17th World Conference on Earthquake Engineering, 17WCEE 2020
Sendai, Japan, September13th to 18th 2020

NEW SYSTEM OF SEISMIC ISOLATION. THE METHOD of SEPARATION of INERTIAL MASSES (MSIM)

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Abstract

"New seismic isolation system “The Method of separation of inertial masses (MSIM) "

The report outlines the essence of the development, which is based on two patents: 1. On the invention "Planar rolling bearing and the method of its application in seismic foundations for the protection of buildings and structures from horizontal oscillations of the earth's crust during earthquakes." and 2. On the utility model "Flat block of rolling elements for planar rolling bearings in seismic construction". For the first time in the world, we have the opportunity to completely separate the inertial mass of the building from the earth's crust, that is, to achieve a real isolation of the building or structure from the horizontal (horizontal components) oscillations of the earth's crust. The device is made of traditional building materials in normal construction conditions, and its use ensures the preservation of the working parameters of buildings and structures after the strongest earthquakes! The method of creating earthquake-resistant foundations using a planar rolling bearing is called "the method of separation of inertial masses (MSIM)". The simplicity of its application in the foundations, the possibility of maintenance and repair of planar rolling bearings during operation and after earthquakes makes it possible to widely use the method of separation of inertial masses, both in new construction and in improving the stability of existing residential buildings, basic facilities and life support systems.

Keywords: separation of inertial masses; real isolation; planar roller bearing; two degrees of freedom; two damping systems; cheapest system of seismic isolation; excluding of damage.

1. Introduction

New system of seismic isolation. "The method of separation of inertial masses (MSIM)".

I thank the organizers of 17WCEE for the invitation and the opportunity to present my development, which is called "The method of separation of inertial masses (MSIM)". The development is based on two patents: 1. Invention "planar rolling bearing and method of its application in seismic Foundations for protection of buildings and structures from horizontal oscillations of the earth's crust during earthquakes"- patent No. 2545569 of February 26, 2015; and 2. Useful model "The flat block of rolling elements for planar rolling bearings in seismic construction" - patent No. 172329 dated July 4, 2017. The inventor and patents owner is your humble servant. My name is Rais Bikmaev. I am a citizen of the Russian Federation. Isolation in an ideal sense means the complete separation of buildings (structures) from the earth's crust, when the earth's crust under the influence of seismic waves is set in motion, but the building (structure) because of its inertia remains at rest. The idea to install buildings on balls or other moving elements, that is, to separate the inertial mass of the building from the earth's crust exists in the world for hundreds of years. There are even patented inventions using spherical rolling elements and other elements, but because of their illusory nature, these inventions have not found their application. And only today, for the first time in the world, we have the opportunity to finally mechanically separate the inertial mass of the building from the earth's crust by placing planar bearings on the ledges of the foundations. Planar bearings cut the Foundation into the upper (fixed) part and the lower (movable) part. The author called this system of seismic isolation «The method of separation of inertial masses (MSIM)". This possibility appeared in connection with the use of cylindrical rolling elements in two parallel layers (rolling fields), located crosswise to each other.

2. The essence of the invention.

2.1. The essence of the invention lies in the design of planar roller bearing (PRB) and method of its use in the seismic Foundation. That is, patented not only the device itself, but also the method of its application.
Allow me to explain the essence of my invention:
Planar roller bearing got its name due to the fact that it consists of three situated horizontally, one above other, flat square or rectangular steel sheets (plates) with high plane properties, between which are placed rolling elements, rods of conventional high strength stainless steel wire with a diameter of 5 mm and step of 10mm in a special backplane device - "carriage". The upper and lower steel sheets of thickness not less than 10mm, and the average steel sheet with thickness of at least 3 mm. Thickness of the steel sheets can be changed in accordance with loads. To the upper steel sheet and to the lower steel sheet (top and bottom of the bearing), rubber sheets with a thickness of 10mm are pre-glued. The rubber evenly redistributes the load to all rollers throughout the Foundation and also partially absorbs vertical loads. Between the first and second steel sheets in the bottom layer the rolling elements are arranged in a direction oriented along the longitudinal axis of the building, and between the second and third sheets, in the top layer, in the direction perpendicular to the first - oriented along the transverse axis of the building. Strictly speaking, the rolling elements into the top and bottom layers are placed cross to each other and oriented along the main axes of a building (structure).
Why did I choose the diameter of 5 mm and step 10 mm? Because, in this case, two line segment of rollers with a length of 10mm (top and bottom) perceive the load on one square centimeter area of the rolling plane of the bearing. This arrangement is selected for illustrative and ease of calculation.
Vertical load from the weight of the building, dynamic loads, snow loads and other loads on the one square centimeter. In real projects the steps of the rolling elements should be selected with consideration of all loads and can be greatly increased. In any case, all loads must be calculated on one linear centimeter of roller. Also, such a diameter allows combine the rolling elements into a single unit - (original device the carriage), from which the rolling elements do not fall out even with very intensive vibrations (displacements) of the earth's crust.

