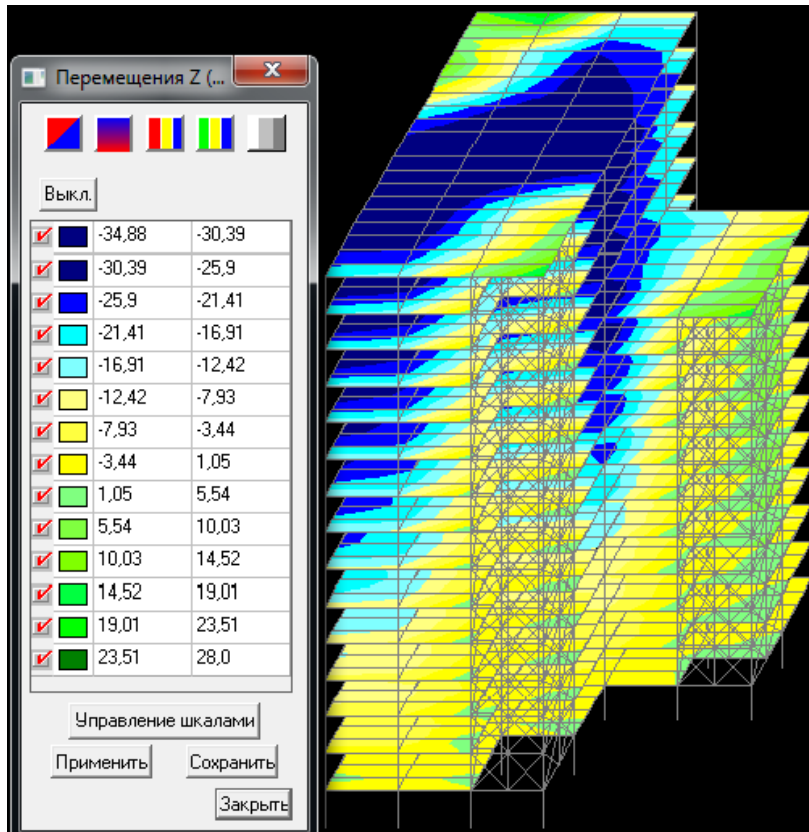
Move on axis X mm at X90 Y90 Z0



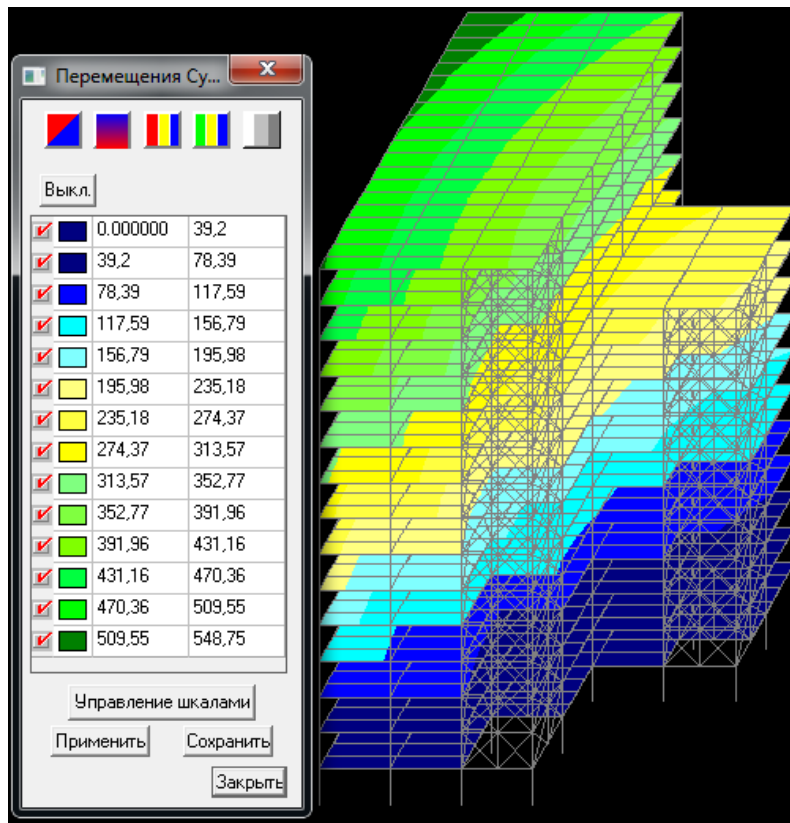
Navigating the axis Y, mm at X90 Y90 Z0



Move on axis Z, mm at X90 Y90 Z0



Total movement mm at X90 Y90 Z0



Analyze how much stress and displacement have changed in specific locations (tabl.5.4.1.).

Table 5.4.1.

Comparison of static and seismic load in 7 points for selected elements

Element number	Floor	Static load		Seismic 7 points	
		Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm	Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm
1	1 (0.000)	1990.27	3.57	5607.6	56.74
1	5 (15.000)	1608.47	12.25	1243.06	149.33
1	10 (30.000)	1651.1	27.1	1784.52	258.73
1	14 (42.000)	1516.28	36.62	1435.13	378.22
2	1 (0.000)	2160.5	7.18	4632.88	56.14
2	5 (15.000)	2127.8	21,22	4837.94	164.17
2	10 (30.000)	2140.24	37.75	5332.21	315.65
2	14 (42.000)	1509.56	45.12	3857.86	419.95
3	1 (0.000)	2129.31	6.35	3349.31	52.61
3	5 (15.000)	2049.14	18.54	3550.67	154.69
3	10 (30.000)	1599.5	32,12	3267.07	297.74
3	14 (42.000)	1582.9	36.76	2067.13	398.21
4	1 (0.000)	1577.7	4.32	3347.18	43.09
4	5 (15.000)	1536.4	11.02	1653.11	122.45
4	10 (30.000)	1580.7	27.69	1929.65	284.51
4	14 (42.000)	1417.6	36.62	1643.19	378.22
5	1 (0.000)	2,173.45	5.36	3225.79	31.26
5	5 (15.000)	2192.7	21.0	3012.82	149.31
5	10 (30.000)	2052.6	43,44	2711.89	350.69
5	14 (42.000)	1543.8	52.25	2420.61	462.61
6	1 (0.000)	1494.7	7,17	3362.41	29.17
6	5 (15.000)	1510.6	20.36	3,113.77	135.11
6	10 (30.000)	1519.9	35.99	2964.82	317.81
6	14 (42.000)	1540.8	38,27	1920.45	424.81

## 5.6. Final comments

According to data obtained conclusions can be drawn:

- Premischennya frame building under seismic loading intensity 7 points to 6.5 times the maximum allowable.
- The stresses in the elements at seychmichnomu exercise intensity by 6 points in the columns of the first floor of the middle row increased by 2 times, and the tension in the main beams increased by 2.1 times.

# Chapter 6 Methods seismic protection

## 6.1. General features methods.

General classification systems seismic protection structures shown in Fig. 6.1.[6] It consists of traditional methods of seismic and special means seismic protection.

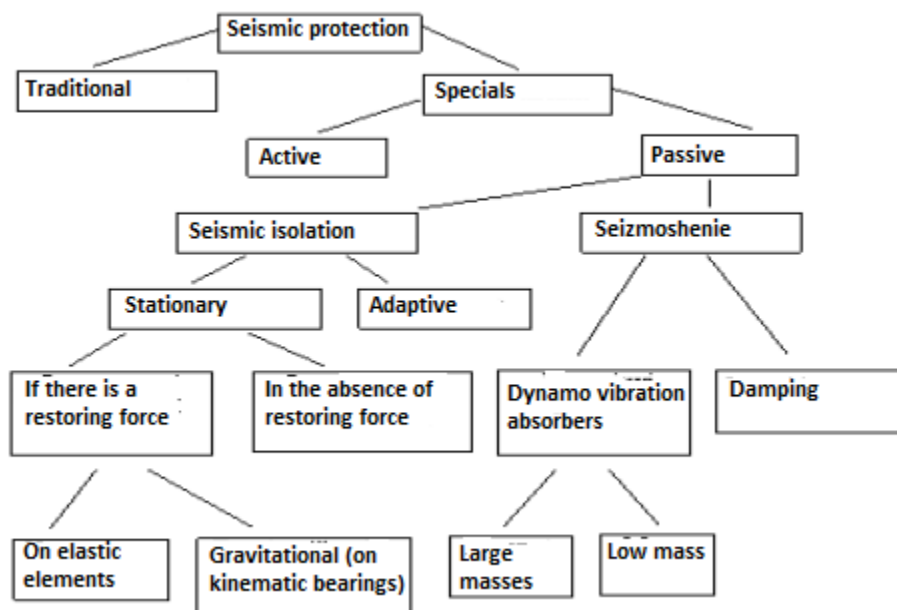


Fig. 6.1. Seismic protection classification methods.

