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MULTI-STORY FRAME REINFORCED CONCRETE BUILDING SEISMIC TESTING OF THE MODEL

ANNOTATION: This article presents the results of testing a building model for seismic impact to determine the dynamic characteristics of a nine-story frame building made of monolithic reinforced concrete. When testing the model for seismic impact, the "load drop" method was used.

KEYWORDS: *monolithic reinforced concrete, frame building, model, seismic, dynamic characteristic.*

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МНОГОЭТАЖНОЕ КАРКАСНОЕ ЖЕЛЕЗОБЕТОННОЕ ЗДАНИЕ СЕЙСМИЧЕСКИЕ ИСПЫТАНИЯ МОДЕЛИ

Аннотация: В данной статье представлены результаты испытания модели здания на сейсмическое воздействие с целью определения динамических характеристик девятиэтажного каркасного здания из монолитного железобетона. При испытании модели на сейсмическое воздействие был использован метод «сброса груза».

Ключевые слова: монолитный железобетон, каркасное здание, модель, сейсмическое воздействие, динамическая характеристика.

INTRODUCTION.

Earthquakes occur frequently in the world. Over the past 100 years, there have been about 2,000 earthquakes with a magnitude of 7 or more in the world. At the same time, there are subtle fluctuations that occur almost without consequences. The earthquake that occurred on December 16, 1920, in Xayyuan County, part of Gansu Province, China, claimed the lives of approximately 270,000 people. The movement of the slabs caused numerous cracks and landslides, the shaking force was 7.8 points and higher. Following the first powerful shock, further tremors occurred, so powerful that the massive destruction encompassed approximately 3.8 thousand square kilometers. Seismic vibrations caused by this earthquake were felt on an area of more than 4 million square kilometers. The provinces of Gansu and Shaanxi in central China suffered the most from the natural disaster. More than 20,000 people died not from destruction, but from the cold, as they lost their homes. In China, many cities, provinces, and districts were damaged. The landslide caused by the earthquake caused the destruction of the entire village of Tsutszyahe. This earthquake is considered the most devastating in history.

On September 1, 1923, an earthquake in Japan with a magnitude of 8.3 struck Tokyo and Yokohama, destroying them almost entirely. The epicenter of the earthquake was 90 km from Tokyo. The tragedy claimed the lives of 174,000 people, and 524,000 went missing. According to official data, about 4 million people were injured. In Yokohama, almost 25% of the city's buildings were destroyed instantly. Due to the strong wind, a rapidly spreading fire started. In Tokyo, buildings collapsed less frequently, but the city also suffered significant damage from the rapidly spreading fire. As a result, almost half of the city was destroyed by fire and an earthquake. This earthquake is considered the most devastating in Japanese history.

On the night of October 4-6, 1948, an earthquake with a magnitude of 7.3 occurred in Ashgabat. The epicenter of the earthquake was located at a depth of 18 kilometers in the city itself. Neighboring districts and cities of Iran were affected by this earthquake. The exact number of victims of this disaster is unknown, with various estimates suggesting between 110,000 and 170,000 deaths in Ashgabat and its surrounding areas. The earthquake almost wiped the city off the face of the earth, with only some buildings remaining intact. Survivors were evacuated using 120 military and civilian aircraft. If the earthquake had started during the day, there might have been fewer casualties. At night, most of the city's inhabitants slept, and people, not knowing what had happened, were trapped under the rubble. This earthquake is considered one of the most destructive in human history.

One of the strongest earthquakes in human history occurred in Chile on May 22, 1960. The magnitude was 9.5, and tremors were felt over an area of 200,000 square kilometers. In addition, the earthquake caused a tsunami with 10-meter waves reaching the coasts of Japan and the Philippines. At the same time, the number of victims is significantly lower than in other similar disasters - about 6,000 people, most of whom died from tsunamis. The consequences of the disaster affected sparsely populated areas.

Another terrible earthquake occurred in the former USSR in the 20th century. On December 7, 1988, a natural disaster occurred in the city of Spitak in the northwest of the Armenian SSR, claiming the lives of 25,000 people. The consequences of the earthquake affected almost 40% of Armenia's territory, injuring and disabling 140,000 people and leaving 514,000 homeless. Orphaned children were taken to other republics of the former USSR for adoption.

The city of Spitak was at the center of a 6.8 magnitude earthquake, and 58 nearby villages were completely destroyed. As a result of a series of tremors, 321 cities and settlements were damaged.

On December 26, 2004, an earthquake occurred in the Indian Ocean near the island of Sumatra, claiming the lives of nearly 300,000 people. The main damage was caused by a tsunami caused by seismic activity. The magnitude of the earthquake ranged from 9.1 to 9.3, and tsunami waves reached the shores of 14 countries. Waves with a height of more than 20 meters were recorded, and they reached the shore at such a height. Geographically, along the subduction zone (the linear zone at the boundary of lithospheric plates), a very large displacement of rock of about 1200 km for a distance of 15 m occurred, as a result of which the Indian Plate shifted under the Burma Plate. This caused such a powerful tsunami that the wave reached the coast of South Africa, located 6.9 thousand km from the epicenter. This earthquake is among the three strongest earthquakes in the history of all observations.

The earthquake that occurred on January 12, 2010, in the Republic of Haiti consisted of several tremors, the strength of the first of which was 7 points, 15 repeated tremors with a magnitude greater than 5. This natural disaster claimed the lives of more than 222 thousand people, injured more than 311 thousand people, and 869 people went missing. The epicenter of the earthquake was located 22 km from the capital of the republic, Port-au-Prince, at a depth of 13 km. As a result of the earthquake, thousands of residential buildings, hospitals, and administrative buildings were destroyed, and about 3 million people were left homeless.

On February 6, 2023, the strongest 7.8 magnitude earthquake since 1939 occurred in Turkey, accompanied by several aftershocks. As a result of the tragedy, more than 50,500 people died in Turkey and 8,476 in Syria, and tens of thousands more were injured [1].

The list of devastating earthquakes can go on and on. However, from the examples given above, one can understand how serious and urgent the problem of earthquake resistance of buildings and structures is.

Even today, strong earthquakes occurring around the world lead to negative consequences. Earthquakes can have a serious impact on people's lives and society as a whole. As a result of the earthquake, buildings and infrastructure were destroyed. Strong earthquakes cause not only the destruction of buildings, but also the deaths and injuries of many people due to fires, landslides, and other consequences. The economic damage caused by earthquakes is also very significant. In addition to physical and economic consequences, earthquakes have a profound psychological impact on survivors. Therefore, the study of the impact of earthquakes on buildings and structures and ensuring the real seismic resistance of operating and designed buildings is one of the important problems of today.

The developed methods for calculating the main load-bearing structures of buildings do not always objectively and accurately meet the requirements of load-bearing capacity. In these cases, there is a need for experimental studies to assess the seismic resistance of buildings and structures. Since conducting field tests for assessing the seismic resistance of buildings is labor-intensive and expensive, it is advisable to test their models.

The article describes the method and results of testing the building model for seismic impact using the "load drop" method to determine the dynamic characteristics of a nine-story frame building constructed from monolithic reinforced concrete.

METHOD, RESULTS.

In the "load drop" method, the seismic load acting on the building was carried out instantaneously as a shock.

The impact arising from testing the model using the "load drop" method is local and does not pose a threat to surrounding buildings. The technology of the vibration process is very simple and does not require large labor and material costs.

The cost of conducting tests can mainly be indicated by the placement of high-precision equipment and sensors according to the model.

