Architectural and planning features of terracing of multi-storey residential buildings on flat terrain

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Abstract. The paper deals with terracing techniques for multi-storey residential buildings on flat terrain. The relevance of terracing application in modern architecture is substantiated, as this architectural and planning method allows not only to radically change the visual qualities of a residential building, but also to enhance the planning qualities of apartments, supplementing them with additional individual open spaces. The paper outlines the classification of terracing techniques for multi-storey residential buildings from the point of forming their volumetric and spatial composition. An analysis of different terracing methods with examples from current world practice is presented. The presented terracing techniques demonstrate the great potential of this method in design practice both for achieving expressive architecture of buildings and complexes, and for improving the quality of urbanized residential environment in general.

Key words: Terracing, multifamily housing development, multi-storey residential buildings, flat terrain, open terraces, architectural and planning features.

1 Introduction:

Terraced high-rise residential development on flat terrain is gaining popularity due to the variety of compositional techniques that enable to blend it seamlessly into both the surrounding natural landscape and the established urban fabric [1]. The great advantage of terracing of residential buildings is that the apartments have their own terrace for relaxation or any activity, which adds comfort to the living space and serves as a unifying link between the apartment and the outer world. In addition, the terracing method allows for extensive landscaping of terraces, which contributes to the visual quality of the urban environment as a whole [2, 3].

The ways of terracing residential buildings on flat terrain can vary. They have a very great potential to create an expressive composition of a building or a residential group. In addition, in domestic practice terracing techniques for multi-storey residential buildings on flat terrain as such are not very common due to outdated codes of practice [4, 5]. If the terracing of low-rise residential buildings on the relief is a historically known technique and is thoroughly studied, the methods of terracing of multi-storey residential buildings on flat areas are used much less often, and practically have not been considered from a scientific perspective.

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This paper presents a classification analysis of the existing variants of terracing on flat terrain of multi-storey residential buildings in the current world practice.

2 Materials and methods:

Historically, terraces, as an architectural technique, originated as a response to the problem of complex topography to achieve the most efficient building density possible [6]. However, with the development of construction technologies, they gained popularity in high-rise urban residential buildings on flat terrain as the main means of artistic expression of a building, and to enhance the "revitalization" of dense and sparsely landscaped urban environment [7, 8].

Currently, the world architectural practice counts a lot of projects with the use of terracing, both in the southern climate, for example, residential construction in Turkey, Israel, Tunisia, and in temperate climate, such as in France, Finland, and Norway. In Russia, the terracing method, in addition to its obvious use in the regions of Krasnodar, Sochi and Crimea, has gained popularity in the design of high-rise and variable storey buildings within the development of Moscow and other large cities where the climate is harsher than in the South of Russia [9]. Nevertheless, the advantages of organizing terraces outweigh the specific features of their operation in the winter season. The use of various terracing techniques is dictated by the willingness to increase the architectural expressiveness of buildings and development as a whole, as well as the strive to increase the "ecological" quality of residential architecture by adding spaces of being in the fresh air [10, 1].

Terraces are seen as a conduit between the internal space of a building and the street environment surrounding the building. In dense urban areas, where landscaping may be limited, terraces are an additional means of greening not only the façade but also the urban architectural environment. In addition, given that most new construction is concentrated on the outskirts of cities, the terracing method can create the necessary intermediate scale between high-rise urban development and private low-rise development [11].

Thus, by utilizing the terracing method, it is possible to retain some of the spirit of the suburban dwelling, offering the consumer a multi-family housing format while retaining the benefits of the individual dwelling house, including private street space, space for gardening, sunbathing and air bathing, etc. [12]. The global experience of the 2019-2022 pandemic, with the prolonged self-imposed isolation of citizens inside apartments, has shown even more benefits of having outdoor terraces when living in an urban apartment.

Speaking of the class of real estate, it should be noted that in residential real estate of standard and comfort class there is currently a tendency to reduce the arrangement of balconies and loggias. However, in the real estate of business and premium class terraces have become widespread. For example, several successful projects of elite terraced real estate within the boundaries of the Boulevard Ring have been implemented in Moscow, projects of high-rise buildings with partial organization of terraces in the south-west and west of the city have been developed, and the Moscow region is actively developing terraced structures.

