Special Elements for Light Prefabricated Concrete Frames Used in Attic Solution

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Abstract: - An attic can be a very good solution applied on existing buildings, especially when dealing with necessary interventions (aging, leaking, thermal rehabilitation, real estate issues). The communist prefabricated concrete blocks, unfortunately still intensively used to be demolished, are of great interest for implementing new living units above the existing ones and having the same infrastructure. Starting from a small analysis of nowadays attic developed solutions and legal constraints, this paper propose a completely new approach, structural and not only (architectural, financial) design that can be a positive reaction to so many old cubic volumes transformed recently in a very colorful manner to a huge “house” with traditional pitched roof. The use of prefabricated composite elements (structural and finishing materials) may be a great opportunity for large scale interventions with significant reduction of costs and site works. Three different types of reinforcement, together with a unique fixing element show that the reinforced concrete, used in small section repeated frames is still a contemporary material, with good fire behavior.

Key-Words: light prefabricated concrete frame, concrete panel blocks, structural frame, attic, flat roof

1 Introduction
As any former communist country, Romania has a very large number of “social” collective housing units, grouped in dormitory quarters around the historical city centers, (a matter demonstrated not just by a simple walk in the city, but also through statistics) [1]. Designed in a centralized institute, most of them were erected very quickly in a quite short period of time. The prefabrication used as the main technological solution was politically imposed. Considering the Post-War demographic expansion and the necessity of minimizing the work process (less time, people involved, human manufacture), a great efficiency was obtained through step by step prefabricated construction components, from inside to outside of the building: structural elements, closing and division walls, equipments, complete bathroom cabins, furniture. The facades were the last prefabricated elements introduced, because of their aesthetical importance – the masonry replacement led to uniform and monotonous exterior vertical surfaces plus lack of building personality. The social(ist) [2] idea that all men were equal was mirrored in cheap / social housing. Like in other states, Romanian production specialized in specific elements – variations through certain modules, typical elements like prefabricated concrete panels, slabs, stairs, carpentries [3]. The massive usage of same details all around the national territory, with no concern for geography / climate / orientation and local architectural characteristics can be noticed these days in each Romanian small or large town (Fig. 1).

Fig. 1 “Grey” Romanian blocks

Considering the permanent technological evolution, the prefabricated element increased its dimensions, with obvious benefits: less involved pieces, faster transportation and assembling reduced number of used components and joints. The weight of panels remained decisive, related with normal crane load capacity and smallest costs [3].
Until 1990 all of these standardized buildings acquired a specific concrete grey color with some individual accents (closed balconies, pitched roof for only one staircase out of the usually three or four in the same construction). An entire generation grew in these neighborhoods having a specific mentality and trying to improve their own comfort with no concern for the general aspect.

20 years later, the overall image is slightly different, but the urban image has not become better. Starting from the practical necessity of roof leaking repairs, most of these matchboxes were endowed with pitched roofs or attics (Fig. 2).

Colorful facades through thermal rehabilitation (sometimes with patches considering just one apartment’s exterior panels), different materials and colors, facades’ equipments – all these showing the switch from state ownership to private property (more than 90%), the social status of each owner and the ability of interpreting the new freedom (and legal constraints) (Fig. 3).

Leaving from the return to a traditional roof and a psychological rejection of flat roof, the attic seemed a perfect and valuable solution for the real estate market. In fact, the result was a complete new level, with same usable area as apartments below, different through slopes, materials, colors, lack of balconies and (even if the nowadays legislation recommends) elevators – for low rise buildings (P+4 stories).

Romania is one of the few European seismic countries and has specific structural requirements. Combining these with the specific request for smaller loading on existing blocks, most of new attics were made out of masonry, wood or metal components (sometimes combined between them). Another legal constrain regards the fire safety of the whole ensemble (new + old), but most of the solutions need additional treatments of structural elements for fire good performance (this usually means extra costs) (Fig. 4).

This paper presents a complete different approach on “attic”, structural material used and the connection between existing and new construction.