Although this method cannot fully reflect the impact of an earthquake on the structure, it can show the condition of individual parts of the building under the influence of strong dynamic loads. This method also allows determining the main dynamic characteristics of the building.

Such seismic impact was carried out as follows (Fig. 1). A frame made of metal angle is fitted on top of the frame, and a ring is welded to the center of its load-bearing side. A block is installed on a fixed support at a distance of 2.0 meters from the test sample-model.

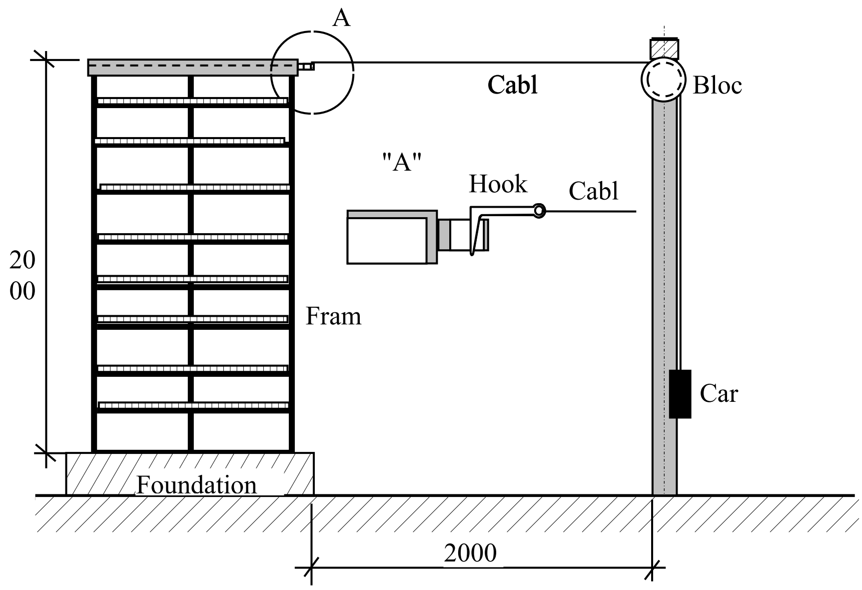

Figure 1. Seismic impact testing scheme of the building model.

The test circuit was carried out as follows. The building model, in addition to its own weight, was loaded with temporary vertical loads, and its dynamic characteristics in free oscillations were determined using measuring instruments (Fig. 2). This process was repeated three times. The graphs obtained during the testing are presented in Fig. 3.

Fig. 2. From the test process.[1]

In addition to its own weight, an instantaneous seismic impact was imitated on a building model loaded with temporary vertical loads using the "Throwing the Load" method, and its dynamic characteristics in the state of forced oscillations were determined using measuring instruments (Fig. 3).

Figure 3. View of the model with instruments.

The test was carried out at the values of "thrown load" of 0.1 kN, 0.2 kN, 0.3 kN, and 0.4 kN. This process was repeated three times for each seismic load. Graphs obtained during the testing process are presented in Figures 4-8.

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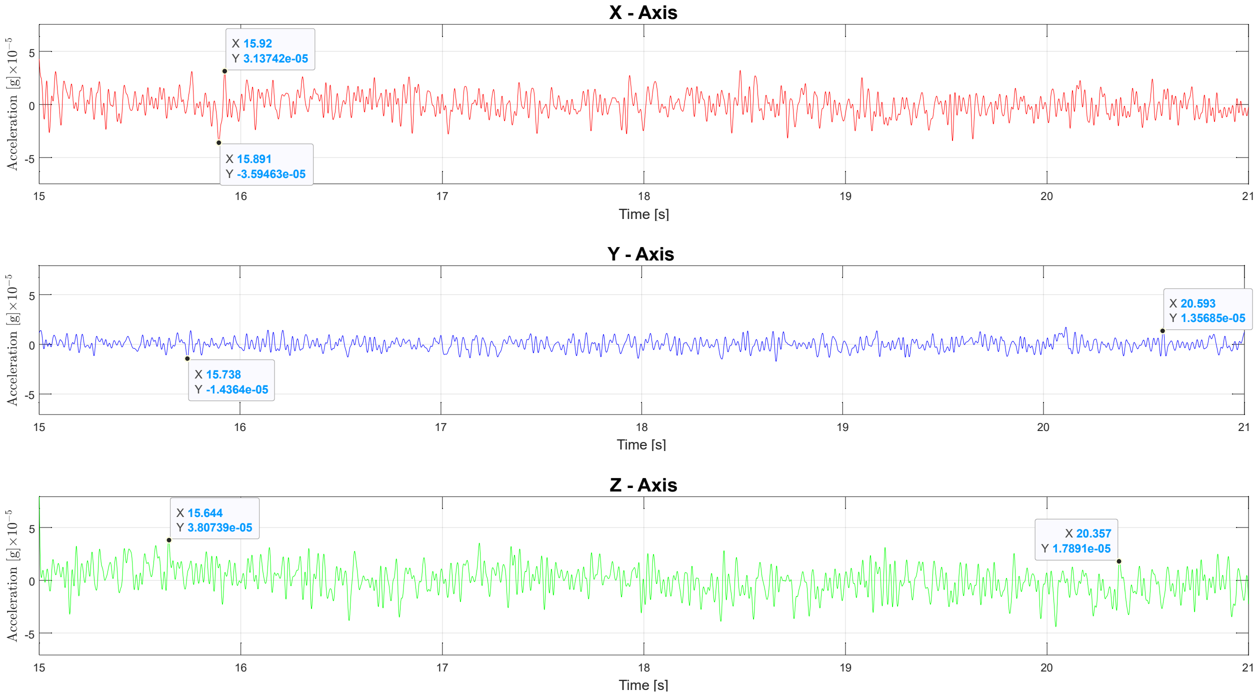
[1] The tests were conducted jointly with the staff of the Institute of Mechanics and Seismic Resistance of Structures of the Academy of Sciences of the Republic of Uzbekistan.

