DOI 10.52209/1609-1825_2021_4_203 UDC 69.059

Determining the Difference Between Three Different Seismic Modular Methods

[1]**RAKHIMOV Murat,** *Cand. Tech. Sci., Associate Professor, rahimov67@mail.ru,*
[1]***RAKHIMOVA Galia,** *Cand. Tech. Sci., Associate Professor, galinrah@mail.ru,*
[2]**TKACH Evgeniya,** *Dr. Tech. Sci., Professor, ev_tkach@mail.ru,*
[1]**ASSAN Aizat,** *master student, asan.aizat@mail.ru,*
[1]*Karaganda Technical University, Kazakhstan, 100027, Karaganda, N. Nazarbayev Avenue, 56,*
[2]*NRU «Moscow State University of Civil Engineering», Russia, 129337, Moscow, Yaroslavl Highway, 26,*
**corresponding author.*

Abstract. *The article deals with three types of seismic effects, namely, dynamic analysis of the oscillation model, dynamic analysis of a complete system, and analysis of static and dynamic structural elements. First, the seismic modules used in the Republic of Kazakhstan are analyzed. Second, in this article, the parameters of the foundation used are examined. Finally, the impact of three different seismac modules on one building is investigated. And also to identify how different modules will affect buildings.*

Keywords: *dynamics, elasticity, modulus, response-spectrum, seismic assessment, inertial forces, acceleration, circular frequency.*

Introduction

To calculate seismic vibrations o the territory of the Republic of Kazakhstan, the developers of LIRA SAPR proposed 3 Modules. In the LIRA SAPR Program 2019, EN 2.03-30-2017* «Construction in the Seismic zone», the chief engineers of the Republic of Kazakhstan suggested to use Modules 60. In 2020, Response-Spectrum Module 41 was recommended to use, and in 2021, Module 61 was recommended to calculate according to the program SP RK EN 1998-1:2004/2012 «Design of seismic-resistant structures». Thus, let us consider what the differences are and how they affect the same building. The behavior of frame buildings of a spatial-coupling scheme with stiffness cores under seismic impacts is considered, taking into account physical nonlinearity [1]. The first component for calculating the foundation of the system has only a change in volume under the influence of medium stresses, and for the second component – only a change in shape [2]. Also, for seismic calculations, the main loads are calculated first, and only then sums up the dynamic loads.

The building, which is planned to be built in the Boraldai district, has a size of 35x50 m, a span of 15x5x15 m, a footrest step of 5 m, a height of 7 m.

As for the base, it consists of 3 layers:

1 – the soil is formed by clay. Modulus deformation – 1000 t/m^2, soil weight – 1.8 t/m^3, natural humidity – 0.05, fluidity limit – 0.2, porosity coefficient – 0.7, specific coupling – 0.5 t/m^2, internal friction angle – 16.

2 – the soil is formed by loam. Modulus deformation – 2000 t/m^2, soil weight – 2.7 t/m^3, natural humidity – 0.15, fluidity limit – 0, porosity coefficient – 0.77, specific coupling – 0.31 t/m^2, internal friction angle – 26.

3 – the soil is formed by loam. Modulus deformation – 2000 t/m^2, soil weight – 2.7 t/m^3, natural humidity – 0.22, fluidity limit – 0.63, porosity coefficient – 0.7, specific coupling – 0.25 t/m^2, internal friction angle – 22.

Research results

A) The first report is conducted according to Module 60. This module is designed by SP RK 2.03-30-2017* «Construction in the Seismic Zone».

Correction factor for seismic forces (equal to one by default). This coefficient is multiplied by the values of the obtained inertial forces and differs from the unit when it is necessary to calculate any non-standard Seismic Impact [3].

a_g – horizontal calculated acceleration at the construction and indicated by formula 1, m/s^2.

$$a_g = \left\{ \frac{a_{g475}}{\frac{2}{3}a_{g2475}} \right\} = \left\{ \frac{0.510}{\frac{2}{3}x0.73} \right\} = 0.510, \qquad (1)$$

where, $a_{gR(475)}$ and $a_{gR(2475)}$ are the reference values of the maximum transverse accelerations at the construction site under consideration on IA-type soils, determined by maps ISA-1475 and ISA-12475;

$a_{g(475)}$ and $a_{g(2475)}$ – values of the highest horizontal accelerations at the construction site under specific soil and topographic conditions and indicated by formula 2;

$S_{(agR(475))}$ and $S_{(agR(2475))}$ – coefficients that characterize the impact of specific soil conditions of the construction site on the intensity of seismic impacts, determined in accordance with table 1 and indicated by formula 3;

S_t – a coefficient that takes into account the topographic effects of increased seismic impacts on the construction site [5].

$$a_{g475} = a_{gR475} \cdot S(a_{g475}) \cdot S_t = 0.38 \cdot 1.34 \cdot 1 = 0.51, \quad (2)$$

$$1,3 \le (2,5 - 3,0 \cdot a_{gR}/g) \le 2,4,$$

$$1,3 \le (2,5 - 3,0 \cdot 0,38) \le 2,4,$$

$$1,3 \le (1,34) \le 2,4. \quad (3)$$

The direction of seismic impact in the global coordinate system is determined by the guiding cosines of seismic impact CX, CY and CZ. Since the condition CX*CX+CY*CY+CZ*CZ=1 must always be met, it is enough to install two cosine guides out of three. The third one is installed automatically.

To calculate the values for this Module, we considered the maximum values for RSN, and the results are shown in figures 1, 2, 3, the oscillation period of the Module 60 in table 2.

B) according to Module 41, the Response – Spectrum Module.

Sets a graph of the response spectrum, according to which you need to calculate – acceleration, speed, or motion. In the corresponding input field, the transition coefficient is set for the specified graph. If, for example, the proportion of free fall acceleration g is shown as the ordinate of the response spectrum graph, then the transition coefficient is equal to g=9.81 m/s [6].

Then we introduce the necessary numbers in the pre-calculated graph.

