International Journal for Computational Civil and Structural Engineering, 14(4) 14-26 (2018)

DOI:10.22337/2587-9618-2018-14-4-14-26

LONG-PERIOD SEISMIC EFFECTS AND THEIR INFLUENCE ON THE STRUCTURAL STRENGTH OF HIGH-RISE BUILDINGS

Yuriy P. Nazarov [1, 2], ***Vladimir I. Travush*** [3, 4, 5]
[1] Joint Stock Company – Research Center of Construction, Moscow, RUSSIA
[2] Eurosoft, Moscow, RUSSIA
[3] Russian Academy of Architecture and Construction Sciences, Moscow, RUSSIA
[4] Urban Planning Institute of Residential and Public Buildings, Moscow, RUSSIA
[5] Research Institute of Building Physics of Russian Academy of Architecture and Construction Sciences, Moscow, RUSSIA

Abstract: Currently, in all building codes, the diagrams of dynamics coefficient are limited to a maximum natural oscillation period of 1.8 s. However, this range is clearly not enough for the calculation of constructions of high-rise structures with characteristic basic periods of about 4-5 s and more. This article analyzes the available seismological data presented in the Center for Engineering Strong Motion Data (CESMD) database. The spectra of Tohoku earthquakes (Tohoku earthquake, Japan, March 11, 2011) and Emberley (New Zealand Earthquake, New Zealand, November 13, 2016) were studied, and dynamic factors for periods of natural oscillations of structures 4–5 s are calculated. The results of the study allow to establish reasonable values of dynamic coefficients in the field of high periods.

Keywords: dynamic analysis, seismic analysis, long-period seismic action, amplification factor, accelerograms, tall buildings

ДЛИННОПЕРИОДНЫЕ СЕЙСМИЧЕСКИЕ ВОЗДЕЙСТВИЯ И ИХ ВЛИЯНИЕ НА ПРОЧНОСТЬ КОНСТРУКЦИЙ ВЫСОТНЫХ ЗДАНИЙ

Ю.П. Назаров [1, 2], ***В.И. Травуш*** [3, 4, 5]
[1] Акционерное общество «Научно-исследовательский центр «Строительство», г. Москва, РОССИЯ
[2] ООО «Еврософт», г. Москва, РОССИЯ
[3] Российская академия архитектуры и строительных наук, г. Москва, РОССИЯ
[4] Городской проектный институт жилых и общественных зданий, г. Москва, РОССИЯ
[5] Научно-исследовательский институт строительной физики
Российской академии архитектуры и строительных наук, г. Москва, РОССИЯ

Аннотация: В настоящее время во всех строительных нормах диаграммы коэффициентов динамичности ограничены максимальным периодом собственных колебаний сооружений в 1.8 с. Однако такого диапазона явно недостаточно для расчета конструкций высотных сооружений с характерными основными собственными периодами порядка 4-5 с и более. В настоящей статье проанализированы доступные сейсмологические данные, представленные в базе данных Center for Engineering Strong Motion Data (CESMD). Исследованы спектры землетрясений Тохоку (Tohoku earthquake, Япония, 11 марта 2011 г.) и Эмберли (Amberley New Zealand Earthquake, Новая Зеландия, 13 ноября 2016), рассчитаны коэффициенты динамичности для периодов собственных колебаний сооружений 4-5 с. Результаты исследования помогут установить обоснованные значения динамических коэффициентов в области высоких периодов.

Ключевые слова: динамический анализ, сейсмический анализ, длиннопериодное сейсмическое воздействие, коэффициент динамичности, акселерограммы, высотные здания

The authors of the National Building Code of Russian Federation SP 267.1325800.2016 [1] faced the following problem: in all the actual building standards governing seismic calculations [1-3], the diagrams of dynamic coefficients are limited to a maximum period of natural oscillations of structures of 1.8 s. This restriction made us seriously think about extending the diagram of the values of the dynamic coefficient to the region of periods that are more characteristic for high-rise buildings - about 4-5 s [4]. In this article authors attempts to analyze the available seismological data and find out what values the dynamic coefficient takes in the field of high periods of natural oscillations of structures.

Long-period seismic vibrations of the soil usually occur in the far zone of impact, remote from the epicenter for hundreds kilometers. For the long-period impacts, the dominant periods of the order about 2–5 s and more (0.2–0.5 Hz) are characteristic. It may cause resonances in such structures as high-rise buildings, telecommunication towers, long-span suspended and cable-stayed bridges, seismic-insulated structures with artificially reduced natural frequencies. Long-period movements of high-rise buildings were observed repeatedly, during large-scale earthquakes in the far zone; it examples can be found in papers [5-7]. Among the most significant it was the following: the July 7, 1952 earthquake in Los Angeles, USA (Kern County earthquake, hypocentral distance about 100-150 km (by the authors of the source material definition), M 7.3); March 28, 1970 in western Turkey (Gediz earthquake, hypocentral distance 135 km, M 7.1); September 19, 1985 Michoacan, Mexico (Michoacan, Mexico earthquake, hypocentral distance about 400 km, M 8.0); March 11, 2011 in Tokyo, Japan (Tohoku earthquake, hypocentral distance about 370 km, M9).

Using the example of the Tohoku earthquake, it is possible to analyze how the intensity and impacts' spectrum change with increasing of distance from the epicenter. In figures 1 and 2, the records from seismic stations of the Japanese network Kyoshin Net (KNET) MYG011 in Oshika at a hypocentral distance of 81.3 km and TKY017 in Tokyo at a hypocentral distance of 373 km (records of seismic stations can be found on the Center for Engineering Strong Motion Data website, CESMD, http : //cesmd.org) are shown. Parameters of seismic impact intensity are presented in table 1, that includes the maximum values of accelerations in each direction and the maximum values of the magnitude of the acceleration vector of seismic impact. In figures 3 and 4, the graphs of the dynamic coefficients for both impacts at 5% damping are constructed using the Odyssey software (developed by Company “Eurosoft”) that allows process accelerograms of earthquakes and obtain the design parameters of seismic impacts [9-11]. In figures 5 and 6 the modules of corresponding acceleration vectors are shown. The direction of NS in table 1 and in figures 1-4 correspond to the original direction "0", EW – "90", Z – "Up". Obviously, that with an increase of the hypocentral distance, the intensity of the impact decreases, and the spectrum shifts noticeably towards longer periods — in the zone of 4–5 seconds, the dynamic coefficient increases from 0.2 to 0.65–0.5. According to the table 1 and figures 3 and 4, the following estimation can be provided: let us consider, that the fundamental natural period of the construction T1 = 5 s, the following dynamic coefficient β and intensity coefficient I (maximum values of acceleration vector modulus of a soil) for earthquakes in Oshika and Tokyo are obtained:

