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Issue **Article**

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ON THE DETERMINATION OF ELASTIC RESPONSE SPECTRUM FOR COMPOSITE STEEL AND CONCRETE CONTINUOUS SPAN SUPERSTRUCTURE WITH A SCHEME L=42.0+63.0+42.0m

***Abstract**: The article discusses the determination of the elastic response spectrum for composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m. Real earthquake records were selected according to their own oscillation periods for composite steel and concrete continuous span superstructure. Also, according to the spectra given in various normative documents (in GEO, SNiP, EN and AASHTO), the calculation of the selected steel structure was made and the values of the maximum forces of the superstructure were determined.On the basis of the results obtained for composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m, the graphs were taken and analyzed, based on which the recommendation provisions for the national annex of the normative document of EN were determined.*

***Key words**: Composite steel and concrete continuous span superstructure, Earthquake accelerogram, The period of own oscillation of superstructure, Elastic response spectrum.*

***Language**: English*

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Introduction

On the basis of the spectral theory of seismic resistance, the determination of the dynamic response spectra is processed in all normative documents, which is based on the results obtained by the calculations of the vertical single-mass cantilever system and does not take into account the very diverse calculation schemes of different constructions. Despite the bridges and all other structures of any system, as well as the system, the stiffness and mass

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difference curves are always unchanged and universal, which in our opinion is a very big assumption and is far from reality.

In 2012, New York University professors published an article focusing on the importance of properly selecting a seismic vertical detector for superstructure [9].

In 2018, Iowa State University professors published an extensive paper where they pointed out that the vertical component of the three components of an earthquake is partially ignored by the use of mitigation coefficients in the regulations and ultimate results are inconsistent with reality [10].

Therefore, in our opinion, it is necessary to determine the elastic response spectra for composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m.

Main part

Composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m (typical constructions, series 3.503.9-110.93) consists of two main beams, longitudinal and transverse connections. Reinforced concrete slab is used in the roadway part, which is connected to the main coils with beams. The gauge of the superstructure is Г=11.5 m, of which the width of the lane of the carriageway is 7.5 m, and the width of the safety lanes is 2.0 m, and the width of the sidewalks is 1.50 m, and therefore the total width of the cross section of the superstructure is 15.90 m. The thicknesses of the lower and upper belt of the main beam are different in different cross-sections and, accordingly, the stiffnesses are also different (Fig. 1).

For the composite steel and concrete continuous span superstructure, the self-oscillation frequencies and periods for the first three forms of oscillation were determined (Table 1), for which the calculation complex MIDAS Civil 2022 was used, processed on the basis of the finite element method.

After determining the self-oscillation periods and frequencies of composite steel and concrete continuous span superstructure, seven accelerograms were selected from the database of accelerograms for each soil category, the dominant periods of which are close to the own (harmonic) oscillation periods of the superstructure under consideration [12].

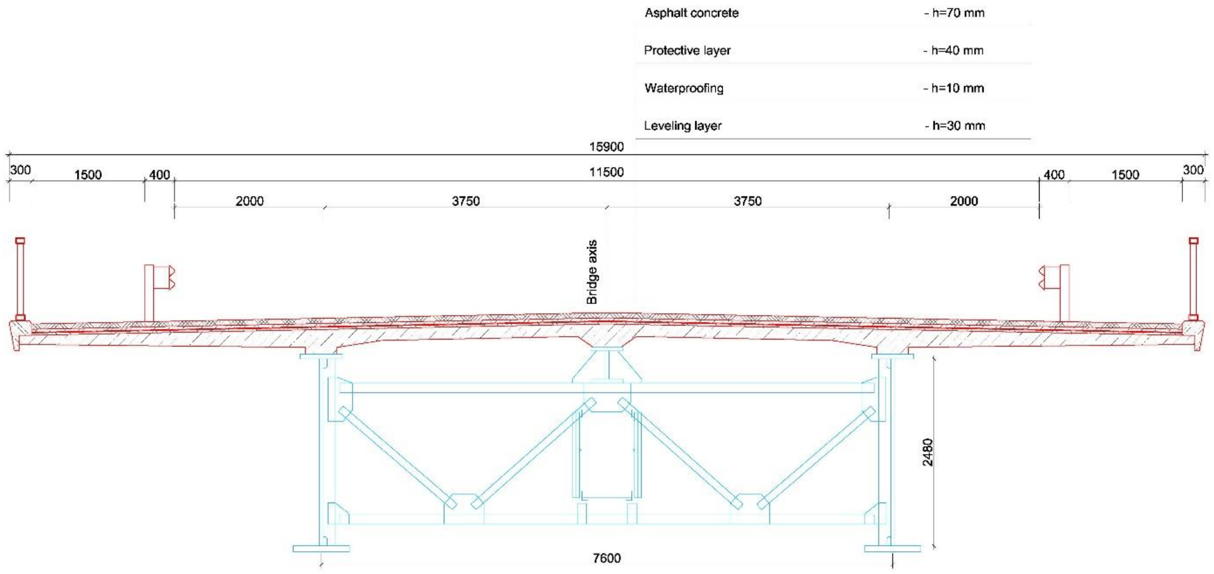


Fig. 1. Cross-section of composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m

