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SEISMIC ISOLATION OF BUILDINGS AND HISTORICAL MONUMENTS. RECENT DEVELOPMENTS IN RUSSIA

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SUMMARY

The history of seismoisolation research and application in Russia and former USSR is presented. Different types of seismoisolation systems implemented in buildings, historical monument are described. A specific kinematics rocking support isolation system, mild steel column isolation system and other systems are presented. Some examples of seismoisolation of existing historical buildings, including a bank building and church in Irkutsk-city (Siberia) are demonstrated in detail. All steps of installment of the steel-rubber supports in the bank building foundation are given. The mathematical models and results of dynamic analysis of the seismoisolation systems are presented.

INTRODUCTION

In the beginning of the 70-th a program of analytical and experimental investigations of structural seismoisolation was carried out Earthquake Engineering Research Center, TsNIISK, Russian Construction State Committee, Eisenberg, [1].

The strong motion accelerograms up to the present time demonstrated very different predominant periods of earthquake ground motions not only during different earthquakes but sometimes even during the same earthquake at distant and the close distances, for example, during Loma-Prieta, 1989, earthquake. The mathematical semi-probabilistic models of earthquake inputs were developed which take in consideration the uncertainty of the predicted spectra and other motion parameters of the future earthquakes and artificial design accelerograms were computer generated, Eisenberg, [1].

Experimental part of the investigation program included:

1. Shaking table model and fragment tests;
2. Full scale building dynamic tests using large exciters. The maximum dynamic loading of the structure by means of an exciter corresponded to the design load of 9 MM – intensity and more;
3. Static and dynamic tests of the elements of seismoisolation system (flexible supports, dampers, dry friction elements a.a.).

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As a result of the research program different structural system of seismoisolation are designed and buildings are constructed recently in Siberia, Far East, Crimea, Caucasus, Middle Asia and others earthquakes dangerous areas. Specific for these systems is that they are simple in construction and are not expensive. Different structures using seismoisolation were constructed taking into account the investigation results. More than 500 buildings and bridges are seismoisolated in Russia and in former USSR countries.

The prevailing amount of constructed seismoisolation systems in Russia is non-rubber seismoisolation. The seismoisolation effect is achieved by using two and sometimes more than two elements. The two elements are 1 – flexibility elements and 2 – dampers. The flexibility elements are flexible columns in the ground storey of the building, or rocking supports (rocking columns, rocking converted mushroom type supports, other configuration rocking supports). The dampers are mild steel hysteretic elements or RC damaged during earthquake diaphragms, or dry friction elements.

The main design demands are large enough critical horizontal displacements of the flexible columns or rocking supports. Several dozens building are constructed on sliding supports and sliding belts of controlled damping. Usually the steel-teflon pairs were the controlled friction elements. Additional elements of seismoisolation used in Russia are horizontal displacement rigid limiters (stops) and reserve disengaging elements for energy dissipation and for frequency spectra adaptation [2].

Recent years steel-rubber supports were used in some seismoisolated buildings constructed in Russia, Eisenberg [5, 6]. Now some buildings with steel rubber seismoisolation supports are in design process. One of these buildings will be constructed at Alexandrov-city, Sakhalin (a 4 storey school building). The steel-rubber supports for this building are produced in China, Shantou, “Vibro-Tech” Company.

As a result of studies in Moscow EERC the seismic safety of buildings with soft ground stories was exonerated. The reason of many buildings with soft ground stories collapses during recent earthquakes was reinforced concrete as material of bearing ground story columns, not the flexibility of the ground story itself. Design of soft ground story buildings with steel columns as seismoisolation elements combined with dampers and fuse elements is presented.

APPLICATION OF BUILDING SEISMOISOLATION ON KINEMATIC SUPPORTS

Seismoisolation of buildings on kinematic supports is most spread in two Siberian seismic regions of Russia. 77 dwelling-houses were built in the Irkutsk region (near Baikal Lake) in 1984–2003 and 25 buildings in the Kemerovo region in 1997 –2003. Seismoisolation design of these buildings is shown in Figure 1.

Kinematic support elements are used to decrease lateral seismic loads on building superstructures. Kinematic support element (KSE) is a tetrahedral truncated pyramid with spherical lower part. KSE rests freely on the below-support part, on the top it has hinge joint with the above-support part. A hinge joint with a superstructure provides lateral mobility in all directions. A hinge joint consists of a joint tie and a small square steel plate. Besides, a hinge joint serves as a displacement restrainer, because a joint tie develops increasing resistance to KSE turning. Gravitation force holding KSE in the state of stable equilibrium determines its lateral stiffness, it depends on superstructure weight, KSE height, and pivot curvature radius. KSE dimensions depend on vertical load value, material strength, and earthquake action intensity. Sometimes, (for example metallic pillars) are used to increase dampening quality of these systems. Such dampers serve also as restrainers (stops) of lateral displacements. The proposed damper design supposes seismic vibrations energy dissipation, due to development of material non-elastic deformation.