2.093333333 0.11394 2.100334448 0.11432107 2.10738255 0.114704698 2.114478114 0.115090909 2.121621622 0.11547973 2.128813559 0.115871186 2.136054422 0.116265306 2.14334471 0.116662116 2.150684932 0.117061644 2.158075601 0.117463918 2.165517241 0.117868966 2.173010381 0.118276817 2.180555556 0.1186875 2.18815331 0.119101045 2.195804196 0.119517483, and so on. Using these

Table 1 – The values of coefficients $S_{(agR(475))}$ and $S_{(agR(2475))}$

Types of soil conditions by seismic properties	The values of the coefficients $S_{(agR(475))}$ and $S_{(agR(2475))}$, depending on the values $a_{gR(475)}$ and $a_{gR(2475)}$, respectively
IA	1,0
IB	1,0 ≤ (1,4 – agR/g) ≤ 1,2
II	1,1 ≤ (2,0 – 2,5 · agR/g) ≤ 1,6
III	1,3 ≤ (2,5 – 3,0 · agR/g) ≤ 2,4

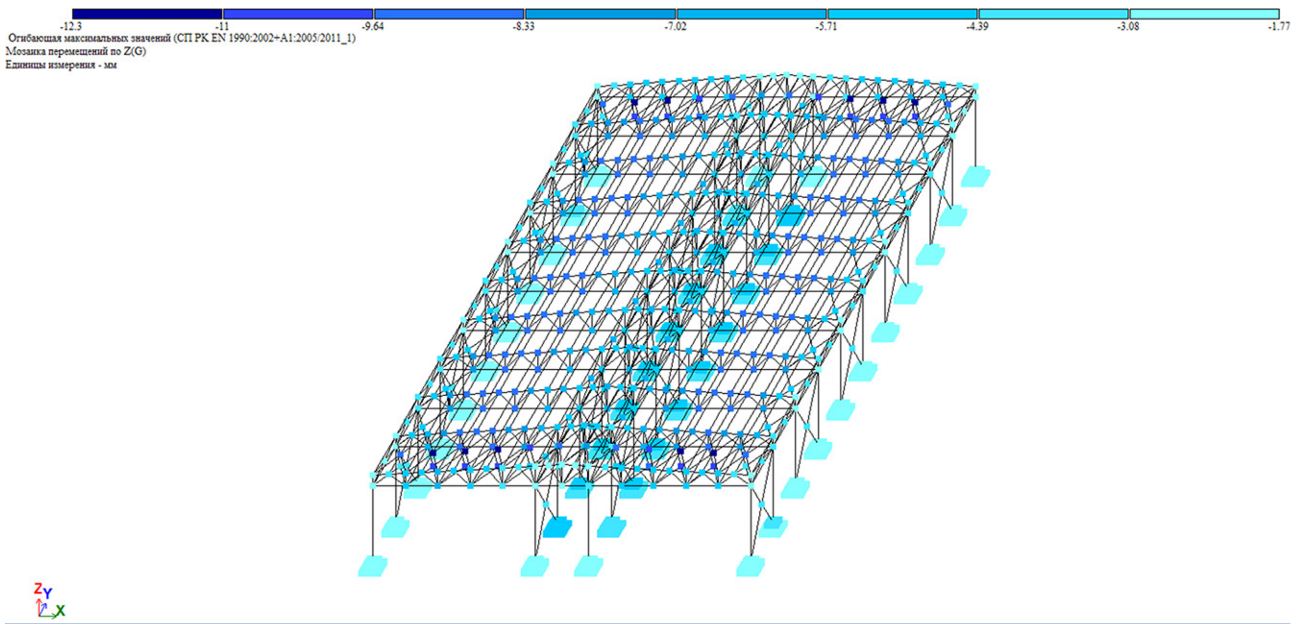

Figure 1 – Maximum displacement indicator along the Z (G) axis

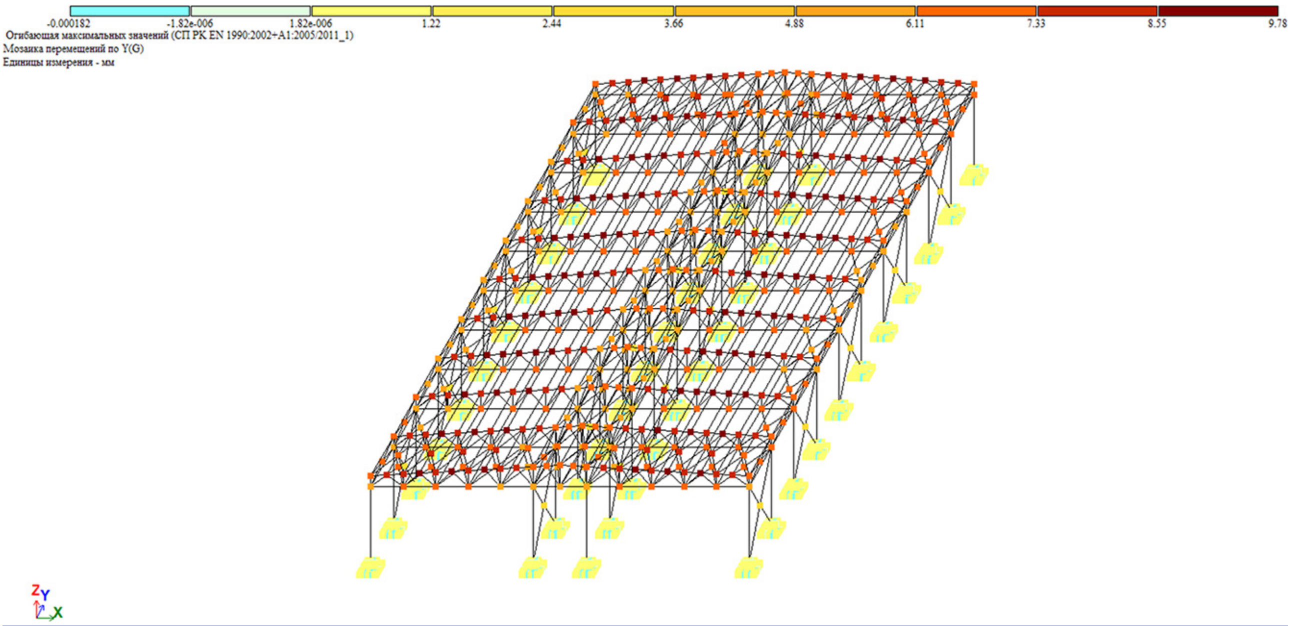

Figure 2 – Maximum displacement indicator along the Y (G) axis

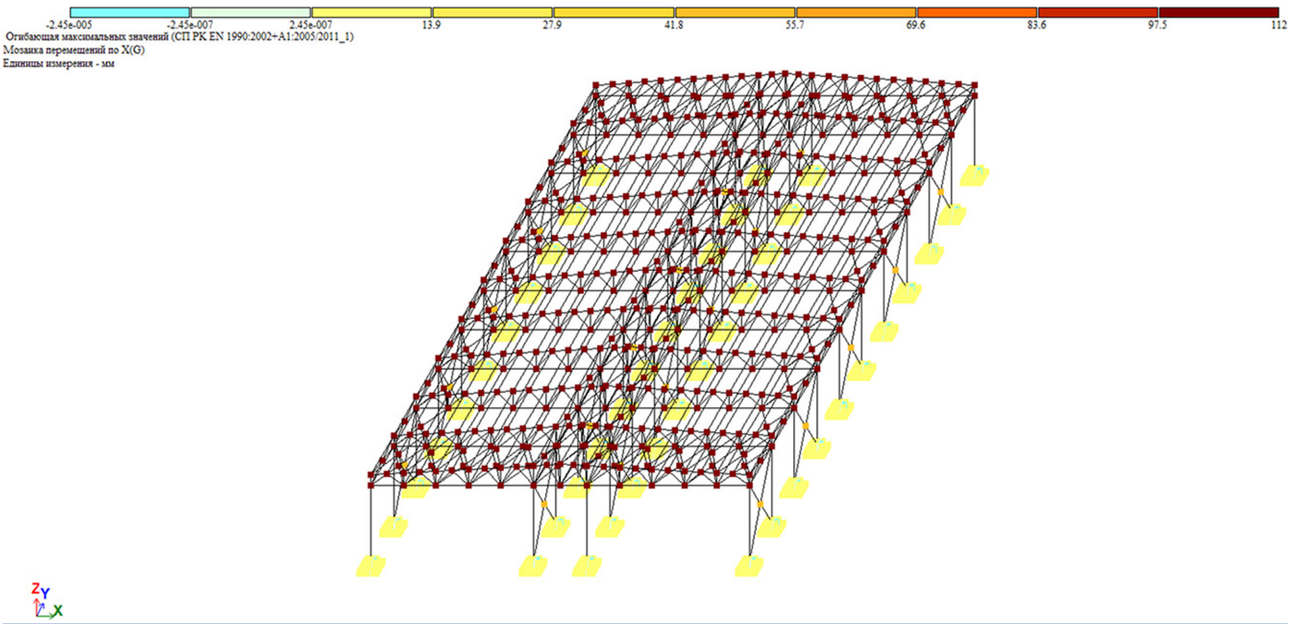

Figure 3 – Maximum displacement indicator along the X (G) axis

numbers, a graph line is displayed in the following figure.

The spectral acceleration graph is usually constructed depending on the oscillation period T. As it turned out, there is the following relationship between the circular frequency and the oscillation period, the graph of which is shown in Figures 4 and indicated by formula 4:

