

MODULAR PRECAST METALLIC BALCONIES FOR BUILDINGS AND PROCESSES FOR MAKING THE SAME

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Abstract: *Modular precast metallic balconies for buildings and processes for making the same refer to a prefabricated metal structure applied to existing buildings with no balconies which are designed to improve the quality of life in rural or urban areas, providing occupants with an area with more natural light and access to open space..*

Key words: *Construction quality and safety, sustainability, development, quality management.*

1. INTRODUCTION

In the case of multy storey buildings, the classic solution for balconies is an external extension of the slab, made in the most common situations, of reinforced concrete. Building the balconies involves designing and constructing a platform as an intrinsic element of the structure of the building; this platform is an element of reinforced concrete (console), which supports a vertical load on the upper horizontal side.

The reinforced concrete slabs are the most used in civil constructions, they best respond to the technical and economic conditions imposed on the floors in the modern civil constructions. According to the research, the boards in the console are plates embedded on one side and free on the other sides, where the resistance reinforcement is disposed perpendicular to the embossed side. [1]

This solution for making the balconies has disadvantages:

- a) the heavy weight of the reinforced concrete console, which increases the load to which the whole structure of the building is subjected;
- b) the relatively large workload required for the execution and completion of the balcony after the execution of the reinforced concrete console;
- c) the total length of execution time, imposed by the need to strengthen the concrete after casting and attaining the minimum required resistances imposed by the standards;
- d) reduced possibilities of diversification of the dimensions and of the architectural design of the balconies thus realized;
- e) the impossibility of applying to the existing constructions, because the realization of the reinforced concrete console would involve substantial interventions to the structure of the building, with unacceptable labor, costs and realization times;
- f) the assessment of the concrete characteristics of the structural elements is a complex process that is a component of the environmental control of the construction works. [2]

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For the same purpose, it is also known the solution of balconies made of wood that are used for wood buildings or attached to buildings made of other materials. The main structural elements of these balconies are wood beams at relatively small distances (0.5-1.00m); the maximum length of such balconies is up to 5-6m, and they are sited usually on masonry walls or on reinforced concrete elements.[3]

This solution for making the balconies has some disadvantages also:

- a) reduced load capacity, which implies the need for additional strength elements;
- b) deterioration of the resistance characteristics in time, due to the drying of the wood in the structure of the balcony;
- c) reduced life in situations of poor or incomplete maintenance; they need periodic treatments necessary to eliminate or reduce the effects of the destructive action of microorganisms (caries, fungi, bacteria, molds);
- d) relatively demanding maintenance from the point of view of antimicrobial treatments and coating with protective films against external environment factors.

The problem solved by using modular precast metallic balconies is to provide an additional exterior or interior space (open or closed balcony) to help improve the performance of the existing building and the quality of life, as well as to increase the value of the building. The modular prefabricated metal balcony product overcomes the aforementioned drawbacks in that, for the purpose of making balconies to existing buildings which do not have, it is prefabricated from metallic materials and can be applied practically to any type of building without major intervention to the building's structure because the horizontal platform of the balcony is a component part of the prefabricated balcony assembly.



Figure 1: Prefabricated metal balcony applied to existent building

The positive effects of modular precast metallic balconies are:

- easy access to an open space outside the building;
- possibility to refresh the air from the interior spaces with fresh air from outside;
- widening the visual perspective towards the exterior of the building;
- extension of the interior space bounded by the exterior walls of the building;
- enhanced natural illumination of the interior space;
- the consequent increase in the quality of living and comfort for occupants.

2. THE CONSTRUCTIVE SOLUTIONS

Constructive solutions Type 1 - Balcony in console without supporting elements

Attached to the walls of a building, there are two beams fastened on the wall of the structure by means of clamping elements (a metal plate and threaded bolts); each of these beams is realized from two U rolled shapes, connected with round rods, welded or bolted. The horizontal distance between the beams equals the opening of the balcony.

