CIVIL ARTIFITIAL STRUCTURE, EARTHQUAKE INFLUENCE

Made by Team 6

Part 1: Analysis

- Plan:
  - 1. Analysis of the problem:
    - 1.1. Wave Equation.
    - 1.2.Quantitative relationships.
    - 1.3.Wave Propagation Characteristics.
  - 2. Solving problem with principles of seismic resistance:
    - 2.1. General principles.
    - 2.2. Follow through principles.
    - 2.3. what are oscillations of linear oscillator for?

Part 2: Numerical Solution and Static Analysis Method

- Plan:
- 1. Introduce to audience Static Analysis Method
- 2. Show the numerical solution of problem statement

1.1. Wave Equation.

Wave Equation

The phenomena of wave propagation involves three characteristics:

I. The ground moves and changes the density

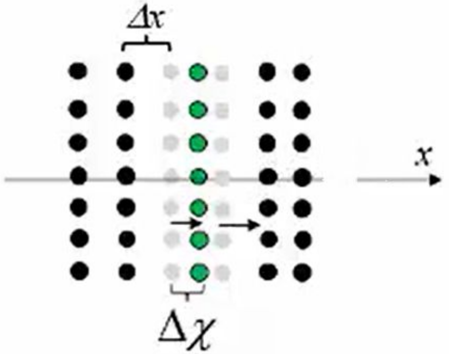
II. The changes in density correspond to changes in pressure

III. The pressure changes initiate particle motion

1.2. Quantitative relationships.

Quantitative relationships

We expect that ground movement can be represented as particle movement at the smaller scale. As particles are displaced from their equilibrium position, we expect that will lead to local volume and density changes.



At left we see a row of particles (green) displaced from their equilibrium position (grey) a distance $\Delta\chi$. We can simplify the development by assuming we have a plane wave so that the volume change is proportional to the displacement and in the limit that displacements are very small we can write -

$$I.\ \Delta\rho = -\rho_o \frac{\partial \chi}{\partial x}$$

i.e. the equilibrium density times the fractional volume change ΔV/V

1.3. Wave Propagation Characteristics.

Wave propagation characteristics

$$I.\ \Delta\rho = -\rho_o \frac{\partial\chi}{\partial x}$$

where $\Delta\rho$ is the change in density, ρ_o is the equilibrium density and the plane wavefront travels in the x direction.

II. The particle motions produce changes in pressure with $P(\rho_o + \Delta\rho)$ increasing or decreasing relative to the equilibrium pressure. We can represent this change by looking at the Taylor series expansion of P.

$$P(\rho) = P(\rho_o) + \Delta\rho \frac{\partial P}{\partial\rho}$$

$\Delta P = \Delta\rho \frac{\partial P}{\partial\rho} = k\Delta\rho$ and k is a constant for any given material

1.3. Wave Propagation Characteristics.

Wave propagation characteristics

$$I.\ \Delta\rho = -\rho_o \frac{\partial \chi}{\partial x}$$

$$II.\ \Delta P = k\Delta\rho$$

III. The third characteristic results from application of Newton's second law of motion that $F=ma$.

In our plane wave example, we select a volume of length Δx and area $A=1$. This yields an enclosed mass of $\rho_o \Delta x$ which undergoes an acceleration $a = \frac{\partial^2 \chi}{\partial t^2}$

Hence *ma* equals $\rho_o \Delta x \left(\frac{\partial^2 \chi}{\partial t^2} \right)$, the force perpendicular to the wavefront.

1.3. Wave Propagation Characteristics.

Wave propagation characteristics

$I. \quad \Delta\rho = -\rho_o \dfrac{\partial \chi}{\partial x}$

$II. \quad \Delta P = k \Delta\rho$

$III. \quad F = \rho_o \Delta x \left(\dfrac{\partial^2 \chi}{\partial t^2} \right)$

The third feature describing wave propagation is related to the driving force and the driving force is related to a change in pressure of a pressure differential acting over the distance Δx. So we can rewrite F in terms of the change in pressure per unit volume using unit area on the wavefront to yield

$$F = -\frac{\partial P}{\partial x} \underbrace{\Delta x}_{\Delta V} = \rho_o \Delta x \left(\frac{\partial^2 \chi}{\partial t^2} \right)$$

$$\rho_o \left(\frac{\partial^2 \chi}{\partial t^2} \right) = -\frac{\partial P}{\partial x}$$

where ∂P is the change in pressure ΔP relative to its equilibrium pressure so that

$$\rho_o \left(\frac{\partial^2 \chi}{\partial t^2} \right) = -\frac{\Delta P}{\partial x}$$

1.3. Wave Propagation Characteristics.

Wave propagation characteristics

I. $\Delta\rho = -\rho_o \dfrac{\partial \chi}{\partial x}$

II. $\Delta P = k\Delta\rho$

III. $-\dfrac{\partial P}{\partial x} = \rho_o\left(\dfrac{\partial^2 \chi}{\partial t^2}\right)$

In the expression below, we'll substitute *II)* for ΔP

$$\rho_o\left(\frac{\partial^2 \chi}{\partial t^2}\right) = -\frac{\Delta P}{\partial x} \quad \text{to obtain} \quad \rho_o\left(\frac{\partial^2 \chi}{\partial t^2}\right) = -\frac{k\Delta\rho}{\partial x}$$

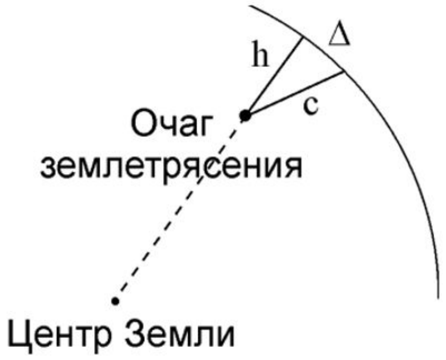
Then substitute *I)* for $\Delta\rho$ to obtain

$$\rho_o\left(\frac{\partial^2 \chi}{\partial t^2}\right) = \rho_o k \frac{\partial^2 \chi}{\partial x^2}, \text{ and thus}$$