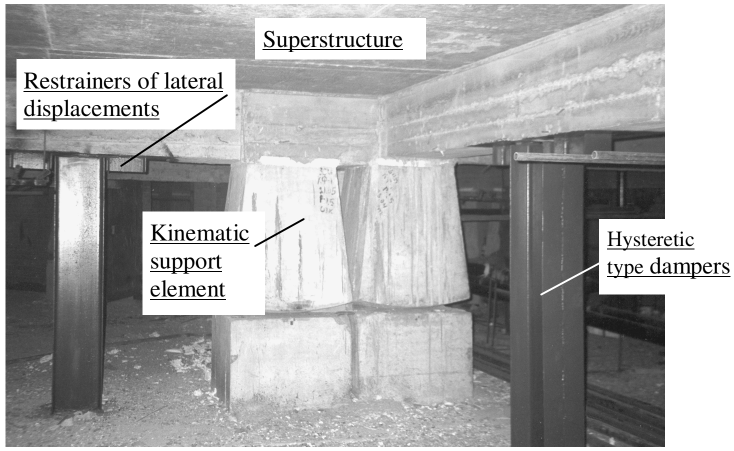


Figure 1. Fragment of the Seismic isolated building on kinematical rocking supports

Most houses built in Russia on KSE base are multi-storey buildings (for example the dwelling house in Novokuznetsk – Figure 2). Earthquake loading reduction makes it possible to increase the number of storeys, improve planning concepts, and reduce material consumption for structures. KSE location in a basement premise enables free layout planning and enables to arrange a parking area.

Figure 2. General view of seismoisolated buildings

In order to estimate earthquake loading reduction by means of seismoisolation system, analysis was carried out for the buildings with kinematic support elements and the building without seismoisolation system, with conventional strip foundation and the same superstructure (non-isolated building). The structural features of buildings with seismoisolation and an non-isolated building were taken into consideration in static and dynamic design models.

Alternating character of progressive and torsional earthquake loads was taken into account in building analysis, and their most unfavourable for elements' stressed state directions were assumed. The design model of action was characterised by:

– vector of progressive motion acceleration $\ddot{\vec{X}}_o = \left|\ddot{X}_{io}(t)\right|$, ($i$ = 1, 2, 3);

– vector of turning (rotation) angle acceleration $\ddot{\vec{\alpha}}_o = \left|\ddot{\vec{\alpha}}_{io}(t)\right|$, ($i$=1, 2, 3).

As an example of earthquake action parameters, vector orientations in space determined by their directional cosine angle were used.

Analysis results are presented below: the first three shapes of natural vibrations and displacements of seismoisolated buildings and buildings without kinematic support elements (Table 1).

Table 1. Comparing of results

Non-isolated building	Seismoisolated building
PERIODS OF NATURAL VIBRATIONS	
T_1 = 0.306 sec.	T_1 = 1.562 sec.
T_2 = 0.238 sec.	T_2 = 1.533 sec.
T_3 = 0.232 sec.	T_3 = 1.451 sec.
Difference of ground and upper floor lateral displacements along earthquake action direction – total building skewness	
1.4 mm	0.4 mm
	Maximum displacements at kinematic supports level along earthquake action direction is ~ 19 mm.

Comparison of two buildings' periods of natural vibrations shows that at fundamental period of KSE based building is 1.562/0.306 = 5.1 times greater that that of a non-isolated building. Difference of the ground and top floor lateral displacements along earthquake action direction equals: a – non-isolated building – 1.4 mm; b – KSE-based building – 0.4 mm (rigid body deformation type). Design maximum displacements at kinematic supports level along earthquake action direction are ~ 19 mm, that is an order of magnitude less than maximum permissible value ~ 200 mm, determined on the basis of KSE and above-support structures geometric dimensions.

The dynamic effect of earthquake load reduction on the building on kinematic supports and non-isolated building in terms of cross forces ratio at ground floor level equals: 4555.5/2277.7 = 2.0 (Figure 3).

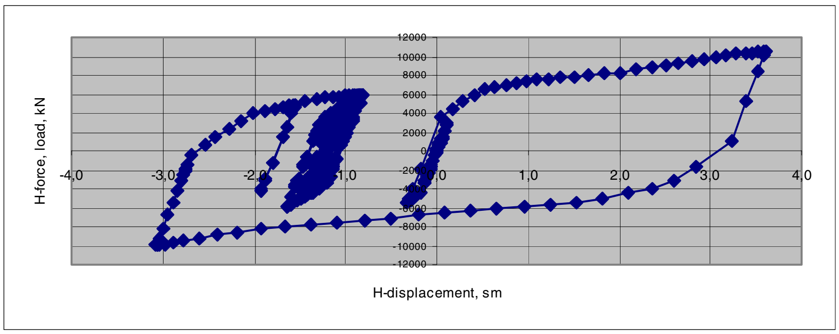
Figure 3. The dynamic effect by KSE

Direct dynamic analysis for real accelerograms was carried out to enable computer-aided analysis of earthquake response of non-seismoisolated and kinematic supports based buildings.

