# EXPERIENCE OF RECONSTRUCTION AND REHABILITATION OF HISTORICAL BUILDINGS IN THE DOWNTOWN OF TBILISI

**Igor TIMCHENKO[1], Givi HOMERIKI[2], Merab MAMARDASHVILI[3] And Hugh DOCHERTY[4]**


## SUMMARY

The purpose of the paper is to present the reconstruction and rehabilitation of the historical city center of Tbilisi based on information gathered by local building organizations and with the participation of international building and design companies. A survey of the modern day conditions of development of the historical center of the city of Tbilisi and reconstruction works is included in this paper. This paper addresses the existing problems of reconstruction and their solutions by modern scientific methods, and highlights the importance of insurance in the preservation of the historical center. As an example, we will use the reconstruction of one of the most beautiful buildings in the city, hotel Tbilisi, and try to show the methods and ways of reconstruction of historical buildings using modern research methods and approach.


## INTRODUCTION

Georgia and its capital, Tbilisi, are located in the seismic zone of moderate seismicity. Within last 2 thousand years there have been a number of strong earthquakes. The last intensive earthquakes occurred in Armenia (Leninakan M=6.0, 1927; Spitak M=6.9- 7.1, 1988) and in Georgia (Kartli M=6.0, 1920; Racha 6.9-7.1, 1991). These earthquakes demonstrated how unexpected and unpredictable the time and the shock force could be in comparison with other natural disasters that allow some time for the population to prepare. The last earthquakes of unexpectedly strong intensity in Armenia and Georgia (with intensity on 1-2 degrees, on MSK scale, more than expected) made it necessary to revise maps of seismic hazard of Georgia and the Caucasus and to critically evaluate the conditions of existing development of large cities. At present, new maps of seismic hazard in Georgia are being issued, as well as works on specifying the seismicity of Tbilisi. New seismic standards are being developed. Taking into account raised seismicity of Georgia and Tbilisi more serious requirements are applied to the buildings under reconstruction from the point of view of their vulnerability. In the regions of high seismicity, the reconstruction of the city historical center becomes a complicated task.

## CONDITION OF FORMER DEVELOPMENT OF THE DOWNTOWN

Buildings with anti-seismic measures began to be built from the beginning of the 1960's of this century. Non-anti-seismic buildings 50-100 years old were built in the historical center of the city, which coincides with its business center. The historical center is composed as a rule from 2-3 story brick buildings without anti-seismic measures. Floors as a rule are wooden. Walls are massive with thickness up to 1 meter and more. Many buildings are architectural and historical monuments. The history of the city is closely combined with its architecture, which results in its modern appearance. Preservation of the historical center of the city is the main task.


[1] *Institute of Structural Mechanics & Earthquake Engineering (SMEE); Center AGESAS, Tbilisi*
[2] *Seismo Ltd., Tbilisi*
[3] *Seismo Ltd., Tbilisi*
[4] *Waterman International, London*

City authorities used to give consideration to the reconstruction of the downtown up until now. The role of the state in planned reconstruction of downtown changed when the economic state of the country worsened. Nevertheless, works on reconstruction of the buildings in the historical center are carried out actively by entrepreneurs. Offices, shops, hotels, etc. are placed in these historic buildings.

Unfortunately, the technical condition of the buildings in the historical part of the city is very poor. Many of the buildings are totally depreciated. Due to poor ground conditions and anthropogeniuos underground waters (the level of which rose as a result of long exploitation of the buildings by state authorities buildings structures) the building are characterized by irregular deformations. Very often the deformations are caused by disrepair of water and sewage networks (which are mostly depreciated). Many buildings have damages of II and III degrees by EMS scale. There are some cases of spontaneous collapse of the buildings. The condition of residential buildings is still getting worse as a result of the difficult economic state of the republic.

The following typical measures are carried out under reconstruction of the old buildings: strengthening of wooden floors or their replacing by reinforced concrete; fixing of foundations; fixing of damaged walls elements; reinforcement of the whole building by steel bars; demolition and re-building of walls parts. If possible the stories are overbuilt. As a rule, the old building facades are restored with preservation of their architectural appearance.