This balcony is a modular console type metallic structure that is attached to structural elements of the building by means of metal parts, called "insert pieces". The pieces will be attached to the structure of the building by means of chemical anchors. The metal structure of the balcony console features a rigid frame made of welded rectangular pipes. The non-structural elements attached to the balcony will feature Deck plating, which will be the floor and the metal railing made of stainless steel circular elements to be trapped on the three sides of the balcony.

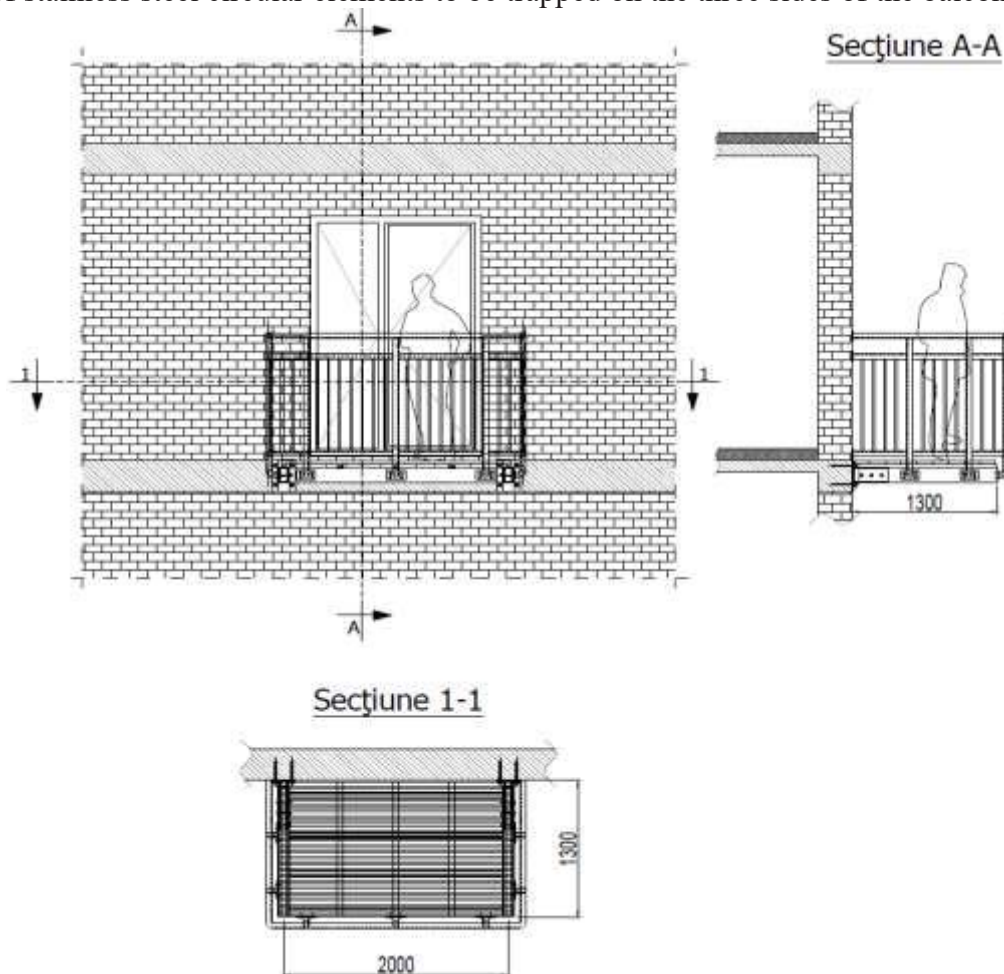


Figure 2: Constructive solution Type 1

At certain levels, between the U rolled shapes, it will be introduced a RHS beam, with a particular head – similar to a hammer. These RHS beams are the lateral consoles which support the structure of the balcony. Between the two consoles, there will be other long RHS beams, which will form the perimeter of the balcony.