Results from a sensor placed on the floor level of the 1st floor

Accelogram X, Y, Z



Results from a sensor placed on the floor level of the 9th floor

Accelogram X, Y, Z

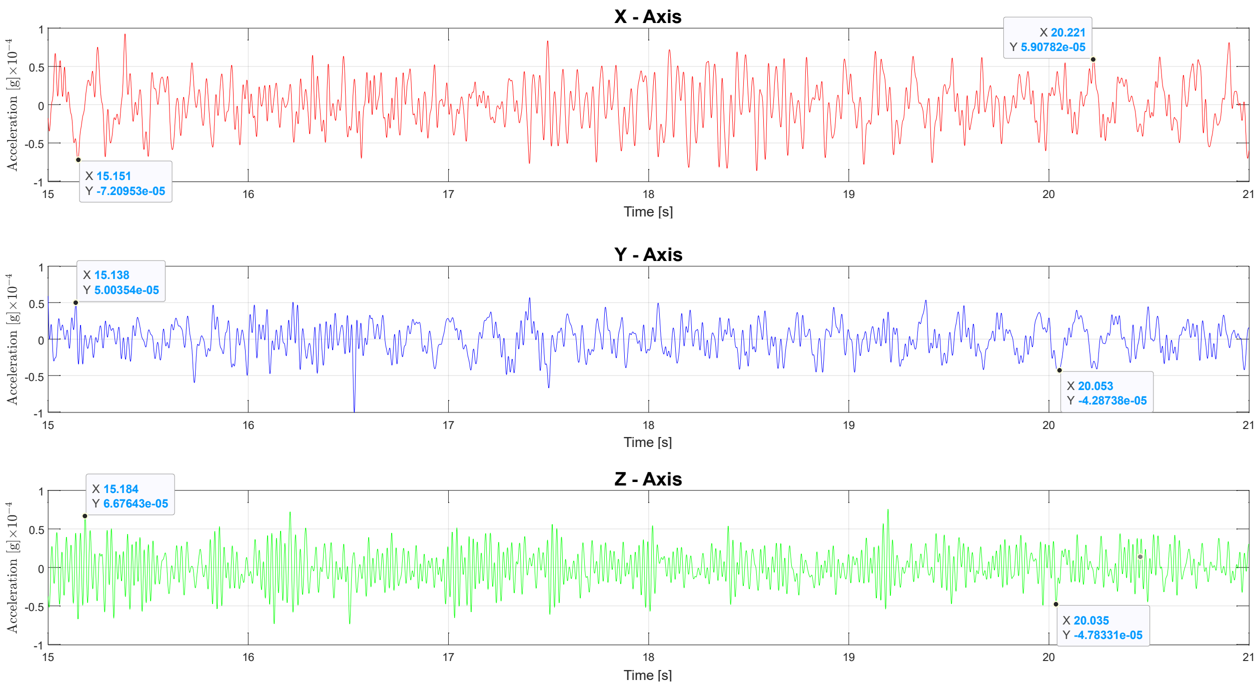
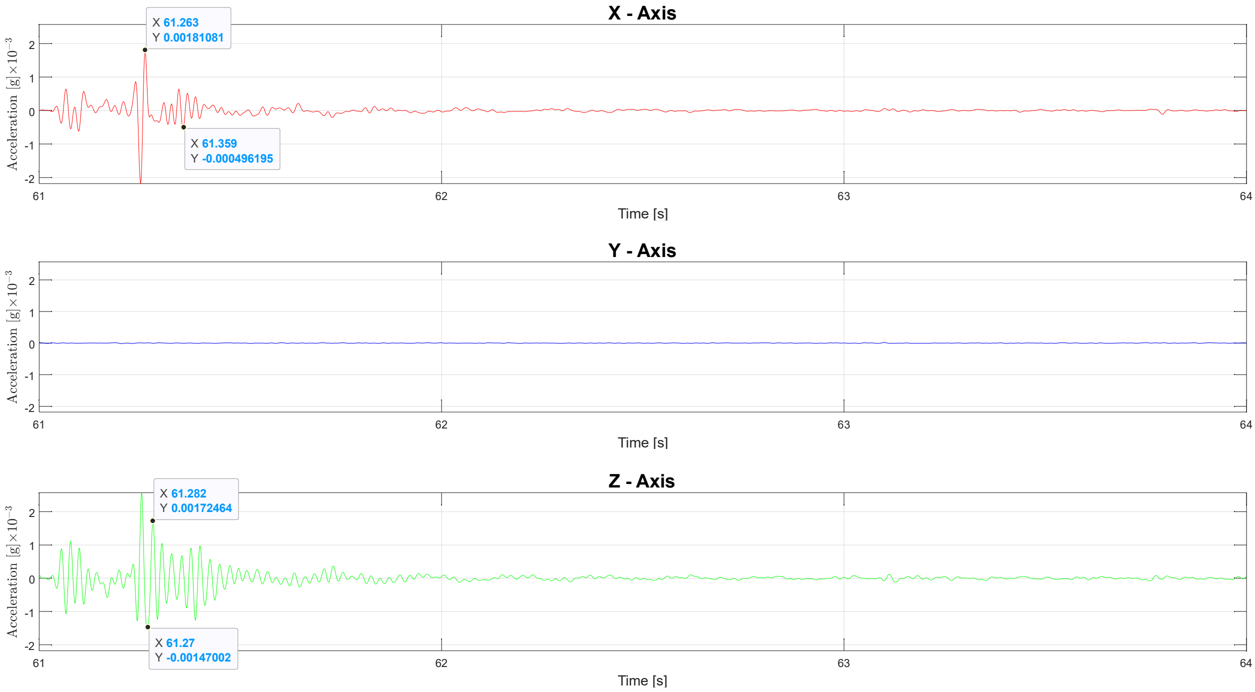


Fig. 4. Accelogram from the resting state of the building.

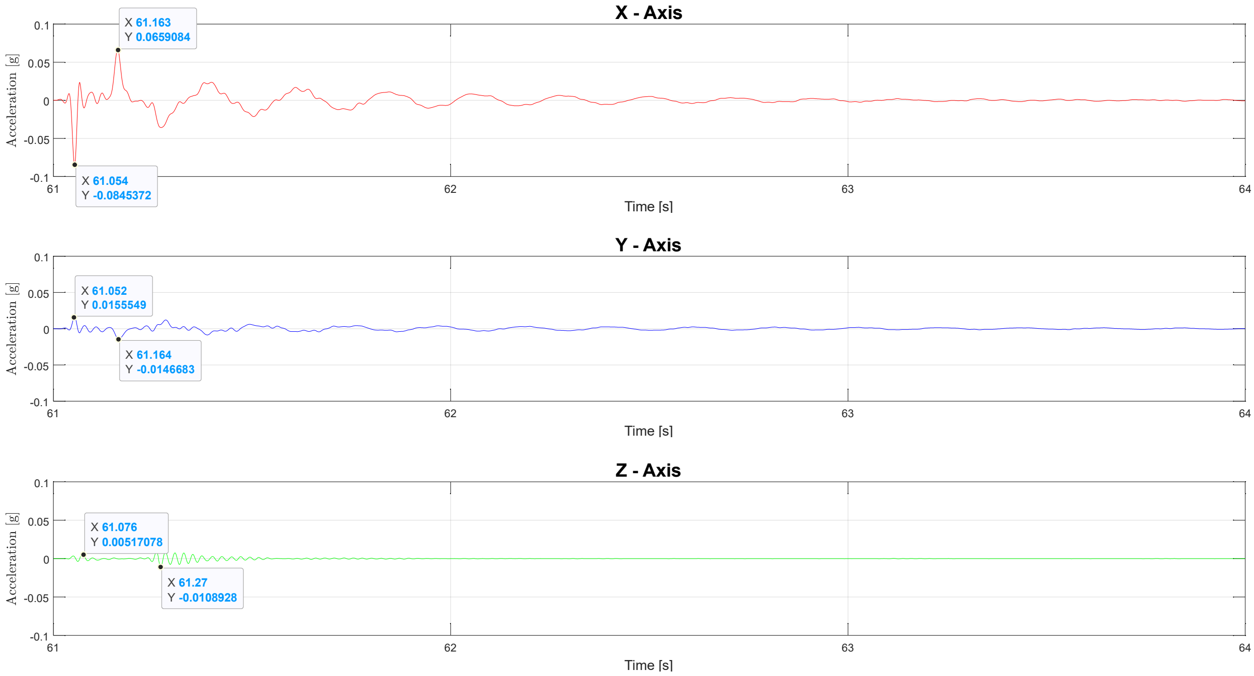
Results from a sensor placed on the floor level of the 1st floor