Heavy earthquakes are characterized by severe social and material damages. Complex geological and engineering conditions worsen the seismic effect. The above mentioned earthquakes with different intensity have occurred on the territory of Tbilisi, which according to its geopolitical location, is one of the major cities in the Caucasus and has remained the capital of Georgia since the 5th century.

The high seismic risk of old buildings as well as modern cities' historical centers with high population density call for new approaches in the execution of the works on the development of urban environment, reconstruction, regeneration and remodelling of existing buildings.

Grave consequences of the Spitak earthquake of December 7, 1988 revealed not only the major problem of seismic protection in new constructions, but also raised a number of other issues connected with old building and the problems in the course of works on reduction of the consequences of the destructive earthquake.

To determine the first stage construction works and security for the citizens, it is necessary to research of urban buildings, register houses and then process this data. Such research will help to determine the existing risk of buildings in case of earthquake (seismic risk), as well as the ways of its reduction.

## STANDARD REQUIREMENTS UNDER BUILDING RECONSTRUCTION

At present in Georgia there are no standards, which regulate the works on reconstruction of buildings and structures, and evaluation of seismic resistance of existing residential buildings. Planning of reconstruction is carried out according to active building codes [1-3] and British Standards [4-8]. The analysis was made on the active and perspective loading, and actual condition of structures materials. Analysis is made on basic and special combinations of loading.

## RECONSTRUCTION OF THE HOTEL TBILISI BUILDING

The hotel building was built in 1914-1921 (Fig.1). Earlier there were 2 and 3 storeyed buildings with thickness of walls up to 2 meters. Under construction of the hotel Tbilisi old walls of the building were partially used. The building was built without anti-seismic measures. The building is 5 storeyed with two basement storeys. Underground area has projections in the basement area. The building is of non-symmetrical shape in plane and located on the slope. Along the whole height of the building there is a courtyard inside (Fig.2).

Information about ground conditions was obtained from three drills and seven boring pits. Ground is loamy with availability of dense elements. The consistency is soft. Boring pits were drilled 10 and 19 meters deep below basement level. Level of underground water stabilizes at depth of 6.3 m below basement level. Design pressure of the ground totals 2 $kg/cm^2$. According to seismic characteristics the ground is taken as of II category.

**Fig. 1. General view of the Tbilisi hotel**

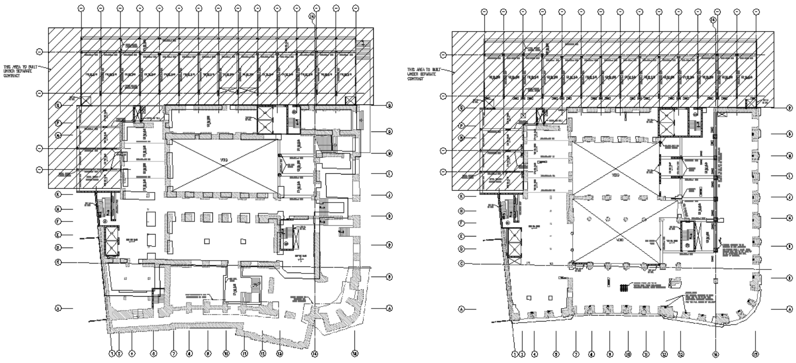

**Fig. 2. Plans at level -4.5m; +15.6m and cross-section of the building.**

Foundations under walls are of concrete and do not need fixing. Walls are from brickwork on cement mortar and faced by white limestone. Slabs are from solid reinforced concrete with hollows. Rectangular hollows are formed using framework. After reinforcement of the slab the framework was folded up and extracted from the hollows. Then the next floor was constructed.

From the back façade dwellings are adjoined to the building, from left side - the building of drama theatre. The main façade looks on the main arterial road of the city - Rustaveli Avenue. As one of the versions the possibility of extension in the form of reinforced concrete framework from the back façade at place of dwellings was examined.

Total stability of the building is ensured by combination of existing and new reinforced concrete structures. Vertical elements include bearing walls and reinforced concrete columns. Facades are built from bearing brickwork (clay brick 1850 kg/cm$^3$) with width of 1.6 m in the basement, 1.4 m at ground floor level, 0.85 m at 4$^{th}$ and 5$^{th}$ floors. Concrete columns differ by size and shape; their condition is satisfactory. New ones replace existing stairs and elevators.

