International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 10, October 2017, pp. 1756-1762, Article ID: IJCIET_08_10_177
Available online at http://http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=10
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

THE PROBLEMS OF THE INCREASE IN LOAD-BEARING CAPACITY IN THE SEISMIC CONSTRUCTION

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

ABSTRACT

This article is devoted to the task of ensuring the operability of operated buildings that have been damaged by accidents, earthquakes and other causes. In article 2 important questions are allocated: need of definition the rational level of increase in the bearing capacity of damaged structures; need of development of a technique to prioritize buildings and their structures for recovery/reinforcement activities. The volume and nature of constructive anti-seismic measures and, consequently, the costs of these activities, are usually of an empirical nature and insufficiently substantiated by technical and economic studies. It is specified in article that the consequence of this is that the initial costs for seismic protection of buildings, as well as the cost of restoration in case of damage from an earthquake, fluctuate within very wide limits; or the demolition of the affected buildings without proper economic justification.

In order to solve the above-mentioned problems, we propose in this article a calculation technique for determining the rational level of increasing the load-bearing capacity of structures, taking into account its residual service life and the period of unattended operation of damaged structures.

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

Cite this Article: Asmik Rubenovna Klochko and Aleksey Konstantinovich Klochko, The Problems of The Increase In Load-Bearing Capacity In The Seismic Construction, International Journal of Civil Engineering and Technology, 8(10), 2017, pp. 1756-1762.
http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=10

1. INTRODUCTION

The complexity of a task of ensuring operability of the operated buildings, which have sustained some damage owing to accidents, earthquakes and other reasons, is in the following: if for the new buildings the task is reduced to determining the necessary reserve of load-bearing capacity of structures taking into account its reduction in time to the minimum acceptable level, then for the damaged buildings it is also necessary to take into account the level of residual load-bearing capacity of their structures. This circumstance brings the question of assessing the real state of damaged structures to the forefront since the decisions of other important issues depend on its correctness. Let's point out two of them:

- An important problem is to determine the rational level of increase in the bearing capacity of damaged structures. This problem is based on the fact that the current building codes based on the concepts of new construction are used in the calculations of the amplification without additional clarification and consideration of all specific issues. The consequence of this is, for example, the following: in calculating the longevity of new structures, the initial life of the strength is provided by means of reliability coefficients for materials, loads, and operating conditions. At the same time, the values of these coefficients are taken such that the durability of the structures corresponds to the normative period of operation. But for the structures to be reinforced, the durability is not a standard parameter and depends on the remaining life of the building they are part of. And the residual service life of the building may be several times less than the standard period. Therefore, with the reinforcement of structures or the inclusion of new structures in the bearing system of the old building, the determination of the initial strength resource with the use of the above coefficients is impractical, since this obviously leads to an overestimated cost. It is necessary to develop a new calculation technique that would allow to determine the rational level of load-bearing capacity of the structure that would correspond to the remaining period of operation and take into account its actual state before the reinforcement. But at the moment there is no such method.
- Usually, after the impact of a seismic load, a large number of buildings and their structures receive varying degrees of damage, while maintaining their operational usefulness. And the material and labor resources of design and construction organizations do not allow to restore/strengthen all damaged buildings and structures in a short time. Therefore, some buildings, structures must be rebuilt/reinforced immediately, and others - later. Therefore, it becomes necessary to prioritize buildings and their structures for recovery/reinforcement activities. And for this, it is necessary to have a calculation technique, with the help of which it would be possible to determine, on the basis of the actual state of the structures, the permissible periods of their operation in a damaged condition. But at the moment such technique does not exist.

The poor knowledge of the above-mentioned issues in practice is manifested in the uncertainty of the actions of management bodies and design and construction organizations in dealing with the restoration of cities, populated areas, as well as individual structures that have experienced seismic shaking. The volume and nature of constructive anti-seismic measures and, consequently, the costs of these activities, are usually of an empirical nature and insufficiently substantiated by technical and economic studies. The consequence of this is that the initial costs for seismic protection of buildings, as well as the cost of restoration in case of damage from an earthquake, fluctuate within very wide limits. And sometimes there is another extreme - the demolition of the affected buildings without proper economic justification.

