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REVIEW ARTICLE

RESEARCH ON THE EFFECTIVENESS OF USING THE RUBBER-SOIL METHOD

M.S. Salauat, A.K. Aldigaziyeva, A.A. Bashayeva

Satbayev university, 050013, Almaty, Kazakhstan

Abstract. *The main purpose of the article is to study and analyze the seismic insulation of buildings. The effectiveness of reducing seismic impacts transmitted to the building through seismic insulation. During the study, experimental studies were conducted to evaluate the behavior of the rubber-soil mixture under seismic impacts. The method involves mixing recycled rubber with soil to create a cushion that absorbs and dissipates seismic energy. This method not only increases earthquake resistance but also offers an eco-friendly solution by using waste materials such as car tires. The effectiveness of the mixture was tested using standard compaction methods and instruments such as SOYUZDORNY and ZETLAB to measure the difference in accelerations. The results showed a significant reduction in the transmission of seismic waves, while the rubber-soil mixture showed lower acceleration values compared to conventional soil. In addition, this method is cost-effective and affordable, which makes it suitable for use in regions with limited economic opportunities and prone to earthquakes. The method also minimizes the complexity of construction and allows for faster implementation in various soil conditions. Its environmental benefits include reduced waste and minimal environmental impact, which contributes to the achievement of sustainable development goals. The rubber primer method, which reduces seismic impact and uses readily available materials, is a promising alternative to traditional seismic insulation methods. Thus, this approach provides a double advantage - increased safety, environmental friendliness and long-term sustainability of construction projects, providing an innovative solution to modern earthquake-resistant construction challenges.*

Keywords: *Seismic isolation, seismic waves, rubber-soil method, earthquake engineering, sustainable construction, ground vibration, seismic resistance.*

***Corresponding author**
Madina Salauat, e-mail: madina022102@gmail.com

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РЕЗЕҢКЕ-ТОПЫРАҚ ӘДІСІН ҚОЛДАНУ ТИІМДІЛІГІН ЗЕРТТЕУ

М.С. Салауат, А.Қ. Алдигазиева, А.А. Башаева

Сәтбаев университеті, 050013, Алматы, Қазақстан

Аңдатпа. *Мақаланың негізгі мақсаты – ғимараттардың сейсмикалық оқшауланууын зерттеу және талдау. Сейсмикалық оқшаулау арқылы ғимаратқа берілетін сейсмикалық әсерлерді азайтудың тиімділігі қарастырылды. Зерттеу барысында резеңке-топырақ қоспасының сейсмикалық әсерлер кезіндегі қасиеттерін бағалау үшін эксперименттік зерттеулер жүргізілді. Бұл әдіс қайталама өңделген резеңкені топырақпен араластырып, сейсмикалық энергияны сіңіріп, таратуға қабілетті жастықша жасауға негізделген. Аталған әдіс жер сілкінісіне төзімділікті арттырумен қатар, автомобиль шиналары сияқты қалдық материалдарды пайдалану арқылы экологиялық жағынан тиімді шешім ұсынады. Қоспаның тиімділігі стандартты тығыздау әдістері және SOYUZDORNY мен ZETLAB сияқты құралдар арқылы үдеулердің айырмасын өлшеу жолымен тексерілді. Нәтижелер сейсмикалық толқындардың берілуі айтарлықтай азайғанын көрсетті, ал резеңке-топырақ қоспасы кәдімгі топыраққа қарағанда төмен үдеу мәндерін көрсетті. Сонымен қатар, бұл әдіс шығын тұрғысынан үнемді әрі қолжетімді, сондықтан экономикалық мүмкіндіктері шектеулі және жер сілкінісіне бейім аймақтарда қолдануға қолайлы. Әдіс құрылыс үдерісін жеңілдетіп, әртүрлі топырақ жағдайларында тезірек іске асыруға мүмкіндік береді. Экологиялық артықшылықтарына қалдықтардың азаюы мен қоршаған ортаға зиянның төмендеуі жатады, бұл тұрақты даму мақсаттарына қол жеткізуге ықпал етеді. Сейсмикалық әсерді азайтып, оңай қолжетімді материалдарды пайдаланатын резеңке негізіндегі әдіс дәстүрлі сейсмикалық оқшаулау тәсілдеріне тиімді балама бола алады. Осылайша, бұл тәсіл қауіпсіздікті арттырумен қатар, экологиялық тазалық пен құрылыс жобаларының ұзақмерзімді тұрақтылығын қамтамасыз етіп, қазіргі заманғы сейсмотұрақты құрылыс міндеттеріне инновациялық шешім ұсынады.*

Түйін сөздер: Сейсмикалық оқшаулау, сейсмикалық толқындар, резеңке-топырақ әдісі, жер сілкінісі техникасы, тұрақты құрылыс, жер дірілі, сейсмикалық төзімділік.

