

# The Constructive Schemes, the Durability and the Consumer Properties of Multi-Story Residential Buildings

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## Abstract

The article is devoted to the assessment of the structural layout of the residential buildings constructed in St. Petersburg in recent decades. The main emphasis was placed on identifying the eligibility of the project parameters and changes over time of consumer properties of residential buildings. Based on the analysis of design solutions, the author developed guidelines for determining the optimal structural schemes of the building structural framing. The proposed recommendations will improve the economic parameters and to extend the comfortable use of a residential building.

**Keywords:** structural layout, residential building, project parameters, consumer properties, economic parameters

## INTRODUCTION

Construction of residential buildings at all times and in all countries has always been an important direction in forming an urban structure, creating the comforts of living conditions for the population. Modern level of living space of 30 m<sup>2</sup> or more per person revealed a number of inconsistencies constructive schemes of residential buildings of mass construction and consumer qualities of the apartments [1].

The constructive scheme of the building structural framing must allow, within the outer contour of the apartment, to make different planning decisions. This is especially important when changing needs of families during the period of its existence. Therefore the design of a residential building, its parameters depend on the consumer qualities of each apartment, the possibility of its flexible layout, and multiple options for the types of apartments on the floor.

Also, the constructive scheme of the building is determined by the requirements for ensuring the free layout of lower floors designed to perform common functions: Commerce, physical education, sports, leisure, entertainment, catering.

The design of the frame of the building, its parameters are directly dependent on the necessity of providing Parking spaces for all residential houses in the level of the basements.

Construction of residential buildings with narrow step of the transverse walls does not allow designing the apartments with room's area of more than 20 – 24 m<sup>2</sup>, to increase or decrease the number of bedrooms in the apartment, to implement the requirements of universal design for the disabled [2].

In the framework of the code of nation-building in economically developed countries, all newly constructed homes must be accessible to persons with disabilities [3-10].

Residential building designed primarily for the following groups [11]:

1. Families with young children who need the apartment to have room for easy maneuvering in a wheelchair, to provide convenient connection to local area, remote from the dangers of the city.
2. People who have received a temporary injury that limits their mobility (for example as a result of work, sport or traffic accident).
3. Family, including people with disabilities.
4. People with disabilities, which come to visit in the other families. Families in which temporarily there may be people with physical restrictions in movement.
5. Aging families that are looking for the coexistence of adolescents or other adult helpers.
6. Elderly people who need special residential services.

A constructive frame dwelling house should allow designing comfortable flats for all the above types of families, including the elderly and persons with disabilities. Apartments for the above basic types of families, as a rule, for a more convenient stay fit using the techniques of universal design. Design methods, taking into account the principles of universal design to help disabled and elderly with limited physical mobility to live in an apartment, in a house in a residential complex. [8-10].

However, the projects of apartments, is made subject to the methods of universal design, improve the movement of disabled people in the apartment, but do not solve the problem of comfortable accommodation of different types of families, the problem of adaptation planning solutions apartments to the changing needs. *That is, using the methods of universal design we can only partially alleviate some of the conditions of being in a certain space are disabled , but does not to solve the problem of the adaptation of the family to life in the apartment.*

Future direction in the improvement of living environment for all types of families, including the elderly and disabled, we see the conscious application and evaluation of the constructive scheme of a residential building. Constructive scheme of buildings, load-bearing elements of the frame dwelling house must have the possibility to adapt the

apartment to the requirements of the family. The external dimensions of the apartments, as a rule, involve several variants of planning solutions, variants of the mutual arrangement of individual rooms in the apartment, or their mutual connection. *One of the main design principles of the residential building is the development of design solutions, when the time physical operation of the building corresponds with the duration of comfortable, functional use this building by the different population groups.*

The ability to adapt to the changing functions of the family should be included in building construction not only in apartments but also in the framework of the residential floor area. Within the residential floors should provide for the possibility for several variants of the merging or separation of apartments. The design of the frame of the building is also determined by the functional need to organize on the lower floors of residential building large areas for public spaces. Design and calculation of frame houses are connected with the functioning of the basement floors for Parking of the tenants and for the other services [12].