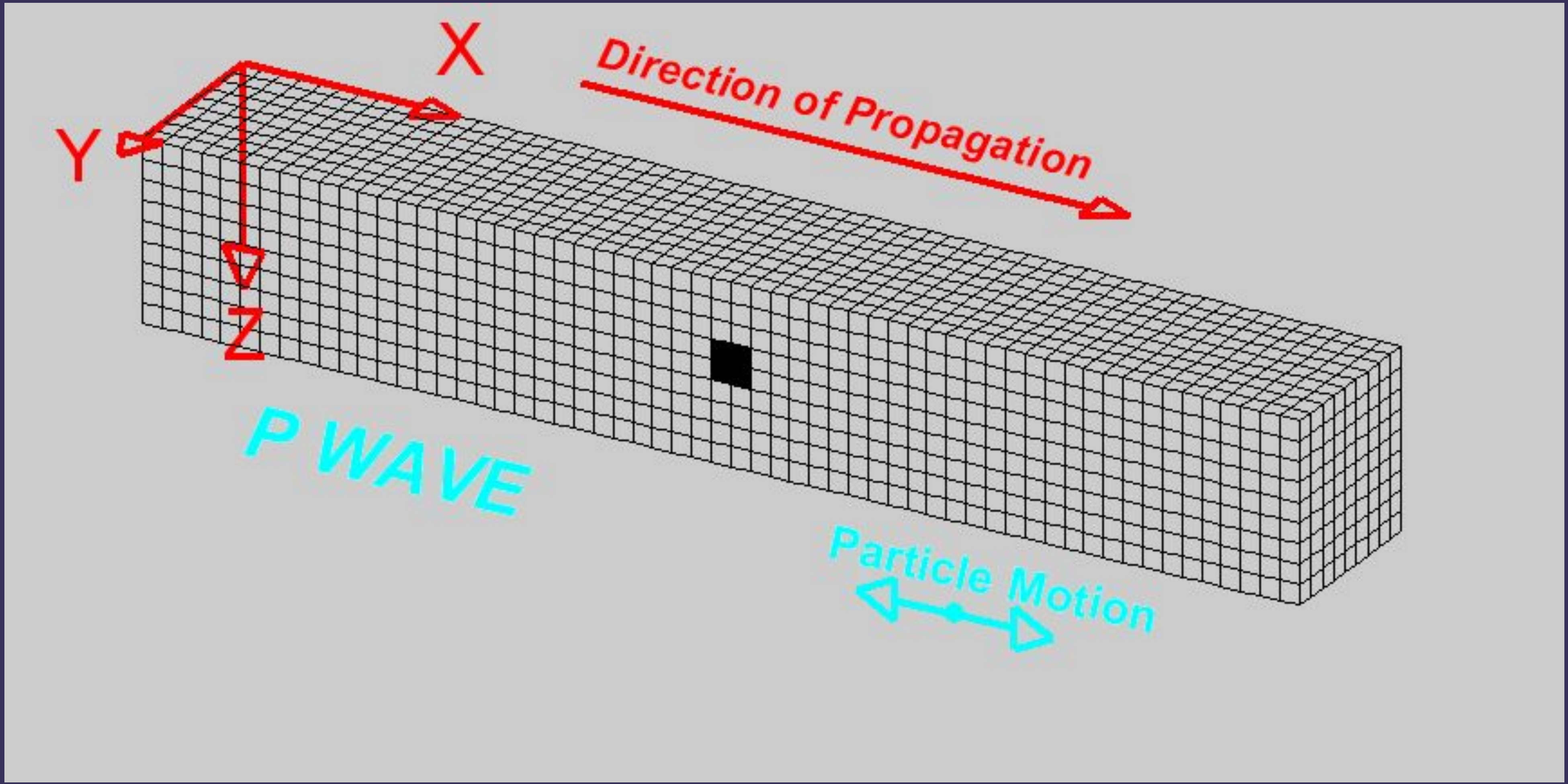
$$\frac{\partial^2 \chi}{\partial x^2} = \frac{1}{k}\frac{\partial^2 \chi}{\partial t^2},$$ the wave equation.

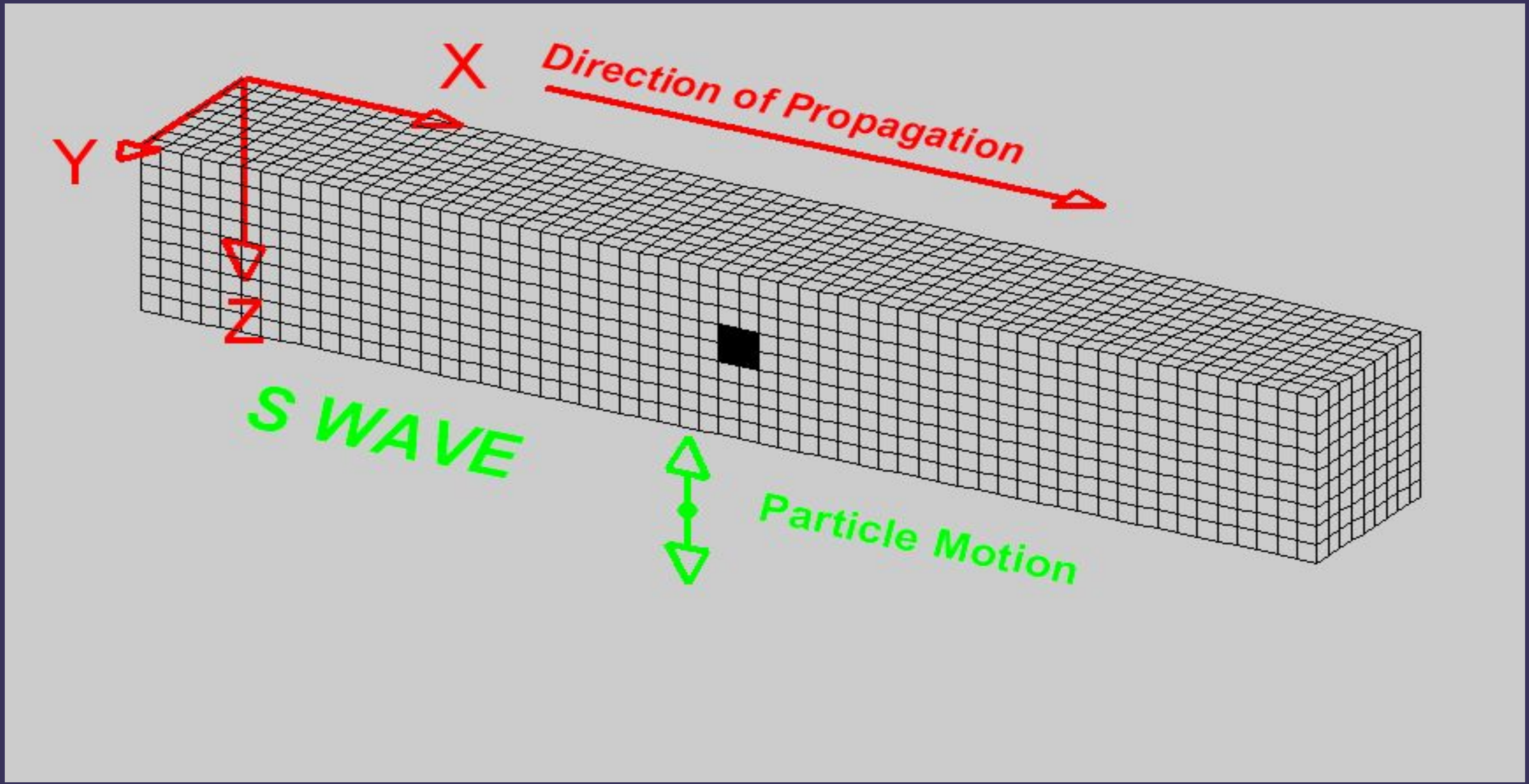
1.3. Wave Propagation Characteristics.