2.2. Mandatory requirements.
For the effective application of the method of separation of the inertial masses (MSIM) in the seismic foundations, required the execution of three main conditions:
2.2.1. The Separation of the inertial masses, that is, the body of the building is separated from the "table", from the earth's crust by implanting planar roller bearings in the body of the Foundations on the ledges of the Foundations;

2.2.2. Installation on each ledge of the Foundation the crumpling elastic-dampers between the bearing (fixed) and moving part of the Foundation from a deformable viscous elastic materials which provides shock absorption the horizontal inertial loads and allow fixing of the building in the design position;
2.2.3. Installation of deformable zone around the perimeter of the building in the level moving (relative to earth's crust) part of the Foundation from materials of backfilling or special designs from deformable, viscous-elastic materials with a thickness corresponding to the maximum calculated amplitude of oscillations of the earth's crust.
Deformable zone around perimeter of the building, in addition to deformable dampers on the ledges of the Foundation, provides fixation of the buildings in the design position and the energy absorption of seismic oscillations.
The subgrade combines the lower part of the Foundation into one solid block, and the stiffness of the upper part of the Foundation is provided by a monolithic disk of overlapping.

2.3. Two degrees of freedom.
Since rolling bodies (rollers) in two parallel planes are oriented along the main axes of the building and are located crosswise to each other, the building has the ability to move in a horizontal plane in any direction by 360°. In this case, torsion is excluded, since the rollers in two planes roll strictly each only in its direction. To verify this, put two round pencils on the table, put a book on top of them; put two more round pencils on the book perpendicular to the lower pencils and one more book on pencils. Now try moving the top book in any direction along the horizon. Under your influence, the top book will roll in a horizontal plane in any direction and there will be no torsion of building (top book).

2.4. Technology of implantation of the planar rolling bearing to the foundation body
The technology of implanting a planar rolling bearing into the Foundation body is very simple and does not require special skills of workers.
First, on the freshly laid concrete on the ledge of the Foundation horizontally, it is necessary to lay the lower steel sheet of the planar bearing with a rubber layer down. The horizon must be checked using geodetic instruments. In this position, the lower bearing sheet is left until the concrete hardens (2-3 days). After concrete solidification, the final field Assembly of the flat bearing is carried out, and the upper steel sheet is laid with a rubber layer upwards. Then collect the formwork and placed concrete to the top part of the Foundation. Thus, planar roller bearings are organically and tightly implanted into the Foundation body.

2.5. Damping devices.
From the top side of each ledge of the basement before the plane bearing retained niche, corresponding to a calculated value of the maximum oscillation amplitude (displacement) of the earth's crust. In these niches are installed dampers from deformable materials (wood, rubber, foams, foam, etc.). Due to the fact that the area of crumpling dampers are known, we can easily calculate the total area of the crushable dampers, and on the basis of the inertial mass of the building, and the modulus of elasticity of materials to choose the construction materials for the manufacture of these dampers. The author prefers the foam because of its durability and ease of installation during pouring of the Foundation. That is, before the concrete casting of the upper part of the Foundation in the formwork (niche) just installed prism of foam, sealed in plastic wrap. The foam has another very important property. Deforming, it not immediately regains its shape as it happens, for example, with a spring or rubber. This property allows damp the oscillations, but not to aggravate them additional elastic reaction. The crushable perimeter of the building becomes the main damping device, which takes most of the load from the inertial mass of the building.

2.6. Flat blocks of rolling elements (Flat Backs).
For the successful implementation of the method of separation of the inertial masses (MSIM), as additional, by me was patented useful model for PRB. It's called the "Flat block of rolling elements for a planar rolling bearings in seismic construction" (Flat Backs).
Field of the rolling plane of the bearing is forming from the necessary number of plastic "Flat Backs", depending on the size of surface of the planar roller bearing. Plastic Flat Backs are welded to each other by melting with use the thermoelectric knife or extruder forming the whole rolling plane. Currently prototypes of the Flat BAKs manufactured. They were successfully tested and are preparing to mass-produce them.
Flat Backs (plastic carriage) is molded in injection molding machines. Its size in plane 401 by 201мм and a thickness of 4.0 mm, in which are mounted rollers with a diameter of 5.0 mm and a length of 195mm of

high-alloy stainless steels. Bulkheads of carriage with cross-section of 4.0 by 4.0mm distributed in the lattice with a step of 10mm. Outer transverse bulkhead with cross-section of 3,0 by 4.0 mm and the outer longitudinal bulkheads with cross-section of 3.0 by 4.0 mm. Between the bulkheads the gaps with cross-section of 6.0 by 4.0 mm and length 195 mm, with a step of 10 mm – a total of 40 pieces, in which should be inserted to 40 pieces of cylindrical steel rollers with a diameter of 5.0 mm and a length of 195mm (Fig.1). Depending on the load on the Foundation steel rollers in the carriages can be set with step of 20mm, or even 30mm.

