doi: 10.18720/MCE.76.9

Seismic input models for tuned mass damper designing

Расчетное сейсмическое воздействие для сооружения с динамическим гасителем колебаний

Y.U. Albert,
JSC "VNIIG im.B.E.Vedeneeva", Saint Petersburg, Russia
A.A. Dolgaya ,
JSC "Transmost", St. Petersburg, Russia
T.V. Ivanova,
JSC "VNIIG im.B.E.Vedeneeva", Saint Petersburg, Russia
O.P. Nesterova,
A.M. Uzdin,
Petersburg State Transport University, St. Petersburg, Russia
J. Guan,
China University of Petroleum, Huadong, China
D.A. Ivashintzov,
O.K. Voronkov,
V.B. Shtilman,
S.G. Shulman,
A.A. Khrapkov,
JSC "VNIIG im.B.E.Vedeneeva", Saint Petersburg, Russia

Д-р техн. наук, ст. науч. сотрудник И.У. Альберт,
АО "ВНИИГ им. Б.Е. Веденеева", г. Санкт-Петербург, Россия
канд. техн. наук, инженер А.А. Долгая,
ОАО «Трансмост», г. Санкт-Петербург, Россия
канд. техн. наук, ученый секретарь Т.В. Иванова,
АО "ВНИИГ им. Б.Е. Веденеева", г. Санкт-Петербург, Россия
аспирант О.П. Нестерова,
д-р техн. наук, профессор А.М. Уздин,
Петербургский государственный университет путей сообщения Императора Александра I, г. Санкт-Петербург, Россия
PhD Ю. Гуань,
Нефтяной Университет Китая, Циндао, КНР
д-р техн. наук, профессор, гл. науч. сотрудник-консультант Д.А. Ивашинцов,
д-р техн. наук, гл. науч. сотрудник-консультант О.К. Воронков,
д-р техн. наук, ст. науч. сотрудник В.Б. Штильман,
д-р техн. наук, профессор, гл. науч. сотрудник С.Г. Шульман,
д-р техн. наук, профессор, гл. науч. сотрудник А.А. Храпков,
АО "ВНИИГ им. Б.Е. Веденеева", г. Санкт-Петербург, Россия

Key words: tuned mass damper; seismic input; mathematical modeling

Ключевые слова: динамический гаситель колебаний; сейсмическое воздействие; математическое моделирование

Abstract. The subject of investigations is seismic input models for tuned mass damper designing. Some features of simulating design accelerograms for estimating seismic stability of a structure with a mass damper are considered. The method of accelerogram modeling, proposed by Dolgaya A.A., approved by the Building Ministry of Russian Federation and included and in the corresponding Recommendations in 1996, is considered as the basic one. In accordance with this method, an accelerogram is modeled by a sum of three damped sinusoids. The sinusoid frequencies are chosen as dangerous for the structure, and the amplitudes and damping parameters are chosen so that the kinematic and energy characteristics of the model input correspond to the actual ones. The main feature of MD designing is the presence of close frequencies, and the choice of a dangerous frequency is not unambiguous. Features of choosing a dangerous frequency and the influence of various characteristics of real accelerograms on the generated synthetic accelerogram are considered.

Альберт И.У., Долгая А.А., Иванова Т.В., Нестерова О.П., Уздин А.М., Гуань Ю., Ивашинцов Д.А., Воронков О.К., Штильман В.Б., Шульман С.Г., Храпков А.А. Расчетное сейсмическое воздействие для сооружения с динамическим гасителем колебаний // Инженерно-строительный журнал. 2017. № 8(76). С. 98–105.

Аннотация. Рассматриваются особенности моделирования расчетных акселерограмм для оценки сейсмостойкости сооружения с динамическим гасителем колебаний. В качестве базового рассмотрен метод А.А.Долгой, вошедший в Рекомендации Госстроя РСФСР, утвержденные в 1996 году. В соответствии с этим методом акселерограмма моделируется набором из трех затухающих синусоид. Частоты синусоид подбираются опасными для сооружения, а амплитуды и показатели затухания выбираются так, чтобы кинематические и энергетические характеристики модельного воздействия соответствовали натурным. Основной особенностью конструкций с ДГК является наличие близких частот, и выбор опасной частоты не является однозначным. Рассматриваются особенности выбора опасной частоты и влияние различных характеристик воздействия на вид синтетической акселерограммы.