***Автор корреспондент**
Мадина Салауат, e-mail: madina022102@gmail.com

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НАУЧНАЯ СТАТЬЯ

ИССЛЕДОВАНИЕ ЭФФЕКТИВНОСТИ ИСПОЛЬЗОВАНИЯ РЕЗИНОВО-ПОЧВЕННОГО МЕТОДА

М.С. Салауат, А.К. Алдигазиева, А.А. Башаева

Сатпаев университет, 050013, Алматы, Казахстан

Аннотация. *Основной целью статьи является изучение и анализ сейсмоизоляции зданий. Эффективность снижения сейсмических воздействий, передаваемых на здание с помощью сейсмоизоляции. В ходе исследования были проведены экспериментальные исследования для оценки поведения резиново-грунтовой смеси при сейсмических воздействиях. Метод заключается в смешивании переработанной резины с грунтом для создания подушки, которая поглощает и рассеивает сейсмическую энергию. Этот метод не только повышает сейсмостойкость, но и предлагает экологичное решение за счет использования отходов, таких как автомобильные шины. Эффективность смеси была проверена с использованием стандартных методов уплотнения и приборов, таких как SOYUZDORNY и ZETLAB, для измерения разницы в ускорениях. Результаты показали значительное снижение передачи сейсмических волн, в то время как резиново-грунтовая смесь показала более низкие значения ускорения по сравнению с обычным грунтом. Кроме того, этот метод является экономически эффективным и доступным, что делает его пригодным для использования в регионах с ограниченными экономическими возможностями и подверженных землетрясениям. Этот метод также сводит к минимуму сложность строительства и позволяет быстрее внедрять его в различных почвенных условиях. Его экологические преимущества включают сокращение отходов и минимальное воздействие на окружающую среду, что способствует достижению целей устойчивого развития. Метод резиновой грунтовки, который снижает сейсмическое воздействие и использует легкодоступные материалы, является многообещающей альтернативой традиционным методам сейсмоизоляции. Таким образом, такой подход обеспечивает двойное преимущество - повышенную безопасность, экологичность и долгосрочную устойчивость строительных проектов, обеспечивая инновационное решение задач современного сейсмостойкого строительства.*

Ключевые слова: *сейсмоизоляция, сейсмические волны, резино-почвенный метод, сейсмостойкое строительство, устойчивое строительство, вибрации грунта, сейсмостойкост*

***Автор-корреспондент**
Мадина Салауат, e-mail: madina022102@gmail.com

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CONFLICT OF INTEREST

The authors state that there is no conflict of interest.

АЛҒЫС / ҚАРЖЫЛАНДЫРУ КӨЗІ

Зерттеу жеке қаржыландыру көздерін пайдалана отырып жүргізілді.

МҮДДЕЛЕР ҚАҚТЫҒЫСЫ

Авторлар мүдделер қақтығысы жоқ деп мәлімдейді.

БЛАГОДАРНОСТИ / ИСТОЧНИК ФИНАНСИРОВАНИЯ

Исследование проводилось с использованием частных источников финансирования.

КОНФЛИКТ ИНТЕРЕСОВ

Авторы заявляют, что конфликта интересов нет.

1 INTRODUCTION

Currently, the main issue in construction is enhancing the seismic stability of buildings. Specialists are conducting numerous studies to address this problem. Today, there are several new methods for improving seismic stability. One of these methods is the rubber-soil method for reducing seismic effects. This article aims to understand the effectiveness of the rubber-soil method. During the research, soil was studied both individually and in combination with rubber, leading to conclusions and analyses. The research was conducted using the 'ZETLAB' device and software.

Seismic Waves.

There are two methods to protect buildings from seismic effects and external vibrations:

1. Protecting the structures from the entry of surface waves, which carry the main part of the seismic energy, by using isolation methods.
2. Constructive solutions aimed at creating earthquake-resistant buildings.