2.7. Load capacity of the rollers.

Rollers with a diameter of 5.0 mm and a length of 195mm made of high-alloy stainless steel with indicators allowable stress in pressure for at least 500-600 MPa for the variable (pulsating) loads. Rollers can be also made from appearing in the recent new composite structural materials that should be in accordance of the requirements of strength and durability, as well as neutrality for oils and aggressive environments.

As for strength, steel roller with a length of 10 mm (1 cm) is able to take the load up to 100 kg (allowable stress for alloy and high-alloy steel). Taking into account the fatigue limit of metals under dynamic loads and with the loss of up to 10-15% of the area in the plane of displacement of the rolling bearings, we can easily ensures several times the limit of allowable stress! Load capacity of the steel rollers are huge! It should be noted that the steel rollers of flat roller bearings must be quite loaded – at least 3-5 kg/cm per unit length to create enough friction force to prevent sliding of steel roller between a steel plates of the planar bearing. On the other hand these loads are necessary in order to neglect of inertial masses of rollers. With the weight of 10mm of steel roller 1.54 grams, load from 3-5kg exceed of own weight of the roller nearly 2000-3500 times, allows to neglect the own weight of the rollers.

3. Which casts doubt on the efficiency of the MSIM.

3.1. The inertia of the rollers.

Because a lot of them. With the richest variant of completeness of the planar bearings on the one square meter, we have 1000 rollers with a diameter of 5mm and a length of 195mm. The weight of one roller is 30 grams. The weight of the Set is 30 kilograms.

The weight of the steel roller with a length of 10mm - one and a half gram!

With loads on the one linear centimeter (10 mm) of roller from 3kg to 25kg or more, the weight of the roller to several thousand times smaller than the load. It allows neglect of its own inertial masses of rollers.

3.2. Force of rolling friction.

As is known, the reaction from of rolling friction only occurs when the deformation of the rolling elements in contact with the plane rolling. We consider only the elastic deformation, since plastic deformation is not allowed to recognize the rollers round.

That is, the stronger material (steel) - a smaller coefficient of rolling friction.

In any case, resistance forces arising at the points of contact of rolling elements with the plane of the bearing should be close to zero, and this can be achieved only through the selection of more durable materials for the rolling elements and steel sheets.

Requirements for hardness of the rolling elements and the rolling surfaces should be adequate for the calculated loads. That is, the strength of structural materials is easily calculated and selected from catalogs.

3.3. The corrosion instability of metals (steel) in a humid environment.

It should be noted that this argument is one of the most serious against the use of the method of separation of the inertial masses. But, on the one hand, we have the age-old practice of long-term preservation of metals from corrosion, and, on the other hand, we can use high-alloy stainless steel which excludes not only superficial, but also internal structural corrosion.

The ability to repair after the earthquake and the possibility of a planned replacement at end of lifetime is a very strong argument against the corrosion.

After the earthquake, using a system of horizontal jacks, first, the building returns to its original (designed) position and, if necessary, repair of planar bearings, and in the niches should be installed new dampers instead of the removed old. At the perimeter of the building restores the crumpling zone with the replacement of the used materials.

4.Economy. The cost of one square meter of flat roller bearing in its most saturated version of stainless steel with rubber, with anthers and with preservative grease is not more than 3000USD.

For an approximate calculation of the cost of using the method of inertial masses separation, we take the 24-storey residential building presented in the experiment, with dimensions of 32M x 32M and 75m of height. The maximum weight of this building is 20,000 tons. Taking into account the dynamic coefficient of 1.5 which corresponds to the earthquake intensity with magnitude 8 of Richter (9-10 points on the MSK-64 scale in Russia) the weight of the building will be 30 000 tons. With a load of 20.0 kg per square centimeter of planar bearing, we need 150 square meters of rolling bearings, with a load of 15kg = 200, with a load of 10kg = 300 and with a load of 5kg = 600 square meters of rolling bearing. The estimated cost of the building without engineering systems and finishing is 30 000 000 USD.

The estimated cost of MSIM: 3000 x 150 = 450 000$; 3000 X 200 = 600 000$; 3000 x 300 = 900 000 $. 3000 x 600 = 1800 000$. The cost of seismic isolation system in the total cost of the building, respectively, in the first case = 1.5%, in the second case = 2.0%, in the third case = 3.0% and in the fourth = 6%. These figures are unprecedented for earthquake-resistant construction. They indicate that, MSIM is the world's cheapest seismic isolation system.

