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Techical Science Building and Architecture Seismic Response of Frame Buildings with Combined Earthquake Protection System

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Abstract: This article shows methods of seismic protection of buildings and structures. Technical options for seismic protection are covered.

Keywords: seismic, rubber-metal, dry friction elements, shut-off elements, horizontal forces, maximum displacements.

Introduction. The modern problem is to ensure seismic resistance of buildings and structures, especially for objects of increased responsibility. In this regard, the search for ways to effectively increase the seismic resistance of buildings and structures in recent years has been aimed at developing an active seismic protection system. Traditional methods of ensuring seismic resistance associated with increasing the bearing capacity of structures, seismic protection systems can reduce the levels of inertial forces that occur in buildings during an earthquake. The article considers methods of seismic protection of buildings and structures that could be practiced in design and construction.

Problem statement. Recently, to ensure seismic resistance and reliability of buildings and structures, seismic isolating rubber-metal supports [6] are increasingly used, which have sufficient vertical rigidity and good horizontal flexibility.

In buildings with a rigid structure, these systems are highly effective. But in flexible buildings, they cause problems associated with large movements during seismic impacts. As one of the ways to solve this problem, this article considers a seismic isolation system with rubber-metal supports supplemented with dry friction elements and switching elements. In the largest European countries today, most manufacturers of seismic isolation supports produce the same seismic protection supports. Many companies produce a wide range of rubber-metal supports, which, depending on the types of rubber, are classified as soft, normal and rigid. In addition, they are manufactured with and without a lead core. In this paper, rigid rubber-metal supports with a lead core are considered as more effective for flexible buildings. Figure 1 shows the calculation scheme of the combined seismic protection system under consideration.

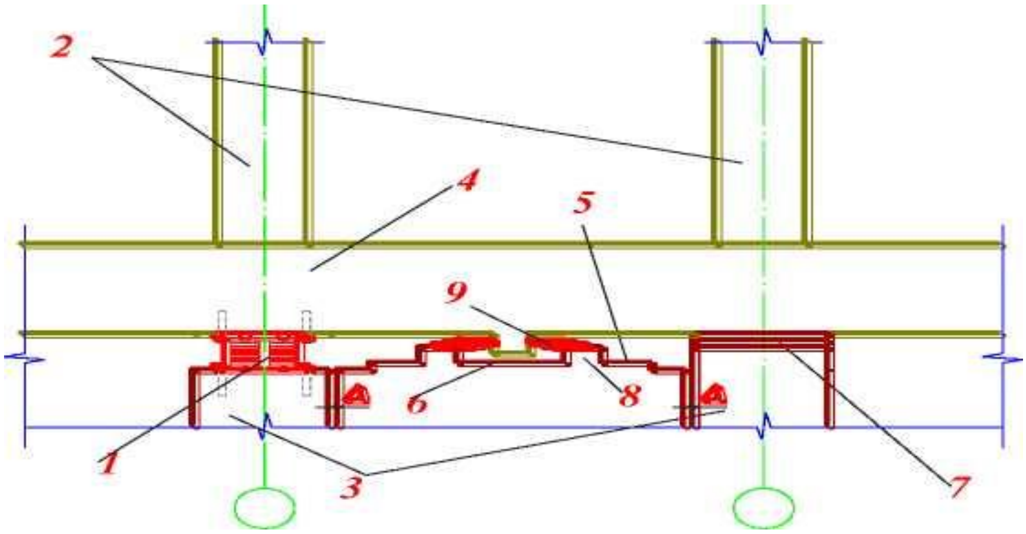


Fig. 1. Combined seismic protection system:

1-rubber-metal support; 2-building columns; 3-building base columns; 4-reinforced concrete support belt; 5-stiffening diaphragm; 6-gap between the protrusion from the belt; 7-friction elements; 8-limiter; 9-switching element

Research methods. Let us imagine a calculation-dynamic model of a combined seismic protection system in the form of a cantilever rod with n+1 with the number of concentrated masses, as shown in Fig. 2.

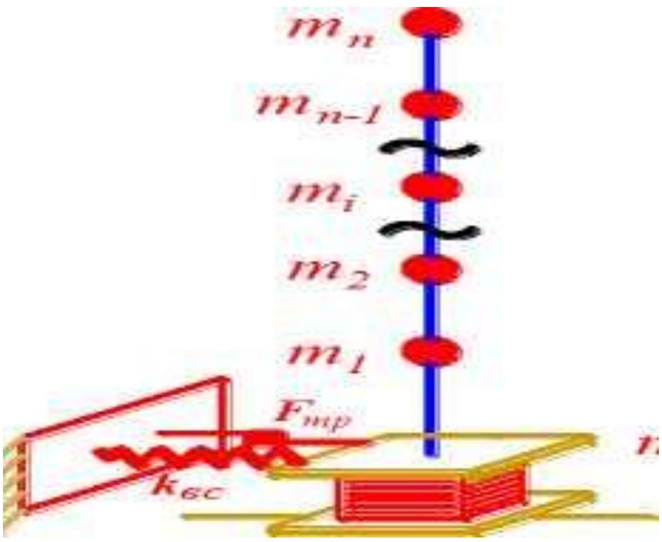


Fig.2.Dinamic model of the building with a combined seismic protection system, including rezinometallic bearings, dry friction elements and switching elements