$$\omega = \frac{2\pi}{T}. \tag{4}$$

To calculate the values for this Module, we have reviewed the maximum indicators for the RSN and the results are shown in figures 5, 6, 7, oscillation period of the Module 41 in table 3.

C) Module is conducted according to Report 1. This module is carried out according to EN 1998-1:2004/2012 «Design of seismic-resistant structures». Correction factor for seismic forces (equal to one by default). This coefficient is multiplied by the values of the obtained inertial forces and differs from the unit when it is necessary to calculate any non-standard Seismic Impact [4].

a_g – horizontal calculated acceleration at the

Table 2 – Oscillation period of the module 60

Loading	N	Eigen values	Rad./sec.	hertz	period	Distribution coef.	Mass	Sum of masses
6 – (module 60)								
6	1	20,45815	4,523069	0,72023	1,38843	1,034648	56,0251	56,0251
6	2	67,72128	8,229294	1,31039	0,76312	0	0	56,0251
6	3	381,3606	19,52846	3,10962	0,32158	-0,00007	0	56,0251
6	4	461,1051	21,47336	3,41932	0,29245	-2,6E-05	0	56,0251
6	5	566,7372	23,80624	3,79080	0,26379	-0,1341	0,00135	56,0265
7 – (module 60)								
7	1	20,45815	4,523069	0,72023	1,38843	0,000044	0	0
7	2	67,72128	8,229294	1,31039	0,76312	0,00001	0	0
7	3	381,3606	19,52846	3,10962	0,32158	-1,1676	52,0992	52,0992
7	4	461,1051	21,47336	3,41932	0,29245	0,00014	0,00000	52,0992
7	5	566,7372	23,80624	3,79080	0,26379	-0,04684	0,00016	52,0993