## 6.2. Traditional methods provide earthquake resistance.

1. **The brick building. Brick buildings up to four floors is the most common type of buildings in seismic areas.**

Strength and deformation properties of stone masonry such that they do not resist the action of seismic loads. Vulnerabilities

buildings in earthquake areas is a combination of longitudinal and transverse walls. The action of horizontal forces in the plane of overlap shear hardest in areas perceived connections overlap with the walls. Therefore, the stone walls are arranged individual-concrete inclusion, which significantly increase the carrying capacity of masonry structures.

In buildings wall stability and the stiffness of the bearing walls of reinforced concrete reinforced strapping zamonolichuvannya, seismic zones and seismic core.

**2. Frame building. The construction of large buildings in seismic areas considered more appropriate, because they are about 2 times lighter than brick and have higher spatial rigidity. New buildings of reinforced concrete structures can withstand tremors measuring up to 8 points or more.**

Frame-building to improve the mechanical strength should be designed with longitudinal and transverse bearing walls, combined with each other and with floors and surfaces in a single spatial system that takes seismic loads. Exterior walls are counting on the horizontal load. In buildings over 5 floors using panels with double reinforcement. Overlap panel recommend that "the room" with grooved edges.

**3 Prefab building. In frame buildings design that takes horizontal seismic load can be: frame, frame with filling, frame with vertical relationships, diaphragms or cores rigidity. For seismic perception of hard concrete frame building components to be reinforced using welded, spiral or closed clamps.**

In frame buildings account for more horizontal seismic loads, setting the aperture and ligaments. Some earthquakes cause the

destruction of buildings of frame columns with large movements of the ground floor. One possible way to preserve the pillars of the ground floor, and thus the building as a whole, is the application on the ground floor of reserve rigid vertical elements (tears) that are disabled (collapsing) in oscillation amplitude rise buildings in some seismic action. Excluding these restructuring causes tearing of the internal structure of the system, changing its dynamic performance and reliability of structures under seismic actions of various types [6].

### **6.3. Special seismic protection.**

Special seismic protection is today one of the most promising areas in the field of earthquake engineering. According to the accepted classification all special seismic ablation methods can be divided into active (with an additional source) and passive. This division corresponds to the terminology prevailing theory of vibration protection. Active seismic protection includes additional energy and elements that govern the work of these sources, but its implementation requires a significant investment on the arrangement and operation. This eliminates the possibility of widespread use of active seismozahystu for building structures. Next we consider special methods of passive seismic protection not using extra energy. These methods are divided into seismic isolation and seismic ablation. In systems provided seismic isolation reducing mechanical energy, received from the base structure by setting frequency oscillation frequencies prevailing structures of action. There adaptive and fixed seismic isolation system.

In adaptive systems dynamic characteristics of structures irreversibly change during the earthquake, "adapting" to the seismic

action. For example, in the lower part of the building between the bearing studs downstairs establishes contact panel (Fig. 6.2.1.) That are disabled (destroyed) with intense seismic action when action spectrum is dominated by a period equal or close to free oscillation period of constructions. After disconnecting the frequency of free oscillations panels falling period increases, resulting in a decrease in seismic activity. As disadvantages adaptive systems indicate that after the destruction of relationships that are switched off during the earthquake need their recovery is not always possible to implement in practice. In fixed systems dynamic characteristics are stored in the earthquake.

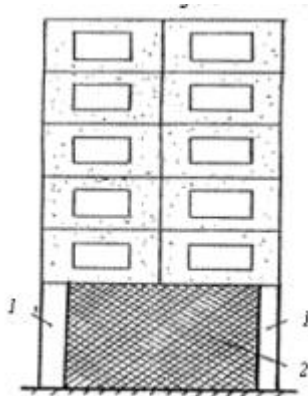


Fig.6.2.1. Example of Adaptive seismic isolation 1 - bearing risers, 2- coherent panel.

Basic principles of arrangement seismic isolation foundations are reduced to the following:

- they should be used in areas for which confidently predicted high and medium frequency earthquakes with a period of acceleration of less than 1 s. (In areas which are characterized by low-frequency earthquakes, seismic isolation construction is not recommended.)

- they must necessarily include additional means seismic ablation system, reducing dangerous isolated relative displacement

of the object; such means can be enerhopohlynannya special devices, such as dynamic dampers, enerhopohlynachi dry and viscous friction, etc. All designs seismic isolation foundations can be divided into two groups, depending on whether there is or there is no turning force at the mutual displacement seismic isolation parts of the building. Seismic isolation, which does not provide the turning force acting on seismic isolation of structures realized by arranging the sliding zone (Fig. 6.2.2). When the earthquake lowest horizontal load friction is overcome and there is slippage of the upper base plate relative to the lower. This manages several times to reduce the load on the equipment and the building. The advantage of this design is its relative simplicity and clarity of work. The disadvantages to be considered a lack of opportunities to regulate friction forces.

In systems seismic ablation, including enerhopohlynachi and dynamic dampers, a significant effect of vibration is achieved through the use of special energy absorbers with increased dissipative properties. Mechanical energy designs, swinging transformed into other forms of energy, which leads to a damping of vibrations or the redistribution of power from the protected design to the absorber.

The scattering of energy systems seismic ablation is due to:

- Force of plastic deformation,
- dry or viscous friction;
- plastic elements;
- dynamic oscillation.

Energy-absorbing dry or viscous friction applied systems seismic isolation foundations can be used not only as indissoluble connection between the object and the foundation, but also as a

movement limiters that are installed with a specified gap. They are the most convenient in terms of practical implementation and operation.

In systems with dynamic seismic ablation Oscillation mechanical energy design, which varies, not only can move into other forms of energy, but also redistributed the design of the defending to the absorber. To ensure the efficient operation of Oscillation requires a substantial increase in extinguishing the masses. Systems seysmohasinnya of Oscillation used to protect skyscrapers.

