Experience of Development and Implementation of a House Project by an Architect

S N Zolotukhin¹, E A Byndyukova¹, A G Chigarev¹

¹Department of Building Structures, Basements and Foundations, Voronezh State Technical University, 20 letiya Oktyabrya, 84, Voronezh, 394006, Russia

E-mail: ser6812@yandex.ru

Abstract. This paper proposes to build individual, economical residential buildings in the suburban and rural areas, in the structure of which new materials are combined with reusable ones. Some practical recommendations on their design and construction are given. It is shown, that the correct choice of space-planning solution and the re-use of building materials in housing construction leads to money saving. The new housing should be not only cheap but also rational in the broad sense of the word. Different professionals should take part in the process of rational construction: architects, designers, economists, consultants in infrastructure and communications. The role of architects is indicated when the consumer chooses the future planning of the house. The architect, together with scientists and engineers, takes into account the possibility of building structures from existing used materials. Experts in the field of building structures evaluate the possibility of building the foundation and supporting structure of a future house from existing used materials obtained after demolition. The experience of other countries shows the possibility of transforming buildings using only the building materials already existing in them without using new ones. Foreign scientists are working on the concept of developing reusable construction materials, products and structures, their certification. As evidence of the effectiveness of the proposed approach, the author gives an estimate of the construction of a house with an attic and a comparison of its total actual cost with the market average in the Voronezh region.

1. Introduction
In order to stabilize and improve the state of urban development, the Ministry of Regional Development of Russia, the RAACS, the leading research and design institutes of the country prepared the concept of the urban development doctrine to 2020 and the strategy for the development of the building complex [1]. The concept implies the rejection of excessive territorial development of cities in favor of their active reconstruction. In the XXI century, it is planned to rebuild the areas of mass residential construction of the 1960-70s and to demolish time-worn houses. "The priority content of urban planning at the municipal level should be a comprehensive reconstruction of existing buildings by demolishing and replacing dilapidated buildings with modern ones, reconstruction of residential buildings with houses of the first mass series, and then quarters and neighborhoods with large-panel houses of all series ..." [1]. Thus, it can be assumed that in the near future the number of buildings to be demolished will increase. Moreover, due to the shortage of land in the major cities of Russia and the increase in their value, not only dilapidated residential buildings but also buildings that are in a working technical
condition built in a reconstructed area will be demolished. There will be the problem of the reuse of a huge amount of materials, products and structures, resulting from the reconstruction.

2. Topicality
According to the decision of the government of the Russian Federation, up to 2025, 9.5 million square meters of dilapidated housing should be demolished. Demolition by the crushing method of 1 m³ leads to the appearance of 1 m³ of construction waste, the removal of which to domestic waste dumps has already led to environmental problems in the Moscow region. Studies by various authors [2, 6b 15] show that the bearing capacity of a brick does not fall during its operation under favorable temperature and humidity conditions, and even increases and the strength of reinforced concrete structures grows almost constantly under the same conditions. Therefore, the reuse of building materials, products and structures is an urgent task that scientists and builders should solve.

The development strategy of the construction complex provides for the expansion of the volume of construction of private residential family houses in suburban areas and rural areas. Thus, the issues of designing and building low-rise residential buildings were and will remain topical, and “…using the experience of successful projects of residential units will ensure the creation of a high-quality residential environment …” [3].

In world practice, now there is a new direction of construction associated with the dismantling of buildings and the reuse of building materials and structures. A number of works [2, 8–10] note that most of the materials and structures remaining after the disassembly of a building can be reused in construction. However, they do not address issues related to the design and construction of buildings that include the above elements in their three-dimensional structure.

To date, many projects and methods have been developed for the construction of low-rise residential buildings. There are people with different financial capabilities among developers. Those who have considerable sums usually do not care about the question of reducing the cost of construction and home improvement. However, common developers, with average incomes, need to familiarize themselves with the basics of design and construction, because, before moving to a new house, you need to go through a thorny path, take a lot of decisions and not make a mistake at the same time.

As it is known, by the beginning of construction, the builder should have a house project, a building permit and a contract with a contractor. By the time of choosing (or ordering) a project, he/she may have difficulties. The house must meet the needs of the family, successfully fit into the environment, have high artistic qualities, and at the same time have a low cost. Often the main focus is on the choice of projects of houses with high economic performance and low cost. The developer who wants to build a house at the lowest cost should know that its cost depends on the spatial solution, as well as the functional planning organization of apartments.