2. DETERMINATION OF THE LEVEL OF INCREASING OF LOAD-BEARING CAPACITY AND TERMS OF UNATTENDED EXPLOITATION OF STRUCTURES

One of the most important and complex tasks for restoration/reinforcement of structures is to determine the level of increase in their load-bearing capacity, which should be such that there is no prohibitive state, including emergency, during the residual service life. For a detailed presentation of all the nuances of this problem, let us consider the scheme of the construction work in time by analogy with the technique in [1, 2-6].

From the very beginning of the operation and until the first seismic load test, the structure operates under normal conditions. Consequently, the decrease in the load-bearing capacity over time follows an exponential law due to the internal degradation of the materials of the structure [1]:

$R(t) = [R] \cdot e^{-\lambda \cdot t}$ (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 degradation of construction materials.

At present, the parameter λ has been little studied. Observations of different authors indicate that different buildings (wooden, stone, concrete) have different wear rates. In this paper, we will borrow the value of λ from [7], where λ = 0.0053 · 1 / year.

The initial level of the bearing capacity [R] is adopted in such a way that, gradually decreasing, it reaches the minimum permissible level $R^{н}_{min}$ only by the end t = T of the estimated service life (Figure 1, curve 1-3).

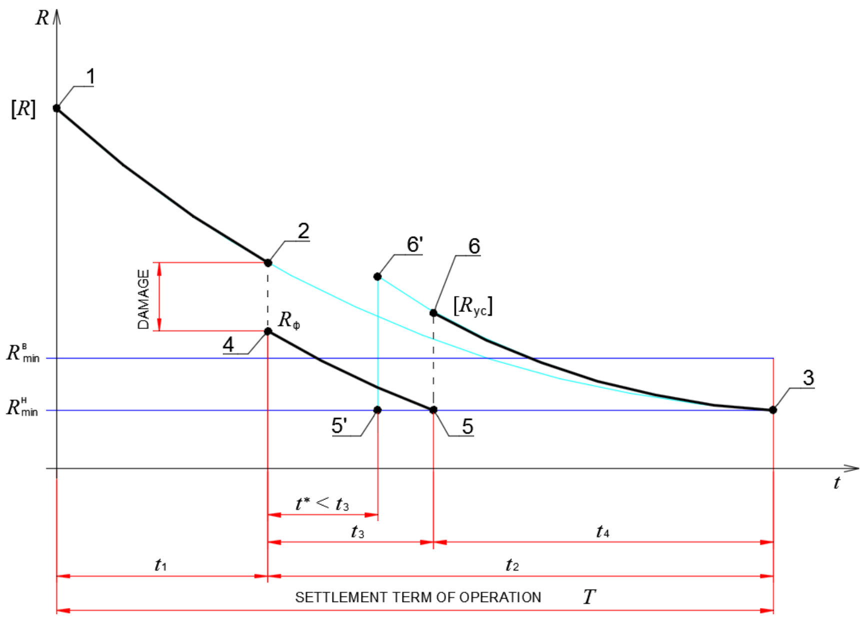

Figure 1 Dependence "the bearing ability - time" in conditions increases in the bearing ability of the damaged designs

Here, as in [1, 8-10], under the upper level $R^{\text{н}}_{min}$ is meant the level of the load-bearing capacity at which the structure does not receive or almost does not get damaged, and below the lower level $R^{\text{н}}_{min}$ is understood the level at which the structure receives the ultimate degree of damage in the event of an earthquake impact of the estimated value.