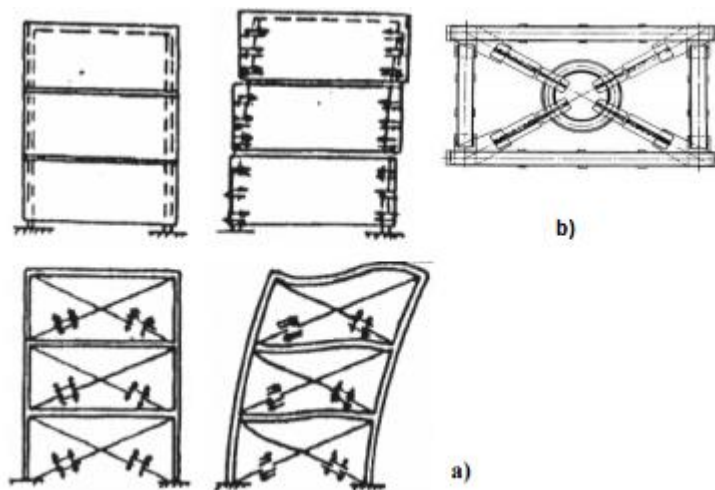
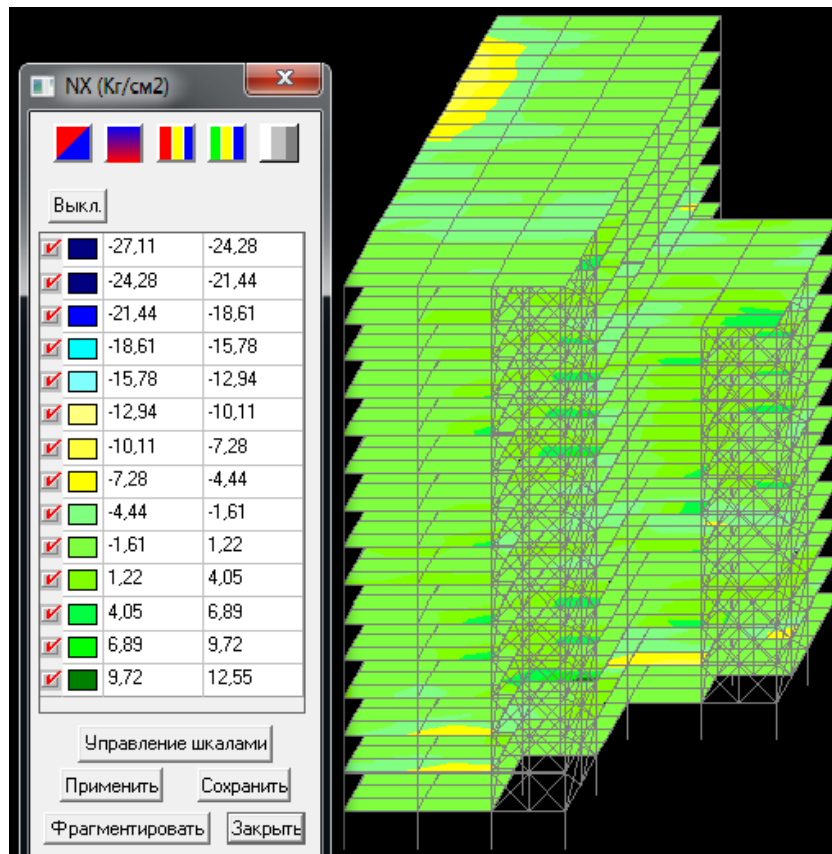


Fig.6.2.2. Examples of systems energy-absorbing elastic-friction connections (a). Plastic energy-absorbing in communication systems steel frames (b).

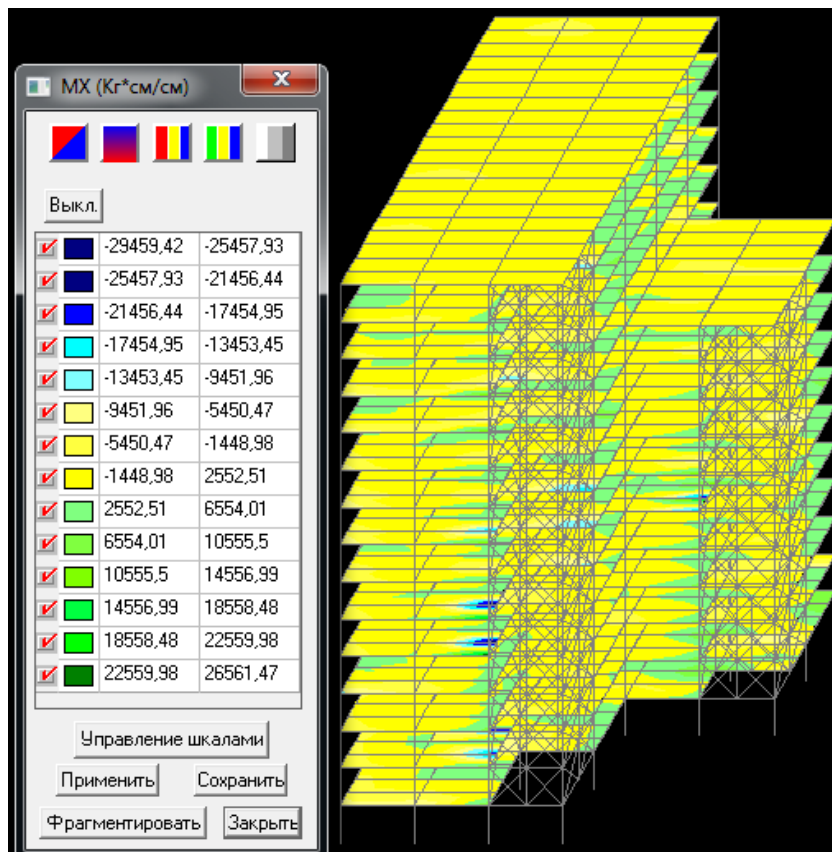
#### **6.4. Strengthening the building frame sections basic way to increase the load-bearing elements.**

To analyze the effectiveness of increasing seismic frame public building sections will increase the basic bearing elements by 20%. For selected items and calculate the change in stress displacement data obtained by the calculation is listed in the table 6.3.1.