3. Formulation of the problem
The purpose of the design was to obtain a project of a house with economic advantages and intended for two families. To achieve this goal, it was necessary to solve the following main tasks:

1. To identify the features of space-planning solutions for low-rise buildings with low cost;
2. To identify design solutions to reduce the cost of finishing work;
3. To carry out work on the construction of a low-rise residential building with the re-use of building materials, products and structures resulting from the demolition of dilapidated housing;
4. To prove the possibility of designing and constructing low-rise buildings with the re-use of materials formed during the element-by-element dismantling of buildings and structures;
5. To compare the cost of 1 square meter of the residential house built on this technology with a market value of 1 square meter of total housing in the city of Voronezh.
4. Theoretical part

The results of the analysis of projects of low-rise residential buildings with low cost led to the following conclusions:

- low-cost houses have a simple three-dimensional structure and configuration in the plan, their facades have a minimum number of projections and details;
- the foundations of economical houses are made monolithic or prefabricated, with a basement where a number of rooms are located (sauna, dressing room, restroom, garage), technical rooms, etc., which reduces the cost of 1 square meter of the house and improves its comfort;
- the walls are made of wood, brick or gas silicate blocks, using cheap finishing materials, for example, the use of siding, which is well combined with panels and tiles for brick, wood, etc., helps to elevate the façade;
- the cost of the house is affected by the functional planning organization of the apartments; the most economical are three-, five-room apartments with a common intercommunicating room and accommodation on two levels;
- to connect the rooms in such apartments, instead of the common house stairs, lightweight wooden stairs are used, which are located in the hallway or in the common room;
- adjacent location of the kitchen and bathroom, as well as two bathrooms vertically, helps reduce the amount of pipes;
- cheap low-rise houses have a simple roof of gable shape, the construction of which, unlike broken, hip and half-hipped, does not require complex structural solutions and the use of expensive materials (shingles, ceramic tiles, etc.)
- under the roof of low-cost houses, there is usually an attic, which not only provides additional living space but also gives a unique character to the architectural appearance of the house;
- it is rational to include elements of vintage masonry of old brick, painting the surface of the brick without plaster in the design of interiors of budget projects;
- at the device of roofs, the rafters from the open old boards, on which the boardwalk are laid, are used;
- for houses with gable roofs not adjacent to the pavement of city streets and surrounded by lawns, the drain is made free, which saves the developer from the costs associated with the construction of the drainage system.

The peculiarities of low-cost houses can be taken into account when drafting a design assignment in the case of ordering a project of a house in a project organization. An architect will help to realize the idea of the developer, to design the house, taking into account the size of the family, as well as the characteristics of the land.

The works [2, 6, 7, 14 - 16] show the possibility of justifying the extension of the service life of building structures and materials using expert methods. In the process of substantiation, several expert methods are used based on the use of various parameters (damage, reduction in bearing capacity, physical wear) of building structures to justify the possibility of further safe use of materials and building structures after dismantling a building.

A review of the experience of foreign countries was carried out in order to compare the achievements of the authors with global trends in the field of reuse of building materials and structures. Finland and Poland are developing reuse of building materials and structures in the renovation of apartment buildings. They transform one building into another or into several smaller buildings and structures, using materials only from the original building [17, 18]. In the construction industry in Austria, they follow a similar path, but they also incorporate a building material passport into the BIM system [19]. Determining the volume of materials suitable for reuse is a worldwide trend, as it is considered by scientists from all continents [20-23].
5. Practical significance

The findings of the authors were used in the development of the house at 10, Ispyateley str., Voronezh. The plans, facade and section of the house are shown in Fig. 1-6, the explication of the premises is in Table 1, the cost types of construction works made in 2011-2014 and used structures and materials are in Table 2.

The experience of the project showed that in the house of the chosen type, the volume of wall materials and the cost of engineering equipment are reduced, the heat loss is reduced (by reducing the wall area), which confirms the correctness of the choice of its space-planning solution. The planning solution of the house allows the transformation of the premises inside it. For example, by introducing an additional partition, the attic space of 80 m² was divided into three parts. Installing a sliding partition made it possible to combine two attic rooms into one.

Recycling of structures and materials obtained during the demolition of emergency housing in the city of Voronezh contributed to the economic effect of the construction. The construction of a house from reusable materials was carried out by professional executives-builders, under the guidance and supervision of the staff of the Department of Building Structures, Basements and Foundations, which ensured the correctness of the selected engineering solutions. Quality control over the strength indicators of building materials, products and structures was carried out at the Center for Collective Use of VSTU, which ensured the reliability of the materials used.

The inclusion of the basement floor with an area of 121.3 m² and the reuse of structures (foundation bearer, foundation block, slabs) and materials (brick, gas silicate blocks) during its construction resulted in a cost of 1 sq. meter of space of the premises located in it equal to 48.6 euros.