From this we can draw a conclusion about the necessity of designing of residential buildings on the basis of *permanent use comprehensible methods of expert "gerontological evaluation of the design parameters"*. This will facilitate the creation of optimal conditions for the adaptation of the apartments, of premises for communal use and public service premises. In accordance with the principle of matching the

location of the support structures and maximum size of unsupported spaces of the residential floors of the house gives a possibility to calculate and to assess a prospective consumer the cost of the building. The basis for calculation is the pattern of changes of the functional requirements typical of families during their life cycle.

## METHODOLOGY

### Assessment

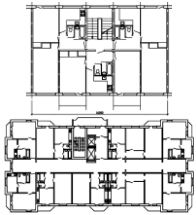
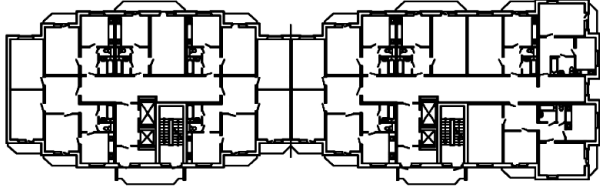
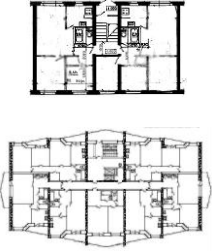
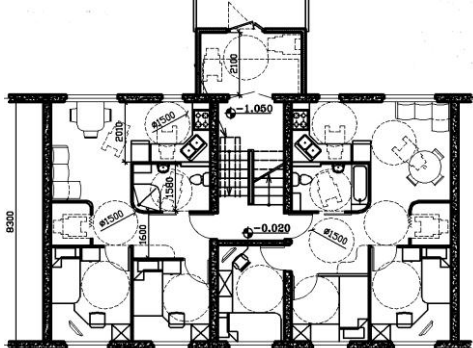
The evaluation applied the constructive scheme of a residential building, the efficiency of the chosen design parameters associated with the opportunity is the location of the necessary types of apartments [13-14].

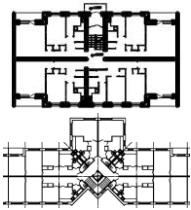
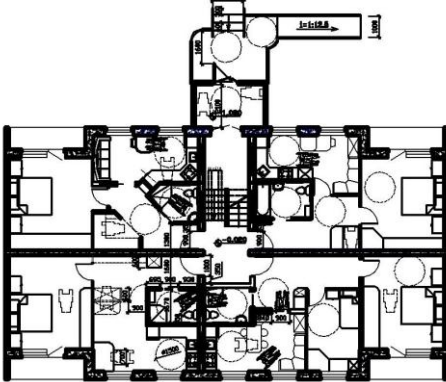
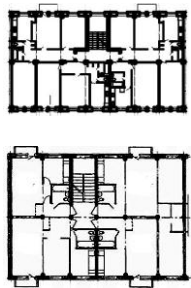
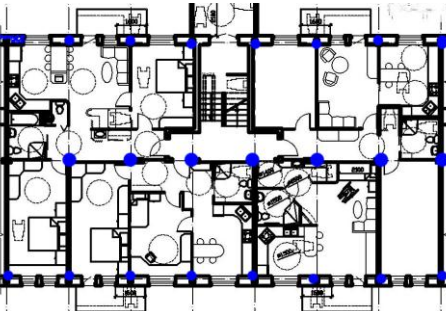
The quality of the apartment depends on the ability of its layout adapting to changing family type, its value.

The objectives of this study were: assessment of design solutions of the residential buildings constructed in St. Petersburg in the second half of the 20th century; identify the conditions under which the principle of best fit between the parameters of the construction of the frame and ease of use of the building over a long period of its existence.

In the development of project documentation for reconstruction or major repairs of residential buildings, which received mass application in the urban construction in the 60-80-ies of the twentieth century (Table 1), it is necessary to provide conditions of accessibility of people with limited mobility to all structural elements of a house.