Introduction

Tuned mass dampers (MD) were proposed by H. Fram in 1911 [1, 2]. In the years that followed, many well-known specialists were engaged in optimizing the MD tuning and damping [3–5]. The summing up of studies on the MD problems is given in a well-known monograph by B.G. Korenev and L.M. Reznikov [6]. Since the end of the 70-s of the last century proposals to use the MD for seismic protection of buildings and structures have been made [7–11]. In the recent 20 years the MD began to be widely used for structure protection, i.e. for high-rises building protection against winds and earthquakes in Taipei, Shanghai and other countries [13, 14]. At present, the MD are produced by leading firms in the field of vibration protection such as Maurer Söhnes, FIP Industrial and others. Not long ago investigations on applying the MD in designing non-symmetrical buildings of complicated configuration [15, 16] as well as for non-linear systems [17] and bridges [18] are begun. In order to increase the MD efficiency for seismic protection of structures, it was proposed to use the MD of large mass with a part of the structure itself, being used in the MD [6, 7]. In particular, in [7], it was discovered that there exists the critical mass of the MD, above which the dynamic damping effect disappears, and the MD turns into Lanchester damper. The description of the MD for seismic protection of structures is included in textbooks and teaching aids, as well as in the Guidlines [20, 21]. In the presence of a large number of studies and the apparent simplicity of the problem, attempts to use the MD still bring surprises for scientists. For example, in 2016-17 the essential dependence of the MD tuning, damping and the critical mass on damping in the structure was found [12]. Foreign specialists also found the necessity of taking into account damping in the construction [23, 24]. However, analyzing systems with heterogeneous damping faced with certain difficulties. The normative version of the response spectra method (RSM) cannot be used for inhomogeneous damping. A complete version of the RSM of damped systems was proposed in [15, 25], but has not been used in designing practice yet. The main method of assessing seismic resistance of heavily damped systems remains time-history calculation using accelerograms of earthquakes. Such calculations give designers some freedom, which can result in completely different estimates of seismic resistance. One can see this sort of results in paper [19]. In the authors' opinion, the main problem here is to set seismic input.

The study aim is founding seismic input features for estimating the seismic stability of structures with the MD, in order to exclude errors and ambiguous results of such assessment.

Two approaches to generating design accelerograms have been developed in the earthquake engineering practice. These approaches are described in detail in scientific [16] and educational [8] literature. The first approach is generating design accelerograms for the building site. It can be used when reliable seismological information is available and if the authors of the design accelerograms are ready to bear financial and legal responsibility for them, which is possible when designing highly responsible structures. For mass and especially typical designing it is necessary to use the second method of generating accelerograms, i.e. generating accelerograms for the structure. In this case, the input spectral composition is chosen as dangerous for the structure, and the generated process parameters are chosen so that the characteristics of the model input correspond to the actual ones. In its turn, generating accelerograms for a structure includes 5 methods as follows:

1. Using a package of accelerograms of past earthquakes
2. Choosing a set of narrowband processes
3. Setting a single broadband process
4. Generating a process with a spectrum that coincides with the normative response spectrum
5. Generating a narrowband process dangerous for the structure

Albert Y.U., Dolgaya A.A. Ivanova T.V., Nesterova O.P., Uzdin A.M., Guan J., Ivashintzov D.A., Voronkov O.K., Shtilman S.G., Shulman V.B., Khrapkov A.A, Seismic input models for tuned mass damper designing. *Magazine of Civil Engineering*. 2017. No. 8. Pp. 98–105. doi: 10.18720/MCE.76.9.

