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RECENT DEVELOPMENTS IN SEISMIC ISOLATION AND ENERGY DISSIPATION IN RUSSIA

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ABSTRACT

Recent developments in seismic isolation of civil buildings and cultural centers in Russia are presented. Rubber and non-rubber isolation supports are described. Several high-rise buildings and two Cultural Center buildings with steel-rubber seismoisolation are considered. Research studies were provided for artificial design accelerograms development. Steel column supports were studied as isolation elements, as well [1-6].

33-storeyed apartment building in the city of Sochi Northern Caucasus. The building consists of two equal blocks connected with suspension structures at the level of 16-20 storeys. In this project rubber bearings are installed in places where the suspended part is supported by the load-bearing structure, 4 bearings in each of 6 tiers. A distinctive feature of the solution is non-traditional seismoisolation bearings location.

22-storeyed building of administrative-and-trade complex in the city of Sochi. The building consists of 22-storeyed high-rise section of business center and 6-storeyed section of trade center. Bearings are installed at the level of the sixth storey and only provide isolation of high-rise section of the building.

24-storeyed housing building in the city of Sochi. The bearing system above seismoisolation supports level consists of RS diaphragms, frames columns and monolithic walls, and RS floors.

16-storeyed Hotel building in the city Petropavlovsk-Kamtchatsky, Kamchatka, Far East. The building has a complicated architectural design, with vertically changing volume and non-symmetrical mass and rigidities plane distributions. The vertical bearing system: along the building perimeter RC monolithic walls and in the inner building part RC frames. The frames are designed to resist only the vertical loads. All seismic loads are resisted by RC walls. The seismoisolation supports are mounted on the foundation plate.

A Cultural center seismoisolated building including a Drama Theater in Chechen Republic, city of Grozny, is designed. Steel-rubber supports are used. A Drama Theatre building reconstruction and strengthening in the town of Gorno-Altaysk (Siberia) was performed using seismoisolation. [4].

Keywords: isolation supports, high-rise buildings, seismic isolation, .

1. INTRODUCTION

The first application of seismoisolation in USSR is a steel spring-pendulum suspended 4 storey building. The building was designed by engineer F.D.Zelenkov and constructed in Ashkhabad (Middle Asia) in 1959. It became clear later that the amplitudes of earthquake displacements of this building are very high even during low intensity earthquakes. When in usual nonisolated buildings the inhibitions felt no motions, the inhabitants of isolated building run to the street because of the large amplitudes. The reasons is the high flexibility and low energy dissipation in this building [1].

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

The strong motion accelerograms up to the present time demonstrated very different predominant periods of earthquake ground motions not only during different earthquakes but sometime even during the same earthquake at distant and the close distances, for example, during Loma Prieta, 1989, .Earthquake. The mathematical models of earthquake inputs as random processes were developed (Eisenberg, 1976) which take in consideration the uncertainly of the predicted spectra and other motion parameters of the future earthquakes.

Attention was paid to the recent strong earthquake records analysis from point of view of the seismoisolation application and future developments.

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.).

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.

Design of different structures using seismoisolation were developed taking into account the investigation results.

More than 550 buildings and bridges are seismoisolated in Russia and in former USSR countries.

Some provisions concerning seismoisolation were included in the current Russian Seismic Building Code (2004). Design Regulations were developed for specific types of seismoisolation. The regulations are developed in the Earthquake Engineering Research Center, Russian Association Earthquake Engineering, Russian Construction State Committee, and adopted in design practice.

Recent years steel-rubber supports were used income seismoisolated buildings constructed in Russia [2, 3]

Principally the seismoisolation effects in horizontal direction are the same in steel-rubber supports isolation and in systems with flexible columns or rocking' supports combined with dampers.

The difference is in the cost values and in technology of construction simplicity. So the type of seismoisolation to use is the choice of proprietor and designer.

Now some buildings with steel rubber seismoisolation supports are in design process. One of these buildings was constructed at Alexandrov-city, Sakhalin (a 4 storey school-building) [6]. The design earthquake intensity is more than 9 MSK-degree.

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 expected earthquakes[4].

This is first completion of rubber-steel seismic isolation in an existing building in Russia. Some results of the building seismic response analysis are presented.

These and several others example of steel-rubber seismoisolation in Russia were presented at the 13 WCEE, Vancouver Seminars on Seismoisolation [5].

