University of Banja Luka I Faculty of Architecture, Civil Engineering and Geodesy
ISSN 2712-0570 I UDC 72

AGG+

2024_12(1)

AGG+ Journal for Architecture, Civil Engineering, Geodesy and Related Scientific Fields
АГГ+ часопис за архитектуру, грађевинарство, геодезију и сродне научне области

044-050

Categorisation I Preliminary report
DOI I 10.61892/AGG202401007J
Paper received I 28/02/2024
Paper accepted I 10/07/2024

Zaza Jangidze
Georgian Technical University Construction Civil and Industrial Engineering, Georgia, jangidzezaza@gmail.com

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ABSTRACT

From the point of view of modern construction, the damage to reinforced concrete large-panel and frame buildings is especially interesting. The construction of this building is very diverse. Their use has a short history. Therefore, the systematisation of damages and generalisation of results for such buildings is more difficult. Below are some statements sufficiently substantiated with factual material. It is similar to the skeleton of large-panel buildings. However, the resistance of reinforced concrete wall panels is, of course, much higher than the resistance of stone piles. That is why the panels themselves are rarely damaged by earthquakes. Relatively weak points of large-panel buildings are the edges of the panels, the support nodes on the roof panels and other connections. It is in these places that cracks, broken corners and other injuries develop during earthquakes. Three methods of restoration-reconstruction of damaged large-block multi-story buildings are proposed: metal diagonal web member and system-variable rigid in the interior space of the building, using today's terminology with seismic insulators, with the arrangement of additional frames; with reinforced-concrete pylons built over the entire height and perimeter of the building and by arranging loggias in their space; By building pylons along the longitudinal facades of the building and building a floor/floors on top of the building, along with arranging additional frames with seismic insulators if necessary.

Keywords: *Seismic Resistance, Seismic Hazard Zone, SHZ, Buildings, Sustainability, Constructions with Discrete Parameters.*

1. INTRODUCTION

The relevance of the research topic/issue and the novelty of the research in the paper is an attempt to consider several noteworthy or problematic issues identified in the process of performing the mentioned works and to further discuss-determine-specify-solve them. They will be specifically analysed in the appropriate chapters and paragraphs. At the end of this work, we will try to include the solutions and definitions in the list of its novelties, but still, in its introduction, we will single out the terminological problems in the Georgian language that are easily noticeable in almost all similar issues, as well as typical for all areas of our life, including issues of earthquake-resistant construction. These problems are very noticeable among public groups at the level of amateurs of this or that issue, but also, unfortunately, even among professional specialists. Fortunately, today's beneficial changes in many areas of life give us hope that for Georgian professional engineering terminology and various fields of science, proper services will be created for the thorough resolution of similar issues. Moreover, despite always using common sense and logical approaches, we have no claim to the final truth when interpreting and formulating one or another issue below under our point of view.

Under the terms of seismic resistance is determined the ability or capacity of a building structure to withstand dynamic loads caused by earthquakes and strong wind conditions. Loads have its magnitude and direction defined on the local coordinate system acting through the object. To preserve human life, expensive equipment, as well as material and cultural values, it is necessary to ensure seismic resistance of buildings.

For new constructions, seismic resistance of buildings is achieved by using the norms and rules mostly based on the study and analysis of the results and outcomes of earthquakes. For the existing buildings, with a study of each element where visible damage is observed by the user, tenant and/or owner. With that case, everything begins with the examination of the technical condition of the damaged house.

The development of models of seismic hazard zones (SHZ) for a given area consists of two main stages:

- Identification of potentially active areas originating from earthquakes in the study region;
- Determination of their seismic activity level.

The use of such an approach effectively captures the intra-spatial variability of seismicity in the SHZ, the recurrence characteristics of earthquakes, and their epistemic error.

The database includes historical data; the results of field geological studies; all types of geological processes identified in the field (landslides, landslides, rockfalls) and hazard database; Compilation of the base of the catalogue of geological hazards; geological hazards zoning map, where all types of geological processes are depicted; Various thematic maps (geology, exposure of slopes, inclination of slopes as a basis for determining the energy potential of the terrain, etc.).

2. METHODS

The stability of irregular reinforced concrete structures under seismic impact can be calculated using various methods, such as linear and nonlinear static and dynamic analysis.

The method used will depend on the type and level of damage to the structure, as well as the level of seismic hazard [1]. Failures in reinforced concrete structures may include Torsion failure.

Linear static analysis methods, such as the equivalent lateral force method, can be used for structures with small disturbances. Nonlinear static analysis methods, such as Pushover analysis, can be used for structures with moderate to severe disturbances. Nonlinear dynamic analysis methods, such as ageing analysis, can be used for structures with severe disturbances and high seismic hazards. These methods involve simulating the behaviour of the structure under various earthquake ground motions [2]. It is important to note that seismic design codes have different provisions for irregular structures such as UBC97, NEHRP, ASCE7, IBC, IS1893, etc.