These methods are considered in detail in [17]. We only note that the use of this or that technique is always a trade-off between ensuring the danger of the design input for the structure and the similarity of the input to real accelerograms. Thus, for the oscillator, the input in the form of a rectangular sine with the natural oscillator frequency is the most dangerous. For the structure it is possible to set the input in the form of successive harmonics so that each oscillation mode of the structure passes through resonance. Such inputs are dangerous for the construction, but are not like real accelerograms at all. If deliberately dangerous input led to acceptable technical solutions, their further specification and approximation to the real ones would not be necessary. However, as a rule, this does not occur, and the task of specifying the design input is rather urgent. Below, the authors consider setting the abovementioned narrow-band process to be dangerous for the building in calculating structures with the tuned mass damper (MD).

Materials and methods of research

At the description statement of input model a multiparameter narrow-band process can be defined in various ways [18–20]. Below, the model proposed in [18] is considered, but the conclusions obtained on its basis are valid for other models of this type. In accordance with [18], the velosigram of the model input is presented as the sum of three damped sinusoids

$$\dot{y}(t) = \sum_{i=1}^{3} A_i e^{-\varepsilon_i t} \cdot \sin \omega_i t \qquad (1)$$

In the process under consideration frequencies ω_i are chosen as dangerous (resonant) for the structure. The amplitude A_2 is determined by the condition $\dot{y}(t) = 0$. The rest 5 parameters A_1, A_3, ε_1, ε_2, ε_3 are set so that the characteristics of the model process correspond to the field data. In [19] peak ground accelerations (PGA), depending on the frequency of oscillations, and Arias intensity I_A were accepted as the input characteristics. Recent studies make it possible to take into account a wider range of seismic input characteristics. The analysis of these characteristics is given in [21]. When generating the impact, the authors took into account 5 characteristics of real accelerograms.

1. Peak ground acceleration, $\ddot{y}_0^{(\max)}$, PGA.

2. Coefficient of process harmonicity κ,

$$\kappa = \frac{\ddot{y}_0^{(\max)} \cdot y_0^{(\max)}}{\left(\dot{y}_0^{(\max)}\right)^2} \qquad (2)$$

where $y_0^{(\max)}$ is the maximum displacement of the base, and $\dot{y}_0^{(\max)}$ is the maximum velocity of the base.

3. Arias intensity I_A

$$I_A = \frac{\pi}{2g}\int_0^T \ddot{y}_0^2 dt. \qquad (3)$$

4. Absolute cumulative velocity CAV

$$CAV = \int_0^T \left|\ddot{y}_0\right| dt \qquad (4)$$

5. Seismic energy density SED

$$SED = \int_0^T \dot{y}_0^2 dt \qquad (5)$$

The first two characteristics are referred to kinematic ones, and the next three are attributed to energy characteristics.

The foregoing approach is aimed at generating a dangerous design input and taking into account important features of actual impacts.

Two features of the method of input generating under consideration, which are not taken into account in [18, 19] should be noted.

First, the parameters of the input are determined approximately, parameter weighting factors are given for each parameter and the difference between the characteristics of the model and the actual input is minimized taking into account these parameters. Thus, it is possible to construct the infinite number of model processes with a given spectral composition. Secondly, in [19, 20] the first component of the process is considered as the main one. It is assumed that it accounts for minimum half of the SED value, i.e. the following condition takes place.

$$A_1^2 > A_2^2 + A_3^2 \tag{6}$$

The foregoing statement of the problem of seismic input generating is suitable for calculating structures with a rarefied spectrum in which the main part of the seismic load is provided by the first oscillation mode. Meanwhile, in design practice, one has to deal with structures having a dense spectrum. In this case, a dangerous mode is not known in advance. The simplest object of this type is the construction with the MD. The specifics of the input setting for such structures are discussed below.