For the first time in the world, we have the opportunity to refuse the high standards of design of structures and elements of buildings as for clamped into the ground base, or limit their strengthening to a reasonable level. I am referring to simplifications in the design of building elements, of course, given the seismic activity of the territory. It is enough to provide for each given building the maximum longitudinal and transverse stiffness, but special seismic calculations are performed only for areas with maximum seismic activity. That is, when using MSIM in earthquake-resistant construction, the seismic activity of the territories can be safely reduced by two or three points. In this case, we are talking about the optimization of the economy in the construction of earthquake-resistant buildings. With all responsibility, I predict a decrease in the cost of earthquake-resistant construction worldwide by 10-15%!

5. Design-dynamic model. Principles and benefits

The excluding of the elastic reactions in the structures and elements of buildings during horizontal oscillations of the earth's crust until complete exhaustion of the softening ability of the dampers on the ledges of the basement and around the perimeter of the building becomes the main advantage of the method of separation of inertial masses over other known systems.

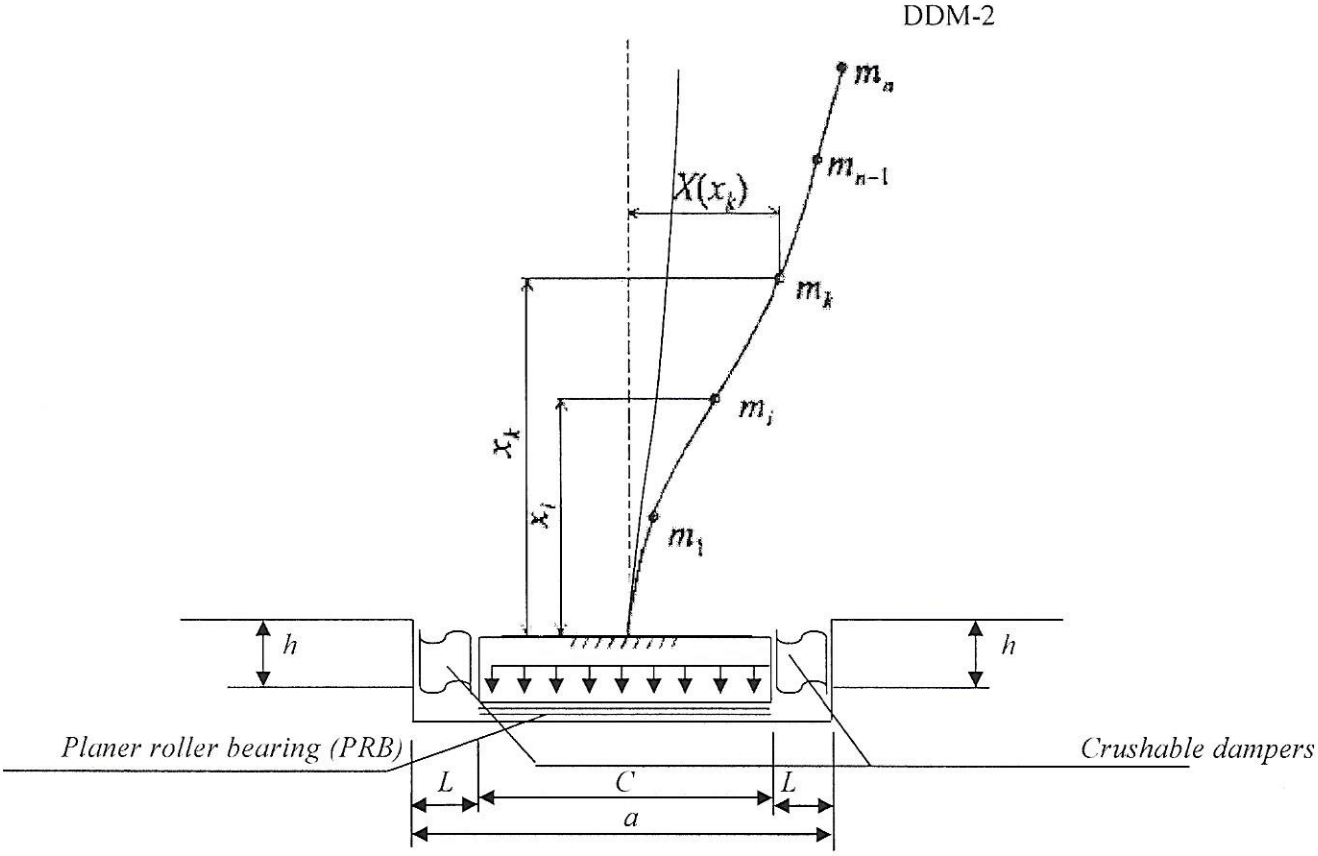


Fig.1

On the Fig.1 presented design scheme (design-dynamic model) DDM-2 for the method of separation of the inertial masses. To calculate the planar bearings, dampers and other parameters within a given oscillation amplitude, additional geometric and physical data are required, as indicated below DDM-2 (dynamic calculation model):