**Table 1:** Option floor plan of a residential building

Schematic diagram of the type of structural frame of the building	Option floor plan of a residential building for the appropriate structural system	Name of the structural system
		The constructive structural model of a building with transverse load-bearing walls with a narrow step
		The constructive structural model of a building with transverse load-bearing walls with a wide step

		<p>The constructive structural model of a building with longitudinal load-bearing walls</p>
		<p>The constructive structure of frame-panel buildings</p>

The possibility of implementing this task are largely determined by the constructive characteristics of the buildings, the structural parameter, the presence or possibility of a lift or a vertical lifting devices, the organization type of the input node directly to the stairwell or the lobby space in front of the stair-Elevator node.

To assess the possibility of adapting existing residential buildings to the modern requirements of population was conducted in accordance with the analysis of their structural schemes.

It is established that all residential buildings of St. Petersburg from the 60-ies of the 20th century, performed by one of the three structural schemas are: - transverse load-bearing walls with a narrow step; transverse load-bearing walls with wide step, buildings with longitudinal bearing walls (table 1).

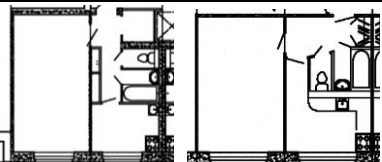
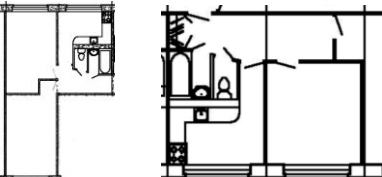
#### Prerequisites for the realization

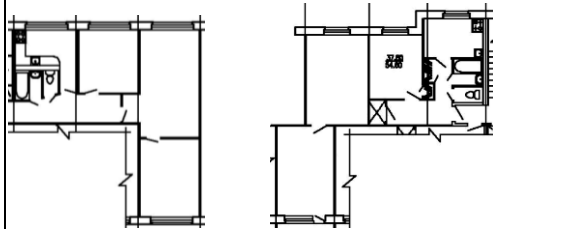
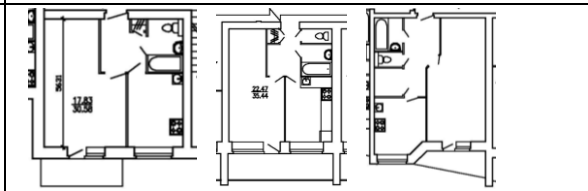
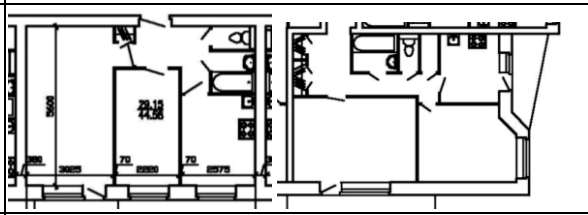
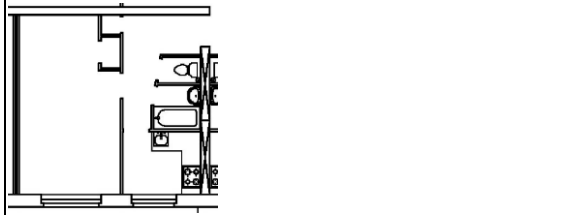
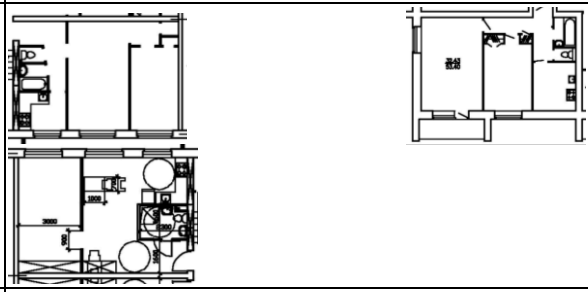
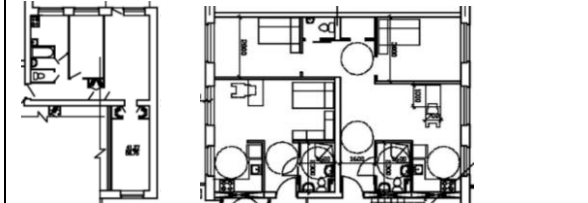
Therefore, by analogy with the Floor constructive schemes of residential buildings of mass building, all planning decisions apartments of the buildings can also be classified according to the type of structural scheme: with a narrow pitch of the transverse walls; with wide step transverse walls; with wide step longitudinal walls, frame type (Table 2).