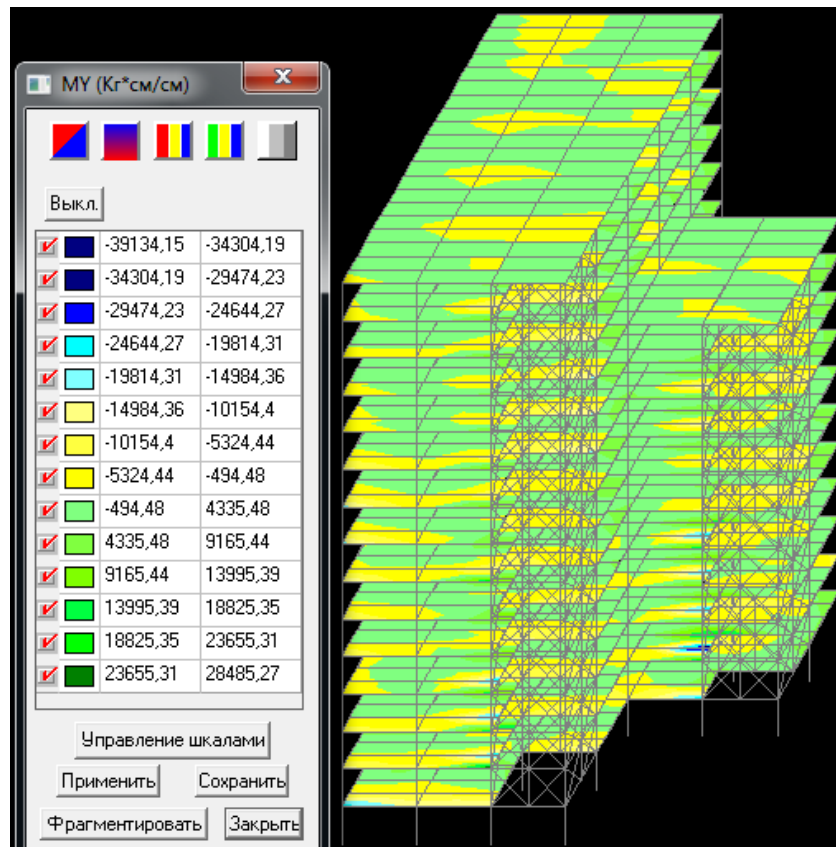
### NX at X90 Y90 Z0



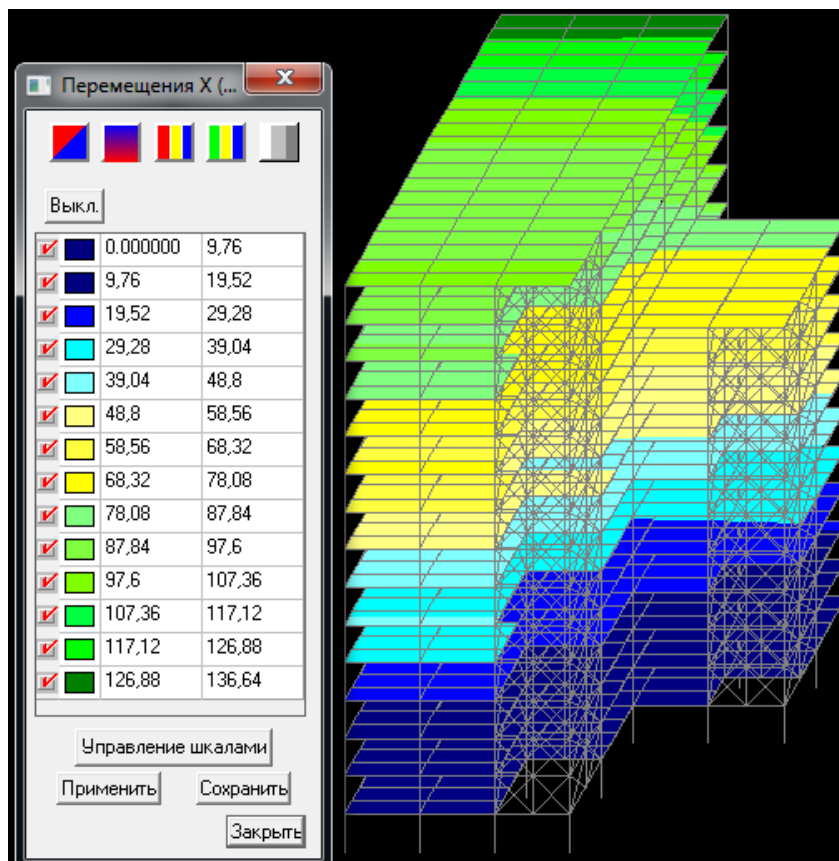
### MX at X90 Y90 Z0



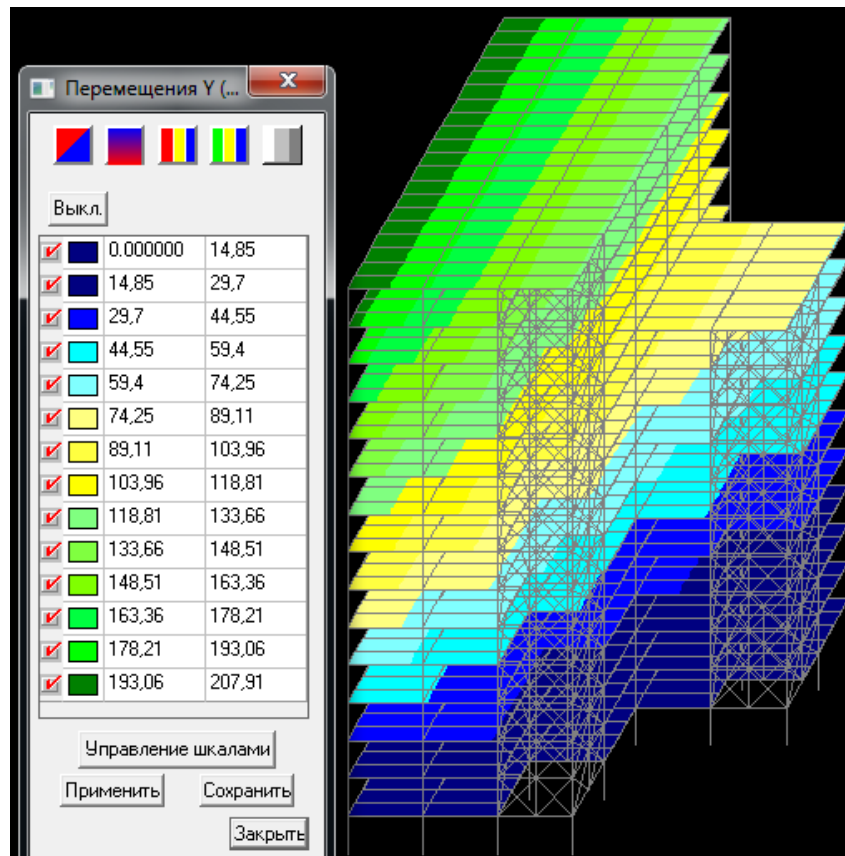
MY at X90 Y90 Z0



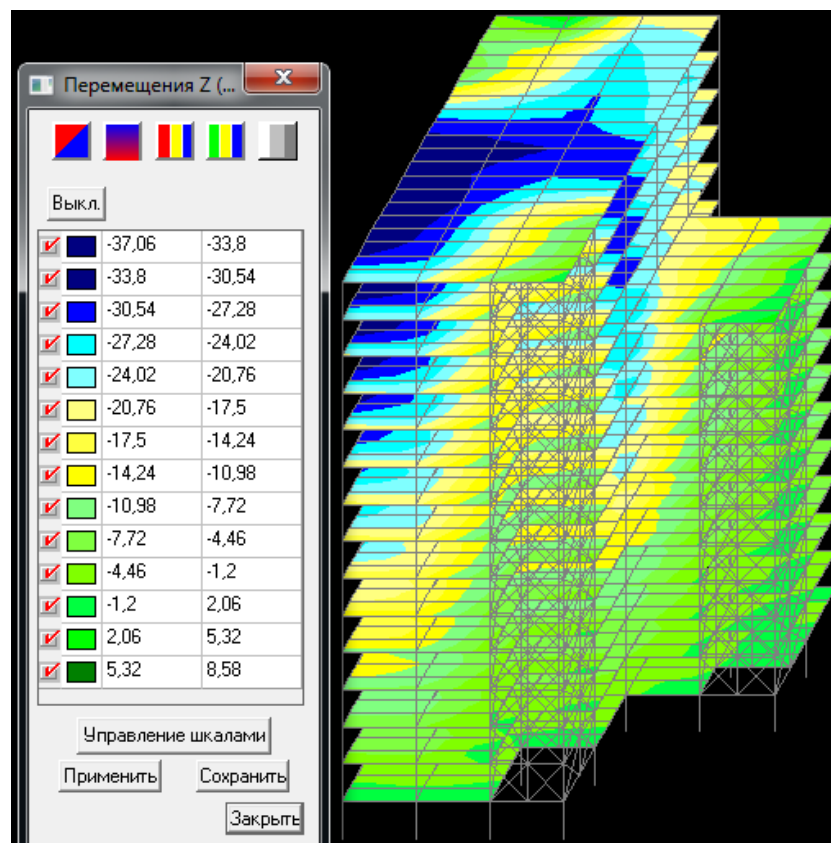
Displacement on axis X mm at X90 Y90 Z0



Displacement the axis Y, mm at X90 Y90 Z0



Displacement on axis Z, mm at X90 Y90 Z0



## Total displacement mm at X90 Y90 Z0

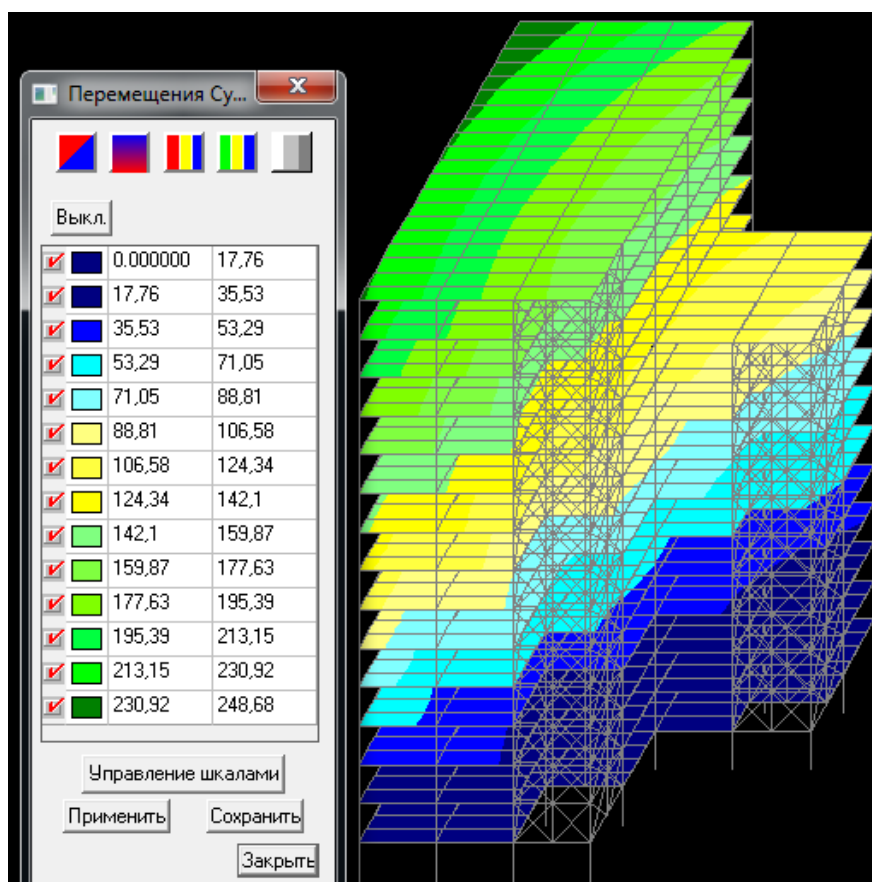


Table 6.4.1.