Accelogram X, Y, Z

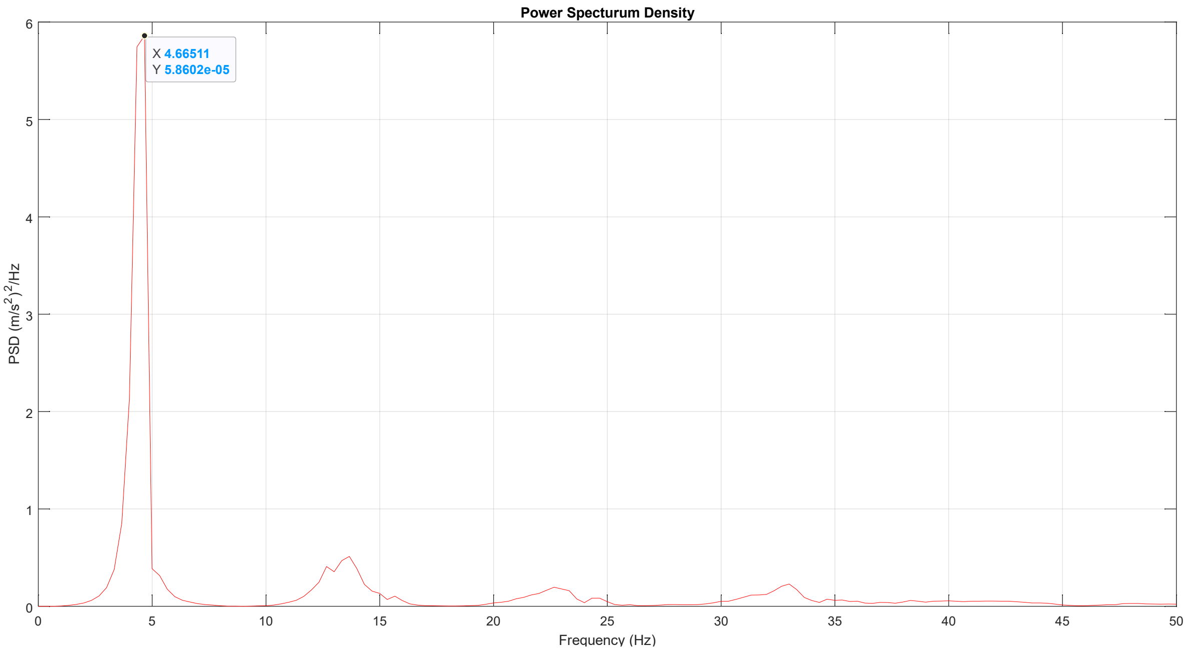


Results from a sensor placed on the floor level of the 9th floor

Accelogram X, Y, Z



Spectral power density X



Y

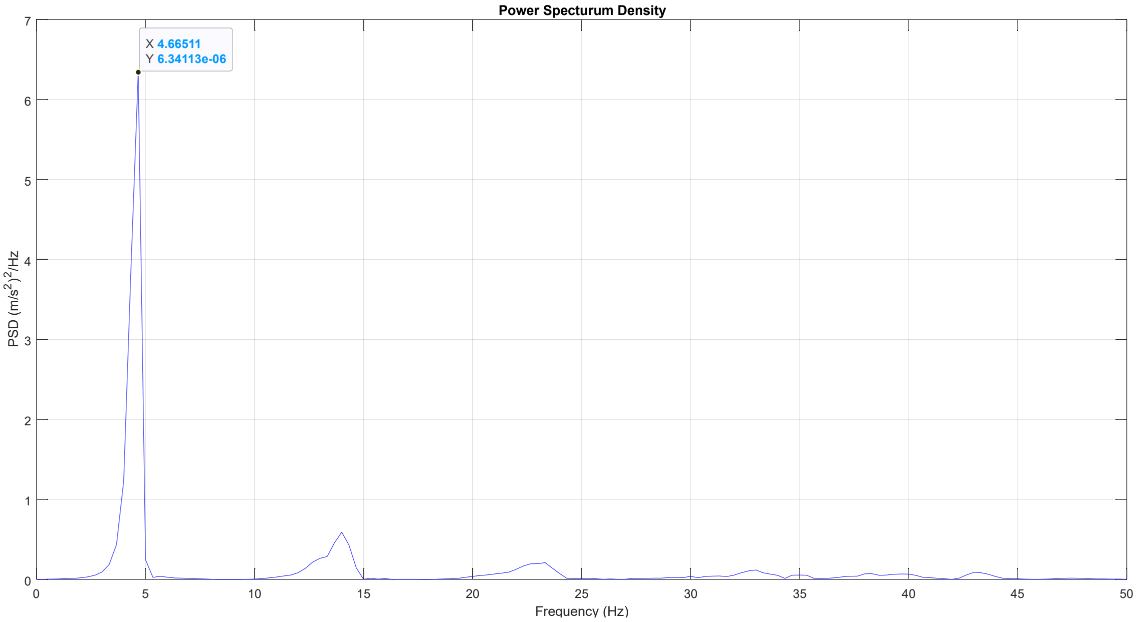
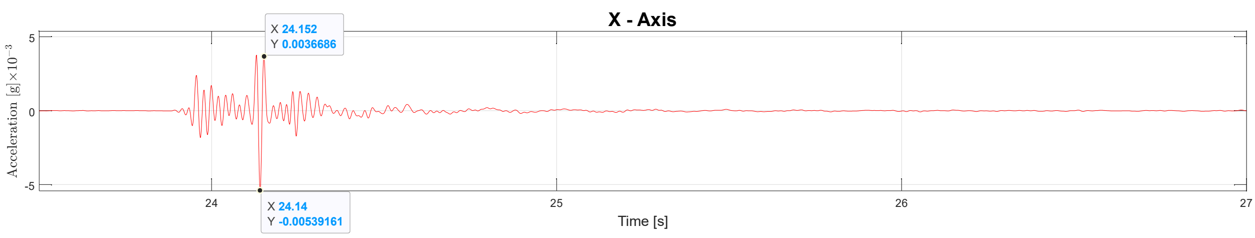
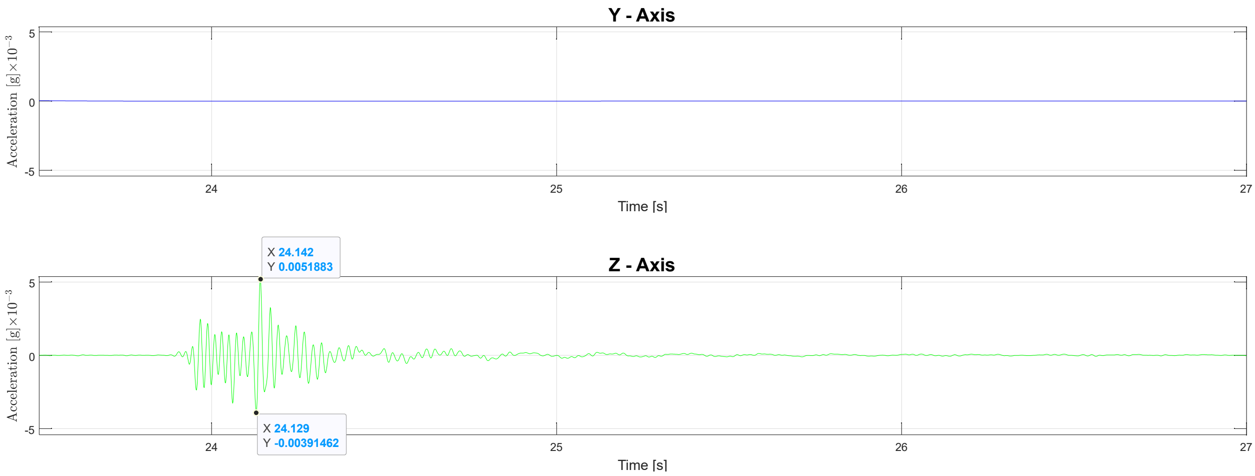


Figure 5. Accelogram from the upper part of the building when it is freed from a position pulled by a cable with a force of 10 kg*.