Constructive solution Type 2 - Balcony in console without supporting elements, with circular corner

This type of balcony has a modular metallic structure similar to the console balcony structure without supporting elements but is only studied and thought for the types of balconies applicable to the corner of the building for which the corner balcony module has a circular shape. The corner module strength elements are U-profile welded to the beams of the frame. The non-structural elements of this balcony are similar to the console balcony elements without supporting elements.

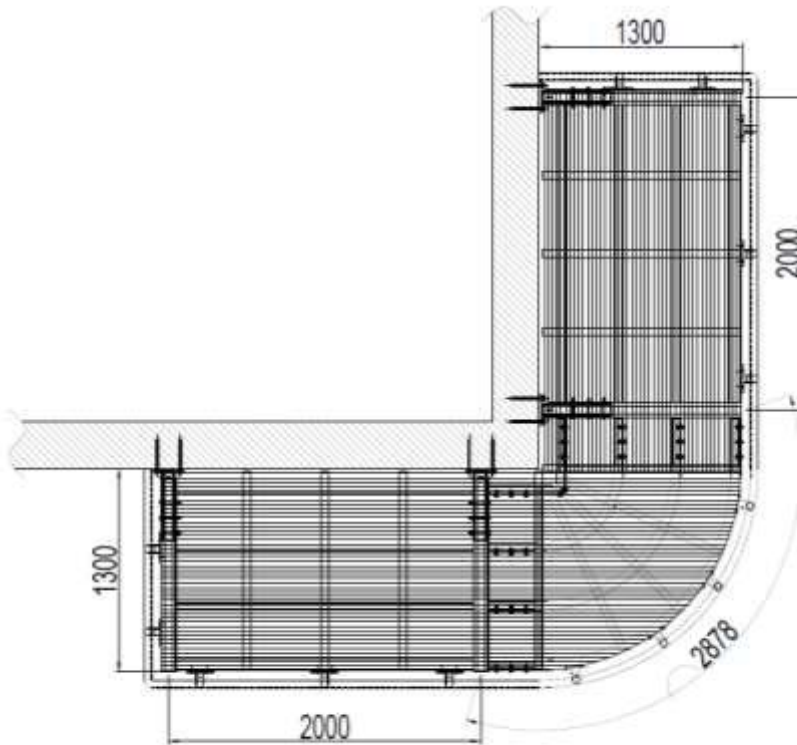


Figure 3: Constructive solution Type 2

Constructive solution Type 3 - Balcony in console with stiffening elements - tie beam type

This type of balcony is a metal construction in which a large part of the structural elements of resistance and support are made of welded plates. Balcony fasteners are U-shaped profiles with variable sections made of welded sheets that catch on the building wall along the entire height of the level. The support elements are the tie beam elements representing a straight-circular pipe with the heads provided with clamping devices. The metallic structure of the balcony console features a metal frame made up of main beams of welded sheet with variable section and secondary beams of rectangular pipes welded to the main beams.

The platform of the balcony can be realized as light as possible, using different solutions resistant to weather exposure. The same solution is adopted to secure the hand-rail of the balcony. Then introducing the vertical elements at the corner of the balcony and along the openings (the parapet) we will form a rigid body (hand rail – parapet – platform of the balcony) connected to the building wall.