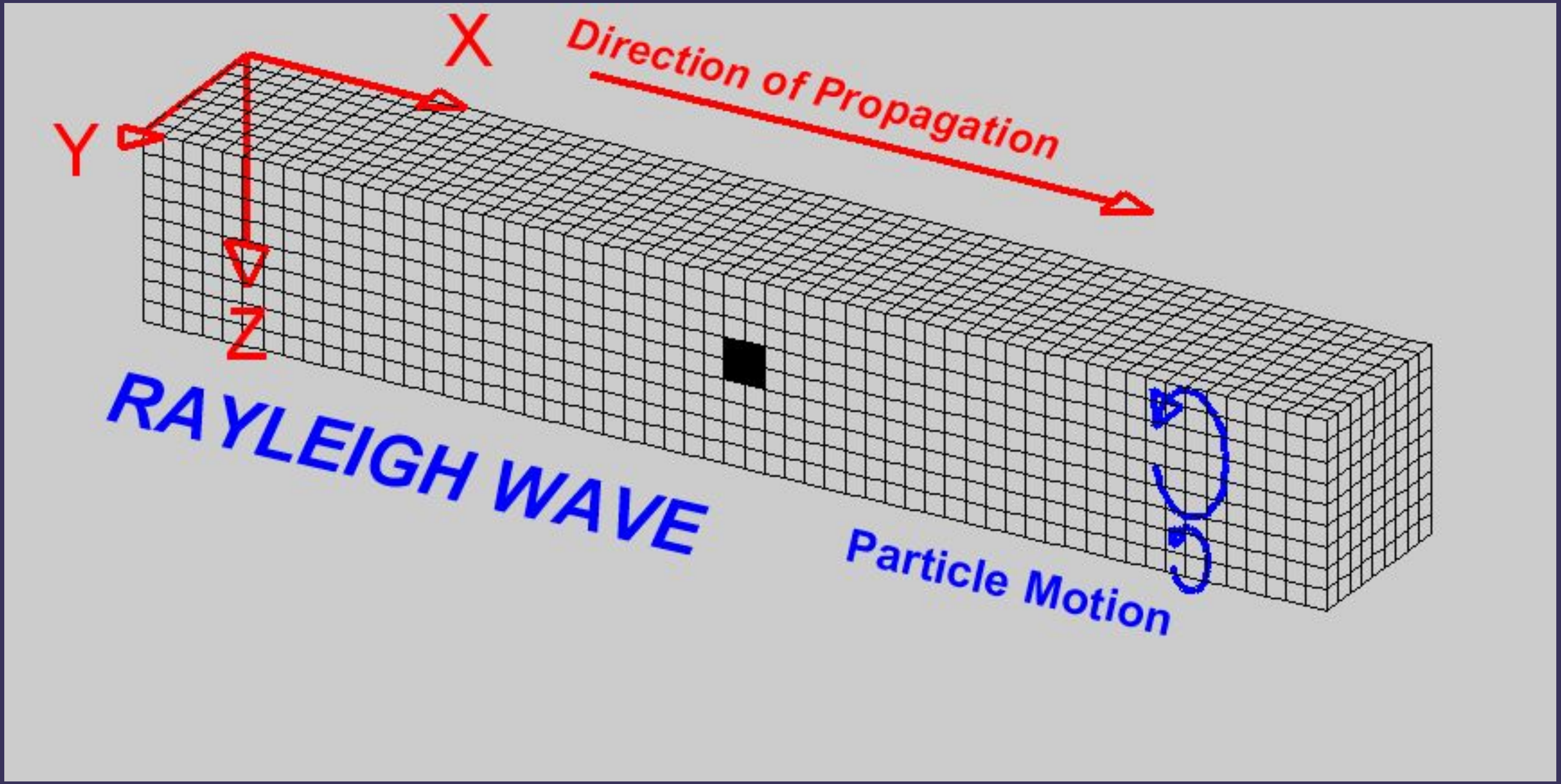
Vibrations during an earthquake



$$c = \sqrt{\Delta^2 + h^2}\,.$$


X
Y
Z
Direction of Propagation
P WAVE
Particle Motion


X
Y
Z
Direction of Propagation
S WAVE
Particle Motion


X
Y
Z
Direction of Propagation
RAYLEIGH WAVE
Particle Motion

2.1. General Principles of structure’s seismic resistance

2.2. Follow through principles.

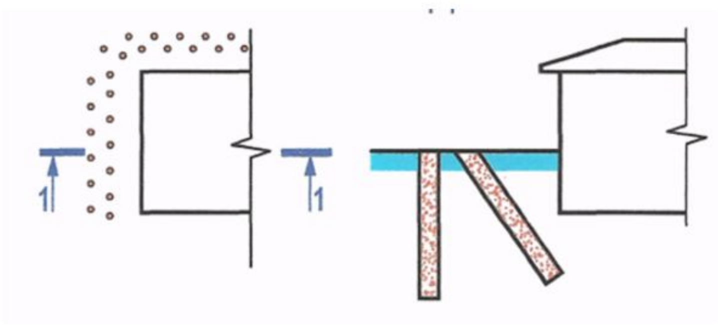


Рисунок 4.1 – Схема антисейсмического экрана

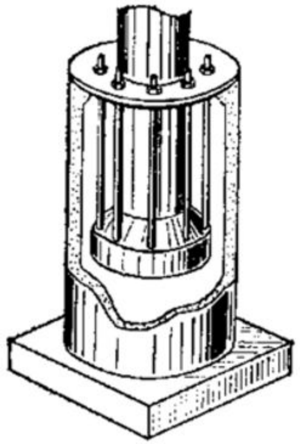


Рисунок 4.2 – Фундамент на тяжах

2.2. Follow through principles.

The principle of providing conditions that facilitate the development of plastic deformations in structural elements