Results from a sensor placed on the floor level of the 1st floor

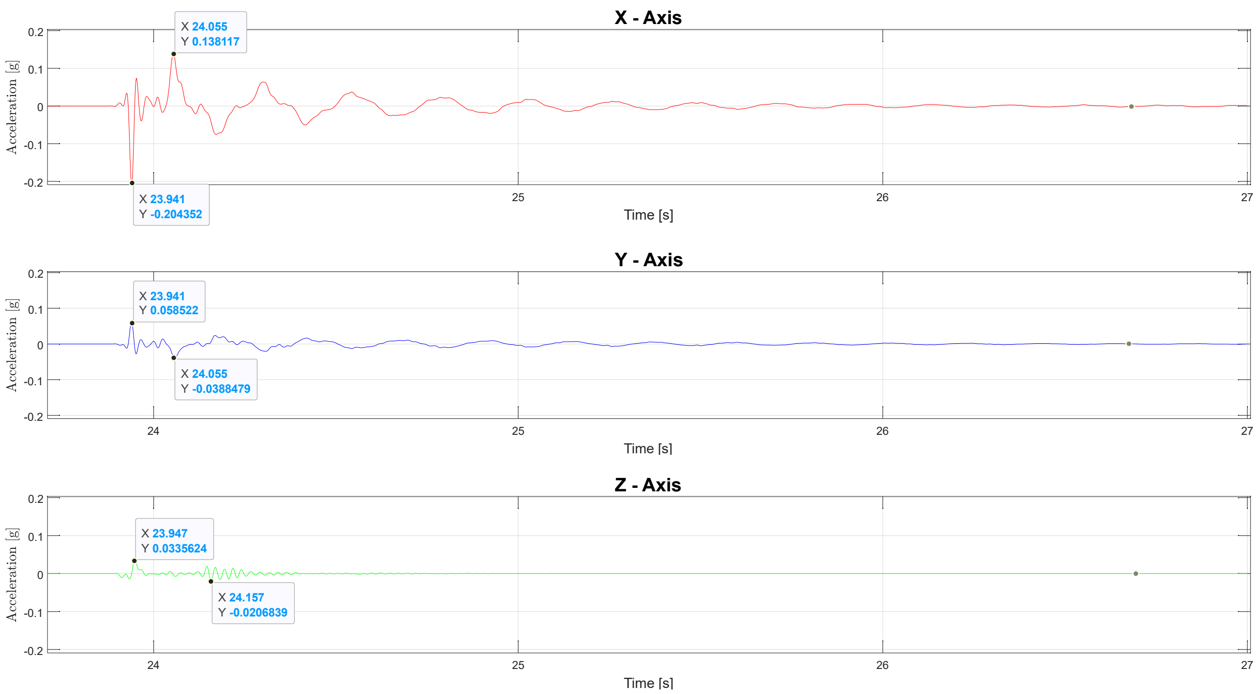
Accelogram X, Y, Z



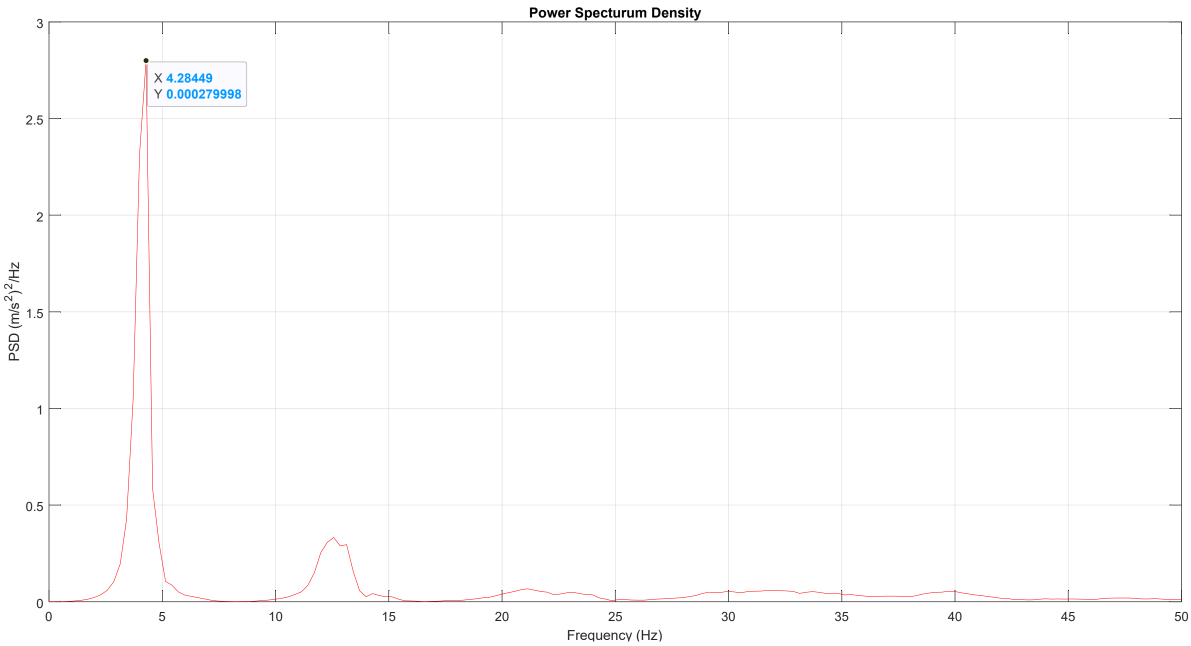


Results from a sensor placed on the floor level of the 9th floor

Accelogram X, Y, Z



Spectral power density X



Y