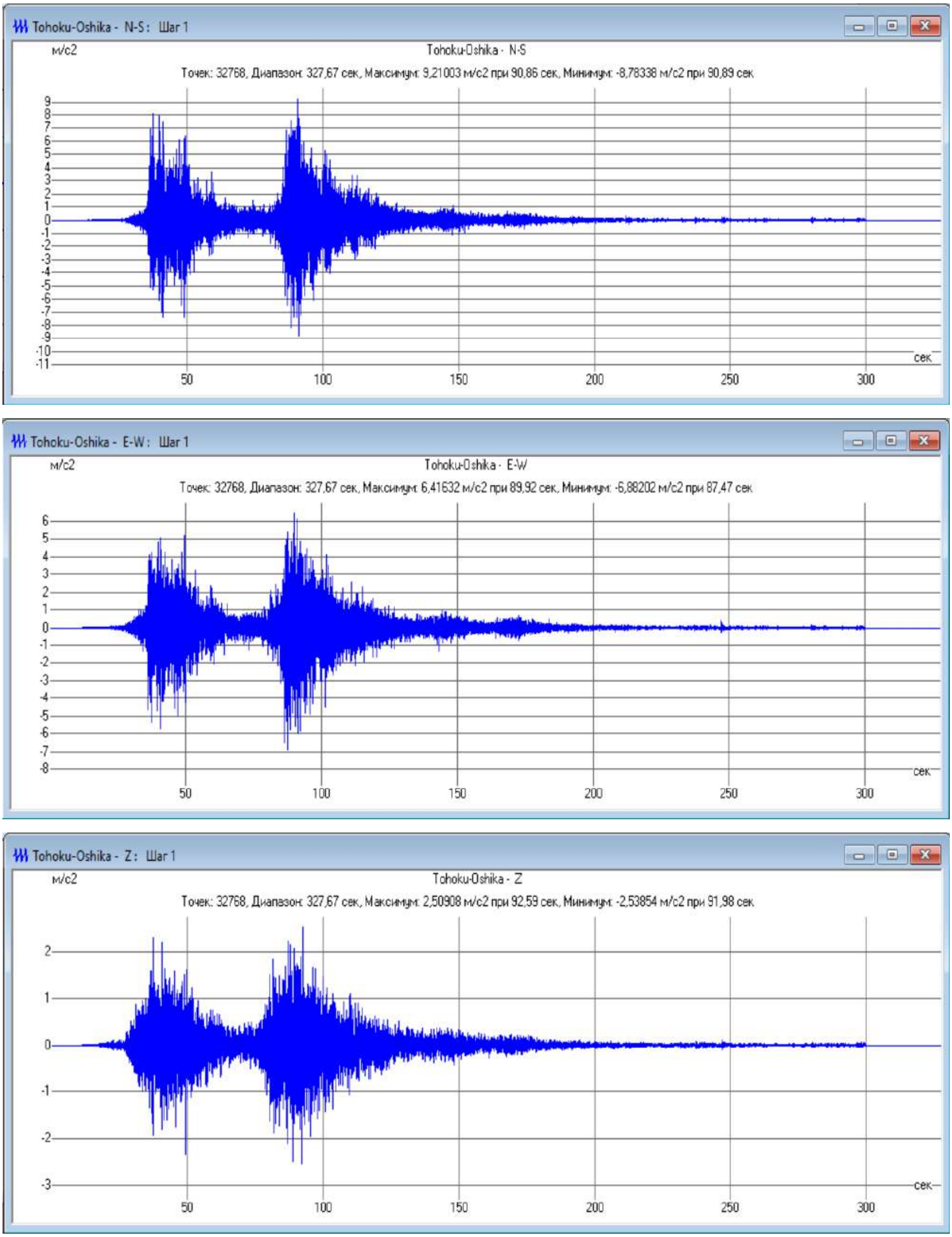
$$\beta_{Osh}(T_1) = 0.15, \quad I_{Osh} = 9.39\ \text{м/с}^2,$$
$$\beta_{Tky}(T_1) = 0.5, \quad I_{Tky} = 2.24\ \text{м/с}^2.$$

Then, at ratio of the intensities

$$I_{Osh}/I_{Tky} = 9.39/2.24 = 4.20,$$

the internal forces for the first mode of oscillations for the two impacts are related as

$$I_{Osh}\beta_{Osh}(T_1)\big/\big(I_{Tky}\beta_{Tky}(T_1)\big) = \\ = 4.20 \cdot 0.15/0.50 = 1.26.$$



Tohoku-Oshika - N-S: Шаг 1

Tohoku-Oshika - N-S

Точек: 32768, Диапазон: 327,67 сек, Максимум: 9,21003 м/с2 при 90,86 сек, Минимум: -8,78338 м/с2 при 90,89 сек

Tohoku-Oshika - E-W: Шаг 1

Tohoku-Oshika - E-W

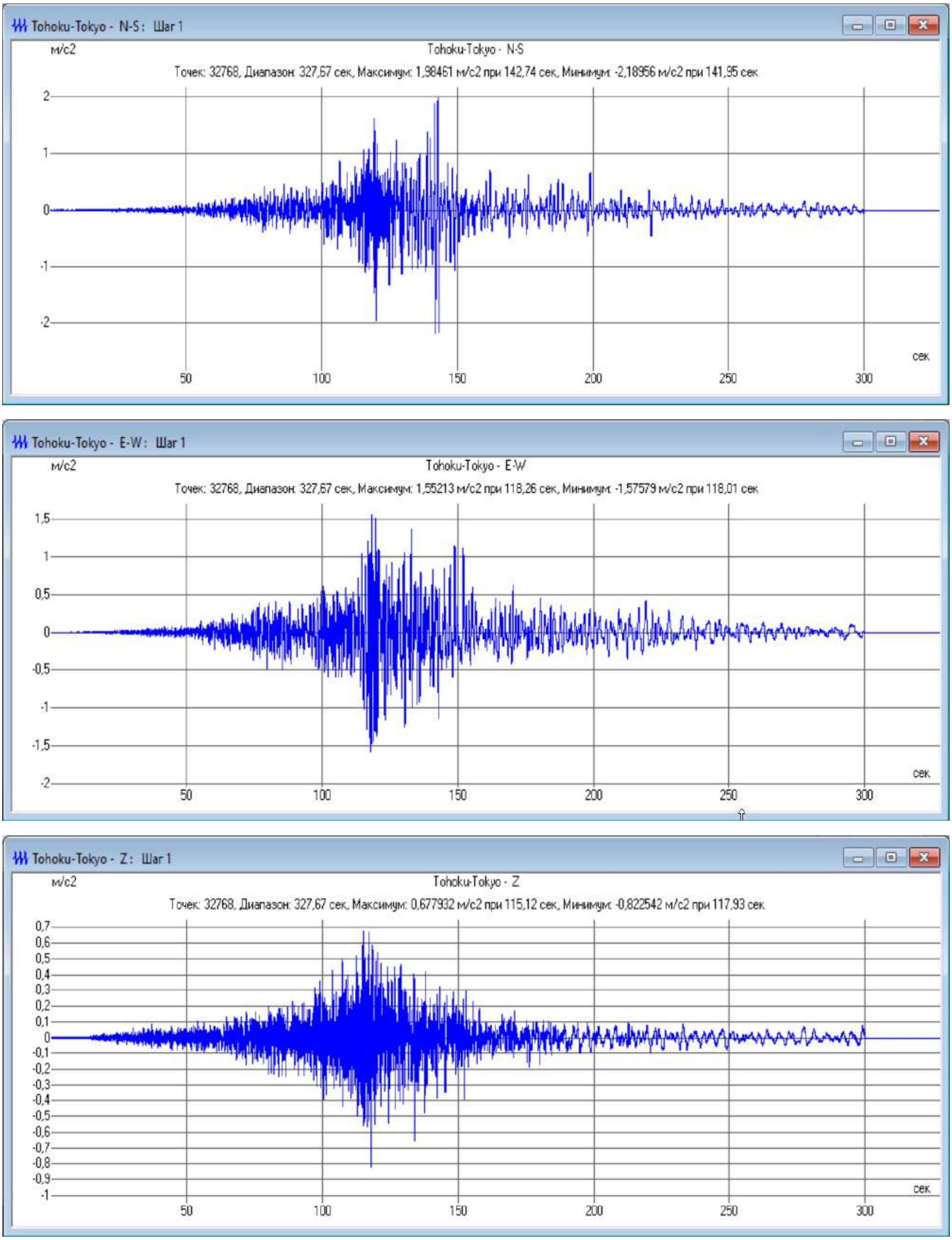
Точек: 32768, Диапазон: 327,67 сек, Максимум: 6,41632 м/с2 при 89,92 сек, Минимум: -6,88202 м/с2 при 87,47 сек