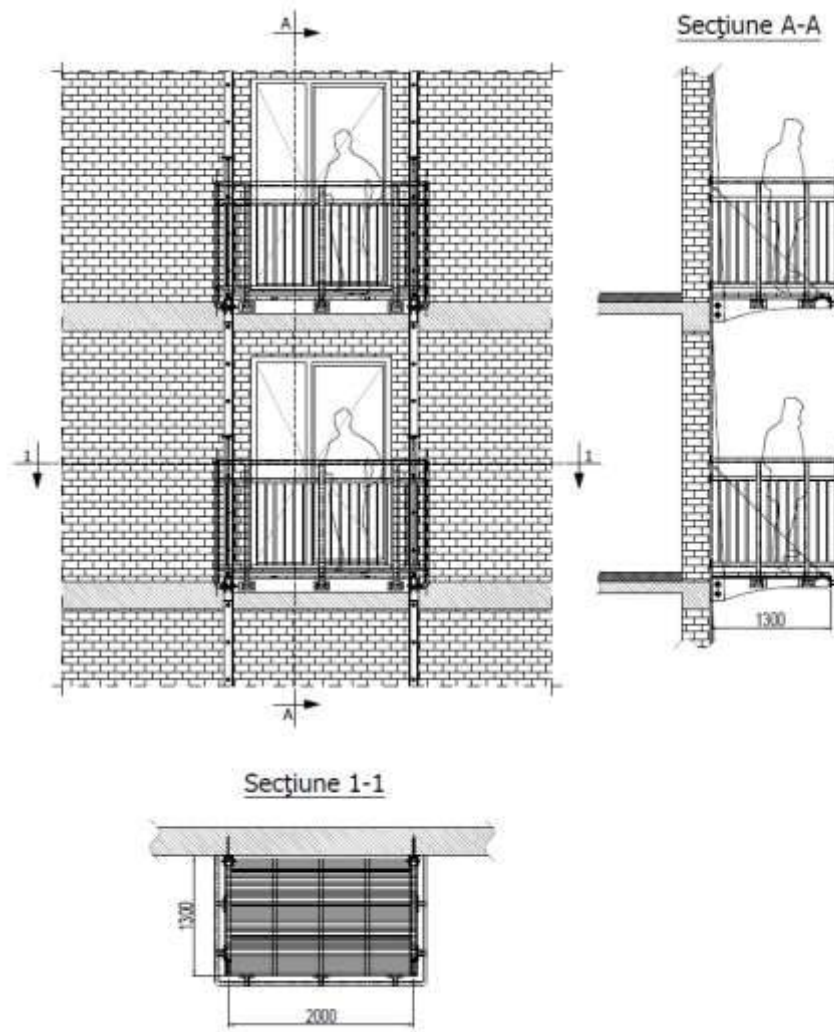


Figure 4: Constructive solution Type 3

This article will present three types of modular metallic buildings for balconies with an opening of 2.00m and a width of 1.30m. The difference between the balconies will show the type of the balcony's grip by the structural elements of the existing building, the shape of the railing and the static scheme of the balcony.

The solution has the following advantages:

- makes possible to build a balcony on existing buildings, thereby achieving significant beneficial effects on the quality of life and the comfort for the occupants of the building, while increasing the market value and use value of the buildings in question;
- due to the structural integrity, the modular prefabricated metal balcony applied to the buildings, transmits the building loads to the weight of the assembly and the external loads through the vertical elements, which determines that the proposed structure can be included in the category of partially self-supporting structures;
- by completing the prefabrication of the new balcony type and assembly systems, the product provides great flexibility under various conditions and specific requirements generated by the large diversity of existing buildings, the product being practicable in all possible situations;

- thanks to the used gripping methods, the prefabricated, modular metallic balcony applied to the buildings allows for simple installation, requires small mounting times and ensures high positioning precision on the building wall;
- provides high reliability and maintenance and maintenance costs are reduced;
- being a fully prefabricated product, there are the necessary conditions for the quality assurance of the execution, the sorto-type-dimensional diversification and the design of the assemblies made of balconies;
- Due to the gripping methods used, the loads transmitted to the building through the vertical elements are incomparably smaller than other gripping methods, which results in a dissipation of the effort on the entire surface of the vertical elements mounted and the decrease of the efforts in the platform support area;
- is a method that allows in the economic variant to obtain standardized products, modular (depending on the desired opening), verified and certified, for which the approval of the location will be easier;
- it is an economical construction method, the total costs being even lower compared to the existing variants due to the prefabrication and quick mounting scheme.