Buildings with transverse walls with a narrow pitch are mainly used in panel construction houses.

The main types of planning decisions apartments by number of rooms are shown in Table 2.

**Table 2:** The main types of planning decisions apartments

Type of apartment (number of rooms)	Planning scheme of apartments in residential sections of mass housing development	Name of the structural system
1-room		The constructive structural model of a building with transverse load-bearing walls with a narrow step
2-room		

3-room		
1-room		The constructive structural model of a building with transverse load-bearing walls with a wide step
2-room		
1-room		The constructive structural model of a building with longitudinal load-bearing walls
2-room		
3-room		

From the above material we can conclude: a residential building with options structural frame is less than 6.9 m have limited capacity in contingency planning types of apartments within the same area.

Therefore, in terms of the range of renovation, adaptation of buildings for people with limited mobility is not always possible.

#### ***Design, development of alternative solutions***

To determine the cost of the fixture of the apartment to the changing demands of the disabled population in the work was used the cost and income approaches, the method of analogues.

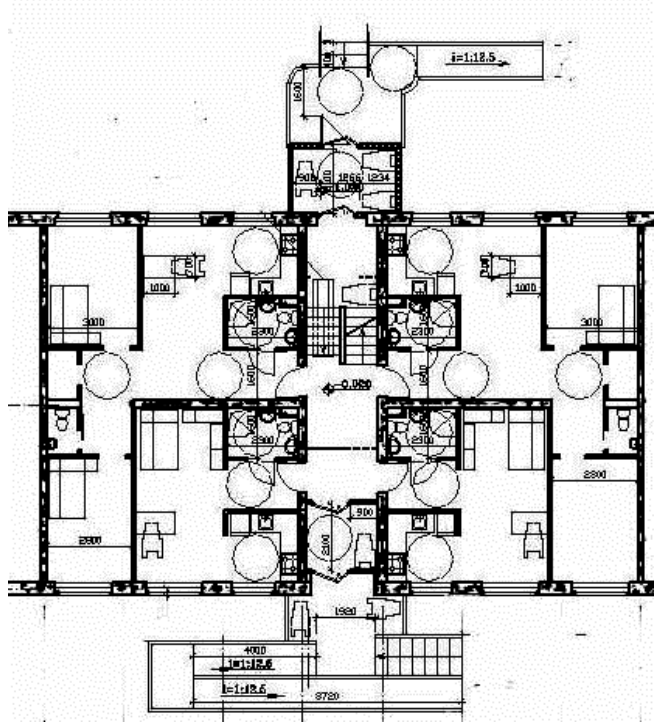
As analogues, were chosen the typical projects of the buildings of St. Petersburg.

For each object was used the cost approach and calculated the necessary volume of reconstruction activities.

Cost-based approach was used a calculation method based on the use of current prices needed for reconstruction and construction activities, in accordance with the amount of planned work [15].

The resulting indicators were calculated on the aggregated indicators, in accordance with the official documentation governing the pricing in the construction (Territorial estimate normative framework the NATIONAL). It was established that the full cost of repairing the apartment for a family with a

person who has a disability, and has to move with the help of a wheelchair, makes 20% of its original value. Therefore, it is appropriate at the stage of design and construction of a new home in advance to provide the opportunity to stay in the apartment people with different levels of physical activity. This approach is not only humane but also economically feasible (figure 1).



**Figure 1.** An example of a preliminary evaluation of the partial redevelopment of the first floor in the model of section 507 of the series (Saint Petersburg)

The cost of the adaptive renovation of the first floor of the building is 30 000 \$.  
The adjacent area is 20 000 \$.

Total construction cost of apartments of the first floor is 200 000 \$.

Therefore, adaptation of apartments for the life of the disabled population, excluding the cost of the fixture adjacent area, is 15 % ( $30000/200000=15\%$ ).