The engineer must know the code and the level of disturbance of the building to use the correct method of analysis and design.

2.1. EUROCODE 8-PUSHOVER

Pushover analysis is a method used in earthquake engineering to evaluate the seismic performance of buildings and other structures [3]. It is based on the concept of "stressing" a structure through a series of incremental load-displacement steps, simulating the effects of seismic forces on the structure.

Eurocode 8 is the European standard for earthquake-resistant design of structures, and it contains guidelines for Pushover analysis. Here are some key aspects of Pushover analysis in Eurocode:

- Load patterns: Eurocode 8 recommends several load patterns for Pushover analysis, including unitary, triangular and trapezoidal patterns. These load patterns represent the different types of lateral loads that a building may experience during an earthquake and can be used to evaluate the performance of various structural elements.
- Plastic joint formation: Pushover analysis relies on the formation of plastic joints in structural elements, which represent local failure points of the structure. Eurocode 8 defines the properties of plastic joints, including strength, deformation capacity and energy dissipation capacity.
- Capacity curves: The results of Pushover analysis are usually presented in the form of capacity curves, which show the relationship between the applied load and the corresponding displacement or deformation of the structure. Eurocode 8 gives guidance on how capacity curves should be plotted and interpreted, including how to determine the limit state of the structure and the failure mechanism.
- Nonlinear analysis: Pushover analysis is a nonlinear analysis method that takes into account the nonlinear behaviour of structural members under load. Eurocode 8 guides how to model the nonlinear behaviour of materials and structural elements, including the use of plastic joints and other damage models.
- Verification and validation: Eurocode 8 emphasises the importance of verification and validation in Pushover analysis. This includes checking the input parameters and assumptions used in the analysis and validating the results against experimental data or other established criteria.

Overall, the Pushover analysis in Eurocode 8 is a valuable tool for assessing the seismic performance of buildings and other structures. By simulating the effects of seismic forces and identifying potential failure mechanisms, Pushover analysis can help engineers design more earthquake-resistant structures and improve the safety of buildings and their occupants.

2.2. AIMS AND OBJECTIVES OF THE RESEARCH

The criteria for the accident of damaged buildings have been introduced according to the rate of opening of cracks in the load-bearing structures, which should become a part of the reconstruction methodology for the restoration of the damaged buildings of the existing city housing fund.

A reconstruction-reinforcement-strengthening concept was developed for one specific group of dilapidated residential buildings - for extensions ("buildings" with main and added parts built at different times). The concept of restoration-reconstruction and strengthening-reconstruction for large-block multi-story buildings will be developed so that the group can be strengthened relatively among the mass-series groups (types) of capital buildings.

Three methods of restoration-reconstruction of damaged large-block and frame multi-story buildings will be proposed: in the inner space of the building, metal indirect and system-variable rigid, in today's terminology - seismic isolators, with the arrangement of additional frames; with reinforced-concrete pylons built over the entire height and perimeter of the building and by arranging loggias in their space; By building pylons along the longitudinal facades of the building and building a floor/floors on top of the building, along with arranging additional frames with seismic insulators if necessary.

3. RESULTS

Using the proposed method, increasing the level of seismic safety by changing the construction solution of the building is carried out by rigidly connecting the upper part of the building with a specially built auxiliary structure with certain dynamic characteristics, which takes over a significant part of the impact of inertial forces during an earthquake.

Thus, as the analysis of the results of devastating earthquakes shows, large-panel buildings built under the requirements of normative documents have a fairly high seismic resistance. At the same time, their high level of seismic resistance is ensured by lower costs of materials (for example, in a 16-story large-panel building, compared to other construction system houses of the same height (frame, monolithic, etc.), the cost of metal is reduced by 15-20% per 1 square meter of the total area) and labour costs - by 20-25%).

4. DISCUSSION

The practical value of the research is determined by the implementation of the mentioned scientific innovations in practice and the optimisation of design solutions for the restoration and reconstruction of damaged residential buildings. The effectiveness of the proposed construction system with seismic isolators - simplicity, because the use of seismic isolation in practice allows to reduce the magnitude of the horizontal seismic load on the building by 2-5 times, depending on the seismological conditions and according to the type of building. The realisation of the research results is confirmed by the official document of the implementation of one part of them in practice and the undeniable technical-organisational efficiency of other scientific-practical novelties of the work.

The building calculated and constructed by the normative documents, in which the appropriate increase in price is provided, is intended to absorb only one earthquake or two earthquakes of relatively low intensity, after which the building must either be demolished and a new one built or strengthened by engineering measures.

Both of them are associated with large labour costs, money and time, which will always create big problems for us, especially in housing construction. It was these circumstances that prompted scientists to start searching for new systems of protection against seismic impacts. During the last 20-30 years, several practical methods of seismic isolation systems have been created, which, as mentioned above, are widely used outside our country.