3. PRACTICAL SIZING

The main elements of the balcony structure can be sized very easy, using basic engineering skills, as exemplified below.

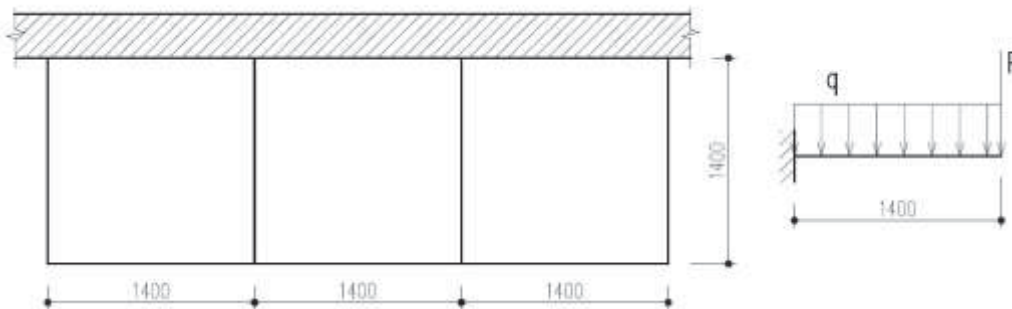


Figure 5: Numerical sizing example

A. Main beam design

- Load assigns
 - a) Permanent loads :
 - self weight : 5 kN/m²
 - self weight of handrail: 2 kN/m
 - b) Live loads :
 - occupancy: 3 kN/m²
- Loads on the main console:

$$q = 1.35 \times 5 \times 1.4 + 1.5 \times 3 \times 1.4 = 15.75 \text{ kN/m} \quad (1)$$

$$P = 1.35 \times 2 \times 1.4 = 3.78 \text{ kN} \quad (2)$$

- Maximum bending moment

$$M_{\max} = 3.78 \times 1.4 + 15.75 \times 1.4^2/2 = 20.73 \text{ kNm} \quad (3)$$

- Size of the main beam

$$W_{\text{nec}} = 20.73 \times 10^3/235 = 88.2 \text{ cm}^3 \quad (4)$$

thus we consider

$$\text{RHS } 180 \times 80 \times 5 \quad (W_{\text{eff}} = 113 \text{ cm}^3) \quad (5)$$

B. Beam end fixture

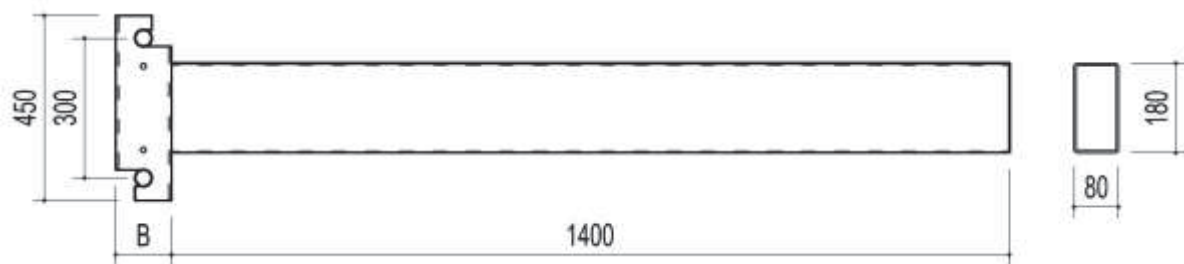


Figure 6: Beam end fixture

- Size of round rods

$$H = M_{\max}/0.3 = 20.73/0.3 = 69.1 \text{ kN} \quad (6)$$

$$A_{\text{nec}} = 214.65 \text{ mm}^2 \quad (7)$$

So the rod should have a diameter $D \geq 16.6 \text{ mm}$, thus we consider $D = 20 \text{ mm}$

C. Calculations of the connection: Column base/Rectangular tube

The gripping pieces are inserts pieces whereby the main beams of the metallic balcony are anchored to the beams of the existing building. As a result, the insertion pieces play the role of the main resilience elements that take over the loads transmitted by the structure of the balcony and transmits them to the main strength elements of the building.