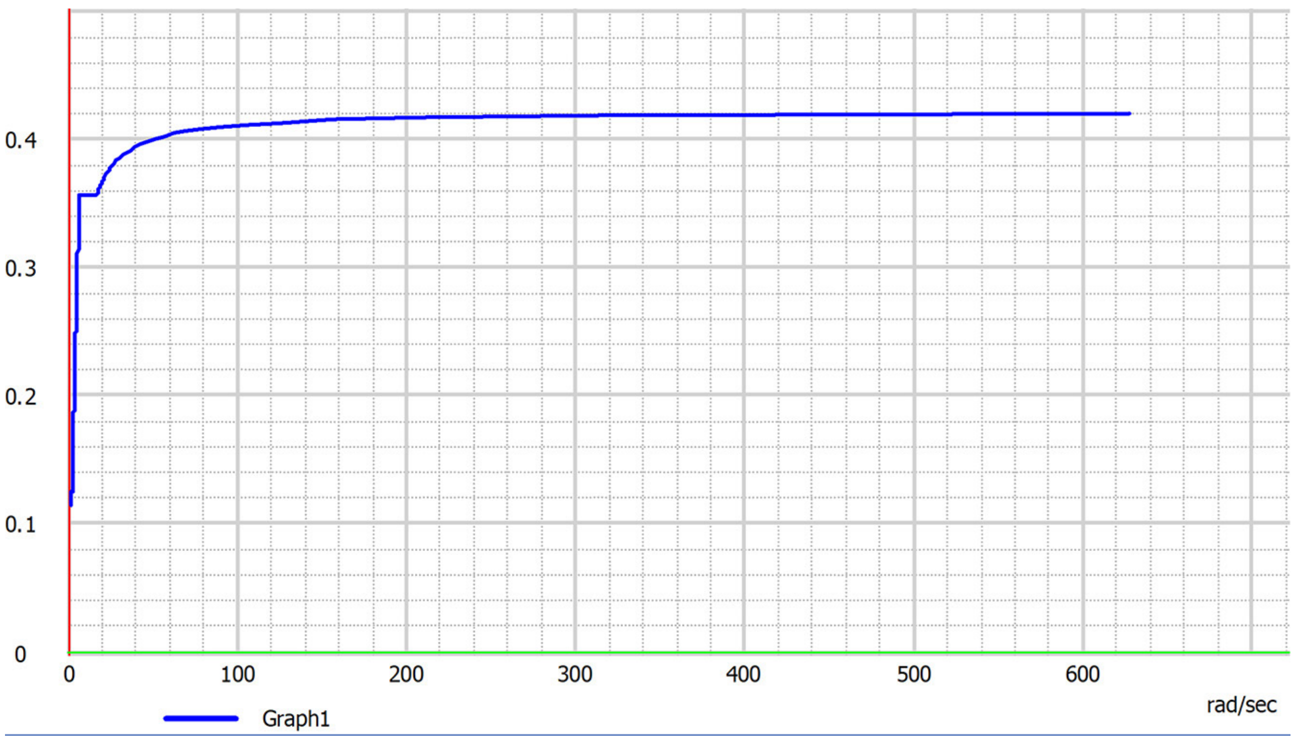

Figure 4 – The line graph of the dynamic effect

construction and indicated by formula 5, m/s^2.

$$a_g = \left\{ \frac{a_{g475}}{\frac{2}{3} a_{g2475}} \right\} = \left\{ \frac{0.510}{\frac{2}{3} x 0.73} \right\} = 0.510, \quad (5)$$

where, $a_{gR(475)}$ and $a_{gR(2475)}$ are the reference values of the maximum transverse accelerations at the construction site under consideration on IA-type soils, determined by maps ISA-1475 and ISA-12475;

$a_{g(475)}$ and $a_{g(2475)}$ – values of the highest horizontal accelerations at the construction site under specific soil and topographic conditions and indicated by formula 6;

$S_{(agR(475))}$ and $S_{(agR(2475))}$ – coefficients that characterize the impact of specific soil conditions of the construction site on the intensity of seismic impacts, indicated by formula 7;

S_t – a coefficient that takes into account the topographic effects of increased seismic impacts on the construction site [2].

