

NEW CHALLENGING APPROACH FOR ANALYSIS AND UPGRADING OF MASSIVE BUILDING STRUCTURE: CASE STUDY OF NEW BELGRADE POST-WAR MEGA BLOCKS

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Summary

The New Belgrade represents the city of post-war social housing where some 250000 inhabitants live on more than 4000 hectares. It was planned as a modern city to be the administrative center of New Yugoslavia, but the post-war demand for dwellings and new incoming populations turned the plan from 'administrative city' to 'city of housing', as a consequence of the political and economic crisis. Conventional design approach and 'cast in place' construction with large panel couldn't respond for the complex post-war situation.

By modernizing the technology and applying industrial construction methods building structure become a prefabricated systems' configuration of two technologically independent parts: load-bearing structure and building envelope. Partition walls and different supply systems has been installed independently from load-bearing level. Different Yugoslav construction technologies has been developed by industry to control and to satisfy the flexibility performance of the systems' building process. Massive structure become a systems' configuration model of primary construction (load-bearing system) and secondary construction (building envelope). Finally, the 'open' quality of the Yugoslav IMS skeleton construction technology is flexibility in the production and assembly of elements of the primary and secondary construction. Flexibility value of systems' model and open hierarchy assemblies will be considered for integration of new regeneration and energy efficient systems, toward more flexibility and energy efficiency at the building level, with the special emphases for the potential benefit of new infill industry development for housing systems rehabilitation from "inside".

Keywords: Mega-block, IMS systems' configuration, decomposition, New Belgrade

1 Introduction

1.1 Massive structure as a solid model

Most of the massive, post-war housing buildings in Europe are demolished or planed for demolition because the building unsuitability for spatial and technical adaptability. The conventional construction process has created strong burden conditions to the dynamic and changing society of the 21st century. 'Closed' – 'static' massive structure where materials, and components rely on each other in order to provide the desired functionality, are not sustainable if we compare the average lifespan in use with the technical lifespan of the building structure. The post-war massive structure mostly built as a mixed construction

systems by traditional approach, prefabrication of building parts and an assemblies of industrialized components, is defined as a closed systems' configuration where elements (components and subsystems) rely on each other by mixed functions and fixed connections. Adaptability process of strongly dependent parts in the solid model is related with a high rehabilitations costs, important demolition process and waste production. The key obstacles for successful transformation and upgrading of post-war social housing are:

- Inflexible load-bearing structure because of the fixed connections between components and materials;
- Inflexible load-bearing structure because of cross-bearing system (large panel support system receives loads in both directions: longitudinal and lateral);
- Load-bearing interior partitions (inflexible building layout);
- Lack of the load-bearing structure for reconfiguration and modular extensions;
- Fixed integrations between load-bearing and non-load-bearing parts of the structure;
- Inflexible and old installations' systems that cannot be adapted and exchanged;
- Lack of accessibility to the components that have shorter life circle and should change with more frequency;
- Lack of the configuration for new energy-systems integration;
- Physical and functional dependences in the building structure and labyrinth of interfaces that create complexity for buildings to transform.

1.2 Prefabrication of residential architecture in New Belgrade

In 1940', Europe clearly defined the problem that existing construction methods cannot meet quantitatively or economically the current needs of post-war housing demand. In the 60', the state of former Yugoslavia had the urgent issue to rebuild a devastated housing area. Before 1960, almost the only technology used in construction was cast in place concrete with large panels. At the moment of rapid housing re-building, the building strategy had been set up to ensure the next main issues: lower construction costs, short delivery time, control of building process, narrow and clear specialized job, avoiding mistakes, avoiding complexity. Industrialization of housing started with the construction by concrete sandwich panels with preinstalled pipes and ducts, arranged into cross-bearing structure. Traditional building process with sandwich panels couldn't work according to the demand and time conditions because of the complexity of building process, a number of non qualified workers, complex workout on the site, long time schedules, non sufficient economical support, to many construction errors dealing with complex relations between different building function and corresponding technical systems. According to the need for more flexibility and simplicity of construction process, building process has been segmented according to main building parts: load-bearing system, building façade, interior walls and supply systems. That was the first transition step from "closed" concrete 'cast in place structure' where components rely on each other by mixed functions and fixed connections to "open" prefabrication, through detachment and independence of different systems and components. Division of the building process by independent technologies set up the first systems' configuration for housing structure: load-bearing system (primary construction) and façade system (secondary construction). Jugomont, IMS Žeželj, Rad-Balency, Ratko Mitrović, Neimar NS 71, Trudbenik, and many other companies produced prefabricated and semi-prefabricated systems and components for building structure.