Records of the heaviest Earthquakes (El-Centro, 1940, Bucharest, 1977, Gazli, 1978, Spitak, 1988, Erzincan, 1993, Kobe, 1995) were used as real accelerograms. Bucharest Earthquake records show that spectral characteristics are more hazardous for more flexible buildings, specifically for the buildings on kinematic supports in question. Seismic response analysis for the buildings to be compared reveals that seismic load for the worst Bucharest accelerogram action was reduced more than 3 times, maximum displacements were lowered by an order of magnitude and do not exceed 3.6 cm.

Deforming diagrams for the building with kinematic support elements model are presented in Figure 4: a – general diagram, including deforming of supports and damping elements, b –diagram of damping system deforming.

a)



b)

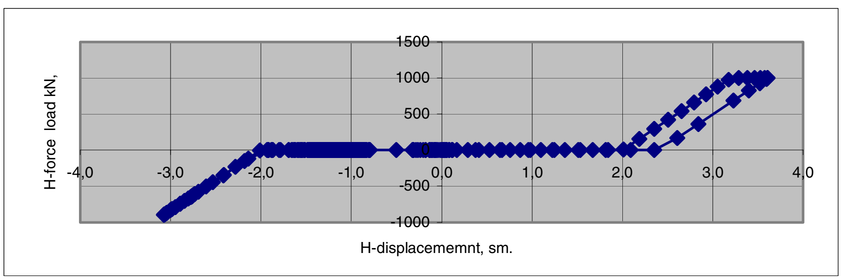


Figure 4. Seismic isolated building earthquake response. Bucharest, N-S

Investigation results enable the conclusion that seismic isolation system consisting of kinematic supports reduces earthquake load 2 – 3 times, compare to a non-isolated building.

SEISMOISOLATION FOR UPGRADING OF AN EXISTING HISTORICAL BUILDING IN IRKUTSK-CITY, SIBERIA-RUSSIA

A historical building of an Irkutsk Bank needed retrofitting and upgrading as observation and analysis have brought to conclusions that the seismic reliability of the building doesn’t meet the current Seismic Building Code requirements. The bank building was retrofitted using seismic isolation to prevent the damage by earthquakes expected in the future (Figure 5).

The building consists of three blocks. The external bearing system is: brick wall, thickness is 64 cm. The internal system is reinforced concrete columns and brick masonry. The building height is 3 to 4 stories, where walls and columns lower storey were cut at their mid height and LRB's (lead rubber bearings) were installed.

The decision to install seismic lead rubber bearings in the mid level of the ground floor was taken to provide maximum seismic isolation of the existing walls and building columns. The total number of seismic bearings to be installed is 108 (Figure 6). Every bearing is designed for 2500 kN load. All the bearings have equal dimensions: diameter – 510 mm, height – 216 mm.

The high-damping steel-rubber supports were produced at the Shantou-city (Southern China) "Vibro-Tech Industrial and Development Co Ltd". The dynamic tests of supports were carried out in South China Construction University in Guangzhou with participation of Russian experts. Due to the reduction of seismic force by isolation, strengthening of the structure above isolators has come to be unnecessary. The part of structure below isolators has been strengthened. A specific construction technology of supports installation in the existing building without its exploitation interruption was developed. The site dynamic tests of the full scale building to investigate the dynamic properties of the seismoisolated building and the correlation between the actual and design values were carried out.

Figure 5. General view of an Irkutsk Bank
a –before reconstruction; b – after reconstruction

The numerical analysis of earthquake response of this Building was carried out in EERC, Moscow by J.Eisenberg and V.Smirnov. The results of the investigation are that in case of the seismoisolation high damping (27% of critical damping) supports both response acceleration and response displacements are sufficiently lower comparing to non-isolated existing building.

The maximum response displacements of the seismoisolated building do not exceed 2.5 cm, maximum response acceleration are in the limits of 550 gals. These values are not hazardous for from point of view of the building safety.

The method of seismic isolation of the existing bank building has revealed the advantages of this method comparing to the conventional methods of retrofitting and strengthening of the buildings located in highly hazardous seismic zones.

1. Seismic isolation of the ground floor part of the building enabled to preserve the building exterior look and to avoid architectural features violation.
2. The result of comparative nonlinear analysis of isolated and non-isolated buildings and that both displacement and acceleration in isolated buildings are significantly lower than in non-isolated ones.

