Calculation of costs for seismic rehabilitation of historical buildings

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Abstract:

The years 1918-1940 in Bucharest saw the construction of the buildings which gave the central part its present day look. Research about inter-bellum Bucharest and its buildings is widespread and information about them is both available and reliable. Disaster prevention includes the reduction of seismic risk through retrofitting existing buildings in order to meet seismic safety requirements. The planning of alterations to existing buildings differs from new planning through an important condition: the existing construction must be taken as the basis for all planning and building actions. This paper presents the differences in the methods of approaching and calculating the costs for the rehabilitation of old buildings when seismic retrofit becomes a special issue.

1 Introduction

Prevention of disasters caused by earthquake has become more and more important in recent years. The target of economic efficiency of retrofit measures on existing buildings has a special importance, besides their structural, functional and aesthetic aspects. The mounting of retrofitting systems is, regarding the estimation and calculation of costs, a special form of rehabilitation of endangered buildings. Planning of further measures is based on information about the building and its location. While in some western countries there are elaborated methods for estimating costs, in the countries like Romania, this is not the case.
4 Special conditions for retrofitting existing buildings

The methods based on surface and volume costs are not appropriate in this case, as the measures taken to retrofit does not affect in the same way the whole building substance but mainly the bearing elements. Retrofitting measures are not oriented towards the new use of the building.

4.1 Performance level

The seismic performance of a building can achieve one of the following three objectives [4]: immediate occupancy, damage control or life safety. The first criteria means normal use. The building can be used immediately after the earthquake, although some installations and non structural elements might be damaged. The second one means damage limitation. Non structural elements may be stronger damaged, structural elements may be damaged in isolated places. The last criteria is defined as collapse prevention. The building may suffer non repairable damage, but it should at least not collapse.

For this proposed methodology, the rehabilitation expense degree used for the estimation of upgrading existing buildings in existing methods corresponds to the three performance objectives in seismic design. The present danger degree corresponds to the damage degree in case of normal upgrading.

4.2 Decision support

The decision of adopting local measures is similarly to usual renewal of old buildings based on state of building substance (Figure 1). In case of global measures, new elements have to be built in. Detailed calculations cannot be found at the time of the estimation of costs. As static calculations take time in the planing process, the methodology proposed here creates a framework, in which these values can be introduced.
4.3 Types of buildings

Town analysis differentiates between three types of historical buildings. Buildings with cultural value belonging to national heritage. Buildings with architectural value which are representative for a certain building style. The knowledge of that style can help in considering retrofit methods for that building restricting through the demand to maintain the characteristics of that style. Buildings with environmental value are existing buildings with a positive influence on the townscape. In this case, the building record is the basis for town image analysis. For all of these different levels of the depth of the costs, also influenced from the rehabilitation necessity and the balance of the life expectancy of the building.

4.3.1 Inter-bellum Bucharest buildings

New building technologies such as the wide-scale use of reinforced concrete reached Romania in the years between 1920-1945 [5]. The most recent buildings were residential ones: villas, apartment blocks or social houses. The seven to eleven floor high apartment blocks, with a unreinforced masonry infill concrete frame structure, designed to resist vertical loads only are exposed to high seismic risk.

The inter-bellum architecture in Bucharest has a non contextual approach, concentrated to set new landmarks in the build context (Figure 2). The buildings lie stylistically very close to turn-of-century European styles. This means a lack of ornaments and gaining aesthetics through simplicity, like the preservation of the right angle and the use of a pure 90°. An important feature of the architectural stile of this period is the emphasis of the horizontal lines through window bands and balconies. Balconies and bow windows are bounded to one continuous facade area. The transition element between bow window and balcony is in most cases a corner window stressing the non bearing character of these facade elements. Vertical accents through non-bearing elements are exceptions. Another feature of these buildings are the recesses in the facade. As the modern reinforced concrete buildings were much higher then the existing ones in the neighbourhood, there was a rule that each floor over the cornice line should have about a one meter return to the one bellow. Through this, the shadow image of a slope roof was generated through an interesting flat roof play.

![Figure 2: Street front with an inter-bellum building](image-url)
parts are working properly together and also details like reinforced and not reinforced walls. A rapid visual screening has to be done before, in order to specify where to search after structural details. By digitising the building record the bearing parts should be clearly differentiated from the other but divided accordingly to the structure, which allows the costs calculation.

