

CONTROL OF VIBRATION IN THE REINFORCED CONCRETE FRAME OF BUILDINGS OF EARTHQUAKE-RESISTANT MULTI-STORY BUILDINGS

Kayumov Asilbek Dilshatbekovich

Senior Lecturer, Andijan State Technical Institute, Uzbekistan, Andijan city.

asilbekqayumov38@gmail.com

Annotation: This article provides detailed instructions on examination needed to conduct calculation methodology by seismic resistance levels.

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Suspension of a huge mass at the top of a building is one of the methods of shock absorption, which is often used in skyscrapers.

A huge pendulum is supported on steel cables, and elastic liquid shock absorbers are placed between the mass and the structure. In case of vibrations, the building begins to rock. And the ball performs the function of a pendulum, oscillating in the opposite direction. This is how the counterweight to vibrational forces is created. Pendulums are adjusted to the building's vibration frequency to avoid resonance. An example of such technology for earthquake-resistant construction is Taiwan's Taipei skyscraper 101.

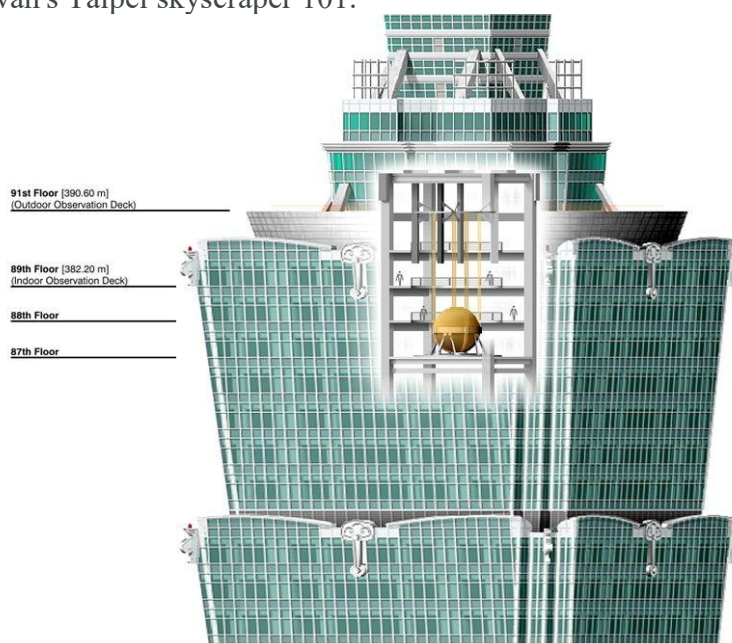


Figure 1. Adjusted mass dampers

Multi-frequency oscillation damper

A system of vibration control devices that, in the event of vibrations occurring, oscillates with

resonant frequencies. It consists of interfloor diaphragms, a set of consoles acting as inertial dampers. They have different periods of natural oscillations.

Oscillating main wall

A low-cost technology that successfully works in conjunction with the use of basic rubber and steel bearing insulation. **Seismic-resistant multi-story buildings with a reinforced concrete frame** have a wall of the building's central trunk oscillating at the building's lower level to prevent the concrete of the wall from collapsing. In addition, engineers are reinforcing the two lower floors of the building with steel and installing tension reinforcements along the entire height. Steel cables pass through the central shaft of the building. They act as rubber bands that can be stretched by hydraulic jacks to increase the temporary resistance of the central core to rupture.

Technologies for earthquake-resistant construction contribute to the slowing down of vibration and the reduction of amplitude. The shock absorbers are placed at all levels of the structure, with one end attached to the beam and the other to the column. The shock absorber is a vibration damper in the form of a piston placed inside a cylinder filled with silicone oil. Due to horizontal tremors during earthquakes, the pistons begin to move and exert pressure on the oil. This is how mechanical energy in vibrational energy is converted into heat.



Figure 2. Seismic protection devices made of shock absorbers.

In many skyscrapers of the world, there is a "secret" device that protects the building from strong movement due to wind and earthquakes. Dampers are devices for dampening vibrations, which are installed directly on the structural frame of a building or structure. There are many varieties that are selected based on a specific project:

- **Inertial damper.** It is usually made in the form of a concrete block, which oscillates with the resonant frequency of the object. This is facilitated by a spring-like mechanism under seismic load.