Recently, due to some architectural, economical social and other reasons the investors pay attention to high-rise building construction. They are designed and constructed in different areas of Russian Federation, in seismic hazardous areas, as well. The authors participate in the designing process, and they firstly used seismoisolation in high-rise building in Russian Federation design (Caucasus, Sochi-city, Krasnodar, Far East, Kamchatka and other areas).

In this paper some of designs of high-rise buildings are presented. All of the seismoisolation devices are steel-rubber supports.

2. RUBBER SEISMOISOLATION

2.1. At the Fig. 1 a 33-storeyed building in the city of Sochi is presented. The building consists of two equal blocks connected with suspension structures at the level of 16-20 storeys. Rubber bearings are installed in places where the suspended part is supported by the load-bearing structure, 4 bearing in each of 6 tiers. A distinctive feature of the solution is non-traditional seismoisolation bearing location.

Total buildings area is around 60000 sq. m. Helicopter platform with 35 m diameter are provided at +99.500 marks in each block.

The load-bearing framework of blocks – trifolium “lobes” of high-rise part of the building is a three-dimensional wall system, created by orthogonally crossing monolithic reinforced-concrete walls with regular pitch as per the architectural-planning concept.

The ladder-and-lift until, which constitutes the stiffening the core, is located in the central part of each block. The building foundation – Fondedile piles with diameter to 2 m, connected with foundation frame 2 m thick ground floor 2 is already performed.

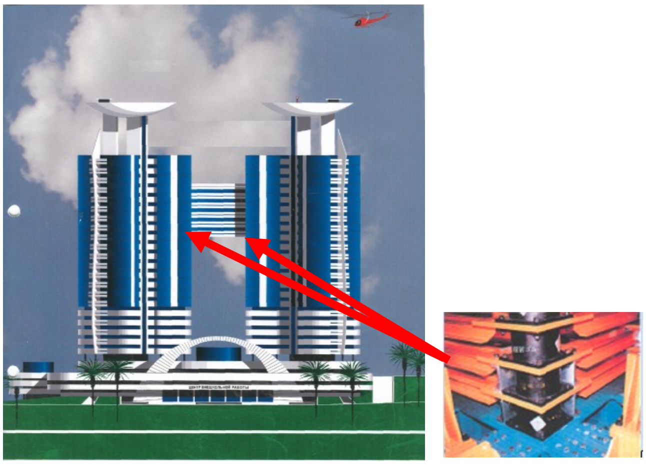

Figure 1. 33-storeyed building in the city of Sochi

2.2. The next seismoisolated object which is shown at the Figure 2 is the Business Center 22-storeyed building in Sochi. It includes a building house, a movie theatre, stores, underground parking area, and office space.

Building height is around 100 m (99.9 m) [Fig. 2]. The building consists of two blocks of high-rise office centre and 4-storeyd shopping-and-entertainment centre, separated with a lateral aseismic joint.

The building has two underground semibasement floors and 21 over ground storeys with a special, prominent by structure composite shape above the 21st roof floor. The total building area is 50000 sq. m, building length – 66 m, variable width – 36-40 m.

The structural system includes cast-in-situ reinforced-concrete walls, pillars diaphragms, stiffening cores, and floor structures. In the underground part of the building, the rigid boxlike system, formed by trench back walls, control reinforced concrete walls, and base slab. The building foundation is cast-in-situ reinforced concrete slabby framework, 1500 mm thick, along the piles (∅1000 mm), arranged under the bearings (columns, walls) below the foundation slab. Column cross-sections: 1200×2400 mm, 1200x1200 mm and 600×600 mm. Cross-sections of reinforced-concrete walls: from 400 mm below to 150 mm in the upper storeys. The thickness of floors in the storeys is 24 cm.

Seismoisolation system is located at the level of the 5th storey and consists of 200 rubber bearing supports with lead cores. Design load-carrying capacity of each bearing is 500–1150 tons. Maximum lateral displacements, determined on the basis of calculations, is 12 cm. Damping is 20.0 %. Tolerable displacements – 30 cm.