At present, there are still no criteria for the suitability and safety of operation of building structures and buildings in general. It is believed that with the physical wear of 65 - 70% or damage to the building of the fourth and more degree with seismic influences, further safe use of it becomes impossible. Then, as the maximum permissible degree of destruction of buildings, we can assume [i] = 3.2 (as in [7]), which corresponds to approximately 65% of the building wear. In [7] it is noted that buildings with seismic resistance I_c receive less than the fourth degree of damage if the intensity of the seismic action is I $= I_c + 2$. Consequently, it can be assumed that the lower minimum allowable limit of the load-bearing capacity of the structures $R^{\text{н}}_{min}$ was at a level corresponding to the seismic resistance of the building by two points less than the calculated one.

Accepting this assumption, suppose that at some time $t = t_1$ the structure undergoes a seismic load of the calculated value and, due to the manifested damages, its load-bearing capacity sharply decreases (Figure 1, point 2 goes to point 4). In this case, the most important task for the further planning of measures to restore/reinforce the damaged structure is to determine its actual load-bearing capacity. Obviously, only with the help of careful research, you can obtain the information necessary to determine the need for repair and recovery works and its volume, as well as for the correct timing and level of restoration work.

If you continue to operate the structure in a damaged condition, then (see Figure 1) the curve 2-3 will move to position 4-5. From the moment of the intersection of the curve 4-5, the boundary $R^{\text{в}}_{min}$ the further operation of the structure will be carried out under the conditions of economic risk, and after reaching the level $R^{\text{н}}_{min}$ (point 5) - under non-economic risk.

The estimated life term of the structure is expressed in terms of T years. Then (see pic.1):

$$T = t_1 + t_2 \tag{2}$$

where t_1 is the period of operation of the structure before the earthquake; t_2 is the remaining life of the structure after the earthquake, which can be determined from the general plan of restoration of the structure:

$$t_2 = t_3 + t_4 \tag{3}$$

where t_3 is the time interval after the earthquake and before the reinforcement of the structure (the period of unattended operation); t_4 is the life after the reinforcement.

When determining the level of reinforcement of the structure, one must proceed from the fact that the limit state is permissible only at the end of its service life. In this case, the problem is reduced to determining the reservation size of the calculated parameter $[R_{yc}]$, for which it would be equal to $R^{\text{н}}_{min}$ in a given period of time - t_4 (Figure 1). Then formula (1) for the lower admissible level $R^{\text{н}}_{min}$ can be written in the form:

$$R^{\text{н}}_{min} = [R_{yc}] \cdot e^{-\lambda \cdot t_4} \tag{4}$$

Hence,

$$[R_{yc}] = R^{\text{н}}_{min} \cdot e^{\lambda \cdot t_4} \tag{5}$$

It is seen from (5) that, the smaller the t_4, the lower the reservation level of the calculated parameter $[R_{yc}]$ and, therefore, the less the cost of increasing the load-bearing capacity of the structure. But on the other hand, the smaller t_4 , the longer the lifetime of the unreconstructed structure is t_3. However, t_3 has a limit value - this is the maximum service life at which the residual load-bearing capacity of a unreconstructed structure, gradually decreasing, reaches a lower limit (Figure 1, point 5):

$$R(t_3) = R^{н}_{min}. \quad (6)$$

It follows from this that the rational level of the load-bearing capacity at reinforcement corresponds to the time $t = t_3$.

During t_3, the reduction in the load-bearing capacity of the damaged structure (Figure 1, curve 4-5) proceeds analogously to formula (1):

$$R(t) = R_{ф} \cdot e^{-\lambda \cdot t} \quad (7)$$

where $R_{ф}$ - the actual load-bearing capacity, determined by the results of the survey.