We represent the system of differential equations of motion of the above-mentioned nonlinear dynamic model subjected to seismic impact in the form:

m о Уо +с о У о+с 1 (У о- У i)+ R (Уо) + Р і д пуо+€ у0+к ± (у 0- у±)=- m 0 угр

m1У 1 + с 1 (3>1 - У о) + c2(yi - У 2) + к ! (у ! - Уо) + к 2(у ± - у2) = - m ± (угр + у0) (1)

m{y{ + ci(yi - yi_i) + ci+i(yi - yi+i) + kj(yj - yi_i) + к1+1(y{ - yi+1) = -m^p + ^o)

тпуп сп(уп уп-1) кп(уп уп-1) = тп(угр М

где i=2+n-1.

Here m0 is the mass concentrated at the level of the top of the rubber-metal supports; t1, t2, ..., mi, ..., tp-1, tp are the concentrated masses at the levels of the floors; k1, k2, ..., ki..., kp-1, kp are the floor-by-floor rigidities of the building; с 0, с 1, c2, ..., cn_v cn are the floor-by-floor attenuation coefficients; ygr is the seismic action represented as a real accelerogram or a non-stationary random process; U(y0) is the nonlinear restoring force in the rubber-metal supports; is the displacement at the level of the top of the rubber-metal supports, y2, ..., yn are the displacements of the corresponding masses, and y0, y 1, ..., yn, y0, yi, . . ., yn are the velocities and accelerations of these masses. The restoring force R (y0) is represented as [24]

R (У0) = Ay0(1-s i gn o) + (B y 0 + q (F r B d 1))1(s i gn o + (1 - s i gni]/))(1- s i gnr) +(Ay0 + q (AC + F1-D))s ignr . (2)

In system (1), FTp is the friction force in the sliding supports.

With the same number of them with rubber-metal supports, FTp = fTpO, 5'Уп= 1 mig, (3) where, fTp is the coefficient of sliding friction in the supports.

Unit function s igny0 = { 1 к 0Г d a У0 ^ 0 (4)

1, when a y0 < 0. The restoring force in the switching elements is designated by €y0. Here, according to the “Force-displacement” dependence shown in Fig. 3

€ = to vs! ,when 1yo1<Ь i

to vs2 ,when b! <1yo1< b 2

to vs3 ,when b 2 <1Уo1< b 3 (5)

0,when bз<1Уo1

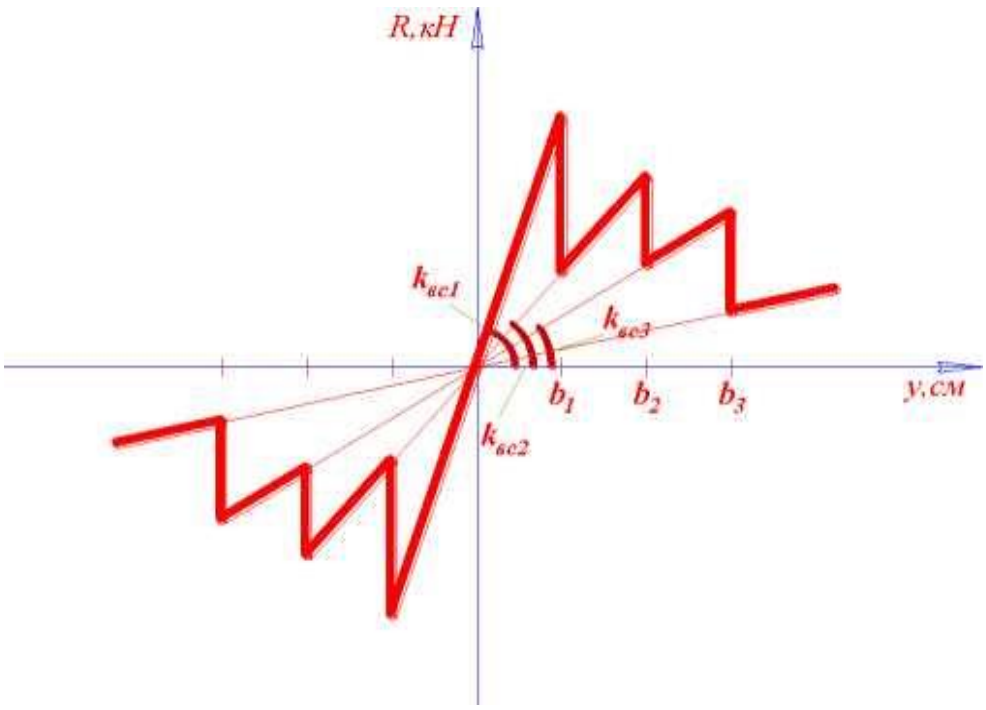


Fig.3. The plot of the «Restoring force-displacement» relationship for a system of three consecutively-off elements