Results and Discussion

Setting the seismic input to assess the effectiveness of MD. When calculating systems with the MD, it is necessary to deal with at least three characteristic frequencies. This fact is illustrated in Fig. 1, which shows the gain-frequency characteristic of an oscillator with eigen frequency k_0 and with static displacement A_{st}. For the structure without the MD the dangerous frequency is ω_0, and for the structure with the MD there are two dangerous frequencies ω_1 and ω_2, and the amplitudes of oscillations at these frequencies coincide. In this regard, for the example under consideration it is necessary to generate three design accelerograms: the basic one, for calculating a structure without the MD, and two accelerograms dangerous for a structure with the MD. This means that algorithmically in the first generation the frequency ω_1 should be used as the first main frequency, and in the second generation the first main frequency must be ω_2.

For example, let us consider a bridge pier with two spans, for which the second span of the system acts as the MD due to its connection with the pier by an elastic-damping joint (Fig. 2). Such technical solutions are considered in the literature [7–9, 22]. The pier has dense sandy soils in the base with a deformation modulus E_0 = 300 kg/cm^2 (30 MPa). The dynamic characteristics of the pier are given in Table 1. The MD under consideration is the MD of big mass and its optimum damping, i.e. inelastic resistant ratio γ, exceeds the critical value. The letter is difficult to achieve, therefore, in this example γ = 0.5 (25 % of critical value) is considered.

Table 1. Dynamic characteristics of the structure for which the calculated accelerogram is generated

Mode characteristics	**Pier with one span**			**Pier with two spans with the second span used as the MD**		
	The mode number			The mode number		
	1	2	3	1	2	3
Period, T, s	0.425	0.0433	0.0142	1.767	0.412	0.0433
Frequency, ω, s^{-1}	14.80	145.03	441.8	3.556	15.246	145.03
Inelastic resistant ratio, γ	0.167	0.228	0.141	0.478	0.165	0.185

Table 2. Characteristics of generated inputs

Object to be calculated		Structure without the MD	Structure with the MD	
			Dominance on the first mode	Dominance on the second mode
Input characteristics	PGA, м/с^2	5.415	2.074	5.383
	I_A, м/с	2.874	0.303	3.911
	CAV, м/с	11.230	3.459	14.072
	SED, м^2/с	0.053	0.122	0.181
	κ	3.465	3.00	2.378

The results of calculating structures using generated accelerograms are shown in Figures 3–5 and in Table 3.

Table 3. Some results of structure calculations

Characteristics of structure calculations		Design accelerograms		
		For the structure without the MD	For the structure with the MD	
			At the first mode tuning	At the second mode tuning
displacements, m	The first span (structure top)	0.0587	0.011	0.0374
	The second span (MD)	-	0.001	0.0027
accelerations, m/s^2	The first span (structure top)	12.80	2.462	8.89
	The second span (MD)	-	0.123	0.534

Note, that the calculating the system with the MD using the accelerogram dangerous for the structure without the MD, gives an incorrect estimate of the MD efficiency. In this case, the maximum shift of the MD is 0.002 m, the maximum displacement of the structure is 0.027 m and the corresponding maximum accelerations are 0.385 m/s^2 and 6.605 m/s^2.

Conclusions

The abovementioned investigations made it possible to discover some peculiarities of seismic input setting for structures with tuned mass dampers. Among them one can stress the following

1) When generating seismic input in the form of a narrow-band process dangerous for a structure, several inputs corresponding to several resonant frequencies should be generated. In the example considered, the second natural frequency of the structure with the MD turned out to be dangerous.

2) It should also be stressed that when evaluating the effectiveness of the MD using accelerograms of earthquakes, the calculation of the structure without the MD and with the MD should be carried out using different accelerograms

Acknowledgements

The work has been carried out with the support of RFBR grant № 16-58-53095 "Development of the theory of limit states to ensure seismic stability of operated railway bridges and those under constriction".