a - is the length of the Foundation ledge;

b –transverse dimension of q (the width of the Foundation);
c- Longitudinal size of the PRB;
h - Height of the clamping damper;
L - Maximum calculated amplitude;
d - Distributed inertial mass (total weight of the building and all other vertical loads) per unit of reference area. Design-dynamic model (DDM-2) for the method of separation of inertial masses remains exactly the same as DDM-1 [1] for the calculation of the limit states for particular load combination but with a few additions from below. The method of separation of inertial masses and the method of calculating elastic reactions naturally complement each other.
First, within the maximum estimated amplitude begins to act the method of separation of inertial mass (DDM-2), and then, after the exhaustion of the possibilities of dampers, the loads starts transferring on the top of the Foundation and on the building itself and only then in the structures of the building emerge tensions caused by the inertial seismic loads (DDM-1). But, by this time the maximum design load should be end! What about vertical loads?
What usually happens in hard nodes of buildings and structures? The horizontal loads and vertical loads aggravating to each other to destroy the hard node and convert it to a hinge. The building collapses. In my case, vertical load is cut off and appears in a pure form and it is easy to take into account using the coefficient of dynamic.
The report outlined the technology of implanting PRB in the foundations of buildings during new construction. But, very important, we have the possibility to implantation of PRB in the foundations in existing buildings and facilities. It's enough to cut the slits in existing foundations and after installation PRB made the padding concrete into slits. Then necessary to install the dampers on the ledges of the Foundation and around the perimeter of the building.
The method of separation of inertial masses does not negate any of the postulates in existing regulations for construction in seismic areas, but rather fits into the theoretical scheme of these regulations. As soon as the dampers on the ledges of the basement and dampers along the perimeter of the building will exhaust its possibilities, they will transmit seismic impacts to the upper part of the Foundation and to the building itself. This is possible with the occasional unpredictable increase of seismic activity. But we should not be afraid. Because we have the huge base of earthquake monitoring and written records of instrumental observation around the world. Having such data, we can with the probabilistic accuracy assign the maximum amplitude of the earth's crust for any territory. Errors will excluded by the application of the safety factor (1.1 -1.3).
With confidence we can say that the method of separation of inertial masses puts off the moment of impact of the seismic loadings on the buildings and structures. In fact, using this method (MSIM) in the design of earthquake-resistant buildings, the regulatory value of seismic activity of areas we can reduce on the 2-3 points by Richter (for Russia on 2-3 points on the MSK-64 scale).
I think a fair indication of regulatory documents that the Buildings and structures with application of seismic isolation systems should build, as a rule, on soils of I-II categories by seismic properties. If necessary the construction on the grounds folded by soils category III-IV requires special justification. For soil category III and IV, I would also like to note that the method of calculations bases on the soil subsidence are unwanted due to the possible inclinations of the planes of the bearings. In this case, I consider it necessary the use of soil replacement or strengthening grounds by installing driving piles.
And very important point of application of MSIM is the ability to use the hanging piles because MSIM due to the softening abilities of dampers excludes the critical rocking of the piles during the earthquake, which excludes the reduction of the friction forces side surface of the piles.

The benefits of MSIM compared to other systems:

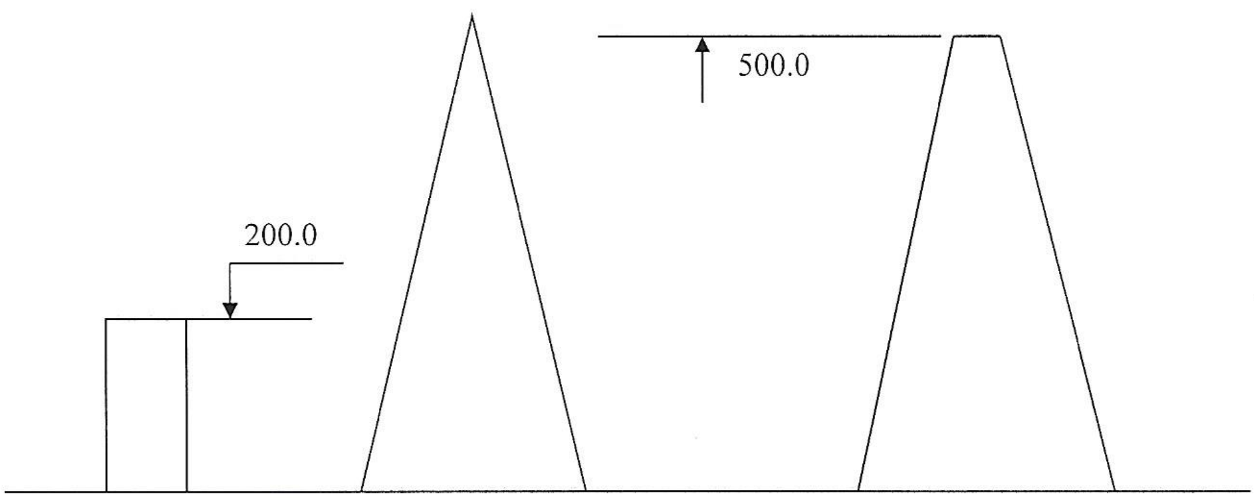
1. Passive seismic isolation system on the principle - "Built-Forgot»;
2. Use of the entire area of the Foundation support surface;
3. Huge bearing capacity of PRB - up to 1000 tons per 1m2;
4. The bearing thickness (PRB) is 55-80mm, but the insulating layer thickness is only 10mm! The safety of the building in case of destruction of the planar bearing is ensured!
5. Service life of MSIM-100 years without replacement of materials;
6. The ability to absorb horizontal alternating movements of the earth's crust during earthquakes is much higher (ten times more). That is, significantly increased the possibility of horizontal displacements of the superstructure relative to the substructure, compared with other seismic isolation systems (up to 600 mm), which allows to absorb all the energy of the earth's crust oscillations.

