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SEISMIC ISOLATION OF BUILDINGS WITH APPLICATION OF THE KINEMATICS BASES

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SUMMARY

The traditional method of ensuring of seismic resistance of buildings provides for a heightening of a carrying capacity of constructions at the expense of magnification of their sizes and durability. The magnification of the sizes of constructions, on the other hand, results in magnification of a rigidity and weight of a building that, in turn, gives a rise to ascending a slugged (seismic) load.

Recently, in building branch of industry a new method of increasing of seismic resistant was found out, and it was conditionally called as seismic isolation. The seismic isolation constructions loosen link with a foundation that results in a modification of dynamic properties of buildings and lowering of effects of earthquake. The sliding belts (SB), turning off links (TL), rubber-metallic legs (RML) and many others are referred to such constructions. Wide application of seismic isolation systems is restricted to complexity of manufacture and mounting or high price. The kinematics bases (KF), designed in the Kazakh Research and Experimental Design Institution of Earthquake Engineering and Architecture (KAZNIISSA) and offered for mass application are also referred to this type of seismic isolation. The KF bases have been examined for almost of three decades and were already used in more than 400 experimental houses. The earthquakes happened on the Kamchatka peninsula, Kuril Islands, in cities of Irkutsk and Alma-Ata became a functional test of KF in real conditions.

This is a simple cost-effective and at the same time reliable solution of seismic isolation, which became popular in the Russia and Kazakhstan. While comparing with RML, which requires replacement because of aging of rubber, KF does not lose its dynamic properties and durability, and it's cost is 10-20 times less.

INTRODUCTION

Construction of KF

The construction of KF (fig. 1,2) is represented by a mobile element with a spherical abutment resting on a bedplate or other solid foundation. The hinge link with over based structure ensures movability in a horizontal plane on all directions. KFs are made of concrete of 300-400 mark and are reinforced by steel grids.

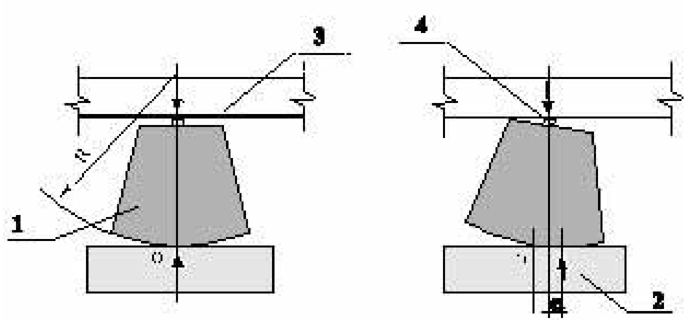


Fig. 1. A constructive system of KF
1 - KF; 2 - bedplate; 3 - tie beam; 4 - hinge junction

The hinge connection is executed by means of connecting anchor and flat steel washer, which is square in the plan. The hinge connection is simultaneously a clipper of shifts, as the connecting anchor creates increasing resistance to turn of KF. From the constructive scheme of the base it is obvious that the gravitation force retaining KF in a status of a stable equilibrium, defines its horizontal rigidity and depends on a weight of an over based structure, height of KF and radius of curvature R of an abutment. The sizes of the kinematics base depend on magnitude of a vertical load, durability of a used material and intensity of seismic effect.

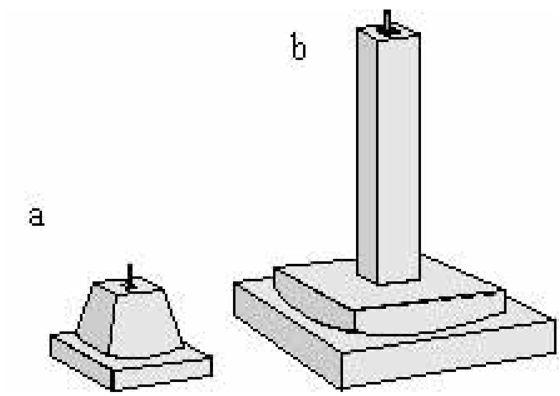


Fig. 2. The different shapes of KF: a) a curbstone; b) the rack

Estimation of seismic resistance of buildings and efficiency of seismic isolation