When organizing terraces, it is necessary to consider the construction norms and specific features of the planning structure of the dwelling, which must be followed in the design [13]. The ways of terraces arrangement have a direct relationship with the functional features of the interior.

When designing terraces in multi-storey residential development it is necessary to take into account such urban planning features of the place as: the need for "health enhancement" of the urban environment, the density of the building, the type of surrounding development, the location of the site for design, the elevation of the site, attractive view and other features of the initial parameters for construction [14-16].

In the course of research and systematization of terracing techniques, several groups of terraced residential buildings on flat terrain have been identified, according to the techniques of the formation of the overall composition of the building. They include:

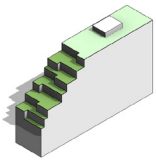
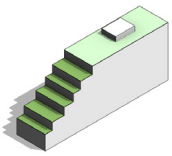
- End terracing;
- Longitudinal façade terracing;
- Back terracing with cantilevers;
- Diagonal terracing;
- Mixed terracing.

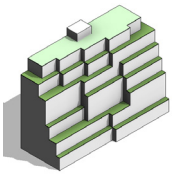
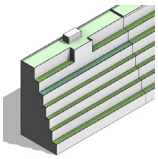
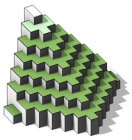
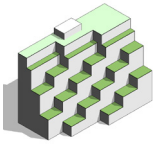
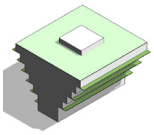
To analyze the classification more accurately, several groups were divided into subgroups, specifically:

- end terracing techniques:
- within entire planning units;
- within individual parts of planning units.
- Longitudinal façade terracing techniques:
- horizontally across the entire façade;
- within individual parts of façade.
- Diagonal terracing techniques:
- diagonally across the main façade;
- spatial, on the diagonal of the building's volumetric shape.

Thus, the table of classification of existing variants of terracing of multi-storey residential buildings on flat terrain currently based on the world practice was compiled (Table 1).

Table 1. Classification analysis

		Scheme	Examples	Information
End terracing	within individual parts of planning units			«Rue Camille Claudel», Clichy, France, 2017 arch. Hamonic+Masson & Associés
	within entire planning units			Project «Scala», Canada, 2022 arch. Walman Architects

Longitudinal façade terracing	within individual parts of façade			«The West Residence club», New York, USA, 2022, arch. Concrete
	horizontally across the entire façade			«Kaufpark Alterlaa», Vienna, Austria,1986, arch. G. Glyuk
Diagonal terracing	spatial, on the diagonal of the building's volumetric shape			«79 & Park Residences», 2018, arch. BIG
	diagonally across the main façade			Office and res. building, Vienna, Austria, 2005, arch. Coop Himmelb(l)au
Back terracing with cantilevers				«The Orgues de Flandre» Paris, France, 1980, arch. Martin Van Trek
Mixed terracing				«Valley», Amsterdam, the Netherlands, 2022 arch. MVRDV

3 Discussions:

3.1 End terracing.

The end terracing technique provides for the placement of terraces on the end of residential buildings, which, as a rule, have a narrow enclosure. According to the way of organizing terraces with regard to the internal planning structure, two subgroups can be distinguished.

3.1.1 End terracing within entire planning units.

In this method of terracing, the facade is shaped by cascading into commensurate indents, with terraces organized at each descending level. Typically, end shifts are made by floor-by-floor shifting of entire floor plan structures, such as an apartment or room. In terms of the perception of the overall composition of the building, this technique can be particularly effective at panoramic views, in a relatively spacious area with the necessary view characteristics. Or, for example, when perceived from highways, squares, from the mirror of bodies of water, etc.
The structural systems used in such terracing are usually framed with transverse or cross-braced girders, less often frameless with load-bearing transverse walls. In this case, the transverse support is necessitated by the need to transfer the transverse load as the structures are displaced in height.