3. The method of gradual isolation of lead rubber bearings in the building blocks enables normal work of the bank.

DESIGN OF A CHURCH BUILDING SEISMOISOLATION

The design of church building in Irkutsk-city seismoisolation in now carried out (Figure 7). Kharlampiyevskaya (Mikhailo-Arkhangelskaya) church is a historical and cultural monument built in 1779-1790.

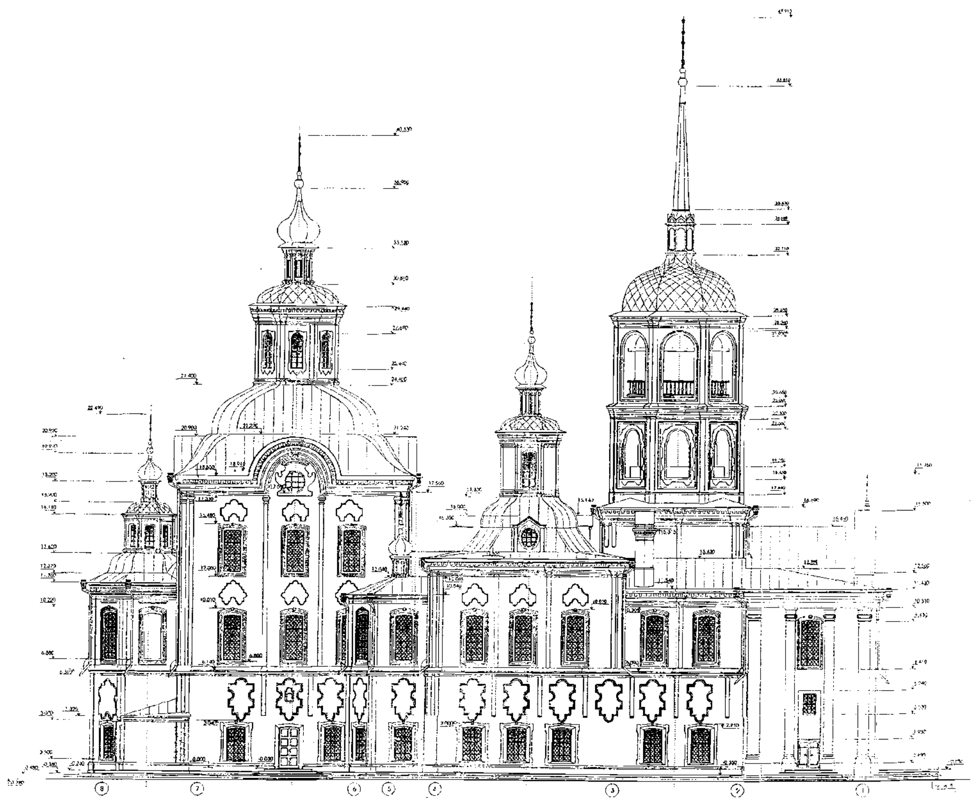


Figure 7. Church buildings

The structural concept includes an asymmetric in plan, columnless brick masonry structure. The building consists of several parts with different design, connected by walls in one unit, except for the porch. Its walls do not have bonding with main building walls. The northern and southern side-chapels have similar structural concept in the form of two-storey parallel bays of different length. On the east side, the bays are completed with the multifaceted apses.

Side-chapels' ground floor is spanned with cylindrical brick vaults, including strippings in the wall vaulted bay. In the first floor, the northern side-chapel narthex and the southern side-chapel refectory are spanned with cylindrical brick vaults. The northern and southern side-chapel churches and the southern side-chapel altar are spanned with octagonal tent brick vaults. The altar apses in the ground and the first floor are spanned with multifaceted closed brick vaults.

The foundations are of shallow, strip, stone masonry type with the artificial subgrade, consisting of pebble and fine sandy loam mixture poured with mortar. The masonry is made of loam Flemish bricks on mortar. Wall thickness is 1.26–2.35 meters. To provide building earthquake stability seismoisolation system, including metal-rubber supports is used in Mikhailo-Arkhangelskaya church foundations.

In order to reduce lateral seismic loads, metal-rubber isolators are installed on the church building superstructures. It is enabled by pliable bracing between building superstructures and foundation. It also provides seismoisolating support dampening quality. These measures are used to increase building natural period of vibrations and to decrease transmission of earthquake power and ground motion to the building superstructures. Estimated building weight is 158060 кN. Total number of rubber-metal seismoisolating supports are 92.