Table 1

L=42.0+63.0+42.0 m			
Oscillation form	Circular frequency rad/s	Frequency 1/s	Period s
1	*2*	*3*	*4*
1	5.978	0.951	1.051
2	13.154	2.093	0.478
3	26.589	4.232	0.236

Earthquake peak accelerations have different magnitudes in mutually orthogonal directions. Since the vertical register is especially dangerous for the superstructure, therefore, such records of vertical oscillation were selected, the oscillation period of which is as close as possible to the oscillation periods of the structure.

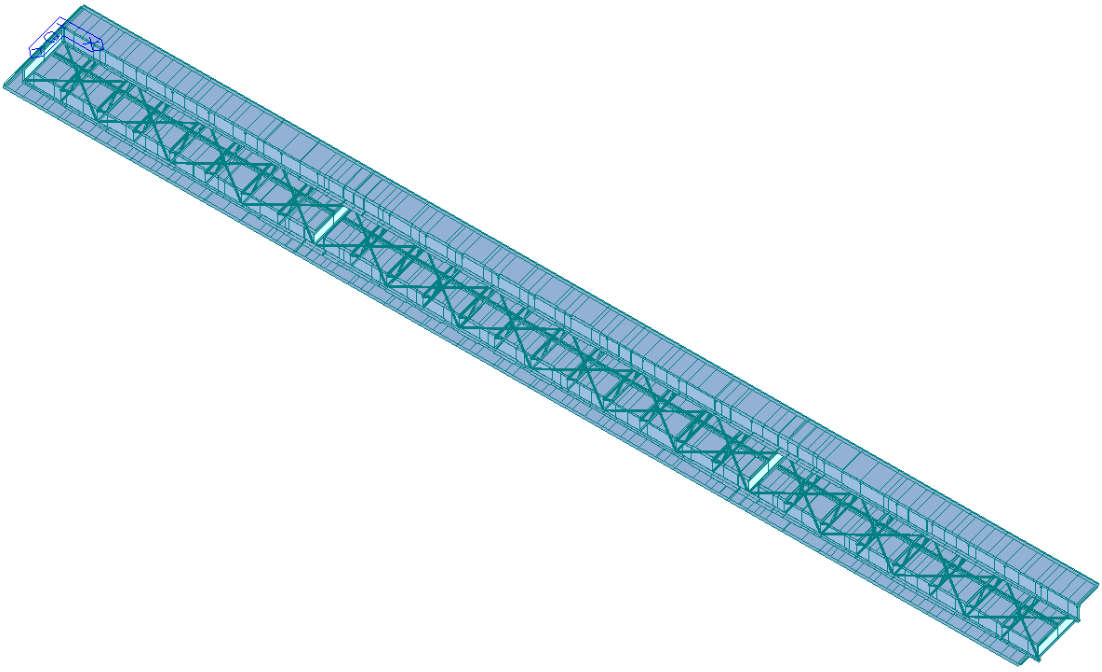
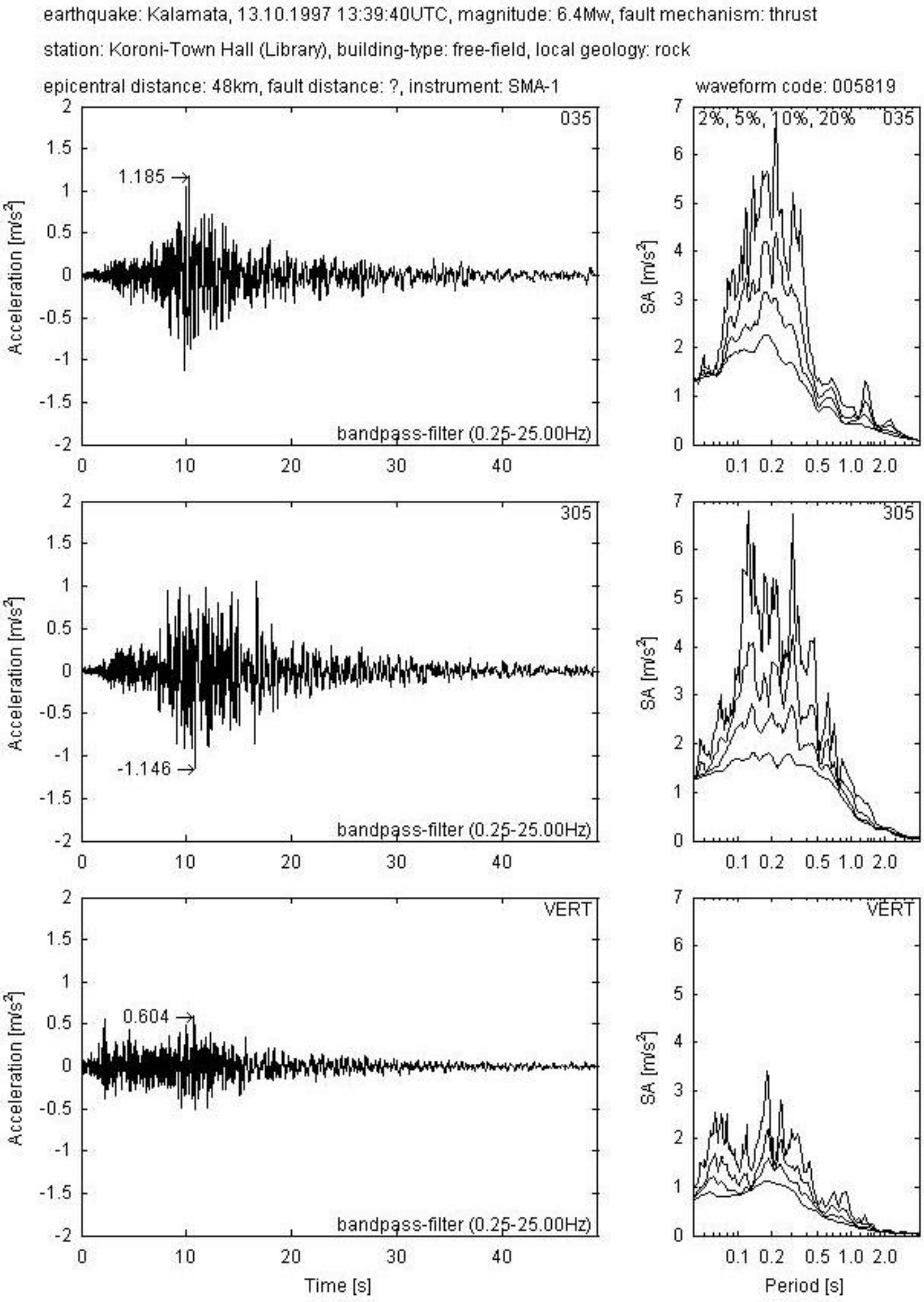