References

1. Frahm H., *Schlingertanks zur Abdämpfung von Schiffsrollbewegungen, Jahrbuch d.* Schiffbautechnick Ges.. 1911. Bd. 12.
2. Frahm H *Device for damping vibrations of bodies.* U.S. Patent 0989958. 1909.
3. Warburton G.V. Optimum absorber parameters for various

Литература

1. Frahm H. Schlingertanks zur Abdämpfung von Schiffsrollbewegungen, Jahrbuch d. Schiffbautechnick Ges.. 1911. Bd. 12.
2. Frahm H Device for damping vibrations of bodies. U.S. Patent 0989958. 1909.
3. Warburton G.V. Optimum absorber parameters for various

combinations of response and excitation parameters. *Earthquake Engineering and Stucture Dynamics.* 1982. Vol. 10. No. 3. Pp. 381–401.

4. Timoshenko S.P. *Kolebaniya v inzhenernom dele* [Fluctuations in engineering]. Moscow: Nauka. 1976. Pp. 209–216. (rus)
5. Savinov O.A. O primenenii dinamicheskogo gasitelya kolebaniy [On the application of a dynamic vibration damper]. *Trudy nauchno-issled. sektora L.O. tresta glubinnykh rabot* [Proceedings of the Research Sector of the Leningrad Branch of the Trust of the Deep Works]. 1940. No. 2. Leningrad, Moscow: Gosizdat stroitelnoy literatury. Pp. 30–35. (rus)
6. Korenev B.G., Reznikov L.M. *Dinamicheskiye gasiteli kolebaniy* [Dynamic vibration absorbers]. Moscow: Nauka, 1988. 303 p. (rus)
7. Korenev B.G., Polyakov V.S. Optimalnyye parametry dinamicheskogo gasitelya kolebaniy pri vozdeystviyakh tipa seysmicheskogo [Optimal parameters of the dynamic vibration damper under the action of the seismic type]. *Seysmostoykoye stroitelstvo.* 1977. No. 3. Pp. 37–42. (rus)
8. Tseytlin A.I., Kim L.I. Seysmicheskiye kolebaniya mnogoetazhnogo zdaniya s "gibkim" verkhnim etazhom. Snizheniye materialoyemkosti i trudoyemkosti seysmostoykogo stroitelstva [Seismic vibrations of a multi-storey building with a "flexible" upper floor. Reduction of the material consumption and labor intensity of earthquake-resistant construction]. *Tezisy dokladov Vsesoyuznogo soveshchaniya* [Theses of the reports of the All-Union Conference]. Moscow: Stroyizdat. 1982. 85 p. (rus)
9. Nikitin A.A., Uzdin A.M. Primeneniye dinamicheskikh gasiteley kolebaniy dlya seysmozashchity mostov. Ekspress-informatsiya VNIIIS. Ser.14 [Application of dynamic vibration dampers for seismic protection of bridges. Express information VNIIIS]. *Seysmostoykoye stroitelstvo.*1986. No. 9. Pp. 20–24. (rus)
10. Aldemir U., Yanik A., Bakiogl M.U. Control of structural response under earthquake excitation. *Comput-Aided Civil Infrastructure Engineering.* 2012. No. 27(8). Pp. 620–638.
11. Nikitin A.A., Tsibarova M.Yu., Uzdin A.M. K voprosu o primenenii dinamicheskikh gasiteley kolebaniy bolshoy massy dlya energeticheskikh sooruzheniy [To the question of the application of dynamic absorbers for large-scale oscillations for power structures]. *Materialy konferentsiy i soveshchaniy po gidrotekhnike: Povysheniye nadezhnosti energeticheskikh sooruzheniy pri dinamicheskikh vozdeystviyakh* [Materials of conferences and meetings on hydraulic engineering: Increasing the reliability of power structures under dynamic influences]. Leningrad: Energoatomizdat. 1989. Pp. 242–245. (rus)
12. Castelliano M.G., Kuznetsova I.O., Nikitin A.A., Verholin V.V., Uzdin A.M. The study of FIP-INDUSTRIALE devices for the earthquake protection of bridges in Russia. *Proceedings of 8-th world Seminar on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures.* Yerevan, Armenia. 2003. Pp. 407–416.
13. Tamboli A., Joseph L., Vadnere U., Xu X., Tall buildings: sustainable design opportunities. *Council on Tall Buildings and Urban Habitat. 8th World Conference.* Dubai, 2008.
14. Tuan A.Y., Shang G.Q. Vibration control in a 101-storey building using a tuned mass damper. *Journal of Applied Science and Engineering.* 2014. Vol. 17. No. 2. Pp. 141–156.
15. Lin J.-L., Tsai K.-C., Yu Y.-J. Coupled tuned mass dampers for the seismic control of asymmetric-plan buildings. *Earthquake Spectra*. 2010. No. 26(3). Pp. 749–778.
16. Lavan O., Daniel Y. Full resources utilization seismic design of irregular structures using multiple tuned mass