k vc I - rigidity in the state of operation of all switching elements;

k B c 2 - rigidity in the state of switching off of the elements of the first level;

k B c z - rigidity in the state of switching off of the elements of the second level;

b i - displacement at which the switching off of the elements of the first level occurs;

I&2 - displacement at which the switching off of the elements of the second level occurs;

bз - displacement at which the switching off of the elements of the third level occurs.

Below are the results of the study of the influence of switching elements and dry friction elements on the displacements of rubber-metal seismic isolation bearings and the tops of columns in 5-story frame buildings.

In the considered combined seismic protection system, consisting of rubber-metal bearings with a lead core, dry friction elements with a friction coefficient of 0.2 and switching elements, the following values of the stiffness of the switching elements and the ultimate displacements at which the switching off of these elements occurs were adopted:

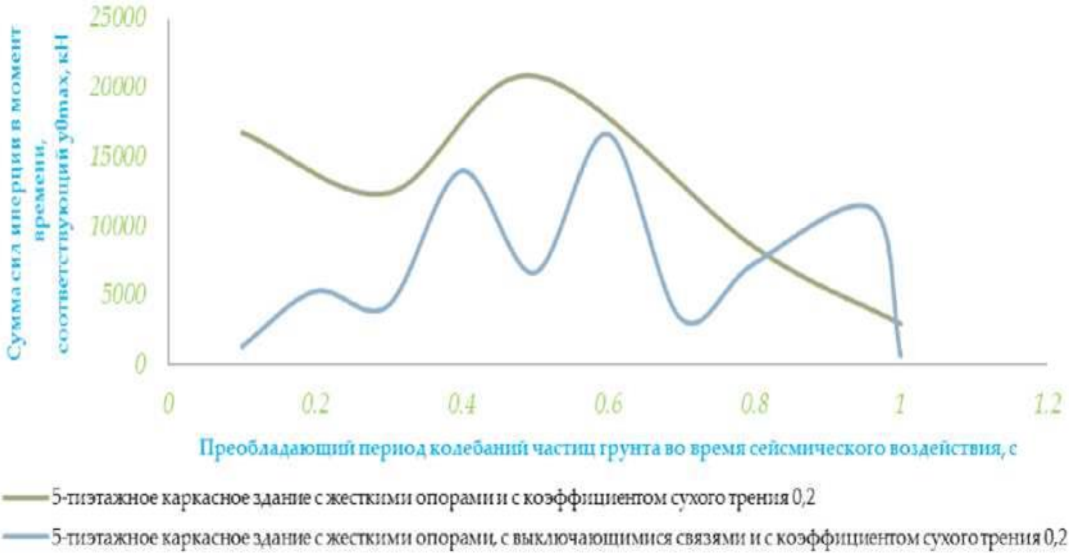
k Bc i - 9616.6 k H / CM; b 1 - 6 CM ;

k Bc2 - 6400 k H / cM; b 2 - 8 CM ;

k B c3 - 3205 k H / CM; b3 - 10 CM

Discussion of results. The maximum values of horizontal shear seismic forces at the moment of time corresponding to the maximum displacement of the lower concentrated mass are shown in Fig. 4.

a)



b)