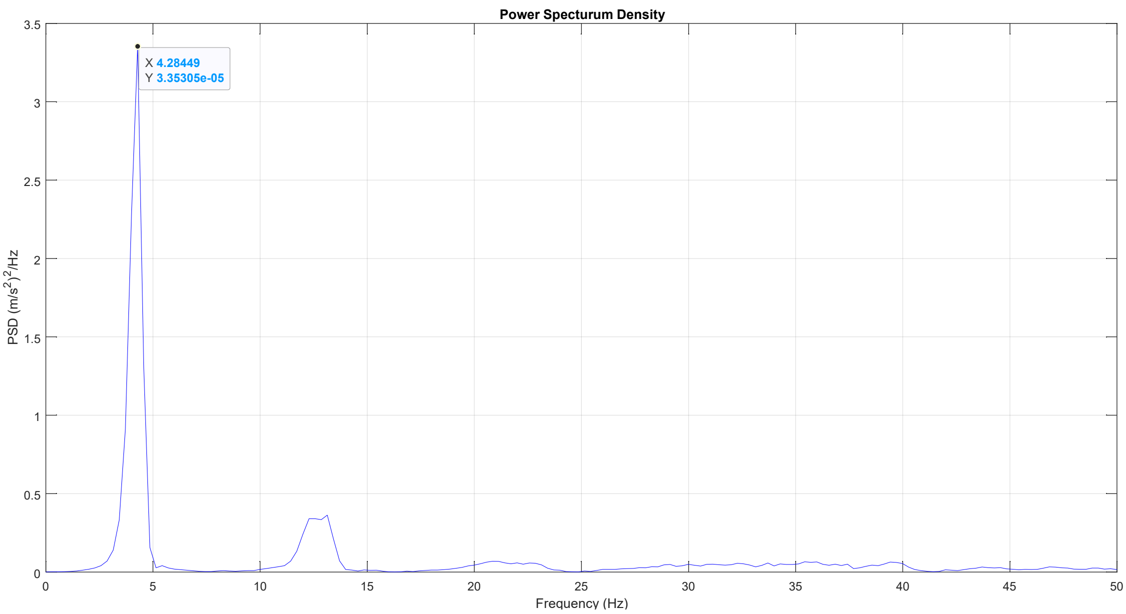
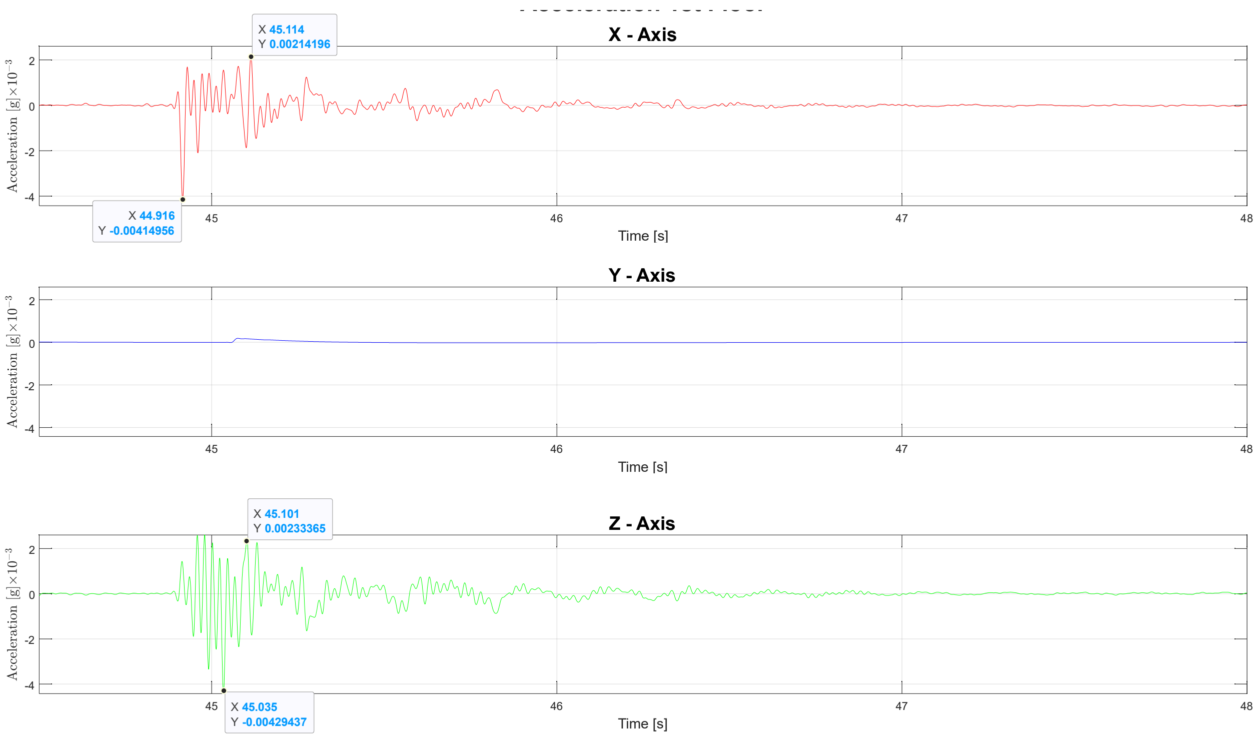


Figure 6. Accelogram and displacement of the building when it is pulled from the top with a force of 20 kg* using a cable and released.

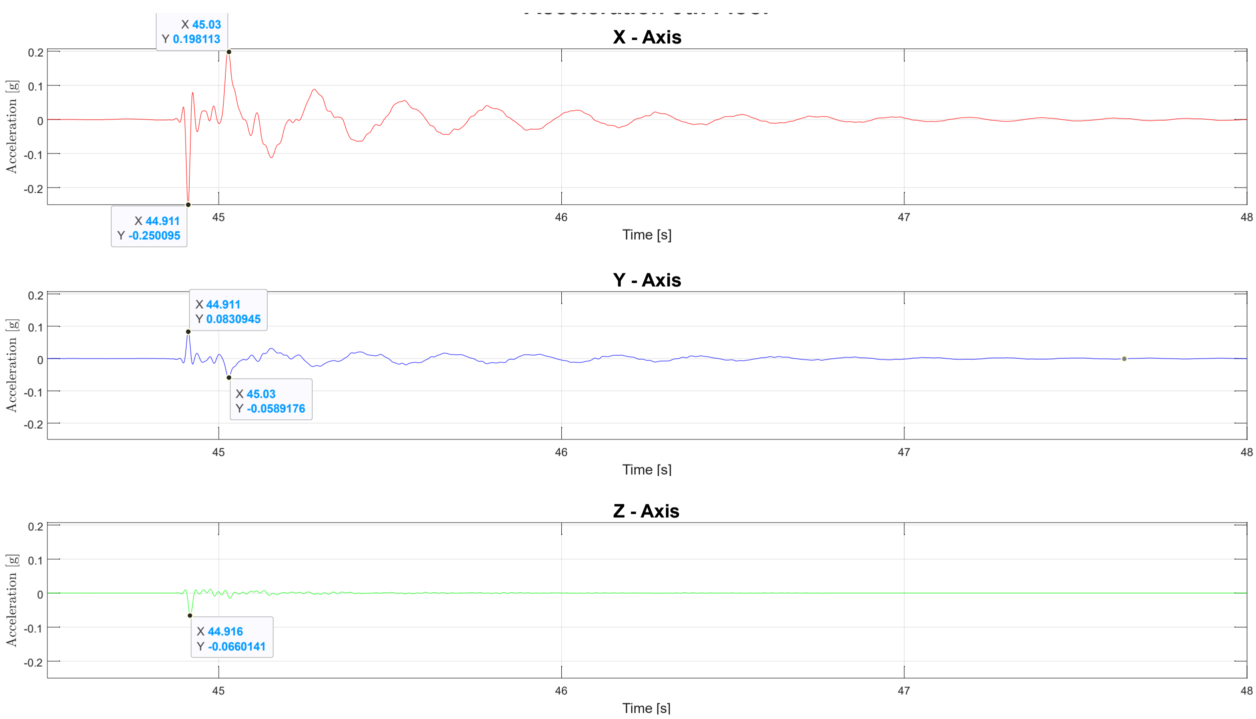
Results from a sensor placed on the floor level of the 1st floor