Comparison of seismic load in 6 points for a building with normal sections and buildings with sections increased by 20%

Element number	Floor	Seismic 6 points		Seismic 6 points (+ 20%)	
		Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm	Tension, $\sigma$ , kg / cm <sup>2</sup>	Displacement, $\Delta$ , mm
1	1 (0.000)	2104.7	28.63	2,476.94	24.39
1	5 (15.000)	2,264.74	75.58	2,142.36	65.84
1	10 (30.000)	1,450.59	144.32	1,405.78	126.54
1	14 (42.000)	1,491.58	190.42	1,387.54	166.78
2	1 (0.000)	3207.3	29.72	3,036.55	24.16
2	5 (15.000)	<b>3,223.97</b>	87.06	<b>3,162.34</b>	73.19
2	10 (30.000)	2767.6	166.18	2,508.08	141.26
2	14 (42.000)	1905.4	219.28	1,787.29	187.25
3	1 (0.000)	2,425.48	27.68	2,101.69	22.6

3	5 (15.000)	2,438.78	81.43	2,120.79	68.73
3	10 (30.000)	1,962.19	155.41	1,914.09	122.6
3	14 (42.000)	1,503.15	206.07	1,453.81	176.74
4	1 (0.000)	1,913.21	22.28	1,961.53	18.55
4	5 (15.000)	1,634.46	59.74	1,358.89	53.74
4	10 (30.000)	1,597.55	144.32	1,453.59	123.84
4	14 (42.000)	1,502.79	190.42	1,491.04	165.09
5	1 (0.000)	2,645.57	16.65	2,877.34	12.99
5	5 (15.000)	2,528.65	79.04	2,111.19	66.51
5	10 (30.000)	2406.7	185.15	1,985.12	157.75
5	14 (42.000)	1,611.22	243.09	1,524.42	208.07
6	1 (0.000)	2,882.76	15.81	2,920.39	12.47
6	5 (15.000)	2813.8	71.2	2,909.21	60.22
6	10 (30.000)	2,700.66	165.61	2,626.59	142.34
6	14 (42.000)	1,930.79	219.92	1,520.68	190.11

According to data obtained conclusions can be drawn:

- Displacement frame building under seismic loading intensity 6 points with increasing cross sections at 20% decreased 40 mm compared to the movement in the sections that satisfy the static load.
- The stresses in the elements at seismic intensity exercise intensity in 6 points while increasing sections of the main frame bearing elements in public buildings decreased 1.2 times.
- The tension and movement do not meet the requirements of marginal states. Increased cross-section is an effective method seismic protection.

**6.5. Boost frame building means the installation of additional structural elements.**

To analyze the changes of stresses and displacements in the metal frame building public relations install additional systems that are installed in longitudinal and transverse direction. To analyze the efficiency of the given method of analysis to perform seismic load intensity of 6 points. The resulting data is listed in table 8.1. and perform comparison.

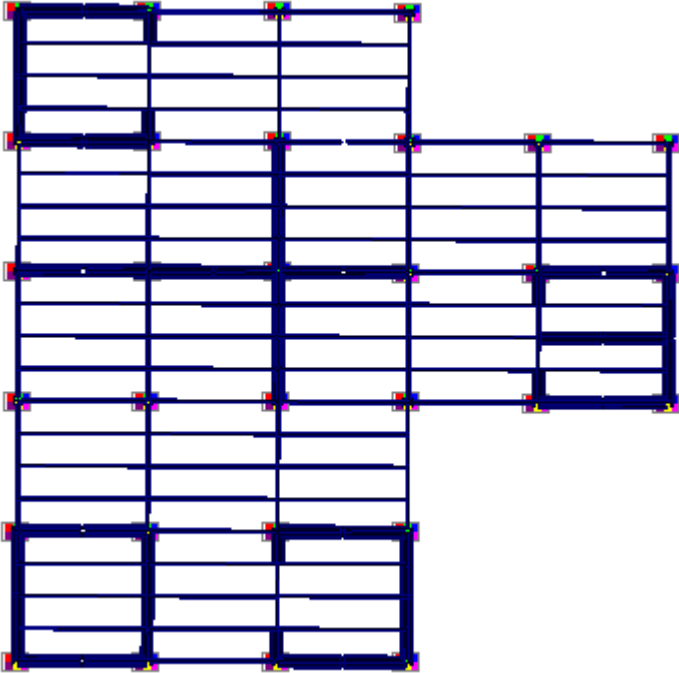


Fig.8.1. Location of additional bonds in the background.

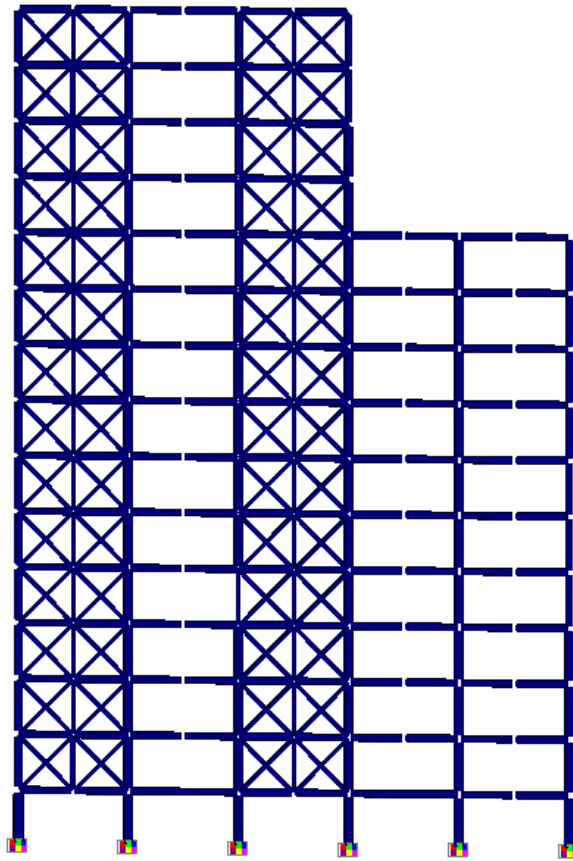


Fig.8.2. Location of bonds in the transverse direction.