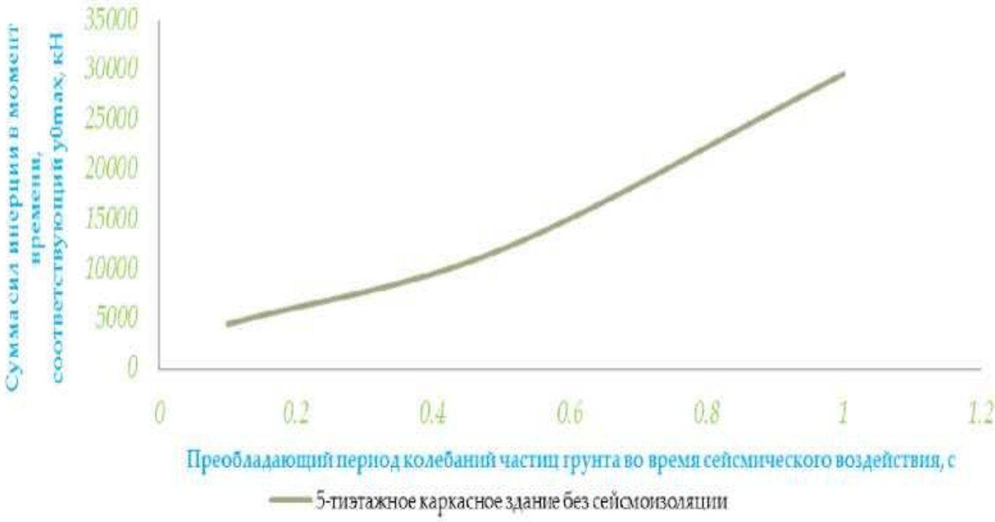


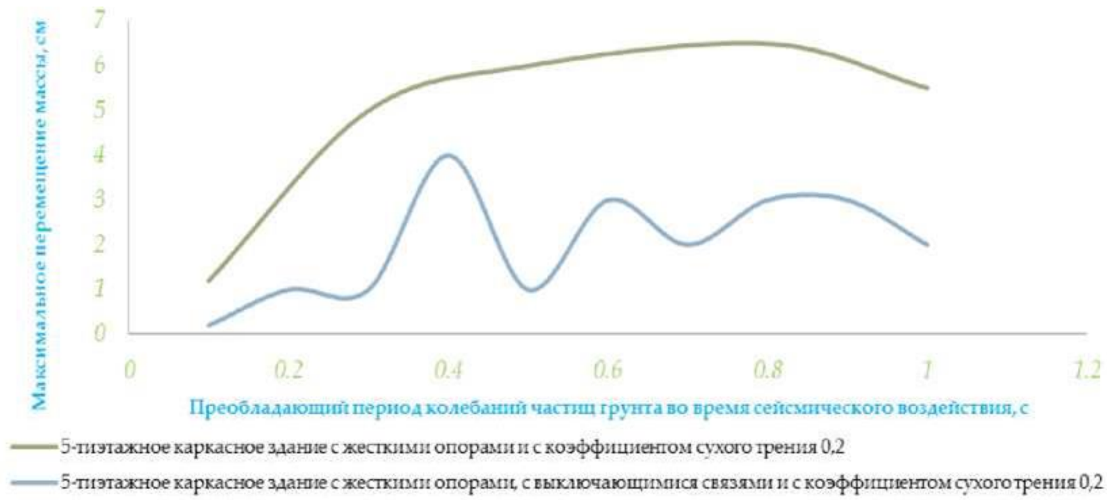
Fig.4. Graphs of horizontal seismic shifting seismic forces for a 5-story frame building: A - with a combined seismic protection system; Б - without seismic isolation

The graphs show that the use of a combined seismic protection system consisting of RMSO, dry friction elements and switching elements in frame buildings reduces the maximum floor shear forces by almost 1.5 times at the time when the displacement of the rubber-metal support is maximum.

Compared to a building without seismic isolation systems, an almost twofold decrease in these forces is observed under low-frequency seismic impacts.

The maximum values of horizontal mass displacements of the system under consideration are shown in Fig. 5.

a)



b)

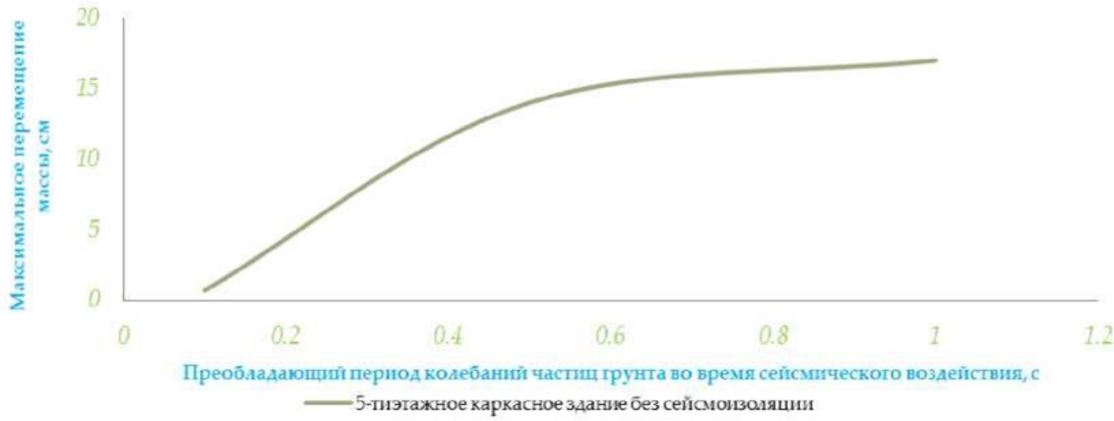


Fig.5. The graphs of the movements of concentrated masses for a 5-story frame building: a - with a combined seismic protection system; б - without seismic isolation

It follows from Figures 5a and 5b that the combination of rubber-metal bearings only with dry friction elements leads to a decrease in maximum mass displacements by 2-3 times, and with dry friction and switching elements - 4-5 times.