combinations of response and excitation parameters // Earthquake Engineering and Stucture Dynamics. 1982. Vol. 10. № 3. Pp. 381–401.

4. Тимошенко С.П. Колебания в инженерном деле. М.: Наука. 1976. С. 209–216.
5. Савинов О.А. О применении динамического гасителя колебаний // Труды научно-исслед. сектора Л.О. треста глубинных работ. 1940. № 2. Л., М.: Госиздат строительной литературы. С. 30–35.
6. Коренев Б.Г., Резников Л.М. Динамические гасители колебаний. М.: Наука, 1988. 303 с.
7. Коренев Б.Г., Поляков В.С. Оптимальные параметры динамического гасителя колебаний при воздействиях типа сейсмического // Сейсмостойкое строительство. 1977. № 3. С. 37–42.
8. Цейтлин А.И., Ким Л.И. Сейсмические колебания многоэтажного здания с "гибким" верхним этажом. Снижение материалоемкости и трудоемкости сейсмостойкого строительства // Тезисы докладов Всесоюзного совещания. М.: Стройиздат. 1982. 85 с.
9. Никитин А.А., Уздин А.М. Применение динамических гасителей колебаний для сейсмозащиты мостов. Экспресс-информация ВНИИИС. Сер.14. // Сейсмостойкое строительство.1986. № 9. С. 20–24.
10. Aldemir U., Yanik A., Bakiogl M.U. Control of structural response under earthquake excitation // Comput-Aided Civil Infrastructure Engineering. 2012. № 27(8): Pp. 620–638.
11. Никитин А.А., Цибарова М.Ю., Уздин А.М. К вопросу о применении динамических гасителей колебаний большой массы для энергетических сооружений // Материалы конференций и совещаний по гидротехнике: Повышение надежности энергетических сооружений при динамических воздействиях. Л.: Энергоатомиздат, 1989. С. 242–245.
12. Castelliano M.G., Kuznetsova I.O, Nikitin A.A., Verholin V.V, Uzdin A.M. The study of FIP-INDUSTRIALE devices for the earthquake protection of bridges in Russia // Proceedings of 8-th world Seminar on Seismic Isolation, Energy Dissipation and Active Vibration Control of Structures. Yerevan, Armenia. 2003. Pp. 407–416.
13. Tamboli A., Joseph L., Vadnere U., Xu, X. Tall buildings: sustainable design opportunities // Council on Tall Buildings and Urban Habitat. 8th World Conference. Dubai, 2008.
14. Tuan A.Y., Shang G.Q. Vibration control in a 101-storey building using a tuned mass damper // Journal of Applied Science and Engineering. 2014. Vol. 17. № 2. Pp. 141–156.
15. Lin J.-L., Tsai K.-C., Yu Y.-J. Coupled tuned mass dampers for the seismic control of asymmetric-plan buildings // Earthquake Spectra. 2010. № 26(3). Pp. 749–778.
16. Lavan O., Daniel Y. Full resources utilization seismic design of irregular structures using multiple tuned mass dampers // Structure Multidiscip Optim. 2013. № 48(3). Pp. 517–532.
17. Mohebbi M., Joghataie A. Designing optimal tuned mass dampers for nonlinear frames by distributed genetic algorithms // Struct Des Tall Spec Buildiungs. 2012. № 21(1). Pp. 57–76.
18. Hoang T., Ducharme K.T., Kim Y., Okumus P. Structural impact mitigation of bridge piers using tuned mass damper // Engineering Structures. 2016. Vol. 112. Pp. 287–294.
19. Elias S., Matsagar V. Effectiveness of tuned mass dampers in seismic response control of isolated bridges including soil-structure interaction // Latin American Journal of Solids and Structures. 2017. № 14. Pp. 1–18.
20. Инструкция по оценке сейсмостойкости эксплуатируемых мостов на сети железных и автомобильных дорог (на территории Туркменской ССР). Ашхабад:Ылым,1988.106 с.
21. Рекомендации по проектированию гасителей колебаний для защиты зданий и сооружений, подверженных