According to the calculations, natural fundamental period of vibration of base-isolated building reached 2.4 s, maximum design displacements of rubber bearing supports at design accelerations 400 gal made up 12 cm. –

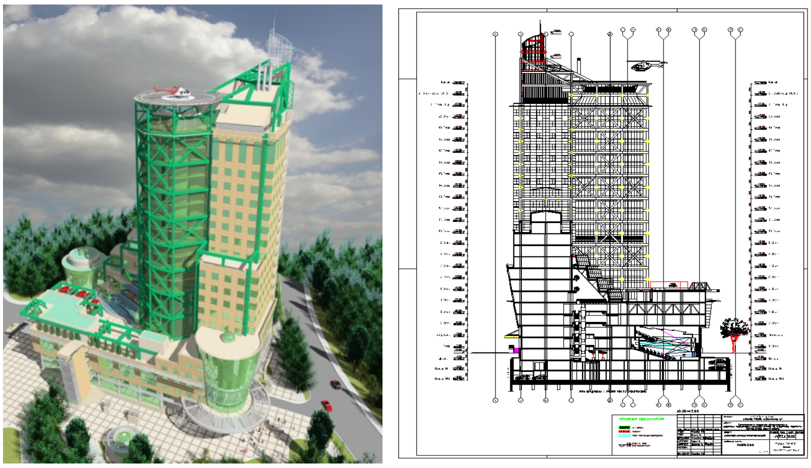

Figure 2. The 22-storey building of Business Center in Sochi.

2.3. A 27-storeyed housing building in Sochi-city is presented at the Fig. 3. Building height is 93.6 m The bearing system above seismoisolation supports level consists of RC diaphragms, frames columns and monolithic walls, and RC floors. The foundation RC flat is 2000 mm thick. Columns cross sections are maximum 1500×1200 mm minimum 600×600 mm upper the 15.900 m level. The weight of the building above the isolation layer is 75000 kN.

Seismoisolation - 193 elastomeric seismic isolators with high damping rubber compounds, including supports of type SI-H 1000/168 in number of 149 and supports of type SI-H 1100/168 in number of 44. The manufacturer of supports "FIP Industrial" Italy. Supports of type SI-H 1000/168 can perceive the maximum vertical loading - 14000 kN and type SI-H 1100/168 – 18000 kN. The maximum possible lateral displacements is 250 mm. Damping is 20.0%.

Figure 3. 27-storeyed housing building in Sochi-city.

2.4. At the Fig. 4 a 24-stored housing building is shown which is an inhabited complex "Dawn" designed for construction in Sochi under the Resort avenue, with a seismoisolation system [Fig.4]. On a functional purpose the building is inhabited and includes premises of parking places, cafe and residential zone. The building is asymmetrical in the plan and has variable height. The building consists of the high-rise inhabited block and 3 floor lay levels, separated from a high-rise part with a horizontal seismic joint.

The form of a high-rise part of object in the plan – is U-shaped, consisting of two rectangles. Spatial rigidity of designs is provided with teamwork of frames, diaphragms, columns and monolithic RC walls on a premise contour, beams and monolithic RC slabs. Upper storeys bearing system is of RC walls, and diagrams foundation is RC plate thickness 2 meters on piles by diameter 1 m.

The cross-section of columns of ground floors is 1500x1200 mm. Above 3.6 m cross-section of all columns is 600x600 mm.

The section of RC walls of socle and basement floors is accepted 600 mm. The section of walls of elevated floors is accepted 400 mm to level 10 floors, further 200 mm.

Slabs - not cutting monolithic RC plates, leaning against columns and linearly leaning against walls. A thickness of plates on floors above a mark 0.000 is 240 mm, below this mark (underground floors) plates have a thickness of 400 mm.

The total number of steel rubber bearing supports with lead cores are 160 pieces of type GZY 700 V5A. They are installed on the foundation plate surface.

Figure 4. 24-stored housing building is shown which is an inhabited complex "Dawn"

Figure 5. Panorama view of a whole street in Sochi-city

2.5 The building Fig. 6 is designed under the individual project and has the complicated space-planning decision. Planning decision of the building underlines a relief of a construction site (hillside) and, therefore, vertical longitudinal section of the building is designed in the form of the multistage elements. In this connection the bottom part of a building carries out partially functions of a retaining construction.

The building is divided into 4 parts by seismic joint. The whole volume of the building can be divided conditionally on high-rise and bottom parts, including 12 blocks of a various configuration in the plan.

The high-rise part of the building represents three volumes of different height, divided among themselves withseismic joint: the central block and two, mirror-symmetric block adjoining it.