Tohoku-Oshika - Z: Шаг 1

Tohoku-Oshika - Z

Точек: 32768, Диапазон: 327,67 сек, Максимум: 2,50908 м/с2 при 92,59 сек, Минимум: -2,53854 м/с2 при 91,98 сек

Figure 1. Accelerograms of Tohoku earthquake (station MYG011, Oshika, hypocentral distance 81.3 km).



Tohoku-Tokyo - N-S: Шаг 1

Tohoku-Tokyo - N-S

Точек: 32768, Диапазон: 327,67 сек, Максимум: 1,98461 м/с2 при 142,74 сек, Минимум: -2,18956 м/с2 при 141,95 сек

Tohoku-Tokyo - E-W: Шаг 1

Tohoku-Tokyo - E-W

Точек: 32768, Диапазон: 327,67 сек, Максимум: 1,55213 м/с2 при 118,26 сек, Минимум: -1,57579 м/с2 при 118,01 сек

Tohoku-Tokyo - Z: Шаг 1

Tohoku-Tokyo - Z

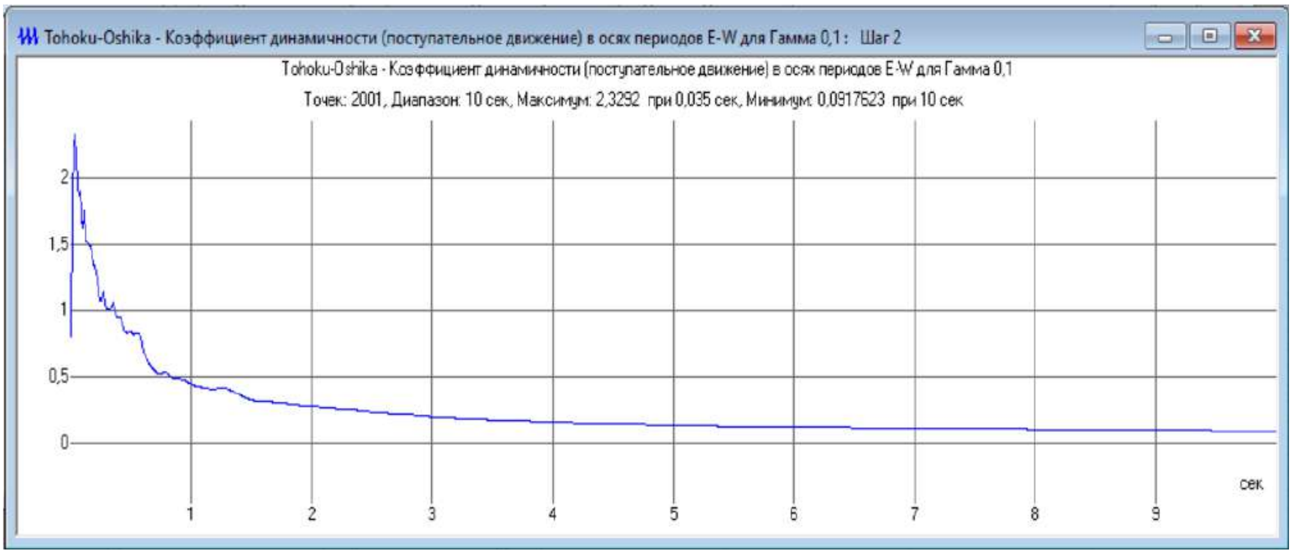
Точек: 32768, Диапазон: 327,67 сек, Максимум: 0,677932 м/с2 при 115,12 сек, Минимум: -0,822542 м/с2 при 117,93 сек

Figure 2. Accelerograms of Tohoku Earthquake
(TKY017 station, Tokyo, hypocentral distance 373 km).

Tohoku-Oshika - Коэффициент динамичности (поступательное движение) в осях периодов N-S для Гамма 0,1 : Шаг 2

Tohoku-Oshika - Коэффициент динамичности (поступательное движение) в осях периодов N-S для Гамма 0,1

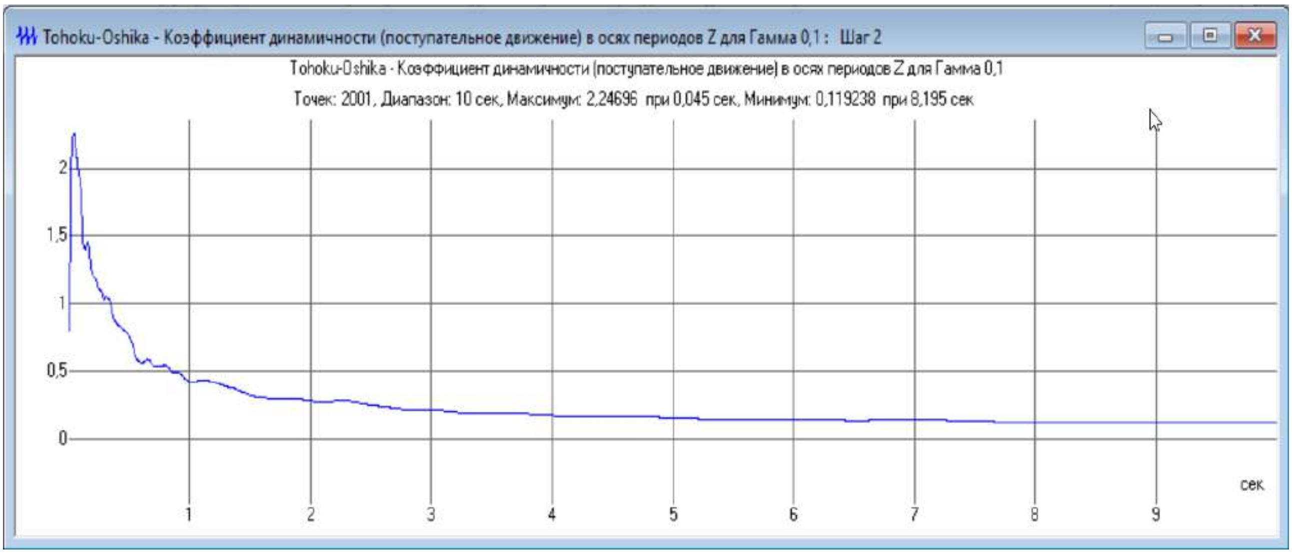
Точек: 2001, Диапазон: 10 сек, Максимум: 2,45244 при 0,035 сек, Минимум: 0,089444 при 10 сек