Fig. 2. The reference model of the composite steel and concrete superstructure of the scheme L=42.0+63.0+42.0 m

For this purpose, various accelerograms (classified by seismicity for different ground categories) were selected from the accelerogram data bank, whose main phases were decomposed into harmonics (based on the Fourier series). Harmonics allowed us to select the required accelerogram.

The calculation model of the composite steel and concrete continuous span superstructure was processed (Fig. 2) in complex calculation program MIDAS Civil. The accelerations of the composite steel and concrete continuous span superstructure were determined by using the direct dynamic method. The acceleration spectra were calculated based on the program SeismoSignal 2023. To determine the acceleration spectrum, the real record of the three-component Kalamata earthquake - accelerogram (Fig. 3) was used. The vertical component of accelerogram was separated (Fig. 4) and normalized (the ordinates were divided by the maximum ordinate) in order to exclude the magnitude factor (the selected accelerograms have different magnitudes) (Fig. 5).



earthquake: Kalamata, 13.10.1997 13:39:40UTC, magnitude: 6.4Mw, fault mechanism: thrust
station: Koroni-Town Hall (Library), building-type: free-field, local geology: rock
epicentral distance: 48km, fault distance: ?, instrument: SMA-1
waveform code: 005819

Margaris, B.(2001)

Fig. 3. Kalamata earthquake record (code: 005819)

As a result of analyzing vertical normalized accelerograms subjected to the 1997 Kalamata 6.4 magnitude earthquake (one of the seven accelerograms selected as an example for visualizing the task) of the composite steel and concrete continuous span superstructure, accelerations were obtained. The results were compared to the normalized accelerations and determined how many times they were increased in the case of the real structure (Fig. 6).