The terraces are similar and roughly equal in size for each apartment. The terrace area may belong to one apartment, but more often (in large multi-storey complexes) to two apartments, whereas various kinds of partitions are used for the isolation. There are design solutions, when the terrace is designed as a place for recreation for tenants of the whole floor or wing of the building, when access to it is directly from the corridor of the residential section.

3.1.2 End terracing within individual parts of planning units.

The general composition of the building in this case is similar to the previous type, also has a cascading structure, but it is complicated by various kinds of displacements of smaller volumes. End shifts are made mainly by reducing or changing the layout of the apartments and shifting them relatively slightly in the plane of the façade. Such ends may be more attractive when viewed from closer points.

This technique is good for harmonizing lapidary and low-information surrounding buildings of simple geometric parallelepipeds. The structure of such ends has more complex arrangement and can enhance the uniqueness of the layout in a residential building.

Structural systems used in this case can be different: framed with cross or transverse arrangement of girders, frameless with mixed spacing of transverse walls, frameless with western volume blocks, various kinds of monolithic solutions. Terraces can vary in size, providing great variety for apartment design, while generally maintaining excellent insulation, as their contours largely do not overlap.

3.2 Longitudinal façade terracing.

The longitudinal method of terracing is usually used in the compositions of multi-sectional residential buildings with a long facade length. Two subgroups can be distinguished according to the terracing techniques.

3.2.1 Longitudinal façade terracing horizontally across the entire façade.

The façade is typically an elongated sectional structure in which there is a floor-by-floor shift of the entire horizontal façade. As the height of the floor area increases, the area of apartments decreases and the number of apartments may change. This technique strongly influences the apartmentography indicators of a residential building or complex. Buildings with this terracing technique are recommended to be located in areas with high views, which one would like to make accessible to most of the apartments. The method is often used in resort architecture with shoreline locations.

The structural system is usually framed with longitudinal girders, less often frameless with longitudinal bearing walls. Monolithic solutions may be used. The longitudinal distribution of loads is due to the need to shift some of the structures along the entire horizontal of the façade. The planning difficulty with this type of terracing is the great depth of enclosure of the lower apartments. Therefore, this technique can be recommended for smaller buildings with the organization of non-residential premises on the lower floors. The terraces are platforms bounded on both sides by partitions, forming a single contour along the entire plane of the façade. Often partitions are organized "green", using creeping varieties of plants that don't require much soil.

3.2.2 Longitudinal terracing within individual parts of façade.

The façade with longitudinal terracing of individual parts is less geometric and monotonous compared to the previous type. In its basis, it has a cascading longitudinal displacement of volumes, complicated by additional shifts depending on internal planning combinations. As storey height changes, the amount of envelope displacement may change, which is generally perceived as a reduction in size of the building composition with height gain. It is advisable to use this type of building in more dense buildings, when the viewer from the outside can perceive individual parts and fragments of the façade. The surrounding development should be in line with the building or lower in height than it.

The structural system can be framed with longitudinal or cross-braced girders, frameless with mixed spacing of load-bearing longitudinal walls, volume-block frameless or frameless with block walls. Monolithic solutions are also applicable. Longitudinal loads play an important role in the selection of a particular design. In this type, the issue of isolating the space of terraces is solved in different ways: somewhere by simple partitions of horizontal sections, and somewhere by displacement of terraces in space, which brings variety not only in the façade composition, but also increases the number of unique planning solutions in the building.

3.3 Diagonal terracing.

The diagonal terracing method is based on the diagonal displacement of terrace volumes in different planes. As a rule, the development with this type of terracing has a small number of floors, rarely used in combination with other compositional techniques in high-rise construction.

3.3.1 Diagonal terracing across the main façade.

This type of terracing is characterized by the diagonal sliding of the terraces along the diagonal of the entire façade. This solution should be subject to a certain spacing and scale. As the number of storeys increases, the area of part of the storeys decreases. This diagonal sliding of the stepped parts of the façade visually makes the façade dynamic, mobile and can increase its scale. The principle of terracing along the diagonal of the main façade is characterized by a clearly planned floor-by-floor geometry of the apartments. The building is well perceived from closer views and its structure is clearly visible. Buildings of this type can be located both on sites with panoramic views and in a fairly dense urban development.