We must say that almost the entire bearing frame of the house was built with the reuse of materials. Technical solutions for the foundation from recycled materials are shown in patents [9-11]. They were used not only for building the foundation, but also for walls, partitions, slabs of the first floor, and rafters.

Vinyl siding was used for the external finishing of the walls; metal sheets with imitation of masonry from natural stone were used to finish the basement.

It should be noted that the main construction and installation work was carried out in 2011-2014. The cost of each type of work, during construction, was determined on the basis of prices prevailing in the market for building materials and structures, including used ones, as well as an individual agreement with contractors (bargaining).

Table 2 shows the process of building the house in stages (years). It shows the cost of the work performed in each year and the structures and materials used in the construction process.

Figure 1. Ground floor plan. Figure 2. Section.
Figure 3. First floor plan.

Figure 4. Initial construction stage.

Figure 5. Attic floor plan.

Figure 6. The house after construction.
Table 1. The explication to the floor plan of the building (structure), located in the city of Voronezh.

| Letter according to plan | Floor | Room number (apartment) | Number of a room, kitchen, etc. | Premises purpose: living room, kitchen, etc. | Total area | Including the area of residential / Main apartment | Including the area of Subsidiary | Including the area of Loggias, balconies, terraces, etc. and storerooms, etc. | Including the area of Other | Height of the premises in internal volume | Including the area of common premises Total area |
|--------------------------|-------|-------------------------|---------------------------------|---------------------------------------------|-----------|-----------------------------------------------|---------------------------------|---------------------------------------------|---------------------------------|-----------------------------------------------|-----------------------------------------------|
| A gr 1                   | 1     | 1                       | Garage                          | 23.2                                        | 23.2      | 23.2                                          | 2.45                             | 2.45                                         | 2.45                            | 2.45                                         | 2.45                                         |
| A gr 1                   | 1     | 2                       | Workshop                         | 8.6                                         | 8.6       | 8.6                                           | 2.45                             | 2.45                                         | 2.45                            | 2.45                                         | 2.45                                         |
| A gr 1                   | 1     | 3                       | Boiler room                      | 17.8                                        | 17.8      | 17.8                                          | 2.45                             | 2.45                                         | 2.45                            | 2.45                                         | 2.45                                         |
| A gr 1                   | 1     | 4                       | Sauna                            | 8.2                                         | 8.2       | 8.2                                           | 2.45                             | 2.45                                         | 2.45                            | 2.45                                         | 2.45                                         |
| A l 1                    | 1     | 5                       | Cold annex                       |                                              |           | 12.4                                          | 2.50                             | 2.50                                         | 2.50                            | 2.50                                         | 2.50                                         |
| A l 1                    | 1     | 6                       | Entrance hall                    | 5.0                                         | 5.0       | 5.0                                           | 2.80                             | 2.80                                         | 2.80                            | 2.80                                         | 2.80                                         |
| A l 1                    | 1     | 7                       | Corridor                         | 2.5                                         | 2.5       | 2.5                                           | 2.80                             | 2.80                                         | 2.80                            | 2.80                                         | 2.80                                         |
| A l 1                    | 1     | 8                       | Sitting room                     | 22.0                                        | 22.0      | 22.0                                          | 2.80                             | 2.80                                         | 2.80                            | 2.80                                         | 2.80                                         |
| A l 1                    | 1     | 9                       | Bathroom unit                    | 3.7                                         | 3.7       | 3.7                                           | 2.80                             | 2.80                                         | 2.80                            | 2.80                                         | 2.80                                         |
| A l 1                    | 1     | 10                      | Kitchen                          | 12.7                                        | 12.7      | 12.7                                          | 2.80                             | 2.80                                         | 2.80                            | 2.80                                         | 2.80                                         |
| A l 1                    | 1     | 11                      | Living room                      | 11.4                                        | 11.4      | 11.4                                          | 2.80                             | 2.80                                         | 2.80                            | 2.80                                         | 2.80                                         |
| A l 1                    | 1     | 12                      | Parlour                          | 40.9                                        | 40.9      | 40.9                                          | 4.20                             | 4.20                                         | 4.20                            | 4.20                                         | 4.20                                         |
| A l 1                    | 1     | 13                      | Bedroom                          | 22.4                                        | 22.4      | 22.4                                          | 2.68                             | 2.68                                         | 2.68                            | 2.68                                         | 2.68                                         |
| A l 1                    | 1     | 14                      | Study                            | 19.0                                        | 19.0      | 19.0                                          | 2.68                             | 2.68                                         | 2.68                            | 2.68                                         | 2.68                                         |
| **Living quarters 1:**   |       |                         |                                 | 197.4                                       | 197.4     | 115.7                                         | 81.7                             | 2.45                                         | 209.8                           |                                              |                                              |
| A gr 2                   | 2     | 1                       | Garage                          | 59.2                                        | 59.2      | 59.2                                          | 2.45                             | 59.2                                         |                                              |                                              |
| A l 2                    | 2     | 2                       | Entrance hall                    | 7.5                                         | 7.5       | 7.5                                           | 2.80                             | 7.5                                          | 2.80                            | 7.5                                          | 2.80                                          |
| A l 2                    | 2     | 3                       | Living room                      | 12.6                                        | 12.6      | 12.6                                          | 2.80                             | 12.6                                         | 2.80                            | 12.6                                         | 2.80                                          |
| A l 2                    | 2     | 4                       | Kitchen                          | 13.1                                        | 13.1      | 13.1                                          | 2.80                             | 13.1                                         | 2.80                            | 13.1                                         | 2.80                                          |
| A l 2                    | 2     | 5                       | Corridor                         | 2.6                                         | 2.6       | 2.6                                           | 2.80                             | 2.6                                          | 2.80                            | 2.6                                          | 2.80                                          |
| A l 2                    | 2     | 6                       | Bathroom unit                    | 3.8                                         | 3.8       | 3.8                                           | 2.80                             | 3.8                                          | 2.80                            | 3.8                                          | 2.80                                          |
| A l 2                    | 2     | 7                       | Sitting room                     | 22.5                                        | 22.5      | 22.5                                          | 2.80                             | 22.5                                         | 2.80                            | 22.5                                         | 2.80                                          |
| **Living quarters 2:**   |       |                         |                                 | 121.3                                       | 121.3     | 35.1                                          | 86.2                             |                                              | 121.3                           |                                              |                                              |
| **Total on living quarters** |       |                         |                                 | 318.7                                       | 318.7     | 150.8                                         | 167.9                             | 12.4                                         | 331.1                           |                                              |                                              |
Table 2. The cost of construction works and used structures and materials in 2011-2014.