Estimation of seismic resistance of natural facilities under researches is executed according to the accepted calculated pattern and criteria of a limiting status. In practice of experiment the most convenient criteria of seismic resistant of buildings are the distortions of levels Δ, connected with a degree of damages of constructions. These data can be obtained during static and dynamic testing to be presented as a force characteristics R(Δ), graphically introduced by a diagram of deformation. The distortions consolidate a heterogeneous deformation of level and mean its integrated measure. The maximum admissible distortions correspond to limiting statuses introduced beforehand. For example, at [Δ] = H/500 *(H is a store height)* only damage of walls happens, and at [Δ] = H/200 - roof fall of overlapping happens. Taking into account the integrated criteria, the calculated dynamic pattern can be accepted as consoles with a discontinuous distribution of stored masses mi and stored diagram R(Δ), see fig. 3.

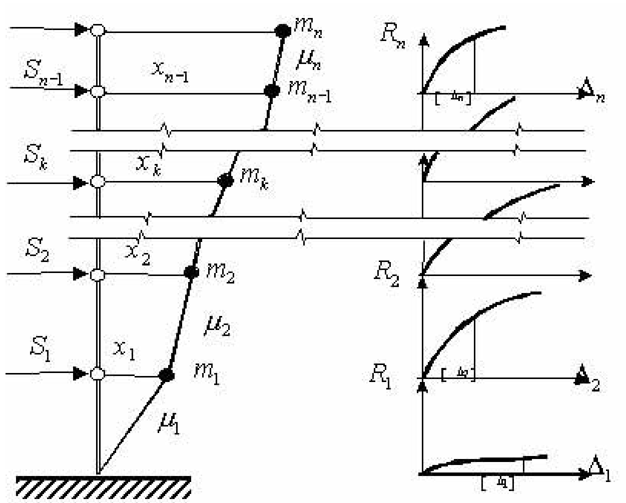


Fig. 3. The model of the dynamic pattern of a building

The calculated pattern is mostly considered to be conditional. The principal requirement to that is that it should correspond to a dynamic status of a building during testing, i.e. frequency and shapes of resonance oscillations, and also its dissipative ability.

Mathematical map of such pattern is the system of the nonlinear differential equations, at which the right member is expressed through accelerations of a foundation $\ddot{x}_0(t)$:

$$m_i \ddot{x}_i(t) + \mu_i \dot{x}_i(t) + \left[R_i(\Delta_i) - R_{i+1}(\Delta_{i+1})\right] = m_i \ddot{x}_0(t),$$

(1)

where:, μ_i, $R(\Delta)$ parameters of fading and deformation of levels.

The generalized coordinates xi (t) at a numerical integration reflect an oscillation of masses mi and distortions Di in time that in functional form can be presented as output signals of transformation L (t)

$$x_i(t) = L(t)\ddot{x}_0(t)$$

(2)

Considering the accepted pattern as a semblance of natural facility, the legitimacy of a human controller L (t) is supposed at an input signal F (t), calling a resonance condition of oscillations:

$$x_i(t) = L(t)F(t)$$

(3)

Identifying in (3) parameters mi, Ri (Δi) according to outcomes of vibrato tests, the calculated seismic oscillations then can be obtained from (2).

The effects in (2) are set by a defined gang accelerograms, taken from a world databank, or realizations of non-stationary, casual process, which is taking into account a seismological situation on a site of construction.

The methodical approach to an estimation of seismic resistance shall remain the same for seismically isolated building as well. The dynamic peculiarities of seism isolation are presented by force characteristics R1 (Δ1) of the lower level - floor. The essential conditions for seism isolation to be effective are:

- reduced rigidity of the lower level - $R1(\Delta 1) << Ri\ (\Delta i)$, $i > 2$
- increased dissipate ability of a seismically isolated building.

The effect of seism isolation means a decrease of seismic loads in comparison with loads on buildings - analogs without seism isolation.