The following sequence of works was offered for supports installation in the existing church building (Figure 8). Foundation replacement and exterior wall seismoisolation installation are carried out in the following sequence:
1. The mortar is injected via injectors (1), to reinforce the upper zone (4) of ground pad (5) (Figure 8a).
2. The antiseismic belt (8) is provided (Figure 8c, d):
- 3 meter long trenches (24) are dug with some intervals;
- Trench bottom is smoothed and covered with two layers of polyethylene film (7);
- Formwork panels (6) are installed;
- Support antiseismic belt (8) with embedded parts (26) for seismic supports fixing (Figure 8c).
3. After the support antiseismic belt is arranged in the whole building, each second hole is open in places where seismic supports are to be installed (25), the walls must be fastened (10), pillar formwork (11, 12) is provided, and support columns (14) for seismic supports are cast in situ (Figure 8e).
4. Wells in ground-and-concrete mass (4) are drilled via holes (27), left in support seismic belt, and coupling bolt studs (9) are passed through them. Bolts are tightened, wells pressure grouting via special channels (18) is carried out, and additional strengthening of ground-and-concrete is provided (4).
5. Each second foundation column along the perimeter is dug out (after reaching 70 percent concrete strength), hole bracing is dismantled, and formwork is removed. Then foundation slabs (19) are installed and foundations are connected (31) (Figure 8f, g).
6. The rest foundations are erected with separate foundation slabs connected into a continuous belt.
7. The foundations for the interior walls are laid down in a similar way.
8. After all foundations are ready and the support antiseismic belt is underpinned, the trench under the whole building is to be open for ground floor arranging. Basement solid-cast reinforced-concrete walls (20) and solid-cast reinforced-concrete ceiling over the basement (22), resting on support antiseismic belt and rigidly connected with it are erected (Figure 8g).
9. Cantilevered solid-cast reinforced-concrete plate (21), rigidly built in the outside branch of support antiseismic belt, which has to overlap the distance between the belt and basement wall is installed along exterior walls contour. A horizontal antiseismic joint, 50 mm high, separating the building overground part from the underground part is provided between the upper basement wall batter and cantilevered plate (21). The joint is stuffed with mineral wool plate, wrapped in polyethylene case, and is sealed with thiokol sealant.
10. After complete basement closing seismic supports are erected.
11. Seismic supports underpinning is to be provided in the following succession:
– Seismic supports (16) are hung in the recesses which were left when concreting support columns (Figure 8f, g) to the top embedded parts (27) with four bolts (29);
– Lower embedded parts (similar to 27) with foundation bolts (15) are hung with the help of four bolts on the lower connecting plates of seismic supports;
– Reinforced concrete support pads (17) (Figure 8f, g) are concreted under embedded parts, 50 mm gap is to be left between a support pad and an embedded part which must be carefully caulked with firm fine concrete, grade V20.

12. After all seismic supports are installed, they are loaded by filing off and removing support columns (30) from under antiseismic support belt.