**Podium structures.** Structural diagram of the lower ground floors should take into account differences in a constructive frame overlying and underlying floors. The function of the overlying and underlying floors involves different schema columns of the upper and underground levels. In this regard, constructive framework different levels should correspond to a single modular. Underground car Parking can be achieved by the following design scheme: longitudinal step load-bearing columns from 7.8 m or more provides for the possibility of three Parking spaces, the longitudinal step load-

bearing columns from the 10.5 m and more are provided to the device with four Parking spaces.

## RESULTS

The Engineering and design aspect of residential buildings. Technical parameters of the engineering-design of the base housing are formed, in particular, and under the influence of social requirements of society: the possibility of transforming residential apartment and residential complexes in time, the interchangeability of the engineering and structural elements (depending on the physical or obsolescence), the quality of products, hygienic requirements and ergonomic parameters of a person.

The use of a particular construction technique depends on the choice of the existing and future building systems of residential buildings and complexes (structural, technological, engineering), relevant social, sanitary, town planning and other local conditions, economic possibilities of the society. A comprehensive account of the requirements of people in the structure of residential units, particularly low-mobility groups of the population, requires the choice of these architectural and structural systems of buildings, which would ensure a reasonable increase in the possibility of reconstruction and transformed residential complexes, the inclusion of additional elements of the residential and service purpose without increasing the boundaries of the occupied territory.

The logistical factor of the living environment is a comprehensive purposeful use of building materials, constructive systems, technologies of their manufacture and Assembly, engineering systems and equipment, construction of transformable comfortable accommodation with a long term mental deterioration and appropriate dynamics needs change.

The basis of the structural systems is the principle of selection of the structural frame and the rigidity of a residential building.

Engineering equipment includes heating system, water supply, sewer, mechanical utilities, garbage removal, electricity supply, gas supply system, low voltage system, providing heat, etc.

Used building materials are grouped by purpose: frame of the building, for walling (horizontal, vertical, inclined), finishing materials (interior and exterior).

To evaluate the applied engineering and technical solutions is proposed to use a matrix of indicators (table. 4). Evaluation of options for adapting residential buildings to change over the life needs of the population is carried out for the main planning levels: apartments, residential floors, residential section, and only residential complex.

**Table 3:** Engineering-structural matrices evaluation of functional gerontology requirements for the dwelling

The structural level of the dwelling	Engineering and structural evaluation of functionally gerontological settings residential home			
	Framing	Enclosing elements	Internal Separate partitions	System utilities
Apartment	The provision of redevelopment due to: large-span structures, replacement of walls, columns or piers, without beam ceilings	Effective heat protection, the possibility of reconstruction for additional lighting, connecting with a loggia or extension of the premises living room	Ensure the transformation of the internal space of the apartment	Ensure the variability of planning an apartment
Residential floor	Providing the possibility of combining a number of adjacent apartments	the possibility of reconstruction	The use of sound insulating double interroom partitions	Accessibility to the engineering system on the part of its internal corridors, passages, recreation
Section residential building	The possibility of inclusion in the planning structure of the dwelling building the functional blocks for service (functional units for maintenance)	the possibility of reconstruction	The use of fire walls	The centralized dispatch service, the autonomy of the wiring system, back-up sources
Residential complex	Provide constructive possibilities of the built and attached units	the possibility of easy replacement and renovation	The use of fire walls	Possibility of autonomous engineering wiring for service assignment blocks

## DISCUSSION

Method of assessing the effectiveness of the construction of a residential building schemes is based on the principle of matching four variables: distances between load-bearing structural frame members; the total area of structurally-

planning cells; the number of options of the types of apartments by number of bedrooms; structural and quantitative changes of the family within the minimum area for one person (up to 18-20 m<sup>2</sup>).