Tohoku-Oshika - Коэффициент динамичности (поступательное движение) в осях периодов E-W для Гамма 0,1 : Шаг 2

Tohoku-Oshika - Коэффициент динамичности (поступательное движение) в осях периодов E-W для Гамма 0,1

Точек: 2001, Диапазон: 10 сек, Максимум: 2,3292 при 0,035 сек, Минимум: 0,0917623 при 10 сек

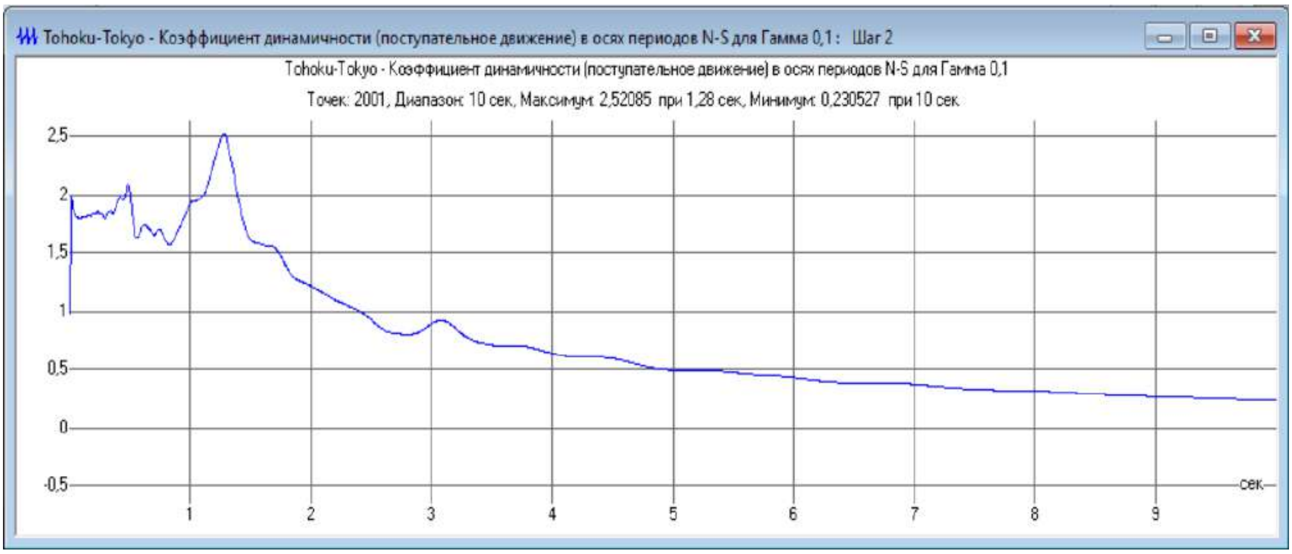


Tohoku-Oshika - Коэффициент динамичности (поступательное движение) в осях периодов Z для Гамма 0,1 : Шаг 2

Tohoku-Oshika - Коэффициент динамичности (поступательное движение) в осях периодов Z для Гамма 0,1

Точек: 2001, Диапазон: 10 сек, Максимум: 2,24696 при 0,045 сек, Минимум: 0,119238 при 8,195 сек

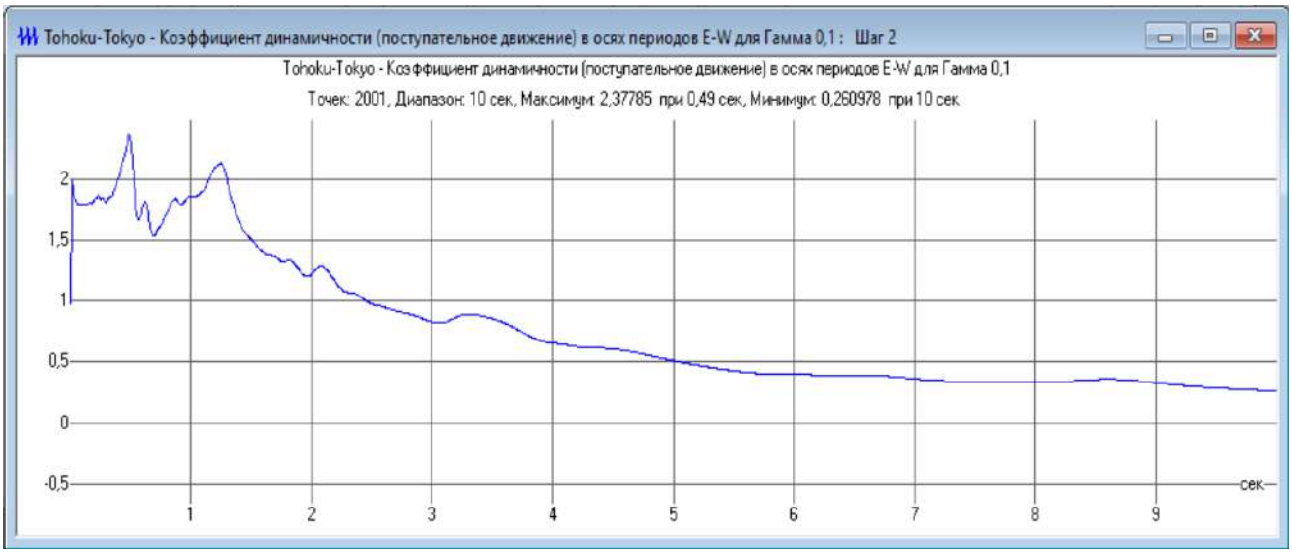
Figure 3. Dynamic coefficients of the Tohoku earthquake (station MYG011, Oshika, hypocentral distance 81.3 km).



Tohoku-Tokyo - Коэффициент динамичности (поступательное движение) в осях периодов N-S для Гамма 0,1 : Шаг 2

Tohoku-Tokyo - Коэффициент динамичности (поступательное движение) в осях периодов N-S для Гамма 0,1

Точек: 2001, Диапазон: 10 сек, Максимум: 2,52085 при 1,28 сек, Минимум: 0,230527 при 10 сек



Tohoku-Tokyo - Коэффициент динамичности (поступательное движение) в осях периодов E-W для Гамма 0,1 : Шаг 2

Tohoku-Tokyo - Коэффициент динамичности (поступательное движение) в осях периодов E-W для Гамма 0,1

Точек: 2001, Диапазон: 10 сек, Максимум: 2,37785 при 0,49 сек, Минимум: 0,260978 при 10 сек

Tohoku-Tokyo - Коэффициент динамичности (поступательное движение) в осях периодов Z для Гамма 0,1 : Шаг 2

Tohoku-Tokyo - Коэффициент динамичности (поступательное движение) в осях периодов Z для Гамма 0,1

Точек: 2001, Диапазон: 10 сек, Максимум: 2,40842 при 0,435 сек, Минимум: 0,174067 при 10 сек

Figure 4. Dynamic factors of the Tohoku earthquake (TKY017 station, Tokyo, hypocentral distance 373 km).