7. The possibility of any damage after the strongest earthquakes is excluded. There is no need for special calculations of the absolute limit state (Risk Reduction of Disaster). Significantly reduces the requirement for such calculations. For each project it is enough to provide the maximum longitudinal and transverse stiffness and sufficient bearing capacity of the passing structures (overlapping, beams, etc.)
8. It eliminates the need for special structures that limit the movement of the building beyond the calculated amplitudes. These limiting structures are ledges of the Foundation and soil backfill around of foundations.
9. A negligible inertial mass of rolling elements in comparison with loads, which allows the PRB to react extremely thinly to alternating horizontal displacements of the earth's crust with different oscillation frequencies from minimum up to 50HZ.
Important! The frequency characteristics of earthquakes do not matter!
10. The weight of one roller with a length of 195mm - 30грамм. The load capacity of the roller is up to 2000kg. Loads can exceed the weight of the roller in tens of thousands of times, which allows you to neglect its own inertial mass of rollers.
11. Possibility of repair after earthquakes, and also, planned replacement during operation if such need arises;
12. Guaranteed preservation of operational parameters of buildings and structures after the strongest earthquakes. Important! Not limitation of damage, but exclusion of damage!
13. The cheapest and most effective seismic isolation system in the world!

CONCLUSION:

The content of the report confirms the significant advantage of the method of separation of inertial masses using flat rolling bearings over all other seismic isolation systems for mass construction, with the exception of high-rise buildings, where horizontal vibrations of the earth's crust in the foundations can cause negative loads. However, it is not so much the height of the building, but its size in terms of volume and planning solutions. When choosing the height of the building for MSIM, it is necessary to take into account its dimensions in the plan. There should be limits to the normative ratio of the height of the building (prism) to its dimensions in the plan, no more than 4 or 5. The load capacity of flat rolling bearings is sufficient for the construction of buildings with a constant unchanging regularity in height up to 200 meters. Buildings of greater height-up to 500 meters can also be constructed using MSIM, but then the shape of the building should be an elongated pyramid or truncated pyramid, that is, with a constant changing regularity along the height. (Fig.2)

Many people may ask why the report does not present theoretical mathematical calculations confirming the validity of the super efficiency of the new seismic isolation system. I usually answer this question as follows. The tests of method of separation of inertial masses on a vibrating table have shown that the loads from the horizontal oscillations of the base are reduced in dozens of times. This gives me the right to say that even in the strongest earthquakes the loads are reduced to such a minimum, when special calculations for seismic loads are not required. It is enough to provide the maximum for each object longitudinal and transverse stiffness and increased bearing capacity of the overlapping.



Фиг. 2

In Fig. 3 below shows the principle of the destruction of the lower part of the building when it exposed to horizontal oscillation of the earth's crust during earthquakes.
During horizontal oscillations of the earth's crust the main inertial mass of the building remains stationary and the lower part of the building, carried away by the Foundation collapses. In the end, there is the collapse. The upper part usually falls on the lower part and is destroyed completely, or remains standing in a dilapidated condition.