2 Closed versus open systems configuration model

2.1 Definition of massive structure as open systems' configuration model

A 'closed' systems' configuration has a complete set of assembly elements needed for construction and architectural solutions that can be fully accomplished with these elements alone.[1]. The main feature of an "open" systems' configuration is flexibility – the possibility of adapting production for different elements' assemblies and parallel assembly processes for different building parts. The massive structure evolved to systems' configuration model where different systems has been prefabricated independently, on the construction site or in the manufacturer field. Building primary construction or load-bearing structure has been separated as independent functional and technical level. Constructors started to design flexible structure based on load-bearing system and envelope system together with architects to built the structure according to the needs of the particular design. Design of housing had become the design and building of more flexible "support" [2]. Transition from solid model to "open" model underlined new era for systems' assembling according to different building parts. Different technologies started to be developed for load-bearing systems and envelope systems. In the further development of the technology of prefabrication, the systems production was divided into the elements of primary construction and those of the secondary construction or façades, which made things easier in coordination between building structure and architectural design. Further development of the building industry was defined with full prefabrication and thus a complete industrialization of production of all elements belonging to primary and secondary constructions. This kind of systematic approach of building parts into systems' configuration has been approved by open prefabrication of the individual systems and components. The most significant fabricant was IMS Žeželj for skeleton frame. Main exit of IMS skeleton was the development of technology for industrialized prefabricated elements to be assembled according to the needs of individual project.

2.2 IMS Building industry

IMS Building Technology is a system for load-bearing construction with prefabricated elements of the skeleton. IMS is a modular system. A square or rectangular module, is 3.6 m by 3.6 m up to 7.2 m by 7.2 m and forms the basic unit. All other combinations can be made in the range between 3,6 m to 7,2 m. The module is composed of four columns and the floor between them. Slabs and columns are linked together by post-tensioning (Fig.1). Full set of components includes: columns, normal or cantilevered floor slabs and stairway-supporting staircase girders and steps, edge girders, shear walls (stiffening diaphragms), exterior wall panels, partition walls. An important characteristic of the IMS Building Technology is that represents an 'open' system, which can accommodate various subsystems, differing in both technology and materials and manufacturer. It offers a wide variety of different buildings produced out of relatively small number of typical elements.