dampers. *Structure Multidiscip Optim*. 2013. No. 48(3). Pp. 517–532.

17. Mohebbi M, Joghataie A Designing optimal tuned mass dampers for nonlinear frames by distributed genetic algorithms. *Struct Des Tall Spec Buildiungs.* 2012. No. 21(1). Pp. 57–76.
18. Hoang T., Ducharme K.T., Kim Y., Okumus P. Structural impact mitigation of bridge piers using tuned mass damper. *Engineering Structures.* 2016. Vol. 112. Pp. 287–294.
19. Elias S., Matsagar V. Effectiveness of tuned mass dampers in seismic response control of isolated bridges including soil-structure interaction. *Latin American Journal of Solids and Structures.* 2017. No. 14. Pp. 1–18.
20. *Instruktsiya po otsenke seysmostoykosti ekspluatiruyemykh mostov na seti zheleznykh i avtomobilnykh dorog (na territorii Turkmenskoy SSR)* [Instruction on the assessment of seismic resistance of operated bridges on the network of railways and highways (on the territory of the Turkmen SSR)]. Ashkhabad:Ylym,1988.106 p. (rus)
21. *Rekomendatsii po proyektirovaniyu gasiteley kolebaniy dlya zashchity zdaniy i sooruzheniy, podverzhennykh gorizontalnym dinamicheskim vozdeystviyam ot tekhnologicheskogo oborudovaniya i vetra* [Recommendations for the design of vibration dampers for the protection of buildings and structures subject to horizontal dynamic influences from process equipment and wind]. Moscow: TsNIISK im. V.A.Kucherenko,1978. 68 p. (rus)
22. Nesterova O.P., Uzdin A.M. Osobennosti raboty dinamicheskikh gasiteley kolebaniy pri silovom i kinematicheskom vozmushchenii dempfirovannykh sooruzheniy [Features of the operation of dynamic vibration dampers in the case of force and kinematic perturbations of damping structures]. *Izvestiya rossiyskoy Akademii raketnykh i artilleriyskikh nauk.* Moscow. 2016. No. 2(92). Pp. 84–89.
23. Hori Y., Kurino H., Kurokawa Y. Development of large tuned mass damper with stroke control system for seismic upgrading of existing high-rise building. *International Journal of High-Rise Buildings.* 2016. Vol. 5. No. 3. Pp. 167–176.
24. Shayeghi A., Shayeghi H., Eimani Kalasar H. Application of PSO technique for seismic control of tall building. *International Journal of Intelligent Systems and Technologies.* 2009. No. 4. Pp. 28–35.
25. Nesterova O.P., Vorobyeva K.V.,Uzdin A.M. Otklik na statyu A.G.Tyapina «Neklassicheskoye dempfirovaniye v sisteme «osnovaniye-sooruzheniye» i vopros primenimosti spektralnogo metoda rascheta usiliy» [Response to the article of A.G. Tyapin "Non-classical damping in the" foundation-construction "system and the question of the applicability of the spectral method of calculating the effort"]. *Seysmostoykoye stroitelstvo. Bezopasnost sooruzheniy.* 2017. No. 2. Pp. 60–63. (rus)

горизонтальным динамическим воздействиям от технологического оборудования и ветра. М.: ЦНИИСК им. В.А.Кучеренко,1978. 68 с.