Areas of main damages - at axes 12-14/G-O where the whole structure from roof to basement is lacking. At axes 7-14/O-Q the walls reach the 5$^{th}$ floor, but floor slabs of 5-6 floors and roof are lacking.

Within the reconstruction of the building the following tasks were to be solved: replacement of damaged and amortized structures, rehabilitation of floors (part of the floor was collapsed as a result of shell hit, liquidation of overfall of floor heights, raising of seismicity of the whole building, and bringing of the building into correspondence with existing standards of seismic construction.

Under working out of reconstruction project the following typical factors determining the choice of the project decision were taken into account: constructive scheme of the building - existence and pitch of cross and longitudinal walls, and other interim supports for floors; construction of the main bearing elements of the building: foundations, walls, and slabs; physico-mechanical characteristics of materials; correspondence of existing planning to standard requirements; presence and location of auxiliary areas; belonging of the building to architectural monuments, presence of important architectural elements of the building; influence of surrounding development; characteristics of the site, possibility of location of tower cranes, presence of access roads, trees; geology of the area; efficiency of the project design from the point of view of expenditure of constructive materials, following operating expenses per unit of the building under reconstruction.

Within the reconstruction a new reinforced concrete frame is arranged inside the building at axes 12-14/G-O. At axe 14 the RC frame is supported by a brick wall and linked with existing columns. These columns are fixed by reinforced concrete casing along the whole height of the building. But at some areas it is not possible to arrange rigid joints at places where crossbars are adjacent to existing columns. At level of basement floor slab, at level of next to last floor slab hinged support is arranged.

## STRUCTURAL ANALYSIS

Numerical analysis of the building structures was carried out on the base of finite element method with use of computer complex LIRA-MIRAGE. During the work on the project different versions of architectural-planning and constructive decisions were reviewed: with and without annex; with different location of reinforced concrete cores (core 1-4); detailed investigation of reinforced concrete slab structure at axes 12-14/G-O was carried out.

Numerical structural analysis of the hotel Tbilisi building after reconstruction is performed on the three-dimensional model with account of the building codes [1-3]. Structural elements of the building (walls, columns, beams, slabs, diaphragms) are approximated by the linear, shear and plate finite elements with the appropriate mechanic characteristics and dead and live loadings.

Desined seismic intensity of the construction site is 7 degrees by the MSK scale. Concrete - B25, Steel AI, AIII. Construction according to necessary seismicity - this peculiarity remains under reconstruction of old buildings.

In calculation we admitted real characteristics of existing materials and ground. Calculation of rigidity diagrams was done with regard for reinforced concrete foundations and base grounds below them.

The results of numerical structural analysis contain the following data: general information, graphical part, initial information (task) for computer analysis, displacements of nodes under each type of loading, strengths in the elements and stresses in various sections of finite elements, combinations of loads, amount of required steel in reinforced concrete elements.

FE structural model of the building is shown in Fig. 3. Under working up of the model we allowed an elastic influence of ground below foundations. In Fig. 4 only RC cores of rigidity are shown. Dynamic characteristics of the building are as follows. Natural period of first mode in longitudinal direction is 0.34 sec., in cross direction - 0.39 sec. Ignoring cores of rigidity, periods of natural vibrations are 0.51 and 0.53 sec, respectively. Fig. 5 shows the first mode of natural vibrations in transversal direction. Deformation of the top floor is shown in Fig. 6.

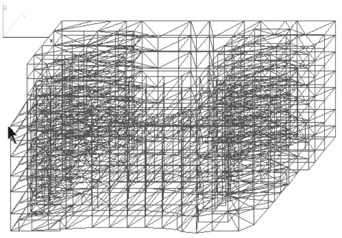

**Fig. 3. FE model of the building.**

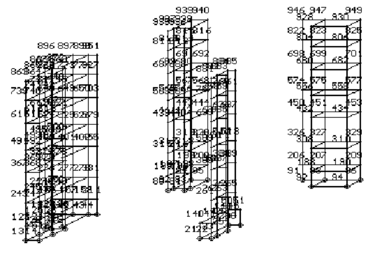

**Fig. 4. RC cores.**

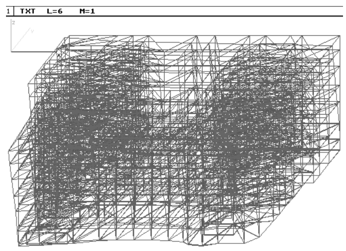

**Fig. 5. First mode of natural vibrations**

There is slight twisting of the building in plan caused by non-coincidence of mass and rigidity centers.