| Stage | List of work performed | Year of work | Cost of materials, structures and works |
|-------|------------------------|--------------|------------------------------------------|
| 1     | Execution of "zero cycle" works. Digging of a ditch, the device of the foundation from foundation bearers and foundation blocks. Backfilling. Rising walls and partitions of the basement of gas silicate blocks and bricks; laying reinforced concrete slabs of the 1st floor; construction of a 1st floor box from gas silicate blocks; Laying the internal partitions of the 1st floor and brick pipes; installation of the 1st floor ceiling and structures of the rafters made of wood (bars, logs), roof assembly | 2011 | €16 497 |
| 2     | Installation of 12 windows and 4 entrance doors; decoration and insulation of the basement; finishing facades with warm siding with; eaves trim with siding. | 2012 | €5477 |
| 3     | Making monolithic areas of the ceiling. Installation of plasterboard ceilings on the first floor of the house with insulation; Constructing floor attic of boards and chipboard; insulation of the side walls and ceiling of the attic; decoration of the walls and ceiling of the attic with plasterboard and PVC panels. | 2013 | €3694 |
| 4     | Engineering supply of the building (electricity, gas, water, sewerage, heating) | 2014 | €7 336 |
| Total: | | | €33 004 |

So, the cost of the house with the exterior finishing of the facades and the interior roughing was 33,004 euros. If we add the value of the land equal to 11,094 euros to this sum, we get 44,098 euros. Dividing this amount by the house area of 331.1 m², we get the cost of 1 sq. meter of its total area. It is equal to 133.2 euros. At the same time, the average market value of 1 square meter of the total area of residential premises in the Voronezh region in 2014 was 432.9 euros. This cost is 3.25 times bigger than the calculated one. Therefore, the cost of a built house purchased in 2014 at a market price would have been 143,322.8 euros.

6. Conclusions
The theoretical analysis of space-planning decisions, determining the strength characteristics of reusable materials, which was held with the participation of architects, designers, engineers of various departments of the VSTU, made it possible to reduce the cost of building a residential house by more than 3 times. The constructed building complied with sanitary-and-epidemiologic norms, aesthetic requirements, and comfort conditions. The environmental problem of using materials, products and structures formed after the demolition of buildings and structures was solved.