Table 1. Tohoku Earthquake intensity at stations MYG011 – Oshika and TKY017 – Tokyo.

Station	Maximum acceleration, m/s^2			
	NS	*EW*	*Z*	*Modulus*
MYG011	9.21	6.88	2.54	9.39
TKY017	2.19	1.58	0.82	2.24

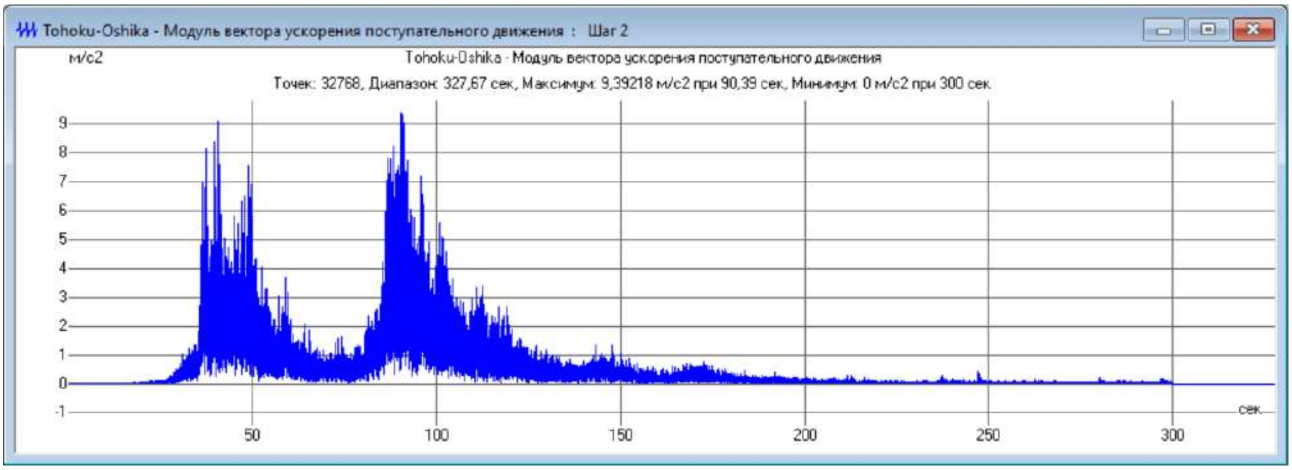


Figure 5. Seismic impact modulus (station MYG011, Oshika).

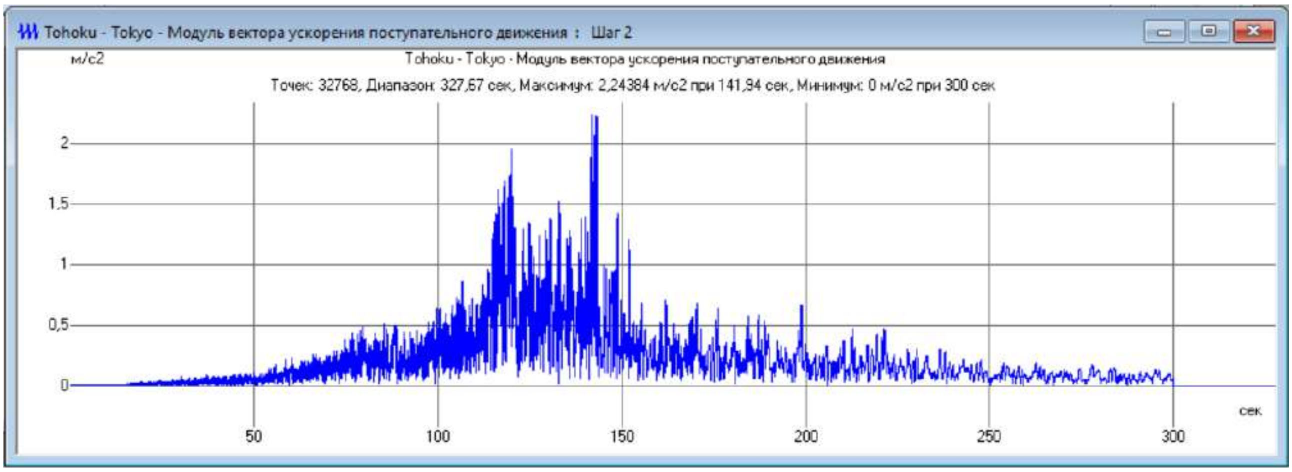


Figure 6. Seismic impact modulus (station TKY017, Tokyo).

Thus, although the intensity in the far zone falls more than 4 times, the internal forces (calculated by the linear spectral method) corresponding to the near zone are higher than the forces for the far zone about only 26%.

To obtain an averaged reasonable estimation of the dynamic cofficient for long-term impacts, it is required to analyze the spectrums of real earthquakes in the region of large periods for tens and hundreds of similar records. As a first step to this work, we consider the Emberley earthquake (New Zealand, November 13, 2016, M7.8 Emberley New Zealand Earthquake of 13 Nov 2016), presented in the CESMD database with instrumental records from 83 seismic stations. On the CESMD website, it can be found ready-made Emberley acceleration spectrums with a range of natural periods of up to 4 s and 5% damping (Fig. 7).

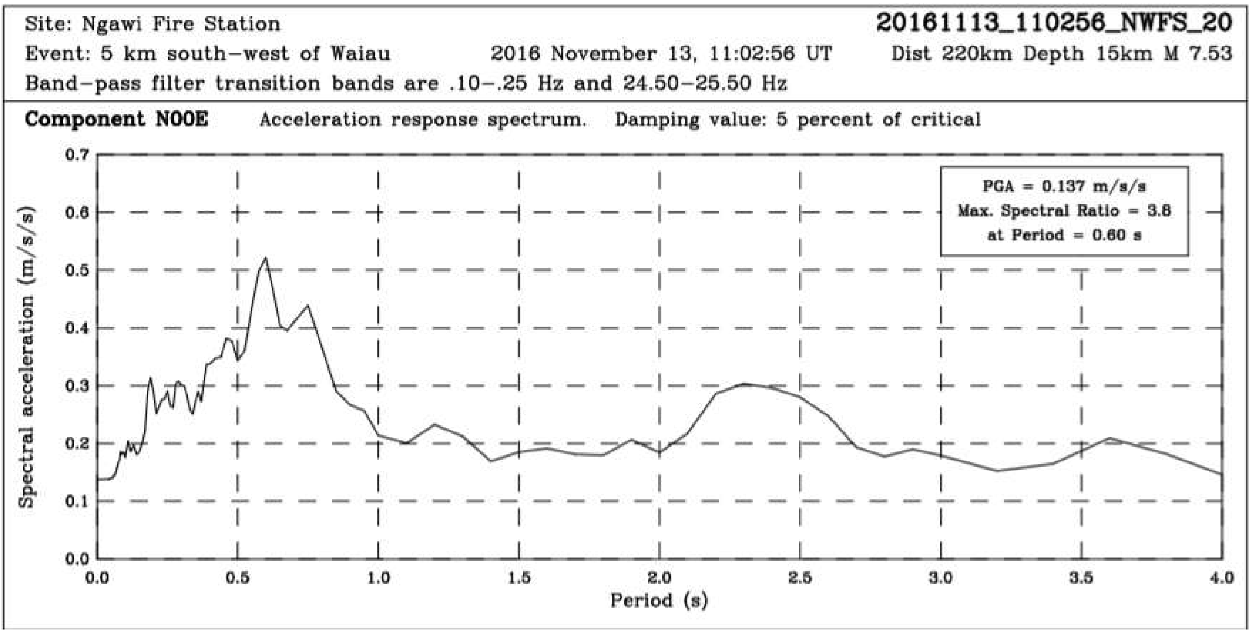


Figure 7. Spectrum of horizontal acceleration of Emberley earthquake in the CESMD database.