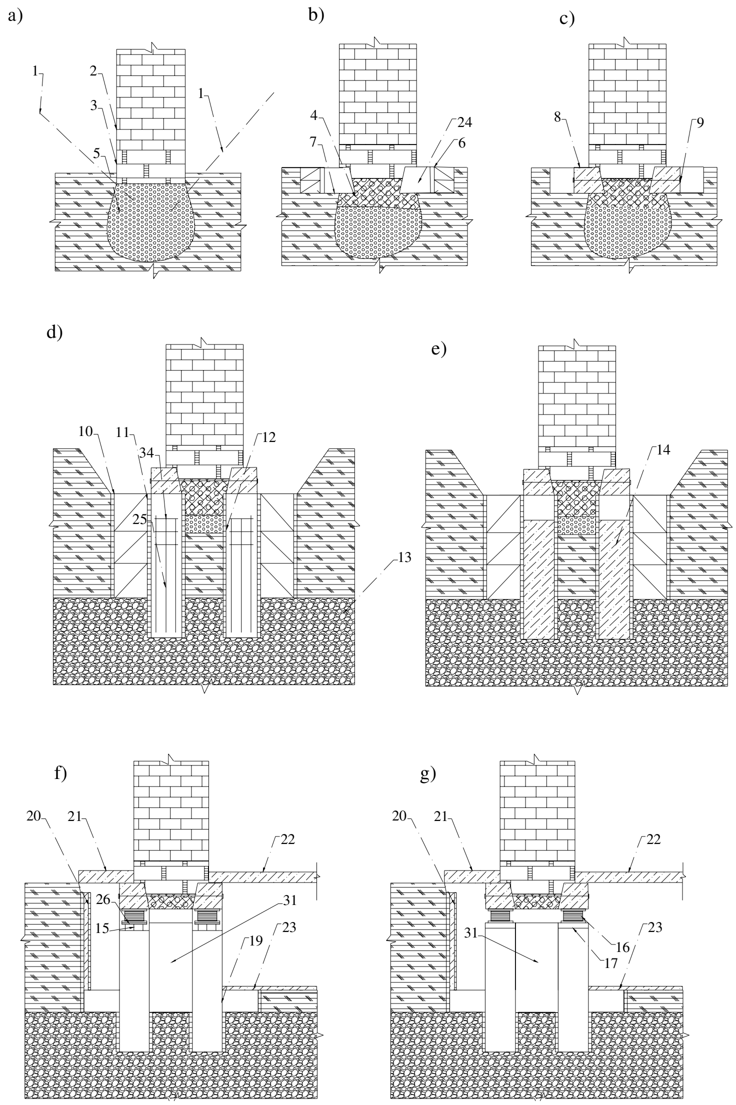


Figure 8. The sequence support installation

INCREASE OF SEISMIC RESISTANCE OF EXISTING SCHOOL BUILDING ON SAKHALIN ISLAND

The individual project of comprehensive school in the town of Aleksandrovsk-Sakhalinskyi was developed in 1988 on the basis of current Building Code «Construction in Seismic Regions». School construction was not completed and was stopped in 1994. After disastrous Sakhalin Earthquake in 1995, design earthquake intensity was specified in many Sakhalin regions. Now, after the new zoning maps were introduced, design accelerations in Aleksandrovsk-Sakhalinskyi were doubled. School building consists of four blocks separated with aseismic joints. The structural scheme is a frame comprising prefabricated reinforced concrete elements (Figure 9).

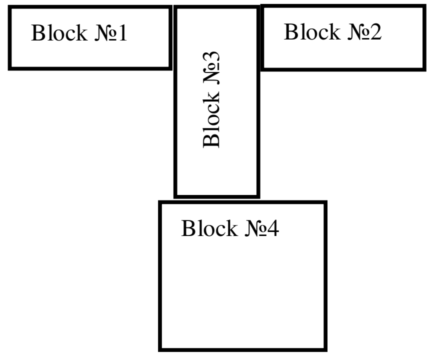


Figure 9. Plan of school building

Blocks No. 1 and No. 2 are three-storey, including a basement. Storey height is 3.3 meters, basement height – 2.9 meters. Dimensions in plan are 12x33 meters. Block No. 3 is three-storey, including a basement. Dimensions in plan are 18x30 meters. Block No 4 is three-storey, it includes halls with two tiers of windows in the first floor and in the ground floor. Storey height is 3.3 meters, height of halls with two tiers of windows is 6.6 meters, ground floor height is 3.3 meters. Dimensions in plan are 24x27 meters.

Basic structural components of the building are as follows: foundations - solid-cast reinforced-concrete plate 400 mm thick; frame – prefabricated reinforced concrete columns and beams, basement walls consist of reinforced concrete panels; exterior walls are made of three-layer panels, and ceiling consists of prefabricated reinforced concrete slabs. In order to increase school earthquake resistance, it was suggested to install seismoisolating supports in the foundation, in the mid level of the ground floor. Support installing is shown in Figure 10.

Figure 10. Support installing

3D analysis for static and seismic loads of all school blocks was carried out. Diagram of dynamic factor received on the basis of the real earthquake records and with due regard to the site conditions was used in seismic load analysis.

Application of seismoisolation system, consisting of rubber-metal supports in basements of school blocks enabled to reduce design seismic loads to the values corresponding to 8 MSK-degree, for which non-isolated school building was designed.

SEISMOISOLATION OF BUILDINGS WITH OPEN SOFT GROUND STOREYS

Why Buildings with Open Soft Ground Storeys are Used?

One of the reasons is associated with the architectural and functional preferences. Open spaces are attractive for space-planning solutions and solving purely architectural tasks. They are required for restaurants, shopping centres, banks, fitness-centres, as well as for garages, parking areas, and passages. Open spaces are arranged with the help of columns, frames, arches, and other similar load bearing elements, instead of wall panels, which restrict layout planning freedom. It is the first aspect of the problem.

Another reason in favour of soft ground storeys is connected with the attempts to isolate the buildings to be erected in hazardous seismic regions. Just for seismoisolation purposes, engineer Green (California, USA) offered to use flexible columns in the ground floor. In 1935 he was awarded the USA patent on seismoisolation of the building, consisting of flexible columns in the ground floor.

The view that buildings with soft ground floor have low seismic resistance is widely spread in the world scientific community. This view occurs in textbooks, reports at the latest international conferences on earthquake resistant construction, in reports on earthquake consequences, in normative documents, where coefficients increasing design seismic loads are stipulated. Really, during many earthquakes of the 20th century the buildings with open ground floor were severely destroyed. Total failure often occurred.

Information on heavy destruction of such buildings is contained in descriptions of earthquake consequences in San-Fernando (1971), Spitak (1988), Loma-Prieta (1989), Nortridge (1994), Turkey, Taiwan, Greece (1999), India (2001), Algeria (2003), and many others. The analysis of destruction and its reasons was undertaken in the work. It was shown that dominating view that buildings with soft ground floor have low earthquake resistance should not be taken as the universal. This view is fair for some structural concepts and is not appropriate for other solutions.