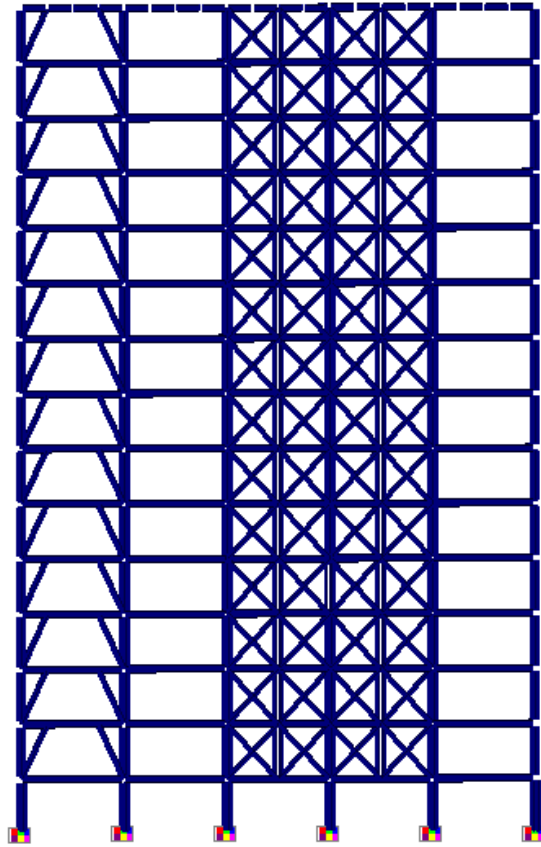
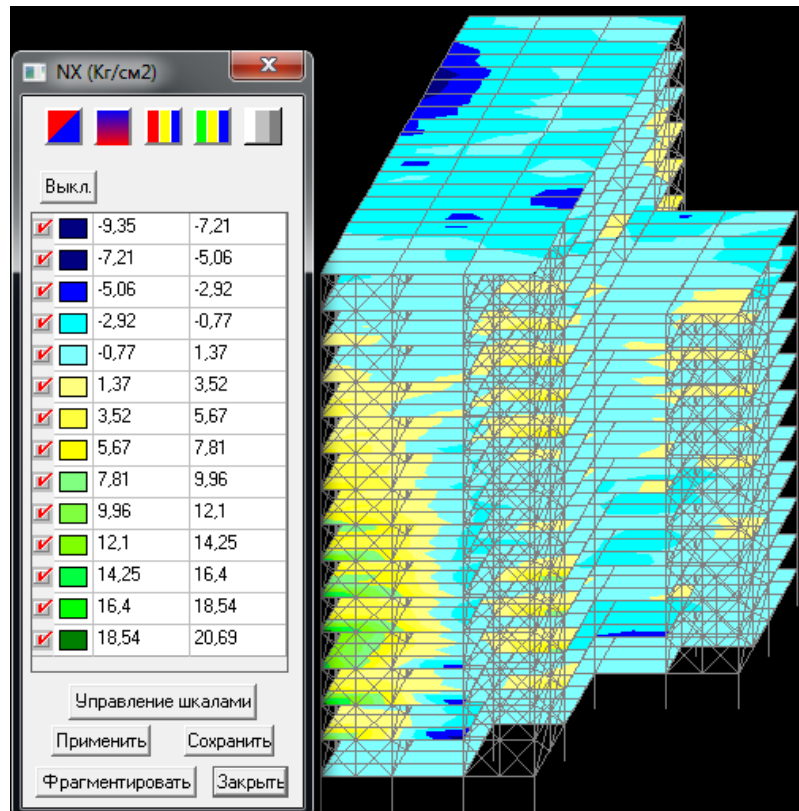
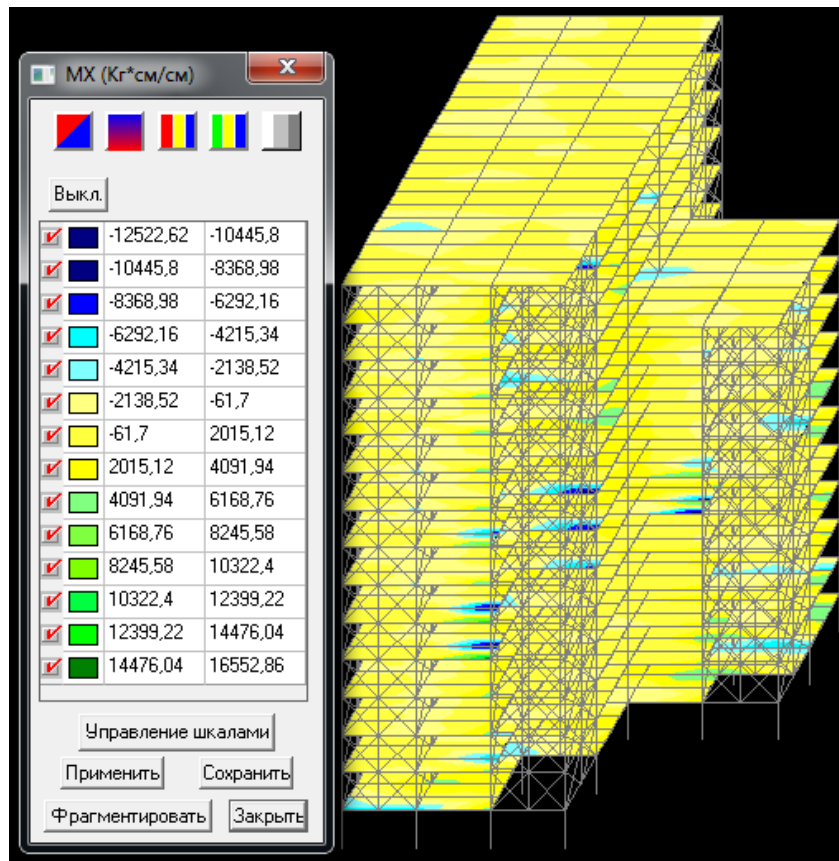


Fig.8.3. Location of bonds in the longitudinal direction.