Table 2. Emberley Seismic Impact Parameters in the zone of 200-300 km from the epicenter (http://cesmd.org).

No	Station, code	Epicentral distance (km) and magnitude	Direction	DCmax (Max. Spectral Ratio)	PGA, m/s^2	S_a at T=4 s, m/s^2	**DC at T=4 s**
1	2	3	4	5	6	7	8
1.	Harihari Fire Station, HAFS	209 km M7.53	Hor1 Hor2 UP	3.5 4.1 4.3	0.161 0.213 0.062	0.075 0.090 0.075	**0.466** **0.423** **1.210**
2.	Wellington, WEL	214.8 M7.53	Hor1 Hor2 UP	3.3 3.7 3.6	1.202 1.455 0.669	0.400 0.450 0.400	**0.333** **0.310** **0.600**
3.	Wellington Te Papa Museum, TEPS	214.8 M7.53	Hor1 Hor2 UP	5.3 5.1 3.1	0.936 1.593 0.446	0.300 0.450 0.300	**0.321** **0.282** **0.673**
4.	Wellington Emergency Management Office, WEMS	216.2 M7.53	Hor1 Hor2 UP	3.5 3.2 3.2	1.321 1.478 0.547	0.450 0.45 0.30	**0.341** **0.304** **0.548**
5.	Makara Bunker, MKBS	216.2 M7.53	Hor1 Hor2 UP	3.1 3.7 3.1	0.911 0.618 0.395	0.50 0.20 0.20	**0.549** **0.324** **0.506**
6.	Wellington Pottery Association, POTS	216.4 M7.53	Hor1 Hor2 UP	3.9 3.6 2.5	0.795 0.638 0.371	0.25 0.25 0.25	**0.314** **0.392** **0.674**

1	2	3	4	5	6	7	8
7.	Quartz Range, QRZ	216.6	Hor1	3.4	0.158	0.125	**0.791**
		M7.53	Hor2	3.6	0.188	0.125	**0.665**
			UP	3.2	0.127	0.100	**0.787**
8.	Aotea Quay Pipitea, PIPS	217.4	Hor1	4.0	2.094	0.8	**0.382**
		M7.82	Hor2	3.0	2.710	0.5	**0.185**
			UP	3.0	0.845	0.3	**0.355**
9.	Ngawi Fire Station, NWFS	220.7	Hor1	3.8	0.137	0.15	**1.095**
		M7.53	Hor2	3.3	0.190	0.11	**Figure 7**
			UP	2.8	0.079	0.10	**0.579**
							1.266
10.	Newlands, NEWS	222.3	Hor1	2.6	0.950	0.505	**0.526**
		M7.82	Hor2	3.6	0.569	0.400	**0.703**
			UP	2.9	0.538	0.125	**0.233**
11.	Petone Overbridge/ PTOS	225.0	Hor1	3.3	0.706	0.300	**0.425**
		M7.53	Hor2	3.4	0.743	0.250	**0.336**
			UP	2.6	0.359	0.125	**0.348**
12.	Petone Victoria Street, PVCS	225.7	Hor1	2.9	1.900	0.500	**0.263**
		M7.53	Hor2	3.5	1.211	0.500	**0.413**
			UP	3.2	0.506	0.200	**0.395**
13.	Petone Municipal Building, PGMS	225.9	Hor1	4.0	1.301	0.500	**0.384**
		M7.82	Hor2	4.2	1.370	0.500	**0.365**
			UP	3.7	0.404	0.200	**0.495**
14.	Whataroa Fire Station, WHFS	227.3	Hor1	4.5	0.136	0.080	**0.588**
		M7.53	Hor2	3.8	0.112	0.060	**0.536**
			UP	4.3	0.066	0.030	**0.455**
15.	Lower Hutt Normandale, LHRS	228.5	Hor1	3.0	0.699	0.125	**0.179**
		M7.82	Hor2	3.9	0.633	0.400	**0.632**
			UP	2.5	0.361	0.125	**0.346**
16.	Lower Hutt Normandale, LHBS	229.1	Hor1	3.3	0.987	0.250	**0.253**
		M7.82	Hor2	3.3	0.637	0.375	**0.589**
			UP	3.6	0.348	0.200	**0.575**
17.	Lower Hutt St Orans College, SOCS	229.7	Hor1	3.9	1.685	0.450	**0.267**
		M7.82	Hor2	4.5	1.252	0.500	**0.400**
			UP	3.4	0.617	0.100	**0.162**
18.	Fairfield, FAIS	230.7	Hor1	3.7	0.827	0.450	**0.544**
		M7.53	Hor2	3.3	0.823	0.400	**0.486**
			UP	3.1	0.349	0.200	**0.573**
19.	Foxton Beach School, FXBS	311.0	Hor1	3.2	0.952	0.600	**0.630**
		M7.82	Hor2	3.2	0.860	0.800	**0.930**
			UP	4.5	0.285	0.400	**1.404**
20.	Paraparaumu Primary School, PAPS	259.4	Hor1	3.6	0.860	0.500	**0.581**
		M7.53	Hor2	4.4	0.915	0.250	**0.273**
			UP	4.1	0.393	0.125	**0.318**
21.	Te Horo House, THOB	274.9	Hor1	4.6	0.939	0.500	**0.532**
		M7.53	Hor2	3.6	1.042	0.800	**0.768**
			UP	4.4	0.257	0.100	**0.389**

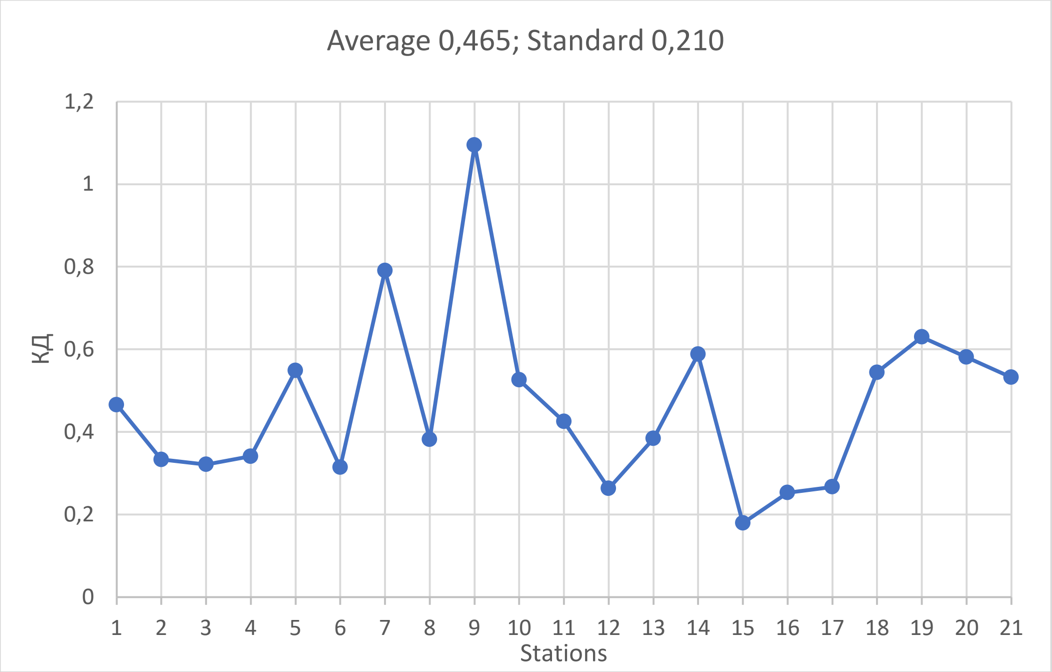


Figure 8. *Dynamic coefficients of the Emberley earthquake when moving propagates in a horizontal direction 1.*