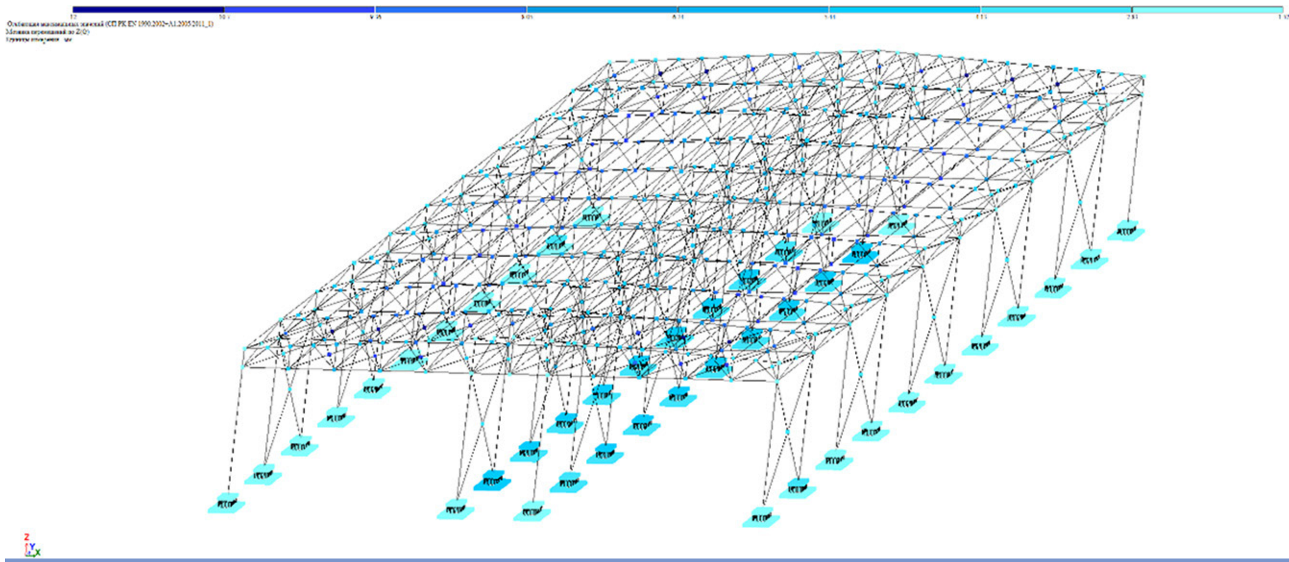

Figure 5 – Maximum displacement indicator along the Z (G) axis

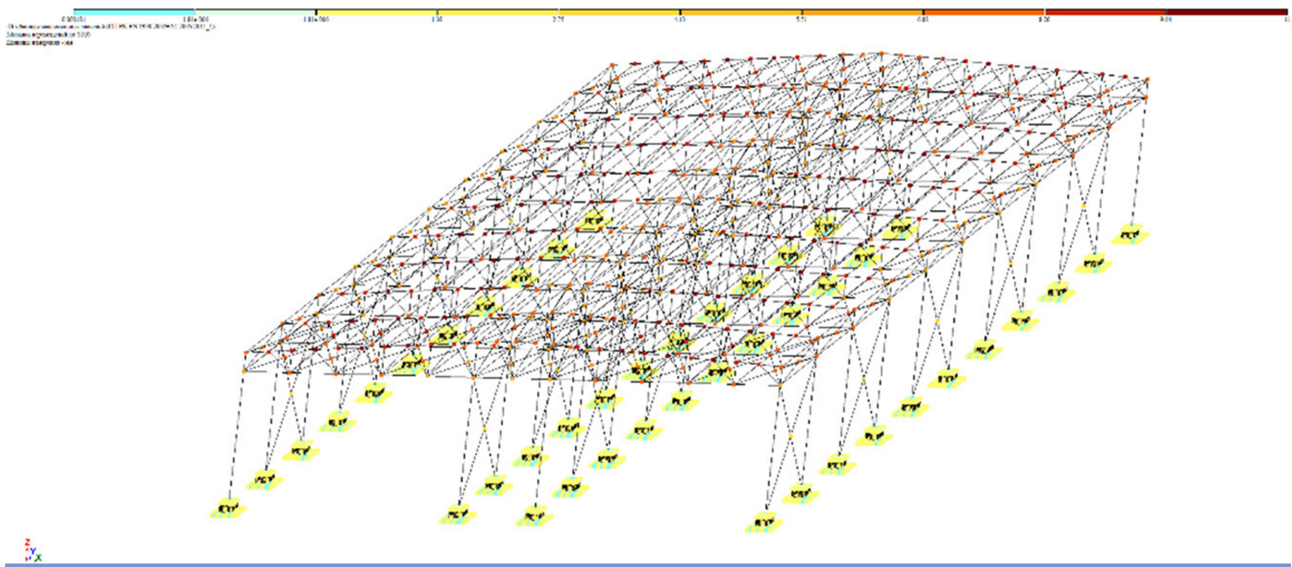

Figure 6 – Maximum displacement indicator along the Y (G) axis

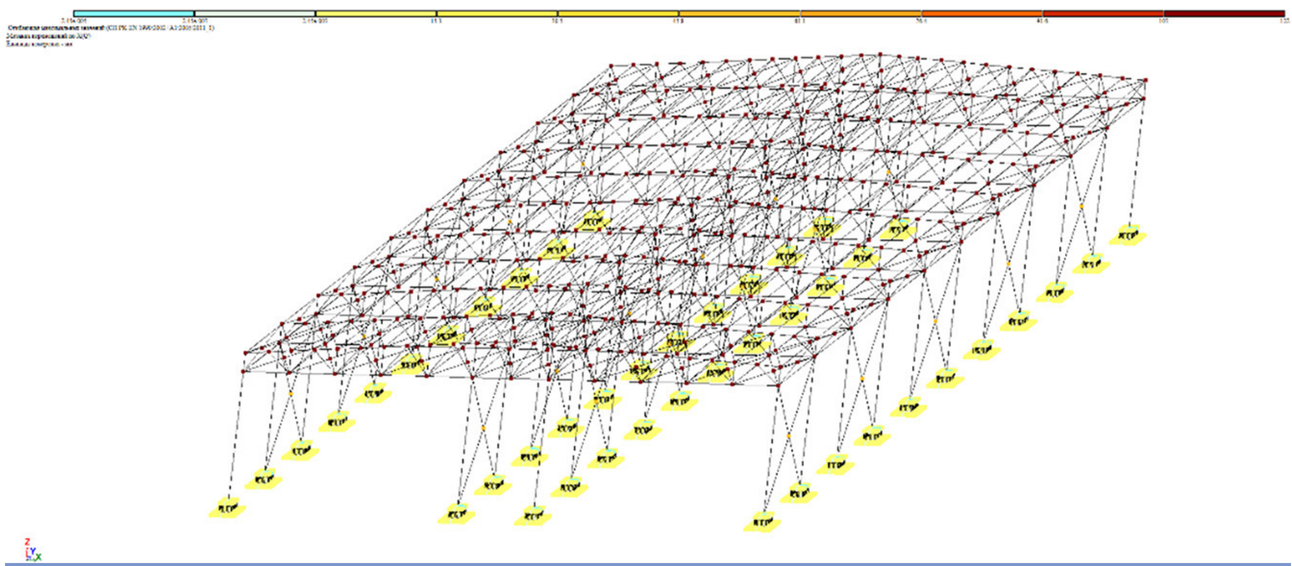

Figure 7 – Maximum displacement indicator along the X (G) axis

$$a_{g475} = a_{gR475} \cdot S(a_{g475}) \cdot S_t = 0.38 \cdot 1.34 \cdot 1 = 0.51, \quad (6)$$

$$1,3 \le (2,5 - 3,0 \cdot a_{gR}/g) \le 2,4,$$

$$1,3 \le (2,5 - 3,0 \cdot 0,38) \le 2,4,$$

$$1,3 \le (1,34) \le 2,4. \quad (7)$$

The direction of seismic impact in the global coordinate system is determined by the guiding cosines of seismic impact CX, CY and CZ. Since the condition CX*CX+CY*CY+CZ*CZ=1 must always be met, it is enough to install two cosine guides out of three. The third one is installed automatically [5].