Based on the study of the proposed methods, with given instructions, assumptions and restrictions, the seismic resistance of the building is not improved initially, by increasing the stiffness of its structural joints and elements. That result is achieved by using structural elements, built on its own, separately in the perimeter of the building, with the ability to integrate into the object structure.

The reliability and infallibility of the main results are due to the use of substantiated methods of theoretical and experimental research-analysis, the successful implementation of residential and other types of buildings-reconstruction projects and technological-organisational preparation in the past-current practical processes, as well as the coincidence of the results obtained by other authors. In the cities of the most seismically active countries of the world, there is a significant number of low-rise buildings that do not have sufficient strength reserves in case of a strong earthquake. These buildings were designed and built with norms in which the level of seismic resistance is much lower than the modern seismic resistance norms. In the case of a strong earthquake, these buildings can be seriously damaged, which will cause the death of people and the destruction of material values. A clear example of this is the Turkey-Syria earthquake in 2023, which killed thousands of people.

The problem of strengthening these buildings has great social-economic and historical significance. It is known that many countries have national programs for the reconstruction and strengthening of such buildings.

5. CONCLUSION

The results of research carried out in the paper allow the following conclusions to be made:

- The following observation can be made from the review, the problem of refinement of calculation under the conditions of stability of reinforced concrete structures with irregularity during seismic impact is relevant and is in the stage of active development.
- The transfer of traditional analytical and numerical calculation methods to the considered class of problems faces difficulties related to violations of the geometrical regularity of the structure and the nonlinear nature of the deformation.
- Most of the investigations are devoted to building different models of structural deformation and obtaining differential relationships between loads, deformation components and forces. There is practically no calculation of the stability of reinforced concrete structures with irregularity during seismic impact.

6. ACKNOWLEDGEMENTS

This research PHDF-22-2724 has been supported by Shota Rustaveli National Science Foundation of Georgia (SRNSFG).

7. REFERENCES

[1] D.R. Gurgenidze, G.O. Kipiani, G. 0. Badzgaradze and E. R Suramelashvili, “Analysis of thin-walled spatial systems of complex structure with discontinuous parameters by method of large blocks,” in *Contemporary Problems of Architecture and Construction*, 1st ed., United Kingdom, London: Taylor & Francis, 2021, pp.172-178.

[2] G. Kipiani, “Synthetic structure of industrial plastics,” in *Architecture and Engineering*, vol. 1. Saint Petersburg, Russia: Saint Petersburg State University of Architecture and Civil Engineering, 2016, pp.26-30.

[3] G. Kipiani, “Definition of Critical Loading on Three-Layered Plate with Cuts by Transition from Static Problem to Stability Problem,” *Advanced Materials Research,* vol. 1020, pp. 143-150, 2014.

AUTHORS' BIOGRAPHIES

Zaza Jangidze

Ph.D. of Civil and Industrial Engineering awarded by Georgian Technical University, Research Scientist, Structural Engineer, Master of Civil and Industrial Engineering, graduated in Georgian Technical University, Author of 15 scientific publications, Structural Engineer at Q Engineering.

ПРОРАЧУН СТАБИЛНОСТИ НЕПРАВИЛНИХ КОНСТРУКЦИЈА ХЕТЕРОГЕНОГ СИСТЕМА ТОКОМ ЗЕМЉОТРЕСА

Са становишта савремене градње, оштећења армиранобетонских зграда са великим панелима и рамовима су посебно занимљива. Конструкција ових зграда је веома разнолика, а њихова употреба има релативно кратку историју. Због тога је систематизација оштећења и генерализација резултата за такве зграде тежа. Испод су наведени неки ставови који су довољно поткријепљени чињеницама. Слична је конструкцији великих панелних зграда. Међутим, отпорност армиранобетонских зидних панела је, наравно, много већа од отпорности зидова од камена. Зато су сами панели ријетко оштећени земљотресима. Релативно слабе тачке великих панелних зграда су ивице панела, тачке ослонца на кровним панелима и друге спојнице. Управо на тим мјестима долази до појаве пукотина, ломљења спојева и других оштећења током земљотреса. Предложене су три методе за рестаурацију-реконструкцију оштећених вишеспратних зграда са великим блоковима: метални дијагонални затезни елементи и систем-промјенљива крутост у унутрашњем простору зграде, користећи данашњу терминологију са сеизмичким изолаторима, уз постављање додатних рамова; са армиранобетонским стубовима изграђеним дуж цијеле висине и обима зграде и постављањем лођа у њиховом простору; постављањем пилона дуж уздужних фасада зграде и изградњом спрата/спратова изнад зграде, уз постављање додатних рамова са сеизмичким изолаторима по потреби.

Кључне ријечи: *сеизмичка отпорност, зона сеизмичке опасности, ЗСО, зграде, одрживост, конструкције са дискретним параметрима*