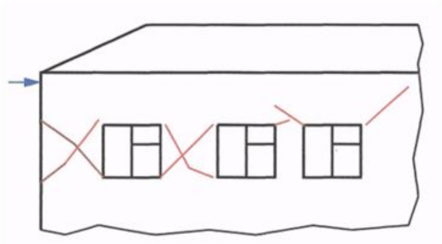
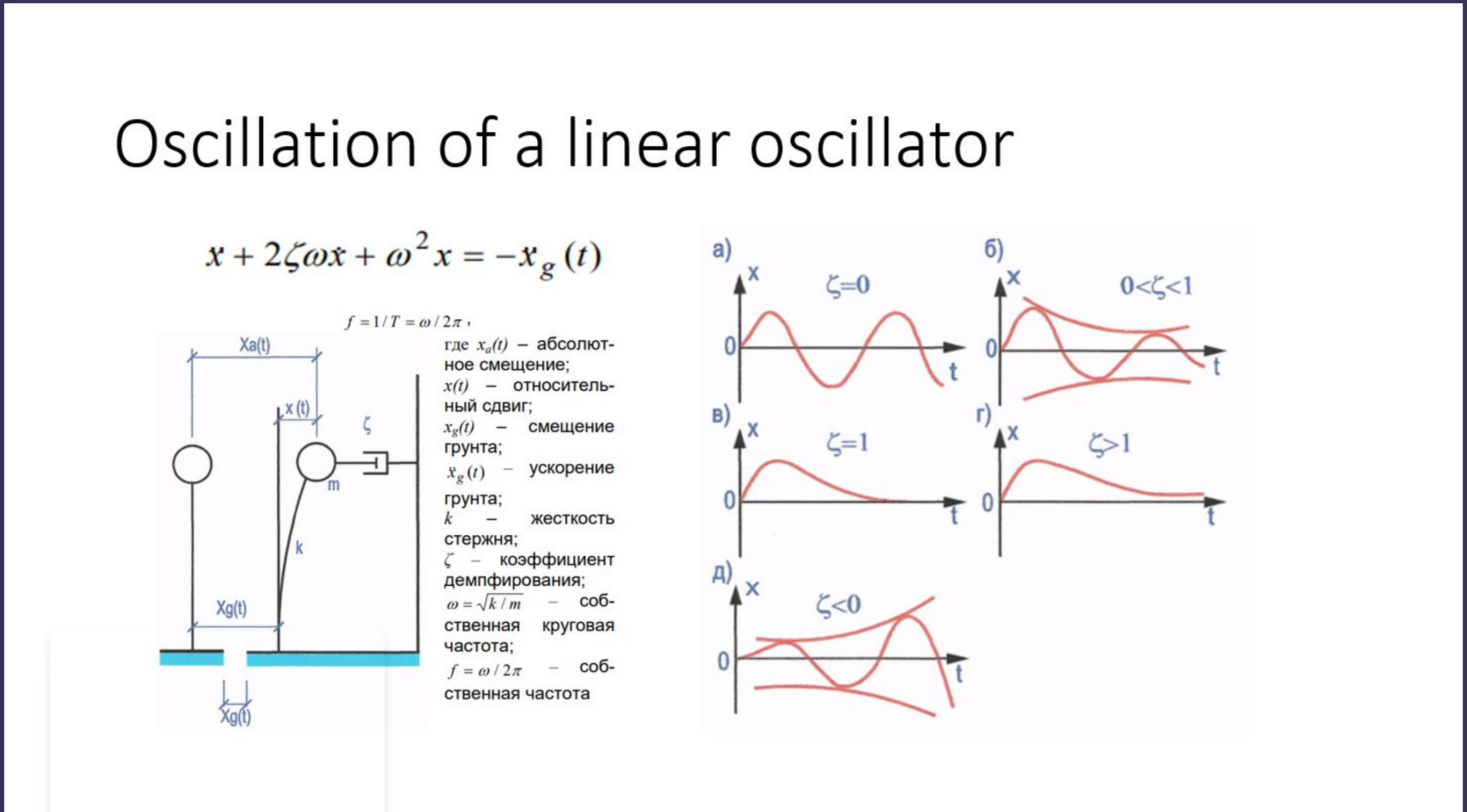


Рисунок 4.3 – Разрушение угловых и разнопрочных простенков

2.3. what are oscillations of linear oscillator for?



Part 2.

1 Introduction to Static Analysis Method

- Plan:
- 1. Short analysis
- 2. Introduction to Mathematical Model
- 3. Provide the Analytical Solution

1. Short analysis

2. Introduction to Mathematical Model

Lateral Force at Different Levels

$$Q_i = \left(\frac{W_i h_i^2}{\sum_{j=1}^{n} W_j h_j^2} \right) V_B$$

where

Q_i = design lateral force at floor i;

W_i = seismic weight of floor i;

h_i = height of floor i measured from base; and

n = number of storeys in building, that is, number of levels at which masses are located.