The building record has different detailed ranges. Damages and construction type and materials are recorded also in not so detailed ones. The most deep details are made when working with monuments. Building record plans in Bucharest have additionally different exactness levels. Sometimes there are no records available, sometimes they contain no hints to the structural system. Due to the needs of detailed static calculation the building record has to be a detailed one. It is important to have control about the exactness achieved on the site and possible post editing in the office. Professional equipment is expensive and sometimes not available; thus, the record methodology must allow computer assistance but be easy to make with low-end equipment.

The classical building record results in the plans of different building floors, one after the other and without 3D reference. One possible approach is 3D laser scanning of the existing buildings with marking of the elements, which are defining the GIS modules. If possible interior scanning and correlation of the 2D plans obtained from the vectoring is very useful. Otherwise, the exterior scanning and use of plan sketches of the building can help.

A further step is the detailed damage record. This means its position and dimension and information about its causes, risk potential and redemption possibilities. This step is in case of retrofitting even more important as the simple building record, but cannot be made without it.

The data from the building record have to be stored in a room book. This consists of a database table where all rooms of the building and their subordinate elements, with their characteristics, are stored. The building elements which belong to a room are the elements surfaces and only if they are exterior parts, the whole elements. This means that the static measures should be divided into under elements, if needed. After developing the static measures, these will be recorded in a second book, the measures book.

5.2 Retrofit elements

The decision support algorithm described in this paper helps choosing retrofit elements. The retrofit measures provided result in some building elements. Further division levels are here like the interior and exterior wall in their bearing parts and a subdivision of these into linear, surface and node elements (Figure 5 and 5). A retrofit element consists of all works which have to be done in order to strengthen, repair, rebuild or even build a constructive component. In case of building retrofit we cannot speak only of "new" building elements but also not only about the "old" ones. Thus, the elements taken in account are named "retrofit elements" and are from four different types: old elements, which are simply strengthened existing building elements; new elements, which are completely new elements, added in the old substance and by which it should be
The use of this methodology requires a clear identification of the building elements and their marking in the 3D digital GIS model. This has also the advantage, that the quantities can be calculated through the CAD software. Thus, the building elements can be edited as service specification for costs calculation in consecrated Tendering-Allocation-Billing modules. Therefore, the elements should consist only of given service specification positions given in an already defined database or, when not, the costs for the new services should be provided separately. The costs for this elements do not need to be calculated fictitious as average from the ones of existing buildings but can be really leaded back to the execution steps which caused them.

5.3 Spatial relationship

Tracing of costs gets a spatial relation. The building will be divided in simple elements as nodes (points), beams or columns (lines), floors or walls (areas). The executed works are related to this elements and static programs can also communicate with them. This elements will be assigned as in a GI-System, using the concepts of edge, surface and node. The advantages of using a GI type systems lie in the wide calculation possibilities, the highlighting of the elements, which are causing the most costs and not at least in the possible compatibility with static programmes. This compatibility derives from the trimmed data storage in CAD and database.

5.4 Database

The transition to GIS is made through bounding the data to spatial elements. The content of the database (Figure 6) details is a detail which will not be described in this paper.

![Diagram](attachment:entity-relationship-diagram.png)
The costs are resumed to rooms, which enable further use of the database for building management, but also during the time of execution, for example to control the "Out of use" times and find better strategies. A second resume to the whole element would be interesting for static purposes.

6 Conclusions

As the method wasn’t applied until now, statements about the certainty degree of the calculated costs cannot be made. Certainty degrees can only be estimated when another methods or databases are in use in the same region, and this is not the case for Romania. An advantage of the methodology is, that from the same database a service directory can be held out. The modular structure of the database allows starting generalisation of the methodology. As soon as the method has been used for some projects, the values can be also stored according to a standardised format in order to build a database of retrofitted objects. This will help estimating costs for similar future projects.

References

taken care of the connection new/old; retrofitted elements, which are old elements with new extensions and finally replaced elements, which are new build elements instead of the deteriorated old ones.

Figure 4: Retrofit elements and retrofitted elements, the example of linear ones

Figure 5: Retrofit elements and retrofitted elements, the example of flat ones
4.3.2 Retrofit considerations about historical buildings

One of the advantages of this methodology is the break-up with statistics, thus permitting a customised approach in applying the methodology to different kinds of buildings. It is possible to develop guidelines about the characteristics to be maintained in the case of a building which belongs to a certain style (Figure 3) and to provide a catalogue with the adequate building elements in this case. However, this shouldn’t replace consulting an architect. For example, retrofit measures based on the extension of the active building’s element section are causing the greatest problems for architecturally or environmentally valuable buildings. The steps of this methodology are reaching an adequate depth to evaluate the suitable methods for this type of historical buildings and could therefore, be thus used.