The seismic joint between blocks is accepted equal 600 mm. That is caused taking into account design displacements.

The central block has the sizes in the plan in axes 65,2×63,2 m. The covering mark of the building in the central part is +95,3 m and decreases further the to a mark of +69,4 m. The zero floor has height of 4,20 m, a technical floor - 2,50 m, a typical floor - 3,30 m.

Two blocks mirror-symmetric in the plan have identical high-rise marks and differ from each other by the quantity of the floors which are settling down more low ±0,000 m, and depth of an arrangement of a foundation plate.

The zero floor includes premises of the entrance group, and a lobby. Over a zero floor the technical floor for a lining of communications is designed. On typical floors are inhabited apartments. In bottom parts settle down a parking, office premises, subsidiary premises and pool.

High-rise part of the building is a system with cross-section and longitudinal bearing walls, including external walls. Spatial rigidity of the building to resist the wind and seismic loadings is provided with teamwork of the vertical bearing walls united by disks of flat slab construction.

The foundation of all blocks are piles with monolithic plate grid foundation, thickness of 1500 mm. In blocks 2-2, 4-1 and 4-2 thickness of monolithic plate grid foundation is 800 mm. Plates of these blocks separate from other plates temperature and shrinkable joints. Cast-in-place piles are accepted continuous section without expansion. Piles under plates 1-3 are accepted by diameter 1500 mm in a rocky ground not less than 6,0 m. Piles under plates of blocks 2-2, 4-1 and 4-2 have diameter 1200 mm.

Walls are accepted RC monolithic variable thickness on height, designed on 9 MSK degree of seismic intensity. The thickness of external and internal walls is accepted from 600 mm to 300 mm. Flat slab construction - monolithic RC, thickness of 200 mm.

The high-rise part of the building completely separates from bottom parts. Under high-rise blocks seismoisolation is arranged. As seismoisolation is accepted elastomeric supports with lead cores.

Application of seismoisolation causes an exception of contact of ground with a part of building above supports to provide access to supports for their routine maintenance and replacement if necessary. It is offered to arrange a retaining wall on perimeter of an underground part of the building separated from it, calculated on perception of loadings from a ground (taking into account seismic loads).

Estimated weight of isolated parts of the building: the block 1-1 - 533927,64 кН; the block 2-1 - 1059570,97 кН; the block 3-1 - 547065,20 кН.

Two types of rubber bearing supports with lead core are eccepted: type GZY500V5A - ¢510 x h164,0 mm, design bearing ability 2800 кН, type GZY600V5A - ¢620 x h216,2 mm, design bearing ability 4000 кН, design displacements - 124 mm.

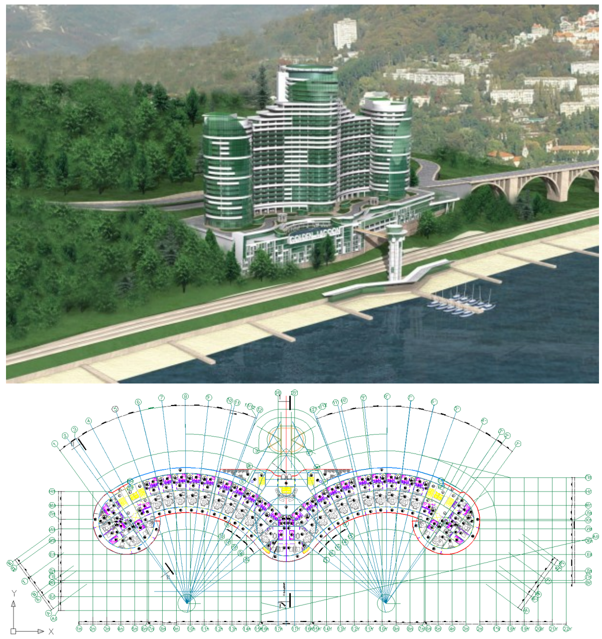

Figure 6. High-rise building in Hosta region of Sochi town.

2.6. At the Fig. 7 a 16-storeyed hotel building in the city Petropavlovsk-Kamchatsky is shown. The building has a complicated architectural design, with vertically changing volume and non-symmetrical mass and rigidities plane distributions. The sizes are 65 m to 43 m at the base floor and 41 m to 35 m at the 14th floor level.

The vertical bearing system: along the building perimeter RC monolithic walls and in the inner building part RC frames. The frames are designed to resist only the vertical loads. According the design all seismic loads are resisted by RC walls.