STATIC ANALYSIS METHOD

$$V_B = A_h \times W$$

V_B = Design Base Shear

A_h = Design Horizontal Acceleration Coefficient

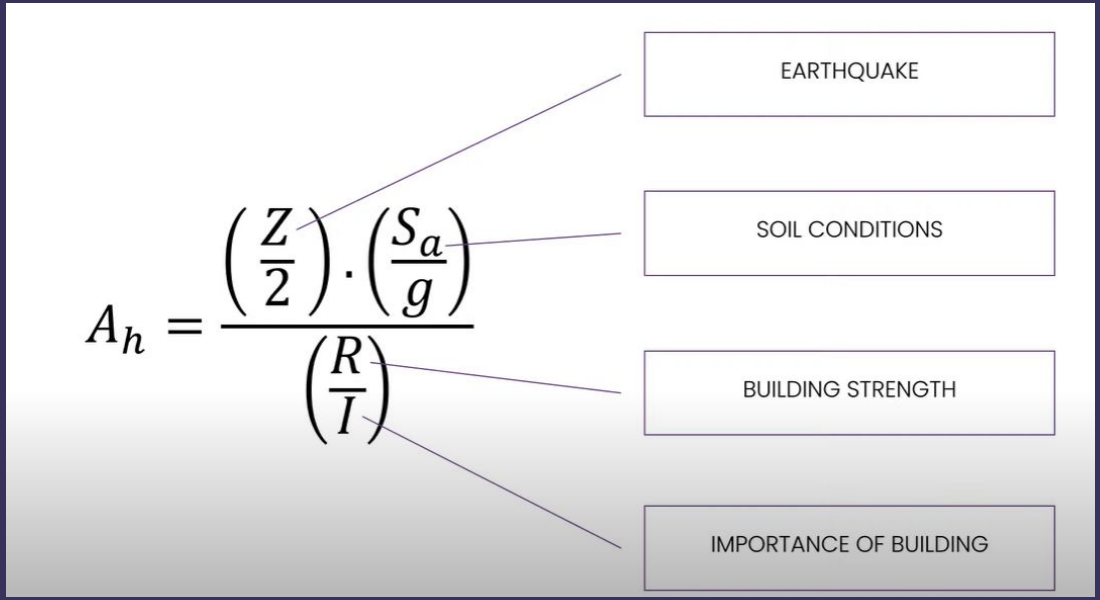
W = Seismic Weight of Building

3. How to solve a problem of horizontal force and what we need?

IS 1893 (Part 1) : 2016

Town	Zone	Z
Jhansi	II	0.10
Jodhpur	II	0.10
Jorhat	V	0.36
Kakrapara	III	0.16
Kalpakkam	III	0.16
Kanchipuram	III	0.16
Kanpur	III	0.16
Karwar	III	0.16
Kochi	III	0.16
Kohima	V	0.36
Kolkata	III	0.16
Kota	II	0.10
Kurnool	II	0.10
Lucknow	III	0.16
Ludhiana	IV	0.24
Madurai	II	0.10
Mandi	V	0.36
Mangaluru	III	0.16
Munghen	IV	0.24
Moradabad	IV	0.24
Mumbai	III	0.16
Mysuru	II	0.10
Nagpur	II	0.10
Nagarjunasagar	II	0.10
Nainital	IV	0.24
Nashik	III	0.16
Nellore	III	0.16
Osmanabad	III	0.16
Panjim	III	0.16
Patiala	III	0.16
Patna	IV	0.24
Pilibhit	IV	0.24
Pondicherry (Puducherry)	II	0.10
Pune	III	0.16
Raipur	II	0.10
Rajkot	III	0.16
Ranchi	II	0.10
Roorkee	IV	0.24
Rourkela	II	0.10
Sadiya	V	0.36
Salem	III	0.16
Shillong	V	0.36
Shimla	IV	0.24
Sironj	II	0.10
Solapur	III	0.16
Srinagar	V	0.36
Surat	III	0.16
Tarapur	III	0.16
Tezpur	V	0.36
Thane	III	0.16
Thanjavur	II	0.10
Thiruvananthapuram	III	0.16
Tiruchirappalli	II	0.10
Tiruvannamalai	III	0.16
Udaipur	II	0.10
Vadodara	III	0.16
Varanasi	III	0.16
Vellore	III	0.16
Vijayawada	III	0.16
Vishakhapatnam	II	0.10

$$A_h = \frac{\left(\frac{Z}{2}\right)\cdot\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$



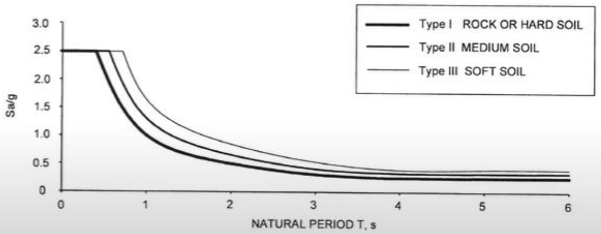
3. How to solve a problem of horizontal force and what we need?

Z = 0.36

Design acceleration coefficient for different soil types

$$A_h = \frac{\left(\frac{Z}{2}\right)\cdot\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

IS 1893 (Part 1) : 2016



2A SPECTRA FOR EQUIVALENT STATIC METHOD

$$\frac{S_a}{g} = \begin{cases} \text{For rocky or hard soil sites} & \begin{cases} 2.5 & 0 < T < 0.40 \text{ s} \\ \frac{1}{T} & 0.40 \text{ s} < T < 4.00 \text{ s} \\ 0.25 & T > 4.00 \text{ s} \end{cases} \\ \text{For medium stiff soil sites} & \begin{cases} 2.5 & 0 < T < 0.55 \text{ s} \\ \frac{1.36}{T} & 0.55 \text{ s} < T < 4.00 \text{ s} \\ 0.34 & T > 4.00 \text{ s} \end{cases} \\ \text{For soft soil sites} & \begin{cases} 2.5 & 0 < T < 0.67 \text{ s} \\ \frac{1.67}{T} & 0.67 \text{ s} < T < 4.00 \text{ s} \\ 0.42 & T > 4.00 \text{ s} \end{cases} \end{cases}$$

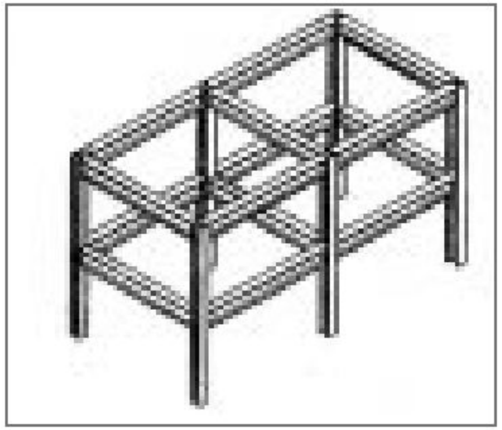
3. How to solve a problem of horizontal force and what we need?

a) Bare MRF buildings (without any masonry infills):

$$T_a = \begin{cases} 0.075h^{0.75} & \text{(for RC MRF building)} \\ 0.080h^{0.75} & \text{(for RC-Steel Composite MRF building)} \\ 0.085h^{0.75} & \text{(for steel MRF building)} \end{cases}$$

3. How to solve a problem of horizontal force and what we need?

MRF – moment resisting frame buildings



Moment-resisting frame systems can be steel, concrete, or masonry construction. They provide a complete space frame throughout the building to carry vertical loads, and they use some of those same frame elements to resist lateral forces. Shear walls (and braced frames) are not used in this system, as shown in Figure 1(b).

Masonry infill is masonry (кирпичная кладка) is used to fill the opening structural spaces

3. How to solve a problem of horizontal force and what we need?

Masonry infill is masonry (кирпичная кладка) is used to fill the opening structural spaces

b) Buildings with RC structural walls:

$$T_a = \frac{0.075h^{0.75}}{\sqrt{A_w}} \geq \frac{0.09h}{\sqrt{d}}$$

For reinforced concrete buildings

Example:

Reinforced concrete

A heavy, reinforced concrete column, seen before and after the concrete has been cast in place around its rebar frame

3. How to solve a problem of horizontal force and what we need?

There also many kinds of building, and for each there is corresponging formula. But generally most common is this one.

d is area of base in X Z directions

Next part of pazzle is R (Response Reduction Factor) or (building strength) Which depend on different conditions, either it is Reinforce concrete or steel structured

$Z = 0.36$

$\left(\frac{S_a}{g}\right) = 2.5$

$$A_h = \frac{\left(\frac{Z}{2}\right) \cdot \left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

Table 9 Response Reduction Factor *R* for Building Systems
(*Clause* 7.2.6)

Sl No. (1)	Lateral Load Resisting System (2)	R (3)
i)	**Moment Frame Systems**	
	a) RC buildings with ordinary moment resisting frame (OMRF) (*see* Note 1)	3.0
	b) RC buildings with special moment resisting frame (SMRF)	5.0
	c) Steel buildings with ordinary moment resisting frame (OMRF) (*see* Note 1)	3.0
	d) Steel buildings with special moment resisting frame (SMRF)	5.0

Response Reduction Factor

Reinforce concrete or steel structured (Ordinary or special moment resisting)

3. How to solve a problem of horizontal force and what we need?

Table 8 Importance Factor (*I*)
(*Clause* 7.2.3)

Sl No. (1)	Structure (2)	*I* (3)
i)	Important service and community buildings or structures (for example, critical governance buildings, schools), signature buildings, monument buildings, lifeline and emergency buildings (for example, hospital buildings, telephone exchange buildings, television station buildings, radio station buildings, bus station buildings, metro rail buildings and metro rail station buildings), railway stations, airports, food storage buildings (such as warehouses), fuel station buildings, power station buildings, and fire station buildings), and large community hall buildings (for example, cinema halls, shopping malls, assembly halls and subway stations)	1.5
ii)	Residential or commercial buildings [other than those listed in Sl No. (i)] with occupancy more than 200 persons	1.2
iii)	All other buildings	1.0

Importance factor

$Z = 0.36$

$\left(\frac{S_a}{g}\right) = 2.5$

$$A_h = \frac{\left(\frac{Z}{2}\right)\cdot\left(\frac{S_a}{g}\right)}{\left(\frac{R}{I}\right)}$$