Graphs of maximum displacements and residual deformations of the RMSO are shown in Figures 6 and 7. It follows from Figure 6 that the maximum displacement level of the top of the rubber-metal bearings under consideration, equal to 40 cm, in the seismic protection system without switching elements reaches at prevailing periods of seismic ground vibrations exceeding 0.8 s, and with switching elements - at periods exceeding 1.0 s.

Fig.b. Graphs of the dependence of the maximum displacement of the top of rubber-metal supports |yo|max on the prevailing period of ground vibrations for 5-storey frame buildings with a combined seismic protection system.

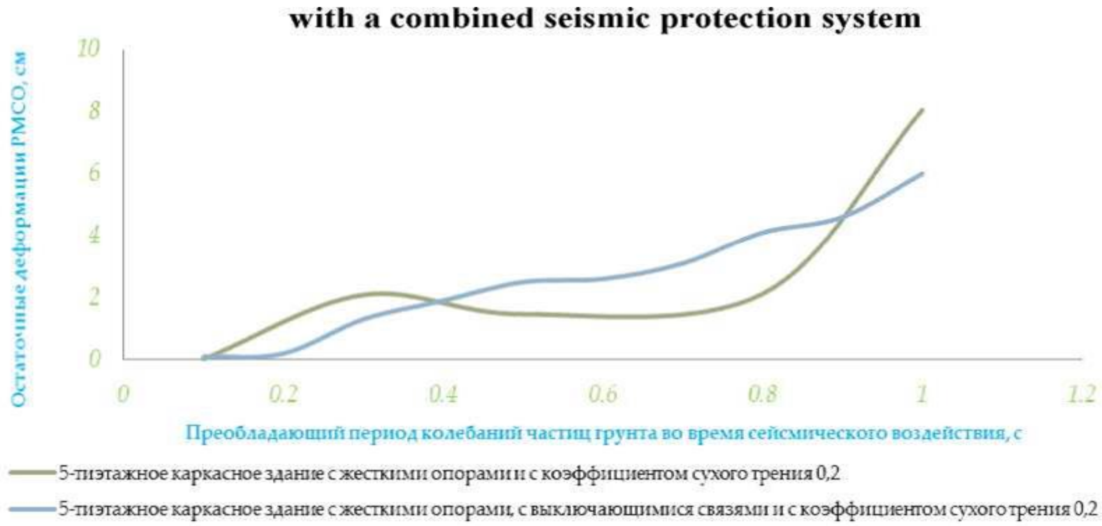


Fig. 7. Graphs of the dependence of the maximum residual displacements [| y_0 |3 _of the prevailing period of soil oscillation for 5-story frame buildings with a combined seismic protection system

Fig. 7 shows the efficiency of introducing switching elements into the seismic protection system.

Results

The research documented how integrating seismic protection components with rubber-metal bearings, dry friction elements and switching elements decreased the force of horizontal shears and framework movement in five-story structures. Buildings using this combined seismic protection system experienced 1.5 times less maximum horizontal shear forces compared to unisolated buildings. Buildings equipped with dry friction elements and switching elements experienced 2-3 times less displacement which further increased to 4-5 times total displacement reduction. A seismic impact brought fewer maximum displacements of rubber-metal bearings after adding switching elements.

Discussion

The experimental results prove that combined seismic protection achieves reduced seismic forces while lowering overall mass displacements. Due to its unique design the system provides maximum benefits during seismic impacts with low frequencies. The implementation of switching components improves rubber-metal bearing performance by expanding their protective range against seismic events.

Conclusion

Introduction of switching elements into the seismic isolation system with rubber-metal supports and dry friction, allowing the system to adapt to the resonant frequencies of base soil vibrations, significantly increases the efficiency of seismic protection of flexible structures under low-frequency impacts.

For example, while in 5-storey frame systems without seismic isolation the maximum horizontal shear force exceeds 25,000 kN at prevailing periods of seismic ground vibrations exceeding 0.8 s, then with a combined seismic protection system the shear force does not exceed 10,000 kN. Here the maximum displacements of the building at the levels of mass concentration are also reduced by 4-5 times.

The introduction of switchable elements into the seismic protection system allows expanding the area of effective application of rubber-metal supports by increasing the range of possible prevailing periods of seismic ground vibrations, at which the maximum displacement of the top of the rubber-metal supports does not exceed the maximum permissible value, and reducing the maximum residual displacements of rubber-metal supports with a lead core.