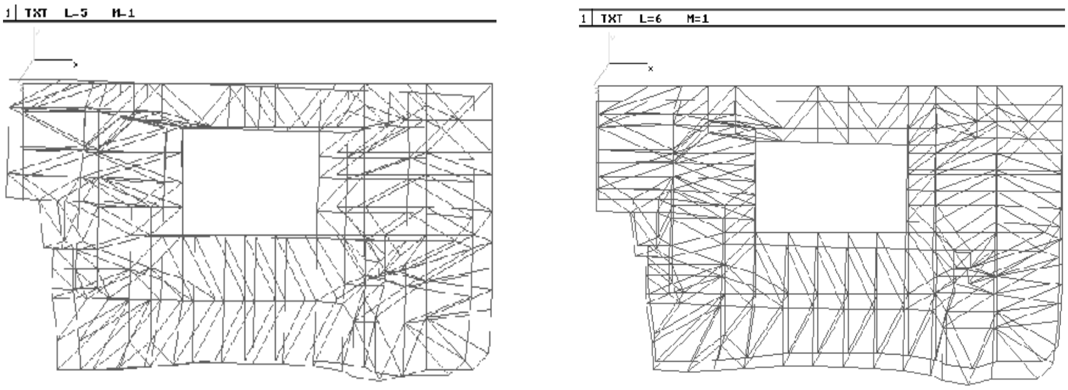


**Fig. 6. Deformation of the top floor at seismic effect.**

Detailed analysis of reinforced concrete slab in axes 12-14/J-O with cantilevers under basic and special combinations of loading was also carried out. Deformed state is shown in Fig.7, and bending moments' diagrams are shown in Fig. 8.

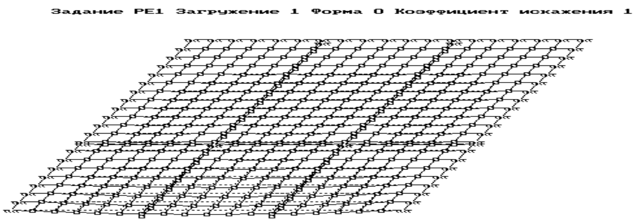


**Fig.7. Deformed state of RC slab at vertical load.**

Maximum horizontal shift of the building top under seismic load is up to 30 mm. Maximum vertical deformation of the slab cantilevers is 7 mm. Numerical analysis allowed carrying out rational reinforcement of cores of rigidity and reinforced concrete structures.

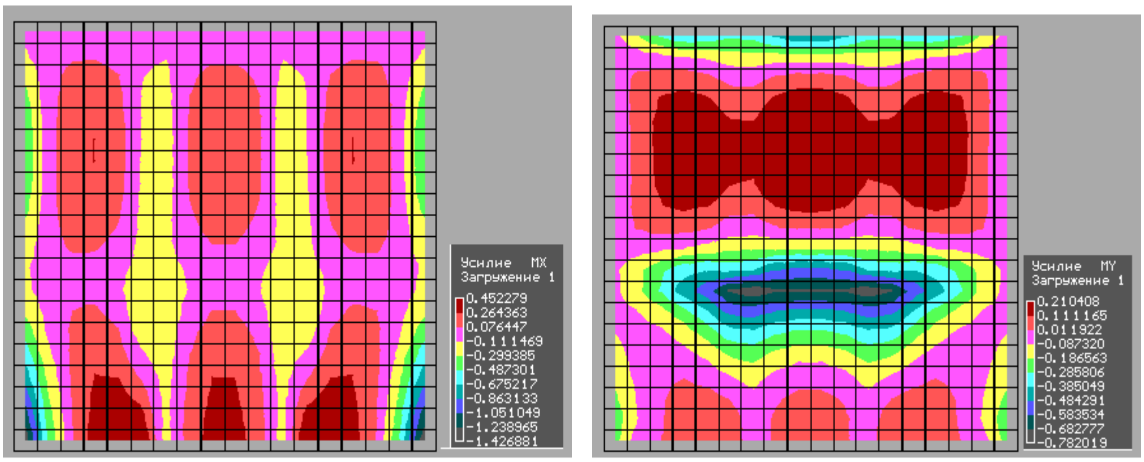


**Fig. 8. Bending moments Mx (left) and My (right) at dead load.**

## IMPORTANCE OF INSURANCE IN PRESERVATION OF RESIDENTIAL FUND

Consequences of strong earthquakes in Transcaucasian region (Spitak 1988, Racha 1991) are not liquidated yet. The main reason - absence of means to help population financially, and absence of earthquake insurance. As a result of difficult economic condition of Georgia new construction is nearly not conducted. Existing residential fund is getting old and the state has no means for its maintenance and reconstruction. According to the latest seismological data seismicity the Caucasus area including Georgia has grown up, i.e. seismicity risk and vulnerability of residential fund as a whole has grown up. Situation in this part is still growing worse without any adequate reaction of the state bodies. In such conditions the population has to take care of residential fund itself, i.e. it's important to insure against earthquakes.

At present in Georgia there is no effective economical policy of insurance against earthquakes for protection of population property. There is no scientifical method of insurance in earthquake engineering in the republic. The reason - complexity of working out of such method, which needs united efforts of different specialists: geophysicians, geologists, builders, economists. At present owing to support of western funds and firms and efforts of Georgian specialists methodology of insurance against earthquakes is being worked out in Center of Applied Geophysics, Engineering Seismology and Seismic Protection of Structures (AGESAS). This project is supported by Eurasia Fund at the expense of the United States Agency for International Development (USAID). Point of view presented in this paper may not coincide with position of the USAID or Eurasia Fund. Methodology of insurance in earthquake engineering is mainly purposed for the city of Tbilisi. and its build environment. Information about this work can be found at the official web-site of the Center of Applied Geophysics, Engineering Seismology and Seismic Protection of Structures (AGESAS) (**http://www.osgf.ge/seismo/agesas.html**).

The following main factors, which effect the decision concerning insurance of the building are taken into account for existing project or the one under construction or reconstruction: location of the building, its closeness to active seismic faults; probability of earthquake of definite intensity at definite region and at definite period; the building structure (type of the building, architectural-planning solution; quality of constructive works, seismicity level), which determine vulnerability of the building and property. Obtained data (in form of maps of seismic risk, seismic hazard, seismic microzonation, expert system of making decisions) can be used by municipal authorities and private entrepreneurs for planning of new construction and reconstruction of existing residential fund.

Thus, the base for decisions shall be objective information about place and strength of possible earthquake as a reason of damage on the one hand, and on the other hand - objective information about the object to be insured taking into account its physical condition, and its possibility to resist earthquake with damage grade forecast. Effectiveness of insurance methodology directly depends on extent of accuracy of this information. A potential client will tend to repair his property or to carry out corresponding anti-seismic measures in order to pay less insurance installment. In other words, there will be selfregulation of preservation of residential fund. Special support of the State and different public funds can also help. In such cases economical policy will be very productive. Creation of effective insurance methodology in earthquake engineering will promote development of entrepreneur activities of independent insurance companies, real estate companies, etc. under market economics. Such an approach to the matter of insurance can be an information material, which will assist in taking right decisions under insurance, pricing of residential by the population and insurance companies as well (and also real estate firms, etc.).

## CONCLUSIONS

A complex approach based on modern analysis methods is needed under reconstruction of historical and architectural monuments. Reconstruction of such buildings is carried out with preservation of historical facades and inner re-planning and structures replacement. Absence of normative requirements complicates reconstruction works. Successful results are determined first of all by designers' and builders' experience, modern research methods, creative approach, and comparison of alternative variants.

Arrangement of rigid RC cores has an influence on general rigidity of the building and its dynamic characteristics. A set of measures, i.e. new joints, new RC frame and cores with old structures ensure three-dimensional rigidity and seismic stability of the building.

The main ways of maintenance of technical condition of historical development at corresponding level are in attraction of private capital, foreign investors, creation of regulating mechanism with the help of insurance under support of state bodies.

Experience in reconstruction of historical and architectural monuments showed effectiveness of international cooperation.

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