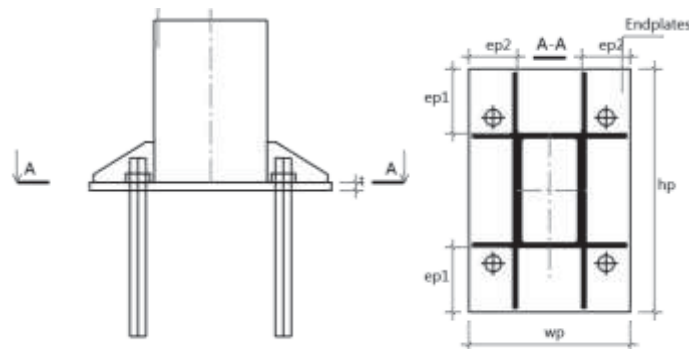


Figure 7: Insert piece

General Information

Column: TREC 140x80x5

Hb1 =	140 mm	Column height
Wb1 =	80 mm	Column width
twb1 =	5 mm	Web thickness
tFb1 =	5 mm	Flange thickness
Ab =	20.88 cm ²	Section area
Iby =	540.7 cm ⁴	Moment of inertia
Wpl =	96.25 cm ³	Plastic section modulus
W =	77.24 cm ³	Elastic section modulus
fyb =	235 MPa	Resistance

Bending in web plane

Verification of bending capacity:

$$M_z/MR_{dz} = 0.97 < 1.0 \quad (8)$$

The condition is satisfied (97%)

Bending in plane of flanges

Verification of bending capacity :

$$M_y/MR_{dy} = 0 < 1.0 \quad (9)$$

The condition is satisfied (0%)

Biaxial bending verification:

$$M_z/MR_{dz} + M_y/MR_{dy} = 0.97 < 1.0 \quad (10)$$

The condition is satisfied (97%)

Shear verification

Verification of shear capacity:

$$V_z/V_{j,Rdz} = 0.06 < 1.0 \quad (11)$$

The condition is satisfied (6%)

Shear in flanges plane

Biaxial shear verification:

$$V_y/V_{j,Rdy} + V_z/V_{j,Rdz} = 0.06 < 1.0$$

(12)

The condition is satisfied (6%)

Welds control

$$\sqrt{(\sigma_{perp}^2 + 3(\tau_{perp}^2 + \tau_{par}^2))} \leq f_u/(\beta_w * \gamma_{M2}); 0 \text{ MPa} < 360 \text{ MPa} \quad (13)$$

The condition is satisfied (0%)

$$\sigma_{perp} \leq 0,9 * f_u / \gamma_{M2}; 0 \text{ MPa} < 259.2 \text{ MPa} \quad (14)$$

The condition is satisfied (0%)

Vertical weld check

Forces applied along web

$$\text{Sqrt}[(\sigma_{\text{perp}}^2 + 3(\tau_{\text{perp}}^2 + \tau_{\text{par}}^2)] \leq f_u / (\beta_w * \gamma M_2); 158.36 \text{ MPa} < 360 \text{ MPa} \quad (15)$$

The condition is satisfied (44%)

$$\sigma_{\text{perp}} \leq 0,9 * f_u / \gamma M_2; 17.36 \text{ MPa} < 259.2 \text{ MPa} \quad (16)$$

The condition is satisfied (7%)

Forces applied along flages

$$\text{Sqrt}[(\sigma_{\text{perp}}^2 + 3(\tau_{\text{perp}}^2 + \tau_{\text{par}}^2)] \leq f_u / (\beta_w * \gamma M_2); 0 \text{ MPa} < 360 \text{ MPa} \quad (17)$$