References:

In preparing this article, materials on this topic from the websites journal.imras.org and samdaqi.edu.uz were used.

1. Сейсмическая реакция каркасных зданий с комбинированной системой сейсмозащиты – тема научной статьи по строительству и архитектуре читайте бесплатно текст научно-исследовательской работы в электронной библиотеке Кибер Ленинка https://yandex.ru/search/?
2. Plevkov V.S., Mal’ganov A.I., Baldin I.V. Zhelezobetonnye i kamennye konstruktsii seysmostoykikh zdaniy i sooruzheniy. Moscow: Izdatel'stvo ASV; 2010. 290 s. [Plevkov V.S., Mal’ganov A.I., Baldin I.V. Reinforced concrete and stone constructions of earthquake-proof buildings and structures. Moscow: Izdatel'stvo ASV; 2010. 290 p. (in Russ.)]
3. Ayzenberg Ya.M. Sooruzheniya s vyklyuchayushchimisya svyazyami dlya seysmicheskikh rayonov. Moscow: Stroyizdat; 1976. 228 s. [Ayzenberg Ya.M. Buildings with shutdown connections for seismic areas. Moscow: Stroyizdat; 1976. 228 p. (in Russ.)]
4. Ayzenberg Ya.M., Neyman A.I., Abakarov A.D., Deglina M.M., Chachua T.L. Adaptivnye sistemy seysmicheskoy zashchity sooruzheniy. Moscow: Nauka; 1978. 248 s. [Ayzenberg Ya.M., Neyman A.I., Abakarov A.D., Deglina M.M., Chachua T.L. Adaptive systems of seismic protection of constructions. Moscow: Nauka; 1978. 248 p. (in Russ.)]
5. Ayzenberg Ya.M., Deglina M.M., Mazhiev H.N. Seysmoizolyatsiya i adaptivnye sistemy seysmozashchity. Moscow: Nauka; 1983. 141 s. [Ayzenberg Ya.M., Deglina M.M., Mazhiev H.N. Seismic isolation and adaptive seismic protection systems. Moscow: Nauka; 1983. 141 p. (in Russ.)]
6. Ayzenberg Ya.M., Abakarov A.D. Osobennosti rezervirovaniya dlya povysheniya nadezhnosti stroitel'nykh sooruzheniy pri vozmozhnykh seysmicheskikh i drugikh katastroficheskikh vozdeystviyakh. Stroitel'naya mekhanika i raschet sooruzheniy. 1987; 4:47-50. [Ayzenberg Ya.M., Abakarov A.D. Reservation features for improving the reliability of building constructions with possible seismic and other catastrophic impacts. Structural Mechanics and Analysis of Constructions. 1987; 4:47-50. (in Russ.)]
7. Ayzenberg Ya.M., Smirnov V.I., Akbiev R.T. Metodicheskie rekomendatsii po proektirovaniyu seysmoizolyatsii s primeneniem rezinometallicheskikh opor. Moscow: Rossiyskaya akademiya sportivnykh sooruzheniy; 2008. 46 s. [Ayzenberg Ya.M., Smirnov V.I., Akbiev R.T. Methodical recommendations for the design of seismic isolation using

rubbermetallic supports. Moscow: Rossiyskaya akademiya sportivnykh sooruzheniy; 2008. 46 p. (in Russ.)]

8. Eliseev S.V. Dinamicheskie gasiteli kolebaniy. Novosibirsk: Nauka; 1982. 144 s. [Eliseev S.V. Dynamic vibration absorbers. Novosibirsk: Nauka; 1982. 144 p. (in Russ.)]

9. Kazina G.A., Kilimnik L.Sh. Sovremennye metody seysmozashchity zdaniy i sooruzheniy. Obzor. Moscow: VNIIS; 1987. 65 s. [Kazina G.A., Kilimnik L.Sh. Modern methods of seismic protection of buildings and constructions. Review. Moscow: VNIIS; 1987. 65 p. (in Russ.)]

10. Katen-Yartsev A.S., Nazin V.V., Zelenskiy G.A., Shulyak Yu.M. Dinamicheskie ispytaniya zdaniy s gravitatsionnymi sistemami seysmoizolyatsii v Sevastopole. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1977; 14(7):19-22. [Katen-Yartsev A.S., Nazin V.V., Zelenskiy G.A., Shulyak Yu.M. Dynamic tests of buildings with gravity seismic isolation systems in Sevastopol. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1977;14(7):19-22. (in Russ.)]

11. Martynov N.V. Aktivnaya seysmozashchita: varianty razvitiya i kriticheskiy analiz prakticheskikh vozmozhnostey. Simferopol’: 2013; 216 s. [Martynov N.V. Active seismic protection: development options and critical analysis of practical possibilities. Simferopol’: 2013; 216 s. (in Russ.)]