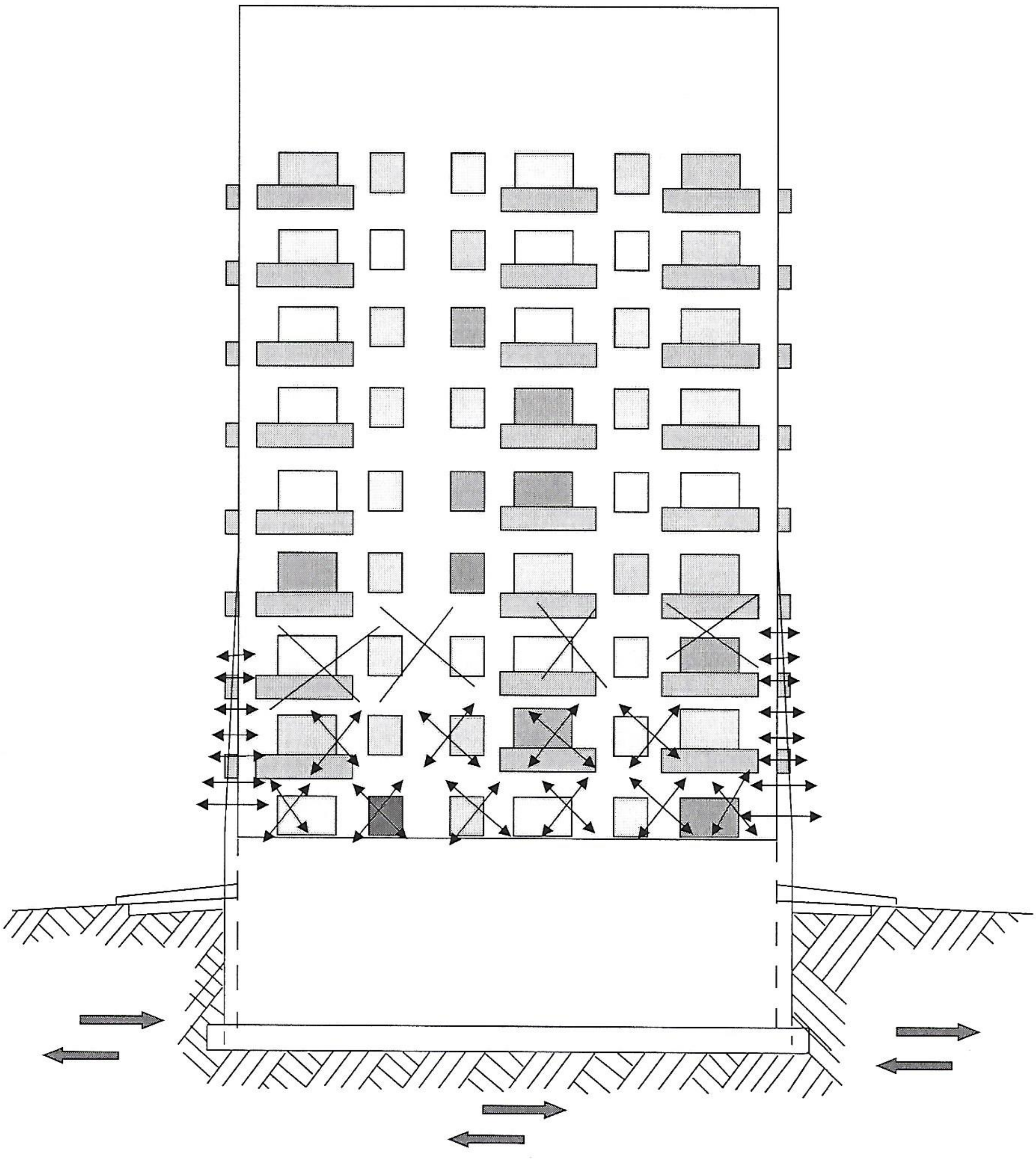


Fig.3

In Fig.4 shows a method of separation of the inertial mass in action. The inertial mass of the building is separated from the inertial mass of the earth through the introduction (implantation) of planar roller bearings in the body of the Foundation. Horizontal ledges of the Foundation on which installed planar roller bearing cut the foundation on the upper stationary and lower movable parts. And viscous-elastic dampers installed on the benches of the foundation and along the perimeter of the building largely reduce the impact of horizontal oscillation of the earth's crust on the building. The building remains unharmed.