Taking into account (6), formula (7) at the end of term t_3 takes the form:

$$R^{н}_{min} = R_{ф} \cdot e^{-\lambda \cdot t_3} \quad (8)$$

From here you can determine the deadline for the operation of the structure in a damaged condition:

$$t_3 = \frac{1}{\lambda} \cdot ln \frac{R_{ф}}{R^{н}_{min}} \quad (9)$$

Then, taking into account formulas (3) and (5), the rational level of increase in the load-bearing capacity of the structure can be determined by formula:

$$[R_{yc}] = R^{н}_{min} \cdot e^{\lambda \cdot (t_2 - t_3)} \quad (10)$$

If, for some reason, the reinforcement of the structure should take place before the rational time (t* <t_3), then in formula (10) we need to replace t_3 by t*. Then, as follows from (10), the reservation level of the calculated parameter $[R_{yc}]$ will be slightly higher (Figure 1, size 5-6 becomes 5'-6') and, consequently, the cost of increasing the load-bearing capacity of the structure is greater.

Thus, having determined the efforts in the structures of the load-bearing framework of the building, corresponding to the level of $R^{н}_{min}$, and knowing the value of the coefficient λ for the given construction site, it is possible to determine the level of the initial reservation of any structure in the building that ensures its safe operation for a specified period of time.

Example

As part of the frame building, there is a damaged girth rail. It is required to find a rational level of its reinforcement, if it is known that the building is located on the site, the seismicity of which is estimated I = 9 points, and the remaining service life of the building is 40 years. According to the survey data, the actual load-bearing capacity of the girth rail for bending moment is equal to: in the span section, $M^{np}_{ф}$ = 18 kNm, in the key section $M^{on}_{ф}$ = 30 kNmB.

The pulls in the girth rail from external loads, determined in the seismic resistance of the building I_c = I- 2 = 7 points, constitute:

in the span section M^{np}_{min}= 17,2 кН·м;

in the key section M^{on}_{min}= 28,4 кН·м.

Using formula (9), we define the deadline for the maintenance of the girth rail:

for the span section: $t^{np}_{3} = \frac{1}{0,0053} \cdot ln \frac{18}{17.2} = 8.6$ лет

for the key section : $t^{on}_{3} = \frac{1}{0,0053} \cdot ln \frac{30}{28.4} = 10.3$ года

Consequently, the reinforcement should be made not later than t_3 = 8.6 years. By this time, the reinforcement levels according to formula (10) are:

in the span section: $[M]^{np} = 17.2 \cdot e^{0.0053 \cdot (40-8.6)} = 20.3$ кНм;

in the key section: $[M]^{on} = 28.4 \cdot e^{0.0053 \cdot (40-8.6)} = 33.5$ кНм.

Now suppose that the reinforcement of the girth rail is made immediately after the damage (t* = 0). Then the reinforcement levels will be:

in the span section: $[M]^{np} = 17.2 \cdot e^{0.0053 \cdot 40} = 21.3 > 20.3$ кН·м;

in the key section: $[M]^{on} = 28.4 \cdot e^{0.0053 \cdot 40} = 35.1 > 33.5$ кН·м.

If the girth rail is reinforced later than t_3 = 8.6 years (t* = 10 years after the survey), then at this time the reinforced structure will have, according to formula (7), the following bearing capacity:

in the span section: $M^{\text{пр}}_{10} = 17.2 \cdot e^{-0.0053 \cdot 10} = 16.3$ кН·м < $M^{\text{пр}}_{min} = 17.2$ кН·м

in the key section: $M^{\text{оп}}_{10} = 28.4 \cdot e^{-0.0053 \cdot 10} = 26.9$ кН·м < $M^{\text{оп}}_{min} = 28.4$ кН·м

From the analysis of the results obtained, it should be concluded that if the reinforcement is performed without using the period of unattended operation of the structure (immediately after the damage), then the level of its reinforcement increases, and the total cost of reinforcement, respectively, increases. If the reinforcement is done after this period, the load-bearing capacity of the structure falls below the minimum permissible level and, therefore, there is a threat of a non-economic nature.