As a financially inefficient alternative to many seismic isolation methods, the soil-rubber method can be considered. This approach has been practically implemented in foreign countries, showing good results. For example, according to Zornberg's research, mixing 35-40% rubber with soil increases the strength of the mixture during displacement.

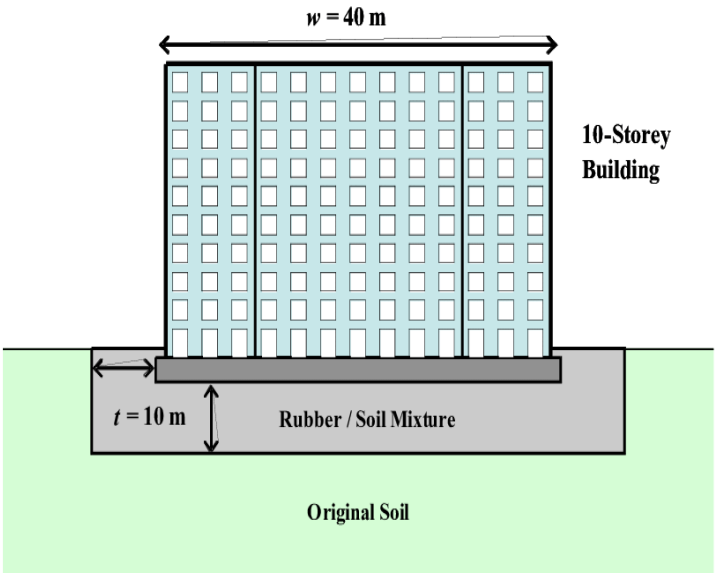

Figure 1 - Schematic drawing of the proposed seismic isolation method using a layer of rubber-soil mixture (RSM)-the cushion.

2 LITERATURE REVIEW

Among the many notable benefits are the capacity to lessen both vertical and horizontal ground vibrations as well as the significant consumption of the massive global stockpile of scrap tires. A number of parametric studies and numerical simulations have been run to show the resilience and efficacy of the suggested approach. It can, on average, reduce ground accelerations by 60–70% in the horizontal direction and 80–90% (**Fundamentals of the Theory of Seismic Stability of Structures**) in the vertical direction.

Five key concerns have been recognized with respect to the idea and practicability of the suggested approach: (1) nonlinear site response; (2) soil resonance effects; (3) liquefaction; (4) ground settlement; and (5) environmental consequences. (**Hing Ho Tsang & Nelson Lam, 2007**).

A inexpensive and easy seismic isolator that can shield low-rise buildings from earthquake disasters is the rubber-sand mixture (RSM) cushion. Examining how isolated systems behave seismically under various site circumstances is crucial. (**Energy dissipation capacity of rubber-soil systems under cyclic loading**) The main purpose of the article is to study and analyze the seismic insulation of buildings. The effectiveness of reducing seismic impacts transmitted to the building by means of seismic insulation. In the course of the study, experimental studies were conducted to evaluate the behavior of the rubber-soil mixture under seismic influences. The method involves mixing recycled rubber with soil to create a cushion that absorbs and dissipates seismic energy. This method not only increases earthquake resistance, but also offers an eco-friendly solution by using waste materials such as car tires. (**Rationing in earthquake-resistant construction**)The effectiveness of the mixture was tested using standard compaction methods and instruments such as SOYUZDORNY and ZETLAB to measure acceleration differences. (**Designing earthquake-resistant structures**) The results showed a significant reduction in the transmission of seismic waves, while the rubber-soil mixture showed lower acceleration values compared to conventional soil. In addition, this method is cost-effective and affordable, which makes it suitable for use in regions with limited economic opportunities and prone to earthquakes. This method also minimizes the complexity of construction and allows for faster implementation in a variety of soil conditions. Its environmental benefits include reduced waste and minimal environmental impact, which contributes to the achievement of sustainable development goals. The rubber primer method, which reduces seismic impact and uses readily available materials, is a promising alternative to traditional seismic insulation methods. Thus, this approach provides a double advantage - increased safety, environmental friendliness and long-term sustainability of construction projects, providing an innovative solution to the challenges of modern earthquake-resistant construction.Site classification by utilizing 195 ground motion records with various response spectrum characteristics, notwithstanding the actual site's complexity. (**Mengtao Wu & Wenhui Tian, 2023**).