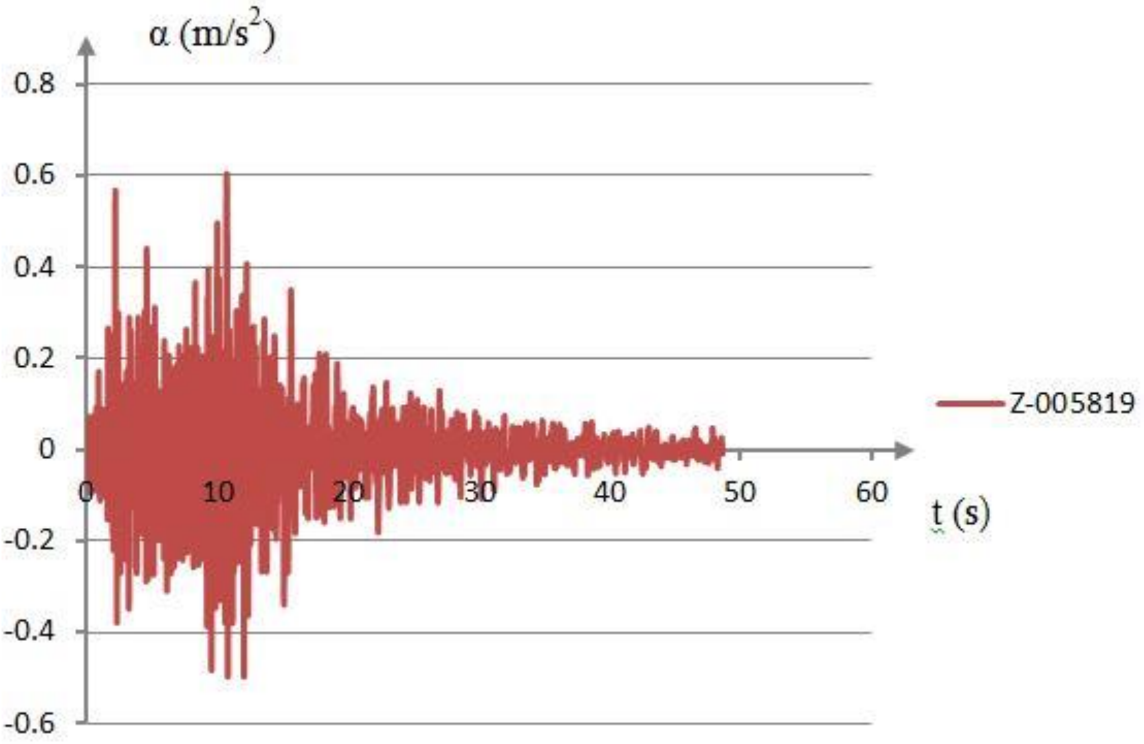


Fig. 4. Vertical accelerogram of the Kalamata earthquake (code: 005819)

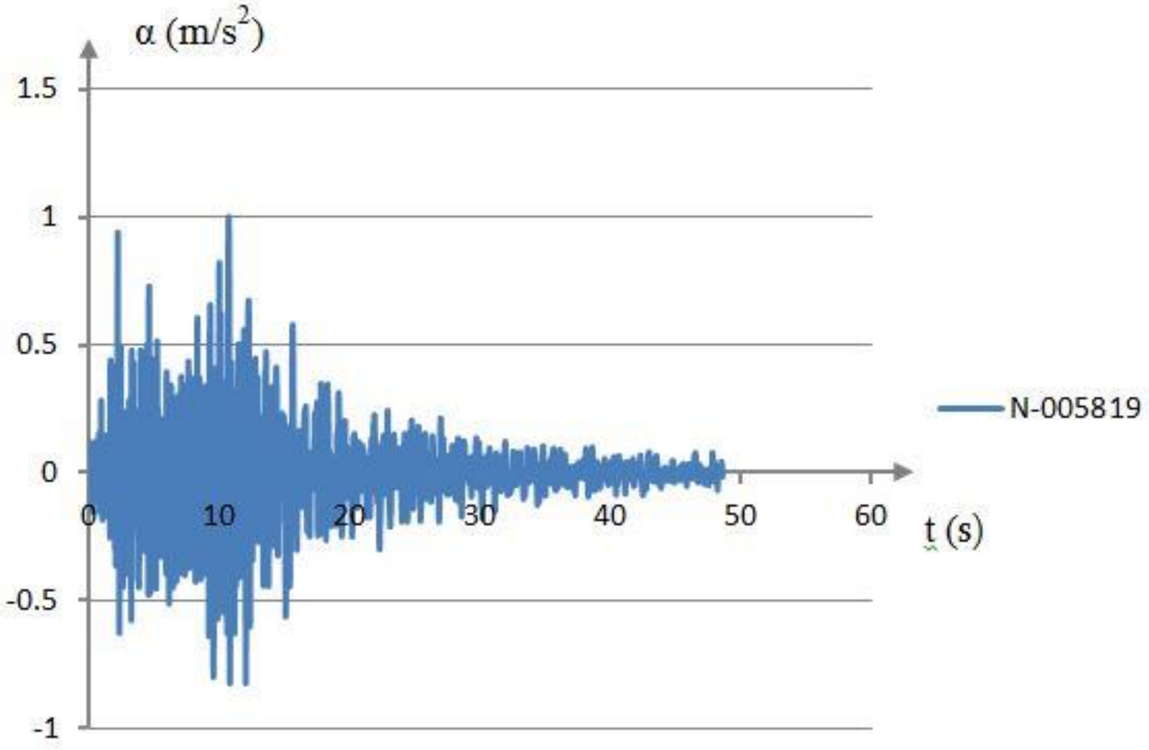


Fig. 5. Vertical normalized accelerogram of Kalamata earthquake (code: 005819)