Accelogram X, Y, Z

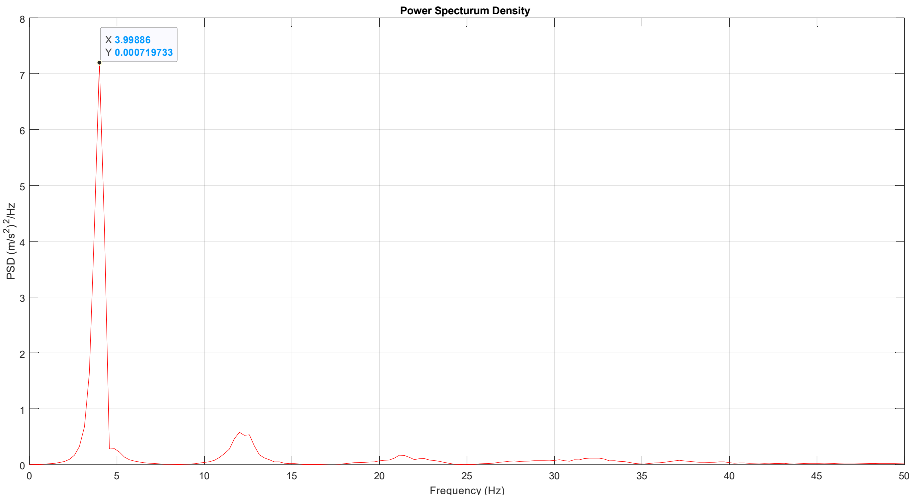


Results from a sensor placed on the floor level of the 9th floor

Accelogram X, Y, Z



Spectral power density X



Y

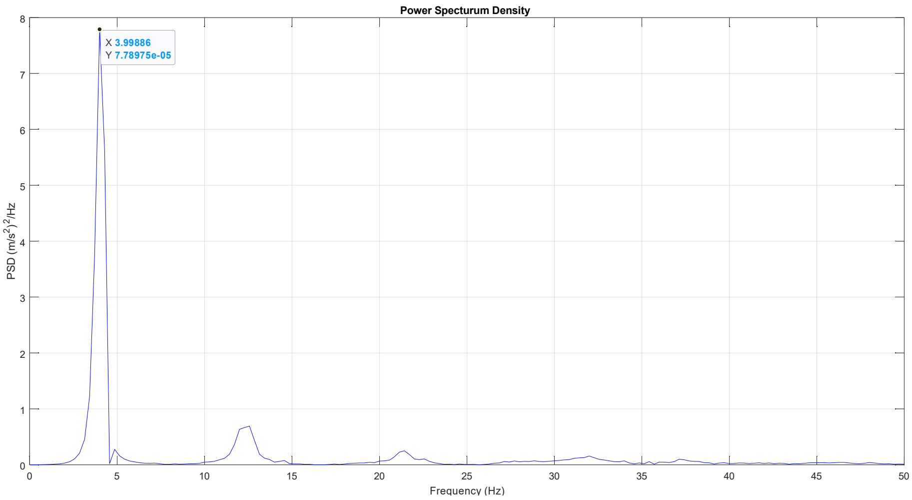
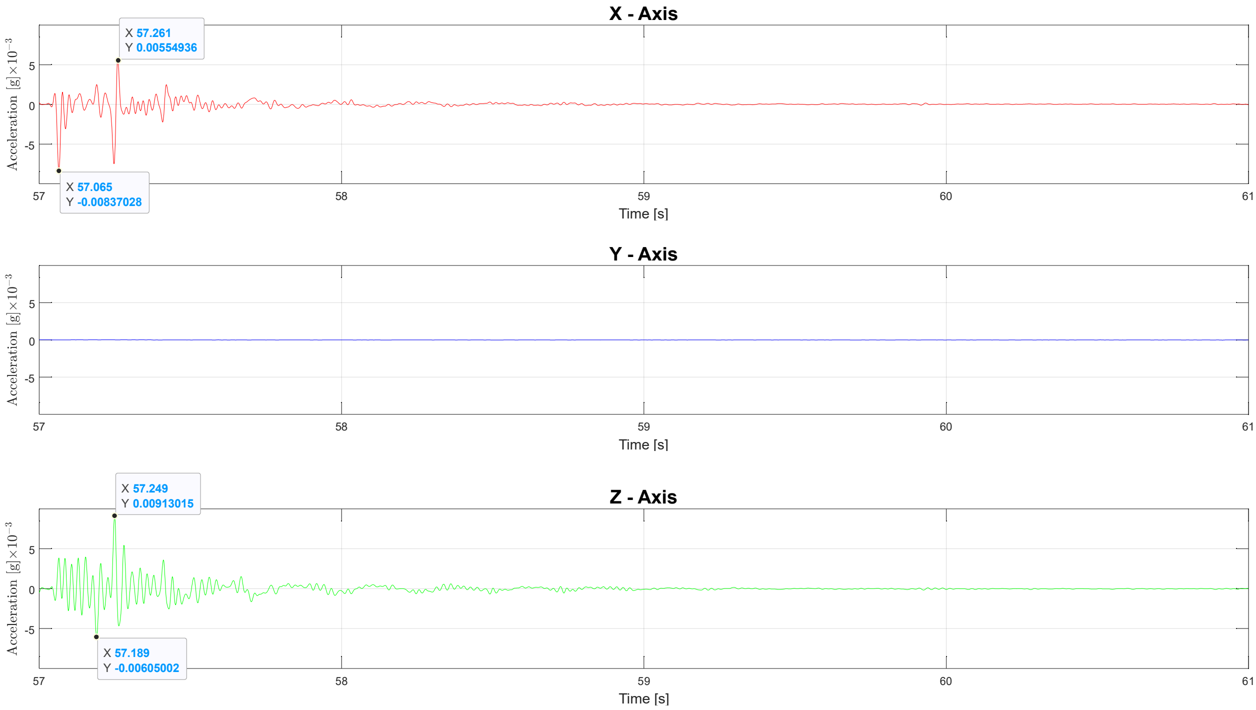


Figure 7. Accelogram and displacement of the building when it is pulled from the top with a force of 30 kg* using a cable and released.

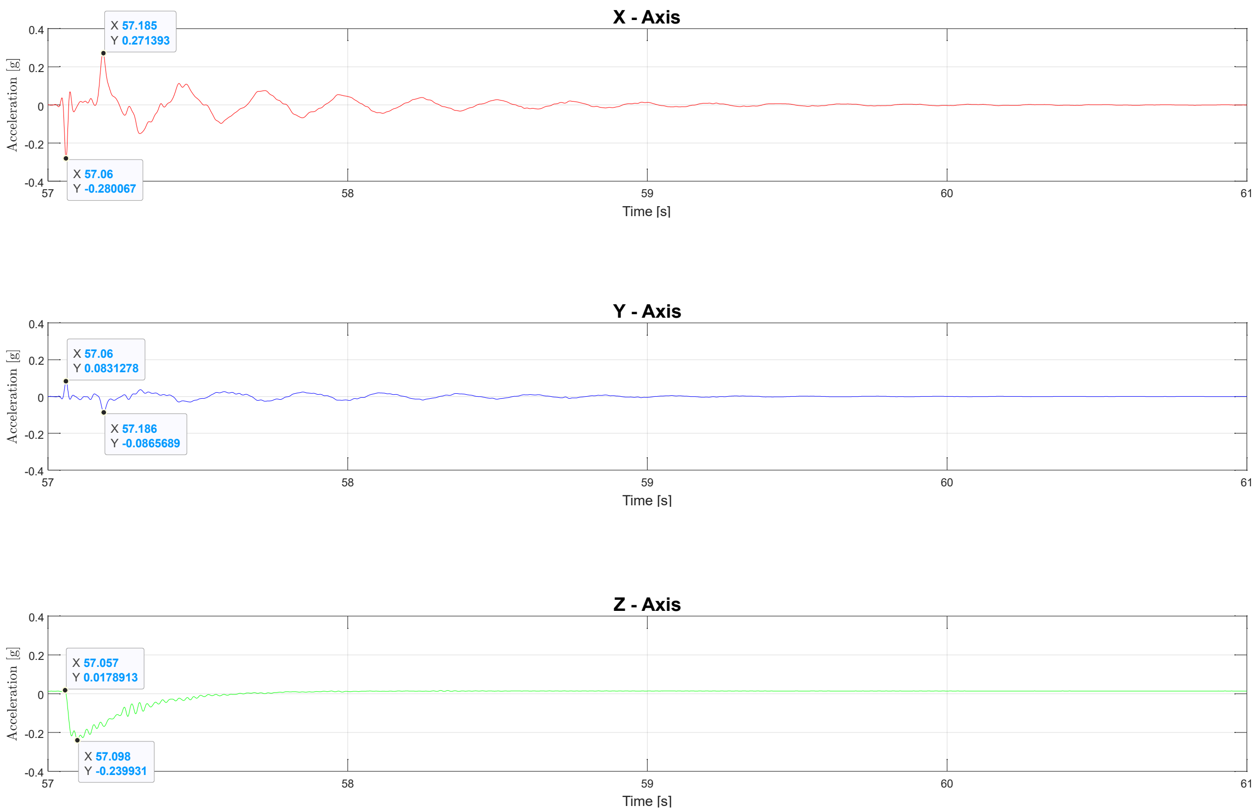
Results from a sensor placed on the floor level of the 1st floor