The condition is satisfied (0%)

$$\tau_{\text{perp}} \leq 0,9 * f_u / \gamma M_2; 0 \text{ MPa} < 259.2 \text{ MPa} \quad (18)$$

The condition is satisfied (0%)

Additional condition

$$M/M_c, Rd = 0.15 < 1.0 \quad (19)$$

The condition is satisfied

$$V/V_c, Rd = 0.02 < 1.0 \quad (20)$$

The condition is satisfied

Final verification

Connection verification:

Verification of connection	FEd – force	FRd - capacity	Ratio FEd/FRd
Horizontal welds - force in web plane	24.78 MPa	360 MPa	7 %
Horizontal welds - force in flanges plane	0 MPa	360 MPa	0 %
Vertical welds - force in web plane	158.36 MPa	360 MPa	44 %
Vertical welds - force in flanges plane	0 MPa	360 MPa	0 %

Table 1: Connection verification

The connection conforms to the (EN 1993-1-8:2005/AC:2009)

4. CONCLUSIONS

The purpose of the modular precast metallic balconies is to provide an additional exterior or interior space, open or closed balcony, to help improve the quality of life, the performance of the existing building within its lifetime limits, and to increase the value of each building concerned.

In order to achieve the purpose of the product, the starting point was that the structure must be prefabricated, built upon a metallic structure in order to be applied to any type of building without affecting its structural strength, since the balcony's horizontal platform is a component part of the prefabricated assembly.

According to the research, most of the buildings designed without balconies or loggias are old buildings that have been subjected to numerous seismic actions, having reached or exceeded the specified level of exposure; that is why the patented product started from the idea of a prefabricated structure, designed so that the interventions have a minimal effect on the structural resistance and are non-destructive.

Following the analyses and because of the structural integrity, the conclusion was that, by using modular precast metallic balconies for buildings, the loads resulting from the weight of the assembly, as well as the external loads resulting from vertical elements are transmitted to the building. Consequently the proposed structure can be included in the category of partially self-supporting structures.

Due to the implementation of quality management systems in the execution process as well as in the product assembly, it was possible to carry out a simple and fast assembly, which ensures with great precision the position of the product on the surface of the building.

Therefore the necessary conditions for the quality assurance of the execution, the dimensional diversification and the design of the assemblies made of balconies are complied with. This is a method which, in an economic variant, allows the obtaining of standardized modular products, depending on the verification and certification of the desired space.

The main effect of the application of this product is that it makes it possible to extend the existing space by adding balconies to the existing buildings, with significant beneficial effects on the quality of life for the occupants and the comfort of occupying the premises while increasing the market value of the buildings.

Professor Voiculescu Dragos attended the studies at Technical University of Civil Engineering Bucharest, taking his degree in 1989, then following doctoral studies, and in 1999 he obtained the



scientific title of doctor-engineer, in the field of technical science, the specialization of metal constructions.

Starting with 1998 Professor Voiculescu Dragos is an Associate Professor at Technical University of Civil Engineering Bucharest in the field of metallic constructions and in present, Vice-dean at Faculty of Civil, Industrial and Agricultural Buildings.

During his professional activity, Professor Voiculescu Dragos has sustained courses and seminars in the field of Metal Constructions, optional courses of special Metal Construction and Reinforcement and Rehabilitation of Metallic Structures in English and French, leading bachelor and dissertation projects and participate in licensing exams committees.

Professor Voiculescu Dragos is one of the authors of the patent proposal no. RO132314-A0, dated 05 Jul 2017, concerning the modular precast metallic balconies for buildings named "Modular precast metallic balconies applicable to buildings and process for making the same" (2017).

Professor Voiculescu Dragos is also a projects verifier certified by Ministry Of Regional Development And Public Administration Romania to requirements A1 and A2 and responsible for specialized courses and activities in the field of design procedures regarding silos, bunkers and metal tanks.

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