The foundation is a flat plate 800 mm thick [Fig. 7]. The seismoisolation supports are mounted on the foundation plate. To make possible the seismic motion of building part above isolation supports a RC retaining wall around the underground building part was envisaged.

Three types of seismoisolation steel rubber supports of different bearing capacity 400, 500 and 600 tons were used in the buildings design. The supports will be installed in the open technical floor what make it easy the supports exploitation.

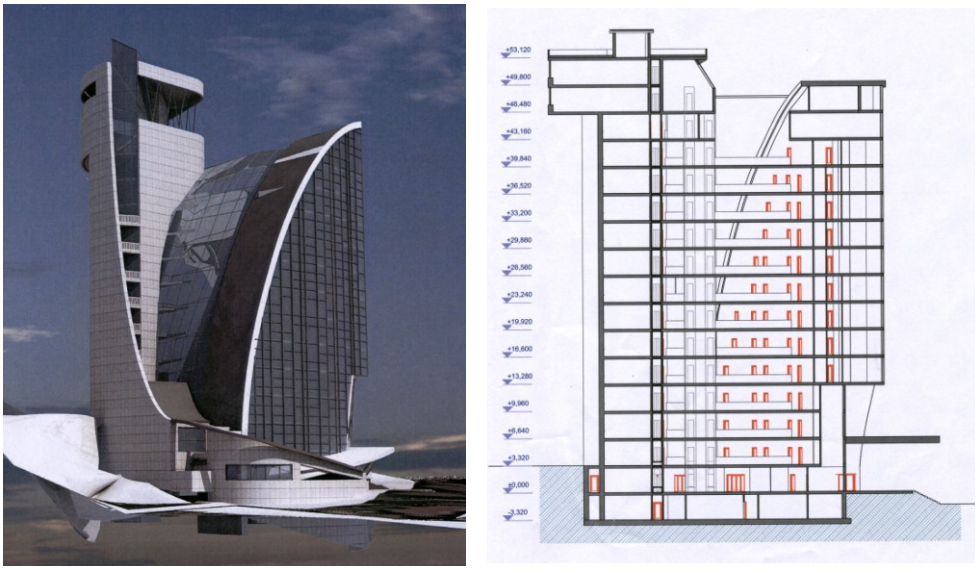

Figure 7. 16-storeyed hotel building in the city Petropavlovsk-Kamchatsky

2.7. Two examples of the Cultural Centre Buildings seismoisolation are presented below. One is in Chechen, Northern Caucasus, Grozny-city. The other is in Altay, Siberia, in both cases the seismoisolation systems were installed in reconstruction process to increase the seismic resistance and safety which is not enough.

Now the construction of one building is finished, the construction of another will be finished in some months.

At the Fig. 8 is Gorno-Altaysk (Siberia) National Drama Theatre before strengthening. At the reconstruction Fig. 9 the fragments of isolation supports installation are shown. At this picture Fig. 8b is the theatre after reconstruction.

Figure 8. Gorno-Altaysk (Siberia) National Drama Theatre.

Here is the state Concert Hall in Groznyy-city [Fig. 9]. Chechen war damages are seen [Fig. 9 left]. And the actual seismic capacity is 2 MSK degrees lower than the design one if using the current Russian Code. It means seismic load 4 times higher than the initial design load. One of the reconstruction goals was to increase the buildings seismic safety. Seismoisolation will be used to achieve this goal. In some months the work will be finished. The building after reconstruction is shown at Fig. 9 right.

In all the buildings we used steel rubber supports produced in China, Shantou “Vibrotech Co.” Their test were fulfilled in Guangzhou University with our participation.

 

Figure 9. State Concert Hall in Grozny-city.

3. CONCLUSIONS

3.1.1. A huge program on seismoisolation research and implementation was undertaking in USSR with this paper authors participation in 1970-74. More than 550 constructed buildings are seismoisolated.

3.2. Recent years investor and architects are often interested in high rise buildings. This interest is caused by social economical and other reasons, in particular with the X1V winter Olympic Games in Sochi-city, which is situated in a high seismic hazardous area. This is the reason of the expanding design of high-rise buildings. And the team which the paper authors represented provides scientific, seismological and engineering works, as well as design works in most of seismoisolated buildings. Some examples are shown in this paper.

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