Why Buildings with Open Soft Ground Storeys were Collapsed?

To understand and rank the reasons of aforementioned multiple destructions of buildings with open soft ground floor, the following fact, which was beyond attention of many experts who described and analysed this phenomenon, should be emphasised. In all aforementioned cases load bearing elements were, in fact, reinforced-concrete columns, frames and door ways.

Usually according to architectural-and-functional requirements and taking into consideration conditions which might increase flexibility and improve seismoisolation, ground floor columns are made thin, with minimum permissible cross-sections 20, 30, 40 cm. Columns are often loaded with considerable building dead-weight and other vertical static loads, they are often heavily reinforced.

In the process of earthquake action local cracks, damage, non-elastic deformation, and concrete crushing occur. Some cracks are tolerable by earthquake resistance theory and reinforced concrete design standards, but concrete is disengaged as a load bearing element. Due to loss of rigidity, lateral displacements increase, and concrete destroying continues. Longitudinal reinforcement itself, without concrete cannot resist to vertical static plus seismic loads. Loss of stability and rod buckling of "steel flowers" type occurs. This damage mechanism, called "gravitational mechanism "or" gravitational model" of seismic damage is described in details in Eisenberg [10]. Gravitational mechanism is the major factor which causes failure of soft ground floor reinforced concrete columns and as a result building collapse.

There are other factors which cause collapse of buildings with soft ground floor on reinforced concrete supports. In some cases, the real amplitude-frequency spectrum of earthquake action differs from that used in standards and designs. As a result, ground floor flexibility can lead to resonance with the most hazardous components of seismic motion, rather than to seismoisolation effect. Such phenomena are used to be accompanied by degradation of column rigidity, due to earthquake crack growth. Such destruction mechanism of reinforced concrete frame buildings has occurred in the town of Gumri (former Leninakan), during Spitak earthquake on December 7, 1988.

Nevertheless, there is still architectural and functional need in the ground floor open space. Development of market economy, area urbanisation increases demand in it. It gives the rise to objective contradiction: from functional and aesthetic point of view architects often need open ground floor with load carrying structures consisting of frames and thin columns. However, in many cases reliability requirements make such solution unacceptable.

Earthquake Resistant Buildings with Open Soft Ground Floor

The conclusion was made on the basis of investigation that the main reason why buildings with soft ground floor are collapsed is not ground floor flexibility, but reinforced concrete, the material columns, frames, door ways in the ground floor are made of. This conclusion leads to the following consequence: if ground floor load bearing elements are not made of reinforced concrete, but of more homogenous material, for example, of steel (preferably mild ductile steel), a building with such supports would not specifically differ (in terms of seismic vulnerability) from other steel frame buildings which are well-known as highly earthquake resistant. Very simple example confirms this conclusion.

Example

Maximum lateral seismic displacements at the level of upper point of soft ground floor with steel columns as load bearing structure are to be computed. Several superposed storeys have higher rigidity (Figure 11).

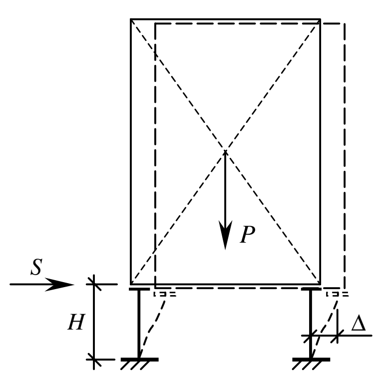


Figure 11. Model of building

Let us determine maximum lateral seismic displacement, based on condition of bending moment equality $M_v = P\Delta$ due to action of vertical forces P at lateral displacements Δ (effect P- delta) and bending moment $M_n = SH$ due to action of lateral seismic forces S:

$$P \cdot \Delta = S \cdot H\,, \tag{1}$$

where H – height of ground floor columns, we get:

$$\Delta = \frac{S \cdot H}{P} \tag{2}$$

At maximum design seismic loads and maximum values of spectral dynamic factor the value S/P ≤ 0.1 depending on natural periods. After substitution of the value in (2), we get Δ=(0.1-0,2)H. If, for example, H=3.5 м, then Δ_{max}=(35-70) cm. Those are the values of maximum lateral seismic displacements permissible when steel columns in the ground floor are used.

The real maximum magnitude of seismic response (displacements) defined via direct dynamic analysis with use of the strongest earthquakes accelerograms for elastoplastic system at S/P=(0.1-0.2) in most cases does not exceed 10-30 cm, i.e. is much more lower than the computed value Δ_{max}. Use of steel columns as seismoisolating elements combined with dampers, disengaging bracing and displacement stops enable to restrain lateral displacements to tolerable values and at the same time to reduce significantly seismic loads (forces) on the superposed building stories.