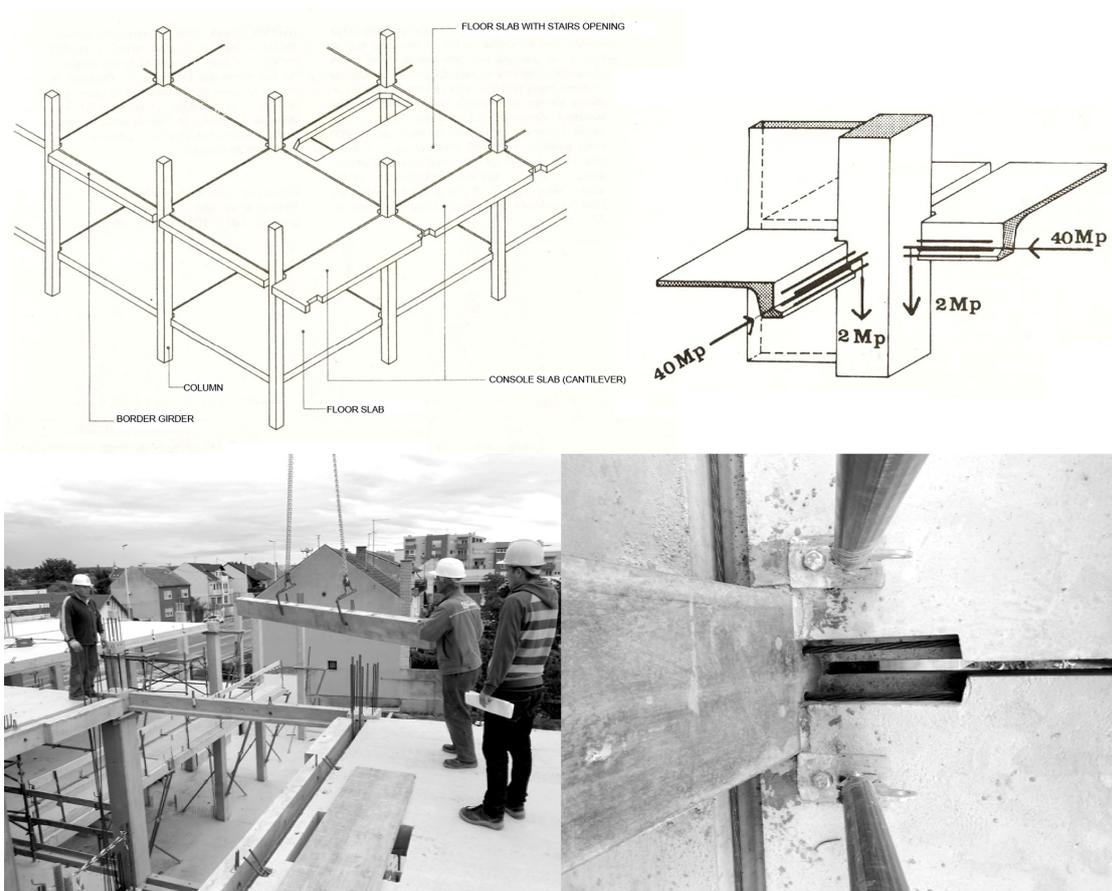


Fig. 1 IMS system of prefabrication, axonometric of basic components: concrete column, pre-stressed slabs, corner slab, edge rib[1]; Column-slab joint in IMS BT. Top view showing standard floor slab to the left and cantilever to the right. Steel tendons are visible already post-tensioned and awaiting the casting of concrete for system girders [1].

2.3 IMS Building structure as open systems configuration

Systems' configuration model is based on systematization of structural elements into independent technical levels according to main building functions (load-bearing, enclosing, partitioning and services). On the Fig. 2 is shown the systematization of four main building parts in IMS structure: IMS skeleton frame, building envelope, interior partitioning walls and service systems. Red line shows that building foundation and basement floor are reinforced masonry construction and belong to one hierarchical level. Blue lines shows the independent technical levels. IMS skeleton is on the second level which means that is first to be assembled. On the III level are independent systems for facade, roof, interior partitions and services. Some of the tower buildings have the roof construction built in traditional way (red arrow between IMS skeleton and roof masonry contraction (Fig. 2)) . On the IV level are placed different components, subsystems and systems of different building parts. Evidently, most post-war housing buildings deal with no energy efficient systems, neither with the basic services. All green field are actually missing in most of the housing buildings. It can be observed that there is no interior systems beside the interior partitions. This open assembly hierarchy allow for the IV level to integrated additional systems for the sustainable rehabilitation of the existing housing buildings.

