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CHANGE OF THE LOAD-BEARING CAPACITY OF THE STRUCTURES IN TIME IN SEISMIC CONSTRUCTION

Asmik Rubenovna Klochko, Aleksey Konstantinovich Klochko
Moscow State University of Civil Engineering (MGSU), 26,
Yaroslavskoye Shosse, Moscow, 129337, Russia

ANNOTATION

In article the analysis of the structures condition working in seismic activity zones is carried out. It is revealed that the degradation processes proceeding in materials of structures and also the seismic mode of the region influence on durability of structures. The intensity of influence depends on density of a total seismic stream in the region. It is proved that in deciding of restoration need and/or structures strengthening it is necessary to apply the differentiated approach: each structure has to be restored or strengthened proceeding from her concrete state, taking into account requirements for safety during the residual term of operation. At mitigation of consequences of an earthquake it is necessary to observe sequence of the buildings and structures demanding restoration, strengthening or demolition. The sequence has to be taking into account terms of maintenance free operation of the structures and risks connected with their operation in the damaged state.

Key words: Structural-Load Capacity, Seismic Construction, Seismically Active Zone.

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1. INTRODUCTION

The task of providing buildings with the ability to continuously maintain their operability throughout the life of the operation is the main task of construction. This task is particularly complex in seismically dangerous areas. One reason is related to the fact that the security issues in earthquake-resistant construction are at variance with the issues of its economics: on the one hand, the insufficient reliability of the building in case of an earthquake threatens with great losses, and on the other hand, the desire for absolute security inevitably leads to extremely high costs. Therefore, providing security through minimizing the total cost of constructing a building is a very difficult task and there is not yet a single methodology for determining the optimal balance between the level of safety and economy of earthquake-proof construction.

Another reason is the fact that the bearing capacity of their structures is continuously decreasing during the operation of buildings. It occurs mainly because of the degradation processes occurring in the materials of the structures. Studies show that such a reduction has a very low intensity, flows throughout the life of the structure and is well described by exponential law. In earthquake-prone areas, the reduction of load-bearing capacity is also due to the impact of seismic loads. In this case, it occurs instantaneously, sometimes spasmodically, without any regularity. Such a change is random, and the degree of loss of load-bearing capacity depends on the degree and nature of the damage received.

Since both internal (material degradation) and external (seismic effects) conditions have a wide range of indicators, it becomes clear that the deterioration of the state of structures operating under seismic conditions is a complex and poorly predicted process.

In order to study the problems related to durability, the period of unattended operation, the level of increase in bearing capacity, etc., the article analyzes in detail the state of structures operating under conditions of seismic activity of the territory.

2. ANALYSIS OF THE CONDITION OF STRUCTURES WORKING IN SEISMIC ACTIVITY ZONES

The norms [1] indicate that the calculation of buildings, taking into account the seismic effect, is carried out according to the load-bearing capacity. Following this in the article, we will describe the changes in the strength characteristics of structures in time through the "load-bearing capacity - time" dependence. At the same time, under the term "load-bearing capacity" we shall adopt the definition given in [2, 3-5], according to which "load-bearing capacity" is the quality of the structure in strength, stability and endurance.

The bearing capacity of structures is determined by the variability in time of internal properties (materials) and external conditions (loads and impacts). The processes caused by external conditions and taking place in the materials of the construction are basically irreversible and contribute to the deterioration of its strength properties. One of the properties of these processes is their ability to accumulate damages, which, in the end, leads the design into a state of unfitness (failure). Depending on the speed of deployment, failures are subdivided into gradual ones, which occur with low intensity and arise as a result of aging, wear, and sudden failures, which appear instantaneously, abruptly and, most often, have a random character [6-9].

Let us consider the scheme of the operation of the structure in time by analogy with the technique in [10].

From the very beginning of the operation of structures operating under normal conditions, because of the degradation processes occurring in its body, the bearing capacity begins to gradually decrease (Figure 1). Such a decrease is well described by the exponential law [10]:

$$R(t) = [R] \cdot e^{-\lambda \cdot t} \tag{1}$$

where R (t) is the load-bearing capacity of the structure at time t; [R] - initial level of load-bearing capacity; λ is the total coefficient characterizing the relative rate of loss of the load-bearing capacity of the elements as a result of corrosion, aging, and the like.