22. Нестерова О.П., Уздин А.М. Особенности работы динамических гасителей колебаний при силовом и кинематическом возмущении демпфированных сооружений // Известия российской Академии ракетных и артиллерийских наук. 2016. № 2(92). С. 84–89.
23. Hori Y., Kurino H., Kurokawa Y. Development of Large Tuned Mass Damper with Stroke Control System for Seismic Upgrading of Existing High-Rise Building // International Journal of High-Rise Buildings. 2016. Vol. 5. № 3. Pp. 167–176.
24. Shayeghi A., Shayeghi H., Eimani Kalasar H. Application of PSO technique for seismic control of tall building // International Journal of Intelligent Systems and Technologies. 2009. № 4. Pp. 28–35.
25. Нестерова О.П., Воробьева К.В., Уздин А.М. Отклик на статью А.Г. Тяпина «Неклассическое демпфирование в системе «основание-сооружение» и вопрос применимости спектрального метода расчета усилий» // Сейсмостойкое строительство. Безопасность сооружений. 2017. № 2.С. 60–63.

Альберт И.У., Долгая А.А., Иванова Т.В., Нестерова О.П., Уздин А.М., Гуань Ю., Ивашинцов Д.А., Воронков О.К., Штильман В.Б., Шульман С.Г., Храпков А.А. Расчетное сейсмическое воздействие для сооружения с динамическим гасителем колебаний // Инженерно-строительный журнал. 2017. № 8(76). С. 98–105.

Yuliy Albert
+7(812)493-93-18; AlbertYU@vniig.ru

Anzhelika Dolgaya,
+7(921)992-58-99; anzhelika-dolgaya@yandex.ru

Tatiana Ivanova,
+7(812)493-93-63; IvanovaTV@vniig.ru

Olga Nesterova,
+7(960)280-59-75; Neona975@yandex.ru

Aleksandr Uzdin,
+7(921)788-33-64; uzdin@mail.ru

Jhy Guan,
329953890@qq.com

Ivashintzov D.A.
535-26-04; IvashintsovDA@vniig.ru

Sergey Shulman,
493-93-40;

Oleg Voronkov,
493-93-90; VoronkovOK@vniig.ru

Vladimir Shtilman,
493-93-78; ShtilmanVB@vniig.ru

Anatoliy Khrapkov,
493-93-30; khrapkovaa@vniig.ru

Июля Ушерович Альберт,
+7(812)493-93-18; эл. почта: AlbertYU@vniig.ru

Анжелика Александровна Долгая,
+7(921)992-58-99;
эл. почта: anzhelika-dolgaya@yandex.ru

Татьяна Викторовна Иванова,
+7(812)493-93-63; эл. почта: IvanovaTV@vniig.ru

Ольга Павловна Нестерова,
+7(960)280-59-75;
эл. почта: Neona975@yandex.ru

Александр Моисеевич Уздин,
+7(921)788-33-64; эл. почта: uzdin@mail.ru

Юхай Гуань,
эл. почта: 329953890@qq.com

Ивашинцов Дмитрий Александрович
+7(812)535-26-04;
эл. почта: IvashintsovDA@vniig.ru

Олег Константинович Воронков,
+7(812)493-93-90;
эл. почта: VoronkovOK@vniig.ru

Владимир Борисович Штильман,
+7(812)493-93-78;
эл. почта: ShtilmanVB@vniig.ru

Сергей Георгиевич Шульман,
+7(812)493-93-40;

Храпков Анатолий Александрович
+7(812)493-93-30;
эл. почта: khrapkovaa@vniig.ru

Albert Y.U., Dolgaya A.A. Ivanova T.V., Nesterova O.P., Uzdin A.M., Guan J., Ivashintzov D.A., Voronkov O.K., Shtilman S.G., Shulman V.B., Khrapkov A.A, Seismic input models for tuned mass damper designing. *Magazine of Civil Engineering*. 2017. No. 8. Pp. 98–105. doi: 10.18720/MCE.76.9.