To calculate the values for this Module, we have reviewed the maximum indicators for the RSN and the results are shown in figures 8, 9, 10, oscillation period of the Module 61 in table 4.

Table 3 – Oscillation period of Module 41

Loading	N	Eigen values	Rad./sec.	hertz	period	Distribution coef.	Mass	Sum of masses
6 – (module 41)								
6	1	20,46061	4,523341	0,72027	1,38835	1,034658	56,0252	56,0252
6	2	68,2289	8,260079	1,31529	0,76028	0	0	56,0252
6	3	395,3361	19,88306	3,16609	0,31584	0,000093	0	56,0252
6	4	478,941	21,88472	3,48482	0,28695	-6,4E-05	0	56,0252
6	5	562,2705	23,71224	3,77583	0,26484	-0,14698	0,00101	56,0262
6	6	566,7704	23,80694	3,79091	0,26378	0,131919	0,00131	56,0275
7 – (module 41)								
7	1	20,46061	4,523341	0,72027	1,38835	0,000043	0	0
7	2	68,2289	8,260079	1,31529	0,76028	0,000003	0	0
7	3	395,3361	19,88306	3,16609	0,31584	1,181712	52,3165	52,3165
7	4	478,941	21,88472	3,48482	0,28695	0,000094	0	52,3165
7	5	562,2705	23,71224	3,77583	0,26484	-0,00492	0,00000	52,3165
7	6	566,7704	23,80694	3,79091	0,26378	0,049286	0,00018	52,3167