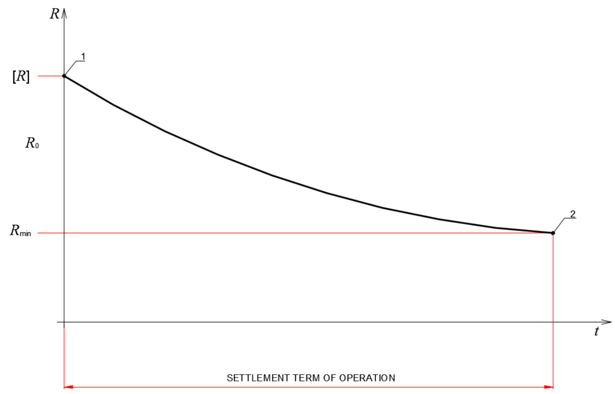

Figure 1 Dependence "the bearing ability - time" forthe designs operated in usual conditions

Dependence (1) is of a statistical nature, since there is a dispersion of indicators of both internal and external conditions.

If the minimum permissible level of load-bearing capacity R_{min} is set for the period of the estimated service life, it is possible to achieve the level of the initial load-bearing capacity with such a resource [R] = R_{min} +R_0, so that, gradually decreasing, it reaches a minimum permissible level only towards the end of the calculated service life (Figure 1, curve 1-2).

For structures operating in earthquake-prone conditions, it is economically inexpedient to aim for such a high initial reservation [R], so that any damage to structures during strong earthquakes is prevented. For earthquakes of low intensity, which occur relatively often (once or several times in the estimated time of operation of the building), the bearing structures of the building must remain intact or almost undamaged. And in the case of destructive earthquakes, which are rather rare events, very significant (the maximum permissible degree) of destruction.

In accordance with this assumption, the minimum permissible level of load-bearing capacity R_{min} in terms of the seismic activity of the territory is conditionally represented in two levels (Figure 2). The upper level is $R^{в}_{min}$, at which the structure does not receive or almost does not get damaged, and the lower level is $R^{н}_{min}$, at which the structure receives the maximum degree of damage in case of earthquake impact of the calculated value. Obviously, the difference in these levels is the greater, the higher the seismic activity of the territory.

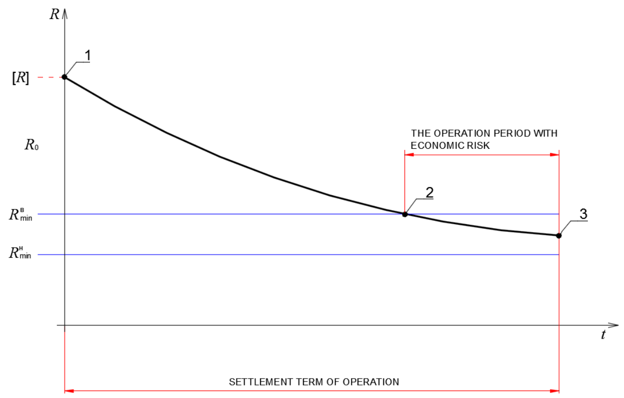

Figure 2 Dependence "the bearing ability - time" for the designs operated in seismic conditions

Taking a small initial resource of strength R_0, you can get some savings. But instead of this saving, starting from the moment of the intersection of the curve (1-3) with the upper-level $R^{в}_{min}$ (point 2), the operation of the construction will be connected with a certain risk. Here, of course, we can only talk about economic risk. Reducing the initial reservation to a level that would threaten non-economic losses is unacceptable.

Now consider the case when, at some point in time of building operation, an earthquake with an intensity less than the calculated one (Figure 3).