The structural system may be framed with cross-braced girders, frameless with load-bearing longitudinal walls, or volumetrically block frameless or frameless with setback blocks. As the storey increases, the necessary distribution of loads on the lower floors must be considered due to the displacement of structures. The isolation of terraces in this type is organized by their staggered displacement, in rare cases the design of partitions is envisaged.

3.3.2 Spatial terracing on the diagonal of the building's volumetric shape.

In this type of terracing, the shaping is quite complexly arranged, providing for the systematic displacement of volumetric elements along the diagonal axis in space as the storey increases. The lowest and the highest point of the site are spatially diagonal from each other, and the shifting structures are organized between them according to a certain algorithm with a certain combination. The terraces are organized within the boundaries of the spaces between the displacements of the volumes. A successful perception of this type of terracing is achieved from both near and far points, as the building is a kind of organized ensemble of volumetric structures. Such a building can be located either in an open area with excellent views or in a dense urban area [17].

The structural system can be framed with cross-braced girders or volume-blocked frameless with block decks. The need to organize a large enough space without isolation in the lower part of the building complicates the design process. There parking or commercial premises are usually organized with access from the back of the facade. Terrace isolation is generally superior because each of the planning structures has its own adjustable shear pitch, otherwise partitions are installed.

3.4 Back terracing with cantilevers.

The method of back terracing is characterized by the use of cantilevered structures and is designed often in cramped conditions, on a small-sized plot or when subordinated to the general ensemble of the architectural environment. The shaping includes a reverse cascading floor-to-floor shift along all or part of the façade, achieved by commensurately increasing the building volume in height by the width of the terraces. The amount of terrace outreach is characterized by cantilevered structures of different lengths. Often, this type of building is designed based on cramped conditions that need to be diversified with a terraced structure. Views are generally downgraded and the terrace is used as a place to be outdoors in a cramped urban environment [18].

Structural system is often characterized by a rigidly fixed stiffening core with cantilevered outriggers. Buildings of this type require particularly careful construction, which certainly increases the cost of construction. As in sub-type 2.1, this type of terracing presents the problem of the great depth of the upper floor enclosure, which requires some creativity on the part of the designers of the apartments' layout. Such a complex structure type must be justified by the context and conditions, whereas the design achieves the uniqueness of the architectural environment. The isolation of the terrace space is achieved by the arrangement of partitions within the boundaries of the common terraced contour.

3.5 Mixed terracing

The mixed terracing technique can combine all the above techniques, but can be formed according to completely different laws, so it is a separate type. Examples of its application in housing are currently unique rather than generally available. Its volumetric composition is able to create original high-rise dominants with a single complexly organized structure, where the building is deployed on all compass points and is well perceived from both near and far

panoramic views. This type of terracing usually has its own individual structure and is quite complex, uniquely designed. Formation includes displacement or rotation of separate or planned connected volumetric members, built in a certain algorithm and subordinated to the general artistic and spatial laws [19]. Terraces, in turn, are arranged within the boundaries of spaces obtained through the displacement of volumes. The angles of successful perception of the building are practically unlimited, especially considering that such volumes are dominant in the surrounding development [20].

The structural system is usually a frame system with cross-braced girders or a rod system with a rigidly loaded central core against which displacements and rotations occur, with the possible use of cantilevers. The isolation of the terraces is usually excellent in this type of terracing, which is achieved by clearly organized offsets of the volumes separating the planning structures.

4 Conclusions:

Thus, the architectural and planning features of terracing of multi-storey residential buildings on flat terrain were analyzed with the development of an appropriate classification. Each type of terracing requires its own specific design approach, both in terms of the urban planning situation and in terms of planning and structural requirements. The functional quality of the apartments is greatly improved as they are complemented by individual outdoor recreational spaces. At the same time, all the above techniques of terracing high-rise residential buildings significantly enhance their artistic expression and enrich the surrounding urban environment.

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