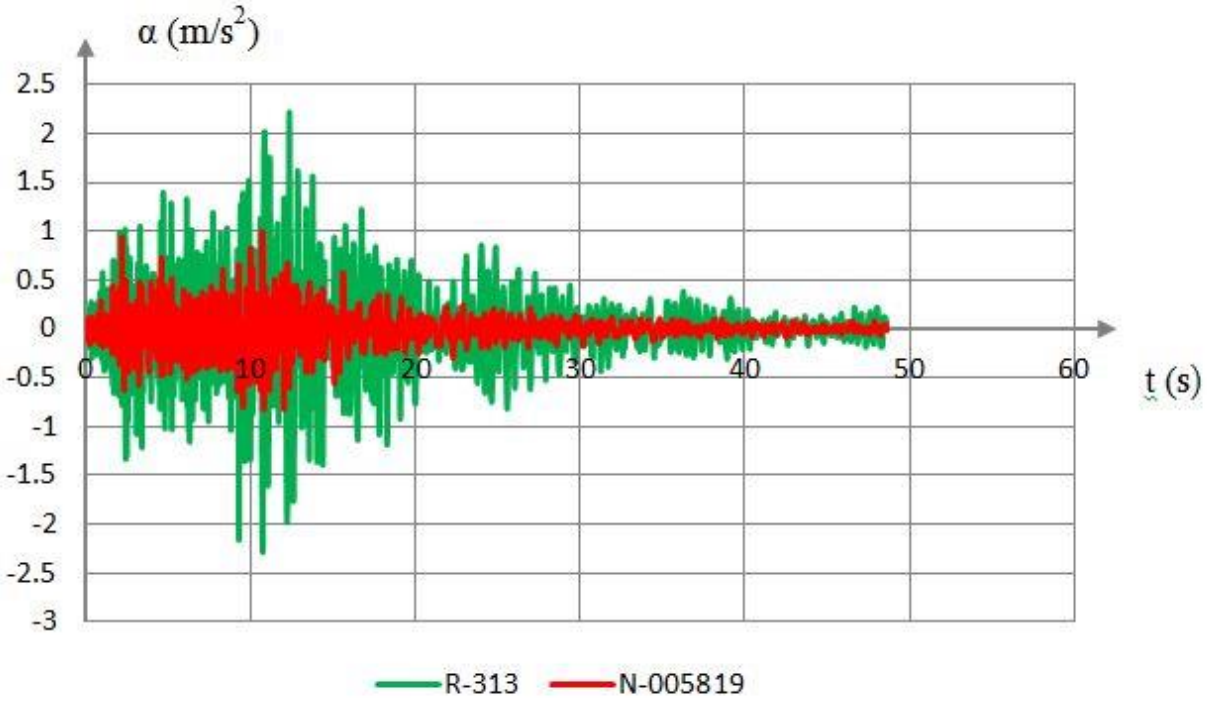


Fig. 6. Vertical normalized accelerogram (code: 005819) and the response of the composite steel and concrete superstructure with a scheme L=42.0+63.0+42.0m (in the form of accelerations) under the impact of the Kalamata earthquake

For this specific case, the maximum acceleration of the response of the superstructure was 2.29 m/s^2. Their spectra were constructed accordingly and are presented in fig. at 7.

The same approach was applied to the rest of the selected accelerograms, which allowed us to work out the acceleration spectra (Fig. 8).

Spectra of accelerations (using all seven accelerograms) for soils of category I in terms of seismicity are given in fig. 8, which includes the spectra provided by normative documentation (GEO [1,11], SNiP[2,3,4], EN[5,6] and AASHTO[7, 8]).