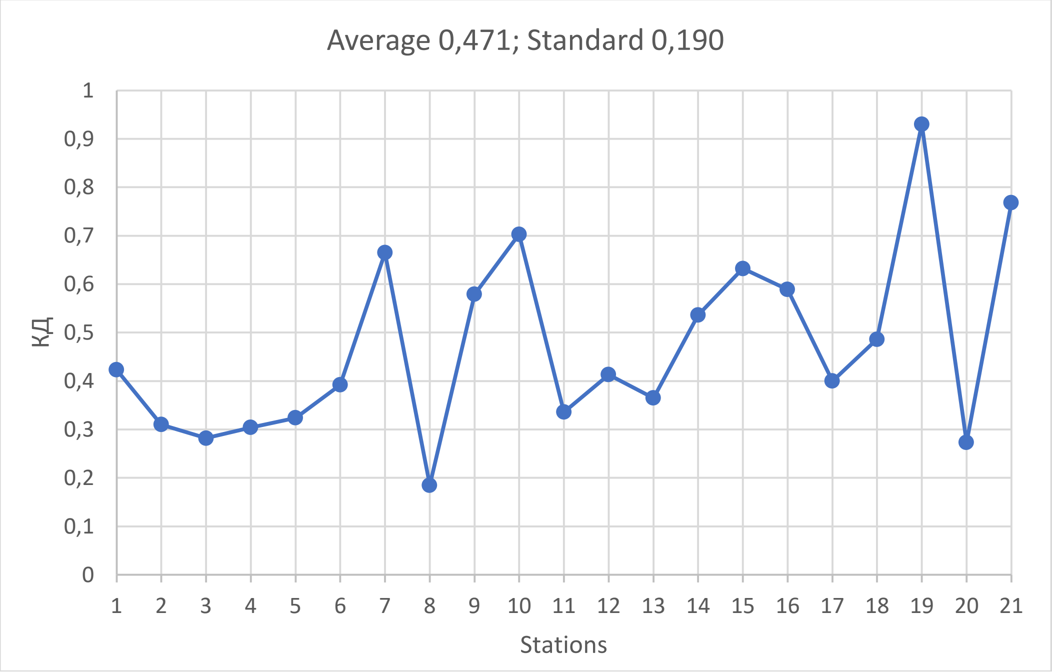


Figure 9. *Dynamic coefficients of the Emberley earthquake when moving propagates in the horizontal direction 2.*

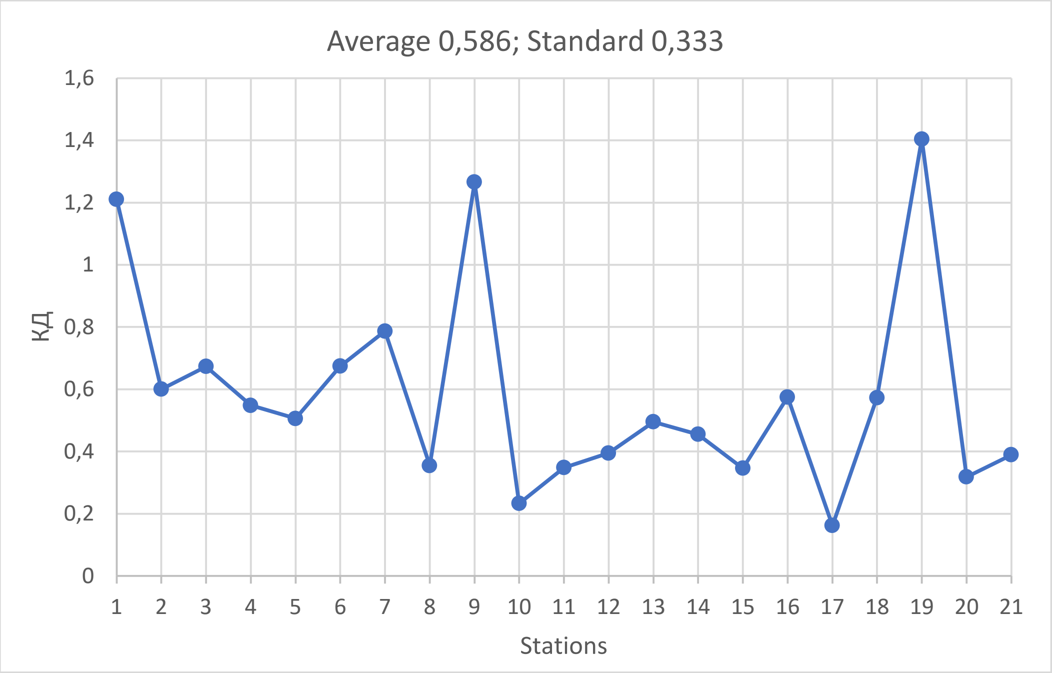


Figure 10. Dynamic coefficients of the Emberley earthquake when moving propagates vertically.

Let us consider the recordings from stations with epicentral distances (these definitions are taken from the initial data) from 200 to 300 km (41 stations in total) to record precisely the long-period seismic movement. Using the records from 41 stations, we have selected only those, the dynamic coefficient for horizontal-motion of which at least for one direction exceeds 0.3 for the period T = 4 s. It is turned out that there are only 21 seismic stations with such recording parameters. Table 2 contains the following data from 21 seismic stations: the name of the seismic station with its code, epicenter distance and magnitude; for each station, the values of maximum dynamic coefficients (Max Spectral Ratio) for two horizontal and vertical directions, peak ground accelerations (PGA), spectral acceleration Sa and dynamic coefficient at T = 4 s, that equals to the ratio of Sa and PGA are presented. The obtained dynamic coefficient values are shown in Figures 8-10, there the average values of dynamic coefficients and it standards are given too.

Analysis of the records of the Emberley earthquake using data from 41 far-zone seismic stations showed that at the half of the all cases, the values of dynamic coefficients of horizontal movement at a period of natural oscillations of structures equal to 4 s exceed 0.3, while the average DC values are about 0.465-0.471 (figures 8, 9), and the maximum values of DC can reach 1 or more. Investigations in the evaluation of dynamic coefficients in the field of high periods should be continued, and the obtained values should be taken into account when developing construction standards governing calculations of high-rise structures for the seismic resistance.