Steel Columns as Seismoisolation Elements

When designing such seismoisolated buildings the task appears to determine optimal column cross-sections which could provide sufficient flexibility of seismoisolated buildings. It is known that in practical design fundamental periods must not be lower than 1.2-2 seconds.

The optimal seismoisolation effect is achieved when combination of the following elements is achieved:
1) columns or frames which provide flexibility and high natural periods;
2) dampers of hysteretic type;
3) stand-by elements to be disengaged at some earthquake actions predicted for the construction site;
4) stops - restrainers of extreme lateral seismic displacements.

The effect of vertical load (i.e. number of stories), cross-section shape, and column height on fundamental period of seismoisolated buildings (5–12 storeys) was investigated in Eisenberg J.M. [11]. Two column types were investigated: steel and reinforced concrete columns with stiff reinforcement in the form of flange beam. Column cross-sections are presented in Figure 12.

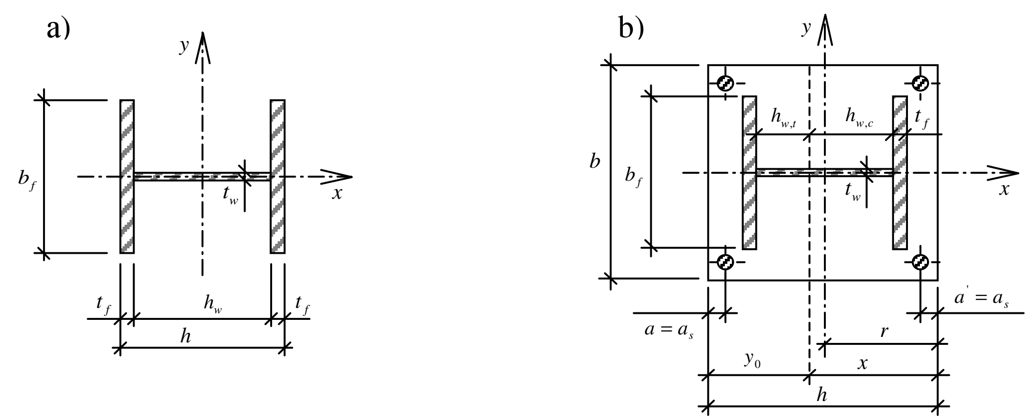


Figure 12. Column cross-sections

Column strength and stability according to the current Building code was taken into account in the analysis. In Tables 2 and 3 the results of fundamental period analysis of 5-12-storey buildings with ground floor steel columns are presented.

Table 2. Geometric Parameters if Steel Columns and Building Natural Periods

Load, кN	Flange beam cross-section height (*h*) and flange width (b_f), meters				Values of natural periods (*T*), sec.			
	At column height, meters				At column height, meters			
	3.3	4.2	4.8	6.0	3.3	4.2	4.8	6.0
1800	0.35×0.35	0.40×0.40	0.40×0.40	0.40×0.40	1.018	1.239	1.513	2.115
3000	0.45×0.45	0.50×0.50	0.50×0.50	0.50×0.50	0.810	1.041	1.271	1.756
4000	0.50×0.50	0.50×0.50	0.50×0.50	0.50×0.50	0.750	1.072	1.305	1.782

Table 3. Geometric Parameters of Concreted Steel Columns and Building Natural Periods

Load, кN	Column cross-section height (*h*) and cross-section width (*b*), meters				Values of natural periods (*T*), sec.			
	At column height, meters				At column height, meters			
	3.3	4.2	4.8	6.0	3.3	4.2	4.8	6.0
1800	0.35×0.35	0.35×0.35	0.35×0.35	0.40×0.40	2.604	3.499	4.172	5.064
3000	0.45×0.45	0.45×0.45	0.45×0.45	0.45×0.45	2.045	2.778	3.818	4.602
4000	0.45×0.45	0.45×0.45	0.45×0.45	0.50×0.50	2.020	2.854	3.468	4.203

Use of the above structural system enables to achieve two aims: 1) to get ground floor open space which architects need in buildings and 2) to reach high seismoisolation effect. Design lateral seismic load on superposed storeys can be reduced 2-4 times and even more. Besides, steel frames as seismoisolation elements make it possible to design highly reliable, earthquake resistant seismoisolated buildings.

CONCLUSIONS

Some new Projects of seismoisolated structures used in Russia recently are presented.

Among them are newly constructed buildings and existing buildings, which are strengthened.

Rubber and non-rubber seismoisolation supports were used.

Provisions for seismoisolated buildings of different seismoisolation types were prepared.

Mild steel columns or frames as base isolation elements are presented. Two aspects of their seismoisolation ability are taken into account in design. The one is the building flexibility achieved using these columns. The other aspect is energy dissipation and large enough permissible (safe) horizontal displacement.

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