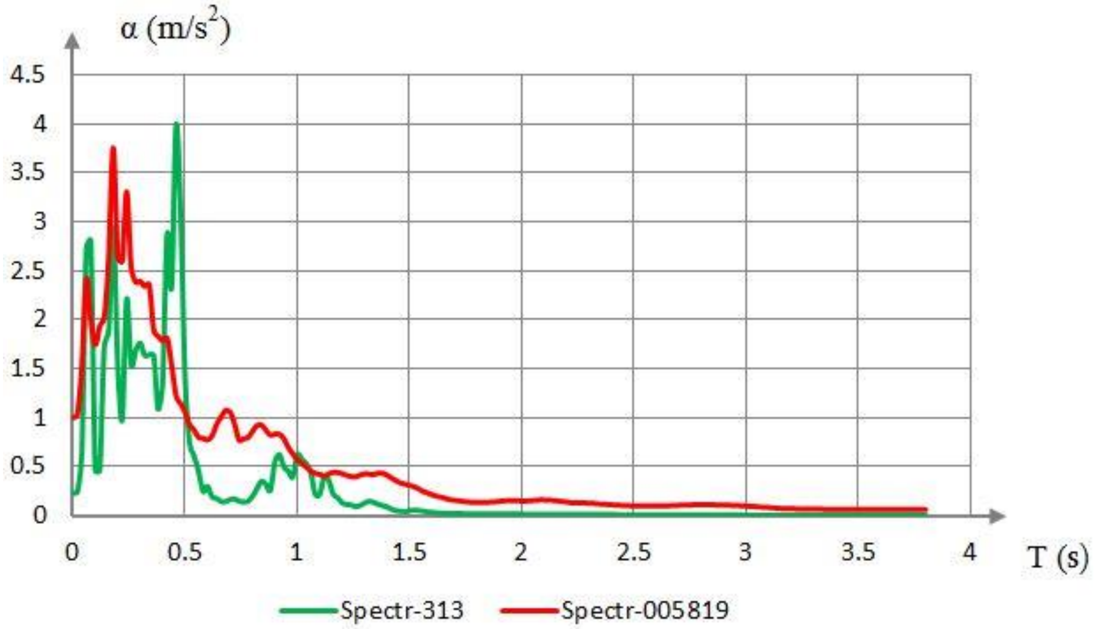


Fig. 7. The vertical normalized spectrum of the Kalamata earthquake (code: 005819) and the response spectrum of the superstructure with a scheme L=42.0+63.0+42.0 m

The same approach was implemented for category II and III soils during the construction of composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m. Seven accelerograms were selected and the spectra of accelerations were obtained as results of their impact. They are shown along with the spectra provided by different normative documents (GEO [1,11], SNiP[2, 3, 4], EN[5, 6] and AASHTO[7, 8]) in fig. 9 and fig. at 10.

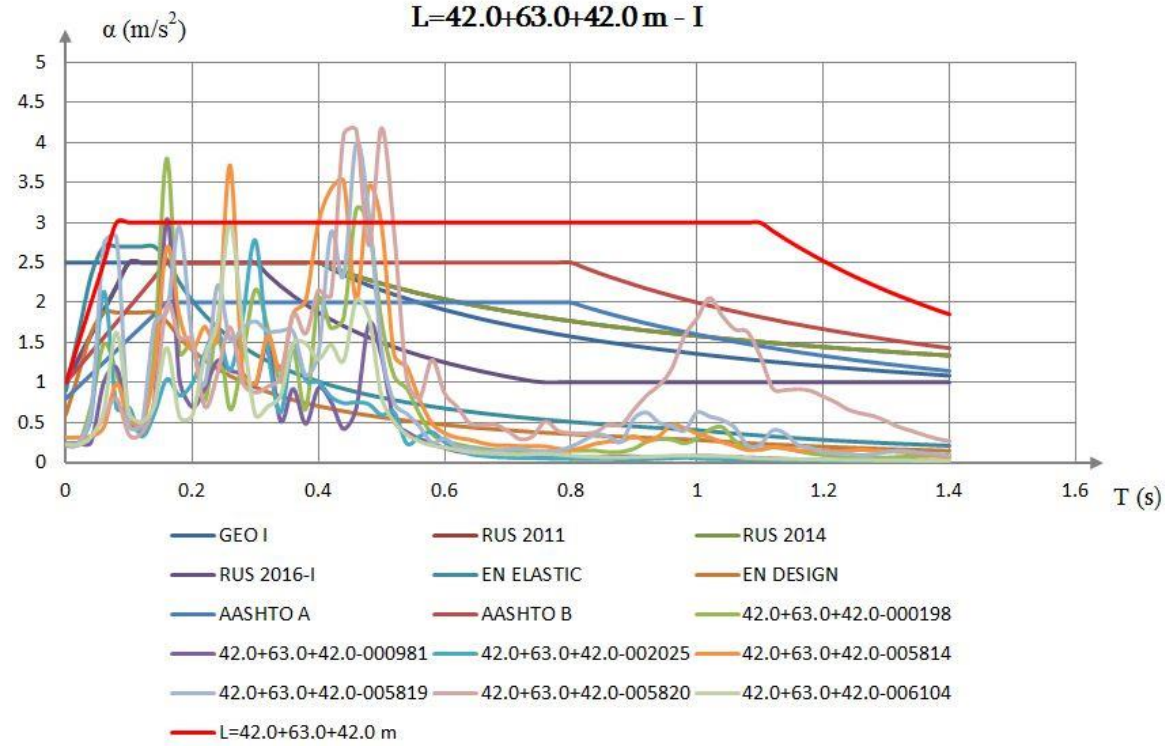


Fig. 8. Response spectra of the superstructure with a scheme L=42.0+63.0+42.0 m for soils of category I