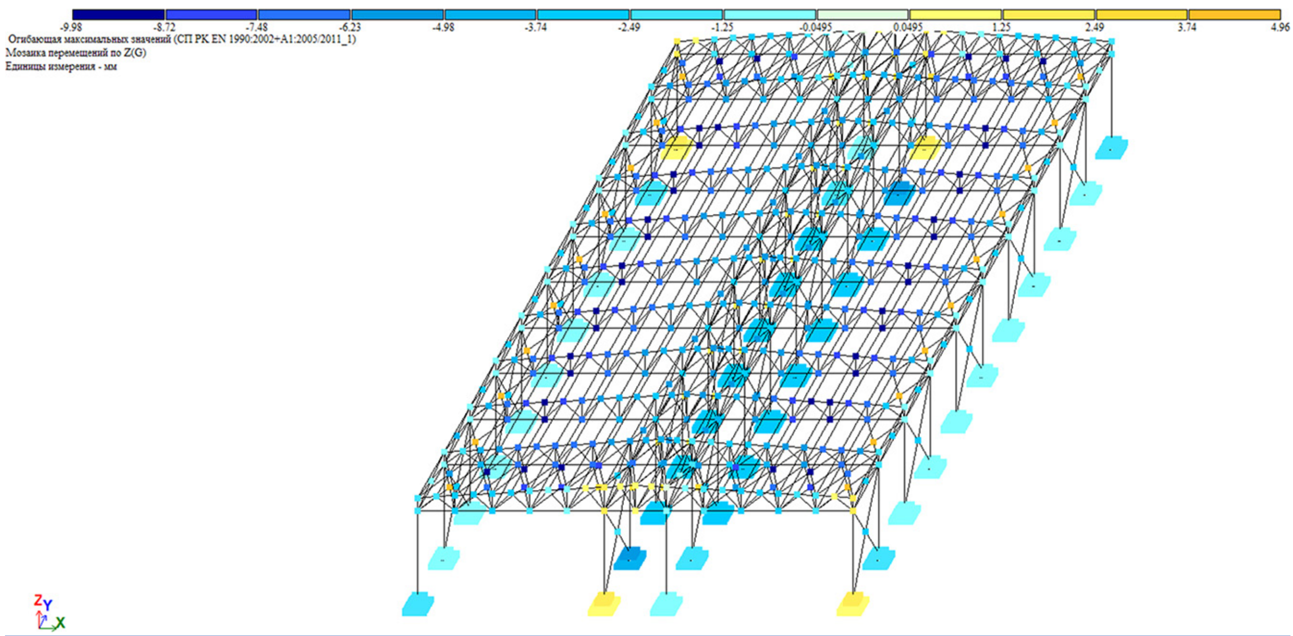

Figure 8 – Maximum displacement indicator along the Z (G) axis

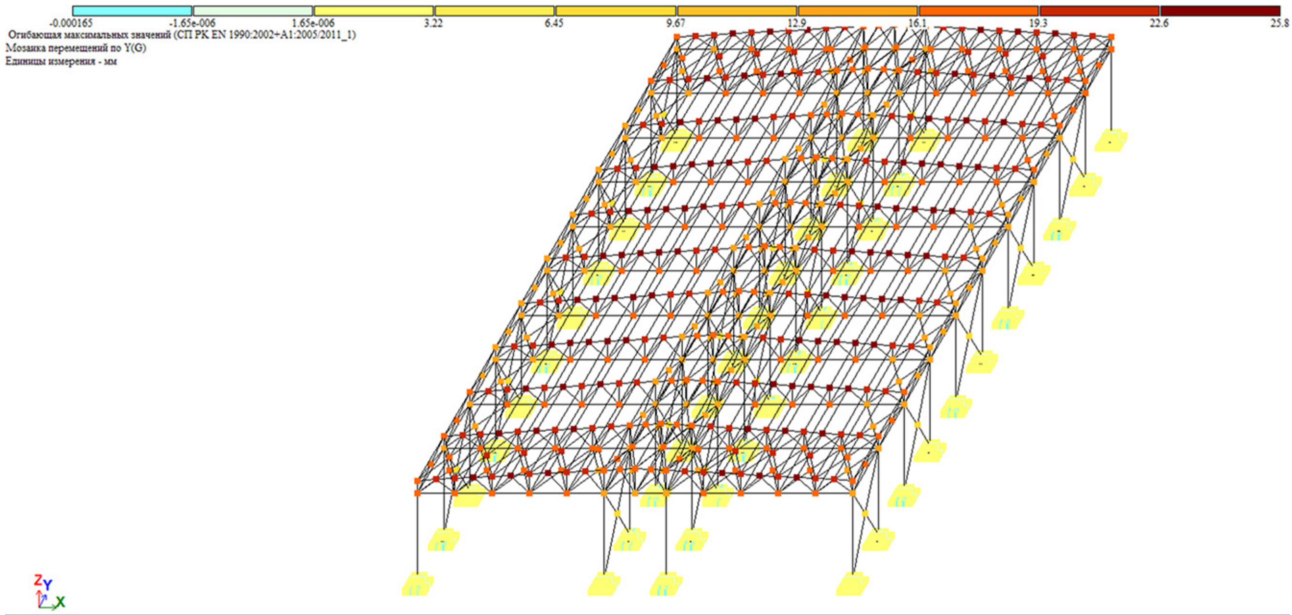

Figure 9 – Maximum displacement indicator along the Y (G) axis

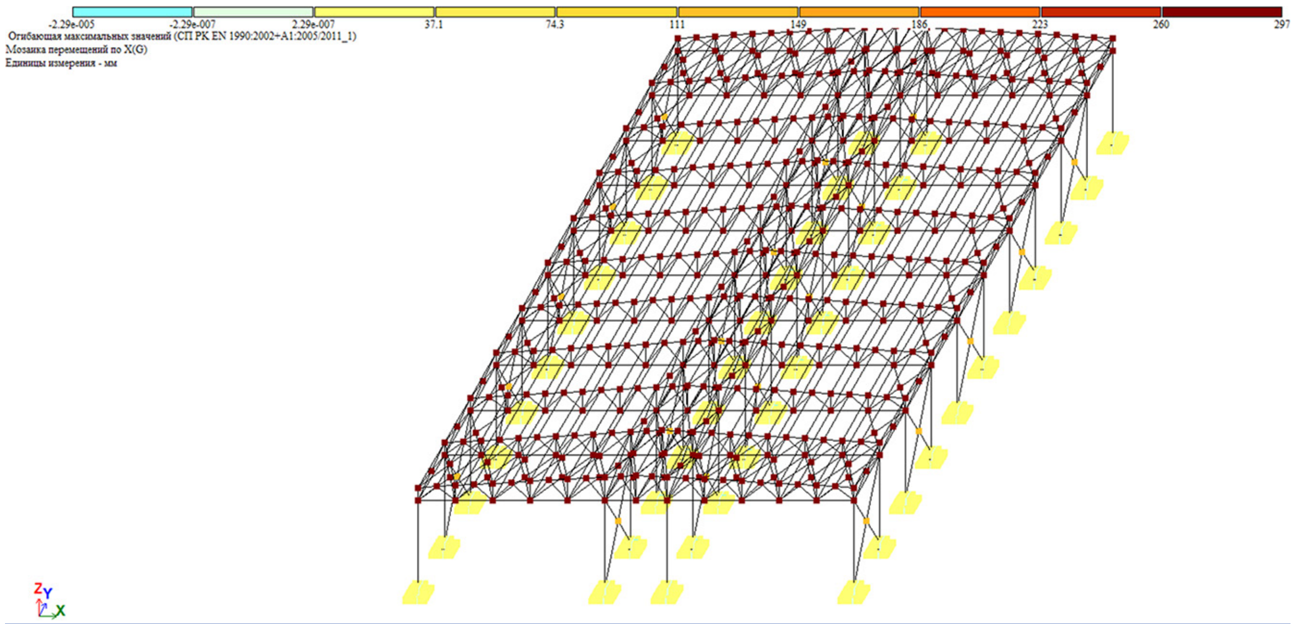

Figure 10 – Maximum displacement indicator along the X (G) axis

Conclusion

In conclusion, it is possible to observe the results of various calculations based on 3 different modules. Despite the apparent advantages, we have studied some deviations. For example, in Module 60 on the Z axis, the maximum indicator (-12.3; -1.77), in Module 41, the maximum indicator (-12; -1.52), in Module 61, the maximum indicator (-9.98; 4.96). Maximum indicator in Module 60 is on the Y-axis (-9.78; 0.000182); maximum indicator in Module 41 (-0.000181; 11); Module 61 contains maximum (-0.000165; 25.8) indicators. On the X-axis, Module 60 has a maximum indicator (-112; 0.000113); a maximum indicator is in Module 41 (-2.45 e-005; 122); a maximum indicator in Module 61 (-2.29 e-005; 297).

As you can see, the same type of foundation, the same building, even if the loads are the same, the results in the conclusion are different. Therefore, it is necessary to follow the warnings made by the chief engineers and to use the module specifications of the new LIRA SAPR program. All these calculations were done under the LIRA SAPR 2020 program, based on the opinion of the chief engineers that consider the program Module 41, the Response-Spectrum method to correspond to reality. We came to the conclusion that the calculated results of this module are correct.

Table 4 – Oscillation period of the Module 61

Loading	N	Eigenvalues	Rad./sec.	hertz	period	Distribution coef.	Mass	Sum of masses
6 – (module 61)								
6	1	20,45815	4,523069	0,72023	1,38843	1,034648	56,0251	56,0251
6	2	67,72128	8,229294	1,31039	0,76312	0	0	56,0251
6	3	381,3606	19,52846	3,10962	0,32158	-0,00007	0	56,0251
6	4	461,1051	21,47336	3,41932	0,29245	-2,6E-05	0	56,0251
6	5	566,7372	23,80624	3,79080	0,26379	-0,1341	0,00135	56,0265
7 – (module 61)								
7	1	20,45815	4,523069	0,72023	1,38843	0,000044	0	0
7	2	67,72128	8,229294	1,31039	0,76312	0,00001	0	0
7	3	381,3606	19,52846	3,10962	0,32158	-1,1676	52,0992	52,0992
7	4	461,1051	21,47336	3,41932	0,29245	0,00014	0,00000	52,0992
7	5	566,7372	23,80624	3,79080	0,26379	-0,04684	0,00016	52,09938