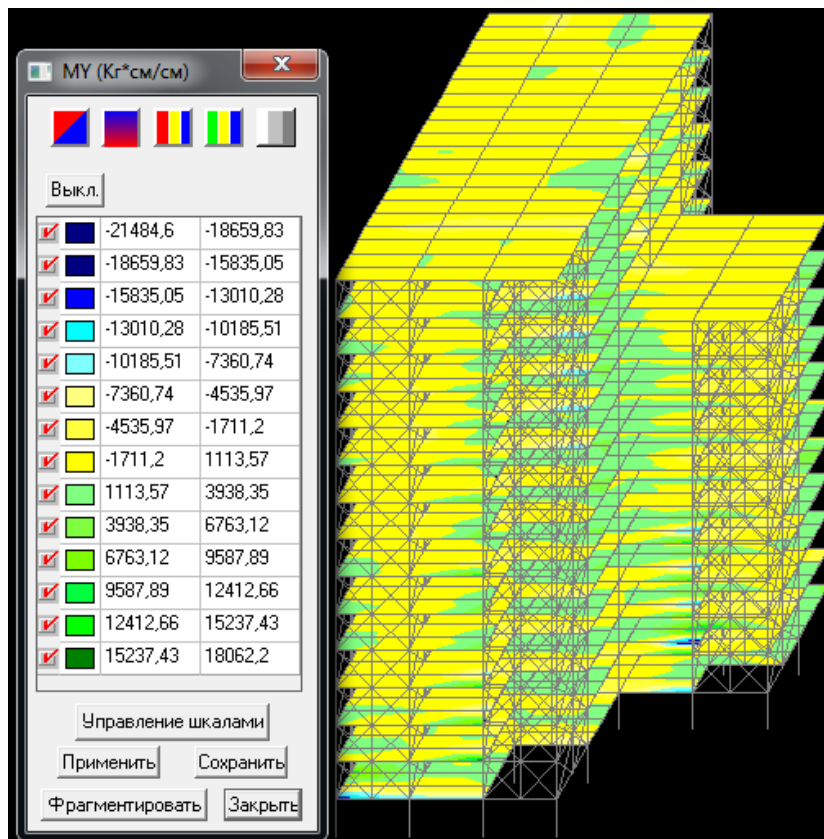
NX at X90 Y90 Z0



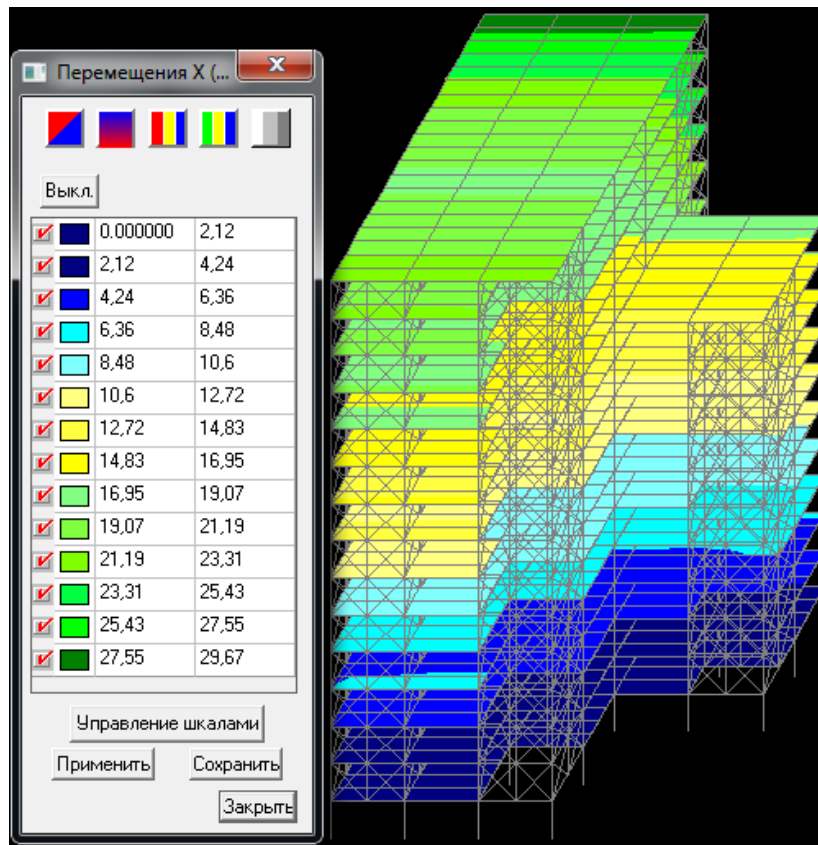
### MX at X90 Y90 Z0



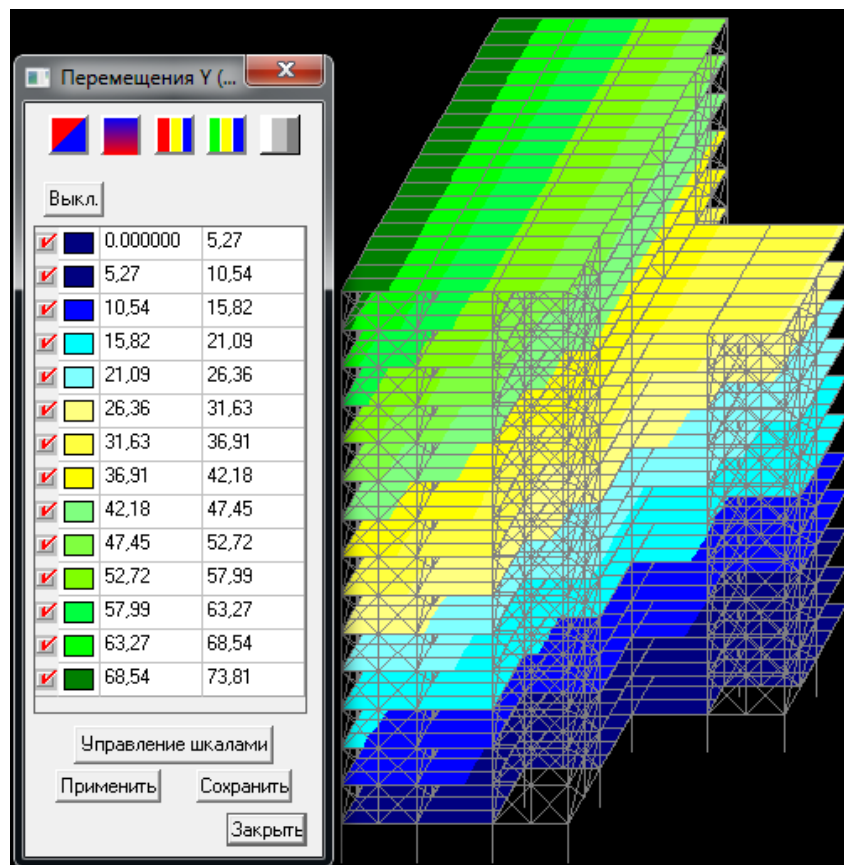
### MY at X90 Y90 Z0



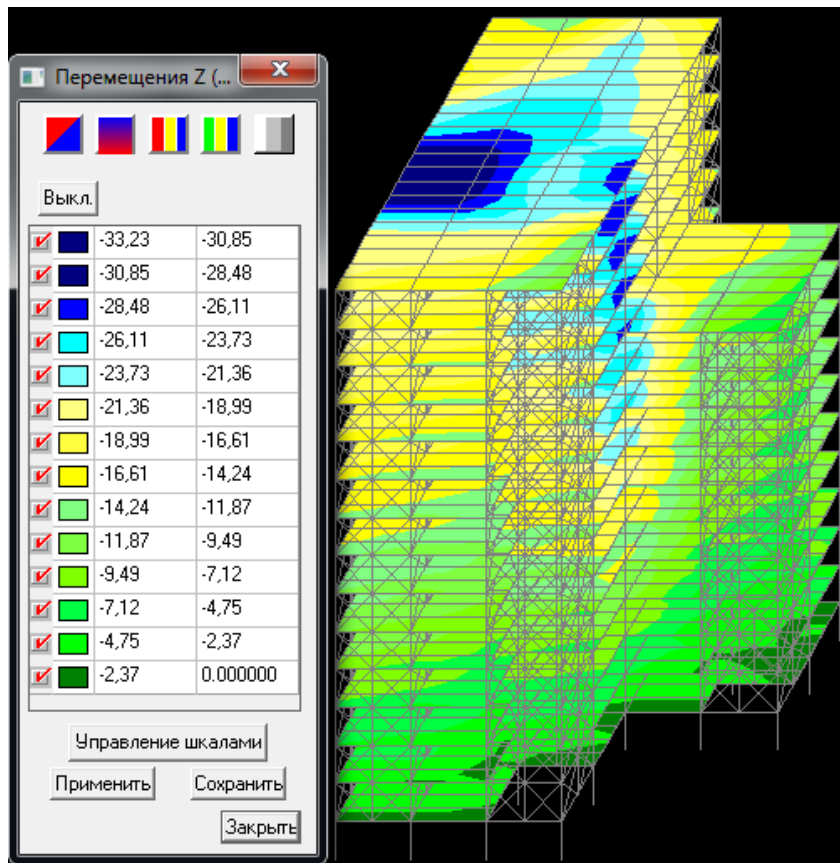
Displacement on axis X mm at X90 Y90 Z0



Displacement the axis Y, mm at X90 Y90 Z0



Displacement on axis Z, mm at X90 Y90 Z0



Total displacement mm at X90 Y90 Z0

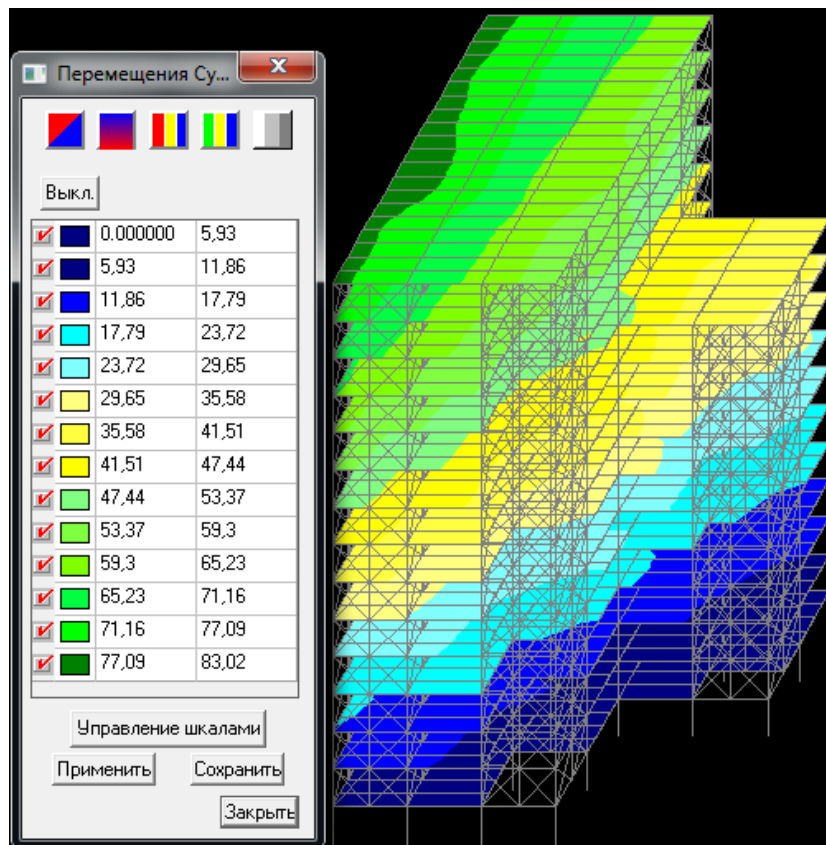


Table 6.5.1.