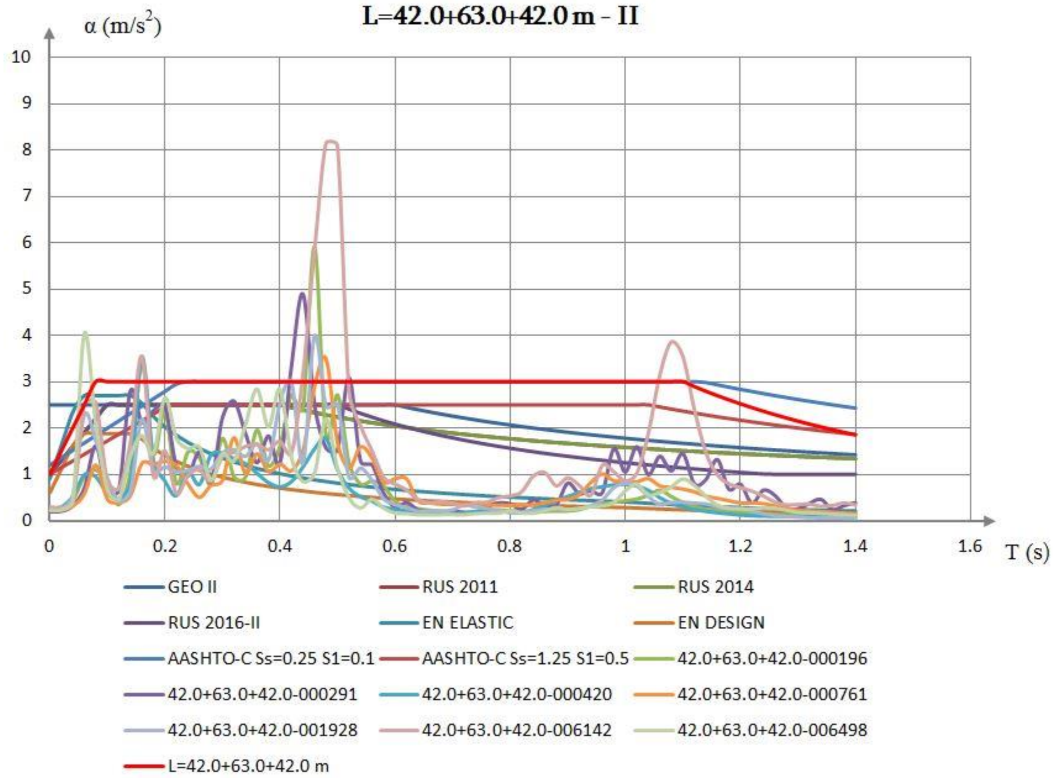


Fig. 9. Response spectra of the superstructure with a scheme L=42.0+63.0+42.0 m for soils of category II

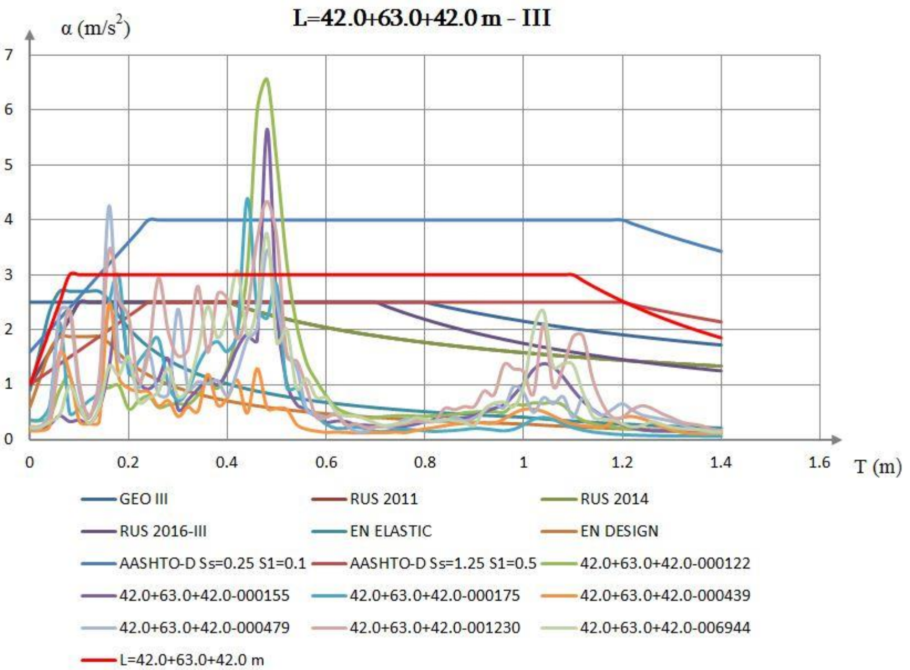


Fig. 10. Response spectra of the superstructure with scheme L=42.0+63.0+42.0 m for soils of category III

The calculation of the selected superstructure was carried out with the spectra obtained by us for the soils of different categories, as well as with the methodology provided by different normative documents (GEO [1,11], SNiP[2,3,4], EN[5,6] and AASHTO[7,8])).

For the composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m calculations were made for all three soil categories at different levels. The results of seismic forces are presented in Table 2.