5 Costs calculation methodology

Structural studies to design the retrofit measures are taking a long time and as there are no tools for calculating costs this happens usually after generating unnecessary time wasting. Through this methodology after the building survey acquisition of data for costs determination will take place in almost the same time when engineering measures are in project such the estimation of costs can take place as soon as the retrofit measures are designed.

5.1 The building record

The way the building record is made has to focus on the elements present on the last division level. The building record has to focus onrecognising the structural elements and their problems. This means not only the damages but also clear differentiation between bearing and non bearing parts, identifying which bearing.
through the comparison of some key types of areas such as gross floor area or main function area. This estimation is possible in incipient stages of planning. The other norm can be used only in later stages of planning but is more precise. It relies on classifying building elements after their execution type. Its structure has different depth levels. On the first level a building is divided into real estate, furnishing up and making accessible, building – building engineering, building – technical assets, external arrangements, equipment and works of art, building extra expenses. This division is called "vertical division". On this level the building costs can be estimated. An example of horizontal division of the third costs group (building engineering) differentiates building cavity, foundation, external walls, internal walls, floors, roofs, building structural mountings and other measures for building engineering. On this level the building costs can be calculated. On a third level for example the external walls are divided into bearing external walls, not bearing internal walls, external columns, external doors and windows, exterior finishes of exterior walls, interior finishes of exterior walls, modulated external walls, anti-glare shield, external walls, others. On this level the building costs can be plotted. Further levels are allowed according to the specific requirements of each project.

3.2 Existing buildings

Methods for evaluating costs of upgrading new buildings were only developed beginning with the last decade. The cost estimation and calculation methodologies can be classified after the criteria of the system used, e.g. system of space usage, system of building surfaces, system of building elements and system of execution steps. The future use of the building is generally the only required knowledge for a cost estimation making use of a database of already constructed buildings. For a costs calculation there are more details about the use of the spaces in the building needed. The way of execution and the building substance is generally taken in account only for the costs plot.

Rolf Neddemann [2] developed a method for estimation and calculation renewal costs of old building on the basis of the method used for new ones. He goes further as the last described level in a system of a new defined type of elements: the "old building elements". The advantage of using ready-made service packs during the planning within the element methodology influenced his decision: Each restoration pack has a description, a current number and descriptions and numbers for the individual building services which have to be executed to build that element. While the building elements were taken into account before only as a collection of single execution steps, Neddemann tries to define real constructional elements. According to his approach, a building can be divided into elements, which consist of their own constructionable parts.
2 Requirements on this methodology

A major goal is, to find a method which doesn’t require location specific values. The only criteria should be the information available on each particular location, such as knowledge about the specific building practice in that country, the characteristics of the existing building and the possible retrofit measures.

The method should be flexible. It should be possible to apply it in different regions, to adapt it to different requirements and to extend and develop it according to the growth of knowledge in this field. It should be computer based as computer based tools prove to have many advantages such as; proper interface for the many actions required in the complex process of seismic retrofit; possibility of the use of a large database; adaptability of the database to different local prices and the prevention of man-made errors.

3 General methods of costs planning

Planning the costs for buildings includes the method to be employed, an adequate structural analysis of the building, scheduling of the structural elements and their quantities, the calculation of the costs itself, the documentation of the results accompanied by an analysis and for the optimising of alternatives.

There is wide range of cost elements, which can be used in different stages of planning. However, the range of methods is more influenced by the availability of comparison data, according to the level of precision required. The kind of data available can be very different from one location to another and there is a strong relationship between the data collected and the specific costs estimation methods of that country. For example, in the USA surveys were undertaken more than ten years ago. At the beginning of the last decade, on behalf of the Federal Management Agency, these were converted into a database, which allows the estimation of costs of retrofit for the described buildings [1]. The Baukosteninformationszentrum in Stuttgart, Germany, has collected more detailed information for building costs [2]. As seismic risk is not a major problem there, this information can only be used for new buildings or for general renewal of the old ones, according to the cost calculation and estimation practice. In Romania there was no such data collected, but the more detailed a method is, the easier it is to find location specific catalogue data.

3.1 New buildings

There are two main German indexes concerned with the structure of a building with regard to costs: one of them giving a better understanding of constructing a building regarding the estimation of costs, while the other one is better suited for a calculation [3].

According to the first standardised index, a building will be divided into spaces with different functions. Using a database with buildings having similar construction types and functions the costs for a new building can be estimated...