This technique is very much cost effective in comparison with other conventional techniques. Besides, the installation process of this technique is also very much easier. So, this technique can be used in economically backward yet earthquake-prone countries. So, using this type of seismic isolation can be very cost effective and a simpler alternative to earthquake hazard mitigation than conventional base isolation techniques. (**Radhikesh P. Nanda & Sayantan Dutta, 2018**).

3 MATERIALS AND METHODS

"The equipment for testing soil using the standard compaction method includes the following components: a device for mechanically or manually compacting the soil, (**Seismic isolation using rubber-soil mixtures: concept and feasibility**) a mold for the soil sample, and a SOYUZDORNIY device. Looking at the images provided, we can observe the differences in acceleration. During the research, clay and rubber were first mixed in a 60/40 ratio and tested. The prepared rubber-soil mixture is compacted using the 'SOYUZDORNIY' device. (**Seismic safety of buildings and structures**) The prepared mixture is placed into the device. The soil sample examination was conducted in the following order:

- The sample was transferred from the desiccator to a metal cup and thoroughly mixed.
- Soil was placed into the mold to a thickness of 50-60 mm, compacted by hand, and excess soil was removed.

- Compaction was carried out by dropping a weight 40 times from heights of 10 cm, 20 cm, and 30 cm onto the soil.

- Each time the weight was dropped from different heights, results were recorded using 'ZETLAB'." (**Seismic performance of rubber-sand mixture cushion under varying site conditions**)

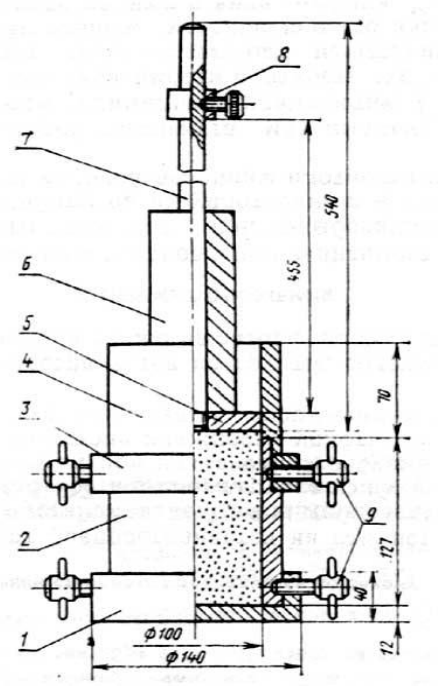

Figure 1 – Device “SOYUZDORNIY”

4 RESULTS AND DISCUSSION

The differences in accelerations within the mixture were identified using the device shown below.

Figure 2 – Device “ZETLAB”

Using the provided device, we determined the effectiveness of the rubber mixture. First, we examined the results by testing only the soil. Then, we conducted research by combining rubber and soil. We noticed the differences between the two. (**Earthquake-resistant structures of buildings**)