Accelogram X, Y, Z

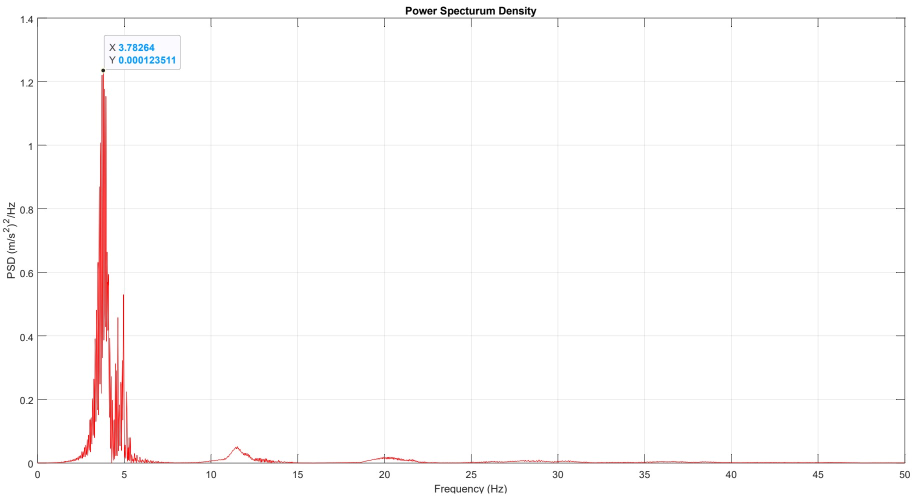


Results from a sensor placed on the floor level of the 9th floor

Accelogram X, Y, Z



Spectral power density X



Y

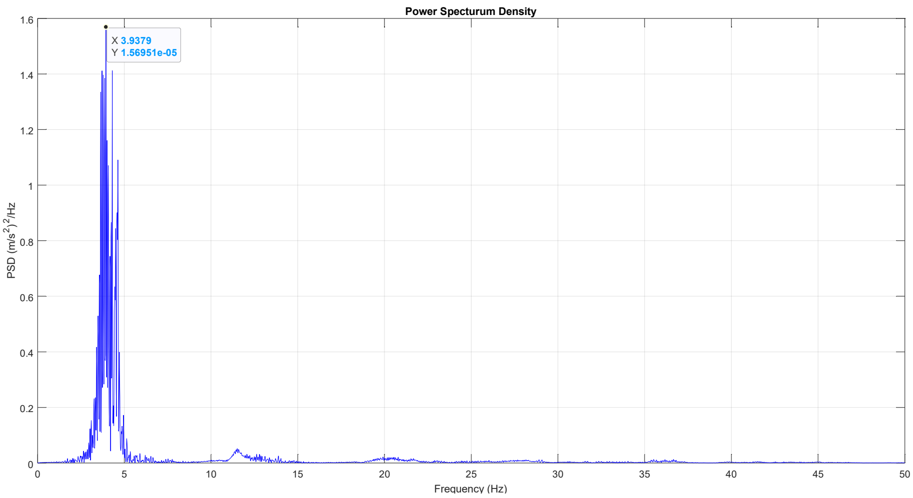


Figure 8. Accelogram and displacement of the building when it is pulled from the top with a force of 40 kg* using a cable and released.

Based on these accelerograms, a Power Spectrum Density (PSD) graph was constructed, and the average frequency of the building is presented in Table 1.

Table 1

TYPE OF TEST	TEST No.	X Frequency (Hz)	Y Frequency (Hz)	Average X_Y Frequency (Hz)	Average Frequency (Hz)
with a force of 10 kg stretched	TEST 004	4,665	4,665	4,665	**4.178**
	TEST 005	4.536	4.536	4.536	
	TEST 006	4.502	4.568	4.535	
	Average	**4.568**	**4.590**	**4.579**	

state					
With a force of 20 kg stretched state	TEST 007	4,248	4,248	4,248	
	TEST 008	4,284	4,284	4,284	
	TEST 009	4,248	4,248	4,248	
	Average	**4,260**	**4,260**	**4,260**	
With a force of 30 kg stretched state	TEST 010	3,999	3,999	3,999	
	TEST 011	3,998	3,998	3,998	
	TEST 012	3,999	3,999	3,999	
	Average	**3,999**	**3,999**	**3,999**	
with a force of 40 kg stretched state	TEST 013	3.964	3.964	3.964	
	TEST 014	3.782	3,937	3.8595	
	TEST 015	3,799	3,799	3,799	
	Average	**3.848**	**3,900**	**3.874**	

Taking into account the characteristics of the tested model, the frequency is calculated using the Lira-SAPR-2024 program and is shown in Figure 9 [7].

Частоты собственных колебаний

Файл Редактировать Опции

Частоты собственных колебаний

A	B	C	D	E	F	G	H	I
			Частоты					
№ загруж	№ формы	Собст.значения	Круг.частота (рад/с)	Частота (Гц)	Период (с)	Коэф.расп пред.	Мод.масса (%)	Сумма мод. масс (%)
3	1	0.033	29.998	4.774	0.209	0.610	27.807	27.807
3	2	0.033	29.998	4.774	0.209	- 0.849	53.971	81.777
3	3	0.025	39.992	6.365	0.157	0.000	0.000	81.777
3	4	0.011	91.649	14.586	0.069	- 0.552	7.512	89.289
3	5	0.011	91.649	14.586	0.069	- 0.319	2.511	91.801
4	1	0.041	24.249	3.859	0.259	0.956	60.759	60.759
4	2	0.041	24.249	3.859	0.259	0.562	21.019	81.778
4	3	0.031	31.788	5.059	0.198	0.000	0.000	81.778
4	4	0.013	74.079	11.790	0.085	- 0.300	2.118	83.897
4	5	0.013	74.079	11.790	0.085	0.580	7.904	91.800

Figure 9. Lira - frequency obtained from SAPR software.

CONCLUSIONS.

In the research process, an analysis of the seismic impact of the 1/15 model of a multi-story frame reinforced concrete building was carried out, and its dynamic characteristics were compared with the results of practical tests and calculations in the Lira-SAPR 2024 program.

According to the test results, the frequency of the main oscillation in the building was 4.1 Hz, and in the calculated model - 4.77 Hz. The difference between these two values does not exceed 15%, i.e., the practical results show that the model is sufficiently accurate and reliable.

Based on the obtained results, the following conclusions can be drawn:

1. The calculated model, compiled in the Lira-SAPR 2024 program, describes the seismic forces acting on the building with an accuracy close to real conditions.

2. The correspondence between the results of practical tests and calculations confirms the correct determination of the model's dynamic characteristics.

3. The results of seismic analysis can serve as a reliable criterion for assessing the stability of multi-story frame reinforced concrete buildings and their design in seismic regions.

4. The research results will serve as a basis for the development of recommendations for optimizing building structures, reducing vibration frequencies, and increasing seismic safety in the future.

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