REFERENCES

1. К расчету многоэтажных каркасных зданий на сейсмические воздействия / Э.В. Бубнович, Ю.К. Демченко // ҚазҰТУ ХАБАРШЫСЫ. № 4. 2012. 112 с.
2. Расчет осадок фундаментов с учетом влияния локальных изменений сжимаемости и напряженного состояния основания здания / Утенов Е.С. // Труды университета. – Караганда: Изд-во КарГТУ, 2009. Вып. 3. – С. 65-68.
3. ҚР ҚЖ 2.03-30-2017* Сейсмикалық аймақтағы құрылыс – АҚ ҚазҚСҒЗИ 2018, Астана, 237 с.
4. ҚР ЕЖ EN 1998-1:2004/2012 Сейсмикаға төзімді конструкцияларды жобалау – АҚ ҚазҚСҒЗИ 2017, Астана, 245 с.
5. Расчеты на сейсмические воздействия в ЛИРА-САПР 2019 в соответствии с нормами Республики Казахстан и Кыргызской Республики / Водопьянов Р.Ю. Москва, 2019. 39 с.
6. Реализация новых функций для расчета по нормам СП РК EN во втором релизе ПК ЛИРА-САПР 2020 / Водопьянов Р.Ю. Москва, 2020. 63 с.

Үш түрлі сейсмикалық модульдік әдістердің арасындағы айырмашылықты анықтау

[1]***РАХИМОВ Мурат Аманжолович,*** *т.ғ.к., доцент, rahimov67@mail.ru,*
[1]****РАХИМОВА Галия Мухамедиевна,*** *т.ғ.к., доцент, galinrah@mail.ru,*
[2]***ТКАЧ Евгения Владимировна,*** *т.ғ.д., профессор, ev_tkach@mail.ru,*
[1]***АСАН Айзат Дәулетқызы,*** *магистрант, asan.aizat@mail.ru,*
[1]*Қарағанды техникалық университеті, Қазақстан, 100027, Қарағанды, Н. Назарбаев даңғылы, 56,*
[2]*ҰЗУ «Мәскеу мемлекеттік құрылыс университеті», Ресей, 129337, Мәскеу, Ярославль тас жолы, 26,*
**автор-корреспондент.*

Аңдатпа. *Мақалада сейсмикалық әсердің үш түрі қарастырылады, атап айтқанда тербеліс моделін динамикалық талдау, тұтас жүйені динамикалық талдау және статикалық және динамикалық құрылымдық элементтерді талдау. Біріншіден, Қазақстан Республикасында қолданылатын сейсмикалық модульдер талданады. Екіншіден, бұл мақалада пайдаланылатын іргетастың параметрлері қарастырылады. Соңында үш түрлі сейсмикалық модульдің бір ғимаратқа әсері зерттеледі. Сондай-ақ, әртүрлі модульдер ғимараттарға қалай әсер ететінін анықтаймыз.*

Кілт сөздер: *динамика, серпімділік, серпімділік модулі, жауап спектрі, сейсмикалық бағалау, инерция күші, үдеу, шеңберлік жиілік.*

Определение разницы между тремя различными сейсмическими модульными методами

[1]***РАХИМОВ Мурат Аманжолович,*** *к.т.н., доцент, rahimov67@mail.ru,*
[1]****РАХИМОВА Галия Мухамедиевна,*** *к.т.н., доцент, galinrah@mail.ru,*
[2]***ТКАЧ Евгения Владимировна,*** *д.т.н., профессор, ev_tkach@mail.ru,*
[1]***АСАН Айзат Дәулетқызы,*** *магистрант, asan.aizat@mail.ru,*
[1]*Карагандинский технический университет, Казахстан, 100027, Караганда, пр. Н. Назарбаева, 56,*

[2]НИУ «Московский государственный строительный университет», Россия, 129337, Москва, Ярославское шоссе, 26,

*автор-корреспондент.

Аннотация. *В статье рассматриваются три типа сейсмических воздействий, а именно динамический анализ модели колебаний, динамический анализ целостной системы и анализ статических и динамических структурных элементов. Во-первых, анализируются сейсмические модули, используемые в Республике Казахстан. Во-вторых, в этой статье рассматриваются параметры используемого фундамента. Наконец, исследуется влияние трех различных сейсмических модулей на одно здание. А также определить, как различные модули повлияют на здания.*

Ключевые слова: *динамика, упругость, модуль упругости, спектр-ответ, сейсмическая оценка, силы инерции, ускорение, круговая частота.*

REFERENCES

1. K raschetu mnogoetazhnyh karkasnyh zdanij na sejsmicheskie vozdejstviya / E.V. Bubnovich, Yu.K. Demchenko // QazŪTU HABARŞYSY, No. 4. 2012. 112 p.
2. Raschet osadok fundamentov s uchetom vliyaniya lokal'nyh izmenenij szhimaemosti i napryazhennogo sostoyaniya osnovaniya zdaniya / Utenov E.S. // Trudy universiteta. – Karaganda: Publ. KarGTU, 2009. Vyp. 3. – pp. 65-68.
3. QR QJ 2.03-30-2017* Seismikalyq aimaqtağy qūrylys – AQ QazQSĞZİ 2018, Astana, 237 p.
4. QR EJ EN 1998-1:2004/2012 Seismikağa tözımdı konstruksialardy jobalau – AQ QazQSĞZİ 2017, Astana, 245 p.
5. Raschety na sejsmicheskie vozdejstviya v LIRA-SAPR 2019 v sootvetstvii s normami Respubliki Kazahstan i Kyrgyzskoj Respubliki / Vodop'yanov R.Yu. Moscow, 2019. 39 p.
6. Realizaciya novyh funkcij dlya rascheta po normam SP RK EN vo vtorom relize PK LIRA-SAPR 2020 / Vodop'yanov R.Yu. Moscow, 2020. 63 p.