12. Mikhaylov G.M. Ispol'zovanie uprugofriktsionnykh sistem v seysmostoykom stroitel'stve. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1974; 14(3):36-38. [Mikhaylov G.M. The use of elastic-friction systems in earthquake-resistant construction. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1974; 14(3):36-38. (in Russ.)]

13. Mnakatsanyan V.L., Peshmaldzhyan O.V., Dilanyan A.A. Issledovanie seysmostoykosti friktsionnykh fundamentov sooruzheniy. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1982; 14(3):23-27. [Mnakatsanyan V.L., Peshmaldzhyan O.V., Dilanyan A.A. Investigation of earthquake resistance of the friction foundations of constructions. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1982; 14(3):23-27. (in Russ.)]

14. Pavlyk V.G. Printsip proektirovaniya seysmostoykikh zdaniy s povyshennymi dissipativnymi svoystvami. Materialy Vsesoyuznogo soveshchaniya po proektirovaniyu i stroitel'stvu seysmostoykikh zdaniy i sooruzheniy. Frunze: 1971.S.210-218. [Pavlyk V.G. The principle of design of earthquake resistant buildings with increased dissipative properties. Materialy Vsesoyuznogo soveshchaniya po proektirovaniyu i stroitel'stvu seysmostoykikh zdaniy i sooruzheniy. Frunze: 1971.S.210-218. (in Russ.)]

15. Polyakov V.S., Kilimnik L.Sh., Cherkashina A.V. Sovremennye metody seysmozashchity zdaniy. Moskva: Stroitel'noe izdatel'stvo; 1989. 320 s. [Polyakov V.S., Kilimnik L.Sh., Cherkashina A.V. Modern methods of seismic protection of buildings. Moscow: Stroitel'noe izdatel'stvo; 1989. 320 p. (in Russ.)]

16. Primenenie sistem seysmoizolyatsii v zdaniyakh i sooruzheniyakh (SShA): Ekspress informatsiya / VNIIS. 1985; 14(12):2-6. [Application of seismic isolation systems in buildings and structures (USA): Express information. VNIIS. 1985; 14(12):2-6. (in Russ.)]

17. Saakyan A.O., Saakyan R.O., Shakhnazaryan S.Kh. Povyshenie seysmostoykosti karkasnykh zdaniy so stvolami zhestkosti s pomoshch'yu dempfernykh ustroystv. Referativnyy sbornik. TsNIIS. 1975; 14(11):2-6. [Saakyan A.O., Saakyan R.O., Shakhnazaryan S.Kh. in Seismic resistance increase of frame buildings with stiffeners by means of damper devices. Referativnyy sbornik. TsNIIS. 1975; 14(11):2-6. (in Russ.)]

18. Savinov O.A. Seysmoizolyatsiya sooruzheniy (kontseptsiya, printsipy ustroystva, osobennosti rascheta). Izbrannye stat'i i doklady «Dinamicheskie problemy stroitel'noy tekhniki». SanktPeterburg: 1993. S. 155-178. [Savinov O.A. Seismic insulation of

constructions (concept, device principles, calculation features). Izbrannye stat'i i doklady «Dinamicheskie problem stroitel'noy tekhniki». Saint-Petersburg: 1993. P. 155-178. (in Russ.)]