2 Selected study case building
During the communist period, there were few types of collective designed and erected through the country, sometimes with small local details (different treatment / design for the exterior layer of prefabricated vertical panel) (Fig. 5).
As general features, the 30 cm modulation and limitation of concrete panels to 5.5 tones (movable with cranes type 110T). Some of the most widespread types were: 1013, 1168 (3 and 4 levels, 2 x 4.8 m bays), 744 and 774 (5 levels), 944 and 1400 (for our greatest seismic area, 2 x 5.4 m bays, 4 levels, 2.7 m story height), 1340/C (newer, with larger structural openings, also 5 levels) (Fig. 6).

The 770 block type, with specific features extracted from its description brochure [4], along its 30 years of existence, is probably the most prevalent type in Romania, usually having 5 levels (even 11 levels on main boulevards or large cities). It is a rectangular building with 12 sections (4 Pa, 4 Pb and 4 Pc), 6 types of apartments, 88 types of different blocks (depending on opening positions in end’s bay panel) and 72 types of prefabricated panels.

The equipments and bathroom cabins are also prefabricated, with interior drainage system. All fenestrations are from wood, except the entrance metallic doors (Fig. 7).

The study case was developed on three different sections, Pa1 + Pb3 + Pc1, without structural settlements (Fig. 8).
2.1 Hypothetical building structurally analyzed

The studied building had several constructive solutions, the last one being that from 1983, when the seismic loads were already included in structural calculus, along with wind and gravitational loads.

The concrete diaphragms are disposed on two perpendicular directions in a cellular system, with exterior walls made out of three layers (reinforced concrete B250 10 + 5 cm and autoclaved aerated concrete GBN-T 15 cm) and interior walls single layer of reinforced concrete B250 of 14 cm. The slabs were made out of 13 cm of reinforced concrete, while the general technical basement has walls of 20 cm concrete type B150 and continuous foundations from B75. The ramps and stairs are also prefabricated, the roof being flat and with a thermal insulation usually made out of autoclaved aerated concrete GBN-T or thermal / expanded clay (with a thickness of 22 - 39 cm) and a bituminous hydro-insulation protected with 4 cm of gravel. The entire structural system forms a rigid box with a good seismic behavior.

The structural grid has several short side bays (between 3.00 m and 5.40 m) and only two longitudinal bays of 5.40 m for each section (Pa, Pb or Pc) of the same block (770).

2.2 Structural constraints for new attic

One of the most general (and applied) principle when building an attic on top of an existing building is that the whole weight of new construction has to be equivalent (or lightly bigger) to the structural and non-structural elements of existing roof.

Most of solutions, even using reinforced concrete can cope with this constraint. The complete removal of finishing materials (thermal and hydro insulation, moisture barrier protection layers), even if it costs too much, solves this weight problem. An estimated weight of all enumerated above layers is 350 kg / sqm.

Another important criterion is the right connection between the existing structure (prefabricated panels disposed on the structural grid mentioned before) and the new attic. Taking into consideration that the block beneath has just three long axes (two exterior and one interior in the middle), the support for new structural elements has to be quite close to the existing panels.

Another contemporary comfort issue (and legally imposed for constructions with more than 4 levels) is the necessity of an elevator. From structural point of view, the small and cellular usable space between structural concrete panels and the position of internal staircase leaves less options to put a new, vertical circulation connected with the existing one: outside of the building with no disturbance for the occupants or inside the building, but affecting at least one room / one apartment on each level.

2.3 Architectural (and not only) self imposed constraints

Considering that an attic affects very serious the urban image of these dormitory areas, some self imposed constraints were made on the proposed solution: the legal aspects regarding sunlight for all living spaces, minimal legal usable surfaces and equipments; contemporary (open space) apartments; a volume that integrates the existing and strengthen the cubical originally block; elevator for upper existing and new levels (Fig. 9).

The issue of a quick execution and energy efficiency was taken into consideration through smaller disturbance of existing residents (no relocation during site works) by using only prefabricated composite materials (starting from structural elements, vertical and horizontal closures, windows and doors modulated with dimensions of including walls), energy efficient [5] (Fig. 10).
3 New attic structural solution
The designed new level (more a penthouse than a traditional attic) presents a structure made out of identical light reinforced concrete frames, placed on the existing structural grid. Each frame consists of 3 columns and 2 beams and uses C30/37 concrete (exposure class XC1+XC4+XF3). The columns unload on longitudinal axes existing walls and the connection between the edge column and beam is done through the vertical closing elements (to minimize thermal bridges).