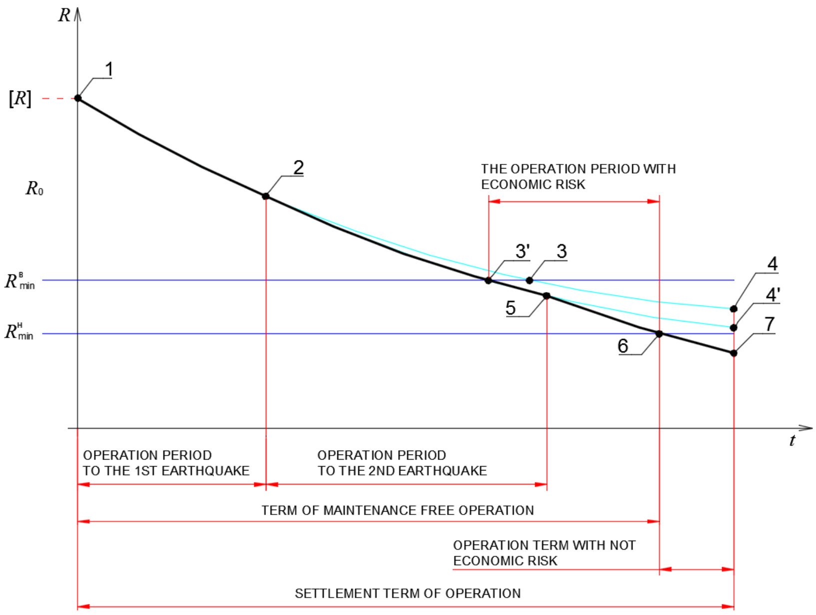

Figure 3 Dependence "the bearing ability - time" in the conditions of seismic influences

The deformations, deflections, cracks, punctures, weakening of the adhesion of the reinforcement to the concrete, both in the body of the structures and in the nodes of their interfaces, resulting in an increase in the intensity of corrosion and wear of the structures. Thus, the speed of reducing the level of load-carrying capacity in the structures increases. In Figure 3, this circumstance is represented, as the transformation of the curve 1-2-3-4 into the curve 1-2-3'-4'. The consequence is both an increase in the level of risk (point 4 assumes position 4') and the period of operation of the structure with economic risk (point 3 assumes position 3'). Obviously, it is economically expedient to aim for the curve to reach the lower level $R^{н}_{min}$ by the end of the service life. However, this depends on the seismic regime of the construction area, since in the case of a repeated impact of the seismic load, curve 5-4', similarly to the first case, can be transformed into curve 5-7, which intersects the lower level of the load-bearing capacity $R^{н}_{min}$ at point 6. From this point on, the further operation of the building will be carried out in conditions of non-economic risk. It is clear that with multiple seismic shocks with an intensity less than the calculated one, the load-bearing capacity graph of the structure will be at the level of the minimum permissible $R^{н}_{min}$ much earlier, therefore, the period of unattended operation of the structure will be significantly less than the estimated one.

In the case of an earthquake of the project value or above project value, the load-bearing capacity of the structure, due to the damage manifested, decreases sharply. This is shown in Figure 4 by the transition from point 2 to point 4.

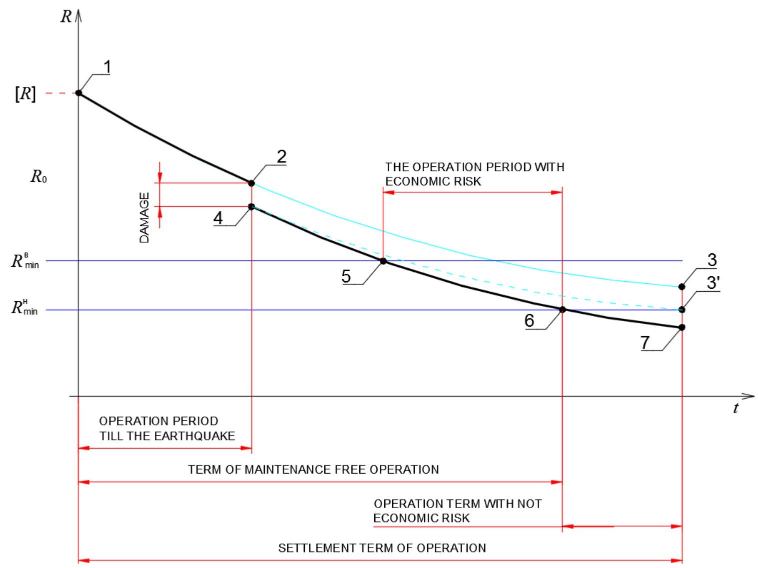

Figure 4 Dependence "the bearing ability - time" at seismic influence of beyond design basis size

If you continue to operate the structure in a damaged state, curve 2-3 will move to position 4-7. Obviously, the more significant is the damage (2-4), the greater is the risk (point 3 assumes position 7 instead of 3').