REFERENCES

1. SP 267.1325800.2016. Zdanija i Kompleksy Vysotnye. Pravila Proektirovanija. [High-rise Buildings and Complexes. Design Rules].
2. MGSN 4.19-2005. Vremennye Normy i Pravila Proektirovanija Mnogofunkcional'nyh Vysotnyh Zdanij i Zdanij-Kompleksov v Gorode Moskve [Temporary Design Codes and Rules of Multifunctional High-Rise Buildings and Buildings-

Complexes in the City of Moscow]. Moscow, Moskomarhitektura, 2005, 126 pages.

3. SP 14.13330.2014 SNiP II-7-81* Stroitel'stvo v Sejsmicheskih Rajonah [Construction in Seismic Areas].
4. **Travush V.I., Belostotsky A.M., Vershinin V.V., Ostrovsky K.I., Petryashev N.O., Petryashev S.O.** Chislennoe Modelirovanie Fizicheski Nelinejnoj Dinamicheskoj Reakcii Vysotnyh Zdanij pri Sejsmicheskih Vozdejstvijah Urovnja MRZ [Numerical Simulation of Physically Non-Linear Dynamic Response of High-Rise Buildings Under Maximum Design Earthquake Excitation]. // International Journal for Computational Civil and Structural Engineering, 2016, Volume 12, Issue 1, pp. 117-139.
5. **Lee W.H.K., Kanamori H., Jennings P., Kisslinger C.** International Handbook of Earthquake and Engineering Seismology. Part B. New York – London. Academic Press, New York, London, 2003, 1031 pages.
6. **Çelebi M., Kashima T., Ghahari S. F., Abazarsa F., Taciroglu E.** Responses of a Tall Building with US Code-Type Instrumentation in Tokyo, Japan – to Events Before, During and After the Tohoku Earthquake of March 11, 2011. // Earthquake Spectra, Volume 32, Issue 1, pp. 497-522.
7. **Morita K., Kashima T.** Dynamic Properties Change of Soil – Structure Interaction of SRC Building Before and After the 2011 off the Pacific Coast of Tohoku Earthquake. // Second European Conference on Earthquake Engineering and Seismology. Istanbul, Aug.25-29, 2014.
8. Perspectives on European Earthquake Engineering and Seismology. Volume 2. Second European Conference on Earthquake Engineering and Seismology (2ECEES), Istanbul, Turkey, 2014. Springer Open. 2015.
9. **Nazarov Yu.P.** Analiticheskie Osnovy Rascheta Sooruzhenij na Sejsmicheskie Vozdejstvija [Analytical Foundations of Seismic Analysis]. Moscow, Nauka, 2010, 468 pages.
10. **Nazarov Yu.P.** Raschetnye Modeli Sejsmicheskih Vozdejstvij [Computational Models of Seismic Effects]. Moscow, Nauka, 2012, 414 pages.
11. **Nazarov Yu.P., Pozniak E.V.** Opredelenie Kojefficienta Dinamichnosti v Raschetah na Sejsmostojkost [Determination of Dynamic Coefficient in Seismic Analysis]. // Stroitelstvo: Nauka i Obrazovanie, 2015, No. 1.

СПИСОК ЛИТЕРАТУРЫ

1. СП 267.1325800.2016. Здания и комплексы высотные. Правила проектирования.
2. МГСН 4.19-2005. Временные нормы и правила проектирования многофункциональных высотных зданий и зданий-комплексов в городе Москве. – М.: Москомархитектура, 2005. – 126 с.
3. СП 14.13330.2014 "СНиП II-7-81* Строительство в сейсмических районах.
4. **Травуш В.И., Белостоцкий А.М., Вершинин В.В., Островский К.И., Петряшев Н.О., Петряшев С.О.** Численное моделирование физически нелинейной динамической реакции высотных зданий при сейсмических воздействиях уровня МРЗ. // International Journal for Computational Civil and Structural Engineering, 2016, Volume 12, Issue 1, pp. 117-139.
5. **Lee W.H.K., Kanamori H., Jennings P., Kisslinger C.** International Handbook of Earthquake and Engineering Seismology. Part B. New York – London. Academic Press, New York, London, 2003, 1031 pages.
6. **Çelebi M., Kashima T., Ghahari S. F., Abazarsa F., Taciroglu E.** Responses of a Tall Building with US Code-Type Instrumentation in Tokyo, Japan – to Events Before, During and After the Tohoku Earthquake of March 11, 2011. // Earthquake Spectra, Volume 32, Issue 1, pp. 497-522.
7. **Morita K., Kashima T.** Dynamic Properties Change of Soil – Structure Interaction

of SRC Building Before and After the 2011 off the Pacific Coast of Tohoku Earthquake. // Second European Conference on Earthquake Engineering and Seismology. Istanbul, Aug.25-29, 2014.

8. Perspectives on European Earthquake Engineering and Seismology. Volume 2. Second European Conference on Earthquake Engineering and Seismology (2ECEES), Istanbul, Turkey, 2014. Springer Open. 2015.
9. **Назаров Ю.П.** Аналитические основы расчета сооружений на сейсмические воздействия. – М.: Наука, 2010. – 468 с.
10. **Назаров Ю.П.** Расчетные модели сейсмических воздействий. – М.: Наука, 2012. – 414 с.
11. **Назаров Ю.П., Позняк Е.В.** Определение коэффициента динамичности в расчетах на сейсмостойкость. // Строительство: наука и образование, 2015, №1.

Yuriy P. Nazarov, Advisor of the Russian Academy of Architecture and Construction Sciences, Professor, Dr.Sc., Director of Eurosoft; Joint Stock Company – Research Center of Construction; 61, Rjasansky pr., Moscow, 109428, Russia (in building of The State Research Institute for Buildilng and Structures named after V.A. Kucherenko (TSNIISK), 4-th floor); phones: +7 (499) 170-10-80,
170-10-84, 174-79-91, 174-79-98;
E-mail: info@eurosoft.ru.

Vladimir I. Travush, Full Member of the Russian Academy of Architecture and Construction Sciences, Professor, Dr.Sc., Vice-President of the Russian Academy of Architecture and Construction Sciences; Vice-Director of City Design Institute for Residential and Public Buildings; building 5A, 5, Nizhny Susalny pereulok, Moscow, 105064, Russia; phone/fax: +7 (495) 775-75-65,
+7 (495) 909-39-39; e-mail: travush@mail.ru.

Назаров Юрий Павлович, советник РААСН, доктор технических наук, профессор; директор ООО «Еврософт»; Акционерное общество «Научно-исследовательский центр «Строительство»; 109428, Россия, Москва, Рязанский пр-т, дом 61, стр. 1, 4-й этаж (здание ЦНИИСК им. В.А. Кучеренко); тел. +7(499)418-01-52, 170-10-80, 170-10-84, 174-79-91;
E-mail: info@eurosoft.ru.

Травуш Владимир Ильич, академик РААСН, доктор технических наук, профессор; вице-президент Российской академии архитектуры и строительных наук; заместитель генерального директора ЗАО «ГОРПРОЕКТ»; 105064, Россия, г. Москва, Нижний Сусальный переулок, д.5, стр. 5А; тел./факс: +7 (495) 775-75-65, 909-39-39; e-mail: travush@mail.ru