- Hysteresis damper. Helps to improve seismic characteristics by dissipating seismic load energy. Includes 4 groups of dampers.
- Liquid viscosity damper. Installs in the building structure, being an additional damping system. It has an oval hysteresis loop, and its damping depends on the speed. Although slight maintenance may be required, viscosity dampers generally do not require replacement after an earthquake.
- Friction dampers. As a rule, there are two main types: linear and rotational. They dissipate energy through heat. The damper operates on the principle of Coulomb friction. When used in earthquake-resistant conditions, wear is not a problem and maintenance is not required.
- Metal elastic dampers. They have a reserve of flexibility, allowing them to absorb earthquake vibrations. This type of damper absorbs a large amount of energy, however, it requires replacement after an earthquake.

Viscoelastic dampers. It can be used for both wind and seismic applications. They are usually limited to small displacements.

At different levels of seismic resistance, to ensure the overall spatial rigidity of the structure, the roofing system must have a predetermined level of stress-strain state that ensures its elastic operation during an earthquake, i.e., rational design models of structures must be applied with their mandatory justification (including experimental studies).

To avoid brittle destruction in structural elements, it is necessary to adjust the dimensions of the section being cut during design to meet the limitations of current norms. The main requirements for ensuring the seismic resistance of structures by property levels are equivalent to the requirements of the fourth level of the state of reinforced concrete structures.

Level 1 a. The structure meets the design elasticity conditions, the load from seismic effects, and the displacement angle between floors satisfy the conditions of current norms; a rational structural diagram and its design model are used when calculating the structure. The calculation takes into account the reliability coefficients for load, materials, building, and the correction coefficient of seismic load combinations.

For structures of types A and B, it is possible not to calculate the values of internal forces under seismic influences; individual earthquake-resistant structures of different elements satisfy the minimum of the main conditions. For structures of types C, D, and E, to conduct a nonlinear analysis of the behavior of structures during moderate and strong earthquakes, the design of structures at the stage of small earthquakes is carried out first according to these norms, then a nonlinear analysis is carried out and the properties are corrected during moderate and large earthquakes. According to the corrected results, further design is carried out.

Level 1 b. The seismic load on all elements satisfies the operating conditions of the structure at the elastic stage, and the seismic resistance of various elements meets the minimum of basic requirements. Reliability coefficients for load, materials, building, and seismic load combination coefficient are accepted, but the change in internal forces during seismic impacts is not calculated.

Level 2. The seismic load on the weakened and critical sections satisfies the design conditions for the elastic stage. All structures undergo nonlinear analysis, allowing for the approximation of material properties in the specified cross-sections to the flowability conditions. The occurrence of cutting and other fragile destruction is not permitted; individual earthquake-resistant structures of various elements satisfy their minimum tensile condition.

Level 3. In the weakened or critical sections of the structure, no flowability occurs, i.e., the change in internal forces under seismic influences is not calculated. The seismic resistance load is calculated according to the norms (the reliability coefficients for load, materials, building, and the combination coefficient for seismic load are taken as 1.0). Structures are subjected to nonlinear analysis, it is permissible to approximate the properties of the cross-sectional material to fluidity, but intersecting and other fragile breaks should not occur; individual earthquake-resistant structural elements satisfy minimal conditions for average extensibility.

Level 4. The structure undergoes nonlinear analysis, the weakened or critical sections of the structures can transition to a fluid state, but at the same time, the condition of limiting deformations is met (for example, the relative displacements of the floors of reinforced concrete structures are 1/500-1/300). In vertical elements, the occurrence of cutting and other fragile destruction is not permitted; individual earthquake-resistant structures of different designs satisfy the minimum plasticity conditions.

Level 5. The structure undergoes nonlinear analysis, its weakened or critical sections may transition to a fluid state, however, the deformation limitations for strong earthquakes are met; individual earthquake-resistant structures of different designs satisfy the ultimate plasticity conditions.

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