From the moment when curve 4-7 crosses the boundary $R^{в}_{min}$ (point 5), further operation of the structure is carried out under conditions of economic risk. When curve 4-7 crosses the level $R^{н}_{min}$ (point 6), the structure is in a state of unfitness for further operation. Considering this circumstance, when developing a program for eliminating the consequences of an earthquake, it is necessary to carefully select and prioritize objects and structures that require urgent restoration, reinforcement or demolition. Obviously, these issues cannot be solved without a thorough study of the state of the damaged structure and determining its residual load-bearing capacity.

The improvement of seismic forecasting techniques often leads to the fact that, after clarification, seismicity of the territory increases. In Figure 5, this change is indicated by a corresponding increase in the upper and lower bounds of the minimum permissible levels of load-bearing capacity (for example, line 3-4 rises to level 5-6). The consequence of this is that the period of unattended operation of structures is dramatically shortened and the operational period with economic risk comes faster (point 7 moves to 7 '). The period (point 8) is also not excluded when the further operation of the structures will be carried out in conditions of non-economic risk. In this case, there will be a need to reinforce undamaged buildings and structures.

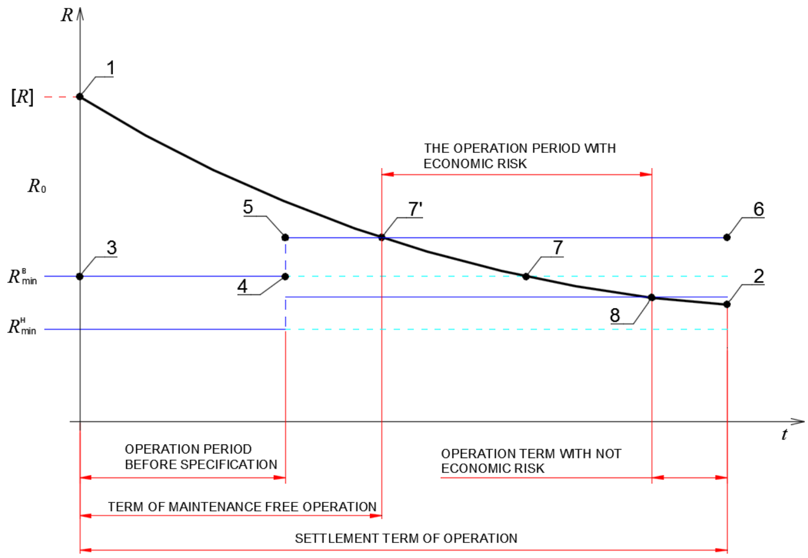

Figure 5 Dependence "the bearing ability - time" for the designs operated in conditions increases of level of seismicity of the territory

From the above analysis of the state of structures operating under conditions of seismic intensity, the following conclusions can be drawn:

- in addition to the less intensive degradation processes taking place in the materials of structures, the life of the structures is affected by the seismic regime of the region (scoring, shaking). The intensity of such influence directly depends on the density of the total seismic flow in the region. The overall degradation of strength characteristics of structures may have different intensities because of the difference in the flow of earthquakes in different regions. Therefore, the calculation of the longevity of structures in relation to (1) can be made only if the coefficient λ is determined in accordance with the seismic regime of the area;
- the need to strengthen the structures can arise not only because of the high degree of structural damage but also because of the increased seismic level of the construction area. Therefore, when deciding on the need to restore and/or reinforce structures, a differentiated approach must be applied: each structure must be rebuilt or reinforced based on its specific state, taking into account the requirements for ensuring safety during the remaining service life. When developing an earthquake response program, it is necessary to select carefully the order of buildings and structures that require restoration, reinforcement or demolition. The order should be drawn up taking into account the periods of unattended operation of structures and the risks associated with their operation in a damaged condition.

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