References
[1] 2013 Reconstruction and renovation of the existing buildings of a city: textbook ed. P G Grabovogo, V A Kharitonov 2nd ed. (Moscow: Prospect) 712 p
[2] Shmelev G D 2019 Justification of the possibility of reuse of building materials and structures Housing and Communal Infrastructure 1(8) pp 25-35
[3] Tselykh E A 2016 Prospects for the formation of a living environment in Russia Architectural studies 1(5) pp 56-62
[4] Lisitsian M V, Pashkovskiy V L, Petunina Z V 2010 Architectural design of residential buildings (Moscow: Arkhitektura) 488 p
[5] Asaul A N, Kazakov Yu N, Pasyada N I, Denisova I V 2005 Low-rise housing construction (St. Petersburg: Gumanistika) 563 p
[6] Shmelev G D 2014 Expert method for predicting the residual life of building structures from their physical wear Construction and reconstruction 3(53) pp 31-39
[7] Shmelev G D 2017 Physical depreciation, current and capital repairs of residential buildings Management of socio-economic systems: theory, methodology: proceedings of the international scientific-practical conference: in 2 parts (Penza: Publishing house: “Nauka i prosveshchenie”) pp 28-31
[8] Zolotukhin S N 2018 Rational construction with the reuse of building materials, structures, products after the demolition of a building Resource-efficient technologies in the building complex of the region 10 pp 206-209
[9] Zolotukhin S N 2018 Opportunities for creating a regional cluster of construction waste reuse Resource-efficient technologies in the construction complex of the region 10 pp 209-212
[10] Kolodyazhny S A, Zolotukhin S N, Abramenko A A, Kukina O B, Vazov A Yu, Lobosok A S, Milovanova V I 2017 Method of manufacturing continuous slab foundations of box-section from ribbed slabs patent for invention RUS 2647521 http://www.1.fips.ru/fips_serv/fips_servlet
[11] Kolodyazhny S A, Zolotukhin S N, Abramenko A A, Kukina O B, Vazov A Yu, Lobosok A S, Milovanova V I 2018 Method of construction of the foundation of the walls using ribbed floor slabs (coatings) patent for invention RUS № 2671019 C1 http://new.fips.ru/registers-doc-view/fips_servlet?DB=RUPAT&DocNumber=2671019&TypeFile=html
[12] Kolodyazhny S A, Zolotukhin S N, Abramenko A A, Kukina O B, Vazov A Yu, Lobosok A S, Milovanova V I 2018 Method of volumetric cementation of soils patent for invention RUS 2656656 http://new.fips.ru/registers-doc-view/fips_servlet?DB=RUPAT&DocNumber=2656656&TypeFile=html
[13] Shmelev G D 2017 Express evaluation of the probability of unforgettable work of construction structures Proceedings of the winners of the IV International Scientific and Practical Conference: European Scientific Conference In 3 parts Part 1 pp 41-43
[14] Shmelev G D 2017 Complex methodology of the calculated substantiation of the residual resource of construction structures Proceedings of the winners of the XI International Scientific Conference: World science: problems and innovations In 2 parts Part 1 pp 79-81
[15] Shmelev G D 2017 Methodology of estimation of the technical condition and calculation of forecasting and substantiation of the residual time of the service of construction structures proceedings of the IX International Scientific and Practical Conference: International innovation research In 2 parts Part1 pp 62-64
[16] Huuhka S, Kaasalainen T, Hakanen J H, Lahdenpöyö J 2015 Reusing concrete panels from buildings for building: Potential in Finnish 1970s mass housing Resources, Conservation and Recycling vol 101 pp 105-121
[17] Jerzy Charytonowicz, Maciej Skowroński 2015 Reuse of Building Materials Procedia Manufacturing vol 3 pp 1633-1637
[18] Melih Honic, Iva Kovacic, Helmut Rechberger 2019 Improving the recycling potential of buildings through Material Passports (MP): An Austrian case study Journal of Cleaner Production 217 pp 787-797
[19] Julia L K 2019 Nujaholza, Freja Nygaard Rasmussenb, Leonidas Miliosa 2019 Circular building materials: Carbon saving potential and the role of business model innovation and public policy Resources, Conservation & Recycling 141 pp 308–316
[20] Giovanni Brambilla, Monica Lavagna, George Vasdravellisb, Carlo Andrea Castiglioni 2019 Environmental benefits arising from demountable steel-concrete composite floor systems in buildings Resources, Conservation & Recycling 141 pp 133–142
[22] Fernanda Cruz Riosa, Wai K. Chonga, David Graua 2015 Design for Disassembly and Deconstruction Challenges and Opportunities Procedia Engineering 118 pp 1296 – 1304
[23] Negar Mohtashami 2016 Quantitative assessment of deconstruction buildings using a Building Deconstruction Matrix Pacific Science Review B: Humanities and Social Sciences 2 pp 113-117