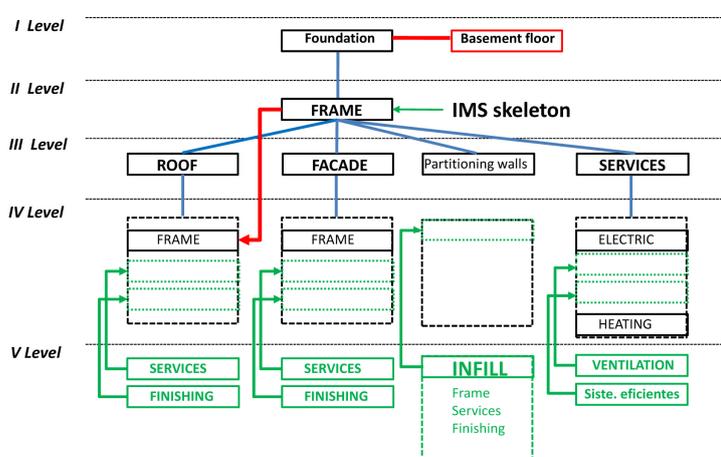


Fig. 2 Systematic approach according to independent functional and technical levels for generating of systems' configuration model

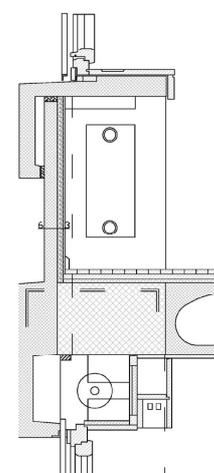


Fig. 3 Detail of the façade of the high-rise building in block 22: Insufficient thickness of the element and poorly executed joints[3]

Almost none of the New Belgrade housing projects was built fully "in the system" [3] which is considered as systems' configuration flexibility value, a primer value of "open prefabrication" for the new industrial process of mixed systems in one building structure. The systematization of building elements into independent technical levels allows for the structure to be technologically flexible. Different technologies has been applied for different building parts and different technologies will be applied for its sustainable retrofiting. According to modular coordination rules Yugoslav industrialized technologies for construction lanced different products on the international market but different products from international market has been integrated for housing systems in New Belgrade. This open systems' configuration can integrated new energy efficient systems.

3 How the IMS system solved the reinforced masonry construction problem?

3.1 Building design = Structure design = Systems' Configuration

The objective was to develop building technology to be capable for modifications according to the new requirements of the specific architectural design and new control requirement (it was easier to control building by parts than building as a whole). In the further development of the technology of prefabrication, the system production was divided into the elements of primary construction and those of the secondary construction or façades, which made things easier for building process and more flexible for architectural design. Building structure has been designed for flexibility in the building layout (Fig.5). The process of designing and constructing them was 'open' and its participants cooperated very actively, often reaching quite specific technological solutions to adapt to the needs of individual design. Design of building structure was possible according to the modifications and transformation of IMS components assembly. The skeletal system of IMS evolved from a 3.60m range (Block 21,

building B9) to that of 7.20m, with 2.10m consoles (for the district of Cerak Vinogradi). The creative approach of final architectural design had one customized application of prefabricated system which represented a modification of the original configuration according to the needs of a particular project design.

We can emphasize that Yugoslav building industry has created a methodology for systematic building approach by division of building process according to main building functions, to obtain more flexibility of the structure. Independent development of industrialized technologies and 'open' prefabrication of IMS system has been used for design and assembly of load-bearing system as the most permanent building part. Yugoslav industry, set its own systematic approach on this prefabricated model, considering prefabrication a multidisciplinary approach in which all professions would have an equal share. Until the mid-1980s, the performance of 57 local and foreign systems was comparatively analyzed and applied for different building parts [3], 20 of which were actually extensively used. Flexibility in design (Fig.4) and permanent technological improvement became the main strength of IMS presence on the international market.

The same reasons that guided the segregation of building process for different building parts will be used in decomposition of the building structure for analysis of dependency conditions and connections between different systems and components. Type of joint and the interface between elements in connections will highlight the dependency conditions in the systems' configurations.