3. CONCLUSIONS

1. The limit of operational capacity is characterized by the magnitude of the ultimate deformation still possible in operation. Termination of operation is possible only because of the danger of further use. Following this, we introduce the concepts of upper and lower minimum permissible load-bearing capacity. Under the upper minimum allowable level is understood a level at which, in the event of an earthquake impact of the estimated value, the structure does not receive or almost no damage. Under the lowest minimum allowable level, a level is assumed at which the structure receives extreme damage in the event of an earthquake impact of the estimated value. On the basis of this classification, a method for determining the rational level of reinforcement of reinforced concrete structures have been developed.
2. According to the proposed method, the rational level of reinforcement is determined on the actual state of the structures and takes into account their residual service life. The technique allows to determine the deadline for the operation of structures in a damaged state and makes it possible to make up the order of the reinforcements of both damaged buildings and structures within a single building.
3. The rational level of reinforcement corresponds to the moment when the bearing capacity of a non-reinforced structure reaches its lowest minimum allowable level. If the structure is reinforced

earlier than this time, then there is an increase in material costs. If the structure is reinforced later than this time, then there is a threat of a non-economic nature.

REFERENCES

[1] Klochko, A. K. and Klochko, A. R. Some features of calculation of the reinforced concrete bent elements and economic assessment of design, MATEC Web Conf. Volume 117, 2017, RSP 2017 – XXVI R-S-P Seminar 2017 Theoretical Foundation of Civil Engineering, 00078, 24 July 2017, p. 6. https://doi.org/10.1051/matecconf/201711700078.

[2] Dzhinchvelashvili, G.A. Mkrtychev, O.V. and Keleshev, M.F. The concept of the normative document of new generation on aseismic construction. In the collection: Concrete and reinforced concrete - a prospection scientific works of the III All-Russian (the II International) conferences on concrete and reinforced concrete: in 7 volumes, 2014, pp. 416-421.

[3] Baikov, V.N. and Sigalov, E.E. Reinforced concrete structures. General course. 5th ed. Moscow: Stroyizdat, 1991, 767p.

[4] Roitman, A.G. Reliability of constructions of operated buildings. Moscow: Stroyizdat, 1985, 175 p.

[5] SNiP 2.03.01-84*. Concrete and reinforced concrete structures. Minstroj Rossii. Moscow: GP CPP, 1995, 77 p.

[6] Háussler-Combe, U. Computational methods for reinforced concrete structures/ Wiley Blackwell, 2014, 354 p.

[7] Arutyunyan, R.G. Determination of the rational reinforcement of reinforced concrete structures operating under seismic conditions by the method of search optimization. Ph.D. Dissertation, Moscow: MGSU, 2000, 185p.

[8] Grozdov, V.T. To determination of boundary value of relative height of the compressed concrete zone ξ_R when calculating of the assembly and monolithic and strengthened reinforced concrete designs. *Izv. Vuzov. Construction and architecture*, **1**, 1994, pp.113-114.

[9] Ayzenberg, Ya.M. and Smirnov, V.I. Aseismic construction. Safety of constructions. 14th European conference on aseismic construction, Macedonia, Ohrid, August-September, 2010, 5, 2010, pp. 74-80.

[10] Sandeep G S and Gururaj Patil, Comparative Study of Lateral Displacement and Storey Drift of Flat Slab and Conventional Slab Structures In Different Seismic Zones, International Journal of Civil Engineering and Technology, 8(7), 2017, pp. 567–580.

[11] SK Gousia Tehaseen and J D Chaitanya Kumar, Effect of Change of Storey Drift and Storey Height In Multi Storey Building with Varying Seismic Zones. International Journal of Civil Engineering and Technology, 8(1), 2017, pp. 583–590.

[12] M.P. Mishra, Dr. S.K. Dubey, Possibility of Drift Control in SoftStoried RCC Buildings in Higher Seismic Zones. International Journal of Civil Engineering and Technology, 8(9), 2017, pp. 1100–1110

[13] Dzhinchvelashvili, G.A. and Mkrtychev, O.V. The analysis of concepts of normative documents on aseismic construction. In the collection: Dangerous natural and technogenic geological processes in mountain and foothill territories of the North Caucasus the IV International scientific and practical conference, 2014, pp. 274-289.