Comparison of stress and displacement values for normal and  
building buildings with additional structural elements

Element number	Floor	Seismic 6 points		Seismic 6 points (+ additional links)	
		Tension, $\sigma$ , kg / cm <sup>2</sup>	Moving, $\Delta$ , mm	Tension, $\sigma$ , kg / cm <sup>2</sup>	Moving, $\Delta$ , mm
1	1 (0.000)	2104.7	28.63	2484.7	10.29
1	5 (15.000)	2,264.74	75.58	1,583.25	22.97
1	10 (30.000)	1,450.59	144.32	1,684.18	42.49
1	14 (42.000)	1,491.58	190.42	1,488.77	55.37
2	1 (0.000)	3207.3	29.72	2,085.37	12.07
2	5 (15.000)	3,223.97	87.06	1,875.28	29.8
2	10 (30.000)	2767.6	166.18	1,767.07	51.54
2	14 (42.000)	1905.4	219.28	1,402.66	65.46
3	1 (0.000)	2,425.48	27.68	1852.1	11.14
3	5 (15.000)	2,438.78	81.43	1,683.95	26.37
3	10 (30.000)	1,962.19	155.41	1,743.55	45.89
3	14 (42.000)	1,503.15	206.07	1,348.94	58.22
4	1 (0.000)	1,913.21	22.28	1,621.08	9,44
4	5 (15.000)	1,634.46	59.74	1,476.75	19,23
4	10 (30.000)	1,597.55	144.32	1,458.58	42, 67
4	14 (42.000)	1,502.79	190.42	1,423.92	55.37
5	1 (0.000)	2,645.57	16.65	2,570.08	8.94
5	5 (15.000)	2,528.65	79.04	2,370.31	27.18
5	10 (30.000)	2406.7	185.15	2,187.39	57.41
5	14 (42.000)	1,611.22	243.09	1,931.52	74.33
6	1 (0.000)	2,882.76	15.81	2,727.59	9.1
6	5 (15.000)	2813.8	71.2	2,366.24	22.98
6	10 (30.000)	2,700.66	165.61	2,273.94	46.52
6	14 (42.000)	1,930.79	219.92	1,799.89	59.61

According to data obtained conclusions can be drawn:

- by establishing links zmenshyty could move to the limit.
- tension in the frame elements also zmenshylys an average of 1.1 times.
- installation of additional structural element of an effective method seysmozahystu building in the intensity of the load at 6 points, 7 points but this method is not enough. You must use special techniques seismic protection.

# **Chapter 7 Conclusions**

## **7.1 General conclusions on research.**

During research made the same conclusions:

1. A calculation model of public buildings in the complex SCAD program.
2. Before the settlement of the building have been made static and seismic loading and calculations were performed.
3. The calculations by displacement and stress in the elements of the building of the static and seismic loads.
4. Preferably increasing values of forces and displacements in frame building under seismic loading.
5. Checked increase efficiency sections basic elements nusuchyh 20% as a means seismic protection. The given means not proved effective.
6. Installed additional structural elements and amended scheme to achieve stability and strength.
7. The analysis of the results and on the basis of their proposed design options and technical solutions frame building.

## **7.1 Recommendations for the design of the results of the calculation.**

Analyzing the data in the calculation can make the following recommendations for the design of a seismic dangerous regions of Ukraine:

- For the construction zone of probable earthquake intensity of 5 points makes no sense to use special measures seismic protection. It is enough to use in the construction of high-strength steel. Moving does not significantly exceed the maximum allowable under the most unfavorable angles of application of force. There are seismic load combinations in which tension and movement do not exceed the limit values.
- For designing steel buildings in an area where a possible earthquake intensity 6 points should take special seismic protection means. To ensure stiyosti building and strength enough to perform traditional means. For example, a public building, it was determined that enough staging horizontal longitudinal and transverse links and the use of high-strength steel. It was also determined that increasing sections bearing structures by 20% does not ensure the fulfillment of the boundary conditions.
- For designing steel buildings in seismic zone 7 points does not make sense to use traditional means seismic protection. In this case you must install special equipment.

## References.

1. SBC B.1.1-12: 2014 "Construction in seismic regions of Ukraine", Ministry of Construction, Architecture and Housing and Communal Services of Ukraine, Kyiv 2014.

2. A.M. Uzdin, T.A. Sandovych, Nasser A.I.-Amin Samih Mohomad Basic theory of seismic and seismic construction of buildings and structures. - St. Petersburg: Izd VNYYH them. B. E. Vyedyenyeyeva, 1993 - p. 176.

3. A.N. Birbraer// Calculation of structures on seismic stability. - Science, St. Petersburg, 1998 - p. 255.

4. S. Okamoto// Earthquake resistant engineering structures. M.: Stroiizdat, 1980.

5. SBC B.1.2-12: 2006 "Loads and effects", the Ministry of Construction, Architecture and Housing and Communal Services of Ukraine, Kyiv 2006.

6. Metal structures. Ed. Belen E.I. Stroiizdat, M., 1986

7. Calculation of steel structures. J.M. Lihtarnikov etc. "Builder", Kyiv, 1984.

8. Metal structures. In three vols., Gorev V.V. Higher. HQ., M., 1997. d- (1 TA-557s).

9. Steel Structures: Design Guide / Pod Society. N.P.Melnikova - M. : Stroiizdat. M., 1972. - 328 p.

10. Metal structures. Designer's Guide. N.P. Melnikova Stroiizdat, M., 1980 g.

11. Vasil'chenko V.T., Rutman A.N., Lukyanenko E.P.// Reference design metallic structures. - Kyiv: Builder, 1990. - 312 p.
12. The dynamic calculation of structures for special effects. Under. Ed. BG Korenev, IM Rabinovicha.- Moscow: Stroiizdat, 1981.- 741 p.
13. VA Volosuhin, V.P., V.N. Morgunov// Earthquake resistant construction sites and waterworks. Tutorial. - Novocherkassk YURHTU, 2007. - 167 p.
14. Polyakov S.V. // Seismic design of buildings: Textbook. Guidelines for schools. - the second ultrasound. - M.: High. School, 1983. - 304 p., IL.
15. Eisenberg J.M. // Buildings with excluded for seismic areas. M.: Stroiizdat, 1976. 232 p.
16. Eisenberg J.M. // Seismic isolation tall buildings earthquake-resistant construction. Security structures. №4, 2007. p. 41-43.
17. Avidon G.E., Carlin E.A. // Features fluctuations buildings with foundations seismic isolation.
18. AM Kurzanova and Y.D. // Cherepynsko earthquake engineering. Security structures. №1, 2008.s. 42-44.
19. Computational Seismology and Geodynamics: Collected papers and monographs. Releases. 1-45. M .: Science; Geos; URSS, 1966-2016.
20. ISO B. 1.1-28: 2010

21. Medvedev S., Sponheuer W., Karník V., Neue seismische Skala Intensity scale of earthquakes, 7. Tagung der Europäischen Seismologischen Kommission vom 24. 9. bis 30. 9. 1962 in Jena, DDR, Berlin: Akademie-Verlag, 1964, pp.69-76.