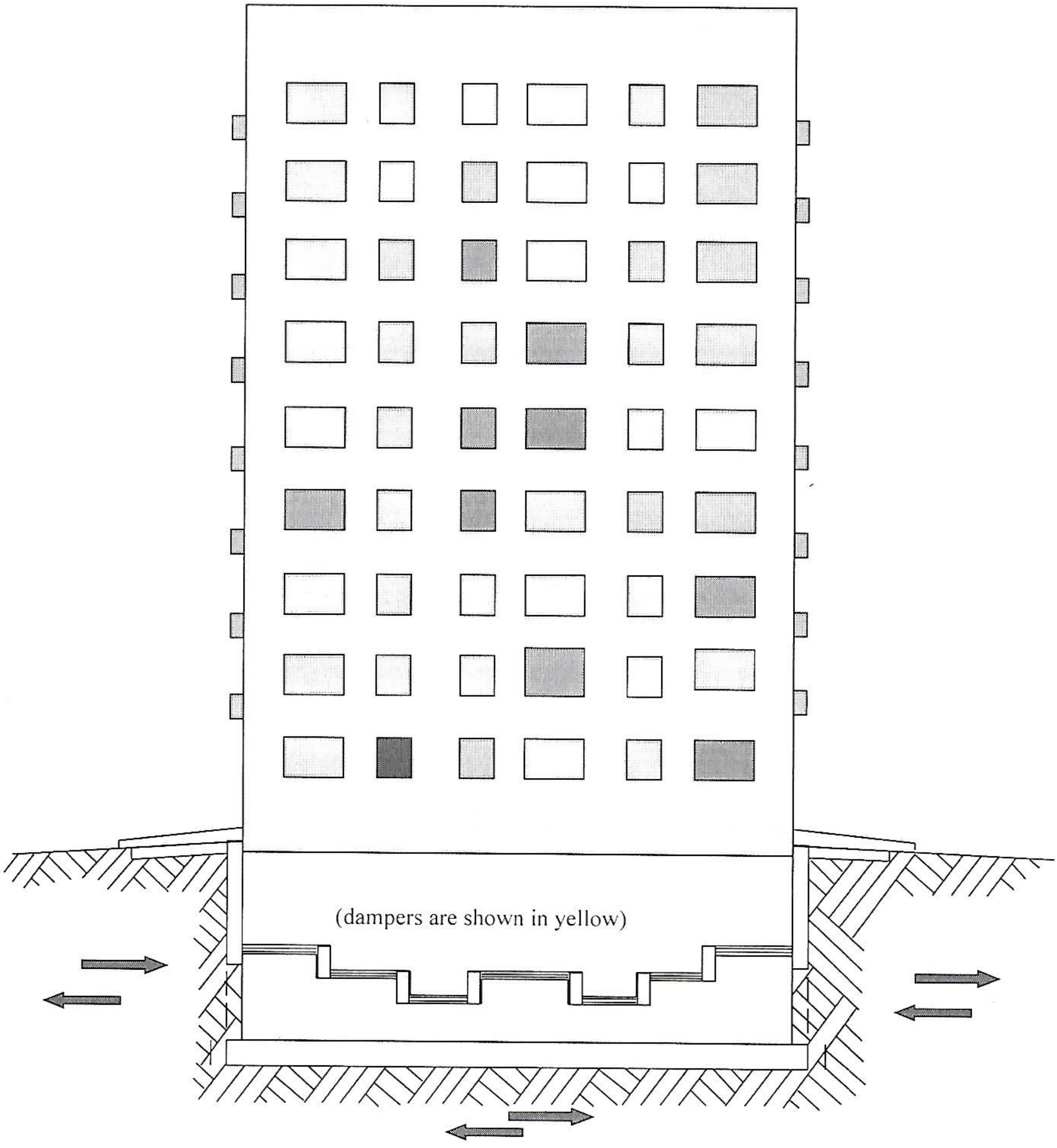


Fig.4

Theoretical substantiation.

The tests conducted with use MSIM showed that planar rolling bearings can reduce seismic loads from horizontal vibrations of the earth's crust tenfold! This fact gives me the right to say that the use of MSIM will not only limits the damage from strongest earthquakes, but also excludes any destruction!
A mathematical description of the loads that occur in building structures when using MSIM can be represented as:

$$F = \frac{M \bullet A \bullet k_1 \bullet k_2 \bullet k_3 \bullet k_4 \bullet k_n \bullet k_{n+1}}{10 \div \infty}$$

This means that loads in building structures and building elements are reduced by ten times or more when using MSIM…
In a number of countries, seismic loads in buildings using seismic isolation systems are calculated using a modified acceleration spectrum (the acceleration spectrum transformed by the seismic isolation systems). To do this, they develop a theory to determine the decrease in the value (modification) of the acceleration spectrum.
If we rely on the method of calculation using modified acceleration spectra, I argue that the loads arising in the superstructure (over insulators) during the strongest earthquakes will not be greater than in earthquakes of magnitude 5 on Richter. This is the revolutionary nature of the MSIM, which in itself does not require any special calculations. In Russia, the 12-point scale MSK-64 was adopted for calculations. Only those objects that are located in areas with a normative seismic activity of more than 6 points are subject to seismic resistance calculation. For Russia, the loads arising in the structures of buildings during the strongest earthquakes will be no more than 6 points MSK-64 at the facilities using MSIM. That is, the objects built with the use of MSIM, go beyond the interests of regulatory documentation for earthquake-resistant construction!
My Motto: No destructions! No Deaths! Never!

1. References

[1] The set of rules SP 14.13330.2018 "Construction in seismic regions", Chapter 5. "Seismic loads"

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