19. Smirnov V.I. Seysmoizolyatsiya zdaniy sooruzheniy. Promyshlennoe i grazhdanskoe stroitel'stvo. Moscow: 1997; 12:37-39. [Smirnov V.I. Seismic insulation of buildings. Industrial and civil construction. Moscow: 1997; 12:37-39. (in Russ.)]
20. Uzdin A.M., Sandovich T.A., Salikh Amin Al'-Naser-Mokhamad. Osnovy teorii seysmostoykosti i seysmostoykogo stroitel'stva. Sankt-Peterburg: Izdatel'stvo VNIIG imeni B.E. Vedeneeva. 1993; 176 s. [Uzdin A.M., Sandovich T.A., Salikh Amin Al'-Naser-Mokhamad. Fundamentals of the theory of seismic stability and earthquake-proof construction. SaintPetersburg: Izdatel'stvo VNIIG imeni B.E. Vedeneeva. 1993; 176 p. (in Russ.)]
21. Cherepinskiy Yu.D. K seysmostoykosti zdaniy na kinematicheskikh oporakh. Osnovaniya, fundamenty i mekhanika gruntov. 1972; 3:13-15. [Cherepinskiy Yu.D. On seismic resistance of buildings with kinematic supports. Soil Mechanics and Foundation Engineering. 1972; 3:13-15. (in Russ.)]
22. Cherepinskiy Yu.D. Seysmoizolyatsiya zdaniy (Sbornik statey). Moscow; 2009. 358 s. [Cherepinskiy Yu.D. Seismic insulation of buildings (Collected papers). Moscow; 2009. 358 p. (in Russ.)]
23. Chudentsov V.P., Soldatova L.L. Zdaniya s seysmozolyatsionnym skol'zyashchim poyasom I uprugimi ogranichitelyami peremeshcheniy. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1979; 14(5):1-3. [Chudentsov V.P., Soldatova L.L. Buildings with seismoisolating sliding belt and elastic stoppers of movement. Seysmostoykoe stroitel'stvo: Referativnyy sbornik. TsNIIS. 1979; 14(5):1-3. (in Russ.)]
24. Yusupov A.K. Proektirovanie seysmostoykikh zdaniy na kinematicheskikh oporakh. Makhachkala: Lotos; 2006. 423 s. [Yusupov A.K. Design of seismic resistant buildings on kinematic supports. Makhachkala: Lotos; 2006. 423 p. (in Russ.)]
25. Abakarov A.D., Omarov Kh.M. Approksimatsiya zavisimosti «Sila-peremeshchenie» dlya seysmoizoliruyushchikh rezinometallicheskikh opor so svintsovym serdechnikom. Vestnik Dagestanskogo gosudarstvennogo tekhnicheskogo universiteta. Tekhnicheskie nauki. 2012;
26. 4(27):61-70. [Abakarov A.D., Omarov Kh.M. Approximation of the "Force-Displacement" dependence for seismically insulating rubber-metal supports with a lead core. Herald of Daghestan State Technical University. Technical Sciences. 2012; 4(27):61-70. (in Russ.)]
27. 27.AbdurahmanovA.KO‘PQAVATLITURARJOYBINOLARISEYSMIKHOLATLARIVAZ ILZILABARDOSHLILIGINIOSHIRISHhttps://doi.org/10.5281/zenodo.109504036.
28. 28.AbdurakhmanovAkhmatjonMakhammadovich.THEORETICALASPECTSINTHEFORM ATIONOFPEDAGOGICALSCIENCES,Internationalscientificonlineconference173.IMPOR TANCEOFMATHEMATICSINCOMPUTERSCIENCE.https://doi.org/10.5281/zenodo.1121 9951
29. A.Abdurakhmanov, “METHODOLOGICAL GUIDELINES (INSTRUCTIONS) FOR DETERMINING THE DESIGN SEISMIC LOAD FOR BUILDINGS AND STRUCTURES.” Andijan, Nombr one , 2025. 169 p.
30. Khadjimurad M. Omarov, Abakar D. Abakarov. "The Seismic Response Investigation on the Multi-Storey Buildings with Seismically Insulating Rubber-Metal Supports" , Materials Science Forum, 2018 Июль 2017 года. Вестник Дагестанского государственного технического университета. Технические науки 44(1):116-126 DOI: 10.21822/2073-6185-2017-44-1-116-126

31. Буриев А., Абубакирова Х. (2024). МЕТОДЫ СЕЙСМОЗАЩИТЫ ЗДАНИЙ. Наука и инновации в системе образования, 3(11), 42–47. извлечено из https://inlibrary.uz/index.php/sies/article/view/51145

Internet sites

1. https://yandex.ru/search/?
2. 2022-2-1%20.pdf https://samdaqi.edu.uz/sites/default/files/institut-ilmiy-jurnali/2022-2-1%20.pdf
3. Том 44, № 1 (2017) https://vestnik.dgtu.ru/jour/issue/download/18/19
4. СЕЙСМИЧЕСКАЯ РЕАКЦИЯ КАРКАСНЫХ ЗДАНИЙ С КОМБИНИРОВАННОЙ СИСТЕМОЙ СЕЙСМОЗАЩИТЫ https://vestnik.dgtu.ru/jour/article/download/373/337
5. СЕЙСМИЧЕСКАЯ РЕАКЦИЯ КАРКАСНЫХ ЗДАНИЙ С КОМБИНИРОВАННОЙ СИСТЕМОЙ СЕЙСМОЗАЩИТЫ. http://elibrary.ru/item.asp?id=29407216
6. ОПТИМАЛЬНЫЕ ПАРАМЕТРЫ СИСТЕМ АКТИВНОЙ СЕЙСМОЗАЩИТЫ СООРУЖЕНИЙ С РЕЗИНОМЕТАЛЛИЧЕСКИМИ ОПОРАМИ. http://elibrary.ru/item.asp?id=35390109
7. https://www.atlantis-press.com/article/125914134.pdf
8. http://omtc.knuba.edu.ua/article/download/225981/225689
9. https://www.researchgate.net/publication/361873696_Ensuring_the_seismic_resistance_of_a_building_using_a_geotechnical_seismic_insulating
10. http://dstu.ru/fileadmin/Dokumenty/Programmes/Dissertacija_Omarova_KH.M..pdf