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Seismo-isolating supports for dwellings

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ABSTRACT: The reinforced seismoisolating support constructions offered to lessen the 8-9 intensity of horizontal seismic load on dwellings to the level of 6-7 intensity are described in the paper. The main stages and the results of experimental full-scale tests of seismoisolating support with the aim of identification of its designed model are summarized. The results of field dynamical tests of full-scale 5-storey large panel buildings with seismoisolating supports on seismic explosion load and on statical load break along with the building large horizontal displacement are presented. Opinion on the ways of practical use of the research results are set forth.

CONTENTS

Some constructive variations of seismoisolating reinforced concrete support for lessening the horizontal seismic load for 1-2 intensity on residential buildings are worked out in the V.A.Kucherenko TsNIISK. All the support constructive elements are made of common reinforced concrete. The primary construction of seismoisolating support is shown on Fig.1

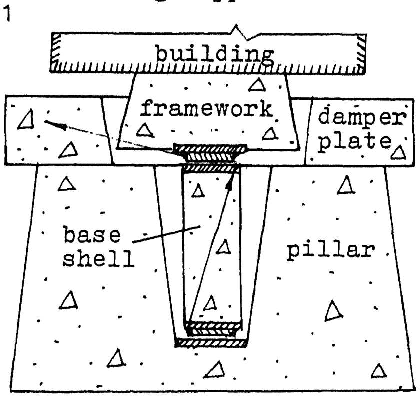

Fig.1.Seismoisolating support

The seismoisolating support includes base shell, pillar, framework, damper plate.

The lower butt of the pillar is supplied with a lug on which the pillar has the possibility to perform the oscillating displacements inside the base shell. The framework, supplied underneath with a square or round in plan flat metal plate with a lug, freely rests upon the upper butt of the pillar with a possibility of pillar oscillation reciprocating displacements. The damper plate is separated from the framework by a gap, that gives the damper plate the possibility of dry friction sliding upon the upper part of the base shell. The pillar height and the dimension of its lug are determined so that at the beginning of the building displacement, the displacement vector of the building would form an angle with horizon α_0 , which tangent would not exceed 0,05 or 0,1 in connection with the allowed seismic influence magnitude on building (6 or 7 intensity).

The pillar deviates from the vertical position under the influence of seismic load. Along with this the seismic load that influences the above layed building does not exceed the dimension $Q tg\alpha_0$, where the Q is the building weight.

Upon the pillar deviation from the vertical position the acting load on it from the building weight Q forms the restoring moment $M = Qz$ with a variable arm of force z .Along with the increase of pillar inclination the dimension of the arm of force z and accordingly the restoring moment M lessen. The results of seismoisolating support full-scale tests show that the dependence between the horizontal force magnitude that inclines the pillar and the horizontal displacement of its top is essentially nonlinear.

Full-scale tests were performed on seismoisolating supports meant for lessening the seismic load intensity on building to the level of 7-intensity. The tests were carried out on seismic shaking tables with load carrying capacity of $2 \cdot 10^3$ kN specially built in the field conditions.

As a result of performed tests was worked out an experimental dependence "restoring force - displacement" on different vertical load values on the support, verified the support seismoisolating capacity upon the kinematic influence from the basis of vibration and impulsive loads.

The statical tests were carried out in three stages. On the first stage the vertical load on four supports was 640 kN, on the second - 1160 kN, on the third - 1840 kN (the designed load for a 9-storey block-section).

Due to the statical tests the following conclusions can be drawn:

- In the field of designed vertical loads the value of the highest restoring force does not exceed one tenth of the vertical load value.
- Elasto-plastic deformations in the support assemblies have an essential influence on the value of restoring force.
- In the field of large displacements (1-6 cm) the dependence between the horizontal restoring force and the horizontal displacement is essentially nonlinear.

The statical tests were concluded by the dynamic break tests of statical load. As a result of 21 load break the total number of vibration cycles exceeded $2 \cdot 10^2$, more than $1,2 \cdot 10^2$ cycles with amplitudes from 5 to 60 mm. Without exception all the vibrograms testify the "soft" character of damped vibrations. The vibration period lessens from the value 1,3÷1,4 sec under the 50÷60 mm displacement amplitude down to the value 0,6÷0,7 sec under the 0,5 mm amplitude.

In all the tests the value of the pillar top residual horizontal displacements did not exceed some tenth parts of millimeter.

Upon testing the seismoisolating support by kinematic vibration influence from the side of basis, the highest acceleration at the basis level was 0,43 g, at the building level - 0,15 g. Under the influence of the experimental impulsive load the highest acceleration at the basis level was 0,57 g, at the building level - 0,14 g.

Test results on vibration and impulsive load give the main conclusion that in the field of designed load the seismoisolating capacity of tested supports is enough to lessen the 8-9 intensity of kinematic horizontal load down to the 7-intensity level.

On the base of full-scale tests the designed building model on seismoisolating supports is presented in common case as a system with geometrical nonlinear elasto-plastic constraint i.e. seismoisolating supports located between the building and surrounding i.e. foundation soil.

The average logarithmic decrement value calculated with the aid of free damped vibrations oscillogram equals 0,5.

A perfected seismoisolating support was used for seismoisolation of large panel 5-storey buildings of non-seismic series 121.