The numerous tests with the help of force guys, vibrators and explosive devices, and also calculation and theoretical analysis of a seismic response of these houses testify to a high effectiveness of KF – a decrease of a seismic load reaches 3-4 times and more. Such effect allows receiving significant safety factor of constructions. Therefore more often, criterion of seismic resistant becomes not a distortion of the upper levels, but admissive movements in a level of KF - $[\Delta 1]$.

The elastic - nonlinear association $R1(\Delta 1)$ makes houses on KF "hardy" in conditions of dynamic effects, that ensures seismic resistant at long and frequently repeating earthquakes.

Use of KF in construction

The majority of houses constructed in Russia on KF is referred to multi-store building. The reduction of seismic loads allows increasing numbers of store, to improve expected projects, to reduce expenditure of a material in constructions.

In figure 4 the section and interior of a cellar of an apartment in city Irkutsk is exhibited. A location of KF in a basement area has allowed setting a parking place there. The traditional columns in this case reduce seismic resistance and are not used in practice in high seismic risk zones. The same solutions were realized in Alma-Ata (now Almaty). The frame brick houses are constructed there in seven-storied fulfillment instead of five-storied, admissive by normative request.

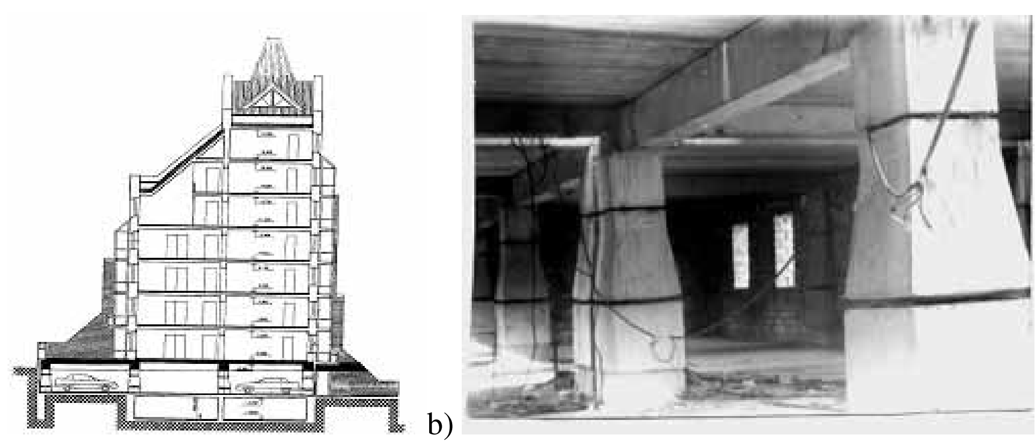
a)  b)

Fig. 4. The building of KF in the city of Irkutsk: a) section; b) interior of a cellar

In few-storied houses without a cellar the construction of the base becomes considerably simpler. In this case a tie-beam serves as a foundation for houses, see figure 5.

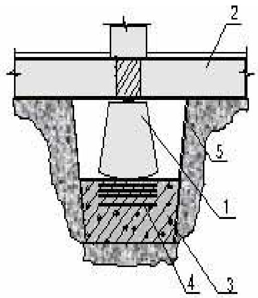


Fig. 5. Unit of the KF base
1 – KF; 2 – a beam; 3 – a concrete pillow; 4 – a reinforced grid; 5 – rammed ground

In countryside the people in need are forced to build houses of clay blocks (saman), with no calculation on seismic effect. The minimum kit of constructive elements of a tie beam becomes an effective guard even at earthquake of 9 numbers. Cost of this kit is very low. The absence of objections concerning scientific outputs, construction and design solutions, and also technique of construction convinces in perspective of seismic protection with application of KF.

REFERENCES

The outcomes of researches of seismically isolated properties of KF were repeatedly published. The standard documentation on designing is developed and many houses in seismically dangerous areas of Russia and Kazakhstan are constructed. In the above presented material the following publications of Yuriy CHEREPINSKIY were used:

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