For lateral stability, on long side of frames some vertical bracing were provided, also along the closing vertical elements. The sway reduction on short side is done also with metal vertical (and diagonal) bracing. The horizontal metal bracing from the new flat roof level ensures, together with roof panel the spatial bracing of the whole new level structure (Fig. 11).

3.1 Concrete prefabricated frame
Some components of the prefabricated frame have a trapeze section with small dimensions – edge columns and beams (14 / 35 / 18 cm), while the central column is rectangular, having 14 / 30 cm (fig. 12).

Fig. 12 Concrete prefabricated frame

Regarding reinforcement issues, there were three solutions analyzed: classical with steel bars (PC 52, Ø6 – 16, 251.4 kg of reinforcement / frame); mixed with steel bars (PC 52 Ø6 – 12, 152.5 kg of reinforcement / frame) and corrugated steel fibers (l/d ≥100, l=50 mm, d=0.5 mm, $f_y=1200$ N/sqmm, 137 kg of reinforcement / frame); only with corrugated steel fibers (l/d ≥100, l=50 mm, d=0.5 mm, $f_y=1200$ N/sqmm (Fig. 13, 14, 15).
3.2 Specific concrete elements

The edge column (SP1) is a 3D element with a upside-down L shape, being placed on the exterior side of last upper slab, above the transverse structural wall and the jointing with perpendicular long side exterior walls (Fig. 16).
being protected with a light canopy. It gives an architectural rhythm for the new upper volume placed on top of existing “matchbox”.

The central column (SP2) is placed in the middle of new space, above the intersection of transverse and longitudinal walls. It has a small enlargement on its upper side for a better connection with the new two trapeze beams (Fig. 17).

![Fig. 17 Column SP2](image)

The two horizontal beams (GP1) are interior placed and have a mechanical fixation with the three columns, without monolith poured concrete (Fig. 18).

![Fig. 18 Beam GP1](image)

3.3 Special joint elements
For a good anchoring of the new structure to the existing one, a rigid support system without monolith poured concrete is proposed. A special piece of steel (shoe) that allows bolts fixing and chemical anchors in the slab and wall underneath (45 cm depth) is founded in each column, interior positioned through the reinforcements. It weights 22.10 kg / piece for edge columns and 11.95 kg / piece for the middle column. To protect and cover this mounting area, a pouring expansive grout (Sika producer) filled the gaps (Fig. 19, 20).

![Fig. 19 Column Sp1 base connection](image)
In a similar manner, the same system is used and adapted for the connection of columns and beams. The steel piece offers bolts fixing and threaded rod. Pouring grout (Sika 318) is used for protecting the screws and rods ends. The connection piece SP1 – GP 1 weights 31.80 kg each, while GP1 – SP2 – GP1 is 45.50 kg / piece (Fig. 21, 22).
4 Conclusion
Similar interventions on this kind of buildings have been done all over Europe, especially in countries where these neighborhoods had social problems and there were empty buildings. Eastern European countries (like former Czechoslovakia, Poland or Hungary) had to deal with over populated blocks, but without seismic constraints. The vertical extension with even 2 or three levels was done with light structures, usually wooden or metallic [6].

The novelty of presented structure consists of a mixture between an ensemble solution, by using reinforced prefabricated concrete in repeated frames and fixing these elements to the existing structure with with column shoes and chemically anchored bolts to the internal structural walls.

This fastening system, placed punctually above the intersection of longitudinal and transverse concrete panels, allows a quick and stable enough mounting for the new level.

The connection elements between new column and old walls (through the upper last floor) and new columns and beams were the same, no matter what kind of reinforcement was proposed.

The three types of reinforcements used, because by introducing corrugated steel fibers the labor for reinforcement is smaller (costs are smaller), shows that, from a financial point of view, prefabrication on large scale (multiple similar constructions) together with a shorter period of site works affects the owner in a positive way.

By using reinforced concrete as main structural material, the sustainable aspect is improved, along with a regained respect for a traditional prefabricated modern building and a very good fire behavior.

References: