DIAGNOSTICS AND DEVELOPMENT OF RECOMMENDATIONS ON SEISMIC STABILITY OF HOUSING SYSTEM UNDER RECONSTRUCTION OF HISTORIC CITY CENTER

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ABSTRACT

Existing information on historical sites of the cities was analysed and history of construction of aseismic buildings was studied. Database for expert system and programmes for seismodiagnostic under conditions of reconstruction were created . Expert system using database on architecture and town planning was introduced. Corrections were made during reconstruction and alternative projects were designed. Historic center of Tbilisi was reconstructed using seismodiagnostic.

KEYWORDS

Expert system, Seismodoagnostics, Functional analysis, Database, Historic center, Reconstruction-Regeneration, Architecture, Town planning, Economical estimation, Traditions of aseismic construction.

Investigation object is seismic diagnostic of Tbilisi city historic center (Republic of Georgia). Theme choice is conditioned by location of Georgia in the zone of active seismic effects together with other Caucasian republics Armenia and Azerbaidjan. Seismicity of Georgian territory as a part of Caucasian seismoactive region refers to the Mediterranean Seismic Belt (Fig. 1).

Capital of Georgia Tbilisi is located on the slopes of the Trialeti chain in the river Mtkvari ravine.

Because of active seismic effects separate aseismic structures were built during 1500 years' development of the city. That's why lots of ancient architectural monuments have been survived. Their existence prove high construction culture of the past.

Safe support of rocky site and principle of deep basement in the soil, big length of the bearing walls, additional supports for the floors provided strength of structures. In this respect original structural solutions are very interesting in such dwelling houses as "Darbazi", in sulphur bath-houses complexes, in the series of public, cult and fortification structures that preserved characteristic aspect and city colour during many centuries. Alongside with this there are mass housing systems that were built without consideration of seismic effects. These are 19-th and 20-th century houses as earlier ones were wholly demolished under Persian invasion.

From 1801 keeping historic planning principle present housing systems arise instead of demolished city parts. Trade and administrative buildings and also 3-4 story houses appeared in central parts of the city. The city was developing like terraces along the river Mtkvari up the rocky hills. Under development of Tbilisi its historical part remained to be the center with multifunctional loads attracting large groups of people and transport. This nessecited their reconstruction works.

Reconstruction-regeneration of historical part of Tbilisi took more than two centuries. But aseismicity of the buildings was not considered properly. Last earthquakes in Georgia increased importance of aseismic

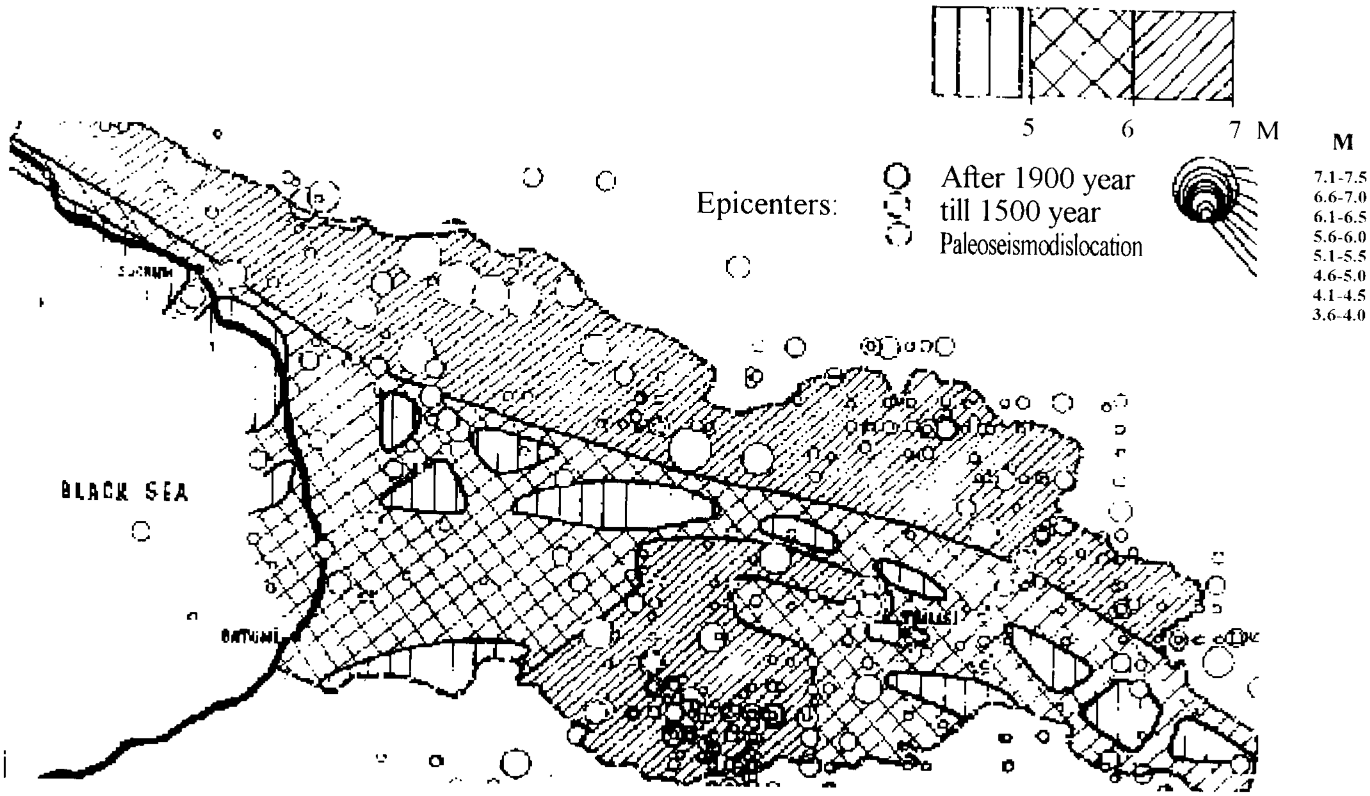

Fig. 1. Map of seismic regioning of Georgian territory.

In this respect we got great experience that served as database. For desired results it was necessary to have all data on external and internal load reasons effecting town-planning of the old city and its separate structures as well.

Ecology, transport, population density, etc. were referred to external reasons; composition of buildings with individual planning, compositional, structural and building characteristics - to internal ones.

Systematisation and use of data factors is based on the discussion logic.

Thus in some cases soil factor predetermined direction and character of reconstruction. Under renovation of Baratashvili street some houses impossible for reconstruction were demolished as sandy and clay fillings of the old ravine should not be safe base for structures. And other structures located behind them supported on the fortification wall and rocky soil survived after reconstruction and did well with street shape.

During reconstruction of the embankment alongside Sioni church part of existing housing was demolished because of the hydro-electric station construction causing increase of river water level that influenced the soil strength (Fig. 2).

Great importance has structural factor as in houses of old regions aseismicity was not considered and they had no rigidity belts. Large spans between bearing walls showed their unsafety. Weakening of bearing structures was caused by engineering structures, their communications being laid by cutting of foundations.

In link housing buildings have common bearing walls forming one stretched space with demolishing effect on each other. This problem was solved by demolishing of intermediate mostly failured houses. New objects or recreational spaces took their place and formed apart standing aseismic buildings. Factors diversity led to contradictious solutions. Though at complex estimation of the existing problems logic program operators of the expert system allow evaluation of their relative significance. This allows the designer various possible choice ways.

Complex problem solution is seen in historic city center where requirements of various factors were met. New discharging roads helped to solve two especially important factors - increasing car flow through historic body preserving narrow housing.

Unevaluation or ignorance of these factors revealed in case of K.Tsamebuli square of the sixties referring structures of the old church. This led to its further demolition.

Drainage for large objects (Siony monastery, Caravansarai) had uneven influence on favourability of the adjoining housing.

Fig. 2. Reconstruction of the embankment alongside Sioni church.

Experience and reconstruction science development revealed necessity of more full and competent study of the existing problems and solution ways. In this connection seismodiagnostic program using expert system method during reconstruction has been developed. It was introduced into practice with corrections in the developed projects. Considering existing housing of the Vertskhli street and adjacent region under its reconstruction according to the recommendations of the expert system common drainage is possible instead of earlier local drainages.

Demolishing old houses and out of date small buildings inner courts were widened, open passages in closed spaces were created for better communication and activisation of city media. Technical condition of the housing is estimated (Fig. 3).

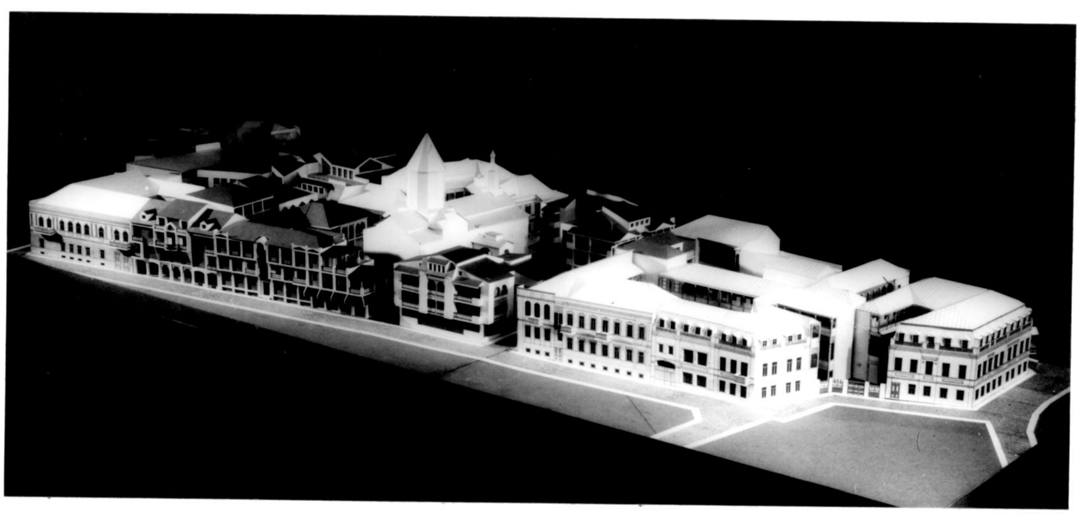

Fig. 3. Reconstruction of the Vertskhli street and adjacent region.

Expert system evaluating housing condition of the Wine Lift Left side considered impossible to realise existing reconstruction project. Alternative project considers demolition of the whole housing and its change by new modern houses preserving scale and character of the old city (Fig. 4).

Expert system and its work consists of databases compiled by expert employees knowledge, computer for procedure operators, interface program between user and computer.

Methodological bases was housing complex estimation method allowing comparative evaluation of various sites of the whole territory according to seismo-diagnostic factors. The program shows interinfluence of factors: that of mobility, structure strength, geological, climatic and social-economical effects in the problems for safety provision of housing fund, working activity of citizens, their moral and physical rest.

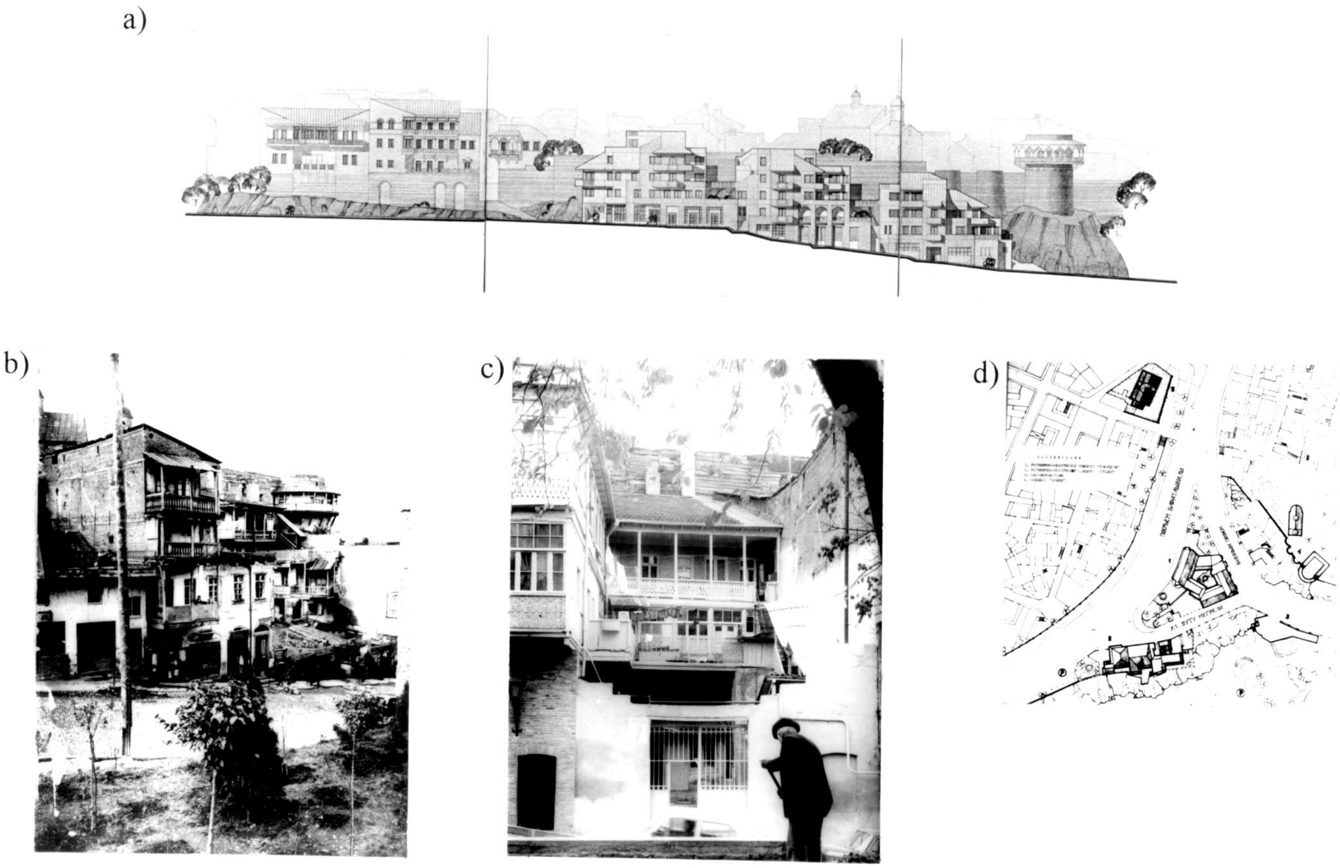

Fig. 4. Reconstruction of the Wine Lift :
a) Project of the Reconstruction; b) Historical Photo: c) Actual View; d) Plan of Reconstruction Site.

Data comparison is done by qualitative and quantitative estimation. Function parameters are established in determinatively acceptable limits;

Given diagnostic program consists of subprogram complex. Some of them are:
formation of selectional number of areas - division of territories into separate areas;
determination of factor informativity according to each type of functional use - outer indices (natural, demographic, transport), inner ones (structural elements);
complex estimation of housing by cost method - estimation of factors according to price increase of their factors;
complex estimation of territory by roll methods - qualitative seismic evaluation;
synthethized complex estimation, creation of complex estimation model determined by roll method, creation of complex estimation model determined by cost method, printing out of KO values by synthesised printing out of KO values according to the cost method.

Link between programs is established by information passage and design results in the files on the disk.

In the program of housing complex estimation is used by group method of arguments consideration. For optimal model construction of KO it is necessary to show operator's length:

$$c_l = a_0 + a_1 x_j + a_2 x_l + a_3 x_j x_l + a_4 x_3^2 + a_5 x_l^2$$

For each type of functional use there exists ideal factor value when reorganization of reconstruction is most favourable. . Value of j-th area on i-th factor of K-th function looks like :

$$\tilde{X}_{ij}^{(k)} = X_{ij} - X_{ij}^{(k)}$$

X_{ij} - value of i-th factor of j-th cell;

$X_{ij}^{(k)}$- standard value of i-th factor for K-th type of functional use.

$\tilde{X}_{ij}^{(k)}$- value of j-th cell according to i-th factor or K-th type of functional use.

Obtained area values characterise them only from one factor point of view. Complex estimation of aseismicity degree of housing is reached by some ways. The most important is estimation cost supposing comparison of cost increase according to each considered factor.

Seismodiagnostic design of housing on the example of Vertskhli street showed that reconstruction of houses, territory handling require great capital investments and its ignorance may lead to material lack. After reconstruction works aseismicity of structures will increase and thus cultural-historical heritage will be preserved.

By means of the program complex and by-factor estimation of housing will be possible. In this case investigated factor is purpose function.

For example in the soil problem limitations for housing were indices of historically important objects and their technical economical characteristics where purpose function was strength factor of soils.

Practical designs can be made by simplified design model of seismo-diagnostic estimation of city center housing. Very often X and Y values describe some functional dependence Y(x). Dependence (correlation) between them may be established by means of choice factor of correlation (R) that will obtain values from -1 up to 1. Correlation factor close to 1 show that X and Y values are correlated.

Design showed that empirical data are approached by linear or degree dependences:

$$Y_i = A_1 + B_i X_i$$

or

$$Y_i = A_2 X_i^{B_2}$$

Y_i -enlarged aseismicity value indices of city center, in thousand rouble/ha;
$X_i^{B_2}$ -city population number, thousand persons;
A_i, A_2, B_i, B_2 -empiric factors.

To find main parameters of analytical function that with minimum meanquadratic error was approaching to initial function we use formulas of linear approach.

$$A_1 = 1/n(\sum_{i=1}^{n} Y_i - B\sum_{i=1}^{n} X_i)$$

$$B_1 = \frac{\sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i - n\sum_{i=1}^{n} X_i Y_i}{(\sum_{i=1}^{n} X_i)^2 - n\sum_{i=1}^{n} X_i^2}$$

$$R_1 = \frac{\sum_{i=1}^{n} X_i Y_i - \sum_{i=1}^{n} X_i \sum_{i=1}^{n} Y_i / n}{\sqrt{(\sum_{i=1}^{n} X_i - (\sum_{i=1}^{n} X_i)^2 / n)(\sum_{i=1}^{n} Y_i^2 - (\sum_{i=1}^{n} Y_i)^2) / n}}$$

or for degree approach

$$A_2 = \exp[\frac{1}{n}(\sum_{i=1}^{n}\ln Y_i - B_2\sum_{i=1}^{n}\ln X_i)]$$

$$B_2 = \frac{\sum_{i=1}^{n}\ln X_i \sum_{i=1}^{n}\ln Y_i - n\sum_{i=1}^{n}\ln X_i \ln Y_i}{(\sum_{i=1}^{n}\ln X_i)^2 - n\sum_{i=1}^{n}\ln X_i^2}$$

$$R_2 = \frac{\sum_{i=1}^{n}\ln X_i \ln Y_i - \sum_{i=1}^{n}\ln X_i \ln Y_i / n}{\sqrt{(\sum_{i=1}^{n}(\ln X_i)^2 - (\sum_{i=1}^{n}\ln X_i)^2 / n)(\sum_{i=1}^{n}(\ln Y_i)^2 - (\sum_{i=1}^{n}\ln Y_i)^2 / n}}$$

here R_1 and R_2 are selected correlation factors accordingly for linear or degree dependencies.

Selected correlation factor served as design model for seismodiagnostic estimation . From two dependencies those parameters were chosen whose selected factor was closer to 1. For example problem of expenses relativity for reconstruction works towards real expenses reveal preference of determine solution version

Sum of chosen dependencies gives us ultimate estimated model. Procedure packets of expert system allow us to determine cost of seismic measures during reconstruction in different areas. Expert system allows us to use solutions for one programme as initial conditions for other programme. This approach helps to combine quantitative and analytical tasks. Databases of these programmes are identical with expert knowledge packets.

Developing databases we set and solve tasks for synthesis and analysis of object models which change in space and time.

Results obtained:

1. Information on reconstruction of historical centres of the cities has been collected and processed. Database was created.
2. Expert system for seismodiagnostic of old city reconstruction was developed.
3. Projects on apartment buildings in "old city" were developed.
4. Corrections were done in the existed projects of districts adjacent to Leselidze street and that of right side of the Wine Lift.

Developed program complex of the expert system simplifies orientation and choice of the designer's own direction considering complex of natural, engineering and functional factors.

Expert system introduction on the databases for town plannig and architecture and corresponding computer technics will minimize time needed for obtaining data and project solutions, decrease labour consumption caused by obtaining documentation on consumers' requests, increase quality of project solutions, lead to economy and labour of financial resources, increase effectivity of capital investments.

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