**Table 4:** Examples of expert evaluation of consumer qualities of frame structures

building frame	indicators expert assessment by building frame of the apartments by residential buildings		
	the total area of structurally-planning cells	the number of options of the types of apartments by number of bedrooms	structural and quantitative changes of the family within the minimum area for one person (up to 18-20 m <sup>2</sup> )
7.8m x 7.8m	60.8 m <sup>2</sup>	1-2-3	60 m <sup>2</sup> -30 m <sup>2</sup> -20 m <sup>2</sup>
7.8m x (7.8m+3.9m)	91.2 m <sup>2</sup>	1-2-3-4-5	90m <sup>2</sup> -45m <sup>2</sup> -30m <sup>2</sup> -23m <sup>2</sup> -18 m <sup>2</sup>
7.8m x (7.8m+7.8m)	121.6 m <sup>2</sup>	2-3-4-5-6	60m <sup>2</sup> -40m <sup>2</sup> -30m <sup>2</sup> -24m <sup>2</sup> -20m <sup>2</sup>

The optimal solution for the parameters of the structural frame for long term physical existence of a residential building does not happen.

Our task is to determine the conditions under which the principle of the best match between structure and comfortable use of the building over a long period of existence is realized.

The principles set out above can be implemented by using applied at the present stage of construction of residential buildings of a number of structural systems [16 - 19].

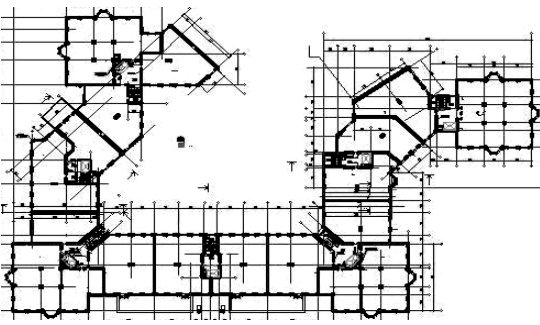
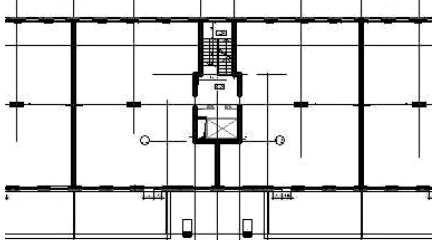
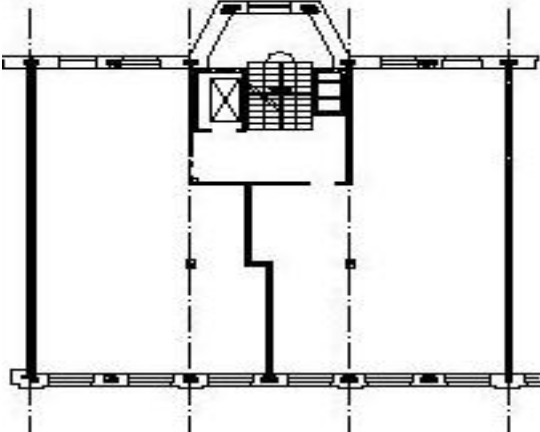
**CONCLUSION**

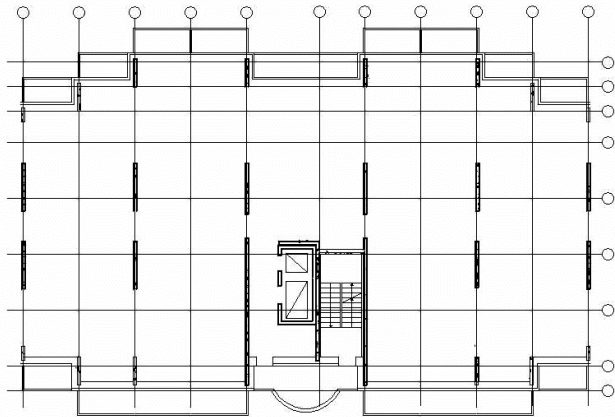
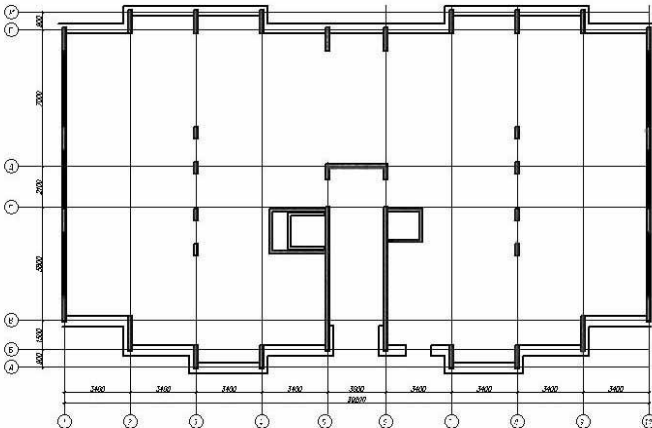
The quality of the design solution of a residential building must meet the following requirements:

1. The design of the frame of the lower floors usually needs to provide the ability to design large multi-function rooms;

2. The lightweight over ground construction systems must to minimize earthworks for underground of construction decision;
3. A convenient construction in cramped urban conditions.
4. The multiplicity of architectural solutions with the general form of the residential house and small elements of the facade.

**Table 5:** Variants of design schemes residential section providing plan's flexibility in the design of apartments

	Examples of planning decisions story residential section	Notes
1		Scheme of a multi-apartment house
2		The design concept of semi-detached residential section with internal elevator assembly
3		The design concept of semi-detached residential section with an outer location of elevator assembly

4		The design concept of multi-family residential section with an outer location of elevator assembly
5		The design concept of multi-family residential section with internal elevator assembly

Good examples of the use construction parameters in the urban residential projects of buildings are shown in the Table 5. Buildings with spans of more than 7 meters, as confirmed by our calculations, can to provide the required flexibility in the design of apartments, the flexible layout of the first floor. The spans of 7.8 m offer a cost-effective location of parking spaces in the basement. When the parameters of a constructive frame are the 7 and more meters, the thickness of the floor slab is taken about 300 - 400 mm. The slab thickness 300-400 mm can effectively solve communications wiring and make a reliable soundproofing (excellent acoustic insulation), fire resistance.

For urban projects of residential houses in the near future will effectively use a modular construction system. In projects of residential buildings there is a real need to use a different structure of constructive framework for the various floors in the same building, for example:

- Premises of cultural and community services on the ground floor;
- Offices on the lower or upper floors;
- The parking places in the basement or ground floors of the houses;
- Residential apartments on the upper floor
- The penthouses or the public rooms on the roof

- Variable frame of the building structure, which allows the use of different mesh structural supports on the different floors.
- Operation top floor regardless of autonomous operation lower floors.

It is also possible to optimize the use of modular construction in the residential buildings by designing the modules to incorporate only the parts of the building such as bathrooms, kitchens and any others rooms. Modules can be supported by shallow floor beams so that the overall floor depth is minimized. A typical plan form of a mixed framed is shown on the table 5. In the underground floors the podiums can be made of more powerful designs with an increased pitch of the columns and girders to support the above floors with different forms.

Constructive structure of residential building design should allow a comfortable apartment for all types of families, including lone elderly and disabled. Flats for the main types of families tend to fit through universal design techniques. These methods are based on the design tools that allow disabled and elderly with limited mobility to live in an apartment, in a house, in a residential complex.



But universal design techniques do not solve the problem, but only improve living conditions.

Further direction in improving the living environment for all types of families, including the elderly and disabled, we see in the conscious application and evaluation of structural layout of a residential building. The design parameters of a bearing skeleton of an apartment house should provide the possibility of adapting the area of apartments for different types of families, for the duration of physical deterioration of the building [20]. Ability to adapt to the changing function of the family must be incorporated in the design of the building, not only within the boundaries of the apartment, but also in the area of the residential floors. Within the housing floor should be possible arrangement of several basic types of options flats, various embodiments of connection or disconnection of flats.

Hence, we come to the conclusion about the need to develop an effective method of assessing the design parameters of an apartment house, which will be observed during conditions of adaptation of apartments, common areas and public services. It is necessary for compliance with the principle of matching the location of supporting structures, values unsupported spaces of an apartment house to changing during the whole lifetime of the building functional needs of the population. In accordance with the principle of matching the location of the supporting structures and the maximum size of unsupported spaces residential floors house is possible to calculate and evaluate the prospective customer value of the building. The calculation is based on the pattern of changes of the functional needs of a typical family in a period of their life cycle.