Table 9 Response Reduction Factor *R* for Building Systems
(*Clause* 7.2.6)

Sl No. (1)	Lateral Load Resisting System (2)	R (3)
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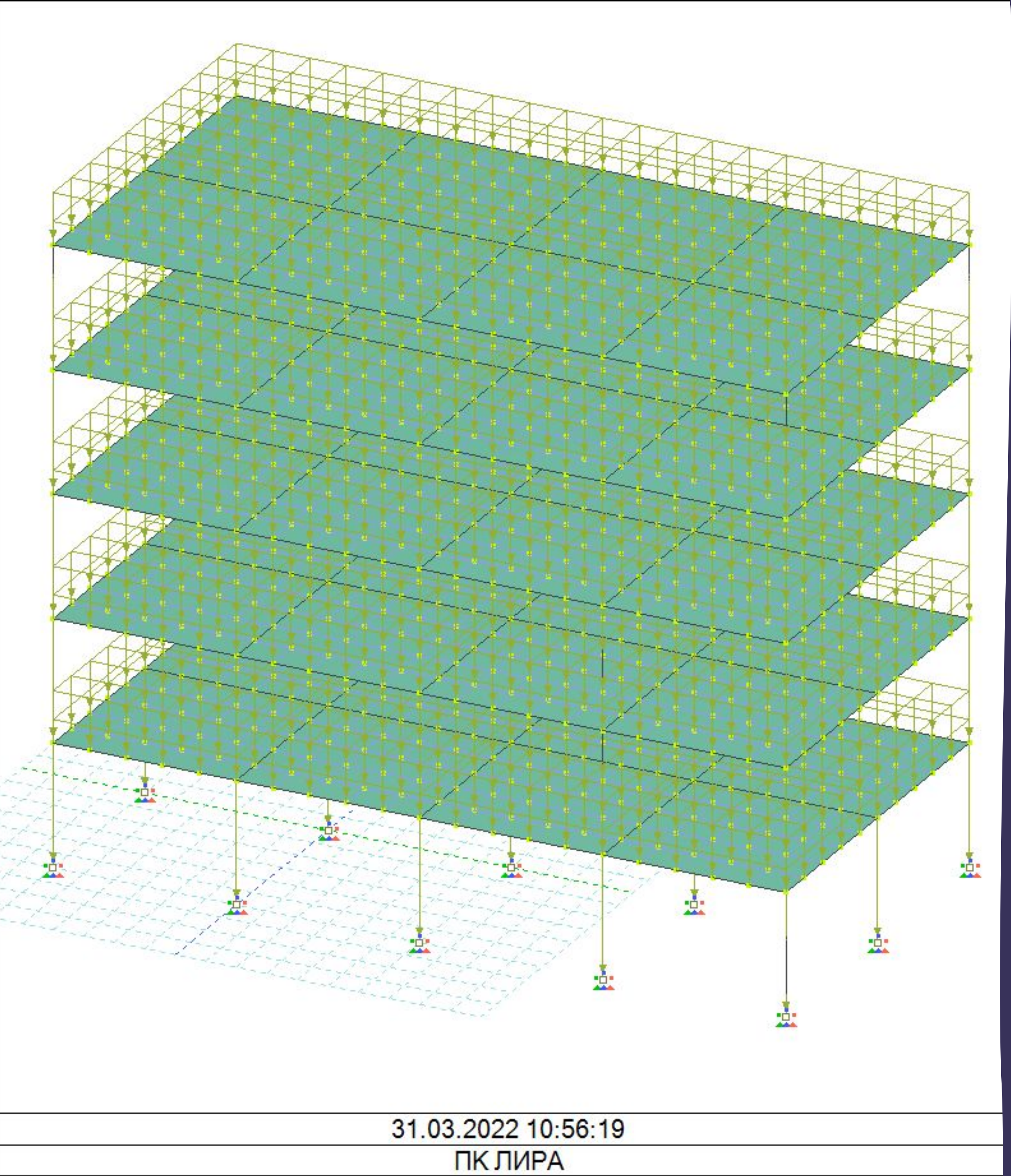
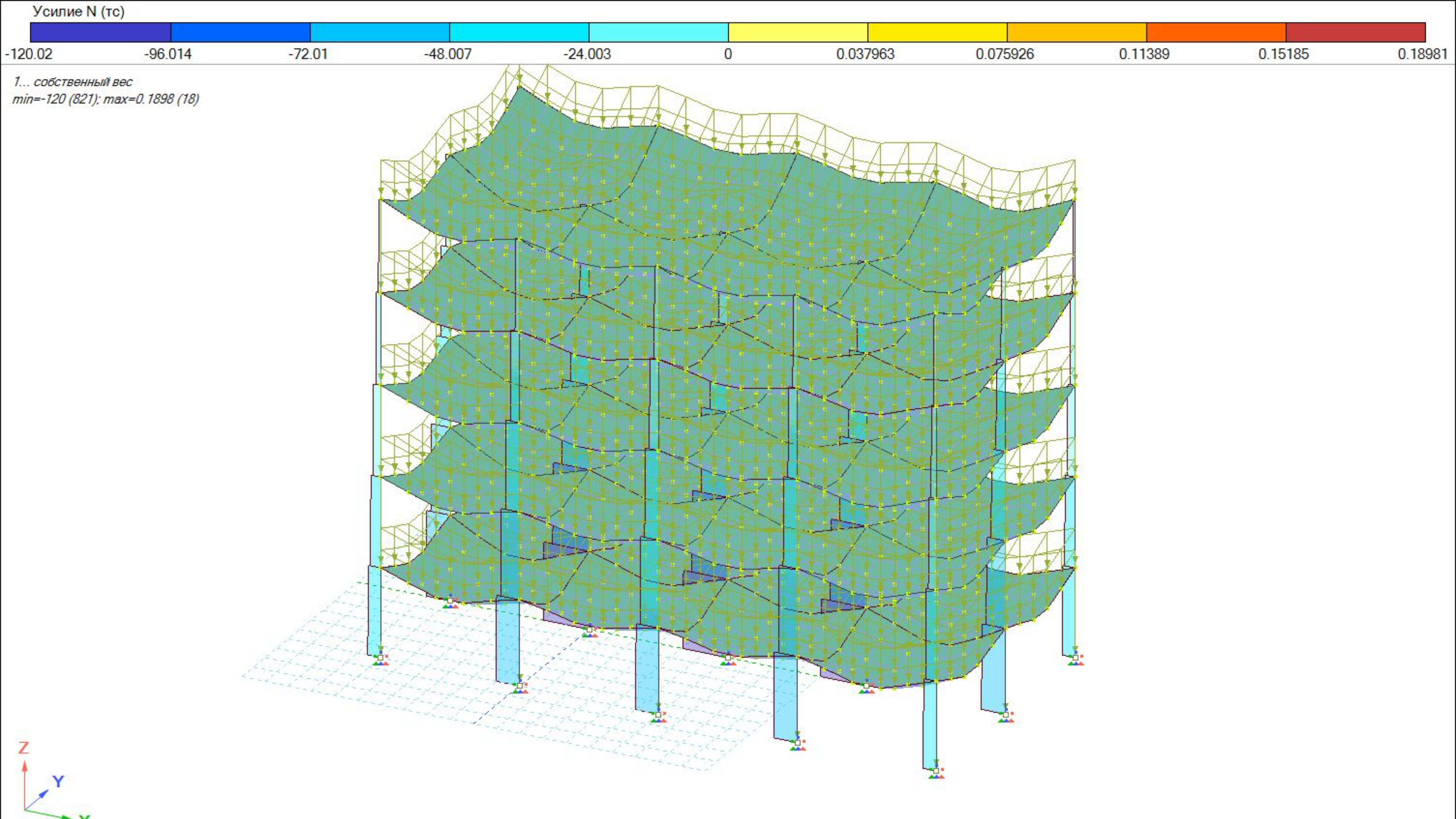
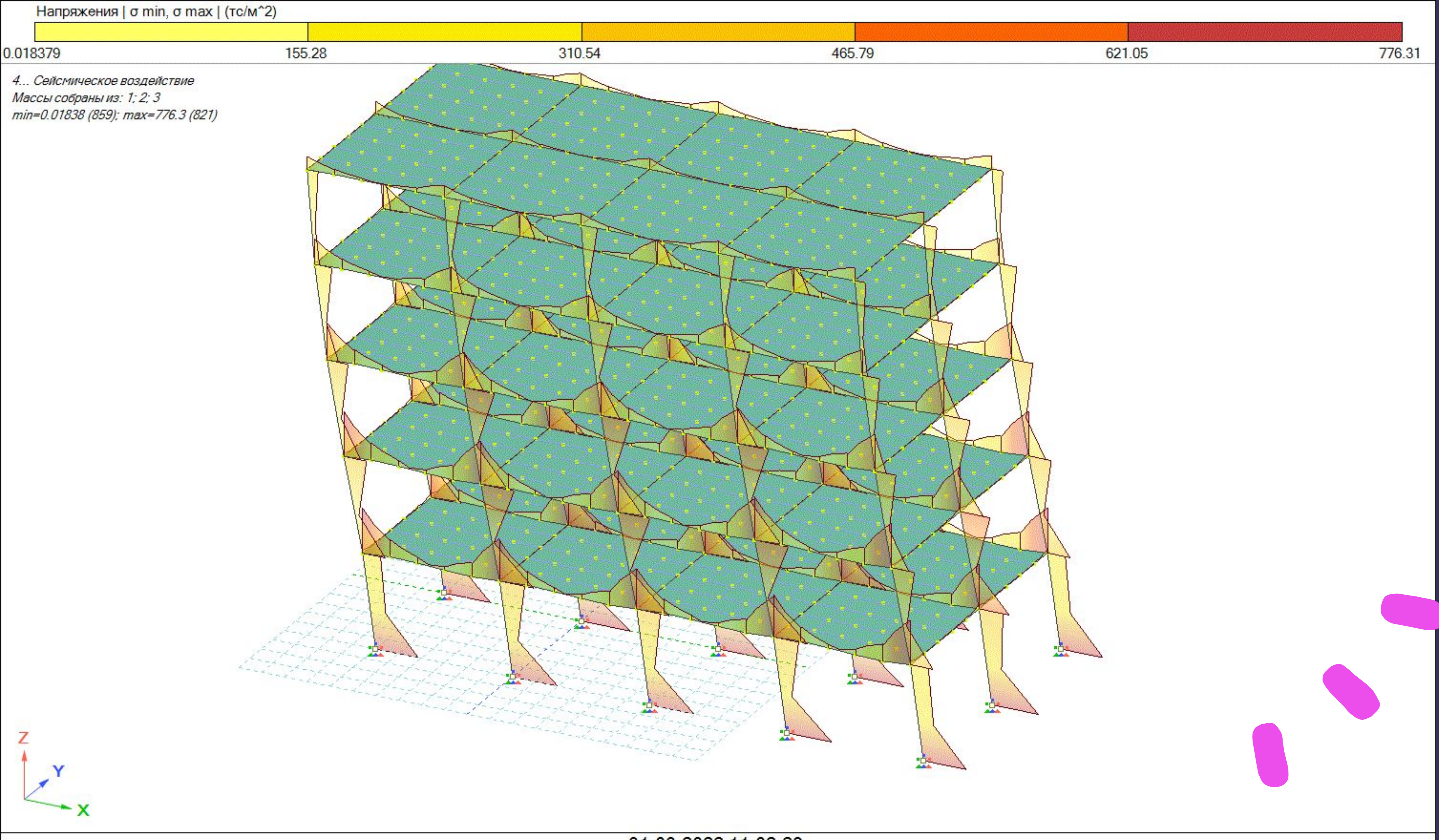
	d) Steel buildings with special moment resisting frame (SMRF)	5.0

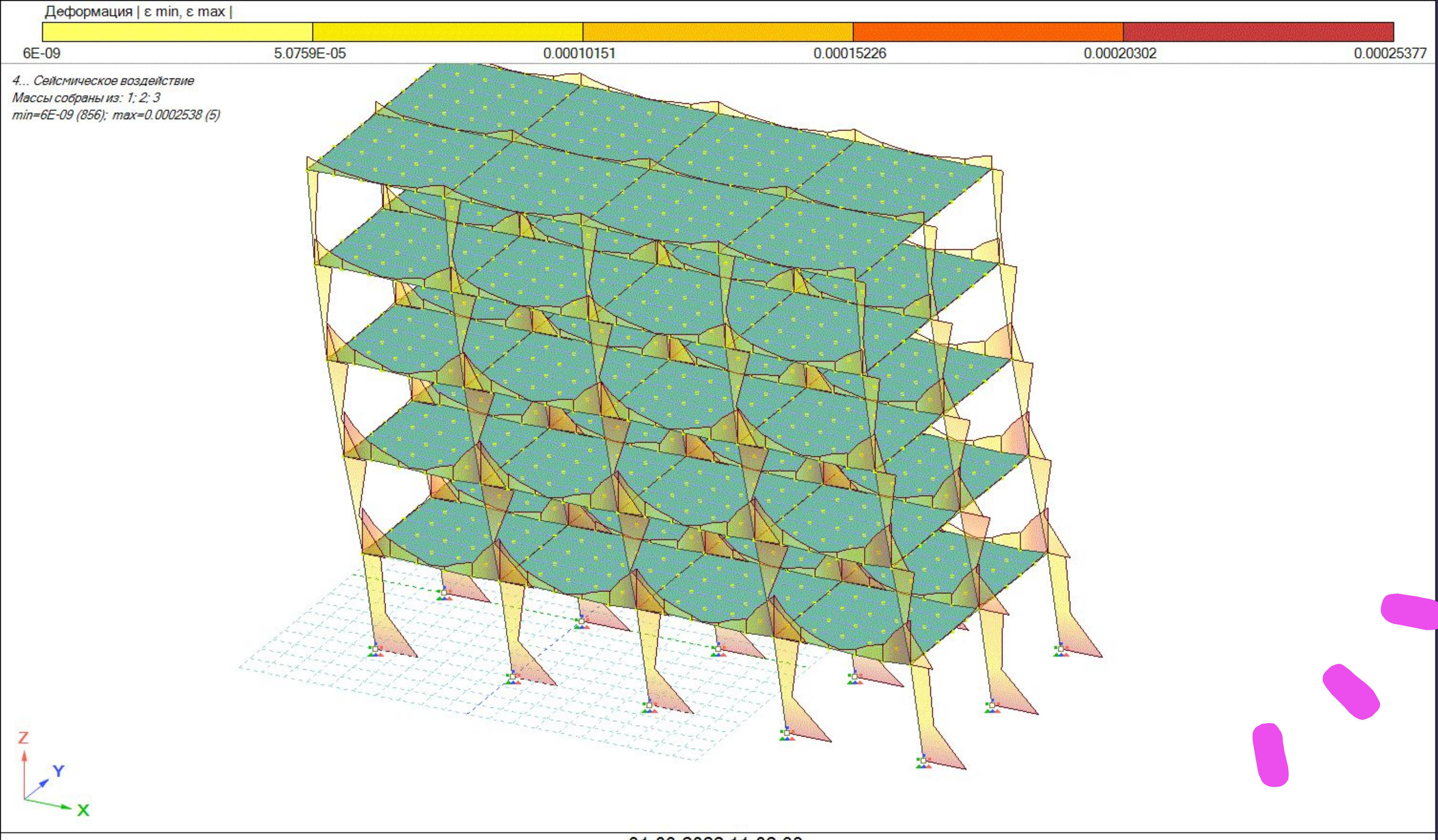
Response Reduction Factor

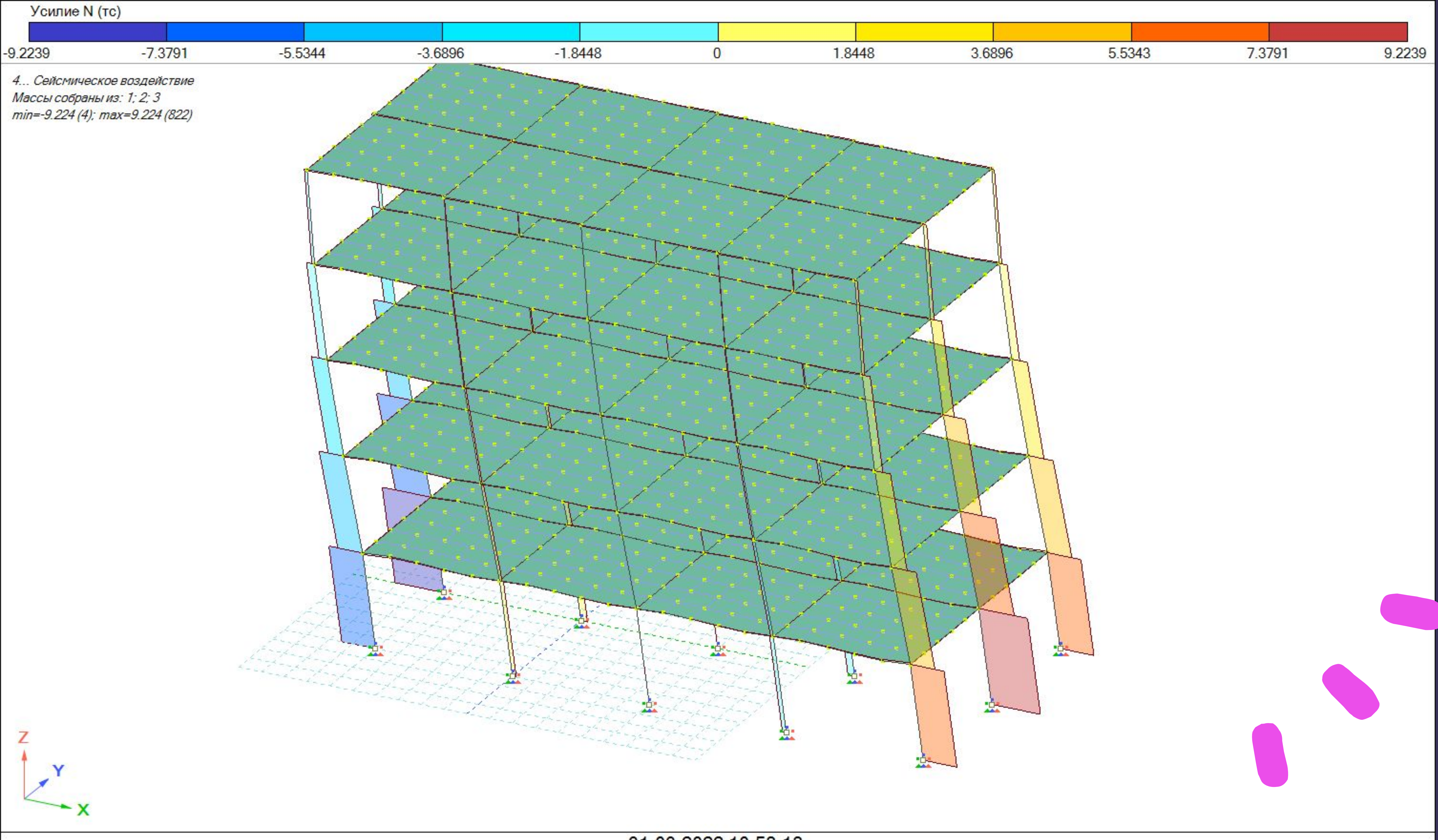


2 Numerical Solution


Усилие N (тс)
-120.02
-96.014
-72.01
-48.007
-24.003
0
0.037963
0.075926
0.11389
0.15185
0.18981
1... собственный вес
min=-120 (821); max=0.1898 (18)
Z
Y
X


Напряжения | σ min, σ max | (тс/м^2)
0.018379
155.28
310.54
465.79
621.05
776.31
4... Сейсмическое воздействие
Массы собраны из: 1; 2; 3
min=0.01838 (859); max=776.3 (821)
Z
Y
X


Деформация | ε min, ε max |
6E-09
5.0759E-05
0.00010151
0.00015226
0.00020302
0.00025377
4... Сейсмическое воздействие
Массы собраны из: 1; 2; 3
min=6E-09 (856); max=0.0002538 (5)
Z
Y
X


Усилие N (тс)
-9.2239
-7.3791
-5.5344
-3.6896
-1.8448
0
1.8448
3.6896
5.5343
7.3791
9.2239
4... Сейсмическое воздействие
Массы собраны из: 1; 2; 3
min=-9.224 (4); max=9.224 (822)
Z
Y
X

Thank you for paying attention!