Table 2

L=42.0+63.0+42.0 m composite steel and concrete continuous span superstructure								
№	Name	Static	7 Intensity		8 Intensity		9 Intensity	
		M,t*m	M, t*m	%	M, t*mm	%	M, t*m	%
1	L=42.0+63.0+42.0	**1488.79**	188.39	12.7	376.77	25.3	753.54	50.6
2	GEO-I		53.23	3.6	127.75	8.6	276.79	18.6
3	GEO-II		63.71	4.3	127.43	8.6	254.85	17.1
4	GEO-III		70.31	4.7	112.5	7.6	210.94	14.2
5	RUS-2011		57.87	3.9	115.75	7.8	231.49	15.5
6	RUS-2014		61.18	4.1	122.36	8.2	244.72	16.4
7	RUS-2016-I		55.93	3.8	111.85	7.5	223.71	15.0
8	RUS-2016-II		78.39	5.3	156.79	10.5	313.57	21.1
9	RUS-2016-III		88.87	6.0	177.74	11.9	355.49	23.9
10	EN ELASTIC		167.23	11.2	334.47	22.5	668.93	44.9
11	EN DESIGN		92.91	6.2	185.82	12.5	371.63	25.0
12	AASHTO-A		210.8	14.2	421.61	28.3	843.22	56.6

13	AASHTO-B		263.51	17.7	527.01	35.4	1054.02	70.8
14	AASHTO-C		395.16	26.5	774.34	52.0	1311.8	88.1
15	AASHTO-D		537.96	36.1	924.78	62.1	1462.64	98.2

The graph presented in Fig. at 11 was developed to visualize the results calculated on the basis of various normative documents (GEO, SNiP, EN and AASHTO), as well as the spectra obtained by us.

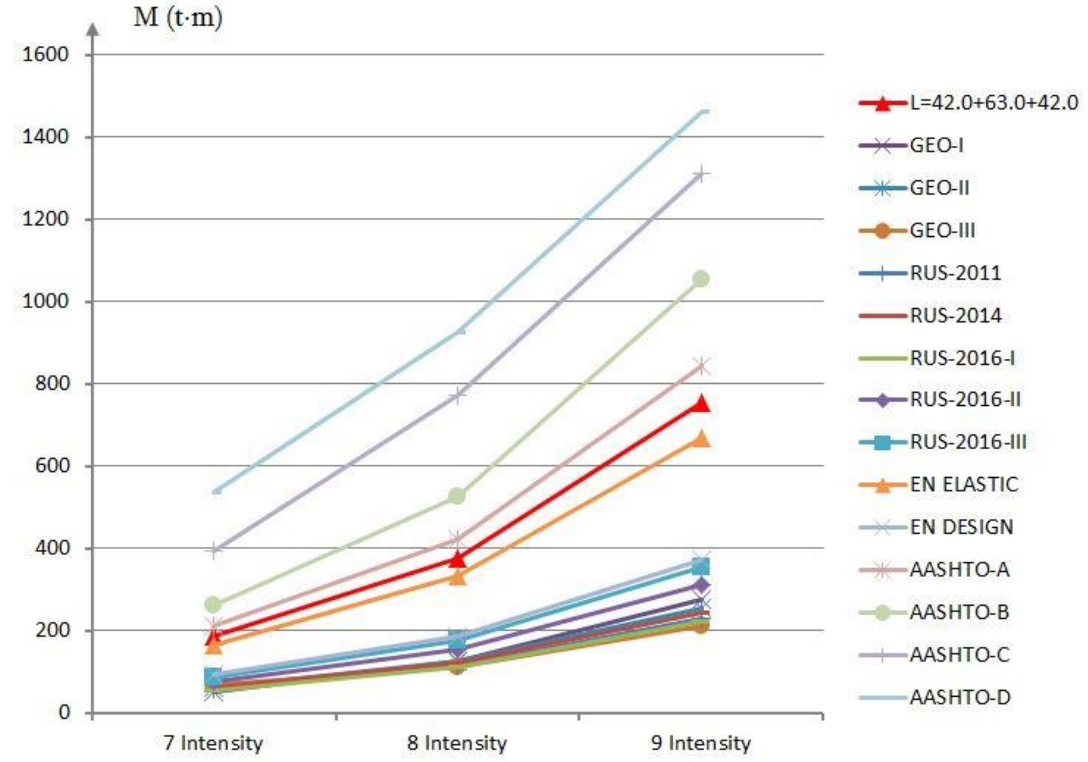


Fig. 11. According to various normative documents and new spectra, the values of the forces of the superstructure with a scheme L=42.0+63.0+42.0 m

Studies have shown that taking into account the first three periods of self-oscillation of the composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m the magnitudes of the forces determined by the spectrum of the response obtained on the basis of the selected accelerograms are significantly higher than the forces obtained by the spectra given in the normative documents of GEO and SNiP. The results also exceed those given in the normative documentation of EN the magnitude of the force received by the spectrum.

CONCLUSION

1. The spectra obtained by the impact of accelerograms on the composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m give much more force values than the spectra obtained without taking into account their own oscillation periods.
2. Like the EN normative document, we use one vertical response spectrum for all soil categories.
3. Various normative documents (GEO, SNiP and AASHTO) consider the coefficients of the soil category, while EN neglacts the soil coefficients. This circumstance must be taken into consideration while developing the national annex of this norm.
4. Studies have shown that it is necessary to use wide-area spectra for the long-period composite steel and concrete continuous span superstructure with a scheme L=42.0+63.0+42.0 m.

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