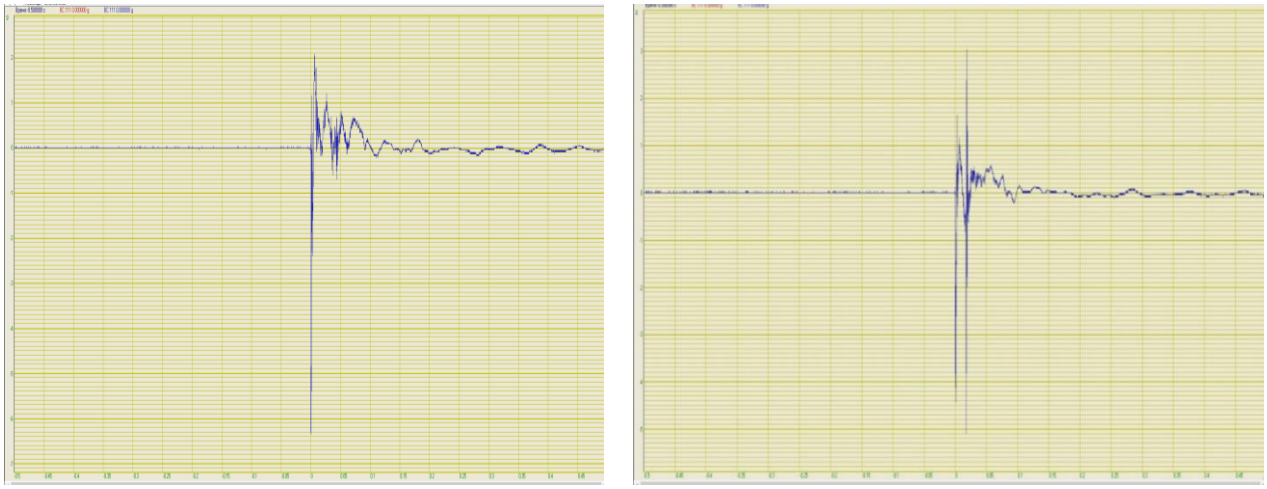

Figure 3 – Results of using clay in the ZETLAB

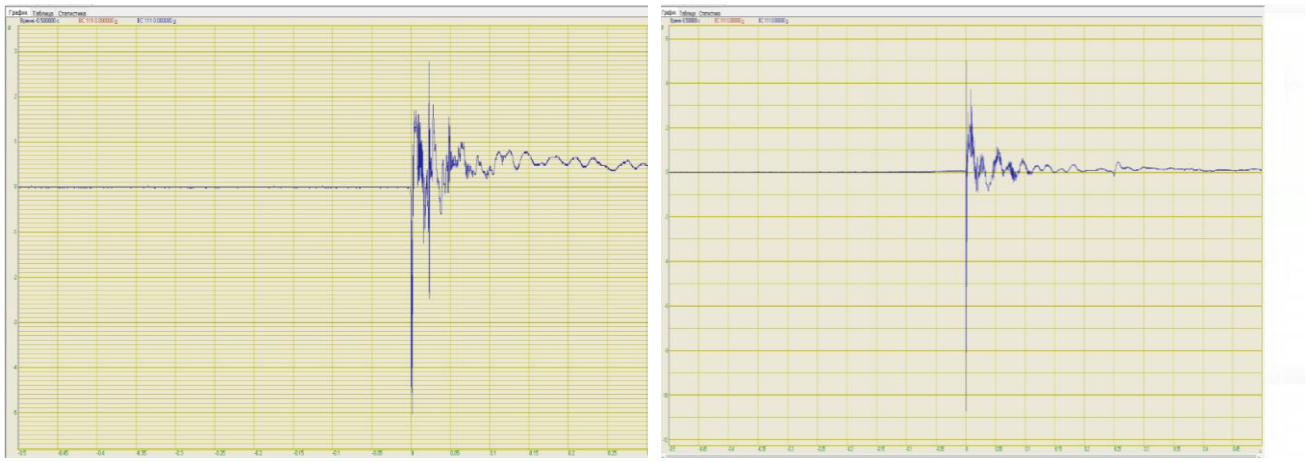

Figure 4 – Results of using the rubber and soil method in the ZETLAB program

In addition to the observed reduction in acceleration values, it was noted that the rubber-soil mixture exhibited enhanced energy absorption characteristics (**GOST 22733-2016**). This indicates that the mixture not only dampens seismic waves but also dissipates a significant portion of the energy, thereby protecting the structure from sudden shocks. The rubber component, due to its elasticity, contributed to reducing both vertical and horizontal ground motion, as confirmed by the data obtained through the ZETLAB system (**Construction in seismic zones**).

Moreover, the stability of the mixture under repeated cyclic loading was tested, simulating aftershocks. The results showed that the rubber-soil mixture maintained its structural integrity without noticeable degradation in damping capacity. This resilience suggests its potential for long-term use in seismic isolation applications, particularly in regions experiencing frequent seismic activity (**Soil behavior during earthquakes**).

Furthermore, field modeling and small-scale structural simulations demonstrated consistent

performance across varying moisture contents in the soil, which is a critical factor in real-world conditions. The mixture's adaptability to different site environments further enhances its practical value (**Dynamic properties of tire-derived aggregates for seismic applications**).

5 CONCLUSIONS

In the last two to three decades, the global scientific community's attention to ensuring the seismic stability of structures using seismic isolation methods has significantly increased. Dozens of articles and reports of both theoretical and practical nature have been published, and international conferences are being held. In the Republic of Kazakhstan, several initiatives have also been established on this topic, and the work of domestic scientists plays an important role in this field; however, the scope of practical application is significantly lower compared to foreign countries.

To summarize the research conducted, we observed differences in the values of accelerations. The results demonstrated the effectiveness of the method of adding rubber to clay. As the acceleration values decreased, the effects of seismic waves also diminished. Therefore, the method of combining clay and rubber is effective in reducing seismic effects and is also economically beneficial.

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