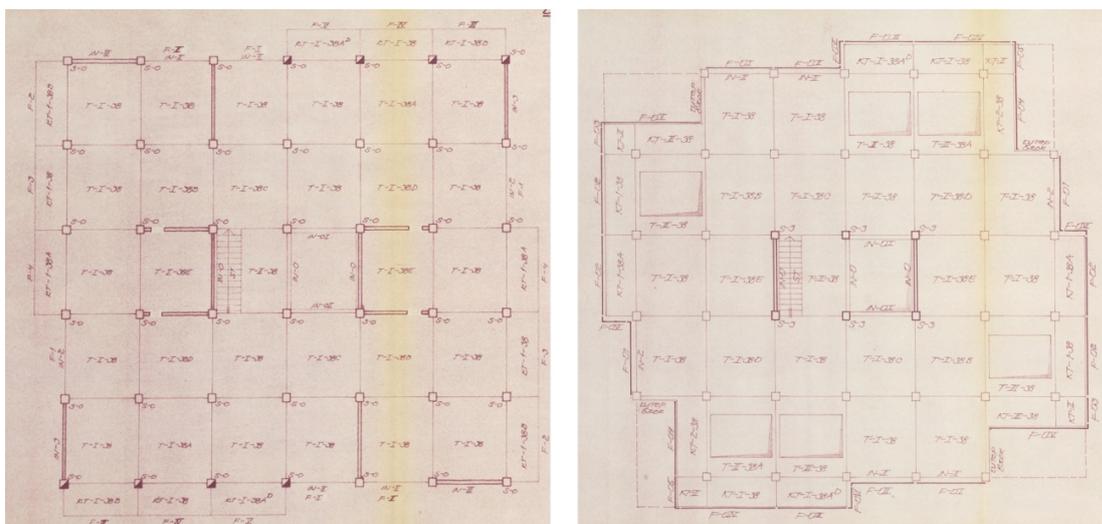


Fig. 4 Open plan of tower housing building in IMS system: Two different layout of two stories in the same building-variations of the building envelope (source: Historical Archives of New Belgrade)

3.2 Important aspect of IMS building technology

- Building structure was an integral part of the design process (design of integrated building systems and components);
- Producing the smallest possible number of component capable of being assembled into the greatest possible variety of structures;
- Open hierarchy assemblies for flexibility in the building layout (Fig.5) and façade (Fig. 6 and7), (post-tensioning is used to simplify load-bearing structure);
- Aspects of the interdisciplinary analysis of architectural design and;

- System is suitable for the erection of apartments, schools, hospitals, public buildings, office buildings, hotels, entertainment structures;
- IMS building technology has successfully been implemented in the production of high, medium and low-standard housing, in Europe as well as in developing countries;
- "Open" technology of prefabricated construction \neq technology of "open" prefabricated system: first refers to open building process where different systems of different manufactures were applied in one systems' configuration model which led to the products exchange between different international markets; second refers to open configuration model as flexible frame for flexibility in the building layout (fig.5), where new components and system can be integrated for future sustainable reconstruction of massive housing buildings.