## REFERENCES

- [1] Nikolaev S.V., 2016. Architectural-Urban Development System of Panel-Frame Housing Construction. *Zhilishchnoe Stroitelstvo*, 3: 15-24.
- [2] Centre for Excellence in Universal Design 2015. Universal Design Guidelines. For Homes in Ireland. National Disability Authority
- [3] Housing design guidelines., 2015. Universal Design Australia.net.au/.../housing-design-guidelines/  
<http://universaldesignaustralia.net.au/category/housing-design-guidelines/>
- [4] Universal Design or Smart Housing. 2003. Department of Housing Portfolio Standards. Queensland – Smart State/  
<http://www.hpw.qld.gov.au/SiteCollectionDocuments/UniversalHousingDesignBooklet.pdf>
- [5] Proposal for Change to the National Construction Code. 2014. / Series Accessibility in housing. Rights & Inclusion Australia ABN 60 149 775 100  
<https://aduhdblog.files.wordpress.com/2016/05/accessibility-in-housing-abc-b-proposal-with-insets.pdf>
- [6] Imrie, R., 2003, the impact of Part M on the design of new housing. London: Centre for Accessible Environments.
- [7] Carnemolla, P. and C. Bridge, 2011, Home Modifications and their impact on waged care substitution, in Home Modification Information Clearinghouse. University of NSW: Sydney.
- [8] Saugeres, L., 2010. (Un) accommodating disabilities: housing, marginalization and dependency in Australia. *Journal of Housing and the Built Environment*, 26(1): p. 1-15.
- [9] Smith, S., et al., 2012. Population Aging, Disability and Housing Accessibility: Implications for Sub-national Areas in the United States. *Housing Studies*, 27(2): p. 252-266.
- [10] Bringolf, J. Barriers to universal design in housing. Urban Research Centre, College of Health and Science. [(Doctoral dissertation)] 2011 September 16, 2012]; Available from: <http://handle.uws.edu.au:8081/1959.7/506910>.
- [11] Livable Housing Design Guidelines, 2nd Edition. 2012, Livable Housing Design [http://livablehousingaustralia.org.au/library/help/Livable\\_Housing\\_Design\\_Guidelines\\_Web1.pdf](http://livablehousingaustralia.org.au/library/help/Livable_Housing_Design_Guidelines_Web1.pdf)
- [12] Residential and mixed-use buildings., 2016. SteelConstruction.info [http://www.steelconstruction.info/Residential\\_and\\_mixed-use\\_buildings](http://www.steelconstruction.info/Residential_and_mixed-use_buildings)
- [13] Multi-story office buildings, 2016. SteelConstruction.info [http://www.steelconstruction.info/Multi-storey\\_office\\_buildings](http://www.steelconstruction.info/Multi-storey_office_buildings)
- [14] Steel buildings in Europe. Multi-Storey Steel Buildings. Architect's Guide. [http://sections.arcelormittal.com/fileadmin/redaction/4-Library/4\\_SBE/EN/MSB01\\_Architect\\_s\\_Guide.pdf](http://sections.arcelormittal.com/fileadmin/redaction/4-Library/4_SBE/EN/MSB01_Architect_s_Guide.pdf)
- [15] Krundyshev, B., 2014. Architectural adaptation of the residential sections for wheelchair users. *Zhilishchnoe Stroitelstvo*, №11, – p. 35-41.
- [16] Multi-story Residential Building using steel., 2003/ The Steel Construction Institute
- [17] Christian Müller, Matthias Oppe., 2008. Conceptual design and design examples for multi-storey buildings/ Eurocodes. Background and Applications [http://eurocodes.jrc.ec.europa.eu/doc/WS2008/EN19\\_93\\_6\\_Mueller.pdf](http://eurocodes.jrc.ec.europa.eu/doc/WS2008/EN19_93_6_Mueller.pdf)
- [18] Bastow Place, Mulgrave, Victoria 3170, Australia. The Images Publishing Group Pty Ltd, 2015. 248 p.
- [19] Wood Antony, 2010. Tall buildings: search for a new typology. PhD thesis, University of Nottingham, 28 p.
- [20] Krundyshev, B., 2016. Architectural gerontological aspect in social housing. *Architecture and Construction of Russia*, №1-2, – p. 44-57.