The perfected support has two pillars instead of one, an increased angle of slope of inner walls in the pillar base shell permits the pillar upon strong oscillation "to roll" from the lug's rib on the pillar butt's rib. "The rolling" is considered as a first ultimate state coming out as a result of heavy non-designed earthquake. Second ultimate state is the copercussion between the pillar and the base shell wall. The full-scale tests were performed on a field seismoplatform with load capacity $4 \cdot 10^3$ kN. A 2-storey building fragment series 121 on seismoisolating supports was subjected for testing.

During the static tests process were performed 8 cycles of loading with the amplitude of horizontal top displacement up to 60 mm, including: 3 cycles of "loading-unloading", 5 cycles of "loading-break". Repetition of cycles "loading-unloading" was accompanied by monotonous lessening of the highest value of restoring force from 143 kN to 87 kN under the unchangeable vertical static load on seismoisolating supports of 2950 kN. A partial restoration of the highest force value from 87 kN to 105 kN took place as a result of two days "rest" of the supports. The value of residual horizontal displacements on the stage of static tests did not exceed 4 mm, and in the last loading cycles was not more than some tenth parts of millimeter. Due to the static tests it was stated that the value of the highest restoring force does not exceed one-twentieth of the support vertical load value. Along with this in the field of large displacements the dependence between the horizontal restoring force and the top support horizontal displace-displacement is essentially nonlinear.

The results of tests by static load break state the the free damped oscillation of the building has "the soft" nonlinear character and that a noticeable influence on this have the elasto-plastic deformations of seismoisolating support node elements.

During the vibration tests process were written down 38 vibrograms and 18 accelerograms with the displacement amplitudes from 53 to 162 cm/sec^2 with a frequency of 2 to 7,3 Hz. Along with this the oscillation of the seismoplatform base was aroused by the vibromachine located on it. The highest acceleration value at the level of seismoisolating supports foot (i.e. the seismoplatform level) was 162 cm/sec^2, and accordingly 49 cm/sec^2 at the level of the ground floor of seismoisolated fragment.

A suspended pendulum with the mass load 7.10^3 kg and the length of rigid suspension 2,7 m was used to get the seismoplatform impulsive loading. Between the seismoplatform and the load was placed the one--sided horizontal connection. Under the influence of pendulum the highest level of acceleration at the level of seismoisolating supports foot was 310 cm/sec^2, and at the level of the ground floor of seismoisolated fragment - 65 cm/sec^2.

The results of tests on static, vibration and impulsive loading lead to the conclusion that seismoisolating capacity of the supports is enough for lessening the kinematic horizontal load from 7-8 intensity to 6-intensity.

Test results of full-scale building fragment series 121 are included in the main principles for designing a 5-storey 90-apartment house series 121 on seismoisolating supports. Building designed model and method for earthquake calculation on accelerogram are worked out for calculating the value of the highest horizontal displacements of the building support upper part. In a correctly designed building these displacements must not exceed the amplitude of free displacements of the pillar upper part upon its oscillation only on the lug surface.

Full-scale tests on kinematic loading of the seismical type with 7-8 intensity of a 2-storey fragment (with dimensions equal to one room) of large panel building series 121 on seismoisolating supports with the vertical load equal to the weight of three upper floors caused no damages at all. Due to the high seismoisolating level the shear and bending deformations were not practically observed. With all the various dynamic loading the fragment with superloading performed the oscillation as a rigid body.

On the base of test results the designed model of 5-storey large panel residential building on seismoisolating supports is presented at the first approximation as a flat non-conservative oscillator composed of one concentrated mass that accomplishes the horizontal oscillations with one degree of freedom towards the elastic nonlinear constraint.

As a base for building and the foundation model of constraint were taken the results of the seismoisolating support full-scale tests on variable horizontal loading with a constant vertical load which is equal to the weight of real 5-storey building series 121. The generalized skeleton of diagram curve "restoring force-displacement" was used as an elastic constraint characteristic. The hysteresis curve area in cycles "loading-unloading" was applied for the absorption of energy upon the constraint deformations.

Independently from the construction of dwellings on seismoisolating supports and their number of storeys these dwellings must be designed on accelerogram influence using the SNiP II-7-81 (Building Code and Regulations) that are in action in Russian Federation. The spectral method design of these buildings is not rightful by reasons of:

1 The designed building model on seismoisolating supports is essentially nonlinear, so the design method based on addition of building own oscillation forms with corresponding dynamic coefficients defined by SNiP II-7-81 cannot be applied to these buildings.

2 There is no K_1, K_2, K_ψ coefficient meaning for buildings with seismoisolating systems in SNiP II-7-81. It would be quite wrong to state the value of these coefficients only by the indications of overground part of the building for the ultimate state, coefficients of attenuation, other dynamic characteristics of common seismoresistant buildings and buildings on seismoisolating supports, as a rule, they are essentially different.

CONCLUSION

Application of the worked out method of building seismic protection permits to errect the buildings with designed seismic resistance less for 1-2 intensity of the building site seismicity. The application of seismoisolating supports permits to increase the number of storeys in buildings with designed seismoresistance that corresponds the site seismicity but having no seismic protection. As a result the cost of 1 m^2 of dwelling is reduced to 3-12% and the steel expense lessens to 4-7%.

The experience in application of seismoisolating supports in engineering states that customers and builders in Russian Federation have the highest practical interest in the possibility of changing the deficit seismical series of dwellings on less deficit series with lessened seismic resistance. Such change permits to increase the rate of constructions, to raise the comfort and reduce their cost.