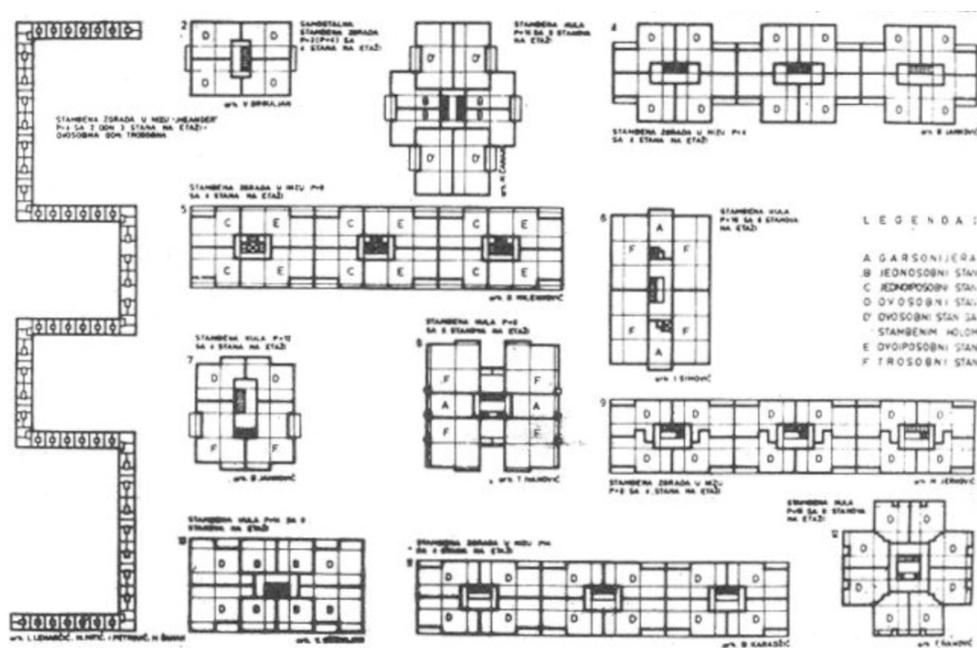


Fig. 5 Different housing layouts in IMS system: Modular Range 420/420 mm

3.3 Integrated building reconstruction

Analysis of building structure efficiency by its decomposition on systems and components is possible because of independence of different technical levels. Adaptability measures will be questioned for the different building levels (facade, interior partitions, supply systems). Instead of switching of or breaking down the parts of the structure, systems approach works by mapping larger groups of interacting elements and allowed an analysis of in between connections. Structural levels are applied for open hierarchy assemblies in which load-bearing structure is a higher level and serves as the setting and context in which lower levels operate. All examples of the facade layouts (Fig.6, 7) are the customized solution for the different housing building where the load-bearing structure is IMS system. Evidently the IMS prefabricated skeleton system was completely separated from façade system, interior partitions and services. This situation of independency of different functions and corresponding technical levels is the main flexibility value of "open" prefabrication technology. External walls are designed so that they can be changed when the renovation takes place in the future. That would be possible with interior partitions and some of HVAC supply systems as well.

IMS base building is the part of a multi-unit building that serves as a flexible frame for dwelling units. The base building normally includes the building's primary structure; building envelope (roof and facade) in whole or part; public circulation and fire egress (lobbies, corridors, elevators and public stairs); and primary mechanical and supply systems (electricity, heating and air conditioning telephone, water supply, drainage, gas, etc.) up to the point of contact with individual occupant spaces.

Finally, the new reconstruction cinereous should be planed to support more efficiency of building structure by increasing its transformation capacity for the individual dwellings upgrading. For that reason, upgrading the massive structure for more flexibility and adaptability of various functional and technical levels can be seen as a key integrate factor for sustainability of massive housing. The building structure should be analyzed by decomposition method for systematization of different components and subsystems into clusters and the relations between them. Decomposition process according to independency of different parts and performance evaluation value needs to be integrated at an early reconstruction phase.

4 Conclusions

The analysis of massive structure as open systems' configuration with independent load-bearing construction and facade, supports the new approach for integration of infill level as an opportunity for building sustainable rehabilitation. For new approach it is necessary to analyze with precision the dependency condition between services and supply systems in the building structure. Some building service networks are more dependent by fixed connection. The analysis will allow finding out the "structural spots" that are less dependent.

New retrofitting "infills" may drive the building industry towards new developments of "infill" technologies. Buildings which are designed as the systems' configurations with independent systems can create conditions for adaptability in different time and by different parties. Subdivision can then be translated into the specifications for connections (type of joint between parts) to be integrated latter on. Evidently, one of the potential is possibility to integrate new infill set of functions and corresponding technical systems, in some cases with no demolition at all, according to main IMS advantages:

- Design, composition, dimensions and location of structural components into independent functional and technical levels;
- IMS concrete skeleton designed and built as flexible system, enables flexible solutions, greater space-planning capabilities and wider range of possibilities for building interior design (open systems' prefabrication);
- Isolation of load-bearing assembly as independent technical level allows a number of different layout designs and customized solution for the facade modeling;
- Possibility to change the surface of the floor plan, either by additional construction or changes in the boundaries of units out of the support limits.



Fig. 6 Building B9, Block 21, 1960: Architects: Mihajlo Canak, Leonid Lenarcic, Milosav Mitic, Ivan Petrovic



Fig. 7 Block 28, 1974, New Belgrade: Architect Ilija Arnautovic

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